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Geology, Hydrology, and Mineral Resources of Crystalline Rock Areas of the Northeastern United States

W. Harrison, D. Edgar, P. Barosh, J. Ebel, G. Kuecher,

M. Tisue, S. Tsai, M. Winters, M. Flower, and M. Sood

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ARGONNE NATIONAL LABORATORY
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Argonne, Illinois 60439

GEOLOGY, HYDROLOGY, AND MINERAL RESOURCES OF CRYSTALLINE ROCK AREAS OF THE NORTHEASTERN UNITED STATES

by

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Graphics by M. Stahl and B. Termaat

Energy and Environmental Systems Division
Geoscience and Engineering Group

October 1983

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through
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*The plates are available under separate cover in ANL/ES-136, Part 2.

FOREWORD

This topical report was used as a data base for the "Northeastern Regional Geologic Characterization Report," Public Draft, May 1983, prepared by Battelle Memorial Institute, Columbus, Ohio. The U.S. Department of Energy sponsored the present work, first through Battelle's Office of Nuclear Waste Isolation (ONWI) and subsequently through the Office of Crystalline Repository Development (OCRD). Project monitors for this Argonne National Laboratory effort were Ronald R. Nicks, Dale E. Markley, and Stephen J. Kowall of ONWI and OCRD. Wyman Harrison of Argonne's Energy and Environmental Systems Division (EES) was the project manager and is responsible for the materials presented by each contributor to the report; he was assisted in project administration by Dorland E. Edgar and Abraham E.J. Van Luik, also of EES.

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Appendix	Catalog of Earthquakes of the Northeastern United States	J. Ebel
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Plate II	Distribution of Described Crystalline Rock Bodies of Maine	M. Flower, M. Sood, G. Kuecher, W. Harrison, and M. Tisue (assisted by B. Bach, H. Levine, S. Lovett, G. Swihart, R. Warner, and C. Witt)
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Plate IV	Distribution of Described Crystalline Rock Bodies of Vermont	M. Flower, M. Sood, G. Kuecher, and M. Tisue (assisted by B. Bach, K. Borgelt, and C. Witt)
Plate V	Distribution of Described Crystalline Rock Bodies of Northeastern New York	M. Flower, G. Kuecher, and and M. Tisue (assisted by S. Lovett)
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Plate IX	Distribution of Described Crystalline Rock Bodies of New York, New Jersey, and Pennsylvania	M. Flower, G. Kuecher, M. Sood, W. Harrison, and M. Tisue (assisted by B. Bach, H. Levine, F. Trent, and R. Wogelius)

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In addition to the above reviewers, the entire report was reviewed in draft form by personnel of EG&G, Idaho, Inc., and the U.S. Geological Survey, Reston, Va. Although these latter reviews were conducted mainly to aid OCRD in its composition of a pre-screening document based on the present report, many technical criticisms and suggestions from these reviewers were incorporated into this report.

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GEOCHRONOLOGY

Era	Period	Million Yr Ago*		Northeastern Region Orogenic Association
Ceno-zoic	Tertiary	1.6		
		66	100	
Mesozoic	Cretaceous			
		144		
	Jurassic		200	
		208		
	Triassic	245		Post-Alleghenian
Paleozoic	Permian			
		286		Alleghenian
	Pennsylvanian		300	
		320		
	Mississippian			Post-Acadian
		360		
	Devonian		400	Acadian
		408		
	Silurian			
		438		
	Ordovician			Taconic
		505	500	
	Cambrian			
		570		
Precambrian	Late Proterozoic		600	Avalonian
			700	
		1000	1000	
	Middle Proterozoic		1100	Grenville
		1600	1600	

*Based on Decade of North American Geology 1983 Geologic Time Scale, Geol. Soc. America (1983).

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Graphics by M. Stahl and B. Termaat

ABSTRACT

This report, which includes a series of maps, is a compendium of the available information on several topics of importance in defining the geologic setting of crystalline rocks in Maine, New Hampshire, Vermont, northeastern New York (the Adirondack Mountains), Massachusetts, Rhode Island, Connecticut, southeastern New York, northern New Jersey, and southeastern Pennsylvania. Crystalline rocks are defined herein as bodies of medium- to coarse-grained igneous and high-grade metamorphic rocks. The study was undertaken to provide background information to assist in evaluating the geologic suitability of such rocks for isolating high-level radioactive waste. Topics covered include the geologic history of the region; patterns of earthquake occurrence, earthquake magnitudes and horizontal ground accelerations, crustal stress, regional fault domains, and Holocene faulting and vertical crustal movements; surface processes, anticipated climatic changes, and possible effects of renewed glaciation; landforms and surficial deposits; regional surface-water and ground-water hydrology; and the commercial potential of rock and mineral prospects and mines located within or near crystalline-rock complexes.

EXECUTIVE SUMMARY

Sponsored by the U.S. Department of Energy (DOE), this study was undertaken to provide background information to aid in evaluating the suitability of crystalline rock bodies of the northeastern United States for isolating high-level radioactive waste. Crystalline rocks are defined herein as medium- and coarse-grained igneous and high-grade metamorphic rocks. The report characterizes the geologic setting of the crystalline rocks by summarizing information on the geologic history, seismicity and tectonics, surface processes, physiography and surficial deposits, hydrology, and economic geology of Maine, New Hampshire, Vermont, northeastern New York (Adirondack Mountains), Massachusetts, Rhode Island, Connecticut, southeastern New York, northern New Jersey, and southeastern Pennsylvania. Plate I shows the distribution of all types of rocks in the region.

GEOLOGIC HISTORY

The overview of the geologic history of the northeastern United States in this report focuses mainly on developments during Precambrian through late Paleozoic time, beginning about 1100-1200 million years (m.y.) ago with the Grenville orogeny and ending with Mississippian through Permian mountain building in the central and southern Appalachians and minor post-tectonic granite intrusions in New England. Geologic activities during Mesozoic and Cenozoic time are also briefly discussed.

Each crystalline body is considered in both a chronologic and tectonic context. Four broad chronologic groupings of crystalline rock bodies established for this report are Middle and Late Proterozoic (about 1600-570 m.y. ago), Cambrian to Silurian (about 570-408 m.y. ago), Devonian to Pennsylvanian (about 408-286 m.y. ago), and Permian to Cretaceous (about 286-66 m.y. ago). Because the several tectonic and igneous events that produced these crystalline rocks generally took place over long periods, this report discusses the rock bodies in terms of their relationships to the main tectonic episodes, rather than in terms of their absolute ages. All individual or related plutons and crystalline rock bodies meeting a minimum 78-km^2 (30-mi^2) criterion are presented on a series of state maps (Plates II-IX) where they are grouped by tectonic association; that is, Grenville and Avalonian, Taconic, Acadian and post-Acadian, or Alleghenian and post-Alleghenian (see Geochronology, p. xxi).

SEISMICITY AND TECTONICS

Assigning priorities to areas within the northeastern United States with respect to their desirability for detailed field studies will require evaluation of a comprehensive data base on regional seismicity and

tectonics. This report integrates, summarizes, and assesses the quality of the available information. A map of the historical seismicity of the region for the period 1534-1977 and a catalog of seismic events through 1980 indicate pockets of seismic activity scattered throughout the region. Northwestern Connecticut, western Massachusetts, southern and northeastern Vermont, northern New Hampshire, and west-central and north-central Maine are relatively free of activity. Microearthquake detection networks in the region show that some areas are quite active today, especially the central Adirondack Mountains and the area near Moodus, Conn.

The magnitude-intensity relationship for earthquakes in the region was determined to be $M = 1 + 0.6\ I_{MM}$, where M denotes magnitude and I_{MM} is the Modified Mercalli intensity; this relationship was used to estimate the sizes of historical earthquakes for which no instrumental measurements are available. Earthquake recurrence relationships also were investigated, and a table of return times is given in the report for Modified Mercalli intensities I_{MM} = VI-X for the entire region and for portions thereof. For the entire northeastern region, mean return times are estimated to be 0.6 yr for an intensity-VI earthquake; 1.5 yr for VII; 53 yr for VIII; 1,923 yr, IX; and 70,000 yr for X.

Seismic regionalization maps have been prepared for the region. Zones of high seismicity identified in this type of analysis will be useful for assigning priorities for further study of specific areas. Some evidence presented in this report indicates that the level of seismic activity in New England varies as a function of time, but it cannot be proven that this relationship is not an artifact of the data.

Estimates of maximum horizontal ground acceleration suggest that peak acceleration for an I_{MM} = IX event in New England would be about 0.51 g. The duration of strong ground motion for an intensity-IX event is estimated at about 5.7 s. A comparison of values for ground motion attenuation in the northeastern region with those in other regions of the United States indicates that attenuation in the Northeast is less than that in the West but somewhat greater than that in the Midwest.

The tectonics data base assembled for this report consists of published research primarily in the fields of geology, remote sensing, seismic profiling, aeromagnetic surveying, and gravity surveying. The regional tectonic picture that emerges from an interpretation of this data base is summarized below.

Eight pre-Mesozoic fault-and-fracture domains are identified on the basis of direction of their trends, age, or some combination of these two. The predominant fault trends coincide with the major Paleozoic northeast- and north-trending compressional faults, and with northwest-trending cross-faults that appear to be younger. These pre-Mesozoic fault domains consist of (1) the Nashoba thrust belt, which is probably the structural zone with the greatest amount of movement in the northeastern region; (2) the southeastern

New England platform, which is dominated by northeast and north to north-northeast fault trends; (3) the Merrimak province, which is dominated by northeast- to north-northwest-trending thrust faults; (4) the coastal Maine volcanic belt, which has diverse fault trends; (5) the central domal belt, which consists of fault-bounded domes that trend generally north-northeast to north; (6) the Hudson Highland-Berkshire belt of northeast- to north-northeast-trending faults; (7) the Champlain-Taconic overthrust belt, which is a very narrow zone of northeast- to north-trending, eastward-dipping thrust faults; and (8) the Adirondack dome, where the dominant pattern is one of abundant east-northeast- to north-northeast-trending high-angle faults.

The distribution of Mesozoic and post-Mesozoic faulting and fracturing is still poorly known, with most of the available information restricted to areas of Mesozoic rock. The youngest fracture trends in the northeastern region are northwest and north to north-northeast.

The tectonic events in the region are summarized in Sec. 3.2, and evidence for Quaternary igneous activity, faulting, and vertical crustal movements is examined. No Quaternary igneous activity is known, and the only warm springs in the region are at Saratoga Springs, N.Y., Sand Springs, Mass., and an area along the New York-Massachusetts border. The following kinds of evidence for Holocene (last 8000 yr) faulting are summarized and evaluated in this report: reactivated bedrock faults, offsets of striated or polished surfaces of Pleistocene age, offsets in levels of Pleistocene marine delta surfaces, scarps along faults, offsets in areas adjacent to the northeastern region, fault plane solutions, offset drillholes in highway cuts, and lineaments that may reflect faulting. The features discussed in Sec. 3.3 that are located in Lake Champlain and at Passamaquoddy Bay, Maine, seem to be due to Holocene faulting; those at Saratoga Springs, N.Y., and perhaps those at Sears Island in Penobscot Bay, Maine, also may be due to Holocene faulting.

The considerable body of evidence that vertical crustal movements are presently occurring is summarized and evaluated in this report. Also examined is the relationship of indicated movement to areas of relatively high seismic activity. Significant areas of subsidence are Passamaquoddy Bay, on the Maine-New Brunswick border; southern Maine, where releveling data suggest that the rate of subsidence increases toward the New Hampshire coast; and, probably, the lower Connecticut Valley and the entrance to Raritan Bay, N.J. There is evidence for uplift in the central Appalachian highlands of eastern Pennsylvania; in northern New Jersey; and in the Adirondack Mountains, where the rate of uplift may approximate 0.05 mm/yr or more. Areas of indicated vertical movements coincide with areas of high seismic activity; most earthquakes occur in subsiding lowlands, with concentrations of activity centered in bays and river valleys.

The causes of seismicity in the region are examined in some detail. Among the mechanisms considered are isostatic rebound, proximity to granitic plutons, stress buildup at the borders of basic plutons, crustal movements within the so-called "Boston-Ottawa seismic belt", rifting associated with

continued opening of the North Atlantic Ocean basin, and reactivation of zones of crustal weakness. None of the proposed causes is entirely satisfactory in accounting for the overall distribution of seismicity, although some of the proposed causes may contribute to the seismicity in specific instances.

Seismicity and crustal movements in the northeast are also considered in some detail in an effort to develop a basis for delineating areas of low projected seismicity and faulting. The criteria used for delineating such areas are (1) location relative to zones of present or past seismic activity, (2) susceptibility to strong ground motions from earthquakes with epicenters located both within and adjacent to the northeastern United States, (3) location relative to known or suspected vertical movements, (4) location relative to suspected Holocene fault movement, (5) location along the landward border of Cretaceous and Tertiary sedimentary rocks, (6) location along major northwest- to north-northeast-trending extensional faults and grabens, and (7) location relative to areas of Cretaceous igneous activity. The application of these criteria permits identification of areas having the highest regional tectonic stability. Among these are west-central and north-central Maine, northern New Hampshire, southern and northeastern Vermont, western Massachusetts, and northwestern Connecticut. On the basis of present understanding of the seismicity and tectonics, these areas are believed to have the lowest probability of experiencing damaging earthquakes or surface faulting.

SURFACE PROCESSES

Most of New England has undergone limited landscape change during the postglacial period. The comparatively low rate of denudation for much of the region has been confirmed in several investigations. It has been estimated that the average denudation rate is 4.8 cm/1000 yr (1.9 in./1000 yr). Such an erosion rate is equivalent to removal of 44-57 $t/km^2 \cdot yr$ (126-163 $tons/mi^2 \cdot yr$) of surface material. Other studies have indicated even lower erosion rates. Differential rates of weathering and erosion of underlying rocks of differing susceptibility to these surficial processes has been the primary mechanism in developing the present landscape.

Although it is difficult to identify pre-Wisconsinan (youngest glacial episode) drift sheets in New England, evidence of older drift in Pennsylvania, New Jersey, and the southeastern coastal areas indicates that the whole region has been repeatedly glaciated. The depth of glacial erosion continues to be a subject of debate. Local geologic and topographic conditions strongly influence this process. The bedrock topography of most of the region is fundamentally the same as the stream-carved landscape that predated the Pleistocene. The thickness of glacial drift deposited at the margin of a glacier is one indicator of the extent of glacial erosion. The average thickness of drift in New England is estimated to be 5-10 m (16-33 ft). However, because much of the eroded material lies beneath sea level, as much as 20 m (65 ft) or more of erosion may be inferred. Other studies suggest that at least 100 m (330 ft) of bedrock has been eroded during the last 2.8 m.y.

The most pronounced glacial erosion occurred within the preglacial stream valleys paralleling the general direction of ice movement. Topographic highlands experienced varying degrees of erosion, depending on their location relative to the continental ice sheet. These upland areas also probably experienced alpine and cirque glacial erosion before and after being overridden by continental glaciers. Evidence of cirque glaciation is present in the Adirondacks, the White Mountains, and several other upland areas.

During Pleistocene glaciation and deglaciation, the Earth's crust was subjected to enormous variation in stress caused by loading and unloading of ice sheets. The present position of the New England shoreline is the result of the interaction between postglacial eustatic changes and crustal movement. Although the general patterns of vertical crustal and eustatic changes have been described, the absolute magnitude and timing of these events at specific locations within the region remain in question.

A late Wisconsinan low-stand sea level occurred at approximately 120-125 m (395-410 ft) below the present sea level during the glacial maximum between 20,000 yr before present (B.P.) and 17,000 yr B.P. The Late Wisconsinan glacial recession and melting produced a Holocene transgression between about 14,000 yr B.P. and 7,000 yr B.P. Recession was progressive from south to north through the region, and local oscillations in the rate of coastal submergence have been noted. Between 14,000 yr B.P. and 11,000 yr B.P., rapid melting appears to have resulted in a change in relative sea level to an estimated 30 m (100 ft) above present level. Submergence at some coastal locations in excess of 50 m (165 ft) has been proposed. Following ice recession, post-glacial crustal rebound overtook the rising sea level and arrested marine transgression. Rates of uplift as great as 6 cm/yr (2.4 in./yr) have been proposed.

The progression of crustal warping and eustatic changes is complicated by the Valderan glacial re-advance, which reached a maximum around 10,500 yr B.P. Evidence indicates that uplift continued concurrently with falling sea level.

During the last 6000-8000 yr, the relationship between eustatic and tectonic events has been complex, and the results of many investigations to decipher these complexities for the northeastern region are discussed. During this time, portions of the region have experienced coastal upwarping, which apparently occurred as pulses of activity with total amounts of uplift that tended to increase to the northwest. The overall trend of rising sea level and coastal submergence was also marked by periods of increased and decreased rates.

Deep-sea cores indicate that continental ice cover was at a minimum at 125,000 yr B.P. to 120,000 yr B.P. (probably the Sangamon Interglacial), followed by two periods of strong ice growth centered around the dates 115,000 yr B.P. and 75,000 yr B.P., and separated by an oscillating period. Each ice-growth phase probably lasted about 10,000 yr and, in combination, these two

phases are thought to have accounted for at least half of the net ice growth toward the maximum Wisconsinan ice volume. The glacial maximum occurred from almost 20,000 yr B.P. to 16,000 yr B.P., and was followed by a major warming of the climate between approximately 16,000 yr B.P. and 13,000 yr B.P. Paleoclimatic evidence indicates that the long-term postglacial warming culminated in a climatic maximum from about 8000 yr B.P. to 4100 yr B.P., with two extremes near 5000 yr B.P. and 6000 yr B.P. Two recent intervals of cooling and minor alpine glacial expansion occurred during the Little Ice Age (250-330 yr B.P.) and from 3300 yr B.P. to 2400 yr B.P.

Several investigations have presented evidence to indicate a strong periodicity in climatic and glacial cycles. It has been noted that Pleistocene glacial epochs averaged 90,000 yr in length and that interglacial intervals averaged only 10,000 yr. It has also been observed that significant glacial growth has recurred about every 2500 yr during the Holocene. Recent studies indicate that a new cycle of continental glaciation may develop within the next 10,000 yr.

PHYSIOGRAPHY AND SURFICIAL MATERIALS

A physiographic province is a large area of the Earth's surface having a distinct geologic structure and a unified geomorphic history. The northeastern study region encompasses an area of approximately 259,000 km^2 (100,000 mi^2) and incorporates portions of six physiographic provinces. Of primary concern for the purposes of this report are those portions of the region where crystalline rocks occur at or near the land surface. These areas include essentially all of the New England and Adirondack provinces, and that portion of the Piedmont province occurring within the northeastern region.

The New England physiographic province extends, with minor exceptions, east and north from the eastern margin of the Hudson River Valley, and covers approximately 163,200 km^2 (63,000 mi^2). This area consists of mountains in the northwest that grade eastward into a plateau that slopes gently toward the ocean. Plutonic rocks, which are very resistant to erosion, underlie roughly one-sixth of the province and are widely distributed. The New England province is divided into the Taconic, Green Mountain, New England Upland, White Mountain, and Seaboard sections. Because of its small size, and for convenience of presentation, the portion of the Piedmont province in the region is included as a section within the New England province.

The White Mountain section covers about 25,000 km^2 (9700 mi^2) in the southwestern third of Maine and northern New Hampshire. Relief up to 1200 m (4000 ft) is present, and the section is considerably dissected. Maximum altitudes exceed 1825 m (6000 ft) in the White Mountains, where Mount Washington is the highest peak at 1917 m (6280 ft). The section has been glaciated by both continental and valley glaciers. The effects of valley glaciation are most obvious, and cirques are a prevalent feature. In the southern part of the White Mountains, glacial deposits are widespread and

reach a maximum thickness of 30 m (100 ft). At least two distinct tills have been identified, but considerable controversy exists over the origin and differentiation of the units. Outwash deposits of sand and gravel fill many of the valleys to varying depths.

The Green Mountain section consists of the Green Mountain range of central Vermont and the Hoosac Mountains in northwestern Massachusetts. The mountains are fairly rugged, with sharp crests and generally steep slopes. Elevation in this 8000-km^2 (3100-mi^2) area average about 600 m (2000 ft), although some peaks reach 1200 m (4000 ft). The Green Mountains acted as a barrier to inflow and diverted much of the ice immediately to the west of the mountains toward the south. A fairly continuous cover of this till is found at lower elevations. Kame-terrace gravels and lake sediments are found along the lower slopes of the mountains.

The Taconic section includes about 5200 km^2 (2000 mi^2) in southwestern Vermont, eastern New York, western Massachusetts, and northwestern Connecticut. In the Taconic mountains, most summit altitudes are between 550 m (1000 ft) and 600 m (2000 ft), although some reach 760 m (2500 ft). In the central portion of the section, the Rensselaer plateau is overlain by thin, poorly developed, boulder-strewn soils. Thick deposits of till and outwash cover the Vermont Valley floor.

The New England Upland section extends from the highlands in southeastern Pennsylvania and northern New Jersey through inland Connecticut, central Massachusetts, much of Vermont and New Hampshire to central and northern Maine. This area of 89,500 km^2 (34,500 mi^2) is basically a southeastern-sloping, maturely dissected plateau that has been modified by glaciation. Elevation ranges from about 120 m (40 ft) to 670 m (2200 ft). Outwash, kames, kames terraces, and kame deltas are among the most conspicuous stratified drift deposits. Eskers also occur in the section. Unstratified drift is present throughout most of the section. Two types of till have been identified. One, a compact and dense till, was deposited beneath the advancing glacial ice. This till is most extensive on lower slopes and attains a maximum thickness of about 9 m (30 ft). The second till, a loose or ablation till, was deposited as the ice melted or wasted away. This latter till occurs extensively on uplands, where it has maximum thicknesses of about 9 m (30 ft). Other origins of these two till types have also been proposed. The thickness and distribution of the various types of drift are highly variable throughout the section.

The Seaboard Lowland section covers 35,000 km^2 (13,500 mi^2) and stretches 10-97 km (6-60 mi) inland in Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine. In comparison to the adjacent New England Upland, the lowland is smoother and lower in elevation. The boundary between the two occurs in the 120-150 m (400-500 ft) contour range. In the northern half of this section, the thickest till (up to 30 m [100 ft]) is found in drumlins and end moraines. In general the till rarely exceeds 3 m (10 ft) in thickness. Kames, kame terraces, outwash plains, and valley trains

are present and contain significant accumulations of stratified sediments. Marine deposits resulting from late-glacial inundation are prevalent in the northern coastal area. To the south, deposits of outwash and end moraines are locally abundant. As many as six different drifts have been identified by some researchers. Ground moraine is generally thin but locally exceeds 12 m (40 ft) in thickness.

The Piedmont includes 5200 km^2 (2000 mi^2) in the southwestern portion of the study region in northern New Jersey, eastern Pennsylvania, and southeastern New York. The upland portion has a gently rolling topography; the lowland portion (Triassic lowland) is relatively flat. This section has fairly low relief with elevations in New Jersey averaging 60-90 m (200-300 ft). A well-developed terminal moraine crosses the Piedmont lowland in New Jersey and contains deposits that are about 60 m (200 ft) thick. South of this feature, stratified drift deposited by glacial meltwaters is locally very thick and forms extensive flatlands as well as valley fill. Kames, kame terraces, and eskers are found throughout this area. Pre-Wisconsinan drift occurs at several sites.

The Adirondack province occupies approximately 26,000 km^2 (10,000 mi^2) in northeastern New York. Bordering the province are the St. Lawrence Lowland on the north, Lake Champlain on the east, the Mohawk Valley on the south, and the Black River and Tug Hill cuesta on the west. Elevations in the western plateau area average about 300 m (1000 ft); in the rugged mountains to the east, numerous peaks are higher than 1200 m (4000 ft). These highlands were overridden by ice at least once, and probably several times, during the Pleistocene. Glacial drift is scattered throughout the area, and cirques are evident on many of the mountain peaks. Till in the Adirondacks is locally as much as 40 m (130 ft) thick. Glaciofluvial deposits are prevalent throughout the area. A well-developed esker system crosses the Adirondacks from northeast to southwest, suggesting that ice stagnated on the northwestern flank of the highlands for a period of time during the final retreat from the areas.

HYDROLOGY

The northeastern study region lies within three water resource regions: (1) the New England region lying to the northeast of the Lake Champlain and Hudson River basins, (2) the Great Lakes region, which includes all drainage to Lake Ontario and the St. Lawrence River, and (3) the Mid-Atlantic region, which incorporates the area northeast of the regional drainage divides of the Ohio and Great Lakes basins and west of the divide with the New England region. Data describing the surface-water and ground-water conditions in the study region are available from a number of federal and state organizations.

Due to the number of population centers and industrial centers in the northeast, estimated water use is fairly high even though some states are sparsely populated. Average regional withdrawal use increased from about

142.1 x 10^6 m^3/d (37,500 x 10^6 gal/d) in 1960 to about 212.7 x 10^6 m^3/d (56,200 x 10^6 gal/d) in 1980. The 1980 value represents approximately 12.5% of the total water withdrawn in the U.S. in that year. As one would expect, New York, Pennsylvania, and New Jersey collectively accounted for more than 75% of the regional water use. Of the total water withdrawn in 1980, only about 5% was supplied by ground-water sources.

The largest drainage basin contained totally in the study region is that of the Hudson River. Next in size are the watersheds of the Delaware, Connecticut, and Penobscot rivers. Although the Susquehanna drains about 71,200 km^2 (27,500 mi^2) of area, much of the basin lies west of the regional boundary defined for this study.

The northeastern United States contains a large number of natural lakes and ponds. Lake Champlain is the largest, with an area of 1,269 km^2 (490 mi^2). Moosehead Lake in Maine and Winnepesaukee Lake in New Hampshire both have areas exceeding 186 km^2 (72 mi^2). The region is also the site of approximately 285 controlled natural lakes and reservoirs with individual usable storage capacities of at least 6.17 x 10^6 m^3 (5000 acre-ft).

The climate is humid and exhibits variations with elevation, latitude, and distance from the ocean. Annual temperatures in the region average from about 13°C (55°F) near the southern boundary to less than 3°C (38°F) in northern Maine. Mean annual precipitation averages about 104 cm (41 in.) and is distributed fairly evenly throughout the year. Extremes range from less than 76 cm (30 in.) near the northern end of Lake Champlain to more than 175 cm (70 in.) in some mountainous areas in New Hampshire.

There is very little seasonal variation in runoff in the study region compared to much of the rest of the country. Due to annual fluctuations in precipitation, average annual runoff can vary significantly from one year to the next. Runoff is fairly uniform throughout the region and averages between 50 cm (20 in.) and 76 cm (30 in.) over most of the states. Between approximately 50% and 75% of the total average annual precipitation is consumed by runoff.

Long-term average streamflow from the region is about 6370 m^3/s (225,000 ft^3/s [cfs]). Almost one-fourth of this total is carried by the major rivers in Maine. The Susquehanna, Connecticut, Hudson, Penobscot, Delaware, St. John, Merrimack, and Androscoggin rivers are the largest in terms of mean annual discharge. During low-flow conditions, stream-flow values range from 10% to 15% of the long-term average flow during dry years.

Flooding occurs more or less annually throughout the region. Severe flooding results from hurricanes and from intense spring rainfall during rapid melting of large snowfall accumulations. The mean annual flood potential for a typical 780-km^2 (300-mi^2) watershed ranges from less than 141 m^3/s (5000 ft^3/s) to more than 226 m^3/s (8000 ft^3/s). Data describing observed peak flow with recurrence intervals from 2 to 100 years are presented for several loca-

tions in the region, and methods for estimating flood magnitude and frequency at ungaged stream locations are discussed.

In the northern part of the region, surface-water quality is characterized by low hardness (less than 60 mg/L hardness as $CaCO_3$) and low values of total dissolved solids (TDS) -- generally less than 120 mg/L. In the southern and western portions of the region, these values tend to increase due to the increased abundance of sedimentary rocks.

Ground water occurs in surficial deposits of primarily glacial origin, unconsolidated coastal plain sediments, consolidated sedimentary rocks, and crystalline igneous and metamorphic rocks. Unconsolidated deposits related to Pleistocene glaciation that are of hydrologic importance include unstratified drift (till), stratified drift (outwash), and lacustrine and marine sediments. Water yields from these types of deposits are variable from one location to another and depend on local geologic characteristics. Stratified drift deposits, usually associated with alluvium, are the best source of large quantities of water and are widely used for water supplies. It is not uncommon for wells to produce more than 63 L/s (1000 gal/m) from aquifers of this type. Comparatively small quantities of water can be obtained from the other types of glacial materials. The quality of water from surficial aquifers is generally good throughout most of the region. Concentrations of TDS are generally less than 200 mg/L, and the water is relatively soft.

Although coastal plain sediments are found in only a small portion of the region, they are among the more important aquifers. Because they contain thick units of largely permeable, unconsolidated sediments, large quantities of water can be produced from relatively shallow wells. Well yields in excess of 126 L/s (2000 gal/m) are not unusual.

Sedimentary rock aquifers range in age from Cambrian through Triassic, and the proportion of sedimentary rocks generally increases from north to south in the region. Hydrologic conditions are variable in these formations and do not appear to reflect a consistent regional pattern of variation. In general, limestones tend to be the most prolific sources of water, followed by sandstones and shales. Yields from individual wells approaching 126 L/s (2000 gal/m) are possible from some carbonates with extensive solution features. Well yields near 31.5 L/s (500 gal/m) have been recorded from sandstones at several locations, and some shales, often considered to be poor and unreliable sources of water, may provide more than 0.63 L/s (100 gal/m). A brief overview of the ground water availability and quality characteristics for each state is provided.

Crystalline rocks have low primary porosities and permeabilities. As a consequence, secondary porosities and permeability resulting from fracturing and weathering determine the capability of igneous intrusive and coarse-grained metamorphic rocks to store and transmit water. Undoubtedly, fracture characteristics are the dominant factors that determine ground-water conditions in crystalline rocks. Laboratory and field data for porosity and

hydraulic conductivity determined from crystalline rocks in many geographic areas indicate that porosity in this rock type generally ranges from 0.1% to 3%. Hydraulic conductivity ranges from 10^{-12}cm/s (0.4×10^{-12} in./s) to about 10^{-3}cm/s (0.4×10^{-3} in./s).

A number of studies indicate that the greatest concentration of fractures in crystalline rocks occurs in the upper 90-150 m (300-500 ft). Because of this condition, most ground-water wells in these rocks do not extend beyond this depth range. However, evidence exists that indicates that fractures can occur at much greater depths.

Well yield and other data are presented that illustrate the ground-water characteristics of crystalline rocks in each of the states in the northeastern region. These data demonstrate that even though individual wells usually yield small quantities (0.63 L/s [10 gal/m] or less), crystalline rocks are a significant source of good-quality ground water in the region, due to the large number and widespread distribution of wells completed in these rocks. Furthermore, under optimum local conditions, yields of a few tens of liters per second (several hundred gallons per minute) can be produced. However, almost no information is available to indicate ground-water conditions at depths greater than 150-300 m (500-1000 ft).

ECONOMIC GEOLOGY

Section 7 of this report provides detailed coverage of extractive industries in, or within 3.2 km (2 mi) of, crystalline rock bodies that have been or are being worked for constructional, monumental, and inscriptional granites; crushed granite; and associated trap rocks. Also covered in some detail are pegmatite bodies and minerals associated with mafic, ultramafic, and metamorphic rocks. Covered in considerably less detail are various commercial rocks and minerals of significantly less economic potential than those in the aforementioned categories. All of the active and inactive mines falling within the 3.2-km (2-mi) exclusionary radius are identified in Plates II-IX.

Extractive industries more than 3.2 km (2 mi) from the boundaries of the plutons considered in this report are of much less interest and are given minimal coverage. This 3.2-km (2-mi) distance conforms to the "preliminary exclusion radius" adopted by the Office of Crystalline Repository Development (OCRD). Minerals industries that are typically farther than this 3.2-km (2-mi) radius from any pluton are the limestone, peat, petroleum and, in most cases, the sand and gravel industries.

The commercial potential of the stone industry in the northeast is poor; only in rare instances could quarrying in plutons be considered an impediment to repository siting. Although data for 1977-1979 indicate a modest increase in total igneous rock mining in the northeastern United States, most of the increase can be attributed to mining of trap rock in the

five more southern states. Reactivation of building-stone quarries for crushed rock products may occur in rare instances, but abandoned sites are essentially uneconomic. The trend in the granite industry for the foreseeable future will be toward fewer operators, fewer quarries, smaller and more specialized markets, and marginal profits.

The prognosis for the pegmatite and gem-mining industries is also poor. The best mines have been exhausted, and the uneconomic ones have been abandoned. Also, with respect to repository siting, it should be noted that pegmatites of economic importance usually occur in schists beyond the boundaries of the granitic plutons, outside the 3.2-km exclusion radius.

Analysis of the commercial potential of mafic and ultramafic minerals can be summarized as follows. There is at present no mining of nickel ore in the region, and it is doubtful if commercial nickel mining will ever again become profitable in the northeast. Although the cobalt resources of Maine and Pennsylvania total nearly 90,720 t (100,000 tons), cobalt is not being mined because the ore is low-grade and cannot compete with cobalt mined elsewhere. It is doubtful that cobalt mining will ever become commercially feasible. Emery is mined only at Peekskill, N.Y. The Chester, Mass., deposits might be mined in the future if economic factors become favorable. Commercial deposits of iron ore consist largely of magnetite and occur in New York, New Jersey, and Pennsylvania. The MacIntyre mine at Lake Sanford, N.Y., is producing magnetite ore as a coproduct of titanium dioxide, but all other magnetite operations in the region are closed. Pennsylvania and New Jersey closed their last iron mines in 1977 and 1978. New discoveries of iron ore are very unlikely. There is no mining for chromite anywhere in the northeastern region today; known deposits are too small to pay even the development costs. Although asbestos mines and prospects occur in all states of the region except New Jersey and New Hampshire, a mine at Lowell, Vt., is the only significant producer.

Most metamorphic rocks and minerals of commercial interest occur beyond the 3.2-km (2-mi) exclusion radius. Slate is mined at Monson, Maine, and in a belt 40 km (25 mi) long around Poultney, Vt. The prognosis for the slate industry is poor. Commercial marble lies entirely outside areas of granitic plutons. It is mined for decorative stone in Vermont and for cement manufacture in the small "geologic marble" areas of Maine. The talc deposits mined in New York and Vermont follow the main belt of ultramafic rocks that runs from Massachusetts to Canada. Vermont leads the nation in talc production, and many abandoned talc mines occur in the northeast. New York is the principal garnet-producing state in the region. The Barton mines have nearly depleted deposits of garnet at Gore Mountain, but permission has been granted to open a mine at Ruby Mountain, where reserves are expected to last 25 yr. Garnet is also being mined near West Paris, Maine. Corundum is not mined in the region, although several states have deposits that are presently noncommercial. For graphite also, deposits exist but are not profitably exploitable at present. Wollastonite is found, in minor commercial quantities, only in Essex and Lewis counties, N.Y.

Other rock and mineral resources of the region have not been extensively evaluated because they do not occur within or near granitic rocks. Notable exceptions include copper, molybdenum, zinc, gold, manganese, uranium, lead, silver, and sulfur. Copper is found in a variety of host rocks in the northeastern United States, and the main occurrences are cataloged in this report. The last copper produced in the region was from the Douglas mine near Castine, Maine, which was closed in 1977. A major copper-zinc prospect has been discovered at Bald Mountain, Maine, but this body is far from any plutons. Although molybedenum resources occur in the region, none are of commercial interest. Zinc is economically the most important metallic resource in the northeast, and this report inventories the most significant deposits. Mines producing zinc in 1977-1979 were the Balmat mine, St. Lawrence County, N.Y.; the Franklin-Sterling Hill mine, Sussex County, N.J.; and those of the Lehigh District, Lehigh County, Penn. Gold is not produced in commercial quantities in the region. Subeconomic deposits of manganese are scattered throughout the region, all well away from crystalline rock bodies. The only uranium resources of possible economic interest are found in the somewhat uranium-enriched granites in New Hampshire, in metamorphic rocks in southern Vermont, and in sandstones in Vermont. However, none is commercially feasible to mine at present. Lead-silver and sulfur deposits in the region are small and of no commercial interest.

Nonmetallic, sedimentary materials that are not directly associated with crystalline rocks are considered only briefly in this report. Sand and gravel is the leading mineral commodity in the region. Nearly all significant mining operations of this type are at some distance from crystalline rock bodies. Lime is probably the third most important resource after sand and gravel and trap rock, but lime, also, occurs too far from crystalline rocks to be of concern.

Although a few minor exceptions are noted above, there is a waning dependence of states in the northeastern United States on local rock and mineral resources. Local extractive mineral industries, in most cases, should not be a critical consideration in further studies relating to the possible siting of a deep underground repository in a crystalline rock body in the region.

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This topical report reviews and analyzes available geologic information relating to crystalline rock areas in the northeastern United States. The study was undertaken to help evaluate the suitability of such areas for isolating high-level radioactive waste.

Crystalline rocks are defined here to include medium- and coarse-grained igneous and high-grade metamorphic rocks. The nine states of the northeastern region (Plate I) have numerous outcrops of crystalline rocks. The present study summarizes the geologic history of the region, and presents data on the seismotectonic environment, physiography and surficial deposits, surface processes, hydrology, and economic geology of the region's crystalline rock areas. A companion report (Harrison et al., 1983) deals with the size, shape, location, relative and absolute age, origin, petrography, structure, and geophysics of the many crystalline rock bodies of the region. A draft of these reports was used as a source for a separate report, a review draft of which was published by the Office of Crystalline Repository Development (1983a).

Preparation of the report involved no field work and relied mainly on published literature. Some supplemental information gathered from the public domain and from knowledgeable experts was incorporated to increase the comprehensiveness and utility of the report.

1.2 SPONSORSHIP

This work was sponsored by the U.S. Department of Energy (DOE) to provide background geological information for its Crystalline Rock Project (Office of Crystalline Repository Development, 1983b). The present report is being published on behalf of DOE as a multiple-use resource document of potential benefit to many users in government, academic institutions, and industries. As such, it represents a transfer to the public of knowledge gained through expenditure of public funds.

1.3 PLATES

Accompanying this report under separate cover are nine plates. Plate I shows the distribution of major crystalline rock bodies and faults in the northeastern United States. Plates II-IX, which were used to compile Plate I, show the distribution of crystalline rocks in Maine; New Hampshire; Vermont; northeastern New York (the Adirondack Mountains); Massachusetts; Rhode Island; Connecticut; and southeastern New York, northwestern New Jersey, and

southeastern Pennsylvania, respectively. In addition, Plates II-IX show the locations of major faults, active and inactive mines, and quarries.

All plates were prepared by the authors of this report from available published information, including the most recent versions of state geologic maps. Boundaries of crystalline rocks shown on state maps were modified, wherever possible, to reflect information obtained from more recent publications. Thus, crystalline-rock boundaries shown on the accompanying plates may not always correspond with those on previously published state geologic maps. Some of these boundaries remain controversial because of local overburden, inadequate field data, or conflicting geologic interpretations. Bedrock maps change over time as new information becomes available, as different geologists assume responsibility for compilations, and as guidelines for map compilation change.

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2 GEOLOGIC HISTORY

The Appalachian Mountains are a major geologic feature of great complexity along the eastern margin of North America. In the northeastern United States, this orogenic belt is predominantly a region of metamorphic and igneous rocks that formed in many stages over long periods of time in a tectonically active zone. Blocks of preexisting continental crust, thick sequences of sedimentary and volcanic rocks, magmatic intrusions, and fragments of sea floor have been important in the geologic history of this belt. Although it is much smaller in area than the Appalachian Mountains, the Adirondack region in northeastern New York has experienced an equally complex history.

The study region defined in this report includes the Adirondack region and the northern Appalachian Mountains, i.e., New England, northeastern and southeastern New York, northern New Jersey, and southeastern Pennsylvania. The region can be divided into the following tectonically distinct zones, proceeding from northwest to southeast (see Fig. 2.1).

1. Grenville Province. The Adirondack area in northeastern New York exposes rocks of Precambrian age that were intensely deformed and metamorphosed during the Grenville orogeny approximately 1100 million years (m.y.) ago. Rocks of comparable age that share this history are thought to underlie much of the western portion of the northeastern region. Their easternmost extent marks the boundary between continental and oceanic environments at the end of the Grenville episode.

2. Foreland Facies. To the south of the Adirondacks are sedimentary rocks typical of those formed from continental shelf deposits. The degree of deformation increases in intensity to the east.

3. Taconic Region. To the east of the foreland area are sequences of deformed and metamorphosed lower Paleozoic carbonate rocks. Also occurring in this zone are large masses of slates that were displaced westward over Cambrian to Middle Ordovician carbonates and shales. These detached rocks are transitional in character between a continental shelf facies and a more oceanic clastic sequence that includes volcanics.

4. Precambrian Massifs. Still farther to the east-southeast is a linear belt of discrete massifs of Precambrian basement rocks. The belt extends from northern New Jersey through southeastern New York, western Connecticut, and

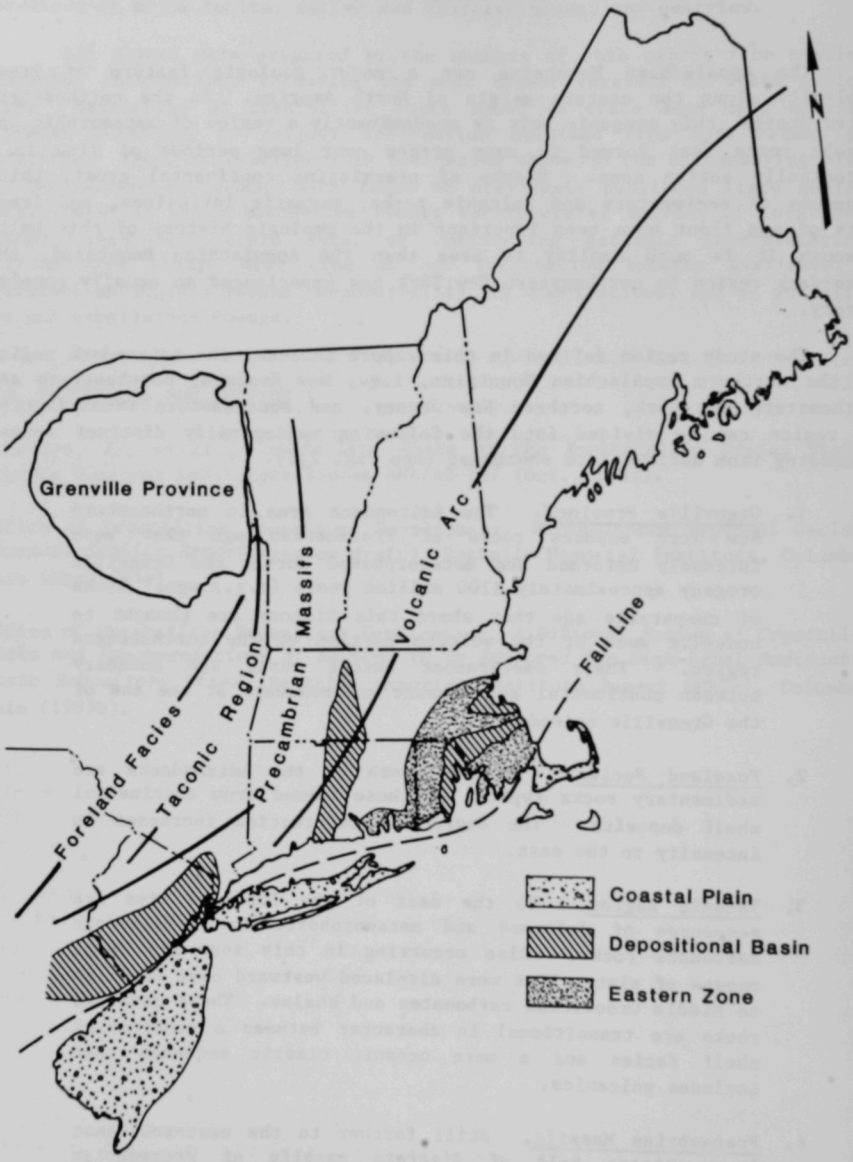

Fig. 2.1 Tectonic Zones of the Northeastern United States

Massachusetts to northern Vermont. These areas were once covered with lower Paleozoic formations and probably mark the boundary between predominantly carbonate deposits to the west and predominantly clastic deposits to the east.

5. Volcanic Arc. East of the massifs is a broad zone thought to contain the deeply eroded remnants of a volcanic arc system that contributed volcanics and clastics during the early Paleozoic, mainly to the west; that is, into the basin east of the continental shelf. This band has been intensely affected by several episodes of folding, igneous intrusion, and intense metamorphism.

6. Eastern Zone. Although the history of this zone is still somewhat enigmatic, the zone is now thought to be a strip of proto-African continent that was welded to North America during the Acadian orogeny in the Devonian period.

7. Depositional Basins. In the Carboniferous and Triassic-Jurassic periods, a relatively small number of fault-bounded basins developed; these basins received thick sequences of predominantly continental-type deposits.

8. Coastal Plain. Sediments were deposited along the eastern seaboard of the northeastern region in a Late Cretaceous sea. Remnants of these deposits occur on Staten Island and Long Island.

The zones that were folded and metamorphosed during the Paleozoic era tend to converge to the southwest. Because the grade of metamorphism also increases southwest along the strike of each belt, deeper and deeper crustal rocks are exposed in that direction.

The geology of the northeast has been the subject of intense study for many years. Considerable information is now being integrated into a comprehensive history of the region based on the unifying theory of plate tectonics. This theory suggests that the Adirondack region and Appalachian orogenic belt can be understood in terms of the opening, closing, and reopening of the Atlantic Ocean basin and predecessor basins.

2.1 PRECAMBRIAN

A wedge of sandstones, limestones, and shales accumulated in a continental shelf environment along the southeastern margin of the Canadian shield. These sediments were deeply buried and then subjected to severe

deformation and metamorphism at very high temperatures and pressures. This event, called the Grenville orogeny, likely occurred 1100-1200 m.y. ago. At this time, sequences of clastic sedimentary rocks and volcanics underwent partial melting to form magmas that were intruded upward into the metasedimentary rocks. Anorthosites and olivine gabbros are characteristic of these intrusives, but they also include charnockites, syenites, and granites.

Basement rocks of the Grenville province are exposed mainly in the Adirondack Mountains but also crop out where later orogenies have brought them closer to the surface. The Hudson Highlands, for example, is a northeasterly trending upland dated at 1100 m.y. This upland extends from southeastern Pennsylvania through northern New Jersey and southeastern New York into western Connecticut. The long straight valleys in the highly resistant metamorphic rocks are the result of erosion along faults.

Other outcrops of Grenville rocks, discussed in Secs. 2.3 and 2.4, played a role in the deformation that accompanied the three later orogenies affecting the region.

On the Canadian border north of Rangely, Maine, are basement rocks that have a minimum isotopic age of 1500 m.y. These Precambrian rocks are lithologically different from the Grenville province rocks mentioned earlier and may underlie much of northwestern Maine.

A belt of Precambrian rocks is exposed in coastal Maine and in eastern Massachusetts and Connecticut. There has been considerable controversy about these rocks, but most sources now describe them as "Avalonian" and agree that these exposures are part of the proto-African continent that was welded to the North American continent during the Acadian orogeny in the Devonian period. This eastern zone was left behind when the continental masses began to rift apart early in the Mesozoic era, thereby forming the modern Atlantic Ocean.

The rocks of the eastern zone are a heterogeneous sequence of largely eugeosynclinal deposits, terrigenous clastics, and volcanics. The sequence was subsequently faulted, weakly metamorphosed, and intruded locally by granodiorite about 540-600 m.y. ago. The belt then formed a continental platform on which sediments were deposited that became basal conglomerates and sandstones, grading upward into shales, algal limestones, and oolitic iron ores.

2.2 LATE PRECAMBRIAN THROUGH EARLY ORDOVICIAN

Following the Grenville orogeny, and as the proto-Atlantic Ocean basin began to open in the late Precambrian, a continental shelf was gradually built eastward. The thick sequences of sediments were typical of miogeosynclinal deposition, and field studies indicate marine transgression. Rocks formed from these deposits include sandstones of Early Cambrian age, mixed shales and

limestones of Middle Cambrian age, and limestones of Late Cambrian and Early Ordovician age.

To the east of the predominantly carbonate section, there was a gradual transition to a pelitic-to-clastic sequence, formed in deeper water, that coarsened and thickened to the east. Interbedded with the clastic sediments were great thicknesses of volcanic deposits, indicating the presence of a volcanic arc further to the east. Volcanic activity reached a climax in Early-Middle Ordovician time. The boundary between the continental shelf further west and the trough developing just to the west of the volcanic arc may mark the then edge of the North American continent. In other words, the crust was oceanic in character to the east of this boundary.

In the area considered to contain the roots of the volcanic arc, exposures consist of tonalite and amphibolite intruded into by granodiorite and granite. The section to the east of the arc is relatively thin with far less volcanic material. Paleozoic faunas and paleomagnetic pole positions strongly support this interpretation. This history also is compatible with the general tenets of plate tectonic theory, which suggest development of a subduction zone along the eastern edge of the northeastern region.

2.3 MIDDLE ORDOVICIAN THROUGH EARLY DEVONIAN

The first events of the Taconic orogeny occurred at the beginning of the Middle Ordovician. Block faulting caused fragmentation of the carbonate shelf at the same time as the developing subduction zone caused an uplift on the continental side of the volcanic arc. Sediments derived from this uplift were deposited as unconformable syntectonic flysch deposits that graded westward into shales. Although a period of faulting and uplift also is recorded in the Adirondacks area, seas completely covered northern New York by Middle Ordovician time.

Continued uplift to the east of the Adirondacks resulted in westward transport of slices of eugeosynclinal sediments over continental shelf sediments of Cambrian to Middle Ordovician age. Later thrusts and nappe structures involved crystalline rocks, including Precambrian gneisses. Although there are no present-day exposures of ocean-floor rocks in the displaced masses themselves, the presence in New York and further west of sand grains containing ocean-floor minerals indicates that oceanic rocks were thrust westward at this time. These events were accompanied by folding and regional metamorphism at great depths.

Both felsic and ultramafic bodies were intruded during the Taconic orogeny. The ultramafics occur in a continuous belt from western Connecticut and Massachusetts through Vermont and into Quebec (see Plate I). There is a second belt in northernmost New Hampshire and western Maine. These rock units include dunite, peridotite, pyroxenite, serpentinite, and talc-carbonate. Some of these have been interpreted as having been derived from oceanic crust.

Granitic intrusives of Ordovician age belong to the Oliverian series. This series is found principally along the volcanic arc, which now forms the Bronson Hill anticline and its extension into Maine. Rock types include quartz diorite, granodiorite, quartz monzonite, syenite, and granite, all of which show weak to strong tectonic fabrics.

Following the events of the Taconic orogeny, deltaic and coastal plain deposits were built across northern New York. Angular unconformities occur between Ordovician and Silurian rocks throughout most of the northeastern region. The highland areas created by the Taconic orogeny were eroded steadily until, by the beginning of the Early Silurian, a sea covered most of the geosynclinal area and probably the Adirondack region. Volcanism was still important, especially in coastal Maine. Thick sequences of Silurian and Early Devonian clastic sediments were deposited in a wide belt extending through central New England.

In Late Silurian-Early Devonian time, a minor tectonic event took place within the eugeosyncline in central Maine, an event that involved folding and erosion. This anomaly illustrates that individual events of a particular type did not occur simultaneously along the Appalachian orogenic belt, even though the broad outline of events was essentially similar. It is also true that the same pattern of events can be clear in certain areas but difficult to discern in other areas. For example, one of two parallel zones may be far narrower, having experienced a higher degree of deformation and, as is often the case, a more complex sequence of folding events. Although there is general agreement that the Taconic orogeny closed the oceanic basin between the Precambrian continental mass and the volcanic arc, the detailed history of the rocks sandwiched in between is still being worked out.

2.4 MIDDLE DEVONIAN THROUGH LATE DEVONIAN

The Acadian orogeny of the Devonian period had major repercussions throughout the northeast. The entire area was subjected to intensive compressive forces caused by the final closing of the proto-Atlantic Ocean basin. A collision occurred between a major continental mass (likely a proto-African continent) and the Grenville province rocks, the sedimentary series that were deformed during the Taconic orogeny, the volcanic arc belt, and the thinner sediments just to the east of the arc. Rocks were thrust north and west against the more rigid craton. The mostly felsic volcanics of Silurian-Devonian age in northwestern Maine were generated by partial melting of crust as a result of this collision. Isotopic dates obtained from both metamorphic and intrusive rocks of this period average 350-400 m.y. There were few effects from this orogeny in the central and southern Appalachians.

Major intrusions of granitic rocks occurred during this time interval, and the activity continued into the Mississippian period in some areas. Prominent among these intrusions are those belonging to the syntectonic New Hampshire plutonic series, which occur to the east of the Bronson Hill

anticline but west of the eastern (Avalonian) zone (see Fig. 2.1). These plutons form blocklike bodies or large sheets and consist of coarse to very coarse-grained granodiorite, quartz monzonite, and granite. A posttectonic group of plutons also has been identified in eastern Massachusetts, in northeastern Vermont, in northern and extreme southeastern New Hampshire, and in central areas of Maine as well as along its coast. This posttectonic plutonic series spans the entire range of intrusive rock types -- ultramafics, gabbros, norites, granodiorites, monzonites, and granites. These plutons were emplaced into previously metamorphosed rocks and appear to have been differentiated at depth and intruded as individual bodies of distinct composition.

The earliest Devonian structural features were recumbent folds and associated thrusts, many of which now face west. In central Massachusetts and in Connecticut, however, west-facing recumbent folds were refolded so that some of them now face east. Some recumbent folds were refolded into upright, isoclinal folds. The overall pattern that developed was of a series of anticlinoria and synclinoria, where the different styles of deformation depended on whether there were major differences in rheological properties in the thick sequences being folded.

The crustal shortening effected in the region during the Taconic and Acadian orogenies required enormous compressive forces. Plate tectonics provides a theory, which explains the generation of forces of those magnitudes by postulating that the earth's surface is separated into approximately a dozen large plates that shift and move with respect to each other, possibly in response to convection currents below the crust. The movements of plates result in the drift and gradual accretion of continental masses accompanied by the creation, growth, and demise of ocean basins.

2.5 MISSISSIPPIAN THROUGH PERMIAN

In the Mississippian period, scattered locations in the northeastern United States experienced regional faulting, which created basins with alternating marine and nonmarine deposition. The most well-known and best-preserved of these is the Narragansett basin in Rhode Island, which developed in an intermontane environment and which contains a mostly nonmarine sequence with minor coal measures and volcanics. The Worcester basin in Massachusetts, small areas in east-central Maine, and a minor relict coal basin near Pelham Bay in New York also appear to be Carboniferous basins of this general type. Representative rocks of this facies are red and gray conglomerates, red and gray sandstones and shales, and coal beds. Although the faults are basically block faults, there is evidence in a few cases of some lateral movement.

The last episode of mountain building in the central and southern Appalachians occurred during late Paleozoic time. Only the southern part of New England was affected by this Alleghenian orogeny. Additional folding is recorded in southeastern New York. Also, Carboniferous rocks in Rhode Island were metamorphosed to sillimanite grade, which transformed the coal in the

Narragansett basin to graphite. The areal extent of this metamorphism is uncertain, but evidence for regional metamorphism of this age has been reported in Massachusetts and Connecticut.

The metamorphosed Pennsylvanian rocks of Rhode Island were intruded by posttectonic granite, and other small intrusions thought to be late Paleozoic in age have been identified in the region.

2.6 MESOZOIC AND CENOZOIC ERAS

During the Triassic period, a system of basins bordered by normal faults developed in the general area of the present shoreline. These basins are evidence that tensional forces began to rift apart the two continental masses, an event that marked the earliest beginnings of the modern Atlantic Ocean.

By this time, the original Appalachian Mountains had been eroded to a land of low relief. Sediments that were later transformed into red conglomerates, sandstones, and shales were deposited in down-faulted blocks in west-central Massachusetts, central Connecticut, and central New Jersey. The large grain size of many of these sedimentary rocks suggests that the source areas exhibited considerable relief. The relief was apparently maintained by subsidence of the basins and/or continued uplift. The continental deposits were intruded by basaltic magmas to form dikes, sills, and pipes. Some of these magmas were extruded on the surface as flows. Because these igneous rocks are relatively more resistant than the surrounding sedimentary rocks, they stand out as hills and ridges. A thick Jurassic sedimentary sequence, now the target for petroleum exploration, underlies the present continental shelf. During the Mesozoic era, many plutons were intruded, principally in New Hampshire but also in Vermont and Maine.

The zone of rifting caused by the opening of the Atlantic Ocean basin occurred somewhat to the east of the original Acadian suture, resulting in rocks being left behind that had been part of the proto-African continental mass. These rocks now form the eastern zone of the northeastern region and crop out in east-central Maine along the coast, in eastern Massachusetts, in the eastern third of Connecticut, and in Rhode Island.

During the Cretaceous, some of the Triassic-Jurassic basin structures (now submerged) and the east coast generally were inundated by a sea, and unconsolidated marine gravels, sands, silts, and clays were deposited. In the northeastern region, this coastal plain is now submerged, except for scattered areas that include southern New Jersey, Long Island, Block Island, Martha's Vineyard, and Nantucket.

Either extensive erosion and later post-Permian uplift has created the present landscape, or the physiography is the result of continuous erosion since Permian time. It has certainly been affected by continental glaciation

during the Pleistocene. The last major advance of the ice sheet extended to Long Island at a time when the island was part of the Connecticut mainland. A veneer of glacial sediments, consisting of clay, sand, gravel, and till, covers much of the northeastern United States.

Although continental glaciation was responsible for the basic landscape in the Adirondacks area, valley glaciers shaped many of the details of that landscape after the last ice sheet retreated about 14,000 yr ago. The most recent uplift of this area may have begun as little as 5 m.y. ago. At the center of the Adirondacks domal uplift, the rate of rise is now 3 mm/yr (0.12 in./yr), which is many times the average rate of erosion. This presents the interesting anomaly of a geologically youthful surface superimposed on ancient rocks.

The Atlantic Ocean is continuing to open, with new oceanic crust being formed along the Atlantic Ridge, and sediments are accumulating in continental shelf environments along the eastern fringes of the North American continent.

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3 SEISMOTECTONIC ENVIRONMENT

3.1 SEISMICITY OF THE NORTHEASTERN UNITED STATES

3.1.1 Need for Evaluation

This study integrates and summarizes the relevant published research relating to the seismicity of the northeastern United States. The most recent seismological studies are emphasized, and an effort is made to assess the quality of the results and interpretations of the sources. An understanding of the relationships between regional seismicity and structure is required to determine the sizes and locations of earthquakes expected to occur in a region and to see if estimates of potential surface faulting are needed. Where these relationships are unknown, the potential for future seismic activity is best assessed by studying and extrapolating from the seismic record.

3.1.2 Nature of the Historical Record

Numerous investigators have published catalogs of the seismicity of the northeastern United States and southeastern Canada. Most often cited are those of Brigham (1871), Godfrey and Mather (1927), Heck and Eppley (1958), Brooks (1960), Smith (1962 and 1966), Coffman and von Hake (1973), Weston Geophysical Research, Inc. (1977), and Chiburis (1981). The later catalogs generally rely on historical data published in earlier catalogs. Newspapers, letters, diaries, books, and published articles were sources for the compilers of the earlier catalogs. Of the more recent catalogs, those of Weston Geophysical Research, Inc. (1977) and Chiburis (1981) contain systematic corrections of the earlier data, based on reevaluation of the original sources. The first seismographs were installed in the northeastern region in 1925.

While the latest catalogs (cf. Chiburis, 1981) contain the most complete seismic history that can be obtained for the region, the accuracy of the data is far from certain. Several biases exist because of the sources of information used. In the first place, gradual expansion of the population away from the first settlements along the eastern coast introduces a spatial inhomogeneity in the data. Using a scheme for temporal development of the population distribution in New England, Weston Geophysical Research, Inc. (1977) concluded that spatial bias in reported earthquakes existed through the 1700s. Also, the haphazard manner in which seismic events were recorded led to uncertainties as to the date, time, and sometimes even the existence of some of the earthquakes. This is particularly true of written reports from secondhand sources or from records written many years after the earthquakes took place. For example, Brigham (1871) reported large seismic events from central Connecticut on May 16, 1791, and May 18, 1791, while Smith (1962) and

Weston Geophysical Research, Inc. (1977) concluded that there was only one large earthquake, a shock that took place on May 16. The May 18 event is ascribed to inaccurate newspaper reports. Errors in newspaper dispatches seem to be an especially common problem with the entire data set (Weston Geophysical Research, Inc., 1977).

There are two other problems in using the historical record to determine macroseismic parameters, such as maximum intensity and total "felt area," that is, the total area over which the shock can be felt. First, the limits of the felt area cannot be determined accurately from the original sources. In general, it has been assumed that if there was no "felt report" (i.e., a report of date, location, and any damage done or how the shock felt) from a locality, the shock was not felt there (Weston Geophysical Research, Inc., 1977). As minor events may have gone unreported, the felt areas of some events are probably underestimated. Second, it is often difficult to judge the maximum epicentral intensity from the original reports. Early sources tend to give very general descriptions of damage, and the effects of the shaking may be exaggerated. There is also some uncertainty as to the kind of building materials used and the related damage.

The accuracy of the historical record is also a function of time and size of event. Chiburis (1981) estimated that the catalog of events with maximum intensities between III and VII is essentially complete after 1725. However, given that the population probably did not fill the region until about 1780 (Weston Geophysical Research, Inc., 1977), this estimate may be somewhat optimistic. Nonetheless, the historical record is probably the most complete for the largest events. The accuracy of the location of events in the various catalogs was estimated by Smith (1962) and by Chinnery and Rogers (1973) to be, at best, about 20 km (12 mi). For the oldest events and especially for earthquakes possibly originating from offshore, the location error is much larger. A complete and updated version of Chiburis's (1981) catalog of earthquakes of the northeast is given in the appendix.

3.1.3 Distribution of Seismicity

Several maps of the historical seismicity of the northeastern United States have been published (Smith, 1962; Weston Geophysical Research, Inc., 1977; and Chiburis, 1981). Because these maps were drawn from the same data base, they show essentially the same spatial distribution of seismicity. Figure 3.1 is the map of Chiburis (1981), which includes modern instrumental data through the year 1977. Plotting of the estimated maximum epicenters on this map (1,990 events) was randomized with up to 0.03° variations from the listed coordinates to avoid artificial alignments due to the 0.1° precision of the geographic locations. The locations throughout Chiburis's catalog are generally no more accurate than 0.03°, and most are much less accurate. Thus, such a randomized plot (Fig. 3.1) does not affect accuracy of location. Intensities of events with only reports of magnitude were derived from a

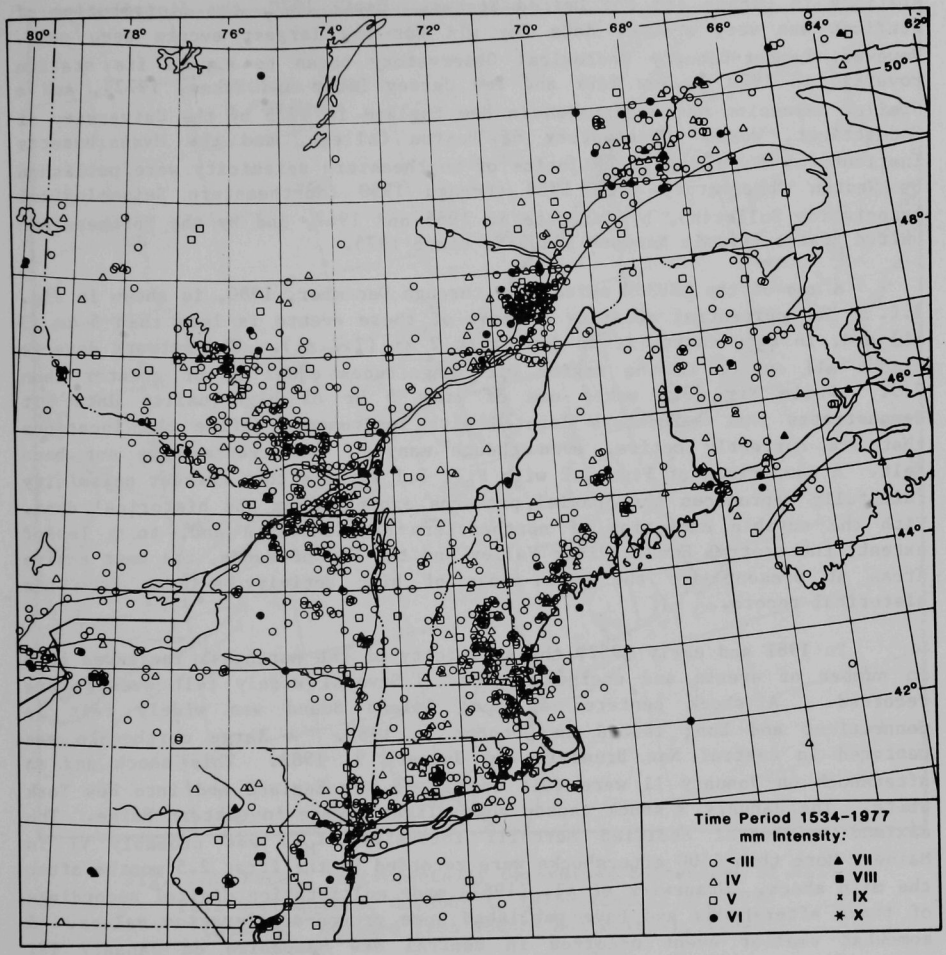


Fig. 3.1 Historical Seismicity of the Northeastern United States and Southeastern Canada, 1534-1977 (Source: Adapted from Chiburis, 1981)

magnitude-intensity relation described in Sec. 3.1.4. Figure 3.1 shows that there are regions of more intense seismicity, namely the La Malbaie region of Canada northwest of Maine, northeastern Massachusetts, central New Hampshire, central Connecticut, southeastern New York, and a broad area extending from northern New York northwest into Ontario. Smaller clusters dot coastal and central Maine.

Since 1925, earthquake data have been recorded by seismographic stations in Canada and the United States. Until 1970, the distribution of stations was very sparse; data for all but the largest events were poor. However, Lamont-Doherty Geological Observatory began to expand its station coverage in 1970 in New York and New Jersey (Sbar and Sykes, 1977), and a similar expansion was undertaken in New England in 1975 by the University of Connecticut, Weston Observatory of Boston College, and the Massachusetts Institute of Technology. Bulletins of northeastern seismicity were published by Weston Observatory from 1938 through 1950 (Northeastern Seismological Association Bulletin), by Turcotte in 1966 and 1967, and by the Northeastern United States Seismic Network (NEUSSN) since 1975.

A map of the NEUSSN epicenters through December, 1980, is shown in Fig. 3.2. The epicentral accuracy of most of these events is less than 5 km (3 mi) and, in many cases, it is less than 2 km (1.2 mi). The network detects almost all events in the region with magnitudes equal to or greater than 2.0. While Fig. 3.2 makes use of only 5 yr of high-quality data, it demonstrates that epicenters located with instruments define the locations that are currently active, even though many of the events have not been felt. A comparison of Fig. 3.2 with Fig. 3.1 reveals that current seismicity faithfully reproduces the spatial patterns exhibited by the historical data. With the notable exception of northeastern Massachusetts and, to a lesser extent, the central Hudson River Valley and the Bay of Fundy, the most active areas at present are the same areas of high activity evident from the historical record.

In 1981 and early 1982, the seismicity of the northeast increased both in number of events and energy released. Several widely felt events were recorded. A shock centered in Long Island Sound was widely felt in Connecticut and Long Island on October 2, 1981. A large earthquake was centered in central New Brunswick on January 9, 1982. This shock and an aftershock on January 11 were felt in all of New England and into New York State. The January 9 shock caused some slight damage in eastern Maine. The maximum epicentral Modified Mercalli intensity (I_{MM}) was probably VI in Maine. More than 1500 aftershocks were recorded in the first 2.5 months after the main shock. Granswick et al. (1982) made multistation digital recordings of these aftershocks and have published some ground-acceleration values. A somewhat smaller event occurred in central New Hampshire on January 19, 1982. This earthquake had an I_{MM} between V and VI. The event was felt at distances up to about 320 km (200 mi) from the epicenter.

Because there are pockets of seismic activity scattered all through the region, there appear to be only a few areas that are more than 50 km (30 mi) from any earthquake epicenter. Central New York appears relatively free of activity, as do northeastern Vermont, northwestern New Hampshire, and west-central Maine. Although central Vermont appears relatively aseismic in the historical record, it has had several events during the 5-yr period of Fig. 3.2. Conversely, central Massachusetts, which has been quiet recently (see

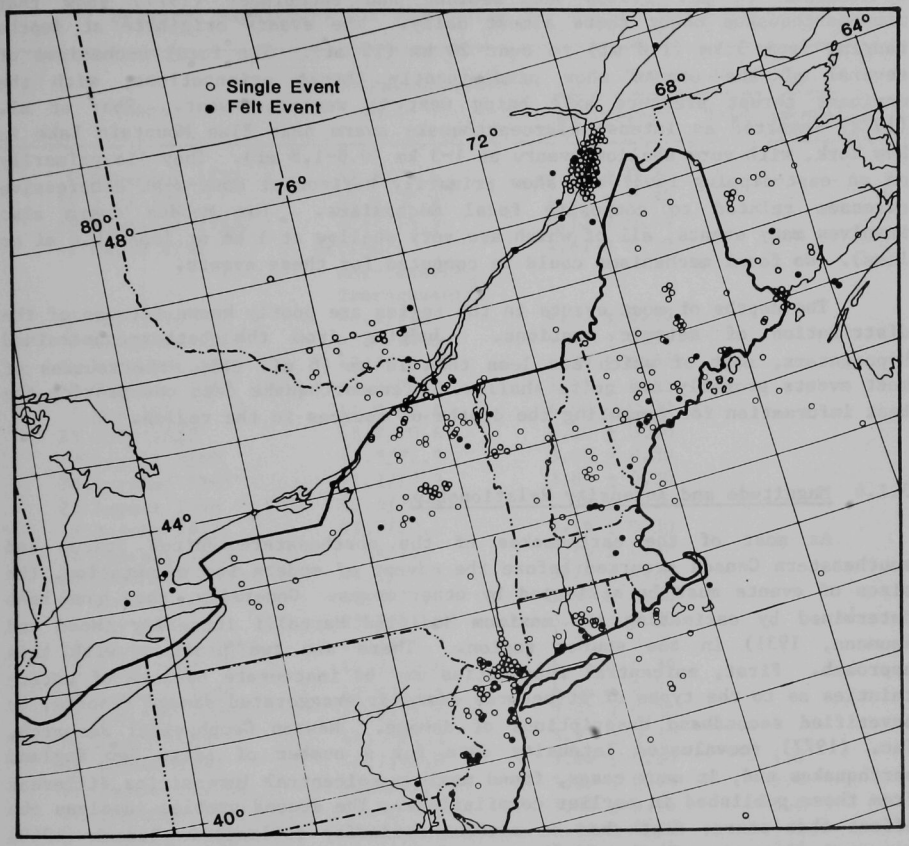


Fig. 3.2 Recent Instrumentally Determined Epicenters of All Felt Earthquakes, October 1, 1975-December 31, 1980 (Source: Adapted from NEUSSN Bulletin 21, 1980)

Fig. 3.2), has experienced some small felt shocks historically, primarily in the area of the Connecticut River valley (see Fig. 3.1).

Microearthquake detection networks in the northeast show that some areas are quite active today. Three locations where microearthquakes occur in large numbers are the La Malbaie area in Canada (Leblanc et al., 1973; Leblanc and Buchbinder, 1977; and Stevens, 1980), the central Adirondack Mountain area in New York (Sbar et al., 1972; and Aggarwal et al., 1975), and the Moodus area in central Connecticut (Ebel, 1982b). Surveys of the La Malbaie region

by Leblanc et al. (1973) and Leblanc and Buchbinder (1977) show that microearthquakes occur there almost daily. The events originate at depths ranging from 3 km (1.8 mi) to over 20 km (12 mi). The focal mechanisms of several of the events show predominantly thrust orientations, with the dominant thrust pressure axis being west to west-northwest. Sbar et al. (1972) reported an intense microearthquake swarm near Blue Mountain Lake in New York, with very shallow events at 1-3 km (0.6-1.8 mi). They lie primarily on an east-dipping fault and show primarily horizontal east-west compressive stresses related to composite focal mechanisms. The Moodus swarm also involves many events, all of which are very shallow at 1 km or less (0.6 mi or less). No focal mechanisms could be computed for these events.

The depths of most events in the region are poorly known because of the distribution of seismic stations. Judging from the better-constrained hypocenters, most of which are less than 10 km (6 mi) deep, the sources of most events probably are quite shallow. Microearthquake data now provide the best information for computing the depths of sources in the region.

3.1.4 Magnitude and Intensity Relationship

As most of the earthquakes of the northeastern United States and southeastern Canada occurred before the advent of modern instrumentation, the sizes of events must be estimated by other means. Generally, they have been determined by estimating the maximum Modified Mercalli intensity (Wood and Neumann, 1931) in the source region. There are two problems with this approach. First, epicentral intensities may be inaccurate because of uncertainties as to the types of structures damaged, exaggerated damage reports, or unverified secondhand descriptions of damage. Weston Geophysical Research, Inc. (1977) reevaluated intensity data for a number of large New England earthquakes and, in many cases, found maximum epicentral intensities different from those published in earlier compilations. The second problem involves the effect that source depth has on maximum intensity estimates. Barosh (1969) reported that the shallower the earthquake hypocenter, the larger is the maximum intensity for an earthquake of a given magnitude. As earthquake depths are totally unknown for the historical events and are only poorly known for recent data from all except a few areas, there is an added uncertainty in determining the size of events from the historical record.

Several studies have addressed methods of determining magnitudes from both noninstrumental and instrumental data. Street and LaCroix (1979) proposed using the area inside the intensity-IV contour to determine an equivalent earthquake magnitude for historical data. Their results for some large New England earthquakes are given in Table 3.1. The most serious drawback to their approach is the inherent arbitrariness in drawing the intensity-IV contour. Nevertheless, their work has provided some reasonable numbers for the magnitudes of older events.

Table 3.1 Dates, Approximate Locations, and Estimated and Instrumentally Measured Magnitudes for Some Large New England Earthquakes

Date	Epicentral Location (N°/W°)	Magnitude (M_{bLg}) Estimated[a]	Instrumental
9 November 1727	42.8/70.6	4.96 ± 0.30	
14 June 1744	42.5/70.9	4.71 ± 0.30	
18 November 1755	42.7/70.3	6.02 ± 0.15	
11 March 1761	Offshore northeastern Massachusetts	4.61 ± 0.30	
16 May 1791	41.5/72.5	4.35 ± 0.30	
9 November 1810	43.0/70.8	4.01 ± 0.30	
28 November 1814	43.7/70.3	4.29 ± 0.30	
5 October 1817	42.5/71.2	4.33 ± 0.25	
5 May 1821	44.8/68.8	4.00 ± 0.30	
23 July 1823	42.9/70.6	4.10 ± 0.30	
9 August 1840	41.5/72.9	3.80 ± 0.30	
26 October 1845	41.2/73.3	3.87 ± 0.30	
25 August 1846	42.5/70.8	4.30 ± 0.30	
8 August 1847	41.7/70.1	4.16 ± 0.30	
16 January 1855	44/71	4.15 ± 0.30	
23 December 1857	44.1/70.2	3.78 ± 0.30	
23 November 1884	43.2/71.7	3.81 ± 0.30	
1 May 1891	43.2/71.6	3.81 ± 0.30	
25 September 1897	44.7/68.7	4.27 ± 0.30	
15 July 1905	44.2/70.0	4.54 ± 0.30	
7 January 1925	42.6/70.6	4.06 ± 0.25	
9 October 1925	43.7/71.1	3.95 ± 0.30	
25 April 1928	44.5/71.2	3.91 ± 0.30	
22 August 1938	44.7/68.8	3.86 ± 0.30	4.0
20 December 1940	43.8/71.3	5.27 ± 0.15	5.4
24 December 1940	43.8/71.3	5.27 ± 0.15	5.4
14 January 1943	45.3/69.6	4.64 ± 0.30	4.4
28 December 1947	45.2/69.2	3.90 ± 0.30	4.3
5 October 1949	44.8/70.5	4.26 ± 0.30	4.5
26 April 1957	43.6/69.8	4.66 ± 0.30	4.8
10 April 1962	44.1/73.4	4.38 ± 0.25	4.1
16 October 1963	42.5/70.8	3.95 ± 0.30	3.7
26 June 1964	43.3/71.9	3.90 ± 0.30	2.9
9 January 1982	47.0/66.5		5.5[b]
9 January 1982	47.0/66.5		4.8[b]
11 January 1982	47.0/66.5		5.2[b]
19 January 1982	43.5/71.6		4.4[b]

[a]The magnitude is determined from the amplitude of 1-Hz Lg waves. It is calibrated against m_b and is appropriate for the central United States (Nuttli, 1973).

[b]M_L values.

Sources: Street and LaCroix (1979); M_L values from Ebel (1982a).

Table 3.2 Types of Magnitude Measurements for Eastern U.S. Earthquakes

Magnitude	Description
m_b	The magnitude of the earthquake is determined from teleseismic short-period body waves and calibrated against the M_L scale in southern California (Gutenberg, 1945a and 1945b).
M_L	The magnitude is determined from short-period surface waves using Wood-Anderson instruments and is appropriate for southern California earthquakes (Richter, 1935). This was the first magnitude scale to be used. A revision of this scale, which calibrates northeastern U.S. magnitudes to those from southern California, was introduced by Ebel (1982b).
M_{bLg}	The magnitude is determined from the amplitude of 1-Hz Lg waves. This scale is calibrated against m_b and is appropriate for the central United States (Nuttli, 1973).
M_N	This is the magnitude reported by NEUSSN for northeastern U.S. earthquakes; it is found by applying the M_{bLg} scale to the amplitude of 5-10-Hz Lg waves. Correct calibration to M_{bLg} is assumed.
M_c	The magnitude is determined from the duration of the coda for an event. This measure is calibrated to M_N; scales were introduced by Rosario (1979) and Chaplin et al. (1980) for the northeastern region.
M	This is most often an unspecified local magnitude and is usually assumed to be reasonably well calibrated against M_L and m_b.

For modern instrumental data, magnitudes are usually determined using the formula derived by Nuttli (1973) for 1-Hz Lg waves in the central United States. This magnitude is referred to in the literature as M_{bLg} or M_N. Rosario (1979) and Chaplin et al. (1980) derived coda magnitude scales (M_c) that were calibrated against the M_N values reported by Weston Observatory for New England earthquakes. Descriptions of the different kinds of magnitude measurements used in the central and eastern United States are given in Table 3.2. In their paper on the spectra of earthquakes of various sizes for the central and eastern United States, Street and Herrmann (1976) analyzed the relationship between the corner period, moment, and magnitude of the event. They stated that the method of applying the Nuttli formula to 5- to 10-Hz

waves as is routinely done in the northeastern United States tends to give a distorted magnitude value. They suggested that M_N values for events in the central and eastern United States may overestimate the true M_{bLg} magnitude by about 0.3. Ebel (1982b) computed magnitudes for over 100 earthquakes in the northeastern United States and southeastern Canada using a modification of the Richter (1935) magnitude scale (M_L) appropriate for New England and found that the New England M_N values overestimate the M_L values by about 0.4. He concluded that the modified Richter (1935) formula allows northeastern United States and southeastern Canada earthquake magnitudes to be calibrated directly against those from southern California. Street and Turcotte (1977) reported on the relationships among magnitudes, intensities, and moments for some larger earthquakes of the northeast.

The relationship between maximum epicentral intensity and earthquake magnitude has been explored for New England by Chinnery and Rogers (1973) and Chiburis (1981). Chinnery and Rogers plotted data from the Smith (1962) catalog and found that the relationship between magnitude M and intensity I_{MM} is $M = 1.2 + 0.6\ I_{MM}$. Chiburis (1981) also plotted magnitude versus intensity for 134 events from his catalog (see Fig. 3.3). The least-squares lines were calculated from the entire data set and from the average magnitude at each intensity level. From a regression analysis of the data, he found that $M = 1.17 + 0.55\ I_{MM}$; by finding an average magnitude for each intensity and fitting a straight line through the average-intensity points, he found $M = 1 + 0.6\ I_{MM}$. These relations are close to the relationship $M = 1 + 2/3\ I_{MM}$, which was determined by Gutenberg and Richter (1956) using data from many regions.

3.1.5 Recurrence Relationships

Recurrence relations and mean return times for earthquakes in the northeastern region have been analyzed. Chinnery and Rogers (1973) used the Smith (1962 and 1966) catalog for southern New England and computed the recurrence relation $\log N_c = 4.00 - 0.57\ I_{MM}$, where N_c is the number of events with intensity greater than or equal to I_{MM}. Using their relation $M = 1.2 + 0.6\ I_{MM}$, $\log N_c = 5.15 - 0.95\ M$. Shakal and Toksoz (1977) took a different approach with the Smith (1962 and 1966) data. They selected the maximum event in each 5-yr time interval between 1725 and 1975 and computed mean return times using the extreme-value method (see Table 3.3).

Pulli (1983) also calculated recurrence times for the Boston-New Hampshire area from the historic data set through 1975. His recurrence relations are $\log N_c/yr = 1.539 - 0.498\ I_{MM}$ for intensity data and $\log N_c/yr = 2.369 - 0.830\ M_b$ for the data when the events are assigned magnitudes based on their epicentral intensities. For the instrumental data since 1975, Pulli (1983) found $\log N_c/yr = 2.142 - 0.829\ M_b$ to be the body wave magnitude. Return times based on Pulli's intensity-recurrence relation are given in Table 3.3.

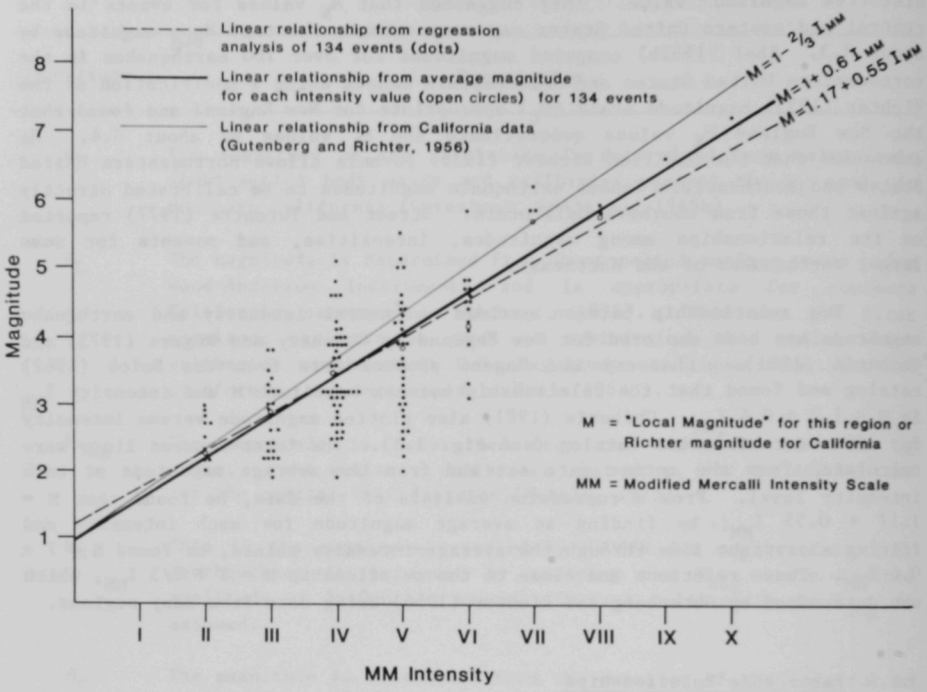


Fig. 3.3 Magnitude Versus Intensity of 134 Earthquakes in the Northeast (Sources: Gutenberg and Richter, 1956; Chiburis, 1981)

Ebel (1983) determined a recurrence curve for the instrumental data in New England since 1975 (without aftershocks or multiple events). His curve is $\log N_c/yr = 2.87 - 0.84\ M_c$ where M_c is the coda magnitude of Rosario (1979). Return times based on this data set are given in Table 3.3. It should be noted that the area covered by the Ebel (1983) studies includes not only all of New England but also up to 100 km from the New England coast.

Chiburis (1981) computed the following recurrence relationship from his data set: $\log N_c/yr = 2.908 - 0.42\ I_{MM}$ and $\log N_c/yr = 3.623 - 0.715\ M$. He then recomputed recurrence curves for the northeastern United States only, excluding La Malbaie, and found $\log N_c/yr = 2.284 - 0.484\ I_{MM}$ ($\log N_c/yr = 3.091 - 0.807\ M$). For the La Malbaie area, he found $\log N_c/yr = 2.755 - 0.417\ I_{MM}$ ($\log N_c/yr = 3.45 - 0.695\ M$). Finally, he computed mean return times for each intensity by averaging the time intervals between shocks (see Table 3.3).

Table 3.3 Mean Return Times for Earthquakes with Intensities VI-X

Location	Area (km^2)[a]	Return Time (yr) VI	VII	VIII	IX	X	Source
Southern New England	38,710	--	--	180	700	2,500	Chinnery and Rogers (1973)
Boston and New Hampshire	29,460	--	--	360	1,400	5,000	Chinnery and Rogers (1973)
Boston and New Hampshire	29,460	28	88	278	876	--	Pulli (1983)
Southern New England (1725-1974)	97,000	25	55	130	--	--	Shakal and Toksoz (1977)
Boston and New Hampshire (1725-1974)	39,500	30	65	140	--	--	Shakal and Toksoz (1977)
NE U.S.	--	0.6	1.5	53	1,923	70,000	Chiburis (1981)
La Malbaie area	--	4.2	13	39	118	360	Chiburis (1981)
Ramapo fault	--	--	300	1,050	--	--	Aggarwal and Sykes (1978)
New England (1975-1982)	250,500	10	31	98	312	994	Ebel (1984)

[a] 1 km^2 = 0.386 mi^2.

Aggarwal and Sykes (1978) discussed the earthquake statistics of the Ramapo fault zone in southeastern New York and gave a recurrence relation of $\log N_c = 1.70 - 0.73\ m_b$. They also estimated mean return times for large events (see Table 3.3). Recurrence rates of New England earthquakes of intensity VIII seem to be roughly 200 yr but are on the order of a few thousand years for earthquakes of intensity IX. Return times for the Ramapo fault system are much longer.

3.1.6 Regionalization

Because earthquakes do not occur randomly throughout the region but cluster in a few areas, some investigators have attempted to map the active areas. Devine and Hadley (1974) delineated the broad-scale active regions in the eastern United States by counting the number of events in all 1° by 1°

rectangles in the region and then contouring the values. Barosh (1978) mapped the active areas by contouring areas with many events visually. Chiburis (1981) used a weighted-averages scheme of Caputo (1974) to spatially filter the seismicity map to enhance areas of high activity. A map of the results of this last process is shown in Fig. 3.4. The shaded regions show the percentage of seismic activity relative to that of the La Malbaie region. The number beside each area shows the percentage of the total number of events in the catalog that have taken place there. The filtering was done at a sufficiently fine scale so that structures 0.6° apart can be resolved. Areas of high activity are approximately the same as those of Barosh (1978). However, if events after 1925 only are used (see Fig. 3.5), some areas (e.g., eastern Massachusetts) appear much less active. If one compares Figs. 3.4 and 3.5 to Fig. 3.2, it becomes evident that the areas of high seismicity found in the regionalization analysis are the same ones that are seismically active today.

3.1.7 Variation of Seismicity with Time

There is some evidence that the level of seismic activity in New England varies as a function of time. In studying the Smith (1962 and 1966) catalog, Chinnery and Rogers (1973) noted that the seismicity of eastern Massachusetts seems to have quieted significantly since the late 1700s, while the activity in central New Hampshire has increased during that same period. Because of the uncertain quality of the data, they questioned whether this is a real effect. Shakal and Toksoz (1977) presented two arguments in support of the seismic activity in southern New England being nonstationary in time. They plotted the total number of events and seismic energy release against time and found that each quantity was much greater from 1725 through 1824 than from 1825 through 1924. They also showed statistically that the activity from 1725 through 1849 occurred at a higher rate than that exhibited since 1849. However, it appears that their analysis included aftershocks of the large events, which may bias their data somewhat. Street and LaCroix (1979) raised the point that Shakal and Toksoz (1977) overestimated the energy of several of the events during the 1700s. Therefore, the first point of Shakal and Toksoz seems open to question.

Chiburis (1981) plotted the time distribution of the larger events (I_{MM} = VI or greater) and of all the events in his entire catalog area (northeastern United States and southeastern Canada) and found three abnormal increases in activity: in 1845, 1925, and 1974. He attributed these to increases in population or instrument density and not to actual changes in the earthquake occurrence rate. Thus, although the historical catalogs seem to show an earthquake process that is not uniform over time, the nonuniformity may be an artifact of the data.

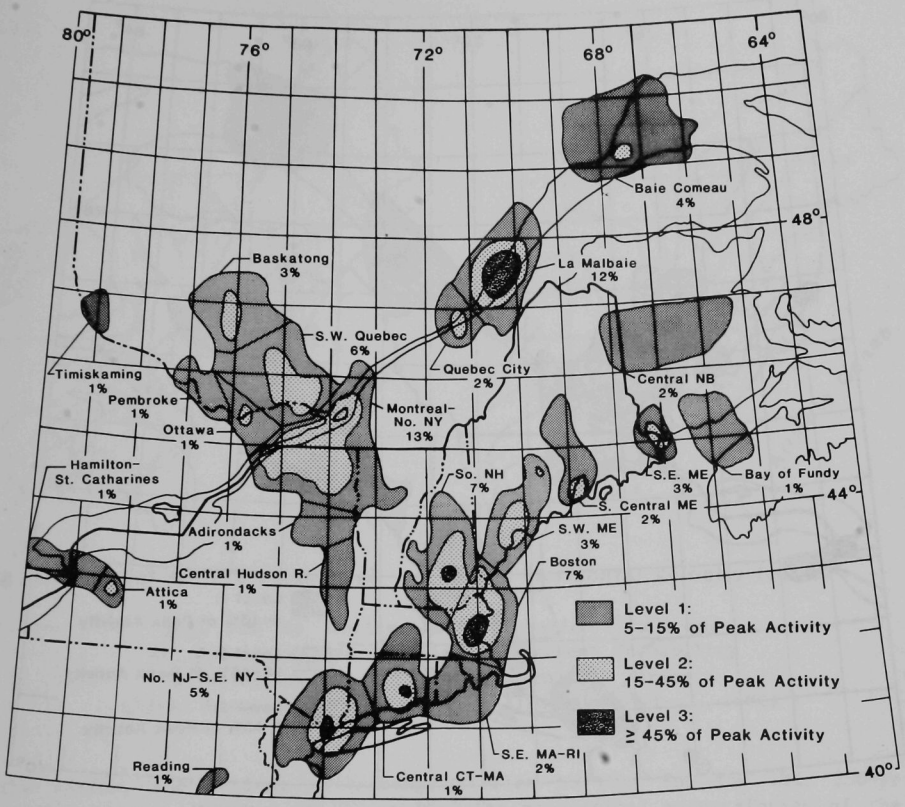


Fig. 3.4 Contour Map of Relative Seismic Activity in the Northeast, 1534-1977 (Source: Adapted from Chiburis, 1981)

3.1.8 Maximum Expectable Horizontal Accelerations

Using the data contained in the seismic catalogs for the entire United States, Algermissen et al. (1982) studied the probabilities of occurrence of particular maximum values of ground acceleration. In their analysis, they correlated peak intensity values with horizontal ground acceleration on hard rock sites and took into account in each region the repeat time for large earthquakes. They produced a series of national maps showing contours of the

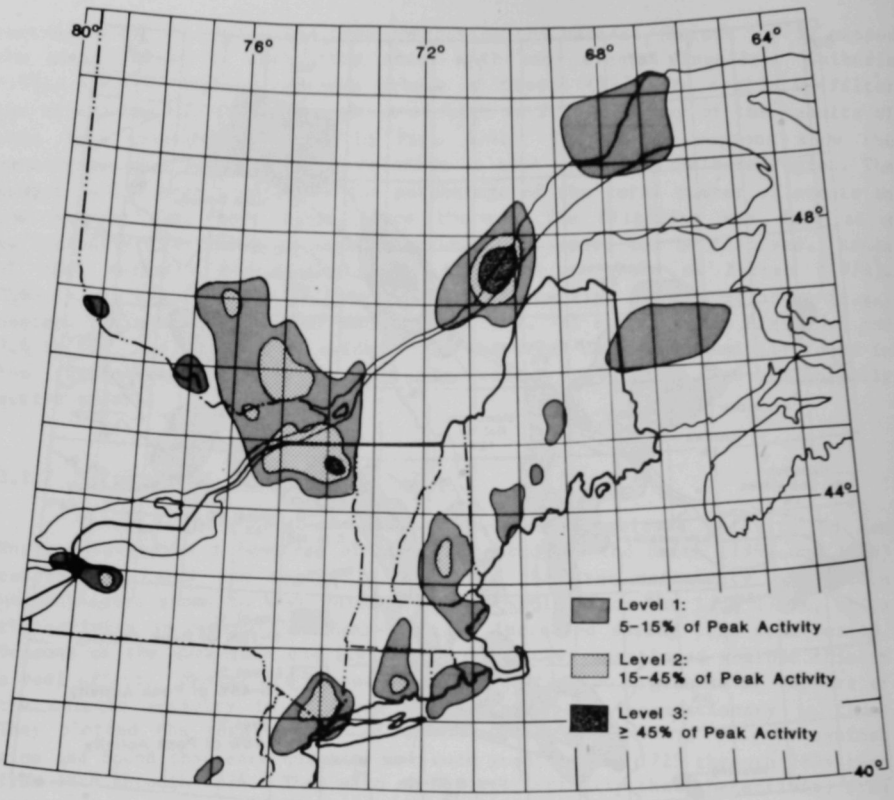
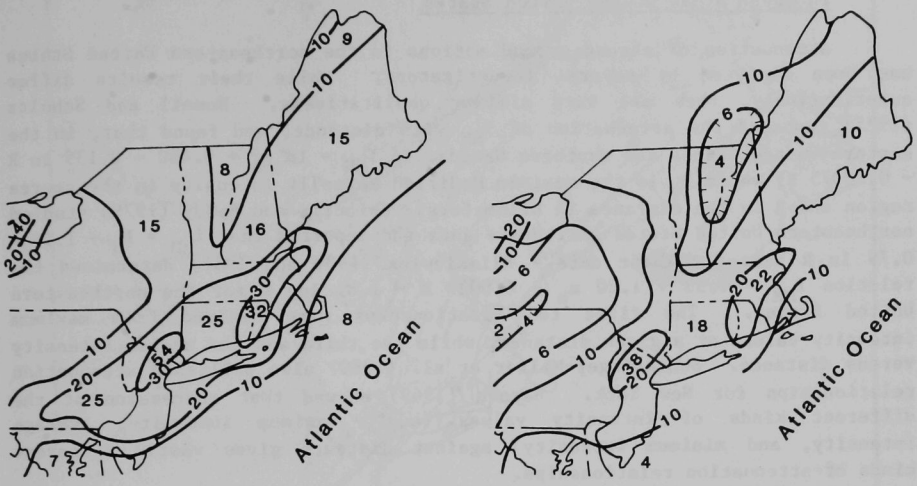


Fig. 3.5 Contour Map of Relative Seismic Activity in the Northeast, 1925-1977 (Source: Adapted from Chiburis, 1981)

horizontal accelerations and velocities in rock that have a 90% probability of not being exceeded in 10, 50, and 250 yr. Their contours that have a 10% probability of being exceeded in 250 yr are shown in Fig. 3.6. The range of the 10%, 250-yr accelerations in the region is from 0.05 to 0.54 g (49 to 530 cm/s^2), and the corresponding horizontal velocity range is from 2 to 38 cm/s (Fig. 3.6 a and b, respectively).

If one ignores the time factor and merely asks what the maximum horizontal ground acceleration would be from the largest possible earthquake in



a. Horizontal acceleration (%g) b. Horizontal velocity (cm/s)

Fig. 3.6 A: Horizontal Acceleration (% g); and
B: Velocity (cm/s), with a Ten-Percent Probability
of Being Exceeded in Northeastern Rock during a
250-yr Exposure Period (Source: Algermissen et al. 1982)

the region, one arrives at a range similar to that for the 10%, 250-yr accelerations. McGuire (1977) studied the statistical uncertainties of the catalog of earthquakes for the entire eastern United States and showed that the probability of the largest possible event having already been observed in any single area is 25-40%. Chinnery (1979) reported that there is no reason to believe that the largest possible event has indeed occurred in New England. Trifunac and Brady (1975a) and Murphy and O'Brien (1977) analyzed the correlation of peak ground acceleration a_H with maximum epicentral intensity for large numbers of events. The Trifunac and Brady (1975a) relationships for hard-rock sites (log aH = 0.014 + 0.030 I_{MM}, which gives slightly higher acceleration values than the Murphy and O'Brien relation) suggest that the peak acceleration for an I_{MM} = IX event in New England would be about 0.51 g (500 cm/s^2). For an I_{MM} = X event in La Malbaie, it would be about 1.02 g (1000 cm/s^2). Trifunac and Brady (1975b) also found a relationship between acceleration duration and maximum source intensity. For an I_{MM} = IX event, the duration of strong ground motion should be about 5.7 s.

3.1.9 Comparison of Ground Motion Attenuation with Values in Other Areas of the United States

Attenuation of strong ground motions in the northeastern United States has been analyzed by several investigators; while their results differ quantitatively, they are very similar qualitatively. Howell and Schultz (1975) compared the attenuation of I_{MM} with distance, and found that, in the eastern United States and southern Canada, $\ln I_{MM} = \ln I_o + 0.480 - 0.139 \ln R - 0.00075 R$, where I_o is the maximum Modified Mercalli intensity in the source region and R is the distance in kilometers. Chiburis and Reddy (1979) studied northeastern United States earthquake data and reported that $I_{MM} = I_o + 1.25 - 0.79 \ln R$ best fit their data. Klimkiewicz (1980 and 1981) determined the relation $I_{MM} = 2.53 + 1.20\ m_b - 0.0027\ R - 1.84 \log R$ for the northeastern United States. The first two relationships were derived from maximum intensity values at a given distance, while the third was for median intensity versus distance. Schlesinger-Miller et al. (1980) also published attenuation relationships for New York. Barosh (1969) showed that regression of the different kinds of intensity values (e.g., maximum intensity, average intensity, and minimum intensity) against distance gives vastly different kinds of attenuation relationships.

Howell and Schultz (1975) reported that attenuation of intensities in the northeastern United States is much less than in the Cordilleran or San Andreas regions. However, Street (1976) studied the attenuation of 1-Hz Lg waves in the northeastern United States and demonstrated that their attenuation is greater than that found for the central part of the country. He also showed that, for a given magnitude, earthquakes in the East are felt over a smaller area than those in the Midwest. To summarize, while attenuation in the Northeast is much less than that in the West, it is somewhat greater than that in the Midwest.

3.1.10 Focal Mechanisms and Stress

Focal mechanisms, which have been computed for a large number of events in the northeastern region, give some clue as to the present state of stress in the crust and the causes of present seismicity. However, the focal mechanisms in the region that have been computed are for relatively small events. In many cases, therefore, the focal mechanisms are very poorly resolved. Because uncertainties in near-focus crustal structure and source depth also contribute to uncertainties in the data, focal mechanism solutions must be examined carefully.

Fault-plane solutions for New England were studied by Graham and Chiburis (1980). Although they presented 18 focal mechanisms for events throughout all of New England, only six of them had enough high-quality readings so that a unique fault-plane solution (or range of fault-plane solutions) could be resolved. Focal mechanisms for the New York-New Jersey area have been published by Aggarwal and Sykes (1978), Sbar and Sykes (1973

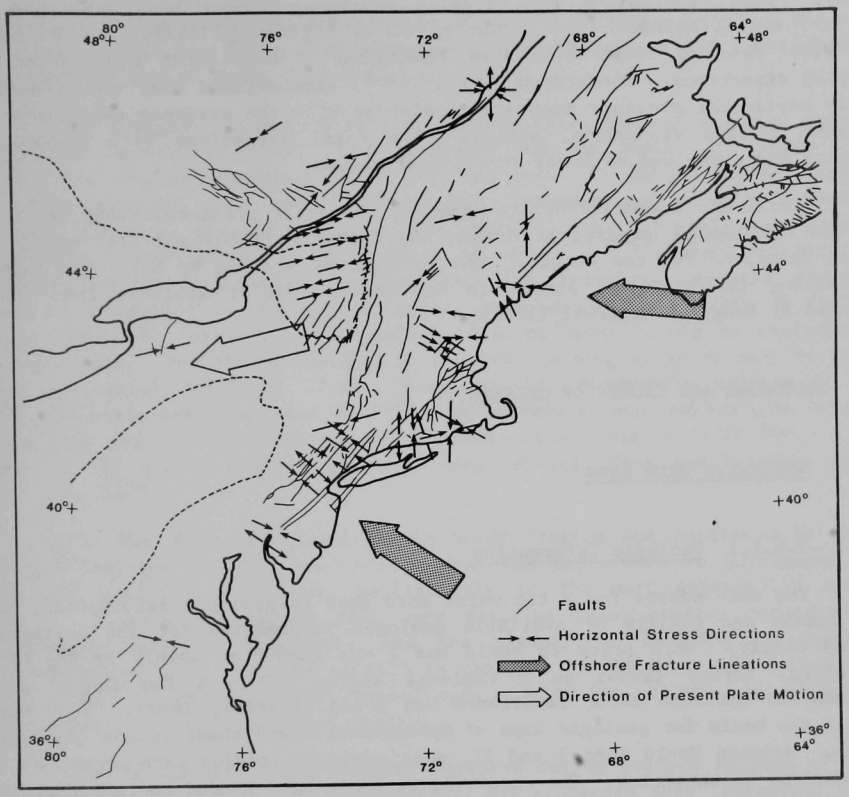


Fig. 3.7 Principal Horizontal Stress Directions, Offshore Fracture Lineations, and Present Plate Motion (Source: Adapted from Yang and Aggarwal, 1981)

and 1977), and Sbar et al. (1972). Yang and Aggarwal (1981) attempted to synthesize all available data on focal mechanisms and stress in the northeastern United States and adjacent Canada. The quality of some of the data cannot be assessed, because the first motions have not been published.

In general, the pressure axes for all of the data are horizontal and trend from east-northeast to west-northwest (see Fig. 3.7). The directions shown in the figure are from in situ stress measurements and from published focal mechanisms. The stippled arrows show the trends of offshore fracture lineations; the open arrow indicates the direction of present plate motion. A few earthquakes with predominantly horizontal tension also have been found in New York and New England (Sbar and Sykes, 1973 and 1977; Graham and Chiburis,

1980). Focal mechanisms for Canadian earthquakes have been published by Leblanc and Buchbinder (1977), Horner et al. (1978 and 1979), and Herrmann (1979). Most of these also show predominantly horizontal compression in varying directions. Richardson et al. (1979) demonstrated that the predominantly horizontal pressure axes are consistent with the stresses expected from present motions of crustal plates. The focal mechanisms with horizontal tension are explained as local stress aberrations.

Pulli and Toksoz (1981) re-examined the fault plane solutions for five of the earthquakes studied by Graham and Chiburis (1980) and also presented three solutions for new events. The conclusions reached by Pulli and Toksoz concerning the state of stress in New England differ somewhat from those reached by Yang and Aggarwal (1981).

3.2 TECTONICS AND CAUSES OF SEISMICITY

3.2.1 Tectonics Data Base

3.2.1.1 Geologic Information

The main source for a tectonics data base is geologic information, but the amount and quality of available geologic information for the northeast varies widely. Work prior to World War I was conducted mainly by the U.S. Geological Survey (USGS) on a regional scale. Only a few faults were delineated, although their importance was noted (Russell, 1892). Such work formed the basis for geologic maps of Massachusetts and Rhode Island (Emerson, 1917). Between World Wars I and II, most geologic studies were sponsored by New England universities. The resulting geologic maps tended to interpret the regional geology in terms of metamorphic processes and ductile deformation, with little attention paid to stratigraphy, brittle-fracture deformation, and recent tectonics. Such interpretations were used to construct the state geologic maps of Vermont (Doll et al., 1961), New Hampshire (Billings, 1955), Maine (Doyle et al., 1967), and Connecticut (Rodgers et al., 1956). This work was of very limited practical application for investigating the causes of seismicity.

Soon after the end of World War II, USGS began an extensive program of geologic mapping of 7.5-min quadrangles at a scale of 1:24,000. Cooperative programs between the states and USGS were initiated to map the entire states of Massachusetts, Rhode Island, and Connecticut, as well as selected areas in New Hampshire, Vermont, and Maine. In the early stages, emphasis was again placed on petrology, geochemistry, and metamorphic processes, with little or no attention being paid to faults or joints. Pleistocene surficial deposits also were mapped on a quadrangle basis, but the effort was largely separate from the bedrock work. As a result, the possibility that bedrock faults might

offset surficial deposits and provide evidence of Pleistocene or Holocene tectonic disturbance was seldom addressed. One product of this period was a new geologic map of Rhode Island (Quinn, 1971).

The intensive highway expansion program after the war resulted in many extensive bedrock road cuts that exposed numerous small- and large-scale faults not easily recognized in natural outcrop. At the same time, similar fracture patterns were recognized through increased use of aerial photos, Landsat imagery, and aeromagnetic and gravity data. Finally, as mapping progressed, much greater understanding of structural features was obtained through increased information about the stratigraphy. As the geologic quadrangle mapping became more detailed, progressively more data on faults, particularly in eastern Massachusetts and Connecticut, could be included in bedrock maps. Because of changes in the USGS mapping program, many of these maps are still in draft form. Most geologic quadrangle mapping at the 1:24,000 scale was phased out by 1975, and subsequent mapping has been largely in aid of regional compilations of 2° sheets at a scale of 1:250,000. A few maps of the entire region have been compiled (cf. King and Beikman, 1974; Williams, 1978).

The New England Seismotectonic Study Program was initiated in July, 1976. Geologic mapping for this program was undertaken to supplement the existing geologic data base, particularly in the most seismically active areas. Mapping has varied from very detailed local studies conducted to understand geologic structures and the history of faulting to regional reconnaissance work designed to fill in the gaps in the available information on regional structures. Also, consultants working for utility companies have undertaken some local detailed studies.

The recognition of structural features during bedrock mapping of most of New York, New Jersey, and Pennsylvania has proceeded more logically, i.e., work has progressed from reconnaissance to gradually more detailed studies of structures, with control provided by stratigraphic studies. The soon-to-be-released map of Pennsylvania contains much new information on faults. However, large areas, particularly in the Adirondack Mountains, are covered only by reconnaissance mapping.

3.2.1.2 Remote Sensing Information

Remote sensing techniques are especially important in New England because crystalline basement rocks are at or near the surface in much of the region. Structures in the basement rocks were etched out and emphasized by continental glaciation. Although these structures are often mantled by a thin veneer of till and glacial outwash, they usually are well expressed in the topography.

Air photo and Landsat data have been used to interpret much of the more recent geologic and geophysical data, but few separate remote sensing studies

have been made. Such studies can contribute greatly to an understanding of bedrock structure, especially when used in conjunction with geologic and geophysical data. General Landsat studies have been made of lineaments in New York (Isachsen, 1976; Isachsen and McKendree, 1977); Pennsylvania (Gold and Parizek, 1979); Pennsylvania and New York (Podwysocki, 1979; Podwysocki et al., 1979); Delaware, New Jersey, and eastern Pennsylvania (A.M. Thompson, 1978, 1979, and 1980); and Vermont (Jones, 1979). Preliminary studies have been conducted for Maine (Carter, 1978). Local areas, such as in eastern Pennsylvania (Canich and Gold, 1979), southwestern Connecticut (Barosh and Pease, 1981), central Maine (Barosh, 1981b), and eastern Maine (Gates, 1979) also have been studied. Much of this work could be greatly improved by using the new, enhanced, 1:250,000-scale Landsat images. Although early experimental side-looking radar has been used to good advantage by Banks (1974), such modern radar mapping is not now available for New England.

Remote sensing may reveal a great variety of features, but most of the prominent lineaments in much of the northeastern United States appear to represent geologic structures. Thus, the images can be used to plan geologic investigations. All of the prominent lineaments that have been investigated in New England have proved to represent fault traces, and most known major faults that have been mapped on the ground are represented, at least in part, by lineaments.

Modern Landsat mapping can serve as a geologic base map, if lineaments are drawn from careful observation. Such a sensitively drawn lineament map can then provide a probable fracture pattern for an area prior to any ground investigation. However, statistical treatments of lineaments appear to be of limited value, as are maps depicting the lineaments as arrays of rigid, straight-line segments.

3.2.1.3 Seismic Profiling Studies

Seismic reflection and refraction studies have been of limited value in discerning geologic structures within the crystalline rocks of the northeastern region because of the similar seismic velocities in igneous and metamorphic rocks. Seismic profiling studies are useful for locating (1) interfaces between bedrock and unconsolidated overburden, (2) possible offsets of these interfaces, and (3) possible offsets of structures within the unmetamorphosed rock and unconsolidated sediments in the region.

Shipboard seismic studies have been very useful because continuous profiles can be made. Several shipboard seismic studies have revealed faults, including the New Shoreham fault, which cuts Cretaceous rock south of Block Island, R.I. (McMaster, 1971); faults of post-Pennsylvanian age extending into and offshore of Narragansett Bay (Collins and McMaster, 1978; McMaster and Collins, 1978; and McMaster et al., 1980); faults bounding the Triassic-Jurassic basins offshore of New England (Ballard and Uchupi, 1975); and a number of other faults that cut offshore Mesozoic rocks (Grow, 1981a).

Seismic profiles obtained in a preliminary survey of Lake Champlain suggested offsets of Pleistocene strata by reactivated bedrock faults (Hunt and Dowling, 1981); more detailed work appears to confirm this (Hunt, 1981). However, similar suggestions concerning offsets of sediments in Lake George, N.Y. (Isachsen and Wold, 1977) were not confirmed (Isachsen, 1981a). A search for displacements in sediments in Long Island Sound offshore of the Triassic-Jurassic Hartford graben is still in progress (Dowling, 1981). Finally, considerable new seismic data are being acquired farther offshore in the search for oil and gas. These data are providing new insights on types and extent of post-Paleozoic faults (Grow, 1981a).

3.2.1.4 Aeromagnetic Studies

Aeromagnetic maps (see Fig. 3.8) have proven very useful tools in mapping the geology of the crystalline rocks of the northeastern United States (Barosh and Pease, 1974; Alvord et al., 1976; Barosh, 1976c; and Barosh et al., 1977b). A complete set of aeromagnetic quadrangle maps of southern New England has been published by the USGS at a scale of 1:24,000. Such maps also are available for scattered areas in northern New England, New York (especially in southeastern New York and in the Adirondack region), and parts of Pennsylvania. A regional map at 1:250,000 scale for southern New England (Harwood and Zeitz, 1976) and one at 1:125,000 scale for Connecticut (Zeitz et al., 1974) are available. A regional map is in preparation for New York State at a scale of 1:250,000 (Isachsen, 1981), and reconnaissance maps are available for northern New England (Zeitz et al., 1972), most of New Jersey (U.S. Geol. Survey, 1979), and the offshore area in the Gulf of Maine (Kane et al., 1972). A series of recent maps by USGS covers the offshore area south and east of Long Island and southeastern New England. In addition, a good regional map that covers a broad area extending from Cape Cod Bay into southern New Hampshire was prepared for studies relating to the Pilgrim Unit 2 nuclear power plant.

Local marine surveys exist for Narragansett Bay (Collins and McMaster, 1978), offshore Rhode Island (McMaster and Collins, 1978), offshore Cape Ann (Weston Geophysical Research, Inc., 1976), offshore northeastern Maine (Malloy and Harbison, 1966), and coastal Long Island Sound (Dowling, 1981). A ground magnetic survey of southern Rhode Island has been prepared by Frohlich (1978). A recent aeromagnetic map compilation of the entire Appalachian region, at a scale of 1:1,000,000, covers all but the western margin of the northeastern United States (Zeitz et al., 1980).

Most major and minor faults are well expressed as lineaments on the aeromagnetic map of southern New England, and extensions of these faults generally can be traced beneath the surficial cover by following extensions of

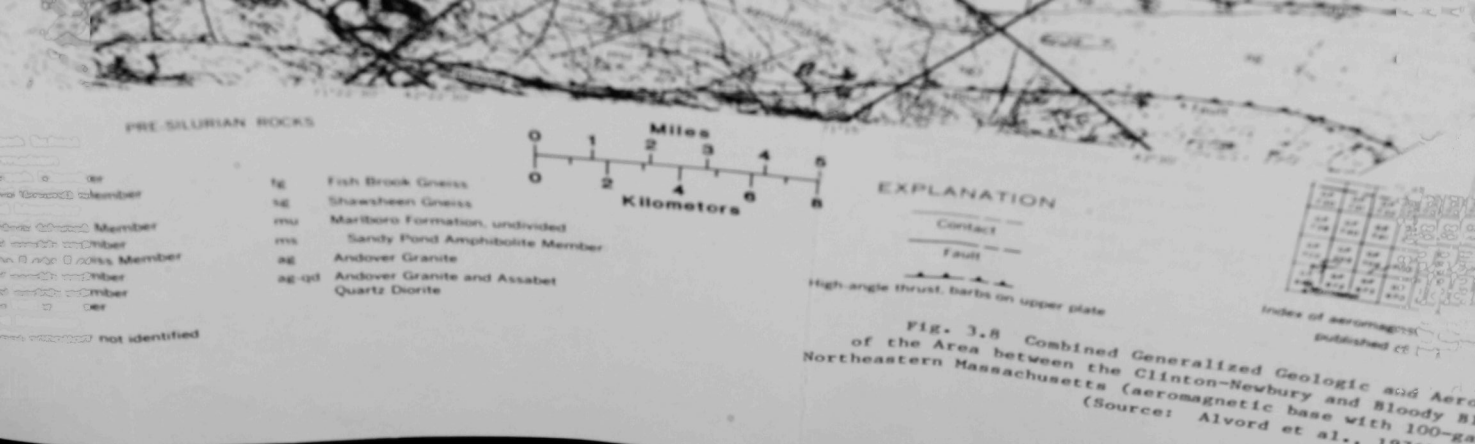
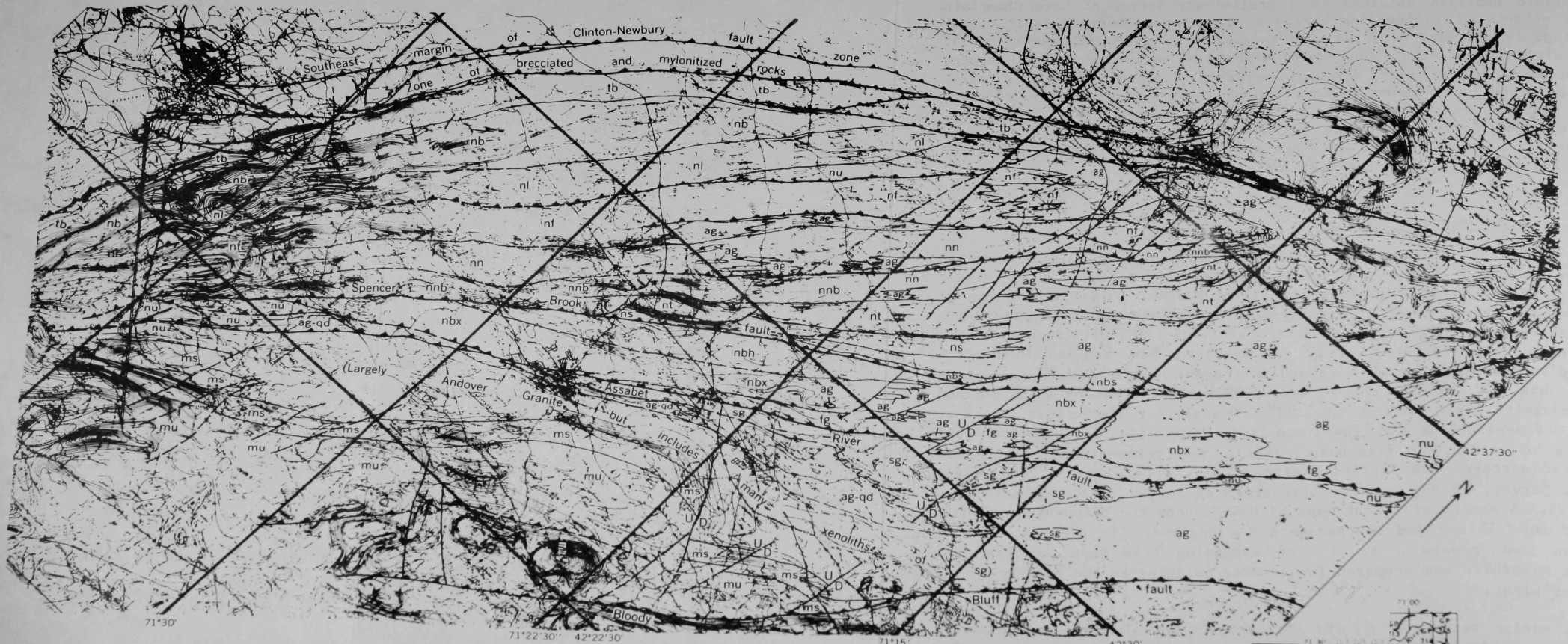


Fig. 3.8 Combined Generalized Geologic and Aero
of the Area between the Clinton-Newbury and Bloody Bl
Northeastern Massachusetts (aeromagnetic base with 100-ga
(Source: Alvord et al., 1976)



PRE-SILURIAN ROCKS

- tb Tadmuck [illegible] nist
- Nashoba [illegible]
- nb Beaver [illegible] mber
- nl Long P[illegible] s Member
- nf Fort Po[illegible] r
- nn Nagog P[illegible] ss Member
- nnb Nashoba [illegible] ember
- nt Tophet S[illegible] eiss Member
- ns Spencer [illegible] mber
- nbs Billerica [illegible] mber
- nbh Bellows Hill Member
- nbx Boxford Member
- nu Nashoba, member not identified

- fg Fish Brook Gneiss
- sg Shawsheen Gneiss
- mu Marlboro Formation, undivided
- ms Sandy Pond Amphibolite Member
- ag Andover Granite
- ag-qd Andover Granite and Assabet Quartz Diorite

Miles: 0 1 2 3 4 5
Kilometers: 0 2 4 6 8

EXPLANATION

Contact

Fault

High-angle thrust, barbs on upper plate

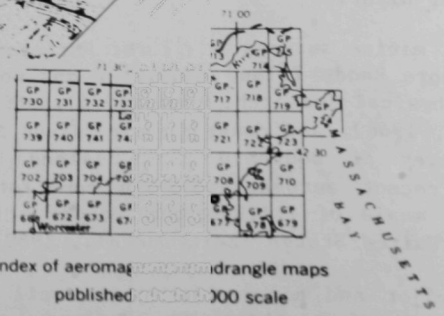


Fig. 3.8 Combined Generalized Geologic and Aeromagnetic Map of the Area between the Clinton-Newbury and Bloody Bluff Fault Zones, Northeastern Massachusetts (aeromagnetic base with 100-gamma contour interval) (Source: Alvord et al., 1976)

the lineaments. When investigated in the field, many magnetic discontinuities have proved to represent fault traces. Examples of this have occurred in central Maine (Barosh, in press), along the Northern Fall Line (A.M. Thompson, 1981), in the Moodus area of Connecticut (London et al., 1981), and in southwestern Connecticut (Tillman, 1980; Barosh and Pease, 1981). The position of aeromagnetic lineaments can be refined by use of ground magnetic surveys (Schwab and Frohlich, 1979).

A series of aeromagnetic studies in southern New England by USGS personnel in 1971-1972 was compiled into a regional lineament map of southern New England (Barosh, 1976c; Barosh et al., 1977b), and a similar map is being prepared for New York State (Isachsen, 1981). The area along the Northern Fall Line also was studied (A.M. Thompson, 1979).

3.2.1.5 Gravity Studies

Gravity studies have been useful for identifying regional structural features that extend deep into the crust. Where the gravity mapping is sufficiently detailed, much-smaller-scale, near-surface structural features can be identified.

Hildreth (1979) compiled a gravity map of the entire northeastern United States at a scale of 1:1,000,000, using all of the available data, regardless of variations in detail or station spacing. The map includes a listing of previous gravity studies in the region (see Fig. 3.9). Although the contouring is very uneven, it includes all of the detail. Bothner et al. (1980) prepared a similar map using most of the same data, but digitized the data to smooth the contours and eliminate inequalities. However, smoothing tends to degrade the map's usefulness for identifying local structures. Another gravity map of most of the region was compiled by Haworth (1981) at a scale of 1:1,000,000. Maps of the Lewiston and the Sherbrooke 2° sheets in Maine and New Hampshire, at a scale of 1:250,000, are being prepared by the USGS. Weston Geophysical Research, Inc., also has assembled gravity maps of the region at various scales.

As part of the New England Seismotectonic Study, new gravity surveys were made of the northern New Jersey coastal plain (Sugarman, 1981), the Moodus area of south-central Connecticut (Kick, in prep.), Narragansett Bay (Collins and McMaster, 1978), Rhode Island (Frohlich, in prep.), the Cape Ann area of Massachusetts (Kick, in prep.), the area north of Penobscot Bay in central Maine (Tyler, in prep.), and the Passamaquoddy Bay area of Maine and New Brunswick (Wang and Tyler, in prep.). In addition, the central portion of the Hartford graben was surveyed by Burger et al. (1980).

Some abrupt regional changes in gravity data that might represent structures were noted on early maps (cf. Kane and Bromery, 1968). Experience has subsequently shown that major faults are apparent on gravity maps that

gravity map of Massachusetts: U.S. ..., scale 1:250,000.

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..., Moranda-Waswanipi: Canadian Dept. ... Bouguer Gravity Map Series No. 80, scale ...

..., Toronto-Ottawa: Canadian Dept. ... Bouguer Gravity Map Series No. 133, scale ...

..., Upper Ottawa River: Canadian Dept. ... Bouguer Gravity Map Series No. 134, scale ...

..., Parent-Trois Rivieres: Canadian ... Bouguer Gravity Map Series No. 135, ...

9. Canada Earth Physics Branch, 1974, Ottawa-Montreal: Canadian Dept. Energy, Mines and Resources, Bouguer Gravity Map Series No. 138, scale 1:500,000.

10. Canada Earth Physics Branch, 1975, Bouguer anomaly map of New Brunswick: Canada Earth Physics Br., Open File No. 316, scale 1:500,000.

11. Canada Earth Physics Branch, 1975, Bouguer anomaly map of Nova Scotia: Canada Earth Physics Br., Open File No. 317, scale 1:500,000.

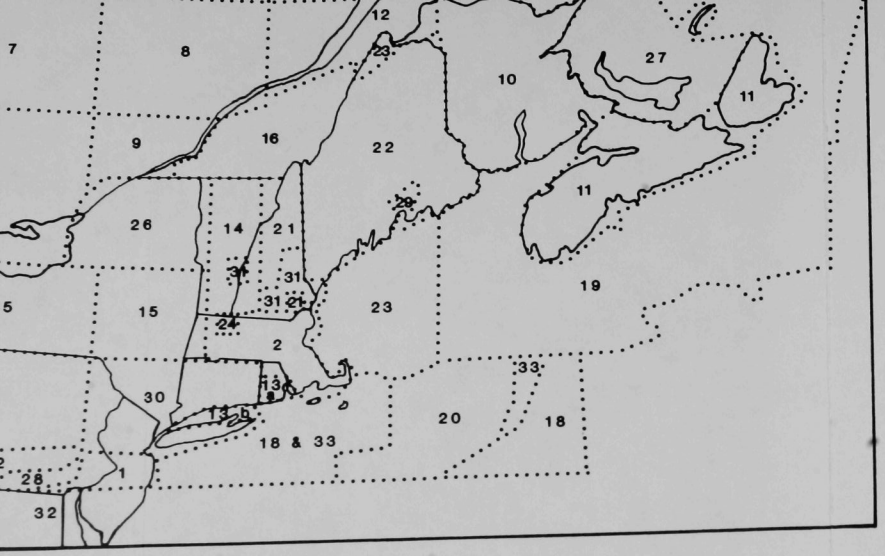
12. Canada Earth Physics Branch, 1978 Map of Bouguer anomaly -- Eastern Townships, Canada: Canada Earth Physics Br. Computer plot, 22 March 1978, scale 1:5,000,000, (contoured by C.P. Hildreth, April 1978).

13a. Collins, R.P., 1978, Geophysical investigation of the structural framework of the southern portion of the Narragansett Basin, Rhode Island (Ph.D. thesis): Kingston, R.I.: University of Rhode Island, 150 scale ca. 1:500,000.

13b. Dehlinger, P., 1978, Marine gravity: Elsevier Scientific Publishing Co., Amsterdam Oxford, New York.

14. Diment, W.H., 1968, Gravity anomalies in northeastern New England, in Zen, E-an, W.S. White, J.B. Hadley, and J.B. Thompson, Jr., eds., Studies in Appalachian geology -- northern and maritime: New York, Interscience Publ., p. 399-411, scale ca. 1:750,000.

Fig. 3.9 Sources of Gravity Information United States and Adjacent Areas (Source: Hildreth, 1979)



Sources of Gravity Information

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er Gravity Map Series No. 79,

nda-Waswaniti: Canadian Dept.
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nto-Ottawa: Canadian Dept.
vity Map Series No. 133, scale

Ottawa River: Canadian Dept.
ity Map Series No. 134, scale

c, Parent-Trois Rivieres: Canadian
, Bouguer Gravity Map Series No. 135,

9. Canada Earth Physics Branch, 1971d, Ottawa-Montreal: Canadian Dept. Energy, Mines and Resources, Bouguer Gravity Map Series No. 136, scale 1:500,000.

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11. Canada Earth Physics Branch, 1977b, Bouguer anomaly map of Nova Scotia: Canada Earth Physics Br., Open File No. 77-6, scale 1:500,000.

12. Canada Earth Physics Branch, 1978 Map of Bouguer anomaly -- Eastern Townships, Canada: Canada Earth Physics Br. Computer plot, 22 March 1978, scale 1:1,000,000, (contoured by C.T. Hildreth, April 1978).

13a. Collins, B.P., 1978, Geophysical investigation of the structural framework of the southern portion of the Carboniferous Narragansett basin, Rhode Island (Ph.D. thesis): Kingston, R.I., University of Rhode Island, 150 scale ca. 1:300,000.

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the United States: U.S. Geol. Surve

Fig. 3.9 Sources of Gravity Information fo
United States and Adjacent A

have contours at 2-mgal intervals or less. Detailed gravity maps, especially when combined with magnetic surveys and geologic mapping, are useful for bringing out the local and regional structures in the northeastern region (Barosh, 1979). Gravity profiles that show the effects of faulting have been made across several faults in the region, including the Clinton-Newbury fault zone in Massachusetts (Taylor et al., 1980) and the Watch Hill fault zone in Rhode Island (Frohlich, 1981).

3.2.2 Regional Tectonic Interpretation

3.2.2.1 Fault and Fracture Domains

Mapped faults, and fault and fracture trends inferred from remote sensing and geophysical data, can be used to delineate distinct fault and fracture domains based on the kinds of faults and their trends, or the age of faulting, or some combination of the two. Some overlapping of the domains established by these criteria should be expected, because of reactivation of fractures at different times (perhaps with different kinds of movements) or because of changing locations of fault movements with time.

The predominant fault trends in the region (Barosh and Johnson, 1978) (see Plate I) are the major Paleozoic northeast- and north-trending compressional faults, and the northwest-trending cross faults, which generally appear younger (Barosh, 1976b). The pattern of aeromagnetic lineaments reflects these trends well (Barosh et al., 1977b), as do trends from remote sensing data (Banks, 1974; Isachsen and McKendree, 1977). Mesozoic and younger faults are predominantly northeast-trending extensional faults, but there are important northwesterly and northerly trends as well. Many of these faults appear to follow preexisting Paleozoic fractures. The Mesozoic or younger faults can generally be distinguished by their more brittle features (slickensides, breccia, or gouge), whereas the older ones tend to be marked by ductile flow, mylonite, and (commonly) pegmatite. Faults and fractures should be separated as much as possible by age, because the younger fractures moved under tectonic conditions much more like those of the present than the older ones and are, therefore, more important in understanding present-day movements in the northeast.

Pre-Mesozoic Domains. Although sufficient information is available for southern New England to delineate many fault and fracture domains (Banks, 1974; Barosh and Pease, 1974; and Wise, 1979), insufficient information is available to make similar distinctions elsewhere in the region. Nevertheless, a number of generalized fault domains can be determined that generally coincide with larger Paleozoic structural provinces (see Fig. 3.10).

Nashoba Thrust Belt. The Nashoba thrust belt that crosses eastern Connecticut and eastern Massachusetts is predominantly a zone of northeast-trending, high-angle, west-dipping thrust faults that exhibit west-over-east

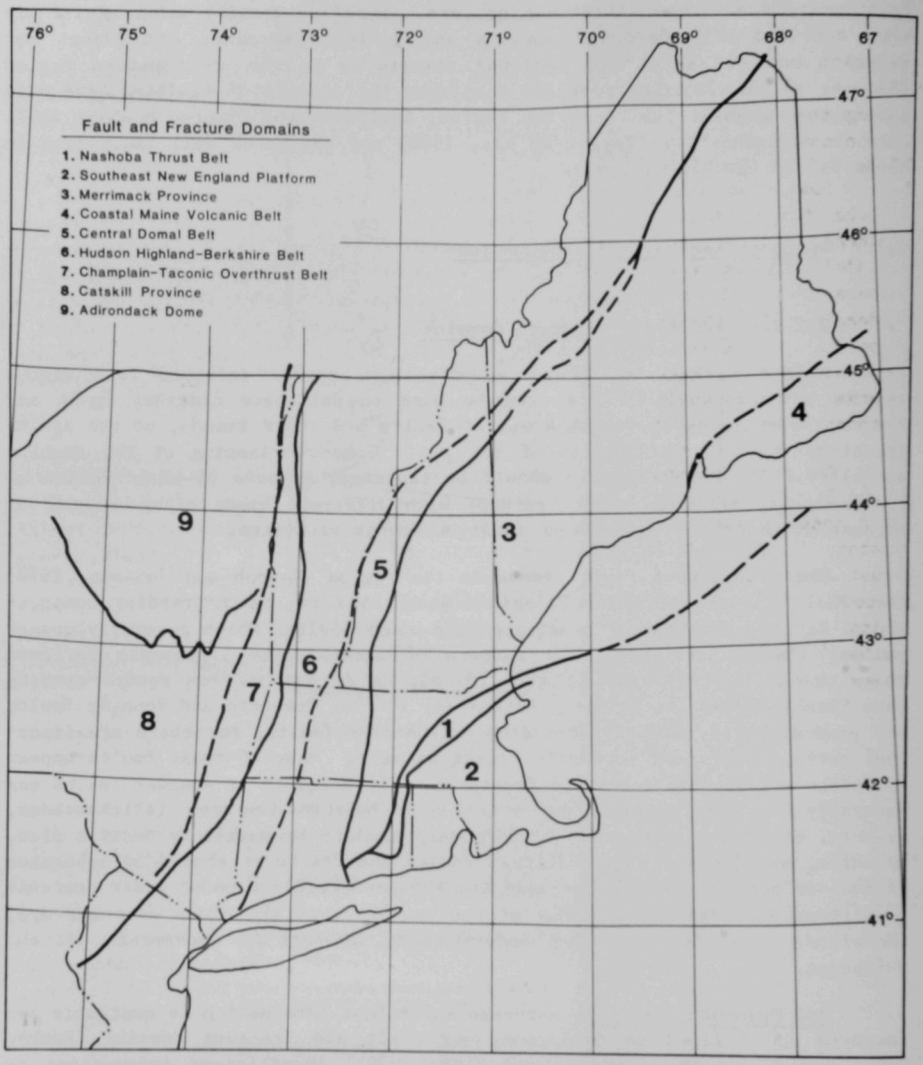

Fig. 3.10 Fault Domains of the Northeastern United States

and right-lateral components of displacement (see Fig. 3.11). This major structural zone separates the southeast New England platform (part of the Avalonian block) from the Merrimack province. This zone may continue offshore to the northeast and come ashore again at the southern edge of New Brunswick (Rast et al., 1976). The faults in this zone moved at least several times during the Paleozoic, probably to the greatest extent of any structural zone in the northeast.

Southeast New England Platform. Most of the area southeast of the Nashoba thrust belt appears dominated by northeast and north to north-northeast fault trends (see Fig. 3.11). This is exemplified by Narragansett Bay (McMaster et al., 1980) and the shape of the Narragansett basin, which appears to be mainly fault-bounded. In northeastern Massachusetts, there is a subdomain of northeast to east-northeast to eastern trends that controls the shape of the Boston basin (LaForge, 1932; Kaye, 1981) and cuts Cape Ann (Dennen, 1978). Many faults of these trends seem to be northerly-dipping reverse faults with some right-lateral component of displacement on northeasterly trends (Barosh and Pease, 1978).

Another subdomain of this region lies along the Connecticut-Rhode Island border, adjacent to the Nashoba thrust belt and south of the Honey Hill fault zone in southeastern Connecticut (see Fig. 3.11). Here, thrust faults separate large folds. In Connecticut south of the Honey Hill fault, these thrust faults strike roughly east-west, dip gently to the north, and are cut by some later north-trending cross faults. Near Rhode Island, the thrust faults bend to the north and appear to have east dips where they extend northward along the eastern Connecticut border (Barosh, 1981c; Barosh and Hermes, 1981).

Merrimack Province. Northwest of the Nashoba thrust belt and east of the Bonemill Brook fault zone in Connecticut and Massachusetts is a region dominated by northeast- to north-northeast-trending thrust faults, which is much less intensely deformed than the Nashoba belt. Although it has been referred to as a synclinorium (Billings, 1956), it seems to form more of a moderately to gently westward-dipping wedge of rocks. The dips of the thrust faults range from nearly flat in south-central Connecticut to steep in northeastern Massachusetts (see Fig. 3.12). The thrusts are complex and have a great deal of west-over-east displacement in northeastern Connecticut (Peper et al., 1975). On the basis of geologic trends, aeromagnetic data, and information from a tunnel in bedrock that traverses the region (Callaghan, 1931), the amount of displacement appears to diminish northward into central Massachusetts. In central Massachusetts there appears to be relatively simple, open, gentle folds cut by widely spaced thrusts, although J.B. Thompson et al. (1968) depicts a complicated structure for this region.

The province widens to the north, with more northerly trends dominating in central and northern New Hampshire and more northeasterly trends dominating in southeastern New Hampshire and Maine (Smith and Barosh, 1981). Northwest-trending, high-angle cross faults have been mapped in eastern Connecticut

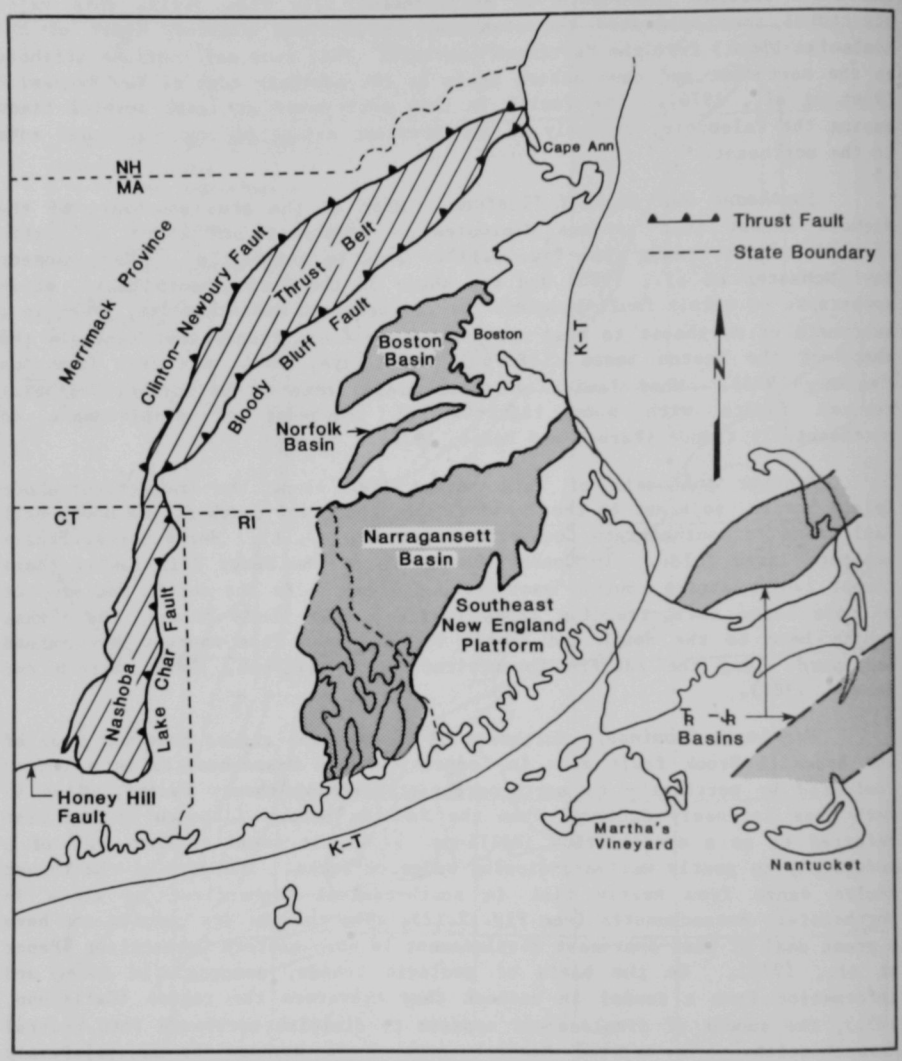

Fig. 3.11 Sketch Map of Southeastern New England Showing Major Tectonic Provinces and Basins

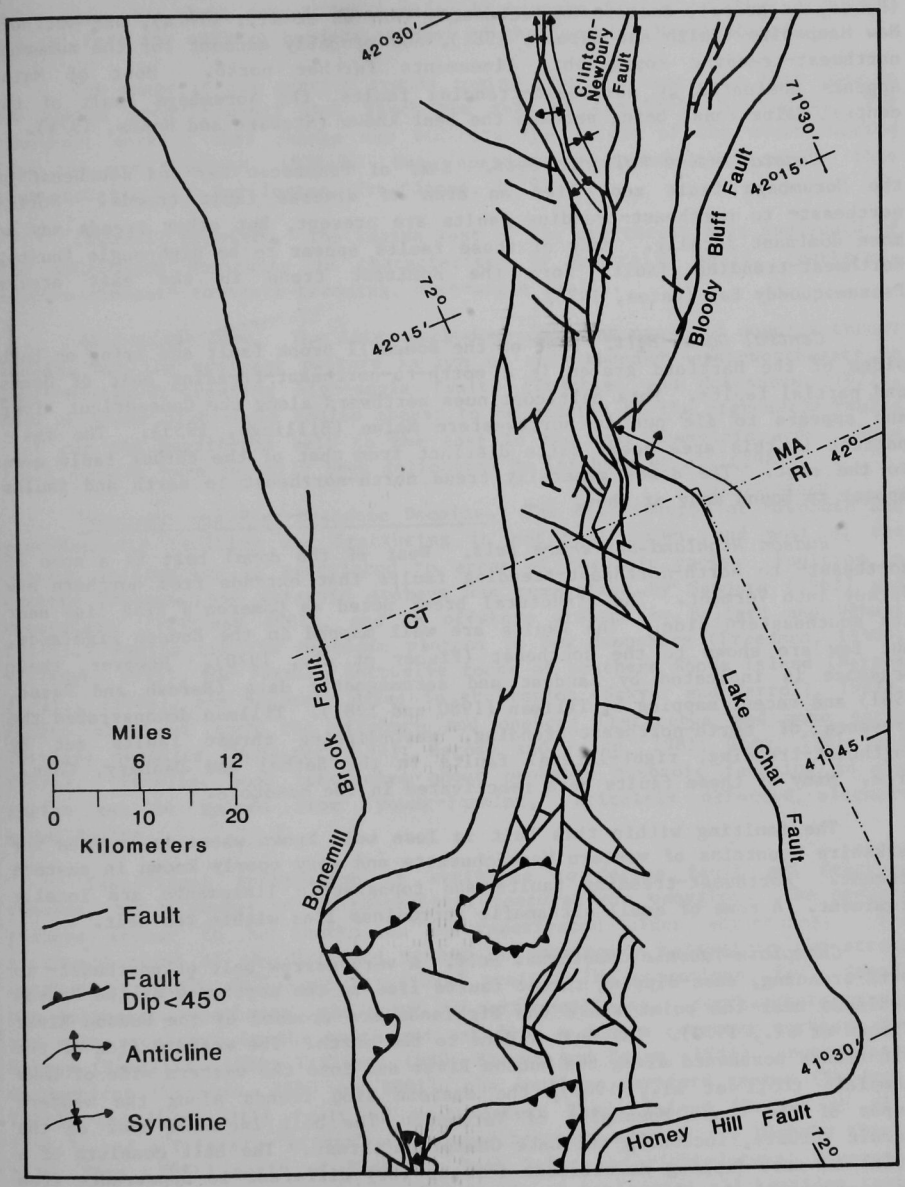

Fig. 3.12 Simplified Structure Map of South-Central Massachusetts and Eastern Connecticut (Source: Pease and Barosh, 1981)

(Pease, in prep.), eastern Massachusetts (Barosh et al., 1977a), and southern New Hampshire (Smith and Barosh, 1981), and probably account for the numerous northwest-trending topographic lineaments further north. Most of Maine appears dominated by northeast-trending faults, the Norumbega fault of the central Maine coast being perhaps the best known (Stewart and Wones, 1974).

Coastal Maine Volcanic Belt. East of Penobscot Bay and southeast of the Norumbega fault zone lies an area of diverse fault trends. North-northeast- to northeast-trending faults are present, but other trends may be more dominant locally. Many of these faults appear to be high-angle faults. Northwest-trending faults form the dominant trend in the east around Passamaquoddy Bay (Gates, 1975).

Central Domal Belt. West of the Bonemill Brook fault and lying on both sides of the Hartford graben is a north-to-northeast-trending belt of domes and partial faults. This belt continues northward along the Connecticut River and appears to die out in northwestern Maine (Billings, 1955). The fault pattern in this area seems quite distinct from that of the thrust fault area to the east. The domes generally trend north-northeast to north and faults appear to bound many of them.

Hudson Highland-Berkshire Belt. West of the domal belt is a zone of northeast- to north-northeast-trending faults that extends from northern New Jersey into Vermont. The structural break noted as Cameron's Line lies near its southeastern side. The faults are well mapped in the Hudson Highlands, but few are shown to the southeast (Fisher et al., 1970). However, their presence is indicated by Landsat and aeromagnetic data (Barosh and Pease, 1981) and recent mapping by Tillman (1980 and 1981). Tillman demonstrated the presence of north-northeast-trending, west-dipping thrust faults cut by northeast-trending, right-lateral faults in the Bethel and Danbury, Conn., area. Many of these faults were reactivated in the Mesozoic.

The faulting within this belt is less well known where it crosses the Berkshire Mountains of western Massachusetts and very poorly known in eastern Vermont. Northwest-trending faults and topographic lineaments are locally prominent. A zone of small ultramafic intrusions lies within the belt.

Champlain-Taconic Overthrust Belt. A very narrow belt of northeast- to north-trending, east-dipping thrust faults lies to the northwest of the Hudson Highlands near the point where the Highlands are crossed by the Hudson River (Fisher et al., 1970). The belt widens to the north. The western side of the belt trends northward along the Hudson River and into the western side of Lake Champlain (Doll et al., 1961); the eastern side trends along the western slopes of the Green Mountains of Vermont. The belt includes most of the Taconic thrusts, including the Lake Champlain thrust. The belt consists of a series of east-dipping decollement thrusts very different in appearance from the deep-seated thrusts in the Nashoba thrust belt. The thrust faults are cut by high-angle, north-northeast- to north-trending extensional faults in the Lake Champlain-Lake George area (Stanley and Sarkisian, 1972). Aeromagnetic

and topographic data suggest that these high-angle faults continue southward and may form the eastern borders of many of the Taconic thrust sheets.

The magnetic and gravity trends coming from the west into this zone do not change greatly until they reach the axis of the Green Mountains. The lineament marking this change may indicate the extent of the overthrusting from the east (Barosh, 1976a). Some northwestern trends occur across this zone, notably near Burlington, Vt. (Jones, 1979).

Catskill Province. The region west of the overthrust belt and south of the Adirondack Mountains is characterized by generally small, scattered, north-northeast- to north-trending, high-angle faults.

Adirondack Dome. The Adirondack dome contains many old complex thrust faults, but the dominant pattern is one of very abundant east-northeast- to north-northeast-trending high-angle faults (Isachsen and McKendree, 1977). Some of these high-angle faults appear to be related to the high-angle faults that cut the overthrust belt to the east in the Lake Champlain area. Some fault domains have recently been delineated by Isachsen et al. (1981).

Mesozoic and Post-Mesozoic Domains. The distribution of Mesozoic and post-Mesozoic faulting and fracturing is not well known, and most of the present information is restricted to areas of Mesozoic rocks. Faulting in onshore Triassic and Jurassic grabens was summarized by Sanders (1963) and Manspeizer (1980 and 1981), and in offshore grabens by Ballard and Uchupi (1975). Faults cut the Mesozoic plutons in New Hampshire (Freedman, 1950); Billings, 1955), the Permian intrusive rocks of southern Rhode Island (Hermes et al., 1981a), and Mesozoic dikes in the region (Sawyer and Carroll, 1981). Faults also cut both the offshore and onshore Cretaceous and some early Tertiary deposits (McMaster, 1971; Barosh and Pease, 1981; Grow, 1981a and 1981b). Finally, some inferences about probable Mesozoic faulting in the region can be gained from "young-looking," brittlely deformed, slickensided faults.

Insufficent information is available to define fault and fracture domains, but a number of characteristic features are emerging. The onshore grabens appear to be controlled by reactivated older structures. The northward trend of the Hartford graben is apparently related to the strong northward-trending Paleozoic structural grain. The predominant fault trends are northeast, northwest, and north to north-northeast. Northeastern trends are more prominent in the south and may form a domain covering northern New Jersey (Ratcliff, 1980; Tillman, 1980; Barosh and Pease, 1981), southeastern Connecticut (Tillman, 1980 and 1981), the southern Hartford graben (Sanders, 1968), the Watch Hill fault of southwestern Rhode Island (Hermes et al., 1981a), and a Triassic "sliver" at the southeastern edge of the Nashoba thrust belt (Kaye, 1981) north of Boston. Both left- and right-lateral movements have been described in this zone. The domain of horizontal slickensides found by Wise (1979) in western Connecticut may be part of this zone. If such a regional zone exists, it is en-echelon in character and not a continuous fracture zone.

The northwestern and north-to-north-northeastern trends appear to be the youngest fracture trends in the region. They clearly cut the northeast-trending Watch Hill zone in Rhode Island (Smith and Barosh, 1980; Hermes et al., 1981a). In all of the areas of detailed work for the New England Seismotectonic Study, these trends were the youngest found, although their ages could not usually be determined. The New Shoreham fault zone, which cuts Upper Cretaceous deposits offshore near Block Island, trends north and northwest (McMaster, 1971).

3.2.2.2 Tectonic Styles

There appear to be many real differences in tectonic style in space and time across the northeastern United States, but many differences are due to different interpretations of similar data. A good example of this is the southeastern New York-southwestern Connecticut region (Fisher et al., 1970). The Hudson Highlands, with its series of high-angle, northeast-trending faults, is bordered to the northeast by complex thrust slices of the Taconic allochthon and to the southeast by a complex fold pattern. Thus, this region appears to exhibit three distinct styles of deformation. Aeromagnetic and Landsat data and some recent mapping (Tillman, 1980) suggest that these areas are not nearly as different as originally thought and that the apparent differences have a lot to do with interpretation. Another striking difference in style is thought to occur between northeastern Connecticut, an area shown to be cut by moderately west-dipping thrust faults (Peper et al., 1975), and that to the north in central Massachusetts, which is depicted as a series of large, extremely convoluted folds (J.B. Thompson et al., 1968). These are differences in interpretation, not in geology. The region abounds in similar examples.

Real differences in tectonic style exist between the areas delineated as Paleozoic fault domains. The Nashoba thrust belt is characterized by high-angle thrust faults with deep-seated ductile styles of movement, whereas the Champlain-Taconic thrust belt is characterized by thrust faults of a shallow decollement type. The western edge of the southeastern New England platform along the Connecticut-Rhode Island border is characterized by large folds that range from compressed to slightly overturned, and which are broken by thrust faults (Barosh and Hermes, 1981). This style of thrusting contrasts sharply with that in the adjacent domains to the west (see Fig. 3.12). The platform to the east consists of apparently less-deformed rock cut by basins that are largely controlled by faults and which have broad northeast-trending folds. The faults bounding the Cambrian rocks of the Boston basin appear to be high-angle reverse faults (Kaye, 1981), whereas the faults bordering the Pennsylvanian metasedimentary rocks in the Narragansett basin are most likely normal.

In southern New England, the Merrimack province mainly has gently west-dipping thrust sheets with linear intrusive rocks 390-450 m.y. old that intruded along the earlier thrust faults, perhaps during periods of reactiva-

tion. The adjacent central domal complex is quite different in style and consists of a belt of large gneiss domes associated with anticlines and some synclines, both of which are bordered and cut by faults. The Maine volcanic province has a complexity of styles that reflects its volcanic nature, including circular intrusives and ring complexes (Karner, 1968 and 1974) that mark the lower parts of volcanic complexes.

Finally, the extensional structures forming the Hartford graben are very different from the structures that formed the domes to either side. Although these extensional structures likely extend into the domal areas, this has not yet been demonstrated.

Thus, there are great differences in structural style across the region. Certain of the structures were formed at different locations, levels, and times in the Appalachian orogenic belt, and others were formed in response to the opening of the Atlantic Ocean basin. It is very important to recognize these styles in trying to construct a tectonic history of the region that will be useful in studying today's movements. However, reliable geologic information is available only for part of the region. Therefore, when reviewing the available data, it is imperative to find whether enough basic stratigraphy has been done for structural control and whether the basic data on the map agree with the interpretations presented. The fact is that many well-publicized tectonic styles are the result of imaginative interpretations that may be incorrect.

3.2.2.3 Ages of Tectonic Events

Over the last 10 yr, improved radiometric dating, several fossil finds, extended stratigraphic correlations, and offshore investigations have resulted in a vastly improved, more consistent geologic history of the region. Many features are older, and some periods of deformation have less distinct boundaries, than previously thought. Knowledge of Mesozoic and Tertiary events has been greatly increased by results from offshore geophysical surveys and drilling.

The main periods of deformation that have affected the region are: (1) the Precambrian Grenville event recorded in the basement rocks along the western edge of the northern Appalachians and the platform beyond, (2) a very late Precambrian orogeny recorded in southeastern New England and in part of the central domal belt, (3) a mid-Ordovician to mid-Devonian series of events that affected the entire region, (4) a Permian orogeny that mainly affected the southern part of the region, (5) a Late Triassic to Early Jurassic rifting that is more prominent in the southeastern half of the region, and (6) a downwarping, mainly offshore, of the edge of the continent accompanying the opening of the Atlantic Ocean basin that began in the Early Jurassic and that may be continuing today.

Much of the stratigraphic record, intrusive rocks, metamorphic effects, and structural features reflecting these events are discussed in reports in King (1951), Zen et al. (1968), Cady (1969), Rodgers (1970), Lyons and Brownlow (1976), Page (1976), Rast et al. (1976), Manspeizer (1980), Bally et al. (1981), and the guidebooks of the annual New England intercollegiate geologic conferences. A brief summary of recent findings and some comments on lesser tectonic events are presented below.

The Adirondack dome consists of a 1100 m.y.-old terrain that was intruded and deformed at least five times (McClelland and Isachsen, 1979; Wiener et al., in press); it is similar to rocks exposed in the nearby southern edge of the Canadian shield and presumably similar to the basement rocks buried beneath the Paleozoic cover elsewhere in New York. The Precambrian rocks of the Hudson Highlands and Berkshire Mountains may have experienced some of these same events.

The southeast New England platform was extensively intruded (Zartman and Naylor, in press) and its western edge was folded and apparently thrust-faulted in the late Precambrian (Barosh and Hermes, 1981). Although no deformation of similar age can be proven across its western boundary, the parallelism of late Precambrian structures with the western border of the platform suggests that the structures deformed against a block to the west or that later thrusting on the west was closely controlled by the late Precambrian structures to the east. This second possibility was probably either the start of, or a precursor to, plate collision along the Nashoba thrust belt between the proto-African plate (of which the southeastern New England belt is a part) and the North American plate to the northwest. A few intrusives in the central domal belt also date from about this time (Zartman and Naylor, in press).

Eocambrian-Cambrian uplift and volcanic activity about 590 m.y. ago (Kaye and Zartman, 1980) shed conglomerates and volcanic debris eastward into the Boston basin and volcanic materials to the north. These deposits apparently interfinger at the eastern edge of the Boston basin with finer-grained sedimentary rocks containing Cambrian fossils.

Plate collision caused widespread deformation in the northeastern region during the period from the mid-Ordovician to mid-Devonian. Extensive thrusting, apparently due to underthrusting of the proto-African plate from the east-northeast, accompanied this collision. This event is marked by numerous intrusions with ages of 375-450 m.y., especially in the Nashoba and Merrimack provinces in southern New England (Zartman and Naylor, in press). Many of the older intrusive bodies were emplaced along thrust faults that cut rocks older than mid-Ordovician. The intrusive rocks generally are foliated and were affected by later movements. Some of the later intrusive rocks crosscut the structures. To the west, gravitational thrusts occurred along the Champlain-Taconic belt and, farther east, uplift caused unconformities during the Silurian.

A volcanic chain of varied lava types extended along the southeastern coast of Maine during the Late Silurian and Early Devonian, with intrusions occurring beneath the volcanic centers. An unusual thickness of Silurian volcanics in the Passamaquoddy Bay region of Maine and New Brunswick indicates a depression in this area (Gates, 1981). A fault sliver of Late Silurian or Early Devonian volcanic rocks along the southeastern side of the Nashoba Belt north of Boston (Shride, 1976) suggests that the chain may have extended offshore into northeastern Massachusetts. An apparently circular intrusive lying offshore north of Cape Ann (Weston Geophysical Research, Inc., 1976) may represent a part of this chain or, perhaps, be a Mesozoic volcano related to those in New Hampshire.

Numerous irregular to circular and generally massive igneous bodies were intruded into Maine and New Hampshire during the Devonian. Some also occur to the south, including one in central Rhode Island (Hermes et al., 1981b). These intrusions metamorphosed Silurian and Early Devonian rocks up to staurolite grade in places. Thrusting was reactivated in the region, at least within the Merrimack and Nashoba provinces. In southeastern New Hampshire, one Late Silurian(?) formation has a 35 km (21-mi) right-lateral separation, which may represent offset across a zone of high-angle thrust faults. The uplift accompanying this orogenic period is recorded by thick Devonian sedimentary sequences in the Catskill region of New York. Late orogenic high-angle extension faulting continued the movements into the Late Devonian, at least in southeastern Maine, where Late Devonian red beds filled a fault trough, as it developed, in Passamaquoddy Bay (Gates, 1981).

Basin formation, probably aided by faulting, affected at least the southeastern New England platform, trapping terrestrial sedimentary rocks of Middle Pennsylvanian age that are now preserved in the Narragansett basin (Shaler et al., 1899).

The southern part of New England was metamorphosed and intruded during the Permian, and the Pennsylvanian sediments were deformed. The metamorphism, which occurred about 240 m.y. ago, reached a high grade in the southwestern corner of the Narragansett basin and extended northward across much of southern New England (Zartman et al., 1970). The massive Narragansett Pier granite in southern Rhode Island was intruded relatively passively, i.e., with little disturbance of the bordering rocks (Hermes et al., 1981a). Some of the north-northeast- and northeast-trending faults that cut Narragansett basin rocks may have occurred at this time.

Rifting accompanied by high-angle extensional faulting and graben formation began at least by the Late Triassic and heralded the opening of the modern Atlantic Ocean basin. Fluvial and lacustrine sediments were trapped in active grabens extending across southern New England and offshore from northern New Jersey (Ballard and Uchupi, 1975; Hubert et al., 1978; and Manspeizer, 1980 and 1981). Much of the extensional faulting in the region was controlled by older compressional faults. The extensional faulting was accompanied by tilting within the basins, probably due to rotation on listric

faults. Faulting and filling continued into the Early Jurassic, when igneous activity produced diabasic flows, sills, and dikes. Some dike systems are very long. The Higganum dike system extends northeastward from Long Island (Dowling, 1981) along the southeastern edge of the Hartford graben into the southern coast of Maine. This system must reflect some sort of deep fracture zone.

Northeast-trending faults cut these rocks and the Permian section in Rhode Island. This faulting has an apparent right-lateral component in the Newark basin (Manspeizer, 1981) and a left-lateral component in the Hartford graben. Ballard and Uchupi (1975) consider the offshore fault pattern to be explained best by a left-lateral component of displacement. Northwest- and north-to-north-northeast-trending faults occurred contemporaneously with and following these northeastern faults.

The rifting phase that formed these grabens stopped towards the end of the Early Jurassic or by the Middle Jurassic, at least offshore. Here, evaporites were deposited at the edge of the continent as it sagged downward (Grow, 1981a). As downwarping continued, the environment became more open marine. Significant downwarping occurred during the Late Cretaceous, when very thick marine deltaic sediments were deposited offshore and in the marine coastal plain of New Jersey. Similar movements and deposition continued into the Tertiary. The adjacent onshore area was apparently rising at this time and provided the sediment source.

Some igneous activity accompanied the deformation during the late Mesozoic. The north-trending belt of massive White Mountain granitic plutons was emplaced about at the end of the Jurassic and at the beginning of the Cretaceous (Billings, 1955). These intrusions were probably deeper parts of a volcanic chain active at this time. Remnants of slightly younger volcanic calderas, such as Mt. Pawtuckaway and Mt. Ossipee (Lyons, 1981), also occur in the same area. Also about this time, the Great Stone Bank pluton intruded into coastal plain deposits offshore of New Jersey (Grow, 1981a).

Faulting apparently accompanied the downwarp of the continental edge. Sedimentologic studies on the coastal plain suggest left-lateral, northeast-trending fault movement during deposition (Brown et al., 1972); growth faults occur offshore, which cut up through at least the Upper Cretaceous (Grow, 1981a). Other faulting on the northern coastal plain summarized in Barosh and Pease (1981) and the north- to northwest-trending New Shoreham fault south of Block Island (McMaster, 1971) also cut Upper Cretaceous sedimentary rocks.

3.2.2.4 Quaternary Igneous Activity and Faulting

No Quaternary igneous activity is known; the only reported warm springs are Sand Spring in the northwestern corner of Massachusetts and the nearby Lebanon warm springs in New York (Waring, 1965); the more temperate Saratoga Springs in New York are not too far away.

The problem of whether Quaternary faults occur in the northeastern region was not studied until recently, even though a number of features were noted in the early part of this century that could be due to post-Pleistocene faulting. Since the general opinion was that they did not exist, and given that most field work was basically mineralogic or petrologic in nature, little useful information was obtained. The mapping of Pleistocene deposits, which may have shown offsets, was conducted separately from any studies of bedrock faults. Also, the general lack in the region of rocks of Mesozoic and Tertiary ages made identification of young faults difficult. What younger rocks there are in the region are generally poorly exposed or occur offshore. Moreover, Pleistocene glaciation would have removed much of the obvious evidence of prior faulting. Consequently, only the post-Pleistocene, or Holocene, part of the Quaternary is available for study; that is, about the last 12,000 yr. Yet another complication is that Pleistocene deposits usually are faulted from nontectonic causes, which has meant that little attention has been given to these faults. Finally, since earthquakes of the size usually experienced in New England generally do not produce surface faulting, it is not surprising that proven Quaternary faults are lacking. Nonetheless, there is the following evidence of Holocene faulting in the region.

Reactivated Bedrock Faults. A bedrock fault cuts the Pleistocene at Sears Island in Penobscot Bay, Maine (Rand and Gerber, 1976). Although this fault has been interpreted as due to compaction by ice, the fault lies in a major northeast-trending fault zone that controls part of the shape of the bay (Barosh, 1981b; Rogers, in prep.).

A number of apparent offsets of Pleistocene sediments across bedrock faults were found by a seismic survey in Lake Champlain northwest of Burlington, Vt. (Hunt and Dowling, 1981). A more detailed seismic survey (see Fig. 3.13) combined with coring indicates a series of north-northwest-trending extensional faults (Hunt, 1981).

Offsets of Pleistocene Striated or Polished Surfaces. Offsets of Pleistocene striated or polished surfaces have been noted at a number of places in New England (Woodworth, 1907; Kaye, 1976; W.B. Thompson, 1979; and Boone, 1981). These data have been summarized by Adams (1981), Metcalf (in prep.), Oliver et al. (1970), and York and Oliver (1976). Because many of these small offsets are away from slopes, areas of blasting, or other activities of man, and since they do not look like ice wedging, they may well represent actual tectonic offsets. However, frostquakes do occur in the region, which can affect the local surfaces like dynamite blasts (Barosh and Smith, 1980). Also, the unloading of rocks by man (and perhaps by glacial scraping) can cause rocks to move because of residual stress. This has made it more difficult to prove the tectonic origin of these offset surfaces. Some of the larger offsets, such as the two 15-cm (6-in.) offsets in northwestern Maine described by Boone (1981), might be tectonic.

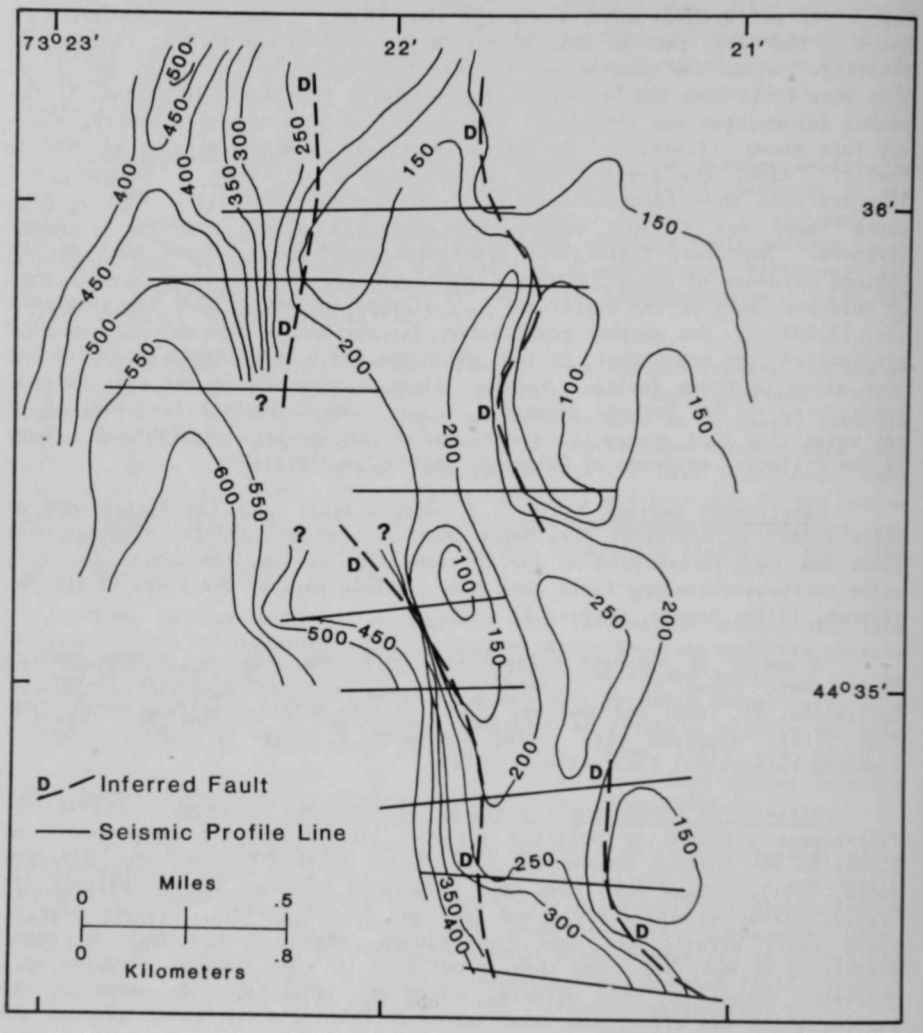

Fig. 3.13 Bedrock Map of Central Lake Champlain Showing Inferred Faults and Seismic Profiling Lines (Source: Hunt, 1981)

Offsets in General Levels of Pleistocene Marine Delta Surfaces. The levels of marine deltas formed at the edge of the ice cap as it retreated across Maine have been studied by W.B. Thompson and Anderson (1981) and W.B. Thompson and Crossen (1981) to determine the general post-Pleistocene rebound surface and to look for other warping or discontinuities that might be due to tectonic movement. A northwest-trending discontinuity in the general levels has been found recently in the Passamaquoddy Bay area. This strongly suggests post-Pleistocene offset by faulting. Another possible warping or offset is found west of Portland, Maine (Crossen, 1981).

Surface Scarps along Faults. Scarps along faults may be due to direct offset, weathering back of earlier tectonic offset, or differential weathering. Several scarps in the Adirondack region associated with faults have been investigated by Young and Putnam (1979) and Isachsen (1981b). Scarps in the Saratoga Springs area appear to lie directly over bedrock faults and to represent direct offsets; however, attempts to trench across them to prove post-Pleistocene offset have not yet been successful (Putnam, 1981). The presence of carbon dioxide wells along some of the scarps is further evidence that they are active, because such wells elsewhere in the world are almost always located on active faults (Young and Putnam, 1979).

Offsets in Adjacent Areas. Quaternary offsets in areas adjacent to the northeastern region suggest that similar offsets probably occur within the region. A fault displaced probable Pleistocene gravel in Washington, D.C. (Darton, 1939). This occurred near the Northern Fall Line, which is controlled by a structure that extends northeastward into southwestern Connecticut (Barosh and Pease, 1981). Post-Pleistocene movements were reported from the maritime provinces of Canada, where terraces at the north end of Cape Breton, Nova Scotia, were reported offset (Neale, 1963). Several large displacements of striated surfaces were noted in St. John, New Brunswick (Matthew, 1894).

Fault Plane Solutions. Fault plane solutions have now been determined for a number of earthquakes in the Northeast (Aggarwal and Sykes, 1978; Graham and Chiburis, 1979; Yang and Aggarwal, 1980, and Pulli and Toksoz, 1981). Although some of these may be poorly constrained and in considerable error, enough good solutions exist to show that initial movements recorded by seismographs in the region suggest that the earthquakes originated on a plane of movement. Such a plane indicates fault movement at the earthquake hypocenter. A comprehensive list of fault plane solutions for the northeastern region has recently been published by the Office of Crystalline Repository Development (1983).

Offset Drillholes in Highway Cuts. In south-central Connecticut (Block et al., 1979) and several places in the central Appalachians (Schafer, 1979 and 1981b; Zoback and Zoback, 1980), drillhole scars on the faces of deep roadcuts are offset apparently due to faulting. Only movements that appear to be upward were considered, because the studies tried to eliminate any

features that might be due to blasting or slumping. Downward or normal movements were disregarded, as they could be due to slumping.

Offset drillholes can be seen for a few miles along Route 11 in Connecticut, just north of the Honey Hill fault zone. The movement is up, north-over-south, along gently north-dipping planes roughly parallel to the Honey Hill fault. The movement did not occur all at one time, but gradually over several years (Block et al., 1979). Most of the movement occurs on the faces of the nearly detached rock septa left between the two expressway road beds; little offset is seen on the outer road cuts. No scarps occur on the surface, as would be expected if the measured rate of movement had been occurring away from the road, nor have any nearby wells been offset (Sawyer, 1981). The movements appear to be caused by locked-in strain, which was released when the opening of the road cut altered the local stress field. Similar movements have been reported from many quarries in New England. Totally detached blocks with no external stress field other than the atmosphere deformed similarly in over- and under-coring studies. Such movements can be ascribed only to locked-in stress (Preston, 1981); they do not appear to result from present-day tectonic stress. Similar conclusions have been reached for movements observed farther south (Hatcher and Webb, 1981).

Geomorphic Lineaments. Prominent topographic lineaments (with or without stream offsets) and low, subtle scarps may be surface expressions of faulting. Such features may be very useful in identifying active faults, especially in drier climates. However, similar features can be produced by glaciation. For example, the action of ice can etch out preexisting structures and produce low channel banks, benches, and terraces. The local prominence of topographic lineaments like the regional northerly and northwesterly trends could be ascribed to etching rather than recent movement, especially as they may be oriented near the direction of ice flow. Attempts to discern subtler fault features among the glacial features under low-angle sunlight conditions have not been successful (Sanders et al., 1981).

At present, the features described above at Lake Champlain, N.Y., and at Passamaquoddy Bay, Maine, appear to result from Holocene faulting; those at Saratoga Springs, N.Y., and perhaps at Sears Island, Maine, also may be attributed to Holocene faulting.

3.2.3 Vertical Crustal Movements

There is now considerable evidence (Barosh, 1980) that vertical crustal movements, unrelated to post-glacial isostatic rebound, are occurring in the northeast (see Fig. 3.14). Furthermore, the indicated areas have a spatial relation to areas of relatively high seismic activity.

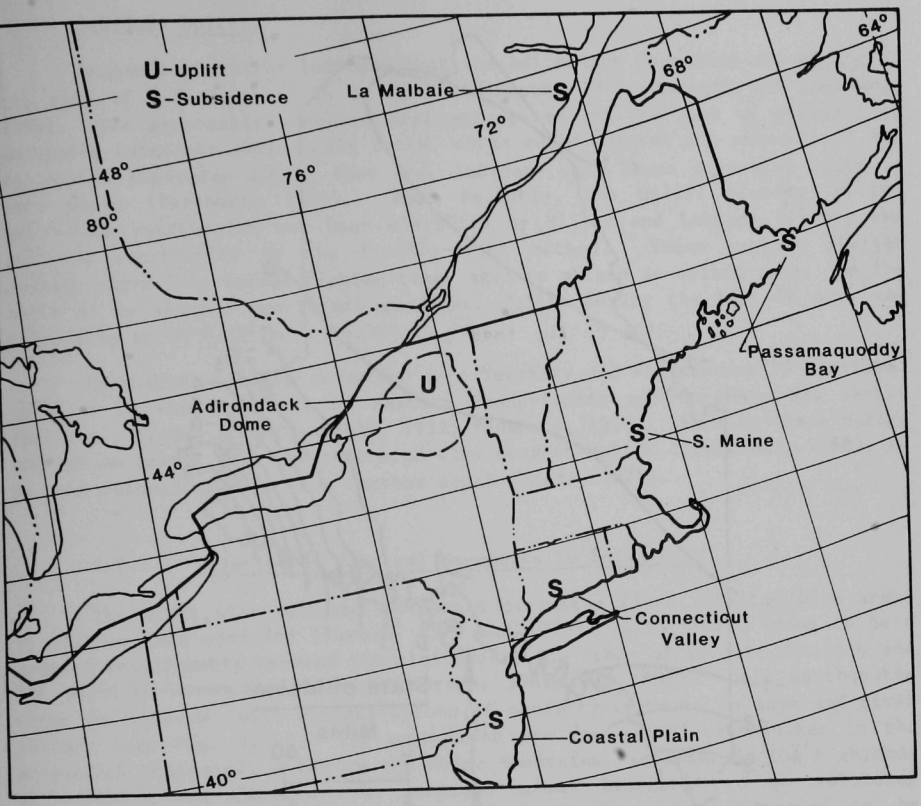

Fig. 3.14 Areas of Recent Vertical Movement in the Northeastern United States and Adjacent Canada (Source: Barosh, 1982)

3.2.3.1 Subsidence

Recent releveling studies indicate that the edge of Passamaquoddy Bay on the Maine-New Brunswick border is subsiding at the rate of 9 mm/yr (0.35 in./yr) (see Fig. 3.15) relative to Bangor, Maine (Tyler et al., 1979; Tyler and Ladd, 1981). This subsidence appears to be centered on the Bay and has been corroborated by investigations of historic construction along the coast (Smith and Bridges, 1981a and b), by studies of archaeological sites (Sanger, 1981) and salt marshes (Anderson and Race, 1981; Anderson et al., 1981; and Borns, 1981), and by tidal-gage data (Walcott, 1972). The subsidence has been noted on the New Brunswick side of the bay as well.

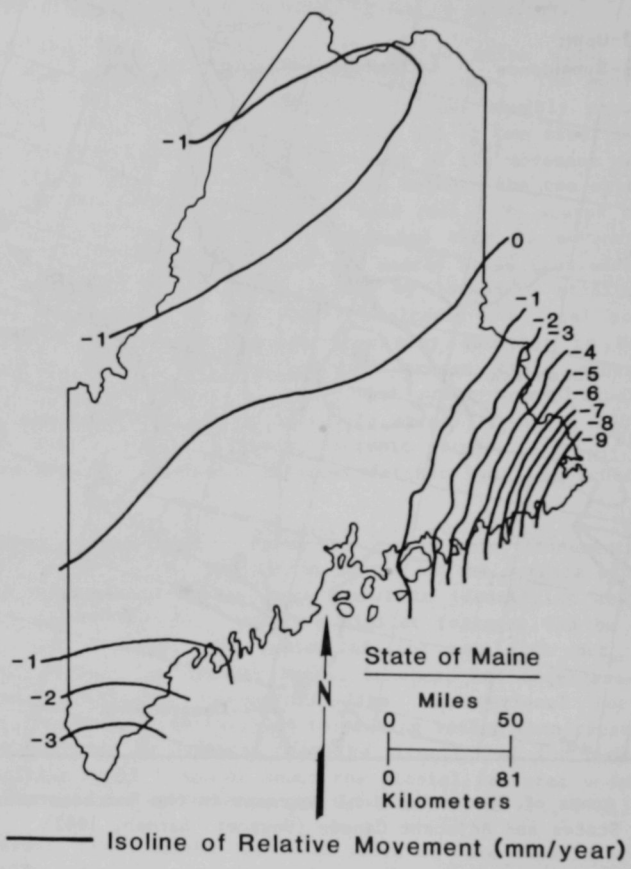

Fig. 3.15 Rate of Relative Vertical Crustal Movement in Maine as Inferred from Leveling Surveys (Sources: Tyler and Ladd, 1981; Tyler et al., 1979)

Subsidence appears to be occurring in other areas as well: releveling data indicate that it is taking place in southern Maine, with the rate increasing towards the New Hampshire coast (Tyler and Ladd, 1981). Relative changes in level line data across the lower Connecticut valley suggest subsidence (Brown, 1978). In addition, tidal-gage data from Sandy Hook, N.J., indicate an abnormal rise in sea level (Walcott, 1972), which indicates that the entrance to Raritan Bay may be subsiding.

3.2.3.2 Uplift

Releveling studies indicate that the Adirondack Mountains are rising at the rate of 3.5 mm/yr (0.14 in./yr) (Isachsen, 1975; Barnett and Isachsen, 1980). The apparently youthful drainage system and the lack of evidence of onlapping Paleozoic sedimentary rocks, which would suggest the presence of the Adirondack Mountains during that era, indicate that these mountains could be very young (Isachsen, 1975). More recently, the uplift history of the Adirondack anorthosite has been clarified by Miller and Lakatos (1983), who analyzed anorthosite by the fission-track method. These authors plotted apatite elevations versus fission-track ages to obtain an uplift rate. On the basis of an assumed geothermal gradient, uplift during the last 86 m.y. was calculated to be 0.05 mm/yr (0.002 in./yr).

Geomorphic studies of warped late-Tertiary and Pleistocene(?) erosional surfaces in the highlands of eastern Pennsylvania and northern New Jersey indicate a rising area (Campbell, 1933; Fenneman, 1938). Fission-track dating studies on quartz from the same area also suggest uplift (Zimmerman, 1980), as do some releveling data from farther south (Meade, 1971).

3.2.3.3 Relation of Vertical Movements to Seismicity

The areas with vertical movements discussed above coincide with areas of high seismic activity (Barosh, 1979 and 1980). Also, there seems to be a general relationship between the altitude of the areas of seismic activity and the vertical movements observed (Barosh, 1981a and 1982). Most earthquakes occur in lowlands, with concentrations of activity centered in bays and river valleys (see Fig. 3.16). The exceptions are the upland earthquakes in the Adirondack Mountains, a few in the White Mountains, and some in the highlands of northern New Jersey. In general, areas indicated to be subsiding correspond to areas of earthquakes in lowlands; areas indicated to be uplifting correspond to areas of earthquakes in uplands. This suggests that areas in which earthquakes are concentrated but where there is no evidence thus far of vertical movement may nevertheless be moving, probably in the direction indicated by their present relative elevations.

3.2.4 Stress

Stress orientations derived from focal plane solutions (see Sec. 3.1.10) and in situ strain measurements need to be reviewed carefully, as they cannot be matched against observed fault movements in the northeastern region. The in situ strain measurements are from Paleozoic rocks and represent stress fields younger than the rocks. Observed movements in these rocks take place along foliation and shear planes, which parallel Paleozoic movement directions. Movements appear to be due to residual strain and are brought about by changed conditions resulting from a drill hole or road cut. The movements are unrelated to the present-day stress field.

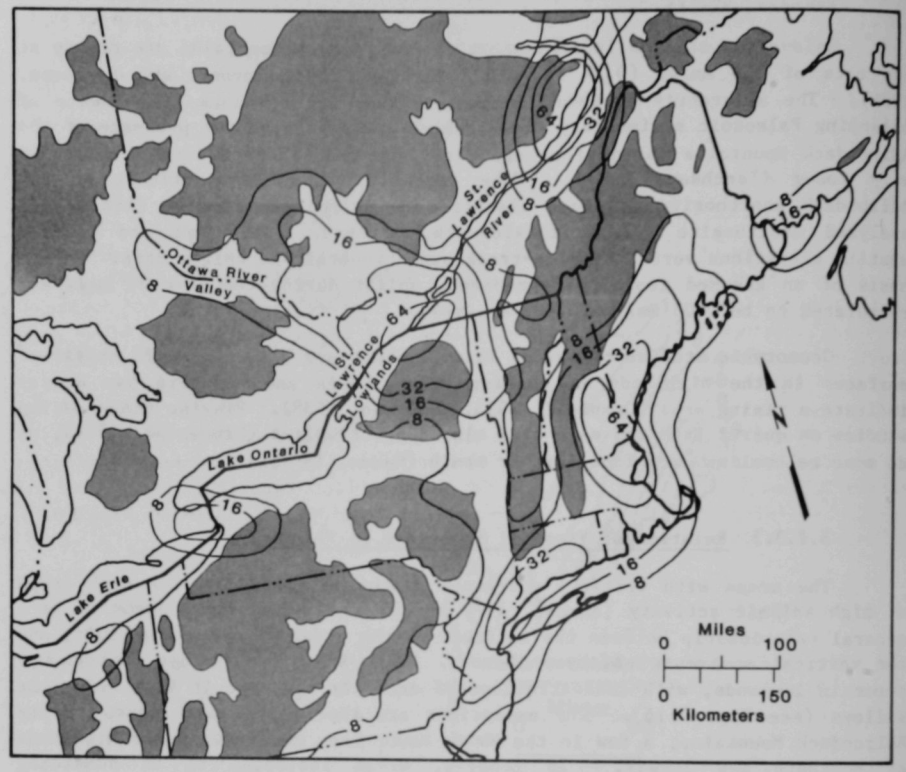

Fig. 3.16 Northeastern United States and Adjacent Canada Showing Elevations Over 305 m (1000 ft) Above Sea Level (shaded) and Contours of Seismic Frequency (contours show areal distribution of earthquake epicenters with epicentral I_{MM} = III and greater, as indicated by total number per 100,000 km^2 (39,000 mi^2) during 1800-1972. Contours are generalized, and are shown only as a guide for estimating regional seismicity) (Source: Adapted from Hadley and Devine, 1974)

The probably Holocene extensional faults. which are young, near-vertical northwest- and north-to-northeast-trending faults, and the local association of earthquakes with subsidence and grabens, together suggest that present tectonics are associated with extensional features.

The orientations of the principal horizontal stresses derived from seismologic and geologic data are in general agreement; however, the seismo-

logic data emphasize the compressional aspect, whereas the geologic data emphasize the extensional stress at right angles. The significance of this and reasons for it are as yet unknown. Despite this general match, it is possible that movements are mainly vertical and that the principal horizontal stress is quite weak or that the observed features are secondary to some larger-scale and hitherto-missed transcurrent movement across the region.

3.2.5 Causes of Seismicity

A variety of causes have been proposed to account for the seismicity in the northeastern United States (Woollard, 1958). Some of these are an attempt to find causes not related to faults, because surface faulting is not known to be associated with any of the earthquakes and because very few faults were previously recognized in the areas of seismic activity. However, recent geologic mapping by USGS, especially in eastern Massachusetts (Barosh et al., 1977a) and eastern Connecticut (Pease, in prep.), and by the New England Seismotectonic Study has revealed an abundance of faults, both in the region as a whole (Barosh and Johnson, 1978) (see Plate I) and in the seismically active areas. Therefore, support for the earlier hypotheses was based on incomplete information. A brief summary of the proposed causes of seismicity in the region is presented below.

3.2.5.1 Isostatic Rebound

Local stresses resulting from the southward tilting of the region caused by domal uplift of the Canadian shield following removal of Pleistocene ice have been proposed many times as the cause of seismicity (Leet, 1942). This theory does not account for the seismic trends that extend beyond the areas of glaciation, nor does it offer any explanation of why earthquakes repeatedly occur in the same areas. Furthermore, the rebound, which amounts to a tilt of about 0.8 m/km (4.2 ft/mi), is now considered to have taken place only during the first 4000 yr after the ice retreated. In addition, most of the vertical movements occurring now are subsidence, the opposite of rebound.

3.2.5.2 Granitic Plutons

Earthquakes in the region have been considered to be related to granitic plutons (Collins, 1937; Billings, 1942). Although granitic plutons occur throughout New England, their distribution does not show a particularly close relationship with areas of relatively high concentrations of earthquake epicenters.

3.2.5.3 Basic Plutons

Stress buildup at the borders of basic plutons arising from density differences between the pluton and surrounding rocks, has been proposed to account for major seismic events (Kane, 1977; Simmons, 1977). Gravity and magnetic highs, interpreted as buried basic plutons, have been noted in several seismically active areas in the eastern United States. Kane (1977) suggests that these highs are related to the seismicity. There are several problems with this hypothesis. First, the overall distribution of basic plutons shows a poor correlation with earthquake concentrations. Second, basic plutons and basic dikes usually occur in areas with faults, which generally control their emplacement and which could account for movements. Third, the stress buildup requires uniform conditions around the plutons, whereas in New England the designated plutons are in highly faulted, nonuniform areas.

3.2.5.4 Northwest-Trending Crustal Structure -- The Boston-Ottawa Seismic Belt

A general concentration of earthquake epicenters between Boston and Ottawa (Ont.) has long been noted (Hobbs, 1904). Sbar and Sykes (1973) and others have discussed this northwest-trending zone more recently. They suggest that the epicenters form the "Boston-Ottawa seismic zone," and that some unknown geologic cause, perhaps in the mantle, might account for the offshore Kelvin seamounts and the Mesozoic White Mountain plutons, as well as the major earthquakes of the region.

A close look at the trends of seismicity in the region, however, shows that the Boston-Ottawa zone may be a very weak trend, if it is present at all. Also, the Mesozoic intrusives said to be associated with the trend are not well aligned with it. A cluster of epicenters appears to form a seismic zone that extends northwestward from the end of Lake Champlain through Ottawa and beyond, but its extension to the southeast across New England is far from certain. Epicentral clusters in eastern Massachusetts and New Hampshire may appear to merge with the cluster northwest of Lake Champlain to form an overall Boston-Ottawa seismic zone, but only on very-small-scale maps of the region. On larger-scale maps of the region, the clusters in New England appear to be separate and to have trends of their own.

The zone is not particularly noticeable on the New England portion of maps showing epicenters or frequency of earthquakes for the period 1800-1972. The area of low seismicity in eastern Vermont and north-trending epicentral clusters in eastern New Hampshire both conform to the grain of regional geologic structure, that is, they are at an angle to the proposed zone. The geologic structure of southeastern New Hampshire (Hussey, 1981) and eastern Massachusetts is known well enough to preclude the discovery of large, surface, northwest-trending geologic structure(s) crossing this area. Although some northwest-trending topographic lineaments (N. 55-70° W.) are

present (Barosh, 1976a; Jones, 1979) that may be small faults, faults of this trend are also present outside the zone and strike slightly more westerly than the Boston-Ottawa seismic zone (N. 45° W.). During the past 5 yr, some small earthquakes have been located in eastern Vermont (Raica and Vudler, 1981) near the most prominent topographic lineaments.

The trend of the intrusive rocks forming the Kelvin seamounts is irregular, but they appear to trend toward eastern Connecticut rather than Boston. The Mesozoic White Mountain plutons trend north, not northwest, and those of the Monteregion Hills in Canada trend westward.

Thus, the foregoing analysis does not reveal any northwest-trending features aligned along a belt passing through Boston and Ottawa that would suggest some cause for the observed seismicity. Although the newly found, low-level seismicity in eastern Vermont does lie near a belt of northwest-trending topographic lineaments, this belt passes well to the north of Boston.

3.2.5.5 North Atlantic Rifting

Minor adjustments of the earth's crust resulting from the continued opening of the Atlantic Ocean basin may account for the seismic activity in the northeastern United States and adjacent Canada (Barosh, 1981a and 1982). Most of the activity occurs in embayments and bays along the continental margin, where the crust is known to be or appears to be subsiding. These areas lie along the offshore Cretaceous and Tertiary deposits from New Jersey to the New Hampshire border. These offshore deposits are missing further north, because they were deposited mainly to the east of a hinge line. East of this line, the crust has been bent down to the east. An increase in the southeastward tilt of Late-Pleistocene, marine-delta surfaces at the Maine coast (W.B. Thompson, 1981) suggests that the hinge line continues northward along the Maine coast and that it was active in post-Pleistocene time. The subsidence and earthquakes appear to occur on local irregularities along this margin, such as at the bends in the Cretaceous contact across Raritan Bay and east of Boston. Such relationships would appear to apply to the earthquakes in the Charleston and New Madrid regions as well.

Most of the seismic activity in northern and northwestern New York is part of a northeast-trending lowland belt of seismic activity that extends along the St. Lawrence River, with offshoots along the Ottawa River-southwestern Quebec area and Lake Champlain. This belt of seismic activity roughly parallels the Atlantic coast and continues southwestward through the New Madrid region to Arkansas. High-angle extensional faults or grabens lie along the St. Lawrence, Ottawa, and Lake Champlain areas (Forsyth, 1981; Kumarapeli and Saull, 1966). These structures appear to outline some sort of rift system (Kumarapeli and Saull, 1966) that may still be active (Forsyth, 1981; Hunt, 1981; and Hunt and Dowling, 1981).

Most of the lowland seismic activity between this St. Lawrence-Arkansas belt and the Atlantic coast is associated with north-to-northeast- and northwest-trending high-angle extensional faults and grabens and high-angle faults that may be extensional. Examples are the Lake Champlain-Lake George-Saratoga Springs area, the Hartford graben, the southern part of the Narragansett basin, Passamaquoddy Bay and, at least in part, the Merrimack valley in New Hampshire and the Penobscot Bay area in Maine.

Activity in the uplands appears to have a somewhat different character. The activity in the New Jersey highlands, which is at the northern end of a general northeast-trending upland belt extending southwestward to the Great Smoky Mountains, appears to have seismic activity associated with northeast-trending faults (Aggarwal and Sykes, 1978; Yang and Aggarwal, 1980). This belt lies just west of the Cretaceous margin. The activity in the Adirondack uplift could be related to this belt, but separated from it by a gap across the Catskill Mountains. The activity in the White Mountains may be related to a north-trending volcanic chain that could have risen along an extensional structure. The 1940 Ossipee earthquake in the White Mountains is near a Cretaceous volcanic caldera dated at 120 m.y. (Lyons, 1981), as was the 1973 earthquake to the north at the Quebec-Maine border.

The features described above appear to be related to extensional forces resulting from continued opening of the Atlantic Ocean basin. The seaward sagging of the crust along the Atlantic margin, which began in Early Jurassic time (Grow, 1981a), may be continuing, with the activity now concentrated at irregularities along its inner edge. The same force also may have activated the following extensional structures: (1) along the parallel belt that passes through the St. Lawrence and (2) north- to north-northwest- and northwest-trending structures between this belt and the Atlantic coast. An area just inland from the coastal sag in the central Appalachians rose upward in the mid-Mesozoic, probably as a consequence of the sag, and shed sediments onto it. The Adirondack Mountains may have also done so, but the situation in New England is more complex, perhaps due to the influence of more northerly striking Paleozoic structural trends and the development of a Mesozoic volcanic chain in New Hampshire. The forces acting at the margin today are probably similar to those that have operated on the region since the Late Cretaceous, but likely in a much diminished form.

3.2.5.6 Reactivation of Zones of Weakness

Sykes (1978) and Sbar and Sykes (1977) suggested that the modern seismicity is due to the reactivation of ancient zones of crustal weakness in the present tectonic stress field. Alexander and Lavin (1982) favored a related idea, that the seismicity of the eastern United States is due to the activation of major crustal blocks, 100 km (62 mi) in extent, in the present stress field. As discussed by Sbar and Sykes (1977) and Yang and Aggarwal (1981), there are very few examples where earthquakes can be directly

orrelated with particular mapped faults. The Ramapo fault (Aggarwal and ykes, 1978) and a strand of the Norumbega fault (Ebel, 1983) are fauls that ay have been the focus of seismic activity. Yang and Aggarwall (1981) roposed that there is a general correlation of earthquake activity with aleotectonic provinces, and that there are concentrations of activity within hese paloetectonic zones.

3.2.5.7 Incompleteness of Available Explanations

From the preceding review of the causes of seismicity, it appears that none of the proposed causes is entirely satisfactory in accounting for the overall distribution of seismicity, although some of the proposed causes may contribute to the seismicity in specific instances. A satisfactory explanation for seismicity in the northeast must account for the easterly and northeasterly as well as northwesterly horizontal compressive stresses, the diffuse pattern of the regional seismicity, and the local concentrations of earthquakes. Most of the proposed explanations invoke the present plate tectonic motions as the source of the regional stress field that is causing the earthquakes, but they fall short in explaining the reason for the particular locations of seismic activity, inactivity, and stronger earthquakes.

3.3 AREAS OF LOW PROJECTED SEISMICITY AND FAULTING

The task of pinpointing areas of high tectonic stability in the northeastern United States must be attempted using an incomplete data base, as is true for most other regions. There is no reason to believe that all of the areas presently capable of producing moderate to large earthquakes have experienced such events during the historic time period. Furthermore, whether an earthquake in the region would produce surface faulting is extremely difficult to estimate with the data at hand. Nevertheless, the seismological and geological data and analyses that have been presented in Secs. 3.1 and 3.2 contain consistent and plausible ideas that can be used to deduce areas in the northeastern region with the lowest probabilities of seismicity and surface faulting.

In particular, the seismological and geological analyses make it clear that there are at least seven major criteria that should be used to identify areas of possible future tectonic and earthquake activity. The criteria below have been developed from known locations and effects of earthquakes, known and suspected areas of surface movements, and geologic features that appear to be related to seismicity.

1. Location relative to zones of present or past seismic activity. This criterion eliminates many areas that stand out in the regionalization analysis of Sec. 3.1.6, i.e., many of the lowland areas of Maine, most of southern and

central New Hampshire, eastern Massachusetts, most of Rhode Island, central Connecticut, and Adirondack Mountains, and the lowland areas of New York and New Jersey.

2. Susceptibility of area to strong ground motions from earthquakes with epicenters located both within and adjacent to the northeastern region. The areas eliminated by this criterion are best illustated in Fig. 3.17 (mapped from data in the Appendix), which shows the maximum intensities experienced during the historic record. The proximity of northernmost Maine to La Malbaie, Quebec, for instance, represents some hazard in that area, even though very few earthquake epicenters occur there

3. Location relative to known or suspected vertical movements. Areas undergoing probable vertical movements should be eliminated. These include the coastal embayments of Maine, the Boston embayment, the southern Connecticut region and the Raritan Bay region, all of which are sites of known or suspected subsidence, and the Adirondack Mountains and the upland areas of northern New Jersey, which are apparently rising. These areas are experiencing seismic activity, as has been pointed out in Sec. 3.2.3.

4. Location relative to suspected Holocene fault movement. This criterion rules out the Lake Champlain-Saratoga Springs area, the Passamaquoddy Bay area, and the northern Penobscot Bay area.

5. Location relative to the landward border of the Cretaceous and Tertiary deposits. This criterion eliminates the area near the Fall Line of New Jersey and along the coast of Connecticut to the north where the contact swings offshore. Alongshore areas of Massachusetts, New Hampshire, and possibly Maine also are ruled out.

6. Location relative to major northwest- and north-to-north-northeast-trending extensional faults and grabens. In addition to regions already eliminated above, this criterion pinpoints areas like the Lake Champlain-Lake George area, the Hartford graben, Lower Narragansett Bay, Passamaquoddy Bay, and possibly the Merrimack River Valley as having a potential for low stability.

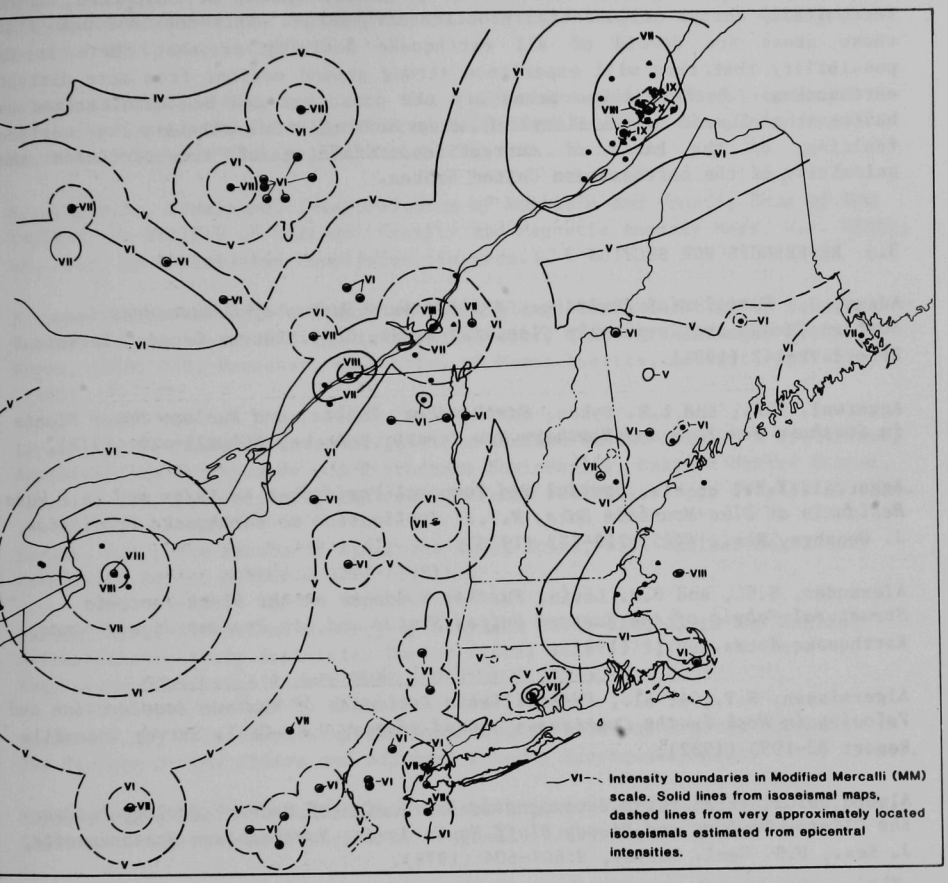

Fig. 3.17 Epicenters and Intensity Boundaries of Moderate to Large Earthquakes in Northeastern United States and Adjacent Canada, 1534-1979

7. Location relative to areas of Cretaceous igneous activity. This criterion rules out the area along the north-trending Cretaceous volcanic vents in the White Mountains.

By applying these criteria, three areas have been identified as having the highest stability in the tectonic region. These are northwestern Maine, eastern Vermont through northwestern Connecticut, and central New York State. They appear to be characterized by very low historic and present

seismic activity and are removed from presently known, or suspected, major tectonically active or potentially active structures. This does not mean that these areas are devoid of all earthquake activity or that there is no possibility that they will experience strong ground motions from more distant earthquakes. Rather, these areas are the ones that can be characterized as having the lowest probability of experiencing an earthquake or surface faulting, on the basis of current understanding of the tectonics and seismicity of the northeastern United States.

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4 SURFACE PROCESSES

4.1 DENUDATION PROCESSES

Present-day erosion and weathering rates for New England can be used to estimate the amount of erosion that will take place in the northeastern region in the future. Such estimates assume that the present rate of erosion is known accurately and that the rate approximates those of the past and future.

Although little research has been devoted to stream and slope processes in the northeastern region, a few generalized statements can be made. Most of New England has undergone limited landscape change during the postglacial period. Vegetation blankets the area, slowing many erosion processes. Many of the depressions in the region are partially filled with bog and swamp sediments. The most notable postglacial changes have taken place along the coast and have been related to postglacial eustatic changes and crustal movements.

The comparatively low rate of regional denudation for much of New England has been confirmed in several studies attempting to calculate regional erosion rates for the United States by measuring suspended sediment and total dissolved solids in rivers or estuarine sedimentation rates. Judson and Ritter (1964) calculated a denudation rate for the North Atlantic states of 4.8 cm/1000 yr (1.9 in./1000 yr). Ritter (1967) calculated that such an erosion rate would remove 44-57 $t/km^2 \cdot yr$ (126-163 $tons/mi^2 \cdot yr$) of surface material from this region.

Variations in topography, surface materials, and size of drainage basins affect the rate of erosion. For the central New England region (Vermont, New Hampshire, Massachusetts, and Connecticut), Gordon (1979) determined an erosion rate of 13 $t/km^2 \cdot yr$ (37 $tons/mi^2 \cdot yr$). Gordon attributed this low rate to the stability of the surface and to the presence of erosion-resistant materials. The principal sediment source is thought to be the glacial lake deposits along many of the river banks in the region. Gordon believes that bank erosion is responsible for the nearly constant sediment yield, as estimated from estuarine sedimentation, of the drainage basins in central New England for the past 800 yr.

Calculations of average denudation rates are of limited usefulness in determining the rate of change of surface relief in central New England because the dominant activity of the river systems that discharge into Long Island Sound continues to be rearrangement of glacial debris. In other words, the denudation rate for the drainage basin is more a measure of the rate of insertion of sediment into streams than a bedrock surface erosion rate. According to Gordon (1979), erosion of stream banks in this region may be a rate-limiting process for denudation.

Differential rates of weathering and erosion of underlying rocks have been the primary mechanism in the formation of the major physiographic provinces in New England (Rahn, 1971). Mountainous areas are to a large degree underlain by granite, rolling hills are underlain by schist and other metamorphic rocks, small valleys in metamorphic terranes are underlain by marble, and the broad Connecticut lowland is underlain by Triassic and Jurassic sandstones and shales. Similarly, from a study of the topography and geology of the Appalachian highlands between northeastern New York and Alabama, Hack (1980) concluded that variations in altitude and relief are more closely related to differential erosion of bedrock than to differential uplift.

Of special interest in this study is the weathering of granites. Although granites are relatively resistant to chemical weathering in the climate of the northeastern region, physical weathering is locally important. Exfoliation, or sheeting, and jointing of granite is caused by expansion of the rock through the removal of overburden pressure, either by erosion or deglaciation (Chapman, 1958; LeGrand, 1949; and Jahns, 1943). Landslides are common in well-jointed granites (Durgin, 1977). The most well known mass movements of material in New England are the debris avalanches that take place on the steep slopes of the White Mountains (Schafer and Hartshorn, 1965) and the Adirondack Mountains (Fisher et al., 1980).

The effects of frost action and wind erosion in New England are minimal. Frost wedging of rocks above timberline on Mt. Katahdin and a few other mountains has produced a cover of coarse rubble. Wind erosion in New England is restricted almost entirely to coastal areas, especially the large dune areas of Cape Cod and elsewhere. Inland, disturbance of once-continuous areas of vegetation has activated a few sand dune areas (Schafer and Hartshorn, 1965).

4.2 EFFECTS OF GLACIATION

4.2.1 Glacial Erosion

Comparison of the glacial drift sheets in central North America reveals that the overlapping drift border patterns for the four Pleistocene glacial ages are not much more than 322 km (200 mi) apart, which is a small fraction of the radii of the ice sheets. This observation implies that the genesis of glaciers and their growth have been much the same during each of the glacial stages (Flint, 1971). Therefore, it is highly probable that the nature and progression of each glacial stage in the northeastern region were very similar.

Although it is difficult to identify pre-Wisconsinan (youngest glacial episode) drift sheets in the New England area (Schafer and Hartshorn, 1965),

evidence of older drift in Pennsylvania, New Jersey, and in southeastern coastal areas indicates that the whole region has been repeatedly glaciated (Stewart, 1961). Schafer and Hartshorn (1965) reported that at least one older till is widespread beneath Wisconsinan drift, and Kaye (1964a and 1961) identified a series of drift units at Martha's Vineyard and in the Boston basin that probably dates to Nebraskan (earliest Pleistocene) time. Evidence that glacial deposits diverted the Housatonic River in northwestern Connecticut in pre-Wisconsinan time has been presented by Warren (1971) as indicating multiple glaciation of that area.

If it can be assumed that all Pleistocene glaciations in the New England area were similar in nature and extent, it may be possible to estimate the effects of future glaciation on New England landforms by investigating past glacial activity in the area.

4.2.1.1 Continental Versus Alpine Glaciation

The depth of glacial erosion continues to be a subject of debate. With the notable exception of White (1972), who is a proponent of deep erosion by continental ice sheets, most researchers have concluded that minimal glacial erosion occurs beneath the central areas of continental ice sheets (Kaszycki and Shilts, 1980; Sugden, 1976; Gravenor, 1975; and Flint, 1971). Maximum glacial erosion and deposition usually occur near the margins of ice sheets (Flint, 1971).

Local geologic and topographic conditions strongly influence the degree of glacial erosion. In mountainous areas with abundant snowfall and steep slopes, glacial erosion can be significant; in regions of low relief, it can be comparatively slight. Glaciers can deeply excavate preexisting valleys oriented in the direction of flow, while adjacent upland areas overridden by thinner parts of the ice sheets remain relatively unaffected by glacial erosion. Glacial flow can also be affected by topography that interferes with or reduces radial glacial flow (Flint, 1971).

In mountainous areas, the stresses applied by moving glaciers may cause development of joints in previously unfractured rocks and aid in glacial quarrying (Trainer, 1973). For example, the influence of jointing on glacial plucking has been shown by Chapman and Rioux (1958) to have played a role in development of asymmetrical valley-and-ridge profiles in Acadia National Park in Maine. However, few measurements exist that can be used to compare the rate of erosion in mountainous areas quantitatively with that in flat terrains. Flint (1971) cited an extreme example of glacial erosion at Sognefjord, Norway, where the total apparent depth of erosion is 2.4 km (1.5 mi). In another mountainous area with optimum conditions for glacial erosion, Reid (1892) estimated an erosion rate for Muir Glacier in southern coastal Alaska equivalent to 600 m (1970 ft) in 30,000 yr (Flint, 1971). On the other hand, Flint provided several examples where erosion by continental ice sheets has had little effect on preglacial features. Furthermore, as noted above,

local variations in topography and geology result in comparatively deep erosion at one location but negligible scour in nearby areas.

Investigating the glacial erosion of Greenland, Sugden (1974) determined that the ice sheet merely modified the preexisting land surface without major transformation of the landscape. Larger rivers maintained integrated drainage patterns and regular valley-floor long profiles reminiscent of nonglacial humid environments. Extrapolating from these findings, Sugden (1976) estimated that Pleistocene glacial erosion removed no more than a few tens of meters (yards) of material from the shield areas.

4.2.1.2 Continental Glaciation of New England

The bedrock topography of much of the New England area is fundamentally the same as the stream-carved landscape that predated Pleistocene glaciation (Schafer and Hartshorn, 1965). In most places, the landscape was modified only slightly by glacial erosion. The most conspicuous result of glaciation, insofar as erosion is concerned, was the removal of the mantle of preglacially weathered rock and the planing off of a few meters (yards) of bedrock (Stewart, 1961).

Most glacially eroded bedrock outcrops in New England display little or no weathering. In some locations, however, rock weathered to depths of approximately 8 m (25 ft) has been found to underlie glacial drift on hills and in valleys. In western Rhode Island, such weathered bedrock is locally continuous (Schafer and Hartshorn, 1965). Although some of this weathering may have occurred during interglacial periods, most of the weathering probably predates the Pleistocene Epoch.

The thickness of glacial drift deposited at the margins of a glacier is the principal indicator of the extent of glacial erosion. The average thickness of drift in New England is estimated to be 5-10 m (16-33 ft). However, as much of the glacial drift derived from the land surface lies below sea level, the average amount of glacial erosion throughout the region could be 20 m (65 ft) or more (Schafer and Hartshorn, 1965). Laine (1980) evaluated the thickness and volume of Pleistocene sediments in the western North Atlantic and concluded that at least 100 m (330 ft) of bedrock has been eroded in Greenland and North America over the last 2.8 m.y. He estimated that 55-95% of this lowering of the surface can be attributed to glacial erosion. When these conclusions were met with some criticism (Andrews, 1982), Laine and Bell (1982) cited additional ocean-sediment data to support the earlier estimate. It should be emphasized, however, that these values represent average surface lowering. Even if the estimates are reliable and accurate, large variations in scour depth can still occur throughout glaciated areas, depending on local geologic and topographic conditions.

Erosion of the New England landscape by glacial ice was augmented by geologic factors that existed before Pleistocene time. The most common causes

of local surface irregularities produced by ice erosion are topography and the structure, fabric, and relative hardness of the bedrock. The influence of bedrock on glacial erosion is readily demonstrated in highly metamorphosed terranes. In Vermont, for example, the patterns of exfoliation that predominated in the schistose, slaty, and gneissic bedrocks were emphasized by glacial erosion, thereby resulting in a linearity of local relief that parallels bedrock structures (Stewart, 1961). Because glacial erosion was concentrated on the softer rock, features carved by the ice tend to parallel the fabric of the rock regardless of the direction of ice movement. As a result, many lakes occupy basins cut in softer rocks, while ridges and outliers are underlain by harder rocks.

Although the general flow of the Laurentian ice sheet was to the south and east, glacial striations and grooves throughout the region document local variations in the direction of ice flow. These variations are chiefly attributable to topographic features that altered the motion of the glaciers. In the case of the Green and Taconic mountains, the ice piled up to cross the mountains; moved parallel to the mountains; and forced its way through stream valleys, cols, and gaps in mountain crests, thereby concentrating the erosion in those areas (Stewart and MacClintock, 1969).

The most pronounced glacial erosion in New England occurred within the preglacial stream valleys. Valleys parallel to the direction of ice flow were deeply scoured, whereas stream valleys perpendicular to glacial flow were generally filled with glacial sediment. For example, the Connecticut River valley is typical of large glaciated valleys in the New England area. Ice invaded the valley from the northeast or northwest and was deflected down the valley, which was thereby deepened and widened (Stewart, 1961). However, it is difficult, if not impossible, to determine quantitatively the amount of glacial erosion that occurred in this and other valleys in New England. Such calculations would necessitate estimating the preglacial depth, width, and shape of each valley.

Topographic highlands experienced varying degrees of glacial erosion, depending on their location relative to the continental ice sheet. As noted by Muller (1965), the intensity of summit reduction increases northward in New York and, in general, toward the center of ice accumulation and growth. Nonetheless, local differences in exposure to major glacial flow account for marked variations in erosive effectiveness north of the drift border. Muller (1965) estimated that summits as much as 80 km (50 mi) north of the limit of glaciation may have been reduced by a minimum of 50 m (160 ft). His estimates were based on hypothetical extrapolations from unglaciated to glaciated terrain and in no way represent an actual measurement of the amount of glacial erosion of summits. Summits within a few kilometers (miles) of the drift border also were affected considerably by glacial scour, and summits near the center of upland areas experienced less reduction than those at the margins of such areas (Muller, 1965).

4.2.1.3 Alpine Glaciation in New England

In addition to having been subjected to continental glaciation, many of the New England highlands have been affected by alpine, or valley, glaciation. Local valley glaciers preceded the Laurentian ice sheet in most if not all of the highland areas and may have postdated the ice sheet as well. For example, Mt. Katahdin and the Presidential Range of the White Mountains experienced cirque glaciation prior to and after being overridden by the Laurentian ice sheet. On Mt. Katahdin, at an elevation of 1605 m (5267 ft) above mean sea level, a mountain ice cap succeeded the ice sheet but preceded cirque glaciers (Flint, 1951).

The Adirondack highlands appear to have split the waning continental ice sheet into flanking lobes, while the highest peaks generated valley glaciers and supported persistent ice fields. By late Wisconsinan time, the Adirondacks were probably the source of local valley glaciers (Muller, 1965). It is possible that the Adirondacks were overtopped by continental ice sheets in pre-Wisconsinan glacial periods. The highland region of northern New Hampshire, western Maine, and northern Vermont is characterized by summit elevations that exceed 914 m (3000 ft). Flint (1951) concluded that this area was the Appalachian center of the Laurentian ice sheet.

4.2.1.4 Periglacial Erosional Features

Fluvial Erosion. Although most stream valleys in New England were modified locally by glacial erosion, most of the relief in these valleys is probably the result of preglacial stream erosion (Schafer and Hartshorn, 1965). In general, it is difficult to determine how much erosion in any given valley is due to preglacial stream erosion and how much is due to glacial ice scour.

Glaciation in New England produced large amounts of detritus that were deposited as glacial drift and associated deposits in all of the bedrock valleys along the New England coast. The deposits are of varied lithologies, ranging from till to marine clays to peat. In some areas, large amounts of glacial debris may have been entrained by proglacial rivers and transported at rates far in excess of those typical of normal subaerial weathering and erosion (Church and Ryder, 1972). Because proglacial stream erosion and sediment transport rates depended on the long profile of the river, water discharge, volume and grain size of the sediment load, and local base-level stability, all streams were not affected uniformly. Furthermore, in some areas of low relief, such as eastern Massachusetts, obstruction of bedrock stream valleys by glacial deposits resulted in conspicuous changes in drainage patterns and sediment transport regimes (Warren, 1971; Schafer and Hartshorn, 1965). The irregularity of the depths of bedrock stream valleys along the New England coast (Upson and Spencer, 1964) testifies to the variability of the erosional phenomena affecting the region.

Wind Erosion. Wind erosion in New England has been most effective in areas of unvegetated glacial debris. For the most part, however, wind has been a very minor erosive force in the area. Mixtures of sand and silt derived from areas of stratified drift that remained unvegetated during deglaciation were deposited by winds throughout much of southern New England. The mantle of eolian material is most extensive in areas of low relief in southeastern New England. In these areas, this material is commonly 1.5 m (5 ft) thick (Schafer and Hartshorn, 1965). The numerous ventifacts, or wind-abraded stones, that have been found throughout New England (Denny, 1936) probably formed in periglacial areas, where abundant supplies of glacially derived sands were exposed.

The most extensive inland dunes in New England are located in southern Massachusetts east of the Connecticut River in the area formerly occupied by glacial Lake Hitchcock (Schafer and Hartshorn, 1965). The short dune-building period followed the early postglacial draining of the lake but preceded post-glacial revegetation of the lake bottom. Similarly, the relatively extensive Albany dunes of eastern New York were derived from deltaic and lacustrine materials brought eastward to glacial Lake Albany by streams draining through the Mohawk valley. This dune field implies that comparatively drier conditions obtained earlier. Donahue (1977) suggested that the Albany dunes were sedentary during much of the dune-building period because of rapid revegetation. The directions of dune blowouts correspond to present-day wind patterns, suggesting that a constant wind pattern, attributable to major topographic controls, has been in existence for a long time.

Frost Action. Periglacial frost features, such as solifluction deposits, clastic dikes, and frost-wedged bedrock, are rare in New England lowlands, but their existence indicates the presence of perennial permafrost for at least a short period of time at the end of the Pleistocene Epoch. The most common frost structures are involutions, or folds, that presumably formed in the active zone of annual freeze and thaw under the periglacial conditions existing during deglaciation (Denny, 1936).

4.2.2 Pleistocene and Postglacial Crustal Movements and Fluctuations in Sea Level

Changes in sea level result in altered base-level conditions which, depending on the magnitude and direction of change, will either enhance or diminish erosional and related fluvial processes. Similarly, crustal movements affect fluvial processes by either increasing or decreasing the gradient from the drainage divide to the mouth of the basin, depending on the direction of movement as well as on the position of the center of movement relative to the existing fluvial system. Because sea-level fluctuations and crustal movements have such a profound effect on the development of drainage basins and other landscape features, the sequences and rates of change of these two phenomena are briefly discussed in this report.

4.2.2.1 Wisconsinan Glacial Maximum and Early Deglaciation

During the glaciation and deglaciation of the New England area from about 23,000 yr before present (B.P.) to 10,500 yr B.P., during the Pleistocene Epoch, the Earth's surface was subjected to enormous variations in stress caused by the loading and unloading of the massive ice sheets. These stresses produced elastic bending, fracturing, and viscous flow or plastic creep in the Earth's crust or mantle. Formation and melting of the ice masses also resulted in eustatic changes. Therefore, the present position of the New England shoreline is the result of the interaction between postglacial eustatic changes and crustal movements.

According to various theoretical models, glacial loading of the crust depresses the central regions beneath an ice cap, thereby causing the crust in areas at the margins of the ice sheet to be slightly uplifted (Bloom, 1967). Thus, the last major glacial advance and retreat of the Laurentian ice sheet during the Late Wisconsinan Stage in North America about 10,000-23,000 yr B.P. (Bowen, 1978) could have produced an uplifted zone throughout the Great Lakes region and along part of the North Atlantic coast (McGinnis, 1968). Some researchers deny the existence of such peripheral bulges, because widespread Tertiary and Quaternary uplift, and lowering of sea levels during periods of glacial maxima make it difficult to demonstrate ice-margin uplift (McGinnis, 1968).

The areas most affected by post-glacial crustal rebound have been determined but the evidence is somewhat sparse (Flint, 1963). The northward rise of silts and clays associated with proglacial lake floors in the Hudson River and Connecticut River valleys suggests that warping affected the northeastern region at least as far south as Newburgh, N.Y., and Hartford, Conn., and possibly further. Similar evidence suggestive of crustal uplift is found throughout the coastal region of New Hampshire and Maine, where the Presumpscot formation, a fossiliferous blue-gray marine clay, has been raised above sea level (Borns and Hagar, 1965). Warped marine strandlines occur in the eastern Maritime Provinces of Canada, in southeastern Newfoundland, and on the coast of Labrador. These features also reveal the extent of the region affected by isostatic rebound. Figure 4.1 illustrates the pattern of postglacial uplift for the northeastern region.

Evaluating relative changes in sea level only, Curray (1965) reviewed many of the findings of geologic investigations of late Quaternary sea levels. His data suggest that the late Wisconsinan low-stand sea level occurred at approximately 120-125 m (395-410 ft) below present sea level during the glacial maximum between 20,000 yr B.P. and 17,000 yr B.P. Sea levels of 130 m (425 ft) below present sea level were calculated by Milliman and Emery (1968) to have occurred approximately 16,000 yr B.P.

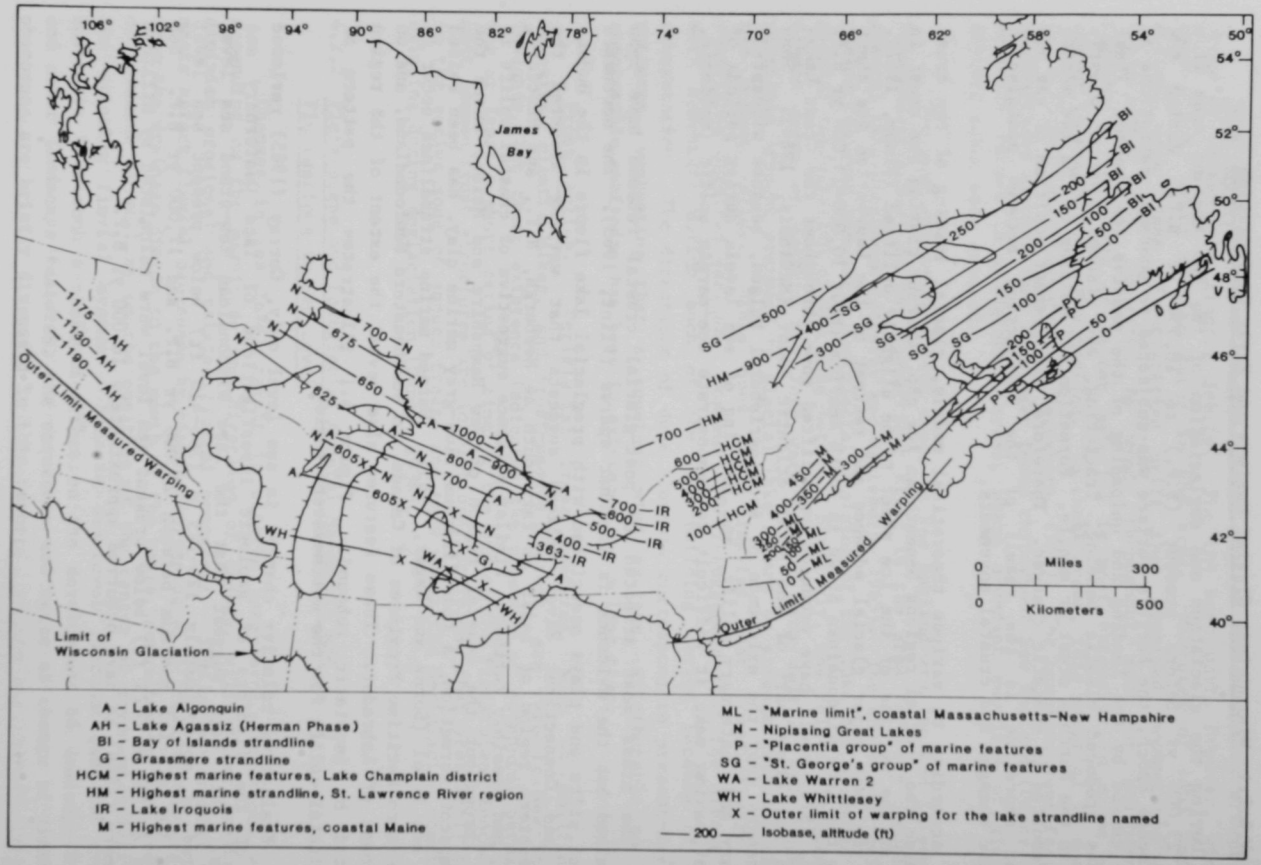

Fig. 4.1 Isostatic Uplift Pattern for the Northeastern and North Central United States and Southeastern Canada (Source: Adapted from Flint, 1963)

The Late Wisconsinan glacial recession and subsequent melting of the ice sheet resulted in the Holocene transgression between 14,000 yr B.P. and 7,000 yr B.P. (Milliman and Emery, 1968). Bloom (1963) used radiocarbon dating of peat samples from various parts of New England to establish that the deglaciation of southern Connecticut occurred more than 13,500 yr B.P.; central Massachusetts, approximately 13,000 yr B.P.; and Portland, Maine, 14,000 yr B.P. Between 14,000 yr B.P. and 11,000 yr B.P., melting of the ice sheet resulted in a rapid change in relative sea level to at least 30 m (100 ft) or more above the present level (Curray, 1965; Flint, 1963). According to radiocarbon dates of salt marsh peats from the Boston area obtained by Kaye and Barghoorn (1964), relative sea level may have been approximately 20 m (65 ft) higher than present sea level about 14,000 yr B.P. Stuiver and Borns (1975) suggested that recession of the ice margin between 13,000 yr B.P. and 12,700 yr B.P. resulted in large-scale submergence of coastal areas of central Maine. According to Bloom (1963), Portland, Maine, was submerged at least 20 m (65 ft) below present sea level approximately 12,100 yr B.P. A maximum submergence of at least 50 m (165 ft) near Portland was estimated to have occurred approximately 11,800 yr B.P. (Bloom, 1963). Although the geologic record for the early stages of the Holocene trangression is incomplete, studies have indicated the magnitude of the submergence that occurred along part of the New England coast, and the data are in agreement with global information on eustatic changes.

Following regression of the ice sheet, a delayed postglacial crustal rebound overtook the rising sea level and arrested marine transgression. In the Boston area, a crustal rise of approximately 90 m (290 ft) was calculated to have occurred between 14,000 yr B.P. and 6,000 yr B.P. (Kaye and Barghoorn, 1964). A maximum rate of uplift of 6 cm/yr (2.4 in./yr) was estimated by Kaye and Barghoorn to have occurred 12,760 yr B.P., with the rate approaching zero at 6000 yr B.P. Stuiver and Borns (1975) indicated that isostatic crustal rebound in Maine exposed the previously submerged Maine coastline approximately 12,100 yr B.P., which contradicts the time of submergence in the same area postulated by Bloom (1963).

4.2.2.2 Valderan Glacial Substage

The progression of crustal warping and eustatic changes is complicated by the late-glacial Valderan substage (10,500 yr B.P. to 8,000 yr B.P.), a glacial readvance that reached a maximum approximately 10,500 yr B.P. (Bowen, 1978; Flint, 1963). However, crustal uplift continued through this substage as sea level fell. Upson and Spencer (1964) proposed that the depths of submerged bedrock valleys (40 m [130 ft] below current sea level) occurring along the New England coastline are the end result of three processes: crustal warping, glacial erosion, and eustatic fall. Regardless of the detailed manner and exact time of formation of these preestuarine surfaces, deposition of estuarine deposits resulted from a rise in sea level that accompanied the waning and eventual retreat of ice following the Valderan advance

in Late Pleistocene and Holocene time. If a minimum sea level coincided with the beginning of the Valderan ice retreat, Upson and Spencer (1964) postulated a sea-level rise of 40 m (130 ft) in 10,500 yr, or a rise of approximately 0.4 cm/yr (0.16 in./yr).

4.2.2.3 Deglaciation (8000 yr B.P. to present)

Bloom (1963) postulated that postglacial reemergence, accompanied by differential upwarping to the northwest, began about 7000-8000 yr B.P. Differential uplift appeared to increase in the direction of increasing glacial ice thickness and, during the last 7000-8000 yr, resulted in upwarping of about 0.6 m/km (3.17 ft/mi) towards the northwest. Bloom (1963) calculated that reemergence of the Maine coastline was on the order of 43-76 m (140-250 ft) above present sea level.

According to Curray (1965), a pronounced slowing of the rate of sea-level rise occurred at 7000 yr B.P., when worldwide sea level was approximately 10 m (33 ft) below its present level. This decrease in the rate of eustatic rise parallels the decreasing rate of crustal uplift described by Farrand (1962) that has been apparent from the time of deglaciation to the present. Flint (1953a) described the crustal upwarping that occurred in North America as pulsatory, with pulses of rapid uplift alternating with times of slower warping. The pulses of rapid uplift noted by Flint occurred during periods of rapid deglaciation of the Laurentian ice sheet, that is, during periods of rapid crustal unloading. Although deglaciation may not be the sole cause of crustal uplift, it may be the most important factor. Ruddiman and McIntyre (1981a) concluded that deglaciation was complete by 6000 yr B.P.

In plotting radiocarbon-dated and pollen-dated events against a hypothetical postglacial eustatic curve, Bloom (1960) noted that postglacial crustal rebound lagged behind the rise of sea level, then exceeded the rise of sea level, and, for the past 6000 yr, has either reversed itself or has been masked by crustal subsidence of other origins.

Although well substantiated with radiocarbon dates, estimates of the rates of eustatic rise over the past 6000 yr are very controversial. Essentially three schools of thought have arisen to explain recent eustatic events (Curray, 1965).

1. Sea level has been slowly and continuously rising throughout time and has reached its present position only very recently.

2. Sea level reached its present position and then remained stable for the past 3000-5000 yr.

3. Sea level first reached its present position 3000-5000 yr B.P. and has been fluctuating above and below its present position since that time.

Upson et al. (1964) described a relative rise of sea level along the Connecticut coast of 1.7-2 mm/yr (0.07-0.08 in./yr) since approximately 6000 yr B.P. They suggested that sea level 6000 yr ago may have been as much as 6-7.5 m (20-25 ft) below present sea level but not lower than 10.5-12 m (35-40 ft) below current sea level.

Several other investigators have refined the estimates of the rate of sea-level rise over the last 7000 yr. Bloom and Stuiver (1962) based their estimated submergence rates for the Connecticut coast on radiocarbon-dated peat samples. From their findings, they determined a land subsidence rate of approximately 0.2 cm/yr (0.08 in./yr) for the period from 7000 yr B.P. to 3000 yr B.P., and a rate of 0.1 cm/yr (0.04 in./yr) for the last 3000 yr. A total submergence of 10 m (33 ft) is estimated to have occurred over the entire 7000-yr period, with approximately 2.7 m (8.9 ft) occurring in the last 3000-yr period.

Keene (1971), in a study of salt marshes in New Hampshire, estimated an average rate of submergence between 6850 yr B.P. and 4000 yr B.P. of 0.23 cm/yr (0.09 in./yr), with a significant decrease in the rate of submergence about 4000 yr B.P. These findings support other evidence indicating that rapid submergence of the coastline has slowed over the past 3000-4000 yr.

In analyzing radiocarbon-dated peats from the New Jersey coast, Stuiver and Daddario (1963) inferred that rapid submergence of 0.3 cm/yr (0.12 in./yr) took place 2600-6000 yr B.P. From 3000 yr B.P. to 2000 yr B.P., the rate of submergence slowed. If sea level has been stable for the past 3000 yr, Stuiver and Daddario hypothesized that New England and New Jersey have been subjected to a considerable amount of crustal subsidence. However, a complex eustatic-tectonic relationship is more likely.

The level of complexity of such eustatic-tectonic relationships was demonstrated in a paper by Harrison and Lyons (1963) on changes in sea level and crustal movements along the New England-Acadian shoreline for the period between 4500 yr B.P. and 3000 yr B.P. From 4500 yr B.P. to 3200 yr B.P., a continuous transgression of the sea was calculated to have occurred at a rate of 0.09 cm/yr (0.04 in./yr). Between 4500 yr B.P. and 3800 yr B.P., the New England-Acadian coastline was calculated to be stable; from 3800 yr B.P. to 3400 yr B.P., crustal downwarping occurred in the Nova Scotia area at the rate of 0.8 cm/yr (0.31 in./yr). From 3400 yr B.P. to 3250 yr B.P., rapid crustal upwarping occurred at a rate of 1.2 cm/yr (0.47 in./yr) in north-central Nova Scotia; and from 3250 yr B.P. to at least 3000 yr B.P., west-central Nova Scotia may have experienced downwarp at a rate of 0.3 cm/yr (0.12 in./yr).

Continued submergence of the New England coastline has been demonstrated by other investigators. Evidence of recent submergence is the drowned

forests of coastal Maine and adjacent regions, and tide-gage records. For the period 1939-1970, Hicks (1972) reported that coastal subsidence increased linearly from zero at Hampton Roads, Va., to a rate of 0.2 cm/yr (0.08 in./yr) in southern Maine. South of Cape Hatteras, vertical land movement has been insignificant. Tyler et al. (1979), in reviewing the evidence of submergence of historic structures and eustatic changes, also suggested the presence of downward crustal movement. According to the U.S. Coast and Geodetic Survey, as cited in Tyler et al., a downwarp to the east of 0.7 cm/yr (0.28 in./yr) (minimum) may have occurred between 1942 and 1966 from Bangor to Calais, Maine. However, this downward crustal movement has been shown by Barosh (1976) to be tectonic in origin and is described further in Sec. 3.2.3 on vertical crustal movements.

Although the general patterns of vertical crustal movements and eustatic changes in response to glaciation and deglaciation have been deciphered, the absolute magnitude and precise timing of these events at specific locations within the northeastern region remain in question. Isostatic adjustments are difficult to segregate from crustal movements of a tectonic nature, and it is often difficult to relate geologic deposits that have been absolutely dated at one locality to specific regional and worldwide geologic events. Furthermore, glacial growth and recession occur at variable rates through time and at different times at different locations. As a consequence, the absolute age of a given glacial event or resulting glacial deposit will often be different at neighboring locations. An additional complication exists in coastal areas where marine transgressions and regressions in response to eustatic changes were occurring simultaneously with uplift or subsidence. Obviously, such a situation complicates the interpretation of geologic evidence and makes it difficult to identify the amount of change associated with each process. A full understanding of the timing, rate, and magnitude of Quaternary geomorphic and geologic processes and their collective effects on the landscape of the northeastern region will be possible only after additional detailed studies have resolved these complexities.

4.2.2.4 Projected Sea-Level Rise over the Next 10,000 Years

In considering potential transgression by the sea over the next several thousand years, those northeastern coastal areas having surface elevations less than 137 m (450 ft) above sea level must be considered. The 137-m (450-ft) figure is used here because the Presumpscot formation, a late-glacial (12,500 yr B.P.) marine deposit of silt and clay occurring along sections of the coasts of Maine, New Hampshire, and Massachusetts, is known to occur up to this altitude. This elevation was formerly at sea level as a result of glacial loading of the crust. Crustal depression and resubmergence of similar kind and magnitude could presumably occur again if a continental ice sheet were to advance.

As for trends in sea-level rise over the next several centuries, climatic warming caused by increases in atmospheric carbon dioxide may have the potential for melting large amounts of glacial ice (e.g., western Antarctic ice sheet), which could cause sea level to rise approximately 7.5 m (25 ft) (Schneider and Londer, 1978). Others believe that the effects of increased atmospheric carbon dioxide will be less drastic (Idso, 1981).

With respect to sea-level rise over the next few decades, Emery (1980) reported that recent increases in sea level have been approximately 3 mm/yr (0.118 in./yr). This value corresponds closely to the 3.1 mm/yr (0.122 in./yr) relative rise of sea level from coastal Maine to Cape Hatteras computed by Hicks (1981) using tide-gage data from presumably stable crustal locations.

4.3 HISTORY OF CLIMATIC CHANGES FROM LATE PLEISTOCENE TO THE PRESENT

Most crystalline rocks of the northeastern region lie within a part of North America that was glaciated as many as four times during the Pleistocene Epoch. Glacial erosion, eustatic fluctuations, postglacial crustal warping, and coastal submergence have occurred with variable magnitude and periodicity in association with climatic change and resulting continental glaciation and deglaciation. To understand and estimate the possible effects that a climatic change of similar magnitude to those of the Pleistocene within the next few thousand years might have on the northeastern region, past climatic events and their frequency, severity, and possible causes must be reviewed.

4.3.1 Sequence of Climatic Changes

The last major stage of glaciation in the Pleistocene (Wisconsinan Stage) probably began no later than 70,000 yr B.P. and no earlier than 100,000-120,000 yr B.P. (Barry et al., 1975; Flint, 1971). Evidence from ice-core studies in Greenland indicates that the Wisconsinan Stage commenced 73,000 yr B.P. (Langway et al., 1973). Data from deep-sea cores were interpreted by Ruddiman et al. (1980) as indicating an ice minimum (probably the Sangamon Interglacial) at 125,000 yr B.P. to 120,000 yr B.P., followed by two periods of strong glacial ice growth centered around the dates 115,000 yr B.P. and 75,000 yr B.P., and separated by an oscillatory period. Each of the ice-growth phases probably lasted about 10,000 yr and, in combination, accounted for at least half of the net growth toward the maximum ice volume.

A major amelioration of the climate prior to 14,200 yr B.P. resulted in rapid dissipation of the Laurentian ice sheet in the New England area by at least 12,500 yr B.P. (Borns, 1973). Ruddiman and McIntyre (1981a and 1981b) reached a similar conclusion based on bottom-sediment data from the North Atlantic that indicated that more than 50% of the ice volume in the Northern Hemisphere disappeared during the period 16,000 yr B.P. to 13,000 yr B.P. that followed the glacial maximum that occurred from 20,000 yr B.P. to 16,000 yr

B.P. These authors noted that glacial limits defined by dated moraines indicate that the ice sheet still occupied between 75% and 80% of its maximum areal extent at 13,000 yr B.P. If the proposed period of rapid melting is correct, the ice sheet must have been much thinner by 13,000 yr B.P. than it was during the earlier glacial maximum (Ruddiman and McIntyre, 1981a). Two major glacial advances accompanied by minor recessions occurred during the Wisconsinan Stage (Soloyanis and Brown, 1979; Borns and Calkin, 1977; Pease, 1970; Pessl, 1966; Kaye, 1964a and 1964b; and Leopold, 1956).

An amelioration of the climate marked the end of the Pleistocene and the beginning of the postglacial Holocene (or Recent) epochs. Paleoclimatic records suggest that long-term Holocene trends include initial global warming that culminated in a climatic maximum from approximately 8000 yr B.P. to 4100 yr B.P., with two extreme maxima near 5000 yr B.P. and 6000 yr B.P. (Langway et al., 1973). Following the climatic maximum, the climate became progressively cooler, reaching a climatic minimum in the Little Ice Age of the early 16th Century (Denton and Karlen, 1973).

Superimposed on these Holocene climatic trends were alternating intervals of alpine glacier expansion and contraction. The intervals of expansion were found by Denton and Karlen (1973) to vary from 600 yr to 900 yr and the intervals of contraction to last up to 1750 yr. To date, there have been at least three important intervals of alpine glacier expansion. The two most recent intervals occurred during the Little Ice Age (200-330 yr B.P.) and again from 3300 yr B.P. to 2400 yr B.P. The oldest interval of expansion, believed to be less extensive than the two later expansion intervals, occurred between 5800 yr B.P. and 4800 yr B.P. (Lamb, 1977; Denton and Karlen, 1973).

4.3.2 Patterns of Glaciation

The broad parallelism and near congruence of the margins of the glacial drift sheets in central North America suggest that the climatic controls that triggered and determined the growth of the first of the Pleistocene ice sheets were repeated during subsequent periods of glaciation. In the process of trying to unravel the causes of glaciation, several reseachers have noted the strong periodicity to the glacial cycles.

Barry et al. (1975) pointed out that geological and biological evidence indicates that Pleistocene glacial epochs generally have averaged 90,000 yr in length. The nonglacial, or interglacial, intervals that were comparable to or warmer than present-day climatic conditions, have lasted, on the average, only 10,000 yr. After studying climatic records, records of glacial retreat and readvance, pollen profiles, and deep-sea cores, Denton and Karlen (1973) concluded that significant glacial growth has recurred approximately every 2500 yr during the Holocene. This pattern of alternating glacier expansion and contraction every 2500 yr also appears to be a pattern of minor climatic variation that may be superimposed on long-term Holocene and Late-Wisconsinan climatic trends. After detailed analysis of the climatic record obtained from

a Greenland ice core for the period from 10,000 yr B.P. to 1000 yr B.P., Langway et al. (1973) found climatic oscillations with periods of approximately 400-2400 yr.

The causes for the climatic oscillations responsible for the glacial cycles remain unclear. The most commonly proposed explanation links such oscillations almost solely to variations in the solar constant or to sunspot activity (Denton and Karlen, 1973; Langway et al., 1973; Bell, 1953; and Flint, 1953b). Variations in solar insolation, increased concentrations of atmospheric dust related to volcanic activity, eccentricities in the Earth's orbit, and orogeny and continental uplift have been suggested as possible triggers for glaciation (Emiliani, 1955; Menzel, 1953; and Van Woerkom, 1953). General reviews of a variety of these and other theories of glaciation are presented in Mitchell (1965) and Bell (1953).

Regardless of the causes of glaciation, evidence suggests that the shift in climate from nonglacial to glacial may occur abruptly. Although early estimates of ice-sheet growth indicate that the Laurentian ice sheet took about 20,000 yr to build to full size, other researchers have suggested that the ice sheet became established about 70,000-100,000 yr B.P. and grew sufficiently within a few thousand years to survive a pronounced warming trend centered around 65,000 yr B.P. According to "instantaneous glaciation" theories, snowpack accretion could occur within a few hundred years (Barry et al., 1975).

Development of the Laurentian ice sheet may have been accelerated by the topographic relief of the New England area (Emiliani, 1955). With the onset of the glacial regime, local glaciers developed rapidly in the Adirondack, Catskill, and White mountains, and on Mt. Katahdin (Flint, 1951), eventually joining the main ice sheet. After the recession of the Laurentian ice sheet, local glaciers probably persisted in these highlands and may have grown during minor periods of readvance of the main ice sheet.

4.3.3 Climatic Change and Reglaciation

Estimating future gross climatic trends is possible using the past as a guide. The Holocene climatic record to date for temperate regions like the North American Midwest and western Europe indicates that the climate warmed from its glacial mode and reached a level warmer than today about 7000 yr ago. Since that time, a cooling trend has dominated, although there have been fluctuations. Pollen studies imply a similar paleoclimatic sequence for earlier interglacial intervals in western Europe. Where sediments have annual laminations, interglacial intervals of 10,000-30,000 yr have been estimated (Wright, 1972). Because the peak of Holocene interglacial warming seems to have passed, continuation of the cooling trend of the past few thousand years could lead to reglaciation in a few thousand years. Bloom (1983) comes to a similar conclusion.

A more detailed prediction of future climate can be based on the hypothesis that Quaternary climatic fluctuations have their origin in systematic and predictable shifts in the geometric relations of the Earth and Sun. The composite curve of orbital fluctuations, when applied to a model that includes lag effects in the growth response of ice sheets, calls for a minor culmination of glacial growth about 23,000 yr from now and a major culmination about 60,000 yr from now (Imbrie and Imbrie, 1980), perhaps of the same magnitude as the last (Wisconsinan) glaciation.

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5 PHYSIOGRAPHY AND SURFICIAL MATERIALS

5.1 PHYSIOGRAPHY

A physiographic province is a large area of the Earth's surface having a distinct geologic structure and a unified geomorphic history. Consequently, the landscape features within a physiographic province are broadly similar in form and origin, and differ significantly from those in adjacent provinces. The northeastern region (see Plate I) encompasses an area of approximately 259,000 km^2 (100,000 mi^2) and incorporates portions of six physiographic provinces.

The majority of the northeastern region lies within the New England physiographic province which, with minor exceptions, extends east and north from the eastern margin of the Hudson River valley into the Canadian provinces of Quebec and New Brunswick (Denny, 1982; Fenneman, 1938). The Appalachian Plateaus province comprises the Mohawk River lowlands, the Allegheny plateau of south-central New York, and the Catskill Mountains of southeastern New York (Thornbury, 1965; Fenneman, 1938). The Northern, or Hudson-Champlain, section of the Ridge and Valley physiographic province includes the Hudson River and Lake Champlain lowlands of eastern New York and northwestern Vermont. The Piedmont province extends from the south into southeastern Pennsylvania and north-central New Jersey. The two remaining physiographic provinces in the region are the Adirondack province, which incorporates the Adirondack Mountains of northeastern New York, and the northern end of the Coastal Plain province, which includes southern New Jersey, Long Island, and the Cape Cod portion of Massachusetts (Thornbury, 1965; Fenneman, 1938).

Of primary concern for the purposes of this report are those portions of the northeastern region where crystalline rocks occur at or near the land surface. These areas include essentially all of the New England and Adirondack provinces, and that portion of the Piedmont province occurring within the region. These are the physiographic areas that are discussed in the text, with the New England province being subdivided as shown in Fig. 5.1. The major landscape features of the northeastern region are illustrated in Fig. 5.2.

5.1.1 New England Physiographic Province

The New England physiographic province covers approximately 163,200 km^2 (63,000 mi^2) and encompasses the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut, as well as small portions of New York, New Jersey, and Pennsylvania. As part of the Appalachian Mountains (Thornbury, 1965; Fenneman, 1938), it consists of northern extensions of the Piedmont, Blue Ridge, and Ridge and Valley provinces found further south. However, the New England province is considered a separate entity because it possesses distinct geomorphic unity.

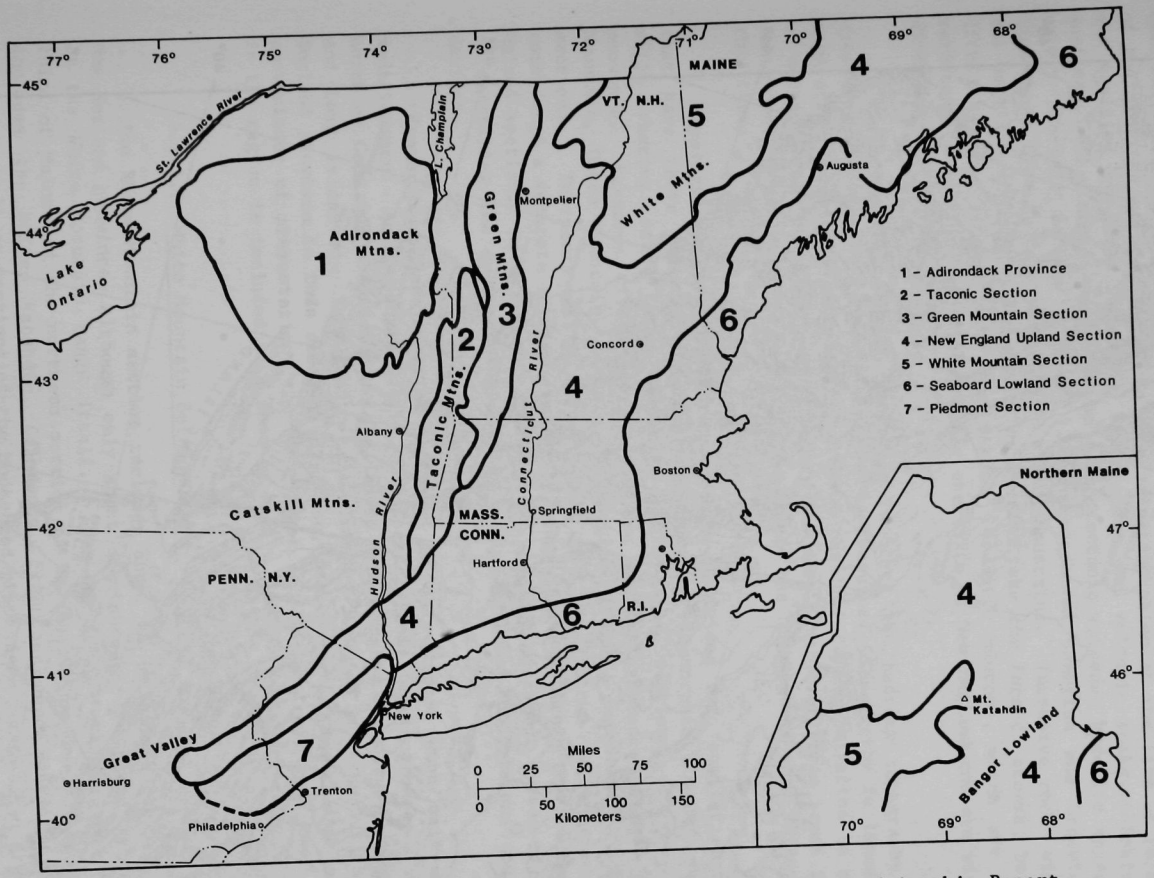

Fig. 5.1 Physiographic Areas of the Northeastern Region Discussed in this Report (Adapted from Minard and Rhodehamel, 1969; Fenneman, 1938)

Fig. 5.2 Landforms of the Northeastern Region (Source: Raisz, 1957)

The New England province consists of mountainous areas in the northwest that grade eastward into a plateau that slopes gently toward the ocean. Rocks of the province were subjected to intense metamorphism at the time of folding and faulting of lower Paleozoic sedimentary and volcanic rocks. Schists, gneisses, and slates resulting from these tectonic episodes underlie approximately one-half of New England. Unmetamorphosed Cambrian and Ordovician limestones form valleys west of the Green Mountains. Intrusive rocks within the province are mostly Paleozoic in age and take the form of stocks, batholiths, sheets, lenses, and ring dikes. Granitic plutons, which are very resistant to erosion, underlie roughly one-sixth of New England and are widely distributed (Fenneman, 1938).

Pleistocene glaciation generally smoothed the bedrock topography and created many areas of rounded, streamlined features. Topography is linear in some areas because of differential erosion parallel to the foliation in belts of metamorphic rocks (Thornbury, 1965). The most notable of these areas is in south-central Maine, where partial submergence has highlighted some valleys of this type.

Physiographic provinces are commonly subdivided into smaller sections that have their own distinct physiographic and geomorphic characteristics while sharing other characteristics with other sections of the same province. Fenneman (1938) divided the New England province into the White Mountain, Green Mountain, Taconic, New England Upland, and Seaboard Lowland sections. Thornbury (1965) argued that the Connecticut Valley could be considered a separate section instead of being included within the New England Upland section. More recently, Denny (1982) used a different system of units in describing the geomorphology of the region. Other subdivisions could be devised.

Fenneman's classification is used in this report with only slight modification. As noted previously, the Coastal Plain province extends as far north as Cape Cod and includes Long Island and southern New Jersey. Cape Cod and Long Island are included in the Seaboard Lowland section of the New England province in this discussion. Also, because of its small size and for convenience of presentation, the portion of the Piedmont province that falls in the region is included as a section within the New England province.

5.1.1.1 White Mountain Section

The White Mountain section includes about 25,000 km^2 (9700 mi^2) of the New England province, although only about one-tenth of this area is occupied by the White Mountain range itself. This section covers the west-central third of Maine and the northern portion of New Hampshire (see Fig. 5.1), and includes the White, Katahdin, Caledonia, Franconia, and Boundary Mountain ranges, as well as portions of the Moosehead plateau of Maine.

All topographic forms in this physiographic section can be attributed to fluvial and glacial processes (Fenneman, 1938), and are mainly erosional in character. Relief of up to 1200 m (4000 ft) is present, and the section is considerably dissected by a radial network of streams. Maximum altitudes exceed 1825 m (6000 ft) in the White Mountains and 1525 m (5000 ft) at Mt. Katahdin. Mt. Washington is the highest peak at 1917 m (6288 ft). At these higher altitudes, frost action has produced rock debris and patterned-ground features (Billings et al., 1979).

Although the section has been glaciated by both continental and valley glaciers, the effects of valley glaciers are the most obvious, with glacial cirques being the most prevalent feature. There has been controversy as to whether these cirques were cut before or after continental glaciation. Goldthwait (1914) felt they were cut both before and after continental glaciation, because in some instances he found no moraine deposits, which should still be present on a freshly cut cirque. Johnson (1917) concluded that the cirques postdate the continental ice sheet, on the basis of a postulated consistency of the chronology of events in the Catskills and Adirondacks with the chronology of events in New England. Thompson (1961a, 1961b, and 1960) also believed that the cirques were formed after the ice sheet left. He attributed the lack of moraines to mass wasting (e.g., rock-glacier movement and felsenmeer creep). However, Goldthwait (1970) interpreted the evidence as indicating that the cirques were formed prior to the last invasion of the ice sheet.

Throughout the southern White Mountains, numerous glacial and glacio-fluvial landforms were developed during the Pleistocene glaciation. These landforms include ice erosional features, such as through valleys and stoss-and-lee topography, as well as meltwater erosional features, such as lateral and col channels. Glaciofluvial depositional features are particularly extensive and include kames, kame terraces, large outwash plains, and esker systems. Many of the bedrock hills in the area have been asymetrically eroded, presumably due to stoss-side abrasion versus lee-side joint-block removal (Newton, 1977).

5.1.1.2 Green Mountain Section

The Green Mountain section has an areal extent of slightly more than 8000 km^2 (3100 mi^2) and consists of the Green Mountain range of central Vermont and the Hoosac Mountains in northwestern Massachusetts. The section is underlain by Precambrian schists, gneisses, and quartzites, which are intruded by both felsic and mafic igneous rocks. A central anticlinorium, a western synclinorium, and an eastern homocline make up the general structure of the section (Thornbury, 1965). Elevations average about 600 m (2000 ft), although some peaks are as high as 1200 m (4000 ft). The mountains are fairly rugged, with sharp crests and generally steep slopes. The mountains impeded the movement of the glacial ice sheet, diverting the ice so that it flowed

parallel to the range along the Champlain basin and the Vermont valley. This flow pattern greatly accelerated the erosion of the valleys (Stewart, 1961).

5.1.1.3 Taconic Section

Covering an area of about 5200 km^2 (2000 mi^2), the Taconic section incorporates the southwestern edge of Vermont, the east-central edge of New York, far western Massachusetts, and extreme northwestern Connecticut (see Fig. 5.1). Three geomorphic forms dominate the section: (1) the present-day Taconic Mountains, which consist of slates, schists, and phyllites; (2) the Valley of Vermont, which lies to the east and is underlain by metamorphosed limestone and dolomite of Cambrian age; and (3) the Rensselaer plateau on the west, which is underlain by Cambrian quartzites and covered by till and glacial boulders (Thornbury, 1965). The post-Ordovician forces that formed the original Taconic Mountains also formed the metamorphic rocks of the present-day Taconic Mountains. This section was glaciated during Wisconsinan time. Till is omnipresent throughout the section, and glaciofluvial material is common in river valleys.

The Taconic Mountains are characterized by sharp ridges and narrow valleys. Although summit altitudes as great as 760 m (2500 ft) exist, most are between 550 m (1800 ft) and 600 m (2000 ft).

5.1.1.4 New England Upland Section

The New England Upland section covers about 89,500 km^2 (34,500 mi^2), which makes it the most extensive section in the New England province. It extends from highland areas in southeastern Pennsylvania and northern New Jersey through inland Connecticut, central Massachusetts, much of Vermont and New Hampshire to central and northern Maine (see Fig. 5.1). It is essentially a southeastern-sloping, maturely dissected plateau that has been modified by glaciation. Elevations range from 120 m (400 ft) to 670 m (2200 ft), and the surface has a regional slope to the southeast. Steep slopes, monadnocks (usually of granite), and glacial features are common in the section (Thornbury, 1965). The New England Upland section is underlain by folded, faulted, and metamorphosed Precambrian and Paleozoic sedimentary and volcanic rocks, and is intruded by granitic plutons and ring-dike complexes.

Three or more cycles of glaciation smoothed the preglacial topography by eroding the bedrock and all preglacial soils. Although end moraines are absent, much sediment was deposited as thin tills. Ice-contact forms, such as kames, kame terraces, and eskers, are abundant (Thornbury, 1965).

5.1.1.5 Seaboard Lowland Section

The Seaboard Lowland section covers 35,000 km^2 (13,500 mi^2) and stretches 10-97 km (6-60 mi) inland in Connecticut, Rhode Island, Massachu-

setts, New Hampshire, and Maine. Although it appears that this section is the sloping margin of the New England Upland section, the topography and geomorphic history are different (Thornbury, 1965).

In comparison with the New England Upland, the lowland is smoother and lower. This change in topography that marks the boundary between the two sections generally occurs in the 120-150-m (400-500-ft) contour range and is partly due to the presence of more easily eroded belts of rock. However, resistant rock is also found at these elevations.

Thornbury (1965) noted that two possible explanations of the origin of this section have been proposed. Early studies suggested that this lowland was an exhumed portion of the Fall Zone peneplain, but this explanation is not generally accepted today. Subsequent investigators have reasoned that the surface was formed by marine planation during the Miocene transgression or, more probably, a late Pleistocene submergence.

As noted earlier, Long Island and Cape Cod are included in this physiographic section even though they are part of the Coastal Plain physiographic province. Cape Cod is underlain by glacial, glaciofluvial, and glaciolacustrine sediments, and is generally less than about 60 m (200 ft) above sea level. Long Island has glacial drift at the surface and is underlain by poorly consolidated Cretaceous sedimentary rocks above Paleozoic gneisses, schists, pegmatites, and granites (Thornbury, 1965). Maximum elevations are about 125 m (400 ft).

5.1.1.6 Piedmont Section

As noted previously, a small portion of the Piedmont physiographic province extends into the southwestern corner of the northeastern region. Because it is a relatively small area, it is treated herein as a section of the New England province. The northern New Jersey-southeastern Pennsylvania-extreme southeastern New York area is complex physiographically because a number of provinces, each with a different set of geologic and geomorphic characteristics, all come together in this vicinity. Figure 5.3 shows the relationship of the Piedmont to the other physiographic units in this area. This figure also shows that the Piedmont continues beyond the northeastern regional boundary. The dashed Piedmont boundary in Fig. 5.1 marks the extent of the crystalline rocks described in this report (see Plate I).

That portion of the Piedmont included in this study covers an area of about 5200 km^2 (2000 mi^2). The upland portion of the Piedmont has a gently rolling topography and is underlain by metamorphic and plutonic rocks. The lowland portion, commonly called the Triassic lowland (see Fig. 5.3), is formed on continental sandstones, shales, and conglomerates of Triassic age that have been broken and tilted by normal faults. In north-central New Jersey, rocks of the Newark group are interbedded with basalt flows and intruded by diabase dikes and sills (Minard and Rhodehamel, 1969; Thornbury,

Fig. 5.3 Diagram Showing the Relationship of the Piedmont to Adjacent Physiographic Units (Source: Thornbury, 1965. Copyright 1965, John Wiley and Sons; reprinted with permission)

1965). Another area of Triassic rocks within the northeastern region occurs beneath much of the Lower Connecticut River valley, which extends from Long Island Sound northward to near the northern border of Massachusetts (see Fig. 5.2).

The Northern Triassic Lowland is partially bordered by three prongs of crystalline rocks that are topographically higher. The Reading prong to the northwest (see Fig. 5.3) is a southern extension of the New England Upland (see Fig. 5.1) and a structural analog of the Blue Ridge to the southwest. The Manhattan prong bounds the area on the northeast, and the Trenton prong is located along the southern boundary (Thornbury, 1965). These crystalline areas are delineated on Plate I.

The Piedmont is an area of generally low relief, with elevations in New Jersey averaging 60-90 m (200-300 ft). The land surface slopes toward the east at a rate of about 3.8 m/km (20 ft/mi) (Thornbury, 1965).

5.1.2 Adirondack Physiographic Province

Located in northeastern New York, the Adirondack physiographic province occupies approximately 26,000 km^2 (10,000 mi^2). It is essentially an extension of Canadian shield geology into the United States and consists of the

Adirondack Mountains and the adjacent plateau to the northwest. Bordering the province are the St. Lawrence Lowland on the north, Lake Champlain on the east, the Mohawk Valley on the south, and the Black River and Tug Hill cuesta on the west (see Fig. 5.2). The rise in elevation from the west is gradual, whereas the rise from the Lake Champlain Lowland is steep. Elevations in the western plateau area average about 300 m (1000 ft); in the rugged mountains to the east, numerous peaks are higher than 1200 m (4000 ft). The highest peak of the Adirondacks, Mt. Marcy, has an altitude of 1629 m (5344 ft) (Thornbury, 1965).

The rocks underlying the Adirondack province consist primarily of Precambrian metamorphics and igneous intrusives. The sequence of deformed metasediments, which includes quartzites, gneisses, schists, and marbles, has a total thickness of up to 610 m (2000 ft) (Thornbury, 1965; Engel and Engel, 1953). However, igneous rocks predominate. Granites are the most abundant rock type and are among the most resistant to weathering. Bordering the Adirondack area are Cambrian and Ordovician sedimentary rocks. The overall structure of the area is generally anticlinal, with northeast-southwest trends. Many topographic features follow this same trend. High-angle normal faulting is common (Thornbury, 1965).

The geomorphic history of the Adirondack province is not well understood. Several investigators have suggested the presence of one or more erosion surfaces, which have been dated to be as old as Precambrian and as young as late Tertiary (Thornbury, 1965). However, none of these interpretations has been completely accepted. The highlands were overriden during the Pleistocene at least once, and probably several times, as ice moved through the area to the south and southeast. At least 2000 lakes of probable glacial origin are found in the province. Glacial drift is scattered throughout the area, and glaciofluvial deposits are abundant. An extensive system of eskers is found in the upland area (see Fig. 5.4), and cirques are present on many of the mountain peaks. Both local glacial scour and general postglacial geomorphic development have been strongly influenced by faults and other structural features. Streams draining the Adirondacks exhibit a roughly radial pattern (see Fig. 5.4), with local structural and bedrock controls being evident.

5.2 SURFICIAL MATERIALS

The glacial chronology and correlative glacial stratigraphy of the northeastern region are not well understood. Flint (1971) compiled stratigraphic information for the eastern United States and presented the correlation chart included here as Table 5.1. Although the correlations are tentative, this table provides a general framework for comparing glacial units that have been defined and studied at different locations.

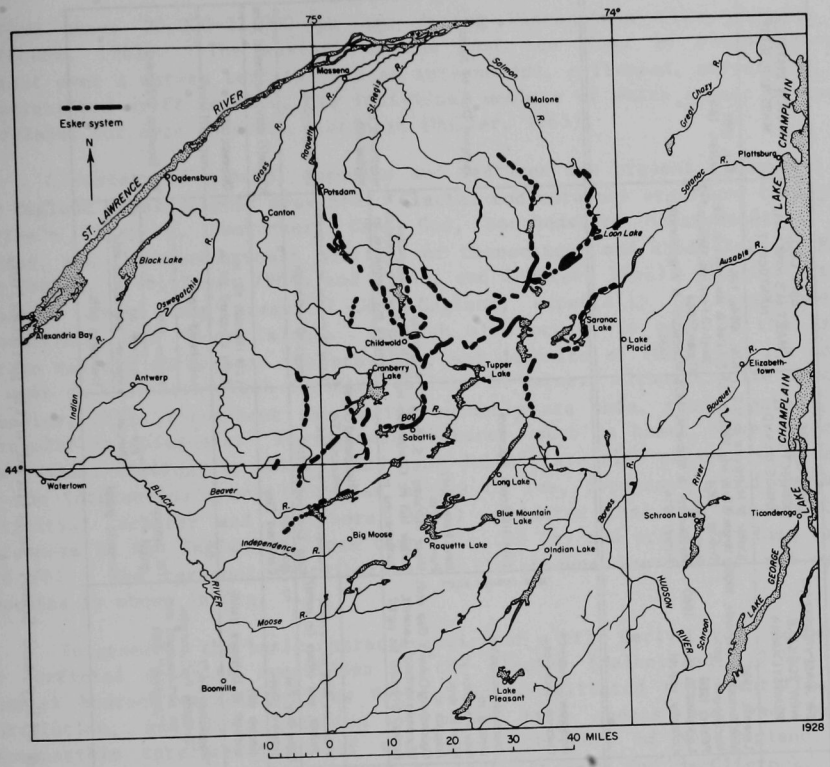

Fig. 5.4 Esker System and Surface Drainage Features of the Adirondack Physiographic Province (Source: Thornbury, 1965. Copyright 1965, John Wiley and Sons; reprinted with permission)

5.2.1 Surficial Materials in the New England Physiographic Province

For the purposes of this study, the most important features of glacial and other surficial deposits are type of deposit and gross composition, maximum thickness, and areal distribution. Although several researchers have reported average drift thicknesses for the northeastern region, glacial and other surficial deposits are highly variable in thickness from one location to another. Presently, specific information on drift type and thickness is available mainly on the local or quadrangle level. As a result, regional extrapolations using this type of data should not be accepted without caution.

Although the details of glacial events in New England are not completely understood, it is well documented that glacial ice covered all of New

Table 5.1 Glacial Drift Stratigraphic Sequences in Eastern United States

Standard sequence		N.E. OHIO N.W. PENNSYLVANIA	SOUTHWESTERN NEW YORK	NEW JERSEY/EASTERN NEW YORK/N.E. PENNSYLVANIA	LONG ISLAND, CONNECTICUT, RHODE ISLAND	CAPE COD, MARTHA'S VINEYARD, NANTUCKET	BOSTON DISTRICT, MASSACHUSETTS
		G.W. White, 1969 Shepps et al., 1959	Muller in H.E. Wright & Frey, eds., 1965a, p.106	Leverett, 1934 MacClintock & Richards, 1936 MacClintock, 1940 Peltier, 1959 Lockwood & Meisler, 1960 Connally, unpubl.	Shafer & Hartshorn in H.E. Wright & Frey, eds., 1965a, p.113 Donner, 1964 Kay, 1960 MacClintock & Richards, 1936 Fuller, 1914	Kay, 1964a, 1964b Schafer & Hartshorn in H.E. Wright & Frey, eds., 1965a, p.113 Ogden, 1963 Woodworth & Wigglesworth, 1934	Kay, 1961 Judson, 1949
Wisconsin	Late	Ashtabula T Hiram T Lavery T Kent T	Valley Heads drift A correlative of Kent Till	Bridgeport readvance Luzerne readvance Rosendale readvance Wallkill m New Hampton m Pellet's Island m Augusta m Ogdensburg/Culver's Gap drift Wisconsin drift of Leverett, Peltier, & others (in part)?	Lake Albany seds. Lake Hitchcock sediments New Haven Clay Hamden Till Minor moraines in S. Conn Harbor Hill m; Charlestown m Ronkonkoma m	Ellisville m Stratified drift, outer Cape Buzzards Bay m.; Sandwich m Vineyard m.; Nantucket m	Lexington Drift of Judson
	Middle	soil					weathered zone marine clay
	Early	Titusville T	Organic sediments at Otto and Gowanda?	Wisconsin drift of Leverett Peltier, and others (in part)?	Manhasset Fm {Hempstead Gravel, Montauk Till, Herod Gravel} Lake Chamberlain Till?	Early Wisconsin m.; outwash proglacial sediments	Till in drumlins
Sangamon		soil		Cape May Fm (marine phase)	Jacob Sand Gardiners Clay		Marine(?) clay; weathered zone
Illinoian		Mapledale T (?)		Illinoian till; outwash in Delaware Valley		Late Illinoian till; m Early Illinoian? till; m	Outwash; till
Yarmouth		Slippery Rock T ("pre–Illin.")	"Pensauken Fm"/ "Bridgton Fm" complex (in part younger) and "Jerseyan" drift	Till; Jameco gravel Mannetto gravel "pre–Illinoian"	weathered zone		marine(?) clay
Kansan						Kansan drift	Till (position uncertain)
Aftonian						Aquinnah cg. Marine– and related seds	
Nebraskan						Nebraskan drift	

Source: Flint (1971). Copyright 1971, John Wiley and Sons; reprinted with permission.

England about 20,000-22,000 yr ago during Wisconsinan time (Schafer and Hartshorn, 1965). The wastage of the last ice sheet by stagnation-zone retreat over a mature terrain left an interbedded, collapsed, stratified, and nonstratified drift complex, the individual members of which cannot be easily correlated for even moderate distances (Muller, 1965).

A variety of glacial deposits and features are present throughout the New England physiographic province. Glacial end moraines are found throughout Martha's Vineyard, Nantucket, Cape Cod, southeastern Massachusetts, Long Island, and the southernmost portions of Connecticut and Rhode Island (Flint and Gebert, 1976; Kaye, 1964a and 1964b; and Schafer, 1961). Glacial outwash deposits cover many areas of New England, especially in Massachusetts, Connecticut, and Rhode Island. Outwash also occurs in many of the larger stream valleys throughout the province, and deposits of this type are common in most of the north-south trending valleys in Maine. Although quite thick in drumlins, tills throughout the region commonly are thin, stony, patchy, and irregular in thickness. Ice-contact features, such as kames, kame terraces, ice-channel fillings or eskers, and kame deltas, are also present as a result of the interaction among irregular masses of ice, topography, and meltwater activity. Schafer and Hartshorn (1965) estimated that the average drift thickness in New England is less than 10 m (33 ft) and probably close to 5 m (16 ft). The regional distribution of Pleistocene ice-contact and marine deposits is shown in Fig. 5.5.

In general, the basic characteristics of a till derive from the bedrock or surficial deposits overridden by the glacier (Mulholland, 1976). The complex bedrock terrain of New England has complicated the identification, correlation, and interpretation of major till sheets and has led to incompatible interpretations of the glacial history of New England (cf., Drake, 1971; Goldthwait, 1971; Pessl, 1971; Stewart and MacClintock, 1969; Muller, 1965; Schafer and Hartshorn, 1965; and Kaye, 1964a).

Despite difficulties in correlating individual tills, it is apparent that the New England area has undergone several cycles of glaciation. Older glacial deposits in Martha's Vineyard, Mass., are believed to be Illinoian or older, and some deposits in Nantucket are clearly assignable to the Sangamon and the preceding Illinoian intervals (Kaye, 1964a). More detailed interpretation of the various deposits awaits further radiocarbon dating analysis and additional detailed field study (Hartshorn, 1981).

5.2.1.1 White Mountain Section

In the southern part of the White Mountain section, glacial deposits are widespread, reaching a maximum thickness of 30 m (100 ft) (Henderson et al., 1977). At least two distinct tills have been identified. The upper unit is characteristically a loose, sandy, gray till, and the lower unit is a much more compact, clay-rich till of olive to olive-brown color. Much controversy exists over the origin and differentiation of these till units (Newton,

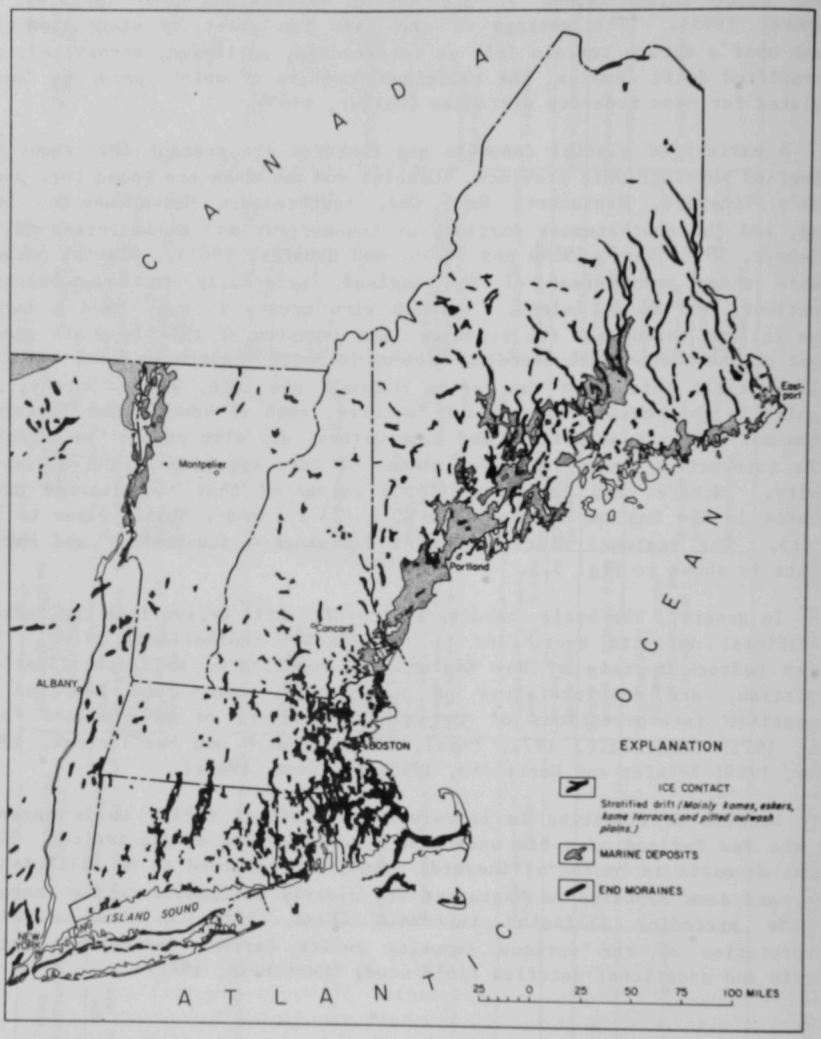

Fig. 5.5 Distribution of Pleistocene Ice Contact and Marine Deposits in New England (Source: Thornbury, 1965. Copyright 1965, John Wiley and Sons; reprinted with permission)

1977). Within this section, outwash deposits of sand and gravel fill many of the valleys to varying depths.

Except on valley floors and areas of higher elevation, the central and northern portions of the White Mountain section are heavily wooded. The forest cover, in combination with the rugged topography, has hindered identification of any but the grossest glacial features. Most of the detailed work has been restricted to the more accessible river valleys and road cuts. Nonetheless, the section is characterized by ice-contact stratified drift and outwash underlain by till in the valleys, thin layers of till and occasional kame terraces on valley slopes, and exposed bedrock on hilltops (Borns and Calkin, 1977).

Two till types -- a loose ablation till and a compact lodgement till -- are characteristic of the area. Both types usually have a uniform silty-sand texture, although ablation till is frequently more stony and sandy than the subjacent basal till. Within limited areas, occurrences of thin, interbedded lacustrine deposits and sandy silt-clay tills are common. Lithologically the two tills are characterized by low-quartz, high-plagioclase feldspar and high heavy-mineral concentrations. The similarity and uniformity of the tills are believed to be a function of the distribution of gabbroic and granitic plutons, and the interspersed pelitic metasedimentary rocks. The rugged topography probably favored mixing of the lithologies at the base of the glacier (Borns and Calkin, 1977).

5.2.1.2 Green Mountain Section

The Green Mountains acted as a barrier to ice flow and diverted much of the ice immediately to the west of the mountains toward the south. Residual boulders or erratics of both distant and local origins, however, show that glacial deposition did take place on the summits of the mountains (Stewart, 1961). Although till is present at lower elevations, the higher peaks are free of such deposits. Below the 945-m (3100-ft) contour, drift is more continuous but generally quite thin. The thickness of the drift varies, depending on the slope and the amount of local erosion that occurred (Christman and Secor, 1961; Stewart, 1961).

Kame-terrace gravels are present in several areas, such as in the Camels Hump and Mt. Mansfield quadrangles of Vermont. Further mapping and measurement elsewhere in the Green Mountain section will be required to learn the extent of the terraces. Lake sediments found along the slopes of the Green Mountains are attributed to small lakes formed at the margins of glaciers (Stewart, 1961).

5.2.1.3 Taconic Section

As in the case of the Green Mountain section, evidence of glaciation in the Taconic Mountains is mostly in the form of grooves, striations, erratics, and valley fills. Although grooves and striations are not readily observed in the densely vegetated areas at high elevations, thin glacial deposits and poorly preserved striations have been noted (Hewitt, 1961; Stewart, 1961).

The Rensselaer plateau, which is located in the central portion of the Taconic section, is overlain by poorly developed, thin, boulder-strewn soils. In the lowlands, glacially deranged drainage is evidenced by the presence of numerous lakes and swamps (Fenneman, 1938). Thick deposits of till and outwash cover the Vermont valley floor, and many of these deposits appear to have been formed during a stagnation phase of the glacial retreat in this area. Absence of frontal moraines also suggests ice stagnation (Stewart, 1961).

5.2.1.4 New England Upland Section

Glacial deposits of the New England Upland section can be divided into stratified and unstratified deposits. Outwash, kames, kame terraces, and kame deltas are among the most conspicuous stratified drift deposits (see Fig. 5.5). Some kames are composed of boulders interspersed with thin silt, gravel, and well-sorted sand beds; others are composed almost entirely of sand (Newton, 1974; Brown, 1931). Most are about 6 m (20 ft) thick, although at least one is 25 m (80 ft) thick (Denny, 1958). Other stratified drift includes eskers and ice-channel fillings. The Pequaket esker near Ossipee Lake in New Hampshire is about 21 m (70 ft) high and 2 km (1.2 mi) long, and is composed of alternating beds of sand and gravel (Newton, 1974). Outwash occurs as a broad, gently sloping sand and gravel plain, with a thickness of around 52 m (170 ft) at West Ossipee (Newton, 1974). Beach deposits and alluvium are also present but in lesser amounts.

Unstratified drift is also present in varying amounts in the New England Upland section. Newton (1974) reported that all areas in the Ossipee Lake quadrangle except valleys are occupied by unstratified drift having an average thickness of 6 m (20 ft). Goldthwait (1968) reported that 64% of the Wolfeboro-Winnepesaukee area is covered by 1 m (3 ft) or more of drift. The thicknesses range from zero to 63 m (208 ft) and average about 11 m (35 ft). Goldthwait also noted that the thickest drift occurs in the valleys. The extreme variability of the thickness and location of the drift is very evident in the New England Upland section.

The tills in this section are generally poorly sorted or unsorted and range in particle size from boulders to clay. Clay makes up 1-11% of the total; silt, 12-38%; boulders and stone, 5-83%; and sand, 57-86% (Goldthwait, 1968). According to both Goldthwait (1968) and Denny (1958), there are two distinct types of till in the section. The first is a compact till called a basal till, which was deposited beneath the advancing glacial ice. Deposits

of this type are rich in silts and clays, and olive gray to gray-brown in color. Pebbles, cobbles, and boulders account for 5-10% of the total material. This till is most extensive on lower slopes and on north- and west-facing hillsides, and attains a maximum thickness of 9 m (30 ft) (Denny, 1958). The second till, a loose or ablation till, was deposited as the glacial ice melted or wasted away. This till is olive gray to white. It is rich in sand and contains 25% boulders, cobbles, and pebbles. This latter till occurs extensively on uplands and mountains, where its maximum thickness is about 9 m (30 ft) (Denny, 1958). Another possible interpretation of the origin of these deposits is that the two tills are the result of two distinct glacial advances separated by an interstadial period (Hartshorn, 1981). Colluvial deposits are scarce throughout this section because most surficial deposits are currently stable.

5.2.1.5 Seaboard Lowland Section

In the northern half of the Seaboard Lowland section, the thickest till (up to 30 m [100 ft]) is found in drumlins, end moraines (Thompson, 1979), and on north-facing slopes (Hanley, 1959). In general, till rarely exceeds 3 m (10 ft) in thickness (Thompson, 1979), contains abundant boulders, and is of two distinct compositions. One is a silty till, with a dusky yellow to dark brown color. Pebbles, cobbles, and boulders in this till are derived primarily from biotite schist and gneiss. The second till is sandy and grayish yellow in color, and was derived mainly from the scour of igneous bedrock.

Many important stratified deposits occur in the northern half of the Seaboard Lowland section. Kames and kame terraces deposited next to wasting ice consist of sands, gravels, and boulders derived from granites, lime silicate rocks, and biotite schists. These deposits range from hundreds of meters (feet) to a few kilometers (miles) in width and are up to 30 m (100 ft) in height (Thompson, 1979). Outwash plains and valley trains occur in river valleys and are generally 5-20 m (15-65 ft) thick (Hanley, 1959). These deposits consist of widely varying proportions of sand and gravel.

In Maine, marine deposits resulting from late-glacial inundation by the sea are abundant (see Fig. 5.5). Of these, the most frequently studied has been the Presumpscot formation, which is a fine silty to sandy clay. The thicknesses of these deposits are as great as 30 m (100 ft) in some river valleys (Thompson, 1979). Other less extensive surficial materials in the northern half of the Seaboard Lowland section include beach deposits, eolian deposits, lakeshore and swamp deposits, alluvium, and colluvium. The thickness of the glacial till along the northern coast of New England is highly variable. Thickness generally decreases with increasing elevation and is greatest in drumlins and end moraines. Much of the area is covered with only thin and patchy till.

Kaye (1976) listed four characteristics of the Pleistocene geology in the Boston basin area: (1) glacial erosion was extremely variable in effectiveness; (2) effects of particular glacial events were patchy and not continuous; (3) older deposits were not always deformed or compacted by subsequent glaciation; and (4) entire sheets of glacial deposits were occasionally relocated intact, a situation that makes age identification difficult.

The glacial deposits found in Martha's Vineyard, Mass., indicate the compositional complexity of the surficial deposits. Six glacial drifts and one interglacial deposit have been identified by Kaye (1964a). These units are discontinuous, texturally variable, and deformed. Two of the glacial drifts are believed to be the terminal moraines of their respective ice sheets (Kaye, 1964b). Later interpretations have differed from those of Kaye, but the great difficulty of interpretation is well recognized (Flint, 1971).

Surficial deposits on Cape Cod and Nantucket are composed of Wisconsinan moraine and glacial outwash. To the north, in the Boston basin, a dense silty and clayey till is overlapped by the Boston blue clay, which was deposited in a marine environment (Schafer and Hartshorn, 1965).

Ground moraine in the southern portion of New England is generally thin but locally attains thicknesses of 12 m (40 ft) or more. Ablation moraine averages about 5 m (15 ft) in thickness but can range up to 30 m (100 ft) (Kaye, 1960). Drumlins composed of compact and well-graded greenish-gray till are also present. Kame terraces, kame plains, and kame deltas are commonly found. Ice-channel fillings and eskers composed largely of gravel were reported by Kaye (1960).

5.2.1.6 Piedmont Section

The northern Piedmont lowland is divided from the southern section by a well-developed terminal moraine that extends northwestward from the mouth of the Raritan River to Morristown, N.J., crossing the Watchung Mountains. This moraine generally is 60 m (200 ft) thick and is very hummocky (Fenneman, 1938). The glacial deposits of the area average 6 m (20 ft) in thickness. The regional drainage network is highly disturbed and weakly developed.

South of the terminal moraine, stratified drift from glacial meltwaters is locally very thick and forms extensive flatlands. Large quantities of stratified drift are found in valleys throughout the area. West of the Palisades ridge, stratified drift filled a deep depression creating the marsh known as Hackensack Meadows (Fenneman, 1938). Kames, kame terraces, kame fields, eskers, and deltas also are found throughout this area (Minard and Rhodehamel, 1969).

In a belt approximately 24-40 km (15-25 mi) wide south of the moraine, stratified and unstratified pre-Wisconsinan drift occurs in discontinuous patches. Many of these deposits are more highly weathered than most tills

found in New England, indicating that they are older. These pre-Wisconsinan tills represent the southern extent of earlier glaciations (Minard and Rhodeland, 1969).

Within the Delaware River valley, terrace remnants and valley-fill deposits composed of Wisconsinan glacial outwash and recent alluvium average 11 m (35 ft) in thickness. These deposits are composed of unconsolidated sand, pebbles, cobbles, silt, and clay (Drake et al., 1961), with the Wisconsinan deposits having a thin cover of loess. Outwash of Illinoian age also occurs along the valley as does older, pre-Illinoian drift (Flint, 1971).

5.2.2 Surficial Materials in the Adirondack Physiographic Province

The till in the Adirondack physiographic province is typified by a pebbly and sandy texture, and locally is as much as 40 m (130 ft) thick (e.g., south of Dannemora [Denny, 1974]). The composition of the drift usually reflects that of the underlying bedrock. In areas underlain by crystalline rocks of Precambrian age, the till is commonly sandy loam or loamy sand. Pebbles or boulders of crystalline rock also are present. In areas underlain by the Potsdam sandstone, the till is stony and has a fine sandy loam or loam matrix. Pebbles and boulders of Potsdam sandstone make up about one-fifth of the total volume. In areas underlain by dolostone, limestone, sandstone, and shale, the till has a pebbly loam to silt loam matrix, and clasts of sedimentary rock account for about 5-10% of the volume (Denny, 1974).

In the Saranac and Great Chazy river valleys, kames and recessional moraines are common. These features are composed of pebbly, sandy till and stratified sand and gravel. Thicknesses range from 1.56 m (5 ft) to 30 m (100 ft), and attain a maximum of 24-30 m (80-100 ft) at Ellenburg Depot (Denny, 1974). Several areas in the province have no surficial deposits. Examples of three such "bare rock" areas are Flat Rock near Altona, the surface on the divide between English River and the North Branch of the Great Chazy River, and an area north of English River (Denny, 1974).

As mentioned earlier, a well-developed esker system is present and crosses the Adirondacks from northeast to southwest (see Fig. 5.4). The esker belt is at least 137 km (85 mi) long and suggests that the ice stagnated on the northwestern flank of the highlands for a period of time during its final retreat from the area (Thornbury, 1965).

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6 HYDROLOGY

The volume and movement of surface and ground waters in the northeastern United States are determined by four main factors: (1) climate, including seasonal and longer-term variations; (2) nature of the underlying bedrock, especially its ability to store and transmit water; (3) nature, thickness, and horizontal extent of glacial and other unconsolidated deposits; and (4) influence of man. For the purposes of this report, the most important hydrologic characteristics of the region are the amount of deep ground water in crystalline rocks and the circulation rates and patterns of that water. Data concerning these characteristics are very limited.

The major sources of water in the region are the sedimentary bedrock and unconsolidated aquifers, and the surface-water hydrologic system, all of which have been investigated much more thoroughly than crystalline rock sources. Crystalline rocks generally yield only small quantities of water from fracture systems, which can be highly variable from one location to another within the same rock body. Consequently, such rocks are usually considered for water-supply development only if other sources are not locally available. If a well in crystalline rocks does not encounter sufficient fractures to provide adequate quantities of water within approximately the first 100 m (330 ft), it is usually abandoned and another drilled at an alternate location. Furthermore, because yields from crystalline units are usually adequate only for domestic supplies, expensive pump tests and other detailed investigations to quantify the hydrologic and hydraulic properties of the rock are not usually undertaken.

Noncrystalline water sources have a bearing on hydrologic conditions within proximal crystalline units. If surface-water features (rivers, lakes, and wetlands) are found above or adjacent to fractured crystalline rocks, active exchange may occur between surface water and any water present in the crystalline rocks. Furthermore, if crystalline rock bodies are in close proximity to known unconsolidated or bedrock aquifers, the possibility of hydraulic interconnection must be acknowledged. Therefore, this section discusses in some detail the surface-water hydrology and the sedimentary bedrock and unconsolidated aquifers of the region, while presenting the available, albeit limited, information on the hydrogeology of the region's crystalline rocks.

6.1 HYDROLOGIC DATA

The basic surface-water hydrologic unit is the watershed, or drainage basin, whose boundaries determine which hydrologic inputs and outputs have to be specified to define the water budget for that unit. Watersheds also serve as reference units for ground-water studies, especially for shallow water-table aquifers, because geomorphic and aquifer units in the northeastern

region are often the result of the same geologic processes. On a local scale, bedrock aquifers are best delineated by petrologic, lithostratigraphic, and small-scale structural features. On a regional scale, larger physiographic basins and major geologic structures play a dominant role in establishing ground-water flow systems.

6.1.1 Drainage Basins

The watershed, or drainage basin, is the basic accounting unit for hydrologic studies. It is defined by drawing a line along topographic highs such that all surface runoff within the bounded area will flow to the basin outlet. The prominent features of a basin are (1) the stream channel network, which consists of the main stem and its tributaries, and the interfluve areas on which overland flow occurs; (2) the topographic relief of the basin, including stream gradients as defined by their longitudinal profiles; and (3) the outlet, or point of concentration, through which all surface runoff generated in the basin passes. These basin features and other related characteristics (e.g., stream frequency, drainage density, basin geometry, stream channel morphology, and valley and floodplain development) will vary, depending on the topography, geology, erosional characteristics, climate, and geomorphic history of the region. In fact, the drainage basin with all its features is the cumulative result of past and present geologic and climatologic processes, and the time over which these processes have been active.

The two most common types of basins found in the region are (1) dendritic, or leaf-shaped, basins that are integrated into regional drainage systems and (2) bandlike basins that contain relatively short parallel to sub-parallel streams that drain directly into the Atlantic Ocean. The larger drainage basins of the region are often assumed to be congruent with ground-water regions, and both surface- and ground-water investigations are commonly organized around the watershed unit.

6.1.2 Data Sources and Availability

The U.S. Water Resources Council (1978) established the following hierarchical structure of hydrologic data-collection units:

- Water Resources Regions. The conterminous United States is subdivided into 18 major geographic areas based on major river basins. These areas have boundaries defined by drainage divides, except where the divides are cut off by international boundaries.

- Water Resources Assessment Subregions. The 18 water resources regions are divided into subregions drained

by a smaller river system or nonintegrated coastal streams. These subregions are shown on the USGS hydrologic unit maps for each state (e.g., U.S. Geol. Survey, 1974).

- Water Resources Accounting Units. Accounting units are used by USGS to design and manage the national water-data network.

- Water Resources Cataloging Units. Cataloging units are the smallest units and represent part or all of smaller surface drainage basins. These basic hydrologic units are used by USGS to catalog water-data acquisition activities for the Catalog of Information on Water Data (U.S. Geol. Survey, 1981).

The crystalline rock areas of the northeastern United States fall in three water resources regions. The New England water resources region includes the area east and north of the Lake Champlain and Hudson River drainage basins. The Mid-Atlantic water resources region includes that portion of the northeastern region east of the drainage divides with the St. Lawrence-Great Lakes and Ohio River basins but west of the New England region. (The Mid-Atlantic region extends beyond the southern limits of the study region to the James River basin in Virginia.) Finally, the Great Lakes water resources region incorporates that portion of the northeastern region in northern New York that drains into Lake Ontario and the St. Lawrence River. Even though Lake Champlain ultimately drains into the St. Lawrence River, its drainage area is included within the Mid-Atlantic water resources region.

Figures 6.1-6.6 show the principal hydrologic areas in Maine; New Hampshire and Vermont; Massachusetts, Rhode Island, and Connecticut; eastern New York; New Jersey; and eastern Pennsylvania, respectively. The hydrologic boundaries in these figures were obtained in most cases from the corresponding hydrologic unit maps published by USGS (e.g., U.S. Geol. Survey, 1974). In some cases, however, standard mapped units were grouped with adjacent units for ease of illustration. For example, some areas represent a composite of smaller basins where no integrated master drainage has developed.

Tables 6.1-6.6 contain information on the primary drainage basin(s) within each hydrologic area illustrated in Figs. 6.1-6.6, respectively. Data summarizing surface- and ground-water quality and quantity are cataloged in the National Water Data Exchange (NAWDEX) system by the hydrologic unit code number given in these tables. Also included in Tables 6.1-6.6 is the number of active and inactive data-collection sites within the hydrologic unit for which data of the indicated category are available from NAWDEX. However, even though more than 400 organizations have contributed data to the NAWDEX system (U.S. Geol. Survey, 1981), basic hydrologic data, as well as data analyses and interpretations, are available from many other sources.

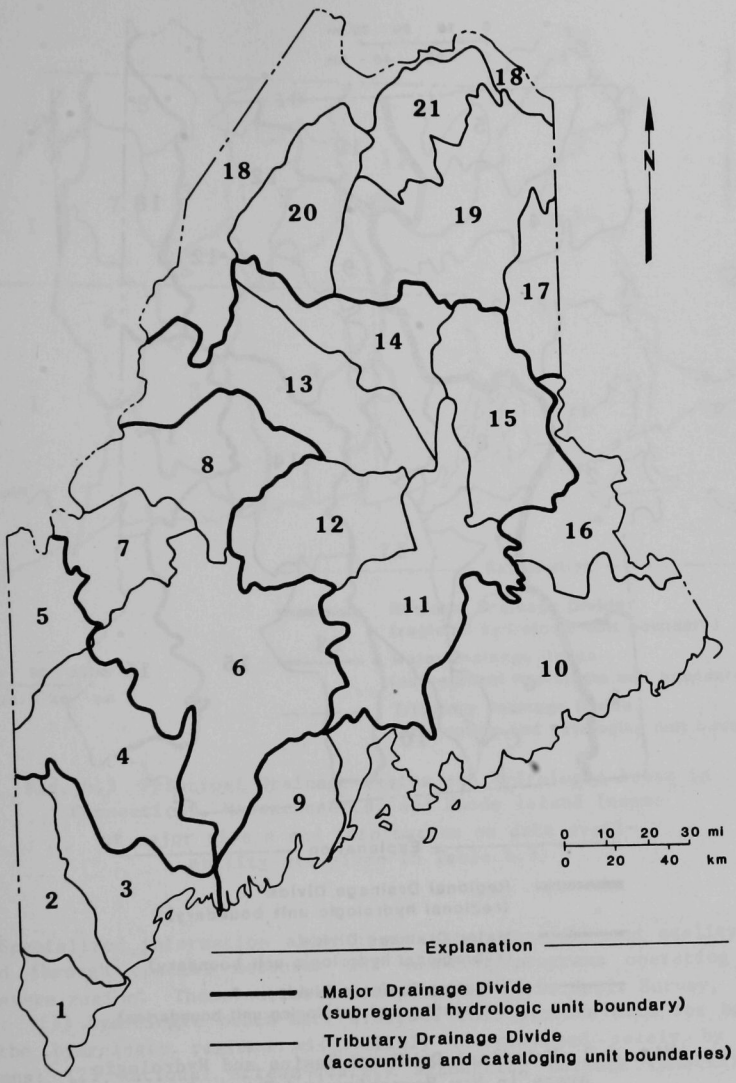


Fig. 6.1 Principal Drainage Basins and Hydrologic Areas in Maine (names of major rivers and information on data availability are given in Table 6.1)

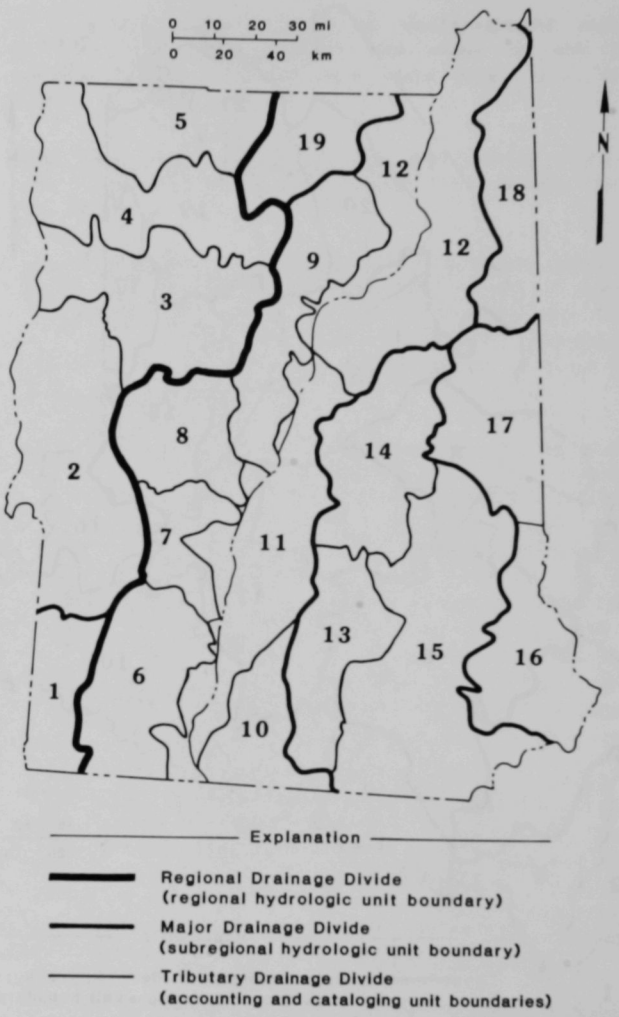


Fig. 6.2 Principal Drainage Basins and Hydrologic Areas in New Hampshire and Vermont (names of major rivers and information on data availability are given in Table 6.2)

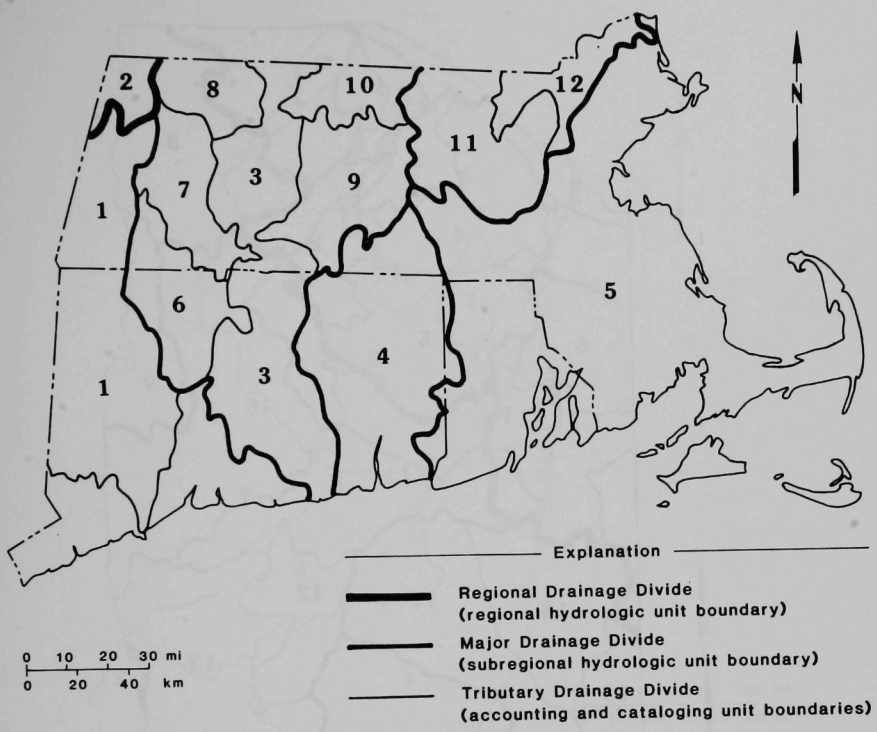


Fig. 6.3 Principal Drainage Basins and Hydrologic Areas in Connecticut, Massachusetts, and Rhode Island (names of major rivers and information on data availability are given in Table 6.3)

Specialized information about river water quantity and quality can be obtained through special networks and sampling programs operating in the northeastern region. These networks and programs (U.S. Geol. Survey, 1982a-j) include: (1) hydrologic bench-mark stations that provide data for basins in which the hydrologic regimen will likely be governed solely by natural conditions; (2) national stream-quality accounting network (NASQAN), which provides data on areal variability of streamflow and water quality; and (3) other networks that have been established to provide baseline information on the occurrence of tritium and other radiochemicals, and pesticides.

The regional surface-water and ground-water conditions of the northeastern United States are discussed in reports by the U.S. Army Corps of Engineers (1972) and U.S. Geol. Survey (1972), prepared for the North Atlantic

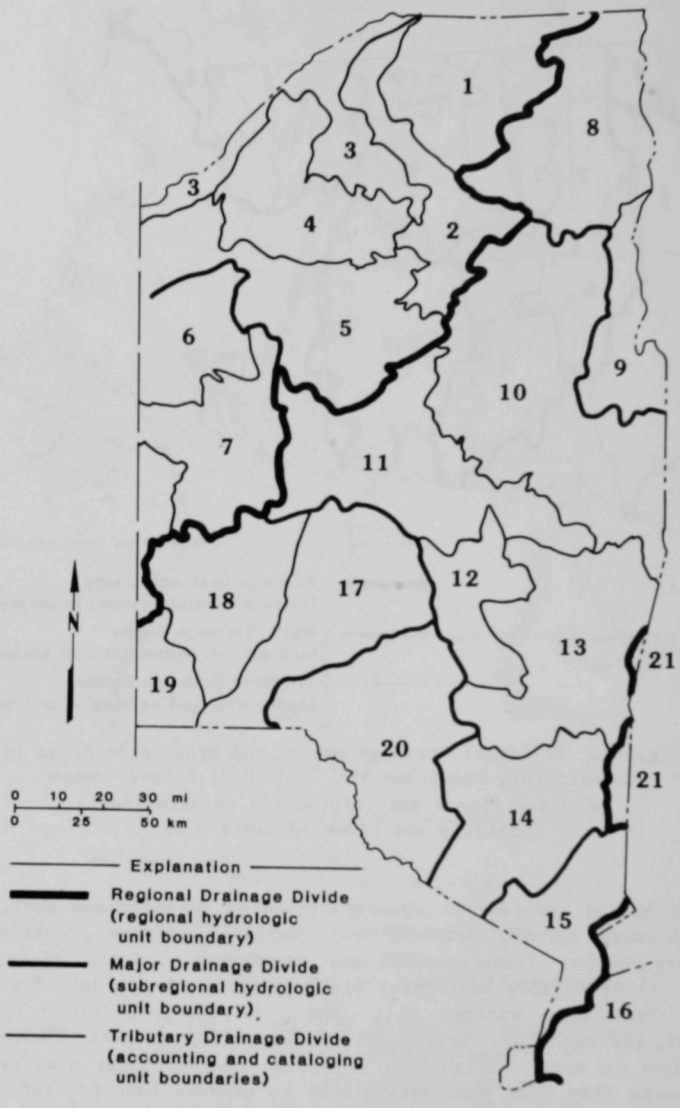


Fig. 6.4 Principal Drainage Basins and Hydrologic Areas in Eastern New York (names of major rivers and information on data availability are given in Table 6.4)

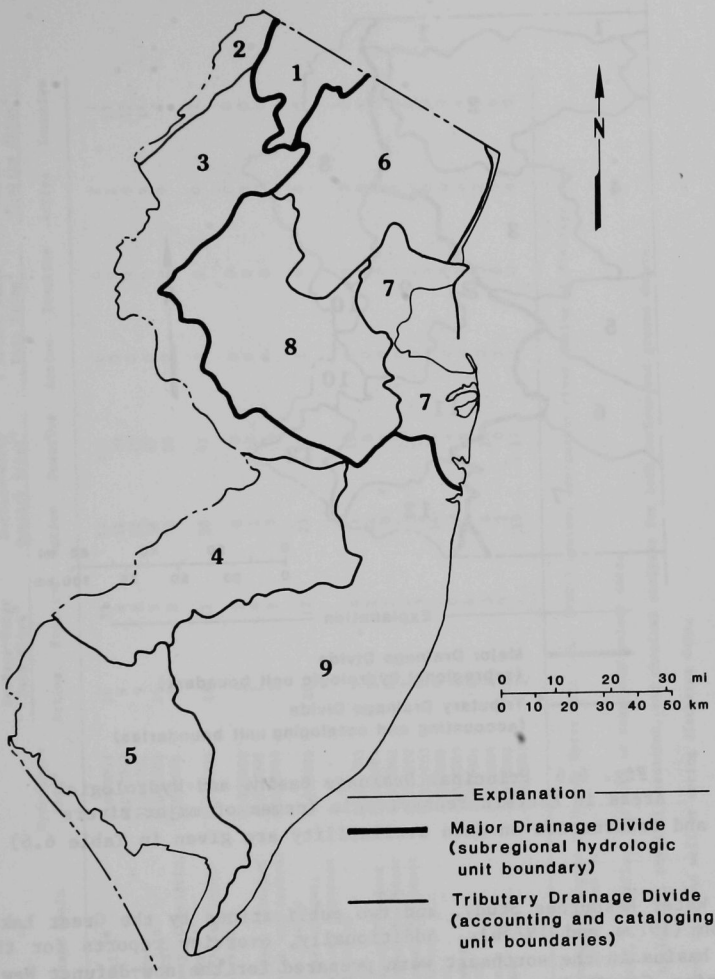


Fig. 6.5 Principal Drainage Basins and Hydrologic Areas in New Jersey (names of major rivers and information on data availability are given in Table 6.5)

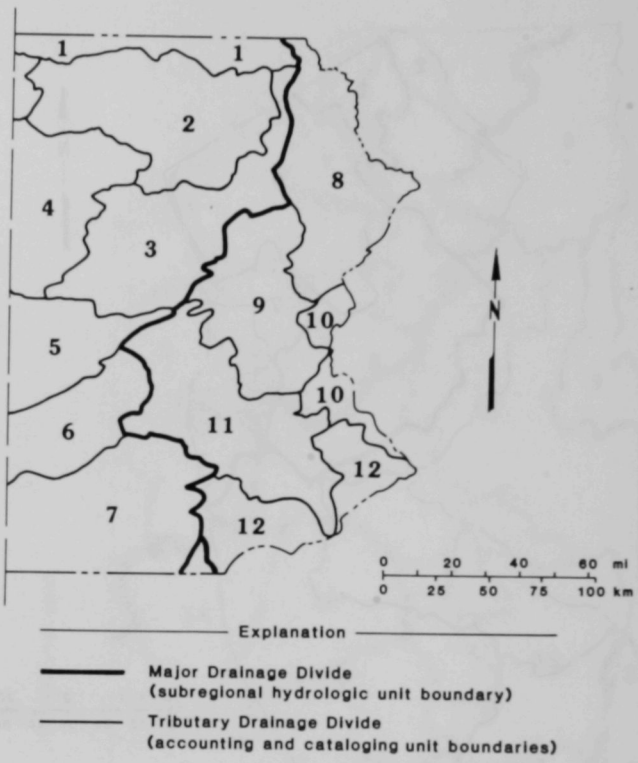


Fig. 6.6 Principal Drainage Basins and Hydrologic Areas in Eastern Pennsylvania (names of major rivers and information on data availability are given in Table 6.6)

Regional Water Resources Study, and two publications by the Great Lakes Basin Commission (1975a and 1975b). Additionally, overview reports for the major drainage basins in the northeast were prepared for the now-defunct New England River Basins Commission (e.g., New England River Basins Commission, 1978). Although the hydrologic information in these overview reports is generalized, the reports provide insight into hydrologic conditions and water use within the respective drainage basins. More-detailed hydrologic investigations have been conducted by the Water Resources Division of USGS and the departments of natural resources and geological surveys of the states making up the region. The numerous reports published by these organizations provided most of the basis for the discussion in this section.

Table 6.1 Summary of Data Indexed by the National Water Data Exchange for the Major Drainage Basins and Hydrologic Areas of Maine

Number on Fig. 6.1	Drainage Basin	Hydrologic Unit[a]	Surface-Water Data Sites[b]		Surface-Water Quality Sites[c]		Ground-Water Data Sites[d]		Ground-Water Quality Sites[c]	
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
1	Salmon Falls[e]	01060003	16	55	17	145	0	0	2	7
2	Saco[e]	01060002	8	9	32	30	0	0	1	17
3	Presumpscot	01060001	9	8	22	78	0	0	0	23
4	Androscoggin[e]	01040002	14	5	38	43	0	0	9	14
5	Magalloway, Cupsuptic, Kennebago[e,f]	01040001	8	2	8	20	0	0	0	4
6	Kennebec-Sebasticook-Carrabassett[g]	01030003	15	11	38	41	2	0	0	12
7	Dead	01030002	3	1	8	0	0	0	0	0
8	Moose, Upper Kennebec	01030001	7	4	1	18	0	0	0	0
9	St. George and several smaller basins	01050003	1	1	3	1	0	0	0	0
10	Union, Narraguagus, Machias, and numerous small basins	01050002	10	12	23	97	1	0	1	4
11	Penobscot	01020005	5	6	11	19	1	0	2	0
12	Piscataquis-Pleasant	01020004	5	2	22	8	0	0	0	0
13	West Branch Penobscot	01020001	0	1	0	2	0	0	0	0
14	East Branch Penobscot	01020002	3	1	2	13	0	0	0	0
15	Mattawamkeag	01020003	1	3	2	12	0	0	0	0
16	St. Croix	01050001	4	2	14	34	0	0	0	0
17	Meduxnekeag	01010005	2	0	3	4	0	0	0	0
18	St. John	01010001	6	4	35	9	0	0	0	4
19	Aroostook	01010004	5	3	8	10	0	0	2	6
20	Allagash	01010002	1	0	2	0	1	0	0	0
21	Fish	01010003	1	1	19	17	1	0	0	0

[a]Identification number for access to Master Water Data Index (MWDI) system; designates river basins of drainage area greater than 1810 km^2 (700 mi^2).

[b]Includes stream-gage, streamflow, and lake or reservoir volume data.

[c]Includes data on biological, physical, sediment, and chemical analyses for both surface and ground waters.

[d]Includes water-level data and well or spring discharge data.

[e]Drainage basin extends into New Hampshire.

[f]Basin names separated by commas indicate discrete, nontributary basins draining a hydrologic area.

[g]Basin names separated by hyphens indicate a tributary situation within a master drainage system.

Source: Based on U.S. Geol. Survey (1981).

Table 6.2 Summary of Data Indexed by the National Water Data Exchange for the Major Drainage Basins and Hydrologic Areas of New Hampshire and Vermont

Number on Fig. 6.2	Drainage Basin	Hydrologic Unit[a]	Surface-Water Data Sites[b]		Surface-Water Quality Sites[c]		Ground-Water Data Sites[d]		Ground-Water Quality Sites[c]	
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
1	Hoosic-Batten Kill[e]	02020003	29	96	28	190	3	0	0	50
2	Poultney, Otter Creek[f]	02020001 02020002	8	32	6	100	0	0	0	10
3	Winooski	02010003	16	26	50	158	0	0	1	3
4	Lamoille	02010005	3	7	41	181	0	0	0	1
5	Missisquoi	02010007	4	2	16	107	0	0	0	1
6	Deerfield, West Branch Deerfield	01080203 01080107	19	57	35	129	0	0	0	32
7	Ottauquechee	01080106	8	13	37	20	0	0	0	2
8	White	01080105	3	5	2	5	0	0	0	2
9	Ompompanoosuc, Waits, Wells, Passumosic	01080103 01080102	8	17	36	49	0	0	0	3
10	Ashuelot	01080201	17	77	34	85	0	0	0	90
11	Middle Connecticut	01080104	11	11	16	44	0	0	0	12
12	Upper Connecticut	01080101	16	15	17	75	0	0	9	7
13	Contoocook-Warner	01070003	13	9	23	15	0	0	0	5
14	Upper Merrimack-Baker, Pemigewasset	01070001	11	9	22	13	0	0	0	8
15	Middle Merimack	01070002	38	142	64	145	0	0	29	82
16	Salmon Falls-Lamprey-Cocheco	01060003	16	55	17	145	0	0	2	7
17	Bear Camp-Saco	01060002	8	9	32	30	0	0	1	17
18	Upper Androscoggin	01040001	8	2	8	20	0	0	0	4
19	Lake Memphremagog	01110000	5	2	67	137	0	0	0	2

[a]Identification number for access to Master Water Data Index (MWDI) system; designates river basins of drainage area greater than 1810 km^2 (700 mi^2).

[b]Includes stream-gage, streamflow, and lake or reservoir volume data.

[c]Includes data on biological, physical, sediment, and chemical analyses for both surface and ground waters.

[d]Includes water-level data and well or spring discharge data.

[e]Basin names separated by hyphens indicate a tributary situation within a master drainage system.

[f]Basin names separated by commas indicate discrete, nontributary basins draining a hydrologic area.

Source: Based on U.S. Geol. Survey (1981).

Table 6.3 Summary of Data Indexed by the National Water Data Exchange for the Major Drainage Basins and Hydrologic Areas of Connecticut, Massachusetts, and Rhode Island

Number on Fig. 6.3	Drainage Basin	Hydrologic Unit[a]	Surface-Water Data Sites[b]		Surface-Water Quality Sites[c]		Ground-Water Data Sites[d]		Ground-Water Quality Sites[c]	
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
1	Housatonic	01100005	50	162	118	358	0	0	21	227
2	Hoosic	02020003	29	96	28	190	3	0	0	50
3	Lower Connecticut	01080205	39	124	50	337	0	0	0	322
4	Thames-Quinebaug-Shetucket[e]	01080201 01100003 01100002 01100001	37	158	56	482	0	0	0	197
5	Blackstone, Taunton, Charles, and numerous smaller basins[f]	01090005 01090004 01090003 01090002 01090001	72	505	43	696	0	0	197	303
6	Farmington	01080207	25	28	18	81	0	0	0	120
7	Westfield	01080206	16	51	22	29	0	0	0	10
8	Deerfield	01080203	10	48	13	30	0	0	0	32
9	Chicopee-Quaboag-Swift-Ware	01080204	21	50	17	61	0	0	0	7
10	Millers	01080202	16	17	21	40	0	0	0	11
11	Nashua, Concord	01070004	43	100	54	121	0	0	81	83
12	Lower Merrimack	01070005 01070002	38	142	64	145	0	0	29	82

[a]Identification number for access to Master Water Data Index (MWDI) system; designates river basins of drainage area greater than 1810 km^2 (700 mi^2).

[b]Includes stream-gage, streamflow, and lake or reservoir volume data.

[c]Includes data on biological, physical, sediment, and chemical analyses for both surface and ground waters.

[d]Includes water-level data and well or spring discharge data.

[e]Basin names separated by hyphens indicate a tributary situation within a master drainage system.

[f]Basin names separated by commas indicate discrete, nontributary basins draining a hydrologic area.

Source: Based on U.S. Geol. Survey (1981).

Table 6.4 Summary of Data Indexed by the National Water Data Exchange for the Major Drainage Basins and Hydrologic Areas in Eastern New York

Number on Fig. 6.4	Drainage Basin	Hydrologic Unit[a]	Surface-Water Data Sites[b]		Surface-Water Quality Sites[c]		Ground-Water Data Sites[d]		Ground-Water Quality Sites[c]	
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
1	Chateaugay, Trout, Salmon, St. Regis[e]	04150306 04150307	13	14	2	39	0	0	0	10
2	Raquette	04150305	8	15	1	40	0	0	0	2
3	Grass and other smaller basins	04150301 04150304	9	11	4	45	0	0	0	2
4	Oswegatchie, Indian	04150302 04150303	4	10	1	33	0	0	0	5
5	Moose-Independence Beaver-Black[f]	04150101	15	33	2	84	1	0	0	49
6	Chaumont, Perch, Sandy Creek, Little Salmon and other smaller basins	04140102	3	13	1	10	0	0	0	6
7	Oneida-Oswego	04140202 04140203	13	25	4	93	1	0	0	14
8	Great Chazy, Saranac, Ausable, Bouquet	02010004 02010006	6	22	6	162	0	0	0	31
9	Mettawee-Poultney, Lake George, and other smaller basins	02010001	5	16	32	265	0	0	0	13
10	Schroon-Sacandaga-Batten Kill-Hoosic-Upper Hudson	02020001 02020002 02020003	37	128	34	290	3	0	0	60
11	Mohawk	02020004	17	52	21	81	1	0	0	66
12	Schoharie Creek	02020005	16	21	2	37	0	0	0	9
13	Catskill Creek-Kinderhook Creek-Taghkanic Creek-Saw Kill-Hudson	02020006	21	87	6	167	2	0	0	28
14	Rondout Creek-Wallkill-Wappinger Creek-Fish-Kill Creek-Hudson	02020007 02020008	20	68	12	281	2	1	0	51
15	Canopus Creek-Rampo-Harlem-East-Lower Hudson	02030101 02030102 02030103	98	99	84	781	4	6	6	129
16	Peconic, Carmans, and other smaller basins	02030201 02030202	79	22	90	459	0	0	517	1563
17	Unadilla-Upper Susquehanna	02050101	15	39	8	115	1	0	0	49

Table 6.4 (Cont'd)

Number on Fig. 6.4	Drainage Basin	Hydrologic Unit[a]	Surface-Water Data Sites[b]		Surface-Water Quality Sites[c]		Ground-Water Data Sites[d]		Ground-Water Quality Sites[c]	
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
18	Tioughnioga-Chenango	02050102	18	58	10	102	1	0	28	42
19	Cayuta Creek-Catatonk Creek-Owego Creek-Susquehanna	02050103	4	28	3	85	1	0	0	45
20	West Branch-East Branch-Mongaup-Neversink-Delaware	02040101 02040102 02040104	46	113	41	485	1	0	0	88
21	Tenmile-Upper Williams	01100005	50	162	118	358	0	0	21	227

[a]Identification number for access to Master Water Data Index (MWDI) system; designates river basins of drainage area greater than 1810 km^2 (700 mi^2).

[b]Includes stream-gage, streamflow, and lake or reservoir volume data.

[c]Includes data on biological, physical, sediment, and chemical analyses for both surface and ground waters.

[d]Includes water-level data and well or spring discharge data.

[e]Basin names separated by commas indicated discrete, nontributary basins draining a hydrologic area.

[f]Basin names separated by hyphens indicate a tributary situation within a master drainage system.

Source: Based on U.S. Geol. Survey (1981).

Table 6.5 Summary of Data Indexed by the National Water Data Exchange for the Major Drainage Basins and Hydrologic Areas of New Jersey

Number on Fig. 6.5	Drainage Basin	Hydrologic Unit[a]	Surface-Water Data Sites[b]		Surface-Water Quality Sites[c]		Ground-Water Data Sites[d]		Ground-Water Quality Sites[c]	
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
1	Walkill	02020007	15	37	6	101	0	0	0	15
2	Flat Brook	02040104	24	52	28	308	0	0	0	70
3	Paulins Kill, Pequest, Musconetcong, and other smaller basins[e]	02040105	28	48	106	343	2	1	0	164
4	Rancocas Creek and other smaller basins	02040201 02040202	59	43	192	582	5	17	12	790
5	Maurice, Cohansey, and other smaller basins	02040206	17	21	16	101	2	9	10	106
6	Hackensack, Rampo-Pequannock-Passaic[f]	02030103	75	71	74	422	3	6	0	72
7	Navesink and other smaller basins	02030104	9	21	73	269	3	5	13	90
8	Millstone-Raritan	02030105	53	79	102	364	2	15	0	76
9	Manasquan, Toms, Wading-Wading-Mullica, Great Egg Harbor	02040301 02040302	39	54	141	369	15	18	18	421

[a]Identification number for access to Master Water Data Index (MWDI) system; designates river basins of drainage area greater than 1810 km^2 (700 mi^2).

[b]Includes stream-gage, streamflow, and lake or reservoir volume data.

[c]Includes data on biological, physical, sediment, and chemical analyses for both surface and ground waters.

[d]Includes water-level data and well or spring discharge data.

[e]Basin names separated by commas indicate discrete, nontributary basins draining a hydrologic area.

[f]Basin names separated by hyphens indicate tributary situation within a master drainage system.

Source: Based on U.S. Geol. Survey (1981).

Table 6.6 Summary of Data Indexed by the National Water Data Exchange for the Major Drainage Basins and Hydrologic Areas in Eastern Pennsylvania

Number on Fig. 6.6	Drainage Basin	Hydrologic Unit[a]	Surface-Water Data Sites[b]		Surface-Water Quality Sites[c]		Ground-Water Data Sites[d]		Ground-Water Quality Sites[c]	
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
1	Upper Susquehanna-Wappasening Creek-Lower Chemung[e]	02050101 02050103 02050105	32	83	14	261	2	0	0	150
2	Towanda Creek-Wyalusing Creek-Tunkhannock Creek-Bowman Creek-Susquehanna	02050106	17	16	36	151	1	2	0	241
3	Lackawanna-Huntington Creek-Fishing Creek-Nescopeck Creek-Catawissa Creek-Susquehanna	02050107	24	14	58	816	2	2	0	596
4	Lycoming Creek-Loyalsock Creek-Muncy Creek-Chillisquaque Creek-Buffalo Creek-West Branch Susquehanna	02050206	22	22	35	237	3	1	0	118
5.	Penns Creek-Middle Creek-Mahanoy Creek-Mahantango Creek-Susquehanna	02050301	10	4	31	279	1	0	0	110
6	Sherman Creek-Conodoguinet Creek-Sawatara Creek-Susquehanna	02050305	20	18	49	349	4	5	5	390
7	Conewago Creek-Codorus Creek-Muddy Creek-Cocalico Creek-Conestoga Creek-Octoraro Creek-Susquehanna	02050306	25	25	65	433	4	1	6	539
8	Lackawaxen and other smaller basins	02040101 02040103 02040104	49	95	48	552	1	0	0	133
9	Lehigh	02040106	29	19	57	323	1	7	0	406
10	Tohickon Creek and other smaller basins	02040105	28	48	106	343	2	1	0	164
11	Schuylkill	02040203	41	30	125	693	5	11	6	807
12	Neshaming Creek, Darby Creek, Brandywine Creek, and other smaller basins[f]	02040201 02040202 02040205	87	65	263	883	12	19	15	987

[a]Identification number for access to Master Water Data Index (MWDI) system; designates river basins of drainage area greater than 1810 km^2 (700 mi^2).

[b]Includes stream-gage, streamflow, and lake or reservoir volume data.

[c]Includes data on biological, physical, sediment, and chemical analyses for both surface and ground waters.

[d]Includes water-level data and well or spring discharge data.

[e]Basin names separated by hyphens indicate a tributary situation within a master drainage system.

[f]Basin names separated by commas indicate discrete, nontributary basins draining a hydrologic area.

Source: Based on U.S. Geol. Survey (1981).

6.2 WATER USE

Water use is expressed by two concepts. Withdrawal use, which is the amount of water withdrawn from surface and subsurface supplies, represents the total stress on the water resources of a particular area. A certain portion of the water withdrawn is returned to the surface-water system and may be available for subsequent use. However, almost all withdrawal use from the ground-water system constitutes a net loss because only a small portion of the water returned to the surface system recharges the ground-water system. Consumptive use is that part of the water withdrawn that is no longer available for other uses because it has been removed from the accessible water environment by evaporation, transpiration, incorporation into products and crops, consumption by man and livestock, etc. For the period 1960-1980, Solley et al. (1983) estimated that consumptive use has averaged about 23% of withdrawal use in the United States.

Withdrawal use may be categorized as follows: (1) public supply, which includes residential-domestic and commercial-industrial use; (2) rural supply, which covers domestic and livestock use, in most cases from ground-water supplies; (3) irrigation, which has a high consumptive fraction; (4) withdrawal from surface waters attendant upon electric power generation, with the water used mostly for cooling purposes; (5) self-supplied industrial use, which is often associated with manufacturing, mining, and mineral processing, and which has a large consumptive component; and (6) other miscellaneous uses, including fire fighting, unmetered public use, and irrigation conveyance losses.

Estimated water use in the northeastern United States during the period 1960-1980 is summarized in Table 6.7. The tabulated data indicate, with some fluctuations, a generally increasing use of water since 1960. Average withdrawal use in the region increased from about 142.1 million m^3 per day (37,500 million gallons per day [mgd]) in 1960 to approximately 212.7 million m^3 per day (56,200 mgd) in 1980, which represents an increase of almost 50%. For 1980, total withdrawal use in the region represented approximately 12.5% of that for the entire country. The percentage of total regional use for each of the nine states remained fairly constant during the 1960-1980 period. In 1980, Rhode Island and Vermont each used less than 1%, and Maine and New Hampshire each used less than 3%. Because of the large industrial and population centers located in New York, Pennsylvania, and New Jersey, these states withdrew 29.9%, 28.5%, and 18.4%, respectively. Table 3.11 shows that withdrawal use is greatest for the industrial sector and for electric power generation. However, much of the water used by steam electric plants in coastal areas for condensor and reactor cooling is saline and does not represent freshwater use.

Of the total water withdrawn throughout the northeastern region in 1980, only 6.1% was supplied by ground-water sources. Vermont had the greatest proportion of water withdrawal from ground-water supplies with 13.4%,

Table 6.7 Estimated Water Use in the Northeastern United States, 1960-1980 (mgd)[a,b]

State/Year	Public Supply		Rural Supply		Irrigation	Electric Power Generation[c]	Self-Supplied Industrial[c]	Total Withdrawal[c]		
	Residential-Domestic	Commercial-Industrial	Domestic	Livestock				Ground Water	Surface Water	Consumptive Use
Maine										
1980	70	34	26	1.7	6.1	760	66	80	1,500	53
1975	71	36	16	0	8.5	620	440	47	1,200	41
1970	72	38	12	2.8	8.9	200	420	36	720	61
1965	60	33	10	3.5	2.5	180	500	44	740	57
1960	55	31	7.4	3.4	0.9	120	350	32	540	49
New Hampshire										
1980	64	25	9.3	0.8	1.6	700	210	65	940	17
1975	55	23	8.5	0.9	5.4	690	210	59	940	21
1970	48	22	11	1.3	2.8	410	190	55	630	18
1965	50	20	6.3	1.4	2.1	230	170	42	440	20
1960	37	17	4.3	1.8	1.4	250	150	32	440	18
Vermont										
1980	33	15	20	9.2	1.4	250	15	45	290	41
1975	30	15	19	8.7	2.2	250	15	43	290	110
1970	30	13	11	8.3	0.1	5.0	46	42	69	13
1965	29	9	7.4	5.4	0.7	53	34	24	110	15
1960	19	13	7.5	6.6	0.8	29	34	28	82	17
Massachusetts										
1980	560	240	32	1.2	19	4,700	370	320	5,600	90
1975	450	330	25	1.4	33	7,300	680	350	8,400	110
1970	440	320	28	2.1	58	2,700	690	350	3,900	140
1965	390	280	38	2.7	11	2,000	600	280	3,100	110
1960	420	170	4.7	3.0	7.5	1,800	580	190	2,800	100
Rhode Island										
1980	77	50	4.9	0.2	5.0	330	36	37	460	15
1975	44	66	4.4	0.2	4.6	330	30	28	460	14
1970	41	62	4.6	0.2	4.5	310	38	39	430	13
1965	71	30	4.8	0.4	0.6	300	45	45	400	27
1960	41	40	1.2	0.4	0.2	300	47	27	400	7.7
Connecticut										
1980	220	140	53	2.2	21	3,000	270	140	3,600	160
1975	210	110	50	3.0	4.3	1,900	320	120	2,500	160
1970	190	170	39	2.5	5.9	2,900	220	150	3,300	180
1965	170	130	46	2.3	10	1,600	270	110	2,100	160
1960	160	97	22	3.0	1.0	1,500	320	78	2,000	120

Table 6.7 (Cont'd)

State/Year	Public Supply		Rural Supply		Irrigation	Electric Power Generation[c]	Self-Supplied Industrial[c]	Total Withdrawal		Consumptive Use
	Residential-Domestic	Commercial-Industrial	Domestic	Livestock				Ground Water	Surface Water	
New York										
1980	1,300	950	130	58	46	13,000	1,200	800	16,000	590
1975	1,400	1,300	120	38	32	19,000	1,600	1,000	23,000	740
1970	1,900	790	120	38	27	13,000	1,500	890	17,000	660
1965	1,600	680	130	33	53	10,000	3,200	840	15,000	620
1960	1,500	590	110	35	28	8,300	3,000	640	13,000	550
New Jersey										
1980	820	250	75	3.0	55	7,400	1,800	730	9,600	380
1975	770	190	110	2.3	140	4,300	1,100	790	5,800	440
1970	780	110	80	2.4	76	4,200	1,000	1,000	5,200	380
1965	510	220	36	3.0	54	4,000	1,500	600	5,700	470
1960	470	200	83	4.7	35	2,700	1,300	540	4,200	240
Pennsylvania										
1980	1,200	350	150	61	160	10,000	3,600	1,000	15,000	920
1975	1,200	480	120	51	34	11,000	4,700	880	17,000	830
1970	870	880	110	28	10	12,000	5,500	770	19,000	450
1965	690	700	100	28	6.7	8,800	5,000	590	15,000	390
1960	650	670	97	32	3.0	6,600	4,900	520	12,000	360

[a]To convert million gallons per day to million cubic meters per day, multiply by 0.003785.

[b]Data rounded to two significant figures.

[c]Includes saline water.

Sources: Solley et al. (1983), Murray and Reeves (1977 and 1972), Murray (1968), and MacKichan and Kammerer (1961).

and Connecticut had the least at 3.7%. Ground water supplied 4.8-7.1% of the total water use in the remaining states of the region.

The U.S. Water Resources Council (1978) published a comprehensive report on the nation's water resources, a portion of which deals with water withdrawal and consumption for the future on a regional basis. Table 6.8 is a compilation of such data for the New England region. As these data indicate, water withdrawals are projected to decrease in the period 1975-2000, whereas overall consumption is expected to about double. The projected decrease of freshwater withdrawal is based on assumptions of increased water recycling by industries in response to the "no discharge" requirements of the Federal Water Pollution Control Act and increased use of saline water for cooling of steam electric plants. Generally, the total water supply in the northeastern region is well in excess of total projected regional needs through the end of the century. However, the locally poor quality of some of the water in the region often precludes its use as a water supply. Moreover, the uneven availability of water supplies with respect to major population and industrial centers has resulted in controversial interbasin diversions. As water requirements grow, these diversions are expected to continue (U.S. Water Resources Council, 1978).

6.3 CLIMATE AND HYDROLOGY

The regional climate is humid, with local climatic variations related to elevation, latitude, and distance from the ocean. In coastal areas, climate is moderated by the presence of the ocean. During the winter, onshore winds tend to maintain higher temperatures, and during the summer, sea breezes cool the adjacent land. Inland, especially in areas of greater elevation and relief, greater extremes in temperature and other climatic conditions occur.

The climatic factors of primary importance to the region's hydrology are precipitation (rainfall and snowfall) and temperature. The effect of climate on hydrology for a typical area in New England like Groton, Mass., is representative of the effect over the entire region. The long-term average precipitation in Groton is about 104 cm (41 in.) per year. Precipitation is fairly evenly distributed throughout the year, with no month being characteristically wet or dry. However, average rainfall conditions are seldom seen: the climate during a given year is usually either wetter or drier than average. During the period 1970-1980, for example, annual precipitation ranged from a low of about 76 cm (30 in.) in 1980 to about 122 cm (48 in.) in 1973. Over longer periods, even greater extremes can occur.

Average annual precipitation is about 104 cm (41 in.) for the region and is distributed fairly evenly throughout the year. Average values range from less than 76 cm (30 in.) near the northern end of Lake Champlain along the New York-Vermont border to more than 175 cm (70 in.) at some isolated locations in the mountainous areas of New Hampshire (U.S. Army Corps of Engineers, 1972). Average annual snowfall is principally a function of

Table 6.8 Estimated Water Use for the New England Region through the Year 2000 (mgd)[a]

Category	Year 1975	1985	2000
Freshwater withdrawals			
Agriculture	53	60	65
Steam electric	1263	1069	375
Manufacturing	2170	1022	781
Domestic	1122	1223	1356
Commercial	361	393	442
Minerals	90	115	153
Public lands	2	2	3
Fish hatcheries	37	55	55
Other	0	0	0
Total	5098	3939	3230
Freshwater consumption			
Agriculture	43	48	52
Steam electric	21	18	167
Manufacturing	192	332	567
Domestic	164	179	196
Commercial	48	52	58
Minerals	11	16	20
Public lands	2	2	3
Fish hatcheries	0	0	0
Other	0	0	0
Total	481	647	1063
Ground-water withdrawals	635	NA[b]	NA

[a]To convert million gallons per day to million cubic meters per day, multiply by 0.003785.

[b]Not available.

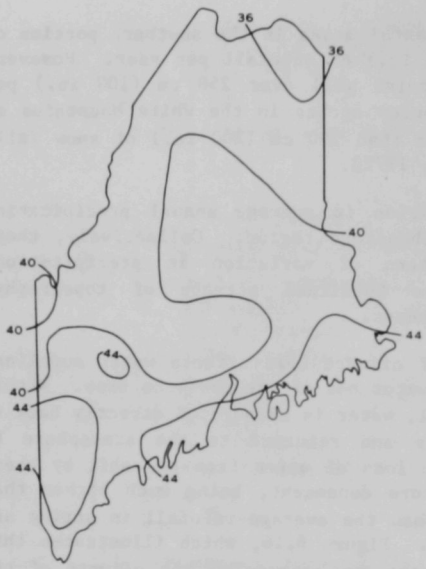
Source: U.S. Water Resources Council (1978).

latitude and, of course, elevation. Coastal areas in the southern portion of the region average less than 50 cm (20 in.) of snowfall per year. However, northern Maine and the Adirondacks receive well over 250 cm (100 in.) per year. The greatest snowfall in the region occurs in the White Mountains of New Hampshire, where an average of more than 500 cm (200 in.) of snow falls each year (U.S. Army Corps of Engineers, 1972).

Figures 6.7-6.15 show the variation in average annual precipitation within each of the states of the northeastern region. Collectively, these figures illustrate the regional pattern of variation in precipitation. Individually, they indicate the more localized effects of topography, proximity to the ocean, and other influences.

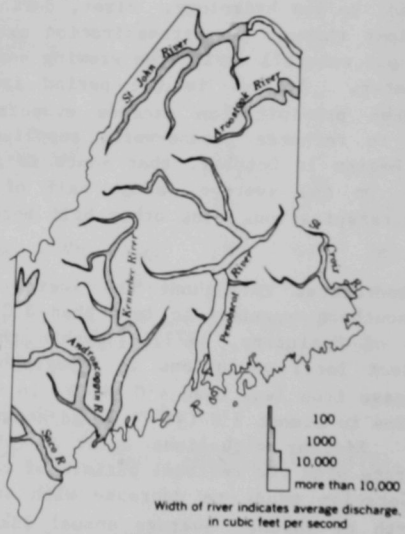
Temperature is another aspect of climate that affects water supplies, as it controls two phenomena that take water out of the resource base. Within the upper 30 cm (1 ft) or so of the soil, water is evaporated directly back to the atmosphere or taken up by plants and returned to the atmosphere by transpiration. Evapotranspiration, the loss of water from the soil by these two processes, is essentially temperature dependent, being much higher than the average rainfall in summer, less than the average rainfall in spring and fall, and close to zero during winter. Figure 6.16, which illustrates this concept graphically, shows that there are two aspects of the climate of the Groton area relevant to its hydrology. First, during the growing season, the amount of water lost through evapotranspiration exceeds the rainfall, which means that almost all rainfall during the growing season is consumed before it becomes ground water. Second, in the period from about October to the following May, when precipitation exceeds evapotranspiration, there is a surplus of water to recharge ground-water supplies. Because ground-water recharge usually begins in October, that month is taken as the beginning of the water year. On the average, about half of annual precipitation is consumed by evapotranspiration. The other half becomes ground-water flow or streamflow.

Annual temperatures throughout the region average from about 13°C (55°F) near the southern boundary to less than 3°C (38°F) in northern Maine (U.S. Army Corps of Engineers, 1972). Within the region, average annual temperatures reflect local variations in topography. For example, average temperatures increase from less than 4°C (40°F) in the central portion of the Adirondack Mountains to almost 7°C (45°F) in adjacent lowlands less than 80 km (50 mi) distant. Similar situations exist in other upland areas of the region. Commensurate with the regional pattern of variation in average annual temperature, evaporation tends to decrease with increased elevation and to increase from north to south. Average annual lake evaporation varies from about 50 cm (20 in.) in northern Maine to about 100 cm (40 in.) in the south. Annual evapotranspiration follows an analogous trend, increasing from about 38 cm (15 in.) in the north to approximately 76 cm (30 in.) in the south (U.S. Army Corps of Engineers, 1972).



MEAN ANNUAL PRECIPITATION, IN INCHES

AVERAGE ANNUAL RUNOFF, IN INCHES



AVERAGE DISCHARGE OF THE PRINCIPAL RIVERS

Fig. 6.7 Average Annual Precipitation, Runoff, and River Discharge in Maine (Source: U.S. Geol. Survey, 1978a)

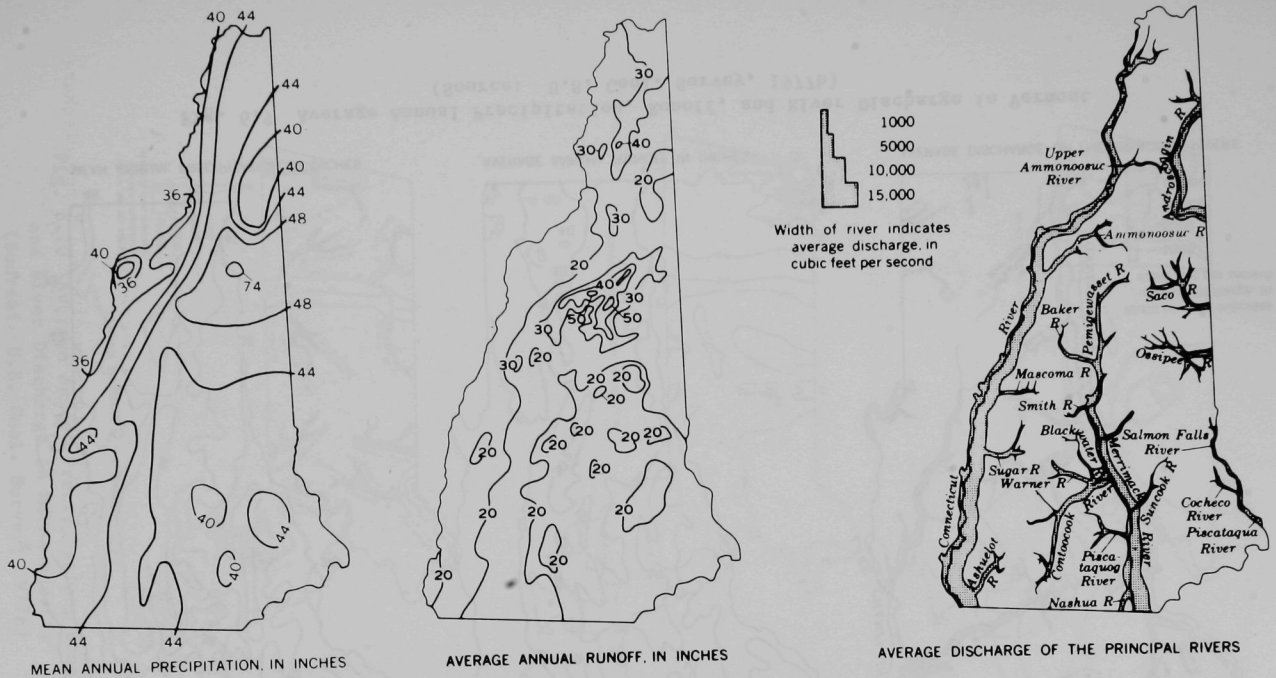


Fig. 6.8 Average Annual Precipitation, Runoff, and River Discharge in New Hampshire (Source: U.S. Geol. Survey, 1977a)

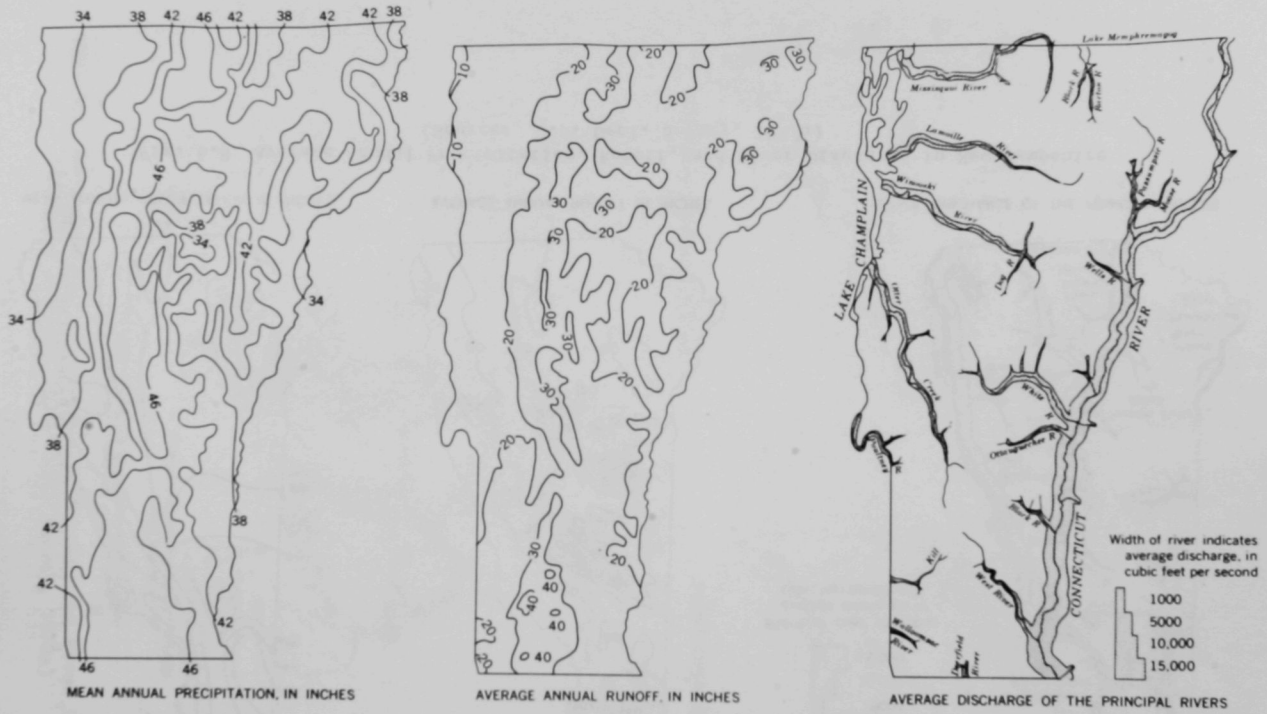


Fig. 6.9 Average Annual Precipitation, Runoff, and River Discharge in Vermont (Source: U.S. Geol. Survey, 1977b)

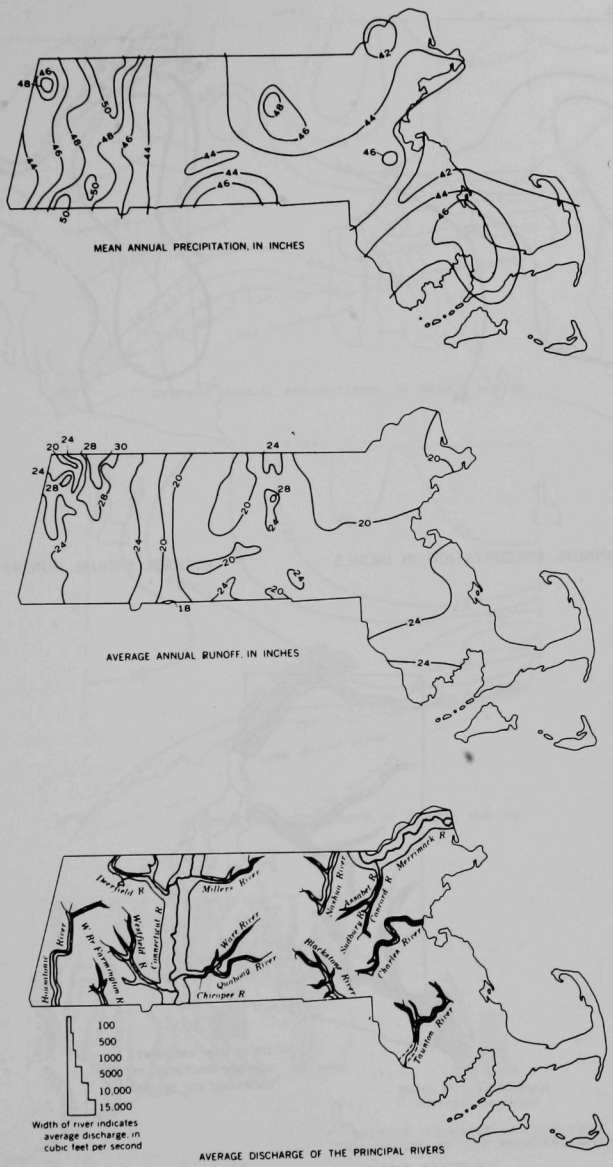
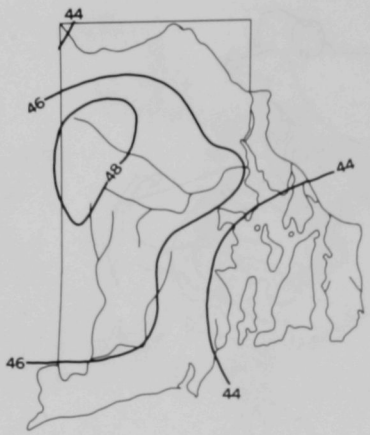
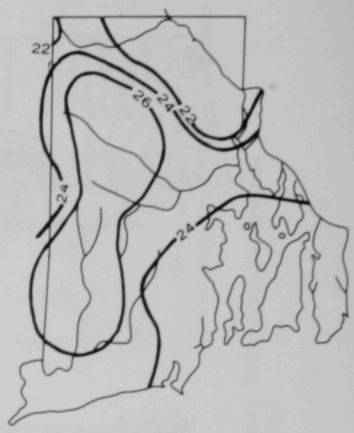


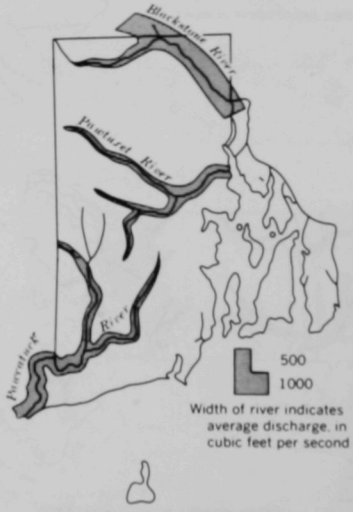
Fig. 6.10 Average Annual Precipitation, Runoff, and River Discharge in Massachusetts (Source: U.S. Geol. Survey, 1977c)



MEAN ANNUAL PRECIPITATION, IN INCHES

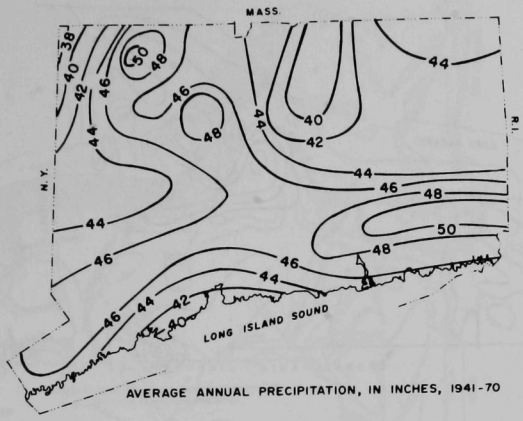


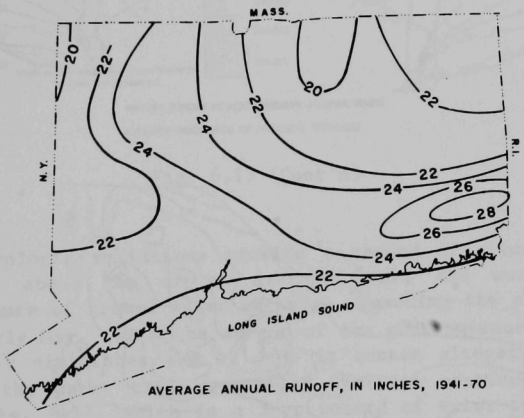
AVERAGE ANNUAL RUNOFF, IN INCHES



AVERAGE DISCHARGE OF THE PRINCIPAL RIVERS

Fig. 6.11 Average Annual Precipitation, Runoff, and River Discharge in Rhode Island (Source: U.S. Geol. Survey, 1977A)





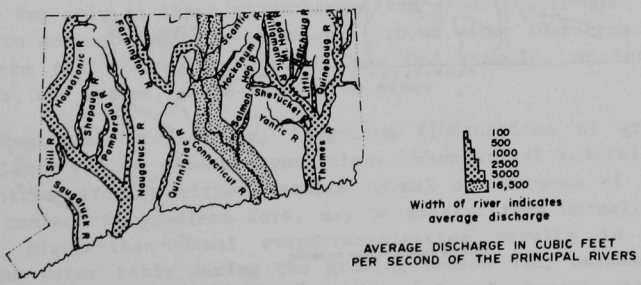
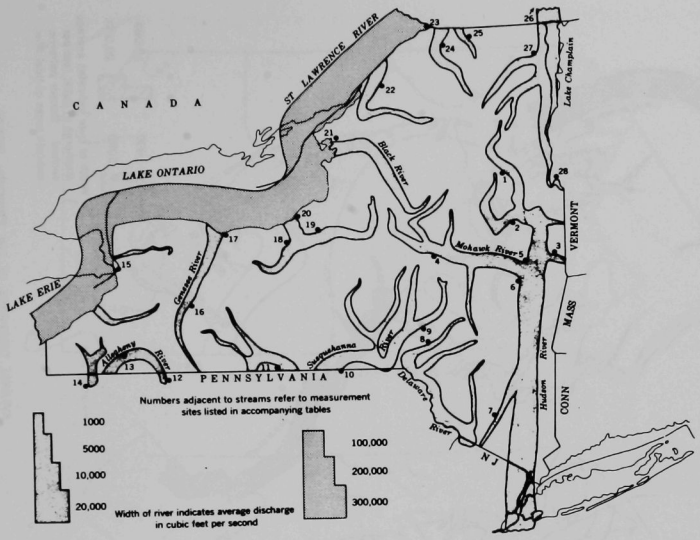


Fig. 6.12 Average Annual Precipitation, Runoff, and River Discharge in Connecticut (Source: U.S. Geol. Survey, 1978b)

MEAN ANNUAL PRECIPITATION, IN INCHES, 1931-64

AVERAGE ANNUAL RUNOFF, IN INCHES

Fig. 6.13 Average Annual Precipitation, Runoff, and River Discharge in New York (Source: U.S. Geol. Survey, 1977e)



AVERAGE DISCHARGE OF PRINCIPAL STREAMS

Fig. 6.13 (Cont'd)

Local hydrologic variations provide a record of climatic variations. From October to about May of an average year, the water table rises continuously because of ground-water recharge, reaching its annual maximum in late April or early May. With the advent of the growing season, ground-water recharge initially diminishes and by June it ceases altogether. During the growing season, the water table generally declines continuously. This is illustrated in Fig. 6.17, which is a 3-yr record of water-table levels in a well on Cape Cod. This decline, or water-table recession, is more than a lack of recharge. Not only is there no recharge, but ground water must be removed from storage to account for the recession. Ground water lost from storage is discharged into the ocean, as in the Cape Cod example, or into rivers, streams, lakes, and swamps, as in the Groton area.

Excluding human influences, long-term fluctuations of ground-water levels are a function of climatic variation. When annual rainfall is below normal, evapotranspiration either remains normal or, because of a greater-than-average number of cloudless days, may be greater than normal. As would be expected, higher-than-normal evapotranspiration results in a greater decline of the water table during the growing season and, because of lower recharge in fall, winter, and spring, also results in lower seasonal high-water levels. If a series of consecutive years has below-normal rainfall, there results a continuous lowering of the water table, punctuated by slight

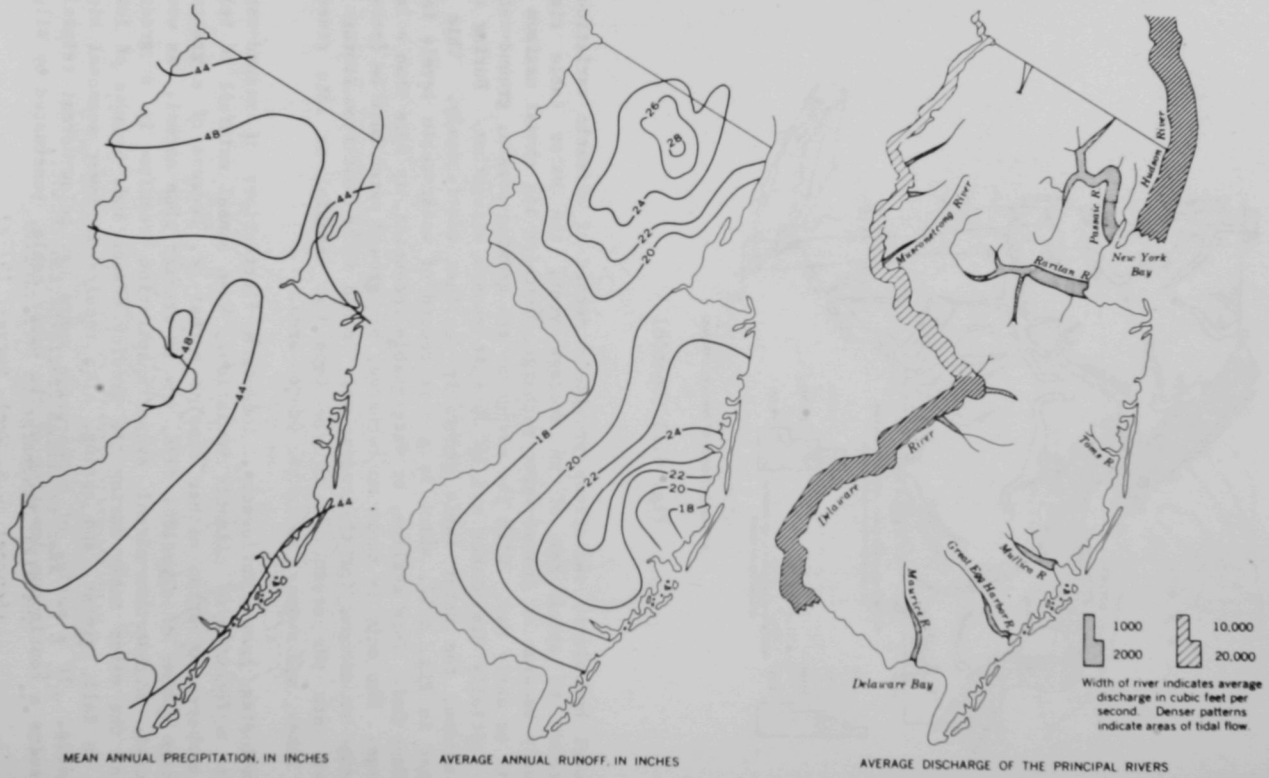
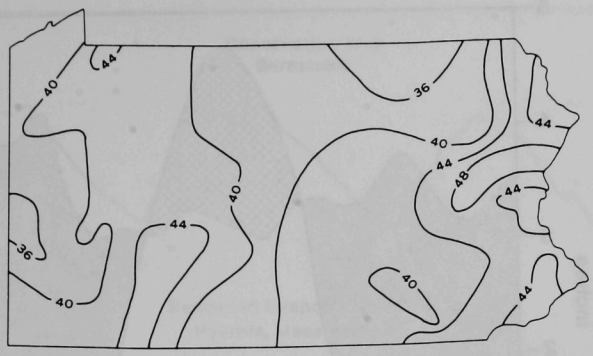
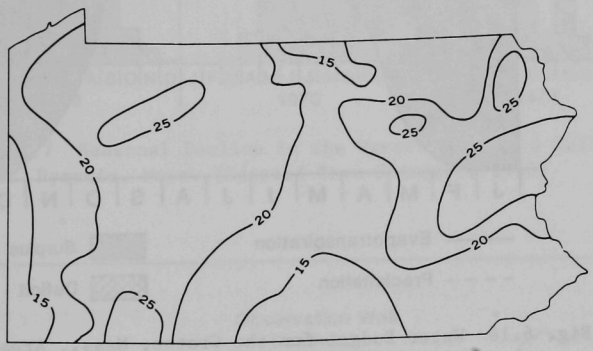


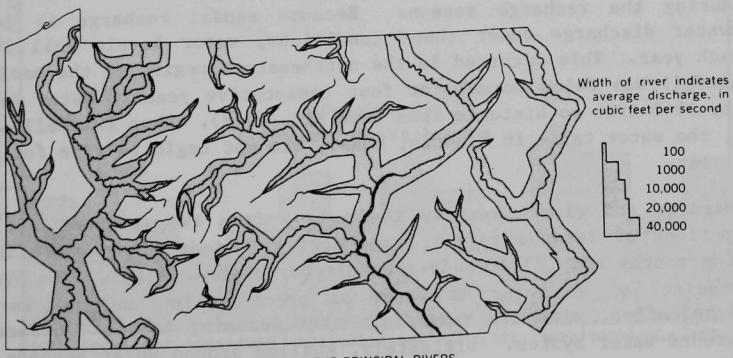
Fig. 6.14 Average Annual Precipitation, Runoff, and River Discharge in New Jersey (Source: U.S. Geol. Survey, 1977f)



AVERAGE ANNUAL PRECIPITATION, IN INCHES



AVERAGE ANNUAL RUNOFF, IN INCHES



AVERAGE DISCHARGE OF THE PRINCIPAL RIVERS

Fig. 6.15 Average Annual Precipitation, Runoff, and River Discharge in Pennsylvania (Source: U.S. Geol. Survey, 1977g)

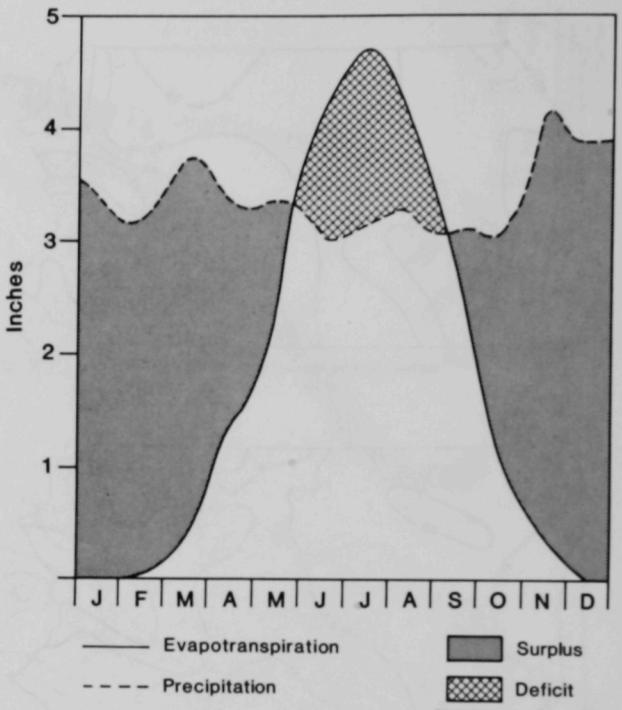


Fig. 6.16 Water Budget for the Groton, Mass., Area

rises during the recharge season. Because annual recharge is less than ground-water discharge under these conditions, water levels fall lower and lower each year. This occurred in the northeastern region in the early 1960s, when rainfall was below normal for four consecutive years. Water levels had fallen by 1965-1966 to historic lows (see Fig. 6.18). When rainfall increased in 1966, the water table in Hyannis, Mass., did not begin to rise for at least another year.

Streams and rivers receive their flow from two sources: (1) runoff during periods of intense rainfall and during periods of snowmelt in winter and spring months and (2) ground-water discharge (base flow). The hydrologic cycle consists of an input of water as precipitation and a loss through evapotranspiration, with the remaining water becoming part of surface runoff or the ground-water system. Ultimately, shallow ground water becomes part of stream discharge as base flow.

In winter and spring months, when ground-water levels are high, the flow of ground water is faster and, therefore, base flow is higher. In the

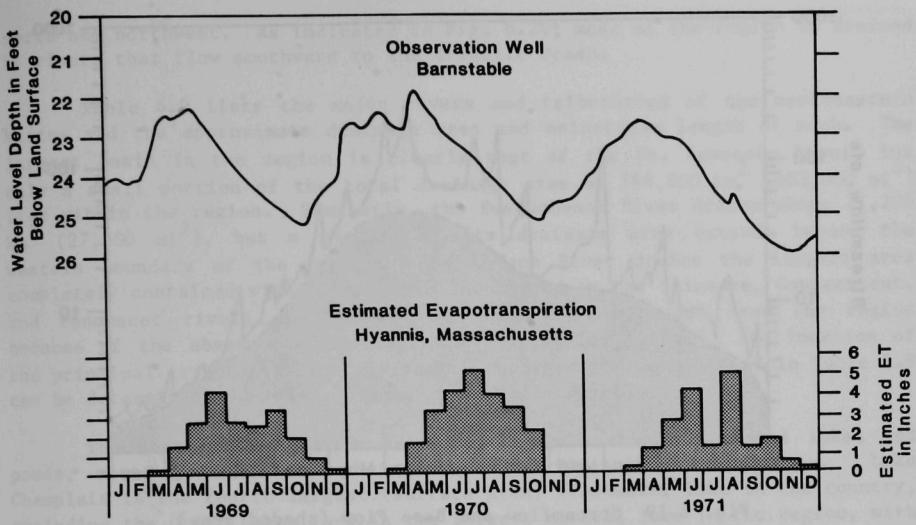


Fig. 6.17 Seasonal Decline in the Water Table in a Well at Hyannis, Mass. (Adapted from Frimpter, 1980)

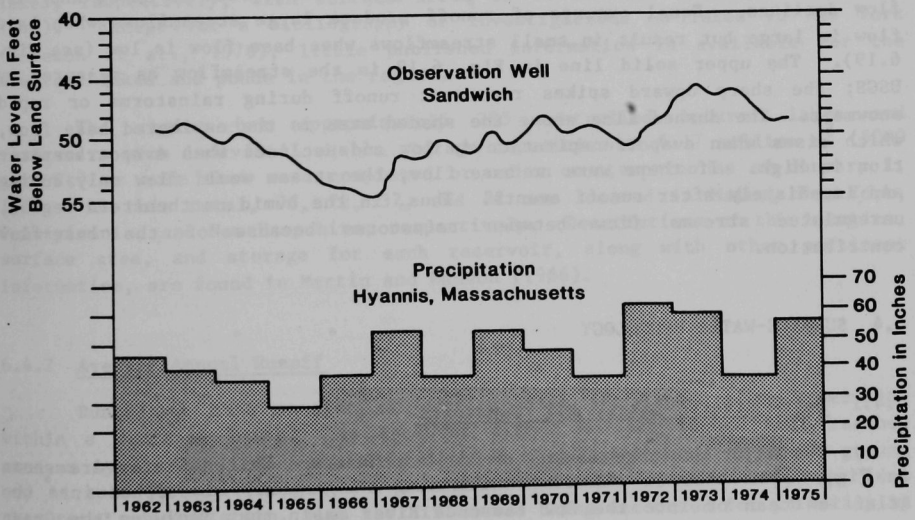


Fig. 6.18 Ground-Water Levels in Hyannis, Mass., during the Drought of the Early 1960s (Adapted from Frimpter, 1980)

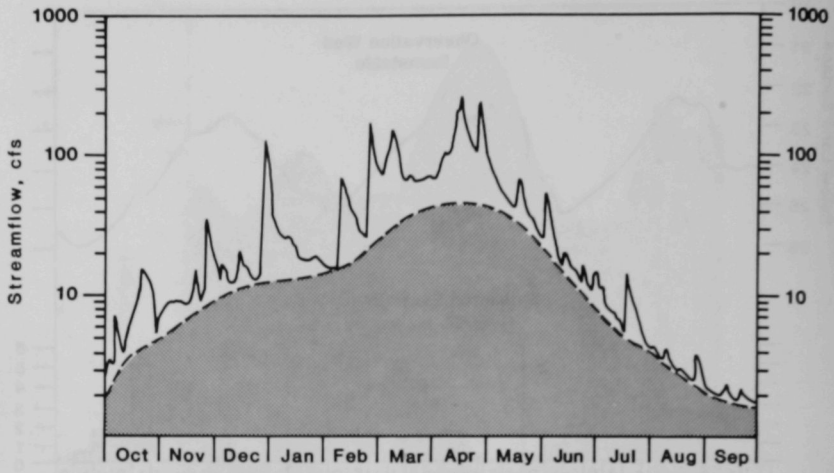


Fig. 6.19 Streamflow and Base Flow (shaded area) of the Squannacook River near West Groton, Mass., Water Year 1965

growing season, the water table declines, ground-water flow is less, and base flow declines. Equal amounts of runoff produce large streamflows when base flow is large but result in small streamflows when base flow is low (see Fig. 6.19). The upper solid line in Fig. 6.19 is the streamflow as measured by USGS; the sharp upward spikes represent runoff during rainstorms or rapid snowmelt. The dashed line above the shaded area is the estimated base flow, which rises when evapotranspiration is low and declines when evapotranspiration is high. If there were no base flow, the stream would flow only during and immediately after runoff events. Thus, in the humid northeastern region, unregulated streams flow between rainstorms because of the base-flow contribution.

6.4 SURFACE-WATER HYDROLOGY

6.4.1 Major Rivers, Lakes, and Reservoirs

The major drainage basins of the northeastern United States are shown in Fig. 6.20. All of the rivers draining the region flow either into the Atlantic Ocean or into the St. Lawrence River basin that includes the Great Lakes. Consequently, a major regional drainage divide separates the headwaters of the Susquehanna, Hudson, and Connecticut rivers from the rivers flowing into Lake Ontario and the Lake Champlain-St. Lawrence lowlands to the

north and northwest. As indicated in Fig. 6.20, most of the region is drained by rivers that flow southward to the Atlantic Ocean.

Table 6.9 lists the major rivers and tributaries of the northeastern states and the approximate drainage area and mainstream length of each. The largest basin in the region is clearly that of the St. Lawrence River, but only a small portion of the total drainage area of 784,800 km^2 (303,000 mi^2) lies within the region. Similarly, the Susquehanna River drains about 71,200 km^2 (27,500 mi^2), but a portion of its drainage area extends beyond the western boundary of the region. The Hudson River drains the largest area completely contained within the region, followed by the Delaware, Connecticut, and Penobscot rivers. (Southern New Jersey is excluded from the region because of the absence of near-surface crystalline rocks.) The location of the principal tributaries in relation to the larger rivers listed in Table 6.9 can be determined from Figs. 6.1-6.6 and Tables 6.1-6.6.

The northeastern states contain a large number of natural lakes and ponds, most of which owe their origin to Pleistocene glaciation. Lake Champlain is the fourth largest (surface area) freshwater lake in the country, excluding the Great Lakes, and is the largest natural lake in the region, with a surface area of 1269 km^2 (490 mi^2) (Bue, 1963). Moosehead Lake in Maine and Winnipesaukee Lake in New Hampshire are the second and third largest in the region, with surface areas of 303 km^2 (117 mi^2) and 186 km^2 (72 mi^2), respectively. Maine, New York, and New Hampshire each have 26, 10, and 3 lakes, respectively, with surface areas of 26 km^2 (10 mi^2) or more (Bue, 1963). Except for a bibliography of investigations on lakes in New York (Greeson et al., 1976), little published information is available for the numerous lakes and ponds in the region.

The region has approximately 285 controlled natural lakes and reservoirs with individual usable storage capacities of 6.17 million m^3 (5000 acre-ft) or more that were completed or under construction as of January 1, 1963. Of this total, 76, 72, 37, and 32 are located in Maine, New York, Pennsylvania, and New Hampshire, respectively. Descriptions of the location, surface area, and storage for each reservoir, along with other pertinent information, are found in Martin and Hanson (1966).

6.4.2 Average Annual Runoff

Runoff is that portion of precipitation that appears as streamflow within a drainage basin. It includes direct surface runoff that reaches streams by overland flow and precipitation that infiltrates into the ground and is subsequently discharged into stream channels. Runoff is always less than total precipitation, with the difference being accounted for primarily by evaporation, transpiration, and surface or subsurface storage.

There is relatively little seasonal variation in runoff in the northeast compared with the rest of the country. Over most of the region,

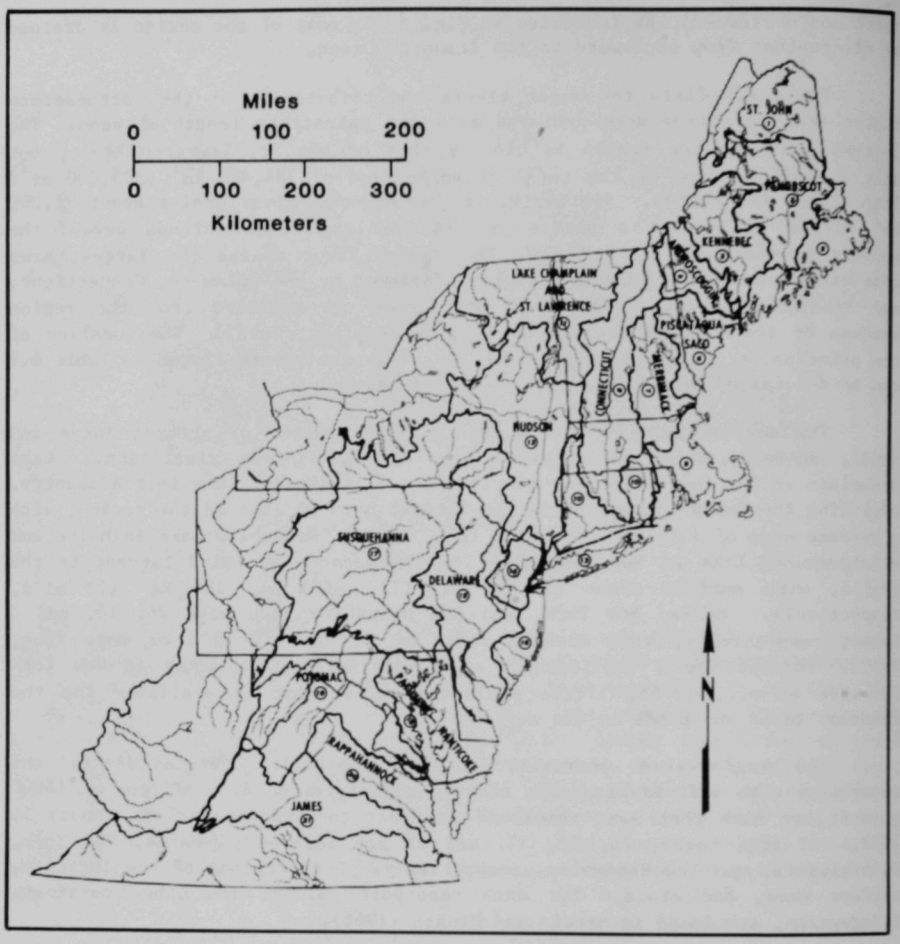


Fig. 6.20 Major Drainage Basins of the Northeastern United States (Not titled are basin 5 -- St. Croix River, Maine, and Atlantic coastal area as shown; basin 9 -- Narragansett Bay and Pawcatuck River drainage, and Atlantic coastal area as shown; basin 10 — Thames and Housatonic River basins; basin 13 -- Long Island; basin 14 from Sandy Hook to Cape May.) (Source: U.S. Geol. Survey, 1972)

Table 6.9 Drainage Area and Mainstream Length of Major Rivers and Tributaries in the Northeastern United States[a]

Hydrologic Area	Major Rivers (Lakes) and Tributaries	Location	Length (mi)	Drainage Area (mi^2)
St. John River Basin	St. John River	Maine	215	8,320[b]
	Allagash		63	1,260
	Fish		63	892
	Aroostook		105	2,440[c]
Penobscot River Basin	Penobscot River	Maine	105	8,570
	West Branch Penobscot		97	2,100
	East Branch Penobscot		47	1,100
	Mattawamkeag		48	1,490
	Piscataquis		76	1,454
	Passadumkeag		43	385
	Kenduskeag		33	214
Kennebec River Basin	Kennebec River	Maine	145	5,870
	Moose		76	735
	Dead		23	878
	Carrabassett		35	400
	Sandy		69	593
	Sebasticook		48	950
Androscoggin River Basin	Androscoggin River	Maine, New Hampshire	161	3,450
	Magalloway		47	439
	Ellis		20	163
	Swift		25	125
	Little Androscoggin		46	352
Maine Coastal Basins	St. Croix River	Maine	77	1,635
	Atlantic Coastal Area			
	Machias		32	450
	Pleasant		43	332
	Union		39	497
Southern Maine, Coastal New Hampshire	Presumpscot River	Maine	24	648
	Saco River	Maine, New Hampshire	124	1,697
	Ossipee		18	455
	Little Ossipee		31	187
	Piscataqua River	Maine, New Hampshire	13	1,022
	Salmon Falls		21	330
	Lamprey		42	211
	Cocheo		34	182
Merrimack River Basin	Merrimack River	New Hampshire, Massachusetts	116	5,010
	Pemigewasset		64	1,021
	Winnipesaukee		23	486
	Contoocook		66	766
	Piscataquog		33	214
	Nashua		34	516
	Concord		16	395
Connecticut River Basin	Connecticut River	Vermont, New Hampshire, Massachusetts, Connecticut	280	11,265[d]
	Passumpsic		23	507
	Ammonoosuc		56	402
	White		58	712
	West		53	423
	Ashuelot		60	421
	Millers		45	392
	Deerfield		73	664
	Chicopee		17	721
	Westfield		57	517
	Farmington		47	602

Table 6.9 (Cont'd)

Hydrologic Area	Major Rivers (Lakes) and Tributaries	Location	Length (mi)	Drainage Area (mi^2)
Southeastern New England	Narragansett Bay	Massachusetts,		
	Taunton	Rhode Island	36	543
	Blackstone		49	540
	Pawtuxet		11	230
	Pawcatuck River	Rhode Island,	22	303
	Charles River	Connecticut	65	299
Thames and Housatonic River Basins	Thames River	Connecticut,	51	1,474
	Shetucket	Massachusetts,	20	1,263
	Quinebaug	Rhode Island	76	744
	Housatonic River	Connecticut,	131	1,950
	Naugatuck	Massachusetts,	41	311
	Tenmile	New York	15	210
	Shepaug		34	158
	Quinnipiac River		45	164
St. Lawrence River Basin	St. Lawrence River	New York	235	303,000
	Grass		110	676
	Raquette		158	1,256
	St. Regis		94	825
	Salmon		47	410
	Chateaugay		75	163
	Lake Champlain Basin	New York,	49	296
	Great Chazy	Vermont	49	296
	Saranac		89	614
	Little Ausable		26	68
	Ausable		20	518
	Bouquet		49	278
	Mettawee		45	437
	Poultney		39	261
	Otter Creek		105	941
	Winooski		90	1,065
	Lamoille		84	716
	Missisquoi		88	617
	Lake Memphremagog Basin			
	Clyde		36	142
	Black		33	135
Oswego River Basin	Oswego River	New York	23	150
	Oneida		18	1,504
	Seneca		62	3,468
Hudson River Basin	Hudson River	New York,	315	12,650
	Schroon	Vermont,	68	568
	Batten Kill	Massachusetts	59	441
	Hoosic		72	730
	Mohawk		155	3,462
	West Canada Creek		70	562
	East Canada Creek		37	291
	Kinderhook Creek		51	512
	Catskill Creek		42	417
	Esopus Creek		68	425
	Rondout Creek		61	411
	Wallkill River		90	786
	Wappinger Creek		34	208
New York Area, Westchester County, Long Island Coastal		New York City, Long Island		1,645[e]

Table 6.9 (Cont'd)

Hydrologic Area	Major Rivers (Lakes) and Tributaries	Location	Length (mi)	Drainage Area (mi^2)
Northeastern New Jersey	Hackensack River	New Jersey, New York	50	197
	Passaic River		86	935
	Elizabeth River		12	23
	Raritan River		81	1,125
Delaware River Basin	Delaware River	New York, New Jersey, Pennsylvania, Delaware	315	12,765
	East Br. Delaware		75	838
	West Br. Delaware		90	648
	Pequest		34	158
	Lehigh		80	1,364
	Musconetcong		45	158
	Assunpink Creek		17	89
	Rancocas Creek		75	335
	Schuylkill		93	1,909
	Brandywine Creek		32	329
	Paulins Kill		42	179
Coastal New Jersey	Swimming River		20	
	Shark River			
	Manasquan River		26	
	Metedeconk River			111
	Toms River		33	196
	Mullica River		45	15
	Great Egg Harbor River		52	
Susquehanna River Basin	Susquehanna River	New York, Pennsylvania, Maryland	444	27,500
	Chemung		44	2,520
	Lackawanna		40	346
	West Branch		228	6,913
	Juniata		86	3,426

[a]To convert miles to kilometers, multiply by 1.6; to convert square miles to square kilometers, multiply by 2.59.

[b]United States and Canadian drainage areas at the international border near Hamlin, Maine.

[c]United States drainage area at the international border near Fort Fairfield, Maine.

[d]Includes 295 km^2 (114 mi^2) of Canadian drainage.

[e]Total land area.

Source: Adapted from Saguinsin et al. (1981).

more than half of the annual runoff occurs in a 3-mo period, generally in late winter and early spring in the northern parts of the region and somewhat earlier in the southern parts. The months of lowest runoff generally are the same throughout the region, that is, June through October, with August and September having the lowest values (Saguinsin et al., 1981).

The average annual runoff for each of the states in the region is shown in Figs. 6.7-6.15. These figures indicate that the amount of runoff is fairly consistent throughout the region, averaging between 50 cm (20 in.) and 76 cm (30 in.) over most of the states. Areas having average annual runoff less than 50 cm (20 in.) occur mainly in western Vermont, northern New York, and central Pennsylvania. Areas with runoff values greater than 76 cm (30 in.) occur in the Adirondack and Catskill areas of New York and in the upland areas of central Maine and southern Vermont. Average annual runoff accounts for about 50-75% of total average annual precipitation for the majority of the region. Areas where this percentage is highest tend to be those with greater elevation and local relief, and those underlain by resistant bedrock.

6.4.3 Streamflow Characteristics of the Principal Rivers

During the 1981 water year, continuous discharge data were collected by USGS at almost 750 recording gaging stations located throughout the northeastern United States (U.S. Geol. Survey, 1982a-j). The three discharge measurements of primary concern for regional water resources evaluation are average flow, maximum flow (peak flow), and low flow. Other indices can be derived that provide additional diagnostic value for understanding regional surface-water hydrology. Unit yield, for example, is the amount of average annual discharge in cubic meters (cubic feet) per second per square kilometer (square mile) of drainage area. In addition, statistical summaries of recorded streamflow during the period of record for any USGS gaging station can be obtained. These summaries contain detailed information on the magnitude and frequency of both high (flood) and low flows, flow-duration characteristics, and other indices reflecting temporal variation in streamflow at the point of measurement. Although a discussion of such analyses is beyond the scope of this report, these summaries can be used as a source of more-detailed information for specific locations within the region.

The long-term average streamflow discharge in the northeast, including the contributing drainage area in Canada, is about 6,370 m^3/s (225,000 ft^3/s [cfs]) (U.S. Water Resources Council, 1978). Almost one-fourth of this amount is accounted for by the major rivers of Maine. Streamflow values vary considerably, depending on location and time of year, especially where there are fewer lakes and ponds to moderate the flow. In a dry year, flows in the region are generally lower than average by approximately 20% (U.S. Water Resources Council, 1978).

Table 6.10 summarizes basic streamflow data for the major rivers and tributaries in the northeastern region. The gaging stations were selected to be as close as possible to the basin outlet, but in most cases the station is somewhat upstream from the outlet. Because the drainage areas given correspond to those of the various gaging stations, they are usually somewhat less than the total basin area (see Table 6.9). Finally, because streamflow is not monitored on all of the larger streams and rivers, data are not available for all of the rivers listed in Table 6.9.

6.4.3.1 Average Annual Discharge

The average annual discharge of a stream is the average of daily average discharges, calculated on a yearly basis, and averaged over the total time of record or over a specified number of years. The average annual discharge in cubic feet per second is given for almost all gaging locations listed in Table 6.10. Where values have not been published, it is assumed that the values would have little significance because of artificial flow regulation by upstream reservoirs or other reasons.

Figures 6.7-6.15 illustrate the regional pattern of average annual discharge in the major rivers draining the individual states in the northeastern region. In these illustrations, the width of the river indicates the average annual discharge at any given point. Although the St. Lawrence River clearly carries the largest average discharge of the rivers of the region, only a small portion of this streamflow is generated within the region. Of those rivers conveying streamflow originating completely or predominantly within the region, the Susquehanna River has the largest average flow. The remaining larger rivers, in terms of average discharge, include the Connecticut, Hudson, Penobscot, Delaware, St. John, Merrimack, and Androscoggin rivers.

6.4.3.2 Low Flows

Low flows generally represent the minimum dependable supply of water available from surface-water sources in any area, unless supplemental upstream storage is provided by reservoirs or controlled natural lakes. Low-flow conditions usually occur annually as a result of seasonally low rainfall and increased evapotranspiration. Under these conditions, streamflow consists almost entirely of ground-water discharge to the surface drainage system. In the northeast, low-flow conditions normally occur from July through October each year, when average streamflow values range from 10% to 15% of the long-term average runoff during dry years (U.S. Army Corps of Engineers, 1972). On occasion, below-normal precipitation occurs for several successive years, which results in extreme low flows such as those that occurred during the 1960s (see Sec. 6.3).

Table 6.10 Summary Streamflow Data for Major Rivers and Tributaries of the Northeastern Region[a]

Hydrologic Area	Major Rivers and Tributaries	Gaging Location	Drainage Area (mi^2)	Average Discharge cfs	Average Discharge in./yr	Unit Yield (cfs/mi^2)	Extreme Flows[b] (cfs) Maximum	Extreme Flows[b] (cfs) Minimum
St. John River Basin	St. John River	at Fort Kent, Maine	5,690	9,682	23.11	1.70	151,000	510[c]
	Allagash	near Allagash, Maine	1,250	1,924	20.90	1.54	29,400	87
	Fish	near Fort Kent, Maine	871	1,402	21.86	1.61	15,800	34
	Aroostook	at Washburn, Maine	1,652	2,647		1.60	43,100	75[c]
	Meduxnekeag	near Houlton, Maine	175	297	23.05	1.70	6,640	3.6
Penobscot River Basin	Penobscot River	at West Enfield, Maine	6,671	11,889		1.78	153,000	1,630
	East Branch	at Grindstone, Maine	1,086	1,943		1.79	37,000	77[c]
	Piscataquis	at Medford, Maine	1,162	2,345		1.79	60,100	99
	Mattawamkeag	near Mattawamkeag, Maine	1,418	2,491	23.86	1.76	29,200	38
Kennebec River Basin	Kennebec River	at North Sidney, Maine	5,403				148,000	2,420[c]
	Dead	near Dead River, Maine	516	853	22.45	1.65	18,000	0
	Carrabassett	near North Anson, Maine	353	715	27.51	2.03	30,800	18
	Sebasticook	near Pittsfield, Maine	572	953		1.67	14,400	4.5[c]
Androscoggin River Basin	Androscoggin River	near Auburn, Maine	3,623	6,119		1.69	135,000	340[c]
	Ellis	at South Andover, Maine	130	249	26.01	1.92	5,630	12
	Nezinscot	at Turner Center, Maine	169	303	24.35	1.79	13,900	5.6
	Little Androscoggin	near Auburn, Maine	328	567		1.73	16,500	14[c]
St. Croix River Basin	St. Croix River	at Baring, Maine	1,370	2,732		1.99	23,500	262[c]
Maine Coastal Basins	Dennys River	at Dennysville, Maine	92.4	195	28.66	2.11	3,930	8.4
	Narraguagus River	at Cherryville, Maine	232	500	29.27	2.16	10,400	3.0
	Sheepscot River	at North Whitefield, Maine	148	246	22.57	1.66	6,420	5.0
	Royal River	at Yarmouth, Maine	141	273	26.29	1.94	11,500	2.3
Southern Maine, Coastal New Hampshire	Presumpscot River	near West Falmouth, Maine	598	974		1.63	12,500	39[c]
	Saco River	at Cornish, Maine	1,293	2,700		4.52	45,000	244[c]
	Ossipee	at Cornish, Maine	452	874		2.09	17,200	65[c]
	Piscataqua River							
	Salmon Falls	at Milton, N.H.	108	197		1.82	3,500	19[c]
	Lamprey	near Newmarket, N.H.	183	278		1.52	5,490	1.0[c]
Merrimack River Basin	Merrimack River	at Lowell, Maine	4,635	7,452		1.61	173,000	199[c]
	Pemigewasset	at Plymouth, N.H.	622	1,357		2.18	65,400	39
	Winnipesaukee	at Tilton, N.H.	471	696		1.48	3,810	48[c]
	Contoocook	at West Hopkinton, N.H.	427	688		1.61	6,620	15[c]
	Nashua	at East Pepperell, Maine	433	558		1.29	20,900	1.1[c]
	Concord	at Lowell, Maine	405	620		1.53	5,410	4.0[c]

Table 6.10 (Cont'd)

Hydrologic Area	Major Rivers and Tributaries	Gaging Location	Drainage Area (mi^2)	Average Discharge cfs	Average Discharge in./yr	Unit Yield (cfs/mi^2)	Extreme Flows[b] (cfs) Maximum	Extreme Flows[b] (cfs) Minimum
Connecticut River Basin	Connecticut River	near Middletown, Conn.	10,882				267,000	
	Passumpsic	at Passumpsic, Vt.	436	735	22.89	1.69	18,200	13[c]
	Ompompanoosuc	at Union Village, Vt.	130	193	20.16	1.48	4,800	1.7
	White	at West Hartford, Vt.	690	1,181	23.24	1.71	120,000	35
	Mascoma	at Mascoma, N.H.	153	215		1.41	5,840	2.0[c]
	Ottauquechee	at North Hartland, Vt.	221	396	24.33	1.79	24,400	2.9
	Sugar	at West Claremont, N.H.	269	402		1.49	14,000	14[c]
	West	at Newfane, Vt.	308	627		2.04	52,300	7.6
	Ashuelot	at Hinsdale, N.H.	420	666		1.59	16,600	10
	Millers	at Erving, Maine	375	625		1.67	29,000	8[c]
	Deerfield	at West Deerfield, Maine	558	1,283		2.30	48,500	28[c]
	Ware	at Gibbs Crossing, Maine	199	288		1.45	22,700	5
	Chicopee	at Indian Orchard, Maine	688	897		1.30	45,200	16[c]
	Westfield	near Westfield, Maine	497	917		1.85	70,300	9
	Farmington	at Rainbow, Conn.	589	1,087	25.32	1.85	69,200	5.1[c]
Southeastern New England	Parker River	at Byfield, Mass.	21.6	35.6	22.38	1.65	489	0.09[c]
	Ipswich River	near Ipswich, Mass.	124	184		1.48	2,680	0.34
	Charles River	at Waltham, Mass.	227	294		1.30	4,150	0.2[c]
	Threemile River	at North Dighton, Mass.	83.8	169		2.02	2,490	5.1
	Blackstone River	at Woonsocket, Mass.	416	753		1.81	32,900	21[c]
	Woonasquatucket River	at Centerdale, R.I.	38.3	71.4		1.86	1,440	2.1[c]
	Pawtuxet River	at Cranston, R.I.	200	339		1.70	4,000	22[c]
	Pawcatuck River	at Westerly, R.I.	295	566	26.06	1.92	4,470	25[c]
	Thames River							
	Willimantic	near Coventry, Conn.	122	211	23.48	1.73	24,200	2.0
	Shetucket	near Willimantic, Conn.	402	706	23.86	1.76	52,200	19[c]
	Quinebaug	at Jewett City, Conn.	715	1,265	24.04	1.77	40,700	16
	Quinnipiac River	at Wallingford, Conn.	110	210	25.92	1.91	5,580	8
	Housatonic River	at Stevenson, Conn.	1,541	2,603	22.94	1.69	75,800	
	Tenmile	near Gaylordsville, Conn.	203	302	20.20	1.49	17,400	5
	Naugatuck	at Beacon Falls, Conn.	259	493	25.85	1.90	106,000	24
St. Lawrence River Basin	St. Lawrence River	near Massena, N.Y.	298,800	242,800		0.81	352,000[d]	139,000[c]
	Oneida	at Caughdenoy, N.Y.	1,382	2,559		1.85	13,800[d]	52[c]
	Black	at Watertown, N.Y.	1,876	4,010		2.14	39,600	10
	Oswegatchie	near Heuvelton, N.Y.	973	1,720		1.77	19,600	130
	Raquette	at Raymondville, N.Y.	1,131	2,043		1.81	13,000	2.2
	St. Regis	at Brasher Center, N.Y.	616	1,044	23.02	1.69	16,800	34
	Lake Champlain	at Rouses Point, N.Y.	8,277					
	Saranac	at Plattsburgh, N.Y.	608	833		1.37	11,500	3.6[c]
	Poultney	below Fair Haven, Vt.	187	249	18.08	1.33	14,800	2.1[c]
	Otter Creek	at Middlebury, Vt.	628	983	21.26	1.57	11,000	92[c]
	Winooski	near Essex Junction, Vt.	1,044	1,697		1.63	45,300	24[c]
	Lamoille	at East Georgia, Vt.	686	1,234	24.43	1.80	23,200	74[c]
	Missisquoi	near East Berkshire, Vt.	479	923	26.17	1.93	17,200	8

Table 6.10 (Cont'd)

Hydrologic Area	Major Rivers and Tributaries	Gaging Location	Drainage Area (mi^2)	Average Discharge cfs	Average Discharge in./yr	Unit Yield (cfs/mi^2)	Extreme Flows[b] (cfs) Maximum	Extreme Flows[b] (cfs) Minimum
Hudson River Basin	Hudson River	at Green Island, N.Y.	8,090	13,700		1.69	181,000	882[c]
	Sacandaga	near Hadley, N.Y.	1,055	2,138		2.03	35,500	5.3
	Batten Kill	at Arlington, Vt.	152	339	30.29	2.23	11,100	37
	Hoosic	near Eagle Bridge, N.Y.	510	942	25.08	1.85	55,400	24
	Mohawk	at Cohoes, N.Y.	3,456	5,701		1.65	143,000	6
	Esopus Creek	at Mount Marion, N.Y.	419	555		1.32	28,000	9.7
	Wallkill	at Gardiner, N.Y.	711	1,051	20.07	1.48	30,800	9.5
Northeastern and Coastal New Jersey	Hackensack River	at New Milford, N.J.	113	103		0.91	4,500	0
	Passaic River	at Little Falls, N.J.	762	1,160		1.52	31,700	0
	Raritan River	at Bound Brook, N.J.	785	1,274		1.62	46,100	37[c]
	Swimming River	near Red Bank, N.J.	48.5	80.6	22.57	1.66	8,910	0
	Manasquan River	at Squankum, N.J.	43.4	75.4	23.60	1.74	2,940	12.9
	Toms River	near Toms River, N.J.	124	216		1.74	2,000	46
	Great Egg Harbor River	at Folsom, N.J.	56.3	86.5	20.87	1.54	1,440	15
Delaware River Basin	Delaware River	at Trenton, N.J.	6,780	11,692		1.72	329,000	1,180
	East Branch	at Fishs Eddy, N.Y.	783				53,300	52
	West Branch	at Hale Eddy, N.Y.	593				28,900	17
	Neversink	at Godeffray, N.Y.	302				33,000	
	Lackawaxen	at Hawley, Penn.	290	483	22.62	1.67	51,900	8[c]
	Brodhead Creek	at Minisink Hills, Penn.	259	561	29.41	2.17	68,800	29
	Lehigh	at Glendon, Penn.	1,359	2,930	29.26	2.16	60,600	210[c]
	Schuylkill	at Philadelphia, Penn.	1,893	2,936	21.06	1.55	103,000	0
	Pequest	at Pequest, N.J.	108	153	19.23	1.42	2,130	12
	Musconetcong	near Bloomsburg, N.J.	143	233		1.63	7,200	8.1
Susquehanna River Basin	Susquehanna River	at Marietta, Penn.	25,990	36,920	19.29	1.42	1,080,000	618
	Chenango	near Chenango Forks, N.Y.	1,483	2,421		1.63	96,000	84
	Chemung	at Chemung, N.Y.	2,506	2,533	13.73	1.01	189,000	49
	Lackawanna	at Old Forge, Penn.	332	497	20.33	1.50	31,000	20
	West Branch	at Lewisburg, Penn.	6,847	10,820	21.46	1.58	300,000	390
	Juniata	at Newport, Penn.	3,354	4,302	17.42	1.28	190,000	207[c]
	Swatara Creek	near Hershey, Penn.	483	842	26.67	1.74	29,400	58
	Conestoga	at Lancaster, Penn.	324	399	16.72	1.23	88,300	7[c]

[a]To convert square miles to square kilometers, multiply by 2.59; to convert cubic feet per second to cubic meters per second, multiply by 0.0283; to convert inches per year to centimeters per year, multiply by 2.54; and to convert cubic feet per second per square mile to cubic meters per second per square kilometer, multiply by 0.0108.

[b]Instantaneous values (discharge at a particular instant of time) unless noted otherwise.

[c]Minimum daily flow.

[d]Maximum daily flow.

Source: Based on U.S. Geol. Survey (1982a-j).

Instantaneous and daily low flows at gaging locations generally occur in late summer or early fall and often are the result of upstream flow regulation. Short-duration low flows for several stream locations in the northeastern region are presented in Table 6.11. Observed minimum flows during the period of record for other streams are given in Table 6.11. Given the large number of flow-control structures in the region, original data sources should be consulted to determine the specific effects of flow regulation.

Extreme low-flow conditions are represented by the minimum average discharge for seven consecutive days, with an average recurrence interval of 50 yr. Discharge values for these conditions are shown in Table 6.12 for several streams in the region.

6.4.3.3 Flood Potential

Flooding generally occurs more or less annually throughout the region as a result of heavy rainfall, hurricanes, and coastal storms. Although floods can occur at any time during the year, they are least likely during winter months. The severity of floods resulting from heavy rainfall is enhanced during the spring when such events occur simultaneously with the rapid melting of accumulated snowfall. Local flood effects are sometimes worsened by the formation of ice jams. Floods occur relatively often on smaller streams in the region, but the effects of flooding tend to be diminished in larger basins because of the dampening effects of natural and artificial storage in lakes, ponds, and reservoirs. However, flood damage has been severe in many of the larger watersheds of the region (U.S. Army Corps of Engineers, 1972).

Data for extreme floods that have occurred at several locations throughout the northeast are presented in Table 6.13, and values for the maximum discharge observed during the period of record for gaging stations on the larger rivers and tributaries are given in Table 6.10. These data indicate that streamflows during historical floods were many times greater than those occurring during average conditions. Crippen and Bue (1977) estimated that floods may occur that are two or three times greater than those known for most streams. Table 6.14 contains the peak discharge values for the 2-, 10-, 20-, 50-, and 100-yr floods for a number of gaging stations in the region. Analogous data can be obtained from USGS for any gaging station in the region with a sufficient period of record to warrant such analysis.

To compare the flood magnitudes of one drainage basin directly with those of another basin, the drainage basins must be of the same size and the floods of the same frequency of occurrence. Figures 6.21 and 6.22 illustrate the expected flood discharge from a typical 780-km^2 (300-mi^2) drainage basin during an average annual flood and 10-yr flood, respectively. The average annual flood is one that will be exceeded in approximately every other year,

Table 6.11 Observed Extreme Low Flows at Selected Locations in the Northeastern United States[a]

Station	Drainage Area (mi^2)	Observed Low Flow (cfs)	Date
Allagash River near Allagash, Maine	1,250	87	9/11/60
St. John River below Fish River near Fort Kent, Maine	5,690	570[b]	4/13-15/48
Mattawamkeg River near Mattawamkeg, Maine	1,418	38	9/19/52
Kennebec River at The Forks, Maine	1,589	85	9/3/53
Androscoggin River near Auburn, Maine	3,257	340[b]	9/28/41
Saco River near Conway, N.H.	386	40	3/16/32
Merrimack River at Franklin Junction, N.H.	1,507	169	8/28/65
Merrimack River below Concord River at Lowell, Mass.	4,425	199[b]	9/23/23
Connecticut River at White River Junction, Vt.	4,092	82[b]	8/8/05
Connecticut River at Thompsonville, Conn.	9,661	968	10/20/63
Gross River at Pyrites, N.Y.	335	59	8/29/34
Walkill River at Pellets Island Mountain, N.Y.	385	3.2	7/66
Mohawk River at Cohoes, N.Y.	3,486	6	9/28/41
West Branch of Delaware River at Hale Eddy, N.Y.	593	17	10/20/03
Delaware River at Port Jervis, N.Y.	3,076	175	9/23/08
Delaware River at Trenton, N.J.	6,780	1,180	10/31/63
Schuylkill River at Philadelphia, Penn.	1,893	0.6[b]	9/2/66[c]
Susquehanna River at Wilkes-Barre, Penn.	9,960	538	9/27/64
Chenango River at Chenango Forks, N.Y.	1,492	84	9/19 and 25/39
West Branch of Susquehanna River at Williamsport, Penn.	5,682	162	9/17/43
Susquehanna River at Harrisburg, Penn.	24,100	1,600	11/29/30

[a]To convert square miles to square kilometers, multiply by 2.59; to convert cubic feet per second to cubic meters per second, multiply by 0.02832.

[b]Average daily flow.

[c]Below diversion point for Philadelphia municipal water supply. Average flow was 266 cfs in water years 1961-1965.

Source: Based on U.S. Army Corps of Engineers (1972).

Table 6.12 Seven-Day, Fifty-Year Low Flows for Selected Locations in the Northeastern United States[a]

Station	Drainage Area (mi^2)	Discharge (cfs)
Nashua River at East Pepperell, Mass.	316	66
Merrimack River at Lowell, Mass.	4,425	885
White River at West Hartford, Vt.	690	78
Connecticut River at White River Junction, Vt.	4,092	730
Chicopee River near Indian Orchard, Mass.	688	102
Connecticut River at Thompsonville, Conn.	9,661	2,050
Grass River at Pyrites, N.Y.	335	62
Walkill River at Pellets Island Mountain, N.Y.	385	12
Delaware River at Trenton, N.J.	6,780	1,270
Schuylkill River at Pottstown, Penn.	1,147	190
Brandywine Creek at Chadds Ford, Penn.	287	46
West Branch of Susquehanna River at Renovo, Penn.	2,975	185
West Branch of Susquehanna River at Williamsport, Penn.	5,682	330
Susquehanna River at Wilkes-Barre, Penn.	9,960	580
Juniata River at Newport, Penn.	3,354	200
Susquehanna River at Harrisburg, Penn.	24,100	1,700

[a]To convert square miles to square kilomters, multiply by 2.59; to convert cubic feet per second to cubic meters per second, multiply by 0.02832.

Source: Based on U.S. Army Corps of Engineers (1972).

whereas the 10-yr flood will be exceeded at irregular intervals that average 10 yr. In other words, there is a 50% probability of an average annual flood and a 10% probability of a 10-yr flood in any given year. As these figures illustrate, the flood potential for a typical 780-km^2 (300-mi^2) watershed in the northeastern region ranges from less than 141 m^3/s (5000 cfs) to somewhat more than 226 m^3/s (8000 cfs) for the average annual flood and from 283 m^3/s (10,000 cfs) to 566 m^3/s (20,000 cfs) for the 10-yr flood.

The historical record of floods at gaging stations in each of the nine states within the region has been analyzed, and equations have been derived for estimating the magnitude and frequency of floods at ungaged locations. Most approaches used in these investigations have involved dividing a given state into areas of similar hydrologic characteristics and computing multiple regression equations for each area for estimating peak discharge of specified recurrence intervals from independent variables. These variables measure some combination of drainage basin characteristics, precipitation, or other

Table 6.13 Extreme Floods Observed through September 1974 at Selected Locations throughout the Northeastern United States[a]

Location	Drainage Area (mi^2)	Date	Peak Discharge (cfs)
Maine			
St. John River at Dickey	2,700	5-1-74	87,200
St. John River at Fort Kent	5,690	5-1-74	148,000
Piscataquis River near Dover-Foxcroft	297	11-4-66	22,800
Pleasant River near Milo	324	11-4-66	28,600
Piscataquis River at Medford	1,161	11-4-66	60,100
Penobscot River at West Enfield	6,670	5-1-23	153,000
Carrabassett River near North Anson	354	3-19-36	30,800
Sandy River near Mercer	514	3-19-36	38,600
Wild River at Gilead	69.5	10-24-59	18,100
Swift River near Roxbury	95.8	10-24-59	16,800
Androscoggin River near Auburn	3,257	3-20-36	135,000
Saco River at Cornish	1,298	3-22-36	45,000
New Hampshire			
Saco River near Conway	386	3-27-53	43,900
Pemigewasset River at Woodstock	193	10-24-59	47,000
Baker River near Rumney	143	11-3-27	25,900
Pemigewasset River at Plymouth	622	3-19-36	65,400
Merrimack River at Franklin Junction	1,507	3-19-36	83,000
Contoocook River at Penacook	766	3-20-36	46,800
Merrimack River below Manchester	3,092	3-20-36	150,000
Connecticut River near Dalton	1,514	3-20-36	48,300
Ammonoosuc River at Bethlehem Junction	87.6	10-24-59	10,800
Ashuelot River at Hinsdale	420	3-19-36	16,600
Vermont			
White River at West Hartford	690	11-4-27	120,000
Ottauquechee River at North Hartland	221	11-27	30,400
West River at Jamaica	179	12-31-48	29,500
West River at Newfane	308	9-21-38	52,300
Connecticut River at Vernon	6266	3-19-36	176,000
North Branch Winnoski River at Wrightsville	69.2	11-3-27	17,200
Winooski River at Montpelier	397	11-3-27	57,000
Mad River near Moretown	139	11-3-27	23,000
Winooski River near Essex Junction	1044	11-4-27	113,000
Lamoille River at Cadys Falls	268	11-27	36,600
Missisquoi River near Richford	479	11-27	45,000
Rock River at Williamsville	42.6	9-21-38	27,200
Middle Branch Williams River above Cheste	27.4	9-21-38	12,200
West River near South Londonderry	89.3	9-21-38	25,200
Whetstone Brook at East Jamaica	36.2	9-21-38	15,500

Table 6.13 (Cont'd)

Location	Drainage Area (mi^2)	Date	Peak Discharge (cfs)
Vermont (Cont'd)			
Lamoille River at Fairfax Falls	559	11-4-27	66,900
West River at West Dummerston	410	9-21-38	65,000
Massachusetts			
Concord River at Lowell	405	3-22-68	4,800
Merrimack River at Lowell	4,635	3-20-36	173,000
Ipswich River near Ipswich	124	3-21-68	2,680
Neponset River at Norwood	35.2	8-19-55	1,490
East Branch Neponset River at Canton	27.2	8-19-55	1,790
Old Swamp River near South Weymouth	4.29	3-18-68	566
Taunton River at State Farm	260	3-20-68	4,980
Wading River near Norton	42.4	3-19-68	1,460
Blackstone River at Northbridge	139	8-20-55	16,900
Little River at Buffumville	27.7	8-19-55	8,340
Deerfield River at Charlemont	362	9-21-38	56,300
Connecticut River at Montague City	7,865	3-19-36	236,000
Westfield River at Knightville	162	9-21-38	37,900
Middle Branch Westfield River at Goss Heights	52.6	9-21-38	19,900
West Branch Farmington River near New Boston	92.0	8-19-55	34,300
North Branch Hoosic River at North Adams	39.0	11-27	9,980
Powdermilk Brook near Westfield	2.50	8-19-55	5,740
Rhode Island			
Adamsville Brook at Adamsville	7.91	12-27-69	316
Branch River at Forestdale	91.2	3-19-36	5,800
Blackstone River at Woonsocket	416	8-19-55	32,900
Woonasquatucket River at Centerdale	38.3	3-18-68	1,440
South Branch Pawtuxet River at Washington	63.8	3-18-68	1,860
Pawcatuck River at Westerly	295	11-27	7,000
Connecticut			
Connecticut River at Thompsonville	9,661	3-20-36	282,000
Mad River at Winsted	18.4	8-19-55	10,200
Valley Brook near West Hartland	7.20	8-19-55	5,400
Farmington River at Collinsville	360	8-19-55	140,000
Burlington Brook near Burlington	4.12	8-19-55	1,690
Salmon Brook near Granby	66.8	8-19-55	40,000
Naugatuck River at Thomaston	101	8-19-55	53,400
Naugatuck River at Beacon Falls	261	8-19-55	106,000

Table 6.13 (Cont'd)

Location	Drainage Area (mi^2)	Date	Peak Discharge (cfs)
New York			
Hoosic River near Eagle Bridge	510	12-31-48	55,400
Scoharie Creek at Prattsville	236	10-16-55	55,200
Esopus Creek at Coldbrook	192	3-30-51	59,600
Beaver Kill at Cooks Falls	241	3-31-51	31,600
East Branch Delaware River at Fishs Eddy	783	10-9-03	70,000
Delaware River at Port Jervis	3,076	8-19-55	233,000
Neversink River near Claryville	65.6	11-25-50	23,400
Tioughnioga River at Itasca	730	7-8-35	61,100
Chenango River near Chenango Forks	1,483	7-8-35	96,000
Tioga River at Lindley	771	6-23-72	128,000
Karr Valley Creek at Almond	27.6	6-23-72	10,900
Canacadea Creek near Hornell	57.9	7-8-35	21,000
Chemung River at Chemung	2,506	6-23-72	189,000
Great Valley Creek near Salamanca	137	9-28-67	28,600
Genesee River at Scio	308	6-23-72	41,000
East Branch Ausable River at Au Sable Forks	198	9-22-38	20,100
Taughannock Creek near Halseyville	56.7	7-35	42,100
Glen Creek at Watkins Glen	21.3	7-35	27,900
New Jersey			
Cakepoulin Creek at Lansdowne	13.7	8-18-55	7,230
Raritan River at Manville	490	9-22-38	36,100
Maurice River at Norma	113	9-2-40	7,360
Delaware River at Montague	3,480	8-19-55	250,000
Delaware River at Riegelsville	6,328	8-19-55	340,000
Delaware River at Trenton	6,780	8-20-55	329,000
Mantua Creek at Pitman	6.75	9-1-40	4,200
Salem River at Woodstown	14.6	9-1-40	22,000
Pennsylvania			
Lackawaxen River at Hawley	290	8-19-55	51,900
Brodhead Creek at Minisink Hills	259	8-19-55	68,800
Pickering Creek near Chester Springs	5.98	6-22-72	2,410
Lehigh River at Stoddartsville	91.7	8-19-55	31,900
Brandywine Creek at Chadds Ford	287	6-22-72	23,800
Susquehanna River at Wilkes-Barre	9,960	6-24-72	345,000
First Fork Sinnemahoning Creek	245	7-18-42	80,000
West Branch Susquehanna River at Renovo	2,975	3-18-36	236,000
Juniata River at Newport	3,354	6-1-89	209,000
Bixler Run near Loysville	15.0	11-1-56	8,780
Swatara Creek at Harper Tavern	337	6-1-89	88,000
Kiskiminetas River at Avonmore	1,723	3-18-36	185,000
Kiskiminetas River at Vandergrift	1,825	3-18-36	185,000

Table 6.13 (Cont'd)

Location	Drainage Area (mi^2)	Date	Peak Discharge (cfs)
Pennsylvania (Cont'd)			
Brodhead Creek at Analomink	124	8-18-55	72,200
Lillibridge Creek near Port Allegany	6.73	7-18-42	16,000
Allegheny River at Port Allegany	249	7-18-42	77,000
Wallenpaupack Creek at South Sterling	14.3	8-19-55	22,200
Freeman Run above Austin	14.6	7-18-42	19,000
Castile Run at Riggle Farm	4.25	6-45-41	10,000
Annin Creek near Turtlepoint	11.4	7-18-42	24,000
Mill Creek at Erie	12.9	8-3-15	13,000

[a]To convert square miles to square kilometers, multiply by 2.59; to convert from cubic feet per second to cubic meters per second, multiply by 0.02832.

Source: Based on Crippen and Bue (1977).

conditions known to affect flood magnitude. Equations and methods of this type have been developed for Maine by Morrill (1975), for Vermont by Johnson and Tasker (1974a), for New Hampshire by LeBlanc (1978), for Massachusetts by Knox and Johnson (1965) and Johnson and Tasker (1974b), for central New England (New Hampshire, Vermont, Massachusetts, and Rhode Island) by Johnson (1970), for Connecticut by Weiss (1975), for New York by Robinson (1961) and Zembrzuski and Dunn (1979), for New Jersey by Stankowski (1974), and for Pennsylvania by Flippo (1977) and Aron et al. (1981). The majority of these publications contain observed flood data, magnitude and frequency relationships for the gaging stations used in the particular investigation, and a means of estimating the peak flow expected to occur during 2-, 5-, 10-, 25-, 50-, and 100-yr floods at ungaged sites within the study area. These publications should be consulted for the particular equations, the conditions for which they are applicable, and the error associated with each.

6.4.4 Surface-Water Quality

As a first approximation, values for total dissolved solids (TDS) provide a measure of the total amount of ions in solution. Total dissolved solids and total hardness (TH) are usually positively correlated, with TH being lower than TDS because it refers only to calcium carbonate and magnesium constituents. A useful correlation exists between TDS and electrical conductivity, where conductivity is proportional to the concentration of ions in solution. Electrical conductivity, which is determined by specific

Table 6.14 Flood Magnitude and Frequency Data for Selected Locations in the Northeastern United States Having Twenty or More Years of Record[a]

Location	Drainage Area (mi^2)	Peak Discharge of Indicated Recurrence Interval in Years (10^3 cfs)				
		100	50	20	10	2
Penobscot River at Veazie Dam, Maine	7,700	142	128	109	96	63
Kennebec River at Augusta, Maine	5,470	185	157	123	101	59
Androscoggin River near Auburn, Maine	3,257	120	100	75	62	39
Merrimack River at Lawrence, Mass.	4,461	136	115	95	81	53
Connecticut River at South Newbury, Vt.	2,825	79	70	58	50	34
Connecticut River at Middletown, Conn.	10,870	235	210	178	153	101
Housatonic River at Gaylordsville, Conn.	994	45	36	26	20	11
Blackstone River at Woonsocket, R.I.	416	24	19	14	10	5
Raquette River at Piercefield, N.Y.	722	8	8	7	7	5
Saranac River at Plattsburgh, N.Y.	608	12	10	9	8	5
Hudson River at Hadley, N.Y.	1,664	44	40	34	30	20
Mohawk River at Schenectady, N.Y.	3,306	129	112	94	82	60
Raritan River at Bound Brook, N.J.	779	48	43	36	32	20
Lehigh River at Bethlehem, Penn. Bethlehem, Penn.	1,279	102	70	58	51	23
Del. River at Trenton, N.J.	6,780	290	260	220	180	110
Schuylkill River at Pottstown, Penn.	1,147	61	54	42	36	20
West Branch of Susquehanna River at Williamsport, Penn.	5,682	278	242	200	169	95
Susquehanna River at Danville, Penn.	11,220	270	250	215	190	130
Susquehanna River at Harrisburg, Penn.	24,100	640	560	480	420	272

[a]To convert square miles to square kilometers, multiply by 2.59; to convert cubic feet per second to cubic meters per second, multiply by 0.02832.

Source: Based on U.S. Army Corps of Engineers (1972).

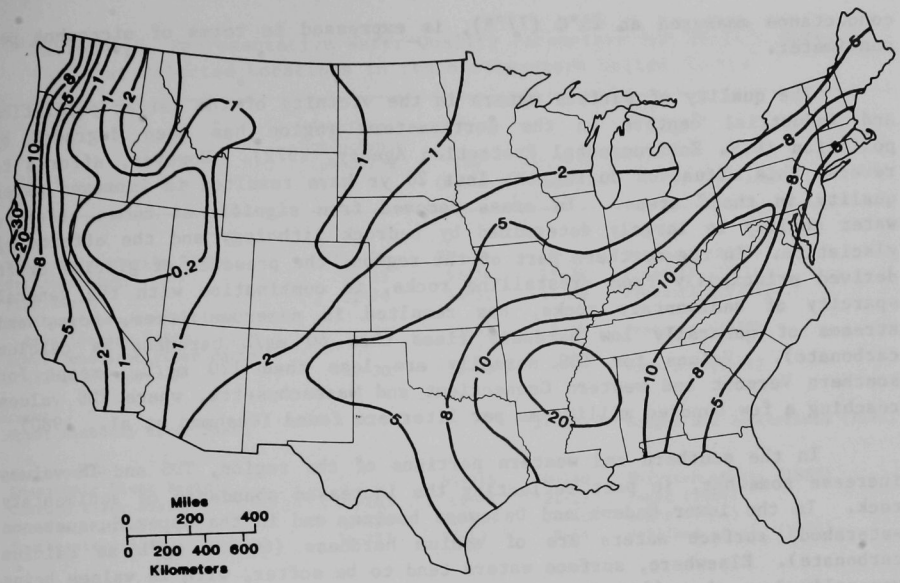


Fig. 6.21 Average Annual Flood Potential (thousand cfs) (Source: Adapted from U.S. Dept. of the Interior, 1970)

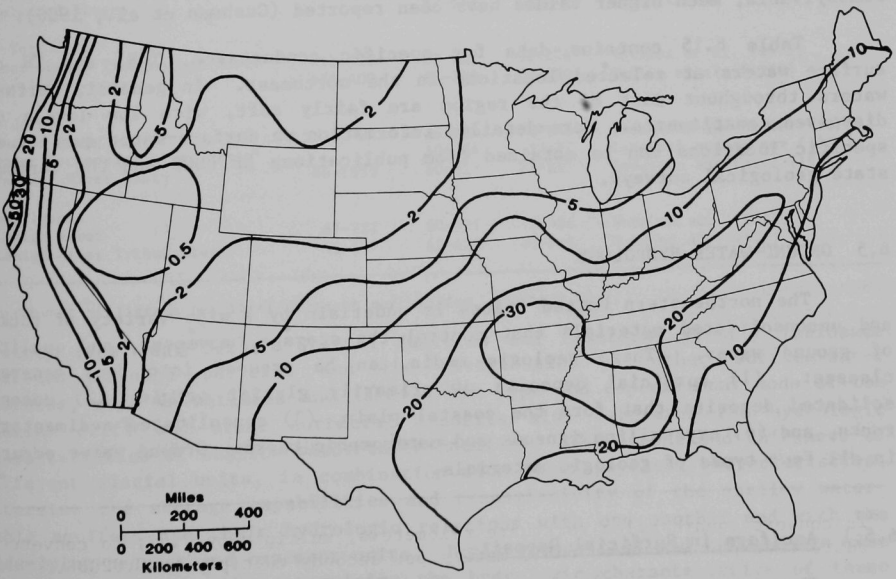


Fig. 6.22 Ten-Year Flood Potential (thousand cfs) (Source: Adapted from U.S. Dept. of the Interior, 1970)

conductance measured at 25°C (77°F), is expressed in terms of micromhos per centimeter.

The quality of surface waters in the vicinity of the larger population and industrial centers in the northeastern region has been degraded by pollution (U.S. Environmental Protection Agency, 1972). However, efforts to reverse this situation during the last 20 yr have resulted in improved water quality in these areas. In areas removed from significant human effects, water quality is largely determined by bedrock lithology and the effects of glaciation. In the northern part of the region, the presence of glacial drift derived principally from crystalline rocks, in combination with the general sparcity of sedimentary rocks, has resulted in numerous lakes, bogs, and streams of generally low hardness (less than 60 mg/L hardness as calcium carbonate). Values for TDS normally are less than 120 mg/L, except for southern Vermont and western Connecticut and Massachusetts, where TDS values reaching a few hundred milligrams per liter are found (Cushman et al., 1980).

In the southern and western portions of the region, TDS and TH values increase somewhat, in part reflecting the increased abundance of sedimentary rock. In the lower Hudson and Delaware basins, and in the upper Susquehanna watershed, surface waters are of medium hardness (60-120 mg/L as calcium carbonate). Elsewhere, surface waters tend to be softer, with TH values being generally less than 60 mg/L. Within the Mohawk-Hudson system and in eastern Pennsylvania and northern New Jersey, TDS levels for surface waters may reach a few hundred milligrams per liter. Locally, particularly in eastern Pennsylvania, much higher values have been reported (Cushman et al., 1980).

Table 6.15 contains data for specific conductance, TDS, and TH of surface waters at selected locations in the northeast. In general, surface waters throughout most of the region are fairly soft, with low levels of dissolved constituents. More-detailed information on surface-water quality at specific locations can be obtained from publications of USGS and the various state geological surveys.

6.5 GROUND-WATER HYDROLOGY

The northeastern United States is underlain by a wide variety of rocks and unconsolidated materials that control the storage, movement, and quality of ground water. These geologic media can be grouped into four general classes: (1) surficial deposits of primarily glacial origin, (2) unconsolidated deposits that form the coastal plain, (3) consolidated sedimentary rocks, and (4) crystalline igneous and metamorphic rocks. Ground water occurs in all four types of geologic materials.

6.5.1 Aquifers in Surficial Deposits

The surficial geology of the northeastern United States, which has important hydrologic implications, is largely determined by its glacial

Table 6.15 Representative Water-Quality Parameters for Surface Water at Selected Locations in the Northeastern United States[a]

Location	Specific Conductance (μmhos/cm at 25°C)	TDS (mg/L)	Hardness (mg/L)	Source
Maine				
Lower Androscoggin River	34-121	21-101	10-34	Prescott (1967)
St. John River	62-83	52-54	25-38	Prescott (1971a)
Fish River	41-74	44-51	17-35	Prescott (1971a)
Windham-Freeport-Portland Area (Sebago Lake)	31	23-32	9-14	Prescott (1976b)
Lower Penobscot River Basin (Floods Pond)	27-30	20-22	8-12	Prescott (1964)
Vermont				
Upper Winooski River Basin			24-252	Hodges and Butterfield (1977)
Massachusetts				
Housatonic River Basin		85-215	60-140	Norvitch et al. (1968)
Concord River Basin	93-165	63-96	21-27	Baker (1964)
Merrimack River	83-190	61-133	21-40	Baker (1964)
Southeastern Area	56-227	38-135	8-64	Williams et al. (1980)
Rhode Island				
Lower Pawcatuck River Basin	42-93	18-68	8-18	Gonthier et al. (1974)
Pawcatuck River		42-47	11-16	Bierschenk (1956)
Chipuxet River		36-63	13-30	Bierschenk (1956)
Bristol Area		87	50	Bierschenk (1954)
Selected Rivers		21-644	8-119	Allen (1953)
New York				
West Branch Tioughnioga River	211-420	82-227	61-206	Shindel et al. (1977)
Cortland County	170-400	85-210	70-130	Buller et al. (1978)
New Jersey				
Ramapo River		36-300	18-246	Vecchioli and Miller (1973)
Upper Hackensack River Basin		104-84	37-77	Carswell and Rooney (1976)
Passaic River Basin	86-1850	60-823	21-217	Anderson and Faust (1973)
Pennsylvania				
Lehigh River	67-221	60-131	22-86	Wood et al. (1972)
Lehigh River Tributaries	52-677	42-429	20-282	Wood et al. (1972)

[a]To convert milligrams per liter to parts per million, multiply by 1.

history (see Sec. 5.2). Glacial features and landforms greatly influence surface drainage patterns and the distribution of other surface-water features, such as wetlands and lakes. The type and depositional mode of the glacial drift and other surficial deposits also determine the hydrologic characteristics of shallow water-table aquifers. The extent and thickness of different glacial units, in combination with other physical characteristics, determine the storage capabilities and transmissivity of the shallow water-table aquifers and their hydrologic relations with one another and with the underlying bedrock and basement units. Drift composition and texture are also of great importance in determining the hydrologic characteristics of these deposits. These attributes are related to the genesis of the various glacial deposits and landforms, and reflect the bedrock over which the ice moved.

End moraines result from an approximate equilibrium between forward motion and melt-back at the ice terminus, and tend to have sorted ice-contact deposits incorporated within or associated with them. Because ground moraines generally have a lower degree of sorting and higher clay content than end moraines, they tend also to have lower permeability. Ground moraines are also more compact because of the weight of stagnant ice. Ice-contact and outwash deposits typically have been sorted into stratified drift by associated fluvial action. Having varying three-dimensional geometries, individual beds may consist of silt, sand, and gravel in varying proportions. Sorted materials almost always have higher hydraulic conductivities than unsorted and unstratified drift deposits.

The thickness and areal extent of glacial deposits are important characteristics influencing hydrologic parameters. Thickness and areal extent determine the total water storage of a unit and thereby its potential water productivity. In regional flow systems, the thickness of the surficial unit, along with other features (e.g., location of bedrock outcrops, hydraulic head in surficial deposits, regional slope, and topographic relief), determines whether only local flow systems are generated in the water-table aquifers and the extent of interaction between unconsolidated and bedrock aquifers. With low-permeability drift, thickness determines the degree of separation between deeper bedrock aquifers and surface waters.

To assess the transmissivity and storage properties of a ground-water system, it is necessary to identify "interior" properties, such as porosity and hydraulic conductivity, and "exterior properties," such as the thickness of the hydrologic unit, its lateral extent as defined by facies changes, its juxtaposition with units of different hydraulic characteristics, and its three-dimensional geometry.

Porosity is a fundamental characteristic that determines the storage capacity of an aquifer material. It is defined as the ratio of pore space to total volume of the sample. Hydraulic conductivity, which describes the ease with which water flows through a geologic unit, depends most strongly on the average size of the pathways through which the water moves. Hydraulic conductivity in clastic geologic materials can be approximated by assuming that average grain size and degree of sorting are the dominant parameters. In-filling of finer particles in the pore spaces between larger grains reduces the diameter of the flow channels. A medium has a hydraulic conductivity of unit length per unit time if it will transmit in a unit time a unit volume of ground water at the prevailing viscosity through a cross section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head through unit length of flow (Lohman, 1972). Hydraulic conductivity is usually expressed in units of meters per day (feet per day) or other appropriate units of length per time.

Transmissivity, another important measure of the hydraulic characteristics of geologic materials, is closely related to hydraulic conductivity. Transmissivity is the rate at which water of the prevailing kinematic

viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient (Lohman, 1972). This variable is equivalent to the product of the hydraulic conductivity and the saturated thickness of the aquifer, and is usually expressed in units of square meters per day (square feet per day).

A third parameter used to evaluate the hydrologic characteristics of water-table aquifers is specific yield. This dimensionless variable is the ratio of the volume of water which, after being saturated, a rock or soil will yield by gravity to its own volume (Lohman, 1972).

From the relationship between hydraulic conductivity and transmissivity, it is evident that the total yield from a water-bearing unit is a strong function of the thickness of the unit. However, in assessing the productivity of drift aquifers, it is not the entire thickness but the saturated thickness that contributes to flow, that is, that portion of the drift below the water table, where intergranular voids are totally filled with water. In some cases, lower portions of the drift may be effectively sealed from upper portions by till or clay layers of very low permeability and may behave hydraulically like a confined or artesian system.

The lower boundary of a ground-water system in surficial or unconsolidated deposits is usually the bedrock surface. The characteristics of the lower boundary depend on the rock types that are in direct contact with the drift. In areas of the region where drift overlies rocks that are generally less permeable, the contact represents a boundary condition of diminished hydraulic conductivity. More permeable bedrock may be hydraulically interconnected with overlying drift materials, with the two media functioning as a larger geohydrologic unit with no significant boundary effects.

Glacial outwash is of special hydrologic interest because of its high water yields. Most deposits of this type are associated with end-moraine and recessional-moraine features. In addition, many stream valleys throughout the region contain accumulations of glaciofluvial sediments that, along with associated alluvial deposits, are excellent sources of ground water. Also of special hydrologic interest are buried bedrock valleys that were cut either preglacially or by proglacial drainage during pre-Wisconsinan or Wisconsinan interstadials. Buried bedrock valleys typically have alluvial deposits at their bottoms that are overlain by till and/or outwash deposits. Consequently, buried bedrock valleys usually contain deposits at their bases that are capable of storing and transmitting large quantities of water.

The location and distribution of the more important geohydrologic units in the surficial deposits of the northeastern region are shown in Fig. 6.23. The area shown in southern Maine that extends into northeastern Massachusetts has widespread deposits of glacial marine silts and clays that are themselves poor sources of water. However, they are important from a geohydrologic standpoint because they are locally interbedded with and overlie sands and gravels that contain good ground-water supplies. The presence of these marine

deposits results in artesian pressures in many of the lower, confined units. All other mapped areas in Fig. 6.23 are where unconsolidated deposits occur that are known or inferred to have high ground-water yields. Many of the deposits in the larger stream valleys are hydraulically interconnected to overlying streams. In this situation, induced infiltration from the stream provides additional recharge during pumping, which results in greater sustained yields (McGuinness, 1963).

Water yields from wells completed in surficial deposits in the region vary from one location to another and depend on the geologic characteristics of the aquifer, well construction, and other local factors. Properly constructed wells in thick glacial sands and gravels can yield up to 24,750 m^3/day (5 mgd) (U.S. Geol. Survey, 1972). Although such extreme yields are relatively rare, it is not uncommon for wells to produce more than 63 L/s (1000 gpm) from aquifers of this type. Table 6.16 contains data describing the geohydrologic characteristics of selected sand and gravel aquifers in the region.

The quality of water in glacial deposits is generally good throughout the region. Because glacial deposits in New England contain few materials originating from carbonate rocks, hardness is generally low, and total dissolved solids concentrations tend to be 200 mg/L or less. Similarly, iron and manganese, though locally elevated, tend to occur in low concentrations. In New York, Pennsylvania, and New Jersey, the abundance of carbonate bedrock increases, as does the content of limestone and dolomite fragments in glacial drift. A corresponding increase in the hardness and degree of mineralization of waters in shallow water-table aquifers has been noted (Great Lakes Basin Commission, 1975b; U.S. Geol. Survey, 1972). Data reflecting the general water-quality characteristics of shallow sand-and-gravel aquifers at selected locations in the northeast are presented in Table 6.17.

6.5.2 Coastal Plain Aquifers

The Atlantic coastal plain extends southward from Cape Cod through Long Island, southern New Jersey, and the extreme southeastern margin of Pennsylvania (see Fig. 6.24). It largely consists of permeable and unconsolidated clay, silt, sand, and gravel ranging in age from Cretaceous to Pleistocene. These sediments form a wedge-shaped body that thickens from 0 m at the western margin to more than 2430 m (8000 ft) along the Atlantic coast in the southern portion of the region. Cyclic sedimentation produced alternating and interfingering layers of fine and coarse deposits. In general, average grain size decreases to the east (U.S. Geol. Survey, 1972).

Because thick units of highly permeable sands and gravels are present within the stratigraphic section, large quantities of water can be produced from coastal plain sediments from relatively shallow wells. Yields to individual wells in units with large saturated thicknesses can exceed 126 L/s (2000 gpm). These deposits have been the source of large water supplies in

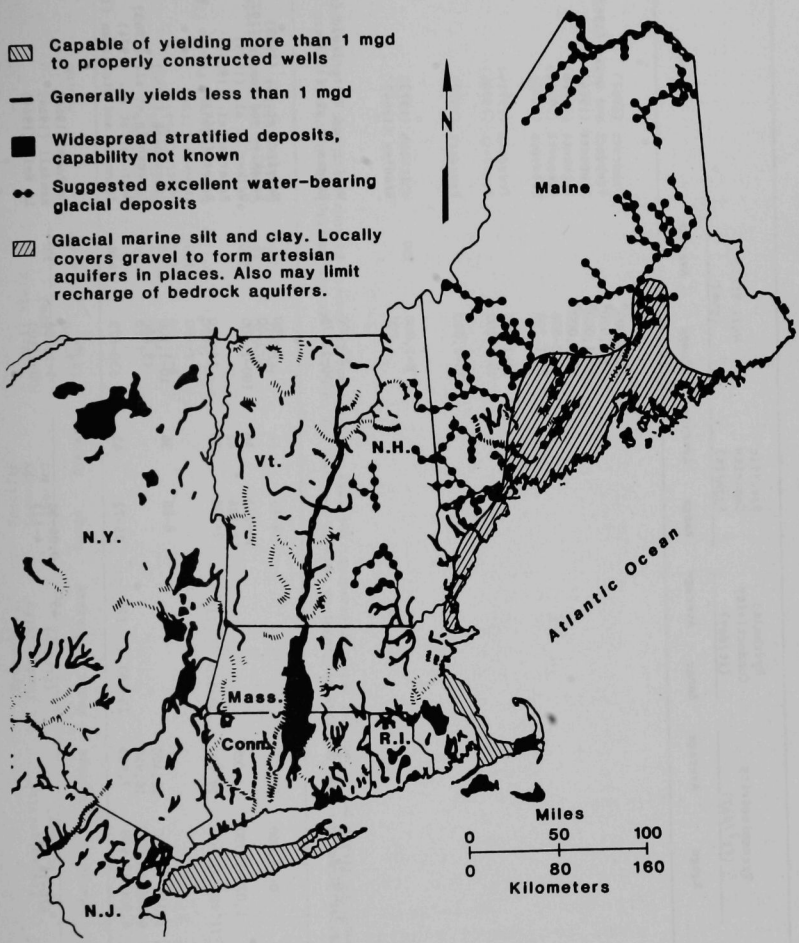


Fig. 6.23 Areal Distribution of Major Hydrogeologic Units in Surficial Deposits of the Northeastern United States (Source: Adapted from U.S. Geol. Survey, 1972)

Table 6.16 Water-Bearing Properties of Selected Sand-and-Gravel Aquifers in the Northeastern United States[a]

Location	Transmissivity (ft^2/day)		Hydraulic Conductivity (ft/day)		Specific Capacity (gpm/ft)		Well Yield (gpm)		Source
	Range	Average	Range	Average	Range	Average	Range	Average	
Maine									
Lower Androscoggin River Basin							60-1,000[b]		Prescott (1967)
Southwestern Area							5-1,000[b]		Prescott and Drake (1962)
Lower Penobscot River Basin							10-1,000[b]		Prescott (1964)
Lower Kennebec River Basin							10-1,000[b]		Prescott (1968b)
Lower St. John River Basin							10-850		Prescott (1971a)
Lower Aroostook River Basin							20-1,700		Prescott (1970)
Meduxnekeag River-Prestile Stream Basins							10-1,000		Prescott (1971b)
Windham-Freeport-Portland Area							10-1,200		Prescott (1976b)
Royal, Upper Presumpscot and Upper Saco River Basins							20-1,000		Prescott (1979)
New Hampshire									
Ashuelot River Basin							8-1,000	300	Whitcomb (1973)
Southeastern Area							700		Bradley (1964)
Vermont									
Rutland Area							50-200		Willey and Butterfield (1983)
Upper Winooski River Basin	5,000-24,000	13,785					150-1,275		Hodges et al. (1977)
Massachusetts									
Housatonic River Basin							1-900		Norvitch et al. (1968)
Nashua and Souhegan River Basin	0->4,000						0->300		Brackley and Hansen (1977)
Charles River Basin					10-275	40	100-1,500	500	Walker et al. (1975)
Wilmington-Reading Area	1,070-9,380	4,020[c]			12-124	42			Baker et al. (1964)
Lowell Area					2-108	20[c]	15-720		Baker (1964)
Rhode Island									
Kingston Area					6-88	36	10-1,100	28	Bierschank (1956)
Potowomut-Wickford Area	1,340-50,920	22,400					<5,600		Rosenshein et al. (1968)
Pawcatuck River Basin	6,400-40,000	16,958							Gonthier et al. (1974)
Branch River Basin	4,900-12,900	7,983	13-480	170	25-72	43	350-675	438	Johnston and Dickerman (1974)
Connecticut									
North Central Area							7-560		Cushman (1964)
Hartford County				45[c]	0.06-50		3-1,200	30[c]	Randall (1964)
Hartford County	670-14,740				4-123		100-1,400		La Sala (1964)

Table 6.16 (Cont'd)

Location	Transmissivity (ft^2/day)		Hydraulic Conductivity (ft/day)		Specific Capacity (gpm/ft)		Well Yield (gpm)		Source
	Range	Average	Range	Average	Range	Average	Range	Average	
New York									
Albany County							1-40	4[c]	Heath (1964)
Putnam County							1-450	33	Heath (1964)
Rockland County							8-1,700	183[c]	Heath (1964)
Dutchess County							4-660	190	Snavely (1980)
Long Island	11,400-33,500	24,400	34-240	110			<460		McClymonds and Franke (1972)
New Jersey									
Passaic County							4-920	16[c]	Carswell and Rooney (1976)
Union County					4-69	19	180-690	394	Nemickas (1976)

[a]To convert square feet per day to square meters per day, multiply by 0.093; to convert feet per day to meters per day, multiply by 0.305; to convert gallons per minute per foot of drawdown to liters per second per meter of drawdown, multiply by 0.207; and to convert gallons per minute to liters per second, multiply by 0.063.

[b]Maximum value exceeds 1000.

[c]Median value.

Table 6.17 Representative Water-Quality Parameters for Sand-and-Gravel Aquifers at Selected Locations in the Northeastern United States[a]

Location	Specific Conductance (μmhos/cm at 25°C)	TDS (mg/L)	Hardness (mg/L)	Source
Maine				
Upper Presumpscot and Upper Saco River Basins	70-420	36-275	8-97	Prescott (1979)
Upper Androscoggin River Basin	40-649	28-144	8-150	Prescott (1980b)
Lower Kennebec River Basin	66-295	58-185	22-87	Prescott (1968b)
Lower Penobscot River Basin	59-313	40-181	18-145	Prescott (1964)
St. John River Basin	41-316	44-207	17-148	Prescott (1971a)
Meduxnekeag River and Prestile Stream Basins	150-352	107-230	61-167	Prescott (1971b)
Southwestern Area	26-358	30-197	9-75	Prescott and Drake (1962)
Lower Androscoggin River Basin	15-448	18-324	2-149	Prescott (1967)
Lower Aroostook River Basin	37-467	46-284	15-270	Prescott (1970)
New Hampshire				
Southeastern	39-432	36-156	16-139	Bradley (1964)
Vermont				
Rutland Area		37-455	26-250	Willey and Butterfield (1983)
Massachusetts				
Housatonic River Basin	48-512	29-278	20-270	Norvitch et al. (1968)
Lowell Area	66-644	33-444	13-140	Baker (1964)
Wilmington-Reading Area	65-146	37-92	17-41	Baker et al. (1964)
Rhode Island				
Providence County	39-193	34-117	8-58	Johnston and Dickerman (1974)
Bristol Area		73-244	32-129	Bierschenk (1954)
Greenwich Area		41-240	14-84	Allen (1956)
Kingston Area		31-118	13-65	Bierschenk (1956)
Connecticut				
North-Central Area		52-259	22-132	Cushman (1964)
West-Central Area	43-202	38-280	14-167	La Sala (1964)
Farmington-Granby Area	46-294	30-191	6-180	Randall (1964)
New York				
Fishkill-Beacon Area		152-390	97-280	Snavely (1980)
Cortland County	375-580	207-298	190-260	Buller et al. (1978)
Albany County		354-534	128-360	Heath (1964)
Dutchess County		72-472	64-336	Heath (1964)
Putnam County		115-600	7-480	Heath (1964)
Rockland County		119-1,321	56-450	Heath (1964)
New Jersey				
Ramapo River Basin	181-338	113-215	75-155	Vecchioli and Miller (1973)
Passaic County	190-207	122-133	65-83	Carswell and Rooney (1976)
Pennsylvania				
Monroe County		<100	<80	Carswell and Lloyd (1979)
Bucks County	82-1,090	63-716	18-319	Greenman (1955)
Lehigh County	128-224	103-176	39-96	Wood et al. (1972)

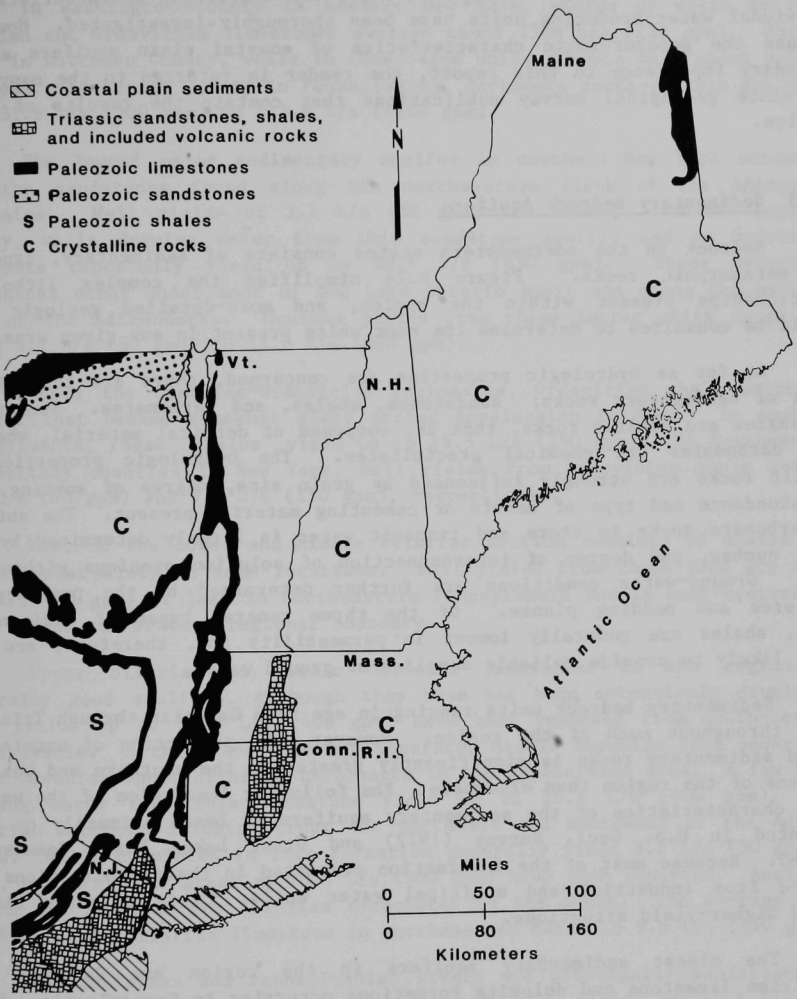


Fig. 6.24 Generalized Regional Distribution of Coastal Plain Sediments and Bedrock Type in the Northeastern United States (Source: Adapted from U.S. Geol. Survey, 1972)

heavily populated areas. As a consequence, the hydrologic characteristics of individual water-producing units have been thoroughly investigated. However, because the geohydrologic characteristics of coastal plain aquifers are of secondary importance in this report, the reader is referred to the many USGS and state geological survey publications that contain the results of these studies.

6.5.3 Sedimentary Bedrock Aquifers

Bedrock in the northeastern states consists of sedimentary, igneous, and metamorphic rocks. Figure 6.24 simplifies the complex lithologic relationships present within the region, and more-detailed geologic maps should be consulted to determine the rock units present in any given area.

As far as hydrologic properties are concerned, there are three basic types of sedimentary rocks: sandstones, shales, and carbonates. Sandstones and shales are clastic rocks, that is, composed of detrital material, whereas most carbonates are chemical precipitates. The hydrologic properties of clastic rocks are strongly influenced by grain size, degree of sorting, and the abundance and type of matrix or cementing material present. The ability of carbonate rocks to store and transmit water is largely determined by the size, number, and degree of interconnection of solution openings within the rock. Ground-water conditions are further determined by the presence of fractures and bedding planes. Of the three general types of sedimentary rocks, shales are generally lowest in permeability and, therefore, are the least likely to provide reliable supplies of ground water.

Sedimentary bedrock units ranging in age from Cambrian through Triassic occur throughout much of the region. However, the proportion of unmetamorphosed sedimentary rocks is significantly greater in the southern and western portions of the region than elsewhere. The following discussion of the water-yield characteristics of the sedimentary aquifers is based primarily on data presented in U.S. Geol. Survey (1972) and Great Lakes Basin Commission (1975b). Because most of the information presented in these publications was derived from industrial and municipal water wells, it is slightly biased toward higher-yield situations.

The oldest sedimentary aquifers in the region are Cambrian and Ordovician limestone and dolomite formations occurring in Pennsylvania. Very limited data suggest that large yields may be possible from wells located in fracture traces. In southeastern Pennsylvania, approximately 533 m (1750 ft) of shale separate the lower units from an Upper Cambrian and Ordovician sequence of carbonates. These upper units are some of the best water producers in the area. Yields from these units in excess of 63 L/s (1000 gpm) are known in the Shenandoah valley and Taconic Mountains area. Average yields are about 19 L/s (300 gpm). In western Massachusetts, where equivalents to these units have been structurally deformed, 17 industrial wells have an average yield of 15.8 L/s (250 gpm).

In Washington County in eastern New York, yields of wells in these Cambrian and Ordovician limestones average about 15.8 L/s (250 gpm). Further south in Dutchess County, wells in these same units produce only about 3.5 L/s (55 gpm). In Lehigh County in Pennsylvania, carbonate rocks of this age yield from 31.6 L/s (500 gpm) to 113.6 L/s (1800 gpm).

The lowest major sedimentary aquifer in northern New York occurs in Cambrian sandstones found along the northwestern flank of the Adirondack Mountains. Well yields of 3.2 L/s (50 gpm) are common. In St. Lawrence County, wells drawing water from this sandstone aquifer and an Ordovician carbonate reportedly yield up to 28.4 L/s (450 gpm). These Ordovician carbonates occur under most of the Lake Ontario basin and along the northern edge of the Adirondacks. Maximum yields from these latter units range from about 3.2 L/s (50 gpm) to 12.6 L/s (200 gpm).

Above the Cambrian-Ordovician carbonates, Ordovician shale units are present that became somewhat slaty during Appalachian folding. In southern Pennsylvania, these "shales" yield up to 15.8 L/s (250 gpm). In Dutchess and Schenectady counties in New York, well yields from Ordovician shale average 3.2 L/s (50 gpm) and 9.5 L/s (150 gpm), respectively.

Most of the Lower and Middle Silurian section consists of shales that are somewhat slaty in some locations. Well yields from these beds are about 4.7 L/s (75 gpm) or less in northeastern Pennsylvania and in west-central New York beyond the western regional boundary.

Upper Silurian to Middle Devonian limestones in the region are generally good aquifers, although they have not been extensively developed. Well yields up to 25.2 L/s (400 gpm) have been reported from south-central Pennsylvania. A thin sandstone bed separates Middle Devonian from underlying Lower Devonian-Upper Silurian carbonates in the Appalachian area. A few wells drawing water from this sandstone yield up to 25.2 L/s (400 gpm). The Silurian Lockport dolomite crops out northwest and southwest of the Adirondacks. Wells completed in this formation generally yield 3.2 L/s (50 gpm) or less, but values as great as 18.9 L/s (300 gpm) have been reported. Analogous yields are reported for Silurian carbonates to the south. The average yield of 28 wells in Silurian limestone in northeastern Maine is 9.5 L/s (150 gpm).

Mississippian and Pennsylvanian strata are principally sandstones and interbedded shales. In north-central Pennsylvania, yields of 37.9 L/s (600 gpm) and 52.4 (830 gpm) have been reported for wells pumping from these sandstones. The highest average yield for this area is about 9.5 L/s (150 gpm). Where wells are located so as to receive abundant recharge from nearby rivers, large sustained yields are possible. In Rhode Island and southeastern Massachusetts, Pennsylvanian, Mississippian, and Devonian rocks provide large quantities of ground water. Many of these rocks have been metamorphosed. Records indicate that some wells in these areas draw water from granitic rocks as well. Average well yields are less than 6.3 L/s (100 gpm) in some parts of these areas and less than 1.6 L/s (25 gpm) in others.

Triassic sandstones, shales, and conglomerates, along with associated basalts, are the youngest rocks of the region forming sedimentary bedrock aquifers. Deep wells in this stratigraphic sequence in central Massachusetts and Connecticut, southeastern New York, northern New Jersey, and southeastern Pennsylvania have moderately high yields. Wells in the Triassic lowland of Massachusetts yield an average of 4.7 L/s (75 gpm), with a maximum reported value of 48 L/s (760 gpm). Further south in Connecticut, wells in Triassic rocks yield an average of 9.9 L/s (157 gpm). Wells in the Triassic rocks of southeastern Pennsylvania yield an average of 10.1 L/s (160 gpm), while wells in correlative units to the north provide average yields of between 1.3 L/s (20 gpm) and 4.7 L/s (72 gpm). In Rockland County in southeastern New York and Union County in northeastern New Jersey, well yields in Triassic sedimentary rocks average more than 18.9 L/s (300 gpm). Where recharge is induced from proximal streams, even higher yields have been recorded.

Information from many sources on well yields from sedimentary rock aquifers at selected locations in the northeastern region is presented in Table 6.18. In addition, Cederstrom (1972) compiled water-yield information from a large number of wells in consolidated rocks of varying lithologies from Virginia to Maine. A summary of these data is given in Table 6.19.

Most ground waters from consolidated rocks in the northeast have a TDS content of less than 500 mg/L, and a few have less than 100 mg/L. Consequently, they are considered to be of good quality for domestic use. Collectively, this water ranges in hardness from soft (less than 60 mg/L total hardness) to very hard (more than 180 mg/L). Water from carbonate rocks tends to have the greatest hardness, whereas water from shales tends to have elevated TDS values. General water-quality information for sedimentary bedrock aquifers at several locations in the region is presented in Table 6.20. More-detailed data on ground-water quality in sedimentary rock aquifers have been reported by USGS and state geological surveys.

6.5.4 Regional Ground-Water Conditions

This section briefly summarizes ground-water availability and quality in each of the nine northeastern states. In addition to the specific references cited, this discussion relies heavily on information presented by Pettyjohn et al. (1979), Great Lakes Basin Commission (1975b), U.S. Geol. Survey (1972), and McGuinness (1963). More-detailed ground-water information for specific locations in the region can be found in these sources and numerous other publications prepared by USGS and state geological surveys.

6.5.4.1 Maine

As is true for the region as a whole, the bedrock in Maine consists of igneous, metamorphic, and sedimentary rocks (see Fig. 6.25). The crystalline rocks have been tightly folded in most areas of the state, and they are

Table 6.18 Well-Yield Data for Selected Sedimentary Rock Aquifers in the Northeastern United States[a]

Location	Rock Type	Well Yield (gpm) Range	Well Yield (gpm) Average	Source
Maine				
Aroostook River Basin	Limestone, shale, siltstone	0-560	41	Prescott (1972)
Aroostook River Basin	Limestone, shale, siltstone	2-400	32	Prescott (1972)
Aroostook River Basin	Shale, argillite, siltstone	2-100	14	Prescott (1972)
Aroostook River Basin	Sandstone, mudstone	3-35	16	Prescott (1972)
Oxford and Cumberland Counties		0-200	11	Prescott (1980a)
Unknown	Silurian and Devonian limestone	4-355	150	Cederstrom (1972)
Vermont				
Rutland Area	Dolomite	50-200	27	Willey and Butterfield (1983)
Massachusetts				
Central Area	Triassic sedimentary rocks	10-100		Walker and Caswell (1977)
Western Area	Cambrian limestone	1,600[b]	250	Cederstrom (1972)
Central Area	Triassic sandstone, shale		65	Cederstrom (1972)
Housatonic River Basin	Carbonates	1-1,400	9[c]	Norvitch et al. (1968)
Connecticut				
Central Area	Triassic sandstone, shale		157	Cederstrom (1972)
Farmington-Granby Area	Arkose, sandstone, siltstone, shale	0-500	8	Randall (1964)
North-Central Area	Sandstone, conglomerate, shale	0.5-578	34	Cushman (1964)
Rhode Island				
Unknown	Sandstone, conglomerate, shale	0-500	30.9	Allen (1953)
New York				
Dutchess County	Limestone	10-600	150	Snavely (1980)
Dutchess County	Shale	0-135	16	Heath (1964)
Dutchess County	Carbonates	1-220	22	Heath (1964)
Albany County	Shale	0-40	5[c]	Heath (1964)
Albany County	Carbonates	1-40	4[c]	Heath (1964)
St. Lawrence County	Sandstone	2-100	18[c]	Heath (1964)
Rockland County	Sandstone	3-1,515	30[c]	Heath (1964)
New Jersey				
Union County			300	Cederstrom (1972)
Passaic County	Sandstone, conglomerate, shale	0.5-225		Vecchioli and Miller (1973)
Passaic County	Paleozoic sandstone, conglomerate, quartzite	1-35	10[c]	Carswell and Rooney (1976)
Passaic County	Sandstone, conglomerate, shale	20-510	130[c]	Carswell and Rooney (1976)
Pennsylvania				
Southeastern Area	Ordovician slaty shale	20-250	90	Cederstrom (1972)
Montgomery County	Carbonates	25-1,500		Newport (1971)
Berks County	Sandstone	6-115	31[c]	Wood and MacLachlan (1978)
Berks County	Dolomite	3-660	139	Wood and MacLachlan (1978)
Lancaster County	Triassic sandstone	1-450	12[c]	Poth (1977)
Lancaster County	Ordovician limestone	1-600	30[c]	Poth (1977)
Lancaster County	Cambrian dolomite	2-70	6[c]	Poth (1977)
Lancaster County	Cambrian dolomite	2-550	30[c]	Poth (1977)

[a]To convert gallons per minute to liters per second, multiply by 0.063.

[b]Maximum values.

[c]Median values.

Table 6.19 Summary of Data for Yields of Deep Wells in Consolidated Rocks from Virginia to Maine

	FORMATION	VIRGINIA	WESTERN MARYLAND	EASTERN MARYLAND	SOUTH-CENTRAL PENNSYLVANIA	SOUTH-EASTERN PENNSYLVANIA	NORTH-CENTRAL PENNSYLVANIA	NORTH-EASTERN PENNSYLVANIA	EASTERN NEW JERSEY
MESOZOIC	Triassic sandstones and shales	[a] 157 (26) (600-955)151				162 (31) (395-300)18			300 (19) (870-400)73
PALEOZOIC	Pennsylvanian sandstones with interbedded shale and coal measures		(75-250)8 (220-200)	75 (12) (300-1276) (300flow-831)	100 (10) (250-175)15 [d] 757 (8) (150-120)61 150 (31) (832-107)25		(250-200) (150-203)20	(80-150)12 95 (15) (160-566)115	
	Mississippian shale and subordinate sandstone in upper part of section and sandstone with subordinate shale in lower part		(130flow-257)	(65-250)	(400-365)65 (100-83)15		150 (19) (600-237)30	110 (47) (375-600)115 (133-800)40	
	Upper Devonian shale, sandy shale, and sandstone		(57-380)40	257 (44-605)	(40-300) (80-300)100 (15-260)30		[f] 62 (30) (300-311) [f] 73 (30) (250-247)47	75 (50) (320-285) 38 (7) (89-266) 48 (8) (75-190)	
	Middle Devonian shale and subordinate sandstone		(24-200)40	25 (50-118)			(100+-153) (300-186)	1107 (5) (100-335)28	
	Devonian — Limestone				[g] (40-385)20		[g] (100-108)		
	Devonian — Sandstone			(200-440)	(250-212)60		(400-244)50		
	Devonian to upper Silurian massive limestone			(400-550) 857 (170-194)	(380-313)115 (500-100)			(250-360) (185-202)	
	Silurian limy shale grading down to sandy shale and sandstone	[h] [i] (300-115)		(175-952)	[j] (386-496)		(160-80+)	75 (11) (130-302) 1007 (12) (200-227)	
	Ordovician shale and minor sandstone	(50-155)29		(50-120)	(60-240)200	90 (50) (250-350)			
	Ordovician to Cambrian massive limestones	(140-801) (150-244) (300-360) (1200-260)10		150 (14) (385-305)46 82 (8) (370-300)150	(500-301)50 (500-365) (375-305)57	(160-402) 120+ (13) (500-42)10 350 (43) (1450-10[illegible]0) 840 (30) (1800-130)			
	M. Cambrian shale	(64-363)20							
	L. Cambrian carbonates	(2950-960)		(300—87)					
	Lower Cambrian sandstone, shale, slate, and quartzite	[k] (45-236)10		50 (6) (103-720)18	[k] (Large-300)	[k] (225-225)			
PRECAMBRIAN	Granite	[l] 90 (44) (380-600)94		507 (4) (100-224)		(75-200)			
	Granite gneiss					40 (8) (100-100)			
	Schist	100 (24) (275-451)12+		100 (15) (300-140)		80 (55) (250-500)			
	Greenstone	259 (3) (35-360)	50 (8) (160-161)10						
	Marble			100+ (12) (200-695)30		(110-69)			

Table 6.19 (Cont'd)

	SOUTH-EASTERN NEW YORK	EASTERN NEW YORK	NORTHERN NEW YORK	WESTERN MASSACHU-SSETTS	SOUTH-EASTERN MASSACHU-SSETTS	CONNECTICUT	RHODE ISLAND	MAINE
	[b]192 (65) (675-252)			[c]65 (16) (125-407)		157 (76) (510-600)105		
PALEOZOIC METAMORPHIC ROCKS					75 (14) (250-504)14		[e]98+ (57) (320-500) 46 (12) (100-477) 64 (12) (150-504)	(140-151)
	150 (22) (550-140)	90? (4) (150-245)						
			(40-204)					
	[h](200-275)		[i](300-386)					
								[i]150 (28) (355-300)40 [j](90-418)8
	[m]60? (150-787)		(150-153)					
	[n]50 (18) (135-300)	(60-160)						
	[o]p 55 (17) (220-228)40 [o]i (37-220)97	(2000-361)	300? (400-416)	[o]q 250 (17) (803-462) [o]r (485-726)31				
VARIOUS AGES	[f]30+ (15) (75-180)				[u]90 (18) (150-189)½			(150-85)
	[f v]35+ (29) (80-80)					(80-122)100		
	[w]65 (47) (280-166)61			(100-87)		(100-200)		(100-208)
	(200-600)							
	90 (19) (300-300)							

EXPLANATION

157
Average yield, in gallons per minute

(29)
Number of samples in the average

(600-955)151
Yield (gpm), depth (ft), and drawdown (ft) of the highest yield well in the sample

a. Greater Washington, D. C., area. Two wells yielding 1,000 and 950 gpm excluded from the average.
b. A well yielding 1,515 gpm excluded from the average.
c. A well yielding 760 gpm excluded from the average.
d. Wells shallow.
e. In descending order, average yields at Providence, Bristol, and East Greenwich, R. I.
f. Many wells shallow.
g. Limy shales.
h. Shaly limestone.
i. Limestone.
j. Slaty or quartzitic rock.
k. Berkeley County, W. Va.
l. Well in sandstone.
m. Seneca County, N. Y. Some wells in Seneca and Wayne Counties, N. Y., yield brackish water.
n. Slaty shales, Dutchess County, N. Y.
o. Taconic sequence.
p. More than half the wells are shallow.
q. Two wells yielding, respectively, 1,400 and 1,600 gpm excluded from the average.
r. Quartzite.
s. Shale.
t. Richmond, Va., area.
u. A well yielding 500 gpm omitted from the average.
v. A well yielding 365 gpm omitted from the average.
w. A well yielding 400 gpm omitted from the average.

Source: Cederstrom (1972).

Table 6.20 Representative Water-Quality Parameters for Sedimentary Bedrock Aquifers at Selected Locations in the Northeastern United States

Location		Specific Conductance (μmhos/cm at 25°C)	TDS (mg/L)	Hardness (mg/L)	Source
Maine					
Lower St. Johns River Basin	Limestone	317	200	150	Prescott (1971a)
Meduxnekeag River and Prestile Stream Basins	Limestone, shale	345-530	213-355	160-271	Prescott (1971b)
Lower Aroostook River Basin	Limestone, sandstone	271-726	154-404	134-281	Prescott (1970)
Vermont					
Rutland Area	Carbonate		169-460	38-450	Willey and Butterfield (1983)
Massachusetts					
Housatonic River Basin	Carbonates	208-874	141-308		Norvitch et al. (1968)
Rhode Island					
Bristol Area	Sandstone, shale		119-177	51-56	Bierschenk (1954)
Greenwich Area			89-130	26-70	Allen (1956)
Connecticut					
Hartford County	Sandstone, shale, conglomerate	126-257	73-204	47-154	LaSala (1964)
Farmington-Granby Area	Sandstone	184-242	52-2510	14-1430	Randall (1964)
New York					
Fishkill-Beacon Area	Limestone, shale		138-423	112-133	Snavely (1980)
Dutchess County	Shale		36-427	20-513	Heath (1964)
Dutchess County	Carbonate		178-491	62-590	Heath (1964)
Albany County	Shale		39-957	4-440	Heath (1964)
Albany County	Carbonate		254-534	128-360	Heath (1964)
Rockland County	Sandstone		52-276	18-256	Heath (1964)
New Jersey					
Ramapo River Basin	Sandstone, shale	194-404	129-278	89-188	Vecchioli and Miller (1973)
Passaic County	Sandstone, shale, limestone	194-823	129-563	84-340	Carswell and Rooney (1976)
Union County	Sandstone, shale	261-1400	200-2660	47-402	Nemickas (1976)
Pennsylvania					
York County	Carbonates, shale	10-1500		17-410	Lloyd and Growitz (1977)
Lancaster County	Limestone, shale, sandstone	75-1510	19-1020	19-630	Poth (1977)
Lancaster County	Conglomerate, sandstone, shale	75-584	56-360	26-274	Johnston (1966)
Chester County	Limestone	50-1000		17-306	Poth (1968)
Monroe County	Shale, limestone, sandstone	57-750	150-400		Carswell and Lloyd (1979)
Berks County	Carbonates, shale	243-588	154-374	102-304	Wood and MacLachlan (1978)
Bucks County	Sandstone, shale	95-1220	30-386	18-660	Greenman (1955)
Montgomery County	Carbonates		32-51	15-52	Newport (1971)
Lehigh County	Carbonates, sandstone	29-940	20-587	10-286	Wood et al. (1972)

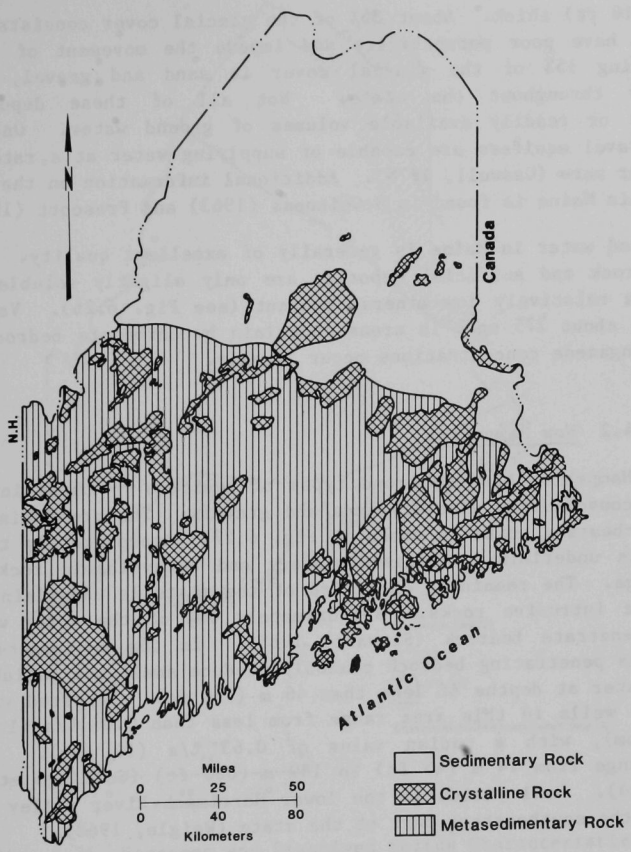


Fig. 6.25 Generalized Distribution of Principal Types of Bedrock in Maine (Source: Adapted from Hussey, 1972; Prescott, 1964)

commonly faulted and fractured. They carry and hold ground water where fractured, but few fractures are large enough to yield large quantities of water to wells. Bedrock wells that range in depth from 15 m (50 ft) to 183 m (600 ft) commonly intersect water-bearing fractures. Of all the wells drilled in Maine, only 30% yield more than 0.6 L/s (10 gpm) (Caswell, 1979). Ground-water resource maps showing yields of bedrock wells, total depths of bedrock wells, bedrock surface topography, and the potentiometric surface for bedrock wells have been prepared for the 10 most populated counties (Caswell and Lanctot, 1978a-e).

Surficial material is almost exclusively of glacial origin. The average thickness of the overburden is about 6 m (20 ft) but may range up to 61 m (200 ft). Surficial deposits in much of the mid-coastal region are less

than 3 m (10 ft) thick. About 85% of the glacial cover consists of clay-rich tills that have poor permeability and impede the movement of ground water. The remaining 15% of the glacial cover is sand and gravel, which occurs irregularly throughout the state. Not all of these deposits contain significant or readily available volumes of ground water. Only 5% of the sand-and-gravel aquifers are capable of supplying water at a rate of 31.6 L/s (500 gpm) or more (Caswell, 1979). Additional information on the ground-water conditions in Maine is found in McGuinness (1963) and Prescott (1963).

Ground water in Maine is generally of excellent quality. Because most of the bedrock and surficial deposits are only slightly soluble, the ground water has a relatively low mineral content (see Fig. 6.26). Values for TDS increase to about 275 mg/L in areas underlain by carbonate bedrock. Elevated iron and manganese concentrations occur locally.

6.5.4.2 New Hampshire

New Hampshire has two broad types of aquifers -- those in bedrock and those in unconsolidated glacial sands and gravels. The areal distribution of these water-bearing units is shown in Fig. 6.27. Approximately two-thirds of the state is underlain by metasedimentary and metavolcanic rocks of middle Paleozoic age. The remaining one-third of the state is underlain principally by Paleozoic intrusive rocks. Approximately 80% of the water wells in New Hampshire penetrate bedrock (Stewart, 1968). In the southeastern portion, drilled wells penetrating bedrock commonly produce small but reliable supplies of ground water at depths of less than 46 m (150 ft). Reported yields of the ground-water wells in this area range from less than 0.06 L/s (1 gpm) to 6.3 L/s (100 gpm), with a median value of 0.63 L/s (10 gpm). Well depths generally range from 14 m (45 ft) to 180 m (600 ft) (Collings et al., 1969; Bradley, 1964). Well yields in the lower Merrimack River valley are similar to those in the southeastern part of the state (Weigle, 1968).

Bedrock in New Hampshire is generally covered by glacial till or stratified drift. Stratified drift is the major source of higher ground-water yields in New Hampshire. Available well records indicate that deposits of this type are as much as 61 m (200 ft) thick and that yields of a few tens of liters per second (a few hundred gallons per minute) are common (Collings et al., 1969; Weigle, 1968; and Bradley, 1964).

Ground-water quality in New Hampshire is excellent. Total dissolved solids concentrations are less than 200 mg/L, and hardness is less than 60 mg/L, except for small portions of the state (see Fig. 6.28).

6.5.4.3 Vermont

Three major rock aquifers are found in Vermont -- Cambrian-Ordovician carbonates, Precambrian and early Paleozoic sedimentary and metasedimentary

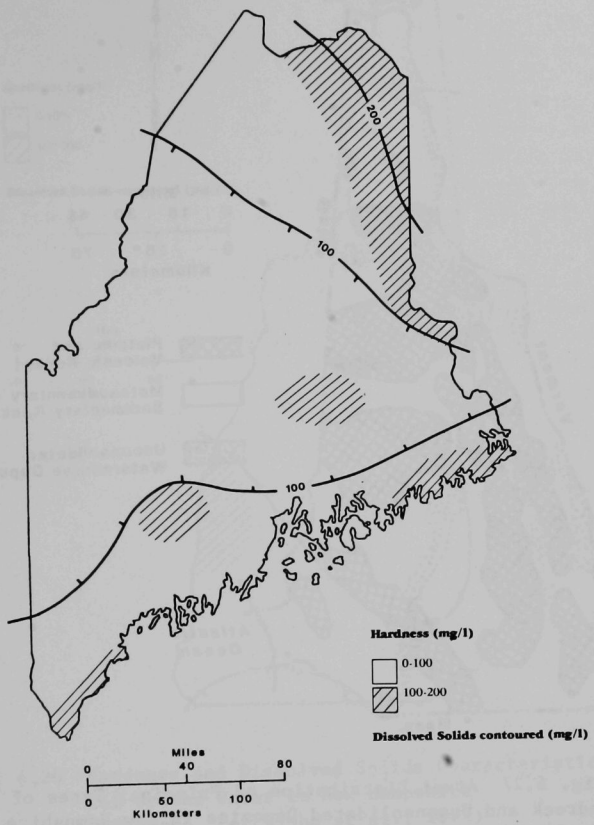


Fig. 6.26 Hardness and Dissolved Solids Characteristics of Ground Water in Maine (Source: Pettyjohn et al., 1979)

rocks, and Paleozoic igneous and metamorphic rocks. Unconsolidated sand-and-gravel aquifers are found in major stream valleys. The areal distribution of these principal aquifers is shown in Fig. 6.29.

Carbonate rocks lying in the western portion of the state are faulted and contain solution openings; these rocks constitute the main aquifer in the state. Reported well yields from these carbonate rocks range from 0.06 L/s (1 gpm) to about 6.3 L/s (100 gpm) (Hodges and Butterfield, 1967a-c). East of the area of carbonate rocks is a highland composed of deformed clastic rocks that are metamorphosed to varying degrees. Data on wells penetrating these rocks are limited. Reported yields of wells in extreme southwestern Vermont

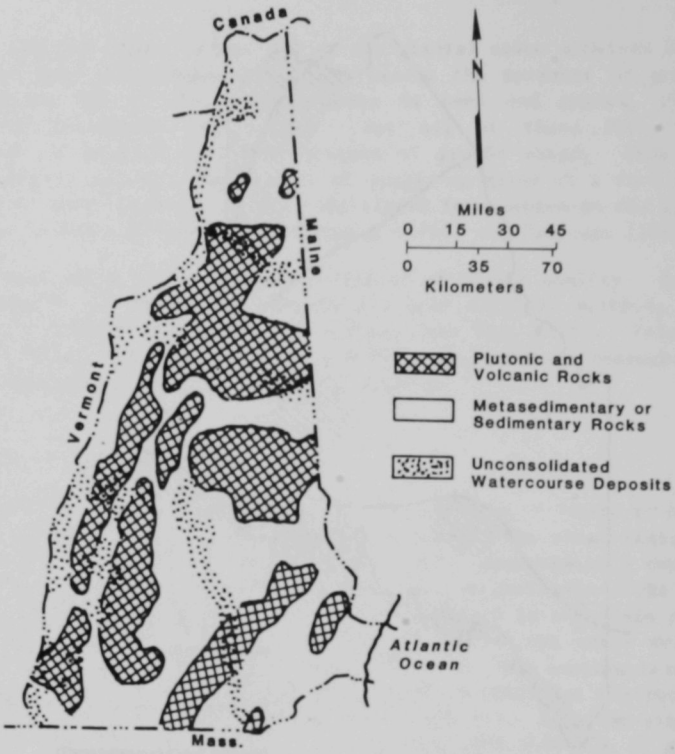


Fig. 6.27 Areal Distribution of Principal Types of Bedrock and Unconsolidated Deposits in New Hampshire (Source: Adapted from U.S. Geol. Survey, 1970)

are 0.3-6.3 L/s (4-100 gpm), with a median value of 0.3 L/s (5 gpm) (Hodges and Butterfield, 1968; Hodges, 1966).

The crystalline rocks in eastern Vermont include prominent carbonate and felsic igneous rock intrusives. Reported yields of several wells in these rocks range from 0.06 L/s (1 gpm) to 6.3 L/s (100 gpm); median yields are from 0.2 L/s (3 gpm) to 1.0 L/s (16 gpm) (Hodges and Butterfield, 1968 and 1967d).

The most productive sand-and-gravel aquifers of Vermont occur in the larger river valleys. Yields of wells in this type of aquifer often vary from one river basin to the next. Reported yields of selected wells in 11 major river basins range from 0.2 L/s (3 gpm) to 75.7 L/s (1200 gpm); reported median yields range from 2.2 L/s (35 gpm) to 22.1 L/s (350 gpm) (Hodges, 1966; Hodges and Butterfield, 1967a-d).

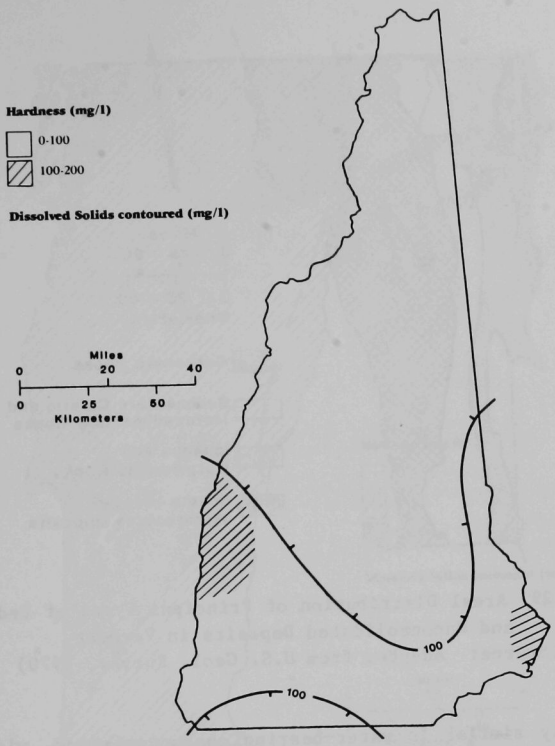


Fig. 6.28 Hardness and Dissolved Solids Characteristics of Ground Water in New Hampshire (Source: Pettyjohn et al., 1979)

Ground-water quality in the state is somewhat variable and generally reflects variations in bedrock lithology and glacial drift composition. Figure 6.30 indicates that the concentration of dissolved solids ranges from less than 100 mg/L to more than 250 mg/L. Similarly, total hardness varies from less than 60 mg/L in the northeastern and southeastern portions of the state to 120-240 mg/L elsewhere.

6.5.4.4 Massachusetts

The water-bearing formations of Massachusetts are of the same general types as those of Maine and Connecticut. The general distribution of the major water-bearing formations in Massachusetts is shown in Fig. 6.31. The most extensive bedrock types are igneous and metamorphic rocks. These crystalline

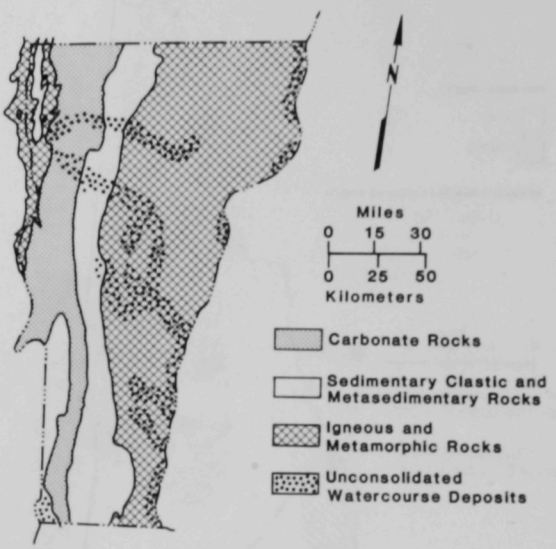


Fig. 6.29 Areal Distribution of Principal Types of Bedrock and Unconsolidated Deposits in Vermont (Source: Adapted from U.S. Geol. Survey, 1970)

rocks are broadly similar in water-bearing characteristics, with well yields usually sufficient for domestic supplies and small-scale industrial and municipal use. The median yield of wells in crystalline rock aquifers is about 0.6 L/s (10 gpm). Well depths range from 30 m (100 ft) to 61 m (200 ft). In the western part of the state, the valley of the Hoosic and Housatonic rivers is underlain principally by carbonate rocks. Well yields from these rocks range from less than 0.06 L/s (1 gpm) to as much as 107 L/s (1700 gpm), with a median value of 0.6 L/s (9 gpm) (Massachusetts Water Resources Commission, 1967).

The central part of the state is occupied by the Triassic lowland, which is underlain by sandstones, shales, and conglomerates, with interbedded basalt flows and diabase sills. Yields reported for wells believed to be finished in Triassic rocks range from less than 0.06 L/s (1 gpm) to 48 L/s (760 gpm), with an average value of about 2.5 L/s (40 gpm) and a median of 0.8 L/s (12 gpm) (Krammerer and Baldwin, 1962). In the eastern part of the state south of Boston, the Norfolk and Narragansett basins contain clastic sedimentary rocks that have experienced various degrees of metamorphism. Reported yields from wells in these rocks range from 0.06 L/s (1 gpm) to 10.7 L/s (170 gpm), with a median yield of about 0.5 L/s (8 gpm) (Williams and Willey, 1970).

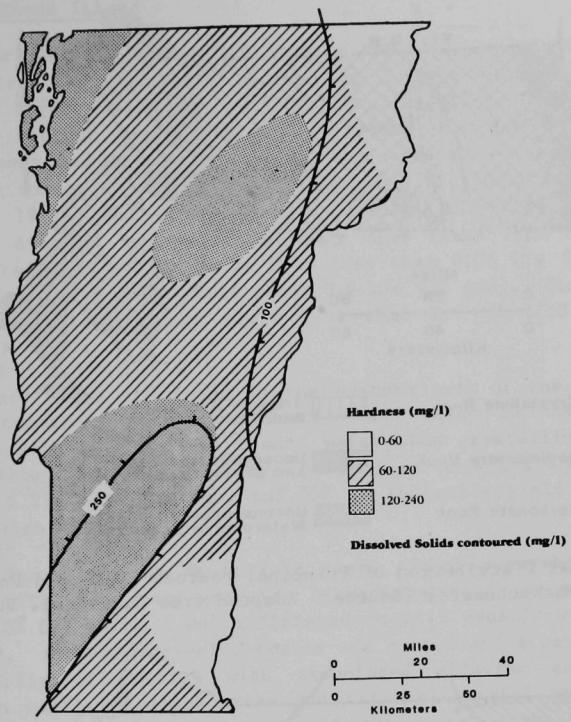


Fig. 6.30 Hardness and Dissolved Solids Characteristics of Ground Water in Vermont (Source: Pettyjohn et al., 1979)

Surficial deposits throughout most of Massachusetts consist of till. As mentioned earlier, till generally has low permeability and is therefore a poor aquifer. During prolonged periods of drought, wells in till frequently go dry. The best aquifers in surficial materials are the unconsolidated sand-and-gravel deposits found in many areas of the state, but particularly in the southeastern portion. Yields of selected wells in these deposits range from less than 0.06 L/s (1 gpm) to 56.8 L/s (900 gpm). Depths of these wells are 0.6-53 m (2-173 ft) (Williams and Willey, 1970; Sammel, 1967).

Most of the ground water in Massachusetts is soft and low in mineral content (see Fig. 6.32). Consequently, it is of good quality and suitable for practically all uses. In the western part of the state, elevated hardness occurs in water from carbonate aquifers. High concentrations of iron and manganese occur locally.

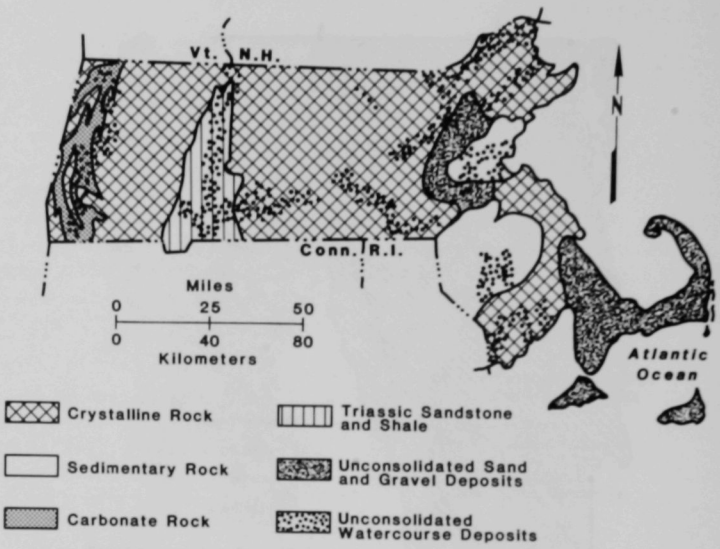


Fig. 6.31 Areal Distribution of Principal Bedrock Types and Unconsolidated Deposits in Massachusetts (Source: Adapted from U.S. Geol. Survey, 1970)

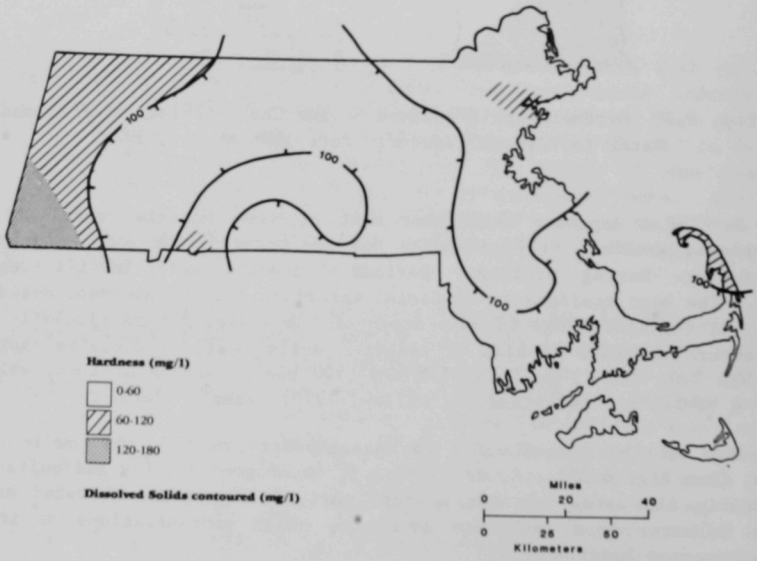


Fig. 6.32 Hardness and Dissolved Solids Characteristics of Ground Water in Massachusetts (Source: Pettyjohn et al., 1970)

6.5.4.5 Rhode Island

Except for Block Island, which lies to the south and is in the coastal plain, the entire state of Rhode Island is located within the glaciated Appalachians. Figure 6.33 is a generalized geologic map showing the distribution of bedrock types and unconsolidated sand-and-gravel deposits. Crystalline igneous and metamorphic rocks are prominent in the western half and southeastern corner of the state. These rocks are quite variable in type and age (Quinn, 1971), and include schist, gneiss, quartzite, marble, green stone, granite, diorite, and gabbro. Their ages range from Precambrian to Permian. Reported well yields range from less than 0.06 L/s (1 gpm) to 6.2 L/s (96 gpm), with the average yield being 0.8 L/s (12 gpm). Sixty percent of wells tapping crystalline rocks yield less than 0.6 L/s (10 gpm) (Allen, 1953).

Sedimentary rocks are found in the eastern part of the state. These rocks are predominantly nonmarine clastics and range in composition from conglomerate to shale. They yield more water than crystalline rocks, with flows ranging from less than 0.06 L/s (1 gpm) to 31.6 L/s (500 gpm). The average yield is 2.0 L/s (31 gpm), and 52% of the wells yield less than 0.7 L/s (11 gpm) (Allen, 1953).

Bedrock formations in Rhode Island are almost everywhere mantled by unconsolidated till, sand, and gravel. In most parts of the state, the till is about 6 m (20 ft) thick. Wells finished in till usually yield less than 0.1 L/s (2 gpm). Sand-and-gravel deposits are sorted and stratified, and are composed primarily of outwash with associated alluvium and ice-contact units. Outwash mantles lowland areas and fills preglacial stream channels. In the northern and northwestern parts of the state, outwash occupies the central parts of valleys and only partly fills preglacial channels. In the valleys of major rivers in the central and southern parts of the state, outwash generally fills and conceals the preglacial channels. Outwash varies greatly in thickness but is generally thickest in the buried channels, where properly constructed and developed wells can produce high yields. Reported yields for wells completed in outwash range from 0.2 L/s (3 gpm) to 170.4 L/s (2700 gpm) (Allen, 1953).

The quality of ground water is very good. The degree of mineralization is low, with TDS values of less than 150 mg/L being characteristic for most of the state (see Fig. 6.34). The water varies from soft to moderately hard, with TH values rarely exceeding 120 mg/L and more commonly averaging about 30 mg/L. Saltwater intrusion presents some local problems.

6.5.4.6 Connecticut

The state of Connecticut is underlain by crystalline or sedimentary bedrock covered discontinuously by unconsolidated stratified drift or till (see Fig. 6.35). Igneous and metamorphic rocks are areally the most extensive

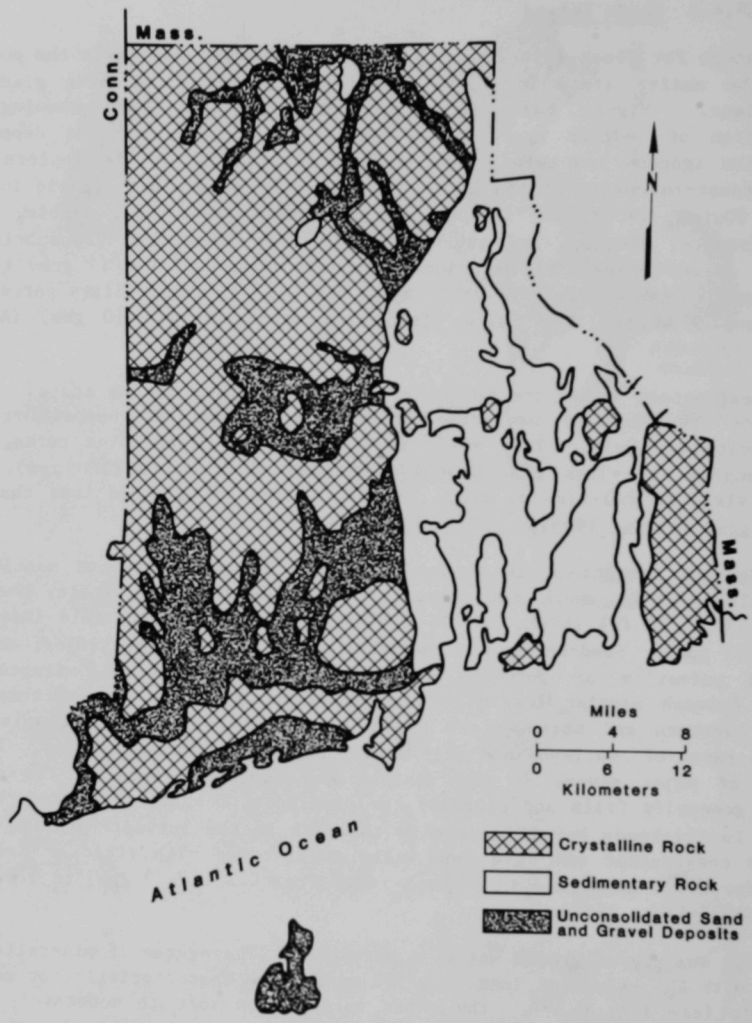


Fig. 6.33 Areal Distribution of the Principal Types of Bedrock and Unconsolidated Deposits in Rhode Island (Source: Adapted from Quinn, 1971)

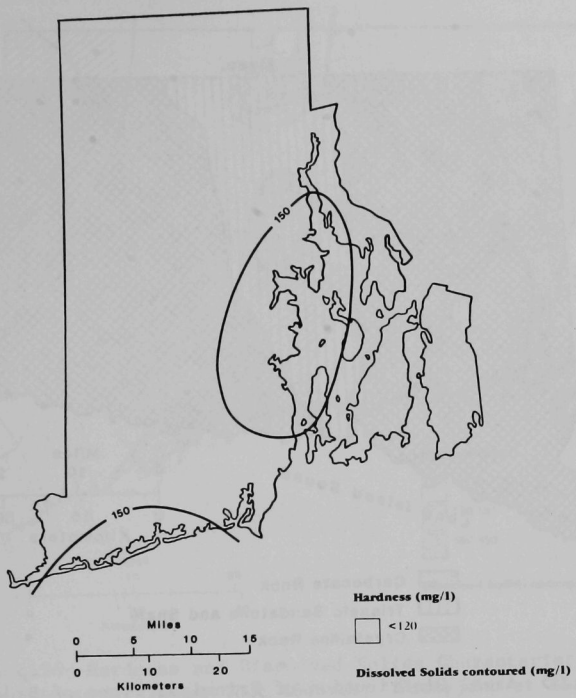


Fig. 6.34 Hardness and Dissolved Solids Characteristics of Ground Water in Rhode Island (Source: Pettyjohn et al., 1979)

types of bedrock in the state and consist primarily of granite, gneiss, and schist. These rocks generally have limited water-storage capacity and yield only small amounts of water for use in domestic, light-industrial, and small public water supply applications. An analysis of records for more than 100 domestic wells tapping crystalline rock aquifers indicates that the average yield is about 0.3 L/s (5 gpm) (Geraghty and Miller, 1965).

Sedimentary rocks are found mostly in the central portion of the state. They consist of Mesozoic sandstone, siltstone, and shale, and contain and transmit water along bedding planes and through open fractures and pore spaces. These sedimentary rocks are more dependable sources of water than the crystalline rock aquifers. The average yield of inventoried wells is 3.5 L/s (55 gpm) (Cushman, 1964).

Carbonate rocks are found only in the western portion of the state and consist of limestones that have been metamorphosed to marble. These rocks have virtually no primary porosity, but saturated zones contain water in

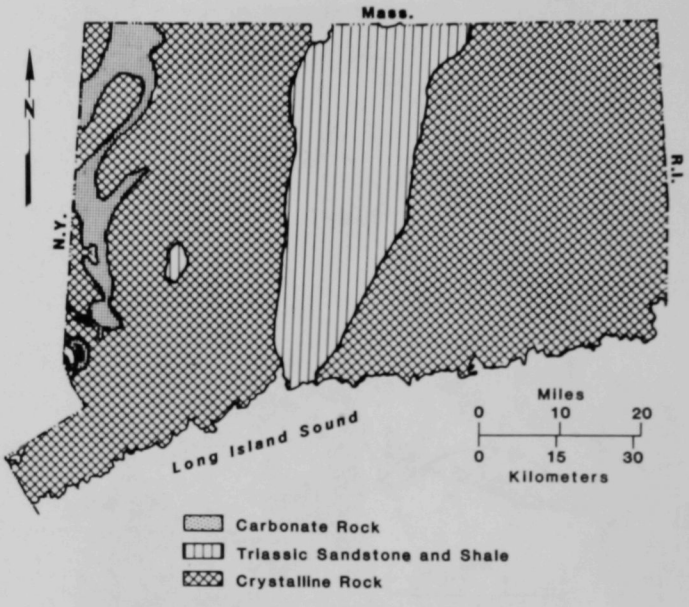


Fig. 6.35 Areal Distribution of Principal Types of Bedrock in Connecticut (Source: Adapted from Meade, 1978)

fractures. A study of well records indicates that the carbonate rocks have a median yield of 0.8 L/s (12 gpm) (Cervione et al., 1972).

Stratified drift is the most productive source of ground water for individual wells and well fields in the state. It occurs almost exclusively in stream valleys and lowlands, where thicknesses range from a few meters (feet) to more than 61 m (200 ft). Well yields in excess of 63 L/s (1000 gpm) can be developed from these sand-and-gravel beds. Till forms a widespread but discontinuous cover over bedrock throughout most of the upland areas and commonly extends beneath stratified drift in valleys and lowlands. This type of deposit is generally thin and of low permeability (Cervione et al., 1972).

Connecticut's ground water is generally of good quality. However, Fig. 6.36 indicates that some locations have high concentrations of dissolved solids and high total hardness values. Most areas of poorer quality are either near the coast and result from salt water intrusion or in the vicinity of dense population and industrialization.

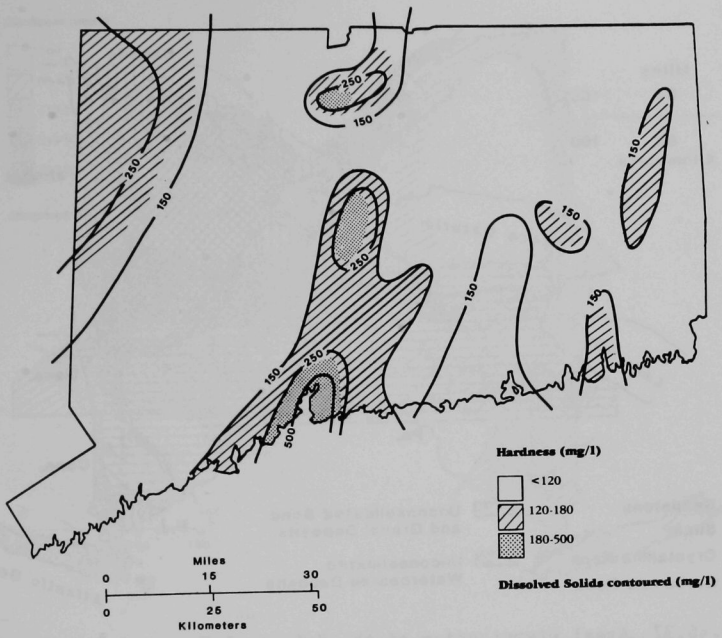


Fig. 6.36 Hardness and Dissolved Solids Characteristics of Ground Water in Connecticut (Source: Pettyjohn et al., 1979)

6.5.4.7 New York

The geologic materials of New York have been classified into six units based on similar water-bearing characteristics (Heath, 1964): crystalline rocks, shales, sandstones, carbonate rocks, pre-Pleistocene coastal plain deposits, and glacial sediments. The areal distribution of these units is shown in Fig. 6.37. Because only the eastern portion of the state is considered in this study, descriptions of the water-bearing units are limited to this area.

Crystalline igneous and metamorphic rocks predominate in the Adirondack Mountains of northeastern New York. The other major outcrop area of crystalline rocks occurs in the southeastern part of the state. Crystalline rocks in these two areas exhibit broadly similar water-bearing characteristics. They have low porosity and are commonly faulted (Kreidler, 1975). Yields of wells in these rocks are generally moderate (0.9-2.2 L/s [15-35 gpm]), and ground water occurs mostly in fractures.

The most extensive surficial deposit in eastern New York is till, which has a variable thickness and is generally considered to be a nonproductive

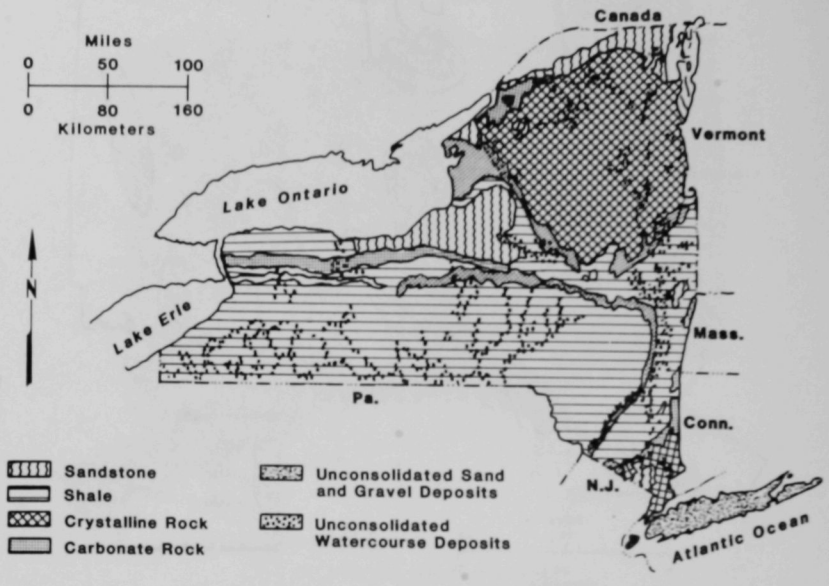


Fig. 6.37 Areal Distribution of the Principal Types of Bedrock and Unconsolidated Deposits in New York (Source: Adapted from Heath, 1964)

geohydrologic unit. The most hydrologically significant unconsolidated deposits consist chiefly of sand and gravel. These deposits are found along the major drainage systems in the Lake Champlain-Upper Hudson River basin and along the lower Hudson River valley. The area of the most extensive sand-and-gravel deposits is the coastal plain of Long Island and Lower Staten Island, where the bedrock is overlain by deposits of Cretaceous age, which in turn are capped by Pleistocene sediments. Depths of wells in the coastal plain area are most commonly 91-305 m (300-1000 ft). Yields from a few tens to more than 63 L/s (several hundred to more than 1000 gpm) can be developed from individual wells in this area.

Water quality is variable. As indicated by Fig. 6.38, areas having the softest water with lowest dissolved solids content tend to be on Long Island and in the Adirondack and Catskill mountain areas. The hardest water with the greatest concentrations of dissolved solids occurs adjacent to Lake Ontario. Such variations reflect differences in bedrock lithology. The most mineralized water occurs in carbonate and shale aquifers, whereas the least mineralized waters are associated with sandstones and crystalline rocks.

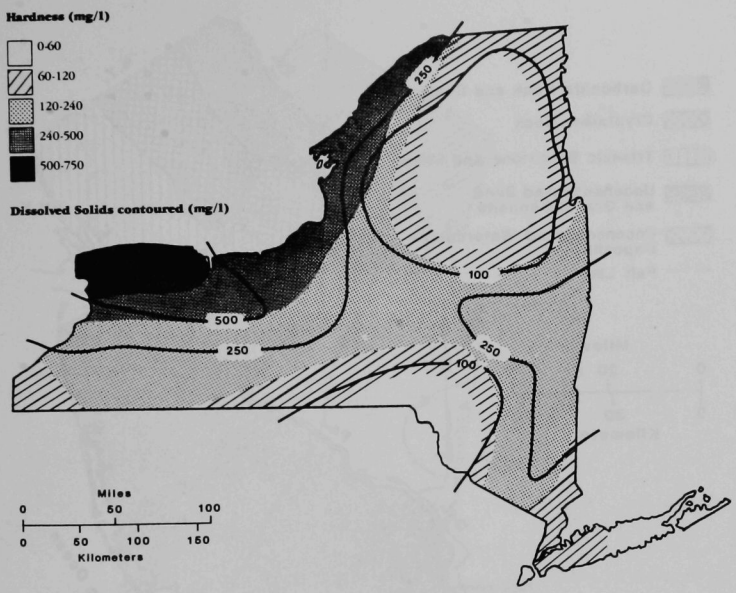


Fig. 6.38 Hardness and Dissolved Solids Characteristics of Ground Water in New York (Source: Pettyjohn et al., 1974)

6.5.4.8 New Jersey

New Jersey is divided by the Fall Line into two regions with different water-bearing formations (see Fig. 6.39). Folded and faulted sandstones, limestones, dolomites, shales, and quartzites occur in the northwestern part of the state. The principal sources of ground water are permeable, fractured sandstones and cavernous limestones. Wells penetrating fault systems can yield a few liters per second (several hundred gallons per minute). Just to the southeast is a belt of Precambrian rocks that consists primarily of gneiss, schist, and granite. Typical well yields from these rocks are 0.3-0.6 L/s (5-10 gpm). A little farther to the southeast are sandstones, shales, argillites, trap rocks, and local occurrences of conglomerate of Triassic age. Most of these rocks are well cemented and have relatively low porosities and few joints. Well yields from these units generally are low (Carswell and Rooney, 1976).

The coastal plain region south and east of the Fall Line accounts for about three-fifths of the area of the state. In this part of the state, there are unconsolidated deposits consisting of sands, gravels, clays, silts, and marls, which form a wedge-shaped mass that thickens to the southeast. These sediments are some of the most prolific sources of ground water in the region.

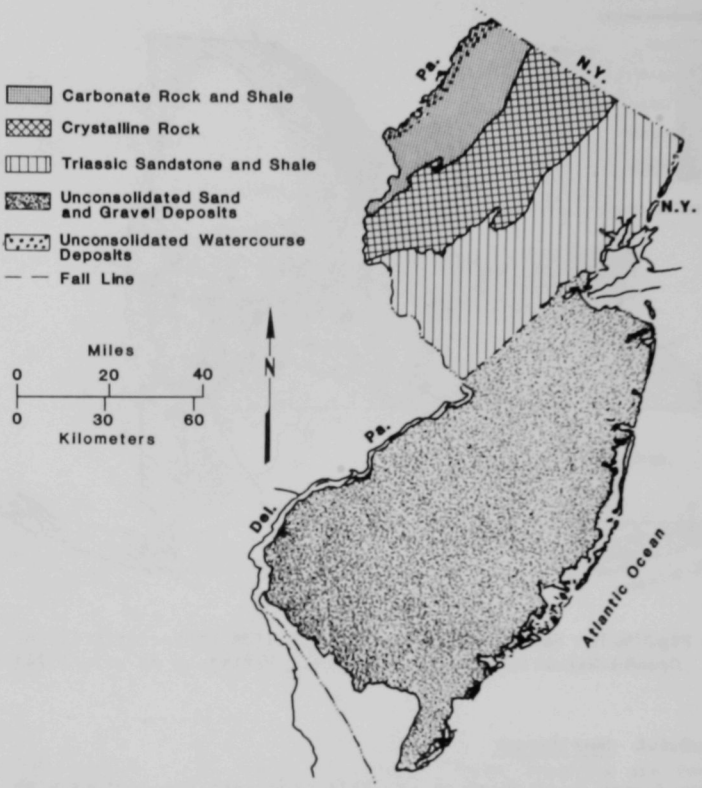


Fig. 6.39 Areal Distribution of the Principal Types of Bedrock and Unconsolidated Deposits in New Jersey (Source: Adapted from Lewis and Kummel, 1950)

In most places in New Jersey, the ground water is soft and of generally good quality. The greatest degree of mineralization is in the northern part of the state, where TDS values in excess of 200 mg/L and hardness values approaching 180 mg/L occur (see Fig. 6.40). Levels of dissolved solids are lowest in the coastal plain area, where TDS values are generally less than 100 mg/L.

6.5.4.9 Pennsylvania

There are six basic hydrogeologic units in Pennsylvania: crystalline rocks of Precambrian and early Paleozoic age, Cambrian-Ordovician carbonate rocks, middle and late Paleozoic sedimentary rocks that include coals,

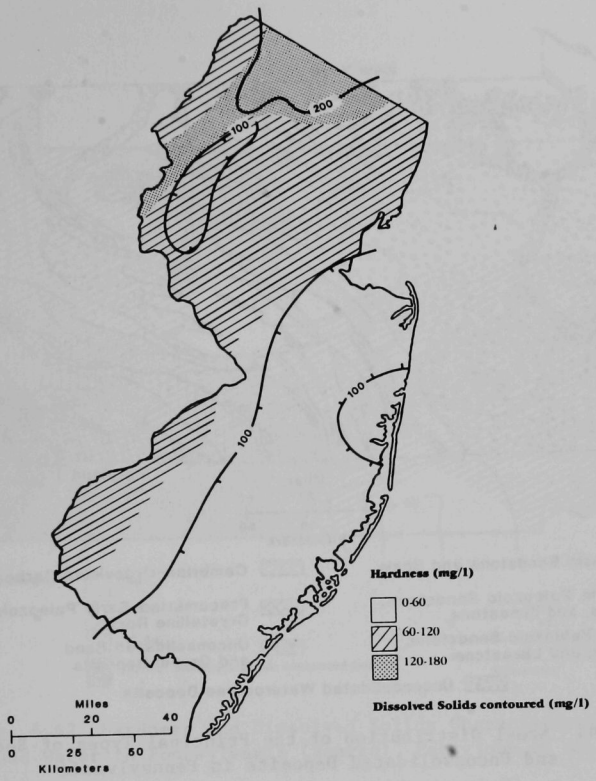


Fig. 6.40 Hardness and Dissolved Solids Characteristics of Ground Water in New Jersey (Source: Pettyjohn et al., 1979)

Triassic sedimentary rocks, and unconsolidated sand-and-gravel deposits. Hydrologic characterization of these rock types is limited to those located in southeastern Pennsylvania.

Igneous, metamorphic, and carbonate rocks are the major bedrock types in southeastern Pennsylvania (see Fig. 6.41). The igneous and metamorphic rocks are the oldest rocks in Pennsylvania and include gneiss, greenstone, serpentinite, anorthosite, schist, and quartzite. Ground water in these rocks is found within fractures and weathered zones under water-table and semi-artesian conditions (Becher, 1970; Emrich, 1966). Information obtained in this study indicates that 50% of the wells in crystalline rocks yield 0.3-1.3 L/s (5-20 gpm) and 25% yield 1.3-6.3 L/s (20-100 gpm).

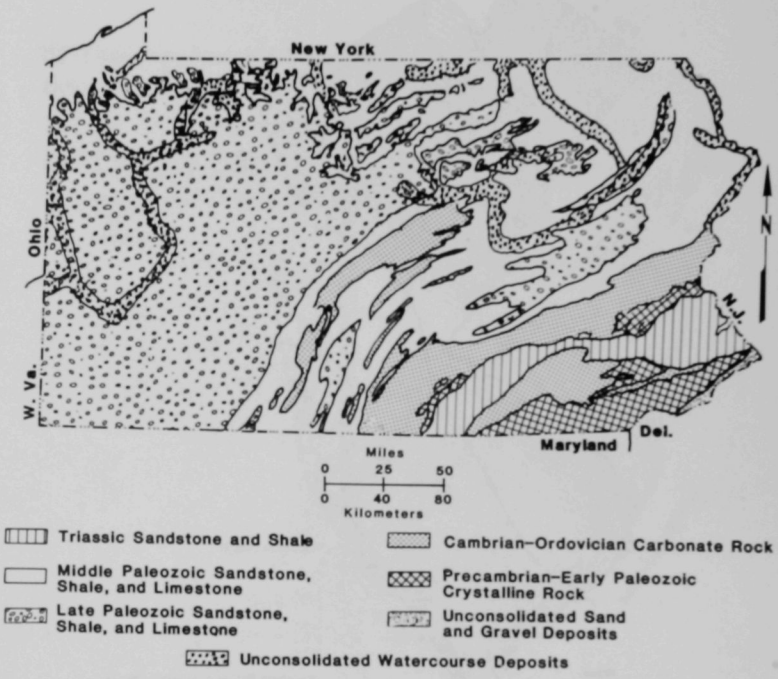


Fig. 6.41 Areal Distribution of the Principal Types of Bedrock and Unconsolidated Deposits in Pennsylvania (Source: Adapted from Willard, 1970)

Carbonate rocks, which crop out in northeast-trending bands (see Fig. 6.41), form one of the principal water-bearing units in the state. Wells tapping the carbonate band lying farthest to the southeast can yield as much as 126.2 L/s (2000 gpm) (Becher, 1970). The Schuylkill River basin is traversed by the Great Valley and Chester Valley, which mark the outcrop of the two southeastern carbonate bands. Yields of wells tapping carbonate units in the Schuylkill River basin are 0.3-15.1 L/s (5-240 gpm) (Briesecker et al., 1968).

Coastal plain sediments are among the most prolific aquifers in Pennsylvania. These deposits are found only in a small area of southeasternmost Pennsylvania near Philadelphia. They consist of gently southeasterly dipping nonmarine Cretaceous units overlain by Pleistocene marine terrace deposits. Wells producing water from these units in the Philadelphia area commonly yield 44.2-69.4 L/s (700-1100 gpm). Northeast of Philadelphia in southeastern Bucks

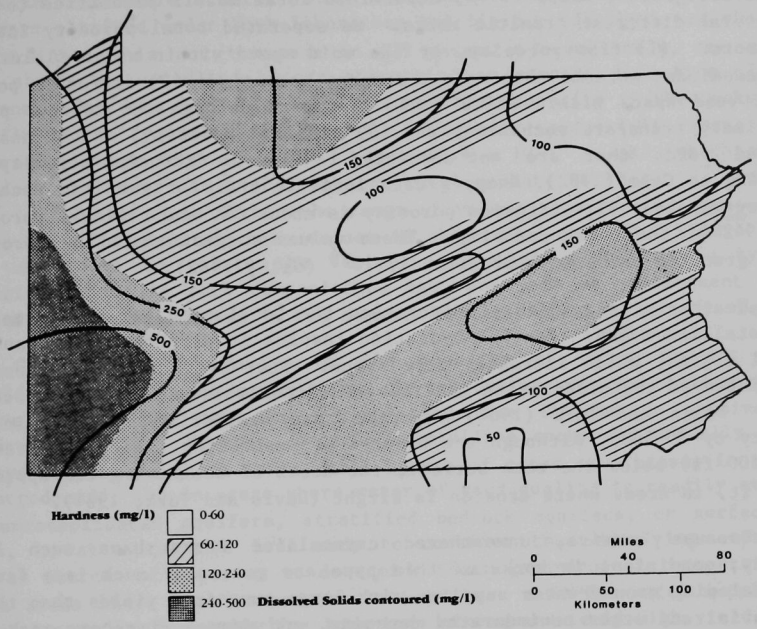


Fig. 6.42 Hardness and Dissolved Solids Characteristics of Ground Water in Pennsylvania (Source: Pettyjohn et al., 1979)

County, wells have an average yield of about 22.1 L/s (350 gpm) and a maximum yield of 69.4 L/s (1100 gpm) (Greenman et al., 1961).

Figure 6.42 shows that ground-water quality is generally better, as determined by the two mapped variables, in the eastern portion of the state than it is in the western portion. In the east, TDS concentrations generally range from less than 100 mg/L to less than 200 mg/L. However, increased mineralization occurs locally in this portion of the state (see Table 6.20).

6.6 HYDROGEOLOGY OF CRYSTALLINE ROCKS

Unweathered and unfractured crystalline rocks are characterized by very low porosities and permeabilities. Krynine and Judd (1957) reported porosities of up to 3% for unweathered crystalline rocks, with the most common value being less than 1%. Freeze and Cherry (1979) noted that porosities are rarely greater than 2%, while Davis and Turk (1964) noted that rocks of this

type generally have less than 1% porosity. Gale (1982) summarized the results of a study of porosity in crystalline rocks conducted by Knapp (1975). In this investigation, Knapp (1975) determined total matrix porosities to be 1-2% for several different granitic rocks. He separated total porosity into three components: (1) flow porosity, or the void space within which fluid flow is the predominant aqueous component transport mechanism; (2) diffusion porosity, or the void space within which ionic transport through the aqueous phase is the primary transport mechanism; and (3) residual porosity, which consists of isolated voids that are not connected to flow or diffusion porosity voids. According to Gale (1982), Knapp's data indicate that for granitic rocks, flow porosity is about 1%, diffusion porosity is about 5%, and residual porosity is about 94% of the total porosity. These values suggest that flow porosity of intact granitic rocks is approximately 10^{-4} (Gale, 1982).

Weathering significantly increases the total porosity and permeability of crystalline rocks. Partial hydration results in differential expansion of mineral grains, which increases pore space. Further increases in pore space are related to the dissolution and removal of unstable minerals by circulating water. Davis and Turk (1964) reported that weathering commonly increases porosity by 30-50%. Although the effects of weathering typically extend 3-30 m (10-100 ft) below the rock surface, the depth of weathering can approach 91 m (300 ft) in areas where erosion is slight (Davis and Turk, 1964).

Because massive, unweathered crystalline rocks have such limited porosity, conditions in rocks of this type are generally much less favorable for developing ground-water supplies with large sustained yields than they are in alluvial and other nonindurated deposits, and many sedimentary rock units. However, the hydraulic conductivity of crystalline rocks is significantly enhanced by fracturing. Two broad categories of fractures exist in crystalline rocks. These are rock expansion features resulting from the release of confining pressures at or near the land surface through the removal of overlying materials by erosion, and fractures resulting from tectonic stress.

Pressure-release fractures are concentrated at shallow depths and diminish rapidly in size and frequency with depth. The number, spacing, size, and orientation of expansion fractures will have little relationship to fractures of structural origin. On the other hand, fractures resulting from tectonic activity (e.g., large faults and shear zones) may extend to great depths and, depending on their openness, may transmit large quantities of water. Fracture zones can be present at depth in plutons that might be considered on the basis of homogeneity and other geologic characteristics as relatively impermeable (Mair and Green, 1981). If fracture zones are encountered by water wells, unusually large yields can result (Cederstrom, 1972). However, Davis (1969) reported that fracturing alone does not increase overall porosities of dense rocks by more than 2-5%. Consequently, even though crystalline rocks may be rather extensively fractured near the surface, the probability of obtaining large quantities of ground water from rocks of this type, even at shallow depths, is very small compared to that for most sedimentary rocks and unconsolidated sediments.

Table 6.21 is a compilation of published values of porosity and hydraulic conductivity for selected igneous and metamorphic rocks. Several entries in this table are for rocks found in the northeastern states. These data were obtained under both laboratory and field conditions, and the method of determination is not the same in all cases. Consequently, the original source should be consulted before attempting to compare data from different locations. The data in Table 6.21 indicate that porosity in the rocks tested generally ranges from about 0.1% to 3%. Hydraulic conductivity varies over a much broader range from about 10^{-12} cm/s (0.4×10^{-12} in./s), which probably approaches the lower limit of laboratory measurement, to about 10^{-3} cm/s (0.4×10^{-3} in./s), which is within the range of values reported for some sedimentary rocks. The mean of these values is about 10^{-8} cm/s (0.4×10^{-8} in./s). It is difficult to relate the variation in these porosity and hydraulic conductivity data to rock composition, age, and mode of emplacement because such information is lacking in the summary publications that were reviewed.

Generalized information on the quantity of water present in the crystalline rocks of the northeastern United States and the ability of water to move through the rock can be inferred from information obtained from ground-water wells. However, because crystalline rocks are normally used as aquifers only where there is no other source of water, two biases in the data are introduced: (1) in areas where water of good quality is readily available from unconsolidated aquifers, stratified bedrock aquifers, or surface-water bodies, no attempts have been made to consider the underlying crystalline rocks as sources of water or to determine their geohydrologic properties, and (2) in areas where the basement rocks have been used for water supply, well information exists primarily for locations of comparatively high yield. Areas that have been drilled unsuccessfully and holes that have been abandoned because of insufficient yield tend not to be documented. Existing information, therefore, probably indicates somewhat higher yields than might be expected throughout the entire rock unit.

Because supply wells in crystalline rocks are usually sufficient only for domestic and rural requirements, there have been no systematic efforts to quantify such parameters as transmissivity and storage coefficient. Such determinations are both costly and time consuming. The only data that are readily available concern well yield and specific capacity. Well yield, which is a measure of the amount of water that a well can produce in liters per second (gallons per minute), is only a general indicator of a rock unit's capability to yield water. Specific capacity is more indicative of the geohydrologic characteristics of a given water-bearing unit. However, both well yield and specific capacity depend heavily on (1) the size of the well, including the diameter and depth; (2) the well completion procedures, such as whether gravel packing is present and the screen characteristics; (3) the degree to which the well penetrates the full saturated thickness of the aquifer; and (4) the rate and duration of pumpage. Thus, some obvious limitations are present in the available data.

Table 6.21 Porosity and Hydraulic Conductivity Values for Selected Igneous and Metamorphic Rocks

Rock Type	Location	Hydraulic Conductivity (cm/s)[a]	Porosity (%)	Source
Gneiss	White Lake	7.5×10^{-10}-7.5×10^{-9}(L)[b]		Brace (1980)
	Colorado		0.5(L)	U.S. Bureau of Reclamation (1953)
	New York		0.8	Windes (1949)
Gabbro	Okanagan Highlands, British Columbia	4.3×10^{-7}		Lawson (1968)
	Unknown	1.9×10^{-4}	43(L)	Morris and Johnson (1967)
	Unknown		0.8	Meinzer (1923)
	Unknown		0.6-0.7	Schoeller (1962)
Granite	Unknown	4.9×10^{-11}-1×10^{-10}(L)		Stimpson (1976)
	Stripa	1.7×10^{-6}-3.4×10^{-5}(F)		Lundstroem and Stille (1978)
	Unknown	7.4×10^{-8}-3.3×10^{-4}(L)		Brace (1980)
	Laramie, Wyo.	8.3×10^{-4}-4.2×10^{-3}(F)		Brace (1980)
	Stripa	8.3×10^{-7}-1.7×10^{-5}(F)		Brace (1980)
	Barre, Vt.	$<9\times10^{-3}$	0.4	Kulhany (1975)
	Silver Plume, Colo.		1.2	Hurr and Richards (1974)
	Maryland		0.08	Windes (1949)
	Nevada		0.09	Windes (1949)
	North Carolina		0.07	Windes (1949)
	Fremont Canyon		0.8	Kulhany (1975)
	Mitidieri Quarry		3.6	Kulhany (1975)
	Valinhos Quarry		3.2	Kulhany (1975)
	Cantareira Quarry		2.2	Kulhany (1975)
	Loveland, Colo.		1	U.S. Bureau of Reclamation (1953)
	Grant Co., Wash.		1.6-2.6	U.S. Bureau of Reclamation (1953)
	Grand Junction, Colo.		0.6	Blair (1956)
	Vermont		0.9	Windes (1949)
	Stripa		1.7	Pratt et al. (1978)
	Lac du Bonnet, Manitoba	3.2×10^{-10}-3.2×10^{-3}(F)		Brace (1980)
	Barriefield, Ontario	4.9×10^{-11}(L)		Ohle (1951)
	Sherman, Wyo.	1×10^{-9}(L)		Pratt et al. (1978)
	Sherman, Wyo.	9.8×10^{-7}(F)	0.002(F)	Pratt et al. (1974)

Table 6.21 (Cont'd)

Rock Type	Location	Hydraulic Conductivity (cm/s)[a]	Porosity (%)	Source
Granite (Cont'd)	Massachusetts	4.4×10^{-9}(L)[b]		Ohle (1951)
	Hardhat	4×10^{-8}(F)		Morris and Johnson (1967)
	Hardhat	7×10^{-8}(F)		Boardman and Skrove (1966)
	Unknown	4.2×10^{-4}(F)		Rasmussen (1964)
	Unknown	1.6×10^{-3}(L)		Morris and Johnson (1967)
	Barre, Vt.		0.08	Hanley et al. (1978)
	Westerley, R.I.		0.1	Hanley et al. (1978)
	Stone Mountain, Ga.		0.3	Brace (1965)
	Unknown		0.4	Franklin and Hoeck (1970)
	Tucson, Ariz.		0.6	Norton and Knapp (1977)
	Unknown		0.7	Mellor (1971)
	Laramie, Wyo.		1.1	Norton and Knapp (1977)
	Westerly, R.I.		1.1	Brace (1965)
	Troy, Ariz.		1.4	Norton and Knapp (1977)
	Unknown		1.4	Kessler et al. (1940)
	Texas Canyon, Ariz.		3	Norton and Knapp (1977)
	Unknown		3	Norton and Knapp (1977)
	Globe-Miami, Ariz.		1.8-5.4	Norton and Knapp (1977)
	Bingham, Utah		6.1	Norton and Knapp (1977)
Granodiorite	Unknown	5.2×10^{-6}		Stimpson (1976)
	Unknown	2.3×10^{-7}		Stimpson (1976)
	Unknown	6.2×10^{-7}		Stimpson (1976)
	Unknown	9.3×10^{-7}		Stimpson (1976)
	Unknown	2.4×10^{-7}		Stimpson (1976)
	Los Alamos, N.M.	5.8×10^{-6}-6.6×10^{-2}(F)		Brace (1980)
	St. Cloud, Minn.	$<9 \times 10^{-7}$	1.5	Unknown
	Unknown	6.7×10^{-11}-7.6×10^{-7}		Brace (1980)
	St. Cloud, Minn.		0.8	Hanley et al. (1978)

[a]To convert centimeters per second to inches per second, multiply by 0.394.

[b](L) = lab measurement; (F) = field measurement.

Sources: Isherwood (1981); Wolff (1981); Brace (1980); and Cherry and Gale (1979).

As noted earlier in this discussion, the water-producing capability of crystalline rocks depends heavily on fracture characteristics, and the number and degree of openness of fractures decrease with increasing depth. Also, porosity related to weathering is confined to the near-surface portion of a rock mass. All of these factors contribute to a general decrease in water yield with depth, a relationship that has been demonstrated in several independent investigations. Davis and Turk (1964) analyzed the records of 2336 water wells in granite and schist in the eastern United States and 239 wells in granodiorite and related metamorphic rocks in the Sierra Nevada in California. Their results, shown in Fig. 6.43, indicate a logarithmic decrease in well yields with increasing depth. Davis and Turk (1964) also summarized the results of a large number of water-injection tests that indicated an analogous decrease in permeability with increasing depth.

From an analysis of more than 2500 wells completed in bedrock in the mid-coastal part of Maine, Caswell (1979) determined that the first water-bearing fracture is most often encountered before drilling 30.5 m (100 ft) and that there is a 90% chance of obtaining water before drilling 61 m (200 ft). The data also indicated that about 50% of available rock fractures occur in the upper 91 m (300 ft) and that most water-bearing fractures are likely to die out at depth below about 152 m (500 ft). In a related study, Stewart (1968) examined well yield and depth characteristics of 1050 wells in crystalline rocks in New Hampshire. He observed that 32% of the wells occur between 31 m (101 ft) and 46 m (150 ft). About 98% of the wells have a depth of 122 m (400 ft) or less, 93% are 107 m (350 ft) or less, and 88% are 91 m (300 ft) or less. Stewart (1968) concluded that the chances of obtaining an adequate domestic water supply were not very favorable at depths greater than 91 m (300 ft).

Thus, the results of several investigations indicate that the greatest abundance of fractures, and consequently the greatest probability of obtaining adequate ground-water supplies from crystalline rocks, occurs at depths less than about 91-152 m (300-500 ft). Because of this situation and the added expense of increased drilling, few water wells extend to depths below 152 m (500 ft). Normally, if sufficient yields have not been encountered by that point, the well is abandoned and another is drilled at an alternate location. As a result, very little is known about the distribution of fractures and ground-water conditions at greater depths in the crystalline rock bodies of the northeastern United States.

Even though the greatest concentration of fractures in crystalline rocks is located near the surface, fractures are known to occur at great depth. For example, a 915-m (3000-ft) hole was drilled in the Conway granite at Redstone, N.H., to evaluate heat flow and geothermal potential, as well as other geologic characteristics of that rock body. Although the greatest number of fractures were encountered in the upper 61 m (200 ft), fracturing was evident throughout the entire length of core removed (Hoag and Stewart, 1977). The deepest fracture zone encountered was at a depth of 884 m (2900

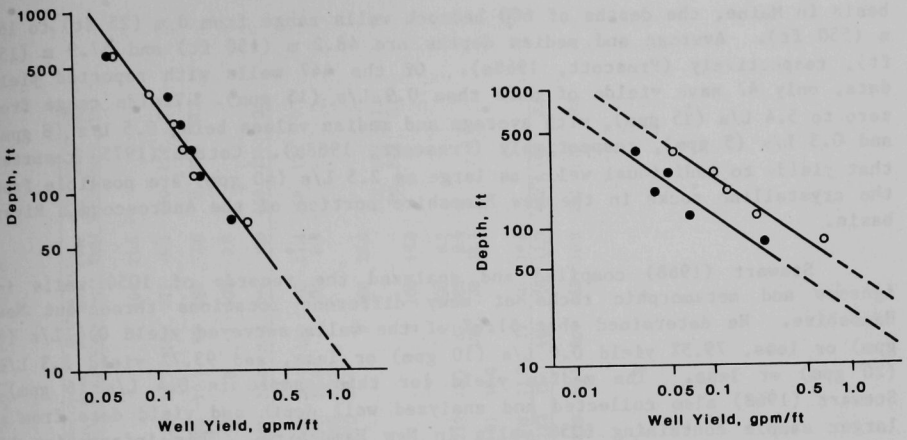


Fig. 6.43 Yield of Wells as a Function of Depth in Crystalline Rocks (Left -- eastern United States: open circles represent mean yields of granitic rocks based on a total record of 514 wells; black dots represent mean yields of schist based on a total record of 1522 wells. Right -- Sierra Nevada, California: open circles represent mean values and black dots represent median values for 239 wells in granodiorite and closely related rocks.) (Source: Adapted from Davis and Turk, 1964)

ft). Consequently, the possibility of deep fracturing in plutonic rocks cannot be dismissed, but it would be impractical to attempt to locate groundwater sources at such depths.

Yields of wells in crystalline rocks are variable from one location to another within the region and are determined principally by local geologic conditions. Cushman et al. (1953) reported average yields of 0.74 L/s (11.7 gpm), 0.65 L/s (10.3 gpm), and 0.57 L/s (9.0 gpm) for water wells in the New England region completed in granite gneiss, schist, and gneiss, respectively. Wells in granite were reported to yield an average of 2.38 L/s (37.7 gpm). Caswell (1979) reported that of the 2552 wells investigated in the mid-coastal area of Maine, 86% yield at least 0.1 L/s (2 gpm) but only 30% yield 0.6 L/s (10 gpm) or more. He also determined that about 52% of the fractures intersected by these wells yield less than 0.1 L/s (2 gpm) and only 15% are capable of yielding 0.6 L/s (10 gpm) or more. The depths of 695 wells in the Upper Androscoggin River basin in Maine range from 9 m (30 ft) to 427 m (1400 ft), with average and median values of 67 m (220 ft) and 58 m (190 ft), respectively (Prescott, 1980b). A sample of 549 wells in this basin ranges in yield from zero to 7.6 L/s (120 gpm), with an average yield of 0.7 L/s (11 gpm) and a median value of 0.3 L/s (5 gpm). Within the Lower Androscoggin

basin in Maine, the depths of 600 bedrock wells range from 8 m (25 ft) to 168 m (550 ft). Average and median depths are 48.2 m (158 ft) and 47.9 m (157 ft), respectively (Prescott, 1968a). Of the 447 wells with reported yield data, only 47 have yields of more than 0.9 L/s (15 gpm). Yields range from zero to 5.4 L/s (85 gpm), with average and median values being 0.5 L/s (8 gpm) and 0.3 L/s (5 gpm), respectively (Prescott, 1968a). Cotton (1975) reported that yields to individual wells as large as 2.5 L/s (40 gpm) are possible from the crystalline rocks in the New Hampshire portion of the Androscoggin River basin.

Stewart (1968) compiled and analyzed the records of 1050 wells in igneous and metamorphic rocks at many different locations throughout New Hampshire. He determined that 51.6% of the wells surveyed yield 0.4 L/s (6 gpm) or less, 79.5% yield 0.6 L/s (10 gpm) or less, and 93.7% yield 1.3 L/s (20 gpm) or less. The median yield for this sample is 0.4 L/s (6 gpm). Stewart (1968) also collected and analyzed well depth and yield data from a larger sample containing 6058 wells in New Hampshire. This information is summarized in Table 6.22.

Table 6.23 contains summary data for well depth and yield obtained from records of 443 wells drilled in crystalline rocks at several locations in Vermont. The few wells that were reported to have no yield were not used to obtain the tabulated averages. The data in Table 6.23 indicate that well depths range from 12 m (40 ft) to 251 m (822 ft) and that well yields range from 0.006 L/s (0.1 gpm) to 12.6 L/s (200 gpm). The overall average depth and yield for this sample of wells are 67.7 m (222 ft) and 1.17 L/s (18.5 gpm). This average yield is somewhat larger than that reported by Stewart (1968) for his sample of wells in New Hampshire.

To the south, Walker and Caswell (1977) mapped the igneous and metamorphic rocks bordering the Connecticut River Valley in Massachusetts as capable of providing less than 0.6 L/s (10 gpm). However, granitic rocks in the southeastern part of the state provide yields averaging 5.7 L/s (90 gpm) (U.S. Geol. Survey, 1972).

Allen (1953) summarized the characteristics of 369 wells completed in igneous and metamorphic rocks in Rhode Island. These wells range in depth from 11 m (35 ft) to 229 m (750 ft) and average 50 m (164 ft). Yields average 0.73 L/s (11.6 gpm) and range from less than 0.06 L/s (1 gpm) to 6.1 L/s (96 gpm). Only 3% of these wells yield less than 0.06 L/s (1 gpm); only 2% yield more than 3.2 L/s (50 gpm). Sixty percent yield less than 0.6 L/s (10 gpm); 86% yield less than 1.3 L/s (20 gpm). To the west in north-central Connecticut, Cushman et al. (1964) reported an average yield of 0.7 L/s (11 gpm) for 89 wells in crystalline rocks.

In describing the water resources of the Champlain and Upper Hudson basins in New York, Giese and Hobba (1970) reported that wells completed in crystalline rock yield from about 0.03 L/s (0.5 gpm) to 2.2 L/s (35 gpm) and

Table 6.22 Weighted Average Depth and Yield of 6058 Drilled Wells in New Hampshire, by Rock Type

Rock Type	Belknap County			Carroll County			Cheshire County			Coos County			Grafton County			Hillsboro County		
	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield
Igneous Rocks																		
White Mountain Plutonic Series	26	184	13.2	72	240	17.4							8	164	21.5			
New Hampshire Plutonic Series	185	203	11.2	341	207	11.6	62	182	14.0	13	228	26.7	150	217	9.1	450	174	9.5
Oliverian Plutonic Series							116	146	13.2	42	209	10.1	79	192	7.6	9	138	11.3
Highlandcroft Plutonic Series										16	190	9.0	1	500	0.5			
	211	201	11.4	413	213	12.6	178	159	12.1	71	208	12.9	238	208	9.0	459	173	9.5
Metamorphic Rocks																		
Littleton Formation	329	155	12.1	134	184	9.8	316	184	9.5	12	460	28.4	150	186	11.4	288	172	9.1
Gile Mtn Formation										21	195	12.9	2	94	8.8			
Waits River Formation										10	165	12.3						
Kidderville Formation										2	75	30.0						
Fitch Formation													9	196	12.4			
Berwick Formation																118	183	11.0
Eliot Formation																76	182	8.6
Clough Formation													2	105	16.0			
Kittery Formation							16	143	7.7				3	490	6.2			
Partridge Formation							11	198	3.3	23	212	13.1	67	163	9.4			
Ammonoosuc Formation													196	158	12.1			
Orfordville Formation										3	91	18.0						
Dixville Formation																		
Rye Formation										22	187	11.2	17	207	14.3			
Albee Formation																		
	329	155	12.1	134	184	9.8	343	183	9.2	93	222	15.0	446	173	11.9	482	176	9.6
Igneous and Metamorphic Average	540	178	11.8	547	206	11.9	521	174	10.2	164	216	14.1	684	185	10.9	941	175	9.5

Table 6.22 (Cont'd)

	Merrimack County			Rockingham County			Strafford County			Sullivan County					
	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield	No. Wells	Aver. Depth	Aver. Yield	Total No. Wells	(Weighted) Average Depth	(Weighted) Average Yield
White Mountain Plutonic Series							14	108	8.6				120	174	15.2
New Hampshire Plutonic Series	164	169	11.3	231	152	9.7	192	167	11.2	150	222	11.5	1938	192	12.6
Oliverian Plutonic Series				8	127	7.2				3	207	2.7	257	170	8.7
Highlandcroft Plutonic Series													17	345	4.8
	164	169	11.3	239	151	9.6	206	163	11.0	153	222	11.3	2332	220	10.3
Metamorphic Rocks															
Littleton Formation	386	165	9.8	73	129	8.0	113	135	10.4	61	130	10.6	1862	190	11.9
Gile Mtn Formation										23	352	4.3	46	214	8.7
Waits River Formation													10	165	12.3
Kidderville Formation													2	75	30.0
Fitch Formation													9	196	12.4
Berwick Formation				170	125	9.4	42	173	10.4				330	160	10.3
Eliot Formation				720	144	9.8	35	134	11.2				831	153	10.1
Clough Formation										2	123	38.5	4	114	27.3
* Kittery Formation				91	130	10.8	10	113	11.2				101	122	11.0
Partridge Formation													19	317	7.0
Ammonoosuc Formation										5	132	5.6	106	178	7.9
Orfordville Formation										105	146	10.0	301	152	11.0
Dixville Formation													3	91	18.0
Rye Formation				63	115	10.1							63	115	10.1
Albee Formation													39	197	12.8
	386	165	9.8	1117	137	9.7	200	142	10.7	196	165	9.7	3726	162	13.4
Igneous and Metamorphic Average	550	166	10.2	1356	140	9.7	406	153	10.9	349	184	10.1	6058	177.2	10.9

Source: Stewart (1968).

Table 6.23 Well Depth and Yield Data for Crystalline Rock Areas in Vermont[a,b]

County	Location	Number of Wells	Well Depth (ft) Range	Well Depth (ft) Average	Well Yield (gpm) Range	Well Yield (gpm) Average
Caledonia	Peacham	9	105-600	279	0.5-50	20
	Groton	32	70-548	202	0.1-50	11
Essex	Newark	16	48-600	247	1-60	24
	Averill-Norton-Lemington	10	100-415	210	1-100	21
	Granby-Guildhall-Maidstone	15	42-525	227	2-100	15
	Brighton-Brunswick	16	55-405	204	1-200	26
	Canaan	5	105-430	278	2-125	37
Orange	Orange-Topsham	21	55-545	245	0.1-100	23
Orleans	Charleston	16	40-465	225	0.2-100	17
	Westmore	24	73-399	227	0.5-80	14
	Morgan	15	63-330	182	0.8-100	25
	Greensboro-Glover	13	73-500	212	0.8-30	9
	Derby	21	60-450	235	1.3-100	18
	Barton	20	48-375	173	1-100	19
Washington	Plainfield	11	98-300	172	0.8-30	10
	Marshfield-Cabot	32	63-505	220	0.3-40	11
Windsor	West Windsor	38	62-500	231	0.2-100	11
	Weathersfield	74	40-750	263	0.3-50	8
	Reading	16	55-347	196	0.5-170	33
	Cavendish	39	50-822	203	0.1-150	17

[a]To convert feet to meters, multiply by 0.3048; to convert gallons per minute to liters per second, multiply by 0.063.

[b]Averages rounded to nearest whole number.

average about 0.8 L/s (12 gpm). Where the crystalline rocks are overlain by permeable unconsolidated deposits in valleys, yields average 1.2 L/s (19 gpm). High-yield wells in granite gneiss have been developed in Westchester County in southeastern New York. Here, wells produce average yields ranging from 2.2 L/s (35 gpm) to 3.2 L/s (50 gpm) (U.S. Geol. Survey, 1972). Frimpter (1972) reported that wells completed in crystalline rock in nearby Orange and Ulster counties yield an average of 0.02 L/s (0.12 gpm) per meter (foot) of well exposed to the aquifer.

According to Miller (1974), open fractures in crystalline rocks in northwestern New Jersey (Sussex and Warren counties) do not usually extend beyond a depth of 91 m (300 ft), although a few wells thought to have intersected fault or shear zones have yielded water from greater depths. However, more than 75% of the wells in these rocks are less than 46 m (150 ft) deep. Reported yields of 1018 domestic wells in the area range from zero to 6.3 L/s (100 gpm), with the average and median values being 0.6 L/s (10 gpm) and 0.5 (8 gpm), respectively. Forty-six percent of these wells yield 0.3 L/s (5 gpm) or less. The average yield of 35 industrial and public supply wells is 9.9 L/s (157 gpm), with a median value of 3.6 L/s (57 gpm) (Miller, 1974).

Poth (1968) investigated the water-bearing characteristics of metamorphic and igneous rocks in central Chester County in Pennsylvania. Because most wells were for domestic supply, they were probably located for convenience and were drilled only to a depth sufficient to supply domestic needs (0.3-0.6 L/s [5-10 gpm]). Consequently, he reported that larger yields than those indicated by the available data were possible. About 10% of the wells studied by Poth (1968) yield more than 3.2 L/s (50 gpm). Within this group of 36 higher-yielding wells, the median yield is 6.3 L/s (100 gpm), but 5% of the wells yield more than 20.8 L/s (330 gpm). The median yield for the total sample is 0.9 L/s (15 gpm), and 5% yield more than 5.6 L/s (88 gpm). About 10% of the water-bearing zones in the higher-yielding wells occur below 52 m (170 ft), but only 4.5% of the zones of the entire sample are below this depth. A summary of the data used from Poth's (1968) study is presented in Table 6.24.

Wood et al. (1972) conducted an investigation of the water resources of Lehigh County in Pennsylvania, where crystalline rocks of the Reading Prong occur. They reported that nine public-supply and institutional wells completed in granite and granite gneiss range in yield from 0.5 L/s (8 gpm) to 6.3 L/s (100 gpm) and have a median value of 3.2 L/s (50 gpm). These wells have a median one-hour specific capacity of 0.25 L/s per meter (1.2 gpm per foot) of drawdown. One-hour specific capacities for eight domestic wells in hornblende gneiss, pyroxene gneiss, and amphibolite range from 0.01 L/s per meter (0.03 gpm per foot) of drawdown to 0.33 L/s per meter (1.6 gpm per foot) of drawdown, with a median of 0.04 L/s per meter (0.17 gpm per foot) of drawdown. Three of the 11 wells with yield information yield 0.06 L/s (1 gpm) or less. Rumbaugh (1983) conducted an investigation of the ground-water conditions in neighboring northeastern Berks County. From data collected from 52 wells in hornblende gneiss and from 31 wells in granite gneiss, Rumbaugh computed the median transmissivity of these units to be 0.69 cm^2/s (0.11 $in.^2/s$) and 0.44 cm^2/s (0.07 $in.^2/s$), respectively. Well yield and specific capacity values were not reported. Additional data for yields from wells in crystalline rocks in Pennsylvania and each of the other states in the region are given in Tables 6.18 and 6.25.

The quality of water from crystalline rocks in the northeastern region is variable and depends on local conditions. Generally, natural waters in the region tend to be fairly soft and only moderately mineralized. Very general

Table 6.24 Summary Data for Wells in Igneous and Metamorphic Rocks in Central Chester County, Pennsylvania

Formation	Reported yield			Specific capacity			Well depth			Casing depth		
	Number of Wells	Range (gpm)	Median (gpm)	Number of Wells	Range (gpm per ft)	Median (gpm per ft)	Number of Wells	Range (feet)	Median (feet)	Number of Wells	Range (feet)	Median (feet)
Baltimore Gneiss												
"Normal" phase	64	1-270	17	10	0.2-8.9	0.93	89	31-359	84	56	10-76	33
Gabbro-intruded phase	55	¾-125	11	9	.06-9.0	2.2	69	45-265	102	50	14-69	39
Graphitic phase	3	½-45	15	0	.....	..	3	50-154	145	2	28-32	30
Setters Formation	5	12-33	16	3	.2-2.5	.6	8	69-140	106	6	17-100	40
Cockeysville Marble	3	3-330	20	4	.1-78.5	3.15	6	33-170	86	4	20-80	42
Wissahickon Formation												
Chlorite phase	41	0-80	8	18	.04-38.2	2.4	63	35-1,000	125	46	15-200	15
Muscovite phase	77	0-350	10.5	20	.06-8.4	.4	115	48-400	112	67	10-157	40
Peters Creek Schist	35	0-312	11.3	18	.03-11.3	1.0	69	32-426	92	36	6-110	29
Chickies Quartzite	6	2-20	12	2	.2	.2	11	42-222	112	9	13-60	22
Hellam Conglomerate Member	0	.....	....	1	.....	.05	8	38-170	68	1	.....	74
Harpers Schist	6	4-30	14	1	.....	1.7	7	28-160	125	5	28-120	36
Antietam Quartzite	0	.....	....	0	.....	..	0	.....	....	0	.....	..
Vintage Dolomite	2	3-665	334	0	.....	..	2	55-300	178	1	.....	208
Kinzers Formation	0	.....	....	0	.....	..	2	65-147	106	1	.....	4
Ledger Dolomite	5	7-150	25	0	.....	..	7	42-400	118	4	5-100	40
Elbrook Limestone	2	15-150	82	0	.....	..	2	85-200	142	2	50-100	75
Conestoga Limestone	9	7-175	20	2	.1- .4	.3	16	42-200	90	8	18-134	49
Gabbro	45	½-125	10	5	.2- 3.9	1.3	52	36-235	94	39	10-87	33
Serpentine	4	4-80	18	1	.....	.6	5	40-310	104	2	15-108	62
Pegmatite	0	.....	..	0	.....	..	1	.....	100	0	.....	..
Diabase	1	.....	½	0	.....	..	1	.....	255	1	.....	23

Source: Poth (1968).

water-quality information for selected locations throughout the region is contained in Table 6.26.

Although this discussion of the regional ground-water characteristics of crystalline rocks is by no means exhaustive, it provides a general overview of the variety of hydrologic conditions present. Crystalline rocks are a significant source of ground water in the region by virtue of the large number and widespread distribution of wells completed in these rocks. Individually, most of these wells yield only small quantities of water, often just enough to supply domestic needs. However, under optimum local conditions, a few tens of liters per second (several hundred gallons per minute) can be produced. Most fractures that supply water to wells are relatively shallow, occurring in the upper 90-150 m (300-500 ft) of the rock mass; therefore, water wells rarely extend beyond this depth. As a consequence, almost no data are available for evaluating ground-water conditions within crystalline rocks at greater depths.

Table 6.25 Well-Yield Data for Crystalline Rocks at Selected Locations in the Northeastern United States[a]

Location	Rock Type	Well Yield (gpm)[a] Range	Average	Source
Maine				
Southern Washington County		10-200	25	Caswell and Lanctot (1976)
Androscoggin County		10-200	17	Caswell and Lanctot (1978a)
Cumberland County		10-200	26	Caswell and Lanctot (1978b)
York County		10-200	25	Caswell and Lanctot (1975b)
Hancock County		10-100	21	Caswell and Lanctot (1977a)
Waldo County		10-100	20	Caswell and Lanctot (1975a)
Kennebec County		10-100	24	Caswell and Lanctot (1977b)
Lincoln and Sagadahoc Counties		10-200	26	Caswell and Lanctot (1978c)
Southern Penobscot County		10-300	28	Caswell and Lanctot (1978d)
Knox County		10-100	20	Caswell and Lanctot (1978e)
Lower Penobscot River Basin	Granite	0.5-100	9	Prescott (1966)
Lower Androscoggin River Basin	Granite	0-85	8	Prescott (1967)
Portland Area	Granite	0-150	11	Prescott (1976a)
Royal, Upper Presumpscot, and Upper Saco River Basins	Granite	0-200	11	Prescott (1979)
Meduxnekeag River-Prestile Stream Basins	Granite	0.25-400	24	Prescott (1971b)
Lower Aroostook River Basin	Granite	0-560	34	Prescott (1970)
Lower St. John River Basin	Granite	2-450	38	Prescott (1971a)
Lower Kennebec River Basin	Granite	0-67	11	Prescott (1968b)
Southwestern Area	Granite	1-150	5[c]	Prescott and Drake (1962)
New Hampshire				
Southeastern Area		1.5-100	9.5[c]	Bradley (1964)
Ashuelot River Basin		<1-32	9	Whitcomb (1973)
Vermont				
Rutland County			5[c]	Willey and Butterfield (1983)
Upper Winooski River Basin	Granite	1-35	5[c]	Hodges et al. (1977)
Massachusetts				
Housatonic River Basin	Gneiss	4-150	15[c]	Norvitch et al. (1968)
Nashua and Souhegan River Basins		2-150		Brackley and Hansen (1977)
Lower Merrimack River Basin			10[c]	Gay and Delaney (1980)
Charles River Basin		1-50		Walker et al. (1975)
Lowell Area		1-130	12[c]	Baker (1964)
Southeastern Area		150[b]	90	U.S. Geol. Survey (1972)
Southern Area	Granite		90	Cederstrom (1972)
Wilmington-Reading Area		0.5-60	10[c]	Baker et al. (1964)

Table 6.25 (Cont'd)

Location	Rock Type	Well Yield (gpm)[a] Range	Average	Source
Rhode Island				
Bristol Area	Granite	1-100	18	Bierschenk (1954)
Kingston Area	Granite gneiss	1-60	14	Bierschenk (1956)
Unknown	Granite	0-96	11.6	Allen (1953)
Connecticut				
North-Central Area	Granite gneiss	0.25-35	10	Cushman (1964)
Bristol-Plainville-Southington Area	Granite gneiss	1-90	9[c]	La Sala (1964)
Farmington-Granby Area	Gneiss	0.75-50	5	Randall (1964)
New York				
Unknown		75[b]	30	U.S. Geol. Survey (1972)
Black River Basin		1-40	5	Waller and Ayer (1975)
Champlain-Upper Hudson River Basins		1-35	12	Giese and Hobba (1970)
Westchester and Putnam Counties	Granite gneiss	48[b]	35	Cederstrom (1972)
Putnam County		0-120	11	Heath (1964)
Rockland County		0-180	12[c]	Heath (1964)
Dutchess County	Granite gneiss	1-45	16	Snavely (1980)
New Jersey				
Sussex County		<1-100	10	Miller (1974)
Warren County		5-157	62	Miller (1974)
Passaic County	Granite gneiss	1-200		Carswell and Rooney (1976)
Pennsylvania				
Chester County	Gneiss	1-270	17[c]	Poth (1968)
Bucks County	Gneiss	2-200	45	Greenman (1955)
Lancaster County		2-70	10[c]	Poth (1977)

[a]To convert gallons per minute to liters per second, multiply by 0.063.

[b]Maximum values.

[c]Median values.

Table 6.26 Representative Water-Quality Parameters for Crystalline Rocks at Selected Locations in the Northeastern United States

Location	Rock Type	Specific Conductance (μmhos/cm at 25°C)	TDS (mg/L)	Hardness (mg/L)	Source
Maine					
Upper Presumpscott and Upper Saco River Basins	Granite	70-360	44-243	30-160	Prescott (1979)
Upper Androscoggin River Basin	Granite	111-495	55-278	34-190	Prescott (1980b)
Lower Kennebec River Basin	Granite	164-344	112-225	14-114	Prescott (1968b)
Lower Penobscot River Basin	Granite	56-686	39-422	39-261	Prescott (1964)
Southwestern Area	Granite	66-211	41-137	20-99	Prescott and Drake (1962)
New Hampshire					
Southeastern Area		113	72	32	Bradley (1964)
Vermont					
Upper Winooski River Basin	Granite	66-240			Hodges and Willey (1977)
Massachusetts					
Lowell Area		69-375	49-239	17-166	Baker (1964)
Wilmington-Reading Area		147-216	94-127	56-82	Baker et al. (1964)
Housatonic River Basin	Gneiss	107-282	74-132		Norvitch et al. (1968)
Rhode Island					
Branch River Basin		51-113	25-84	4-36	Johnston and Dickerman (1974)
Bristol Area	Granite		154-177	82-98	Bierschenk (1954)
Kingston Area	Granite gneiss		56-216	14-121	Bierschenk (1956)
Connecticut					
Bristol-Plainville-Southington Area	Granite gneiss	125-179	77-119	50-75	La Sala (1964)
Farmington-Granby Area	Gneiss		42-111	21-57	Randall (1964)
North-Central Area	Granite gneiss	64-248	58-157	23-91	Cushman (1964)
New York					
Putnam County			43-255	16-390	Heath (1964)
Rockland County			130-195	48-154	Heath (1964)
New Jersey					
Ramapo River Basin		8-203	56-124	30-94	Vecchioli and Miller (1973)
Passaic County	Granite gneiss	92-269	66-159	34-104	Carswell and Rooney (1976)
Pennsylvania					
Lancaster County		25-94		9-17	Poth (1977)
Chester County	Gneiss	15-1150		17-425	Poth (1968)

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7 ECONOMIC GEOLOGY

The purpose of this review is twofold: (1) to provide baseline information on the rock and minerals industry of the northeastern United States and (2) to comment briefly on the commercial potential of each of the major industries covered. Treated with greatest detail are those commercial activities involving exploitation of rocks and minerals in or near the crystalline rock bodies themselves. Extractive industries more than 3.2 km (2 mi) from the boundaries of mapped units (see Plates II-IX) are of much less interest and will be given minimal coverage. Examples of minerals industries usually (or always) more than 3.2 km (2 mi) from the boundaries of crystalline rock bodies are the limestone, peat, and petroleum industries.

7.1 GRANITIC PLUTONS

This section provides detailed coverage of mines in granitic plutons in the northeast that have been or are being worked for constructional, monumental, and inscriptional granites; for crushed granite; or for associated trap rock. The level of detail is deemed appropriate because these mines are the ones most likely to be reopened, if presently inactive, or expanded in the future. They are close to existing railroad systems and have already incurred the expense of overburden removal.

The main types of commercial granitic rocks in the northeastern United States are biotite granite, biotite-muscovite granite, muscovite-biotite granite, quartz monzonite, hornblende granite, hornblende-augite granite, biotite-hornblende granite, riebeckite-aegerite granite, riebeckite-aegerite-biotite granite, quartz diorite, granodiorite, quartz gabbro, and equivalent or associated granitic gneiss. Of these, the most common are biotite granite and quartz monzonite.

There are only a few representatives of mafic and ultramafic igneous rocks in the northeast: gabbro, hypersthene-olivine gabbro, hypersthene gabbro, norite, olivine norite, mica diorite, anorthosite, diabase porphyries, and equivalent or associated mafic gneiss. Gabbros and norites are the predominant commercial mafic rock types in the region. Crosscutting diabase dikes, sills, and injections are scattered throughout mafic as well as granitic plutons.

7.1.1 Commercial Classification of Granitic Rocks

Dale (1908, p. 210) classified the granitic rocks of the northeastern United States according to the following scheme:

For economic purposes, these granites fall naturally into the two classes of constructional and monumental granites. Some granites, however, are noted for their susceptivity of a high polish or possess colors which only become effective on a polished surface. Such are, therefore, termed polish granites. To this class belong also several of the monumental and contructional granites. Still other granites, by virtue of the contrast between their hammered or cut and their polished surfaces, are particularly adapted to inscriptions and are, therefore, classed as inscriptional granites. Here belong the quartz monzonites and diorites because of their large content of soda-lime feldspar. One of the monumental and inscriptional granites, from its remarkable fineness of texture, lends itself to the very finest carving and is, therefore, also classed as statuary granite.

Table 7.1 is modified and expanded from the work of Dale (1923). It includes localities, trade names, scientific names, and economic classifications, where available, for the commercial granitic rocks of the northeast.

7.1.2 Location and Status of Commercial Granitic Rock Mining

The significance of the location of active and historical quarry sites to this study is its value in forecasting future mining activity. If existing granite mines are not being worked, it is unlikely that new ones will be undertaken. This is especially true now that it is prohibitively expensive to strip overburden from underlying minable rock at new sites. Therefore, it is assumed that reserves of stone at inactive and active mines in the region are adequate in quantity and quality to last for many years and that the opening of new, large-scale commercial stone quarries will continue to be uneconomical. One exception may be the orbicular granites of Bethel, Vt. (Bain, 1981).

Plates II-IX show all of the significant granitic rock masses by state and the distribution of the active and inactive commercial stone operations in the northeastern United States. The symbols for active and inactive mines permit easy determination of areas having significant current or future commercial prospects. Historical and projected mining activities in each state are summarized in Table 7.2.

7.1.3 Historical Summary of the Stone Industry

During colonial times, the first quarries of more than local importance were either convenient to water transportation on the coasts of Massachusetts

Table 7.1 Commercial Classification of New England Granites

Class I. Constructional

Locality	Quarry Name	Trade Name	Scientific Name
Connecticut			
Branford	Norcross	Branford red	Pegmatitic biotite granite gneiss
	Stony Creek	Stony Creek red	Pegmatitic biotite granite gneiss
	Opie	Light pink	Biotite granite
	Hoadly Neck, West	Hoadly Neck, West	Biotite granite
	Hoadly Neck, East	Hoadly Neck, East	Biotite granite
Bristol	Dunn	Bristol	Quartz monzonite gneiss
Greenwich	Ritch[a]	Greenwich black	Mica diorite gneiss
Guilford	Leete Island	Leete Island	Biotite granite gneiss
Lyme	Selden Neck	--	Hornblende-biotite granite gneiss
Norfolk	Crissey	Norfolk	Biotite-muscovite granite gneiss
Roxbury	Rockside	Roxbury	Muscovite-biotite granite gneiss
Stonington	Murray	Red westerly	Biotite granite
Torrington	Costello	--	Muscovite-biotite granite gneiss
	Michiel	--	Muscovite-biotite granite gneiss
Maine			
Biddeford	Gowan Emmons	--	Biotite granite
	Wormwood	--	Biotite granite
	Andrews	--	Biotite granite
Black Island	Upper	Black Island	Biotite granite
	Redcliff	Redcliff medium	Biotite granite
Bluehill	White	--	Biotite granite
	Chase	--	Biotite granite
Calais	Multiple	Red Beach	Biotite granite
Clark Island	Clark Island	Clark Island	Biotite-muscovite granite
Crotch Island	Ryan-Parker & Goss	Crotch Island	Biotite granite
	Sherwood Upper	--	Biotite granite
Dedham	Brown	--	Biotite granite
Deer Isle	Settlement	--	Biotite granite
Dix Island	Dix Island	Dix Island	Biotite granite
Frankfort	Mount Waldo	Mount Waldo	Biotite granite
Fryeburg	Eagle Gray	Eagle gray	Biotite granite
Green Island	Latty	--	Biotite granite
Guilford	Queen City	--	Biotite-muscovite granite
	Brawn	--	Biotite-muscovite granite
Hallowell	Stinchfield	--	Biotite-muiscovite granite
Hartland	Hartland	--	Quartz diorite
High Isle	High Isle	High Isle	Biotite granite
Hurricane Island	Hurricane Isle	--	Biotite granite
Jonesboro	Fish	--	Biotite granite
	Bodwell	Jonesboro red	Biotite granite
	Booth Bros.	--	Biotite granite
Jonesport	Hardwood Island	Moose-a-bec red	Biotite granite
Kennebunkport	Day	--	Biotite-muscovite granite
Marshfield	Marshfield	--	Biotite granite
Millbridge	Millbridge	--	Biotite granite
Moose Island	Moose Island	--	Biotite granite
Mount Desert	Hall, McMullen	--	Biotite granite
	Campbell & Macomber	Somes Sound pink	Biotite granite
Norridgewock	Lawton	--	Quartz monzonite
North Jay	Maine & New Hampshire Granite Corporation	North Jay white	Biotite-muscovite granite
Pownal	Pownal	Pownal	Biotite granite
South Brooksville	Bucks Harbor	Bucks Harbor	Biotite granite
South Thomaston	Weskeag	--	Biotite-muscovite granite

Table 7.1 (Cont'd)

Class I. Constructional			
Locality	Quarry Name	Trade Name	Scientific Name
Maine (Cont'd)			
Sprucehead Island	Sprucehead	Sprucehead	Quartz monzonite
Swans Island	Baird	--	Biotite granite
	Toothachers Cove	--	Biotite granite
Vinalhaven	Sands	--	Biotite granite
	Palmer	--	Biotite granite
	Black	--	Biotite granite
Waldoboro	Waldoboro	Waldoboro	Muscovite-biotite granite
Wells	Lord	--	Biotite granite
West Franklin	Bradbury	--	Biotite granite
Woodstock	Bryant Pond	--	Quartz diorite
Massachusetts			
Acton	Harris	Acton	Biotite-muscovite quartz monzonite gneiss
Dartmouth	Dartmouth	--	Slightly biotite-muscovite granite
Fall River	Beattie	Fall River pink	Biotite granite gneiss
	Beattie & Savoie	Fall River gray	Biotite granite gness
Fitchburg	McCauliff	Fitchburg	Muscovite-biotite granite gneiss
Groton	Shaker	Groton	Muscovite-biotite granite gneiss
Lynnfield	Robin Rock	Robin Rock green	Hornblende-augite granite
Milford	Milford	Milford pink	Biotite granite
Monson	Flynt	Monson	Quartz-mica diorite gneiss
New Bedford	New Bedford	Sullivan quarries	Biotite-muscovite granite gneiss
Peabody	Den	Peabody green	Hornblende-augite granite
Pelham	Ward	Pelham	Biotite granite gneiss
Pigeon Cove	Pigeon Cove	Rockport porphyry	Diabase porphyry
Quincy	Winquist	Quincy extra light	Riebeckite-aegirite granite
Rockport	Flat Ledge	Rockport gray	Hornblende granite
	Deep Pit[a]	Bay View gray	Hornblende granite
	Blood Ledge, Cheves	Rockport sea-green	Hornblende granite
Uxbridge	Blanchard	Uxbridge	Biotite granite gneiss
W. Chelmsford[b]	Chelmsford	Chelmsford white	Muscovite-biotite granite gneiss
Westford	Oak Hill	Oak Hill	Muscovite-biotite granite gneiss
	Snake Meadow Hill	Graniteville	Muscovite-biotite quartz monzonite gneiss
West Townsend	Barker Hill	West Townsend white	Biotite quartz monzonite
Wrentham	Curry	Wrentham	Hornblende granite
New Hampshire			
Canaan	Mascoma	Mascoma	Biotite granite gneiss
Concord	Multiple	Concord	Muscovite-biotite granite
Conway	Redstone	Conway pink	Biotite granite
	Redstone Green	Redstone green	Biotite-hornblende granite
	White Mountain	--	Biotite granite
Fitzwilliam	Snowflake	Snowflake	Biotite-muscovite granite
	Thompson	--	Muscovite-biotite granite
Kilkenny	Kilkenny	Kilkenny	Augite-biotite granite
Lebanon	Lebanon	Lebanon pink	Epidotic biotite granite gneiss
Madison	Fletcher	--	Biotite granite
Marlboro	Webb-Marlboro	Marlboro	Biotite-muscovite granite
Milford	Lovejoy	Milford, N.H.	Quartz monzonite
	Pease	--	Quartz monzonite
	Carlton	--	Quartz monzonite (probably)
Stark	Dawson	Stark	Biotite granite
Troy	Troy	Troy white	Muscovite-biotite granite

Table 7.1 (Cont'd)

Class I. Constructional

Locality	Quarry Name	Trade Name	Scientific Name
New York			
Lake Placid[c]	--	Lake Placid granite	Anorthosite
Rhode Island			
Westerly	Redstone	Red Westerly	Biotite granite
Vermont			
Barre	Millstone	Coarse light Barre	Biotite granite
Bethel	Woodbury & Ellis	Bethel white	Quartz monzonite
Derby	Lacasse	Derby gray	Quartz monzonite
Dummerston	Black Mountain	Dummerston white	Quartz monzonite
	Bailey	--	Quartz monzonite
Newark	Packer	Newark pink	Biotite granite
Plymouth	Morrison Hill	Plymouth white	Quartz monzonite
Randolph	Beedle Prospect	Fine white	Quartz monzonite
Rochester	Liberty Hill	--	Quartz monzonite
Woodbury	Fletcher & Woodbury	Woodbury gray	Biotite granite
	Vermont White	Vermont white	Biotite granite

Class I. Constructional (Category Rusty-Faced)

Massachusetts			
Hingham	Hingham, Miller & Hamilton	Hingham, or Weymouth seam faced	Aplite with limonitic stain along joint faces
Rockport	Flat Ledge	Sap faced	Hornblende granite with much limonitic stain

Class I. Constructional (Category Curbing and Trimming)

Connecticut			
Ansonia	Potter	--	Muscovite-biotite granite gneiss
Bolton	Peterson	--	Biotite granite gneiss
Bridgeport	Burlison	--	Muscovite-biotite granite gneiss
Cornwall	Benedict	--	Biotite-muscovite granite gneiss
Glastonbury	Corbin & Brooks	--	Biotite granite gneiss
	Glastonbury Granite Works	--	Biotite granite gneiss
	Danielson	--	Biotite granite gneiss
	Belden	--	Biotite granite gneiss
Litchfield	Mascetti	--	Muscovite-biotite granite gneiss
Seymour	Holbrook	--	Muscovite-biotite granite gneiss
Sterling	Marriott	Oneco	Biotite granite gneiss
	Bennett	--	Biotite granite gneiss
Torrington	Costello	--	Muscovite-biotite granite gneiss
	Michiel	--	Muscovite-biotite granite gneiss
Waterford	Scott	--	Aegirite granite gneiss
Windham	Larrabee	--	Biotite granite gneiss
Maine			
Alfred	Bennett	--	Quartz diorite
East Franklin	T.M. Blaisdell	--	Biotite granite

Table 7.1 (Cont'd)

Class I. Constructional (Category Curbing and Trimming)

Locality	Quarry Name	Trade Name	Scientific Name
Maine (Cont'd)			
Franklin	Robertson[a]	--	Biotite granite
Oxford	Roy	--	Muscovite-biotite granite
Sullivan	Crabtree & Havey[a]	--	Biotite granite
Vinalhaven	Indian Creek	--	Biotite granite
Massachusetts			
Dartmouth	Dartmouth	Dartmouth	Biotite-muscovite granite
Fitchburg	Litchfield[a]	--	Muscovite-biotite granite gneiss
Lynnfield	Robin Rock	Robin Rock	Hornblende-augite granite
Monson	Flynt	Monson	Quartz-mica diorite gneiss
Peabody	Linehan[a]	Peabody green	Hornblende-augite granite
Westford	Merrill[a]	Oak Hill	Muscovite-biotite granite gneiss
	Palmer[a]	Graniteville	Quartz monzonite gneiss
New Hampshire			
Allenstown	Bailey	Allenstown	Muscovite-biotite granite
Hooksett	Shirley	--	Muscovite-biotite granite
Manchester	Kennard Ledge	--	Biotite granite
Milford[d]	Baretta	Milford, N.H.	Quartz monzonite
Nashua	Stevens	--	Muscovite-biotite granite gneiss
Rochester	Langmaid	--	Biotite granite
Stark	Dawson	Stark	Biotite granite
New Jersey			
Glengardener[e]	--	--	Granite gneiss
Mt. Hope[e]	--	--	Granite gneiss
New York			
White Plains[f]	Lake Street	Silver Lake	Granite gneiss
Yonkers[f]	Yonkers	Mile Square	Granite gneiss

Class I. Constructional (Category Breakwater)

Connecticut			
Guilford	Sachem Head	--	Biotite granite gneiss
Stonington	Masons Island	--	Quartz monzonite flow gneiss
Massachusetts			
Rockport	Folly Point Breakwater	--	Hornblende granite
New Jersey			
Glengardner[e]	--	--	Granite gneiss
Mt. Hope[e]	--	--	Granite gneiss
New York			
White Plains[f]	Lake Street	Silver Lake	Granite gneiss
Yonkers[f]	Yonkers	Mile Square	Granite gneiss

Table 7.1 (Cont'd)

Class I. Constructional (Category Paving)

Locality	Quarry Name	Trade Name	Scientific Name
Connecticut			
Sterling	Bennett	--	Biotite granite gneiss
Maine			
Mount Desert	Snowflake	Snowflake	Biotite granite
St. George	Willards Point	--	Biotite-muscovite granite
Vinalhaven	Pequoit	--	Biotite-hornblende granite
	Duschane Hill	--	Biotite granite
	Indian Creek	--	Biotite granite
	Armbrust	--	Biotite granite
Massachusetts			
Rockport	Nickerson	--	Hornblende granite
New Jersey			
Glengardner[e]	--	--	Granite gneiss
Mt. Hope[e]	--	--	Granite gneiss
New York			
White Plains	Lake Street	Silver Lake	Granite gneiss
Yonkers[f]	Yonkers	Mile Square	Granite gneiss

Class II. Monumental

Connecticut			
East Lyme	Malnati & Carlson	Golden pink	Quartz monzonite
Groton	Salter	Groton	Quartz monzonite
	Eckerlein	Center Groton	Quartz monzonite
	Kopp	--	Quartz monzonite
	McGaughey	Mystic	Quartz monzonite
Old Lyme	MacCurdy	--	Biotitic pegmatite
Stonington	New Anguilla	New Anguilla	Quartz monzonite
Thomaston	Plymouth	--	Quartz monzonite
Waterford	Millstone	Millstone	Quartz monzonite
	Waterford	Connecticut white	Quartz monzonite
Maine			
Biddeford	Ricker	--	Biotite granite
Bluehill	Chase	--	Biotite-muscovite granite
Bristol	Round Pond	Round Pond	Quartz diorite
Calais	Gardner Prospect	--	Quartz diorite
	Beaver Lake	--	Mica-quartz diorite
	Shattuck Mountain	Shattuck Mountain	Biotite granite
	Mingo Bailey	--	Biotite granite
	Maine Red Granite Co.	--	Biotite granite
Crotch Island	Sherwood Lower	Sherwood monumental	Biotite-muscovite granite
Freeport	Freeport	--	Biotite-muscovite granite
Hallowell	Stinchfield	--	Biotite-muscovite granite
Lincoln	Lincolnville	Lincolnville	Muscovite-biotite granite
Norridgewock	Taylor	--	Biotite-mucovite granite
Searsport	Bog Hill	--	Biotite granite
St. George	McConchie	Crown black	Norite
	Long Cove	Long Cove	Biotite-muscovite granite
Swanville	Oak Hill	Oak Hill	Biotite granite
West Sullivan	Stimson	--	Biotite granite
Whitefield	Jewett	--	Quartz diorite

Table 7.1 (Cont'd)

Class II. Monumental

Locality	Quarry Name	Trade Name	Scientific Name
Massachusetts			
Acton	McCarthy	Acton, fine	Quartz monzonite gneiss
Becket	Hudson & Chester	Chester dark and light	Muscovite-biotite granite
Braintree	Stacy	Red Braintree	Riebeckite-aegirite granite, altered
Cohasset	Tiffany	Cohasset	Biotite or hornblende granite
Leominster	Leavitt	Leominster	Mica diorite
Otis	Mewhall	--	Biotite-muscovite granite
Quincy	Multiple	Quincy dark, medium, extra dark	Riebeckite-aegirite granite
	Gold-Leaf	Gold-leaf	Riebeckite-aegirite granite
Stoughton	Messer	Stoughton	Biotite or hornblende granite
Townsend	Barker Hill	West Townsend white, red	Quartz monzonite
New Hampshire			
Auburn	Auburn	Deep-pink Auburn	Quartz monzonite
Brookline	O'Rourke	Brookline	Quartz monzonite
	Fessenden	--	Quartz monzonite
Fitzwilliam	Victoria White	Victoria white	Biotite-muscovite granite
Haverhill	Pond Ledge	Pond Ledge gray, pink	Biotite-muscovite granite
Millford	Young	Dark blue New Westerly	Quartz monzonite
	New Westerly	New Westerly blue	Quartz monzonite
	Tonnella	Millford (N.H.)	Quartz monzonite
	Souhegan	Souhegan	Quartz monzonite
Sunapee	Perry Sunapee	Light Sunapee	Biotite-muscovite granite
Troy	Troy	Troy white	Muscovite-biotite granite
New York			
Lake Placid[c]	--	Lake Placid granite	Anorthosite
Rhode Island			
Charlestown	Klondike	Blue-white Westerly	Quartz monzonite
Westerly	New England & Smith	Blue Westerly	Quartz monzonite
		Pink Westerly	Quartz monzonite
Vermont			
Barre[g]	Bruce[a]	Dark Barre	Biotite granite
	Duffee[a]	Medium Barre	Biotite granite
	Jones Light[a]	Light Barre	Biotite granite
Barton	Barnard	Barton	Biotite granite
Cabot	Lambert Prospect	Dark gray	Quartz monzonite
Calais	Patch	Medium gray	Biotite granite
Derby	Lacasse	Derby gray	Quartz monzonite
Groton	Benzie	Vermont blue	Quartz monzonite
Hardwick	Buffalo Hill	Dark-blue Hardwick	Quartz monzonite
Kirby	Grout	--	Biotite granite
	Burke	--	Quartz monzonite

Table 7.1 (Cont'd)

Locality	Quarry Name	Trade Name	Scientific Name
Class II. Monumental			
Vermont (Cont'd)			
Ryegate	Gibson[a]	Ryegate	Quartz monzonite
	Rosa	Fine gray	Biotite granite
		Coarse gray	Biotite granite
Woodbury	Fletcher & Woodbury Granite Co.	Woodbury gray	Biotite granite
	Bashaw	Woodbury Bashaw	Biotite granite
	Imperial Blue	Imperial blue	Biotite granite
	Nicols Ledge, Carter	--	Biotite granite
Class II. Monumental (Category Sculptural)			
Connecticut			
Groton	Salter	Groton	Quartz monzonite
Waterford	Waterford	Connecticut white	Quartz monzonite
Maine			
Hallowell	Stinchfield	Hallowell	Biotite-muscovite granite
New Hampshire			
Fitzwilliam	Victoria White	Victoria white	Biotite-muscovite granite
Milford	New Westerly	New Westerly blue	Quartz monzonite
	Tonella	Milford (N.H.)	Quartz monzonite
Troy	Troy	Troy white	Biotite-muscovite granite
Rhode Island			
Westerly	New England & Smith[a]	Blue Westerly	Quartz monzonite
		Pink Westerly	Quartz monzonite
Vermont			
Barre	Jones Light[a]	Light Barre	Biotite granite
Woodbury	Bashaw	Woodbury Bashaw	Biotite granite
Class II. Monumental (Category Inscriptional)			
Connecticut			
East Lyme	Malnati & Carlson	Golden pink	Quartz monzonite
Waterford	Millstone	Millstone	Quartz monzonite
	Waterford	Connecticut white	Quartz monzonite
Maine			
Addison	Pleasant River	Black granite	Hypersthene-olivine gabbro
Baileyville	Hall	--	Norite
Berwick	Miniutti	--	Gabbro
Calais	Mingo Bailey	--	Norite
Hermon	Hermon Hill	--	Altered diabase prophyry
Lincoln	Heal	--	Olivine norite
Vinalhaven	Bodwell	--	Olivine norite
West Franklin	Bianchi	Emerald granite	Saussuritized gabbro
New Hampshire			
Millford	Souhegan	Souhegan	Quartz monzonite
Sunapee	Perry Sunapee	Dark Sunapee	Quartz diorite

Table 7.1 (Cont'd)

Locality	Quarry Name	Trade Name	Scientific Name
Class II. Monumental (Category Inscriptional)			
Rhode Island			
Westerly	New England & Smith[a]	Pink Westerly	Quartz monzonite
Vermont			
West Windsor	Mower	Ascutney green	Hornblende-augite granite
Windsor	Norcross	Windsor	Hornblende-augite granite
Class II. Monumental (Category Polish)			
Maine			
Crotch Island	Ryan-Parker & Goss	Crotch Island	Biotite granite
Jonesport	Hardwood Island	Moose-a-bec Red	Biotite granite
Moose Island	Moose Island	Crotch Island	Biotite granite
Massachusetts			
Cohasset	Tiffany	Cohasset	Biotite or hornblende granite
Peabody	Linehan & Den	Peabody green	Hornblende-augite granite
Quincy	Multiple	Quincy dark, medium, extra dark	Riebeckite-aegirite granite
Rockport	Flat Ledge[a]	Rockport light gray	Hornblende granite
	Blood Ledge[a]	Rockport sea green	Hornblende granite
	Bay View Prospect	--	Riebeckite-aegirite-biotite granite
	Pigeon Cove Porphyry	Rockport porphyry	Diabase porphyry
New Hampshire			
Conway	Redstone	Conway pink	Biotite granite
		Redstone green	Biotite granite
Madison	Fletcher	--	Biotite granite
New York			
Lake Placid[c]	--	Lake Placid granite	Anorthosite
Vermont			
West Windsor	Mower	Ascutney green	Hornblende-augite granite
Windsor	Norcross	Windsor	Hornblende-augite granite

[a]Additional quarries in the locality produce the same type of stone.

[b]Mould (1981).

[c]Fickies (1981).

[d]Davis (1981).

[e]Dombroski (1981).

[f]Barrego (1981).

[g]Granite currently produced at this locality goes by the name of "Rock of Ages."

Source: Adapted in part from Dale (1923).

Table 7.2 Historical and Projected Commercial Stone Mining by State

State	Remarks
Maine (Plate II)	In 1923, 77% of the 93 commercial granite-quarrying areas was situated within 8 km (5 mi) of the Atlantic coastline. A disproportionate number were located in the Mt. Desert area, and an additional 8% was clustered along the St. Croix River. The remaining 15% was located within 8 km (5 mi) of a railroad. Between 1923 and 1958, several inland quarries were opened along a line trending roughly northeast-southwest and approximately 80 km (50 mi) from the sea. Rand (1958) listed 165 granite quarries and prospects in 1958. Lepage (1981) indicated there are no dimension-stone quarries open today.
New Hampshire (Plate III)	Northern New Hampshire had two granite-quarrying localities -- the Mt. Cabot and Conway areas. Southern New Hampshire had many more, especially in the southeast. All stone quarries in the state were located near the Boston and Maine Railway system. Concord and Milford are the only two quarries currently mining dimension stone (Davis, 1981).
Vermont (Plate IV)	Granitic rocks were mined commercially in eastern and north-central Vermont. The north-south trending Boston and Maine Railway, which parallels the west bank of the Connecticut River, forms one transportation network that services the state's northern quarries. The famous Barre granite quarries (Rock of Ages Co.) are located in north-central Vermont, near Montpelier. There are four dimension-stone quarries currently operating in Vermont, three of which are in the Barre area; the other quarry is in Woodbury (Ratte, 1981).
Massachusetts (Plate VI)	Many granite operations lie between Fitchburg and Rockport, and there were five quarries in the Boston Bay area. On the south coast near Buzzards Bay, there were three more granite-quarrying operations. Other isolated granite quarries were located in an east-west trend from Stoughton to Palmer/Amherst, -- a distance of about 113 km (70 mi). Becket, to the west, was an isolated center. While most of these quarries have closed, West Chelmsford and Milford are still dimension-granite centers (Mould, 1981). Approximately 35% of Massachusetts's stone industry is located within 8 km (5 mi) of water transportation -- the rest are linked to markets by railroad.

Table 7.2 (Cont'd)

State	Remarks
Connecticut (Plate VII)	Two trends in granite production are evident, both of which trend roughly west to east. The northern trend, which extends from Plymouth eastward to the Rhode Island border, also parallels the tracks of the New York, New Haven, and Hartford Railroad. The southern trend extends from Greenwich eastward to the Rhode Island border and parallels Long Island Sound; all of the quarries on this trend were located within 3.2 km (2 mi) of the above-mentioned railroad. Other isolated commercial ventures were located along the Connecticut River or along other railway systems. There are no large dimension-granite quarries left in Connecticut -- only basalt (Quarrier, 1981).
Rhode Island (Plate VIII)	Only two granite-quarrying operations existed, both of which were on the south coast near Block Island Sound and adjacent to the New York, New Haven, and Hartford Railroad. There are no dimension-granite quarries currently operating in Rhode Island, although there is renewed interest in the blue granites of Westerly (Morra, 1981).
New York (Plates V and IX)	Granite gneisses are being mined for construction purposes in East White Plains and Yonkers of populous Westchester County, but these operations now labor under so many environmental and residential ordinances that they may shut down (Barrego, 1981). There are isolated areas of charnokitic or syenitic gneiss elsewhere in the Adirondacks. (The Lake Placid "granite" is really an anorthosite.) Fickies (1981) indicates that trap rock is mined from the Palisades in southwestern New York along the Hudson River.
New Jersey (Plate IX)	No dimension-stone industry remains in New Jersey (Dombroski, 1981). The granite industry is now a crushed-rock industry, mainly because granite gneiss is a poor stone for monumental purposes. Triassic trap rock is mined in the eastern part of the state, while the granite gneiss operations are located west of Wachtung and the Palisades (Dinger, 1981).
Pennsylvania (Plate IX)	This state has no granite industry per se. Some diabases from the Triassic basin in southeastern Pennsylvania are being used as dimension stone, but most of the trap rock is being used as riprap for shore erosion control, as railroad ballast, and as crushed aggregate (Berkheiser, 1981).

and Maine or were close enough to cities to be serviced by teams of oxen. The Quincy granite was the leading building granite during the early 1800s. The rapid growth of American commerce, with the resulting requirements for harbor improvements and coastal protection, created a strong demand for granite for the construction of jetties, sea walls, wharves, and forts. Rock was quarried at first from Quincy and Cape Ann, Mass., and later from Rhode Island and Connecticut.

Prior to 1850 inland granites satisfied only a small market, although a few well-known buildings (e.g., the state capitols of New Hampshire and Vermont) were built of these granites. By 1850, however, the construction of railways for hauling granitic rock created more extensive markets for inland stone. One of these new markets was for granite paving blocks in New York City, Boston, and Philadelphia. Granite curbing also was popular in the big cities.

At the time of the 1860 census, the granite industry in Maine and Massachusetts was considered very prosperous. While the 1870 census suggests a substantial increase in the total value of output of the leading quarries compared with the 1960 census, the comparison is obscured by the high inflation after the Civil War (Dale, 1923). During the 25-30-yr period after the Civil War, the granites that had been the most prominent before the war still led in production. The darker red granites of Maine, the dark bluish-gray granite of Quincy, Mass., and the lighter gray granites of Rockport, Mass.; Hallowell, Maine; and Concord, N.H., were prominent among building stones. However, tastes gradually changed in favor of lighter colored granites; by 1900 the pale-pink granites of the Penobscot Bay district, Maine, and Milford, Mass., had become prominent. The use of granite for monumental stone was popular by 1880, and the granites of Barre, Vt.; Quincy, Mass.; and Westerly, R.I.; became famous throughout the country.

Demand for New England granites reached a peak during 1911-1914; following this period, rapidly increasing production of portland cement created stiff competition. The effect was to restrict granite to more costly buildings.

7.1.4 Commercial Potential of the Stone Industry

The following comments were provided by George W. Bain, Professor Emeritus, Amherst College, Amherst, Mass.

> Dimension stone was the principal carrying product for quarries until the depression of 1929-1935, although some trends were evident which have become dominant factors today. Capacity of a quarry product to resist undesirable change after installation was one factor. Another was a progressive tendency to use expensive dimension stone in large sizes only. Quarries with either sheeting or jointing

at high frequency lost their market because they could not furnish larger sizes competitively: this eliminated most of the quarries in the "northeast kingdom," and also Dummerston in Vermont. Monumental stone was a major market until cemeteries began to become "parks," which discouraged use of headstones and mausoleums. These are irreversible trends affecting the market adversely. Barre and Woodbury, Vt.; Quincy, Mass.; and Branford, Conn., continued to prosper because they could supply on order any size of good quality stone. Others were Milford, N.H., and West Chelmsford, Maine. The highly jointed granite at S. Weymouth, Maine, yielded excellent split face veneer with an antique stain.

In any quarry site, the surface rock and rock to a depth of 50 ft have some supergene carbonates that weather easily and either stain or support lichen growth. Many of the early small operations promoted stone with this quality and fell into disrepute. The carbonate problem is particularly bad in deposits with intense sheeting. Sheeting structures are undesirable and are caused by spontaneous expansion. They are attended by parallel zones of minute fractures that extend for up to a foot from the sheeting surface.

Almost all existing or former granite quarries are on small bodies; those on larger masses are close to the margin and most have been abandoned. The Stony Creek, Milford, and Chelmsford granites are essentially injection gneiss which in some places is almost massive.

Most operations that can furnish blocks of any specified size have attained depth below the zone of frequent sheeting structure. The rock has great internal compressive strain, and spontaneous bursts destroy many blocks. Once a block is removed, however, the stress is dissipated uniformly towards all faces. Operating a quarry profitably to the required depth was attained at a few sites only; none were in Maine, and the most successful were at Barre and Woodbury, Vt.

Figure 7.1 illustrates economic trends for the crushed-igneous-rock and the cut-dimension-granite industries for the period 1977-1979. Although Maine and Rhode Island withheld all information, they are not significant producing states. The approximations prepared by the authors were $11 million (1978) and $12.7 million (1979) for Vermont, and $30 million (1977) and $31 million (1978) for Massachusetts. The five states with significant trap rock mining operations are Massachusetts, Connecticut, New York, New Jersey, and Pennsylvania.

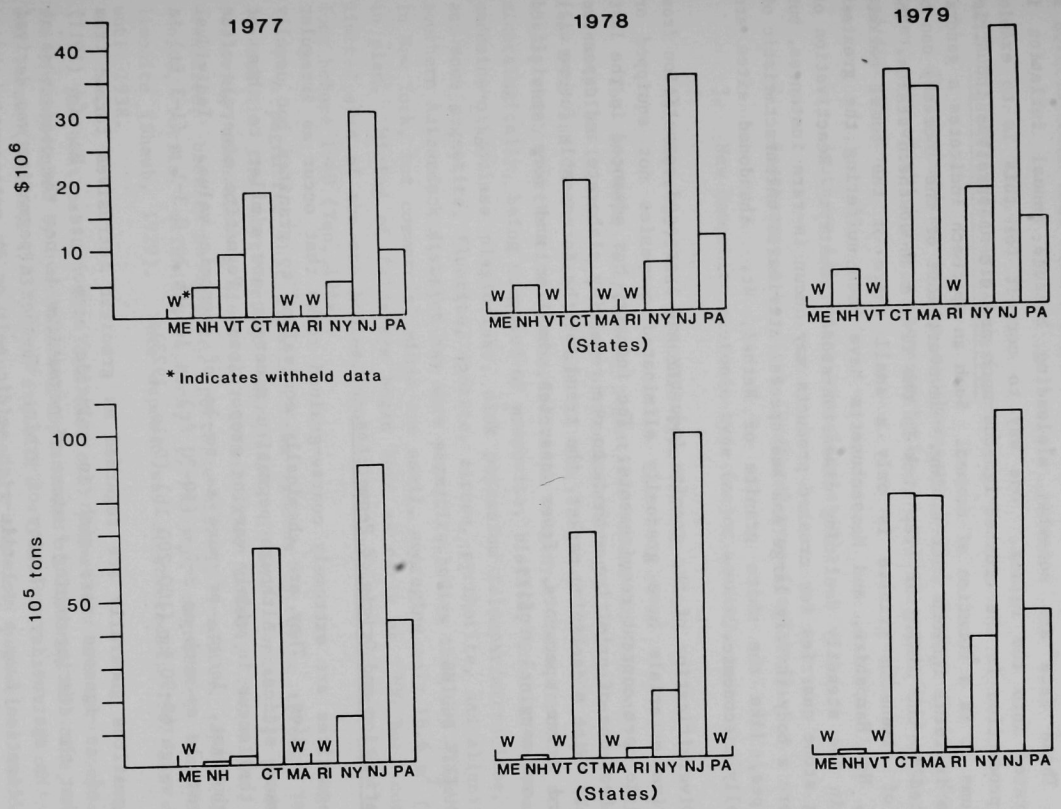

Fig. 7.1 Production Statistics and Economic Value of Crushed Igneous Rock and Cut Dimension Stone (granite), 1977-1979

The total value of both crushed igneous rock and dimension stone in the northeast was greater than $108 million in 1977 (assuming $30 million for Massachusetts), more than $119 million in 1978 (assuming $11 million for Vermont and $31 million for Massachusetts), and more than $159 million in 1979. These data are somewhat misleading because annual inflation is incorporated into the values. One way to correct for this is to examine annual production in the crushed-igneous-rock and dimension-stone industries and assume it is a function of demand. Such an approach indicates a general increase in total igneous rock mining. However, most of the increase can be attributed to the mining of trap rock in the five more southern states. The mining of dimension granite is only a small share of the total market; Vermont, New Hampshire, and Massachusetts have been suffering the greatest losses in the steadily declining dimension-stone industry. Reactivation of building stone quarries for crushed products may occur in rare instances, but only where a body is very large and has special attributes uncharacteristic of rock types, like the white granite of Bethel, Vt. Abandoned sites are essentially uneconomic.

Diversification of the granite industry and increased competition from alternative materials have gradually eliminated companies not equipped or financed to meet current requirements. The industry has advanced in the last century from one of primitive methods to one requiring elaborate and expensive equipment. With a declining market, the trend for the foreseeable future will be toward fewer operators, fewer quarries, smaller and more specialized markets, and marginal profits.

7.2 PEGMATITE BODIES

7.2.1 Definition and Origin of Pegmatites

Pegmatites are extremely coarse-grained rocks that occur as irregular or tabular bodies. They are chemically equivalent to granites but usually contain more silica. Although pegmatite minerals are similar to those of granite, they occur in widely varying proportions. Pegmatite minerals often are so abundant, large, or pure as to be of economic value. Individual crystals can be as much as 3-9 m (10-30 ft) in length by 0.3-1 m (1-3 ft) in width and weigh 45-90 kg (100-200 lb) (Dale, 1923).

Pegmatites generally are regarded as granitic intrusives formed from portions of an igneous mass rich in volatile components. Bastin (1911) claimed that the distinguishing feature of pegmatites is not the coarseness of grain but the extreme irregularity of grain. Whether a pegmatite was derived by crystallization from a volatile-rich acidic melt or by metasomatism is an important question for students of pegmatites. Adirondack-type pegmatites in New York are thought to be derived from melts (Tan, 1966). The remainder of the pegmatites in the northeastern United States are of both types. Those formed from melts are important economically because they are larger and are

the source of many important minerals (Cameron et al., 1949). Gem-bearing pegmatites are characterized by a higher percentage of sodium, lithium, and phosphorus, and probably by more water vapor and a slightly lower temperature of crystallation than normal pegmatites (Bastin, 1911).

7.2.2 Classification of Pegmatites

The pegmatites in the northeastern United States are of four main types, each of which has a characteristic mineralogy, appearance, age, origin, and distribution:

1. Southern Adirondack type (depleted).

2. Southeastern New York (Bedford) type (depleted).

3. New Hampshire plutonic type (major source).

4. Late Devonian plutonic type (rare).

The southern Adirondack pegmatites occur in regions of high-grade metamorphism (granulite facies) of Precambrian age. Age determinations using the K-Ar and Rb-Sr methods fall in the range of 900-1100 m.y. (Isachsen, 1963), which was the time of the Grenville orogeny. These deposits are simple mineralogically, being composed of muscovite, biotite, hornblende, tourmaline, andesine-oligoclase plagioclase, pink potassium feldspar/microcline, quartz, and some magnetite, fluorite, apatite, zircon, pyrrhotite, and allanite. The southern Adirondack district has more pegmatite bodies than any other district in New York, but commercial mines are small, averaging only 18.6 m^2 (200 ft^2) in plan. Mining of feldspars began here as early as 1906 but, due to the limited size of the ore bodies, most of the economic minerals were extracted long before 1940 (Tan, 1966).

A pegmatite that resulted from igneous intrusion through limestone, located in the northwestern Adirondacks (DeKalb Junction), produced the following minerals: diopside, tremolite-actinolite, tourmaline, quartz, uraninite, biotite-phlogopite, perthite-microcline-albite, apatite, molybdenite, rutile, allanite, sphene, pyrrhotite, magnetite, kaolinite, and limonite (Shaub, 1929). This deposit was discovered in 1907 and was mined until 1938.

The southeastern New York (Bedford) pegmatites are very complex. They are distinguished by hydrothermal replacement of lithium, fluorine, beryllium, and boron (Landes, 1933), and exhibit a structure consisting of concentric shells, or zones. In addition, these are the only pegmatites marked by the presence of beryl and large muscovite books (Tan, 1966). Radiometric age determinations indicate that these pegmatites are about 360 m.y. old -- much younger than the Adirondack pegmatites. Only one pegmatite locality in the Adirondacks, Batchellerville, has the complexity of the Bedford type.

The Bedford pegmatite district has three major quarries, all situated within an area of 3.2-km (2-mi) radius south of Bedford Village in densely populated Westchester County, N.Y. Feldspar mining began there in 1878, and annual production of this ceramic-quality feldspar had been several thousand tons per year. Beryl alone averaged 0.9 t/yr (1 ton/yr). A rapid decline in the feldspar market and competition from nepheline closed two of these quarries in 1949. As of 1966, the Baylis quarry was still active.

The New Hampshire plutonic series contains the major pegmatite deposits in the northeastern region. The pegmatites are of many different ages, as shown by their crosscutting relationships. All are white, gray, or buff (Page, 1968). Cameron et al. (1949) suggested the following order of pegmatite age in any given pluton: cross-foliated pegmatites (oldest), segregation pegmatites, layered pegmatites, gneissoid pegmatites, homogenous pegmatites, and zoned pegmatites (youngest). All of these pegmatites crystallized from magmas forcibly injected, as indicated by the development of induced foliation at their edges and by other structures caused by flow of viscous liquids (Cameron et al., 1949). These pegmatites are related to syntectonic and early posttectonic events. Crosscutting faults of late Paleozoic age suggest a minimum age of pegmatitic intrusion at 350 m.y. (Page, 1968).

The simple pegmatites, namely the cross-foliated, segregation, gneissoid, and homogenous pegmatites, have few minerals. They usually consist only of quartz, feldspars, mica, and tourmaline. They are by far the most abundant type, forming dikes from a centimeter to meters in width in granites and other rocks, and irregular dikes, lenses, and pockets in gneisses and schists (Moorehouse, 1959). Simple pegmatites are not important economically.

Complex pegmatites are zoned and result from progressive crystallization of hydrous sialic magmas having low melting temperatures. The magmas probably approximate the eutectic composition of the granitic system. Complex pegmatites often are large, mappable units that may contain many important minerals and gems. They often have a coarse-grained core that may contain rare-earth minerals. A distinct mineral zoning can be identified, which suggests complex paragenesis. Complex pegmatites are relatively rare but are very important economically. Table 7.3 is a list of minerals found in the complex pegmatites of the New Hampshire plutonic series.

In the rich, gem-bearing pegmatites, the zone of sodium and lithium minerals is generally separated from normal pegmatite by a highly garnetiferous zone from several centimeters to 10 cm in width. These garnet bands are frequently used to map the gem-bearing lode. The pegmatite outside this marker band is invariably barren of gems (Bastin, 1911).

The relatively rare pegmatites of Page's (1968) Late Devonian plutonic series are readily distinguished by the presence of flesh-pink potassium feldspar. They have been radiometrically dated as being 330-385 m.y. old by Rb-Sr methods. They are generally more radioactive than the earlier Oliverian (Taconic) or New Hampshire (Acadian) plutonic rocks, and they or Oliverian

Table 7.3 Minerals of the Complex Pegmatites of the New Hampshire Plutonic Series

Allanite	Garnet
Amblygonite	Lipidolite
Andesine/oligoclase (light green)	Muscovite
Apatite	Potassium feldspar (buff to light pink)
Beryl (aquamarine and golden beryl)	Quartz (clear, rose, or smoky)
Biotite	Sphene
Brazilianite	Spodumene
Calcite	Sulfides (associated)
Cassiterite	Topaz
Clevelandite	Tourmaline
Columbite-tantalite (rare-earth minerals)	Uraninite
	Zircon

Sources: Bastin, 1910 and 1911; Sterrett, 1923; Rand, 1957-1959; and Page, 1968.

associated with metallic sulfide mineral deposits (Page, 1968). There are no metallic sulfide deposits associated with the earlier New Hampshire plutonic series rocks.

7.2.3 Distribution and Status of Pegmatite Mining

Table 7.4 gives the distribution of mines and the status of pegmatite mining in the northeast.

7.2.4 Gem Mining Industry

Gemstones in the northeast have pegmatitic, syenitic, ultramafic, and metamorphic associations. Gemstone localities are given in Table 7.5.

7.2.5 Commercial Potential of the Pegmatite and Gem Mining Industries

The large number of pegmatite localities shown on Plates II-IX could give a misleading impression of their importance. Pegmatites of economic importance rarely occur within a granitic pluton. Most are found in schists beyond the boundaries of the granitic body.

Muscovite-bearing pegmatites of New England were removed almost entirely during World War II. Pegmatites containing beryl have insufficient reserves to be exploited except during a strategic emergency (Bain, 1981). Gem-bearing pegmatites yield only enough material to keep mineral clubs

Table 7.4 Distribution of Mines and Status of Pegmatite Mining, by State

State	Remarks
Maine	With the exception of one simple pegmatite, the Getchell Mountain prospect in central Maine (Penobscot County), all 184 commercial pegmatite quarries are located in south-southwestern Maine. The greatest density of mines is in Oxford, Androscoggin, and Sagadahoc counties (Rand, 1957-1959). Many of these pegmatites are mineralogically complex and contain lithium, uranium, tin, boron, beryllium, and rare-earth-bearing minerals and gems. When the Oxford Feldspar Corporation terminated operations in 1977, the ceramic insulator market in Maine ended. One small garnet mine was opened in 1979 in West Paris and, in the same year, Plumbago Mining Corporation discovered a number of gem-bearing pockets at Mount Mica. Spodumene and lepidolite are still mined in Paris. These pegmatite districts belong largely to the New Hampshire plutonic series. The total value of Maine's gem industry is estimated at several thousand dollars (Minerals Yearbook, 1981).
New Hampshire	The bulk of pegmatite mining is in Rumney, Wentworth, Groton, Dorchester, Orange, Alexandria, Grafton, Springfield, and Wilmot counties in the west-central part of the state and Cheshire, Alstead, Marlow, Gilsum, and Sullivan counties in the southwestern part (Meyers and Stewart, 1955). These pegmatite districts belong largely to the New Hampshire plutonic series (see Plate III). Currently, there is renewed interest in the South Ackworth area (Bain, 1981). Gem collectors still pick the dumps but the industry is small. Although the state was once an important source of mica, the state's mica operations have been inactive for many years. Two companies produce fabricated mica products from foreign sources (Minerals Yearbook, 1981).
Vermont	One very small simple pegmatite, the Allen mica mine in Sherburne, has been mined commercially. Only one other pegmatite is of possible future interest; it occurs on the east side of Lake Willoughby in northeastern Vermont (Grant, 1968). The U.S. Saimica Corporation in Rutland manufactures mica products but imports its mica (Minerals Yearbook, 1981).
Massachusetts	Six previously active localities for pegmatite mining are located in western Massachusetts in Hampshire and Worchester counties. Their gem and pegmatite resources are exhausted. Large synthetic sapphires are being produced by Crystal Systems, Inc., of Salem (Minerals Yearbook, 1981).

Table 7.4 (Cont'd)

State	Remarks
Rhode Island	No commercial pegmatites occur in this state.
Connecticut	A major pegmatite mining area was located in Middlesex County in the central part of the state. More than 26 pegmatite mining operations existed in the Middletown-Portland area, and a few more extended north into Hartford County (Pearre, 1957). Isolated pegmatite quarries in western Connecticut include the West Simsbury, West Cornwall, Gaylordsville, and Georgetown prospects. Some feldspar was still being mined in 1977 in Middlesex County; crude mica was recovered as a coproduct and sold for the manufacture of gypsum wallboard and cement (Minerals Yearbook, 1981). Gem collectors still search the Middletown and Roxbury pegmatites, where the world's finest gem garnets were once mined.
New York	The southern and eastern Adirondacks once had over 13 pegmatite mining localities, but their small reserves have been exhausted. A few metamorphosed pegmatites in the northwestern Adirondacks also have been depleted. Far to the southeast, complex pegmatites were once mined from two localities in the Bedford district (Tan, 1966). The pegmatite mining industry in New York no longer exists, but the value of gems collected by amateurs was estimated to be $20,000 in both 1978 and 1979 (Minerals Yearbook, 1981).
New Jersey	No commercial pegmatites are present in this state. The estimated $17,000 value of the New Jersey gemstone industry in 1977-1978 (Kebblish and Widmer, 1979) comes fron non-pegmatitic associations.
Pennsylvania	A few simple pegmatites in southeastern Pennsylvania are present. The Gross Minerals Corporation, located in Adams County, produced 4000 tons of scrap and flake mica in 1979 by pulverizing schists and pegmatites.

Table 7.5 Gemstone Localities, by State

State	Location and Type of Gemstones
Maine	Hancock Co., Little Deer Isle: serpentine; Kennebec Co., Litchfield Twp.: sodalite; Sagadahoc Co., Topsham area: beryl, topaz, tourmaline; Phippsburg area: beryl, apatite; Androscoggin Co., Minot Twp., Mt. Apatite: beryl, topaz, tourmaline, apatite, lepidolite; Poland Twp., Berry Quarry: tourmaline, apatite; Oxford Co., Rumford Twp., Black Mt. Mica Mine: spodumene, lepidolite; Peru Twp., Hedgehog Hill: beryl, chrysoberyl; Newry Twp., Plumbago Mt. area: beryl, spodumene, tourmaline, beryllonite, amblygonite; Hartford Twp., Ragged Jack Mtn.: chrysoberyl; Buckfield Twp.: beryl, tourmaline, pollucite; Greenwood Twp., Noyes Mtn. area: beryl, tourmaline, petalite, pollucite, apatite; Albany Twp.: beryl, quartz; Stoneham Twp.: beryl, topaz, phenakite, beryllonite; Norway Twp., Nobles Corner: tourmaline; Paris Twp., Mt. Mica: beryl, tourmaline; Hebron Twp.: tourmaline; Denmark Twp., Pleasant Mtn.: quartz; Stow Twp., Deer Hill: quartz; Cumberland Co., Windham: staurolite; York Co., Newfield Twp., Straw Hill: sodalite.
New Hampshire	Coos Co., Milan Twp., Greens Ledge: topaz, quartz; Stark Twp., Diamond Ledges: topaz, quartz; Victor's Head: topaz; Percy Peak, Hutchins Mtn., Kilkenny Twp., Northumberland Twp., etc.: quartz; Carroll Co., South Baldface Mtn.: topaz, phenakite; Conway: topaz, apatite; Lovejoy Gravel Pits: topaz; Grafton Co., Sugar Hill area: quartz, staurolite; Groton Twp., North Groton, Palermo Mine No. 1: brazilianite, lazulite; Fletcher Mtn., Valencia Mine: beryl; Sullivan Co., Springfield Twp., Pillsbury Ridge, Reynolds Mine, Columbia Mine: beryl; Chandler's Mill, Smith Mica Mine: lazulite, augelite; Grantham, Claremont: staurolite; Merrimack Co., Wilmot Twp., Grafton, Severance Hill: beryl; South Danbury, Filbert Farm: beryl; Cheshire Co., Gilsum, Wenham Mine: quartz; Island Mica Mine, Britton Mine: beryl; Roxbury Twp., Keene, Bassett Hill: beryl; Westmoreland Twp., Chesterfield Twp.: fluorite.
Vermont	Chittenden Co., Burlington, Parrott Farm: quartz; Washington Co., Cabot: staurolite; Rutland Co., Round Hill: quartz; Windham, Rochester, Warren Valleys: serpentine.
Massachusetts	Essex Co., Newbury Twp., Newburyport: serpentine; Middlesex Co., Westford: andalusite; Worcester Co., Bolton: scapolite; Lancaster: andalusite; Royalston: beryl; Franklin Co., Deerfield: quartz; Hampshire Co., Pelham: apatite; Amherst area: quartz; Goshen, Lithia: beryl, spodumene; Cummington Twp.: rhodonite; Chesterfield Twp.: staurolite; Hampden Co., Westfield Lane Quarry: datolite, prehnite; Chester: diaspore; Nantucket Island, Martha's Vineyard

Table 7.5 (Cont'd)

State	Location and Type of Gemstones
Rhode Island	Cumberland Twp., Diamond Hill, Calumet Hill: quartz; Lincoln Twp., Dexter Quarry, Limerock area: serpentine; Pawtucket: quartz; Briston, Mt. Hope area: quartz.
Connecticut	Hartford Co., East Granby, Roncari Quarry: datolite; Farmington area: quartz; Litchfield Co., Torringford, Woodbury: quartz; New Milford Twp., New Milford, Roebling (Merryall) Mine: beryl; Litchfield Co.-Middlesex Co.: staurolite; Middlesex Co., Middletown area: beryl; Portland Twp., Strickland Quarry: beryl, spodumene, tourmaline, quartz, apatite; Pelton Quarry: quartz; East Hampton Twp., Slocum Quarry: beryl; Middletown Twp., Riverside Quarry: beryl; Haddam Twp., Gillette Quarry: tourmaline; New Haven Co., Guilford Twp., Hungry Horse Hill: iolite; Milford-West Haven: quartz; Fairfield Co., Trumbull Twp., Long Hill: topaz.
New York	St. Lawrence Co., Massena: diamond; DeKalb Twp., Richville, Reese Farm: tourmaline; Mitchell Farm: diopside; Gouverneur: tourmaline; Gouverneur, Oswegatchie River: serpentine; Hailesboro: tourmaline, apatite; Mcomb: fluorite; Fowler: tremolite; Jefferson Co., Muskalonge Lake: fluorite; Pillar Point: barite; Lewis Co., Bonaparte Lake: wollastonite; Natural Bridge: serpentine; Essex Co., Keeseville, Mineville, Opalescent River: feldspar; Newcomb: feldspar, tourmaline; Olmstedville: feldspar; Warren Co., Horicon, Burnt Lake: tourmaline; North Creek area: garnet; Saratoga Co., Saratoga Springs: chrysoberyl; Overlook: quartz; Herkimer Co., Middleville area: quartz; Schoharie Co., Schoharie, Catskill: quartz; Dutchess Co.: serpentine; Putnam Co., Prewster, Tilly Foster Mine: apatite, sphene, chondrodite; Westchester Co., Bedford area: quartz; Portchester: serpentine; Rockland Co.: serpentine; New York Co., Borough of Richmond (Staten Island): serpentine; Kreischerville: amber; Erie Co., Buffalo: calcite.
New Jersey	Sussex Co., Newton, Sparta, Franklin: corundum; Franklin: rhodonite, idocrase, axinite, sphalerite, zincite, willemite, friedelite, hodgkinsonite, serpentine; Ogdensburg: rhodonite, sphalerite, zincite, willemite, friedelite, hodgkinsonite; Passaic Co.: quartz, datolite, natrolite; Great Notch, Paterson, etc.: opal; Paterson area: prehnite; Packanach Lake: pectolite; Bergen Co.: quartz, datolite, natrolite; Essex Co.: quartz; Upper Montclair, Short Hills: prehnite; Morris Co.: quartz; Lake Valhalla: serpentine; Dover: opal; Alan Wood Mine: feldspar; Millinton: prehnite; Union Co., Summit, Plainfield, North Plainfield: prehnite; Somerset Co.: quartz; Somerville: turquoise; Bound Brook, Rocky Hill,

Table 7.5 (Cont'd)

State	Location and Type of Gemstones
New Jersey (Cont'd)	Somerville: prehnite; Hunterdon Co.: quartz; Mercer Co.: quartz; Princeton, Hopewell: prehnite; Burlington Co., Crosswicks Creek, Vincentown: amber; Gloucester Co., Mantua Creek, Oldmans Creek: amber; Salem Co.: amber.
Pennsylvania	Northampton Co., Lower Saucon Twp., South Mtn.: quartz; Easton, Chestnut Hill, Bushkill Creek: serpentine; Lehigh Co., Upper Milford Twp., Shimersville: corundum; Vera Cruz: quartz; Southampton Twp., Vanartsdalen Quarry: feldspar; Montgomery Co.: quartz; Delaware Co., numerous localities for: corundum, beryl, feldspar, garnet, quartz, sphene; Chester Co., numerous localities for: feldspar, quartz, apatite, diaspore, serpentine; Lancaster Co., Bart Twp., Paradise Twp., Fulton Twp., Rock Springs Twp.: quartz; Schuylkill Co., Mahonoy City-Pottsville area: pyrite; Luzerne Co., Hazleton, W. Pittston: pyrite; Wilkes Barre area: anthracite; York Co., York Haven: quartz; Cumberland Co., Carlisle: quartz; Adams Co., Hamilton Twp.-Washington Twp. area: copper rhyolite; Buchanan Valley, Piney Mtn.: piedmontite; Franklin Co., Orrison Cove: quartz; Westmoreland Co., Greensburg: quartz.

Source: Sinkankas (1959).

active; most gem shops in Maine and New Hampshire are stocked with imported material. In sum, the best pegmatite mines have been exhausted, uneconomic mines have been abandoned, and the commercial potential of the pegmatite and gem industries of the northeast is extremely poor.

7.3 MAFIC AND ULTRAMAFIC ROCKS

7.3.1 Definition and Description

Ultramafic rocks are dark colored and contain little or no quartz or feldspar. They are composed chiefly of olivine, pyroxene, and/or amphibole, and commonly contain the following accessory minerals: spinel, magnetite, diamond, melilite, sodalite, and serpentine. Ultramafics are associated with intensely folded mountain chains as intrusive bodies exposed through erosion. Mafic rocks also are dark colored but contain calcic plagioclase in addition to olivine, pyroxene, and amphibole. The most common mafic and ultramafic rocks encountered in the region are listed below:

- Dunites are green, granular rocks composed essentially of olivine, with minor amounts of chromite. They are not mined commercially in the region.

- Peridotites contain olivine and pyroxenes, with little or no quartz or feldspar. Diamond has been reported from peridotites at Massena, N.Y. Steatite (talc) is sometimes associated with unmetamorphosed peridotites or pyroxenites.

- Pyroxenites are composed essentially of pyroxenes.

- Amphibolites are composed essentially of amphiboles. The spinel-free emery deposits of Chester, Mass., are associated with altered amphibolites (Friedman, 1956).

- Cumberlandites are composed chiefly of magnetite, ilmenite, and olivine, with minor amounts of plagioclase and spinel. A small quantity was used as iron ore (Larrabee, 1971). In the northeastern United States this rock type is found only in Rhode Island.

- Serpentines consist primarily of the platy mineral antigorite. Some fibrous chrysotile is found in Vermont, New York, and New Jersey (Dana, 1959). Jade is often associated with serpentines.

- Norites are mafic rocks composed dominantly of orthopyroxenes (usually hypersthene) and calcic plagioclase. The spinel-bearing emery deposits of the Cortland complex in New York are associated with metasomatic alteration of norites (Friedman, 1956).

- Gabbros are mafic rocks consisting primarily of clinopyroxenes (usually augite) and calcic plagioclase.

7.3.2 Distribution of Mafic and Ultramafic Rocks

Mafic rocks in the northeast occur in two poorly defined, subparallel northeast-southwest trending belts and in the Adironack Mountains. They usually crop out in elongate intrusive bodies of small to intermediate size. The largest continuous mafic rock bodies found in the region are the Moxie pluton in west-central Maine (see Plate II), which measures 72 km (45 mi) in length and 3 km (1.7 mi) in width, and the main metanorthosite massif in the Adirondacks (see Plate V). Anorthosite also is found in the Honeybrook area of Pennsylvania.

Ultramafic rocks occur in very narrow, linear belts. In Maine, a belt trends east-west through the west-central part of the state. The belt changes course in Quebec and forms the narrow, north-south trending belt mapped in central Vermont, western Massachusetts, and western Connecticut. The belt changes direction again and runs northeast-southwest through southeastern Pennsylvania and New Jersey.

Chidester (1968) reported that the main structural feature related to the economically important mafic and ultramafic rocks in Vermont is the Green Mountain anticlinorium, with most of the minable minerals located east of the anticlinal axis. In New Hampshire, most ultramafic rocks consist of small occurrences in the narrow Sunday Mountain volcanic member of the Oxfordville formation. In west-central Maine, most ultramafic rocks occur in a belt southeast of the Moose River synclinorium and continue north-northeasterly into Quebec (Larrabee, 1971).

7.3.3 Commercial Potential of Mafic and Ultramafic Minerals

Seven types of ore deposits related to mafic and ultramafic rocks are of potential commercial interest in the northeastern region: nickel, cobalt, emery, magnetite, chromite, asbestos, and talc. Talc is produced through metamorphism of ultramafic rock and is discussed in Sec. 7.4.3.3.

7.3.3.1 Nickel Deposits

All nickel-bearing deposits of possible economic interest in the region are believed to be mafic rocks of Devonian age (Page, 1968). Larrabee (1971) suggested that all nickel-bearing rocks in the region are associated with Devonian gabbros and norite gabbros. The six nickel-bearing localities of possible economic interest are:

- Black Brook Pond Deposit, 13 km (8 mi) northeast of Lake Moxie Deposit, Somerset County, Maine.
- Crawford Pond Deposit, East Union, Knox County, Maine.
- Gap Nickel Mine, Gap, Lancaster County, Penn.
- Hodges Deposit, Torrington, Litchfield County, Conn.
- Lake Moxie Deposit, Troutdale, Somerset County, Maine.
- Mount Prospect Deposit, Litchfield, Litchfield County, Conn.

These localities are sulfide deposits derived from a molten magma (Bastin, 1911). Cameron (1943) believed that the sulfides, though genetically related to the mafic rocks, were introduced by hydrothermal emanations from a deeper seated parent magma. The chief nickel-bearing sulfides present in the region are pentlandite, millerite, and pyrrhotite. These deposits average about 0.6-0.7% nickel, with minor amounts of copper and cobalt.

The Crawford Pond deposit was thoroughly reviewed for possible exploitation by Roland F. Beers, Inc., in 1960. This deposit contains a moderate tonnage of material averaging 0.586% nickel, 0.282% copper, and 0.096% cobalt (Cornwall, 1966).

The other two Maine nickel localities -- Lake Moxie and Black Brook Pond -- belong to the same mafic intrusive body, and both are located in lightly settled Somerset County (Larrabee, 1971). Although these deposits have not been worked commercially, they may have been reviewed recently by St. Joe Lead, New Jersey Zinc, or Superior Mining Company (Bain, 1981). Although these ores are low grade and rather inaccessible, the possibility exists for future exploitation.

The Gap Nickel mine, in Gap, Penn., was the principal nickel producer in North America from 1853 to 1893, producing about 2300 t (2500 tons). The grade of the ore was 1.0-3.0% nickel, with 0.4-0.9% copper. A mineral reevaluation in 1942 indicated a moderate tonnage of material remaining that contains 0.7% nickel and 0.4% copper (Cornwall, 1966). The deposit consists of lenses of massive sulfides near the base of a trough-shaped intrusion 610 m (2000 ft) long and 240 m (800 ft) wide. The high-grade deposits have been extracted and only subeconomic material remains.

The Mount Prospect and the Hodges nickel deposits of Litchfield County, Conn., are separated by 27 km (17 mi). Although it appears on a geologic map that these deposits are separate, they belong to the same subterranean mass, as evidenced by similar host rock relationships and ore mineralization. Mount Prospect ores cover an area of 31 km^2 (12 mi^2) and contain six small deposits of pyrrhotite, pentlandite, and pyrite. The deposits have been worked intermittently since 1835 but are too small and of too low a grade to be commercially exploitable (Cornwall, 1966). The Hodges prospect, because of similar economics, is also abandoned.

In summary, there are no mining operations for nickel ore in the region, and there are no formal, announced plans to mine nickel in the future. It is doubtful that commercial nickel mining will ever again become profitable in the northeastern United States.

7.3.3.2 Cobalt Deposits

Cobalt is an important alloying metal often associated with nickel in ultramafic rocks. Both minerals are silver-white metals with similar melting points, densities, and other physical properties (Cornwall and Vhay, 1968).

The most common cobalt minerals in the region are cobaltite, safflorite, skutterudite, and smaltite. The eight cobalt-bearing localities of possible economic interest are:

- Black Brook Pond Deposit, Somerset County, Maine.
- Crawford Pond Deposits, East Union, Knox County, Maine.
- Gap Mine, Cornwall, Lebanon County, Penn.
- Grace Mine, Morgantown, Berks County, Penn.
- Lake Moxie Deposit, Somerset County, Maine.
- Lake Moxie Deposit, Troutdale, Somerset County, Maine.
- Mount Prospect Deposit, Litchfield, Litchfield County, Conn.
- Phillips Mine, Peekskill, Westchester County, N.Y.

All but one of these deposits occur as massive sulfides associated with altered mafic or ultramafic intrusives. The Maine deposits comprise 65,000 tons of identified cobalt resources (Vhay et al., 1973).

The Cornwall deposits are associated with contact metamorphism of carbonate country rock by sills and dikes of diabase. These deposits are located in southeastern Pennsylvania, where they comprised 33,000 tons of identified cobalt resources in 1973 (Vhay et al., 1973). This deposit has been largely depleted and operations are now closed.

In summary, although Maine and Pennsylvania together possess nearly 91,000 t (100,000 tons) of cobalt resources, they are not being mined because the ore is low grade and cannot compete with cobalt from Canada, Zaire, Zambia, and South Africa. As with nickel, it is doubtful that cobalt mining will ever become commercially feasible in the region.

7.3.3.3 Emery Deposits

Emery is used as an abrasive. It is composed basically of titaniferous magnetite, spinel, and corundum. Common accessory minerals include ilmenite, hematite, pyrite, sillimanite, hoegbomite, cordierite, andalusite, staurolite, and garnet. All of the emery deposits in the region border or are enclosed in basic rocks that seem to have been altered by younger acidic intrusives (Friedman, 1956).

Two types of emery are recognized in the region: black spinel-bearing emery and gray spinel-free emery. Both varieties are found in Peekskill, N.Y.; only the spinel-free variety is found in Chester, Mass.

Two mining companies, DeLuca Emery Mine, Inc., and Emeri Crete, Inc., were responsible for the entire U. S. production of emery in 1978 and 1979. Both companies operate open-pit mines near Peekskill, Westchester County, N.Y. (Minerals Yearbook, 1981). No figures are available for the value of emery production in New York. Emery mines at Chester, Mass., are abandoned.

In summary, the Peekskill, N.Y., area supplies all of the U.S. demand for emery. No estimates of Peekskill reserves are available. The Chester, Mass., deposits might be mined in the future if economic factors, such as higher costs for other abrasives, become favorable.

7.3.3.4 Magnetite and Other Iron Ore Deposits

Commercial iron ores of the northeast are composed largely of magnetite and occur in New York, New Jersey, and Pennsylvania. Magnetite is present in noncommercial quantities as a common accessory mineral in mafic and ultramafic rocks.

New York ranked as one of the most important iron-producing states between the time of the Revolutionary War and 1890, when the discovery of Minnesota's Mesabi Range caused New York production to fall rapidly (Broughton et al., 1966). Limonite ore, such as that found in the Salisbury district of New York, Connecticut, and Massachusetts, was smelted for much of the iron of this period (Hobbs, 1907).

The magnetite deposits of St. Lawrence County in the northwestern Adirondacks are of two principal types (Leonard and Buddington, 1964) -- magnetite deposits in skarn or marble and magnetite deposits, with or without hematite, in granite gneiss. The Benson mine near Star Lake and the Clifton mine near Degrasse were the largest pits for these ores. In terms of crude ore production, the Benson mine was one of the ten largest iron ore mines in the United States between 1840 and 1900. It closed in the early 1900s but reopened in 1941, along with the Clifton mine, for the war effort. From 1943 to 1951, these two mines produced almost 7 million t (8 million tons) of sintered magnetite, which averaged 62.5-63.5% iron (Leonard and Buddington, 1964). The Clifton mine ceased operations in 1951, and the Benson mine closed in 1978. Reclamation is underway at the Benson site.

Titaniferous magnetite is associated with anorthosite in the southern Adirondacks. The deposits are found on the heavily forested slopes of the Hudson River headlands, of which Lake Sanford is a part. They are relatively inaccessible, being approximately 48 km (30 mi) by highway from the nearest railroad and 13 km (8 mi) from the nearest state highway (Stephenson, 1945).

There are four separate ore bodies in the Lake Sanford area, the largest of which is the Sanford Hill ore body (MacIntyre mine). This mine is located in Tahawas, N.Y., and is operated by the Titanium Division of the National Lead Company. The titanium dioxide is used in the manufacture of

pigments for paint, varnish, and the lacquer industry. The primary coproducts are vanadium and magnetite ore. The MacIntyre mine is the only iron mine currently operating in the state (Minerals Yearbook, 1981). Although New York has other low-grade deposits of magnetite and hematite, they are not being mined at present.

The Mount Hope iron ore mine near Dover, N.J., was closed in 1978 for economic reasons. This was the last underground iron ore mine east of the Mississippi River (Minerals in the Economy of New Jersey, 1979).

Magnetite ores of eastern Pennsylvania are associated with contact metamorphic zones on the northern margins of the Mesozoic Newark belt. However, the ores lie in limestones or limy shales belonging to the Paleozoic rather than Mesozoic strata. Magnetite ores of this type have been worked on a large scale in Berks County at Boyertown, at two localities south of Reading (near Fritztown and Joanna Station), in Lebanon County at Cornwall, and in York County, especially near Dillsburg (Spencer, 1906). There are no large-scale iron ore mines remaining today. Bethlehem Steel Corporation's Grace mine, located near Morgantown, was closed in 1977 (Minerals Yearbook, 1981).

Magnetite is a slightly more reduced oxide than hematite and had been added to the open-hearth mix. Today's sintered and partly reduced pellets eliminate the demand. Furthermore, open-hearth furnaces are being phased out as fast as feasible. All the magnetite mines, except the Benson mine, required an expensive underground operation and were not competitive with the large, high-grade ore deposits susceptible to open-pit mining discovered in Brazil, South Africa, and Australia during the 1960s (Bain, 1981).

In summary, most of the commercial iron ore deposits are composed of magnetite. The Adirondacks of New York was once an active iron mining area, but all operations, except for the MacIntyre mine at Lake Sanford, are now closed. Pennsylvania and New Jersey closed their last iron mines in 1977 and 1978, respectively. Prospects for new discoveries of high-grade iron ore are very unlikely, because the region has been thoroughly explored by geophysical surveys.

7.3.3.5 Chromite Mining

The value of chromite depends on its composition. The composition determines whether it will be used in metallurgical, refractory, or chemical applications. It is the only ore of chromium and was mined in southeastern Pennsylvania until the late 1830s. Chromite is found in association with serpentinized ultramafic rocks. Three types of chromite ores have been mined in the region -- massive, disseminated, and placer. The chromite ores range from less than 30% to about 55% chromite. At the Wood mine, Wayne county, the ore varied from 51.56% to 63.38% (Pearre and Heyl, reprinted 1974).

Pennsylvania's chromite deposits are part of a narrow chromium-bearing trend that extends into Maryland. More than 40 abandoned chromite mines and prospects are associated with this trend, about half of which are located in Pennsylvania. All of the chromite ore produced in this country before about 1865, and a substantial part of it until 1875, came from this trend. Pearre and Heyl (reprinted 1974) estimated that 225,000-254,000 t (250,000-280,000 tons) of chromite ore were mined along with about 14,000 t (15,000 tons) of placer chromite. Red Pit, which is located on the Pennsylvania-Maryland state line, was by far the largest chromite mine in the region, producing 136,000 t (150,000 tons). The mines were closed in the late 1880s, because cheaper ores could be obtained through foreign sources. In addition, legal problems and poor mining techniques led to some premature closings. Other mines simply ran out of ore.

Renewed interest in chromium as a strategic metal led to reappraisals of old mines during World War I and World War II. However, from 1945 to 1959, there were no attempts to revive the Pennsylvanian chromite mining industry (Pearre and Heyl, reprinted 1974). There is no chromite mining anywhere in the northeastern United States today, and known deposits are too small to pay even the development costs (Bain, 1981).

7.3.3.6 Asbestos Mining

Crysotile asbestos, a fibrous variety of serpentine, occurs chiefly in serpentinized peridotite (Chidester and Shride, 1962). Although asbestos mines and/or prospects occur in all the northeastern states except New Jersey and New Hampshire, the Ruberoid Asbestos mine of Lowell, Vt., is the only significant producer of asbestos in the region (Minerals Yearbook, 1981). No figures are available for either the production or the value of the asbestos produced here, but Vermont is the nation's second largest producer of asbestos. High-quality asbestos deposits in Quebec have meant that the region's low-quality deposits cannot compete in the market. Also, the public's concern over asbestos as a carcinogen has resulted in significant production cuts.

7.4 METAMORPHIC ROCKS

7.4.1 Definition and Description

Metamorphic rocks have been subjected to sufficient pressure or temperature to alter their pre-existing mineralogical or physical integrity. Two metamorphic facies series have been recognized in the Appalachians: a low pressure/temperature (P/T) facies series in the northern part of the region and an intermediate P/T facies series in the remainder of the Appalachians. These facies series are defined by the polymorphic transitions of andalusite to sillimanite and kyanite to sillimanite, respectively (Morgan, 1972). Low

P/T facies include greenschist, amphibolite, and granulite rocks exhibiting the transition of andalusite to sillimanite. The intermediate P/T facies exhibits the transition from kyanite to sillimanite in the same rock types.

7.4.2 Distribution of Metamorphic Rocks

Metamorphic rocks formed during the Precambrian Grenville orogeny constitute the bulk of the Adirondack mountains. This area is isolated from the rest of the Appalachian system. While most of the eastern half of the northeastern United States exhibits low P/T facies, Vermont, western New Hampshire, western Massachusetts, easternmost New York, northern New York, Connecticut, and southeastern Pennsylvania possess intermediate P/T facies. Some of these areas were affected only by Paleozoic regional metamorphism, whereas others were affected by both Precambrian and Paleozoic regional metamorphism (Morgan, 1972). These latter rocks form a linear trend through central Vermont, western Massachusetts, southeastern New York, northern New Jersey, and southeastern Pennsylvania. The higher-grade metamorphic rocks are the ones of most importance to this study, for they contain the mineralization of commercial interest. The slates are an important exception to this rule.

Regional metamorphism occurred during the Middle Devonian Acadian orogeny (360-340 m.y.), the same episode that was responsible for emplacing the granites and pegmatites in the region (Miyashiro, 1973).

7.4.3 Commercial Potential of Metamorphic Rocks and Minerals

The chief metamorphic rocks and minerals of commercial interest in the northeast are slate, marble, talc, garnet, corundum, graphite, wollastonite, and andalusite-kyanite-sillimanite. These resources will not be treated in detail, because most of them occur beyond the 3.2-km (2-mi) exclusion radius.

7.4.3.1 Slate Resources

Slates are metamorphosed shales and are useful because of their platy cleavage. Slate is mined at Monson, Maine, and in a north-south belt about 40 km (25 mi) long around Poultney, Vt. There are many abandoned slate mines in the northeast. Slate reserves of Maine, Vermont, and New York are cataloged in a recent study by Arthur D. Little (U.S. Bureau of Mines, 1980). This study concludes that the Vermont/New York slate industry needs help "to rejuvenate and hopefully grow, but possibly help to survive in the long run."

7.4.3.2 Marble Resources

Marble is metamorphosed carbonate rock, which finds major use as a decorative stone in costly buildings. Marble is mined in Addison, Rutland,

Chittenden, Windsor, and Franklin counties in Vermont (Minerals Yearbook, 1981). There are many abandoned marble mines in the region. Commercial marble lies entirely beyond areas of granite plutons, but the small "geologic marble" areas of Maine are essential to current manufacture of cement in New England (Bain, 1981).

7.4.3.3 Talc Resources

Talc is a hydrous magnesium silicate and in the northeast is often associated with regionally metamorphosed ultramafic complexes and carbonates. All states in the northeastern region have deposits of talc (Chidester et al., 1964), but it is mined only in Vermont and New York (Minerals Yearbook, 1981). The value of a talc deposit depends on whether it will be used for face powder or for paper filler.

Vermont's talc belt follows the main belt of ultramafic rocks, which parallels the central meridian of the state from Massachusetts to Canada. The state's principal producing localities are underground mines in Lamoille, Windham, and Windsor counties (Chidester et al., 1964). Vermont led the nation in talc production during the biennium 1978-1979, producing over 600,000 t (660,000 tons) valued at over $5 million (Minerals Yearbook, 1981).

New York's talc deposits occur in elongate zones within a northeast-trending belt of impure marble in the Gouverneur district, St. Lawrence County (Chidester et al., 1964). The state's principal production is from underground talc mines near the towns of Edwards and Fowler. New York's talc production and its value increased approximately 3% and 8%, in 1978 and 1979, respectively (Minerals Yearbook, 1981). Many abandoned talc mines are found in the northeastern United States.

7.4.3.4 Garnet Resources

Garnets are iron-magnesium aluminum silicates that occur commonly in metamorphic rocks. Garnets from the region are used as abrasives, and New York is the principal garnet-producing state in the northeast. The Barton mines in Warren County have produced thousands of tons of high-quality almandine garnet from Gore Mountain (Bartholome, 1960), but reserves are nearly depleted. The company that has operated the Barton mines has permission to open a mine at Ruby Mountain; reserves are expected to last for 25 yr (Minerals Yearbook, 1981). Garnet also has been recovered in Essex County as a by-product of mining wollastonite.

Garnet is being mined in Maine, in the West Paris area. These deposits were apparently formed by contact metamorphism related to intruded pegmatites. When fully operational, the garnet mine of Industrial Garnet Extractives, Inc., will operate from spring to fall with about 10 employees (Minerals Yearbook, 1981).

7.4.3.5 Corundum Resources

Corundum is the hardest commonly occurring mineral. It is an aluminum oxide that is often associated with metamorphic rocks, norites, and crystalline limestones. Pennsylvania, New York, New Jersey, Connecticut, Massachusetts, and Maine have occurrences of corundum, but commercial deposits occur only in New York and Massachusetts.

The corundum in New York and Massachusetts is associated with emery deposits; the Pennsylvanian deposits are associated with chromite; the Connecticut deposits occur with talc and kyanite; the New Jersey corundum occurs at a limestone and granite contact; and the Maine deposits are found sparingly in pegmatites (Pratt, 1906). The abrasive plants at Westfield, Mass., use imported corundum and work with prepared mixtures to give emery quality. Their source at Chester, Mass., has not operated since World War I.

7.4.3.6 Graphite Resources

The variety of graphite that is the metamorphic form of coal was mined in the folded coal beds of Pennsylvania. Noncommercial occurrences of graphite, as veins and metasediments, are scattered throughout Massachusetts, Rhode Island, Connecticut, and New Hampshire. There are many abandoned graphite mines in the northeastern region. Only synthetic graphite is now produced in Pennsylvania (Minerals Yearbook, 1981).

7.4.3.7 Wollastonite Resources

Wollastonite is a calcium silicate found in metamorphic rocks. The only commercial wollastonite operations are in New York. Interpace Corporation operates two mines near Willsboro, Essex County; R.T. Vanderbilt Co., Inc., operates the Valentine mine in Lewis County (Minerals Yearbook, 1981). In both instances, the wollastonite is mined for use in paint pigments.

7.4.3.8 Andalusite-Kyanite-Sillimanite Resources

Andalusite, kyanite, and sillimanite are metamorphic minerals with similar chemical composition ($Al_2O_3.SiO_2$) and are used in refractories (Mineral Resources of the Appalachian Region, 1968). Scattered, noncommercial deposits of these minerals are found in Maine, New Hampshire, Connecticut, and Massachusetts (Pearre, 1956 and 1957).

7.4.3.9 Summary of Metamorphic Rock and Mineral Resources

The metamorphic rock industry, like all of the region's previously mentioned mineral resources industries, has be

economic pressures. Rising capital expenditures have forced many small quarries out of business, even though the supply of slate and marble is still adequate. Slate is now being mined from large quarries in western Maine and western Vermont. Vermont supplies all of the region's marble, except for small supplies of "geologic marble" from Maine.

The metamorphic mineral industry has seen gradual consolidation of numerous small mining operations into a few large operations. Metamorphic rock sources that do not have sufficient reserves or a high enough grade to be mined in this fashion have been abandoned. Central Vermont and northern New York produce all of the region's talc. Garnet is produced in Warren County, N.Y., and from the West Paris area in Maine. Corundum is found only in minor deposits associated with the region's emery and chromite deposits. Natural graphite is not mined commercially. Wollastonite is produced only in New York. The region's andalusite-kyanite-sillimanite resources may have become obsolete as a result of the production of synthetic mullite in Pennsylvania.

7.5 OTHER ECONOMIC ROCKS AND MINERALS

Of the other mineral resources indigenous to the region, more emphasis will be placed on those associated directly with plutonic or high-grade metamorphic rocks than those associated with sediments or sedimentary rocks. This is because the latter are usually at some distance from exposed granitic rocks.

7.5.1 Copper Resources

Copper is found in a variety of host rocks in the northeastern United States. It occurs in Vermont largely in association with mica schists (Weed, 1903); in New Jersey and Connecticut in association with shales and sandstones intruded by trap rock (Weed, 1903 and 1911); in Maine associated with siliceous schists (Rand, 1958) and monzonite porphyries (Schmidt, 1978); in Massachusetts in association with crystalline schists; and in New Hampshire in association with pyritized schists or other ores in quartz veins (Weed, 1911). The copper occurs in vein deposits, often in intimate association with pyrite. The one exception in the region seems to be the Pahaquarry, N.J., deposit, which is a noncommercial accumulation of copper-rich nodules formed on a layer impervious to ground-water flow. The most important copper deposits in the area are thought to be strata-bound, metamorphosed occurrences. Since the first discovery of sulfides in 1793, the Vermont copper belt has yielded ore containing an aggregate of about 54,000 t (60,000 tons) of copper (McKinstry and Mikkola, 1954).

Important historical copper mines and prospects in the region are briefly described below. The many small, insignificant copper mines are not described.

- Douglas Mine, Hancock County, Maine. This deposit was opened in 1878 and was worked until 1883. It produced 900-1350 t (1000-1500 tons) of copper valued at about $300,000 (Rand, 1958). The country rock is the Ellsworth schist.

- Catheart Mountain, Somerset County, Maine. This is the most significant porphyry-type copper deposit known in the eastern United States. It covers an area of 1.3 km^2 (0.5 mi^2) of hydrothermally altered quartz monzonite (Schmidt, 1978) and may be related, in a trend, to similar Canadian deposits to the north and Alabama-South Carolina deposits to the south. Schmidt (1978) proposed that these deposits are related to a northwest-dipping Acadian subduction zone located near the Maine and New Brunswick coasts, and that a broad belt in western New Hampshire, northwestern Maine, and southeastern Quebec is the most favorable for future discoveries.

- Milan Mine, Coos County, N.H. Some copper is obtained through magnetic separation of the zinc minerals of the Warren vein (Weed, 1911). The mine is an important producer of pyrite.

- Warren Mine, Coos County, N.H. This is a complexly faulted, noncommercial deposit enclosed in a mica schist.

- Gardners Mountain Mine, Grafton County, N.H. The ore is found in thin veins in four well-marked, cupriferous belts traceable for 20 km (12 mi) (Weed, 1911). The veins occur at a contact of altered diabase and schist.

- Lyman Mine, Grafton County, N.H. This mine is a small deposit of pyritized schist.

- Ely Mine, Orange County, Vt. This is the deepest of the copper mines and one of the great mines of the state (Weed, 1903). The inclined shaft is 1000 m (3400 ft) long (Weed, 1911). The deposit occurs as overlapping lenses of pyrrhotite in foliated, micaceous schists and resembles deposits in Ducktown, Tenn., in mineral character and occurrence (Ross, 1935). The Ely mine shipped over 6.8 million t (7.5 million tons) of copper ore from 1854 to 1890 (Weed, 1903).

- Elizabeth Mine, Orange County, Vt. The main oreshoot of this mine is 1800 m (6000 ft) in pitch length (McKinstry and Mikkola, 1954); another ore body (Reynolds) is found

on its continuation 2.4 km (1.5 mi) northward (Weed, 1911). Like the Ely mine the ore consists of pyrrhotite, with scattered grains of chalcopyrite, pyrite, and sphalerite. The ore assayed at 2.54% copper and 32.15% iron (Weed, 1911).

- Union Mine, Orange County, Vt. This mine produced 28,580 t (31,504 tons) of ore having 8.5-10.0% copper from 1866 through 1881.

- Eureka Mine, Orange County, Vt. The vein is about 2.4 m (8 ft) thick. Selected samples of the rich ore suggest 19.65% copper, 19.52% silica, and 0.02 kg (0.76 oz) silver per ton of ore (Weed, 1911).

- Davis Mine, Franklin County, Mass. This pyrite mine also yields small amounts of copper. The pyrite is interbedded with schist. The total output of pyrite ore was 303,506 t (334,552 tons) through 1892. Subsequent production figures are not available.

- Simsbury Mines, New Haven County, Conn. This mine is possibly the oldest copper mine of America, being first worked in 1709. The ore, chalcocite, is found in a fine-grained yellowish sandstone in contact with trap rock. The ore body's areal extent is 5-8 km^2 (2-3 mi^2).

- Higley Mine, New Haven County, Conn. This mine is located less than 3.2 km (2 mi) from the Simsbury mine and has bornite and red oxides as accessory minerals.

- Bristol Mine, New Haven County, Conn. Bornite, chalcocite, and chalcopyrite ore occurs at a contact between Triassic sandstone and schistose rocks. The mine was worked from 1847 to 1854, reaching a depth of 73 m (240 ft) and yielding over $200,000 of copper in that period (Weed, 1911).

Other small copper ore deposits that should be mentioned are miscellaneous New Haven County, Conn., deposits; the pyrite mines of St. Lawrence and Ulster counties, N.Y.; the pyrite mines of Wachtung Mountain, Griggstown, Somerville, Plainfield, and Arlington, N.J.; and the deposits near East Richford, Strafford (White et al., 1943), and Berkshire (Eric, 1943), Vt. The last copper produced in the region was from the Douglas (Blue Hill) mine near Castine, Maine, which was closed in October, 1977. The mine's ore is exhausted, and the capital investment could not be amortized (Bain, 1980).

The discovery of a major copper-zinc ore body on Bald Mountain, Aroostook County, Maine, is encouraging further exploration. The Superior Mining Company and Louisiana Land and Exploration Company estimate the Bald Mountain deposit (see Plate II) to contain a mininum of 34 million t (37 million tons) of copper and zinc (Minerals Yearbook, 1981). Development just began, and the economic potential is being evaluated. This ore body is far from any plutons.

7.5.2 Molybdenum Resources

Molybdenite and its secondary product, wulfenite, are the most common molybdenum-bearing minerals found in the northeastern United States. These minerals are often associated with granitic pegmatites and porphyries. Although deposits are found in Maine, Vermont, and New Hampshire, the ones in Maine are the most significant. The most important molybdenum-bearing localities of both historical and future interest are listed below:

- Catheart Mountain Prospect, Somersey County, Maine. This is a substantial, though subeconomic, body of copper-molybdenum ore (Schmidt, 1978).

- Catherine Hill Mine, Hancock County, Maine. This mine is in a small deposit found in pegmatite veins associated with granite (Rand, 1958).

- Cooper Mine, Washington County, Maine. The ore body is small and genetically related to granitic pegmatites (Smith, 1904-1905). Segregations of molybdenite of up to 4.5-5.4 kg (10-12 lb) have been reported (Rand, 1958).

- Cuttingsville Occurrence, Rutland County, Vt. This is a small occurrence at Granite Hill (Pearre and Calkins, 1957).

There are no molybdenum deposits of current commercial value in the northeastern United States.

7.5.3 Zinc Resources

Zinc is the most important metallic resource found in the northeast. It is being mined in New York, New Jersey, and Pennsylvania. All occurrences are many miles from granitic plutons. Although exploration for zinc is underway in Vermont, it is uncertain whether development will actually commence.

The zinc minerals occur as strata-bound bodies in carbonate rocks. Although the common zinc mineral is sphalerite, zinc deposits at Franklin-Sterling Hill, N.J., consist of an ore containing abundant franklinite, willemite, and zincite and only rare sphalerite.

An inventory of the most important zinc deposits in the region follows.

- Balmat Mine, St. Lawrence County, N.Y. This was the largest zinc mine in the United States through 1977. Sphalerite occurs with galena. At the northeastern end of this trend is the Edwards mine, where the only economic mineral is sphalerite (Broughton, 1966). The St. Joe Mineral Corporation produced 64,000 t (70,690 tons) of zinc in 1977 and 26,400 t (29,109 tons) in 1978. Although production fell to 12,000 t (13,346 tons) in 1979 (Minerals Yearbook, 1981), the mining outlook remains excellent.

- Franklin-Sterling Hill, Sussex County, N.J. About 212 minerals are recognized in this deposit, but franklinite, willemite, and zincite are the major ore minerals (Wilkerson, 1962). New Jersey's Sussex County produced 30,230 t (33,394 tons of zinc in 1977, 28,800 t (31,807 tons) in 1978, and 31,000 t (34,230 tons) in 1979 (Mineral Yearbook, 1981). Production is expected to decline in future years.

- Lehigh District, Lehigh County, Penn. This is the only area in Pennsylvania that produced zinc in 1978-1979. Zinc is from replacement bodies in Paleozoic limestone. It produced 20,600 t (22,777 tons) of zinc in 1977, 19,000 t (21,009 tons) in 1978, and 21,400 t (23,592 tons) in 1978 (Minerals Yearbook, 1981).

7.5.4 Gold Resources

The discovery of the Ammonoosuc gold district in northwestern New Hampshire and the rush to purchase property in the towns of Lyman, Bash, Lisbon, and Littleton produced great excitement but only small quantities of gold (Meyers and Stewart, 1977). This is the only recognized gold district in the northeastern region. Recent dramatic increases in the price of gold resurrected interest in the old Ammonoosuc gold district (Minerals Yearbook, 1981), but the only activity today is the panning of gold in streams by individuals.

7.5.5 Manganese Resources

Manganese is a metal used in making steel and, since the United States is completely dependent on foreign sources for manganese (Brobst and Pratt, 1973), the low-grade manganese deposits of the northeastern region have been studied rather carefully. Manganese occurs in the region as a black coating on, or as a constituent of, manganiferous slates and shales, most typically as a black manganese oxide.

Manganese occurrences have been noted in Maine, Vermont, Massachusetts, Rhode Island, Pennsylvania (Foose, 1967), and New Jersey. However, the most important deposits are located in Aroostook County, Maine. The more significant of these subeconomic deposits are:

- Dudley Prospect, Aroostook County, Maine. This deposit is a manganiferous shale that was extensively prospected by the Manganese Ore Company in 1944. Reserves are estimated to total more than 19 million t (21 million tons), with 11.4% manganese (Rand, 1958).

- Maple Mountain Prospect, Aroostook County, Maine. This prospect is a large, low-grade deposit in deep-red hematitic slates of Ordovician age. Reserves are estimated at 260 million t (287 million tons) of manganese ore, averaging 8.87% manganese, of which 123 million t (136 million tons) average 11.16% manganese (Rand, 1958).

- Pierce Prospect, Aroostook County, Maine. Three manganiferous deposits occur here, with an average grade of 9.6-12.9%. The lengths of the deposits are 1400-2600 m (4600-8400 ft), and the widths are 16.5-129 cm (6.5-50.7 in.) (Rand, 1958). The deposits occur in impure siliceous hematitic rock and are separated by shales.

Other low-grade deposits that deserve mention are the Chittenden and Kinnry-Cobble Mines of Rutland County, Vt., and the Clinton Point deposit in Hunterdon County, N.J. (Thurston, 1951). There are many other abandoned, subeconomic manganese prospects scattered throughout the northeast. All occur at some distance from crystalline rock bodies.

7.5.6 Uranium and Thorium Resources

Most igneous rocks contain about 0.0002-0.0004% uranium oxide, which represents average abundance in the crust. Some igneous bodies are appreciably richer in this mineral and might qualify as a potential resource. The biotite phase of the Conway granite of Triassic or Jurassic age in central New Hampshire contains an average of 0.0015% uranium oxide and about 0.0064% thorium oxide over 800 km^2 (300 mi^2) (Brobst and Pratt, 1973).

The only significant uranium and thorium resources of possible commercial interest in the northeastern region occur in uranium-rich granites in New Hampshire, in metamorphic terrains in southern Vermont, and in sandstones in Pennsylvania. A West German firm (Uran-Gesellschaft, USA, Inc.) leased 930 ha (2300 acres) near Jamaica, Mt. Holly, Ludlow, and Townshend in southern Vermont, to explore for uranium in metamorphic terrain. After a series of citizens' marches and rallies, the company withdrew its mining request and moved its exploration effort out of the state (Minerals Yearbook, 1981).

Pennsylvania has numerous small deposits of uranium ores contained in the Mauch Chunk sandstones of Carbon County (Wherry, 1913). The Mauch Chunk formation at its type locality near Jim Thorpe consists of a lower unit of predominately red rock about 520 m (1700 ft) thick and an upper unit about 150 m (500 ft) thick. Much of the uranium occurs as small lenticular deposits where carbonaceous material is relatively abundant (Mineral Resources of the Appalachian Region, 1968). Fourteen samples of Mauch Chunk uranium mineralization ranged between 0.002% and 0.67% uranium oxide. Three hundred tons of this ore have been produced, which is the only uranium produced in Appalachia thus far (Mineral Resources of the Appalachian Region, 1968).

Further exploration for uranium might be expected in the region if the price of yellowcake were to rise, although a recent study (Kalliokowski et al., 1978) indicates a low probability of finding significant deposits of uranium in New Jersey, New York, Pennsylvania, Vermont, Massachusetts, or Connecticut.

7.5.7 Lead-Silver Resources

Lead occurs most often in nature as the sulfide ore, galena. Lead deposits typically are strata-bound deposits and occupy brecciated carbonate rocks adjacent to uplifted areas, where there has been a source of warm, mineralizing solutions. Many of the lead deposits in the northeastern region contain small amounts of silver that can be concentrated by melting the lead away.

Lead and some silver are found in Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and New York. However, most of these deposits are very small and of no commercial interest. The only area that was operating in 1980 was in the Balmat-Edwards district of St. Lawrence County, N.Y. Production from St. Joe Minerals Corporation's Balmat and Edwards mine totaled 251 t (2770 tons) of lead and 1753 kg (56,353 troy oz) of silver for 1977; 989 t (1090 tons) of lead and 650 kg (20,911 troy oz) of silver for 1978; and 457 t (504 tons) of lead and 328 kg (10,538 troy oz) of silver for 1979. The recent Bald Mountain copper-zinc discovery in Aroostook County in Maine may have a significant amount of associated lead.

The Pembrooke prospect of Washington County, Maine, averages 0.017 kg/t ore (0.5 oz/ton ore), based on a recently completed coring project (Loiselle,

1981). This low-grade ore would be subeconomic in anything but a large mining operation.

7.5.8 Sulfur (Pyrite) Resources

The pyrite deposits of St. Lawrence and Jefferson counties, N.Y. consist of 19 known occurrences of sufficient magnitude to warrant consideration as possible sources of sulfur (Prucha, 1957).

7.5.9 Other Low-Priority Resources

This section discusses nonmetallic, sedimentary resources that are not directly associated with granitic rocks as defined for this study. Such resources are mined in shallow surface pits, pumped from wells, or extracted directly from seawater. These resources are not shown on Plates II-IX.

Sand and gravel ranked as the leading mineral commodity resource in the northeastern United States in 1979. All nine states in the region produced sand and gravel; New York, New Jersey, Maine, Pennsylvania, and Massachusetts were the leading states. There are hundreds of active sand and gravel operations in the region, and any attempt to catalog and describe these operations is beyond the scope of this study. Also, nearly all significant sand-and-gravel mining operations are at some distance from granitic rock bodies.

Limestone for cement or lime is probably the third leading mineral resource after sand and gravel, and trap rock. It is quarried principally from Paleozoic limestones and is produced by six operations in three counties in Maine and by ten plants in eight counties in Pennsylvania. Bastin (1906) covered the lime industry in Knox County, Maine. Centre, Adams, and Butler are the leading counties in Pennsylvania. New York, Massachusetts, and Vermont are also important producers of lime. Litchfield County, Conn.; Sussex County, N.J.; and Ashton, R.I., are minor producers of lime. The Martin Marietta cement plant in Thomaston, Maine, is the largest cement plant in the region.

Used almost exclusively as a soil conditioner, peat is mined by three companies from Maine's coastal bogs; by seven operators in six counties in New York (Dutchess, Seneca, Cattapaurgas, Broome, Orange, and Westchester); by operators in five counties in Pennsylvania (Luzerne, Lackawanna, Erie, Lawrence, and Pike); by companies in Westchester County, Mass.; and in Sussex County, N.J.

Salt is produced only in New York by five companies, at seven localities in Schuyler, Wyoming, Livingston, Onandoga, and Tompkins counties.

Used for plaster of paris, wallboard, and cement conditioner, gypsum is produced in Genessee County in New York and in Burlington and Camden counties in New Jersey. Imported gypsum is calcined at many locations in the northeast.

Greensand marl is produced for use as a soil conditioner in Glouchester County, N.J., which is the only producing locality for this resource in the nation.

Tripoli is produced in Northumberland County, N.J.

Petroleum is a potential resource in some of the crystalline rock areas of the northeastern United States. Sedimentary rocks have been detected by geophysical means to have been overthrust by crystalline terranes to the east in southeastern Pennsylvania, southeastern New York, and western Connecticut, Massachusetts, and Vermont (McCaslin and Sumpter, 1981). Prospecting for possible deep oil and gas has begun in this "eastern overthrust belt."

Magnesium compounds are being extracted from seawater in Cape May County, N.J.

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APPENDIX

CATALOG OF EARTHQUAKES OF THE NORTHEASTERN UNITED STATES

Adapted from Chiburis (1981) and updated through 1980 by Weston Observatory, Boston College

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1534 0		47.7	70.1	9	10	0.0	PQ LES EBOULEMENTS
1568 0		41.5	72.5	6	7	0.0	CT MOODUS-E.HADDAM
1574 0		41.5	72.5	5	7	0.0	CT MOODUS-E.HADDAM
1584 0		41.5	72.5	5	7	0.0	CT MOODUS-E.HADDAM
1592 0		41.5	72.5	5	7	0.0	CT MOODUS-E.HADDAM
1627 0		42.6	70.8	6	6	0.0	MA ESSEX
1638JUN11	1900	47.7	70.2	9	9	0.0	PQ LA MALBAIE
1638JUL 1		42.5	70.9	3	3	0.0	MA SALEM
1639JAN25		42.5	70.9	3	3	0.0	MA LYNN
1643MAR15	1200	42.8	70.8	4	5	0.0	MA NEWBURY
1643JUN11	1800	42.8	70.8	4	4	0.0	MA NEWBURY
1644MAR14		41.9	70.6	2	2	0.0	MA PLYMOUTH
1653NOV 8		42.6	70.9	4	4	0.0	MA DANVERS
1658APR14		42.5	70.9	5	5	0.0	MA LYNN
1661FEB10	1200	45.5	73.0	7	7	0.0	PQ S.OF GRANBY
1662FEB 5	2300	41.9	70.6	2	2	0.0	MA PLYMOUTH
1663FEB 5	2230	47.6	70.1	10	10	0.0	PQ LA MALBAIE
1663FEB 6	0200X	47.6	70.1	5	5	0.0	PQ LA MALBAIE
1663FEB 6	1500X	47.6	70.1	6	6	0.0	PQ LA MALBAIE
1663FEB 7	1400X	47.6	70.1	4	4	0.0	PQ LA MALBAIE
1663NOV16	X	47.6	70.1	4	4	0.0	PQ LA MALBAIE
1664 0		47.6	70.1	4	4	0.0	PQ LA MALBAIE
1665FEB24	1645	47.8	70.0	8	8	0.0	PQ LA MALBAIE
1665OCT16	0230	46.8	71.2	4	4	0.0	PQ QUEBEC CITY
1668APR 3	1400	42.3	71.1	4	4	0.0	MA BOSTON
1668APR13	1300	47.1	70.5	6	6	0.0	PQ ILE-AUX-GRUES
1668JUN26		42.3	71.1	2	2	0.0	MA ROXBURY
1669NOV30		42.3	71.1	2	2	0.0	MA BOSTON
1670 0		42.3	71.1	2	2	0.0	MA BOSTON
1672FEB 0		48.1	69.8	4	4	0.0	PQ TADOUSSAC
1673DEC 8		48.1	69.8	3	3	0.0	PQ TADOUSSAC
1677DEC13		41.1	73.5	4	4	0.0	CT STAMFORD
1685FEB18		42.7	70.8	4	4	0.0	MA DANVERS
1688SEP 7		41.7	72.9	2	2	0.0	CT N.BRISTOL
1698 0		41.4	73.5	4	4	0.0	CT DANBURY
1701FEB10		42.6	70.9	3	3	0.0	MA DANVERS
1701MAR 8	X	42.6	70.9	3	3	0.0	MA DANVERS
1702 0		41.4	73.5	4	4	0.0	CT DANBURY
1705JUN27		42.4	71.1	4	4	0.0	MA BOSTON
1706 0		42.3	71.1	2	2	0.0	MA BOSTON
1711 0		41.4	73.5	4	4	0.0	CT DANBURY
1721JAN19		42.3	71.1	2	2	0.0	MA BOSTON
1724JUN23		42.3	71.1	2	2	0.0	MA BOSTON
1727NOV10	0340	42.8	70.6	7	9	0.0	MA CAPE ANN
1727NOV10	0435X	42.8	70.6	4	4	0.0	MA CAPE ANN
1727NOV10	0715X	42.8	70.6	4	4	0.0	MA CAPE ANN
1727NOV14	2200X	42.8	70.6	5	4	0.0	MA CAPE ANN
1727NOV18	1620X	42.8	70.6	4	5	0.0	MA CAPE ANN
1727NOV23	2030X	42.8	70.6	2	2	0.0	MA CAPE ANN
1727NOV23	2130X	42.8	70.6	2	2	0.0	MA CAPE ANN
1727NOV24	1000X	42.8	70.6	4	4	0.0	MA CAPE ANN
1727DEC 1	X	42.8	70.6	4	4	0.0	MA CAPE ANN
1727DEC16	X	42.8	70.6	4	4	0.0	MA CAPE ANN
1727DEC19	1500X	42.8	70.6	4	4	0.0	MA CAPE ANN
1727DEC29	0330X	42.8	70.6	4	6	0.0	MA CAPE ANN
1727DEC29	0900X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728JAN 5	0300X	42.8	70.6	4	6	0.0	MA CAPE ANN
1728JAN12		43.6	71.7	3	3	0.0	NH NEW HAMPTON
1728JAN15	0200X	42.8	70.6	3	3	0.0	MA CAPE ANN

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1728JAN18	0200X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728FEB 5	0230X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728FEB 8	1130X	42.8	70.6	4	3	0.0	MA CAPE ANN
1728FEB 9	X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728FEB10	2030X	42.8	70.6	5	6	0.0	MA CAPE ANN
1728MAR 3	0530X	42.8	70.6	3	3	0.0	MA CAPE ANN
1728MAR11	X	42.8	70.6	3	3	0.0	MA CAPE ANN
1728MAR28	0800X	42.8	70.6	3	3	0.0	MA CAPE ANN
1728MAR31	1840X	42.8	70.6	3	3	0.0	MA CAPE ANN
1728APR 1	0200X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728MAY 9	2200X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728MAY16	X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728MAY24	0240X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728MAY29	0100X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728JUN 2	1500X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728JUN 5	0400X	42.8	70.6	3	3	0.0	MA CAPE ANN
1728JUN17	0800X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728JUN19	0800X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728JUN22	1400X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728JUL14	0700X	42.8	70.6	2	2	0.0	MA CAPE ANN
1728JUL30	1500X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728AUG 2	0315X	42.8	70.6	4	4	0.0	MA CAPE ANN
1728SEP25	X	42.8	70.6	2	2	0.0	MA CAPE ANN
1729FEB10	1400X	42.8	70.6	5	5	0.0	MA CAPE ANN
1729MAR30		41.4	73.5	2	2	0.0	CT DANBURY
1729MAR30	1900X	42.8	70.6	4	5	0.0	MA CAPE ANN
1729AUG 6		41.4	73.5	4	4	0.0	CT DANBURY
1729SEP19	2030X	42.8	70.6	4	4	0.0	MA CAPE ANN
1729OCT10	2130X	42.8	70.6	4	4	0.0	MA CAPE ANN
1729NOV10	0340X	42.8	70.6	3	3	0.0	MA CAPE ANN
1729NOV25	1300X	42.8	70.6	4	4	0.0	MA CAPE ANN
1729DEC 9	0100X	42.8	70.6	4	5	0.0	MA CAPE ANN
1730FEB20	0100X	42.8	70.6	4	5	0.0	MA CAPE ANN
1730FEB20	0500X	42.8	70.6	4	5	0.0	MA CAPE ANN
1730MAR 9	1845X	42.8	70.6	4	5	0.0	MA CAPE ANN
1730APR24	0100X	42.8	70.6	4	4	0.0	MA CAPE ANN
1730AUG 8	1400X	42.8	70.6	3	3	0.0	MA CAPE ANN
1730AUG26	1300X	42.8	70.6	3	3	0.0	MA CAPE ANN
1730NOV17	X	42.8	70.6	3	3	0.0	MA CAPE ANN
1730NOV25	1400X	42.8	70.6	2	2	0.0	MA CAPE ANN
1730DEC 7	0120X	42.8	70.6	4	4	0.0	MA CAPE ANN
1730DEC18	0345X	42.8	70.6	3	3	0.0	MA CAPE ANN
1730DEC22	2345X	42.8	70.6	3	3	0.0	MA CAPE ANN
1730DEC24	0330X	42.8	70.6	4	5	0.0	MA CAPE ANN
1731JAN13	0000X	42.8	70.6	4	4	0.0	MA CAPE ANN
1731JAN19	0000X	42.8	70.6	4	4	0.0	MA CAPE ANN
1731JAN23	0500X	42.8	70.6	4	4	0.0	MA CAPE ANN
1731MAR18	2200X	42.8	70.6	2	2	0.0	MA CAPE ANN
1731JUN 6	1400X	42.8	70.6	2	2	0.0	MA CAPE ANN
1731JUL16	1000X	42.8	70.6	4	4	0.0	MA CAPE ANN
1731SEP 3	0200X	42.8	70.6	2	2	0.0	MA CAPE ANN
1731OCT13	0400X	42.8	70.6	4	4	0.0	MA CAPE ANN
1732FEB19	0000X	42.8	70.6	4	4	0.0	MA CAPE ANN
1732SEP16	1600	45.5	73.6	8	9	0.0	PQ MONTREAL
1732DEC 0	X	42.8	70.6	3	3	0.0	MA CAPE ANN
1733JAN10	A.M.	42.8	70.6	3	3	0.0	MA CAPE COD
1733MAR12	X	42.8	70.6	2	2	0.0	MA CAPE ANN
1733OCT10	X	42.8	70.6	2	2	0.0	MA CAPE ANN
1733OCT30	P.M.X	42.8	70.6	2	2	0.0	MA CAPE ANN

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1734JUN28	0320X	42.8	70.6	2	2	0.0	MA CAPE ANN
1734JUL10	2015X	42.8	70.6	2	2	0.0	MA CAPE ANN
1734OCT20	1520X	42.8	70.6	3	3	0.0	MA CAPE ANN
1734NOV23	0500X	42.8	70.6	4	5	0.0	MA CAPE ANN
1734NOV27	1100X	42.8	70.6	3	3	0.0	MA CAPE ANN
1736FEB13	2245X	42.8	70.6	4	4	0.0	MA CAPE ANN
1736APR 1	1530X	42.8	70.6	2	2	0.0	MA CAPE ANN
1736JUL24	1445X	42.8	70.6	3	3	0.0	MA CAPE ANN
1736OCT12	0630X	42.8	70.6	4	4	0.0	MA CAPE ANN
1736NOV23	0700X	42.8	70.6	4	2	0.0	MA CAPE ANN
1736NOV23	1100X	42.8	70.6	3	3	0.0	MA CAPE ANN
1737FEB17	2115	42.8	70.6	4	4	0.0	MA CAPE ANN
1737SEP20	1520	42.8	70.6	4	5	0.0	MA CAPE ANN
1737DEC19	0330	40.8	74.0	7	8	0.0	NY NY CITY
1739AUG13	0730	42.8	70.6	4	5	0.0	MA CAPE ANN
1740DEC25	1135X	42.8	70.6	2	2	0.0	MA CAPE ANN
1741JAN29	0900X	42.8	70.6	2	2	0.0	MA CAPE ANN
1741FEB 5	2050X	42.8	70.6	4	4	0.0	MA CAPE ANN
1741JUN24	1535	42.2	71.2	3	5	0.0	MA BOSTON
1741DEC17	1300	42.3	71.2	4	4	0.0	MA BOSTON
1744MAY27		46.8	71.2	4	4	0.0	PQ QUEBEC CITY
1744JUN13		42.3	71.2	2	2	0.0	MA CAMBRIDGE
1744JUN14		42.6	70.9	2	2	0.0	MA CAPE ANN
1744JUN14		42.6	70.9	2	2	0.0	MA CAPE ANN
1744JUN14	1515	42.5	70.9	6	7	0.0	MA CAPE ANN
1744JUN14	2200X	42.5	70.9	4	5	0.0	MA SALEM
1744JUN15	X	42.6	70.9	2	2	0.0	MA CAPE ANN
1744JUL 1		42.5	70.9	4	5	0.0	MA SALEM
1744JUL 9	X	42.5	70.9	3	3	0.0	MA SALEM
1744DEC23	1700X	42.8	70.6	2	2	0.0	MA CAPE ANN
1745JAN 3	1700	42.8	70.9	3	3	0.0	MA NEWBURY
1745JUN12		42.3	71.1	2	2	0.0	MA BOSTON
1746FEB 3	0200	42.3	71.1	2	2	0.0	MA BOSTON
1746FEB14	0200	42.3	71.1	3	3	0.0	MA BOSTON
1747AUG25	A.M.	43.2	70.9	3	3	0.0	NH DOVER
1751JUL21	A.M.	43.2	70.9	3	3	0.0	NH DOVER
1755NOV18	0912	42.7	70.3	8	9	0.0	MA OFF CAPE ANN
1755NOV18	1029X	42.7	70.3	4	4	0.0	MA OFF CAPE ANN
1755NOV23	0127X	42.7	70.3	5	6	0.0	MA OFF CAPE ANN
1755DEC20	0115X	42.7	70.3	4	3	0.0	MA OFF CAPE ANN
1756JAN 2		42.3	71.1	3	3	0.0	MA BOSTON
1756NOV16	0900	42.3	71.1	3	3	0.0	MA BOSTON
1756DEC 5	0300X	42.3	71.1	3	3	0.0	MA BOSTON
1757JUL 8	1915	42.3	71.1	4	3	0.0	MA BOSTON
1759FEB 2	0700	42.3	71.0	4	4	0.0	MA BOSTON
1760FEB 3		42.3	71.1	2	2	0.0	MA BOSTON
1760NOV 9		42.3	71.1	3	3	0.0	MA BOSTON
1761FEB 0	X	42.3	71.1	3	3	0.0	MA BOSTON
1761MAR12	0715	42.5	70.9	5	5	0.0	MA BOSTON
1761MAR16	X	42.3	71.1	4	4	0.0	MA BOSTON
1761NOV 2	0100	43.1	71.5	4	5	0.0	NH S.OF CONCORD
1764SEP30	1700	45.2	66.1	5	5	0.0	NB ST.JOHN
1766JAN23	1000	43.7	70.3	4	5	0.0	ME PORTLAND
1766JAN24	X	43.7	70.3	2	2	0.0	ME PORTLAND
1766FEB 2		42.0	68.0	6	6	0.0	MA OFF CAPE COD
1766JUN14		42.7	70.9	3	3	0.0	MA ESSEX
1766AUG25		41.5	71.3	4	5	0.0	RI NEWPORT
1766DEC17	1148	43.1	70.8	4	4	0.0	NH PORTSMOUTH
1769OCT19	A.M.	43.7	70.3	4	4	0.0	ME PORTLAND

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1769OCT19	1700X	43.7	70.3	4	4	0.0	ME PORTLAND
1772AUG15		44.4	71.1	2	2	0.0	NH SHELBURNE
1774FEB23	P.M.	37.3	76.7	4	4	0.0	SE
1775MAR16	1900	37.7	78.8	5	5	0.0	SE
1775SEP 8		44.1	70.2	2	2	0.0	ME OXFORD-BATH
1776FEB 7		41.7	71.4	2	2	0.0	RI SOUTHERN
1776NOV 5	P.M.	35.3	83.2	5	4	0.0	SE
1777APR14		53.8	79.0	5	5	0.0	PQ JAMES BAY
1777SEP14		43.0	71.5	2	2	0.0	NH MANCHESTER
1780NOV29		42.5	70.9	4	4	0.0	MA LYNN
1783NOV24	X	41.0	74.5	4	4	0.0	NJ MORRIS CO.
1783NOV30	0200X	41.0	74.5	4	4	0.0	NJ MORRIS CO.
1783NOV30	0350	41.0	74.5	6	5	0.0	NJ MORRIS CO.
1783NOV30	0700X	41.0	74.5	4	4	0.0	NJ MORRIS CO.
1784JAN 2	1000	46.8	71.2	4	4	0.0	PQ QUEBEC CITY
1784JAN12	0830X	46.8	71.2	4	4	0.0	PQ QUEBEC CITY
1786NOV29	2100	42.4	71.1	3	3	0.0	MA CAMBRIDGE
1787FEB25	0600X	42.4	71.1	3	3	0.0	MA CAMBRIDGE
1791JAN13	0900	37.7	78.8	4	4	0.0	SE
1791MAY16	1300	41.5	72.5	6	8	0.0	CT MOODUS-E.HADDAM
1791MAY19	0300X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1791DEC 7	0100	47.4	70.5	8	8	0.0	PQ BAIE-ST-PAUL
1792JAN10		42.5	70.9	2	2	0.0	MA SALEM
1792AUG29	0300X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1792OCT24	0600X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1793JAN11	1300X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1793JUL 6	1100X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1794MAR 6	1900X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1794MAR 7	0400X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1794MAR 9	1900X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1794MAR10	0400X	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1800MAR17		39.8	75.2	2	2	0.0	PA PHILADELPHIA
1800NOV11		42.3	71.1	3	3	0.0	MA BOSTON
1800NOV29		39.8	75.2	2	2	0.0	PA PHILADELPHIA
1800DEC20		43.7	72.3	4	4	0.0	NH NW OF NEWPORT
1800DEC25		41.9	71.1	4	6	0.0	MA WAREHAM-TAUNTON
1801MAR 1	2030	43.1	70.8	4	4	0.0	NH PORTSMOUTH
1802FEB21		44.0	69.0	2	2	0.0	ME KENNEBEC RIVER
1802AUG23	1000	37.6	77.4	5	5	0.0	SE
1803JAN18	1450	42.5	70.9	4	4	0.0	MA SALEM
1804FEB 8		42.5	70.9	2	2	0.0	MA SALEM
1804MAY18		40.8	74.0	3	3	0.0	NY NY CITY
1805FEB 7		44.3	69.8	2	2	0.0	ME AUGUSTA
1805APR 6	1915	42.5	70.9	4	4	0.0	MA LYNN
1805APR25		42.5	70.9	4	4	0.0	MA SALEM
1805MAY12		42.8	70.8	2	2	0.0	MA NEWBURY
1805JUN12	1230	44.5	69.0	4	4	0.0	ME BELFAST
1805AUG12	0000	41.5	72.5	3	4	0.0	CT MOODUS-E.HADDAM
1805DEC30	1100	41.5	72.5	3	4	0.0	CT MOODUS-E.HADDAM
1806JUN13		44.0	69.9	2	2	0.0	ME KENNEBEC RIVER
1807JAN12		42.3	72.6	2	2	0.0	MA NORTHAMPTON
1807JAN14	0400	43.0	71.1	4	4	0.0	NH NEAR EXETER
1807FEB22	1900	43.7	70.5	3	3	0.0	ME WINDHAM
1807MAY 6	1800	43.5	70.5	4	4	0.0	ME SACO RIVER
1808JUN26	1951	44.4	69.0	3	4	0.0	ME BELFAST
1809JAN21		57.0	62.0	5	5	0.0	NF LABRADOR
1810NOV10	0215	43.0	70.8	5	6	0.0	NH PORTSMOUTH
1811JUL 0		41.5	72.5	3	3	0.0	CT MOODUS-E.HADDAM
1812FEB 2	1430	37.6	77.4	4	4	0.0	SE

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1812FEB 9	1400	41.5	72.5	3 3	0.0	CT MOODUS-E.HADDAM
1812APR22	0900	37.6	77.4	4 4	0.0	SE
1812JUL 5	1300	41.5	72.5	3 3	0.0	CT MOODUS-E.HADDAM
1813DEC28	2100	41.5	72.5	3 4	0.0	CT MOODUS-E.HADDAM
1814NOV29	0014	43.7	70.3	5 4	0.0	ME WINDHAM
1816SEP 9		45.5	73.6	7 7	0.0	PQ MONTREAL
1816SEP16	X	45.5	73.6	6 6	0.0	PQ MONTREAL
1817MAY22	2000	45.2	69.3	5 6	0.0	ME DOVER-FOXCROFT
1817SEP 7		42.5	70.9	3 3	0.0	MA LYNN
1817OCT 5	1645	42.5	71.2	6 5	0.0	MA WOBURN
1818OCT11		46.9	71.2	4 4	0.0	PQ N.OF QUEBEC CITY
1819AUG15		45.6	74.3	3 3	0.0	PQ ST-ANDREWS
1819NOV10		45.5	73.6	3 3	0.0	PQ MONTREAL
1821FEB20		46.8	71.2	3 3	0.0	PQ QUEBEC CITY
1821MAY 5	1230	44.8	68.8	5 4	0.0	ME BANGOR
1823MAR 7	1500	43.9	70.0	4 4	0.0	ME BRUNSWICK
1823JUN10	1700	44.8	68.8	5 3	0.0	ME BANGOR
1823JUL23	1155	42.9	70.6	5 4	0.0	NH OFF HAMPTON
1824JUL 9		46.5	66.5	5 5	0.0	NB HOLTVILLE
1827AUG23		41.4	72.7	4 5	0.0	CT NW OF NEW LONDON
1828JUL25	1100	43.9	70.0	4 4	0.0	ME BRUNSWICK
1829JAN 1		43.1	70.8	4 4	0.0	NH PORTSMOUTH
1829AUG27	0200X	43.9	70.0	3 3	0.0	ME BRUNSWICK
1829AUG27	0215X	43.9	70.0	3 3	0.0	ME BRUNSWICK
1829AUG27	2145	44.2	69.8	4 4	0.0	ME GARDINER
1830DEC 2	0100	42.5	70.9	3 3	0.0	MA LYNN
1831MAY 8		47.3	70.5	7 7	0.0	PQ ILE-AUX-COUDRES
1831JUL14		47.6	70.1	7 7	0.0	PQ LA MALBAIE
1832 0		45.0	64.0	4 4	0.0	NS WINDSOR
1833MAR 0		47.7	70.2	4 4	0.0	PQ LA MALBAIE
1833APR 0	X	47.7	70.2	4 4	0.0	PQ LA MALBAIE
1836NOV30		55.5	60.5	5 5	0.0	NF HOPEDALE
1837JAN15	0700	42.5	70.9	4 4	0.0	MA LYNN
1837APR12		41.7	72.7	5 4	0.0	CT HARTFORD
1840JAN16	2000	43.0	75.0	6 5	0.0	NY HERKIMER
1840AUG 9	2030	41.5	72.9	5 4	0.0	CT HARTFORD
1840SEP10		43.2	79.9	5 5	0.0	ON HAMILTON
1840NOV11		39.8	75.2	7 7	0.0	NJ WOODBURY
1841JAN25	A.M.	40.7	74.0	3 3	0.0	NY NY CITY
1842NOV 9		46.0	73.2	6 6	0.0	PQ MONTREAL-TROIS-RIVIERES
1843MAR14		44.4	72.5	4 4	0.0	VT N.OF MONTPELIER
1843OCT24		41.1	71.2	4 4	0.0	MA CANTON
1844JUN 0	0100	41.5	72.4	3 3	0.0	CT MOODUS-E.HADDAM
1844NOV 0		45.5	73.6	4 4	0.0	PQ MONTREAL
1845JAN 1		41.5	72.4	3 3	0.0	CT MOODUS-E.HADDAM
1845OCT26	2315	41.2	73.3	5 6	0.0	CT BRIDGEPORT
1845NOV 0		43.6	72.3	4 4	0.0	NH LEBANON
1846MAY30	1830	42.7	70.3	4 4	0.0	MA CAPE ANN
1846JUL10		43.1	71.3	3 3	0.0	NH DEERFIELD
1846AUG25	0945	42.5	70.8	5 4	0.0	MA MARBLEHEAD
1846SEP12	2330	43.1	71.3	3 3	0.0	NH DEERFIELD
1846OCT30	0200X	43.1	71.3	3 3	0.0	NH DEERFIELD
1846OCT31	P.M.X	43.1	71.3	3 3	0.0	NH DEERFIELD
1846NOV13	0040X	43.1	71.3	3 3	0.0	NH DEERFIELD
1846DEC 2	X	43.1	71.3	3 3	0.0	NH DEERFIELD
1847JAN 1		43.9	66.1	4 4	0.0	NS YARMOUTH
1847JAN 8	2000	44.0	78.0	3 3	0.0	ON GRAFTON HARBOUR
1847JAN12	0430	42.6	73.7	2 2	0.0	NY ALBANY
1847JAN14		44.2	78.2	3 3	0.0	ON

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1847JAN20		44.3	68.3	4	4	0.0	ME BANGOR-CAMDEN
1847FEB 2	X	43.1	71.3	3	3	0.0	NH DEERFIELD
1847FEB 2		44.2	69.1	4	4	0.0	ME CAMDEN
1847FEB14	X	43.1	71.3	3	3	0.0	NH DEERFIELD
1847FEB19		44.4	69.0	3	3	0.0	ME BELFAST
1847FEB21	X	43.1	71.3	3	3	0.0	NH DEERFIELD
1847APR 2	0200	43.7	70.7	3	3	0.0	ME LIMINGTON
1847JUL 9	A.M.	43.3	73.7	3	3	0.0	NY GLENS FALLS
1847AUG 8	1500	41.7	70.1	6	5	0.0	MA BREWSTER
1847SEP29		40.5	74.0	5	4	0.0	NY NY CITY
1847NOV 0		45.5	73.6	3	3	0.0	PQ MONTREAL
1848JAN 1		45.0	63.5	4	4	0.0	NS N.OF HALIFAX
1848FEB 1		43.5	65.5	3	3	0.0	NS YARMOUTH-SHELBURNE
1848MAY23		45.5	73.6	3	3	0.0	PQ MONTREAL
1848SEP 9	0400	40.4	74.0	5	4	0.0	NY NY CITY
1848NOV 6	1015	47.6	69.9	2	2	0.0	PQ GRAND ISLAND
1848DEC11	0800	45.5	73.6	3	3	0.0	PQ MONTREAL
1849FEB 4		41.5	71.6	3	3	0.0	RI NEWPORT
1849FEB15		42.1	72.6	3	3	0.0	MA SPRINGFIELD
1849OCT 8	P.M.	42.5	71.4	4	4	0.0	MA MIDDLESEX CO.
1850JUL20	P.M.	43.7	70.3	3	3	0.0	ME PORTLAND
1850OCT18	0200	37.4	78.4	5	4	0.0	SE
1851JAN 4	0430	44.6	69.6	4	3	0.0	ME ELLSWORTH
1851JAN30	2200	45.6	74.3	3	3	0.0	PQ ST-ANDREWS
1851OCT12	0230	43.1	71.3	3	3	0.0	NH DEERFIELD
1851DEC25	1245	44.0	73.3	3	3	0.0	VT BRIDGEPORT
1852JAN10	1140	41.2	71.4	4	4	0.0	RI OFF COAST
1852FEB11	1040	45.6	73.8	3	3	0.0	PQ ST-MARTIN
1852MAR29	1800	36.6	81.6	6	6	0.0	SE
1852JUN30		43.4	72.3	3	3	0.0	NH CLAREMONT
1852AUG 1		41.4	72.1	3	3	0.0	CT GROTON
1852AUG 3	0400	47.6	65.7	3	3	0.0	NB BATHURST
1852AUG11	P.M.	43.1	71.3	3	3	0.0	NH DEERFIELD
1852NOV28	0445	43.0	70.9	5	4	0.0	NH EXETER
1852DEC15	2100	43.4	78.2	3	3	0.0	NY CARLTON
1853MAR12	0700	43.7	75.5	6	6	0.0	NY LOWVILLE
1853MAR13	1000	43.1	79.4	5	5	0.0	ON ST.CATHARINES
1853MAY 2	1420	38.5	79.5	5	5	0.0	SE
1853MAY24		45.4	75.8	2	2	0.0	ON OTTAWA
1853JUN 3		44.9	65.3	3	3	0.0	NS BRIDGETOWN
1853JUN17		43.7	70.3	3	3	0.0	ME PORTLAND
1853JUN20	X	43.7	70.0	3	3	0.0	ME PORTLAND
1853JUL 0		47.5	70.0	3	3	0.0	PQ LA MALBAIE
1853JUL17	1030X	43.5	70.2	4	4	0.0	ME PORTLAND
1853JUL20	P.M.X	43.7	70.3	3	3	0.0	ME PORTLAND
1853AUG17		41.6	70.9	3	3	0.0	MA NEW BEDFORD
1853SEP 8	0410X	41.6	70.9	3	3	0.0	MA NEW BEDFORD
1853NOV21		43.0	71.9	3	3	0.0	NH ANTRIM
1853NOV28	X	43.0	71.9	4	4	0.0	NH ANTRIM
1853NOV28	0445	43.0	69.0	4	4	0.0	MA CAPE ANN
1854JAN24	1200	42.2	72.3	3	3	0.0	MA PALMER
1854JAN27	1200X	42.2	72.3	3	3	0.0	MA PALMER
1854FEB23	0500	42.5	71.1	3	3	0.0	MA READING
1854OCT 1	X	42.9	72.3	2	2	0.0	NH KEENE
1854OCT25	0300	42.9	72.3	4	4	0.0	NH KEENE
1854DEC 5	0300	45.1	74.2	3	3	0.0	PQ HUNTINGDON
1854DEC11	1530	43.0	70.8	5	4	0.0	NH NORTH HAMPTON
1855JAN 3	0216	39.2	77.5	5	5	0.0	SE
1855JAN13	1040	45.6	73.8	3	3	0.0	PQ ST-MARTIN

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1855JAN16	2300	44.0	71.0	5	4	0.0	ME OTISFIELD
1855JAN17		40.8	73.6	2	2	0.0	NY NASSAU CO.
1855JAN17	0020X	44.0	71.0	4	4	0.0	ME OTISFIELD
1855JAN19	1600	43.7	70.3	3	3	0.0	ME PORTLAND
1855JAN20	0100X	43.7	70.3	3	3	0.0	ME PORTLAND
1855JAN23	2000	42.6	70.4	3	3	0.0	MA NEWBURY
1855FEB 7	0430	42.0	74.0	6	6	0.0	NY HUDSON VALLEY
1855FEB 8	1130	46.0	64.5	7	7	0.0	NB MONCTON
1855FEB19		44.6	69.6	4	4	0.0	ME ELLSWORTH
1855FEB23	1030X	44.6	69.6	3	3	0.0	ME ELLSWORTH
1855MAY29	1000	44.7	71.6	4	4	0.0	NH COOS CO.
1855JUN 0		44.7	65.5	4	4	0.0	NS GRANVILLE MTNS
1855OCT10	0435	37.7	78.8	5	5	0.0	SE
1855DEC17	1900	43.3	73.7	4	4	0.0	NY WARREN
1856JAN16	0800	39.3	78.2	4	4	0.0	SE
1856MAR13	0300	41.4	72.6	4	4	0.0	CT HADDAM
1856MAY 1	1730	45.4	75.8	2	2	0.0	ON OTTAWA
1856JUN10		43.1	72.5	2	2	0.0	VT BELLOWS FALLS
1856DEC28		45.4	75.8	2	2	0.0	ON OTTAWA
1857JUL 1	0345	41.5	72.5	4	3	0.0	CT MOODUS-E.HADDAM
1857OCT23	2015	43.2	78.6	6	6	0.0	NY BUFFALO
1857DEC 8	2000	46.7	68.0	4	4	0.0	ME PRESQUE ISLE
1857DEC23	1830	44.1	70.2	6	7	0.0	ME LEWISTON
1857DEC28	X	44.1	70.2	4	4	0.0	ME LEWISTON
1857 0		58.1	63.1	4	4	0.0	NF HEBRON
1858JAN15		43.1	79.1	2	2	0.0	ON NIAGARA FALLS
1858MAY10	X	45.5	72.1	3	3	0.0	PQ RICHMOND
1858MAY17	2000	45.5	72.1	4	4	0.0	PQ RICHMOND
1858JUN27	X	41.4	72.8	4	4	0.0	CT NORTH HAVEN
1858JUL 1	0345	41.3	73.0	4	5	0.0	CT NEW HAVEN
1858SEP15	2130	47.6	69.8	3	3	0.0	PQ KAMOURASKA
1859 0		48.7	68.0	3	3	0.0	PQ METIS
1860MAR12	A.M.	41.5	72.5	3	3	0.0	CT MOODUS-E.HADDAM
1860MAR17	0230	42.2	70.5	4	5	0.0	MA OFF PROVINCETOWN
1860MAR17	0315X	42.2	70.5	4	5	0.0	MA OFF PROVINCETOWN
1860OCT17	1115	47.5	70.1	8	9	0.0	PQ RIVIERE OUELLE
1861MAR 1		42.4	71.1	3	3	0.0	MA BOSTON
1861MAR 5	1700	40.7	74.2	3	3	0.0	NJ NEWARK
1861JUL13	0200	45.4	75.4	7	7	0.0	ON OTTAWA
1861OCT 0	1403	45.6	73.7	5	5	0.0	PQ ILE JESUS
1862FEB 3	0100	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1862FEB 4	1230	42.5	71.2	3	3	0.0	MA CAMBRIDGE
1863JUN 9	2130	44.5	73.0	4	4	0.0	VT E.OF BURLINGTON
1864APR20	1815	46.9	71.2	6	6	0.0	PQ N.OF QUEBEC CITY
1864APR21	0400	48.5	68.4	3	3	0.0	PQ PTE-AU-PERES
1864JUL29	0000	46.5	53.7	5	5	0.0	NF OFF COAST
1864OCT21	0910	45.5	73.6	4	4	0.0	PQ MONTREAL
1866NOV 9	1610	46.8	71.2	4	4	0.0	PQ QUEBEC CITY
1867DEC18	0800	44.7	75.2	6	7	0.0	NY CANTON
1868MAR 1		44.3	69.7	3	3	0.0	ME AUGUSTA
1869APR 9	1300	42.7	80.8	3	3	0.0	ON VIENNA
1869OCT22	1100	45.0	66.2	6	8	0.0	NB BAY OF FUNDY
1869DEC 0		47.5	70.5	5	5	0.0	PQ BAIE-ST-PAUL
1870FEB 8		44.1	69.8	4	4	0.0	ME GARDINER
1870MAR 4		45.5	73.6	2	2	0.0	PQ MONTREAL
1870MAR17	1100	45.5	66.5	4	4	0.0	NB ST.JOHN
1870OCT20	1630	47.4	70.5	9	9	0.0	PQ BAIE-ST-PAUL
1870OCT23	1130	42.1	72.6	3	3	0.0	MA SPRINGFIELD
1870OCT26	X	47.4	70.5	4	4	0.0	PQ BAIE-ST-PAUL

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1870DEC26	1830	46.8	71.2	4 4	0.0	PQ QUEBEC CITY
1871JAN 3		45.6	74.6	5 5	0.0	ON HAWKESBURY
1871JAN 9		47.5	70.1	5 5	0.0	PQ KAMOURASKA
1871FEB16		47.5	70.4	4 4	0.0	PQ ILE-AUX-COUDRES
1871FEB17	X	47.5	70.4	3 3	0.0	PQ ILE-AUX-COUDRES
1871MAY20	0700	46.8	71.2	4 4	0.0	PQ QUEBEC CITY
1871MAY20	0820X	46.8	71.2	3 3	0.0	PQ QUEBEC CITY
1871JUL20		43.2	71.5	4 4	0.0	NH CONCORD
1871OCT 9	1440	39.7	75.5	7 7	0.0	DE WILMINGTON
1872JAN10	0054	47.5	70.5	7 7	0.0	PQ BAIE-ST-PAUL
1872JUL11	1025	40.9	73.8	4 5	0.0	NY NEW ROCHELLE
1872NOV18	1900	43.2	71.6	5 4	0.0	NH CONCORD
1873JAN11	1000	43.9	70.0	3 3	0.0	ME BRUNSWICK
1873FEB22	1230	44.9	67.0	3 3	0.0	ME EASTPORT
1873FEB26		46.8	71.2	2 2	0.0	PQ BEAUPORT
1873MAR18	A.M.	44.6	75.1	2 2	0.0	NY CANTON
1873MAR22	0430	45.5	73.6	3 3	0.0	PQ MONTREAL
1873APR17	0600	44.5	69.7	3 3	0.0	ME WATERVILLE
1873APR25	1900	44.8	74.2	5 5	0.0	NY MALONE
1873APR30	P.M.	45.0	74.7	4 4	0.0	ON CORNWALL
1873APR30	P.M.	43.3	79.9	4 4	0.0	ON HAMILTON
1873JUL 6	1430	43.0	79.5	6 6	0.0	ON WELLAND
1873JUL 8	A.M.	44.6	63.6	2 2	0.0	NS HALIFAX
1873JUL16	A.M.	42.3	71.8	2 2	0.0	MA WORCESTER
1873SEP30	1150	46.5	76.0	4 4	0.0	PQ GATINEAU RIVER VALLEY
1873SEP30	1150	45.5	73.2	4 4	0.0	PQ ST-HYACINTHE
1873OCT 3	1245	37.2	78.2	4 4	0.0	SE
1873OCT 5	0730	42.9	71.3	3 3	0.0	NH DERRY
1873NOV 5	0430	44.5	73.2	3 3	0.0	VT BURLINGTON
1873NOV 5	0500X	44.5	73.2	3 3	0.0	VT BURLINGTON
1873NOV13	P.M.	44.8	68.8	3 3	0.0	ME BANGOR
1874JAN 5	2100	44.7	75.5	2 2	0.0	NY OGDENSBURG
1874JAN 6		43.6	71.2	4 4	0.0	NH WOLFEBORO
1874JAN25	1700	42.6	71.4	4 4	0.0	MA LOWELL
1874JAN26	0700	43.0	71.5	4 4	0.0	NH MANCHESTER
1874JAN26	1000X	43.0	71.5	3 3	0.0	NH MANCHESTER
1874FEB 1	1930	48.6	68.5	3 3	0.0	PQ RIMOUSKI
1874FEB10		35.7	82.1	5 7	0.0	SE
1874FEB12	1130	43.5	70.5	2 2	0.0	ME SACO
1874FEB28	0335	45.2	67.3	4 5	0.0	ME CALAIS
1874MAR12		43.8	66.1	2 2	0.0	NS YARMOUTH
1874JUL31	0900	46.7	71.9	4 4	0.0	PQ PORTNEUF
1874AUG 3	X	46.7	71.9	4 4	0.0	PQ PORTNEUF
1874NOV24		42.7	70.9	4 4	0.0	MA SALEM-NEWBURY
1874DEC11	0325	40.9	73.8	5 6	0.0	NY NY CITY
1874DEC13	X	40.9	73.8	5 5	0.0	NY NY CITY
1875FEB 9		41.5	72.0	2 2	0.0	CT PRESTON
1875APR30		45.1	74.5	3 3	0.0	PQ HUNTINGDON
1875MAY 6		43.6	71.2	2 2	0.0	NH WOLFEBORO
1875MAY15	1515	42.4	71.1	2 2	0.0	MA CAMBRIDGE
1875JUL28	0910	41.9	73.0	5 5	0.0	CT NW OF TORRINGTON
1875SEP26	0200	41.3	73.3	2 2	0.0	CT STEPNEY
1875NOV 1	0218	42.4	71.1	2 2	0.0	MA CAMBRIDGE
1875NOV 2	0255	33.8	82.5	6 6	0.0	SE
1875DEC 1	0900	42.9	72.3	4 4	0.0	NH KEENE
1875DEC 1	1100X	42.9	72.3	2 2	0.0	NH KEENE
1875DEC18		35.2	80.8	5 5	0.0	SE
1875DEC23	0445	37.6	77.4	7 7	0.0	SE
1876JAN 7		43.3	71.7	2 2	0.0	NH WARNER & CONTOOCOOK

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1876JAN 8	2130	43.2	78.7	2	2	0.0	NY LOCKPORT
1876JAN16	0500	44.5	69.5	3	3	0.0	ME CHINA
1876SEP22	0430	41.5	71.3	5	4	0.0	RI NEWPORT
1876NOV20		44.9	67.0	2	2	0.0	ME EASTPORT
1877FEB18	1920	43.7	70.3	3	3	0.0	ME PORTLAND
1877APR23	1600	43.0	71.3	2	2	0.0	NH AUBURN
1877MAY 3	0320	43.9	78.9	3	3	0.0	ON OSHAWA
1877MAY14	P.M.	42.8	73.9	2	2	0.0	NY SCHENECTADY
1877JUL17	0800	47.8	69.6	3	3	0.0	PQ RIVIERE-DU-LOUP
1877SEP10	0700	42.4	71.1	3	3	0.0	MA CAMBRIDGE
1877SEP10	1459	40.3	74.9	5	4	0.0	NJ BURLINGTON
1877NOV 4	0656	45.2	73.9	6	7	0.0	PQ HOWICK
1877NOV14	1440	45.0	74.8	3	3	0.0	ON CORNWALL
1877NOV16	0738	35.5	84.0	5	5	0.0	SE
1877DEC18	0600X	45.7	76.8	3	3	0.0	ON BEACHBURG
1877DEC18	1000	45.7	76.8	5	5	0.0	ON BEACHBURG
1878FEB 5	1620	40.0	73.8	5	5	0.0	NJ OFFSHORE
1878MAR12		42.7	71.6	2	2	0.0	VT MILFORD
1878OCT 4	0730	41.5	74.0	5	5	0.0	NY HUDSON VALLEY
1878DEC25	0200	40.8	73.8	2	2	0.0	NY FLUSHING
1878DEC29	0232	42.7	74.3	3	3	0.0	NY SCHOHARIE
1879MAR26	0030	39.2	75.5	5	4	0.0	NJ SOUTHERN
1879APR 8	0500	47.4	70.5	3	3	0.0	PQ BAIE-ST-PAUL
1879JUN11		45.6	73.6	4	4	0.0	PQ MONTREAL
1879AUG21	0800	43.2	79.2	4	4	0.0	ON ST.CATHARINES
1879OCT24	2312	41.3	72.9	2	2	0.0	CT NEW HAVEN
1879OCT26	0330	43.0	71.5	4	4	0.0	NH MANCHESTER
1879NOV 3	1215	43.2	71.7	2	2	0.0	NH CONTOOCOOK
1880FEB 9	0100X	45.4	75.8	2	2	0.0	ON OTTAWA
1880MAR29		43.4	70.7	3	3	0.0	ME SANFORD
1880APR 3	0700	46.8	67.9	3	3	0.0	ME FT.FAIRFIELD
1880APR 4	0300X	45.4	75.8	2	2	0.0	ON OTTAWA
1880MAY12	1245	42.7	71.0	5	4	0.0	MA BOXFORD
1880MAY31		45.2	75.3	4	4	0.0	ON NEAR OTTAWA
1880JUL13	0400	43.2	71.6	2	2	0.0	NH CONCORD
1880JUL21	0000	43.0	71.5	3	3	0.0	NH MANCHESTER
1880JUL22	0700X	45.4	75.8	2	3	0.0	ON OTTAWA
1880AUG21		43.2	71.1	2	2	0.0	NH BARRINGTON
1880SEP 6	0530	45.2	73.8	4	4	0.0	PQ MONTREAL-HUNTINGDON
1880SEP 6	0700	45.0	74.8	3	3	0.0	ON CORNWALL
1880SEP23	2300	44.3	73.3	2	2	0.0	VT CHARLOTTE
1880NOV25	0445	46.8	71.2	3	3	0.0	PQ QUEBEC CITY
1880NOV28	1330	47.4	70.5	4	4	0.0	PQ BAIE-ST-PAUL
1880DEC30		49.3	67.3	3	3	0.0	PQ POINTE-DES-MONTS
1881JAN21	0240	44.0	70.0	4	5	0.0	ME BATH
1881FEB 2	0900	42.3	71.1	2	2	0.0	MA BOSTON
1881FEB 3	0900	42.0	70.7	2	2	0.0	MA PLYMOUTH
1881FEB 4		43.0	70.8	2	2	0.0	NH GREENLAND
1881FEB12		43.0	70.8	2	2	0.0	NH PORTSMOUTH
1881FEB27	0355	44.3	69.8	3	3	0.0	ME AUGUSTA
1881MAR19	0230	42.8	73.9	3	3	0.0	NY SCHENECTADY
1881APR 3	0925	43.0	71.9	3	3	0.0	NH ANTRIM
1881APR 7	0501	47.4	70.5	2	2	0.0	PQ BAIE-ST-PAUL
1881APR21	1630	40.9	73.1	3	3	0.0	NY PORT JEFFERSON
1881MAY18	0520	43.2	71.7	3	3	0.0	NH CONTOOCOOK
1881MAY18	0830X	43.2	71.7	3	3	0.0	NH CONTOOCOOK
1881MAY31	0830	47.1	70.4	2	2	0.0	PQ L'ISLET
1881MAY31	0930	47.6	70.1	2	2	0.0	PQ LA MALBAIE
1881JUN19	0825	42.8	70.9	4	4	0.0	MA NEWBURY

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1881JUN19	A.M.	45.4	75.8	2 2	0.0	ON OTTAWA
1881AUG 1	0245	44.8	68.8	3 3	0.0	ME BANGOR
1881AUG13	A.M.	43.2	71.7	3 3	0.0	NH CONTOOCOOK
1881SEP25		42.1	76.8	2 2	0.0	NY ELMIRA
1881OCT 1	0640	47.6	70.2	4 4	0.0	PQ LA MALBAIE
1881OCT 6	0503	43.2	71.6	4 3	0.0	NH BRISTOL
1881OCT31	0640	43.2	71.7	4 2	0.0	NH CONTOOCOOK
1881DEC 4	2330	45.1	74.2	3 3	0.0	PQ HUNTINGDON
1881DEC16	2100	42.3	71.1	3 3	0.0	MA DORCHESTER
1882FEB26	2325	47.6	70.1	2 2	0.0	PQ LA MALBAIE
1882APR 2	A.M.	43.0	74.3	2 2	0.0	NY AMSTERDAM
1882APR17	1900	43.2	71.7	4 4	0.0	NH HOPKINTON
1882MAY 1		41.6	71.4	2 2	0.0	RI E.GREENWICH
1882MAY 8	0900	43.2	71.6	3 3	0.0	NH CONCORD
1882AUG 1	2300X	49.3	67.3	3 3	0.0	PQ POINTE-DES-MONTS
1882AUG15	1530	49.3	67.3	4 4	0.0	PQ POINTE-DES-MONTS
1882SEP20	1700X	49.3	67.3	3 3	0.0	PQ POINTE-DES-MONTS
1882OCT10	1100	45.5	73.6	2 2	0.0	PQ MONTREAL
1882NOV27	2330	43.0	79.2	4 4	0.0	ON WELLAND
1882DEC 4	2330X	43.0	79.2	2 2	0.0	ON WELLAND
1882DEC19	2224	43.2	71.4	5 4	0.0	NH CONCORD
1883JAN 1	0255	45.0	67.0	5 6	0.0	NB PASSAMAQUODDY BAY
1883JAN 1	0758	44.6	67.7	4 4	0.0	ME ADDISON
1883JAN 1	1328X	44.6	67.7	2 2	0.0	ME ADDISON
1883JAN 9	0800	45.1	74.2	2 2	0.0	PQ HUNTINGDON
1883FEB 4	2005	43.6	71.2	4 2	0.0	NH WOLFEBORO
1883FEB28	0330	41.5	71.3	5 5	0.0	RI NEWPORT
1883MAR11	1557	45.4	72.5	3 3	0.0	PQ WATERLOO
1883MAR12		45.1	74.5	4 4	0.0	PQ DUNDEE
1883MAR23	1425	45.1	74.2	2 2	0.0	PQ HUNTINGDON
1883APR 1	0600	43.3	79.9	3 3	0.0	ON HAMILTON
1883OCT15	P.M.	49.3	67.3	3 3	0.0	PQ POINTE-DES-MONTS
1883NOV 5	P.M.X	49.3	67.3	3 3	0.0	PQ POINTE-DES-MONTS
1883NOV22	1600X	49.3	67.3	3 3	0.0	PQ POINTE-DES-MONTS
1883DEC23	0100X	49.3	67.3	3 3	0.0	PQ POINTE-DES-MONTS
1884JAN18	0700	43.2	71.7	4 4	0.0	NH CONTOOCOOK
1884JAN18	1300	34.3	78.0	5 5	0.0	SE
1884JAN26		45.4	66.0	3 3	0.0	NB ROTHESAY
1884FEB16	1400X	49.3	67.3	2 2	0.0	PQ POINTE-DES-MONTS
1884MAR18	1830	47.2	53.0	5 5	0.0	NF ST.JOHN'S
1884MAY31		40.6	75.5	5 6	0.0	PA ALLENTOWN
1884AUG 8		41.3	70.2	2 2	0.0	MA NANTUCKET I.
1884AUG10	1907	40.6	74.0	7 7	0.0	NY NY CITY
1884AUG11	X	40.6	74.0	5 4	0.0	NY NY CITY
1884OCT10	A.M.	42.3	71.1	2 2	0.0	MA ROXBURY
1884OCT24	0515	45.1	74.2	3 3	0.0	PQ HUNTINGDON
1884OCT24	1400X	45.1	74.2	3 3	0.0	PQ HUNTINGDON
1884OCT27	0100	42.8	71.4	2 2	0.0	NH NASHUA
1884NOV13	0050	43.2	71.6	4 2	0.0	NH CONCORD
1884NOV21	2330	49.3	67.3	2 2	0.0	PQ POINTE-DES-MONTS
1884NOV22		48.8	64.5	3 3	0.0	PQ GASPE
1884NOV23	1730	43.2	71.7	5 6	0.0	NH CONCORD
1884DEC 4	0518	42.3	72.7	2 2	0.0	MA NORTHAMPTON
1884DEC17	0700	43.7	71.5	4 3	0.0	NH CENTER HARBOR
1885JAN 3	0700	43.5	71.5	2 2	0.0	NH LACONIA
1885JAN 4	1106	41.3	73.9	3 3	0.0	NY PEEKSKILL
1885JAN31	1005	41.3	73.8	3 3	0.0	NY YORKTOWN
1885FEB 2	1210	36.9	81.1	4 4	0.0	SE
1885FEB 3	0520	45.1	74.2	3 3	0.0	PQ HUNTINGDON

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1885FEB25	1730X	45.1	74.2	3	3	0.0	PQ HUNTINGDON
1885MAR18	1700	43.2	71.7	2	2	0.0	NH CONTOOCOOK
1885MAR19	0045X	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1885MAR24	0122X	45.1	74.2	3	3	0.0	PQ HUNTINGDON
1885APR16	1400	47.5	70.2	3	3	0.0	PQ LA MALBAIE
1885APR26	1030	49.3	67.3	3	3	0.0	PQ POINTE-DES-MONTS
1885APR28	2210	41.3	72.7	3	3	0.0	CT GUILFORD
1885MAY 3	1400	45.2	69.2	3	3	0.0	ME DOVER
1885JUN 0	1500	45.1	66.1	4	4	0.0	NB S.OF ST.JOHN
1885AUG 6	1300	36.2	81.6	5	4	0.0	SE
1885SEP 4	1440	44.3	77.9	3	3	0.0	ON CAMPBELLFORD
1886JAN 6	0010	42.9	71.5	4	4	0.0	NH MERRIMACK
1886JAN 9		41.9	73.1	2	2	0.0	CT WINSTED
1886JAN17	2214	42.8	71.4	4	4	0.0	NH NASHUA
1886JAN25		41.6	73.8	4	4	0.0	NY HOPEWELL JCT
1886FEB 3		41.2	73.2	2	2	0.0	CT BRIDGEPORT
1886FEB13		43.9	78.3	2	2	0.0	ON PORT HOPE
1886MAR21	2200X	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1886MAY16	1525X	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1886MAY18	1930	49.3	67.3	4	4	0.0	PQ POINTE-DES-MONTS
1886AUG 3		43.5	71.5	2	2	0.0	NH MAYFIELD
1886AUG 3		44.3	71.7	2	2	0.0	NH BETHLEHEM
1886AUG12	A.M.	46.0	74.0	4	4	0.0	PQ STE-ADELE
1886AUG19	0800	43.6	79.6	3	3	0.0	ON COOKSVILLE
1886SEP 2		43.2	79.2	2	2	0.0	ON ST.CATHARINES
1886SEP 3		42.5	73.4	2	2	0.0	NY LEBANON SPRINGS
1886SEP 5		41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1886SEP 9		42.5	73.4	2	2	0.0	NY LEBANON SPRINGS
1886OCT15	0330	46.2	60.2	3	3	0.0	NS SYDNEY
1886OCT27	X	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1887JAN 7	1140X	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1887JAN21	1947X	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1887FEB15	1830	49.1	66.5	3	3	0.0	PQ STE-ANNE-DES-MONTS
1887FEB16	1908X	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1887FEB20	0445	45.3	80.0	4	4	0.0	ON PARRY SOUND
1887FEB22	2259X	49.3	67.3	4	4	0.0	PQ POINTE-DES-MONTS
1887MAR11		47.5	70.5	4	4	0.0	PQ BAIE-ST-PAUL
1887MAR20	0350X	45.3	80.0	2	2	0.0	ON PARRY SOUND
1887MAY27	0615	47.4	70.5	5	5	0.0	PQ BAIE-ST-PAUL
1887JUL 1	0200	43.2	71.5	4	4	0.0	NH CONCORD
1887JUL 1	0320	49.3	67.3	2	2	0.0	PQ POINTE-DES-MONTS
1888JAN 6	1930	45.1	74.2	2	2	0.0	PQ HUNTINGDON
1888JAN11	0900	45.8	77.1	4	4	0.0	ON PEMBROKE
1888JAN18		43.2	71.7	2	2	0.0	NH CONTOOCOOK
1888JAN30		41.7	71.2	2	2	0.0	MA FALL RIVER
1888FEB 1	1620	44.7	70.1	4	4	0.0	ME INDUSTRY
1888FEB 5	A.M.	45.4	75.8	2	2	0.0	ON OTTAWA
1888MAR 2	2130	45.1	74.2	3	3	0.0	PQ HUNTINGDON
1888APR19	0530	47.4	70.5	4	4	0.0	PQ BAIE-ST-PAUL
1888JUL 1	2100	45.5	73.6	2	2	0.0	PQ MONTREAL
1888JUL11	0400	44.4	77.0	3	3	0.0	ON BELLEVILLE-KINGSTON
1888AUG15	0115	44.3	70.0	4	4	0.0	ME WAYNE
1888DEC 7	1425	48.5	68.7	4	4	0.0	PQ RIMOUSKI
1889MAR 8		43.5	71.6	4	4	0.0	NH FRANKLIN
1889MAR 8	2340	40.0	76.0	5	5	0.0	PA LANCASTER
1889APR11		43.0	71.5	2	2	0.0	NH MANCHESTER
1889JUL 8		44.6	71.3	2	2	0.0	NH WEST MILAN
1889AUG10		43.4	73.7	4	4	0.0	NY LAKE GEORGE
1890MAR29		43.2	71.5	2	2	0.0	NH CONCORD

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1890MAY18	0130	49.3	67.3	3	3	0.0	PQ POINTE-DES-MONTS
1890SEP26	0803	45.5	73.6	3	3	0.0	PQ MONTREAL
1890OCT29	2230	45.6	75.9	3	3	0.0	PQ MEACH LAKE-HULL
1891JAN15		42.6	71.8	2	2	0.0	MA FITCHBURG
1891MAY 2	0010	43.2	71.6	5	5	0.0	NH NEAR CONCORD
1891MAY30	0000X	43.1	71.5	4	4	0.0	NH NEAR CONCORD
1892MAY 1		43.2	71.5	2	2	0.0	NH CONCORD
1892JUL27	0300	47.8	69.5	3	3	0.0	PQ RIVIERE-DU-LOUP
1892DEC11	1630	44.3	71.7	4	4	0.0	NH BETHLEHEM
1892DEC13	X	44.5	71.5	2	2	0.0	NH LANCASTER
1892DEC14	X	44.3	71.7	2	2	0.0	NH BETHLEHEM
1892DEC26		45.1	74.3	3	3	0.0	PQ HUNTINGDON
1893MAR 9	0530	40.6	74.0	5	5	0.0	NY NY CITY
1893MAR14		42.3	72.7	4	4	0.0	MA LEEDS
1893JUN25		41.9	70.9	2	2	0.0	MA MIDDLEBORO
1893JUL 1		43.1	71.9	2	2	0.0	NH ANTRIM
1893JUL 2		42.9	72.1	2	2	0.0	NH DUBLIN
1893AUG 2		41.7	70.9	2	2	0.0	MA NEW BEDFORD
1893NOV27	1650	45.5	73.3	7	7	0.0	PQ MONTREAL
1894JAN11	0907	49.7	66.8	4	4	0.0	PQ SEPT-ILES
1894FEB24	0400	43.7	79.3	2	2	0.0	ON TORONTO
1894APR10	A.M.	41.6	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1894APR17	1615	45.6	73.3	4	4	0.0	PQ E.OF MONTREAL
1894AUG27	0544	45.5	73.6	3	3	0.0	PQ MONTREAL
1894SEP 3		43.2	72.4	2	2	0.0	NH ALSTEAD
1894NOV 0	1200	47.4	70.0	3	3	0.0	PQ LA-POCATIERE
1894NOV23	1230	41.4	72.1	3	3	0.0	CT NEW LONDON
1894DEC17		42.5	73.8	4	4	0.0	NY S.OF ALBANY
1895APR17	1615	45.6	73.3	4	4	0.0	PQ MONTREAL
1895MAY28	1615	43.0	72.5	3	3	0.0	VT PUTNEY
1895SEP 1	1109	40.7	74.8	6	6	0.0	NJ HIGH BRIDGE
1895DEC 9	0525	45.6	73.3	3	3	0.0	PQ MONTREAL
1896MAR23	0056	45.2	67.2	5	4	0.0	ME CALAIS
1896MAY16	0400	45.9	66.6	4	4	0.0	NB FREDERICTON
1896MAY20		43.2	75.5	2	2	0.0	NY CAMDEN-UTICA
1896OCT22	1030	44.3	71.8	4	4	0.0	NH BETHLEHEM
1897JAN26	A.M.	44.9	66.9	3	3	0.0	NB CAMPOBELLO I.
1897JAN29	0200	44.5	66.8	4	4	0.0	NB GRAND MANAN I.
1897FEB15	0200X	44.7	66.8	3	3	0.0	NB GRAND MANAN I.
1897MAR 7		43.1	79.2	4	4	0.0	ON NIAGARA FALLS
1897MAR23	2307	45.5	73.6	7	7	0.0	PQ MONTREAL
1897MAR26	0504X	45.5	73.6	4	4	0.0	PQ MONTREAL
1897MAR28	0314X	45.5	73.6	7	7	0.0	PQ MONTREAL
1897MAY 3	1718	37.1	80.7	6	6	0.0	SE
1897MAY28	0316	44.5	73.5	6	6	0.0	NY S.OF PLATTSBURG
1897MAY31	1858	37.3	80.7	8	8	0.0	SE
1897JUN29	0400	37.3	79.9	5	5	0.0	SE
1897JUL 1	0920	43.7	71.6	4	4	0.0	NH MEREDITH
1897SEP 5		41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1897SEP25	1805	44.7	68.7	5	4	0.0	ME ELLSWORTH
1897OCT13	0335	44.7	66.8	3	3	0.0	NB GRAND MANAN I.
1897OCT22	0320	36.5	81.1	5	5	0.0	SE
1897NOV27	2056	37.7	77.5	5	4	0.0	SE
1897DEC18	2345	37.7	77.5	5	5	0.0	SE
1898JAN 7	0600	45.1	74.3	4	4	0.0	PQ HUNTINGDON
1898JAN11	0700	44.7	66.8	4	4	0.0	NB GRAND MANAN I.
1898FEB 5	2000	37.0	81.0	6	6	0.0	SE
1898JUN11	0645	42.8	72.6	4	4	0.0	VT BRATTLEBORO-VERNON
1898JUL25		43.3	71.6	2	2	0.0	NH CONCORD-CANTERBURY

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1898SEP17	1554	44.3	69.1	4	5	0.0 ME BELFAST
1898NOV 0	1200	47.4	70.0	3	3	0.0 PQ LA-POCATIERE
1898NOV25	2000	37.0	81.0	5	5	0.0 SE
1899FEB13	0930	37.0	81.0	5	5	0.0 SE
1899MAY16		40.9	74.0	2	2	0.0 NY NY CITY
1899MAY17	0115	41.6	72.6	5	4	0.0 CT MOODUS-E.HADDAM
1899OCT 5	1130	44.0	69.5	4	4	0.0 ME WISCASSET
1900APR 3		41.7	70.9	2	2	0.0 MA NEW BEDFORD
1900DEC31		44.3	72.6	2	2	0.0 VT MONTPELIER
1901MAR 9		43.2	71.5	2	2	0.0 NH CONCORD
1902FEB 3	1200	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1902MAY18	0400	37.3	80.7	5	5	0.0 SE
1902MAY27		40.8	74.2	2	2	0.0 NJ BAYONNE-WAYNE
1902JUL19		43.6	71.9	2	2	0.0 NH GRAFTON
1902AUG11		40.8	74.2	2	2	0.0 NJ BAYONNE-WAYNE
1903JAN21	A.M.	42.1	70.9	5	5	0.0 MA WHITMAN
1903JAN22		42.0	71.3	4	4	0.0 MA ATTLEBORO
1903APR24	1230	42.7	71.0	4	5	0.0 MA MERRIMAC VALLEY
1903DEC25	1230	44.7	75.5	5	4	0.0 NY OGDENSBURG
1904MAR 5	0030	35.7	83.5	5	5	0.0 SE
1904MAR21	0604	45.0	67.2	6	7	0.0 ME EASTPORT
1905FEB 5		42.8	70.8	2	2	0.0 MA NEWBURY
1905MAR 5	0225	43.6	72.3	5	4	0.0 NH LEBANON
1905MAY27		44.3	72.6	2	2	0.0 VT MONTPELIER
1905JUL15	1010	44.2	70.0	6	5	0.0 ME SABBATUS
1905AUG30	1040	43.1	70.7	5	4	0.0 NH ROCKINGHAM CO.
1905OCT22	A.M.	44.9	72.2	4	5	0.0 VT NEWPORT
1905NOV26	0030	41.5	71.3	4	4	0.0 RI NEWPORT
1906MAR 4		43.8	70.2	2	2	0.0 ME PORTLAND-LEWISTON
1906MAR18		44.4	70.0	2	2	0.0 ME READFIELD
1906MAY 8	1330	41.5	72.5	4	4	0.0 CT MOODUS-E.HADDAM
1906MAY 8	1741	38.7	75.7	4	4	0.0 DE SEAFORD
1906MAY14		41.2	73.2	2	2	0.0 CT BRIDGEPORT
1906OCT19	P.M.X	43.5	70.5	3	3	0.0 ME SACO
1906OCT20	1415	43.5	70.5	4	5	0.0 ME SACO
1906OCT21	X	43.7	70.3	3	3	0.0 ME PORTLAND
1906NOV17	1400	45.6	75.4	4	4	0.0 PQ BUCKINGHAM
1906DEC21		47.7	70.8	3	3	0.0 PQ BAIE-ST-PAUL
1907JAN10	1000	41.2	77.1	4	4	0.0 PA WILLIAMSPORT
1907JAN24	1130	42.8	74.0	4	5	0.0 NY SCHENECTADY
1907JAN25	0600	44.1	79.1	4	4	0.0 ON GOODWOOD
1907FEB11	1322	37.7	78.3	6	6	0.0 SE
1907APR 0		47.6	70.1	2	2	0.0 PQ LA MALBAIE
1907JUN29		43.5	70.5	4	3	0.0 ME BIDDEFORD
1907JUL11	X	43.1	70.8	2	2	0.0 ME ME-NH COAST
1907AUG 5	1243	47.7	70.2	4	4	0.0 PQ LA MALBAIE
1907OCT16	0010	42.8	71.0	5	5	0.0 MA NEWBURY
1907NOV14	0500	45.5	76.7	4	4	0.0 ON RENFREW
1908JAN15		43.9	69.9	2	2	0.0 ME BATH
1908FEB 5	0700	42.3	71.2	3	3	0.0 MA NEEDHAM
1908FEB 5	0820	41.4	73.2	4	4	0.0 CT HOUSATONIC VALLEY
1908MAR10	P.M.	47.4	70.5	4	4	0.0 PQ BAIE-ST-PAUL
1908MAY14	0430	44.0	65.8	5	5	0.0 NS YARMOUTH
1908MAY31	1742	40.6	75.5	6	6	0.0 PA ALLENTOWN
1908JUN16	2041	45.1	74.8	5	5	0.0 ON CORNWALL
1908JUL17	0710	45.4	76.4	4	4	0.0 ON ARNPRIOR
1908AUG 8	1200	46.3	67.6	5	6	0.0 NB HARTLAND
1908AUG16		44.6	73.1	3	3	0.0 VT MILTON
1908AUG23	0930	37.5	77.9	4	4	0.0 SE

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1908NOV23	1300	43.5	71.7	4	4	0.0	NH FRANKLIN
1908DEC10		44.6	72.0	2	2	0.0	VT ST.JOHNSBURY
1909FEB 1	0430X	45.5	73.6	3	3	0.0	PQ MONTREAL
1909FEB 1	0820	45.5	73.6	4	4	0.0	PQ MONTREAL
1909APR 2	0725	39.4	78.0	6	5	0.0	SE
1909APR14	P.M.	45.4	66.4	3	3	0.0	NB WELSFORD
1909MAY10	0220	46.1	74.3	4	4	0.0	PQ STE-AGATHE
1909JUN 8	0825X	46.1	74.3	4	4	0.0	PQ STE-AGATHE
1909AUG16	0130	42.3	71.2	3	3	0.0	MA NEEDHAM
1909DEC10	0624	45.4	75.6	4	4	0.0	ON OTTAWA
1909DEC19	2000	46.5	60.5	6	6	0.0	NS CAPE BRETON
1910JAN23	0130	43.8	70.4	4	5	0.0	ME WINDHAM
1910FEB 0		48.0	70.0	6	6	0.0	PQ N.OF ST.SIMEON
1910FEB 8	1400	38.7	78.7	4	4	0.0	SE
1910FEB25	P.M.	43.2	79.8	4	4	0.0	ON HAMILTON
1910MAR 3		44.3	74.2	3	3	0.0	NY SARANAC LAKE
1910APR23		39.2	74.7	3	3	0.0	NJ SOUTHEASTERN
1910MAY 1		40.7	73.5	2	2	0.0	NY NASSAU CO.
1910MAY 8	2110	37.7	78.4	5	5	0.0	SE
1910AUG21	1845	42.7	71.1	4	4	0.0	MA MERRIMAC VALLEY
1910AUG30	1430	43.4	72.1	4	4	0.0	NH LAKE SUNAPEO
1910OCT20	2150	44.3	68.8	4	4	0.0	ME PENOBSCOT BAY
1910OCT25	0930	47.6	69.8	5	5	0.0	PQ ST-PASCAL
1911JAN29		44.7	75.5	3	3	0.0	NY OGDENSBURG
1911FEB 6	1136	42.4	71.1	2	2	0.0	MA CAMBRIDGE
1911FEB10	1022	36.6	79.4	4	4	0.0	SE
1911MAR 2	2130	43.2	71.5	4	4	0.0	NH CONCORD
1911APR21	0300	35.2	82.7	5	5	0.0	SE
1911DEC17		43.9	69.9	2	2	0.0	ME BATH
1912MAR20	1200	45.1	67.4	3	3	0.0	ME CALAIS
1912MAY27	1252	43.2	79.7	5	5	0.0	ON HAMILTON
1912AUG 8	0100	37.7	78.4	4	4	0.0	SE
1912OCT23		49.5	68.0	4	4	0.0	PQ N.OF BAIE-COMEAU
1912DEC11	1015	45.0	68.0	4	6	0.0	ME EASTPORT
1913JAN 1	1828	34.7	81.7	7	7	0.0	SE
1913MAR28	2150	36.2	83.7	7	7	0.0	SE
1913MAR31	1600	42.3	71.8	2	2	0.0	MA WORCESTER
1913APR29	0028	44.9	75.3	6	5	4.4	ON IROQUOIS
1913JUN 8	0630	45.7	74.4	4	4	0.0	PQ BROWNSBURG
1913AUG 3	1645	36.0	84.0	4	4	0.0	SE
1913AUG10	0515	44.0	74.0	4	5	0.0	NY LAKE PLACID
1913NOV 3	1430	41.5	71.5	4	5	0.0	RI KINGSTOWN
1913NOV15		41.5	72.5	3	3	0.0	CT MOODUS-E.HADDAM
1914JAN13	0800	45.2	67.3	4	5	0.0	ME CALAIS
1914JAN14	0000	42.3	71.2	3	3	0.0	MA NEEDHAM
1914FEB10	1831	46.0	75.0	5	7	5.5	PQ NE OF ST.ADELE
1914FEB14	0934	46.4	73.6	5	5	0.0	PQ N.OF STE-EMELIE
1914FEB22	0015	45.0	70.5	4	5	0.0	ME RANGELEY LAKE
1914APR12	2020	49.3	67.7	4	4	0.0	PQ GODBOUT
1915FEB21	0203	42.8	71.1	4	5	0.0	MA MERRIMAC VALLEY
1915FEB21	2341	44.7	73.4	4	4	0.0	NY BEEKMANTOWN
1915JUL27	1600	44.0	65.0	5	5	0.0	NS SABLE RIVER
1915AUG 6	2135	46.8	71.2	3	3	0.0	PQ QUEBEC CITY
1915OCT19	0523	35.8	82.7	5	5	0.0	SE
1916JAN 5	1356	43.7	73.7	5	4	0.0	NY LAKE GEORGE
1916FEB 2	1626	42.9	74.0	5	4	0.0	NY MOHAWK VALLEY
1916FEB 3	0420	43.0	74.0	5	5	0.0	NY MOHAWK VALLEY
1916FEB21	2239	35.5	82.5	7	7	0.0	SE
1916FEB29	0515	46.8	70.9	4	4	0.0	PQ QUEBEC CITY

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1916MAR 2	0502	34.5	82.7	5	4	0.0	SE
1916APR24	1607	47.0	77.0	5	5	0.0	PQ CABONGA RESERVOIR
1916JUN 8	2115	41.0	73.8	4	5	0.0	NY WESTCHESTER CO.
1916AUG26	1936	36.0	81.0	5	5	0.0	SE
1916NOV 2	0232	43.3	73.7	5	5	0.0	NY GLENS FALLS
1916DEC 2	0900X	41.5	72.5	3	3	0.0	CT MOODUS-E.HADDAM
1917JAN26		44.4	74.1	2	2	0.0	NY GABRIELS
1917JAN26	0735	46.8	74.5	5	5	0.0	PQ MONT-TREMBLANT
1917FEB16	0900	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1917MAR11	X	41.5	72.5	3	3	0.0	CT MOODUS-E.HADDAM
1917MAY22	0900	45.1	75.6	5	4	0.0	ON S.OF OTTAWA
1917JUN12	0200	49.0	68.0	5	5	0.0	PQ GODBOUT
1917JUN21		36.0	83.0	4	4	0.0	SE
1917OCT 2	0214	43.3	73.6	3	3	0.0	NY GLENS FALLS
1918JAN14	0720	45.0	67.3	4	4	0.0	ME EASTPORT
1918JAN16	1545	36.0	84.0	5	4	0.0	SE
1918APR10	0209	38.7	78.4	6	6	0.0	SE
1918JUL23	1200	46.9	71.4	4	4	0.0	PQ LORETTEVILLE
1918AUG21	0515	44.2	70.5	6	7	0.0	ME BRIDGETON-NORWAY
1918DEC12	0330	44.8	68.8	4	4	0.0	ME BANGOR
1919JUL11	0140	43.9	70.0	4	4	0.0	ME BRUNSWICK
1919JUL23	1150	43.7	70.3	4	4	0.0	ME PORTLAND
1919AUG11		41.5	72.5	3	3	0.0	CT MOODUS-E.HADDAM
1919SEP 6	0246	38.8	78.2	6	6	0.0	SE
1919OCT26	1028	47.6	70.0	4	4	0.0	PQ RIVIERE-OUELLE
1920FEB 6		48.2	69.7	4	4	0.0	PQ TADDOUSAC
1920MAY23	0800	43.1	71.5	4	4	0.0	NH CONCORD
1920JUN 7	0800	43.5	70.5	4	4	0.0	ME SACO
1920JUL24	P.M.	38.7	78.4	4	4	0.0	SE
1920NOV 8	1926	46.0	73.4	5	4	0.0	PQ ST-THOMAS-DE-JOLIETTE
1920NOV 9	0040	45.0	67.3	4	4	0.0	ME EASTPORT
1921JAN19	1000	43.3	73.7	4	4	0.0	NY GLENS FALLS
1921JAN26	2340	40.0	75.0	5	5	0.0	NJ RIVERSIDE
1921JAN27	A.M.	43.3	73.7	4	4	0.0	NY GLENS FALLS
1921JUL15		36.6	82.3	6	6	0.0	SE
1921JUL29	2114	42.5	70.4	4	4	0.0	MA CAMBRIDGE
1921AUG 7	0630	37.8	78.4	6	6	0.0	SE
1921AUG27	0812	47.0	76.0	5	4	0.0	PQ CABONGA RESERVOIR
1921SEP27	0432	42.1	80.2	3	3	0.0	PA ERIE
1921OCT10	1300	44.8	67.0	4	4	0.0	ME EASTPORT
1922MAY 7	2240	43.4	71.4	4	4	0.0	NH PITTSFIELD
1922JUL 2	2225	46.5	66.6	5	6	0.0	NB BATHURST
1922SEP 9	0600	45.0	67.1	3	3	0.0	ME N.PERRY
1922DEC 8	2124	44.4	75.1	5	5	0.0	NY S.OF CANTON
1923SEP27	0920	46.8	71.2	2	2	0.0	PQ QUEBEC CITY
1923DEC31		39.2	78.0	5	5	0.0	SE
1923 0		42.8	71.0	2	2	0.0	MA GROVELAND
1924JAN 1		39.2	78.0	5	4	0.0	SE
1924JAN 1	0106	34.8	82.5	5	4	0.0	SE
1924MAR 4	1915	47.8	70.2	5	5	0.0	PQ N.OF LA MALBAIE
1924JUL15	0010	45.7	76.5	5	6	0.0	PQ SHAWVILLE
1924SEP30	0852	47.6	69.7	8	7	5.5	PQ LA MALBAIE
1924OCT20	0830	35.0	82.6	5	5	0.0	SE
1924NOV13	1030	36.6	82.2	5	4*	0.0	SE
1924NOV15	0132	45.5	76.3	4	4	0.0	ON NEAR ARNPRIOR
1924DEC26	0500	37.3	79.9	5	5	0.0	SE
1925JAN 7	1307	42.6	70.6	5	5	0.0	MA CAPE ANN
1925MAR 1	0219	47.6	70.1	9	9	6.6	PQ LA MALBAIE
1925MAR 1	0430X	47.6	70.1	6	6	0.0	PQ LA MALBAIE

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1925MAR 1	0525X	47.6	70.1	5	4	0.0	PQ LA MALBAIE
1925MAR 1	0725X	47.6	70.1	5	4	0.0	PQ LA MALBAIE
1925MAR 1	1321X	47.6	70.1	4	4	0.0	PQ LA MALBAIE
1925MAR 1	1410X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	1420X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	1430X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	1539X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	1627X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	1724X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	1835X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	1955X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	2026X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 1	2115X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	0015X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	1135X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	1442X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	1443X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	1529X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	2025X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	2226X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	2314X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 2	2345X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 3	1105X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 3	1323X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 3	1615X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 3	1934X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 3	2333X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 4	0325X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 4	1930X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 5	1720X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 5	2032X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 5	2245X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 5	2343X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 6	1234X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 6	1530X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 6	1910X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 7	0230X	47.6	70.1	5	5	0.0	PQ LA MALBAIE
1925MAR 7	0430X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 8	0000X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 8	1402X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 8	1542X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 8	2245X	47.6	70.1	0	0	0.0	PQ LA MALBAIE
1925MAR 9		42.9	71.5	4	4	0.0	NH GOFF'S FALLS
1925MAR14	1018X	47.6	70.1	4	4	0.0	PQ LA MALBAIE
1925MAR17	1445X	47.6	70.1	4	4	0.0	PQ LA MALBAIE
1925MAR18	1315X	47.6	70.1	4	4	0.0	PQ LA MALBAIE
1925MAR21	1522X	47.6	70.1	6	6	0.0	PQ LA MALBAIE
1925APR 7	2018	43.0	76.1	3	3	0.0	NY SYRACUSE
1925APR10	0930X	47.6	70.1	3	3	0.0	PQ LA MALBAIE
1925APR11	1130X	47.6	70.1	3	3	0.0	PQ LA MALBAIE
1925APR16	0930	45.9	66.6	3	3	0.0	NB FREDERICTON
1925APR24	0756	41.7	70.8	5	4	0.0	MA WAREHAM
1925APR26	0450X	47.6	70.1	4	4	0.0	PQ LA MALBAIE
1925MAY 4	1751	42.5	70.9	4	4	0.0	MA LYNN
1925MAY 6	0914	46.9	71.6	3	3	0.0	PQ QUEBEC CITY
1925MAY23		43.4	77.1	3	3	0.0	NY SODUS PT.
1925MAY31	0357X	47.6	70.1	3	3	0.0	PQ LA MALBAIE
1925JUL 5	X	47.6	70.1	2	2	0.0	PQ LA MALBAIE
1925JUL 6	0933X	47.6	70.1	4	4	0.0	PQ LA MALBAIE

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1925JUL12	1556X	46.9	71.2	2	2	0.0 PQ QUEBEC CITY
1925JUL12	2209X	46.9	71.2	2	2	0.0 PQ QUEBEC CITY
1925JUL14	2120	37.6	77.4	4	4	0.0 SE
1925JUL20	A.M.X	46.9	71.3	3	3	0.0 PQ NW OF QUEBEC CITY
1925JUL27	0220X	47.6	70.1	4	4	0.0 PQ LA MALBAIE
1925JUL27	0900X	47.6	70.1	3	3	0.0 PQ LA MALBAIE
1925OCT 1	1358X	46.9	71.2	2	2	0.0 PQ QUEBEC CITY
1925OCT 9	0500	46.8	71.2	4	4	0.0 PQ QUEBEC CITY
1925OCT 9	1355	43.7	71.1	6	6	0.0 NH OSSIPEE
1925OCT18	2130	44.1	70.2	4	4	0.0 ME LEWISTON
1925OCT19	1205	47.0	73.0	5	5	0.0 PQ NNW OF SHAWINIGAN FALLS
1925OCT24	0130	41.4	73.3	3	3	0.0 CT NEWTOWN
1925OCT27		48.6	71.7	3	3	0.0 PQ ISLE-MALIGNE
1925OCT30	A.M.X	41.5	72.5	4	4	0.0 CT MOODUS-E.HADDAM
1925NOV 1	X	41.5	72.5	2	2	0.0 CT MOODUS-E.HADDAM
1925NOV14	1304	41.7	72.4	5	6	0.0 CT N.OF HEBRON
1925NOV16	0620	41.8	72.7	4	4	0.0 CT HARTFORD
1925NOV22	0600	41.8	71.3	3	3	0.0 MA FALL RIVER
1926JAN 4		41.6	71.8	4	4	0.0 CT VOLUNTOWN
1926JAN22	1957	42.4	71.1	2	3	0.0 MA CAMBRIDGE
1926JAN26	2340	40.0	75.0	5	5	0.0 NJ WESTERN
1926JAN27	A.M.	44.3	74.1	4	4	0.0 NY SARANAC LAKE
1926FEB19	2020	47.7	71.0	4	4	0.0 PQ QUEBEC CITY-CHICOUTIMI
1926FEB21	2155X	47.6	70.9	4	4	0.0 PQ QUEBEC CITY-CHICOUTIMI
1926MAR 1		46.9	71.2	3	3	0.0 PQ QUEBEC CITY
1926MAR 4	2100	42.5	70.9	2	2	0.0 MA LYNN
1926MAR16	0442X	46.9	71.2	3	3	0.0 PQ QUEBEC CITY
1926MAR18	2109	42.8	71.8	5	6	0.0 NH NEW IPSWICH
1926MAY12	0330	40.9	73.9	5	5	0.0 NY NEW ROCHELLE
1926MAY15	1100	43.7	70.2	3	3	0.0 ME PORTLAND
1926MAY22		41.7	73.9	2	2	0.0 NY POUGHKEEPSIE
1926MAY26	0000	44.9	68.7	3	3	0.0 ME ORONO
1926JUL 4	0820	45.4	71.9	3	3	0.0 PQ SHERBROOKE
1926JUL 8	0950	35.9	82.1	7	6	0.0 SE
1926JUL18	0600	47.0	71.5	4	4	0.0 PQ QUEBEC CITY
1926AUG23	1640	45.8	77.1	4	4	0.0 ON PEMBROKE
1926AUG28	2130	44.8	70.4	4	5	0.0 ME FARMINGTON
1926SEP21	1130	48.0	70.5	4	4	0.0 PQ NW OF LA MALBAIE
1926OCT25	0152	42.1	71.0	3	3	0.0 MA BROCKTON
1926OCT27	1840	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1926OCT27	1920X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1926NOV24	1930	45.0	67.5	4	4	0.0 ME CALAIS
1926DEC 8	0352X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1926DEC20	1628X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1926DEC29	0121X	46.8	71.2	3	3	0.0 PQ QUEBEC CITY
1926DEC29	0122X	46.8	71.2	3	3	0.0 PQ QUEBEC CITY
1926DEC29	0125X	46.8	71.2	3	3	0.0 PQ QUEBEC CITY
1926DEC29	0530	46.2	60.2	4	4	0.0 NS SYDNEY
1927JAN 9	0445X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1927FEB 5	1730X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1927FEB 6	1620X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1927FEB 9	2330	47.6	70.1	3	3	0.0 PQ LA MALBAIE
1927FEB10	0040X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1927FEB16	1230	45.4	75.7	2	2	0.0 PQ HULL
1927FEB24	1814X	46.8	71.2	2	2	0.0 PQ QUEBEC CITY
1927MAR 9	0408	43.3	71.4	4	5	0.0 NH CONCORD
1927MAR12	2212	44.6	75.2	4	4	0.0 NY CANTON
1927MAR14	1415X	44.6	75.4	4	4	0.0 NY CANTON
1927MAR20	P.M.X	47.6	70.1	3	3	0.0 PQ LA MALBAIE

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1927MAR29	2030	43.0	76.1	3	3	0.0	NY SYRACUSE
1927MAR30	P.M.	41.7	72.8	4	4	0.0	CT NEW BRITAIN
1927MAR31	2100	43.0	76.1	3	3	0.0	NY SYRACUSE
1927MAR31	2130X	43.0	76.1	3	3	0.0	NY SYRACUSE
1927MAY23	0209X	46.8	71.2	2	2	0.0	PQ QUEBEC CITY
1927MAY23	1814X	46.8	71.2	2	2	0.0	PQ QUEBEC CITY
1927JUN 1	1223	40.3	74.0	7	6	0.0	NJ TOMS RIVER-SANDY HOOK
1927JUN10	0716	38.0	79.0	5	5	0.0	SE
1927JUL25	0056	47.3	71.0	5	5	0.0	PQ SW OF BAIE-ST-PAUL
1927AUG18	0357X	46.8	71.2	3	3	0.0	PQ QUEBEC CITY
1927AUG20		42.3	71.0	4	4	0.0	MA QUINCY
1927OCT24	1100	44.7	73.8	4	4	0.0	NY DANNEMORA
1927NOV13	0050	43.1	79.1	4	4	0.0	ON NIAGARA FALLS
1927NOV24	2140	44.0	60.0	3	3	0.0	NS SABLE I.
1928JAN13	1950	41.2	71.6	4	5	0.0	RI BLOCK I.
1928JAN21	0530	45.3	69.0	4	4	0.0	ME MILO
1928JAN27		48.0	70.2	4	4	0.0	PQ N.OF LA MALBAIE
1928FEB 8	A.M.	45.3	69.0	6	6	0.0	ME MILO
1928FEB 9	A.M.X	45.2	69.2	4	4	0.0	ME DOVER-FOXCROFT
1928FEB17	0529X	45.2	69.2	3	3	0.0	ME DOVER-FOXCROFT
1928MAR18	1525	44.5	74.3	6	5	4.1	NY SARANAC LAKE
1928MAR19	1907	46.6	72.5	2	2	0.0	PQ ST-NARCISSE
1928MAR22	1330X	45.3	69.0	4	4	0.0	ME MILO
1928MAR28	P.M.X	45.3	69.0	4	4	0.0	ME MILO
1928MAR29	A.M.X	45.3	69.0	3	3	0.0	ME MILO
1928APR 1		45.5	74.7	2	2	0.0	ON VANKLEEK HILL
1928APR25	2338	44.5	71.2	5	5	0.0	NH BERLIN
1928APR28	2207	43.2	71.5	4	4	0.0	NH CONCORD
1928MAY22	0024X	43.2	71.5	2	2	0.0	NH CONCORD
1928MAY26		43.2	71.7	2	2	0.0	NH CONTOOCOOK
1928AUG30	0910	44.3	68.6	2	2	0.0	ME BROOKLIN
1928OCT15		45.1	71.4	2	2	0.0	NH PITTSBURG
1928OCT17	0030	42.8	71.6	3	3	0.0	NH WILTON
1928OCT30	1145	37.5	77.5	4	4	0.0	SE
1928NOV 3	0403	36.0	82.6	6	7	0.0	SE
1928NOV 5	0400	43.3	71.0	2	2	0.0	NH ROCHESTER
1928NOV20	0230	45.0	67.2	4	4	0.0	ME NW OF EASTPORT
1928DEC 1	A.M.	50.0	81.5	6	6	0.0	ON FRASERDALE
1928DEC 1		43.3	71.0	2	2	0.0	NH ROCHESTER
1928DEC 8	0412	41.8	72.5	2	2	0.0	CT ELLINGTON
1928DEC12	1907	44.6	69.6	2	2	0.0	ME WATERVILLE
1928DEC25	0200	46.2	67.9	2	2	0.0	ME NEW LIMERICK
1929JAN13	X	43.3	71.0	2	2	0.0	NH ROCHESTER
1929JAN15	0245	43.3	71.0	3	3	0.0	NH ROCHESTER
1929FEB 5	1710	43.3	71.7	2	2	0.0	NH WEARE
1929FEB 5	1909	44.0	70.3	4	5	0.0	ME AUBURN
1929MAR29	0000	45.2	67.3	2	2	0.0	ME CALAIS
1929APR30	1853	45.4	75.7	1	2	0.0	ON OTTAWA
1929MAY11	0930	45.4	71.9	4	4	0.0	PQ W.SHERBROOKE
1929JUN 5	0700	44.8	74.3	3	3	0.0	NY MALONE
1929AUG12	0600	42.2	77.2	3	3	0.0	NY CORNING
1929AUG12	0845X	42.9	78.4	3	3	0.0	NY ATTICA
1929AUG12	1124	42.9	78.4	8	8	5.8	NY ATTICA
1929SEP 9	0159	46.4	76.0	2	2	0.0	PQ MANIWAKI
1929SEP 9	1843	46.2	76.0	1	2	0.0	PQ BURBRIDGE
1929SEP17	0445	42.2	71.0	2	2	0.0	MA HOLBROOK
1929OCT 8	1220	44.0	70.2	3	3	0.0	ME LEWISTON
1929OCT 9	0030	44.5	69.5	3	3	0.0	ME WATERVILLE
1929NOV18	2032	44.5	56.3	10	10	7.2	NF GRAND BANKS

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1929NOV18	2301X	44.5	56.3	0	0	6.0	NF GRAND BANKS
1929NOV18	2320X	44.5	56.3	0	0	4.9	NF GRAND BANKS
1929NOV19	0201X	44.5	56.3	0	0	5.8	NF GRAND BANKS
1929DEC 2	2214	42.8	78.3	5	5	0.0	NY ATTICA
1929DEC 3	1250X	42.8	78.3	4	4	0.0	NY ATTICA
1929DEC 5	1500	44.8	69.7	2	2	0.0	ME SKOWHEGAN
1929DEC 5	1536	45.4	71.9	1	2	0.0	PQ SHERBROOKE
1929DEC13	0058X	44.5	56.3	0	0	4.4	NF GRAND BANKS
1929DEC13	1119X	44.5	56.3	0	0	5.0	NF GRAND BANKS
1929DEC26	0256	38.1	78.5	6	6	0.0	SE
1930JAN 4		43.1	75.3	2	2	0.0	NY CLINTON
1930JAN 4	1430	46.7	65.8	0	0	4.6	NB BLACKVILLE
1930JAN17	P.M.X	42.8	78.3	1	2	0.0	NY ATTICA
1930FEB10	1230	46.2	60.0	2	2	0.0	NS GLACE BAY
1930FEB14	0615	43.4	71.7	4	3	0.0	NH FRANKLIN
1930FEB16	1217	42.8	80.5	3	3	0.0	ON SIMCOE
1930FEB19	1138	45.4	75.8	2	2	0.0	ON WESTBORO
1930MAR11	2330	44.0	70.0	2	2	0.0	ME TOPSHAM
1930MAR19	0015	43.3	71.6	4	4	0.0	NH CONCORD
1930MAR27	1930	42.1	72.7	3	3	0.0	MA W.SPRINGFIELD
1930JUN19	1206	45.7	71.2	0	0	3.6	PQ NE OF SHERBROOKE
1930JUL13	0452	47.5	69.8	0	0	3.1	PQ KAMOURASKA
1930AUG 1	0200	41.5	70.8	3	3	0.0	MA NEW BEDFORD
1930AUG30	0928	35.9	84.4	5	5	0.0	SE
1930OCT 8	0108	48.9	68.7	0	0	3.9	PQ RIVIERE BERSIMIS
1930OCT15	A.M.	44.4	78.4	2	2	0.0	ON BRIDGENORTH
1930OCT16	0035	46.9	65.6	2	2	0.0	NB MILLERTON
1930NOV 2	0235	44.8	74.3	3	3	0.0	NY MALONE
1930NOV13	0600	45.0	69.2	1	2	0.0	ME CORINNA
1930NOV22	0513	47.4	70.5	0	0	2.3	PQ BAIE-ST-PAUL
1930DEC13	2318	47.7	70.2	0	0	3.5	PQ MURRAY BAY
1930DEC19	0134	47.7	70.1	0	0	2.6	PQ LA MALBAIE
1930DEC25	P.M.	44.5	69.6	1	2	0.0	ME WATERVILLE
1930DEC25	2207	47.6	70.2	0	0	4.6	PQ LA MALBAIE
1931JAN 7	0721	47.5	70.5	1	2	0.0	ON OTTAWA
1931JAN 8	0013	47.6	70.2	0	0	5.4	PQ LA MALBAIE
1931JAN24	1229	47.5	70.5	0	0	3.4	PQ BAIE-ST-PAUL
1931MAR20	1314X	47.8	70.0	0	0	3.1	PQ LA MALBAIE
1931APR 6	2050	45.4	75.7	1	2	0.0	ON OTTAWA
1931APR 9	A.M.	45.0	67.0	3	3	0.0	NB DEER I.
1931APR20	1954	43.4	73.7	7	7	5.0	NY LAKE GEORGE
1931APR22		42.9	78.9	4	4	0.0	NY BUFFALO
1931APR30	0557X	47.4	70.5	0	0	2.4	PQ BAIE-ST-PAUL
1931MAY 4	1017	42.4	72.5	3	3	0.0	MA AMHERST
1931MAY 4	1843	44.8	74.3	1	2	0.0	NY MALONE
1931JUN 7	0000	43.2	77.6	2	2	0.0	NY ROCHESTER
1931JUN 7	0230X	43.2	77.6	1	2	0.0	NY ROCHESTER
1931JUL 1	0245	41.6	73.4	4	4	0.0	CT NEW MILFORD
1931JUL24	2011	47.4	70.5	0	0	3.0	PQ BAIE-ST-PAUL
1931AUG 7	A.M.	44.6	65.8	4	4	0.0	NS DIGBY
1931AUG20	0112X	47.4	70.5	0	0	2.5	PQ BAIE-ST-PAUL
1931SEP23	2247	47.0	76.1	0	0	4.5	PQ KAZABAZUA
1931NOV 3	1530	44.6	75.2	2	2	0.0	NY CANTON
1931NOV 8	0408X	47.4	70.5	0	0	2.8	PQ BAIE-ST-PAUL
1931NOV14	1402	47.3	70.2	0	0	3.4	PQ BAIE-ST-PAUL
1932JAN 5	0405	37.5	78.6	5	5	0.0	SE
1932JAN 5	0614X	47.4	70.5	0	0	2.1	PQ BAIE-ST-PAUL
1932JAN 5	1415	47.7	70.0	0	0	3.2	PQ LA MALBAIE
1932MAR 2	0238	47.7	70.0	0	0	2.9	PQ LA MALBAIE

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1932MAR 9	0523	46.5	74.7	0	0	3.8	PQ LABELLE
1932JUN28	2119	47.4	70.5	0	0	2.2	PQ BAIE-ST-PAUL
1932JUL20	2330	42.2	73.2	2	2	0.0	MA LAKE GARFIELD
1932JUL27	0030X	47.5	70.5	2	2	0.0	PQ BAIE-ST-PAUL
1932AUG 2	0737	47.5	70.5	0	0	3.0	PQ BAIE-ST-PAUL
1932OCT15	0310	43.6	71.5	3	3	0.0	NH MEREDITH
1932OCT16	1912	42.9	72.3	2	2	0.0	NH KEENE
1932OCT18	2105X	47.4	70.5	0	0	2.4	PQ BAIE-ST-PAUL
1932NOV 4	0500	43.2	71.5	2	2	0.0	NH CONCORD
1932NOV26	0501X	47.5	70.5	0	0	2.7	PQ BAIE-ST-PAUL
1932DEC 7	X	44.4	74.1	2	2	0.0	NY GABRIELS
1932DEC 7	0315	44.4	74.1	4	4	0.0	NY GABRIELS
1932DEC 7	1645X	44.4	74.1	3	3	0.0	NY GABRIELS
1932DEC21	1120	45.4	75.7	2	2	0.0	ON RUSSELL
1933JAN11	2332X	47.5	70.5	3	3	0.0	PQ BAIE-ST-PAUL
1933JAN17	0530	41.6	70.9	4	3	0.0	MA NEW BEDFORD
1933JAN21	1604	45.3	74.7	0	0	3.8	ON ALEXANDRIA
1933JAN25	0200	40.2	74.7	5	5	0.0	NJ TRENTON
1933JAN30	0422X	47.5	70.5	0	0	2.8	PQ BAIE-ST-PAUL
1933FEB25	0232	45.0	75.7	3	3	0.0	ON CORNWALL
1933FEB25	0943	47.4	69.9	0	0	3.4	PQ ST-PACOME
1933MAY20	1957	44.8	74.7	3	3	0.0	NY LAWRENCEVILLE
1933MAY27	0429	47.6	70.1	0	0	3.0	PQ LA MALBAIE
1933MAY28	1510	38.6	83.8	4	4	0.0	SE
1933JUN26	1410	41.0	73.8	3	3	0.0	NY SCARSDALE
1933JUL14	0448	45.4	75.7	0	0	3.9	ON OTTAWA
1933OCT29	P.M.	43.0	74.7	4	4	0.0	NY ST.JOHNSVILLE
1933OCT30	0053	47.5	70.5	0	0	2.6	PQ BAIE-ST-PAUL
1934JAN30	1030	41.8	72.6	4	4	0.0	CT S.WINDSOR
1934FEB 2	1635	45.4	75.7	2	2	0.0	ON OTTAWA
1934MAR17		43.5	65.5	3	4	0.0	NS SHELBURNE
1934APR11	0300	44.0	72.7	3	3	0.0	VT RUTLAND-MONTPELIER
1934APR11	0324X	44.0	72.7	3	3	0.0	VT RUTLAND-MONTPELIER
1934APR15	0258	44.7	73.8	6	5	4.5	NY DANNEMORA
1934APR15	1805	44.8	74.3	3	3	0.0	NY MALONE
1934JUN 5	2011	44.8	74.3	3	3	0.0	NY MALONE
1934AUG 2	1458	42.6	70.7	4	4	0.0	MA CAPE ANN
1934AUG 2	1459	43.7	70.3	4	4	0.0	ME PORTLAND
1934AUG 2	1750X	43.7	70.3	3	3	0.0	ME PORTLAND
1934AUG 3	0230X	43.7	70.3	4	4	0.0	ME PORTLAND
1934AUG26	1136	44.9	67.0	3	3	0.0	ME EASTPORT
1934OCT29	2007	42.0	80.2	5	5	0.0	PA ERIE
1935JAN 1	0815	35.1	83.6	5	5	0.0	SE
1935JAN15	0115	44.1	70.2	2	2	0.0	ME LEWISTON
1935JAN28	0600	44.8	74.3	4	4	0.0	NY MALONE
1935JAN28	0901X	44.8	74.3	3	3	3.2	NY MALONE
1935JAN30	2020	42.6	71.3	2	2	0.0	MA BILLERICA
1935MAR 4	0240	44.9	67.0	3	3	0.0	ME EASTPORT
1935APR24	0124	42.2	70.2	4	4	0.0	MA OFF CAPE COD
1935JUL17	2156	45.4	75.7	2	2	0.0	ON OTTAWA
1935AUG 9	0730	41.4	72.1	2	2	0.0	CT NEW LONDON
1935SEP13	0349	43.2	71.5	3	2	0.0	NH CONCORD
1935NOV 1	0603	46.8	79.1	7	7	6.2	PQ TIMISKAMING
1935NOV 1	0630	44.3	72.6	2	2	0.0	VT MONTPELIER
1935NOV 1	0630	42.6	74.6	2	2	0.0	NY RICHMONDVILLE
1935NOV 1	0830	38.9	79.9	5	5	0.0	SE
1935NOV 1	1702	46.8	79.1	0	0	4.6	PQ TIMISKAMING
1935NOV 2	0042X	46.8	79.1	0	0	4.7	PQ TIMISKAMING
1935NOV 2	1351X	46.8	79.1	0	0	3.0	PQ TIMISKAMING

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1935NOV 2	1355X	46.8	79.1	0	0	2.7	PQ TIMISKAMING
1935NOV 2	1431X	47.2	78.2	0	0	5.4	PQ NE OF TIMISKAMING
1935NOV 5	1010X	46.8	79.1	0	0	4.5	PQ TIMISKAMING
1935NOV 7	1647X	46.8	79.1	0	0	2.4	PQ TIMISKAMING
1935NOV15	1611X	46.8	79.1	0	0	3.0	PQ TIMISKAMING
1935NOV25	0619X	46.8	79.1	0	0	4.7	PQ TIMISKAMING
1935NOV27	1931X	46.8	79.1	0	0	4.6	PQ TIMISKAMING
1935DEC15	1015X	46.8	79.1	3	3	0.0	PQ TIMISKAMING
1936JAN 1	0800	35.0	84.2	3	3	0.0	SE
1936JAN20	0601X	46.8	79.1	0	0	4.5	PQ TIMISKAMING
1936MAR25	0127X	46.8	79.1	0	0	4.6	PQ TIMISKAMING
1936MAR29	0049	47.3	70.3	0	0	4.0	PQ ILE-AUX-COUDRES
1936JUN14	0540	43.5	71.5	3	3	0.0	NH LACONIA
1936JUN15		43.8	71.4	3	3	0.0	NH CENTER SANDWICH
1936JUN21	0340	44.7	74.2	3	3	0.0	NY MTN.VIEW
1936AUG26	0900	41.4	80.4	3	3	0.0	PA GREENVILLE
1936SEP18	1500	47.5	70.5	1	2	0.0	PQ BAIE-ST-PAUL
1936NOV10	0246	43.6	71.4	5	5	0.0	NH LACONIA
1936NOV10	0402	44.7	71.7	4	4	0.0	VT BLOOMFIELD
1936DEC14		46.3	79.4	2	2	0.0	ON NORTH BAY
1937JAN19	2058	47.5	70.5	0	0	2.2	PQ BAIE-ST-PAUL
1937FEB21		42.1	76.8	2	2	0.0	NY ELMIRA
1937MAR10	0529	44.6	75.2	4	4	0.0	NY CANTON
1937MAR31	1709	45.1	75.7	0	0	2.8	ON KEMPTVILLE
1937JUN 9	0004	40.3	75.9	2	2	0.0	PA READING
1937JUL14	2301	45.4	74.0	0	0	2.8	PQ DORIAN
1937JUL19	0351	40.7	73.7	4	4	0.0	NY NY CITY
1937JUL27	0910	41.8	72.4	4	4	0.0	CT MANCHESTER
1937JUL28	0017	46.7	79.1	3	3	0.0	PQ TIMISKAMING
1937SEP 5	1108	41.5	66.0	0	0	3.5	NS GEORGES BANK
1937SEP24	0645	45.5	73.6	0	0	2.5	PQ MONTREAL
1937SEP30	0758	45.5	65.8	0	0	4.5	NB ROTHESAY
1937SEP30	2208	40.8	74.3	3	3	0.0	NJ VERONA
1937OCT11	2200	41.2	73.8	2	2	0.0	NY WESTCHESTER CO.
1937OCT12	0100X	41.2	73.8	2	2	0.0	NY WESTCHESTER CO.
1937OCT12	0600	43.3	70.5	2	2	0.0	ME KENNEBUNKPORT
1937NOV 6	1431	46.7	75.7	0	0	4.0	PQ BASKATONG RESERVOIR
1937NOV12	1443	45.9	74.3	0	0	3.6	PQ ST-JEROME
1937NOV12	1657X	45.9	74.3	0	0	3.7	PQ ST-JEROME
1937DEC 2	2201	44.5	73.2	2	2	0.0	VT BURLINGTON
1938JAN 6	1328	44.9	75.2	0	0	3.2	ON MORRISBURG
1938JAN24	0529	45.6	76.3	0	0	3.0	ON ARNPRIOR
1938FEB23	1756	46.4	75.4	0	0	3.2	PQ NOMININGUE
1938APR 1	2215	43.3	71.0	3	3	0.0	NH ROCHESTER
1938APR 2	0213X	43.3	71.0	3	3	0.0	NH ROCHESTER
1938APR 3	X	43.3	71.0	2	2	0.0	NH ROCHESTER
1938APR12	1855	46.7	79.1	0	0	3.2	PQ TIMISKAMING
1938APR13	0100	43.2	73.1	2	2	0.0	VT MANCHESTER
1938MAY 5	0033	45.4	74.5	0	0	3.0	ON GLEN ROBERTSON
1938MAY16	1925	40.8	74.3	2	3	0.0	NJ VERONA
1938MAY17	1832	49.0	68.0	0	0	4.6	PQ BAIE-COMEAU
1938JUN14	0402	41.4	73.4	2	2	0.0	CT BETHEL
1938JUN14	1930X	41.4	73.4	1	2	0.0	CT BETHEL
1938JUN15	0507	46.5	66.8	4	4	0.0	NB NAPADOGAN
1938JUN23	0357	42.6	71.4	4	4	0.0	MA CHELMSFORD
1938JUL15	2245	40.4	78.2	6	5	0.0	PA BLAIR CO.
1938JUL26	0818	45.4	75.7	0	0	1.8	ON OTTAWA
1938JUL29	0744	41.0	73.7	3	3	0.0	NY WESTCHESTER CO.
1938AUG 2	0902	41.1	73.7	4	3	0.0	CT GREENWICH

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1938AUG22	1248	44.7	68.8	5	4	4.1	ME BANGOR
1938AUG23	0336	40.1	74.5	5	5	4.6	NJ NEAR TRENTON
1938AUG23	0504	40.3	74.3	0	0	4.8	NJ FREEHOLD
1938AUG23	0518	41.2	73.7	3	3	0.0	NY WESTCHESTER CO.
1938AUG23	0703X	40.3	74.3	4	4	4.6	NJ FREEHOLD
1938AUG23	0711X	41.2	73.7	3	3	0.0	NY WESTCHESTER CO.
1938AUG23	0904X	40.1	74.5	4	4	4.8	NJ NEAR TRENTON
1938AUG23	1311X	40.1	74.2	3	3	0.0	NJ NEAR TRENTON
1938AUG28	0036X	40.1	74.2	3	3	0.0	NJ NEAR TRENTON
1938SEP 7	2318	45.9	74.9	0	0	3.4	PQ NAMUR
1938SEP20		41.5	72.2	3	3	0.0	CT NORWICH
1938SEP28	0433	48.8	69.6	0	0	4.1	PQ NW OF SAULT-AU-MOUTON
1938OCT21	0718	41.2	73.7	2	2	0.0	NY DUTCHESS CO.
1938NOV18	2219	44.8	75.3	5	4	0.0	NY NEAR OGDENSBURG
1938NOV26	0747	47.0	76.2	0	0	4.2	PQ CABONGA RESERVOIR
1938DEC 6	1938	40.8	74.3	3	3	0.0	NJ VERONA
1938DEC25	0746	47.6	75.4	0	0	3.9	PQ NW OF BASKATONG RESERVOIR
1939JAN14	0810	43.3	79.9	0	0	3.3	ON HAMILTON
1939JAN15	0128	45.0	74.0	0	0	2.7	PQ HUNTINGDON
1939FEB 1	1037	42.6	71.4	2	2	0.0	MA CHELMSFORD
1939FEB 6	0521	46.5	81.0	0	0	3.0	ON SUDBURY
1939FEB 9	1511	45.3	74.0	0	0	2.8	PQ VALLEYFIELD
1939FEB21	A.M.	44.8	74.3	2	2	0.0	NY MALONE
1939FEB24	0020	42.9	78.3	3	3	0.0	NY ATTICA
1939MAR16	2021	46.4	77.5	0	0	3.6	ON N.OF CHALK RIVER
1939APR 2	0300	40.0	76.3	2	2	0.0	PA LANCASTER
1939JUN 1	0336	44.6	75.2	3	3	0.0	NY CANTON
1939JUN24	1720	47.8	70.8	0	0	4.8	PQ NW OF LA MALBAIE
1939AUG12		41.5	72.5	2	2	0.0	CT MOODUS-E.HADDAM
1939SEP 4	0517	46.0	76.0	0	0	2.7	PQ KAZABAZUA
1939SEP13	0122	40.8	74.0	2	2	0.0	NJ UNION CITY
1939SEP21	2030	41.4	74.1	2	2	0.0	NY ORANGE CO.
1939OCT10	A.M.	43.4	71.6	3	3	0.0	NH TILTON
1939OCT11	1849	42.9	71.4	3	3	0.0	NH DERRY
1939OCT19	1153	47.8	70.0	6	6	5.8	PQ LA MALBAIE
1939OCT19	1412X	47.8	70.0	0	0	3.4	PQ LA MALBAIE
1939OCT19	1837X	47.5	70.9	0	0	3.5	PQ W.OF LA MALBAIE
1939OCT21	0807X	47.5	70.9	0	0	4.0	PQ W.OF LA MALBAIE
1939OCT21	0859	43.3	73.3	2	2	0.0	NY GLENS FALLS
1939OCT25	1446	42.2	73.9	2	2	0.0	NY HUDSON
1939OCT27	0136X	47.8	70.0	0	0	5.2	PQ LA MALBAIE
1939NOV 7	0240X	47.8	70.5	0	0	4.3	PQ W.OF LA MALBAIE
1939NOV15	0253	39.6	75.2	5	5	0.0	NJ SALEM CO.
1939DEC 2	2025	45.7	75.0	0	0	2.5	PQ ST-ANDRE-AVELLIN
1939DEC 8	0117	48.0	71.4	0	0	3.6	PQ CHICOUTIMI RIVER
1939DEC25	1029	48.0	70.5	0	0	4.1	PQ NW OF LA MALBAIE
1940JAN 2	0205	42.5	71.5	3	3	0.0	MA LITTLETON
1940JAN 3	0130	41.2	71.6	2	2	0.0	RI BLOCK ISLAND
1940JAN 5	0034	46.7	79.1	0	0	3.0	PQ TIMISKAMING
1940JAN28	2311	41.6	70.8	5	4	2.6	MA BUZZARDS BAY
1940FEB10	2057	46.5	76.8	0	0	4.0	PQ N.OF WALTHAM
1940MAR 2	0415	41.5	72.5	3	4	0.0	CT MOODUS-E.HADDAM
1940MAR13	0129X	41.5	72.5	3	3	0.0	CT MOODUS-E.HADDAM
1940MAR26	0200	38.8	78.5	5	5	0.0	SE
1940MAR28	1142	44.7	69.9	0	0	3.8	ME STARK
1940APR12	0158	42.8	74.6	2	2	0.0	NY SE OF ST.JOHNSVILLE
1940APR13	0813	47.7	70.7	0	0	3.8	PQ NW OF BAIE-ST-PAUL
1940APR13	0823	44.8	74.9	0	0	2.6	NY MASSENA
1940APR27	2231	40.0	72.0	2	2	0.0	NY S.OF LONG ISLAND

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1940APR27	2237X	40.0	72.0	2	2	0.0	NY S.OF LONG ISLAND
1940APR27	2244X	40.0	72.0	2	2	0.0	NY S.OF LONG ISLAND
1940MAY10	1923X	40.0	72.0	2	2	0.0	NY S.OF LONG ISLAND
1940MAY16	1400	45.8	73.2	0	0	3.6	PQ L'ASSOMPTION
1940MAY20	0126	44.6	75.2	2	2	0.0	NY CANTON
1940MAY28	2006	40.3	76.9	2	2	0.0	PA HARRISBURG
1940JUN 4	1813X	40.0	72.0	2	2	0.0	NY S.OF LONG ISLAND
1940JUN 4	1814X	40.0	72.0	2	2	0.0	NY S.OF LONG ISLAND
1940JUN20	0643	47.6	70.1	0	0	3.0	PQ LA MALBAIE
1940JUN25	0950	47.2	70.9	0	0	2.5	PQ SEVEN FALLS
1940AUG 4	1620	46.3	74.8	0	0	3.1	PQ LABELLE
1940AUG 7	2357	45.8	74.8	0	0	3.0	PQ MONTEBELLO
1940SEP11	0106	47.0	71.1	0	0	3.5	PQ QUEBEC CITY
1940SEP26	2330	44.7	73.5	3	3	2.9	NY PLATTSBURG
1940SEP27		41.2	75.7	2	2	0.0	NY S.OF MONTICELLO
1940OCT13	1950	48.0	70.6	0	0	4.7	PQ NW OF LA MALBAIE
1940DEC 3	1734	42.5	69.4	2	2	0.0	MA OFF CAPE ANN
1940DEC 3	1735X	42.5	69.4	2	2	0.0	MA OFF CAPE ANN
1940DEC20	0727	43.8	71.3	7	7	5.8	NH OSSIPEE
1940DEC24	1300X	43.8	71.3	2	2	0.0	NH OSSIPEE
1940DEC24	1343X	43.8	71.3	7	7	5.8	NH OSSIPEE
1940DEC24	1432X	43.8	71.3	3	3	0.0	NH OSSIPEE
1940DEC24	1812X	43.8	71.3	3	3	0.0	NH OSSIPEE
1940DEC25	0503X	43.8	71.3	4	4	4.0	NH OSSIPEE
1940DEC27	1956X	43.8	71.3	4	4	3.9	NH OSSIPEE
1941JAN 2	0342X	43.8	71.3	3	3	0.0	NH OSSIPEE
1941JAN 4	1110X	43.8	71.3	3	3	0.0	NH OSSIPEE
1941JAN18	2325X	43.8	71.3	3	3	0.0	NH OSSIPEE
1941JAN21	0227X	43.8	71.3	4	4	3.6	NH OSSIPEE
1941JAN23	0014X	43.8	71.3	3	3	0.0	NH OSSIPEE
1941FEB 1	1828	44.6	75.2	2	2	0.0	NY CANTON
1941FEB12	2223X	43.8	71.3	3	3	0.0	NH OSSIPEE
1941MAR 4	1801	46.1	76.2	0	0	2.8	PQ GRACEFIELD
1941MAR 5	0729	46.3	75.5	0	0	3.0	PQ LAC-DU-CERF
1941APR 3	1953	44.7	73.9	0	0	2.5	NY MALONE
1941APR 4	0810X	44.7	73.9	0	0	3.3	NY MALONE
1941APR29	1405	40.5	72.5	0	0	2.5	NY S.OF LONG ISLAND
1941MAY19	1159	43.8	72.3	0	0	2.0	VT N.OF HANOVER NH
1941JUN 8	2021	52.4	75.3	0	0	5.0	PQ E.OF JAMES BAY
1941JUN22	0959	47.7	70.6	0	0	3.0	PQ CLERMONT
1941JUN26	0405	47.4	76.8	0	0	4.1	PQ CABONGA RESERVOIR
1941JUL 1	1659	43.4	70.2	0	0	2.0	ME OFF KENNEBUNKPORT
1941JUL 5	1208X	47.4	70.5	0	0	2.7	PQ BAIE-ST-PAUL
1941JUL29	0024	41.1	73.8	3	3	0.0	NY WHITE PLAINS
1941AUG30	1521	46.1	67.9	0	0	3.7	ME HOULTON
1941SEP 6	1704X	47.4	70.5	0	0	3.8	PQ BAIE-ST-PAUL
1941OCT 6	1634	47.6	70.7	0	0	4.0	PQ BAIE-ST-PAUL
1941OCT 9	2207	44.0	75.9	2	2	0.0	NY WATERTOWN
1941OCT11	0815	42.3	72.3	4	4	3.0	MA STURBRIDGE
1941OCT20	2129	44.0	75.9	2	2	0.0	NY WATERTOWN
1941OCT21	0523X	44.8	74.8	0	0	2.2	NY MALONE
1941OCT21	0610	44.8	74.8	0	0	3.3	NY MALONE
1941OCT24	1413	45.7	74.3	0	0	3.6	PQ LACHUTE
1941DEC12	2328	44.9	73.6	2	2	2.7	NY DANNEMORA
1942JAN31	0412X	44.7	73.9	0	0	2.7	NY DANNEMORA
1942FEB18	0755	46.8	74.8	0	0	3.1	PQ STE-ANNE-DU-LAC
1942MAR 8	2337	44.2	70.4	4	4	0.0	ME LEWISTON
1942APR23	2040	41.4	72.9	0	0	2.0	CT NEW HAVEN
1942MAY20	1219	45.8	74.7	0	0	4.4	PQ KILMAR

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1942MAY24	0715X	44.7	73.8	0	0	2.9	NY DANNEMORA
1942MAY24	1133	44.7	73.8	0	0	3.9	NY DANNEMORA
1942JUN14	1104	42.4	70.7	2	2	0.0	MA OFF BOSTON
1942JUN14	1630X	42.4	70.7	2	2	0.0	MA OFF BOSTON
1942JUN14	1952X	42.7	70.7	2	2	0.0	MA OFF BOSTON
1942AUG26	1754	46.8	77.5	0	0	4.1	PQ N.OF DEEP RIVER
1942SEP 5	1430	47.0	71.5	0	0	3.1	PQ QUEBEC CITY
1942SEP11	1105	49.2	67.4	0	0	4.4	PQ GODBOUT
1942SEP15	2232	46.8	76.0	0	0	3.3	PQ BASKATONG RESERVOIR
1942OCT 1	2058	44.0	73.6	0	0	2.5	NY LAKE CHAMPLAIN
1942OCT 2	2229	42.6	73.8	0	0	3.0	NY ALBANY
1942OCT24	1727	41.0	75.3	0	0	3.4	PA STROUDSBURG
1942NOV16	0013	46.4	75.1	0	0	3.6	PQ NOMININGUE
1942DEC 5	2110	47.0	76.1	0	0	4.2	PQ BASKATONG RESERVOIR
1942DEC 9	1800	41.8	72.7	2	2	0.0	CT HARTFORD
1943JAN14	2132	45.3	69.6	5	5	4.4	ME DOVER-FOXCROFT
1943FEB10	0945	43.7	70.3	2	2	0.0	ME PORTLAND
1943FEB16	1651	45.8	74.7	3	3	0.0	ON HAWKESBURY
1943FEB28	1640	46.5	75.8	0	0	3.7	PQ MONT-LAURIER
1943MAR 9	0325	42.2	80.9	0	0	4.7	NY LAKE ERIE
1943MAR14	1402	43.7	71.6	0	0	3.9	NH MEREDITH
1943MAR31	1130	42.3	72.6	2	2	0.0	MA NORTHAMPTON
1943MAY 9	1103	44.8	73.8	0	0	3.2	NY DANNEMORA
1943JUN 8	A.M.	43.7	65.7	3	3	0.0	NS YARMOUTH
1943JUN11	2251	41.1	71.8	2	2	0.0	RI BLOCK ISLAND SOUND
1943JUN12		44.5	68.5	2	2	0.0	ME ELLSWORTH
1943JUL 6	2210	44.9	73.1	4	4	4.1	VT SWANTON
1943JUL24	0519	40.0	72.7	0	0	2.5	NJ OFF COAST
1943SEP25	0552	47.6	70.7	0	0	3.3	PQ BAIE-ST-PAUL
1943SEP28	1630	47.3	70.4	0	0	3.8	PQ ILE-AUX-COUDRES
1943OCT15	2300	44.6	74.2	0	0	2.5	NY S.OF MALONE
1943NOV 6	0006	47.4	70.1	0	0	3.9	PQ ILE-AUX-COUDRES
1943DEC 6	0719	47.7	74.9	0	0	3.2	PQ PARENT
1943DEC19	0900	44.6	69.6	4	3	0.0	ME WATERVILLE
1944JAN16	1000	43.2	77.6	2	2	0.0	NY ROCHESTER
1944JAN22	2155	45.8	76.8	0	0	4.3	ON RENFREW
1944FEB 5	1237	47.4	70.5	0	0	4.0	PQ BAIE-ST-PAUL
1944FEB 5	1622	40.8	76.2	0	0	3.7	PA SHENANDOAH
1944FEB26	2058	42.9	78.8	2	2	0.0	NY BUFFALO
1944MAR 6	0546	43.2	71.6	2	2	0.0	NH CONCORD
1944MAR 6	1215X	43.2	71.6	2	2	0.0	NH CONCORD
1944MAR 8	1249	46.7	78.9	0	0	4.1	PQ TIMISKAMING
1944APR 9	1244	49.9	67.4	0	0	5.4	PQ RIVIERE PENTECOTE
1944APR11	2025	44.0	71.7	3	3	0.0	NH WOODSTOCK
1944MAY29	2303	44.7	73.8	2	2	0.0	NY NW OF PLATTSBURG
1944JUN 4	0208	44.2	72.8	3	3	0.0	VT NORTHFIELD
1944JUN 6	0600	47.6	65.7	3	3	0.0	NB BATHURST
1944JUN 9	1519	47.3	70.3	0	0	3.7	PQ ILE-AUX-COUDRES
1944JUN23	0637	49.4	67.8	0	0	5.1	PQ GODBOUT
1944JUN24	2348	46.0	74.3	0	0	3.7	PQ LACHUTE
1944JUL15	1704	47.6	70.1	0	0	3.0	PQ LA MALBAIE
1944SEP 5	0438	45.0	74.9	8	8	5.9	NY MASSENA
1944SEP 5	0830X	45.0	74.9	0	0	3.4	NY MASSENA
1944SEP 5	0851X	45.0	74.9	0	0	4.6	NY MASSENA
1944SEP 5	1056X	45.0	74.9	0	0	3.3	NY MASSENA
1944SEP 5	1110X	45.0	74.9	0	0	2.8	NY MASSENA
1944SEP 7	1355X	45.0	74.9	0	0	2.5	NY MASSENA
1944SEP 8	1011X	45.0	74.9	0	0	2.5	NY MASSENA
1944SEP 8	1935X	45.0	74.9	0	0	2.8	NY MASSENA

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1944SEP 9	2324X	45.0	74.9	0	0	4.1	NY MASSENA
1944SEP13	2200X	45.0	74.9	0	0	2.7	NY MASSENA
1944SEP24	1930X	45.0	74.9	0	0	2.0	NY MASSENA
1944OCT 4	0036X	45.0	74.9	0	0	2.3	NY MASSENA
1944OCT 9	0145X	45.0	74.9	0	0	2.3	NY MASSENA
1944OCT13	0233X	45.0	74.9	0	0	2.7	NY MASSENA
1944OCT14	1326	48.5	67.0	0	0	4.2	PQ BAIE-COMEAU
1944OCT31	0842X	45.0	74.9	0	0	4.0	NY MASSENA
1944NOV 5	1907	48.7	80.8	0	0	5.1	ON TIMMONS
1944DEC14	0314	41.6	72.8	4	4	0.0	CT MERIDEN
1945FEB15	0603	45.8	74.7	0	0	2.3	ON OTTAWA
1945MAR22	0803	43.2	71.6	3	3	0.0	NH CONCORD
1945APR15	1315	43.0	76.4	3	3	0.0	NY CAMILLUS
1945APR15	1420X	43.0	76.4	3	3	0.0	NY CAMILLUS
1945APR15	1530X	43.0	76.4	3	3	0.0	NY CAMILLUS
1945JUN12	0758	47.1	75.4	0	0	4.3	PQ BASKATONG RESERVOIR
1945JUN18	1520	47.2	71.1	0	0	4.7	PQ QUEBEC CITY
1945JUL 2	1329	48.5	76.8	0	0	3.9	PQ SENNETERRE
1945JUL15	1044	44.9	67.0	4	4	0.0	ME EASTPORT
1945JUL24	0156X	45.0	74.9	0	0	2.7	NY MASSENA
1945JUL26	1132	34.3	87.4	6	5	0.0	SE
1945AUG 5	1720	43.6	72.5	3	3	0.0	VT WOODSTOCK
1945AUG28	0137	44.9	67.0	2	2	0.0	ME EASTPORT
1945SEP12	0936	45.0	74.4	0	0	2.8	PQ HUNTINGDON
1945OCT 9	1318	48.1	70.0	0	0	4.9	PQ BAIE-DES-ROCHERS
1945OCT30	1930	44.1	70.2	2	2	0.0	ME LEWISTON
1945DEC 2	1522X	45.0	74.9	0	0	3.0	NY MASSENA
1945DEC 7	0554	47.5	70.2	0	0	3.1	PQ LA MALBAIE
1945DEC28	1023	43.8	71.3	2	2	0.0	NH S.TAMWORTH
1946JAN17	0804	49.4	68.7	0	0	4.3	PQ NW OF BAIE-COMEAU
1946FEB13	1510X	45.0	74.9	2	2	0.0	NY MASSENA
1946MAR16	0420X	45.0	74.9	2	2	0.0	NY MASSENA
1946MAR20	0201	44.3	75.9	3	3	0.0	NY ALEXANDRIA BAY
1946MAR20	0229X	44.3	75.9	2	2	0.0	NY ALEXANDRIA BAY
1946MAR20	0302X	44.3	75.9	2	2	0.0	NY ALEXANDRIA BAY
1946APR21	0505	45.7	73.4	0	0	3.6	PQ NE OF MONTREAL
1946MAY22	1427X	45.0	74.9	0	0	1.7	NY MASSENA
1946MAY27	1430X	45.0	74.9	0	0	2.1	NY MASSENA
1946JUN20	2309	44.4	74.2	2	2	0.0	NY GABRIELS
1946JUN27	2106	44.7	74.5	0	0	3.0	NY ST.REGIS FALLS
1946AUG28	0910	45.7	76.9	0	0	2.7	ON BEACHBURG
1946SEP 1	0439	47.3	71.5	0	0	3.3	PQ JACQUES CARTIER RIVER
1946SEP 4	1929X	45.0	74.9	3	3	2.3	NY MASSENA
1946SEP19	0053	47.7	75.0	0	0	3.2	PQ PARENT
1946SEP26	2119	46.4	72.2	0	0	3.4	PQ DESCHAILLONS
1946OCT 6	0334	47.3	70.3	0	0	1.9	PQ BAIE-ST-PAUL
1946OCT28	2036	41.5	76.6	0	0	3.6	PA LAPORTE
1946NOV10	1141	42.9	77.5	0	0	3.1	NY CANANDAIGUA
1946NOV11	1020X	45.0	74.9	0	0	3.0	NY MASSENA
1946NOV24	1020	45.2	74.7	0	0	3.1	ON CORNWALL
1946NOV28	2200	43.9	73.8	3	3	0.0	NY SCHROON LAKE
1946DEC25	0448X	44.9	74.9	0	0	3.3	NY MASSENA
1947JAN 2	1815	47.0	70.9	3	3	0.0	PQ STE-ANNE-DE-BEAUPRE
1947JAN 4	1851	41.0	73.6	4	5	0.0	CT GREENWICH
1947JAN19	0045	46.8	76.7	0	0	3.9	PQ W.OF BASKATONG RESERVOIR
1947FEB 2	1650	47.7	70.5	0	0	4.2	PQ LA MALBAIE
1947MAR26	2306	46.2	75.0	0	0	2.5	PQ LA CONCEPTION
1947MAR29	1228	47.4	70.2	0	0	4.0	PQ ILE-AUX-COUDRES
1947APR 1	1325	41.0	74.3	3	3	0.0	NJ POMPTON LAKES

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1947AUG 4	0825X	45.0	74.9	0	0	2.1	NY MASSENA
1947AUG 8	0539	46.5	81.1	0	0	4.4	ON SUDBURY
1947AUG14	0218X	45.0	74.9	0	0	2.1	NY MASSENA
1947SEP 1	1332	46.8	77.8	0	0	2.8	PQ LAC DUMOINE
1947SEP14	1929	47.0	81.3	0	0	4.3	ON LAFOREST
1947OCT 3	1528X	45.0	74.9	0	0	2.1	NY MASSENA
1947OCT22	0936	47.6	70.7	0	0	3.8	PQ BAIE-ST-PAUL
1947OCT29	1545X	45.0	74.9	2	2	0.0	NY MASSENA
1947NOV 3	1951	45.7	81.2	0	0	4.5	ON GEORGIAN BAY
1947DEC28	1958	45.2	69.2	5	5	4.5	ME DOVER-FOXCROFT
1948JAN 1	1833	47.3	70.4	0	0	4.9	PQ BAIE-ST-PAUL
1948JAN 1	1844X	47.3	70.4	0	0	3.2	PQ BAIE-ST-PAUL
1948JAN 5	0245	37.6	78.6	4	4	0.0	SE
1948JAN 6	2046	45.4	69.3	4	4	4.0	ME DOVER-FOXCROFT
1948JAN 7	2120X	45.4	69.3	2	2	0.0	ME DOVER-FOXCROFT
1948JAN16	0602	50.0	69.0	0	0	4.3	PQ NW OF BAIE-COMEAU
1948FEB10	0007	36.4	84.1	6	5	0.0	SE
1948FEB28	2119	47.2	74.6	0	0	2.8	PQ MANOUANE
1948APR 4	0244	44.2	73.6	0	0	2.5	NY E.OF LAKE PLACID
1948MAY 4	0223	41.4	71.8	4	4	0.0	RI WESTERLY
1948MAY 7	1202	45.8	73.6	0	0	4.0	PQ NNE OF MONTREAL
1948MAY23	0407X	45.0	74.9	0	0	2.0	NY MASSENA
1948JUN 4	0900	41.3	72.5	3	2	0.0	CT WESTBROOK
1948JUN 9	0304	45.2	73.9	0	0	3.7	PQ HOWICK
1948JUL 7	0715	44.7	75.0	2	2	0.0	NY POTSDAM
1948JUL 7	0738	45.2	73.9	0	0	3.5	PQ HOWICK
1948AUG 3	1904	39.4	72.8	2	2	0.0	NJ ATLANTIC CITY
1948AUG 7		44.0	74.0	2	2	0.0	NY SANFORD LAKE
1948SEP10	0122	45.6	76.0	0	0	2.2	PQ GATINEAU PARK
1948OCT20	1159	44.5	73.2	2	2	0.0	VT BURLINGTON
1948NOV13	1649	46.7	70.3	0	0	3.5	PQ ST-PAUL-DE-MONTMINY
1948NOV21	1541	44.9	67.0	3	3	0.0	ME EASTPORT
1948NOV22	2233	44.6	74.3	2	2	2.9	NY S.OF MALONE
1948NOV29	0456	45.2	69.2	4	4	0.0	ME DOVER-FOXCROFT
1948NOV29	1100X	45.2	69.2	2	2	0.0	ME DOVER-FOXCROFT
1949FEB 3	0131	45.4	75.6	0	0	1.7	ON ROCKCLIFFE
1949FEB 7	0617	44.9	74.9	3	4	0.0	NY MASSENA
1949APR17	0015	41.6	71.5	4	4	0.0	RI N.KINGSTON
1949MAY 8	1101	37.6	77.9	5	5	0.0	SE
1949SEP 2	0548	43.8	71.3	3	3	0.0	NH S.TAMWORTH
1949SEP17	0930	36.8	83.0	5	4	0.0	SE
1949OCT 5	0233	44.8	70.5	5	6	4.0	ME HOUGHTON
1949OCT11	0935	47.5	70.2	0	0	2.5	PQ LA MALBAIE
1949OCT16	2333	45.3	74.8	5	5	4.2	ON ALEXANDRIA
1949OCT30	2051	46.5	72.1	0	0	3.4	PQ PARISVILLE
1949NOV10	0045	45.0	74.9	0	0	2.0	NY MASSENA
1950JAN 6	2318	46.3	77.6	0	0	2.3	PQ RAPIDES-DES-JOACHIMS
1950FEB24	1304	43.0	71.8	3	3	0.0	NH SW OF CONCORD
1950MAR 6	1614	46.0	74.5	0	0	4.0	PQ STE-AGATHE
1950MAR20	2255	41.5	75.8	0	0	3.3	PA NW OF SCRANTON
1950MAR29	1443	41.0	73.6	4	4	0.0	CT GREENWICH
1950APR14	1820	47.8	75.5	0	0	4.9	PQ GATINEAU RIVER
1950JUN19	0414	35.7	84.0	4	4	0.0	SE
1950JUN29	0913	49.9	68.1	0	0	4.8	PQ TOULNUSTOUC RIVER
1950AUG 4	0645	47.3	70.3	0	0	3.2	PQ S.OF ILE-AUX-COUDRES
1950AUG 4	1429	45.2	74.7	0	0	4.0	ON LANCASTER
1950AUG 5	2359X	45.1	74.8	0	0	3.5	ON LANCASTER
1950SEP28	1059	47.6	70.1	0	0	3.0	PQ LA MALBAIE
1950OCT29	0559	45.8	77.1	0	0	3.0	ON PEMBROKE

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1950NOV 7	0251	47.1	70.8	0	0	1.8	PQ BEAUPRE
1950NOV26	0745	37.7	78.4	5	5	0.0	SE
1951JAN26	0327	41.5	72.5	4	4	0.0	CT MOODUS-E.HADDAM
1951MAR31	0350	42.2	72.2	4	4	0.0	MA PALMER
1951JUN10	1720	41.5	71.5	4	4	4.3	RI KINGSTOWN
1951JUN27	1317	45.0	57.0	0	0	5.0	NF OFFSHORE
1951JUN28	0103	50.0	67.5	0	0	4.8	PQ SEPT-ILES
1951JUL25	0022	47.2	71.4	0	0	3.3	PQ JACQUES CARTIER RIVER
1951JUL25	0649X	47.2	71.4	0	0	2.7	PQ JACQUES CARTIER RIVER
1951AUG 2	0032	45.4	75.8	0	0	0.7	ON OTTAWA
1951AUG 8	0936	45.9	74.7	0	0	3.3	PQ ARUNDEL
1951SEP 3	2126	41.2	74.3	5	5	4.4	NY ROCKLAND CO.
1951SEP19	0819	49.3	66.3	0	0	5.1	PQ STE-ANNE-DES-MONTS
1951SEP21	1723	41.3	70.1	2	3	0.0	MA NANTUCKET
1951SEP25	1545	46.2	75.4	0	0	3.7	PQ NOTRE-DAME-DU-LAUS
1951OCT25	0707	45.3	74.7	3	3	3.8	ON ALEXANDRIA
1951OCT25	0730X	45.1	74.8	0	0	2.8	ON ALEXANDRIA
1951OCT28	1258	44.3	70.5	3	3	0.0	ME S.PARIS
1951NOV 6	1754	45.0	73.6	4	4	3.7	NY ROUSES PT.
1951NOV23	0645	40.6	75.5	4	4	0.0	PA ALLENTOWN
1951DEC 8	0437	41.6	73.8	2	3	0.0	NY NEWBURGH
1951DEC28	2233X	45.8	74.5	0	0	2.7	PQ ARUNDEL
1951DEC31	2015	45.8	74.5	0	0	2.9	PQ ARUNDEL
1952JAN24	0929	47.0	77.0	0	0	2.8	PQ CABONGA RESERVOIR
1952JAN30	X	44.5	73.2	2	2	0.0	VT BURLINGTON
1952JAN30	0400	44.5	73.2	6	6	0.0	VT BURLINGTON
1952FEB 2	0620X	46.9	70.5	0	0	2.5	PQ MONTMAGNY
1952FEB 2	1055X	46.9	70.5	0	0	2.5	PQ MONTMAGNY
1952FEB 2	1115X	46.9	70.5	0	0	2.3	PQ MONTMAGNY
1952FEB 3	0233	46.9	70.5	0	0	2.8	PQ MONTMAGNY
1952FEB18	2056	46.3	69.4	0	0	3.3	ME EAGLE LAKE
1952FEB26	0056	46.8	70.2	0	0	3.7	PQ STE-APOLLINE
1952MAR17	0414	47.1	76.2	0	0	3.8	PQ CABONGA RESERVOIR
1952MAR30	1311	47.8	69.9	0	0	4.4	PQ RIVIERE-DU-LOUP
1952APR19	0250	47.5	70.6	0	0	3.8	PQ BAIE-ST-PAUL
1952APR20	1906X	47.5	70.7	0	0	3.5	PQ BAIE-ST-PAUL
1952APR26	0459	47.0	78.5	0	0	3.7	PQ NE OF TIMISKAMING
1952JUL19	0116	46.9	75.8	0	0	4.3	PQ BASKATONG RESERVOIR
1952AUG25	0007	43.0	74.5	5	5	0.0	NY JOHNSTOWN
1952SEP11	0315	38.1	78.5	4	4	0.0	SE
1952OCT 8	2140	41.7	74.0	5	5	0.0	NY POUGHKEEPSIE
1952OCT14	2203	48.0	69.8	5	5	5.1	PQ TADOUSSAC
1952OCT20	0104	57.0	57.0	0	0	5.0	NF OFF COAST OF LABRADOR
1952OCT26	0905	43.6	71.2	2	2	0.0	NH WOLFEBORO
1952NOV20		42.9	76.6	3	3	0.0	NY AUBURN
1952DEC21	1200	44.9	74.9	2	2	0.0	NY MASSENA
1952DEC25	0428	43.9	81.0	0	0	3.6	ON NW OF TORONTO
1953JAN24	0958	49.1	66.0	0	0	5.3	PQ MARSOUI
1953FEB 7	0800	37.7	78.2	4	4	0.0	SE
1953FEB28	0624	48.1	74.4	0	0	3.5	PQ PARENT
1953MAR27	0850	41.1	73.5	5	5	0.0	CT STAMFORD
1953MAR31	0250X	43.7	73.0	3	3	0.0	VT BRANDON
1953MAR31	1258	43.7	73.0	5	5	4.0	VT BRANDON
1953APR26	0117	44.7	73.5	4	4	2.6	NY PLATTSBURG
1953MAY11	0613	44.0	71.1	4	4	0.0	NH CONWAY
1953AUG17	0422	41.0	74.0	4	4	0.0	NJ BERGEN CO.
1953SEP14	2252	49.1	65.2	4	5	5.1	PQ GRANDE-VALLEE
1953SEP17	0553	45.8	74.8	0	0	2.4	ON HAWKESBURY
1953NOV10	2300	36.0	84.0	4	4	0.0	SE

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1953NOV28	1547	45.9	73.1	0	0	2.7	PQ ST.MAURICE RIVER
1954JAN 2	0225	36.6	83.7	6	6	0.0	SE
1954JAN 7	0725	40.3	76.0	6	6	0.0	PA BERKS CO.
1954JAN10	2104	49.2	68.2	0	0	3.9	PQ BAIE-COMEAU
1954JAN22	P.M.	35.3	84.4	5	5	0.0	SE
1954JAN24	0330	40.3	76.0	3	3	0.0	PA BERKS CO.
1954JAN27	0355	45.0	75.7	0	0	2.4	ON CORNWALL
1954JAN31	1230	42.9	77.3	4	4	0.0	NY CANANDAIGUA
1954FEB 1	0037	43.0	76.7	0	0	3.3	NY MONTEZUMA
1954FEB 7	2024	47.6	70.3	0	0	3.8	PQ POINTE-AU-PIC
1954FEB13		42.2	72.6	4	4	0.0	MA SPRINGFIELD
1954FEB13		42.2	72.6	4	4	0.0	MA SPRINGFIELD
1954FEB21	0900	47.7	70.6	0	0	3.5	PQ ST-URBAIN
1954FEB21	2000	41.2	75.9	7	7	0.0	PA WILKES-BARRE
1954FEB24	0355X	41.2	75.9	6	6	0.0	PA WILKES-BARRE
1954MAR28	0058	47.6	70.1	0	0	1.9	PQ LA MALBAIE
1954MAR31	2125	40.3	74.0	4	4	0.0	NJ SANDY HOOK
1954APR12	2122	46.9	76.1	0	0	4.3	PQ BASKATONG RESERVOIR
1954APR21	1545	44.7	73.5	4	4	0.0	NY PLATTSBURG
1954APR27	0214	43.1	79.2	0	0	4.1	ON WELLAND
1954MAY20	2201	45.0	74.2	4	4	2.7	NY MALONE
1954JUN26	0744	46.7	75.0	0	0	2.4	PQ STE-VERONIQUE
1954JUN30	0741	47.0	70.1	0	0	3.7	PQ ST-CYRILLE
1954JUL22	0734	46.7	70.1	0	0	2.1	PQ LAC FRONTIERE
1954JUL29	1956	42.7	70.7	5	5	4.0	MA CAPE ANN
1954AUG11	0340	40.3	76.0	4	4	0.0	PA BERKS CO.
1954AUG28	1523	45.2	56.9	0	0	5.2	NS OFF SE COAST
1954SEP 8	0129	49.0	68.4	0	0	4.3	PQ BAIE-COMEAU
1954SEP11	1855	47.3	75.6	0	0	4.6	PQ N.OF BASKATONG RESERVOIR
1954SEP24	1100	40.3	76.0	2	2	0.0	PA BERKS CO.
1954SEP29	0350	44.0	75.9	1	2	0.0	NY WATERTOWN
1954OCT 7		42.7	71.3	3	3	0.0	NH PELHAM
1954OCT16	0645	44.8	56.8	0	0	5.3	NS OFF SE COAST
1954DEC13	0353	44.6	74.6	4	4	3.6	NY N.OF SARANAC LAKE
1954DEC15	1735	44.8	74.7	2	2	0.0	NY LAWRENCEVILLE
1955JAN 6	2030	36.6	82.2	4	4	0.0	SE
1955JAN 6	2030	36.6	82.2	4	4	0.0	SE
1955JAN12	1725	36.0	84.0	4	4	0.0	SE
1955JAN17	1237	37.3	78.5	5	4	0.0	SE
1955JAN20	0300	40.3	76.0	4	4	0.0	PA BERKS CO.
1955JAN21	0840X	43.0	73.8	5	5	0.0	NY MALTA
1955JAN21	1220	43.0	73.7	5	5	0.0	NY MALTA
1955JAN24	0122	45.1	59.0	0	0	3.6	NS OFF SE COAST
1955JAN25	1934	36.0	84.0	4	4	0.0	SE
1955FEB 1	1240	47.7	70.5	0	0	4.0	PQ BAIE-ST-PAUL
1955FEB 1	1245X	47.7	70.5	0	0	2.7	PQ BAIE-ST-PAUL
1955FEB 1	2048X	47.7	70.5	0	0	3.2	PQ BAIE-ST-PAUL
1955FEB 3	0230	44.5	73.2	5	5	0.0	VT BURLINGTON
1955FEB 3	0406X	44.5	73.2	2	2	0.0	VT BURLINGTON
1955FEB 3	0408X	44.5	73.2	2	2	0.0	VT BURLINGTON
1955FEB 3	0428X	44.5	73.2	2	2	0.0	VT BURLINGTON
1955MAR 3	2103	45.8	74.7	0	0	2.0	PQ STE-AGATHE
1955APR 3	0614X	45.8	74.6	0	0	2.0	PQ STE-AGATHE
1955APR 4	0317	51.6	79.3	0	0	3.6	PQ RUPERT HOUSE
1955APR15	0145	47.6	70.1	0	0	1.8	PQ LA MALBAIE
1955JUN29	0117	43.8	79.6	0	0	3.0	ON TORONTO
1955JUL 1	0137	48.5	80.6	0	0	3.1	ON KIRKLAND LAKE
1955AUG16	0735	42.9	78.3	5	5	0.0	NY ATTICA
1955SEP28	0701	36.6	81.3	5	4	0.0	SE

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1955OCT 7	1809	45.2	73.9	0	0	3.5	PQ SW OF MONTREAL
1955OCT20	2058X	48.9	70.2	0	0	3.2	PQ PORTNEUF RIVER
1955OCT20	2116X	48.9	70.2	0	0	3.3	PQ PORTNEUF RIVER
1955OCT20	2131	48.9	70.2	0	0	3.4	PQ PORTNEUF RIVER
1955NOV 1	0745	46.5	75.9	0	0	3.5	PQ MANIWAKI
1955NOV21	1610	50.6	63.5	0	0	4.9	PQ N.OF HAVRE-ST-PIERRE
1955NOV26	0650	46.3	73.4	0	0	2.0	PQ ST-GABRIEL
1955DEC 3	1138	45.7	75.1	0	0	2.4	PQ NE OF BUCKINGHAM
1956JAN 5	0800	34.3	82.4	4	4	0.0	SE
1956JAN10	1208	45.7	75.5	0	0	3.3	ON NE OF OTTAWA
1956JAN30	0943	47.1	71.2	0	0	3.7	PQ QUEBEC CITY
1956FEB 2	1924	45.5	74.8	0	0	3.1	ON MAXVILLE
1956FEB11	1029	46.0	75.3	0	0	2.0	ON NOTRE-DAME-DU-LAUS
1956FEB16	1029	45.9	75.0	0	0	2.0	PQ NAMUR
1956MAR 6	2338	44.9	75.4	0	0	3.1	ON CARDINAL
1956APR 6	0451	59.4	74.1	0	0	4.9	PQ PAYNE LAKE
1956MAY12	0039	47.9	72.4	0	0	2.6	PQ KISKISINK
1956MAY19	1900	34.3	82.4	4	4	0.0	SE
1956MAY27	2325	34.3	82.4	4	4	0.0	SE
1956MAY26	0044	45.5	73.6	0	0	1.6	PQ MONTREAL
1956JUN 1	1030X	45.3	66.1	0	0	1.7	NB ST.JOHN
1956JUN 1	1140	45.3	66.1	0	0	1.9	NB ST.JOHN
1956JUN 5	0745	56.8	58.9	0	0	5.1	NF OFF COAST OF LABRADOR
1956JUN15	0053	47.1	76.4	0	0	3.9	PQ CABONGA RESERVOIR
1956JUL27	0134	44.7	73.8	0	0	3.4	NY DANNEMORA
1956AUG 3	1251X	49.4	66.2	0	0	4.1	PQ S.OF SEPT-ILES
1956AUG 3	1252	49.4	66.2	0	0	4.3	PQ S.OF SEPT-ILES
1956AUG 3	2211	44.9	74.6	0	0	2.3	NY MASSENA
1956AUG22	1638	45.4	75.6	2	2	2.4	ON OTTAWA
1956SEP 7	1336	35.5	84.0	6	6	0.0	SE
1956SEP21	1700	41.8	71.2	2	2	0.0	MA SWANSEA
1956OCT10	0551	47.3	70.3	0	0	2.7	PQ ILE-AUX-COUDRES
1956OCT27	1440	48.3	69.0	0	0	3.4	PQ TROIS-PISTOLES
1956OCT27	1503X	48.3	69.0	0	0	3.4	PQ TROIS-PISTOLES
1956NOV 4	1153	46.2	75.7	0	0	4.0	PQ MANIWAKI
1956NOV16	0717	46.2	74.8	0	0	2.9	PQ NW OF STE-AGATHE
1956DEC 1	1400	49.4	82.4	2	2	2.3	ON KAPUSKASING
1956DEC28	0141	45.2	74.3	0	0	2.7	PQ HUNTINGDON
1957JAN25	1815	36.6	83.7	4	4	0.0	SE
1957JAN30		44.5	73.2	2	2	0.0	VT BURLINGTON
1957FEB19	0518	48.4	69.9	0	0	3.5	PQ NW OF TADOUSSAC
1957FEB20	1545	44.9	74.9	4	4	0.0	NY MASSENA
1957MAR23	1902	40.6	74.8	6	6	4.8	NJ SCHOOLEY'S MTN
1957APR24	0041	44.4	72.0	5	5	0.0	VT ST.JOHNSBURY
1957APR26	1140	43.6	69.8	6	6	4.7	ME PORTLAND
1957MAY13	0807	46.6	74.1	0	0	2.8	PQ ST-ZENON
1957MAY13	1424	35.8	82.1	6	6	0.0	SE
1957MAY25	1227	46.0	74.3	0	0	2.8	PQ STE-ADELE
1957JUN29	1125	42.9	81.3	0	0	4.2	ON LONDON
1957JUL 2	0933	35.6	82.7	6	6	0.0	SE
1957AUG 4	1240	46.6	67.1	0	0	3.7	NB JUNIPER
1957AUG 6	2350	47.5	70.4	0	0	4.0	PQ BAIE-ST-PAUL
1957AUG17	0130	46.7	70.1	0	0	3.3	PQ LAC-FRONTIERE
1957AUG21	0240	44.8	76.2	0	0	3.0	ON SMITHS FALLS
1957OCT 4	0015	45.3	75.2	0	0	2.1	ON E.OF OTTAWA
1957OCT 9	1416	48.4	69.9	0	0	3.1	PQ NW OF TADOUSSAC
1957OCT16	1913	50.5	64.9	0	0	4.8	PQ N.OF SHELDRAKE
1957OCT27	0848	46.4	78.8	0	0	3.2	ON MATTAWA
1957NOV 2	0400	46.2	75.0	0	0	2.6	PQ LAPELLE

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1957NOV13	2045X	48.7	69.6	0	0	3.3	PQ NW OF SAULT-AU-MOUTON
1957NOV13	2049	48.7	69.6	0	0	3.5	PQ NW OF SAULT-AU-MOUTON
1957NOV13	2054X	48.7	69.6	0	0	3.3	PQ NW OF SAULT-AU-MOUTON
1957NOV24	2006	35.5	83.5	6	6	0.0	SE
1957NOV30	0627	45.0	74.8	4	4	2.5	NY MASSENA
1958JAN11	1636X	44.9	74.9	4	4	0.0	NY MASSENA
1958JAN24	1710	45.0	81.3	0	0	3.5	ON LION'S HEAD
1958FEB 2	0154	46.6	75.4	0	0	2.8	PQ MONT LAURIER
1958FEB 4	0806	57.9	53.5	0	0	5.1	NF LABRADOR SEA
1958FEB12	1329	44.8	75.3	0	0	2.6	ON IROQUOIS
1958MAR 1	1741	46.9	76.0	0	0	3.9	PQ BASKATONG RESERVOIR
1958MAR 5	1153	34.3	77.8	5	5	0.0	SE
1958MAR19	0639	46.0	77.1	0	0	3.1	ON PEMBROKE
1958MAR23	2204	45.6	67.1	0	0	3.4	NB MC ADAM
1958APR 7	0742	46.2	75.2	0	0	2.7	PQ N.OF CHENEVILLE
1958MAY 6	1602	48.6	70.3	0	0	3.7	PQ NE OF CHICOUTIMI
1958MAY 6	1611X	48.6	70.3	0	0	3.5	PQ NE OF CHICOUTIMI
1958MAY 6	1631X	48.6	70.3	0	0	3.4	PQ NE OF CHICOUTIMI
1958MAY 6	1900	42.7	73.8	4	4	0.0	NY ALBANY
1958MAY14	1741	47.0	76.6	0	0	5.4	PQ BARK LAKE
1958MAY16	2230	35.5	82.5	4	4	0.0	SE
1958JUL13	2132	46.2	76.4	0	0	2.4	PQ LAC-DUMONT
1958JUL18	2356	46.7	71.4	0	0	3.2	PQ QUEBEC CITY
1958JUL22	0146	43.0	79.5	0	0	4.3	ON WELLAND
1958JUL25	0345	46.6	75.8	0	0	3.8	PQ MANIWAKI
1958JUL27	0858	47.3	70.3	0	0	3.0	PQ ILE-AUX-COUDRES
1958AUG 4	2025	43.1	80.0	0	0	3.9	ON CALEDONIA
1958AUG 8	2215	47.9	70.4	0	0	4.0	PQ RIVIERE MALBAIE
1958AUG12	0322	48.6	69.4	0	0	3.9	PQ SAULT-AU-MOUTON
1958AUG22	1425	43.0	79.0	0	0	3.6	ON NIAGARA PENINSULA
1958SEP11	1734X	48.5	69.7	0	0	3.5	PQ W.OF SAULT-AU-MOUTON
1958SEP11	1741X	48.5	69.7	0	0	3.5	PQ W.OF SAULT-AU-MOUTON
1958SEP11	1749X	48.5	69.7	0	0	3.9	PQ W.OF SAULT-AU-MOUTON
1958SEP19	1745	43.6	70.2	5	5	0.0	ME CAPE ELIZABETH
1958SEP29	1045	48.4	69.3	0	0	3.8	PQ N.OF TROIS-PISTOLES
1958SEP30	0013	45.2	73.7	5	5	3.7	PQ BEAUHARNOIS
1958OCT20	0616	34.5	82.8	5	5	0.0	SE
1958OCT21	0932	49.6	68.0	0	0	4.1	PQ NNE OF BAIE-COMEAU
1958OCT22	0834	45.9	74.5	0	0	2.4	PQ STE-AGATHE
1958NOV21	2330	44.0	71.7	4	4	0.0	NH WOODSTOCK
1958DEC23	2314	47.0	69.8	0	0	3.7	PQ STE-FELICITE
1959FEB 9	0200	43.0	81.0	0	0	2.4	ON LONDON
1959APR13	2120	41.9	73.3	0	0	3.4	CT S.CANAAN
1959APR16	1636	47.1	70.3	0	0	3.5	PQ BONSECOURS
1959APR24	0158	37.5	80.5	6	6	0.0	SE
1959MAY14	1423X	47.0	70.3	0	0	2.5	PQ BONSECOURS
1959MAY21	0938	46.6	76.5	0	0	3.9	PQ NW OF MANIWAKI
1959MAY24	1052	48.8	79.2	0	0	3.5	PQ LA SARRE
1959MAY29	0216X	46.5	76.7	0	0	3.0	PQ NW OF MANIWAKI
1959JUN13	0115	35.4	84.3	4	4	0.0	SE
1959JUL 7	2317	37.4	80.7	4	4	0.0	SE
1959AUG 1	1352	48.4	68.3	0	0	4.1	PQ RIMOUSKI
1959AUG21	1720	37.4	80.7	4	4	0.0	SE
1959AUG22	0352	47.0	70.8	0	0	3.2	PQ ILE-D'ORLEANS
1959SEP25	0136	50.2	68.2	0	0	3.9	PQ MANICOUAGAN
1959OCT18	0747	45.9	75.1	0	0	2.6	PQ CHENEVILLE
1959OCT27	0207	34.5	80.2	6	6	0.0	SE
1960JAN20	2007	47.0	75.7	0	0	3.7	PQ LAKE BASKATONG
1960JAN22	2053	41.5	75.5	0	0	3.4	PA CARBONDALE

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1960FEB 6	0044	47.8	70.4	0	0	3.3	PQ RIVIERE MALBAIE
1960APR 1	1711	46.9	75.6	0	0	2.5	PQ BASKATONG RESERVOIR
1960APR15	1010	35.8	84.0	5	5	0.0	SE
1960APR23	1147	47.5	70.3	0	0	4.0	PQ LA MALBAIE
1960JUL 9	0734	46.3	73.0	0	0	2.6	PQ E.OF ST-GABRIEL
1960JUL23	0549	45.7	73.7	0	0	2.9	PQ N.OF MONTREAL
1960SEP 4	2340	37.4	79.3	4	4	0.0	SE
1960NOV 3	0411	48.0	74.9	0	0	2.7	PQ PARENT
1960DEC19	1927	45.8	75.2	0	0	2.9	PQ RIPON
1961JAN29	0049	46.4	66.9	0	0	3.8	NB NAPADOGAN
1961MAR13	1055	45.2	75.3	0	0	3.2	ON ORMAND
1961MAR22	1202	45.8	77.1	0	0	2.2	ON PEMBROKE
1961APR20	1313	45.0	74.8	5	5	2.0	NY MASSENA
1961JUL 5	2243	50.3	66.7	0	0	5.0	PQ NW OF SEPT-ILES
1961AUG22	1855	47.3	70.5	0	0	3.4	PQ S.OF ILE-AUX-COUDRES
1961SEP12	0954	45.2	75.3	0	0	2.8	ON SE OF OTTAWA
1961SEP15	0216	40.8	75.5	5	5	0.0	PA LEHIGH VALLEY
1961SEP29	0630	44.9	74.9	4	4	0.0	NY MASSENA
1961OCT 7	2236	48.7	76.6	0	0	3.8	PQ ENE OF SENNETERRE
1961OCT31	2350	46.1	64.8	0	0	1.7	NB MONCTON
1961NOV 1	0341	46.9	79.3	0	0	2.9	ON TIMISKAMING
1961DEC14	0149	43.8	67.8	0	0	3.9	ME OFF SE COAST
1961DEC27	1706	40.5	74.8	5	5	0.0	NJ FLEMINGTON
1962JAN27	1211	45.9	74.9	0	0	4.3	PQ ARUNDEL
1962JAN31	1432	47.5	67.1	0	0	3.5	NB KEDGWICK
1962MAR23	0202	47.2	69.5	0	0	3.3	PQ LAC DE L'EST
1962MAR25	0515	47.6	66.0	0	0	4.0	NB BATHURST
1962MAR27	0635	43.0	79.3	5	5	3.0	NY NIAGARA FALLS
1962APR10	1430	44.1	73.4	5	5	5.0	VT MIDDLEBURY
1962MAY 6		39.9	71.5	2	2	0.0	NY SE OF LONG ISLAND
1962JUN 3	2009	47.0	70.0	0	0	2.9	PQ ST-CYRILLE
1962JUN21	0206	45.4	72.7	5	5	3.9	PQ GRANBY
1962JUL27	1756	47.3	70.7	0	0	4.3	PQ BAIE-ST-PAUL
1962AUG 3	0131	52.0	54.2	0	0	4.8	NF LABRADOR SEA
1962AUG11	0305	47.5	70.1	0	0	4.1	PQ KAMOURASKA
1962AUG17		41.7	71.7	2	2	0.0	RI E.GREENWICH
1962AUG19	1400	46.2	77.8	2	2	0.0	ON DESJOACHIM COLONY
1962OCT 2	2345	44.8	74.3	4	4	0.0	NY MALONE
1962OCT13		41.0	74.3	2	2	0.0	NJ POMPTON LAKE
1962NOV27	0415	41.5	73.8	2	2	0.0	NY POUGHKEEPSIE
1962NOV30	0212	58.8	54.8	0	0	4.5	NF LABRADOR SEA
1962DEC 1	2129	45.6	69.1	0	0	3.0	ME DOVER-FOXCROFT
1962DEC 6		46.1	75.6	2	2	0.0	PQ CEDAR LAKE RESERVOIR
1962DEC15	0058	50.2	66.4	4	4	4.6	PQ SEPT-ILES
1962DEC20		41.0	74.3	2	2	0.0	NH POMPTON LAKE
1962DEC20	0423	52.8	59.4	0	0	4.4	NF SE OF GOOSEBAY LABRADOR
1962DEC29	0619	42.8	71.7	5	5	0.0	NH NASHUA
1963JAN17	1140	37.3	79.9	4	4	0.0	SE
1963JAN30	1450	44.0	75.9	0	0	3.0	NY WATERTOWN
1963FEB16	0800	44.9	73.7	0	0	2.6	NY ROUSES PT.
1963FEB27	0600	43.2	79.6	0	0	3.0	ON GRIMSBY
1963MAR 2	2024	41.5	75.7	0	0	3.4	PA SCRANTON
1963MAR12	0706	57.0	60.0	0	0	3.8	NF OFF LABRADOR COAST
1963APR 4	0853	53.4	59.7	0	0	3.5	NF NEAR GOOSEBAY LABRADOR
1963APR11	1745	34.8	82.3	4	4	0.0	SE
1963MAY19		43.2	73.3	3	3	0.0	NY HUDSON FALLS
1963MAY19	1914	43.5	75.2	3	3	3.5	NY LYONS FALLS
1963JUN 1		42.6	73.0	2	2	0.0	MA NORTH ADAMS
1963JUL 1	1959	42.6	73.8	0	0	3.3	NY ALBANY
							NORTH ADAMS
							NORTH ADAMS
							NORTH ADAMS
							NORTH ADAMS

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1963AUG 1	0634	46.8	66.5	0	0	3.0	NB BOIESTOWN
1963AUG10	0122	47.6	68.7	0	0	2.8	PQ DEGELIS
1963AUG15	1408	45.0	74.9	0	0	2.0	ON NEAR HARRISONS CORNERS
1963AUG26	0241	45.9	74.9	0	0	2.2	PQ NAMUR
1963AUG26	1629	45.2	74.0	0	0	3.5	PQ LERY
19630CT 8	1101	34.2	82.7	0	0	0.0	SE
19630CT 9	0102	44.5	69.5	0	0	2.5	ME CHINA
19630CT10	1459	39.8	78.2	0	0	3.6	PA SYLVAN
19630CT15	1207X	46.2	77.6	0	0	3.0	ON DEEP RIVER
19630CT15	1229X	46.2	77.6	0	0	4.4	ON DEEP RIVER
19630CT15	1359	46.2	77.6	0	0	4.5	ON DEEP RIVER
19630CT16	1531	42.5	70.4	5	6	4.3	MA MARBLEHEAD
19630CT17	0513X	46.2	77.6	0	0	3.0	ON DEEP RIVER
19630CT17	1245	42.7	71.5	3	3	0.0	MA DUNSTABLE
19630CT18	543 X	42.5	70.4	2	2	3.0	MA OFF CAPE ANN
19630CT19	0629	50.0	67.8	0	0	2.9	PQ TOULNUSTOUC RIVER
19630CT25	0849	51.4	61.9	0	0	3.3	PQ N.OF NATASHQUAN
19630CT29	0338	36.7	81.0	5	5	0.0	SE
19630CT30	2236X	42.7	70.8	4	6	3.2	MA OFF CAPE ANN
1963NOV 5	0946	42.7	70.3	2	2	2.7	MA OFF CAPE ANN
1963DEC 4	2132	43.7	71.4	4	5	3.6	NH LACONIA
1964JAN 8	0859X	46.2	77.5	3	3	3.3	ON DEEP RIVER
1964JAN 8	1003X	46.2	77.5	4	4	3.9	ON DEEP RIVER
1964JAN 8	1004	46.2	77.5	5	5	5.0	ON DEEP RIVER
1964JAN20	1337	35.8	82.2	4	4	0.0	SE
1964JAN20	1857	46.8	71.3	0	0	4.0	PQ CHARLESBOURG
1964FEB13	1946	40.4	78.2	0	0	5.2	PA MARKLESBURG
1964MAR 7	2303	34.1	82.8	0	0	0.0	SE
1964MAR13	0415	47.7	70.1	0	0	2.1	PQ LA MALBAIE
1964MAR22	0313	46.4	67.1	0	0	2.8	NB NE OF HOULTON
1964MAR29	0916	44.9	74.9	5	5	0.0	NY MASSENA
1964APR 1	1121	43.4	71.5	4	4	2.4	NH LACONIA
1964APR 5	0540	45.6	74.0	0	0	2.3	PQ MONTREAL
1964APR 5	1321	46.4	81.1	0	0	3.8	ON E.OF ELLIOT LAKE
1964APR 7	0913	49.4	67.9	0	0	2.0	PQ GODBOUT
1964APR17	0652	45.0	69.9	0	0	1.9	ME SOLON
1964APR20	1904	34.0	81.0	5	5	0.0	SE
1964MAY12	0945	40.2	76.5	6	6	4.5	PA LANCASTER
1964JUN 4	2340	44.7	75.3	0	0	2.8	NY OGDENSBURG
1964JUN 5	1815	45.9	68.9	0	0	2.6	ME MT. KATAHDIN
1964JUN16		40.9	74.3	4	4	0.0	PA EASTERN
1964JUN16	1400	45.0	74.2	4	4	2.7	NY MALONE
1964JUN26	1104	43.3	71.5	5	6	3.5	NH CONCORD
1964JUN26	1250	43.3	71.9	0	0	0.0	NH CONCORD
1964JUN27	1917	47.8	79.2	0	0	3.7	PQ REMIGNY
1964JUL 1	2141	49.4	67.4	0	0	3.8	PQ BAIE-TRINITE
1964JUL12	0000	46.7	71.4	0	0	3.4	PQ ST-FOY
1964JUL24	1034	46.7	76.3	0	0	3.3	PQ MANIWAKI
1964AUG 4	0449	46.3	75.1	0	0	2.3	PQ NOMININGUE
1964AUG 6	0249	47.5	69.7	0	0	2.4	PQ ST PASCAL
1964AUG12	0935	50.5	64.9	0	0	3.7	PQ NW OF MINGAN
1964AUG15	0351	48.2	80.0	0	0	5.0	ON ROCKBURST KIRKLAND LAKE
1964AUG25	1118	46.3	75.1	0	0	2.5	PQ NOMININGUE
1964SEP 9	0616	48.4	73.9	0	0	3.1	PQ GOUIN RESERVOIR
1964SEP 9	1147	45.8	75.0	0	0	2.6	PQ CHENEVILLE
1964SEP29	0016X	41.2	73.7	3	3	0.0	NY MT.KISCO
1964SEP29	2026X	41.2	73.7	3	3	0.0	NY MT.KISCO
19640CT 3	2137	45.3	73.8	0	0	2.3	PQ ST-REMI
19640CT17	1413	47.7	67.3	0	0	3.9	NB KEDGWICK

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1964OCT28	0922	46.0	75.7	0 0	2.5	PQ KAZABAZUA
1964NOV 1	1706	45.6	76.3	0 0	2.1	PQ SHAWVILLE
1964NOV17	1708	41.2	73.7	5 5	0.0	NY MT.KISCO
1964NOV21	0530	44.9	75.1	0 0	2.4	ON SOUTH MOUNTAIN
1964NOV21	2250	47.0	67.2	0 0	1.8	NB NE OF PLASTER ROCK
1964NOV25	0750	37.4	81.7	4 4	0.0	SE
1964NOV30	X	41.3	73.9	2 2	0.0	NY MT.KISCO
1964NOV30	0034	42.8	74.9	0 0	2.6	NY N.OF COOPERSTOWN
1964DEC 4	2240	46.6	74.0	0 0	2.6	PQ ST-DONAT
1965JAN 1	1309	44.5	77.6	0 0	2.9	ON NW OF BELLEVILLE
1965JAN 3	1705	43.5	71.5	3 4	3.4	NH LACONIA
1965JAN 8	1229	48.0	78.5	0 0	3.5	PQ MALARCTIC
1965JAN11	1235	45.6	73.9	0 0	1.8	PQ MONTREAL
1965FEB 3	0944	46.0	76.8	0 0	2.8	PQ CHAPEAU
1965FEB19	1025	44.6	79.4	0 0	2.0	ON ORILLIA
1965MAR 1	0222	47.5	71.3	0 0	3.1	PQ NW OF SEVEN FALLS
1965MAR 4	1808	46.9	73.8	0 0	2.6	PQ MATTAWIN RESERVOIR
1965MAR 5	1211	47.7	78.8	0 0	3.2	PQ LAC SIMARD
1965MAR 6	2113	45.0	83.0	0 0	4.2	ON LAKE HURON
1965MAR18	1204X	49.8	67.5	0 0	2.8	PQ RIVIERE-PENTECOTE
1965MAR18	1209	49.8	67.5	0 0	3.1	PQ RIVIERE-PENTECOTE
1965APR 1	0630	46.0	80.5	0 0	3.4	ON FRENCH RIVER
1965APR 7	1241	33.8	82.5	0 0	0.0	SE
1965JUN22	0930	46.8	68.6	0 0	2.9	ME NNW OF HOULTON
1965JUL16	1106	43.0	78.1	4 4	3.2	NY ATTICA
1965AUG27	0155	43.0	78.1	4 4	3.1	NY ATTICA
1965AUG28	1505	47.5	70.6	0 0	2.3	PQ BAIE-ST-PAUL
1965AUG31	0838	46.0	65.3	0 0	3.2	NB HAVELOCK
1965SEP15	1556	46.7	79.1	0 0	3.8	PQ TIMISKAMING
1965SEP29	2057	41.4	74.4	4 4	0.0	NY GOSHEN-MIDDLETOWN
1965OCT 5	1436	49.8	67.7	0 0	4.6	PQ RIVIERE-PENTECOTE
1965OCT 8	0217	40.1	79.8	0 0	3.3	PA SOUTHWESTERN
1965OCT18	1210	53.1	79.3	0 0	3.6	ON JAMES BAY
1965OCT24	1745	41.3	70.1	5 5	0.0	MA NANTUCKET
1965OCT24	1900	41.3	70.1	0 0	0.0	MA NANTUCKET
1965NOV 7	2057	47.1	76.1	0 0	4.5	PQ BASKATONG RESERVOIR
1965NOV14	0412	47.0	74.1	0 0	2.4	PQ ST-MICHEL-DES-SAINTS
1965NOV15	1112	49.4	53.7	0 0	4.0	NF DEADMANS BAY
1965NOV24	2128X	46.9	76.3	0 0	3.7	PQ BASKATONG RESERVOIR
1965NOV28	2326	45.6	57.9	0 0	4.2	NS E.OF CAPE BRETON
1965DEC 8	0302	41.7	71.4	4 5	0.0	RI WARWICK
1965DEC16	1353	47.8	70.6	0 0	4.1	PQ BAIE-ST-PAUL
1965DEC19	0049	51.2	80.8	0 0	4.9	ON MOOSE FACTORY
1965DEC19	0105	47.0	76.4	0 0	3.5	PQ CABONGA RESERVOIR
1965DEC31	2131	59.7	56.8	0 0	4.5	NF LABRADOR SEA
1966JAN 1	1030X	42.8	78.2	0 0	0.0	NY ATTICA
1966JAN 1	1129X	42.8	78.3	0 0	3.0	NY ATTICA
1966JAN 1	1323	42.8	78.2	6 6	4.7	NY ATTICA
1966JAN14	1529	48.9	67.5	0 0	4.5	PQ MATANE
1966JAN14	1614	48.9	67.5	0 0	3.4	PQ MATANE
1966MAR19	2251	46.6	74.8	0 0	2.7	PQ E.OF MONT-LAURIER
1966MAR20	2345	46.5	76.2	0 0	3.2	PQ W.OF MONT LAURIER
1966APR28	1202	44.1	71.9	4 4	0.0	NH BENTON
1966MAY20	0005	44.3	66.5	0 0	3.8	NS BAY OF FUNDY
1966MAY21		41.2	74.0	2 2	0.0	NY SOUTHEASTERN
1966MAY31	1119	37.6	78.0	5 5	0.0	SE
1966JUN19	1924	47.0	70.2	0 0	2.5	PQ MONTMAGNY
1966JUN25	0005	45.2	73.8	0 0	3.4	PQ HOWICK
1966JUN30	0029	44.0	73.4	2 2	2.8	NY LAKE CHAMPLAIN

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1966JUN30	2213	48.0	69.6	0	0	2.3	PQ RIVIERE-DU-LOUP
1966JUL 7	0110	47.9	65.8	0	0	2.3	NB BAIE-DE-CHALEUR
1966JUL11	0236	42.4	71.3	0	0	0.0	MA NEAR WESTON
1966JUL12	0106	49.5	66.0	0	0	3.3	PQ SE OF SEPT-ILES
1966JUL17	0732	49.6	68.4	0	0	3.6	PQ NW OF BAIE-COMEAU
1966JUL20	2008	47.8	70.0	0	0	3.2	PQ LA MALBAIE
1966JUL21	1929X	49.5	68.3	0	0	2.4	PQ NW OF BAIE-COMEAU
1966JUL24	0159	44.4	67.7	5	5	3.6	ME JONESPORT
1966JUL24	2219X	49.6	68.6	0	0	3.7	PQ NW OF BAIE-COMEAU
1966JUL24	2356	47.9	66.2	0	0	2.9	NB BAIE-DE-CHALEUR
1966JUL27	1112X	49.4	68.4	0	0	3.4	PQ NW OF BAIE-COMEAU
1966AUG16	0102X	49.5	68.5	0	0	3.2	PQ NW OF BAIE-COMEAU
1966AUG20	1313	49.6	68.3	0	0	3.5	PQ NW OF BAIE-COMEAU
1966AUG24	0600	36.0	84.0	4	4	0.0	SE
1966SEP11	0425	46.5	77.0	0	0	2.4	PQ COULONGE RIVER
1966SEP19	2133	47.3	70.3	0	0	2.8	PQ BAIE-ST-PAUL
1966SEP23	0120	46.0	75.2	0	0	2.3	PQ LAC GAGNON
1966SEP28	0802X	47.4	70.5	0	0	2.4	PQ BAIE-ST-PAUL
1966SEP28	2011	46.9	65.3	0	0	3.2	NB CHATHAM
1966SEP28	2059	39.3	80.3	4	4	0.0	SE
1966OCT 1	1723	47.7	70.3	0	0	3.0	PQ W.OF CLERMONT
1966OCT 2	0519	46.9	70.4	0	0	2.0	PQ E.OF MONTMAGNY
1966OCT 5	1656	53.0	80.0	0	0	2.9	ON JAMES BAY
1966OCT15	2034	53.4	57.2	0	0	4.4	NF SANDWICH BAY
1966OCT22	0602	47.3	75.0	0	0	2.5	PQ MITCHINAMECUS RESERVOIR
1966OCT22	2214	48.0	69.5	0	0	2.3	PQ RIVIERE-DU-LOUP
1966OCT23	2305	43.0	71.4	4	5	2.7	NH MANCHESTER
1966NOV 7	0731	45.2	69.1	0	0	2.3	ME DOVER-FOXCROFT
1966NOV13	1543	47.0	76.3	0	0	3.6	PQ CABONGA RESERVOIR
1966NOV28	0912	47.3	70.1	0	0	2.2	PQ NE OF MONTMAGNY
1966DEC 1	0622	45.2	69.2	0	0	1.7	ME DOVER-FOXCROFT
1966DEC12	2104	49.0	68.2	0	0	3.4	PQ BAIE-COMEAU
1967JAN 8	0940	45.3	69.0	0	0	1.8	ME MILO
1967JAN11	1900	44.7	72.6	0	0	1.9	VT N.OF MONTPELIER
1967JAN25	0504	47.3	66.8	0	0	2.2	NB MOUNT CARLETON
1967JAN26	0410	44.6	70.9	0	0	2.1	NH N.OF BERLIN
1967FEB 2	1340	41.6	71.2	5	5	3.1	RI NARRAGANSETT BAY
1967FEB 5	0826	44.7	69.1	0	0	1.5	ME WEST OF BANGOR
1967FEB 9	1804X	59.9	76.7	0	0	3.8	PQ SW OF LAC-COUTURE
1967FEB18	1010	59.8	76.2	0	0	5.1	PQ SW OF LAC-COUTURE
1967FEB21	0053	52.0	81.3	0	0	3.9	ON S.OF FT ALBANY
1967FEB22	1421	50.5	63.3	0	0	4.2	PQ LAC ALLARD
1967FEB27	0412	49.2	66.0	0	0	2.3	PQ NW OF MURDOCKVILLE
1967MAR 2	0510	44.7	67.6	0	0	0.7	ME WEST OF MACHIAS
1967MAR11	2339	45.1	67.2	0	0	2.3	ME CALAIS
1967MAR14	0149	46.2	67.3	0	0	2.0	NB WOODSTOCK
1967APR 8	0521	45.8	73.8	0	0	1.7	PQ N.OF MONTREAL
1967APR28	1223	46.3	67.9	4	4	2.5	ME MONTICELLO
1967MAY11	1100	47.4	70.3	0	0	1.8	PQ BAIE-ST-PAUL
1967MAY12	2055	44.8	70.4	0	0	2.3	ME BLUE MOUNTAINS
1967MAY14	2023	44.9	73.9	0	0	2.3	NY MALONE
1967MAY15	2247	42.3	69.8	0	0	2.7	MA NE OF PROVINCETOWN
1967JUN11	0149	46.6	75.0	0	0	3.7	PQ MONT-LAURIER
1967JUN13	1908	42.9	78.2	6	6	3.9	NY ATTICA
1967JUL 1	1409X	44.4	69.9	4	5	3.2	ME AUGUSTA
1967JUL 1	1533X	44.4	69.9	3	3	1.9	ME AUGUSTA
1967JUL 1	1541X	44.4	69.9	0	0	2.1	ME AUGUSTA
1967JUL 1	1555X	44.4	69.9	3	4	3.2	ME AUGUSTA
1967JUL 1	1559X	44.4	69.9	0	0	2.2	ME AUGUSTA

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1967JUL 1	1600X	44.4	69.9	3	3	2.6	ME AUGUSTA
1967JUL 1	1602X	44.4	69.9	0	0	2.5	ME AUGUSTA
1967JUL 1	1605	44.4	69.9	5	5	3.8	ME AUGUSTA
1967JUL 1	1611X	44.4	69.9	3	3	3.8	ME AUGUSTA
1967JUL 1	1612X	44.4	69.9	0	0	3.6	ME AUGUSTA
1967JUL 1	1616X	44.4	69.9	0	0	2.1	ME AUGUSTA
1967JUL 1	1616X	44.4	69.9	0	0	2.1	ME AUGUSTA
1967JUL 1	1619X	44.4	69.9	0	0	3.0	ME AUGUSTA
1967JUL 8	0244	47.0	76.1	0	0	2.5	PQ BASKATONG RESERVOIR
1967JUL 9	0640	46.2	74.7	0	0	2.2	PQ MONT-TREMBLANT
1967JUL 9	1159X	46.9	76.0	0	0	2.4	PQ BASKATONG RESERVOIR
1967JUL12	0632	46.2	75.4	0	0	2.5	PQ NOTRE-DAME-DU-LAUS
1967JUL12	1047	46.4	67.3	0	0	2.1	NB EAST OF HARTLAND
1967AUG 5	0808	48.6	65.0	0	0	4.0	PQ SE OF MURDOCKVILLE
1967AUG 7	0909X	46.1	75.4	0	0	2.2	PQ NOTRE-DAME-DU-LAUS
1967AUG 8	0722X	46.9	70.6	0	0	1.8	PQ E.OF QUEBEC CITY
1967AUG10	0247	46.0	74.8	0	0	2.2	PQ MONT-TREMBLANT
1967AUG13	1907	46.9	70.3	0	0	2.4	PQ E.OF QUEBEC CITY
1967SEP 8	1826	45.2	69.1	0	0	2.5	ME DOVER-FOXCROFT
1967SEP 8	1828X	45.2	69.1	0	0	0.7	ME DOVER-FOXCROFT
1967SEP12	1059	47.0	67.0	0	0	2.8	NB NE OF PLASTER ROCK
1967SEP17	0119	50.7	75.3	0	0	4.4	PQ LAKE MISTASSINI
1967SEP23	1627X	46.9	70.7	0	0	3.4	PQ E.OF QUEBEC CITY
1967SEP30	2239	49.5	65.8	0	0	5.3	PQ S.OF SEPT-ILES
1967OCT25	0329X	50.2	63.6	0	0	3.2	PQ N.OF ANTICOSTI I.
1967OCT25	0705	50.2	63.5	0	0	3.4	PQ N.OF ANTICOSTI I.
1967NOV 2	0335	52.2	58.4	0	0	3.4	NF SE OF GOOSE BAY
1967NOV 9	1424	47.4	70.2	0	0	2.5	PQ BAIE-ST-PAUL
1967NOV22	2210	41.2	73.8	5	5	0.0	NY WESTCHESTER CO.
1967DEC27	0316	58.8	59.3	0	0	3.8	NF LABRADOR SEA
1968JAN13	0310	57.2	58.5	0	0	2.6	NF NE OF NAIN
1968JAN26	0003	49.9	65.4	0	0	2.8	PQ SE OF SEPT-ILES
1968FEB 2	0213	47.6	70.6	0	0	2.7	PQ BAIE-ST-PAUL
1968FEB 4	2256	59.7	77.9	0	0	2.4	PQ SW OF POVUNGNITUK
1968MAR 8	1038	37.3	80.8	4	4	4.1	SE
1968MAR14	2201	48.9	68.2	0	0	2.6	PQ N.OF MONT-JOLI
1968MAR17	1701	59.9	56.4	0	0	3.5	NF LABRADOR SEA
1968MAR29	2330	50.1	67.1	0	0	2.5	PQ PORT-CARTIER
1968MAR30	1528X	47.9	70.5	0	0	3.1	PQ LA MALBAIE
1968APR11	0918	47.6	70.4	0	0	3.5	PQ LA MALBAIE
1968MAY20	0058	46.2	75.0	0	0	1.7	PQ SW OF LABELLE
1968MAY27	1921	46.9	66.7	0	0	3.3	NB W.OF NEWCASTLE
1968JUL24	2316	47.0	71.3	0	0	3.1	PQ N.OF QUEBEC CITY
1968SEP23	0241	34.0	81.5	4	4	3.7	SE
1968SEP23	1538	45.2	69.5	0	0	3.3	ME DOVER-FOXCROFT
1968SEP29	1004	50.1	67.2	0	0	3.6	PQ PORT-CARTIER
1968OCT19	1037	45.3	74.1	5	5	3.2	PQ VALLEYFIELD
1968OCT20	0236	47.5	70.6	0	0	3.6	PQ BAIE-ST-PAUL
1968NOV 3	0833	41.4	72.5	5	5	3.3	CT MOODUS-E.HADDAM
1968NOV 3	2050	46.2	76.3	0	0	3.1	PQ SW OF MANIWAKI
1968NOV 7	2129	47.0	71.6	0	0	1.9	PQ NW OF QUEBEC CITY
1968NOV26	0100	34.1	77.9	4	4	0.0	SE
1968DEC10	0912	39.7	74.6	5	5	2.5	NJ SE OF CAMDEN
1969FEB 2	0424	49.7	55.1	0	0	3.5	NF NOTRE DAME BAY
1969FEB19	0340	47.6	70.7	0	0	2.6	PQ BAIE-ST-PAUL
1969MAR19	0700	45.6	76.2	0	0	2.8	PQ LAC LAPECHE
1969APR25	0014	40.7	74.3	0	0	0.0	NJ PRINCETON-HOPEWELL
1969MAY 5	1714	33.9	82.5	0	0	0.0	SE
1969MAY10	1843	47.5	70.7	0	0	3.6	PQ BAIE-ST-PAUL

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1969MAY10	2001X	47.5	70.7	0	0	3.6	PQ BAIE-ST-PAUL
1969MAY11	0303	43.1	70.5	0	0	2.1	ME OFF SOUTHWESTERN MAINE
1969JUN 4	0936	49.7	81.5	0	0	3.1	ON KAPUSKASING
1969JUN12	1100	46.9	76.0	0	0	2.9	PQ BASKATONG RESERVOIR
1969JUL13	1651	36.1	83.7	5	5	3.5	SE
1969JUL14	0306	47.8	70.1	0	0	3.8	PQ LA MALBAIE
1969JUL23	0834	56.5	46.5	0	0	4.1	NF LABRADOR SEA
1969AUG 5	2153	47.7	52.3	0	0	3.4	NF ST.JOHNS
1969AUG 6	1602	43.8	71.4	5	5	2.6	NH OSSIPEE
1969AUG 7	0457	46.4	75.1	0	0	2.7	PQ NOMININGUE
1969AUG13	0242	43.3	78.2	4	4	2.8	NY ALBION
1969AUG24	0151	43.1	70.5	0	0	2.4	ME OFF SOUTHWESTERN MAINE
1969AUG24	0259X	43.1	70.4	0	0	2.1	ME OFF SOUTHWESTERN MAINE
1969AUG31	0720	47.5	70.1	0	0	3.2	PQ RIVIERE OUELLE
1969SEP27	2253	56.5	57.5	0	0	4.1	NF LABRADOR SEA
1969OCT 6		41.1	74.6	4	4	0.0	NJ OGDENSBURG
1969OCT10	0007	46.4	75.2	5	5	4.2	PQ NOMININGUE
1969OCT10	0816X	46.4	75.1	0	0	2.8	PQ NOMININGUE
1969NOV 4	1206	45.8	74.3	0	0	2.0	PQ MORIN HEIGHTS
1969NOV17	0732	53.4	82.8	0	0	3.5	ON NW OF FT ALBANY
1969NOV20	0600	37.4	81.0	6	6	0.0	SE
1969DEC12	0444	38.0	77.9	0	0	0.0	SE
1969DEC13	1019	35.1	83.0	5	5	0.0	SE
1969DEC15	0920	46.5	76.0	0	0	2.3	PQ MANIWAKI
1969DEC15	1054	54.9	73.4	0	0	2.6	PQ LAC BIENVILLE
1970JAN21	0531	49.0	67.7	0	0	2.7	PQ SE OF BAIE-COMEAU
1970FEB23	1014	46.5	72.3	0	0	2.6	PQ NE OF TROIS-RIVIERES
1970FEB27	0808	48.4	77.8	0	0	3.1	PQ VAL-D'OR
1970MAR 8	0311	53.1	78.2	0	0	2.3	PQ SE OF FT GEORGE
1970MAR 8	1543	49.8	67.8	0	0	2.4	PQ NE OF BAIE-COMEAU
1970APR 6	1129	46.2	74.8	0	0	2.8	PQ SW OF MONT-TREMBLANT
1970APR 7	0335	48.3	79.5	0	0	2.9	PQ W.OF NORANDA
1970APR 9	0058	45.8	74.2	0	0	2.3	PQ ST-JEROME
1970APR13	0456	49.8	81.9	0	0	2.6	ON NE OF KAPUSKASING
1970APR14	0652	47.3	70.9	0	0	2.3	PQ BAIE-ST-PAUL
1970APR16	0008	47.7	70.5	0	0	2.7	PQ LA MALBAIE
1970APR19	1716	49.6	66.8	0	0	2.6	PQ S.OF SEPT-ILES
1970APR19	1718X	49.7	66.5	0	0	2.6	PQ S.OF SEPT-ILES
1970APR25	0046	49.7	81.2	0	0	3.1	ON NE OF KAPUSKASING
1970MAY12	0615	46.9	76.6	0	0	2.0	PQ NE OF MANIWAKI
1970MAY26	1416	47.0	71.8	0	0	2.0	PQ NW OF QUEBEC CITY
1970JUN14	0553	45.4	74.3	0	0	2.2	PQ VALLEYFIELD
1970JUN25	1608	39.6	71.0	0	0	5.0	NJ OFF EAST COAST US
1970AUG 6	0412	44.3	71.0	0	0	2.2	NH SOUTHEAST OF BERLIN
1970AUG 8	0010	45.8	66.1	3	3	3.3	NB E.OF FREDERICTON
1970AUG11	1114	38.4	82.3	4	4	0.0	SE
1970AUG16	0455	59.3	67.7	0	0	3.3	PQ UNGAVA BAY
1970SEP 7	1011	45.7	76.6	0	0	2.4	PQ SHAWVILLE
1970SEP 7	2139	47.9	70.3	0	0	3.2	PQ N.OF LA MALBAIE
1970SEP10	0641	36.1	81.4	5	5	0.0	SE
1970SEP19	1335	42.9	71.9	4	4	2.6	NH GREENFIELD
1970SEP25	2037	52.3	78.5	0	0	3.1	PQ JAMES BAY
1970OCT 3	2013X	46.9	76.0	0	0	2.5	PQ BASKATONG RESERVOIR
1970OCT 9	1635	48.7	71.0	0	0	3.0	PQ N.OF CHICOUTIMI
1970OCT15	1856	47.1	76.3	0	0	3.3	PQ BASKATONG RESERVOIR
1970OCT23	0109	45.6	74.2	0	0	2.3	PQ W.OF MONTREAL
1970OCT28	0732X	46.9	76.0	0	0	2.2	PQ BASKATONG RESERVOIR
1970NOV24	1112X	47.0	76.2	0	0	2.7	PQ BASKATONG RESERVOIR
1970DEC13	0536	42.7	78.7	0	0	2.0	NY SW OF HAMBURG

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1970DEC13	0541	46.0	74.8	0	0	2.1	PQ MONT TREMBLANT
1971JAN 6	0622X	47.2	76.0	0	0	3.0	PQ BASKATONG RESERVOIR
1971JAN19	1344	46.9	75.2	0	0	3.1	PQ MONT LAURIER
1971JAN19	2001	49.2	69.8	0	0	2.4	PQ W.OF BAIE-COMEAU
1971JAN26	1325	49.3	68.0	0	0	2.9	PQ BAIE-COMEAU
1971FEB 5	2340	48.2	78.0	0	0	2.7	PQ VAL-D'OR
1971FEB 7	1859	49.4	67.6	0	0	2.9	PQ E.OF BAIE-COMEAU
1971FEB 8	0810	47.8	68.1	0	0	2.4	NB N.OF EDMUNSTON
1971MAR17	2219	47.2	76.6	0	0	2.7	PQ CABONGA RESERVOIR
1971MAR26	0304	46.8	71.7	0	0	1.9	PQ SW OF QUEBEC CITY
1971MAR26	0911X	46.6	71.6	0	0	1.9	PQ SW OF QUEBEC CITY
1971MAR27	1634X	46.9	71.4	0	0	1.7	PQ NW OF QUEBEC CITY
1971MAR31	2201X	47.0	71.6	0	0	1.7	PQ NW OF QUEBEC CITY
1971APR14	1253	50.8	64.0	0	0	2.7	PQ E.OF SEPT-ILES
1971MAY14	0620	45.1	73.4	4	4	3.2	PQ LACOLLE
1971MAY19	2000	50.6	63.8	0	0	2.9	PQ E.OF SEPT-ILES
1971MAY21	0448	40.7	64.0	0	0	3.5	NS CORSAIR CANYON
1971MAY23	0624	43.8	74.5	5	5	3.9	NY BLUE MTN LAKE
1971MAY23	0929X	43.9	74.5	5	5	3.6	NY BLUE MTN LAKE
1971JUN11	1033	45.7	55.1	0	0	4.2	NF GRAND BANKS
1971JUN21	0135	44.4	56.3	0	0	3.6	NF OFF SOUTH SHORE
1971JUN21	0248X	43.9	74.5	4	4	3.3	NY BLUE MTN LAKE
1971JUN27	1222	46.1	73.4	0	0	2.2	PQ JOLIETTE
1971JUL 6	1747	46.6	76.3	0	0	3.0	PQ NW OF MANIWAKI
1971JUL 9	0505	46.7	81.2	0	0	3.1	ON NW OF SUDBURY
1971JUL10	0814X	43.9	74.5	5	5	3.4	NY BLUE MTN LAKE
1971JUL13	1142	34.8	83.0	4	4	3.8	SE
1971AUG12	2202	48.1	70.5	0	0	2.4	PQ N.OF LA MALBAIE
1971AUG15	0617	47.5	49.5	0	0	4.8	NF GRAND BANKS
1971AUG15	1011X	43.9	74.5	0	0	2.0	NY BLUE MTN LAKE
1971AUG20	0120	46.6	75.7	0	0	2.2	PQ MONT LAURIER
1971SEP12	0506	38.1	77.4	4	4	0.0	SE
1971SEP12	0831	47.6	70.2	0	0	3.2	PQ LA MALBAIE
1971SEP15	2232	46.6	74.4	0	0	2.4	PQ NW OF MONTREAL
1971SEP26	0701	60.0	73.7	0	0	3.9	PQ NORTHERN
1971SEP27	0847	45.7	75.2	4	4	3.2	PQ THURSO
1971OCT13	0238	51.7	80.9	0	0	3.4	ON JAMES BAY
1971OCT21	0054	42.7	71.2	5	5	2.3	MA LAWRENCE
1971OCT27	0713	49.2	67.1	0	0	3.0	PQ E.OF BAIE-COMEAU
1971NOV 3	0553	50.2	66.4	4	4	3.2	PQ SEPT-ILES
1971NOV15	0717	47.4	70.3	0	0	1.2	PQ LA MALBAIE
1971NOV15	1038	45.1	73.9	0	0	3.0	PQ HOWICK
1971NOV21	1317	46.6	72.6	3	3	2.2	PQ N.OF TROIS-RIVIERES
1971NOV22	0529	47.2	76.3	0	0	3.0	PQ CABONGA RESERVOIR
1971NOV23	1632	45.8	76.6	4	4	3.0	ON CAMPBELLS BAY
1971DEC 7	1204	55.1	54.5	0	0	5.4	NF LABRADOR SEA
1971DEC18	1536	46.2	74.6	5	5	3.9	PQ MONT TREMBLANT
1971DEC20	1144X	43.9	74.6	0	0	2.0	NY BLUE MTN LAKE
1971DEC27	1729	46.1	71.5	0	0	2.8	PQ S.OF QUEBEC CITY
1972JAN 5	0240	55.1	54.4	0	0	4.5	NF LABRADOR SEA
1972JAN 5	0809	46.1	76.9	0	0	2.6	PQ N.OF FT COULONGE
1972FEB13	0712	44.3	74.4	0	0	2.2	NY TUPPER LAKE
1972FEB13	1108	47.6	70.3	0	0	2.9	PQ LA MALBAIE
1972FEB15	2352	41.3	73.6	0	0	2.6	NY POUND RIDGE
1972MAR15	1210	43.7	74.7	0	0	2.6	NY OLD FORGE
1972APR 8	2045	47.2	72.5	0	0	1.8	PQ LA TUQUE
1972APR25	0324	46.7	76.0	0	0	3.3	PQ N.OF MANIWAKI
1972JUN 2	0424	45.8	75.9	0	0	2.9	PQ KAZABAZUA
1972JUN16	0901	42.8	73.9	0	0	2.0	NY SCHENECTADY

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1972JUL17	0158	47.9	77.9	0	0	3.0 PQ	VAL D'OR
1972JUL30	1042	46.3	76.1	0	0	2.7 PQ	MANIWAKI
1972AUG 2	0103	47.4	70.6	0	0	2.9 PQ	BAIE-ST-PAUL
1972AUG 5	0310	45.9	75.1	0	0	2.6 PQ	LAC SIMON
1972AUG17	2355	52.6	80.1	0	0	2.5 ON	JAMES BAY
1972AUG18	1935	46.4	75.0	0	0	2.6 PQ	NOMININGUE
1972AUG22	1917	49.5	66.5	0	0	3.9 PQ	S.OF SEPT-ILES
1972AUG31	0606	45.4	76.8	0	0	2.8 ON	RENFREW
1972SEP 5	2100	37.6	77.7	5	5	3.4 SE	
1972SEP12	0915	46.2	77.6	4	4	3.2 PQ	N.OF DEEP RIVER
1972SEP25	1130	47.4	70.7	0	0	2.9 PQ	BAIE-ST-PAUL
1972OCT10	2018	47.2	70.0	0	0	1.9 PQ	LA POCATIERE
1972OCT19	0222	45.8	64.7	5	5	3.0 NB	DORCHESTER
1972OCT19	0222	45.5	74.3	3	3	2.6 PQ	RIGAUD
1972OCT19	0410	45.1	74.2	0	0	1.8 PQ	HUNTINGDON
1972OCT25	2218	47.3	70.1	0	0	2.3 PQ	LA POCATIERE
1972OCT27	0424	47.4	70.5	0	0	1.6 PQ	BAIE-ST-PAUL
1972OCT27	1913	47.5	70.0	0	0	1.9 PQ	LA POCATIERE
1972NOV 2	0515	44.8	74.6	0	0	3.0 NY	MASSENA
1972NOV 5	2229	43.9	74.4	0	0	2.3 NY	BLUE MTN LAKE
1972NOV 6	1253	45.8	64.7	3	3	2.2 NB	DORCHESTER
1972NOV 8	1106	45.9	74.2	0	0	2.4 PQ	PIEDMONT
1972NOV10	1833	47.6	70.2	0	0	1.9 PQ	LA MALBAIE
1972DEC 8	0300	40.1	76.2	5	5	0.0 PA	LANCASTER
1972DEC16	1901	45.8	75.2	4	4	3.9 PQ	MONTPELIER
1972DEC17	0328	45.8	75.2	0	0	2.2 PQ	MONTPELIER
1973JAN 5	0246	47.6	70.4	0	0	1.9 PQ	LES EBOULEMENTS
1973JAN10	0241	41.4	74.0	0	0	1.5 NY	PEEKSKILL
1973JAN14	0808	41.8	72.1	0	0	1.0 CT	CHAPLIN
1973JAN28	1307	48.0	70.0	0	0	3.1 PQ	BAIE-DES-ROCHERS
1973FEB 3	2127	47.4	70.4	0	0	1.7 PQ	LES EBOULEMENTS
1973FEB 9	0446	42.8	78.3	0	0	2.7 NY	SE OF ATTICA
1973FEB10	2012	40.4	70.5	0	0	2.5 MA	S OF MARTHAS VINEYARD
1973FEB18	0941	47.2	70.2	0	0	1.6 PQ	ST-JEAN-PORT-JOLI
1973FEB25	1946	45.2	74.0	0	0	2.9 PQ	HOWICK
1973FEB26	1342	44.5	70.0	0	0	3.0 ME	BELGRADE LAKES
1973FEB28	0821	39.7	75.4	5	5	3.8 NJ	E.OF WILMINGTON DE
1973MAR 7	0405	43.8	74.5	0	0	1.9 NY	BLUE MTN LAKE
1973MAR 7	0504	43.9	75.0	0	0	2.4 NY	N.OF OLD FORGE
1973MAR25	0149	45.3	69.1	0	0	2.8 ME	N.OF MILO
1973MAR30	1004	44.7	73.8	0	0	1.7 NY	LYON MTN
1973APR10	0411	37.3	77.7	4	4	2.5 SE	
1973MAY31	0718	45.0	74.6	0	0	2.2 NY	CANADIAN BORDER
1973JUN11	1008	43.9	73.9	0	0	2.8 NY	E.OF BLUE MTN LAKE
1973JUN14	1509	49.5	66.5	0	0	3.1 PQ	STE-ANNE-DES-MONTS
1973JUN15	0109	45.3	70.9	6	6	4.8 ME	NEAR NH-QUEBEC BORDER
1973JUL10	0438	39.7	75.4	4	4	0.0 NJ	E.OF WILMINGTON DE
1973JUL15	0820	43.9	74.4	0	0	3.4 NY	BLUE MTN LAKE
1973JUL15	1032X	43.9	74.4	0	0	3.2 NY	BLUE MTN LAKE
1973JUL16	0841X	43.8	74.5	0	0	3.3 NY	BLUE MTN LAKE
1973JUL20	1706	49.6	67.0	0	0	3.1 PQ	POINTE-AUX-ANGLAIS
1973AUG 2	0939	47.2	70.3	0	0	1.4 PQ	ST-JEAN-PORT-JOLI
1973AUG24	0417	43.8	72.3	0	0	2.7 VT	EAST CENTRAL
1973AUG29	1008	47.8	70.0	0	0	1.8 PQ	ST-SIMEON
1973SEP10	0611	47.7	70.2	0	0	2.9 PQ	ST.IRENE
1973SEP16	1805	47.5	70.5	0	0	1.5 PQ	LES EBOULEMENTS
1973SEP24	0627	47.3	69.8	0	0	1.6 PQ	LA POCATIERE
1973OCT13	0139	49.6	61.4	0	0	3.1 PQ	ANTICOSTI I.
1973OCT21	0925X	43.8	74.5	0	0	2.2 NY	BLUE MTN LAKE

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1973NOV 8	1741	46.0	75.0	0	0	2.4	PQ LAC-REMI
1973NOV16	0136	47.6	70.3	0	0	3.1	PQ LES EBOULEMENTS
1973NOV27	0729	46.8	68.4	0	0	2.0	ME SW OF CARIBOU
1973DEC27	0549X	47.3	69.9	0	0	1.3	PQ LA POCATIERE
1974JAN 5	1706	44.7	73.9	0	0	1.9	NY LYON MTN
1974JAN 6	0735X	47.3	69.9	0	0	1.4	PQ LA POCATIERE
1974JAN 9	1838	45.9	74.9	0	0	2.7	PQ LAC RAPINEAU
1974JAN12	1558	52.8	67.5	0	0	3.5	PQ CENTRAL
1974JAN15	1455X	44.8	73.9	0	0	2.0	NY LYON MTN
1974JAN19	0542X	44.8	73.9	0	0	1.6	NY LYON MTN
1974JAN20	1055	44.7	73.9	0	0	2.2	NY LYON MTN
1974JAN25	1645	45.9	73.6	0	0	2.7	PQ N.OF MONTREAL
1974FEB12	1000	58.8	75.1	0	0	3.7	PQ NORTHERN
1974FEB13	1814	46.4	75.3	0	0	2.9	PQ MONT LAURIER
1974FEB14	0308	44.7	73.9	0	0	1.9	NY LYON MTN
1974FEB17	1257	49.5	67.1	0	0	3.0	PQ SW OF SEPT-ILES
1974FEB17	1709X	44.7	73.9	0	0	2.1	NY LYON MTN
1974MAR14	1920	46.1	75.1	0	0	2.5	PQ LAC GAGNON
1974MAR16	0710	46.1	67.2	0	0	2.4	NB NW OF FREDERICTION
1974MAR18	1604	44.5	74.9	0	0	2.7	NY S.OF POTSDAM
1974MAR19	1339X	44.4	75.1	0	0	2.1	NY S.OF POTSDAM
1974MAR22	0104X	44.4	75.1	0	0	2.0	NY S.OF POTSDAM
1974MAR23	1446	38.7	77.8	0	0	3.8	SE
1974MAR27	0059X	44.4	75.1	0	0	2.0	NY S.OF POTSDAM
1974APR 7	1503X	44.4	75.1	0	0	2.4	NY S.OF POTSDAM
1974APR 7	2058X	44.4	75.1	0	0	1.7	NY S.OF POTSDAM
1974APR 8	0703X	44.4	75.1	0	0	1.6	NY S.OF POTSDAM
1974APR 8	2208	41.2	74.0	0	0	2.1	NY STONY POINT
1974APR 9	1714X	44.4	75.1	0	0	1.7	NY S.OF POTSDAM
1974APR 9	1743X	44.4	75.1	0	0	1.4	NY S.OF POTSDAM
1974APR28	1419	39.8	75.6	4	4	0.0	DE WILMINGTON
1974APR29	0610	46.0	75.2	0	0	2.8	PQ SW OF QUEBEC CITY
1974MAY30	1804X	44.7	73.9	0	0	2.1	NY LYON MTN
1974MAY31	0228	37.4	80.4	0	0	3.8	SE
1974JUN 2	1442	44.7	74.6	0	0	2.5	NY LAWRENCEVILLE
1974JUN 3	1832	44.4	74.0	0	0	1.9	NY BLUE MTN LAKE
1974JUN 4	0258X	44.7	74.7	0	0	2.1	NY LAWRENCEVILLE
1974JUN 7	1945	41.6	73.9	6	6	3.3	NY WAPPINGERS FALLS
1974JUN20	1836	47.4	70.3	0	0	1.9	PQ LA POCATIERE
1974JUN25	0223	46.6	74.8	0	0	2.7	PQ L'ASCENSION
1974JUN26	1627	45.0	73.8	0	0	2.1	NY CANNON CORNERS
1974JUN30	1655	47.8	70.1	0	0	3.1	PQ E.OF LA MALBAIE
1974JUL 2	0446	49.6	67.4	0	0	3.4	PQ BAIE TRINITE
1974JUL10	0618	45.4	61.1	0	0	2.7	NS OFF NORTHEAST COAST
1974JUL18	0844	46.3	75.2	0	0	2.1	PQ SW OF NOMININGUE
1974JUL21	2054	60.0	71.0	0	0	3.6	PQ W.OF UNGAVA BAY
1974JUL26	0118	44.5	74.4	0	0	2.2	NY TUPPER-SARANAC
1974JUL31	0551	47.4	70.4	0	0	1.5	PQ BAIE-ST-PAUL
1974AUG 1	0045	42.6	77.5	0	0	2.4	NY HORNELL
1974AUG 2	1352	33.9	82.5	5	5	4.3	SE
1974AUG 8	1155	45.9	76.1	0	0	3.2	ON KAZABAZUA
1974AUG12	0343	45.1	73.3	0	0	2.2	PQ SE OF MONTREAL
1974AUG16	0944	47.0	70.6	0	0	2.1	PQ MONTMAGNY
1974AUG19	0537	47.1	75.9	0	0	2.4	PQ BASKATONG RESERVOIR
1974AUG25	1003	46.1	73.3	0	0	2.6	PQ SOREL
1974AUG29	1444	44.7	65.2	0	0	2.3	NS MILFORD
1974AUG31	1036	46.9	75.7	0	0	2.7	PQ FERME NEUVE
1974SEP 7	0823	59.0	71.7	0	0	2.9	PQ W.OF UNGAVA BAY
1974SEP11	2054	43.8	74.2	0	0	2.2	NY BLUE MTN LAKE

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1974SEP15	1401	43.9	73.9	0	0	1.7	NY SCHROON LAKE
1974SEP18	0623	43.4	73.8	0	0	2.5	NY SW OF LAKE GEORGE
1974OCT 1	0636	41.7	71.6	2	2	2.5	RI WEST WARWICK
1974OCT 7	0531	47.5	70.5	0	0	2.7	PQ BAIE-ST-PAUL
1974OCT 8	0910	44.7	73.9	0	0	1.9	NY LYON MTN
1974OCT10	2146	42.3	77.7	0	0	2.2	NY HORNELL
1974OCT23	2252	46.1	75.5	0	0	3.2	PQ VAL-DES-BOIS
1974NOV 2	1347	46.1	75.0	0	0	3.2	PQ LAC-REMI
1974NOV 3	0427X	46.1	75.1	0	0	2.8	PQ LAC-REMI
1974NOV 4	1014	44.5	73.9	0	0	2.1	NY LAKE PLACID
1974NOV 4	1913	45.5	74.8	0	0	1.6	ON HAWKESBURY
1974NOV19	0923	43.5	74.0	0	0	2.3	NY STONY CREEK
1974NOV22	0950	44.3	74.0	0	0	2.4	NY LAKE PLACID
1974NOV23	2108	44.6	73.7	0	0	1.6	NY SARANAC
1974NOV27	1028	43.3	79.1	0	0	3.3	NY LAKE ONTARIO
1974DEC 2	1058	46.3	75.5	0	0	3.5	PQ LAC-DU-CERF
1974DEC21	1451	45.1	74.1	0	0	2.7	PQ FRANKLIN CENTRE
1974DEC22	0525	45.4	67.1	0	0	2.9	NB ST.STEPHEN
1974DEC22	2046	42.4	69.8	0	0	3.0	MA NE OF PROVINCETOWN
1974DEC27	0050	49.1	67.4	0	0	3.5	PQ MATANE
1974DEC27	0429	42.3	71.3	0	0	2.5	MA NEEDHAM
1974DEC27	1451X	42.2	71.3	0	0	2.2	MA NEEDHAM
1974DEC29	1348	47.8	74.4	0	0	2.5	PQ PARENT
1975JAN 4	2040	44.9	74.6	0	0	2.8	NY NW OF MALONE
1975JAN 4	2044X	44.9	74.5	0	0	2.7	NY NW OF MALONE
1975JAN15	1916	44.9	74.6	4	4	2.5	NY BRASHER FALLS
1975JAN17	0010	44.9	66.9	0	0	3.1	NS BAY OF FUNDY
1975JAN27	1140	43.8	73.4	0	0	1.7	NY NEAR VT BORDER
1975JAN28	0015	45.0	73.8	0	0	2.6	NY CANNON CORNERS
1975FEB12	2128	47.3	70.0	0	0	1.7	PQ LA POCATIERE
1975FEB13	1032	46.3	72.7	0	0	2.5	PQ TROIS-RIVIERES
1975FEB20	0806	40.3	73.2	0	0	2.9	NJ SANDY HOOK
1975FEB26	0948	44.7	73.9	0	0	1.6	NY LYON MTN
1975FEB28	1840	46.4	66.0	0	0	2.9	NB BETTSBURG
1975MAR 7	1411	44.9	74.4	0	0	2.2	NY MALONE
1975MAR11	1005	45.8	74.6	0	0	2.1	PQ CALUMET
1975MAR23	1513	47.8	55.2	4	4	3.2	NF FORTUNE BAY
1975MAR30	1602	44.0	74.2	0	0	2.0	NY NEWCOMB
1975MAR31	1708	44.7	56.2	0	0	4.6	NF GRAND BANKS
1975APR 3	1903	45.7	74.2	4	3	3.1	PQ ST-JEROME
1975APR28	1612	44.7	73.7	0	0	1.2	NY LYON MTN
1975APR29	0951	41.6	73.9	0	0	2.3	NY WAPPINGERS FALLS
1975MAY14	0008	43.4	78.6	0	0	2.9	NY LAKE ONTARIO
1975MAY14	0424	44.8	73.6	0	0	1.7	NY BLUE MTN LAKE
1975MAY24	2120X	47.3	75.3	0	0	2.7	PQ MITCHENAMECUS RESERVOIR
1975MAY29	2119	47.2	75.2	0	0	3.2	PQ MITCHENAMECUS RESERVOIR
1975JUN 1	2200	45.9	75.0	0	0	1.5	PQ CHENEVILLE
1975JUN 9	1839	44.9	73.7	6	6	4.2	NY ALTONA
1975JUN11	0516	47.8	69.9	0	0	2.1	PQ RIVIERE OUELLE
1975JUN15	0808	41.6	73.9	0	0	2.0	NY WAPPINGERS FALLS
1975JUN21	0615	46.1	69.4	0	0	2.0	ME NW OF MT.KATAHDIN
1975JUN22	0658	44.5	74.5	0	0	1.5	NY NW OF TUPPER LAKE
1975JUN22	1130	43.6	75.0	0	0	1.9	NY OLD FORGE
1975JUN23	0616	44.7	73.9	0	0	2.3	NY LYON MTN
1975JUN30	0046	47.0	76.9	0	0	2.4	PQ S.OF CABONGA RESERVOIR
1975JUN30	2015	43.4	79.8	3	3	3.0	ON LAKE ONTARIO
1975JUL 1	0010	42.8	78.6	0	0	2.4	NY LANCASTER
1975JUL 1	0726	49.0	67.4	0	0	2.6	PQ MATANE
1975JUL 2	0531	42.2	71.3	0	0	0.9	MA HARDING

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1975JUL 3	1603	44.9	75.2	0	0	1.8	ON MORRISBURG
1975JUL 6	0057	47.4	70.2	0	0	1.9	PQ LA POCATIERE
1975JUL11	0144	44.3	73.9	0	0	2.8	NY WILMINGTON
1975JUL11	0339	44.7	73.9	0	0	2.3	NY LYON MTN
1975JUL12	0607	45.2	75.3	0	0	1.2	ON CRYSLER
1975JUL12	1237	46.5	76.2	4	4	4.1	PQ MANIWAKI
1975JUL12	1759X	44.7	73.9	0	0	2.2	NY LYON MTN
1975JUL15	0158X	47.6	70.1	0	0	1.2	PQ LA POCATIERE
1975JUL16	1022	47.5	70.1	0	0	1.7	PQ LA POCATIERE
1975JUL19	2059	41.4	73.8	3	3	2.3	NY MAHOPAC
1975JUL22	0617	45.3	69.1	0	0	1.7	ME DOVER-FOXCROFT
1975JUL26	1126	42.7	70.7	0	0	1.1	MA CAPE ANN
1975JUL29	0904	44.9	75.0	0	0	2.1	NY MASSENA
1975AUG 3	0103	42.7	70.9	3	3	2.4	MA IPSWICH
1975AUG 4	0458	43.8	74.1	0	0	2.1	NY BLUE MTN LAKE
1975AUG 9	0807	44.5	75.1	0	0	1.8	NY SW OF POTSDAM
1975AUG21	0429	47.4	70.2	0	0	3.1	PQ LA POCATIERE
1975AUG22	1749	41.1	73.9	0	0	2.3	NY LAKE DEFOREST
1975AUG26	2218	41.2	71.2	0	0	2.1	RI RHODE ISLAND SOUND
1975AUG27	2228	46.8	65.4	0	0	3.0	NB CHATHAM
1975AUG30	0614	42.7	78.1	0	0	2.1	NY S.OF WARSAW
1975SEP 2	0621	48.3	69.8	0	0	3.3	PQ SAGUENAY RIVER
1975SEP11	1654	43.9	74.7	0	0	1.6	NY RAQUETTE LAKE
1975SEP14	1913	45.5	69.3	0	0	2.0	ME NORTH OF DOVER-FOXCROFT
1975SEP19	0825	45.1	73.8	0	0	2.2	PQ ST.CHRYSOSTOME
1975SEP23	1511X	43.9	74.6	0	0	1.6	NY RAQUETTE LAKE
1975OCT 6	2221	44.7	57.0	0	0	5.7	NF GRAND BANKS
1975OCT 8	0900	43.5	78.5	0	0	2.6	NY LAKE ONTARIO
1975OCT10	0454X	44.2	70.2	4	3	1.9	ME SABBATUS
1975OCT10	1058	44.1	70.2	3	3	2.2	ME SABBATUS
1975OCT12	0742	49.8	68.6	0	0	2.6	PQ N.OF BAIE-COMEAU
1975OCT12	0837	46.0	74.9	0	0	1.8	PQ LAC-REMI
1975OCT13	0917	45.1	65.9	0	0	3.1	NS BAY OF FUNDY
1975OCT15	0326X	45.1	65.9	3	4	3.0	NS BAY OF FUNDY
1975OCT16	0441	46.0	74.7	0	0	1.8	PQ LAC-REMI
1975OCT21	0425	45.7	77.3	0	0	2.1	PQ GOLDEN LAKE
1975OCT21	0430X	45.7	77.5	0	0	2.1	PQ GOLDEN LAKE
1975OCT21	2050	49.1	68.1	0	0	3.1	PQ BAIE-COMEAU
1975OCT23	2117	49.8	68.6	0	0	4.1	PQ MANICOUAGAN RESERVOIR
1975OCT24	0708X	41.6	74.0	2	2	2.0	NY WAPPINGERS FALLS
1975OCT24	0743	41.6	73.9	2	2	2.2	NY WAPPINGERS FALLS
1975OCT28	2145X	41.6	73.9	2	2	0.0	NY WAPPINGERS FALLS
1975OCT31	0026	42.8	78.2	0	0	0.0	NY ATTICA
1975NOV 2	0409X	41.7	74.0	2	2	0.0	NY WAPPINGERS FALLS
1975NOV 2	1456	46.5	76.3	0	0	2.5	PQ MANIWAKI
1975NOV 3	2054	43.9	74.6	4	4	3.9	NY RAQUETTE LAKE
1975NOV 3	2106X	43.9	74.6	0	0	0.0	NY RAQUETTE LAKE
1975NOV 4	0310	47.1	74.6	0	0	2.4	PQ SW OF MANOUANE
1975NOV 5	1153X	43.9	74.6	0	0	0.0	NY RAQUETTE LAKE
1975NOV 6	1344	45.2	60.8	0	0	2.9	NS OFF CANSO
1975NOV 8	2151	49.8	68.6	0	0	1.6	PQ MANICOUAGAN RIVER
1975NOV10	0302	41.2	74.4	0	0	1.8	NY GREENWOOD LAKE
1975NOV12	0657	46.1	76.3	0	0	2.1	PQ GRACEFIELD
1975NOV14	1057	44.5	74.5	0	0	2.1	NY SANTA CLARA
1975NOV16	1113	41.4	71.0	0	0	2.1	MA BUZZARDS BAY
1975NOV16	1203	47.3	70.5	0	0	2.6	PQ BAIE-ST-PAUL
1975NOV16	1203	46.9	69.7	0	0	0.0	ME NEAR QUEBEC BORDER
1975NOV17	2236X	43.9	74.6	0	0	0.0	NY RAQUETTE LAKE
1975NOV18	1658	44.9	74.1	0	0	1.9	NY MALONE

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1975NOV18	2100X	43.9	74.6	0	0	0.0	NY RAQUETTE LAKE
1975NOV20	1502	42.9	78.2	0	0	1.5	NY ATTICA
1975NOV20	1504X	42.9	78.2	0	0	0.0	NY ATTICA
1975NOV24	0134	46.8	76.3	0	0	2.1	PQ MANIWAKI
1975NOV24	0830	45.8	74.9	0	0	1.5	PQ KILMAR
1975NOV25	2329	47.6	70.1	0	0	2.9	PQ LA MALBAIE
1975NOV26	0155X	47.7	70.1	0	0	2.7	PQ LA MALBAIE
1975NOV29	1222X	42.8	78.2	0	0	0.0	NY ATTICA
1975DEC 1	2341X	42.8	78.2	0	0	0.0	NY ATTICA
1975DEC 3	0146	45.1	74.2	0	0	2.0	PQ ATHELSTAN
1975DEC11	1648	47.8	69.7	0	0	1.8	PQ RIVIERE DU LOUP
1975DEC13	0924	58.0	52.2	0	0	4.5	NF LABRADOR SEA
1975DEC19	1525	47.0	78.8	3	3	3.8	PQ NE OF TIMISKAMING
1975DEC22	0918	46.0	74.3	0	0	1.9	PQ STE-AGATHE
1975DEC31	2009	44.4	67.8	0	0	1.9	ME PETIT MANAN PT.
1976JAN 1	2118X	42.9	78.2	0	0	0.0	NY ATTICA
1976JAN 7	0722	45.9	76.8	0	0	1.9	PQ FT.COULONGE
1976JAN10	2114X	42.8	78.2	0	0	0.0	NY ATTICA
1976JAN13	2115	46.9	76.1	0	0	2.9	PQ NW OF BASKATONG RESERVO.P
1976JAN14	2008X	42.8	78.2	0	0	0.0	NY ATTICA
1976JAN18	0903	46.8	65.7	0	0	1.9	NB BLACKVILLE
1976JAN25	0654	45.5	75.3	0	0	1.0	ON ROCKLAND
1976FEB 2	1444	46.1	75.6	0	0	2.9	PQ NOTRE-DAME-DU-LAUS
1976FEB 2	2114	42.0	82.7	0	0	3.4	ON LEAMINGTON
1976FEB 4	1027	45.9	74.2	0	0	1.9	PQ MORIN HEIGHTS
1976FEB 4	1234	46.1	73.4	0	0	1.5	PQ JOLLIETTE
1976FEB 5	0802	44.0	70.2	0	0	2.3	ME LEWISTON
1976FEB 6	0915	41.7	72.2	0	0	1.9	CT MANSFIELD
1976FEB 8	2327	47.3	70.0	0	0	1.2	PQ RIVIERE OUELLE
1976FEB12	0038	45.6	74.5	0	0	1.7	PQ HAWKESBURY
1976FEB13	0954	44.6	73.6	0	0	1.9	NY SW OF PLATTSBURG
1976FEB16	2228	45.2	74.9	0	0	1.6	ON MAXVILLE
1976FEB20	1442	47.8	66.0	0	0	2.1	NB BATHURST
1976MAR 4	1620	41.4	70.3	0	0	2.7	MA NANTUCKET SOUND
1976MAR 6	0414	41.2	73.8	0	0	2.3	NY OSSINING
1976MAR 7	2157	48.2	78.1	0	0	2.5	PQ MALARCTIC
1976MAR 8	1808	46.8	65.0	0	0	2.8	NB SE OF CHATHAM
1976MAR11	0829	41.6	71.2	5	6	2.9	RI PORTSMOUTH
1976MAR11	0835X	41.6	71.3	0	0	1.8	RI PORTSMOUTH
1976MAR11	2107	41.0	74.4	5	6	2.4	NJ RIVERDALE
1976MAR12	1028X	41.0	74.4	0	0	2.2	NJ RIVERDALE
1976MAR14	2312	41.7	70.0	5	5	2.8	MA S.CHATHAM
1976MAR17	0422	47.8	70.0	0	0	2.0	PQ LA MALBAIE
1976MAR29	2123	49.3	67.9	0	0	3.3	PQ BAIE-COMEAU
1976APR 6	2105	41.5	72.5	0	0	1.8	CT E.HADDAM
1976APR 7	0429	45.3	73.5	0	0	0.9	PQ S.OF MONTREAL
1976APR13	1539	40.8	74.0	6	6	3.1	NJ RIDGEFIELD
1976APR15	1036	44.2	70.1	3	3	2.4	ME N.OF LEWISTON
1976APR24	1022	41.5	72.5	3	3	2.2	CT E.HADDAM
1976APR28	2132	44.6	74.6	0	0	2.8	NY POTSDAM
1976APR30	1950X	41.5	72.5	0	0	1.8	CT E.HADDAM
1976APR30	2040X	41.5	72.5	0	0	1.9	CT E.HADDAM
1976MAY 5	0301	49.6	73.9	0	0	2.9	PQ LAC ST-JEAN
1976MAY 9	1356	43.9	74.7	0	0	1.0	NY RAQUETTE LAKE
1976MAY10	0134	41.5	71.0	4	5	2.7	MA NEW BEDFORD
1976MAY10	0319X	43.9	74.7	0	0	0.0	NY RAQUETTE LAKE
1976MAY11	0755X	40.5	73.8	0	0	1.9	NJ OFF SANDY HOOK
1976MAY11	1318	40.5	73.8	0	0	2.8	NJ OFF SANDY HOOK
1976MAY15	2106	49.8	68.6	0	0	3.3	PQ MANICOUAGAN RIVER

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1976MAY20	1455	47.5	70.3	0	0	2.9	PQ LES EBOULEMENTS
1976MAY26	1826	55.5	52.7	0	0	4.4	NF LABRADOR SEA
1976MAY31	1919X	49.8	68.6	0	0	2.2	PQ MANICOUAGAN RIVER
1976JUN 3	0940X	49.8	68.6	0	0	2.5	PQ MANICOUAGAN RIVER
1976JUN 8	0732	47.3	69.9	0	0	1.2	PQ ST.LAWRENCE
1976JUN12	2100	44.2	71.6	0	0	2.4	NH FRANCONIA
1976JUN14	0531X	44.3	71.7	0	0	2.0	NH FRANCONIA
1976JUN16	2120	47.6	70.1	0	0	1.6	PQ ST.LAWRENCE
1976JUN26	1945	39.8	72.5	0	0	2.9	NY S.OF LONG ISLAND
1976JUL11	0515	47.5	70.5	0	0	2.8	PQ BAIE-ST-PAUL
1976JUL13	0351	45.2	74.1	4	4	2.9	PQ VALLEYFIELD
1976JUL16	1857	43.9	77.7	0	0	2.5	ON COLBORNE
1976JUL28	0204	43.2	70.2	0	0	2.3	ME OFF SW COAST
1976AUG 3	0044	46.9	66.6	0	0	1.2	NB PINEVILLE
1976AUG 3	0257	47.7	70.1	0	0	2.9	PQ LA MALBAIE
1976AUG19	1544	53.9	80.7	0	0	3.1	PQ W.OF FT.GEORGE
1976AUG19	1547X	43.9	74.6	0	0	0.0	NY RAQUETTE LAKE
1976AUG20	2208	41.1	73.8	0	0	2.5	NY MT.PLEASANT
1976AUG21	1400X	43.9	74.7	0	0	0.0	NY RAQUETTE LAKE
1976AUG28	1923	50.1	48.9	0	0	4.0	NF OFF NORTHEAST COAST
1976AUG30	0030	47.7	70.0	0	0	2.1	PQ ST.FIDELE
1976SEP 4	1129	51.8	64.0	0	0	1.7	PQ NEAR NF BORDER
1976SEP16	0651	44.4	75.3	0	0	1.7	NY EDWARDS
1976SEP18	0040	49.4	67.1	0	0	3.4	PQ BAIE TRINITE
1976SEP18	0115	43.8	74.2	0	0	1.6	NY SE OF BLUE MTN LAKE
1976SEP22	0904	41.3	74.0	0	0	1.8	NY INDIAN PT.
1976OCT 3	0705	45.0	74.8	0	0	1.4	NY MASSENA
1976OCT 5	0823	45.2	69.2	0	0	1.7	ME DOVER-FOXCROFT
1976OCT 6	1108	45.6	69.1	0	0	2.1	ME MILLINOCKET
1976OCT20	2342	44.7	73.9	0	0	2.8	NY LYON MTN
1976OCT23	2058	47.8	69.8	5	5	4.2	PQ ST-SIMEON
1976OCT23	2122X	47.8	69.8	0	0	1.3	PQ ST-SIMEON
1976OCT23	2123X	47.8	69.8	0	0	3.1	PQ ST-SIMEON
1976OCT23	2153X	47.8	69.8	0	0	1.6	PQ ST-SIMEON
1976OCT23	2207X	47.8	69.7	0	0	1.8	PQ ST-SIMEON
1976OCT24	0159X	47.8	69.7	0	0	1.6	PQ ST-SIMEON
1976OCT24	1049X	47.8	69.8	0	0	3.6	PQ ST-SIMEON
1976OCT24	1122X	47.9	69.9	0	0	1.9	PQ ST-SIMEON
1976OCT24	1811X	47.8	69.8	0	0	1.3	PQ ST-SIMEON
1976OCT27	0223X	47.8	69.8	0	0	1.6	PQ ST-SIMEON
1976OCT27	0613X	47.8	69.9	0	0	1.8	PQ ST-SIMEON
1976OCT28	1222	45.6	74.7	0	0	1.7	ON HAWKESBURY
1976OCT31	0423	47.4	70.5	0	0	2.5	PQ BAIE-ST-PAUL
1976NOV 1	1751X	47.8	69.9	0	0	2.3	PQ ST-SIMEON
1976NOV 3	2052X	47.6	70.0	0	0	1.7	PQ ST-FIDELE
1976NOV 5	1140X	47.8	69.8	0	0	2.0	PQ ST-SIMEON
1976NOV 5	1650	46.8	75.5	0	0	2.5	PQ MONT LAURIER
1976NOV 5	1807X	43.8	74.6	0	0	0.0	NY RAQUETTE LAKE
1976NOV 6	0609	47.1	76.0	0	0	2.6	PQ BASKATONG RESERVOIR
1976NOV10	0405	47.1	70.6	0	0	1.9	PQ ST.TITE DES CAPS
1976NOV15	1520X	43.6	71.6	0	0	1.5	NH LACONIA
1976NOV22	0443	41.0	73.9	0	0	1.9	NY YONKERS
1976NOV22	2249	43.5	71.6	0	0	1.8	NH LACONIA
1976DEC 1	1851	44.9	74.8	0	0	2.1	NY SW OF MASSENA
1976DEC 3	0813	44.8	75.4	0	0	1.6	NY OGDENSBURG
1976DEC 4	0138	47.5	70.4	0	0	0.8	PQ BAIE-ST-PAUL
1976DEC 5	1632	40.8	74.8	0	0	1.8	NJ SCHOOLEY'S MTN
1976DEC 7	0455X	40.8	74.8	0	0	1.7	NJ SCHOOLEY'S MTN
1976DEC 7	2359	44.4	75.1	0	0	1.5	NY S.OF POTSDAM

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1976DEC14	1223	47.1	69.1	2	2	0.0	ME DICKEY
1976DEC14	1811	49.3	73.0	0	0	3.1	PQ LAC ST.JEAN
1976DEC16	1726	47.1	69.2	2	2	0.0	ME DICKEY
1976DEC16	2020	44.4	73.8	0	0	1.8	NY WILMINGTON
1976DEC17	1030	41.5	72.1	2	3	2.2	CT N.OF GALES FERRY
1976DEC17	1647	47.9	69.7	0	0	1.6	PQ ST-SIMEON
1976DEC23	0925	46.6	67.5	0	0	2.4	NB BRISTOL
1976DEC27	2346	48.0	70.1	0	0	1.9	PQ ST.LAWRENCE
1976DEC29	0002	44.4	73.1	0	0	1.7	VT BURLINGTON
1977JAN 4	0514	47.4	66.6	0	0	2.6	NB HEATH STEELE
1977JAN 7	0005	41.0	74.5	0	0	0.0	NJ GREEN POND
1977JAN 8	0505	47.3	75.6	0	0	2.9	PQ BASKATONG RESERVOIR
1977JAN18	0354	46.7	67.4	0	0	2.7	NB JUNIPER
1977JAN21	2050	40.0	74.3	0	0	2.7	NJ LAKEHURST
1977JAN22	1335	47.5	70.2	0	0	1.1	PQ RIVIERE OUELLE
1977JAN25	1124	46.7	67.4	0	0	2.7	NB GLASSVILLE
1977FEB 4	1449	49.7	66.4	0	0	2.6	PQ ST.LAWRENCE
1977FEB 6	0901	46.8	66.7	0	0	3.0	NB PLASTER ROCK
1977FEB 7	0256	41.6	72.4	0	0	2.1	CT MARLBOROUGH
1977FEB10	1914	39.8	75.5	2	2	0.0	DE WILMINGTON
1977FEB11	1035	49.8	68.6	0	0	1.1	PQ BAIE-COMEAU
1977FEB13	2255	46.7	66.3	0	0	2.8	NB SW OF NEWCASTLE
1977FEB14	0035	47.5	70.4	0	0	3.1	PQ BAIE-ST-PAUL
1977FEB15	0903	46.6	67.5	0	0	1.9	NB N.OF WOODSTOCK
1977FEB24	1248	46.7	67.4	0	0	2.8	NB GLASSVILLE
1977MAR 3	1946	47.3	79.7	0	0	2.9	ON COBALT
1977MAR 7	0944	41.6	72.4	0	0	1.8	CT MARLBOROUGH
1977MAR10	1622	41.2	74.2	0	0	2.2	NY SUFFERN
1977MAR13	2339	46.2	72.5	0	0	1.8	PQ N.OF DRUMMONDVILLE
1977MAR27	1234	45.1	74.7	0	0	1.5	PQ CORNWALL
1977MAR28	0212	49.9	66.6	0	0	1.9	PQ SEPT-ILES
1977APR 6	0638	46.6	67.5	0	0	2.4	NB NE OF BRISTOL
1977APR 6	2031	41.1	70.4	0	0	2.5	MA S.OF MARTHA'S VINEYARD
1977APR 9	1627	45.9	77.8	0	0	2.0	ON DEEP RIVER
1977APR16	1635	49.8	68.6	0	0	1.6	PQ BAIE-COMEAU
1977APR20	2300	48.9	67.4	0	0	1.3	PQ MATANE
1977APR24	0009	47.0	75.8	0	0	2.3	PQ N.OF MANIWAKI
1977APR26	2225X	49.2	68.2	0	0	1.1	PQ BAIE-COMEAU
1977MAY 2	0449	49.6	68.7	0	0	2.1	PQ BAIE-COMEAU
1977MAY 2	2241	47.5	69.9	0	0	2.8	PQ ST-PASCAL
1977MAY 5	0839	43.9	72.3	0	0	2.1	VT LAKE FAIRLEE
1977MAY 8	2242	49.2	66.6	0	0	2.6	PQ CAP-CHAT
1977MAY15	1850	47.4	77.0	0	0	2.6	PQ LA VERENDRYE PARK
1977MAY20	1532	49.3	69.6	0	0	1.9	PQ LABRIEVILLE
1977MAY20	1652	46.2	74.6	0	0	2.1	PQ MONT-TREMBLANT
1977MAY25	0426	46.5	76.1	0	0	2.1	PQ MANIWAKI
1977MAY28	0057	45.1	74.6	0	0	1.2	PQ NEAR MASSENA NY
1977MAY29	1249	47.6	70.2	0	0	1.1	PQ LA MALBAIE
1977JUN 2	1749	49.2	67.3	0	0	2.1	PQ E.OF BAIE-COMEAU
1977JUN 5	0121	47.6	70.2	0	0	1.4	PQ LA MALBAIE
1977JUN 5	0713	49.1	67.8	0	0	2.2	PQ SE OF BAIE-COMEAU
1977JUN 6	0810	47.5	70.1	0	0	1.0	PQ RIVIERE-OUELLE
1977JUN10	1248	40.7	74.9	0	0	1.1	NJ HIGH BRIDGE
1977JUN14	2047	50.3	66.5	0	0	1.1	PQ SEPT-ILES
1977JUN17	0735	45.1	74.2	0	0	1.3	PQ HUNTINGDON
1977JUN20	0505	47.8	70.2	0	0	3.1	PQ LA MALBAIE
1977JUN21	1341	47.5	70.1	0	0	0.9	PQ RIVIERE-OUELLE
1977JUN22	1956	50.1	66.7	0	0	1.0	PQ CLARKE CITY
1977JUN23	0047	47.5	70.0	0	0	0.7	PQ ST.-DENIS

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1977JUL 1	1553	42.9	70.1	0	0	2.6	MA CAPE ANN
1977JUL 2	1113	40.7	74.9	0	0	2.3	NJ HAMPTON
1977JUL 3	0307	47.4	70.2	0	0	1.7	PQ RIVIERE-OUELLE
1977JUL 7	0959	49.7	66.7	0	0	2.6	PQ RIVIERE-PENTECOTE
1977JUL 7	1018X	49.8	66.9	0	0	1.7	PQ RIVIERE-PENTECOTE
1977JUL 7	2027	50.0	66.7	0	0	1.3	PQ PORT-CARTIER
1977JUL11	1723X	50.0	66.7	0	0	1.0	PQ PORT-CARTIER
1977JUL14	0739	46.0	74.4	4	4	3.4	PQ ST-AGATHE-DES-MONTS
1977JUL14	1349X	50.0	66.6	0	0	1.1	PQ PORT-CARTIER
1977JUL14	1934X	50.0	66.6	0	0	1.0	PQ PORT-CARTIER
1977JUL16	1137	44.5	55.8	0	0	3.8	NS OFF EAST COAST
1977JUL18	2232	47.5	70.2	0	0	2.6	PQ RIVIERE-OUELLE
1977JUL19	0553	46.3	66.1	0	0	2.0	NB CENTRAL
1977JUL19	0706X	44.7	74.0	0	0	1.3	NY LYON MTN
1977JUL19	0943	46.3	65.8	0	0	1.6	NB CENTRAL
1977JUL20	2326	44.7	74.0	0	0	1.8	NY LYON MTN
1977JUL26	0326X	47.5	70.1	0	0	0.0	PQ RIVIERE-OUELLE
1977JUL27	0919	47.4	70.3	0	0	1.2	PQ RIVIERE-OUELLE
1977JUL28	0534	47.4	70.3	0	0	0.9	PQ ST-ROCH
1977AUG 2	1125	50.2	65.6	0	0	2.3	PQ SEPT-ILES
1977AUG 5	2225	49.2	68.4	0	0	1.5	PQ BAIE-COMEAU
1977AUG 7	0602	45.7	77.5	0	0	2.4	ON PEMBROKE
1977AUG 8	2120X	50.0	66.7	0	0	1.6	PQ PORT-CARTIER
1977AUG 8	2306X	49.7	67.1	4	4	3.8	PQ POINTE-AUX-ANGLAIS
1977AUG 8	2308	49.8	67.1	4	4	3.9	PQ POINTE-AUX-ANGLAIS
1977AUG 8	2329X	49.7	67.0	0	0	2.8	PQ POINTE-AUX-ANGLAIS
1977AUG 8	2341X	49.8	67.1	0	0	2.0	PQ POINTE-AUX-ANGLAIS
1977AUG 8	2348X	49.6	67.0	0	0	1.1	PQ POINTE-AUX-ANGLAIS
1977AUG 9	0058X	49.7	67.0	0	0	0.6	PQ POINTE-AUX-ANGLAIS
1977AUG10	1009	49.1	68.4	0	0	1.6	PQ BAIE-COMEAU
1977AUG11	2121	48.7	69.4	0	0	2.5	PQ SAULT-AU-MOUTON
1977AUG12	0927	47.1	73.0	0	0	2.3	PQ LA TUQUE
1977AUG17	2005	47.8	70.6	0	0	0.8	PQ CLERMONT
1977AUG22	0401	45.9	75.5	0	0	1.2	PQ VAL-DES-BOIS
1977AUG26	0223	47.7	69.9	0	0	2.1	PQ LA MALBAIE
1977AUG29	0523	47.3	70.2	0	0	2.0	PQ SW OF LA POCATIERRE
1977SEP 1	0100	47.2	66.5	0	0	2.1	NB NORTHERN
1977SEP 2	0553	41.3	73.9	0	0	2.4	NY PEEKSKILL
1977SEP 2	1309X	41.3	73.9	0	0	0.0	NY PEEKSKILL
1977SEP 2	2222X	41.3	73.9	0	0	0.0	NY PEEKSKILL
1977SEP 3	0004X	41.3	73.9	0	0	0.0	NY PEEKSKILL
1977SEP 3	0008X	41.3	73.9	0	0	0.0	NY PEEKSKILL
1977SEP 4	1212	59.7	72.3	0	0	3.6	PQ NORTHERN
1977SEP 8	2359	43.6	70.7	0	0	1.8	ME LITTLE OSSIPEE POND
1977SEP14	1106X	41.3	73.9	0	0	0.0	NY PEEKSKILL
1977SEP17	1847	41.2	74.1	0	0	0.0	NY HAVERSTRAW
1977SEP18	1431X	49.7	66.9	0	0	1.4	PQ POINTE-AUX-ANGLAIS
1977SEP24	1719	58.3	54.2	0	0	4.8	NF LABRADOR SEA
1977SEP28	1721	44.4	73.9	0	0	3.1	NY WILMINGTON
1977SEP29	1844X	41.3	73.9	0	0	0.0	NY PEEKSKILL
1977OCT 2	0551	45.2	69.1	0	0	2.6	ME DOVER-FOXCROFT
1977OCT 4	0732	50.0	66.9	0	0	2.8	PQ PORT-CARTIER
1977OCT 7	1612	44.7	73.7	0	0	2.2	NY DANNEMORA
1977OCT 9	0559	47.4	70.4	0	0	2.5	PQ BAIE-ST-PAUL
1977OCT14	0009	41.6	74.0	0	0	2.2	NY NEWBURGH
1977OCT16	2129	46.6	73.7	0	0	3.0	PQ STE-EMILE
1977OCT19	0807	44.1	75.6	0	0	1.3	NY NE OF WATERTOWN
1977OCT20	0407	47.6	70.2	0	0	1.7	PQ LA MALBAIE
1977OCT24	1809	46.9	67.1	0	0	3.0	NB GRAND FALLS

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1977OCT27	0922	41.1	74.6	0	0	1.5	NJ SPARTA
1977NOV 3	0408	47.5	70.2	0	0	2.3	PQ LES EBOULEMENTS
1977NOV 5	0849	59.1	60.6	0	0	4.2	NF LABRADOR SEA
1977NOV 7	2048	46.3	75.2	0	0	3.0	PQ NOMININGUE
1977NOV12	0558	47.4	70.2	0	0	1.0	PQ LA POCATIERE
1977NOV13	0503	47.7	70.1	0	0	0.7	PQ LA MALBAIE
1977NOV13	0839	50.6	64.8	0	0	3.1	PQ E.OF SEPT-ILES
1977NOV13	1705	42.4	65.1	0	0	2.9	NS OFF SOUTH COAST
1977NOV15	1328	47.4	70.3	0	0	0.4	PQ LES EBOULEMENTS
1977NOV16	0255	41.0	71.5	0	0	2.2	NY MONTAUK PT.
1977NOV16	0306	44.8	74.9	0	0	1.6	NY BRASHER FALLS
1977NOV17	2251X	47.6	70.2	0	0	0.9	PQ LA MALBAIE
1977NOV18	1028	47.7	70.0	0	0	1.1	PQ LA MALBAIE
1977NOV22	2218	48.0	70.9	0	0	0.7	PQ BAGOTVILLE
1977NOV24	0954	47.4	70.4	0	0	0.4	PQ BAIE-ST-PAUL
1977NOV24	1840	49.1	66.9	0	0	1.9	PQ CAP-CHAT
1977NOV24	2131	47.5	70.0	0	0	2.1	PQ ST-DENIS
1977NOV25	0513	45.3	68.0	0	0	2.6	ME S.SPRINGFIELD
1977NOV25	1322	47.5	69.9	0	0	0.7	PQ KAMOURASKA
1977NOV25	1847	46.7	76.4	0	0	3.0	PQ NW OF MANIWAKI
1977NOV27	1357	41.0	74.2	0	0	1.8	NJ OAKLAND
1977NOV28	2026	47.8	69.8	0	0	0.7	PQ ST-SIMEON
1977NOV29	0717	47.4	70.3	0	0	0.4	PQ LES EBOULEMENTS
1977DEC 2	0320	47.7	69.9	0	0	0.8	PQ LA MALBAIE
1977DEC 2	0349	47.7	70.0	0	0	1.1	PQ NE OF LA MALBAIE
1977DEC 4	2350X	40.8	74.8	0	0	1.8	NJ SCHOOLEY'S MTN
1977DEC 4	2350X	40.8	74.8	0	0	2.1	NJ SCHOOLEY'S MTN
1977DEC 5	0915	48.3	69.6	0	0	1.3	PQ TADOUSSAC
1977DEC 6	1751X	40.8	74.8	0	0	1.6	NJ SCHOOLEY'S MTN
1977DEC 7	0834X	40.8	74.8	0	0	1.7	NJ SCHOOLEY'S MTN
1977DEC 8	0239	47.4	70.4	0	0	0.6	PQ BAIE-ST-PAUL
1977DEC 8	1635X	40.8	74.8	0	0	1.5	NJ SCHOOLEY'S MTN
1977DEC 9	1733	41.6	73.9	0	0	2.3	NY HOPEWELL JCT
1977DEC15	0855	43.0	77.4	0	0	2.6	NY ROCHESTER
1977DEC16	0902	46.1	66.8	0	0	2.7	NB FREDERICTON
1977DEC20	0217	44.5	69.6	0	0	1.9	ME CHINA LAKE
1977DEC20	0846	47.7	70.2	0	0	1.8	PQ LA MALBAIE
1977DEC20	1744	41.8	70.7	4	5	3.1	MA WAREHAM
1977DEC20	1754	47.6	70.5	0	0	0.5	PQ ST-URBAIN
1977DEC20	2244X	41.8	70.8	3	3	2.0	MA WAREHAM
1977DEC21	1816	47.4	70.2	0	0	1.1	PQ LA POCATIERE
1977DEC22	1457	46.9	76.9	0	0	3.5	PQ SW OF BASKATONG RESERVOI
1977DEC23	0455	40.8	74.8	0	0	2.3	NJ SCHOOLEY'S MTN
1977DEC23	1620X	40.8	74.8	0	0	1.4	NJ SCHOOLEY'S MTN
1977DEC24	1025X	40.8	74.8	0	0	1.6	NJ SCHOOLEY'S MTN
1977DEC25	1535	43.2	71.7	4	4	3.2	NH HOPKINTON
1977DEC25	1539X	40.8	74.8	0	0	1.5	NJ SCHOOLEY'S MTN
1977DEC26	0000	52.7	79.6	0	0	2.9	PQ JAMES BAY
1977DEC26	1619	45.0	66.9	0	0	2.1	NB PASSAMAQUODDY BAY
1977DEC26	1654X	40.8	74.8	0	0	1.7	NJ SCHOOLEY'S MTN
1977DEC27	1041X	40.8	74.8	0	0	1.4	NJ SCHOOLEY'S MTN
1978JAN 3	0143	43.9	67.6	0	0	2.5	ME OFF SE COAST
1978JAN 4	1928	44.0	70.5	4	4	3.2	ME OTISFIELD
1978JAN 4	1928X	44.0	70.6	0	0	2.4	ME OTISFIELD
1978JAN 5	0820	44.5	67.1	0	0	1.9	ME OFF SE COAST
1978JAN 5	0822X	44.5	67.1	0	0	2.0	ME OFF SE COAST
1978JAN13	0336	46.9	70.3	3	3	2.9	PQ E OF MONTMAGNY
1978JAN13	0515	41.4	74.0	0	0	0.0	NY WEST POINT
1978JAN13	0603X	46.9	70.3	0	0	1.7	PQ E OF MONTMAGNY

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1978JAN14	1847X	41.4	74.0	0	0	0.0	NY WEST POINT
1978JAN15	0741X	41.4	74.0	0	0	0.0	NY WEST POINT
1978JAN18	0028	43.0	72.2	0	0	1.9	NH E OF KEENE
1978JAN21	1156	47.7	70.0	0	0	2.1	PQ LA MALBAIE
1978JAN24	1906	44.6	68.3	0	0	2.0	ME ELLSWORTH
1978JAN24	1909X	44.7	68.3	0	0	1.2	ME ELLSWORTH
1978FEB 2	2238	45.3	74.0	0	0	1.9	PQ VALLEYFIELD
1978FEB 3	1728	44.5	74.0	0	0	1.7	NY WILMINGTON
1978FEB 8	0539	45.3	75.2	0	0	1.9	ON CRYSLER
1978FEB10	0937	41.3	74.0	0	0	0.0	NY TOMPKINS COVE
1978FEB15	0528	40.9	74.4	0	0	1.6	NJ BOUTON
1978FEB15	1449	45.2	69.1	0	0	2.0	ME DOVER-FOXCROFT
1978FEB18	1448	46.3	74.1	5	5	4.2	PQ ST. DONAT
1978FEB19	1025	45.3	67.2	0	0	2.1	NB OAK BAY
1978FEB21	0729	46.8	68.6	0	0	2.4	ME N OF PORTAGE
1978FEB23	0524	46.4	74.1	4	4	3.8	PQ ST. DONAT
1978FEB26	1945	47.8	69.5	0	0	2.1	PQ RIVIERE DU LOUP
1978MAR 4	0425	47.6	70.1	0	0	2.1	PQ LA MALBAIE
1978MAR 5	0753	41.4	74.2	0	0	2.1	NY HIGHLAND MILLS
1978MAR 5	2321	43.5	79.7	2	2	2.1	ON BURLINGTON
1978MAR 9	0326	47.6	69.9	0	0	2.4	PQ ST. DENIS
1978MAR 9	1909X	45.2	67.2	0	0	1.6	ME SE OF CALAIS
1978MAR15	1913	45.2	67.3	0	0	1.9	ME SE OF CALAIS
1978MAR20	0816	43.1	71.5	0	0	2.4	NH NW OF MANCHESTER
1978MAR21	2312	48.0	69.8	0	0	2.2	PQ ST. LAWRENCE RIVER
1978MAR28	0110X	47.7	69.7	0	0	2.3	PQ ST. LAWRENCE RIVER
1978MAR31	1427	43.1	71.6	0	0	2.7	NH DUNBARTON
1978APR 3	2357	40.5	74.1	0	0	2.0	NJ OFF SANDY HOOK
1978APR 5	1445	43.9	74.2	0	0	2.6	NY NEWCOMB
1978APR 7	0607	47.8	69.6	0	0	2.1	PQ RIVIERE DU LOUP
1978APR 7	2244X	48.0	69.7	0	0	1.7	PQ S OF TADOUSSAC
1978APR 8	0821	47.8	69.9	0	0	3.0	PQ ST. SIMEON
1978APR 8	0959X	47.8	69.9	0	0	2.1	PQ ST. SIMEON
1978APR11	2302X	48.0	69.7	0	0	2.1	PQ S OF TADOUSSAC
1978APR14	1613	44.7	69.0	0	0	1.8	ME MONROE
1978APR18	2306	48.1	69.7	0	0	2.4	PQ TADOUSSAC
1978APR26	0934	41.4	71.6	0	0	1.7	RI BLOCK ISLAND SOUND
1978APR27	1955	47.8	70.2	0	0	2.0	PQ LA MALBAIE
1978APR27	2301X	48.0	69.5	0	0	2.0	PQ SE OF TADOUSSAC
1978APR28	1327	45.1	67.0	0	0	1.5	NB PASSAMAQUODDY BAY
1978APR29	0031X	47.6	70.1	0	0	1.8	PQ LA MALBAIE
1978APR30	1500X	47.6	69.9	0	0	2.1	PQ LA MALBAIE
1978MAY 1	1529X	47.7	70.1	0	0	2.0	PQ LA MALBAIE
1978MAY 2	2232X	47.9	70.0	0	0	2.3	PQ ST. SIMEON
1978MAY 9	1206	43.8	75.1	0	0	2.3	NY OLD FORGE
1978MAY13	2155	42.8	78.3	0	0	2.8	NY W OF ATTICA
1978MAY13	2208X	42.8	78.3	0	0	2.6	NY W OF ATTICA
1978MAY16	1940	44.4	70.2	0	0	2.5	ME LIVERMORE
1978MAY18	0129	41.0	74.3	1	1	1.5	NJ BLOOMINGDALE
1978MAY26	0231	47.7	70.1	3	3	3.1	PQ N SHORE ST. LAWRENCE RIVER
1978JUN 4	2323	39.8	71.7	0	0	2.1	RI CONTINENTAL SHELF
1978JUN16	0459	41.0	74.6	0	0	0.0	NJ SPARTA
1978JUN21	1831	43.7	71.4	0	0	1.8	NH WINNIPESAUKEE
1978JUN30	2013	41.1	74.2	4	5	2.9	NJ BETWEEN MAHWAH AND OAKLAND
1978JUN30	2239X	41.1	74.2	0	0	2.2	NJ BETWEEN MAHWAH AND OAKLAND
1978JUL 8	1714	38.5	70.4	0	0	2.4	SE ATLANTIC OCEAN
1978JUL12	1017	46.1	75.7	0	0	2.4	PQ POINT COMFORT
1978JUL13	1738	44.7	73.7	0	0	2.5	NY DANNEMORA
1978JUL13	2351	48.4	69.5	0	0	2.1	PQ N SHORE ST. LAWRENCE RIVER

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1978JUL16	0639	39.8	76.0	5	5	3.1	PA LANCASTER
1978JUL16	1259	47.5	69.9	0	0	2.0	PQ ST. DENIS
1978JUL17	1519	47.5	70.2	0	0	2.0	PQ S OF LA MALBAIE
1978JUL22	1544	47.5	70.0	0	0	2.2	PQ LA MALBAIE
1978JUL23	0516	46.7	66.6	0	0	2.3	NB N OF HOLTVILLE
1978JUL23	2302	41.3	73.9	0	0	2.1	NY PEEKSKILL
1978JUL25	2321	47.9	69.7	0	0	1.9	PQ RIVIERE DU LOUP
1978JUL26	0417	40.4	71.1	0	0	2.8	RI CONTINENTAL SHELF
1978JUL27	2034	47.7	69.8	0	0	2.3	PQ LA MALBAIE
1978JUL28	1030	44.4	75.1	0	0	1.9	NY POTSDAM
1978JUL28	1444	40.6	70.9	0	0	2.4	RI CONTINENTAL SHELF
1978JUL30	1054	45.7	74.4	4	4	3.8	PQ NEAR LACHUTE
1978AUG 1	1742	47.1	70.9	3	3	2.8	PQ N SHORE ST. LAWRENCE RIVER
1978AUG 2	1713	47.5	70.1	0	0	2.2	PQ LA MALBAIE
1978AUG 6	1049	42.5	71.1	0	0	1.6	MA WAKEFIELD
1978AUG 6	1301X	42.4	71.0	0	0	1.8	MA WAKEFIELD
1978AUG 7	0638	44.4	72.6	0	0	1.8	VT NW OF MONTPELIER
1978AUG 7	0757	47.4	70.2	0	0	1.8	PQ LA MALBAIE
1978AUG 7	1754	46.9	66.9	0	0	1.8	NB N OF BEAVER BROOK LAKE
1978AUG 8	1536	44.9	67.5	0	0	1.8	ME S OF COOPER
1978AUG 9	0411	47.4	70.1	0	0	2.2	PQ S OF LA MALBAIE
1978AUG10	0939	47.3	67.9	0	0	1.5	NB N OF ST. LEONARD
1978AUG10	2112	40.5	71.1	0	0	3.5	RI CONTINENTAL SHELF
1978AUG10	2220	48.0	69.6	0	0	1.9	PQ S OF TADOUSSAC
1978AUG14	2255	47.6	70.1	3	3	2.9	PQ LA MALBAIE
1978AUG16	2237	47.9	69.6	0	0	2.5	PQ RIVIERE DU LOUP
1978AUG17	2141	43.5	71.6	0	0	1.9	NH WINNISQUAM LAKE
1978AUG21	0847	44.5	74.5	0	0	3.1	NY POTSDAM
1978AUG25	2001	42.9	70.8	2	2	2.3	NH SEABROOK
1978SEP 1	0333	42.5	71.5	2	2	2.0	MA BOXBOROUGH-ACTON
1978SEP 3	1241	41.4	71.4	0	0	2.8	RI RHODE ISLAND SOUND
1978SEP16	1245	47.5	70.5	2	2	2.0	PQ CHARLVOIX
1978SEP19	0411	41.0	73.9	0	0	1.8	NY YONKERS
1978SEP23	1647	45.3	70.9	0	0	1.9	ME W OF SNOW MOUNTAIN
1978SEP24	0100	45.0	70.4	0	0	2.2	ME NE OF DALLAS
1978SEP27	0304	47.6	70.4	3	3	2.7	PQ CHARLEVOIX
1978SEP27	0843	44.1	73.0	0	0	1.8	VT E OF BRISTOL
1978OCT 3	0315	43.2	78.5	0	0	2.1	NY MEDINA
1978OCT 4	1718	45.2	69.2	0	0	1.7	ME DOVER-FOXCROFT
1978OCT 6	1925	40.1	76.1	6	6	3.0	PA LANCASTER
1978OCT12	0107	44.7	75.1	0	0	2.0	NY MADRID
1978OCT15	2236	43.3	80.6	0	0	1.7	ON DRUMBO
1978OCT20	0539	45.2	66.9	0	0	2.0	NB LAKE UTOPIA
1978OCT24	0337	44.1	73.0	0	0	1.9	VT SE OF BRISTOL
1978OCT26	2153	42.7	77.8	0	0	2.6	NY MOUNT MORRIS
1978OCT27	2352	41.5	71.0	0	0	1.9	MA S OF DARTMOUTH
1978OCT29	2359	43.9	70.4	0	0	2.5	ME CRESCENT LAKE
1978OCT30	0632X	44.0	70.4	0	0	1.6	ME CRESCENT LAKE
1978OCT31	0316X	44.0	70.4	0	0	1.9	ME CRESCENT LAKE
1978OCT31	0449X	44.0	70.4	0	0	2.0	ME CRESCENT LAKE
1978NOV 9	0028	47.9	69.6	0	0	2.2	PQ N OF RIVIERE DU LOUP
1978NOV10	0343	45.7	75.3	0	0	1.5	PQ WOLF LAKE
1978NOV23	0915	43.2	66.3	0	0	2.4	NS OFF SW COAST
1978DEC 4	0205	44.8	70.8	0	0	1.6	ME BLUE MOUNTAIN
1978DEC20	0439	45.0	69.5	2	2	2.2	ME W OF DEXTER
1978DEC28	0924	44.5	73.9	4	4	2.5	NY NW OF WILMINGTON
1979JAN 1	0413	43.5	71.6	0	0	1.9	NH SE OF BRISTOL
1979JAN 7	0922	41.7	72.6	0	0	1.2	CT EAST GLASTONBURY
1979JAN14	0701	44.6	74.7	0	0	0.0	NY SANTA CLARA

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1979JAN17	1256	40.3	73.7	0	0	0.0	NJ OFF SANDY HOOK
1979JAN29	0635	44.8	73.2	2	2	2.8	VT NORTH HERO
1979JAN30	1630	40.3	74.3	4	4	3.5	NJ CHEESEQUAKE
1979JAN31	2142	43.4	72.6	0	0	1.5	VT LUDLOW
1979FEB 1	2307	45.8	69.2	0	0	1.9	ME NAHMAKANTA LAKE
1979FEB 2	0226	40.8	74.7	0	0	1.9	NJ CHESTER
1979FEB11	0721	41.2	73.8	0	0	2.0	NY NEAR CROTON RESERVOIR
1979FEB21	0634	44.1	70.2	0	0	1.9	ME LEWISTON
1979FEB27	0756	47.3	70.1	0	0	2.4	PQ LA POCATIERE
1979MAR10	0449	40.7	74.5	3	3	3.1	NJ BERNARDSVILLE
1979MAR14	0646	43.6	76.6	0	0	1.9	PQ LAKE ONTARIO
1979MAR23	2253	47.7	70.1	3	3	3.1	PQ LA MALBAIE
1979APR18	0234	44.0	69.8	5	5	4.0	ME BATH
1979APR20	1032	45.2	66.0	4	4	3.2	NB BAY OF FUNDY
1979APR21	1333	47.7	70.1	0	0	2.7	PQ LA MALBAIE
1979APR23	0005	43.0	71.2	3	4	3.1	NH CANDIA
1979MAY 4	1902	44.1	73.2	0	0	1.3	VT N OF MIDDLEBURY
1979MAY15	1049	47.6	70.0	0	0	2.6	PQ LA MALBAIE
1979MAY15	2212X	44.1	73.2	0	0	1.4	VT N OF MIDDLEBURY
1979MAY29	2048	45.0	75.0	0	0	3.0	NY MASSENA
1979JUN 7	1345	44.4	73.9	0	0	3.1	NY AUSABLE FORKS
1979JUN12	0945	43.7	75.3	0	0	0.0	NY PORT LEYDEN
1979JUN20	1920	41.4	74.4	0	0	0.0	NY GOSHEN
1979JUN27	1041	45.7	67.3	0	0	2.5	NB N OF JUNIPER
1979JUL 5	1225	47.4	70.4	0	0	2.6	PQ BAIE ST. PAUL
1979JUL 9	0542	43.4	71.5	0	0	2.4	NH S OF LANCONIA
1979JUL14	0059	45.4	66.9	0	0	1.9	NB E OF LAWRENCE STATION
1979JUL28	2329	43.3	70.4	4	4	3.5	ME S OF KENNEBUNKPORT
1979AUG17	0556	47.4	70.4	0	0	2.6	PQ S OF LA MALBAIE
1979AUG19	2249	47.7	69.9	5	5	5.0	PQ CHARLEVOIX
1979AUG24	0721	44.4	70.1	0	0	2.4	ME WAYNE
1979SEP 4	0738	41.6	73.5	0	0	2.8	CT NY BORDER
1979SEP14	0748	45.7	69.1	0	0	2.1	ME S OF MT. KATAHDIN
1979SEP22	0303	44.7	70.1	0	0	2.1	ME E OF FARMINGTON
1979SEP24	1341	45.0	67.1	0	0	1.8	ME PASSAMAQUODDY BAY
1979SEP27	2045	44.7	68.4	0	0	2.2	ME NE OF ELLSWORTH
1979OCT 1	1950	41.7	73.9	0	0	0.0	NY POUGHKEEPSIE
1979OCT 3	0506	47.4	70.5	0	0	1.8	PQ LA MALBAIE
1979OCT12	0850	47.5	70.1	0	0	1.7	PQ LA MALBAIE
1979OCT15	1343X	47.5	70.1	0	0	1.7	PQ LA MALBAIE
1979OCT29	1645	43.5	79.8	0	0	0.0	ON MILTON
1979NOV 1	2108	47.8	69.9	0	0	2.0	PQ LA MALBAIE
1979NOV 8	0113X	43.9	47.5	0	0	0.0	NY BLUE MOUNTAIN LAKE
1979NOV13	0027	44.4	70.3	0	0	2.1	ME SE OF CANTON
1979NOV14	0514	47.3	70.3	0	0	2.1	PQ SW OF LA POCATIERE
1979NOV17	1712X	47.6	69.9	0	0	2.1	PQ LA MALBAIE
1979NOV20	0617	42.2	71.0	0	0	2.2	MA QUINCY
1979NOV29	0258	43.8	74.5	0	0	2.5	NY BLUE MOUNTAIN LAKE
1979NOV30	1057	47.7	70.2	0	0	1.8	PQ LA MALBAIE
1979DEC 1	1614	41.4	74.4	0	0	2.0	NY PINE ISLAND
1979DEC12	0834	41.5	72.0	0	0	1.2	CT SE OF NORWICH
1979DEC23	1944	45.6	66.2	0	0	2.2	NB HAMPSTEAD
1979DEC29	1858	47.6	70.0	0	0	2.1	PQ LA MALBAIE
1979DEC30	1119	45.2	66.7	0	0	2.1	NB NE OF UTOPIA
1979DEC30	1419	41.2	73.7	3	3	2.2	NY MT. KISCO
1980JAN 2	0312	41.6	72.1	0	0	1.0	CT NEAR NORWICH
1980JAN 2	1050	47.4	70.3	0	0	2.3	PQ SW OF LA POCATIERE
1980JAN 7	1030	45.0	67.0	0	0	2.2	NB DEER ISLAND
1980JAN14	0557	43.8	68.1	0	0	2.5	ME S OF MOUNT DESERT ISLAN

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1980JAN17	1012X	41.3	73.9	0	0	1.8	NY PEEKSKILL
1980JAN17	1013	41.3	73.9	0	0	2.7	NY PEEKSKILL
1980JAN21	0616	43.3	79.8	0	0	2.5	ON EAST HAMILTON
1980JAN24	0032	45.6	69.1	0	0	1.9	ME SW OF MT KATAHDIN
1980JAN24	0544	46.1	75.1	0	0	3.2	PQ LAKE GAGNON
1980JAN26	1533	44.3	68.7	0	0	2.1	ME NE OF DEER ISLE
1980FEB 2	0339	47.5	70.1	0	0	0.5	PQ E OF LA MALBAIE
1980FEB 4	0918	44.8	75.3	0	0	2.8	NY NE OF OGDENSBURG
1980FEB 9	1311	43.6	70.8	0	0	2.4	ME W OF BIDDEFORD
1980FEB19	2125	47.5	70.1	0	0	2.2	PQ NE OF LA POCATIERE
1980FEB25	0518	44.3	70.5	0	0	2.3	ME PENNESSEEWASSEE LAKE
1980FEB29	0553	42.6	74.2	0	0	2.4	NY CATSKILL
1980MAR 2	1154X	40.2	75.1	0	0	2.8	PA ABINGTON
1980MAR 5	1706X	40.2	75.1	0	0	2.9	PA ABINGTON
1980MAR 5	1720X	40.2	75.1	0	0	2.5	PA ABINGTON
1980MAR11	0415	46.7	71.9	0	0	3.7	PQ S OF STE-CROIX
1980MAR11	0600	40.3	75.1	0	0	3.3	PA ABINGTON
1980MAR11	0843	47.5	69.9	0	0	2.0	PQ NE OF LA POCATIERE
1980MAR11	1007	38.6	64.3	0	0	2.8	MA WEST KELVIN SEAMOUNT
1980MAR11	1616X	40.2	75.0	0	0	2.8	PA ABINGTON
1980MAR19	0253	45.9	75.5	0	0	1.8	PQ N OF GLEN ALMOND
1980MAR19	1204	46.2	74.8	0	0	1.9	PQ LA CONCEPTION
1980MAR25	1854	41.0	75.0	0	0	2.8	NJ HAINESBURG
1980APR 1	0448	43.8	71.4	0	0	2.0	NH NE OF SQUAM LAKE
1980APR 1	0855	47.2	70.9	0	0	2.6	PQ NE OF QUEBEC
1980APR 3	1657	48.7	68.1	4	0	4.1	PQ S OF MANICOUGAN
1980APR 5	1149	39.8	74.1	0	0	2.9	NJ S OF SEASIDE
1980APR 7	0736	47.4	70.0	0	0	2.3	PQ SE OF LA MALBAIE
1980APR 7	0936	43.1	72.2	0	0	2.7	NH W OF HIGHLAND LAKE
1980APR10	1536	44.7	68.4	0	0	3.0	ME NE OF GRAHAM LAKE
1980APR19	2332	45.1	73.0	0	0	2.8	PQ SE OF MONTREAL
1980APR21	1339	44.7	68.4	0	0	2.5	ME NORTHERN GRAHAM LAKE
1980APR25	0023	41.4	74.4	0	0	2.4	NY FLORIDA
1980APR25	0543	46.7	73.4	0	0	2.9	PQ NW OF GENTILLY
1980APR30	1948	45.6	75.1	0	0	1.3	PQ E OF GLEN ALMOND
1980MAY 2	1523	40.2	75.0	0	0	2.8	PA ABINGTON
1980MAY 2	1902	40.3	75.0	0	0	3.0	PA ABINGTON
1980MAY 4	0856	44.3	69.6	0	0	2.6	ME SE OF AUGUSTA
1980MAY 7	0432	41.0	73.9	0	0	2.6	NY ARDSLEY
1980MAY 7	0906	44.7	68.4	0	0	1.8	ME GRAHAM LAKE
1980MAY10	1244	45.2	69.1	0	0	2.5	ME MILO
1980MAY12	0138	41.3	74.1	0	0	2.4	NY HARRIMAN
1980MAY14	2315	44.3	70.7	0	0	2.1	ME E OF SPECKLED MT
1980MAY19	2340	45.3	75.3	0	0	1.3	PQ E OF OTTAWA
1980MAY20	2133	41.4	74.4	0	0	2.6	NY FLORIDA
1980MAY21	1922	43.0	72.4	0	0	1.6	NH NW OF KEANE
1980MAY23	0049	44.6	73.9	0	0	2.2	NY DANNEMORA
1980MAY23	0839	44.9	74.6	0	0	2.6	NY BOMBAY-MASSENA
1980MAY23	2019	47.5	70.1	0	0	0.3	PQ N OF LA POCATIERE
1980MAY25	1806	47.5	70.1	0	0	1.1	PQ N OF LA POCATIERE
1980MAY27	1802	46.8	69.1	0	0	1.5	ME E OF ROUND POND
1980JUN 6	1315	43.6	75.2	4	0	3.5	NY BOONVILLE
1980JUN12	1819	43.6	75.1	0	0	2.3	NY PORT LEYDEN
1980JUN12	1849	44.4	74.1	0	0	2.6	NY N OR SARANAC LAKE
1980JUN17	0053	47.6	70.1	0	0	1.2	PQ NE OF LA MALBAIE
1980JUN25	0306	45.0	69.4	0	0	1.7	ME NE OF CAMBRIDGE
1980JUN26	0132	45.1	73.0	0	0	2.0	PQ STANBRIDGE STATION
1980JUN28	1731	47.7	70.2	0	0	0.6	PQ N OF LA POCATIERE
1980JUN29	0325X	41.6	72.1	0	0	1.5	CT N OF NORWICH

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1980JUN29	0329	41.5	72.1	0	0	1.8 CT N OF NORWICH
1980JUN29	2104	44.1	72.6	0	0	1.9 VT S OF MONTPELIER
1980JUL 1	0306	47.5	70.7	4	0	3.6 PQ W OF LA MALBAIE
1980JUL 2	0750	47.3	70.4	0	0	3.2 PQ W OF LA POCATIERE
1980JUL 2	0757X	47.3	70.4	0	0	2.7 PQ W OF LA POCATIERE
1980JUL 4	1156	44.5	69.9	0	0	2.5 ME NW OF AUGUSTA
1980JUL 7	2237	45.2	69.5	0	0	2.2 ME DOVER-FOXCROFT
1980JUL12	0754	44.1	70.5	0	0	2.2 ME W OF AUBURN
1980JUL12	1503	44.7	68.8	0	0	2.0 ME S OF BANGOR
1980JUL15	0721	44.7	74.9	0	0	2.2 NY NORWOOD
1980JUL17	0501	44.8	67.4	0	0	1.9 ME NE OF MACHIAS
1980JUL25	0232	45.7	76.2	0	0	1.3 ON N OF FITZROY HARBOR
1980JUL25	0622	45.2	74.2	0	0	3.0 PQ SW OF MONTREAL
1980JUL25	0907	44.4	68.5	0	0	1.5 ME E OF PENOBSCOT BAY
1980JUL25	2224	47.8	70.1	0	0	2.6 PQ N OF LA MALBAIE
1980JUL28	0943	41.5	72.5	0	0	0.8 CT N OF MOODUS
1980JUL29	0237	45.2	66.9	0	0	2.1 NB PASSAMAQUODDY BAY
1980JUL31	0405	45.8	66.8	0	0	1.7 NB S OF FREDERICTON
1980AUG 2	1721	40.4	74.2	0	0	2.8 NJ KEYPORT
1980AUG 4	0032	46.7	65.9	0	0	2.6 NB W OF BLACKVILLE
1980AUG 8	0548	45.9	74.7	0	0	2.1 PQ E OF GLEN ALMOND
1980AUG 8	1015	45.6	65.2	0	0	2.3 NB N OF FUNDY NTL PARK
1980AUG 9	1039	46.0	74.7	0	0	1.7 PQ NE OF GLEN ALMOND
1980AUG11	0303	45.2	73.7	0	0	1.7 PQ S OF MONTREAL
1980AUG11	1454	43.5	75.2	0	0	3.3 NY BOONVILLE
1980AUG20	0935	42.1	83.1	5	0	3.3 OH WESTERN LAKE ERIE
1980AUG25	1314	41.4	67.8	0	0	2.8 MA GEORGES BANK
1980AUG30	0919	39.8	74.9	0	0	3.0 NY MEDFORD
1980AUG31	0623X	44.4	69.5	0	0	2.4 ME E OF CHINA LAKE
1980AUG31	0834	44.4	69.4	0	0	2.6 ME E OF CHINA LAKE
1980SEP 4	0430	41.1	73.8	0	0	2.6 NY THORNWOOD
1980SEP 4	0655	44.3	69.5	0	0	2.7 ME SE OF CHINA LAKE
1980SEP 4	2242	47.6	70.3	0	0	2.3 PQ N OF LA MALBAIE
1980SEP 5	2359	41.7	72.3	0	0	1.8 CT SW OF WILLIMANTIC
1980SEP 8	0559	44.7	69.0	0	0	3.2 ME NE OF DIXMONT
1980SEP10	1730	46.5	67.1	0	0	2.5 NB NASHWAAK LAKE
1980SEP11	1021	47.5	70.1	0	0	2.3 PQ LA MALBAIE
1980SEP21	0407	45.6	74.4	0	0	2.9 PQ W OF MONTREAL
1980SEP21	2052	43.6	74.0	0	0	2.1 NY BAKERS MILLS
1980SEP24	2248	47.0	76.6	0	0	2.8 PQ NW OF MANAWAKI
1980SEP27	0048	41.5	73.7	0	0	2.0 NY PAWLING
1980SEP27	0341	43.5	79.7	0	0	2.1 ON BURLINGTON
1980SEP28	0341	43.4	75.8	0	0	2.2 ON NW OF EFFINGHAM
1980SEP28	2220	43.8	74.1	0	0	2.6 NY SE OF BLUE MTN LAKE
1980SEP29	1459	46.2	69.4	0	0	1.5 ME SW OF EAGLE LAKE
1980SEP30	1826	47.7	69.7	0	0	2.8 PQ E OF LA MALBAIE
1980OCT 2	0013	47.6	69.9	0	0	2.3 PQ N OF ST. DENIS
1980OCT14	0058	43.1	80.6	0	0	3.4 ON SE OF FANSHAWE
1980OCT14	0819	43.9	74.5	0	0	1.0 NY BLUE MTN LAKE
1980OCT15	1702	41.3	73.9	0	0	1.5 NY W OF CROTON RESERVOIR
1980OCT20	0320	45.1	73.9	0	0	2.7 PQ SW OF MONTREAL
1980OCT20	0322X	45.2	73.9	0	0	2.2 PQ HOWICK
1980OCT20	0403X	45.2	73.9	0	0	2.2 PQ HOWICK
1980OCT24	1727	41.3	72.9	0	0	2.8 CT NE OF NEW HAVEN
1980OCT25	0041	41.3	72.9	0	0	2.7 CT NE OF NEW HAVEN
1980NOV 5	0618	45.5	74.2	0	0	2.4 PQ HUDSON
1980NOV 5	2240	43.7	71.4	0	0	2.7 NH LAKE WINNIPESAUKEE
1980NOV 9	1650	45.7	76.1	0	0	1.4 ON N OF FITZROY HARBOR
1980NOV14	1153	47.6	70.3	0	0	1.6 PQ E OF LA MALBAIE
						N OF FITZROY HARBOR
						N OF FITZROY HARBOR
						N OF FITZROY HARBOR
						N OF FITZROY HARBOR

Date	Time	NLat	WLon	Intensity[a]		Mag[b]	State/Province and Location
1980NOV15	1723	41.4	71.0	0	0	1.6	MA W OF CUTTYHUNK ISLAND
1980NOV15	1758	38.0	75.8	0	0	2.6	MD CHESAPEAKE BAY
1980NOV21	0409	45.3	71.0	0	0	2.6	NE OF RUMP MTN
1980NOV22	2128	45.2	69.2	0	0	2.6	ME SW OF MILO
1980NOV23	0039	42.6	71.4	0	0	2.5	MA S OF LOWELL
1980NOV25	0713	45.0	74.6	0	0	2.1	NY BOMBAY
1980NOV30	1735	45.9	74.4	0	0	1.7	PQ NW OF MONTREAL
1980DEC 9	0505	45.5	75.5	0	0	1.4	ON E OF OTTAWA
1980DEC12	2304	41.3	73.9	0	0	1.7	NY ANNSVILLE
1980DEC14	1804	44.7	73.9	0	0	1.9	NY LYON MTN
1980DEC25	1658	44.1	72.1	0	0	2.5	VT NW OF NEWBURY
1980DEC30	0548	45.5	71.5	0	0	2.3	PQ NE OF EAST ANGUS

[a]Modified Mercalli scale.

[b]Local magnitude, regardless of how it was actually determined.

[x]Event is judged to be either an aftershock or foreshock.

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