

Text and References To
Accompany "Map Showing the
Thickness and Character of
Quaternary Sediments in the
Glaciated United States East of the
Rocky Mountains"

U.S. GEOLOGICAL SURVEY BULLETIN 1921



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Text and References To Accompany "Map Showing the Thickness and Character of Quaternary Sediments in the Glaciated United States East of the Rocky Mountains"

By DAVID R. SOLLER

A discussion of map components and sediment distribution and lists of references for a regional, three-dimensional map of glacial deposits

U.S. GEOLOGICAL SURVEY BULLETIN 1921

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, Jr., Secretary

U.S. GEOLOGICAL SURVEY
DALLAS L. PECK, Director



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CONTENTS

Abstract	1
Section 1—Map Description and General Comments	1
Introduction	1
Acknowledgments	2
Digital Map Production and the Base Map	4
Map Units	4
Surficial Mapping	5
Till	5
Stratified Sediment	5
Coarse-Grained Stratified Sediment	5
Fine-Grained Stratified Sediment	6
Organic-Rich Sediment	8
Loess	8
Patchy Quaternary Sediment	9
Geology Beneath Bodies of Water	9
Thickness Mapping	9
Subsurface Mapping	10
Factors Affecting Sediment Texture and Distribution	11
Sediment Texture	11
Sediment Distribution	12
Summary	15
References Cited	18
Section 2—Sources and Reliability of Map Data	20
Connecticut	20
Surficial and Stack-Unit Information	20
Thickness Information	20
Illinois	21
Surficial and Stack-Unit Information	21
Thickness Information	21
Indiana	21
Surficial Information	22
Thickness Information	22
Iowa	22
Surficial and Stack-Unit Information	23
Thickness Information	23
Kansas	23
Surficial and Stack-Unit Information	23
Thickness Information	23
Kentucky	24
Surficial, Stack-Unit, and Thickness Information	24
Maine	29
Surficial and Stack-Unit Information	30
Thickness Information	30
Additional Reference	30

Section 2—Sources and Reliability of Map Data—Continued

Massachusetts	30
Surficial and Stack-Unit Information	31
Thickness Information	31
Michigan	31
Surficial and Stack-Unit Information	31
Thickness Information	31
Minnesota	32
Surficial and Stack-Unit Information	32
Thickness Information	32
Missouri	33
Surficial Information	33
Thickness Information	33
Montana	33
Surficial and Stack-Unit Information	34
Thickness Information	35
Additional Reference	35
Nebraska	35
Surficial, Stack-Unit, and Thickness Information	35
New Hampshire	36
Surficial and Stack-Unit Information	36
Thickness Information	37
New Jersey	37
Surficial and Stack-Unit Information	37
Thickness Information	38
New York	38
Surficial and Stack-Unit Information	38
Upstate New York	38
Long Island	40
Thickness Information	40
Upstate New York	40
Long Island, Staten Island, and Adjacent Waters	41
Additional References	42
North Dakota	42
Surficial and Stack-Unit Information	43
Thickness Information	43
Additional Reference	43
Ohio	43
Surficial and Stack-Unit Information	44
Thickness Information	44
Pennsylvania	44
Surficial and Stack-Unit Information	44
Northeastern Pennsylvania	44
Northwestern Pennsylvania	46
Thickness Information	47
Northeastern Pennsylvania	47
Northwestern Pennsylvania	47
Additional References	47
Rhode Island	47
Surficial and Stack-Unit Information	47
Thickness Information	48
South Dakota	48
Surficial and Stack-Unit Information	48
Thickness Information	49

Section 2—Sources and Reliability of Map Data—Continued

Vermont	49
Surficial and Stack-Unit Information	49
Thickness Information	49
Additional References	50
Wisconsin	50
Surficial and Stack-Unit Information	50
Thickness Information	51
Great Lakes	51
Character of Lake-Bottom Sediments	52
Thickness of Quaternary Sediment Beneath the Great Lakes	52
Atlantic Offshore	52
Character of Bottom Sediments	53
Thickness of Quaternary Sediment	53
Ontario, Canada	54
Surficial Information	54
Thickness Information	54

FIGURES

1. Index map showing outline of the four maps in this series (Soller, in press a,b,c,d) 2
2. Map showing the relative reliability of the surficial geologic data by State 6
3. Diagram showing the range of particle sizes in the mapped surficial units 7
- 4-7. Maps showing:
 4. Relative reliability of Quaternary sediment-thickness data by State 8
 5. Texture of surficial till 12
 6. General lithology of bedrock directly beneath the Quaternary sediments 14
 7. Thickness (simplified) of Quaternary sediments within the mapped area 16
8. Cross sections showing the relations among bedrock topography, Quaternary sediment thickness, and ice lobation 17

METRIC CONVERSION FACTORS

For readers who wish to convert measurements from the inch-pound system of units to the metric system of units, the conversion factors are listed below:

Multiply inch-pound unit	By	To obtain metric unit
square mile (mi ²)	2.590	square kilometer (km ²)
foot (ft)	.3048	meter (m)

Text and References To Accompany "Map Showing the Thickness and Character of Quaternary Sediments in the Glaciated United States East of the Rocky Mountains"

By David R. Soller

Abstract

A 1:1,000,000-scale map of Quaternary deposits has been compiled for the glaciated area of the United States east of the Rocky Mountains (that is, the area covered by the Laurentide ice sheets). Parts of southern Ontario, areas beneath the Great Lakes, and parts of the submerged eastern seaboard are also included on the map. The map has three components that, together, provide the first regional three-dimensional view of these deposits. These map components are the surface distribution of Quaternary sediments, the total thickness of Quaternary sediments, and the distribution of significant buried Quaternary units. For many areas, this is the first map of Quaternary sediment thickness published at any scale. This report provides supporting information for the map, preliminary interpretations of sediment distribution, and the list of geologic sources used to generate the map.

Within the mapped area, there is a particular need for three-dimensional geologic mapping to support decisions on water resources and land use. Approximately 40 percent of the U.S. population resides within the mapped area, which is less than one-quarter the size of the conterminous United States. This map is intended to supplement the more detailed mapping on which it is based and is designed to be a regional planning tool.

Through the Pleistocene, large deposits of thick glacial sediment accumulated between certain late Wisconsinan glacial lobes, on bedrock topographic highs, whereas relatively thin deposits generally accumulated in the adjacent bedrock lowlands occupied by drainage and ice lobes. The lithology of the bedrock and its resistance to erosion in part controlled the patterns of ice lobation and the distribution of thick sediment. On a local scale, the spatial relation of these sediment masses to ice lobation has been suggested in places, and a regional correlation may have been assumed. This map provides the first comprehensive, regional view of glacial sediment thickness to permit such a correlation to be assessed.

SECTION 1—MAP DESCRIPTION AND GENERAL COMMENTS

INTRODUCTION

This Bulletin is a companion to a series of four 1:1,000,000-scale maps that portray the thickness and character of Quaternary sediments within a part of the area covered by the Laurentide ice sheets (Soller, in press a,b,c,d). The mapped area encompasses the glaciated United States east of the Rocky Mountains and also includes parts of southern Ontario, areas beneath the Great Lakes, and part of the Atlantic offshore area (fig. 1). This series of maps, hereafter referred to in places as the "Quaternary sediments map," is a result of regional synthesis and interpretation of available Quaternary geologic data, derived from about 850 sources of information. This section describes the map units, map compilation, and regional patterns of sediment distribution, whereas section 2 contains the geologic source data and a qualitative assessment of data reliability for each State.

The three components of the map combine to provide the first regional, three-dimensional view of these deposits. These map components are the surface distribution of Quaternary sediments, the total thickness of Quaternary sediments, and the distribution of significant buried Quaternary units. Quaternary sediments include glacial and Holocene sediments. Subsurface information is not available for most of the mapped area, and, therefore, the depiction of buried units is uneven. Where buried units are shown, the complex geologic settings in which they occur are greatly simplified because of the small scale of this map series.

This map differs in concept from most published State and regional glacial geologic maps, which generally use stratigraphic or geomorphic map units. Those maps show the chronology of geologic events such as ice

advances or retreats, as determined by the glacial deposits at the surface. Regional maps of continental glacial deposits such as the "Glacial Map of the United States East of the Rocky Mountains" (Flint, 1959) and the "Quaternary Geologic Atlas of the United States" (for example, Lineback and others, 1983) are examples of the traditional, event-oriented approach to mapping. The Quaternary sediments map complements event-oriented maps by showing the thickness and character of glacial sediments without regard to age of the deposit.

Population growth and the resulting increase in demand for agricultural production, construction materials, land development, waste-disposal sites, and ground-water resources have created a growing need for geologic maps that can be directly applied to hydrologic, environmental, and land-use problems. The type of geologic map most appropriate for these applications depicts the texture and other physical aspects of the sediments or rocks to a specified depth; in other words, it is a texturally oriented, three-dimensional geologic map. An effective technique for three-dimensional geologic mapping and applications to hydrogeologic and land-use studies was discussed by Kempton and Cartwright (1984). Their technique is based on three-dimensional lithostratigraphic mapping to a specified depth; map units show the vertical succession of deposits (the stack-unit concept discussed by Kempton, 1981). These maps require detailed subsurface lithologic and stratigraphic information, surficial geologic mapping, and soil mapping. The stack-unit map can directly support water- and land-use studies, especially when combined with other data such as hydrogeologic, topographic, and land-use information. Examples of geologic map investigations that have been applied to water- and land-use issues include, but are certainly not limited to, the map folio of the Hartford North (Connecticut) quadrangle (Pessl and others, 1972), the San Francisco Bay region study (Kockelman, 1976), the Baltimore-Washington urban area study (Froelich and others, 1980), the urban-planning examples given in Robinson and Spieker (1978), and the county-scale geologic and planning studies in Illinois (Hackett and McComas, 1969; Bergstrom and others, 1976; Hunt and Kempton, 1977; Berg and others, 1984).

The glaciated region of the United States depicted in this map series has a particular need for three-dimensional geologic mapping that can support decisions on water-resource and land-use issues including waste-disposal siting and non-point-source pollution. Approximately 40 percent of the U.S. population resides within the mapped area, which is less than one-quarter the size of the conterminous United States. The region also contains a major portion of the Nation's agricultural and industrial capacity.

This map series is a regional overview of the three-dimensional distribution of sediments for a large area and is intended to supplement the more detailed work on which it is based. I hope that this series of maps will generate

interest in more detailed three-dimensional geologic mapping of these, and other, deposits. Particularly in populated areas, detailed mapping is vital to the site-specific planning and assessment of the effects of human activities at and beneath the land surface. In contrast, regional maps such as the four maps of this series serve to place local, detailed mapping in context, to permit the extrapolation of data into unmapped areas, and to depict large-scale, regional geologic features and patterns that are beyond the scope of detailed, local mapping. This series of maps is also a regional planning document that can assist in setting priorities for areas in need of more detailed mapping; subsequent detailed mapping should then be incorporated into an updated regional map. Geologic mapping is an iterative process, and the maps of this series should be considered as only the initial regional view of the glacial sedimentary framework east of the Rocky Mountains.

Acknowledgments

During map compilation and production, I sought advice from many individuals in different disciplines. These

people have contributed to the generation of the map, and I am grateful for their help. I particularly thank Byron D. Stone of the U.S. Geological Survey (USGS) for his suggestions on map concept and project scope, John P. Kempton and Richard C. Berg (Illinois State Geological Survey) for their encouragement to pursue new techniques, Kenneth J. Lanfear, Will R. Stettner, and James R. Estabrook (USGS) for assistance in the technical aspects of map digitization and production, and Carl Koteff (USGS) for his efforts in originating this project.

I also thank the many geologists consulted during this map project for their willingness to share information and insight, for their advice on mapping interpretations, and for their comments during map review. Their names are listed below; I apologize if I have inadvertently omitted anyone.

Atlantic offshore—Robert N. Oldale and Sally W. Needell (both USGS), Francis S. Birch (University of New Hampshire), Joseph T. Kelley (University of Maine), Ralph S. Lewis (Connecticut Geological and Natural History Survey).

Connecticut—Janet R. Stone, John P. Schafer (both USGS).

Great Lakes—Richard L. Thomas (International Joint Commission, Windsor, Ontario), C.F. Michael Lewis (Bedford Institute of Oceanography, Dartmouth, Nova Scotia), Richard J. Wold (EG&G Geometrics, Sunnyvale, Calif.), Peter G. Sly (Canada Centre for Inland Waters, Picton, Ontario), Norm A. Rukavina (Canada Centre for Inland Waters, Burlington, Ontario), John P. Coakley (National Water Research Institute, Burlington, Ontario), David L. Gross (Illinois State Geological Survey), S. Jeffress Williams (USGS), Jonathan A. Fuller (Ohio Geological Survey), Allen S. Hunt (University of Vermont).

Illinois—John P. Kempton, Richard C. Berg, Paul B. DuMontelle, Thomas M. Johnson, Leon R. Follmer, Myrna M. Killey, E. Donald McKay, Jerry R. Miller (all Illinois State Geological Survey).

Indiana—Ned K. Bleuer, Gordon S. Fraser (both Indiana Geological Survey).

Iowa—George R. Hallberg, Timothy J. Kemmis, Raymond R. Anderson (all Iowa Geological Survey).

Kansas—Jane E. Denne (Kansas Geological Survey).

Kentucky—Robert C. McDowell (USGS), Martin C. Noger (Kentucky Geological Survey).

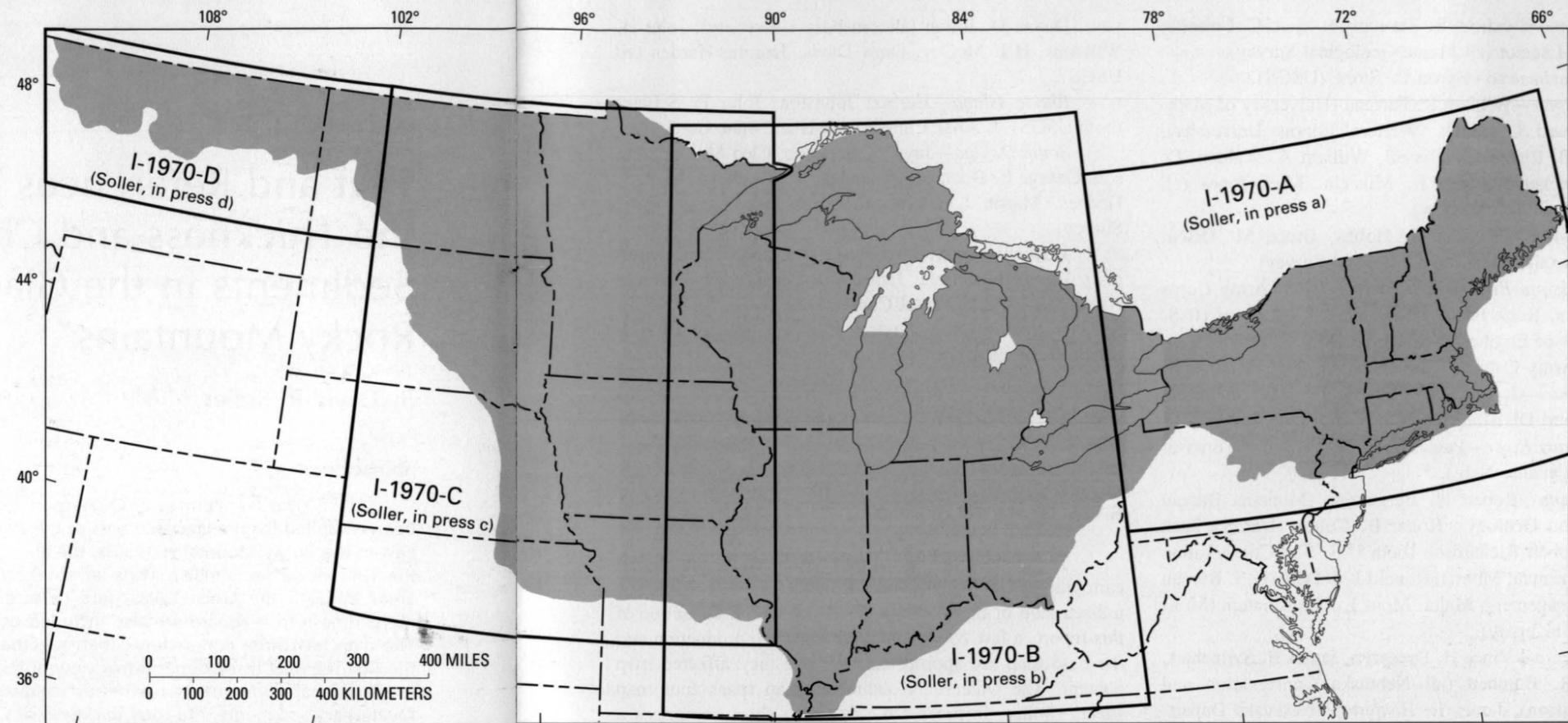


Figure 1. Index map showing outline of the four maps in this series (Soller, in press a,b,c,d). The mapped area is shaded.

Maine—Woodrow B. Thompson, Marc C. Loiselle, E. Melanie Lanctot (all Maine Geological Survey).

Massachusetts—Byron D. Stone (USGS).

Michigan—William R. Farrand (University of Michigan), Richard L. Rieck (Western Illinois University), Robert Reed, Richard P. Bissell, William A. Walden, D. Michael Bricker, Randall L. Milstein, Mick Jones (all Michigan Geological Survey).

Minnesota—Howard C. Hobbs, Bruce M. Olsen, Gary Meyer (all Minnesota Geological Survey).

Mississippi River—Ron Pearson (U.S. Army Corps of Engineers, Rock Island, Ill.), Mike Klosterman (U.S. Army Corps of Engineers, St. Louis, Mo.), Terry Jorgenson (U.S. Army Corps of Engineers, St. Paul, Minn.).

Missouri—James H. Williams, John W. Whitfield (both Missouri Division of Geology and Land Survey).

Missouri River—Paul Barndt (U.S. Army Corps of Engineers, Omaha, Neb.).

Montana—Robert N. Bergantino (Montana Bureau of Mines and Geology), Roger B. Colton (USGS), Jack Rodgers, Robert Richardson (both U.S. Soil Conservation Service, Bozeman, Mont.), Ronald J. Soiseth (U.S. Bureau of Land Management, Malta, Mont.), John Montain (Montana State University).

Nebraska—Vince H. Dreeszen, James B. Swinehart, Raymond R. Burchett (all Nebraska Conservation and Survey Division), James L. Howerton (Nebraska Department of Roads).

New Hampshire—John E. Cotton (USGS), Robert Davis (former New Hampshire State Geologist).

New Jersey—Byron D. Stone (USGS), David P. Harper, Scott Stanford, Ron Witte (all New Jersey Geological Survey).

New York—Allan D. Randall, Forest Lyford, Andrew Cohen, Richard K. Krulik, Herbert T. Buxton (all USGS), Ernest H. Muller (Syracuse University), Parker E. Calkin (State University of New York, Buffalo), Donald H. Cadwell, Robert J. Dineen (both New York State Geological Survey).

North Dakota—John P. Bluemle (North Dakota Geological Survey), Lee Clayton (Wisconsin Geological and Natural History Survey).

Ohio—Dennis N. Hull, Sherry L. Weisgarber, Rene L. Fernandez, Mike Angle, C. Scott Brockman, Richard R. Pavey (all Ohio Division of Geological Survey), John Voytek (Ohio Division of Water), Stanley E. Norris (USGS, retired), Jane L. Forsyth (Bowling Green University), Richard P. Goldthwait (Ohio State University), Stanley M. Totten (Hanover College, Indiana).

Ontario—Edward V. Sado, Peter Barrett, Robert J. Fulton, Robert Geddes (all Ontario Geological Survey).

Pennsylvania—George H. Crawl (Ohio Wesleyan University), Thomas M. Berg, William D. Sevon (both Pennsylvania Bureau of Topographic and Geologic Sur-

vey), Duane D. Braun (Bloomsburg University), John H. Williams, H.J. McCoy, Drew Davis, Jennifer Harden (all USGS).

Rhode Island—Herbert Johnston, John P. Schafer (both USGS), J. Allan Cain (Rhode Island State Geologist).

South Dakota—Jay P. Gilbertson, Cleo M. Christenson, George E. Duchossois, Dennis W. Tomhave, Lynn S. Hedges, Martin J. Jarrett (all South Dakota Geological Survey).

Vermont—Charles A. Ratte (Vermont State Geologist), David Butterfield, James W. Ashley (both Vermont Agency of Environmental Conservation).

Wisconsin—Lee Clayton, John W. Attig (both Wisconsin Geological and Natural History Survey), David M. Michelson (University of Wisconsin), Howard Lorenz (U.S. Soil Conservation Service, Marinette, Wis.).

DIGITAL MAP PRODUCTION AND THE BASE MAP

The maps of this series were produced by new digital cartographic techniques (Soller and others, 1990). Although a discussion of these techniques is not within the scope of this report, a few comments on digital map production and the base map are appropriate, because they affected map content. The Quaternary sediments map spans four map sheets (Soller, in press a,b,c,d). Each sheet comprises a hand-mosaicked group of 4°×6° quadrangles from the International Map of the World Series (1:1,000,000 scale) or Army Map Service 1:1,000,000-scale maps. Because these map sheets include as much as 12° of latitude and longitude and because each quadrangle has unique projection parameters, the mosaic is not precise. Between certain quadrangles, gaps exist in the base map. In order to preserve the registration of the geologic information to the base map without sacrificing the spatial integrity of the digital data, entire map sheets were not digitized. Rather, the four layers of geologic information shown on the map (that is, character of sediments exposed at the surface, thickness of Quaternary sediments, buried units and surface veneer units, and miscellaneous point and line information) were digitized separately for each 4°×6° quadrangle and recombined onto the base map.

MAP UNITS

The map units depict the distribution of sediment textures at the surface, the total thickness of Quaternary sediments, and selected subsurface data. Different colors are used to depict surface sediment character, variations in color intensities depict thickness of Quaternary sediments, and overprinted patterns depict selected subsurface information. On these maps, Quaternary sediments include

glacial and glacially related deposits, a minor amount of Pleistocene nonglacial sediments within the glaciated area, and Holocene sediments that may or may not overlie glacial deposits. The term "glacially related" refers to nonglacial sediments that owe their existence to the activity of glacial ice; for example, the lacustrine sediments deposited in outwash-dammed lakes in northern Kentucky and adjacent States by nonglacial streams. Areas of Quaternary colluvium not derived directly from glacial deposits are small and are not shown.

Existing information from about 850 sources (see section 2) was compiled and reinterpreted to make the maps of this series. The density and detail of this information varied greatly over the region; detailed, sediment-based three-dimensional maps were published for some areas, whereas glacial geologic information was lacking for other areas. An assessment of data quality and reliability for both surficial and thickness information is provided on the Quaternary sediments map and in section 2 of this report.

A three-dimensional map could show the nature and extent of every subsurface unit; however, subsurface data available for the mapped area were sparse, and only well-delineated buried units could be shown. Although subsurface stratigraphy is not well known, the total thickness of these glacial (and postglacial) deposits can be confidently estimated in most places. The Quaternary sediments map, therefore, through the thickness information, shows the generalized framework of the glacial deposits. An understanding of three-dimensional variations in sediment texture within the glacial deposits must come from future three-dimensional studies in greater detail.

Surficial Mapping

The quality of the surficial map data and extent of map coverage varied widely. A relative, and subjective, measure of the quality of the source maps and the resulting reliability of the surficial map data are shown in figure 2. In this context, the term "quality" refers to extent of coverage, level of detail, and suitability of the source maps for reinterpretation.

In general, surficial map units are defined by terrain, map scale, and mapping approach (for example, stratigraphic, geomorphic, or sediment type). As a result, map units may not correlate with units on maps in nearby areas. For example, a map that emphasizes geologic events such as ice stillstand and moraine-building, or inundation by glacial lakes, may not correlate with an adjacent map showing kinds of surficial sediments; where the event-oriented map may show a moraine composed largely of till, the sediments-oriented map shows the actual distribution of sediment types without delineating the moraine. Although surficial geologic maps of one kind or another are available for much of the region, soil survey maps were used to assist

in mapping areas where geologic data were sparse. In many areas, soil surveys were useful, but in some places, for example on till plains that were inundated by glacial lakes or where eolian sand or silt occurs as a veneer over glacial deposits, the soil surveys' usefulness is limited. In rare instances, only topographic map coverage was available, and it was used to interpolate between mapped areas.

To achieve consistency in mapping across such a large area, and to unify the wide spectrum of mapping styles and glacial geologic settings, a simple, uniform classification of deposits was devised. This classification is based on the overall character of the sediment; here, "character" includes consideration of a sediment's lithology, grain size, sorting, stratification, and depositional environment and defines the texture of the sediment as well as its origin. These sediments are classified as glacial till (unsorted and unstratified sediment), coarse-grained stratified sediment, fine-grained stratified sediment, organic-rich sediment, and windblown sediment (mostly loess). Loess is largely silt; eolian sand is included in the category of coarse-grained stratified sediment and is mapped as a veneer (see section on "Subsurface Mapping").

Till

Till, the most widespread map unit, consists of material deposited in contact with glacial ice; the other sediment units on this map were sorted and deposited by water or wind. Till is a poorly sorted and generally unstratified deposit composed of particles ranging in size from clay to large boulders (fig. 3). The relative proportions of these size fractions vary greatly, resulting in a range of texture from dense and compact clayey till, in which few grains are larger than sand size, to loose, sandy till containing abundant boulders and only small amounts of the finer size fractions. Because till covers much of the mapped area, a more comprehensive discussion of its texture is provided in the section on "Sediment Texture."

Stratified Sediment

Sediment released from melting glaciers is generally sorted by running water and is found as a stratified deposit in a variety of settings including glaciolacustrine, glaciofluvial, and outwash plain. These deposits are subdivided by grain size (fig. 3). However, as shown in figure 3 and discussed below, coarse-grained and fine-grained stratified deposits have overlapping textural ranges.

Coarse-Grained Stratified Sediment

Deposits of coarse-grained stratified sediment generally consist of layered sand and gravel, with less common silt and clay beds, deposited in fluvial, glaciofluvial,

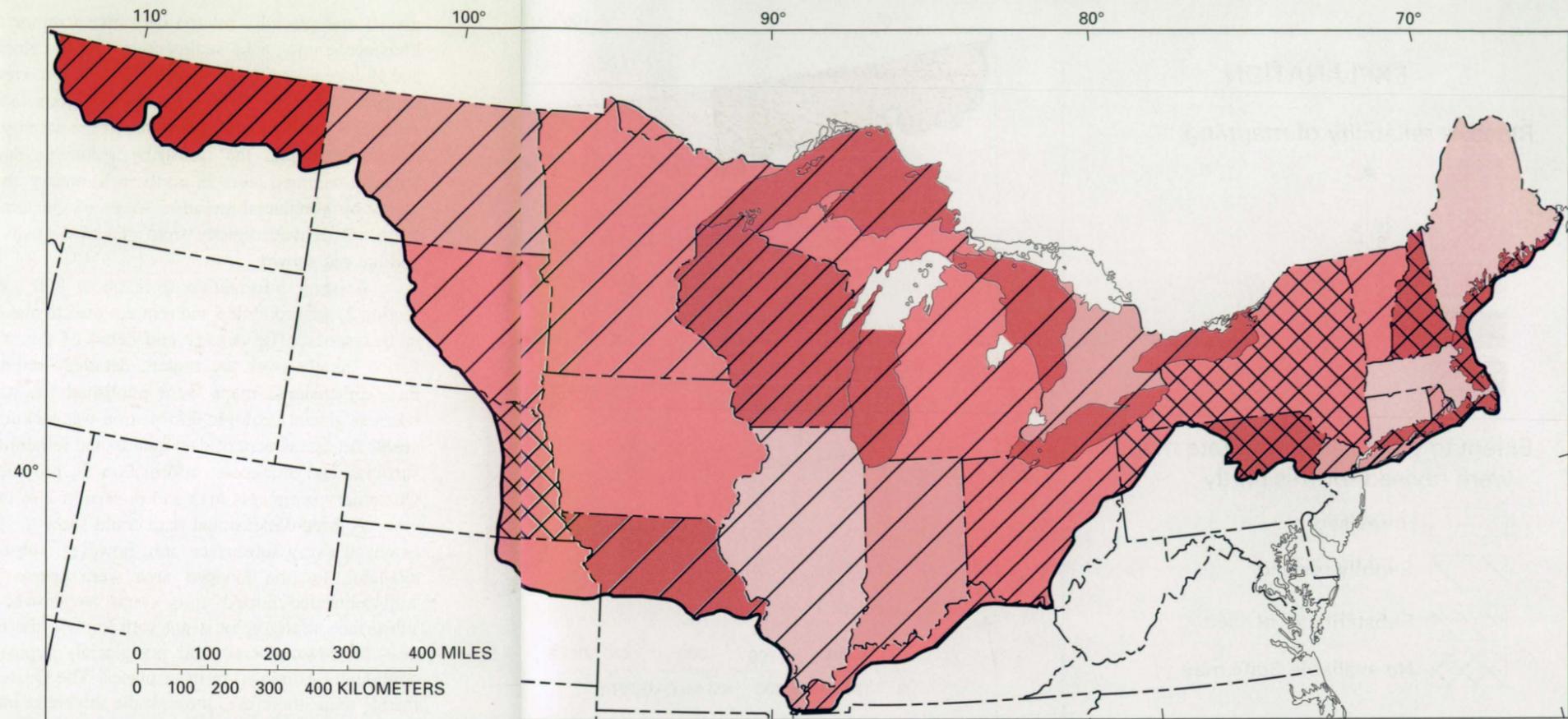
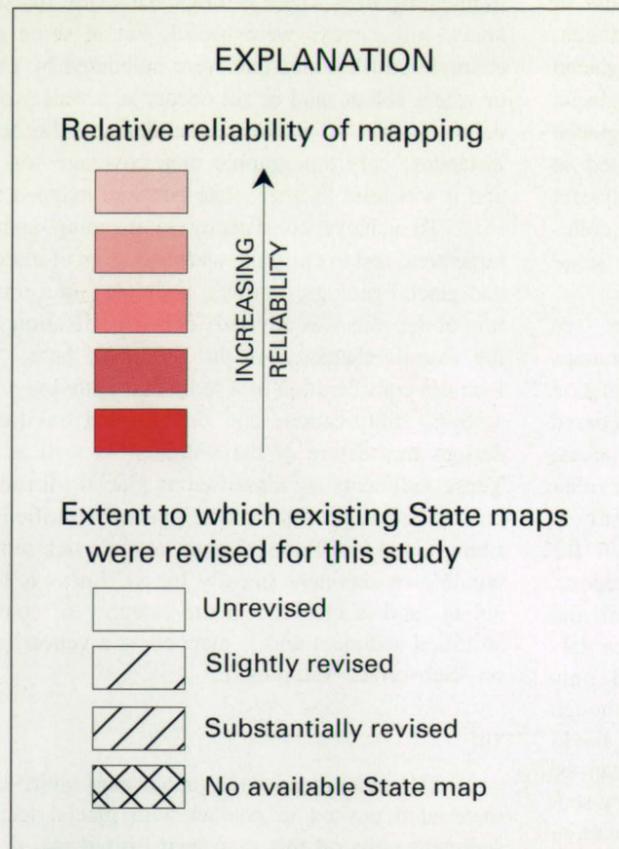


Figure 2. Relative reliability of the surficial geologic data, by State, and the degree to which existing State surficial maps were revised for this study. The degree of revision largely reflects differences in the emphasis of available surficial mapping (for example, stratigraphy, geomorphology, or sediment type). The status and detail of surficial mapping vary greatly from State to State. For example, for

Massachusetts and Connecticut, maps of surficial materials have been compiled at 1:125,000 scale from 1:24,000-scale maps, and these data could be used in this map with no revision. For New York and New Hampshire, detailed surficial geologic mapping is sparse, and the data for this map had to be compiled from a combination of geologic reconnaissance, soil, and topographic maps.

deltaic, and outwash-plain settings. Holocene alluvium has also been included in this unit; in places, it is silty or clayey, and it may overlie glacial sand and gravel. In many valleys, thick glacial meltwater sediments underlie thin Holocene alluvium. During deposition of coarse-grained stratified sediment, changes in flow regime and sediment supply were common, and sediment texture varies correspondingly. Thus, some interbedded fine-grained sediment is included in this unit (see fig. 3). Eolian sand, which has a patchier and more limited distribution than loess, is likewise shown only as a veneer (of coarse-grained stratified sediment).

In some areas, outwash in major valleys dammed tributary stream valleys, creating lakes behind the outwash. Late Wisconsinan lake sediments in tributaries in southern Illinois, southern Indiana, and northern Kentucky formed in this way. In many places, these lakes formed outside the limit of glaciation and thus contain sediments of nonglacial or periglacial origin. Because these lake sediments are

related to glacial action, they are included on the map. Some of these lake sediments and some fluvial deposits (for example, those along the western margin of the mapped area in Nebraska and in the Mississippi River valley in Missouri) are so far beyond the limit of glaciation that their relation to glacial processes is highly speculative.

In Nebraska, near the western limit of glaciation, fluvial sand and gravel of Pleistocene age derived from western sources are interbedded with eastern-source glacial outwash. Of necessity, these western-source sediments have been included in this unit. Some of the section is interbedded loess, or loess reworked and deposited as a silty fluvial unit; this loess is especially common in the upper part of the section but could not be shown separately at this map scale.

Fine-Grained Stratified Sediment

Deposits of fine-grained stratified sediment generally are clay, silt, and very fine sand but include lesser amounts

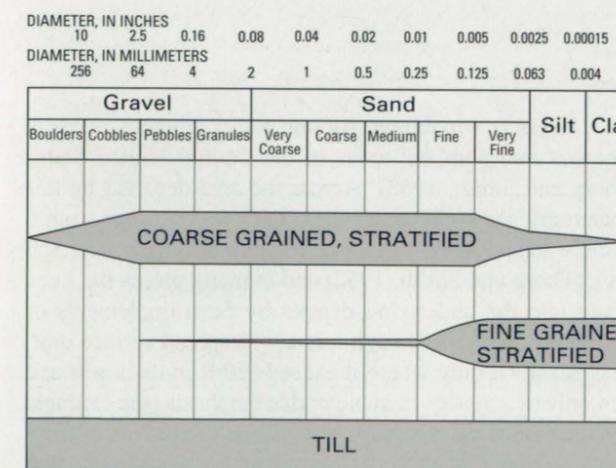


Figure 3. Range of particle sizes in the mapped surficial units (adapted from Stone and others, 1979, figs. 2, 3).

of coarser material (fig. 3), commonly as interbeds. Fine-grained stratified sediments were deposited in quiet water, mostly in proglacial lakes. In some parts of the Great Lakes and the Atlantic offshore area, thick accumulations of Holocene mud overlie fine-grained stratified glacial-lake sediments; these muds are included in this map unit. This unit also includes the finer grained lake sediments that occur in tributaries dammed by outwash in major valleys outside the limit of glaciation. These deposits, as mentioned above, are inferred to be glacially related, but this inference is in some places highly speculative.

On old lake plains, particularly around the Great Lakes, clayey till commonly has been winnowed by lake waters or has incorporated an earlier lake deposit. These tills may superficially resemble fine- or coarse-grained stratified lake sediments, but they retain essential characteristics of till and are mapped as such. On previous maps of this region (for example, Flint, 1959), these lake plains were largely mapped as lake sediment. In Montana and North Dakota, previous maps (Colton and others, 1961, 1963) showed proglacial lakes and inferred lake deposits; these deposits, however, are quite sparse and are not shown on the Quaternary sediments map.

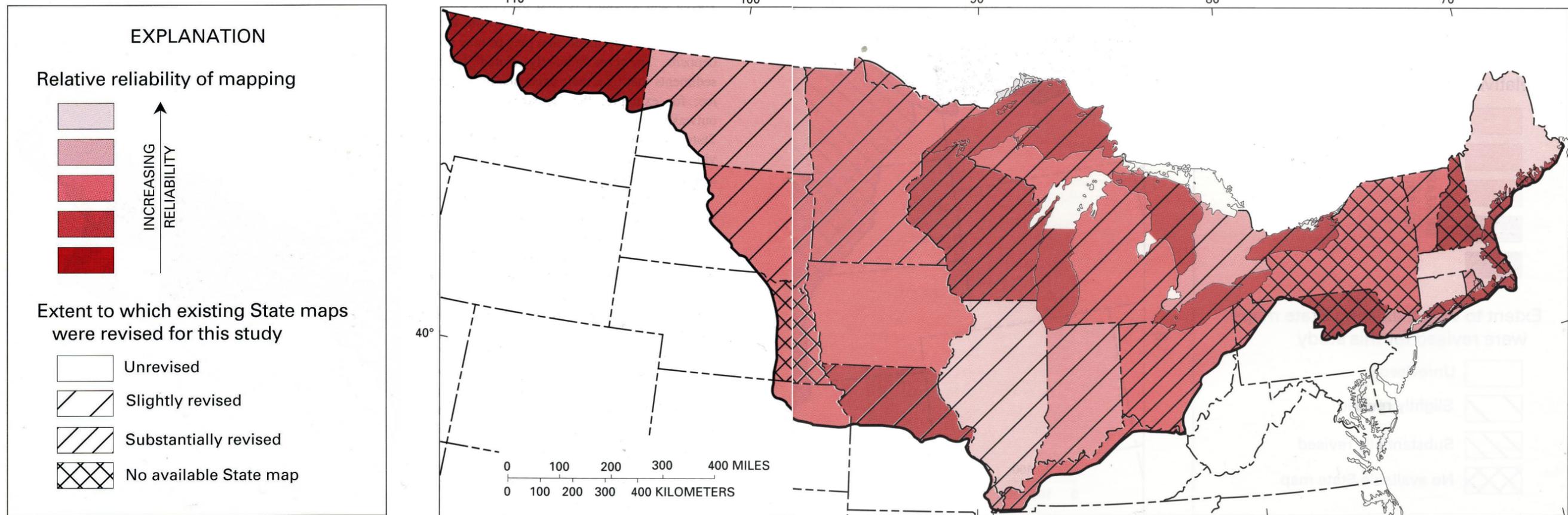


Figure 4. Relative reliability of Quaternary sediment-thickness data, by State, and the degree to which existing State maps were revised for this study. The degree of revision reflects differences in the type of thickness data available and addition of new data by the author. The status and detail of thickness mapping vary greatly from State to State. For example, for Massachusetts and Con-

necticut, thickness mapping has been compiled at 1:125,000 scale from detailed data, and the compilation could be used in this map with no revision. For New York and New Hampshire, information is sparse, and the thickness data for this map had to be gathered from widely scattered well-log data and a few geologic reports.

Organic-Rich Sediment

Organic-rich sediment, consisting mostly of peat, swamp deposits, and marsh deposits, occurs on the youngest (late Wisconsinan) glacial deposits where postglacial drainage is poor. In most areas, it occurs in relatively small patches, but, in northern Minnesota, peat is extensive and covers a poorly drained part of the glacial Lake Agassiz basin. This unit is generally less than 20 ft thick; therefore, where the total thickness of Quaternary sediments exceeds the lowest thickness value mapped (50 ft), the unit is inferred to overlie older Quaternary sediment. In such areas, organic-rich sediment is depicted as a veneer, and the unit known or inferred to lie beneath it is also mapped. Methods for portraying the veneer and the underlying unit on the map are discussed in the "Subsurface Mapping" section and in the explanation on the maps.

Loess

Loess is windblown silt and lesser amounts of sand; it covers many upland areas in the Central United States (Thorp and Smith, 1952). Across the area depicted by this Quaternary sediments map, loess thicknesses range from 0 to more than 100 ft, but loess is commonly less than 8 ft thick (Thorp and Smith, 1952) and in many places has been mixed into the underlying deposit by farm implements or natural processes. Although it is a widespread surface unit, loess is shown only where it exceeds 20 ft in thickness and then only as a veneer to avoid undue emphasis (see example in explanation on the maps and in the "Subsurface Mapping" section below). Loess is generally not shown over stratified deposits in stream valleys because it is assumed that late glacial and Holocene erosion has largely removed the loess or incorporated it into fluvial sediment (that is,

into the coarse-grained stratified unit). However, near the glacial border in Nebraska, thick loess is mapped over outwash deposits.

Patchy Quaternary Sediment

Areas where Quaternary sediment does not blanket the surface are common in some places within the glacial limit. In those areas, patchy Quaternary sediment may occur with exposures of bedrock, of residuum, or of colluvium not derived from glacial deposits. The proportion of nonglacial to glacial material in these areas ranges from numerous isolated exposures of bedrock in an area of thin till to patchy, isolated exposures of till or stratified deposits on a bedrock landscape that has preserved little evidence of glaciation. In many areas, Quaternary sediment is absent or sparse both near the limit of glaciation and in mountainous or dissected areas within the glaciated region. Extensive areas of bedrock occur mostly in upland areas where Quaternary sediments are dominantly till. Therefore, the map color is the same for patchy sediment as for till, and a color pattern is used to distinguish it from areas of continuous till cover. In one broad area in the St. Lawrence

lowland in northernmost New York near Lake Ontario, the patchy sediment is not till but is mostly fine-grained stratified deposits.

Geology Beneath Bodies of Water

Beneath the Atlantic Ocean, the Great Lakes, and some other large lakes, the materials are mapped where data permitted. In most lakes, however, the underlying geology and sediment thickness are unknown. To simplify map preparation and digitizing, a somewhat arbitrary division was used for lakes lacking subbottom geologic information: for relatively small lakes (for example, 5 mi²), geologic data were extrapolated from the surrounding land, but, for larger lakes, extrapolation was not attempted.

Thickness Mapping

The quality and distribution of thickness data vary greatly because the data base ranges from detailed statewide compilations to sparse and poorly distributed control by well logs. A relative, and subjective, measure of the quality of the source maps and the resulting reliability of the thickness data are shown in figure 4. In this context, the

term "quality" refers to extent of coverage and level of detail. For 11 States, this map series provides the first statewide thickness map of Quaternary deposits; it is also the first drift-thickness map for the areas under water. For nearly all of the remaining States, new or unpublished thickness data supplemented the existing maps.

The surficial character of the sediments was compiled and then used, with topography, as a guide for mapping sediment thickness in places of limited data. This procedure improved the continuity and reliability of thickness contours in many areas for two reasons. First, the contact between surficial lithologies may mark a large change in overall thickness of deposits. For example, on the Appalachian Plateau of west-central New York, uplands covered by thin deposits of till are dissected by deep, narrow valleys containing sequences of stratified, water-lain sediment commonly more than 200 ft thick. At the map scale of 1:1,000,000, the contact between till and stratified sediment closely approximates the valley wall; even where thickness data are sparse, this contact serves as the guide to constrain the thickness contours to the stratified sediment areas within the valley. Without the surficial geology as a constraint, the limited well-log data would be of use only as point data; however, where surficial geology and topography are considered, these limited data are used most effectively to project thickness contours into areas with little or no well-log data.

Second, in many areas, topographic relief is sufficient to significantly affect the thickness of the underlying sediments. Some compilations used in the preparation of these maps are so generalized that the thickness contours are not constrained by relief of the land surface. Where thick deposits in a buried valley are deeply dissected by cross-cutting modern drainage, the thickness contours should not cross the low areas of the dissected terrain. On the four maps of this series, where modern stream valleys overlie buried valleys, the thickness contours that depict thick sediments in the buried valleys are generally constrained by the limits of the modern valley, especially where bedrock is exposed along valley walls.

In a few areas, because of lack of available data, the glacial sediments cannot be differentiated from underlying deposits. Beneath the thick drift of Michigan's southern peninsula, red beds of possible Jurassic age are patchily distributed (Schaffer, 1969; Rhoads and others, 1985). The distribution of these red beds is uncertain, and they are difficult to recognize on well logs; therefore, some minor part of the sediment thickness in Michigan as shown on the Quaternary sediments map may be the red beds.

Elliptical landforms, shaped and oriented by over-riding ice, are common in some areas. They are generally composed of dense, compact till, but some are rock cored or entirely rock. The composition of these streamlined landforms can be determined by augering; however, because drill data are uncommon, most maps (including these) treat

all oriented, streamlined landforms as a group. Drumlins are streamlined hills that are generally composed of till; in areas of thin till, these features are relatively thick accumulations of till. In New England, where till is typically less than 15 ft thick on the uplands, till beneath drumlins commonly is more than 40 ft thick. Although less thick than the lowest contour value, and of small size, drumlins are shown on the maps of this series by symbols.

Nearly all thickness and topographic data used to compile the Quaternary sediments map were reported in U.S. customary units (feet). For simplicity and accuracy during map compilation, this system was retained. The contour intervals on the map are 0–50 ft, 50–100 ft, 100–200 ft, 200–400 ft, 400–800 ft, and greater than 800 ft.

Subsurface Mapping

A three-dimensional map could, ideally, portray the nature and extent of every subsurface unit. However, the geometry and textures of nonmarine Quaternary deposits can be quite complex, varying both vertically and laterally over short distances. The data base needed to adequately predict the subsurface geometry of these units is unavailable for most areas. Although the amount and distribution of subsurface information vary greatly from State to State, enough is available to allow the Quaternary sediments map to show a cursory impression of subsurface variability and the general configuration of regional, large-scale glacial textural contrasts in the subsurface.

For some small parts of the continentally glaciated United States, the nature of subsurface glacial lithologies is sufficiently well known to permit detailed three-dimensional mapping. Most of this knowledge comes from local studies related to delineation of buried aquifers. On a somewhat less detailed scale, two notable examples of statewide three-dimensional maps are those of Illinois (Berg and Kempton, 1988, scale 1:250,000) and Connecticut (Stone and others, in press, scale 1:125,000), which show subsurface data by map units representing vertical successions of lithologic units (the stack-unit concept discussed by Kempton, 1981). These two State maps are complex and portray subsurface data effectively. However, their methods of showing detailed subsurface data are not as feasible on a regional scale of 1:1,000,000; data density and reliability are highly uneven from State to State, and, in certain areas, the deposits are too thick and the stratigraphy is too complex to be portrayed by their methods.

In general, the subsurface is not shown on the Quaternary sediments map because data are insufficient. In the areas where the subsurface is well known, the vertical succession of geologic units is depicted on the map in a generalized fashion, as a two-unit stack consisting of either

the surficial unit and a well-mapped buried unit of some significance (for example, an aquifer) at some unspecified depth, or a discontinuous surface veneer of sediment and the underlying unit. These stack units include, but are not limited to, stratified sediments overlying till in a glacial lake basin, sand and gravel aquifers buried beneath till, and areas of peat or of eolian sediments (loess or eolian sand) capping older Quaternary sediments. These buried or veneer units are commonly widespread or thick and may be of economic as well as geologic significance (for example, as aquifers).

These two-unit stacks on the map do not portray the actual vertical succession of units. Where a buried coarse-grained stratified unit is depicted, it may occur at the base of section beneath till, or beneath till that contains numerous interbeds of stratified deposits and peat, or at some other position within the section, perhaps bounded above and below by till. However, the stack does indicate the occurrence of a well-known, significant buried unit. Also, where a veneer of loess is mapped over till, it is not implied that the entire section beneath the loess is till. Stratified deposits may be buried beneath or interbedded with till, as is certainly possible in areas where stack units are not shown.

Through the use of colors and patterns, the stack units emphasize either the surficial or the buried unit. For example, where a patchy veneer of peat or of fine-grained stratified lake sediment overlies a thick sequence capped by till, the till is shown as the solid map color, and the thin overlying unit appears as a pattern of thin lines whose color reflects that unit's lithology. Where the geometry of a buried unit (for example, stratified sand and gravel in a buried valley) is fairly well defined, the surficial unit is shown in a solid color, and the buried unit is represented by a dot pattern of the appropriate color. The Quaternary sediments map also shows lithologic logs from different geologic settings (for example, buried valleys and upland areas) to indicate actual variations in subsurface lithology.

FACTORS AFFECTING SEDIMENT TEXTURE AND DISTRIBUTION

Sediment Texture

Till, the most widespread unit on the Quaternary sediments map, ranges from dense and compact clayey till, in which few grains are larger than sand size, to loose, sandy till containing abundant boulders and only small amounts of the finer size fractions. Areal variations in till texture can significantly affect the rate of recharge to ground water. Also, dense, fine-textured till is a preferred medium for waste disposal. Thus, decisions concerning land use are benefited by a better understanding of till texture. Figure 5 provides a general guide to surficial till

texture. This figure is based largely on textural descriptions by field mappers, supplemented by some textural analyses and in places by geologic interpretation. Regional variations in till texture reflect the effects and interactions of glacier flow, weathering, and the lithology of the underlying bedrock.

Most till was derived from the local substrate, either bedrock or previous glacial deposits. Especially outside the Great Lakes basins, bedrock lithology and till texture are closely related. Sandy till is common on coarse-grained igneous and metamorphic rock terranes and on areas underlain by coarse clastic rocks. Silty till occurs on finer grained metamorphic rocks and on sedimentary units containing sandstone, siltstone, shale, and carbonate rocks. Clayey till is common on areas of shale bedrock (for example, in the Dakotas and Montana). Glaciers that overrode older glacial sediments may have deposited a till similar in character to the underlying unit; where fine-grained glacial lake sediments were overridden by a glacier, a clayey till was commonly deposited. Figure 6 shows the general lithology of bedrock and the outlines of glacial lake basins.

The distribution of sandy, silty, and clayey till is closely related to the differential resistance of bedrock to erosion by water and ice. Erosion was most severe in the finer grained clastic and carbonate rocks, whereas coarse-grained igneous and metamorphic complexes resisted erosion more effectively. This difference in resistance is demonstrated in the Great Lakes region, where ice tended to be directed along formational strike and along the course of preglacial valleys, through zones of relatively weak rocks. The basins of Lakes Michigan, Huron, Erie, and Ontario were in large part sculpted by glacial erosion of certain Paleozoic shales, siltstones, and carbonate rocks, whereas glacial erosion beneath Lake Superior occurred dominantly in faulted Precambrian metasedimentary rocks (see Hough, 1958).

Mode of glacial sediment deposition varied depending on the topographic setting, because topography of the bedrock surface (and, for later ice advances, topography on the surface of older glacial deposits) caused ice to flow in lobes rather than as a regional, uniform sheet. In interlobate areas on many uplands, relatively coarse-grained winnowed till and coarse-grained stratified deposits were deposited in moraines. Of course, topographic setting also exerted some control on till texture outside the Great Lakes basins. For example, on the interlobate area known as the Prairie Coteau in eastern South Dakota, deposition by stagnating ice along lateral moraines produced tills somewhat siltier than the clayey tills of the lowlands to the west and northeast. Similarly, a relatively coarse till occurs in the morainal deposits of central North Dakota and South Dakota. In many lowland areas, fine-grained glacial lake sediments were deposited in basins next to ice lobes. An ice advance over the lake basin commonly produced a clay-rich till due to incorporation of the fine-grained lake sediment. A

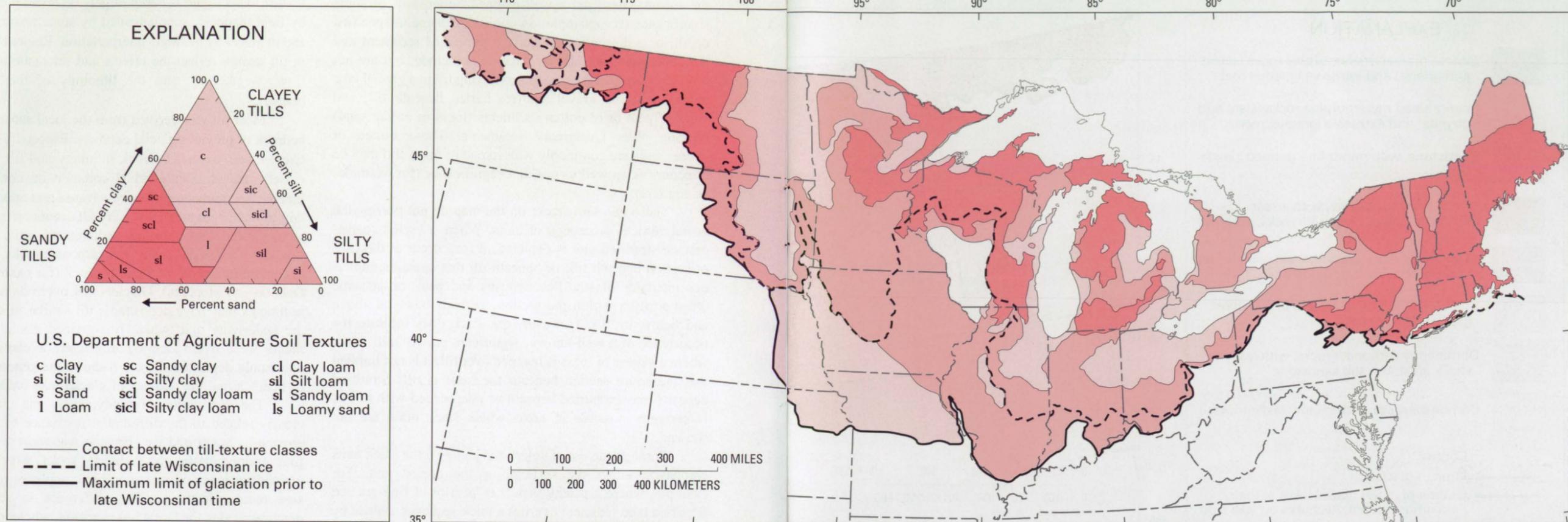


Figure 5. Texture of surficial till, based on U.S. Department of Agriculture textural classification. Textural descriptions from field mappers and some textural analyses were used to compile most of this map. For some places, notably Montana, data were quite sparse, and the

correlation of bedrock lithology, the down-ice part of glacial lake basins, and the distribution of clayey till is apparent in a comparison of figures 5 and 6.

Sediment Distribution

In places, thick glacial sediments occur only in valleys of preglacial or interglacial origin. In New England, and westward to the Appalachian Escarpment in Ohio, the glacial sediment cover is relatively thin, generally less than 20 ft thick on the uplands. However, in this region, modification of preglacial and interglacial valleys by glacial erosion produced deeply incised drainage systems, which are now partly filled with stratified glacial and Holocene sediment, locally more than 200 ft thick in major valleys. West and northwest of the Appalachian Escarpment, sediment thicknesses over a large area are commonly much greater. There, entire preglacial and interglacial drainage systems lack surface expression (for example, the Mahomet valley in Illinois and the Teays system in Ohio and Indiana).

lithology of the bedrock was used as the main guide to texture. In general, however, the map was compiled without reference to the bedrock lithology. See text for a discussion of till texture.

These buried valleys commonly are filled with thick interbedded till and stratified sediment. Beneath the Great Lakes, glacially overdeepened channels are partly or completely filled with till and fine-grained stratified Quaternary sediment, notably in western Lake Superior, southern Lake Huron, and eastern Lake Erie. A simplified thickness map (fig. 7) derived from the 1:1,000,000-scale maps of this series shows the largest of these thick deposits.

The most extensive accumulations of thick glacial sediment are not, however, in filled valleys and other depressions. Large areas in the southern peninsula of Michigan, western Minnesota, and eastern North Dakota and an area in eastern South Dakota, southwestern Minnesota, and western Iowa are underlain by more than 200 ft of glacial sediment (fig. 7). These thick sediment piles are composed of complex and poorly understood deposits of till and coarse-grained stratified sediment accumulated during multiple glaciations. As an example of the stratigraphic complexity in these areas, a well drilled in the Prairie Coteau region of South Dakota penetrated 868 ft of glacial sediment consisting of at least 10 layers of till and inter-

vening gravelly (stratified?) units (South Dakota Geological Survey, written commun., 1987). Well data on the southern peninsula of Michigan indicate 800 to more than 1,200 ft of glacial sediment.

In these and other large areas of thick sediment, the texture of till and stratified sediment is coarse relative to adjacent areas of thinner sediment accumulation (for example, for Michigan, see Farrand and Bell, 1982). This contrast reflects the differing nature of glacial sedimentation between the ice-lobe basins and interlobate areas. In the ice-lobe basins, till and fine-grained stratified sediment predominate. The till is dominantly of basal origin and in places has incorporated fine-grained glaciolacustrine sediments during ice readvance. In contrast, at the ice terminus and in interlobate areas, supraglacial and extramarginal deposition was more common. Consequently, glacial sediment deposited there is dominantly coarse-grained stratified sediment and relatively coarse and poorly compacted till.

Most of these areas of thick sediment accumulation lie beneath late Wisconsinan interlobate positions (see fig. 7) on topographically high areas of the bedrock surface, whereas relatively thin deposits generally accumulated in the adjacent bedrock lowlands occupied by drainage and by

ice lobes (see cross sections in fig. 8). Thick sediment did not accumulate in all interlobate areas; for example, note the area between the Lake Huron and Lake Erie lobes in Lake Erie (fig. 8, section A-A'). The absence of thick sediment there is perhaps due to the lack of a bedrock high needed to restrict the two lobes and stabilize the location of the interlobate area sufficiently to permit a thick accumulation of sediment.

Figure 8, section A-A', shows thinning of glacial sediment up the regional slope of the bedrock, in the direction of the ice terminus near the Appalachian Escarpment (see fig. 7). In contrast, figure 8, section B-B', shows a thickening of sediment along the lateral margin of the James lobe, westward up the regional bedrock slope. The relatively stable position of lateral margins, especially where restricted by regional slope, may account for the thick sediment in these places, in contrast to the relatively unstable margin position of an ice terminus, where thick sediment is less likely to accumulate. Figure 8, section C-C', shows generally thin drift on the upland where the Rainy lobe-Lake Superior lobe boundary is shown, likely because that interlobate position was not stable over time.

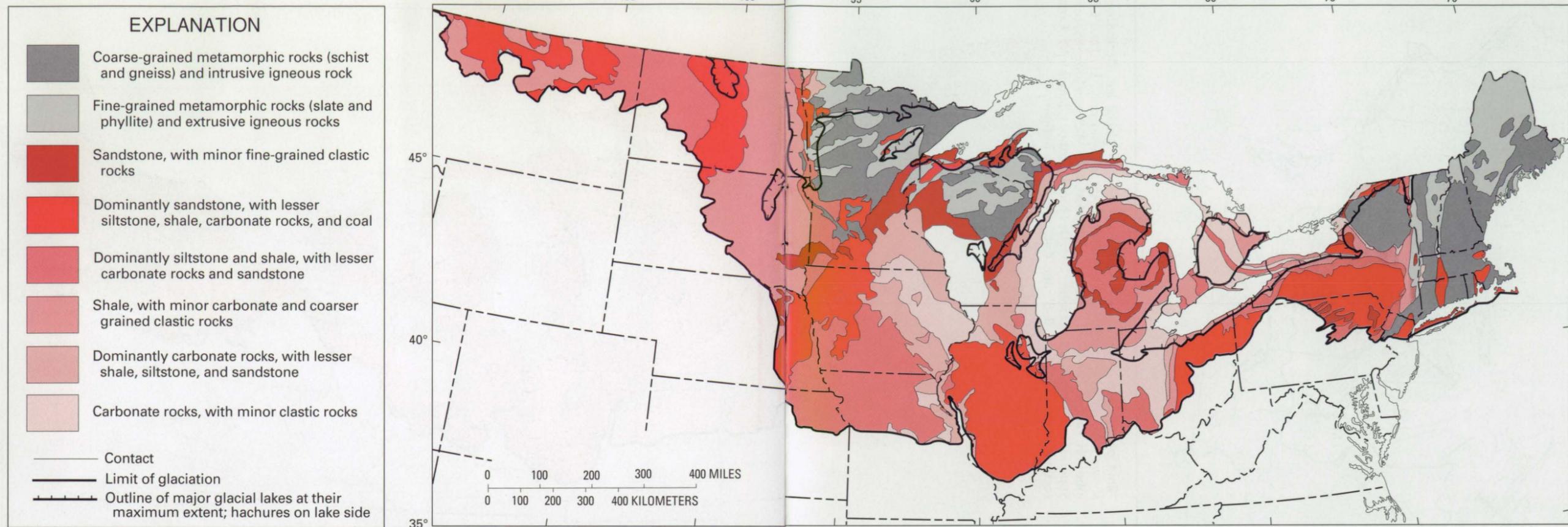


Figure 6. General lithology of bedrock directly beneath the Quaternary sediments. Lithologies are grouped according to dominant grain size and rock origin. The outlines of major glacial lakes are also shown because ice

flowing in glacial lake basins commonly incorporated preexisting lake sediments into the till. Till texture (fig. 5) was greatly influenced by bedrock lithology and major glacial lake basins.

In the lowlands of the Lake Superior lobe, thick drift occurs on a bedrock high that separated two sublobes. The thick sediment in Lake Superior is in part Holocene lake sediment. The correlation among interlobate positions, thick sediment, and bedrock highs underlain by resistant bedrock is most notable for the Paleozoic sedimentary rocks of the Great Lakes region, where there is sufficient lithologic contrast and differential erosion. On the other hand, in New England, the regional predominance of resistant rock types appears to have precluded development of a similar pattern.

For many areas, it is likely that once ice lobation had become established, the ice lobes and interlobate areas recurred at the same general positions in successive glaciations, causing a gradual buildup of sediment volume in the interlobate areas. Late Wisconsinan sediment (see, for example, Mickelson and others, 1983) accounts for only a minor part of the sedimentary sequence in the interlobate areas shown in figure 7. This fact suggests that, at the regional level, the younger glaciations almost certainly did not establish radically different patterns of sediment distribution. As demonstrated by Kemmis and others (1981) and

by other authors, ice traveling over a previously glaciated terrain may incorporate only a part of the underlying glacial sediment and redeposit it as till and will not commonly erode through thick glacial sediment into bedrock. The general configuration of the bedrock surface must have been established before the Pleistocene or during the early (at least pre-Wisconsinan) glaciations and probably generally followed the preglacial topography. Through successive glaciations, bedrock topographic highs separating adjacent ice lobes received additional sediment from the lateral margins of each lobe, adding to the overall thickness of sediment in the interlobate area and further establishing topographic control on ice movement. This conclusion is regionally based and may have less validity at a local scale, where the relation between bedrock topography and ice lobation may in places be lacking or be less clear (see, for example, Kemmis and others, 1981).

The largest area of thick glacial sediment in the mapped area is in Minnesota, west of the Great Lakes, and cannot be satisfactorily correlated with latest Wisconsinan lobe margin positions (fig. 7). Ice flowed into this area from

two directions: the Lake Superior lobe from the northeast and the Red River and Des Moines lobes from the northwest (see discussion in Mayewski and others, 1981, p. 91–93). Ice advances from these lobes were asynchronous. In the latest Wisconsinan, the Lake Superior lobe was retreating northwestward as ice in the Red River and Des Moines lobes expanded south and east. The thick sediment lies to the west and south of the latest Wisconsinan lobe positions, in an area where interlobate positions may have existed before the latest part of the Wisconsinan.

SUMMARY

The maps of this series are a first approximation of the regional, three-dimensional distribution of Quaternary sediments over a very large area. They are intended to support additional research and detailed mapping. They are also intended to supplement the local, detailed studies from which they were compiled and should not be used to infer specific details concerning the local geologic framework. Rather, they are most useful as planning documents. As a complement to detailed mapping, regional maps such as these place local, detailed mapping in context, permit the

extrapolation of data into unmapped areas, and depict large-scale, regional geologic features that are beyond the scope of detailed, local mapping.

Two general points about the Quaternary sediments map should be stressed. First, this map depicts the surface distribution of sediments and the total thickness of the Quaternary deposits; the continuation down to the pre-Quaternary surface ("bedrock") of the glacial unit that lies at the surface cannot necessarily be inferred. However, in places, the surface unit can extend to bedrock, especially where the Quaternary sediment is thin. Second, the materials-based mapping emphasis differs from that of most published State and regional surficial geologic maps, which use stratigraphic or geomorphic map units and focus on the chronology of geologic events such as ice advances or retreats or the history of glacial lakes. Because of this fundamental difference, the distribution of sediments on event-oriented maps may not agree with the distribution on these maps. For example, in many glaciated areas inundated by proglacial lakes, the surficial sediment is commonly till, somewhat altered where reworked by lake waters. On event-oriented maps, however, because of the glacial geologic history, lacustrine clay, silt, and sand are commonly

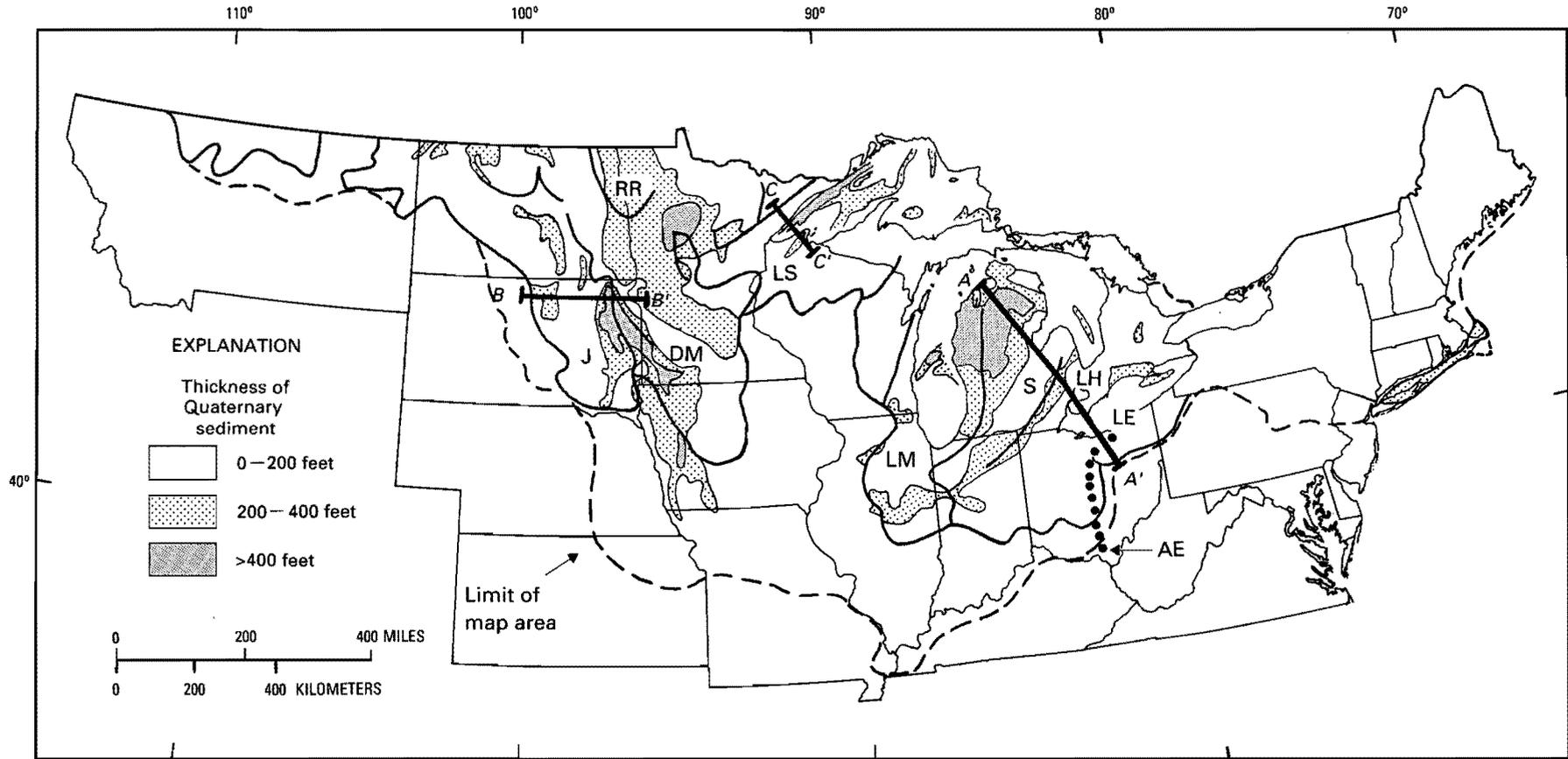


Figure 7. Simplified thickness map of Quaternary sediments within the mapped area and late Wisconsin glacial lobe positions (from Mickelson and others, 1983) as shown by medium-weight solid lines. Some lobe positions, especially in the Eastern United States, have been omitted here for clarity. Only the 200- and 400-ft thickness contours are shown. Dashed line, labeled

"limit of map area," shows the maximum extent of glacial ice. Dotted line shows location of Appalachian Escarpment (AE) in Ohio only. LE, Lake Erie lobe; LH, Lake Huron lobe; S, Saginaw lobe; LM, Lake Michigan lobe; LS, Lake Superior lobe; RR, Red River lobe; DM, Des Moines lobe; J, James lobe. Cross sections along lines A-A', B-B', and C-C' are shown in figure 8.

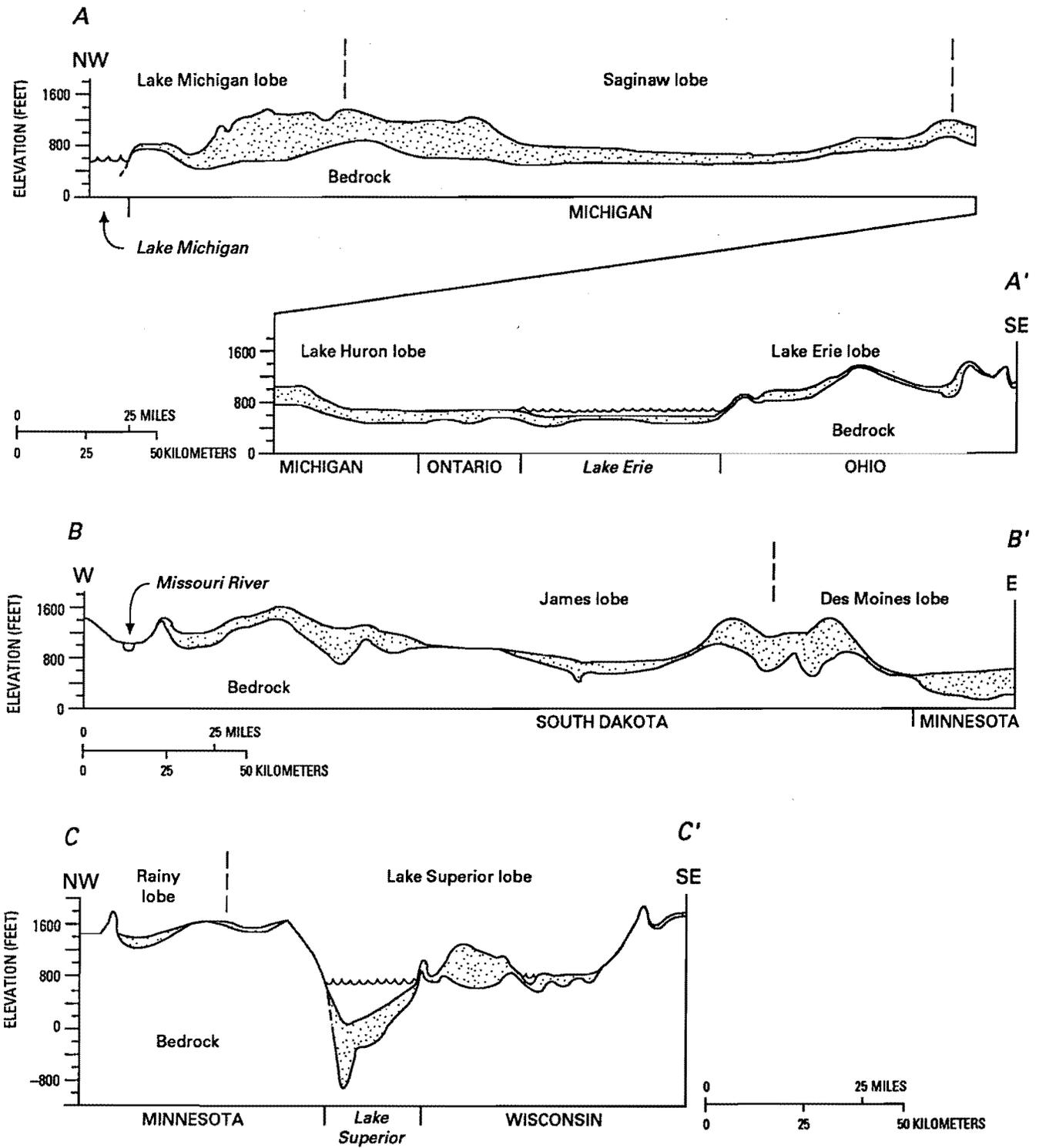


Figure 8. Cross sections showing the relations among bedrock topography, Quaternary sediment thickness, and ice lobation. Stippled areas represent Quaternary sediment. Locations of sections shown in figure 7. Cross section C-C' shows the thick sediment over the bedrock high, which was deposited between two sublobes of the Lake Superior lobe.

mapped (inferentially) throughout a lake plain, although these deposits may be areally less common than till.

Preliminary analysis of the map patterns, in concert with information on till texture, ice lobe pattern, and bedrock lithology, suggests the following conclusions. The differential resistance of bedrock to erosion by water and ice has partly controlled till textural distribution, especially in the Great Lakes basins. Mode of deposition (for example, interlobate area, basal ice, stagnating ice) also greatly affects the texture of the deposited till. Most of the largest areas of thick glacial sediment were late Wisconsinan interlobate areas on topographically high areas of the bedrock surface, whereas relatively thin deposits generally accumulated in the adjacent bedrock lowlands occupied by drainage and by ice lobes. The lithology of the bedrock and its resistance to erosion in part controlled the pattern of ice lobation and the distribution of thick sediment. The thickness of late Wisconsinan sediment accounts for only a minor part of the sedimentary sequence in the thick drift of these interlobate areas. It is likely, therefore, that once ice lobation had become established in an area, there was a tendency for ice lobes and interlobate areas to recur at roughly the same locations in successive glaciations. Thus, the general configuration of the bedrock surface may have been established in pre-Pleistocene time or after the earliest glaciations. Through successive glaciations, the bedrock topographic highs separating adjacent ice lobes continued to receive additional sediment from the lateral margins of each lobe, adding to the overall thickness of sediment in the interlobate area and further emphasizing topographic control on ice movement.

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- and parts of southern Ontario and the Atlantic offshore area (east of 80° 31' West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I-1970-A, scale 1:1,000,000.
- in press b, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern Great Lakes States and central Mississippi Valley States, the Great Lakes, and southern Ontario (80° 31' to 93° West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I-1970-B, scale 1:1,000,000.
- in press c, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern and Central Plains States (90° to 102° West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I-1970-C, scale 1:1,000,000.
- in press d, Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains—Northern Plains States (west of 102° West longitude): U.S. Geological Survey Miscellaneous Investigations Series Map I-1970-D, scale 1:1,000,000.
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SECTION 2—SOURCES AND RELIABILITY OF MAP DATA

The four maps of this series were generated by compiling and reinterpreting existing information derived from published and unpublished maps and reports, basic data, and discussions with other geologists. Those geologists, numbering about 130 and located in the 23 States within the mapped area and in Canada, are listed in the "Acknowledgments" section. Where preliminary versions of published maps were used to generate the maps of this series, they are noted in the following list. Also, significant sources of unpublished information are included. Some stack-unit and other information on the map was interpreted from oral and written communications with scientists listed in the "Acknowledgments" section and is not noted here. The published or otherwise available sources of information, numbering about 850, are listed below.

Surface sediments, or any group of geologic units, are mapped for many purposes, resulting in maps with widely differing themes, content, complexity, and scale. For the region depicted on the maps of this series, source maps were highly varied in nature and map coverage was incomplete. This situation necessitated the adoption of a simple, materials-based classification scheme that could be applied uniformly across the entire region. Because the quality and coverage of data used in assembling these maps vary widely, the reliability of the map series also varies from place to place. Most of the map data are considered moderately reliable, in the qualitative judgment of this author. However, a moderate to major reinterpretation or synthesis of source maps was generally required to adapt them to the classification scheme of this map. In a few States, data were of high quality and reliability and were not reinterpreted. Statewide maps were not available in many States, and the map data were assembled from numerous sources. In these cases, data reliability was generally considered to be low. For many States, the available data were sparse, and map reliability was low to moderately low. In other States, refinement of data during map compilation resulted in relatively higher reliability for the map.

This section is organized alphabetically by State; data sources for the Great Lakes, the Atlantic offshore, and Canada follow the State listings. Each section begins with a brief overview of the character and thickness of the glacial deposits, followed by brief statements on data reliability and types of map data used to compile the surficial-sediment, sediment-thickness, and subsurface parts of the maps (hereafter referred to as the "Quaternary sediments map"). Where the term "map compilation" is used, it refers to compilation of the four maps of this series, not compilation of source maps.

After this introductory material, the sources are given for surficial and stack-unit information and thickness information. For some States, additional references (for exam-

ple, a map showing drumlins only) are listed separately. Because the "Additional References" heading includes only those citations not listed under previous headings, the list of references identified for an additional topic (for example, drumlins) may be incomplete. The heading "Surficial and Stack-Unit Information" may be replaced by "Surficial Information" if the stack-unit information for that State was derived solely from discussions with cooperating scientists or if stack-unit information is not depicted. The format was chosen to limit the redundancies in citations. For sections containing several references, an asterisk preceding a reference denotes the primary reference(s) for that section.

CONNECTICUT

Overview of Quaternary deposits.—Thick sediment in Connecticut is confined largely to the river valleys, where areas of sediment thicknesses between 100 to 200 ft are not uncommon; in places, more than 400 ft of sediment is preserved. Coarse- and fine-grained stratified sediments, deposited by glacial meltwater in glacial lakes, account for the bulk of the valley fill. In contrast, the upland areas are mostly mantled by sandy till. Generally less than 20 ft thick, the till in upland areas is highly variable in thickness. Drumlins, composed of thicker till, are in all parts of the State. In many places, the till is patchy and bedrock exposures are numerous.

Surficial information.—Map data were compiled directly from the new State surficial materials map (Stone and others, in press, scale 1:125,000). It was readily incorporated into the Quaternary sediments map without the need for reinterpretation. The reliability of the map data is considered to be high.

Thickness information.—An unpublished map of the thickness of surficial materials, scale 1:125,000, was compiled by the senior author of the State surficial materials map from numerous well data. The reliability of the map data is considered to be high.

Subsurface information.—The lithology of subsurface units as mapped on the State surficial materials map was simplified and shown diagrammatically on the Quaternary sediments map.

Surficial and Stack-Unit Information

Stone, J.R., Schafer, J.P., London, E.H., and Thompson, W.B., in press, Surficial materials map of Connecticut: Reston, Va., U.S. Geological Survey, scale 1:125,000.

Thickness Information

Stone, J.R., 1986, Thickness of surficial materials in Connecticut: Reston, Va., U.S. Geological Survey, unpublished map, scale 1:125,000.

ILLINOIS

Overview of Quaternary deposits.—Surface sediments in Illinois are dominantly silty till, except in northeastern Illinois, where the surface till in the basin of the Lake Michigan ice lobe is more clayey. Large areas of surficial stratified deposits, generally coarse grained, are confined to the valleys of the Mississippi, Illinois, and Wabash Rivers. Fine-grained stratified deposits occur in tributary valleys of the Wabash River and near Lake Michigan. Excluding northeastern and east-central Illinois, sediment thicknesses outside river valleys seldom exceed 100 ft and are commonly less than 50 ft. In the major river valleys, 50 to 200 ft of stratified sediment commonly is preserved. In the area covered by the latest glacial advance, in northeastern Illinois, sediment thicknesses of 100 to 400 ft are common in places. Extensive preglacial and interglacial drainage networks are buried beneath the till cover; some of these old valleys contain thick coarse-grained stratified sediments that are important aquifers.

Surficial information.—The State map of Quaternary deposits (Lineback, 1979), scale 1:500,000, was used for compilation of the Quaternary sediments map. Although it is a stratigraphic map, the character of sediments within each unit is readily determined, so that extensive reinterpretation of the map units was not necessary. However, due to the stratigraphic emphasis of the map, areas of patchy surface till and numerous bedrock exposure were not delineated, and these had to be interpreted from other map sources. Overall, the reliability of the map data is considered to be high.

Thickness information.—A State map of sediment thickness (Piskin and Bergstrom, 1975), scale 1:500,000, was used to compile the Quaternary sediments map. Reliability of data was moderately high, except in areas of thin sediment cover. Based on a more modern and extensive well inventory, maps by Berg and others (1984) and Berg and Kempton (1988) were used to revise the 50- and 100-ft thickness contours and to improve data reliability overall.

Subsurface information.—The subsurface geology has been extensively studied, and statewide and county maps depicting the three-dimensional nature of the deposits have been produced by the State. For the purposes of the Quaternary sediments map, the statewide maps were adequate to depict the buried aquifers.

Surficial and Stack-Unit Information

Berg, R.C., and Kempton, J.P., 1984, Potential for contamination of shallow aquifers from land burial of municipal wastes: Champaign, Ill., Illinois State Geological Survey, scale 1:500,000.

Berg, R.C., Kempton, J.P., and Stecyk, A.N., 1984, Geology for planning in Boone and Winnebago Counties: Illinois State Geological Survey Circular 531, 69 p.

*Lineback, J.A., 1979, Quaternary deposits of Illinois: Champaign, Ill., Illinois State Geological Survey, scale 1:500,000.

Miller, J.R., Berg, R.C., Johnson, T.M., and Wehrmann, Allen, 1985, Siting a low-level radioactive waste disposal facility in Illinois: statewide criteria: Champaign, Ill., Illinois State Geological Survey and Illinois State Water Survey, contract report to Illinois Department of Public Safety, 13 p., scale 1:3,000,000. Open-file maps (1:1,000,000 scale) were obtained for map compilation.

Piskin, Kemal, and Bergstrom, R.E., 1975, Glacial drift in Illinois: thickness and character: Illinois State Geological Survey Circular 490, 35 p., scale 1:500,000.

Poole, V.L., and Sanderson, E.W., 1981, Groundwater resources in the Saline Valley Conservancy District, Saline and Gallatin Counties, Illinois: Champaign, Ill., Illinois State Geological Survey, Contract/Grant report 1981-2.

Ray, B.W., Fehrenbacher, J.B., Rehner, R., and Acker, L.L., 1976, Soil survey: Stephenson County, Illinois: University of Illinois Agricultural Experiment Station Soil Report 99, 132 p., scale 1:126,720.

Thickness Information

Berg, R.C., and Kempton, J.P., 1988, Stack-unit mapping of geologic materials in Illinois to a depth of 15 meters: Illinois State Geological Survey Circular 542, 23 p., scale 1:250,000. Preliminary version obtained for map compilation.

Berg, R.C., Kempton, J.P., and Cartwright, Keros, 1984, Potential for contamination of shallow aquifers in Illinois: Illinois State Geological Survey Circular 532, 30 p., scale 1:500,000.

Piskin, Kemal, and Bergstrom, R.E., 1975, Glacial drift in Illinois: thickness and character: Illinois State Geological Survey Circular 490, 35 p., scale 1:500,000.

INDIANA

Overview of Quaternary deposits.—Surface sediments in Indiana are dominantly silty till, except in northeastern Indiana, where the surface till in the basin of the Lake Erie ice lobe is more clayey. Large areas of surficial stratified deposits, generally coarse grained, are confined to a broad area in northwestern Indiana and to the valleys of the Wabash and Ohio Rivers and major tributaries. Fine-grained stratified deposits are mostly in tributary valleys of the Wabash and Ohio Rivers. In the northern half of the State, sediment thickness is commonly 50 to 400 ft, the greater thicknesses occurring over the preglacial and interglacial valleys buried by the sediment cover and in the interlobate area of north-central Indiana. Beyond the southern limit of the latest ice advance (Woodfordian), the thickness of sediments is generally less than 50 ft. In places, these older deposits have been eroded, and bedrock is exposed.

Surficial information.—The Quaternary sediments map was compiled mainly from eight 1:250,000-scale

surficial geologic maps published between 1966 and 1979. The map units are not directly applicable to the classification scheme used for the Quaternary sediments map, and so a moderate amount of reinterpretation was required, especially for the stratified deposits. The overall reliability of the data is therefore considered to be moderately high.

Thickness information.—A State map of sediment thickness (Gray, 1983), scale 1:500,000, was used for the Quaternary sediments map. The map is relatively current and relies on a large number of data points (roughly 60,000); the reliability of the map is therefore considered to be moderately high.

Subsurface information.—The character and geometry of glacial units in the subsurface are not well known in Indiana. Despite the lack of subsurface data, a limited number of subsurface units are shown on the Quaternary sediments map on the basis of extrapolation of the trends of buried units depicted in Illinois.

Surficial Information

Bleuer, N.K., Melhorn, W.N., and Fraser, G.S., 1982, Geomorphology and glacial history of the Great Bend area of the Wabash Valley, Indiana: Geological Society of America, North Central Section, 16th Annual Meeting, Field Guidebook, Field trip no. 2, 63 p.

Burger, A.M., Forsyth, J.L., Nicoll, R.S., and Wayne, W.J., 1971, Geologic map of the 1°×2° Muncie quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 5, scale 1:250,000.

Fraser, G.S., 1983, Sand and gravel resources of the Wabash Valley: causes of variability: Indiana Geological Survey Occasional Paper 37, p. 27–42.

Gray, H.H., 1972, Geologic map of the 1°×2° Louisville quadrangle, Indiana, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 6, scale 1:250,000.

———, 1984, Surficial geologic map of southern Indiana: Bloomington, Ind., Indiana Geological Survey, unpublished map, scale 1:1,000,000.

Gray, H.H., Bleuer, N.K., Hill, J.R., and Lineback, J.A., 1979, Geologic map of the 1°×2° Indianapolis quadrangle, Indiana and Illinois, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 1, scale 1:250,000.

Gray, H.H., Forsyth, J.L., Schneider, A.F., and Gooding, A.M., 1972, Geologic map of the 1°×2° Cincinnati quadrangle, Indiana and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 7, scale 1:250,000.

Gray, H.H., Wayne, W.J., and Wier, C.E., 1970, Geologic map of the 1°×2° Vincennes quadrangle and parts of adjoining quadrangles, Indiana and Illinois, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 3, scale 1:250,000.

Johnson, G.H., and Keller, S.J., 1972, Geologic map of the 1°×2° Fort Wayne quadrangle, Indiana, Michigan, and Ohio, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 8, scale 1:250,000.

Lineback, J.A., Bleuer, N.K., Mickelson, D.M., Farrand, W.R., and Goldthwait, R.P., 1983, Quaternary geologic map of the Chicago 4°×6° quadrangle, United States, in Richmond, G.M., and Fullerton, D.S., eds., Quaternary geologic atlas of the United States: U.S. Geological Survey Miscellaneous Investigations Series Map I-1420 (NK-16), scale 1:1,000,000.

Schneider, A.F., and Keller, S.J., 1970, Geologic map of the 1°×2° Chicago quadrangle, Indiana, Illinois, and Michigan, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 4, scale 1:250,000.

Wayne, W.J., Johnson, G.H., and Keller, S.J., 1966, Geologic map of the 1°×2° Danville quadrangle, Indiana and Illinois, showing bedrock and unconsolidated deposits: Indiana Geological Survey Regional Geologic Map no. 2, scale 1:250,000.

Thickness Information

Gray, H.H., 1983, Map of Indiana showing thickness of unconsolidated deposits: Indiana Geological Survey Miscellaneous Map 37, scale 1:500,000.

IOWA

Overview of Quaternary deposits.—Surface sediments in Iowa are dominantly silty till, except in southwestern Iowa, where the till is more clayey. Extensive areas of stratified deposits, dominantly coarse grained, are confined to the Missouri and Mississippi River valleys and major tributary valleys. The thickest sediments occur in western Iowa, where 200 to 400 ft of sediment is common, whereas, in central Iowa, thicknesses of 50 to 200 ft are more common. The deposits thin eastward, in part because of postglacial erosion. In eastern Iowa, the sediments are dissected, and bedrock exposures are numerous.

Surficial information.—A 1:1,000,000-scale statewide compilation (Hallberg, 1979) provided a map adequate for compilation of the Quaternary sediments map. More detailed mapping for the State was not available. The reliability of the data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from a variety of sources, including some thickness maps at scales of 1:250,000 and 1:500,000. Thickness contours for most of the State were constructed by computing sediment thickness from unpublished bedrock topographic and land-surface topographic maps. The reliability of the data is considered to be moderate.

Subsurface information.—The character and geometry of subsurface glacial deposits are not well known in

Iowa. In areas of eolian sand or thick (more than 20 ft) loess cover, the character of the underlying sediment was inferred.

Surficial and Stack-Unit Information

Hallberg, G.R. 1979, Quaternary geologic map of Iowa: Iowa City, Iowa Geological Survey, unpublished maps prepared for the Quaternary Geologic Atlas of the United States series (U.S. Geological Survey Miscellaneous Investigations Series Map I-1420), scale 1:1,000,000.

Thickness Information

Anderson, R.R., 1983, Bedrock topography map of Iowa: Iowa City, Iowa Geological Survey Open-File Map, scale 1:250,000. Compiled from the following sources:

Cagle, J.W., 1973, Bedrock topography of south-central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I-763, scale 1:125,000.

Hansen, R.E., 1972, Bedrock topography of east-central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I-717, scale 1:125,000.

———1973, Bedrock topography of southeast Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I-808, scale 1:125,000.

———1975, Bedrock topography of northeast Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I-933, scale 1:125,000.

———1978, Bedrock topography of north-central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I-1080, scale 1:125,000.

———1985, Bedrock topography of central Iowa: U.S. Geological Survey Miscellaneous Investigations Series Map I-1609, scale 1:125,000.

Munter, J.A., Ludvigson, G.A., and Bunker, B.J., 1983, Hydrogeology and stratigraphy of the Dakota Formation, northwest Iowa: Iowa Geological Survey Water-Supply Bulletin 13, 55 p., scale 1:500,000.

Van Eck, O.J., Anderson, R.R., Black, R.A., and Daut, S.W., 1979, Regional tectonics and seismicity of southwestern Iowa: Iowa Geological Survey Annual Report FY-79 to U.S. Nuclear Regulatory Commission, NUREG/CR-0955, 25 p.

Hallberg, G.R., Anderson, R.R., Reinholtz, P.N., and Pearson, S.G., 1981, Depth to bedrock in northeast Iowa, an isopach of Quaternary deposits: Iowa City, Iowa Geological Survey, scale 1:500,000.

Hoyer, B.E., ed., 1973, Resource development land and water use management, eleven county region, south central Iowa: Iowa Geological Survey Miscellaneous Map Series 4, scale 1:250,000.

Munter, J.A., Ludvigson, G.A., and Bunker, B.J., 1983, Hydrogeology and stratigraphy of the Dakota Formation, northwest Iowa: Iowa Geological Survey Water-Supply Bulletin 13, 55 p., scale 1:500,000.

KANSAS

Overview of Quaternary deposits.—Surface sediments in Kansas are dominantly clayey till. Large areas of surficial stratified deposits, generally coarse grained, are confined to the valleys of the Kansas and Missouri Rivers. These glacial sediments are old, and the deposits are thin where the landscape is dissected; in places, the till cover is patchy, and bedrock or rock residuum exposures are common. Thick surficial deposits are present only in less dissected areas overlying buried preglacial or interglacial valleys.

Surficial information.—A statewide compilation (Denne, 1986), scale 1:1,000,000, provided an adequate map for use in compiling the Quaternary sediments map. Although local, more detailed studies exist for some areas of the State, this map is a modern overview of the surface geology that is well suited to the classification scheme used on the Quaternary sediments map; a reinterpretation of the map was therefore not necessary. The reliability of the data is considered to be moderate.

Thickness information.—A generalized map of sediment thickness was derived from 17 data sources containing well data, cross sections, bedrock topographic maps, and a sediment thickness map of one county. The reliability of the data varies areally depending on the type of data available; overall, the reliability of the data is moderately low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Kansas. In areas of thick (more than 20 ft) loess cover, the character of the underlying sediments was inferred on the Quaternary sediments map.

Surficial and Stack-Unit Information

Bayne, C.K., 1973, Geohydrology of Doniphan County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA-462, scale 1:62,500.

Bayne, C.K., and Schoewe, W.H., 1967, Geology and groundwater resources of Brown County, Kansas: State Geological Survey of Kansas Bulletin 186, 68 p.

*Denne, J.E., 1986, The Quaternary deposits of Kansas: Kansas Geological Survey Geology Series Map 3, scale 1:1,000,000.

Fishel, V.C., 1948, Ground-water resources of the Kansas City, Kansas, area: State Geological Survey of Kansas Bulletin 71, 109 p.

State Geological Survey of Kansas, 1964, Geologic map of Kansas: Lawrence, Kans., scale 1:500,000.

Ward, J.R., 1973, Geohydrology of Atchison County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA-467, scale 1:62,500.

Thickness Information

Bayne, C.K., 1973, Geohydrology of Doniphan County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA-462, scale 1:200,000.

- Bayne, C.K., and Schoewe, W.H., 1967, Geology and ground-water resources of Brown County, Kansas: State Geological Survey of Kansas Bulletin 186, 68 p.
- Bayne, C.K., and Ward, J.R., 1967, Saturated thickness and specific yield of Cenozoic deposits in Kansas: State Geological Survey of Kansas Map M-5, scale 1:500,000.
- Beck, H.V., 1959, Geology and ground-water resources of Kansas River valley between Wamego and Topeka vicinity: State Geological Survey of Kansas Bulletin 135, 88 p.
- Davis, S.N., and Carlson, W.A., 1952, Geology and ground-water resources of the Kansas River valley between Lawrence and Topeka, Kansas: State Geological Survey of Kansas Bulletin 96, Part 5, p. 201-276.
- Denne, J.E., and Miller, R.E., 1985, Basic data for the hydrogeology and geochemistry of glacial deposits in northeastern Kansas: Kansas Geological Survey Open-File Report 85-10.
- Dreeszen, V.H., and Burchett, R.R., 1971, Buried valleys in the lower part of the Missouri River basin, in Pleistocene stratigraphy of Missouri River valley along the Kansas-Missouri border, guidebook for the 20th meeting of the Midwest Friends of the Pleistocene: State Geological Survey of Kansas Special Distribution Publication 53, p. 21-25.
- Emmett, L.F., and Jeffery, H.G., 1969, Reconnaissance of the ground-water resources of the Missouri River alluvium between Kansas City, Missouri, and the Iowa border: U.S. Geological Survey Hydrologic Investigations Atlas HA-336, scale 1:125,000.
- Fishel, V.C., 1948, Ground-water resources of the Kansas City, Kansas, area: State Geological Survey of Kansas Bulletin 71, 109 p.
- Fishel, V.C., and Lohman, S.W., 1948, Ground-water resources of Republic County and northern Cloud County, Kansas: State Geological Survey of Kansas Bulletin 73, 194 p.
- Frye, J.C., and Leonard, A.B., 1952, Pleistocene geology of Kansas: State Geological Survey of Kansas Bulletin 99, 230 p.
- O'Connor, H.G., 1960, Geology and ground-water resources of Douglas County, Kansas: State Geological Survey of Kansas Bulletin 148, 200 p.
- Walters, K.L., 1953, Geology and ground-water resources of Jackson County, Kansas: State Geological Survey of Kansas Bulletin 101, 90 p.
- 1954, Geology and ground-water resources of Marshall County, Kansas: State Geological Survey of Kansas Bulletin 106, 116 p.
- Walters, K.L., and Bayne, C.K., 1959, Geology and ground-water resources of Clay County, Kansas: State Geological Survey of Kansas Bulletin 136, 106 p.
- Ward, J.R., 1973, Geohydrology of Atchison County, northeastern Kansas: U.S. Geological Survey Hydrologic Investigations Atlas HA-467, scale 1:190,000.
- 1974, Geohydrology of Nemaha County, northeastern Kansas: Kansas Geological Survey Ground Water Series 2, 19 p., scale approx. 1:280,000.

KENTUCKY

Overview of Quaternary deposits.—Glacial ice covered a small area of northern Kentucky for a relatively short

time. The glacial deposits that remain on the rugged landscape are relatively old and are thin and highly dissected by modern erosion. In places, they are difficult to distinguish from nonglacial, colluvial material. Glacial and glacially related sediments are dominantly stratified. They are coarse grained in the Ohio River valley and fine grained in tributaries to the Ohio River, which were dammed by glacial outwash in the Ohio River channel.

Surficial information.—The distribution of glacial sediment, largely till, on the uplands was derived from the State geologic map (McDowell and others, 1981). The character of the stratified deposits and the distribution of loess were inferred from the statewide geologic map coverage at 1:24,000 scale. More than 150 geologic maps were used to compile the surface and thickness data. Overall, the reliability of the data and interpretations is considered to be moderate.

Thickness information.—Sediment thickness was derived from geologic unit descriptions on 1:24,000-scale geologic maps and from a limited number of 1:24,000-scale bedrock-surface topographic maps. More than 150 geologic maps were used to compile the surface and thickness data. The reliability of the data is considered to be moderate.

Subsurface information.—The glacial and glacially related deposits in Kentucky are not well described, and their subsurface variability is unknown. In areas of thick loess (more than 20 ft), the character of the underlying sediment was inferred on the Quaternary sediments map.

Surficial, Stack-Unit, and Thickness Information

References for surficial, stack-unit, and thickness mapping are combined into one list to avoid redundancy.

- Amos, D.H., 1965, Geology of parts of the Shetlerville and Rosiclare quadrangles, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-400, scale 1:24,000.
- 1966, Geologic map of the Golconda quadrangle, Kentucky-Illinois, and the part of the Brownfield quadrangle in Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-546, scale 1:24,000.
- 1967, Geologic map of part of the Smithfield quadrangle, Livingston County, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-657, scale 1:24,000.
- 1970, Geologic map of parts of the Alton and Derby quadrangles, Meade and Breckinridge Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-845, scale 1:24,000.
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MAINE

Overview of Quaternary deposits.—Surface sediments in Maine are dominantly till, which is more silty in the northern third of the State and more sandy to the south. In northeastern Maine, peat deposits generally less than 20 ft thick are common. Large areas of stratified deposits are more or less confined to the coastal region that was invaded by the sea following retreat of the last ice sheet. In this area, fine-grained sediment predominates, whereas, in low-lying areas elsewhere, coarser grained stratified deposits occur. Outside the area of marine incursion, sediment thickness rarely exceeds 20 ft except in drumlins, and bedrock exposures are numerous in many places. In the southern third of the State, sediment thicknesses between 50 and 100 ft are more common, especially in partly buried glacial valleys both north and south of the marine limit.

Surficial information.—A State surficial geologic map (Thompson and Borns, 1985), scale 1:500,000, was used for the Quaternary sediments map directly without any reinterpretation of map units. The reliability of map data is considered to be high.

Thickness information.—Thickness data were derived from nearly 80 data sources including well-data publications and sediment-thickness maps. The data coverage and reliability are best in the southern third of the State, due to emphasis of mapping in this more densely populated area. The northern part of Maine is sparsely populated; consequently, data on depth to bedrock are sparse. However, the sediment cover is known to be generally thin, so that the lack of data is less significant than if the sediment cover were very thick. Overall, the reliability of the map data is considered to be moderate.

Subsurface information.—In Maine, the variability of glacial deposits in the subsurface is not well known.

Surficial and Stack-Unit Information

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Thickness Information

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MASSACHUSETTS

Overview of Quaternary deposits.—On the upland areas of Massachusetts, surface sediments are dominantly sandy till. These deposits are generally quite thin (less than 20 ft thick), and bedrock exposures are common in places. A compact, silty till more than 20 ft thick is largely confined to drumlins. The eastern third of the State is covered by roughly equal amounts of till and coarse grained stratified sediment. Thick sediment, dominantly coarse grained and stratified, is largely confined to the valleys and coastal areas of the State. In the valleys and coastal areas west of Cape Cod, sediment thicknesses of 50 to 200 ft are common. On Cape Cod and the southern islands, sediment is locally as much as 400 ft thick.

Surficial information.—Map data were compiled directly from unpublished, 1:125,000-scale data (Stone, 1985). This map information portrays the surficial materials

and so was readily incorporated into the Quaternary sediments map without the need for reinterpretation. The reliability of the map data is considered to be high.

Thickness information.—An unpublished map (Stone, 1986) of the thickness of surficial materials, scale 1:125,000, was compiled by the author of the unpublished State surficial materials map from numerous well data. The reliability of the map data is considered to be high.

Subsurface information.—The lithology of subsurface units is generally known from well data. Selected buried units were shown diagrammatically on the Quaternary sediments map.

Surficial and Stack-Unit Information

Stone, B.D., 1985, Surficial materials of Massachusetts: Reston, Va., U.S. Geological Survey, unpublished map, scale 1:125,000.

Thickness Information

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MICHIGAN

Overview of Quaternary deposits.—On Michigan's southern peninsula, the region northwest and west of Saginaw Bay is covered by sandy till and coarse-grained stratified sediment. There, sediment thicknesses commonly range between 400 and 800 ft. In the area south of Saginaw Bay, surface sediments include clayey, silty, and sandy tills and coarse-grained and fine-grained stratified sediment. Thicknesses vary greatly, from less than 50 ft, in places within the lowlands formerly occupied by ice lobes, to 400 ft in the interlobate areas. On Michigan's northern peninsula, sandy till and coarse-grained stratified sediment predominate. In the coastal areas of the northern peninsula, sediment is generally less than 50 ft thick, and bedrock exposures are common in places. Away from the coastal region, along the Wisconsin border, surficial coarse-grained stratified deposits are dominant, and sediments are generally 50 to 200 ft thick.

Surficial information.—Map data were compiled from a statewide compilation (Farrand and Bell, 1982), scale 1:500,000. In some areas, more detailed mapping was used. The reliability of the map data is considered to be moderate.

Thickness information.—For roughly half of the southern peninsula, 36 county maps of sediment thickness provided significant new data to supplement the available statewide thickness map of Passero and others (1981). For the northern peninsula, surficial geologic and topographic

maps were used to reinterpret the statewide thickness map. Reliability of map data for the southern peninsula is considered moderate; for the northern peninsula, data reliability is considered to be low.

Subsurface information.—In Michigan, the variability of glacial deposits in the subsurface is not well known.

Surficial and Stack-Unit Information

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MINNESOTA

Overview of Quaternary deposits.—Surface sediments in Minnesota are dominantly silty till; areas of sandy till are confined to the northeast, near Lake Superior. The largest areas of surficial coarse-grained stratified deposits are between lobes fringing the ice lobe basin west of Lake Superior and along the margins of glacial Lake Agassiz, in the valley of the Red River, northwest Minnesota. Most areas of fine-grained stratified deposits are confined to the basin of glacial Lake Agassiz. In the northern quarter of the State, a veneer of peat and fine-grained sediment overlies till. The thickest sediment occurs in central and western Minnesota, where thicknesses of 200 to 400 ft are common. To the northeast, the sediments are thin and bedrock exposures are common. To the southeast, the landscape is dissected, the glacial deposits are thin and relatively old, and exposures of bedrock and rock residuum are numerous.

Surficial information.—The Quaternary sediments map was compiled largely from a statewide map (Hobbs and Goebel, 1982), scale 1:500,000. A moderate amount of reinterpretation was required, because the map units are not directly equivalent to map units in the classification scheme used for the Quaternary sediments map. In places, more detailed geologic maps were used to aid reinterpretation. Overall, the reliability of the map data is considered to be moderate.

Thickness information.—Thickness data were compiled from a statewide map (Olsen and Mossler, 1982), scale 1:1,000,000, and unpublished data. Extensive interpolation of data was required for most of central Minnesota, where data are sparse and sediment thicknesses are generally 200 to 400 ft. The reliability of map data is considered to be moderately low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not generally known in Minnesota. However, the general extent of major buried aquifers (from Kanivetsky, 1979) was shown diagrammatically on the Quaternary sediments map.

Surficial and Stack-Unit Information

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Thickness Information

Minnesota Geological Survey, unpublished well logs.

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MISSOURI

Overview of Quaternary deposits.—Surface sediments in Missouri are dominantly clayey till. The till deposits are relatively old and dissected. Large areas of stratified sediment, generally coarse grained, are confined to the valleys of the Missouri and Mississippi Rivers and major tributaries. Sediment thicknesses are greatest, commonly between 100 and 200 ft, on the less dissected areas of the uplands. Thicknesses decrease from north to south, toward the glacial margin, as dissection and the relative area of bedrock exposure increase.

Surficial information.—The Quaternary sediments map was compiled from a statewide surficial materials map (Whitfield, 1982), scale 1:1,100,000, supplemented by unpublished data. A moderate amount of reinterpretation was required. The reliability of the map data is considered to be moderately low.

Thickness information.—A highly generalized statewide compilation (Stohr and others, 1981), scale 1:500,000, served as the basis for compilation of thickness data for the Quaternary sediments map. Cross sections, well data, bedrock-surface and land-surface topographic maps, and surficial geologic information were used to reinterpret the thickness data shown on the statewide compilation. The reliability of the map data is considered to be low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Missouri. However, in a few places, subsurface units were depicted diagrammatically on the Quaternary sediments map. For example, in areas of thick loess (more than 20 ft), the lithology of the underlying unit was inferred.

Surficial Information

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Thickness Information

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MONTANA

Overview of Quaternary deposits.—This report includes only the continentally glaciated portion of Montana that lies east of the Rocky Mountains. Surface sediments are dominantly silty or clayey till, except in easternmost Montana, where the till is more sandy. Large areas of surficial stratified sediment, dominantly coarse grained, are confined to the valleys of major rivers, including the Missouri and Milk Rivers. Sediment thickness is generally less than 50 ft, except over preglacial or interglacial buried valleys, where thicknesses between 50 and 200 ft are common. In northeastern Montana, more than 400 ft of sediment is known to fill buried valleys. Near the glacial margin and on many areas of the glaciated uplands, the till cover is patchy and bedrock exposures are numerous. The numerous glacial lake basins adjacent to the glacial margin, formerly mapped as areas of stratified deposits with bedrock exposures, contain virtually no glacial deposits.

Surficial information.—The character of the surficial deposits has been mapped in only a few areas. For the Quaternary sediments map, the surface sediments information was compiled by interpreting geologic data from 38 publications, ranging from 1:24,000-scale geologic maps to reconnaissance soil surveys. Much of the mapped area in Montana was not covered by these publications. The reliability of the map data therefore must be considered low.

Thickness information.—Thickness data for the Montana part of the Quaternary sediments map were compiled

directly from a previous compilation (Bergantino, unpub. map, 1976), scale 1:1,000,000. That map is considered to be reasonably accurate for that scale. Given the great amount of territory that is largely unmapped, the source map's small scale is appropriate. The reliability of the map data is considered to be moderately low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Montana. However, on the Quaternary sediments map, the locations of some buried aquifers in the major buried channels are shown diagrammatically.

Surficial and Stack-Unit Information

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Thickness Information

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NEBRASKA

Overview of Quaternary deposits.—Surface sediments in Nebraska are dominantly clayey till. Large areas of stratified deposits, generally coarse grained, occur in the valleys of the Missouri and Platte Rivers and along the western margin of glaciation. Sediment thickness is greatest in the north and west, where 100 to 200 ft of sediment is common. To the south and east toward the Missouri River, the deposits are thinner and, in places, are less than 50 ft thick. To the west, in the extensive area of stratified sediment, thicknesses of 200 to 400 ft are common on the uplands away from major valleys such as the Platte.

Surficial information.—The character of surface sediments as shown on the Quaternary sediments map was

derived from geologic and soil maps ranging in scale from 1:190,080 to 1:1,000,000. Extensive interpretation was required, especially for the soil maps, because map units rarely were compatible with the map units used on the Quaternary sediments map. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from thickness maps and from thicknesses computed by comparison of bedrock-surface and land-surface topographic maps. Reliability of the map data is considered to be moderate.

Subsurface information.—Although the character and geometry of the subsurface glacial deposits are not well known, the general location of till buried by stratified deposits along the western margin of glaciation is shown diagrammatically. The location of thick loess (more than 20 ft) and the inferred lithology of the underlying deposits also are shown.

Surficial, Stack-Unit, and Thickness Information

References for surficial, stack-unit, and thickness mapping are combined into one list to avoid redundancy.

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- 1980, General soil map of Sioux City area—Nebraska: Lincoln, Neb., University of Nebraska, scale 1:250,000.

NEW HAMPSHIRE

Overview of Quaternary deposits.—Surface sediments in New Hampshire are dominantly sandy till. Large areas of coarse-grained stratified deposits occur in the Merrimack and Connecticut River valleys and major tributaries and in coastal New Hampshire. Fine-grained stratified deposits also are extensive in coastal New Hampshire and in the Connecticut River valley. On the uplands, where till is the dominant surficial deposit, sediment thicknesses generally do not exceed 50 ft, and, in areas of high relief including the White Mountains, the till cover is patchy and bedrock exposures are numerous. Thick sediments are confined to the river valleys, where stratified sediments may reach 100 ft or more in thickness.

Surficial information.—The Quaternary sediments map was compiled from 20 surficial geologic and soil maps, mostly at scales of 1:62,500 or larger. The surficial geologic map coverage is quite limited, and extensive interpretation of all available data was required. The reliability of the map data is considered to be moderately low.

Thickness information.—Sediment thickness and bedrock topography have not been mapped in New Hampshire, and so the Quaternary sediments map was compiled from well data only. The well data are concentrated in the more populous southern third of the State; throughout the State, well-data coverage permitted only a generalized interpretation of the thickness distribution. Overall, the reliability of map data therefore is considered to be low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in New Hampshire. For the Quaternary sediments map, this lack of data was relatively insignificant because of the

thinness of the glacial sediment throughout the State. In a few areas of stratified sediment, the character of buried units is shown diagrammatically.

Surficial and Stack-Unit Information

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NEW JERSEY

Overview of Quaternary deposits.—Surface sediments in New Jersey are dominantly sandy till. Coarse-grained stratified deposits are confined to river valleys, and fine-grained stratified deposits occur in glacial lake basins in northeastern New Jersey. Sediment thickness is generally less than 50 ft on the uplands. In the highlands of north-central New Jersey, the till cover is patchy and bedrock exposures are numerous. Thicker sediments, generally 50 to 100 ft, are confined to buried valleys and beneath the end moraine of the last glaciation. Beyond the end moraine, the older glacial sediment is patchy and in places is colluviated.

Surficial information.—The Quaternary sediments map was compiled from seven publications, two unpublished maps, and several written communications. Much of the data was taken from high-quality USGS geologic mapping circa 1900. Substantial revision was necessary to adapt data to the classification scheme of the Quaternary sediments map. The reliability of the map data is considered to be moderately high.

Thickness information.—Thickness data for the New Jersey part of the Quaternary sediments map were compiled directly from an unpublished map (Harper, 1986), scale 1:250,000. The reliability of the map data is considered to be moderately high.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in New Jersey. In places, the lithology of units underlying the thin peat deposits was inferred.

Surficial and Stack-Unit Information

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Thickness Information

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NEW YORK

Overview of Quaternary deposits.—Surface sediments in New York are dominantly silty till, except in the Adirondack and Catskill Mountains, where the till is more sandy. Large areas of stratified deposits, mostly coarse grained, occur in major valleys throughout the State and on Long Island. Fine-grained stratified deposits are extensive in the Lake Champlain and Lake Ontario lowlands and in the Hudson River valley. On the uplands, sediment thicknesses are generally less than 50 ft; in mountainous areas, the till is patchy and bedrock exposures are common. Thick sediment is confined to Long Island and to river valleys. In the river valleys of upstate New York and for all of Long Island, thicknesses of stratified deposits are commonly 50 to 400 ft and in some valleys are as much as 600 ft. Here, upstate New York refers to all areas of the State except Long Island.

Surficial information.—A surficial geologic map of the State did not exist, and so more than 60 publications were used to compile data on the surface sediments for the Quaternary sediments map. These publications were of many types, from county soil surveys of the early 20th century to modern, detailed geologic maps. To adapt these different types of maps to the uniform classification system of the Quaternary sediments map, extensive interpretation of all available data was required. Overall, the reliability of the map data is considered to be moderate for upstate New York and high for Long Island.

Thickness information.—Sediment thickness distribution is poorly known for upstate New York, whereas, for Long Island, the density of data allows a good estimate of thickness. For upstate New York, data from 31 publications were used to estimate thicknesses. In general, these data were well logs, and coverage for the State was overall quite low. For Long Island, topographic maps of the top of the underlying Coastal Plain surface contained in 14 publications were used to compile sediment thicknesses. For

upstate New York, the reliability of the map data is considered to be low; for Long Island, it is moderately high.

Subsurface information.—In upstate New York, the nature of the subsurface deposits is not well known, and the Quaternary sediments map shows buried units in only a few areas. On Long Island, however, well control is good, and major buried units are shown diagrammatically.

Surficial and Stack-Unit Information

Upstate New York

- Austin, M.E., Carlisle, F.J., McCracken, R.J., Dushek, L., and others, 1958, Soil survey of Franklin County, New York: Washington, D.C., U.S. Soil Conservation Service, 75 p., scale 1:20,000.
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- Carr, M.E., Gilbert, B.D., Morrison, T.M., and Maxon, E.T., 1911, Soil survey of Jefferson County, New York: Washington, D.C., U.S. Soil Conservation Service, 83 p., scale 1:62,500.
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- Howe, F.B., Buckman, H.O., and Lewis, H.G., 1920, Soil survey of Tompkins County, New York: Washington, D.C., U.S. Soil Conservation Service, 56 p., scale 1:62,500.
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- MacClintock, P., and Stewart, D.P., 1965, Pleistocene geology of the St. Lawrence Lowland: New York State Museum and Science Service Bulletin 394, 152 p., scale 1:125,000.
- Maine, C.H., 1968, General soils report, Warren County: Washington, D.C., U.S. Soil Conservation Service and Warren County Soil and Water Conservation District, 24 p., scale approx. 1:155,000.
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- Maxon, E.T., and Fuller, G.L., 1915, Soil survey of Schoharie County, New York: Washington, D.C., U.S. Soil Conservation Service, 34 p., scale 1:62,500.
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NORTH DAKOTA

Overview of Quaternary deposits.—Surface sediments in North Dakota are dominantly till. In the western half of the State, the till is sandy; to the east, the till is more clayey. Large areas of stratified deposits are associated with the end moraine in south-central North Dakota, where coarse-grained sediments dominate, and in glacial lake basins, where both coarse- and fine-grained sediments are found. Along the eastern border of the State, fine-grained stratified sediment dominates in the glacial Lake Agassiz basin. In the north-central region, both coarse- and fine-grained sediments occur in the glacial Lake Souris basin. Sediment thickness is commonly greater than 50 ft, except along a large north-south ridge in east-central North Dakota and near the glacial margin. An extensive network of buried valleys occurs in central North Dakota, where sediment thicknesses may exceed 400 ft in places. In the Lake Agassiz basin, between 200 and 400 ft of sediment is common.

Surficial information.—Statewide surficial geologic maps were available (Bluemle, 1977; Clayton, 1980) at scales of 1:1,000,000 and 1:500,000, respectively. These maps were used to compile the Quaternary sediments map and were supplemented with more than 10 detailed maps of specific areas to improve the interpretations, since not all geologic units on the statewide maps could be properly interpreted by the classification scheme of the Quaternary sediments map. Overall, the reliability of the map data is considered to be moderately high.

Thickness information.—A preliminary statewide map of sediment thickness (Bluemle, 1971), scale 1:500,000, served as the basis for compilation of thickness data for the Quaternary sediments map. Because the state-

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wide map was generalized and eight more recent maps of smaller areas were available, extensive reinterpretation of the map was required. The reliability of the map data is considered to be moderate.

Subsurface information.—Some county geologic reports contain generalized subsurface data in cross sections. These data were used to show diagrammatically the probable extent of certain major buried units such as extensive aquifers.

Surficial and Stack-Unit Information

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OHIO

Overview of Quaternary deposits.—Surface sediments are dominantly clayey till in the lowlands south and west of Lake Erie in northern Ohio, whereas till is silty to the south of the lake lowlands. Large areas of stratified deposits, generally coarse grained, are confined to the valleys of large rivers such as the Great Miami and Scioto. Fine-grained stratified deposits in places overlie till on the lake lowlands and in ice-gouged valleys in northeastern Ohio. Sediment thickness on uplands is generally less than 50 ft except over the extensive network of preglacial and interglacial buried valleys in central Ohio, where sediment thicknesses in places exceed 400 ft. In the stratified deposits in valleys, sediment is commonly more than 100 ft thick. In the ice-gouged valley beneath the lower Cuyahoga River, thicknesses exceed 600 ft.

Surficial information.—Although a statewide surficial map (Goldthwait and others, 1961), scale 1:500,000, served as the basic data source, several other maps and written communications were also used. The statewide map emphasized glacial ages and ice advances, whereas the Quaternary sediments map emphasizes sediment character; the difference between the two mapping schemes was so great that extensive reinterpretation and incorporation of other, more detailed mapping was necessary. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from maps of bedrock-surface topography, sediment thickness, and land-surface topography and from well data. Seventy-nine publications were used to compile an interim publication (Soller, 1986), which was then used to compile the Quaternary sediments map. The reliability of map data is considered to be moderately high.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Ohio. In places where detailed study has shown the presence of extensive and thick buried units, they were shown diagrammatically.

Surficial and Stack-Unit Information

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Thickness Information

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PENNSYLVANIA

Overview of Quaternary deposits.—Surface sediments are dominantly silty till in northwestern Pennsylvania and sandy till in northeastern Pennsylvania. In northeastern Pennsylvania, large areas of stratified deposits, mostly coarse grained, are confined to large river valleys. In northwestern Pennsylvania, fine-grained stratified deposits occur in deep, preglacial or interglacial buried valleys. Sediment thickness on the uplands is generally less than 50 ft, and, in much of northeastern Pennsylvania, the till cover is patchy and bedrock exposures are numerous, especially near the glacial margin. In the valleys of northeastern Pennsylvania, sediment thicknesses commonly are low, seldom exceeding 100 ft. In northwestern Pennsylvania, sediment thicknesses in the valleys are commonly 100 to 400 ft.

Surficial information.—Surficial mapping in northwestern Pennsylvania by Shepps and others (1959), scale 1:125,000, served as the basis for the Quaternary sediments map without extensive reinterpretation. In contrast, an adequate surficial map did not exist for northeastern Pennsylvania; nearly 50 publications ranging from detailed geologic maps to reconnaissance soil maps were used to compile the Quaternary sediments map. For northwestern Pennsylvania, the reliability of the map data is considered to be moderate, whereas data reliability for northeastern Pennsylvania is considered to be moderately low.

Thickness information.—For northwestern Pennsylvania, sediment thickness was compiled from local sediment-thickness maps, bedrock-surface topographic maps, well data, and general geologic descriptions contained in 13 publications. For northeastern Pennsylvania, thickness data were sparse. The nearly 50 publications used for the surficial mapping, as well as additional sources including a computerized well inventory, were used to compile a generalized map of sediment thickness. The reliability of map data in northwestern Pennsylvania is considered to be moderately low, and, in northeastern Pennsylvania, it is considered to be low.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in Pennsylvania. In only one area, along the shore of Lake Erie, is the nature of the subsurface deposits shown.

Surficial and Stack-Unit Information

Northeastern Pennsylvania

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RHODE ISLAND

Overview of Quaternary deposits.—Surface sediments in Rhode Island are dominantly sandy till. Large

areas of coarse-grained stratified sediment occur in valleys and adjacent to Narragansett Bay. Sediment thicknesses seldom exceed 50 ft, and, in many places, the till cover is patchy and bedrock exposures are numerous.

Surficial information.—A statewide compilation (Lang and others, 1960), scale 1:150,000, was used to compile the Quaternary sediments map; 13 detailed geologic maps were used to refine the mapping in certain areas. The reliability of the map data is considered to be moderately high.

Thickness information.—The thickness information for the Quaternary sediments map was compiled from nine publications. The reliability of the map data is considered to be moderately high.

Subsurface information.—Because of the small size of Rhode Island and the general lack of subsurface studies, buried units were not shown.

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SOUTH DAKOTA

Overview of Quaternary deposits.—Surface sediments in South Dakota are dominantly clayey till in the lowlands, whereas more silty till occurs near the margins of the glaciated area. Coarse-grained stratified deposits are distributed in patches on the uplands known as the Prairie Coteau in eastern South Dakota and in river valleys elsewhere. Fine-grained stratified deposits occur in the basin of glacial Lake Dakota, west of the Prairie Coteau. Sediment

thicknesses vary greatly, from 400 to 800 ft beneath the Prairie Coteau to less than 50 ft in the Lake Dakota lowlands to the west. South and west of the lake basin, sediment thicknesses are commonly 100 ft or more, and they exceed 400 ft over some buried valleys. Along the glacial limit adjacent to the Missouri River, the sediment cover is patchy, and weathered rock commonly is exposed.

Surficial information.—A statewide surficial map (Bretz, 1984), scale 1:500,000, was used to compile the Quaternary sediments map and was supplemented by nine other publications and written communications in order to refine the map data and adapt the map units to the classification system. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from nine references containing bedrock-surface topographic and sediment-thickness maps and well data. The reliability of the map data is considered to be moderate.

Subsurface information.—The character and geometry of glacial deposits in the subsurface are not well known in South Dakota, and only a limited amount of subsurface information, based on extrapolation of data from North Dakota, was shown.

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VERMONT

Overview of Quaternary deposits.—Surface sediments in Vermont are dominantly sandy till. Large areas of stratified deposits are confined to lowlands; these deposits are dominantly fine grained in the Champlain and Connecticut River valleys and coarse grained in other river valleys and in deltaic deposits bordering the Champlain lowlands. Sediment thickness in Vermont is generally less than 50 ft; in mountainous areas, the till cover is patchy and bedrock is exposed in many places. Thicker sediment is confined to valleys, where as much as 100 ft of stratified sediment is preserved.

Surficial information.—A statewide surficial map (Stewart and MacClintock, 1970), scale 1:250,000, was used to compile the Quaternary sediments map. A reconnaissance soil map was used to map areas of patchy till. The reliability of the map data is considered to be moderate.

Thickness information.—Sediment thickness was compiled from hundreds of data points obtained from State well-log files and from well data and cross sections in 12 publications. The reliability of the map data is considered to be low.

Subsurface information.—Although the character and geometry of subsurface glacial deposits are not well known, the general nature of the subsurface deposits in the Connecticut River valley and beneath glacial deltas in the Lake Champlain valley is shown.

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WISCONSIN

Overview of Quaternary deposits.—Surface sediments in Wisconsin are dominantly sandy till, except near Lake Michigan, where tills are silty and clayey. Coarse-grained stratified deposits cover large areas of the uplands in northern and central Wisconsin, especially where glacial interlobate areas existed. Near the Great Lakes and near the nonglaciated area of southwestern Wisconsin, sediment thickness generally is less than 50 ft; in places, the till cover is patchy and bedrock exposures are numerous. In southeastern Wisconsin and on the uplands of northern and central Wisconsin, sediment thicknesses are greater, exceeding 100 ft in many places.

Surficial information.—The distribution of surface sediments was compiled from 35 sources, whose scales ranged from 1:15,840 to 1:1,000,000; mapping emphasis ranged from statewide soil surveys to detailed surficial geologic maps. The reliability of the map data is considered to be moderately low.

Thickness information.—The thickness information for the Quaternary sediments map was compiled mostly from a generalized statewide map by Trotta and Cotter (1973), scale 1:1,000,000. The reliability of the map data is considered to be moderately low.

Subsurface information.—Although the character and geometry of subsurface glacial deposits are not well known, the character of buried sediments in the area inundated by glacial lakes near Green Bay and Lake Winnebago was

shown, albeit diagrammatically, because these glacial lake sediments are thin and discontinuous.

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GREAT LAKES

Overview of Quaternary deposits.—Surficial bottom sediments in the Great Lakes are dominantly fine-grained stratified glacial lake sediments and Holocene muds. In places, till or rock underlie the lake bottom, particularly in coastal areas. Sediment thicknesses vary greatly for the different lakes. In eastern Lake Superior, sediment thicknesses are generally less than 100 ft except over buried valleys or grooves gouged out by the ice. In the western part of the lake, sediments commonly exceed 200 ft in thickness, and, in the deepest parts of the basin, they exceed 800 ft. In Lake Michigan, sediment thickness in the southern basin is generally less than 100 ft, whereas, in the central basin, thicknesses exceed 400 ft in places. No data are available for northern Lake Michigan. In Lake Huron, sediment thicknesses in the axis of the basin are commonly more than 100 ft and in places exceed 200 ft, whereas, elsewhere in the lake, the sediment is much thinner, generally less than 50 ft. In the westernmost part of Lake Erie, sediments are mostly less than 50 ft thick. To the east, sediments thicken, and in the east-central part of the lake, sediments exceed 200 ft in thickness. Along the lake margins, however, sediment is thin to less than 50 ft. Unlike Lake Erie, Lake Ontario is only partly filled with sediment.

Even along the axis of the basin, less than 100 ft of sediment is present. In Lake Champlain, sediments are generally thin except in a series of narrow ice-gouged channels in the central part of the lake.

Surficial information.—The Quaternary sediments map was compiled from five publications, which show the bottom sediment distribution in a highly generalized fashion. The reliability of the map data is considered to be moderately low.

Thickness information.—Sediment thickness was determined from several published and unpublished sources, containing data as varied as sediment thickness, bedrock-surface topography, and cross sections. The reliability of the map data is considered to be moderately low.

Subsurface information.—No attempt was made to characterize buried units beneath the Great Lakes.

Character of Lake-Bottom Sediments

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ATLANTIC OFFSHORE

Overview of Quaternary deposits.—In general, surficial bottom sediments are dominantly fine grained and stratified in Long Island Sound and eastward to roughly the Rhode Island-Massachusetts line. To the east, around Cape Cod, and northward to offshore New Hampshire, coarser grained stratified sediments dominate. Along the Maine coast, till and fine-grained stratified bottom deposits are common. From Long Island Sound eastward to the limit of data at Nantucket Island, sediment thickness exceeds 400 ft over buried valleys; on the submarine uplands, less than 100 ft of sediment is common. North of Cape Cod, sediment thickness is variable but generally thins northward. In offshore areas of Maine, sediment is less than 50 ft thick in most places, exceeding 100 ft only in large buried valleys.

Surficial information.—Fifteen sources were used in the Quaternary sediments map compilation. Bottom grab samples, which sample only the upper few inches of the sea floor, were the most common data available. On some source maps, lithology was estimated by seismic characteristics. Overall, the reliability of the map data is considered to be moderately low.

Thickness information.—In many areas, the thickness of Holocene sediments and thickness of glacial sediments were computed at points along seismic tracklines and were used to calculate total Quaternary sediment thickness. In other areas, bedrock-surface contour maps and bathymetric maps were available, and sediment thickness was computed from those. The reliability of the map data is considered to be moderately high.

Subsurface information.—No attempt was made to characterize buried units offshore.

Character of Bottom Sediments

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Thickness of Quaternary Sediment

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ONTARIO, CANADA

Overview of Quaternary deposits.—In southern Ontario, surface sediments are dominantly silty till, except in the Great Lakes lowlands where the till is clayey. Large areas of stratified deposits, generally coarse grained, are present throughout southern Ontario and are especially

common near Lake Erie. Sediment thickness is mostly between 50 and 200 ft; near the northern coast of Lake Erie and north of Lake Ontario, thicknesses exceed 200 ft.

Surficial information.—A surficial map of southern Ontario (Chapman and Putnam, 1984), scale 1:600,000, was used to compile the Quaternary sediments map. Minor reinterpretation was required to adapt map units to the classification scheme of the Quaternary sediments map. The reliability of the map data is considered to be moderately high.

Thickness information.—A sediment-thickness map prepared by the Ontario Geological Survey (Sado and Easton, 1985), scale 1:125,000, was used to compile the Quaternary sediments map. The reliability of the map data is considered to be moderate.

Subsurface information.—No attempt was made to characterize the subsurface deposits of southern Ontario.

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