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)

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INTRODUCTION

This map portrays the thickness and character of Quaternary sediments in the glaciated Northern and Central Plains States betwen 90° and 102° West longitude. It is one of a series of four maps presenting a regional synthesis and interpretation of available geologic data for the continentally glaciated United States east of the Rocky Mountains (see map, fig. 1). The numerous references (approximately 850) used to compile these maps, the majority of the acknowledgments, and a further explanation of the maps are contained in Soller (1992). Showing both the thickness and character of unconsolidated deposits, this map is in essence a three-dimensional view of the outermost layer of the Earth. Because the character of sediments is depicted on this map without implications regarding geologic time or events, the map complements regional maps that emphasize geologic events, 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).

This map has three data components: the surface distribution of Quaternary sediments, the total thickness of Quaternary sediments, and the distribution of significant buried Quaternary units. The Quaternary sediments shown in this map series are glacial or glacially related deposits (including overlying Holocene sediments). Of limited extent and not shown are areas of Quaternary colluvium not derived from glacial deposits; as used on these maps, the term "Quaternary sediment" does not include this type of colluvium. 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.

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 three-dimensional geologic maps that can be directly applied to hydrologic, environmental, and land-use problems. Such maps depict the texture of surface and subsurface geologic materials, commonly to a specified depth or geologic contact. The glaciated region of the United States depicted in this map series has a particular need for three-dimensional geologic mapping. 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 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 an initial regional view of the glaciated sedimentary framework east of the Rocky Mountains.

ACKNOWLEDGMENTS

During map compilation and production, I sought advice from a number of 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. My appreciation goes to Albert J. Froelich and James P. Owens (USGS) for reviewing the manuscript.

I also thank the many geologists consulted during this project for their willingness to share information and insight, their advice on mapping interpretations, and their comments during map review. Their names are listed in Soller (1992).

DIGITAL MAP PRODUCTION AND THE BASE MAP

The maps of this series were produced by newly developed 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 maps of this series span four sheets (this map sheet, and Soller (1993, 1994, and in press a)). Each sheet consists of a hand-mosaicked group of 4° × 6° quadrangles from the International Map of the World and Army Map Service 1:1,000,000-scale maps. Because these map sheets cover 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 land surface, the total thickness of Quaternary sediments, and selected subsurface data. Different colors are used to depict character of sediment at the land surface. 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.

The density and detail of source 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 shown in figures 2 and 3, respectively (see map), which are discussed in the "Surficial mapping" and "Thickness mapping" sections below.

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.

In the Atlantic Ocean, the Great Lakes, and in some other large lakes, the underlying geology is shown only in places where studies have been made. In these cases, water areas where no geologic data are shown are tinted gray. In most lakes, however, no studies of the underlying geology have been undertaken. To simplify map preparation and digitizing, the author used a somewhat arbitrary division for these lakes: for relatively small lakes, geologic data were extrapolated from surrounding land, while for larger lakes no attempt at extrapolation was made, and they are tinted gray.

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, the term "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. In all four maps, definitions of sediment character are necessarily broader than would be required for any local area, so that the simple, uniform system would be applicable across the entire area, from Maine to Montana.

This classification is limited to the following sediment types: till (poorly sorted and poorly stratified sediment), coarse-grained stratified sediment, fine-grained stratified sediment, organic-rich sediment (peat, for example), and windblown sediment (mostly loess) where it occurs at the surface. Loess is largely silt; eolian sand is included in the category of coarse-grained stratified sediment and is mapped as a veneer. These deposits are each discussed below.

Till

Till, the most widespread unit on these maps, consists of material deposited in contact with glacial ice; in the other units, sediment was sorted by water or wind prior to deposition. Till is a poorly sorted and generally unstratified deposit composed of particles ranging in size from clay to large boulders (see map, fig. 4). The relative proportions of these size fractions can vary greatly due to several factors, resulting in a textural range from dense and compact clayey till with few grains larger than sand size, to loose, sandy till with abundant boulders and only small amounts of the finer size fractions. The dominant grain size and the distribution of particle sizes are generally referred to as the texture of the till. A discussion of the relation between till texture, lithology of the underlying bedrock, and pattern of ice lobation is provided in Soller (1992).

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. 4). However, as shown in figure 4 and discussed below, coarse-grained and fine-grained stratified deposits have overlapping textural ranges.

Coarse-grained stratified sediment

These deposits generally consist of layered sand and gravel, with less common silt and clay beds, deposited in fluvial, glaciofluvial, 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 this unit, 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. 4). 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 occurred 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 geologic 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

These deposits generally are clay, silt, and very fine sand but include lesser amounts of coarser material (fig. 4), 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 previously, 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 lake deposits in areas inundated by proglacial lakes; these deposits, however, are quite sparse and are not shown on the maps of this series.

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 below and in the Description of Map Units.

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 covered by these maps, 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 "Subsurface mapping" discussion below and example in "Stack-unit mapping" section of the Description of Map Units). 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

Quaternary sediment does not blanket the surface in some parts of the glaciated area. There, patchy Quaternary sediment may occur with exposures of bedrock, of residuum, or of alluvium or 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 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.

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 3. 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 crosscutting 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 map (Soller, in press a) may be the red beds.

Elliptical landforms, shaped and oriented by overriding ice, are common in some areas. They are generally composed of dense, compact till, but may be rock-cored or entirely rock. The composition of these streamlined landforms can be determined by augering; however, since 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, and 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 these maps were reported in U.S. customary units (feet). For simplicity and accuracy during map compilation, this system was retained. A metric conversion table is included to assist those readers desiring to work with metric units.

SUBSURFACE MAPPING

Characterizing subsurface variations in lithology is exceedingly difficult in nonmarine Quaternary sediment, because textural variations occur both vertically and laterally over short distances. In Illinois (Berg and others, 1984 [map scale 1:500,000], and Berg and Kempton, 1988 [map scale 1:250,000]) and in Connecticut (Stone and others, 1992 [map scale 1:125,000]), subsurface data are presented by map units each representing a vertical "stack" of lithologic units (see Kempton, 1981, for a discussion of the stack-unit concept). These maps are complex and portray the subsurface data effectively. However, their methods of showing relatively detailed subsurface data are not feasible on the four maps of this series; data density and reliability are highly uneven from State to State, and in certain areas the deposits are too thick and the stratigraphy too complex to be portrayed by their methods.

In general, the subsurface is not shown on the four maps of this series 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. The stack units are shown by colors and patterns on the maps, to convey the existence and general configuration of regional, large-scale geologic features. These stack units include, but are not limited to, the following deposits: 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).

As shown in the examples given in the "Stack-unit mapping" section of the Description of Map Units, these two-unit stacks should not be interpreted to 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. Unmapped, speculative variations in sediment character at depth are not shown here. A comprehensive map of the subsurface, based in part on extrapolation of available data, is the proper role of detailed, three-dimensional mapping, not of a regional map such as this.

Through the use of colors and patterns, the stack units emphasize either the surficial unit or the buried unit, depending in part on their relative thicknesses and in part on knowledge of the subsurface. 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 diagonal stripes whose color reflects that unit's lithology. Where the geometry of a buried unit (for example, stratified sand and gravel filling 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. To illustrate the variations in subsurface lithologies that may actually be encountered at depth, lithologic logs from different geologic settings (for example, buried valleys and upland areas) are shown in figure 5 below.

SUMMARY

The four maps in this series can be placed in perspective by emphasizing the following points:

1. The mapping emphasis differs from 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. The actual character of the sediments is necessarily given a subordinate, albeit significant role on those maps. In contrast, these maps show the character of surficial sediments without regard to age of the deposits. Because of this fundamental difference, the distribution of sediments on event-oriented maps may not agree with these maps. For example, in many glaciated areas inundated by proglacial lakes, the surficial sediment is commonly till, somewhat altered where reworked by the lake water. On event-oriented maps, however, because of the glacial geologic history, lacustrine clay, silt, and sand are commonly mapped (inferentially) throughout a lake plain, although these deposits may be areally subordinate to till. Additionally, while the four maps of this series differentiate between areas where Quaternary sediments have been preserved and where they were eroded or never deposited, maps emphasizing stratigraphy or geomorphology have usually included extensive areas of bedrock or nonglacial sediment in the glacial map units (for example, Flint, 1959; Colton and others, 1961, 1963).

2. These maps depict the surface distribution of sediments and the total thickness of the Quaternary deposits; the continuation of the surficial unit down to the pre-Quaternary surface ("bedrock") cannot necessarily be inferred, although this may commonly be the case especially in areas where the Quaternary sediment is thin.

3. These maps are a regional first approximation of the three-dimensional distribution of sediments over a very large area. They are intended to encourage additional research and detailed mapping. *They are also intended to supplement, not supersede, the local, detailed studies from which they were compiled, and should not be used to infer specific details concerning the local geologic framework; they are not site-specific maps.* Complementing detailed mapping, regional maps such as these place local, detailed mapping in a regional 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. A regional map in many cases will point out a problem or relation that is not apparent on a detailed map, which will allow information from the detailed map to be reinterpreted.

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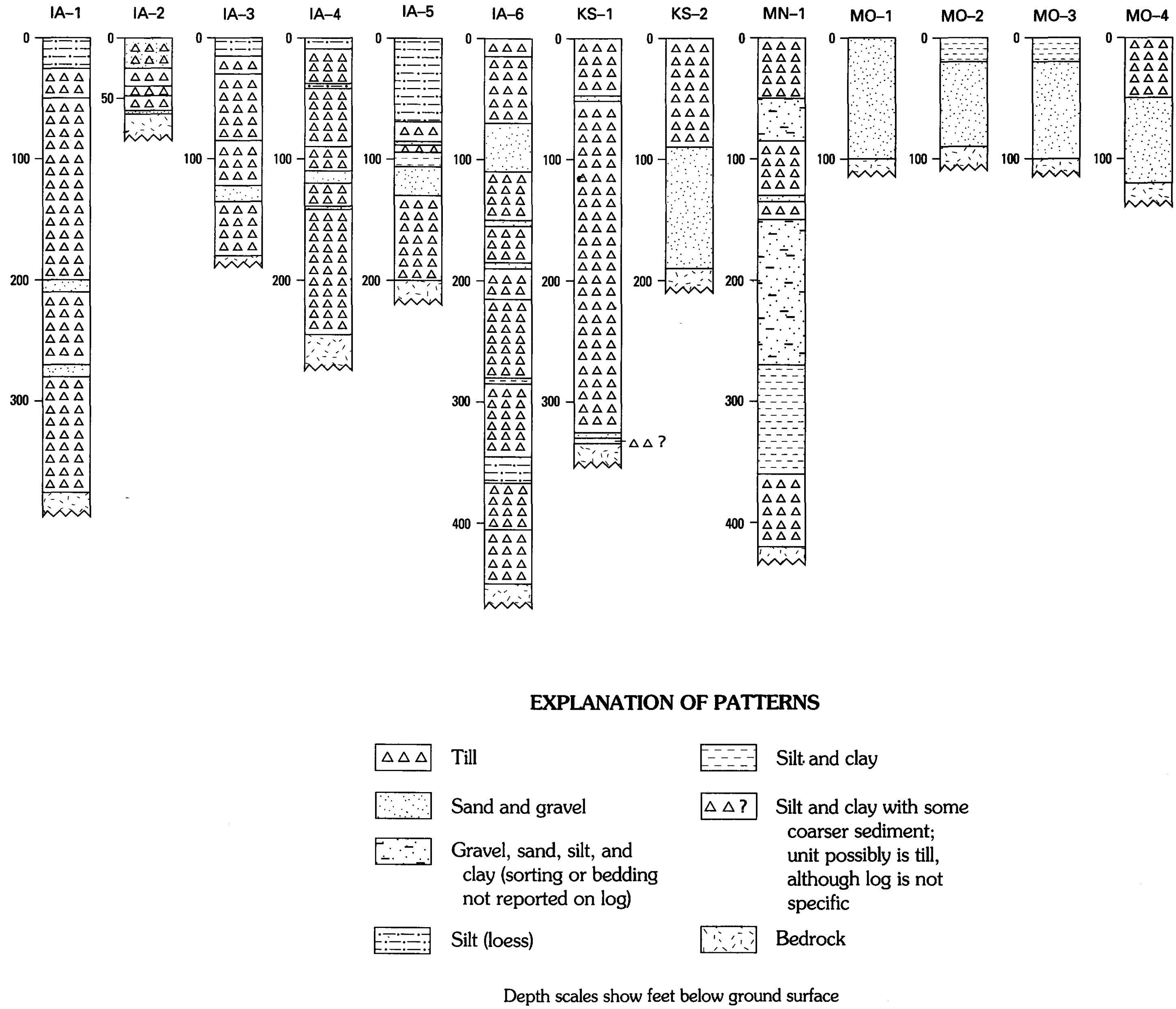

Figure 5.—Selected lithologic logs illustrating subsurface lithologic variations in different geologic settings, including buried valleys, river valleys, and upland areas. Locations are shown on map. Logs were selected to alert the map user to the potential vertical lithologic variations in different settings, and to show the subsurface in certain areas where stack units are mapped. Similar lithologic variations in similar geologic settings are not implied; therefore, extrapolation of log data should be avoided. Depth scales show feet below ground surface.

DESCRIPTION

Iowa

IA–1—Loess over thick section of multiple tills on uplands between Cedar and Iowa Rivers, southwest of Waterloo (Hallberg, 1980, Fourmile Creek composite section)

IA–2—Sand overlying multiple tills, near Iowa River northwest of Iowa Falls (Iowa Geological Survey, unpublished log, Dows Quarry site)

IA–3—Thick section of multiple tills on uplands in southwestern Iowa, south of Massena (Iowa Geological Survey, unpublished log, Massena corehole site)

IA–4—Thick section of multiple tills on uplands in southwestern Iowa near Missouri border, east of Mount Ayr (Iowa Geological Survey, unpublished log, Mount Ayr corehole site)

IA–5—Thick loess over till and stratified sediment, east of the Missouri River valley near Pisgah (between Sioux City and Council Bluffs) (Iowa Geological Survey, unpublished log, boring no. WC–24)

IA–6—Thick section of alternating till and stratified sediment in northwestern Iowa, northeast of Ocheyedan (Iowa Geological Survey, unpublished log, test boring no. D–13)

Kansas

KS–1—Thick till filling buried valley in northeastern Kansas, south of Vermillion (Walters, 1954, test hole no. 4–10–25dd)

KS–2—Till overlying stratified sediment in buried valley on uplands in northeastern Kansas, east of Delaware River and south of Muscotah (Ward, 1973, test hole no. 6–17E–14ccb)

Minnesota

MN–1—Till and stratified sediment on upland in central Minnesota, south of Eagle Bend (Minnesota Geological Survey, unpublished test hole no. CC–19)

Missouri

MO–1—Alluvium in Missouri River valley, east of St. Charles (Emmett and Jeffery, 1968, cross section A–A′)

MO–2—Alluvium in Mississippi River valley, north of St. Charles (Gann and others, 1971, cross section G–G′)

MO–3—Alluvium in Missouri River valley, in west-central Missouri south of Wakenda (Emmett and Jeffery, 1970, cross section A–A′)

MO–4—Till overlying sand in buried valley south of Missouri River valley, in west-central Missouri near Malta Bend (Emmett and Jeffery, 1970, cross section A–A′)

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Figure 5.—Continued

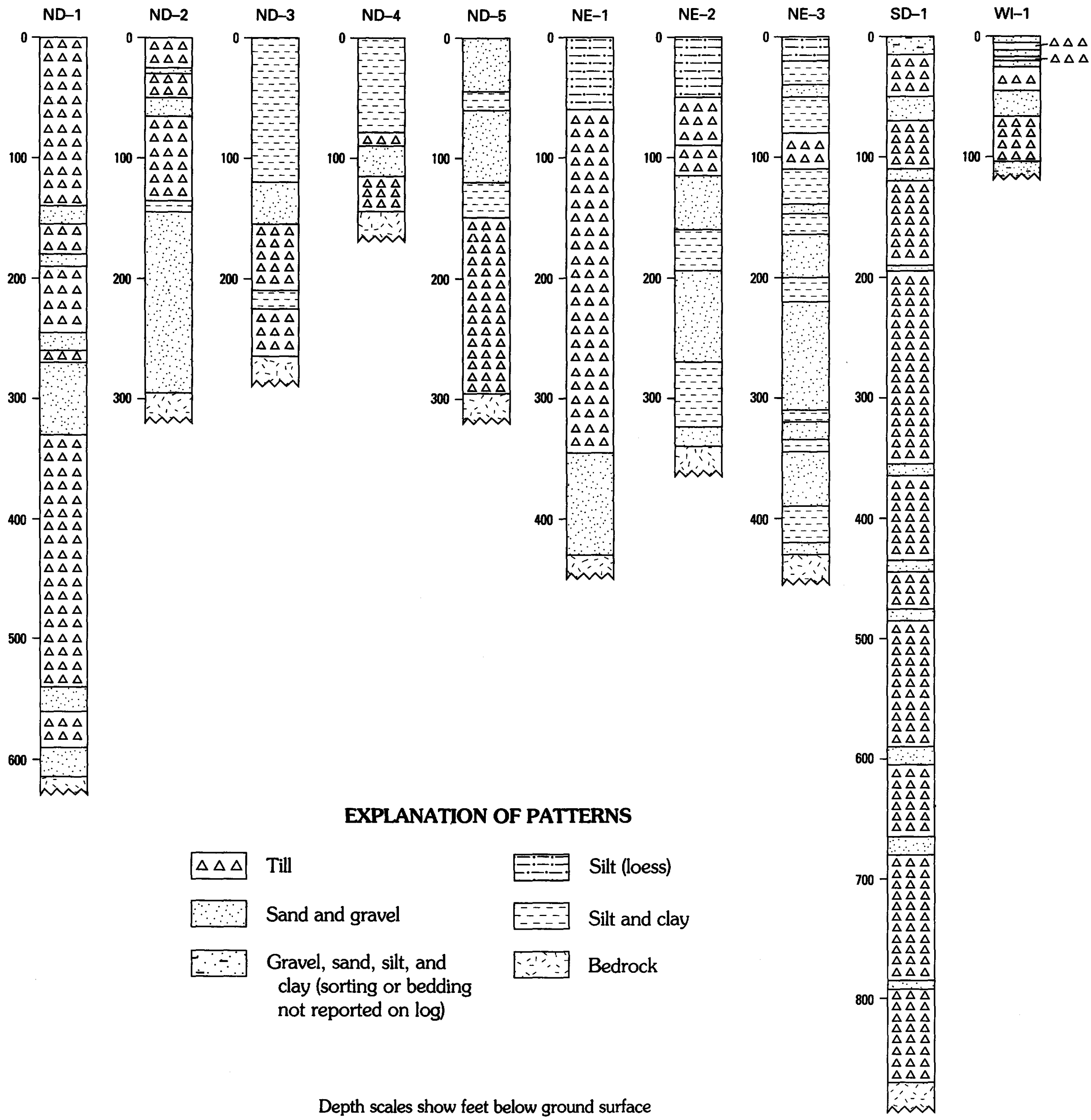

Figure 5.—Continued

DESCRIPTION

Nebraska

NE–1—Thick loess over till and stratified sediment, on the uplands between the Platte and Elkhorn Rivers in eastern Nebraska, southeast of Norfolk (Conservation and Survey Division, 1953, hole no. A21–3–17ad)

NE–2—Thick loess and till overlying stratified sediment, on the uplands between the Platte and Elkhorn Rivers in eastern Nebraska, southeast of Norfolk (Schultz and Smith, 1965, figure 3–16, hole no. CSL–SW–SE–sec.29–22N–4E).

Part of the stratified sediment may be from a western, noncontinentally glaciated source (Vince Dreeszen, Nebraska Geological Survey, personal commun., 1986)

NE–3—Extensive outwash deposits along the glacial margin, in southeastern Nebraska south of Exeter (Keech and Dreeszen, 1968, hole no. 7–1–3aa)

North Dakota

ND–1—Alternating till and sand, beneath stagnation moraine and over a buried valley, in central North Dakota north of Denhoff (Bluemle, 1981, hole no. 5347)

ND–2—Alternating till and stratified sediment in a buried valley, in central North Dakota west of Sheyenne River (Carlson and Freers, 1975, hole no. 5311)

ND–3—Generally fine-grained stratified sediment and till, on the glacial Lake Agassiz plain in northeastern North Dakota, north of St. Thomas (Arndt, 1975, hole no. 5940)

ND–4—Generally fine-grained stratified sediment and till, near western margin of glacial Lake Agassiz in northeastern North Dakota (Arndt, 1975, hole no. 4220)

ND–5—Coarse- and fine-grained stratified sediment of Sheyenne delta built into glacial Lake Agassiz and overlying till, in southeastern North Dakota south of Leonard (Klausing, 1968, hole no. 137–52–31bbb)

South Dakota

SD–1—Thick section of alternating tills and coarse-grained stratified sediment in the interlobate Prairie Coteau region, in eastern South Dakota west of Tunerville (South Dakota Geological Survey, unpublished log, test hole no. DR–7308)

Wisconsin

WI–1—Locally thick occurrence of alternating till and stratified sediment in an otherwise thinly mantled area near Lake Superior, on the Bad River north of Mellen; surficial sand is not widespread enough to be mapped (Mickelson and others, 1984, type section of Copper Falls Formation)

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Figure 5.—Continued

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