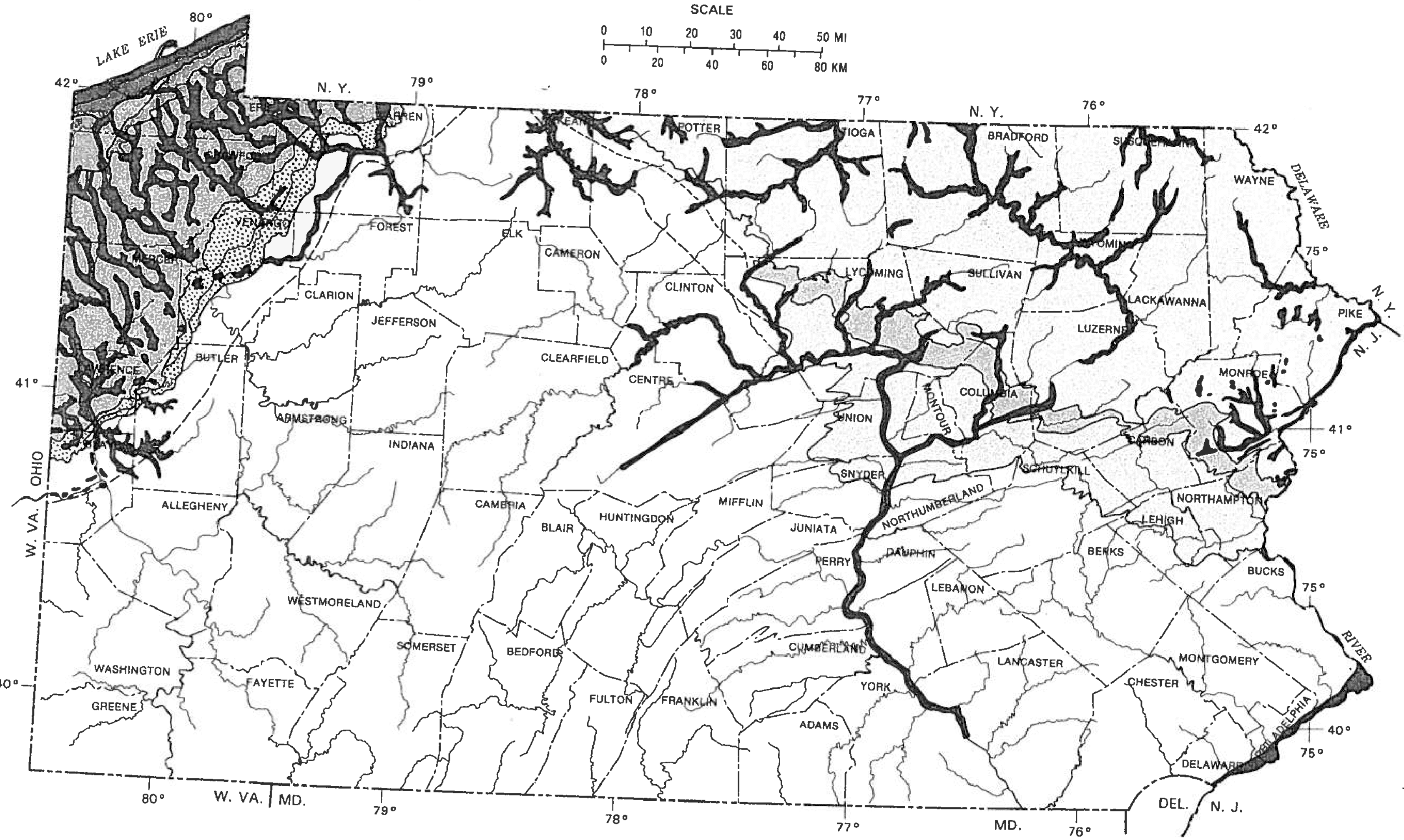

EXPLANATION

RECENT TO LATE ILLINOIAN
(0–198,000 yrs.)

STRATIFIED DRIFT

Sand and gravel in eskers, kames, kame terraces, and outwash, principally in valleys; silt and clay in lake deposits in formerly ice-dammed valleys; lake clays and beach sands and gravels along Lake Erie; thin (Recent) to thick (late Illinoian) soils.

WISCONSINAN
(17,000–22,000 yrs.)

ASHTABULA TILL
HIRAM TILL
LAVERY TILL
KENT TILL

Thick, gray, clayey to silty to sandy till covering over 75 percent of the ground; topography is mainly gently undulating, but there is also some knob-and-kettle topography; thin soil.

OLEAN TILL

Moderately thick, gray to grayish-red, sandy till covering 25 to 50 percent of the ground; very thin till covers an additional 25 percent of the ground; topography reflects the underlying bedrock; thin soil.

LATE ILLINOIAN
(132,000–198,000 yrs.)

TITUSVILLE TILL
UNNAMED TILLS

Thin, gray (Titusville) to brown and grayish-red (unnamed), clayey to sandy till covering 10 to 25 percent of the ground; topography reflects the underlying bedrock; moderately thick, well-developed soil.

PRE-ILLINOIAN
(>770,000 yrs.)

MAPLEDALE TILL
UNNAMED TILLS

Thin, gray, clayey to silty till in patches covering up to 10 percent of the ground; topography reflects the underlying bedrock; thick, well-developed soil, commonly having a yellowish-red color.

SYMBOLS

Southern limit of glacial advance

Approximate limit of Illinoian advance

Approximate limit of pre-Illinoian advance

Figure 15-1. Glacial deposits of Pennsylvania (from Pennsylvania Geological Survey, 1981, and Sevon and Braun, 1997).

CHAPTER 15 QUATERNARY

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INTRODUCTION

The Quaternary Period includes the last approximately 2.8 million years of geologic time (Beard and others, 1982). It is divided into the Pleistocene Epoch, which was marked by several northern- and southern-hemisphere continental glaciations, and the Holocene Epoch, which is the current interglacial period of time that started about 10,000 years ago. Most of the deposits associated with this interval in Pennsylvania are related directly or indirectly to glaciation. For purposes of discussion, the state is subdivided into two areas: (1) the glaciated parts of northwestern and northeastern Pennsylvania, and (2) the nonglaciated remainder of the state (Figure 15–1).

GLACIATED AREA

Four major periods of glaciation are identified in northwestern Pennsylvania (Shepps and others, 1959; White and others, 1969), and it is assumed that the same glaciations occurred in northeastern Pennsylvania, although evidence for the oldest glaciation is lacking. From oldest to youngest, these glaciations are pre-Illinoian (two), Illinoian, and late Wisconsinan (Woodfordian). Available data indicate that the younger pre-Illinoian glaciation was the most extensive, and that all of the glaciations followed similar patterns of advance and deglaciation (Braun, 1988). Most generalizations about glaciation in Pennsylvania are based on data obtained from deposits and erosional features of the last glaciation, the Woodfordian.

Continental glaciation in Pennsylvania derived from the Laurentide ice sheet, which spread south from its center over Hudson Bay in Canada. The ice sheet separated into lobes near its southern margin (Mickelson and others, 1983), and ice flow into Pennsylvania was via the Erie lobe in the northwest and the Lake Champlain-Hudson River lobe in the northeast (Figure 15–2). These lobes did not meet in Pennsylvania, and the unglaciated triangular part of Pennsylvania and New York between the two lobes is called the Salamanca Re-entrant. The maximum thickness of the ice is not known, but it certainly exceeded 1,000

*Deceased.

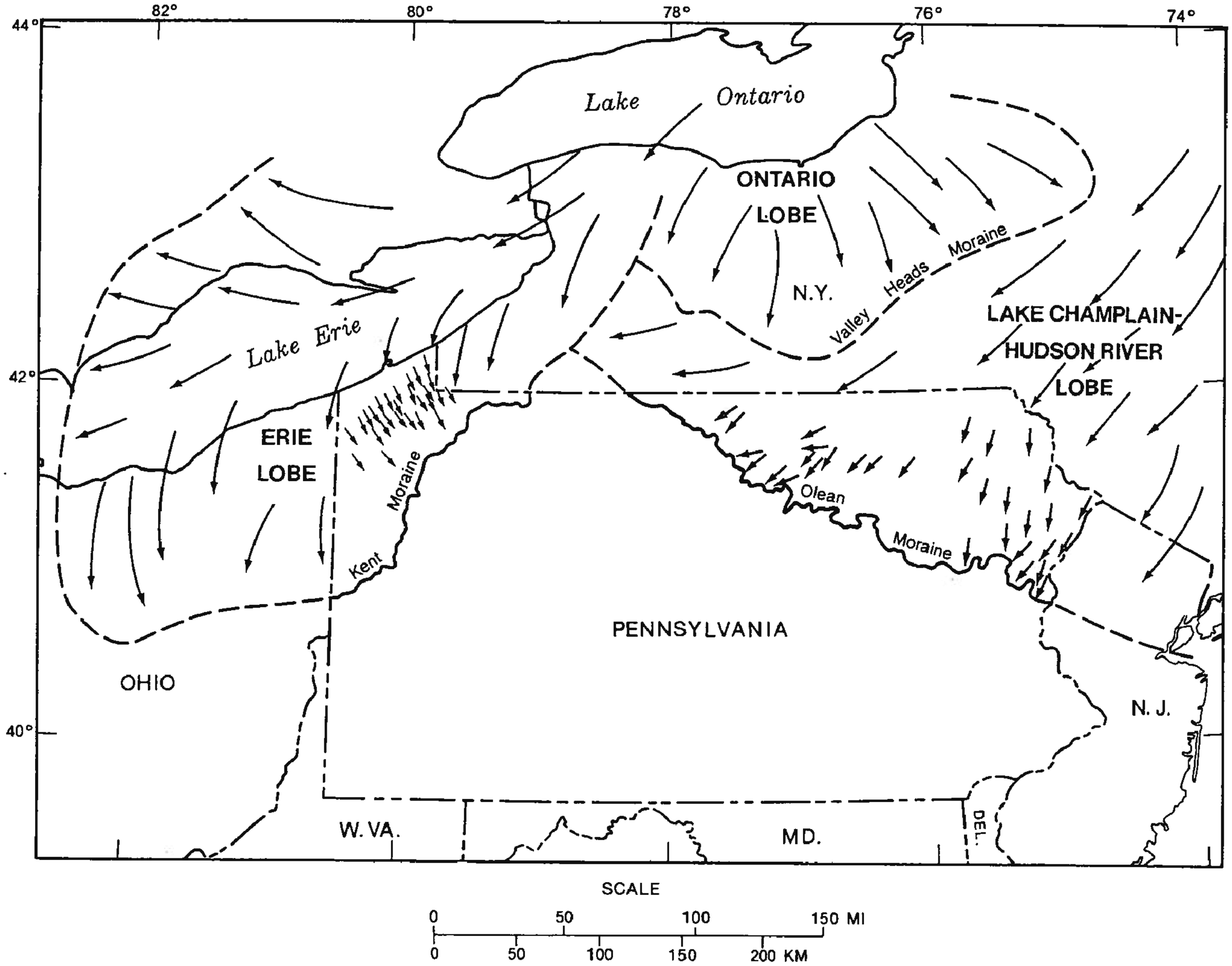

Figure 15–2. Directions of Laurentide ice flow into Pennsylvania during the late Wisconsinan. Ice-flow directions in northeastern Pennsylvania are derived from the orientation of glacial striae, and in northwestern Pennsylvania from linear landforms. Flow directions outside Pennsylvania are from Mickelson, D. M., and others, *The late Wisconsin glacial record of the Laurentide ice sheet in the United States,* in Porter, S. C., ed., *The late Pleistocene,* Volume 1 of Wright, H. E., Jr., ed., *Late-Quaternary environments of the United States,* Minneapolis, University of Minnesota Press, Figure 1–3, p. 5, copyright © 1983 by the University of Minnesota.

feet within a few miles of the southern margin (Sevon and others, 1975). Numerous vertical sequences in the northwest contain repetitions of a till with an intact soil zone at the top overlain by a younger till. These sequences indicate little erosion by ice during repeated advances. This lack of erosion was probably due to the relatively flat, frozen, and texturally homogeneous surface over which successive glaciations traversed. The preservation of multiple till sequences has allowed the development of a good glacial stratigraphy in the northwest (White and others, 1969).

In northeastern Pennsylvania, where topography is very irregular and surface materials heterogeneous, each glaciation eroded most, or all, of any older glacial deposits, as well as some rock. Thus, vertical sequences of deposits of multiple glaciations are rare in the northeast, and knowledge of older glaciations is gained mainly where the deposits have not been overridden by a younger glaciation.

Till is the primary deposit directly associated with glaciation in Pennsylvania. The composition and texture of Woodfordian tills in the northeast very strongly reflect the character of the underlying bedrock (Epstein, 1969; Sevon and others, 1989). Local bedrock influence is considerably less in the northwest (White and others, 1969), presumably because of the lack of local erosion by successive ice advances. Woodfordian tills in the northwest are subdivided on the basis of texture, stratigraphic position, and areal separation by end moraines. Most Pennsylvania tills have a matrix dominated by silt, are stony, and are variable in surface morphology. Woodfordian till is widespread in the northwest and underlies relatively flat to undulating surfaces, whereas till in the northeast occurs primarily along the lower slopes of larger valleys or as fill in small valleys. The thickness of Woodfordian-age tills is variable. Total drift thickness in the northwest is commonly 50 feet or more, whereas the thickness is generally less than 20 feet in the northeast. Till greater than 3 feet thick covers 75 to 100 percent of the surface in the northwest but only 25 to 50 percent of the surface in the northeast.

Limited data on pre-Woodfordian tills suggest textural and compositional patterns similar to Woodfordian tills (White and others, 1969; Marchand, 1978; Wells and Bucek, 1980; Inners, 1981). Pre-Woodfordian tills, where not overridden and eroded by more recent glaciation, have been eroded sufficiently to now cover only a small percentage of the surface: 10 to 25 percent for Illinoian tills and less than 10 percent for pre-Illinoian tills. These deposits are rarely more than 10 feet thick.

Table 15-1 shows the stratigraphic terminology used by the Pennsylvania Geological Survey for glacial drift in Pennsylvania prior to 1989. The age assignments for the tills in northeastern and north-central Pennsylvania are based on comparative degrees of soil development (Sevon, 1974; Sevon and others, 1975), the amount of erosion of a specific till, and some radiocarbon dating (Crowl and Sevon, 1980; Cotter, 1983, 1985). Age assignments in the northwest are based primarily on stratigraphic position and mid-continent correlation (White and others, 1969). Marchand (1978) suggested additional terminology (Penny Hill, Laurelton, and White Deer) for some pre-Wisconsinan drift in north-central Pennsylvania, but the terminology has received limited use. The determination that there was no early Wisconsinan glaciation in Pennsylvania (Braun, 1988; Eyles and Westgate, 1987) required that age assignments shown in Table 15-1 be reevaluated. That reevaluation indicated that materials assigned an early Wisconsinan age are really Illinoian in age and all older materials are pre-Illinoian in age. Identification of lake clays having reversed polarity overlying till in north-central Pennsylvania allowed revision of age assignments in that area and indicated that pre-Illinoian-age materials are greater than 770,000 years old (Gardner and others, 1994).

Wisconsinan ice-contact sand and gravel deposits are common along valley sides in both glaciated parts of Pennsylvania. These deposits are characterized by extreme variability in bedding attitude and texture (Figure 15-3). The surface morphology of these de-

Table 15-1. ***Stratigraphic Terminology Applied to Glacial Deposits in Pennsylvania by the Pennsylvania Geological Survey Prior to 1989***

		NORTHWESTERN White and others (1969)	NORTH-CENTRAL Wells and Bucek (1980)	NORTH-CENTRAL Inners (1981)	NORTHEASTERN Berg and others (1977)
STAGE	SUBSTAGE	UNIT[1]			
Wisconsinan	Late (Woodfordian)	Ashtabula Till Hiram Till Lavery Till Kent Till	Olean drift	Nescopeck Loess Olean drift	Woodfordian drift
	Farmdalian	Paleosol	Paleosol	Paleosol	Paleosol
	Early (Altonian)	Titusville Till	Warrensville drift	Glen Brook Till	Altonian till
Sangamonian		Thick paleosol	Thick paleosol	Thick paleosol; pre-Nescopeck loess	Thick paleosol
Illinoian		Mapledale Till	Muncy drift	Muncy Till	Illinoian till
Pre-Illinoian		Slippery Rock Till			

[1]The term drift is used here where the name is applied to several different types of deposit (e.g., till, ice-contact sand and gravel, outwash, and so forth).

posits is variable, depending on whether the deposit is an esker, kame, kame terrace, delta, or some other type. Comparable pre-Illinoian deposits are rare but do occur locally (Inners, 1981).

Woodfordian outwash sand and gravel deposits occur within the glaciated parts of the state and along some river valleys outside the glaciated area (Figure 15–1). These deposits are flat surfaced, possess less textural variability than ice-contact deposits, and are locally many tens of feet thick. Outwash deposits of pre-Woodfordian glaciations occur mainly as isolated terrace deposits along major rivers.

Woodfordian ice-contact clay deposits occur locally in north-draining valleys that were dammed by ice during deglaciation. Extensive deposits of this type occur in the Cowanesque River valley in north-central Pennsylvania. These deposits are unstable and very susceptible to landslide. Preston (1977) described deposits of similar origin in western Pennsylvania. Older deposits of presumed similar origin are represented by the terrace materials of the Carmichaels Formation in southwestern Pennsylvania (Leverett, 1934; Jacobson and others, 1988).

Following Woodfordian deglaciation, many surface depressions in glaciated parts of the state became the sites of peat bogs. Northeastern Pennsylvania, particularly Pike and Monroe Counties, has the greatest concentration of peat (Cameron, 1970; Edgerton, 1969).

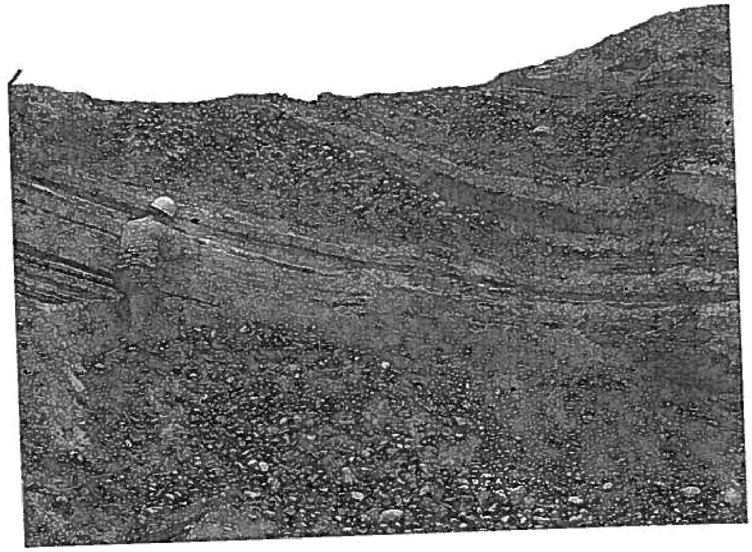

Figure 15–3. Woodfordian ice-contact sand and gravel near Blooming Grove, Pike County.

NONGLACIATED AREAS

During the Quaternary stages of glaciation, the nonglaciated part of Pennsylvania was the site of extensive periglacial activity, variable amounts of erosion, and limited fluvial deposition. Watts (1979) and Whitehead (1973) demonstrated the existence of a tundra environment, probably with continuous to discontinuous permafrost, in even the lower elevations of the state during the Woodfordian. Similar environmental conditions prevailed during each preceding glaciation. Tundra climate and permafrost are optimal conditions for periglacial activity.

The periglacial environment associated with the several glaciations caused extensive mass wasting throughout the nonglaciated part of Pennsylvania through extensive rock breakup and downslope movement of broken material. The hard sandstones that form the crests of linear ridges in the Appalachian Mountain section have numerous planes of bedding and fracture and thus are very susceptible to breakup by freeze-thaw cycles. Pleistocene periglacial activity probably lowered these crests several tens of feet (Cooper, 1944). The broken rock accumulated as talus (Figure 15–4) or became mixed with previously weathered, finer grained material to form stony colluvium. A complex interaction between available clast size, steepness of slope, and severity of periglacial activity produced the many variations of colluvial deposits. Some of these colluvial deposits have complex vertical stratigraphy and demonstrable age multiplicity (Hoover, 1983). Of some interest and economic importance are the numerous shale-chip-rubble deposits (*grèzes litées*) (Figure 15–5) associated with fine-grained rocks such as the Devonian Mahantango, Ordovician Martinsburg, and Ordovician Reedsville shales (Sevon and Berg, 1979).

Strikingly scenic deposits of periglacial origin occur on low slopes as boulder fields. Hickory Run in Carbon County (Figure 15–6) (Sevon, 1969a, 1987a), Blue Rocks in Berks County (Potter and Moss, 1968), Ringing Rocks in Bucks County, and Devils Racecourse in Dauphin County (Martin, 1971) are well-known examples (see Geyer and Bolles, 1979, for details of access).

Eolian deposits in the form of loess are widespread within Pennsylvania (Ciolkosz, Cronce, and Sevon, 1986) but have received little attention except in soils mapping. These surface deposits are in most places less than 5 feet thick and difficult to recognize

Figure 15-4. Talus composed of blocks of Silurian Tuscarora quartzite on the west slope of Brush Mountain near Altoona, Blair County.

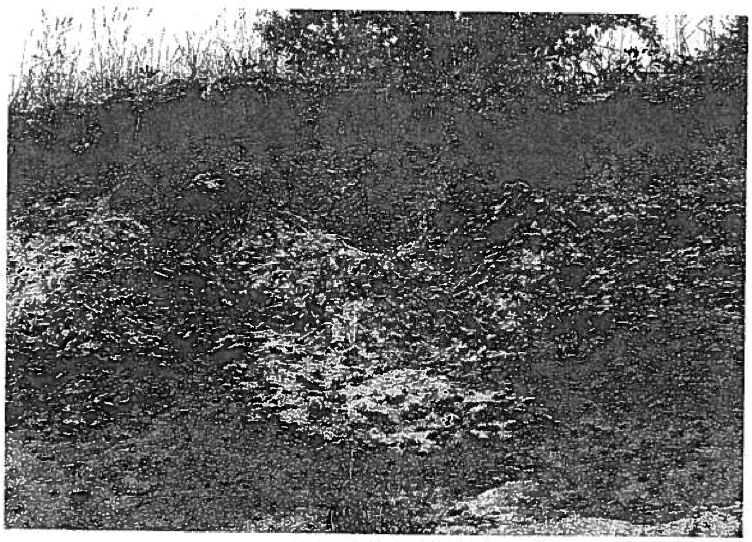

Figure 15-5. Involutions of periglacial origin formed in shale-chip rubble developed from Ordovician Martinsburg shale near Jacksonville, Lehigh County.

except in subsurface vertical exposures. Loess has been mapped and named (Nescopeck Loess and pre-Nescopeck Loess) in Columbia County (Inners, 1981). A small area of dune sand occurs on the east side of the Susquehanna River in Northumberland County (Chase, 1977), and other areas may exist within the state. Both the loess and dune sand formed during the windy and cold periods associated with tundra climate.

A variety of small periglacial features occurs within the state, but these features are generally difficult to detect because they have subtle surface expression or can only be seen in subsurface vertical exposures. These features include ice-wedge casts (Figure 15–7), polygonal patterned ground, involutions (Figure 15–5), pingo scars, and solifluction lobes (Ciolkosz, Cronce, and Sevon, 1986).

Woodfordian outwash sand and gravel deposits occur along the valley bottoms of some of the major rivers in Pennsylvania outside the glaciated area (Figure 15–1) and are locally several tens of feet thick. The deposits are flat surfaced and possess less textural variability than ice-contact deposits. Similar deposits occur along some smaller streams, such as Loyalsock Creek and Lycoming Creek in Lycoming County. Older outwash occurs as isolated terrace deposits along the larger rivers, such as the Susquehanna (Peltier, 1949; Pazzaglia and Gardner, 1993). These various deposits are sometimes given a general age identification, but they have no formal name. Named deposits in southeastern Pennsylvania along the Delaware River include terrace deposits of the Van Sciver Lake beds and the Spring Lake beds, both part of the Trenton Gravel (Owens and Minard, 1979). These beds are texturally variable and have a pronounced down-gradient decrease in grain size. The deposits formed during different pre-Woodfordian periods of glacial to interglacial transition.

Fluvial deposits in the valley bottoms and on terraces of streams not heading in glaciated areas have received little attention in Pennsylvania, except for the work of T. L. Kaktins (1986) on the Juniata River. Deposits are present along most of these streams, and their history is complex.

A significant body of sand occurs in Lake Erie in the form of Presque Isle, a migrating, compound, recurved spit (Thomas and others, 1987) that is land tied at Erie. Other sand and gravel deposits in Erie County comprise onshore lake-parallel, glaciofluvial, glaciodeltaic, and glaciolacustrine sediments formed during former, higher glacial lake levels (Thomas and others, 1987), and offshore deposits associated with a cross-lake glacial moraine (Berkheiser, 1987).

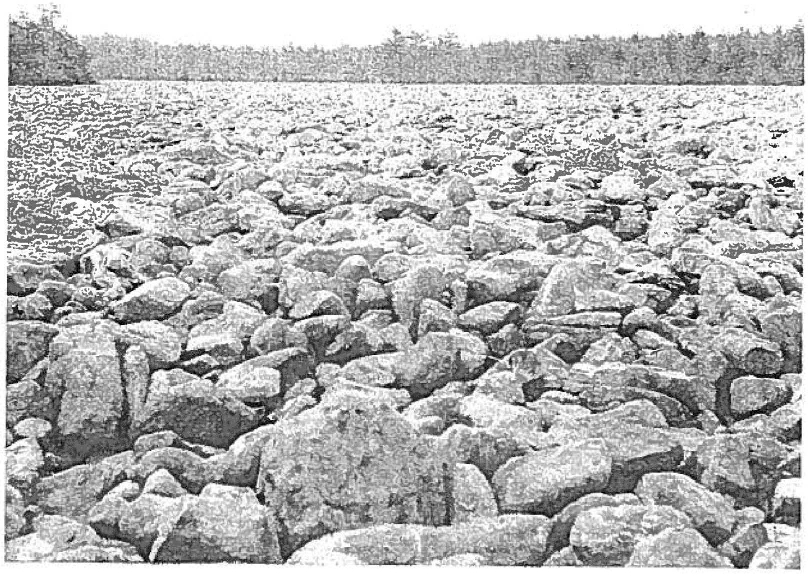

Figure 15-6. Hickory Run Boulder Field, Hickory Run State Park, Carbon County. The smaller rounded boulders in the foreground are about 1 foot in diameter. The distance from the foreground to the treeline is about 1,000 feet.

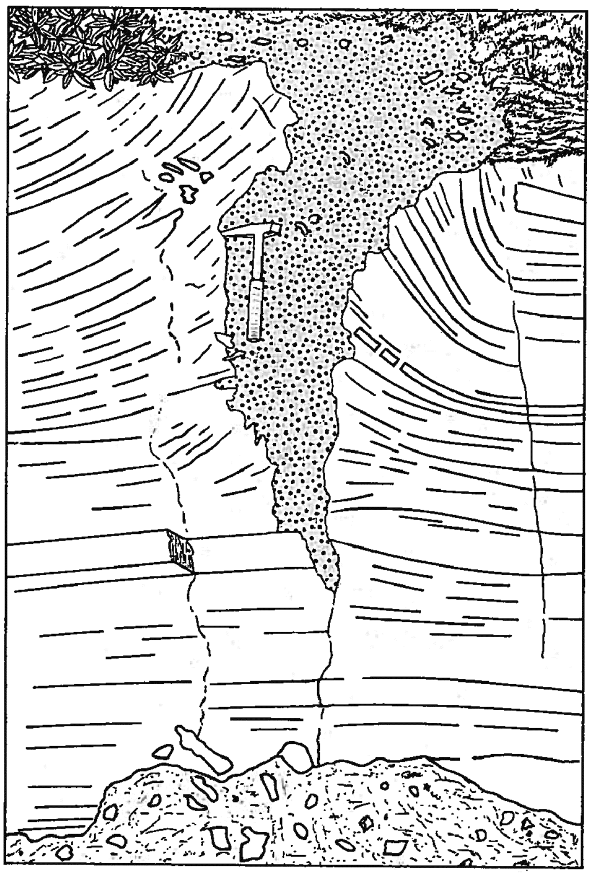

Figure 15-7. Ice-wedge cast in Ordovician Reedsville Shale near Tusseyville, Centre County. Soil material fills the cast to a depth of 64 inches. The cast is 32 inches wide at the top. Sketch made from a photograph taken by Richard Cronce.

The geological observer should be aware that the several Quaternary glaciations were separated by interglacial periods, during which the climate was warmer than, or comparable to, the present climate, which is presumed to be that of another interglacial period. It is difficult to evaluate erosion and sedimentation events during the past interglacials because of the lack of datable materials. Processes occurring at present are probably not a good indicator because of the influence of man on erosion. However, descriptions of the precolonial landscape and streams in eastern North America (Trimble, 1974) suggest that, without the influence of man, physical erosion and sedimentation would be minimal under the present climate.

PROBLEMS AND FUTURE RESEARCH

The following aspects of Quaternary geology in Pennsylvania require research:

1. Determination of the ages of pre-Illinoian drift.
2. Delineation of Illinoian and pre-Illinoian drift boundaries.
3. Development of a colluvium stratigraphy.
4. Determination of the ages of various fluvial terraces in both glaciated and nonglaciated areas.
5. Continued detailed (1:24,000-scale) mapping of surficial materials.

RECOMMENDED FOR FURTHER READING

Flint, R. F. (1971), *Glacial and Quaternary geology*, New York, John Wiley and Sons, 892 p.

Goldthwait, R. P., ed. (1971), *Till—a symposium*, Columbus, Ohio State University Press, 402 p.

Mahaney, W. C., ed. (1976), *Quaternary stratigraphy of North America*, Stroudsburg, Pa., Dowden, Hutchinson, and Ross, 512 p.

Porter, S. C., ed. (1983), *The late Pleistocene*, in Wright, H. E., Jr., ed., *Late-Quaternary environments of the United States*, v. 1, Minneapolis, University of Minnesota Press, 407 p.

Wright, H. E., Jr., and Frey, D. G., eds. (1965), *The Quaternary of the United States*, Princeton, N. J., Princeton University Press, 922 p.