QUATERNARY RESEARCH 47, 1–12 (1997)
ARTICLE NO. QR961870

Late Quaternary Temporal and Event Classifications, Great Lakes Region, North America

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Received August 7, 1996

Several temporal and event classifications are used for the Quaternary glacial and interglacial record in the Great Lakes region of North America. Although based on contrasting principles, the classifications, as practiced, are similar to one another in most respects and they differ little from the classification proposed by Chamberlin a century ago. All are based on stratigraphic units having time-transgressive boundaries; thus the associated time spans and events are diachronous. Where application of geochronologic classification based on isochronous boundaries is not practical or useful, we advocate the use of diachronic principles to establish local and regional temporal and event classifications. Diachronic and event classifications based on such principles are proposed herein for the Great Lakes region. Well-established names, including Wisconsin, Sangamon, and Illinois, are used at the episode (or glaciation/interglaciation) rank without significant redefinition. The Hudson Episode (Interglaciation) is introduced for postglacial time, the current interglacial interval. The Wisconsin Episode is divided into the Ontario, Elgin, and Michigan Subepisodes in the eastern and northern parts of the Great Lakes region and into the Athens and Michigan Subepisodes in the southern and western parts of the Great Lakes region.

INTRODUCTION

Stratigraphic nomenclature for the late Quaternary in the midcontinent region of North America had its beginning more than 100 years ago (Logan *et al.*, 1863; Chamberlin, 1878, 1883), and 1994 marked the centennial of the naming of major glacial events and their associated deposits by Chamberlin (1894). From that early beginning, stratigraphic classifications for the late Quaternary in the midcontinent evolved as several different schemes. Glacial and interglacial

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0033-5894/97 $25.00

deposits eventually were treated as rock units and were given lithostratigraphic names (e.g., Bretz, 1939, 1955; Karrow, 1959; Schneider, 1956, 1961; Shepps *et al.,* 1959; White, 1960, 1961). Subsequently, formal lithostratigraphic classifications were established in many areas, e.g., Indiana (Wayne, 1963), Ohio and Ontario (Goldthwait *et al.,* 1965), Illinois (Willman and Frye, 1970), and Wisconsin (Mickelson *et al.,* 1984). Lithostratigraphic classification has proved useful in both academic and applied investigations of Quaternary deposits. However, a uniform scheme for temporal classification and nomenclature is not in use. Similar but nonetheless different principles and concepts have been used in different classification schemes. As a result, stratigraphic names, commonly even the same name, have been used in reference to temporal units in somewhat different contexts. The consequence is current nomenclatural controversy and confusion.

An understanding of the timing of Quaternary events recorded in midcontinent terrestrial deposits is necessary to address larger questions such as the synchrony (or asynchrony) of ice margin fluctuations in different lobes of the Laurentide ice sheet, the temporal relationships of fluctuations to deposits beyond the glacial border and to glacial deposits and events in other regions as well as to marine and ice core records, and the response of the ice lobes to regional and worldwide climatic fluctuations. The most useful temporal classification system is one that can help to address these larger questions and that at the same time is compatible with the nature of the stratigraphic record.

Quaternary glacigenic sequences are conceptually similar in some respects to the major cratonic rock sequences defined by Sloss (1963), as well as to Pennsylvanian cyclothems in the midcontinent region described by Heckel (1986). Whereas the older sedimentary rock sequences are related in part to diachronous sea level fluctuations, Quaternary glacigenic sequences are related to diachronous ice margin fluctuations. Thus the boundaries of Quaternary glacigenic sequences, like those of their Paleozoic counterparts, are not synchronous. For that reason, geochronologic units, for which synchronous boundaries are required, poorly represent the temporal relationships of glacial fluctuations and are inadequate for comparison of the ages of stratigraphic sequences deposited during those fluctuations. We need temporal units that are related to the diachronous boundaries of glacigenic sequences. If those units are established, our goal then can be to establish controls for the ages of the boundaries on a regional scale.

We and other colleagues have discussed and debated the nomenclatural problems of Quaternary temporal classification during the past decade. Our common goal is to develop more practical temporal and event classification schemes and a more consistent nomenclature. Our objectives in this paper are to report our analysis of the current situation and to suggest revisions and additions to current nomenclature. In summary, our proposed classifications (1) use diachronic principles with respect to definition of temporal and event units, (2) use some names on a regional basis, (3) maintain and use some well-established names without significant redefinition, and (4) introduce names for previously unnamed time intervals and events that have regional significance. We do not formally define the proposed diachronic units here, nor do we abandon geochronologic classification.

BACKGROUND

Since Chamberlin's introduction of the terms East Wisconsin, East Iowan, and Kansan in 1894, many additions, deletions, and modifications have been made to the midcontinent Quaternary classifications. Most of those changes were reviewed by Flint (1965, 1971), White (1973), Frye and Willman (1960), Leighton (1960), Clark (1992), and others, and they are not repeated here. Of more significance from a historical standpoint are the different principles and concepts that evolved to divide and subdivide the glacial drift. It is essential that those principles and concepts be reviewed briefly to clarify how we came to our current situation of controversy and confusion.

The term "stage" has been and continues to be a problem in Quaternary nomenclature. T. C. Chamberlin (1894, 1895) first referred to "stages of glaciation" and to "intervals of deglaciation" that separated them. Although Chamberlin did not clearly explain his use of the term stage, the context of his statements indicate he was referring to intervals of time during which a "glacial formation" of the same name was deposited (e.g., the Kansan formation of the Kansan stage of glaciation). Leverett (1899, p. 19), under Chamberlin's supervision at the time, clearly expressed that usage with the statement: "names of this class were proposed by Chamberlin as a substitute for time phrases which had arisen and which were of controverted application." Thus, as originally introduced by Chamberlin (1894), stage referred to an interval of time. This usage later was sanctioned by the first formal stratigraphic code formulated in the United States (Ashley *et al.,* 1933).

The Ashley code specified (p. 446) that ". . . the time covered by a Pleistocene subdivision of formation rank is called a stage, and the time covered by a Pleistocene subdivision of member rank is called a substage." That usage, however, later conflicted with the use of the term stage in the pre-Quaternary stratigraphic record, in which it was a time-stratigraphic (material) term. As a result, the 1961 code (American Commission on Stratigraphic Nomenclature, 1961) specifically rejected use of the terms stage and substage as geologic time (geochronologic) terms and restricted their use to time stratigraphy (chronostratigraphy). It designated the term age as the corresponding unit of geologic time. The terms stage and substage continue to be widely used in Quaternary literature, but rarely is a distinction made between geochronologic and chronostratigraphic usage; and in many cases the terms stage and substage are used interchangeably in both classifications.

The 1961 code also introduced geologic climate units for the Quaternary. The inferred climatic intervals were to be defined from divisions or subdivisions of Quaternary rocks, but the only referent sediments specifically mentioned were glacial and interglacial deposits. Thus, the terms glaciation, interglaciation, stade, and interstade were introduced as divisions of geologic time based on intervals of interpreted contrasting climates. Those units differed from geologic time units in that their boundaries were not synchronous. In addition, the units were clearly subjective because climatic and genetic inferences were required to recognize and define them. The geologic climate classification essentially formalized the concepts formulated earlier by Chamberlin and Leverett; it also served as an example of geologic event classification. Aspects of geologic climate nomenclature were incorporated into several midcontinent Quaternary classifications (e.g., Gooding, 1963; Clayton, 1966; Dreimanis and Karrow, 1972; Muller and Calkin, 1993), although the term stage (rather than glaciation or interglaciation) continued to be used for the highest hierarchial rank in several of the classifications. More recently (Rose and Menzies, 1996), classification based on inferred climate was referred to as climatostratigraphy, and the terms stage and substage also were used in that classification.

An alternative to geologic climate or event classification was chronostratigraphic and geochronologic classification for the Quaternary, similar to that used for the older parts of the rock record. The latter approach was followed (Table 1) at the Illinois State Geological Survey (Frye and Willman, 1960; Frye *et al.*, 1968; Willman and Frye, 1970). In essence, the temporal units of earlier workers were transposed into material units with type sections. Adjectival endings identified them as time-stratigraphic units, following the practice introduced earlier by Frye and Leonard (1952) in Kansas. Wisconsin became Wisconsinan, Sangamon became Sangamonian, and new names and definitions were introduced for the material substages of the Wisconsinan Stage. Although based on boundaries of rock and soil units that are time-transgressive, chronostratigraphic and geochronologic units by definition have time-parallel boundaries. Away from the type sections the time-parallel boundaries cannot be recognized with certainty. In practice the chronostratigraphic and geochronologic boundaries are considered to coincide with the referent lithostratigraphic and/or pedostratigraphic boundaries in stratigraphic units throughout a region; in fact, however, they coincide only in the type section. As practiced, therefore, the scheme differs little from Chamberlin's classification or from geologic climate classification. The Illinois system has been used at times in other parts of the midcontinent region, e.g., Wisconsin (Black, 1976), Pennsylvania (White *et al.*, 1969), and Ohio (White, 1982), but its use has diminished more recently.

TABLE 1
Illinois and Ontario Chronostratigraphic Classifications

Illinois (Willman and Frye, 1970)	Ontario (Dreimanis and Karrow, 1972)
Wisconsinan Stage	Wisconsin(an) Stage
Valderan Substage[a]	Late Wisconsin(an) Substage
	Driftwood Phase or Stadial
	North Bay Interval or Interstadial
	Valders Phase or Stadial
Twocreekan Substage	Two Creeks Interval or Interstadial
Woodfordian Substage	Port Huron Phase or Stadial
	Mackinaw Interval or Interstadial
	Port Bruce Phase or Stadial
	Erie Interval or Interstadial
	Nissouri Stadial
Farmdalian Substage	Middle Wisconsin(an) Substage
	Plum Point Interstadial
Altonian Substage	Cherrytree Stadial
	Port Talbot Interstadial
	Early Wisconsin(an) Substage
	Guildwood Stadial
	St. Pierre Interstadial
	Nicolet Stadial

[a] Renamed Greatlakean Substage by Evenson *et al.* (1976).

A more widely used scheme of classification for the last glacial cycle was developed in Ontario by Dreimanis and Karrow (1972). It was proposed to better accommodate the geologic record in the northern Great Lakes region, and it included more hierarchial levels (Table 1). Both the noun and the adjectival ending for Wisconsin were included because the authors were not in agreement with respect to nomenclature. Three main substages/subages [early, middle, and late Wisconsin(an)] were recognized, but they were not given geographic names. At a lower rank, the classification adopted the terms stade and interstade from geologic climate classification and adopted the terms phase and interval for the fourth-order divisions below stade and interstade. This nomenclatural system has been used extensively on both sides of the international boundary and in worldwide correlation diagrams.

Another alternative temporal classification was geologic event nomenclature. Wright (1964, p. 630) introduced the term phase to designate "a time of glacier activity, whether identifiable by stratigraphy or morphology." The term was introduced because of a need for smaller units of time related to the deposits of glacial advances (events) within an area and for correlation with time units in other areas. Clayton (1966) used the term phase for minor glacial advances and considered it a subdivision of the stade in geologic climate classification. For the highest rank in the classification, he used glaciation rather than stage. Event classification has been used in Minnesota (Wright *et al.,* 1973), North Dakota (Moran *et al.,* 1976), and Wisconsin (Attig *et al.,* 1985). Although glaciation and phase originally were defined as time units for inferred events, some recent usage has emphasized the event itself rather than the duration of the event. For example, Clayton *et al.* (1992) stated that the terms glaciation and phase are used in Wisconsin for events rather than periods of time. However, the two concepts are not exclusive—event classification in practice includes not only the event but also the time (duration) of the event.

A significant development was publication of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). The code rejected geologic climate classification because of the subjectivity involved for climatic inferences. In part to replace geologic climate classification and also to address problems associated with chronostratigraphic classification (Watson and Wright, 1980), a new temporal classification, diachronic classification, was introduced. Diachronic units are defined on the basis of time-transgressive material units (lithostratigraphic, allostratigraphic, biostratigraphic, or pedostratigraphic units or an assemblage of such units). Diachronic units refer to the time during which the material referent was deposited or originated. In essence, diachronic units are similar to the time units of Chamberlin, to the geologic climate units of the 1961 code (except that a climatic inference is not required), to the geochronologic units of Frye and Willman as generally practiced (but not conceptually defined), and to the temporal aspects of geologic event units. Diachronic units differ from geologic event units in that the emphasis is temporal, designated reference materials are required, and no mention is made of inferred events. With respect to the last point, however, diachronic units will be meaningful or useful only if they are related directly to events of historical significance as inferred from the geologic record.

CURRENT SITUATION

Midcontinent nomenclature evolved as knowledge of Quaternary geology and history mushroomed. Research on land and in the sea, as well as development of new analytical techniques, contributed to a rapid increase in understanding of the Quaternary record. Of particular importance was recognition and refinement of the marine oxygen isotope record (Emiliani, 1955; Shackleton and Opdyke, 1973; Imbrie *et al.,* 1984; Martinson *et al.,* 1987). That record, which primarily reflects global ice volume on land, fundamentally changed the concept of the Quaternary from a time of a few glaciations to one of many glacial/interglacial cycles. Today the marine oxygen isotope record is a global standard to which local and regional records are correlated (e.g., Šibrava *et al.,* 1986; Kukla *et al.,* 1988).

The oxygen isotope record indicates that the last major glaciation consisted of multiple events. Initial ice sheet growth in northern latitudes began soon after the peak of the last interglaciation (^{18}O substage 5e). The deposits and landforms that served as referents for Chamberlin's (1894) East Wisconsin stage of glaciation were deposited later, during ^{18}O stage 2.

In the midcontinent region, as in the ocean basins, evidence for glacial events older than the Wisconsin glacial stage of Chamberlin but younger than his Sangamon interglaciation was reported in several areas (e.g., in Illinois, Leighton and Willman, 1950, Shaffer, 1954; in Indiana, Gooding, 1963; in Ohio, Forsyth, 1957; in Ontario, Dreimanis, 1960), as recently reviewed by Goldthwait (1992). Recognition of those events and deposits resulted in extension of the term Wisconsin back in time to include deposits and events that were older than the "classical" Wisconsin deposits of Chamberlin but younger than Sangamon interglacial deposits (Flint, 1957). In 1960, Frye and Willman redefined the Wisconsin, applying it to both chronostratigraphic and geochronologic units. They used the adjectival form of the term (Wisconsinan), and they defined the Altonian Substage on the basis of some of the older deposits. In his last textbook, Flint (1971) provisionally used the informal terms early, middle, and late Wisconsin, and in 1972 Dreimanis and Karrow introduced them in a nomenclatural scheme. The term Wisconsin was extended by Dreimanis and Karrow to include the deposits, the events, and the time span of the entire last glacial cycle, but the three main divisions of that cycle (early, middle, and late Wisconsin) were not assigned geographic names. The lack of geographic names for the early, middle, and late Wisconsin temporal units is one shortcoming of the current midcontinent classification/nomenclatural scheme. A consequence is that the divisions are sometimes regarded as informal units.

Another nomenclature problem is confusion concerning the form of a name, whether it should be a noun or an adjective. This confusion dates back to Chamberlin (1894), who initially used both forms without comment (e.g., Kansan and East Wisconsin). A later comment indicates that he considered the sound of a term when naming the units. In describing and naming the Aftonian deposits, Chamberlin (1895, p. 272) wrote ". . . this horizon is found between Afton and Thayer, Iowa, and from the former a euphonious name may be taken." The term Illinois initially was used for a drift sheet and the corresponding interval of time (Chamberlin, 1896), but soon thereafter it was changed to Illinoian by Leverett (1898). Although Leverett did not comment about the rationale for the change, apparently he preferred the sound of the name Illinoian.

As a result of the introduction of chronostratigraphic classification in the midcontinent Quaternary (Frye and Leonard, 1952; Frye and Willman, 1960; Willman and Frye, 1970), adjectival endings (e.g., Wisconsinan, Sangamonian, and Yarmouthian) have been used widely. The Dreimanis and Karrow (1972) classification used both the noun and adjectival forms of a name, and that practice still is being followed in association with geologic climate units in some areas (e.g., Michigan, Larson *et al.,* 1994). Others workers use both forms, with the adjectival form used in a chronostratigraphic and geochronologic sense, but not strictly following stratigraphic principles. For example, Fulton and Prest (1987) used Sangamonian and Wisconsinan as chronostratigraphic and geochronologic terms and Sangamon and Wisconsin as event terms. The boundaries for the chronostratigraphic units were based, however, on the marine oxygen isotope record rather than on the boundaries in the stratotype sections established in Illinois by Willman and Frye (1970). Richmond and Fullerton (1986) also used the oxygen isotope record to establish some of their informal time divisions, but they used the noun form, e.g., Wisconsin, for the units. In some areas, e.g., Canada, the adjectival form is used most commonly; in the United States both forms are in use. Some authors clearly explain their use of the noun and adjectival forms. In most cases, however, the same terms are used in different ways by different workers, without distinction.

The time-transgressive nature of Quaternary rock and soil units and the events that produced them contribute significantly to the nomenclatural problems. Glaciation and soil formation, as well as other related events, clearly are diachronous on a regional scale, and records of those events in one area are not synchronous with those in another. For example, the records of the last glacial cycle in east central Canada, in the northern Great Lakes area, and in the southern Great Lakes area all are different from a temporal standpoint. Strict application of the same terminology for the deposits and events in the three areas is impractical if isochronous chronostratigraphic boundaries must serve as the basis for time divisions. That was one reason Dreimanis and Karrow (1972) considered the Willman and Frye (1970) classification to be inadequate for use in Ontario, and it was the major objection of Watson and Wright (1980) in their critique of chronostratigraphic classification. Birks (1982) raised similar concerns about definition of chronozones for the late Quaternary deposits of Europe. Rose and Menzies (1996), in their review and discussion of glacial stratigraphy, also noted that chronostratigraphic units, which in practice commonly are based in part on climostratigraphic inferences, are unlikely to have boundaries that are synchronous on a regional scale. These difficulties are minimized if temporal units are based on time-transgressive lithostratigraphic, allostratigraphic, pedostratigraphic, or biostratigraphic units and are recognized and defined with respect to diachronous boundaries.

In the foreword to *Quaternary Geology of Canada and Greenland,* Fulton (1989) noted that the temporal nomenclature in the volume is a hybrid system that does not follow stratigraphic principles. It utilizes chronostratigraphic terms in a geochronologic sense, and it relates the boundaries of the temporal units to the oxygen isotope record or to the Canadian stratigraphic record, not to the ages estimated for boundaries in the type sections in Illinois. His approach was "an attempt to adapt rational, consistent terminology while making the smallest possible changes from generally accepted uses" (Fulton, 1989, p. 2). Nomenclature revisions are proposed here with the same objective. They are suggested with some reluctance, because confusion and controversy initially accompany any change. However, after long consideration and discussion among the authors, and in response to encouragement from others (e.g., Clark, 1992, footnote, p. 7), we conclude that it is time to formulate classifications that are more consistent, that are more flexible, that better reflect the geologic records being classified, and that will be more effective in the communication of our research.

PROPOSED CLASSIFICATIONS AND NOMENCLATURE

We endorse the use of more uniform and more consistent Quaternary nomenclature in the respective areas of the Great Lakes region. Although the basis for unit definition may vary from area to area, we agree that all temporal or event units will have diachronous boundaries on a regional scale. We adopt well-established names whenever they can be used without significant redefinition or revision, and we introduce new names for significant time intervals that currently lack geographic names. Both diachronic and event classifications are proposed as alternative schemes for use in the region.

Most of the authors of this paper prefer use of the noun form of the geographic name of a diachronic or event unit to clearly distinguish that unit from chronostratigraphic and geochronologic terminology, particularly in areas in which the latter classifications also are practiced. Others of us, however, prefer use of the adjectival form. In this paper the noun form is used, but with the recognition that some workers will choose to use the adjectival form (Table 2, footnote b). If adjectival endings are used for diachronic units, it should be clearly stated that the units are neither geochronologic nor chronostratigraphic units.

The revised nomenclature meshes names from existing classifications in the Great Lakes region, i.e., the classifications of Willman and Frye (1970), Dreimanis and Karrow (1972), and Hansel and Johnson (1992, 1996), and it includes a few new names. The proposed diachronic classification is based on principles suggested in the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). Some diachronic units have been formally defined (Hansel and Johnson, 1996), but not in full accordance with Articles 3 and 95 of the 1983 code. The hierarchy of terms in diachronic classification includes episode, subepisode, and phase. Whereas episodes and subepisodes apply to all or a large part of the Great Lakes region, phases are related to local geographic areas (e.g., most are confined to a single glacial lobe).

Diachronic units are meaningful only if they can relate to geologic events that have regional and/or local significance. In the southern Great Lakes area, these events can be documented by material referents, most of which have been classified previously as lithostratigraphic and pedostratigraphic units (e.g., Hansel and Johnson, 1996). In the parts of the northern and eastern Great Lakes areas in which the drift is thin, discontinuous, or absent and stratigraphic units are difficult to trace, additional types of evidence, such as landforms and erosional features, have been used to divide the last glacial cycle (e.g., Attig *et al.,* 1985). In some of these areas allostratigraphic units also can be defined as a basis for diachronic classification.

An alternative classification based on inferred events is proposed for areas in which definition of diachronic units is not practical because appropriate referent units cannot be defined and for workers who prefer not to use diachronic classification. Event classification is based on inferences derived from a wide variety of geologic evidence. The hierarchy of terms in the proposed event classification includes glaciation/interglaciation and phase.

The two classifications presented in this paper (Table 2) utilize the existing names Wisconsin, Sangamon, and Illinois at the episode or glaciation/interglaciation rank. The name Hudson Episode (Interglaciation) is proposed for the current interglacial interval. It is named for Hudson Bay in central Canada, where marine sediment was deposited in the postglacial Tyrrell Sea in the Hudson Bay Lowland during disintegration of the Laurentide ice sheet (Lee, 1960; Shilts, 1984; Dredge and Cowan, 1989). The Hudson Episode (Interglaciation) refers to postglacial time on a regional basis. It differs from the Holocene Epoch in that the beginning of the Hudson Episode (Interglaciation) is not fixed in time but varies regionally, reflecting the diachronous nature of deglaciation. The Hudson Episode corresponds in character to the Flandrian interval in Europe. However, the diachronic nature of the latter has not always been recognized in classification and locally the Flandrian deposits have been "forced" into a chronostratigraphic framework, as discussed by Birks (1982). Holocene is retained as a chronostratigraphic and geochronologic unit at the series and epoch ranks because of its recognition on a global scale.

Because the terms Kansan, Aftonian, and Nebraskan have been abandoned (Boellstorff, 1978; Hallberg, 1986), the older part of the Quaternary record in the midcontinent region has been referred to simply as pre-Illinoian in recent literature. In this discussion we propose no change in the current undivided aspect of time and events earlier than those based on the deposits of the Illinois Episode (Glaciation). Subdivision of this long interval of time, the pre-Illinois episode (undivided), is needed, and we urge further investigations of these deposits and paleosols.

At this time only the Wisconsin Episode is subdivided (Table 2). The Ontario Subepisode is introduced for the time represented by "early Wisconsin" glaciation in the northern and eastern parts of the Great Lakes region. It is based on the Toronto stratigraphic record (Karrow and Occhietti, 1989) in southern Ontario; it replaces the early Wisconsin(an) interval of Dreimanis and Karrow (1972). In the same area, the Elgin Subepisode is introduced to replace the middle Wisconsin(an) interval; it is named after Elgin County and is based on the classic Port Talbot and Plum Point stratigraphy (Dreimanis, 1960, 1987) that is exposed along the central north shore of Lake Erie south of London, Ontario.

In the southern Great Lakes area, the Athens Subepisode is introduced for the same general interval of time as the Elgin Subepisode. It is named for Athens in central Illinois, and it is based on the record of loess (Roxana Silt) and paleosols (Indian Point and Farmdale) that are exposed in Athens Quarry (Curry and Follmer, 1992). The Athens Subepisode is used in the temporal sense of the combined Altonian and Farmdalian Subages of the Willman and Frye (1970) classification (Fig. 1). Two phases, Alton and Farmdale, are recognized in the Athens Subepisode (Hansel and Johnson, 1996). We use different names in the northern and southern Great Lakes areas for the "middle" Wisconsin interval because of the different nature of the records. In the northern part of the Great Lakes region the material referent record consists primarily of glacial and lacustrine sediment and paleosols or organic accumulations, whereas in the southern part of the Great Lakes region it is chiefly eolian sediment and paleosols. Better integration and correlation of the two records eventually may be possible because glacial deposits related to this interval recently have been recognized, e.g., in Iowa (Bettis *et al.,* 1996) and in New York (Young, 1996).

For the late Wisconsin interval, we introduce the name Michigan Subepisode, taking the name from the state of Michigan, all of which was glaciated and has a landscape and deposits that originated during the latest Wisconsin gla-

TABLE 2
Proposed Diachronic and Event Nomenclature for the Great Lakes Region

	Subepisode		
Episode or *glaciation/interglaciation*[a]	Northern/eastern Great Lakes area		Southern/western Great Lakes area
Hudson[b] Episode			
Hudson Interglaciation			
Wisconsin Episode			
Wisconsin Glaciation	Michigan[b] Subepisode	alton	Michigan Subepisode
	Elgin[b] Subepisode	Farndale	Athens Subepisode Roxana
	Ontario[b] Subepisode		
Sangamon Episode			
Sangamon Interglaciation			
Illinois Episode			
Illinois Glaciation			

[a] Diachronic units are in normal type; event units are in italics. Hansel & Johnson '96
[b] If adjectival endings are used, recommended spellings are Hudsonian, Michiganan, Elginian, and Ontarian.

ciation. Michigan also is centrally located, and it links the eastern and northern Great Lakes records with those to the south and west. The Michigan Subepisode replaces the late Wisconsin(an) interval of the Dreimanis and Karrow (1972) classification. It is equivalent temporally to the Woodfordian, Twocreekan, and Greatlakean Subages of Willman and Frye (1970), as modified by Evenson *et al.* (1976), but it has diachronous boundaries (Fig. 1).

The Wisconsin Episode/Glaciation has been divided into phases in several areas (Wright, 1972; Attig *et al.*, 1985; Hansel and Johnson, 1992, 1996). Subdivision in other areas will be proposed in subsequent publications as the new nomenclature becomes established. The classification developed by Hansel and Johnson (1992, 1996) uses the term phase to record a time of sedimentation (eolian, glacial, or lacustrine) or soil development below the rank of subepisode (Fig. 1). In the glacial record of Illinois, the phases relate to times of major advances or retreats of the margins of the Lake Michigan lobe, as inferred from the sediment and/or landform record. Phases are useful to understand the history of ice margin fluctuations (Fig. 2) and to correlate deposits and events of one lobe with those of other glacial lobes. Such correlations of events assist in resolution of questions pertaining to whether glacial advances in different lobes were synchronous or asynchronous and to whether the glacial events were related to climatic changes or occurred in response to changes in ice sheet dynamics (e.g., see discussions in Clark, 1994; Lowell *et al.*, 1995).

In Minnesota and Wisconsin, phases have been established in the context of event classification. In the different glacial lobes, they delineate major and minor advances or stillstands of the margin of the ice sheet (Wright, 1972; Clayton *et al.*, 1992). The phases are based on both the sediment record and surface morphology. Many phases in the Wisconsin Glaciation are related to and named for end moraines; those of older glaciations mostly are based on lithostratigraphic units. In Iowa, phases delineate major advances or readvances of the margin of the ice sheet, as well as periods of loess deposition or formation of geosols. The phases in a proposed diachronic classification will be based both on the sediment record and surface morphology. Phases associated with the Michigan Subepisode will be named for ice margin positions (moraines), and those associated with the Athens Subepisode will be based on lithostratigraphic or pedostratigraphic units.

DISCUSSION

The classifications proposed here are based on the Quaternary glacial and interglacial sediment, landscape, and soil records in the Great Lakes region. They are flexible, in that the temporal boundaries of diachronic units or events are not fixed at type sections, nor are they arbitrarily based on some other record (e.g., the marine oxygen isotope record). We hope that other workers in the midcontinent region will adopt those aspects of the nomenclature that are appropriate for their studies and will assist us in formulation of more consistent nomenclature in the region. The proposed nomenclature can be extended to adjacent regions, provided that it can be demonstrably tied to the sediment and soil record on which it is based in the Great Lakes region. In areas in which such ties cannot be demonstrated, new nomenclature should be established. Nomenclature from the midcontinent region should not be extended to regions in which the sediment record is significantly different and correlations are uncertain (North American Commission on Stratigraphic Nomenclature, 1983).

Although the boundaries of the proposed units are not

Altonian, Nebraskan, Kansan abandoned terms Per Boellstorff '78, Hallberg '86

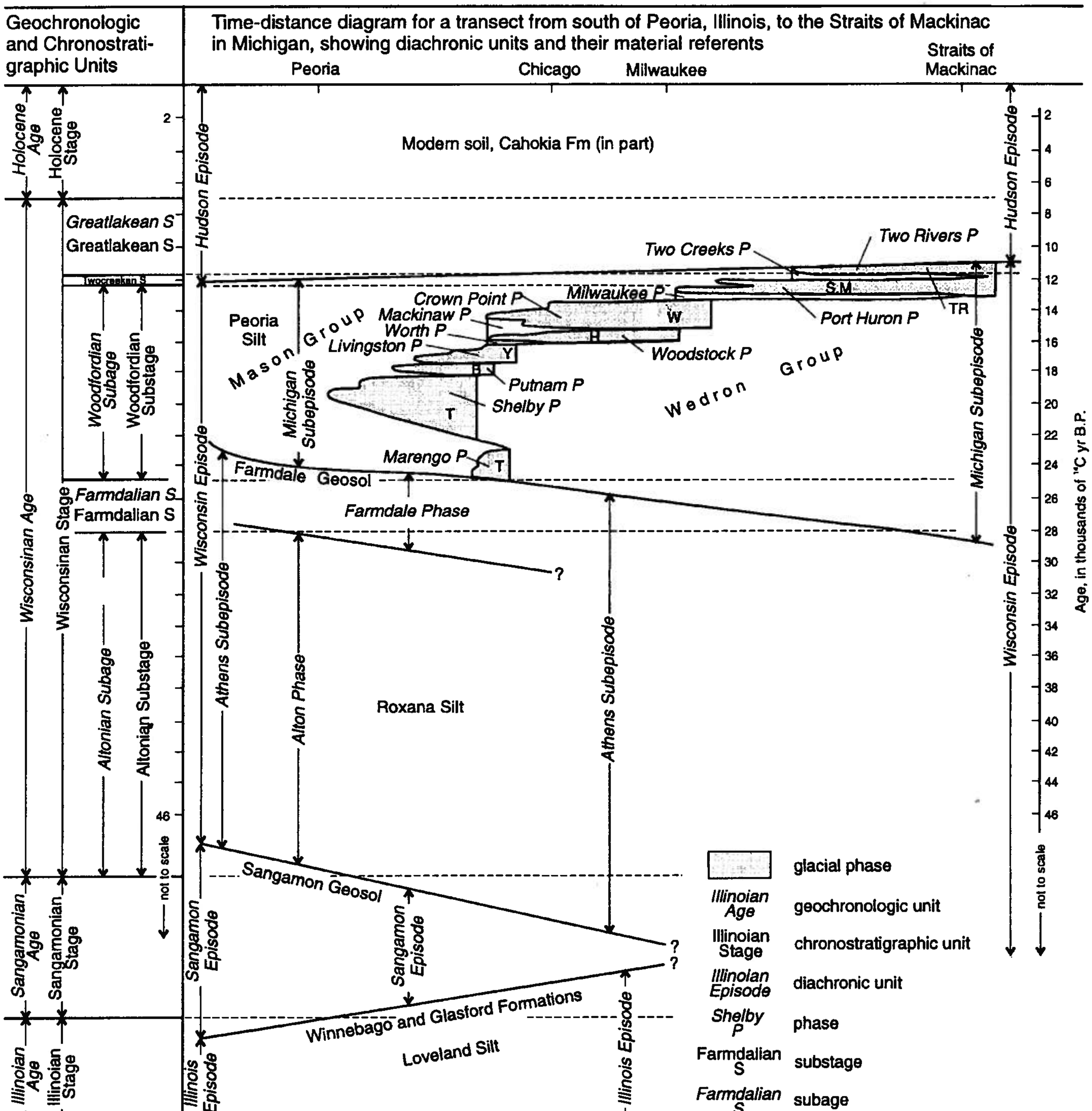

FIG. 1. Geochronologic units, chronostratigraphic units, and diachronic units in the Lake Michigan lobe in a transect from south of Peoria, Illinois, to north of the Straits of Mackinac in Michigan. Dashed lines on time–distance diagram are extensions of geochronologic unit boundaries. Geochronologic and chronostratigraphic units are after Frye *et al.* (1968), as modified by Follmer *et al.* (1979), Evenson *et al.* (1976), and Curry and Follmer (1992); diachronic units and the lithostratigraphic and pedostratigraphic units on which they are based are after Hansel and Johnson (1992, 1996). Material referents for Michigan Subepisode phases include the Tiskilwa Formation (T); the Batestown (B), Yorkville (Y), and Haeger (H) members of the Lemont Formation; the Wadsworth Formation (W); the Shorewood (S), Manitowoc (M), and Two Rivers (TR) members of the Kewaunee Formation; and unnamed lacustrine sediments between some of the units. From Hansel and Johnson (1996).

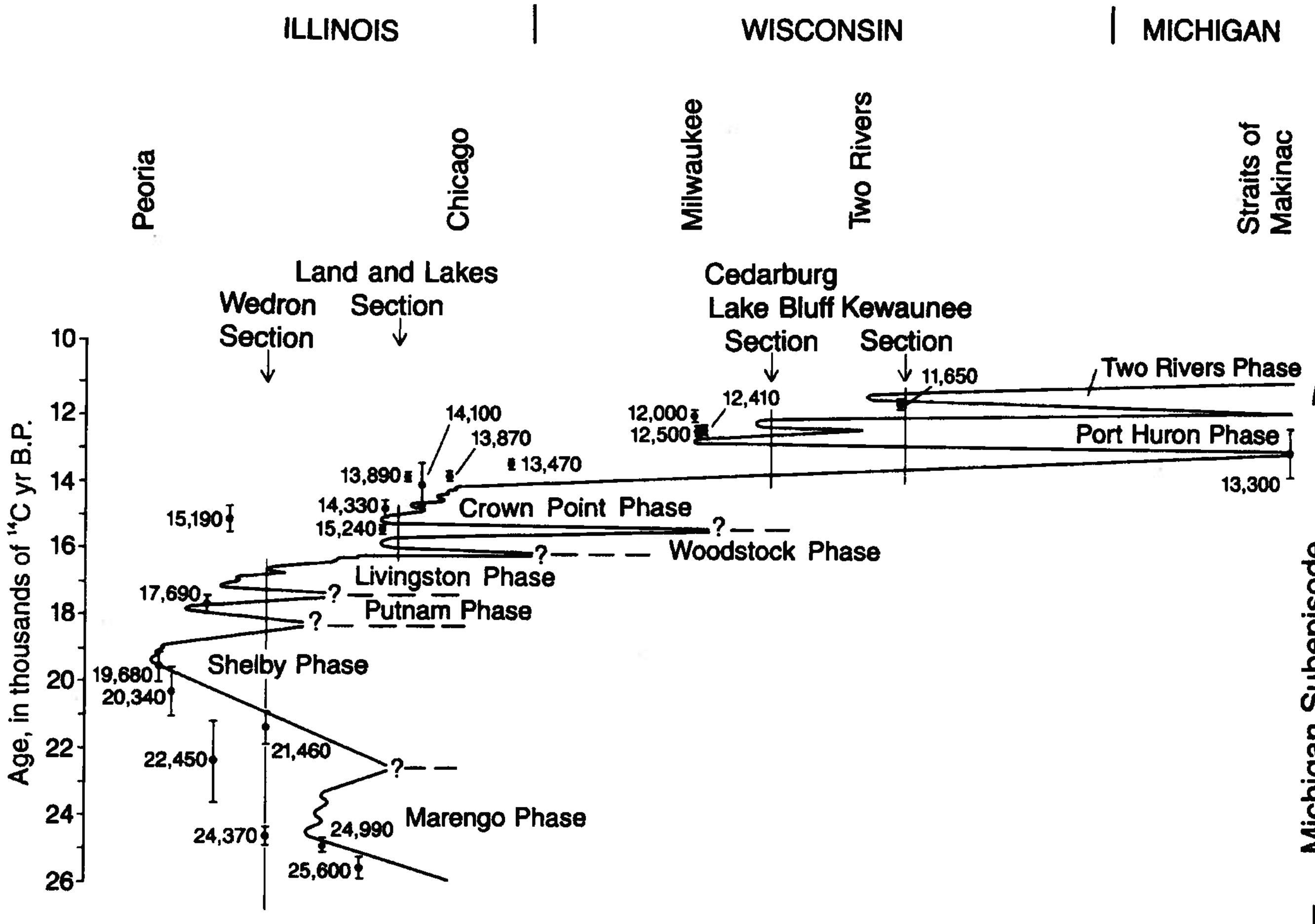

FIG. 2. Schematic time–distance diagram showing glacial phases during the Michigan Subepisode in the Lake Michigan lobe. Locations of some reference sections are indicated on diagram. Selected ages on diagram are in ^{14}C yr B.P. with ±1 standard deviation error bars. Modified from Hansel and Johnson (1992).

fixed in time and vary in age laterally, it is essential to determine as accurately as possible the ages of the boundaries at sites throughout the region. That is the goal of much of our research, as we attempt to reconstruct the floral, faunal, physical, and climatic history of the Quaternary (Birks, 1982). For parts of the record that are beyond the range of radiocarbon dating, it is and will be difficult to determine numerical ages for temporal boundaries. Thermoluminescence ages, amino acid racemization data, paleomagnetic polarity determinations, and other chronological data, used in conjunction with interpretations of the sediment and soil stratigraphy, will allow correlation to the marine isotope or ice core records. Ages from those records then can be used as proxy ages for temporal boundaries in the midcontinent region, as currently practiced. The proxy ages will be only as reliable as the correlations, and they will be subject to revision as new numerical ages are obtained locally and as new insights develop with respect to interpretations of the geology and geologic history.

SUMMARY

In regions in which geochronologic classification is not practical or useful, we strongly advocate the use of diachronic principles in establishment of local and regional temporal and event classifications for the Quaternary Period. Diachronic and event classifications are proposed for the Great Lakes region of North America. We introduce Hudson for the time and events of the current interglaciation or postglacial interval, and we retain Wisconsin for the time and events of the last glaciation, Sangamon for the time and events of the last interglaciation, and Illinois for the time and events of the penultimate glaciation. In the diachronic classification, we introduce the Ontario, Elgin, and Michigan Subepisodes of the Wisconsin Episode in the eastern and northern parts of the Great Lakes region; the three subepisodes are approximately equivalent to the early, middle, and late Wisconsin(an) intervals of Dreimanis and Karrow (1972). We introduce the Athens and Michigan Subepisodes of the Wisconsin Episode in the western and southern parts of the Great Lakes region; the two subepisodes are approximately equivalent to the combined Altonian and Farmdalian Subages and the combined Woodfordian, Twocreekan, and Greatlakean Subages, respectively, of Willman and Frye (1970) and Evenson *et al.* (1976).

ACKNOWLEDGMENTS

Discussions leading to the proposed classifications were initiated in an attempt to better integrate the Ontario and Illinois classifications. The positions expressed were developed in part from presentations for The Legacy of T. C. Chamberlin Symposium at the 1989 Annual Meeting of the Geological Society of America (Johnson, 1989) and for the symposium on Late Quaternary Time Classification in the Great Lakes Region at the 1991 North-Central Section Meeting of the Geological Society of America (Johnson *et al.*, 1991; Karrow, 1991; Larson *et al.*, 1991; Lowell *et al.*, 1991; Schneider, 1991). Aleksis Dreimanis and H. E. Wright, Jr. have contributed to and been supportive of our efforts. Lee Clayton was an active participant in the discussions, and we thank him for his input and critical review of several drafts of the paper. We also thank Robert J. Fulton and David S. Fullerton for critical reviews of the paper; Fullerton was particularly helpful in improving its clarity.

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