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NEW QUATERNARY GEOLOGIC MAP OF INDIANA—AN INTRODUCTION

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ABSTRACT: The surficial geology of more than four-fifths of the State of Indiana has been directly affected by the glacial events of the past million years or so, yet original geologic maps that show Quaternary geology statewide came late on the scene, are few in number, and are mostly at a scale of 1:1,000,000 or smaller.

The most recent Quaternary geologic map of Indiana by H.H. Gray in 1989 is the first to be printed at a scale of 1:500,000. It displays 39 material geologic units, most of which are glacial in origin, and also shows the distribution of 13 types of related morphologic features. Some of these map units and features have never before been discriminated on a statewide map of Indiana; a few are conceptually new.

This map reflects current interpretations in a field of geology where concepts are rapidly changing as the relevant body of knowledge grows. As a consequence the map may soon be subject to revision in detail, but it will nevertheless for the foreseeable future be a basic resource, not only in Quaternary geologic investigations but also in related fields, such as engineering geology, soil science, groundwater studies, land-use planning, and environmental management.

INTRODUCTION AND HISTORICAL BACKGROUND

The surficial geology of more than four-fifths of Indiana is the direct or indirect result of glacial activity, yet until relatively recently glacial studies in this state have not received the attention they merit. For example, when I joined the Indiana Geological Survey in 1954, there were more than 20 specialists on the Survey staff in other fields of geology, but only one in glacial geology. Even today, glacial studies at the Indiana Survey are organized as a sub-field of environmental geology.

Partly as a consequence of this state of affairs, mapping of the glacial deposits in Indiana lagged behind mapping of bedrock geology and initially was carried forward by geologists not associated with the Indiana Geological Survey. Principal among these was Frank Leverett of the U.S. Geological Survey (Leverett, 1897, 1899, 1902), whose work culminated in a monographic treatment (Leverett and Taylor, 1915) that to this day is recognized as the foundation of glacial studies in this region. Indiana University professors C.A. Malott (1922, 1926) and W.D. Thornbury (1932, 1937) introduced refinements and redefined the glacial margins but produced no definitive cartography, and it remained for W.J. Wayne (1958) to prepare the next map that shows the areal glacial geology of Indiana. At 1:1,000,000 scale, however, this map is too small to show much detail, and conceptually it differs only slightly from its predecessors.

In the 1960s and 1970s, mapping emphasis at the Indiana Geological Survey turned to the 1:250,000-scale Regional Geologic Maps (for the most recent example, Gray and others, 1979). These maps show Quaternary deposits in color superposed over gray line patterns that delineate the bedrock geology, and although they are cartographically advanced, they introduced only relatively minor advances in our understanding of the glacial geology. In the late 1970s, however, a large body of new data, based mainly on subsurface studies of the glacial deposits, began to change our concepts of the mechanisms of glaciation in this area (see, for example, Bleuer, 1989). Most importantly, the developing three-dimensional view showed that the sequence of glacial deposits is not as simple as once it was thought to be. When the U.S. Geological Survey began to compile a nationwide series of Quaternary maps at 1:1,000,000 scale (Lineback and others, 1983; U.S. Geological Survey, in preparation), it became possible to incorporate some of the newer concepts into that interpretation. A page-size map (Indiana Geological Survey, 1979), considered an interim product, is an offshoot of that effort.

Some other earlier mapping efforts are worthy of brief note. In the late 1940s and early 1950s, students of W.D. Thornbury at Indiana University compiled, as class projects, a set of glacial materials maps, one for each of Indiana's 92 counties. Most of these were based on classroom interpretations of soil and engineering maps; a few were based on aerial photographs. It was intended to assemble these individual studies into a statewide map at 1:250,000 scale, but the county maps were of such uneven quality that the work was not carried to completion and exists now only in fragmental manuscript form. There are also many derivative maps, most of which are page-size and intended primarily as illustrations (for example, Governor's Water Resource Study Commission, 1980, fig. 5). These generalizations are well suited to their purposes, but none displays new or original data. Not specifically noted here, because this discussion is focused on statewide mapping, are reports of local areas in which Quaternary materials are mapped or described. Only the most recent of these are conceptually up to date.

CONSTRUCTION OF THE MAP

Preparation of a modern statewide bedrock geologic map of Indiana suitable for wall display was an objective of the Indiana Geological Survey for many years. Initial planning under the direction of Charles F. Deiss evolved into the Regional Geologic Maps already mentioned; preparation of a single-sheet wall map became a principal objective of Deiss' sucessor as State Geologist, John B. Patton. In addition to the Bedrock Geologic Map of Indiana that resulted from this program (Gray, Ault, and Keller, 1987), derivative products include maps showing topography of the bedrock surface (Gray, 1982) and thickness of unconsolidated deposits (Gray, 1983). These maps are at 1:500,000 scale. It became obvious that to complete the series, a Quaternary or surficial geologic map was needed, and at Dr. Patton's urging work commenced in 1982.

Given the vast amount of information available and the variety of sources, compilation of the Quaternary geologic map was no small task. In a few places modern fieldwork has resulted in surficial geologic maps that needed only to be generalized; in many more places interpretations could incorporate very good related information, such as soil surveys; and in a few places mapping concepts had to be based on a scattering of original fieldwork and reconnaissance study. Topographic maps, aerial photographs, and satellite imagery were used throughout the study, as were drill-hole data from many sources. In some areas it was necessary to apply interpretations that had been developed in adjacent areas where data were more abundant. There was no concerted program of fieldwork, but many local problems were addressed by *ad hoc* field studies. I will not enumerate all those who helped with the task because they are recognized on the map itself, but there were many. Special thanks, however, go to N.K. Bleuer and Gordon Fraser, who helped in developing viable concepts for mapping.

Compilations were produced county by county, mostly on topographic maps at 1:24,000 scale. These were edge-matched and compared, and then were transferred to a master map at 1:250,000 scale. As the master map developed, the number of cartographic units increased to an unmanageable number, and adjustments were therefore made. To accommodate the continuing flow of new information, the process of correction, reinterpretation, and reconciliation continued until the last possible moment before the map went to the printer.

Concurrent with map assembly, a symbol list was prepared. This evolved into the map explanation, which in final form includes 39 cartographic units (for example, Wisconsinan loam till of Lake Michigan Lobe source) and 13 morphologic features (for example, concentric minor moraines). An inset group, which includes a set of diagrammatic cross sections, a columnar section, and a small-scale map, illustrates subsurface sequences and distribution of the several till sheets as now understood.

Finally, this is a Quaternary geologic map, not a map restricted to glacial geology, and although most of the map units are directly or indirectly related to glacial processes, there are included, notably in southern Indiana, map units that would be omitted from a map showing glacial geology only.

NOTES ON SOME OF THE MAP UNITS

Because a number of the cartographic units shown on this map are new or are newly reinterpreted, a few comments are appropriate. The units are discussed approximately in order of age and in the order shown in the explanation on the map. At this point it will be helpful to the reader to have a copy of the Quaternary map (Gray, 1989) in hand.

Blanket sand (unit *bs*).—South of the Kankakee River, from Newton County to Starke County and southward into White County, lies an extensive area mapped as blanket sand. This material unit is grouped with the eolian association, as is traditional, but its surface is marked not only with dune patches (mapped separately as unit *s*, dune sand, where sufficiently extensive) but also by linear relict drainageways that suggest southward-directed overflow from the Kankakee valley. Furthermore, the blanket sand is transitional laterally into sandy lake deposits (unit *ls*). It is likely, therefore, that the blanket sand is of mixed origin and probably incorporates alluvial and lacustrine elements as well as eolian. Further study into the origin, age, thickness, and exact extent of this material is needed.

Outwash fans (unit *of*) *and intensely pitted outwash deposits* (unit *op*).—Much of what previously has been regarded as outwash plain is mapped as outwash fans or pitted outwash. These are recognized mainly across the northern part of the state and are discriminated from undifferentiated outwash (unit *o*, much of which is valley train) by morphology. Many outwash fans head in morainal areas, have a perceptible gradient, and are marked by abandoned channel segments and other linear trends. In St.Joseph County a large area of pitted outwash, also in fan form, is associated with an area of complex drift (unit *tg*) of the Lake Michigan Lobe. Other areas of pitted outwash are associated with what has been regarded as an interlobate moraine that trends from Fulton County to Steuben County. Associated fan trends, however, suggest that this feature, though complex, is of eastern (Huron-Erie Lobe) source. Linear closed depressions that may be icethrust features mark the surface of some areas of pitted outwash.

Complex drift in chaotic form (unit *tg*) *and in lineated form* (unit *tt*).—These were distinguished from other areas of Wisconsinan till because they include many patches of stratified drift too small to show at 1:500,000 scale. For the most part these areas were recognized through the study of soil maps. Chaotic mixed drift occupies fairly large tracts in and adjacent to areas traditionally associated with the Saginaw Lobe and related areas formerly thought of as interlobate. Lineated mixed drift, in which the intermingled slices of till and stratified drift are linear in form, originated in outwash-carrying sub-ice tunnels or ice-walled channels into which large slabs of till collapsed as the ice wasted. These commonly are at the heads of major proglacial sluiceways throughout much of the area of Wisconsinan drift.

Till associations.—Till units are separated on the map not only by age and sequence but also by source. Lake Michigan Lobe till and Huron-Erie Lobe till are readily discriminated by mineral content; Saginaw Lobe till has been significantly reduced in extent from earlier mapping and is less certainly identified, primarily by the orientation of associated drainageway patterns.

Conventional moraines (symbol *..m*) are rather out of favor these days and so only a few have survived in this mapping, but buried moraines (symbol *../m*) are identified, where known, within the area of Wisconsinan till. The Iroquois Moraine in Newton and Jasper Counties is a classic example; the thickened ridge of Lake Michigan Lobe till is overlain by thin surface till of the Huron-Erie Lobe. Also noted in the explanation is the association of large areas of ablation drift and large-scale dead-ice landforms with particular till units. These imply a surge-stagnation cycle for at least some of the ice sheets that covered large parts of Indiana.

Finally, overprint symbols show various surface morphologic features discernible on aerial photographs or satellite imagery. These include low parallel ridges, concentric minor moraines, relict patterns of jointing, and linear closed depressions that may be ice-thrust features. Some of these features, as well as many small areas of ice-contact stratified drift that are shown only by symbol, are more prominently associated with certain of the till units than with others. Again, association with stagnant ice is implied. Because no regional study has been made of bedrock striations or till fabric and only incomplete tabulations exist, these features are not shown.

Upland and lowland silt complexes (units *ru* and *rl*).—Broad upland areas in southeastern Indiana that traditionally have been mapped as Illinoian till now are known to be occupied by a complex of silt and sandy silt that is not simply loess; neither is it till, nor outwash, nor a lacustrine deposit. This body of material (unit *ru*) is as much as 12 to 15 feet (3 to 5 m) thick and overlies pre-Wisconsinan till, outwash sand, or bedrock. All these have a well-developed but truncated paleosol at their tops. Typically the upland silt complex mantles broad plateaulike areas; the underlying material crops out on adjacent hillslopes. Across the south-central and southwestern parts of the state a similar material (unit *rl*) is extensive in lowland areas, most of which have previously been mapped as lacustrine (both Wisconsinan and older) or as pre-Wisconsinan alluvium. This lowland silt complex overlies the same kinds of older materials as does the upland silt complex.

The origin of these deposits is enigmatic. Probably they are Wisconsinan in age because the degree of development of the underlying paleosol suggests that it is Sangamonian and because surface soil development is slight. For the upland silt, a case can be made for involving cryoturbation or solifluction at the time of the Wisconsinan ice-maximum for the lower parts, which are sandy to finely pebbly, weakly stratified, and made up of degraded material that probably has been reworked from the weathered zone of the underlying strata. This cryogenic phase may have been followed by increasing loessal contribution because the upper 3 to 6 feet (1 to 2 m) of the deposit is primarily silty. A sheetwash-to-eolian origin may fit the lowland silt. Again, a need for further study is indicated.

Distribution of loess in southern and central Indiana (unit *lo* in part).—Loess is mapped as a separate cartographic unit only where it is more than 5 feet (1.5 m) thick, but thinner loess caps all surficial geologic units mapped in southern and central Indiana that are older than latest Wisconsinan. Rather than show the loess as an all-enveloping blanket, I have indicated its distribution in the description of the individual units affected.

Subdivisions within the Mitchell Plain.—The Mitchell Plain of south-central Indiana is a karst plateau underlain by limestones of mid-Mississippian age. Within this physiographic region, three distinctive morphologies are discriminated: areas of relatively thin regolith and moderately steep slopes in which outcrops of limestone bedrock are common (unit 3); areas of abundant and active sinkholes, soils of varied thickness, and no surface drainage (intensive karst; unit 3K); and areas of thick terra rossa regolith and relatively low relief (unit 3T). These aspects of the Mitchell Plain have been recognized for some years but are mapped regionally here for the first time.

USES AND USERS OF THIS MAP

Any geologic map is influenced by concepts current at the time of its preparation; this may be more obvious in Quaternary maps than in others because in this discipline many kinds of studies are rapidly reshaping, modifying, even revolutionizing our thinking. Subsurface studies of Quaternary deposits, not only in Indiana but also in adjoining and related areas, are proceeding apace, and the knowledge generated is adding a third dimension to surface mapping. For example, 3-D maps of defined material bodies make it possible to ''peel'' the deposits, layer by layer, and to create new types of Quaternary geologic maps, new interpretations, and new uses.

That proviso notwithstanding, the new Quaternary Geologic Map of Indiana currently provides the only modern synoptic overview of the surficial geologic materials of the state. It also serves as background to site-specific studies in fields where man's activities interact with these materials, notably engineering geology, soil science, groundwater studies, land-use planning, and environmental management.

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