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Pleistocene Formations in Indiana

William J. Wayne
University of Nebraska-Lincoln, wwayne3@unl.edu

PLEISTOCENE FORMATIONS IN INDIANA

by

WILLIAM J. WAYNE

Indiana Department of Conservation

GEOLOGICAL SURVEY

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JOHN B. PATTON, STATE GEOLOGIST
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BY
WILLIAM J. WAYNE

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CONTENTS

CONTENTS

ILLUSTRATIONS

TABLES

PLEISTOCENE FORMATIONS IN INDIANA

BY WILLIAM J. WAYNE

ABSTRACT

The system of stratigraphic classification used in North America for all sedimentary rock units except nonmarine deposits of the Pleistocene Series established groups, formations, and smaller units based on objectively determined characteristics of the rocks and not on geomorphology or subjective features, such as geologic time. Not all students of the nonmarine Pleistocene have kept these two kinds of units distinct from each other.

The Pleistocene sediments of Indiana and the surrounding States are continental in origin rather than marine, and thus they show far less lithologic homogeneity than sediments and rocks of marine origin. Nevertheless, these Pleistocene sediments can and should be grouped into logical and usable formational units by means of lithologic characteristics. A classification based on lithologic characteristics omits units that are wholly geomorphic, such as terraces, but it does not change many time-lithic units that are now shown on most surficial geologic maps. Instead, these units are given names as formations or members or are regarded as facies.

Three of the six formations proposed in this study of Pleistocene sediments in Indiana, the Jessup, Trafalgar, and Lagro Formations, are composed dominantly of glacially deposited mudstone or till. These formations have upper and lower contacts that coincide with unconformities within the Pleistocene. Other unconformities permit the separation of the Jessup and Trafalgar Formations into members, named here the Cloverdale, Butlerville, Center Grove, and Cartersburg Till Members. These unconformities generally are marked by key beds, such as paleosols and thin fossiliferous beds.

The remaining three units, the Prospect, Atherton, and Martinsville Formations, consist of several related lithofacies, through most of which significant unconformities are difficult or impossible to trace.

This method of classification permits local names to be designated for lithostratigraphic units in the Pleistocene Series that are useful in field studies in Indiana. These units are particularly valuable for use in problems that frequently arise in correlating rocks within a finely divided time sequence. By means of a classification system for Pleistocene sediments, existing terminology of glaciations can be referred to readily and can be correlated as a kind of geologic-time stratigraphy.

Fossil mollusks are found in two of the facies of the Atherton Formation and in thin beds of silt between barren mudstones in the Jessup and Trafalgar Formations. Largely because of environmental changes, the assemblages differ from unit to unit in vertical succession, but differences are slight. Three range zones based on forms of *Succinea* are named, in descending order, the *S. vermeta*, *S. gelida*, and *S. gelida* var. Range Zones. In addition, the fossiliferous parts of the key beds that separate formations and members are termed the lower, middle, and upper *Hendersonia occulta* beds and the *Vertigo alpestris oughtoni* bed.

INTRODUCTION

I wonder whether mankind could not get along without all these names, which keep increasing every day, and hour, and moment; till at last the very air will be full of them; and even in a great plain, men will be breathing each other's breath, owing to the vast multitude of words they use, that consume all the air just as lamp-burners do gas. But people seem to have a great love for names; for to know a great many names, seems to look like knowing a good many things; though I should not be surprised, if there were a great many more names than things in the world.

HERMAN MELVILLE, "Redburn," chapter 13

When man begins to accumulate and to relate bits of factual data, he generally finds the need to classify them. He then finds, to Melville's discomfort, that to use and refer to his classified units he must give names to them. Classification and the resulting terminology are a means to an end: to provide a framework that will facilitate the study and better understanding of the data. Classification as an end in itself is never justifiable.

Stratigraphic classification involves the grouping of strata in the earth's crust on the basis of specific properties or characteristics. Thus rock strata may be referred to units of varying kinds and ranks on the basis of such characteristics as lithology, fossil content, gross properties, and age. Classification of rock units usually involves naming each unit; names of different units and groups of units make up a jargon known as stratigraphic terminology.

Stratigraphers carry on this procedure because they have a threefold responsibility: (1) to subdivide and describe local stratigraphic sections; (2) to correlate these sections with a standard or type section understood by other stratigraphers; (3) to interpret these local sections in order to present the geologic history of the. area. The stratigraphic classification and nomenclature used among North American stratigraphers have been formulated as a means of expediting the first two of these three tasks (Rodgers, 1954). The first, descriptive stratigraphy, is a useful and objective procedure for presenting data. The other two, correlation and geologic history, involve interpretation; thus they are subjective procedures. Hedberg (1958, p. 1883) emphasized that, throughout stratigraphic classification, units resulting from these same two fundamentally different types of stratigraphic practices are used. Objective units are based largely on direct observations and measurements and imply a minimum of interpretation. Such features as lithology, fossil content, and mineral content are used to recognize and establish objective units. Subjective units are based

largely on interpretations of observations. Time, climate, and environment are among the criteria used to establish subjective units.

This dual system of subjective and objective stratigraphic units has not been used generally in the classification of nonmarine sediments of Pleistocene age. Rather, a system similar to that used in Europe, in which there is only a single set of terms, has been the basis for most of the present classification of Pleistocene glacial deposits, but there are some exceptions to this (Frye and Leonard, 1952; Frye and Willman, 1960; White, 1960). 1 intend to present in this report a brief review of Pleistocene stratigraphic classification and nomenclature currently in use in the glaciated part of eastern North America, to suggest some changes in the present classification of Pleistocene rock-stratigraphic units, and specifically to propose formational names for all sediments of Pleistocene age in Indiana.

During the early phases of the development of this classification scheme, I was encouraged by discussions with Henry H. Gray, Indiana Geological Survey, Gerald Richmond, U. S. Geological Survey, and H. B. Willman, Illinois State Geological Survey.

The rock-stratigraphic units that are proposed formally in this report have been applied in preparing areal geologic maps and reports in diverse parts of Indiana. I have made use of some of these formations in the mapping of Johnson County, Ind. (in preparation) and in the Pleistocene geology of the Catlin and Mansfield Quadrangles (in preparation), Parke County, Ind. (fig. 1). Henry H. Gray used four of the formations in mapping the unconsolidated sediments of the Hillham and Huron Quadrangles in south-central Indiana (Gray, Jenkins, and Weidman, 1960). In addition to being used for the maps cited, all prepared at a scale of 1:48,000 or larger, Allan F. Schneider and I used these formations as basic map units for the Indiana part of the areal geology of the Indianapolis Quadrangle, scale 1:250,000 (Wier and Gray, 1961). Areal geologic studies of both a detailed and reconnaissance nature in many other parts of Indiana, including in particular Fountain, Hendricks, Madison, Steuben, and Wabash Counties, provided me with background information that was useful in establishing the formations set forth here.

Names of the major stages of the Pleistocene Series in the Northeastern United States were reviewed in several recent papers by Leighton (1958a, b; 1959) and in many earlier studies (Kay, 1931; Thornbury, 1937). 1 have utilized these stages as part of the

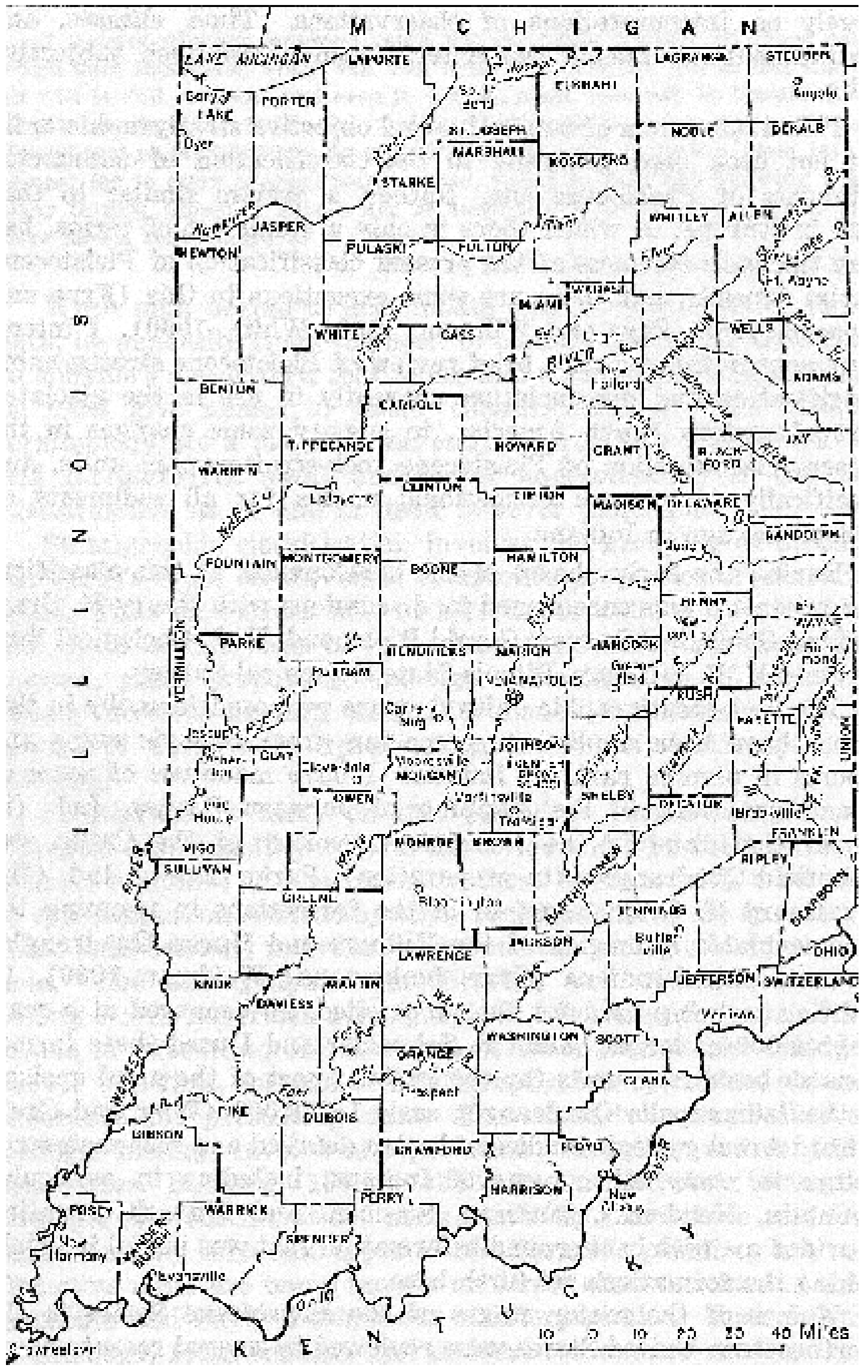


Figure 1.–Index map of Indiana showing county names, major drainage lines, and towns mentioned in the text.

time-stratigraphic classification of the Pleistocene Series and have placed all newly proposed formations in correlation.

SUMMATION

Standard practices of North American stratigraphers have not generally been applied to the classification of glacial sediments of Pleistocene age. The approach generally used has involved interpretation alone rather than description of objective stratigraphic units followed by interpretation. Constructional geomorphic features make this subjective kind of approach a more reliable method of stratigraphic research in glacial sediments than in other rocks; changes in nomenclature and correlation, however, have left many students of these. deposits without an objective and stable stratigraphic framework. In an attempt to improve this undesirable situation, several formations are herewith described as objectively as possible to provide a basic framework of rock-stratigraphic units for use in mapping the Pleistocene sediments in Indiana. This practice follows recommendations in the new "Code of Stratigraphic Nomenclature" (American Commission on Stratigraphic Nomenclature, 1961) that provide for multiple kinds of units in stratigraphic classification for use throughout the geologic column.

1~ The Pleistocene sediments of Indiana are continental rather than marine deposits, and thus they are likely to show far less lithologic homogeneity and continuity than sediments and rocks of marine origin. Nevertheless, it is possible to group the Pleistocene glacial and glaciofluviatile sediments into usable rock-stratigraphic units. The basic principles listed below were used in defining the Pleistocene rock units that are proposed in this report.

1. Currently standard techniques for field identification, description, and delineation of unconsolidated sediments were used.
2. Because many individual lithologic units were too thin and (or) too local to map unless they had extensive distribution as the surface material, the unconsolidated sediments were assigned to units large enough to be meaningful.
3. These units were classified as formations, members, tongues, or beds or as lithofacies of formations.

   Two primary means of separating units were used: (1) lithologic characteristics and (2) distinctive marker beds at major unconformities.
5. Mappable rock units were given local geographic names; they were correlated with time-stratigraphic units already recog-

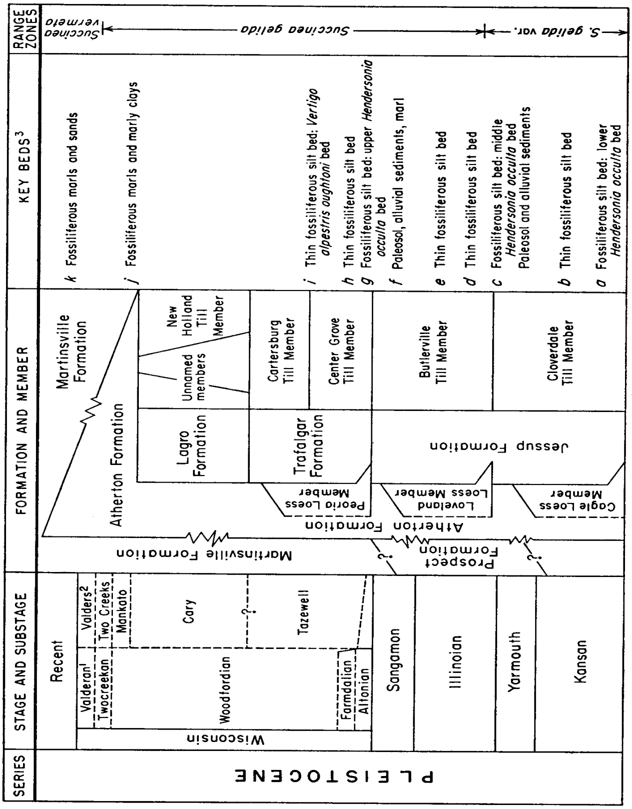


Figure 2.—Pleistocene stratigraphic chart for Indiana.

[1] Substage classification of Frye and Willman, 1960, in this column.
[2] Substage classification of Leighton, 1960, in this column.
[3] Letters refer to fossiliferous beds. (See also fig. 7 and table 2.)

nized in the Pleistocene in conformity with established stratigraphic practice.

6. Geomorphology was recognized as an invaluable aid in determining continuity and extent of rock units and in interpreting geologic history, but physiographic features were not used as the sole basis of the map units.

7. Biostratigraphic data, used in conjunction with other stratigraphic information, aided in recognizing some of the rock units.

RESUME OF NEW PLEISTOCENE FORMATIONS IN INDIANA

The six formations discussed below are proposed for use as rock-stratigraphic units in the Pleistocene Series in Indiana (f ig. 2). Their distribution is shown in figure 5.

Martinsville Formation.--Named from exposures along White River north of Martinsville, the Martinsville Formation includes two kinds of sediments that are treated here as facies. The alluvial facies, consisting of muds, silts, sands, and gravels, are primarily fluviatile sediments of nonglacial origin that have been deposited on modem flood plains. Locally this facies includes small areas of slopewash (colluvial) deposits and quiet-water sediments that commonly have high organic content. Because these sediments have been deposited on flood plains, their areal distribution generally can be outlined by the use of geomorphology. Peat, gyttja, marl, clay, and silt-quiet-water sediments of nonglacial origin that have been deposited in sloughs, lake basins, and bogs-are regarded as paludal facies of the Martinsville Formation. The paludal sediments commonly are fossiliferous.

The alluvial facies of the Martinsville Formation is present throughout Indiana as relatively thin ribbons of sediment in stream valleys. Discontinuous lenses of the paludal facies, of the formation are scattered over the northern half of the State. The upper part of the formation has been deposited during the Recent Age; the basal sediments in many of the lenses of paludal facies are Wisconsin in age.

Atherton Formation. -- The Atherton Formation is named from the village by that name near Terre Haute. It consists of coarse - to fine - grained sorted sediments that were deposited by glacial meltwater and similar sediments closely associated and intertonguing with them (fig. 3). The Atherton Formation has at least four distinct lithofacies: (1) gravel and sand of glacial outwash deposits (outwash facies) ; (2) silts, sands, and clays of glacial lake sediments (lacustrine facies), which commonly interfinger with out

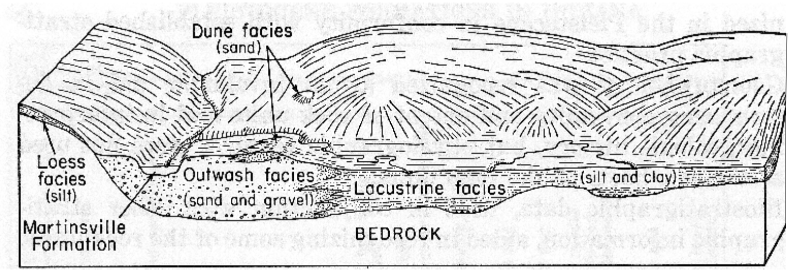


Figure 3.–Block diagram showing gradational relationships of outwash, dune, lacustrine, and loess facies of the Atherton Foramtion.

wash sediments; (3) sand of dunes (dune facies), generally derived from and overlying outwash material; and (4) silts and clays of loess deposits (loess facies), which have been derived f rom the outwash facies. The Atherton Formation in some localities includes deposits of more than a single glaciation; such deposits can be distinguished readily in vertical sequence only in the loess and lacustrine facies.

The outwash gravel and sand facies of the Atherton Formation is a surface unit of the Pleistocene sediments, throughout Indiana. In the northern quarter of the State it is present in broad plains and in valley fill sediments, but throughout the remainder of the State it is limited mostly to valleys. The distribution of the lacustrine silt facies of the formation closely parallels that of the outwash facies. The dune sand facies is found along some: parts of the lower Wabash Valley and the valleys of both forks of the White River, but the most extensive tracts of this facies are associated with the outwash and lacustrine facies in northwestern Indiana. Mappable areas of the loess silt facies lie only along major valleys, such as the Wabash and Ohio Valleys, but tongues of loess -ire traceable into other Pleistocene formations.

Agewise, sediments of the Atherton Formation span the entire Pleistocene Series. Most of the upper part of the formation, as shown on surf icial geologic maps, however, is assigned to the Wisconsin Stage. Only in a few valleys in the southern third of Indiana is the surficial part of the unit Illinoian (or Kansan) in age.

Fossils are present, and locally are even abundant, in the loess and lacustrine facies, but the outwash and dune facies generally are barren of organic remains.

Prospect Formation.--The Prospect Formation is named from the typical exposure near the village of Prospect in Orange County. It is composed of gravelly and sandy silts, generally yellow brown to orange brown, which ordinarily are mantled with a veneer of

yellowish-brown clayey silts; the sediments have been weathered so that the deposit generally exhibits a zonal soil profile. Thickness of the unit is variable but generally ranges from less than 1 meter to about 5 meters. The sediments of the Prospect Formation are primarily nonglacial and fluviatile in origin and can be recognized from their position of preservation on old, high-level, abandoned flood plains. Locally, the formation includes glacial sediments that are genetically related to lacustrine facies of the Atherton Formation. So far the Prospect Formation has been recognized only in the unglaciated part of southern Indiana. It correlates with sediments of the Sangamon Stage and with older sediments.

Lagro Formation.--Glacially deposited mudstone and associated lenses of clay, silt, sand, and gravel, all of glacial origin, constitute the Lagro Formation, which is named from the village of Lagro in Wabash County. The formation has three members, each of which has distinctive physical characteristics and separate geographic distribution; lithologically, two are dominantly clay-rich till, and the third, which lies in the area between the other two, is silty, sandy, and gravelly till. The easternmost of these members, the New Holland Till Member, is the only one named. Each member includes sediments of three environmental facies: end moraine till, blanket till, and kame. The thin (.45 to .80 meter thick) soil profile that caps all members of the formation has a brown B zone.

The formation lies at the surface in the northern one-fourth of the State, mostly in the area north and northeast of the Mississinewa, Wabash, Tippecanoe, and Kankakee Rivers (figs. 1 and 5).

The Lagro Formation is late Wisconsin in age and correlates, in part at least, with deposits of the Cary Substage and with the deposits of the upper part of the Woodfordian Substage of Frye and Willman's (1960) classification.

Trafalgar Formation.--The Trafalgar Formation is named from the village of that name in Johnson County. This formation is composed dominantly of massive conglomeratic mudstone, but it includes minor amounts of gravel, sand, and silt. The formation consists of two members separated by a thin fossiliferous silt bed, which is referred to as the *Vertigo alpestris oughtoni bed*. The soil profile that caps the formation has a brown B zone and is leached of carbonates to a depth of 0.80 meter to 1.25 meters. A thin yellowish-brown silt layer mantles the lower member of the formation where it is not overlain by the upper member, named here respectively the Center Grove Till Member and the Cartersburg Till Member. Each member consists of three environmental facies: end moraine till, blanket till, and kame.

The Trafalgar Formation is the principal surface geologic unit in the central third of Indiana, from the Wabash River on the north to the Wisconsin glacial boundary on the south. Sediments included in the Trafalgar Formation have been correlated, in part at least, with sediments of the Tazewell Substage and are included in the lower part of the Woodfordian Substage of Frye and Willman's (1960) classification.

Jessup Formation.--The Jessup Formation, named from a village in Parke County, consists dominantly of conglomeratic mudstone but includes minor amounts of gravel, sand, and silt and thin beds and lenses of peat. In some parts of Indiana the Jessup Formation consists of two members, each of which contains two units or more that are separated by thin fossiliferous silt beds. Where the upper member of the formation, named here the Butlerville Till Member, is exposed at the surface, the soil has been leached of carbonates to a depth of 3 to 4 meters. Where this member is buried, the part of the paleosol that has been leached of carbonates is about 1.5 meters thick and in well-drained places ordinarily is distinctly orange brown. The newly named Cloverdale Till Member of the Jessup Formation, which underlies the Butlerville, is dominantly conglomeratic mudstone but includes minor amounts of other lithologies. Locally, it includes three, units that are separated by thin fossiliferous silt beds, but all three have not been observed in a single exposed section. The orange-brown paleosol capping the member where it is buried beneath younger sediments is 2.5 to 3.5 meters thick. In the few places where the Cloverdale is exposed at the surface, it has been leached of carbonates to depths exceeding 6 meters. Lenses of peaty silt separate the Cloverdale and Butlerville Till Members in some exposures.

The Jessup Formation is the surficial unit of the Pleistocene Series in both the eastern and western thirds of southern Indiana. North of the Wisconsin glacial boundary it is overlapped by the Trafalgar Formation but is recognizable in many outcrops. The upper member (Butlerville) of the formation is assigned to the Illinoian Stage, and the lower member (Cloverdale) is assigned to the Kansan Stage.

BIOSTRATIGRAPHY

Three forms of *Succinea*, a pulmonate mollusk, allow three range zones to be set up for the Indiana Pleistocene deposits. They are named the *Succinea gelida* var., *Succinea gelida*, and *Succinea vermeta* Range Zones (fig. 2). In addition, nine fossiliferous beds

are recognized in the Pleistocene deposits. Three of these beds are named tongues of the Atherton Formation that are interbedded with the till formations; the other six beds are thin lenses of silt that lie between tills in the Trafalgar and Jessup Formations (fig. 2).

Hendersonia occulta is a significant element of the fauna in three of the key beds that are used to mark formation and member boundaries. The lower *Hendersonia occulta* bed underlies the Jessup Formation; the middle *Hendersonia occulta* bed lies between the Cloverdale and Butlerville Till Members of the Jessup Formation; and the upper *Hendersonia occulta* bed lies between the Jessup and Trafalgar Formations. The thin fossiliferous zone that lies between the Center Grove and the Cartersburg Till Members of the Trafalgar Formation is the *Vertigo alpestris oughtoni* bed.

LITHOLOGIC TERMS FOR PLEISTOCENE SEDIMENTS

Most of the descriptive lithologic terms peculiar to unconsolidated sediments, such as muck, peat, gyttja, clay, silt, sand, and gravel, are fairly straight forward and not likely to be misunderstood. A few, however, such as marl, loess, and till, seem to have more than one connotation and require clarification of their usage in this report. Some terms have ' both genetic and lithologic meanings. "Outwash," for example, refers to the origin of the sediment; sand and gravel generally are regarded to be the equivalent lithologic term. The term "marl," though used in more than one sense by geologists, refers to a fine-grained, generally light-colored, and highly calcareous sediment deposited in fresh-water lakes. Other terms, such as "loess" and "till," may have been wholly or largely descriptive at first, but by association they have taken a meaning that now includes origin. This dual state seems unfortunate, because "till" and "loess" in particular could be useful in referring to sediments with specific lithologic characters if their definitions had not been restricted to include only deposits of a specific origin.

Without reference to origin, most loess can be described simply as "massive silt." No purely lithologic term that does not carry some implication of genesis is currently in use, however, for the nonindurated sediments that, after diagensis, could be classified as conglomeratic graywackes.

With its current meaning (Flint, 1957, p. 109, 111-113) the word "till" may be used for any sediment, almost without regard to its lithologic characteristics, as long as direct deposition by glacial ice can be demonstrated. This meaning is not fully satis-

factory, because all the criteria necessary to indicate that a sediment was deposited directly by ice may not be available at the time that a field geologist describes the sediment. In actual practice, however, most geologists imply a specific lithology when they employ the word "till" and probably would hesitate to apply it to an ice-laid sediment that lacked certain characteristics normally expected in a till.

Perhaps there is a need for such a nongenetic term. Many authors seem to be groping for a word with this meaning when they use such expressions as "till-like" and "till?" or simply place quotation marks around the word "till." "Till" appears in quotes presumably to suggest that the sediment in question looks like and has the lithic characteristics of till but that it might conceivably have had some origin other than deposition by glacial ice. Many geologists will undoubtedly continue to use "till," either in quotes, or without, as a relatively nongenetic lithologic term even though other terms are proposed to replace it. In this report I propose to use the term "mudstone" for lithologic description and reserve "till" for use when I wish to imply genesis as well as lithology.

"Mudstone," as I have used it throughout this report, refers to a poorly sorted elastic sediment that has a relatively fine-grained matrix, which is poorly to moderately well indurated. Pleistocene mudstones in Indiana are commonly clayey sandy silts that contain more or less abundant angular to rounded pebbles, cobbles, and boulders, the softer varieties of which are likely to be scratched or striated. The composition of the particles that make up the sediment is generally variable, and the sediment ordinarily includes materials exotic to the area. The term "conglomeratic" is used to describe those mudstones that contain pebbles or larger rock fragments in noticeable amounts. Most of the glacially deposited mudstones in Indiana are conglomeratic.

Mudstone is distinctive because. of its wide range in particle size and composition. It commonly grades into silty clay, clayey silt, clayey sand, and silty gravel. Conglomeratic mudstones are massive, and they seldom show internal bedding, although both platy and columnar types of structure are commonly observed. These sediments generally are some shade of gray or are brownish gray in places where they have not been altered by percolating ground water. The color alteration most frequently noted is produced by oxidation of ferrous compounds, and the result is a change in color from gray to yellowish brown or orange brown.

Pettijohn (1957, p. 261-275) had recognized and attempted to handle the terminology problem when he proposed the term "paraconglomerate" for this rock group. He then used the term "till" for paraconglomerates, that can be demonstrated to be of glacial origin and the adjectival "tilloid" as a noun for sediments of roughly similar characteristics that can be demonstrated to be of nonglacial origin. Flint, Sanders, and Rodgers (1960, p. 507-509) recently offered a review of the terms that have been proposed for poorly sorted sediments composed largely of a clayey, sandy,and silty matrix with larger particles dispersed through it. They then proposed "symmicton" for the sediment that has such a composition and "symmictite" for its lithified equivalent. Coined terms, such as "paraconglomerate," "symmictite," or "rudaceous calcilutyte," as such a sediment would come out in Grabau's (1932, p. 28) terminology, even though well designed for a specific use, tend to remain unused by geologists in favor of terms that may be somewhat less specific but that are more descriptive.

Miller (1953, p. 26-27) reviewed the terms available in the currently used classifications that might be usable for sediments of this type. He deplored their inadequacy, and then selected the name "conglomeratic" sandy mudstone for a poorly indurated sediment that resembles many tills but that he believed to be a marine deposit. He used quotation marks within the term to imply that the adjective "conglomeratic" did not fully fit all characteristics of the fragments in the gravel fraction. Miller's descriptive term, "conglomeratic" sandy mudstone, can be applied equally well to the poorly sorted clastic sediment that generally is called till in the Midwestern United States. This sedimentary material commonly is sufficiently well compacted to have a physical toughness and hardness comparable to that of many sedimentary rocks that have undergone more extensive diagenesis; thus choice of the word “'mudstone” is justified.

REVIEW OF PRESENT PRACTICES OF CLASSIFYING AND MAPPING PLEISTOCENE GLACIAL DEPOSITS

Classification of Pleistocene sediments has been approached from many different disciplines, including physiography, sedimentation, historical geology, archaeology, and climatology. Because emphasis has long been placed on deciphering glacial history largely through physiographic studies, the stratigraphic record generally has received only secondary attention. Most North American students of Pleistocene deposits have been geomorphologists whose principal field research has been done in glaciated areas.

Their dominant interest has been to work out in detail the geomorphic history of a region, and thus they have made extensive use of a time-stratigraphic classification only. Whatever bits of data-geomorphic, paleontologic, stratigraphic, or archeologic could be pieced together have been used by glacial geologists. A scarcity of good exposures and the almost ephemeral nature of many that did exist have combined to deter geologists whose interests have been primarily stratigraphic from examining Pleistocene sediments. Broad areas of youthful constructional topography, on the other hand, have offered a fertile field of study for geomorphologists.

One basis for subdivision of the Pleistocene is the succession of climatic changes that took place during this epoch as interpreted from studies of soils, landforms, and fossils, as well as from sediments of glacial and nonglacial origin. Although Lyell did not originally define it in this way in 1833, the Pleistocene Epoch came to be regarded as synonymous with "Great Ice Age" (Wilmarth, 1925, p. 43-53).

Standard procedure in mapping Pleistocene glacial deposits has been to distinguish all individual lithic units that are at the surface. Each unit recognized has considerable geographic extent and generally a recognizable physiographic expression. A genetic designation, such as end moraine, ground moraine, outwash gravel, and lake deposits, is commonly used on maps showing glacial geology. These surface units ordinarily are not given any rock-stratigraphic name; rather, they are handled rather loosely within the existing time-stratigraphic classification in which the stage is the fundamental unit. Because of the lack of specific rock-stratigraphic units, names of constructional and erosional geomorphic features (moraines and terraces) often have been applied locally to the lithic units associated with the geomorphic features.[1] The result has been a hodgepodge of terms, many of which are difficult to, use, and correlate. (See Hedberg, 1959, p. 676-678.)

Even though virtually all surficial lithic and morphologic units are shown on most glacial geologic maps, similar geologic units that lie buried beneath the surface generally are ignored. This mapping procedure has worked reasonably well if the mapping

[1]Terrace names, such as the Shelbyville, Maumee, or Mississinewa Terraces' are geomorphic terms solely and ordinarily should not be used as rock-stratigraphic terms for the deposits that underlie the landforms (American Commission on Stratigraphic Nomenclature, 1959, p. 671-672). Similarly moraine names, for example, the Shelbyville, Champaign, and Valparaiso Moraines, and other names should not refer to the deposits that constitute those constructional landforms.

scale is about an inch to the mile (1:62,500) or smaller, but awkward problems can arise in representing geology along valleys if mapping is done on a larger scale. These problems are particularly noticeable in an area that has been so deeply dissected by streams that more than one unit of glacial drift is exposed in a valley wall.

The problem is somewhat simplified on small- or medium-scale maps, because the scale may preclude the possibility of showing a vertical sequence of Pleistocene glacial sediments, even though established practice has long been to show thin bedrock units of formation rank on maps of 1:62,500 scale or larger. In preparing and using reasonably accurate maps with a scale as large as 1:24,000, however, it becomes essential to show Pleistocene rock-stratigraphic, units that crop out beneath the surficial materials along eroded slopes.

The time-stratigraphic terms in use for the Pleistocene sediments have a built-in disadvantage that is not common to most terms applied to the record of marine deposition. Deposits of the Pleistocene ice sheets share the characteristic of other continental deposits in that they contain many hiatuses in the record of deposition. Thus, ideally they should not have been chosen to represent the standard record of the Pleistocene Epoch in North America; unfortunately, however, most of the areas in which marine deposits were laid down during Pleistocene time are still under water and therefore are not available for study except in drill cores and bottom samples.

All these difficulties point up the need to apply the same general stratigraphic, principles in the study and classification of sediments left by Pleistocene glaciers that are used in the study and classification of other sedimentary deposits, regardless of age or origin, and that were recommended in the recent decisions by the American Commission on Stratigraphic Nomenclature (1958, 1959, 1961).

Glacially deposited units provide excellent examples of nonmarine progressive overlap and offlap. (See Leighton, 1958b, p. 703.) The basic difference between nonmarine and marine transgression is that marine formational units overlap each other toward the source of sediment, whereas many nonmarine units overlap in a direction away from the source of sediment. (See Grabau, 1932, p. 739-741.)

THE ROCK-STRATIGRAPHIC CONCEPT APPLIED TO PLEISTOCENE STRATIGRAPHY

In North America the basic local rock-stratigraphic unit for many years has been the formation. A formation is fundamentally a mappable unit of rock that can be readily identified in the field. Ordinarily, a formation is a body of rock strata distinguishable by lithologic homogeneity; a formation, however, may consist of strata that are characterized by heterogeneous lithologic characters (American Commission on Stratigraphic Nomenclature, 1961, p. 650). The extreme lack of homogeneity exhibited by many Pleistocene glacial deposits undoubtedly has been a major deterrent to those who may have~ wished to establish formational units for use in glaciated areas. The authors of the 1933 "Stratigraphic Code" (Ashley, and others, 1933, p. 441) specifically recommended that formal names "not be applied to deposits of merely local extent"; this recommendation supported the philosophy of treating Pleistocene glacial sediments as "a thing apart."

In theory, a formation should be independent of age considerations, but, in practice, many formation boundaries happen to be roughly time-parallel and are so defined. One of the most important elements in the designation of a formation is its mappability over an area wide enough to make it a useful rock-stratigraphic unit in areal geologic studies. The American Commission on Stratigraphic Nomenclature regards delineation at a scale of 1:25,000 as adequate for establishing the mappability of a formation.

A formation may be divided into members or smaller units if recognition of greater lithostratigraphic detail is needed or desired. The formation may be completely subdivided, or one member or more may be formally designated even though the rest of the formation may remain undivided. Members are useful if it is desirable to present greater stratigraphic detail than can be shown by the use of undivided formations; whether or not these members are mapped depends on the scale used in mapping and compilation. A named member may extend from one formation into another.

Formal nomenclature normally is not applied to the smallest lithostratigraphic unit, the bed. Beds are thin units; some of them have distinctive character and wide distribution.

In designating formations of Pleistocene age in this report, several principles have been kept in mind. Foremost among these is the concept that, with few exceptions, the lithic units now mapped on most surficial geologic maps should not be changed.

Most of the units now shown seem to be essential for satisfactory interpretation of the geology.

One effect of setting up Pleistocene formations in this manner has been to eliminate units that are wholly geomorphic in definition, but I do not intend for this to prevent the proper use of geomorphic features as a major aid in delineating and interpreting mappable lithologic units. Erosional terrace surfaces, for example, would not ordinarily be shown except on a geomorphic map, but sediments now remaining in terraces might appear as a particular lithic unit.

Because of the transitory nature of most exposures of unconsolidated sediments, Leighton's (1958b, p. 702) admonition is well taken; hence not only a type section but also a few additional reference sections have been designated (Appendix A). As old exposures become slumped or covered, new exposures that can also be utilized for reference will turn up from time to time. Nearly all the sections that I have selected as type sections or reference sections in this study are stream bluffs that should be swept clean of debris regularly for many seasons. Furthermore, they were selected in areas where most of the lithic units are so persistent that the stream is likely to expose additional supplemental sections nearby that are similar to those used here to define and describe the units.

KEY BEDS FOR FORMATIONAL BOUNDARIES

The simplest approach to the classification of two or more stratified bodies of rock of similar lithology that lie adjacent to each other in a vertical sequence is to group all the strata into a single formation. If this procedure should result in a formation that is in any way unwieldy, some means other than gross lithology alone generally can be employed to separate the strata into usable stratigraphic units. The "key-bed" technique provides a method by which this can be done for many Pleistocene deposits.

A key bed is a thin but distinctive unit that has relatively great geographic extent. (See Hedberg, 1961, p. 1082.) Horizons that have considerable lateral extent and can be readily identified, such as the top or bottom surface of a key bed, make useful planes of reference for defining and subdividing formations. Key beds that are adjacent to unconformities also may permit the reconciliation of terminology for both time- and rock-stratigraphic classification if beds of this kind can be found in the field. Buried peat, thin fossiliferous silt beds, and paleosols (buried soil profiles) con-

stitute key beds in Indiana that are useful for delimiting formational boundaries in Pleistocene sediments (fig. 4).

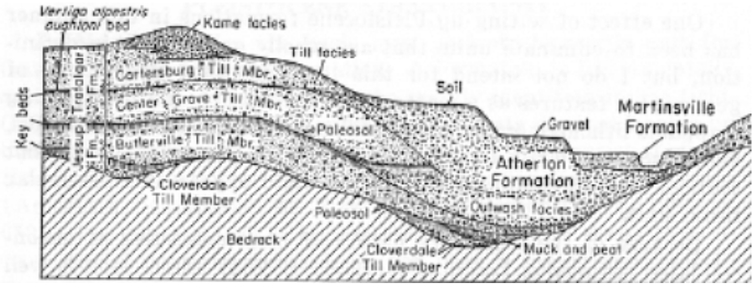


Figure 4.–Cross-sectional diagram showing interrelationships for certain formations, members, facies, and key beds.

In preparing areal geologic maps, both surficial and bedrock, the present soil, which has formed at the surface across many lithologies, is disregarded or is included with the immediately underlying rock unit (American Commission on Stratigraphic Nomenclature, 1956, p. 2009). Paleosols, likewise, are not in themselves rock units and should not be considered as such. Their upper surfaces, however, may be mappable horizons that separate i4owionees of lithologic units. A palposol indicates cessation of deposition for some length of time; the paleosol thus marks an important unconformity, Because nonglacial sediments, such as stream and lake deposits, were deposited contemporaneously with the development of the paleosol with which they are associated, a formation boundary based on the paleosol as a key bed should be at the upper surface of such nonglacial deposits and soil. A Pleistocene rock-stratixraphic unit., as visualized here, thus may include a complete cycle of glacial and nonglacial sediments.

FACIES

The facies concept is both valid and useful when applied to the subdivision of Pleistocene glacial secUments; basically, facies have long been used in mapping glacial deposits, although this term has not actually been applied. Facies, as used in this paper, refers to those "areally segregated parts of differing nature belonging to any genetically related body of sediments" (Moore, 1949, p. 8). They consist of laterally definable parts of a unit that were deposited more or less contemporaneously, that commonly intertongue, and that can be identified physically. Differences between facies. may consist of any features or combination of features that seem significant to the observer (Moore, 1949, p. 7).

One kind of facies most frequently found is the one used by stratigraphers to designate areally segregated bodies of differing lithology within a single depositional unit. This facies was referred to by Weller (1958, p. 633) as intertongued lithofacies and is the kind of facies for which Wheeler and Mallory (1956, p. 2719) proposed the term "lithosome." Within bodies of glacial and glaciofluvial deposits, areally segregated bodies of differing lithology are common (fig. 3). Sand and gravel are deposited in streams fed by glacial meltwater, but tributary streams become ponded, and their valleys receive only fine-grained sediments. The coarse clastics of a delta commonly intertongue with finer grained bottom sediments laid down in the same body of water. Intertonguing lithologies such as these certainly are lithofacies of a single conveniently recognized depositional unit (fig. 3).

Because of the thin and discontinuous nature of many individual lithologic units in glacially derived sediments, it is impractical to show all of them as separate units of formation or member rank on areal geologic maps. Where intertonguing lenses of this type are found at the surface, however, many of them, even though thin, can be outlined with little difficulty and have sufficient extent to be shown on an areal geologic map. These lenses, then, can be regarded as lithofacies of a single formation.

If facies are employed to designate the sediments of a particular depositional environment, any and all features characteristic of a deposit of that environment may be used to delineate the facies. In areas of original deposition still undissected by erosion, constructional geomorphic form, or the shape of the deposit, can be used as an effective aid, both to determine the existence and to locate the boundaries of the facies in places where it is to be shown on a map. In this respect, students of surficial geologic deposits, including Pleistocene glacial deposits, have a material advantage in the study of stratigraphic facies that is not shared by geologists who work with older rocks. Constructional geomorphology, coupled with lithologic distinctness, can be an excellent aid in recognizing depositional environments.

Several principles have been followed by stratigraphers to designate different facies (Weller, 1958, p. 610-626). One of the simplest, if each facies has a limited extent and is part of a formation defined by marker beds, is to designate each distinct type of lithology as a lithofacies and to use a descriptive name, such as gravel facies or silt facies, in referring to it (Grabau, 1932, p. 648-

657; McKee, 1949, p. 45). Terms suggesting the environment of deposition or mode of origin, such as aeolian facies, have definite dangers, but they can be used to advantage for the surficial lithofacies of very young deposits. Pleistocene glacial sediments fall into this category, and such terms as lacustrine facies, outwash facies, and kame facies should not be objectionable.

THE PLEISTOCENE FORMATIONS, SEQUENCE A

The formational units of the Pleistocene Series that I propose here can be grouped for discussion into two sets or sequences of lithologic units. Although these sets might readily be termed "groups," I have not selected formal group names. One of these two suites includes all the units that are composed dominantly of conglomeratic mudstone (till), a poorly sorted sediment; the other is comparatively well-sorted sediments, gravel, sand, silt, and clay. These two informal groups seem to be compatible with the principles used in the primary separation of sediments of Pleistocene age in highly generalized mapping.

Within both sequences, I have chosen to discuss the units from youngest to oldest. This reversal of the normal order was selected to emphasize the significance of key beds and soil stratigraphic units that mark the tops of most of the formations. Reversal of order also brings out more readily, by starting with the rock units and soil at the present surface, the physical relationships of paleosols and other key beds to the units in which they belong.

The distribution of all units described in this report is shown in a generalized manner in figure 5. Because the boundaries of units are based on mapping that ranges from reconnaissance to highly detailed in quality, some local modification of the boundaries shown may be expected as a result of additional detailed studies.

Three of the units defined in this study, the Martinsville, Atherton, and Prospect Formations, are composed dominantly of relatively well-sorted water-laid sediments. In many small-scale maps of sediments of Pleistocene age, some or all of the deposits in these formations commonly are grouped together for purposes of generalization (see Wayne, 1958b; Geological Society of America, 1959) and for convenience are here referred informally to sequence A.

MARTINSVILLE FORMATION

Definition, description, and distribution.--The Martinsville Formation is the name proposed here for silts, sands, and gravels deposited along the flood plains of modern streams and the peaty

and calcareous muds of small lakes and sloughs. These sediments commonly are grouped together as a single map unit, such as "Quaternary alluvium" (see Hutchison, 1960, pl. 1; Wier, 1952, pl. 1), but rarely have they been treated as a formally named stratigraphic unit. Typically, the sediments included in the Martinsville Formation contain thin and lenticular lithic units of diverse origin, which currently are undergoing some degree of accumulation, and thus are so young that they ordinarily do not exhibit a zonal soil profile.

Because individual exposures of the Martinsville Formation are generally short lived, no specific cut has been designated as a type section. Readily accessible exposures are abundant along White River and White Lick Creek between Martinsville and Mooresville (fig. 1), where bank scour is active; therefore this region is here designated the type area of the Martinsville Formation (pl. IA; Appendix A, section 7).

The Martinsville Formation includes sediments that are sufficiently diverse in character so that the formation can be treated most conveniently as two facies. One facies consists dominantly of elastic sediments, silt, sand, and gravel, which are common to nearly all flood-plain deposition, and is here referred to as the alluvial facies (pl. 1A). The other facies consists mainly of sediments that have been laid down in quiet water and that are rich in organic matter, particularly peat, gyttja, and marl; this facies is referred to as the paludal facies (pl. 1B).

The alluvial facies of the Martinsville Formation is widely distributed on the flood plains of valleys throughout the State of Indiana. The alluvial facies, which is dominantly silt and sand, but which contains lenses of gravel and organic muds, may range in thickness from a veneer perhaps 25 to 50 centimeters (1 to 2 feet) to 10 meters (30 feet) or more along large rivers. The base of this facies lies on an erosional unconformity.

The paludal facies of the Martinsville Formation is most abundant in the northern part of Indiana, where calcareous marl, gyttja, and peat, commonly mixed with varying amounts of sand, silt, and clay, have accumulated in depressions on the surface of the uppermost glacial deposits. The basal contact may be either sharp or gradational, but rarely is it disconformable. Such paludal sediments are also found intimately related to elastic deposits of the Martinsville Formation in sloughs and ox-bow lakes on the flood plains of large rivers and in some sinkhole ponds in the karst region of southern Indiana. Some of the lithic characteristics of

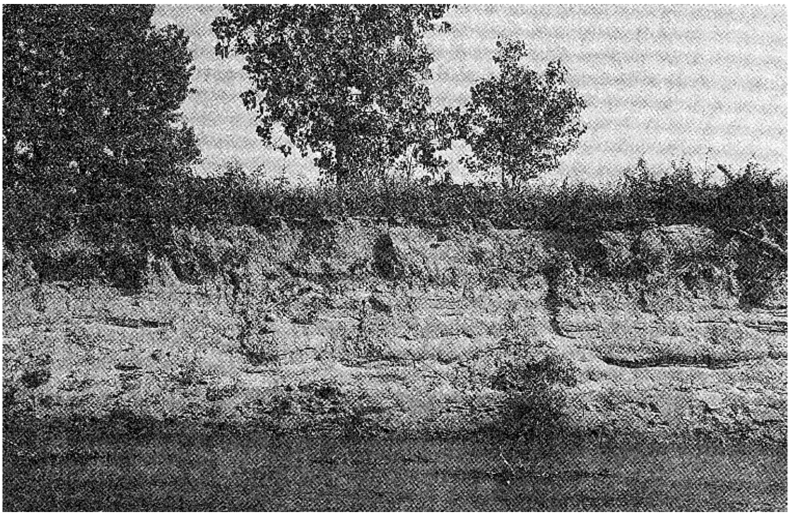
this facies of the formation are illustrated in Appendix A, sections 20, 21, and 22.

Fossils.-Fossils are rare in the alluvial facies of the Martinsville Formation. Wood and mollusk remains have been found, however. One of the more fossil-rich localities is exposed in the face of an abandoned gravel pit in the NE¼ SE¼ sec. 29, T. 12 N., R. 1 E., 1 mile northwest of Martinsville. Shells of fluviatile mollusks, along with remains of a few land snails, are bedded within the gravelly sand in this locality. A partial list of species includes *Anguispira kochi, Haplotrema concavum, Mesodon clausus, Mesodon elevatus,* and *Succinea ovalis,* all land snails now living in the same region.

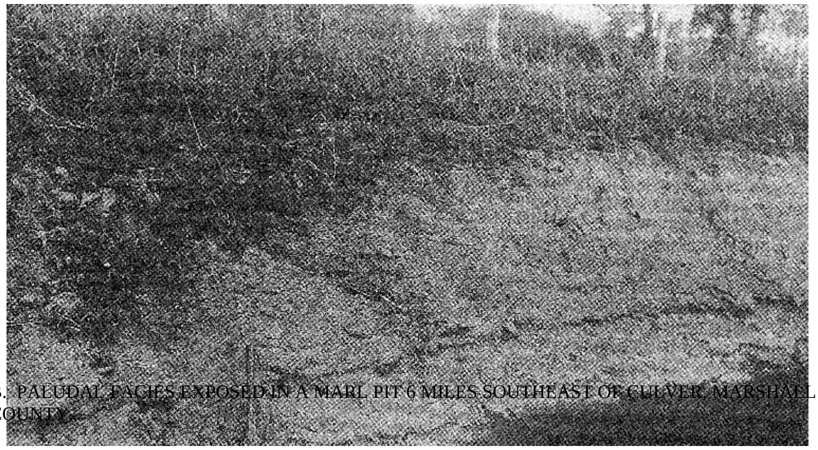
Most of the deposits of the paludal facies of the Martinsville Formation are highly fossiliferous and contain mollusks (pl. 1B), ostracodes, spores, pollen, wood fragments, and, less commonly, the remains of vertebrates. The fossil remains of many of the large, extinct Pleistocene vertebrates that have been found in Indiana (Hay, 1912, p. 549; Melhorn, 1960, p. 189-190; Wayne, 1960, p. 182) have been recovered from this facies of the Martinsville Formation. Osborn's (1936-42, p. 1093-1095) type specimen of *Parelephas jeff ersonii* was taken from peat in this stratigraphic unit in Grant County. *Mastodon americanus* remains are abundantly preserved in the paludal facies of the Martinsville Formation in Indiana, but other vertebrates, particularly *Castoroides ohioensis,* have also been found.

At least two molluscan zones can be recognized in cores of marl from the Martinsville Formation. The lower is in the *Succinea gelida* Range Zone and contains a faunal association characterized by *Gyraulus circumstriatus, Valvata tricarinata, Valvata sincera, Lymnaea dalli,* and *Succinea gelida.* The upper is the *Succinea vermeta* Range Zone and contains a much larger fauna that includes *Lymnaea palustris, Lymnaea stagnalis, Helisoma anceps, Gyraulus parvus, Lymnaea parva,* and species of *Goniobasis, Pleurocera, Campeloma, Amnicola,* and *Physa.* Most of the present aquatic mollusk fauna of Indiana (see Goodrich and van der Schalie, 1944) is likely to be found in the marl facies of the Martinsville Formation.

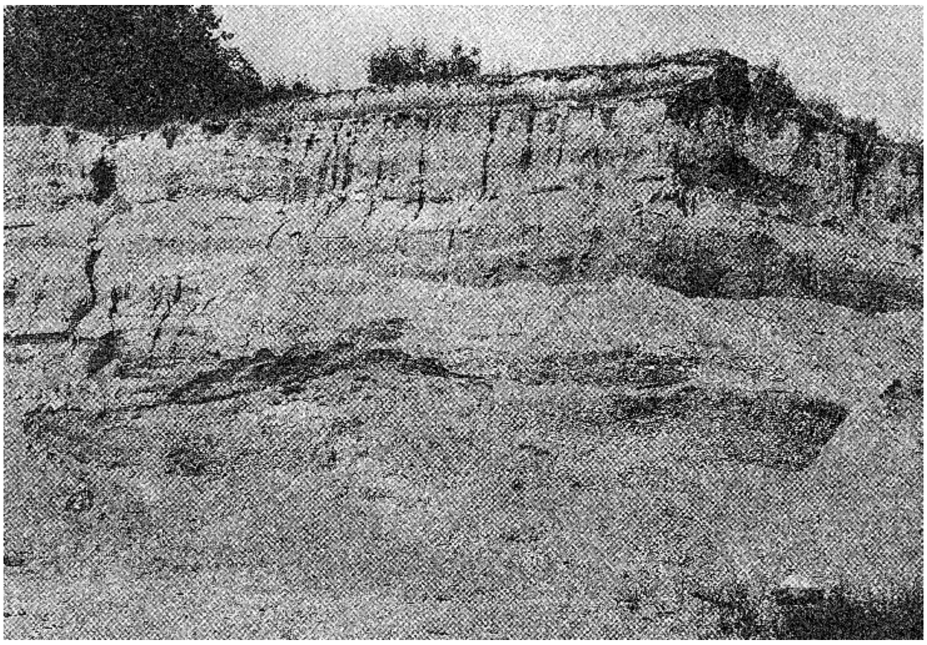
Peat in the Martinsville Formation generally contains abundant pollen as well as other kinds of plant remains, but mollusks are rare. Pollen diagrams prepared from the study of cores or a vertical series of samples show two major zones and several minor zones that may be used to work out details of forest history (Englehardt,



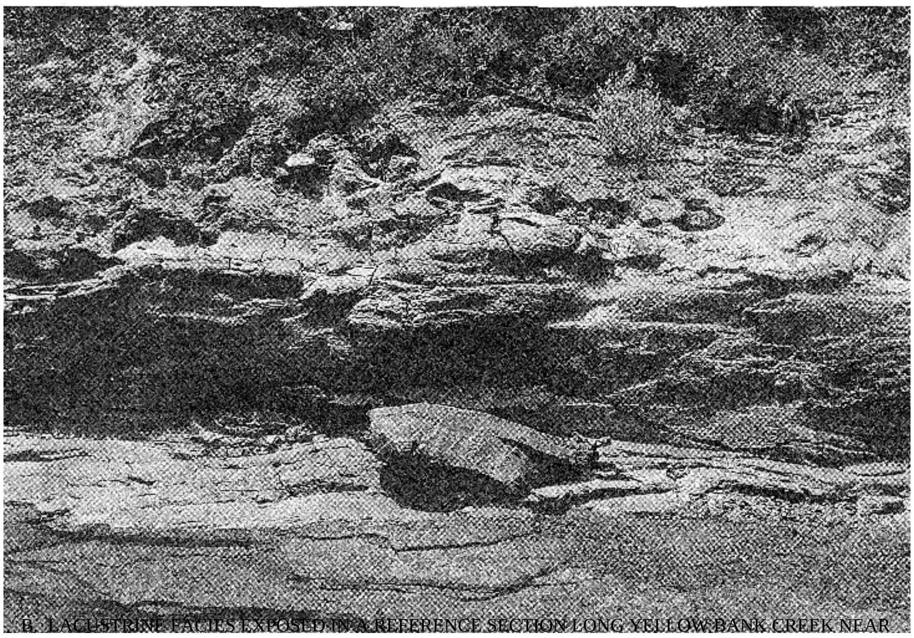
A. ALLUVIAL FACIES EXPOSED ALONG WHITE LICK CREEK 1 MILE SOUTH OF



B. PALUDAL FACIES EXPOSED IN A MARL PIT 6 MILES SOUTHEAST OF CULVER, MARSHALL COUNTY.



A. OUTWASH FACIES EXPOSED IN A GRAVEL PIT NEAR HOLLAND, WABASH COUNTY.



B. LACUSTRINE FACIES EXPOSED IN A REFERENCE SECTION LONG YELLOW BANK CREEK NEAR BROOKVILLE, FRANKLIN COUNTY.

ATHERTON FORMATION

1960). Typically, a complete profile contains a lower zone characterized by abundant Picea and Abies pollen overlain by a zone in which deciduous pollens predominate. The transition between these two major zones generally has a relatively high proportion of Pinus pollen.

Age *and correlation*.--Most of the sediments of the alluvial facies of the Martinsville Formation in Indiana are not more than a few thousand years old, and thus they are entirely postglacial, or Recent, in age. According to currently accepted interpretations (Cooper, 1958, p. 943; Broecker, 1957, p. 1703), the time boundary between the Wisconsin and Recent Ages is placed 10,500 to 11,000 years before the present (B.P.). It corresponds to the time in radiocarbon chronology of rapid worldwide increase in mean annual temperature, rise of sea level, and melting of continental glaciers. Radiocarbon dates from the few wood samples that have been dated indicate deposition within the past 5,000 to 7,000 years (Appendix B, dates W-59, W-666, and W-832). Radiocarbon dates from the paludal facies sediments (Appendix B, dates W-61, W-64, W-65, and W-325) show that nearly all quiet-water sediments have been deposited during the past 13,000 years. Nonglacial sediments began to accumulate as soon as the last glacial ice had melted from each local watershed; therefore the Martinsville Formation is of different ages in different areas. In many places the lower part is late Wisconsin in age, and the upper part is Recent (fig. 2). The time of transition from the coniferous forest cover that existed in Indiana during the Wisconsin glaciation to the present deciduous forest cover probably took place between 5,000 and 7,000 years ago according to the single radiocarbon date available (Appendix B, date C-500).

ATHERTON FORMATION

Definition.-The name Atherton Formation is here proposed for a group of intertonguing and interrelated unconsolidated sediments that resulted from glacial action but that were deposited extraglacially. These sediments, gravel, sand, silt, and clay, all were derived primarily from glacial outwash and were sorted and deposited by meltwater currents or wind action or in the quieter water environment of glacial lakes. As most of these sediments are closely interrelated in their distribution and lithologic characters as well as in their origin (fig. 3), 1 have chosen to treat them together as a single unit of formation rank.

The village of Atherton (fig. 1), half a mile east of U. S. Highway 41 and about 10 miles north of Terre Haute, is centrally located

in an area in which many exposures are available and in which all variations of the formation can be examined; it is, therefore, designated as the type area of the Atherton Formation. Because the Atherton Formation includes laterally intertonguing sediments that represent four distinct environments of deposition, hence four distinct facies, one cannot pick a single exposure that is likely to display the entire formation; thus a type section has not been designated.

Because of the nature of their deposition, the several facies of the Atherton Formation both intergrade and intertongue with each other and intertongue with any or all of the till formations of the Indiana Pleistocene. Stratigraphic names are already on record for some tongues of the loess facies of the formation that show such relationships, but there is no such nomenclature for the other facies of the formation. Selective use of the concept of arbitrary cutoff (Wheeler and Mallory, 1956, figs. 4-6) has been made here to avoid undue repetition of formational names wherever intertonguing of the Atherton Formation with other units is extensive.

Outwash facies.-The outwash facies of the Atherton Formation (pl. 2A) consists of stratified coarse-grained sediments (gravel and sand) which were deposited in sheets and as valley fill by glacial meltwater currents. It is distributed throughout the State of Indiana (fig. 5), but in the southern third of the State this facies of the formation is almost wholly restricted to the valley fill sediments of rivers that carried glacial meltwater. In the type area near Atherton, good exposures of the outwash facies can be examined along the banks of the dry bed of Spring Creek from U. S. Highway 41 southeastward for about 2 miles.

The outwash facies of the Atherton Formation intertongues and intergrades with other facies of the formation and intertongues with all till formations of the Indiana Pleistocene. It is disconformably overlain by the Martinsville Formation throughout most of the State. Tongues of the outwash facies are overlain in central Indiana by both the Lagro Formation and parts of the Trafalgar Formation. The outwash facies also intertongues extensively with the Jessup Formation (Appendix A, , section 13). It overlies disconf ormably all the till formations and virtually all the Paleozoic formations of Indiana.

Fossils are rarely found in the outwash facies of the Atherton Formation. From time to time, however, teeth or bones of mammoths and mastodons have been found by gravel pit operators.

Dune facies.--The dune facies of the Atherton Formation consists of sand that has been eroded and redeposited by wind action. Because of the sorting action of the depositing agent, a very high percentage of most dune sands, commonly 80 to 90 perecent, is medium to fine (0.42 to 0.175 millimeter) in size. (See Bieber and Smith, 1952, p. 15-18.) Individual grains normally show a higher degree of sphericity than do sands deposited by aqueous currents. Such windblown sand intertongues with water-laid gravels, sands, and silts of the Atherton Formation in many places; thus the dunal sand bears a true facies relationship to the other sediments of the formation with which it is associated.

Dune facies of the Atherton Formation can be recognized readily in the type area, where it forms a significant physiographic feature on both the terraces and the adjacent upland east of Atherton. Road cuts provide exposures of the sand of this facies.

In mapping the Atherton Formation, one ordinarily can distinguish the dune facies wherever it is a practical map unit. Where one cannot distinguish it either because the scale of the map makes it impossible or because the unit is so thin and discontinuous that boundaries cannot be readily established, a more practical solution may be to include it with one or more, of the other facies. It is found extensively along the valleys of the Wabash and White Rivers, and broad areas (fig. 5) of northern Indiana, where the outwash facies and lacustrine facies make up much of the surface, are extensively covered with sand of the dune facies.

Although other facies of the Atherton Formation include sediments that are older than Wisconsin in age, the dune facies as presently recognized does -not. Undoubtedly there are buried dunes at many places in the State, but only rarely are they recognizable. Petrographic studies ordinarily are necessary in order to suggest a dunal origin of buried sand bodies. Dune facies sands generally contain no fossils.

Loess facies.--Massive, locally fossiliferous, and brownish-yellow silt as much as 20 meters thick constitutes the loess facies of the Atherton Formation. The maximum thickness of the facies is limited in Indiana to a fairly narrow belt along the east side of the Wabash and White River valleys and along the Ohio Valley, and exposures of the facies are abundant in those areas (Appendix A, sections 1 and 6). This facies thins abruptly to less than a meter in thickness over most of the rest of southern Indiana. (See Thorp and Smith, 1952.) The silt of the loess facies drapes unconformably over many other geologic units of Paleozoic, Tertiary, and Pleisto-

cene age. It intertongues and intergrades with lenses of the dune facies to such an extent in some places along the Wabash Valley that the two are difficult to separate. Thin but recognizable tongues of the loess facies are interbedded with the Jessup and Trafalgar Formations, but south of the maximum extent of these two units, only the Martinsville Formation overlies the loess facies of the Atherton Formation.

The loess facies of the Atherton Formation includes at least three distinct stratigraphic units that have been differentiated on the basis of composition, color, superposition, and soil profile or paleosol (key-bed equivalent). Names for most of these stratigraphic units have been in common usage among glacial geologists for many years; they are here proposed as formal members and tongues of the Atherton Formation in Indiana (loess facies).

The uppermost member in the loess facies has long been known as the Peoria (Peorian) Loess, originally named by Leverett (1898, p. 185-188). Usage and meaning of the name have changed since its original definition (see Leighton, 1958a, p. 294-297), however, and the term is currently used in Indiana in the manner in which it was used by Leighton and Willman (1950, p. 617-619). The Peoria Loess Member, here so designated and regarded as part of the Atherton Formation (loess facies), is commonly fossiliferous and calcareous along the Wabash and Ohio Valleys, where its thickness exceeds 2 meters. North of the Wisconsin glacial boundary, the Peoria Loess Member splits into two tongues; the lower one seems to be equivalent to the Morton Loess of Frye and Willman (1960, p. 7). The name Morton Loess Tongue is proposed for this unit in Indiana as well as in Illinois. The upper tongue may be the Indiana equivalent of the Richland Loess in Illinois (Frye and Willman, 1960, p. 7), but I have not adopted the term in this report.

Beneath the Peoria Loess Member, the loess of the Atherton Formation includes three older stratigraphic units that commonly are covered by slopewash and that may be absent from some exposures; thus they seldom have been observed. Directly beneath the light yellowish-brown silt of the Peoria loess is a grayish-brown silt that rarely is calcareous or fossiliferous and that commonly is capped with a thin layer of dark-gray silt containing a noticeable amount of humus. This unit has been called the Farmdale Silt in Illinois (Frye and Willman, 1960, p. 7) and is here designated the Farmdale Loess Member of the Atherton Formation in Indiana (Appendix A, section 1).

The Farmdale Loess Member is underlain by a clayey orange-brown silt that commonly is less than 2 to 3 meters thick, and thus exposures of calcareous and (or) fossiliferous silt are rarely found. The key-bed soil profile extends through the complete thickness of most exposures of the unit. The name Loveland Loess has been applied to this unit by glacial geologists for several years (Leighton and Willman, 1950, p. 601-602). The original type section in Iowa is no longer available, but a new section adjacent to the old one was described recently for reference use (Daniels and Handy, 1959, table 1). This unit has been recognized in exposures in central and southern Indiana, particularly along the bluffs of the Wabash and Ohio Valleys, and is here designated the Loveland Loess Member of the Atherton Formation. Although this unit is generally nonfossiliferous, a few fossiliferous exposures are known where it intertongues with the Jessup Formation.

The lowermost member in the loess facies of the Atherton Formation, the Cagle Loess Member (Wayne, 1958a, p. 10), is rarely identifiable except where it is found as a tongue at the base of the Jessup Formation (Appendix A, section 6). In this position it is separated from the other members (and tongues) in the loess facies of the formation. The only good exposure of the Cagle loess is the type section, in which it is a dark grayish-brown calcareous fossiliferous silt. There it overlies rocks of Pennsylvanian age and is overlain by the Jessup Formation. It is undoubtedly present in many other parts of the State but is thin and generally highly weathered, and thus it is difficult to recognize (Appendix A, section 1).

Lacustrine facies.--Much of the sand and gravel (outwash facies) of the Atherton Formation was deposited in valleys that carried meltwater flowing from continental glaciers, where it accumulated and blocked the mouths of tributary valleys. Fine-grained sediments that were laid down in the quiet water of the lakes that were formed constitute the lacustrine facies of the Atherton Formation (pl. 2B). These sediments commonly intertongue and (or) intergrade with the coarser materials of the outwash facies.

Although many of the smaller streams tributary to the Wabash River were ponded and contain sediments of the lacustrine facies of the Atherton Formation, few good exposures of this facies have been recorded near Atherton. Spring Creek east of Atherton does have some exposures of the lake silt facies in its valley in see. 6, T. 13 N., R. 8 W.

Good reference sections are necessary to clarify this facies of the Atherton Formation. An excellent section is exposed at the spillway of the water supply reservoir for Bloomington, along Bean Blossom Creek (Wayne, 1958a, p. 12). A similar exposure of fossiliferous laminated lake silt facies is swept clean regularly by Yellow Bank Creek about 3 miles northwest of Brookville in Franklin County (Appendix A, section 12). Additional exposures near the mouth of the valley make it apparent that the lake silt facies along Yellow Bank Creek grades by intertonguing into the outwash facies of the Atherton Formation (fig. 3) along Whitewater River.

In his discussion of lake plains in southwestern Indiana, Fidlar (1948, p. 47-69) described the types of materials that he found in outcrops and in borings in these deposits. Thornbury (1950) reviewed these and similar deposits in all of southern Indiana and the deposits of some large ice-marginal lakes in central Indiana. Cuts in the areas designated in these reports undoubtedly will expose sediments referable to the lacustrine facies of the formation.

Fossils.-Fossils have been collected from most of the sediments of the Atherton Formation, but those in the outwash facies have been limited to occasional finds of bones and teeth of mammoths and mastodons. Invertebrate fossils have been rarely found in the coarse clastic sediments. In contrast, silts of the lacustrine and loess facies of the formation have yielded large numbers of invertebrate fossils. Some of the snails described by Thomas Say in the early part of the 19th century were collected from silts of the loess facies near New Harmony.

The lacustrine facies probably is more variably fossiliferous than any other part of the Atherton Formation. Although the bulk of sediments of this facies probably is devoid of fossils, fossils are abundant locally in the silts and clays. Mosses, wood fragments, ostracodes, and fresh-water mollusks have been collected from many exposures of these fine-grained sediments, but relatively few of them have been studied. Most of the remains of extinct Pleistocene mammals that have been found in central and southern Indiana have been recovered from lacustrine silts of the Atherton Formation. Mollusks recovered from the loess facies of the Atherton Formation probably have been studied more than the fossils from any other facies of the formation (Wayne, 1959b; Leonard and Frye, 1960). The Peoria Loess Member of the Atherton Formation is very fossiliferous locally along the Wabash and Ohio Valleys. Fossils have been recovered from the lower members of

the loess facies only where these members extend as tongues into the Jessup and Trafalgar Formations.

The upper part of the Peoria Loess Member contains an assemblage of land snails characterized by small species that have more northerly affinities as compared to the modern fauna of eastern North America. Typical and fairly common species in this assemblage are *Succinea gelida, Hendersonia occulta, Gastrocopta armifera, Columella alticola, Pupilla muscorum, Vertigo alpestris oughtoni, Vertigo modesta, Stenotrema leai,* and *Deroceras laeve.* Most of these species, along with a few others, are also typical of the several thin tongues of Peoria loess that are found interbedded with members of the Trafalgar Formation (q. v.).

A different assemblage has been collected from the lower part of the Peoria Loess Member; it is characterized by many more large woodland snails, such as the polygyrids. This assemblage, along the Ohio River, includes *Anguispira kochi, Anguispira alternata, Haplotrema concavum, Triodopsis multilineata, Succinea ovalis Hendersonia occulta,* and many smaller species commonly found in deciduous woodlands. It lacks, however, such species as *Columella alticola* and *Vertigo modesta,* which are fairly common in the upper part of the member.

Northward along the Wabash Valley, the lower assemblage undergoes gradual changes that reflect the climatic gradient during the Wisconsin glaciation. It loses many large species that characterize it at the south edge of the State, and the upper and lower assemblages become more similar. *Anguispira alternata, Succinea ovalis,* and *Stenotrema fraternum* seem to be limited to the lower assemblage, however, at least as far north as the point where the Peoria Loess Member splits into tongues that interbed with the Trafalgar Formation.

No fossils have been recovered from the Farmdale, Loveland, or Cagle Loess Members of the Atherton Formation except at places where these units are buried as individual tongues within the Trafalgar and Jessup Formations. Farmdale loess in exposures along the Wabash Valley generally contains no fossils, and it has not been positively identified elsewhere in Indiana. Fossils likewise are sparse in exposures of a tongue of Loveland loess, but they have been recovered from the upper part of a few exposures (Wayne 1959b, p. 13-14). In most of these exposures the snail specimens are found to be crushed, but the flat shell of *Deroceras laeve* and identifiable specimens of *Succinea gelida* var., *Succinea* cf. *S. ovalis,* and *Hendersonia occulta* are fairly common.

Fossils have been collected from the Cagle loess only in the type section (Wayne, 1958a, p. 10). The most abundant species in the collection is *Strobilops labyrinthica;* others noted include *Hendersonia, occulta, Succinea gelida* var., *Carychium exile canadense, Discus cronkhitei,* and *Stenotrema leai.*

Age and correlation.--The Atherton Formation is a unit that was deposited while glacial ice nearby provided a source for the sediments. Key beds, in particular paleosols and accumulations of organic debris, can be traced in the lacustrine and loessal facies but rarely can be found in the coarser outwash gravel facies of the formation.

As glaciation was the mechanism that induced deposition of virtually all sediments included in the Atherton Formation, the formation can be correlated with the glacial episodes of the Pleistocene Epoch. Interglacial episodes are represented locally in the fine-grained facies of the formation by lack of deposition or by paleosols, thin intercalated beds or lenses of peat, fossiliferous silts or sands, and shingled gravels.

The lower part of the formation thus undoubtedly includes sediments of Kansan age; the upper part is Illinoian in age in some areas, but it is Wisconsin in age in most. Rarely are exposures in any single area adequate to permit the examination of sediments correlatable with all of these glacial stages, but the Pleistocene history of a few of the valleys in which the Atherton Formation has been studied has been outlined well enough (Wayne, 1958a) to infer that sediments of all three glaciations undoubtedly are present.

PROSPECT FORMATION

Definition, description, and distribution.--Scattered deposits of brown to orange-brown silts, sands, and gravels found in Southern Indiana capping eroded terraces 20 to 50 feet above the flood plains of present streams are here named the Prospect Formation. These sediments are alluvial in origin, and their general lithology is similar to that of the alluvial facies of the Martinsville Formation, but they are more deeply weathered and generally exhibit a zonal soil profile.

The type section of the Prospect Formation is a road-cut exposure along U. S. Highway 150 at the west edge of the village of Prospect, about 2 miles north of French Lick, in Orange County (fig. 5, location 2; Appendix A, section 2). The fluviatile sediments in the type section of the Prospect Formation underlie an

abandoned and entrenched strath of Lost River and now occupy a position about 16 meters (50 feet) higher than the flood plain of the river.

Sediments identifiable as the Prospect Formation have been observed throughout most of southern Indiana, particularly in the unglaciated part of the State, but have not been recognized north of the Wisconsin glacial boundary. As the formation is composed of unconsolidated sediments and stands fairly high above present stream levels, natural exposures are scarce. The formation occupies a distinctive geomorphic position, however, and thus its presence may be suspected wherever a high-level strath is observed in the unglaciated part of Indiana. Segments of the Prospect Formation are particularly of note in the abandoned segments of karsted valleys.

The thickness of the formation is not known, but because of the manner in which it was deposited it likely is not thicker than 12 or 14 meters (35 or 40 feet). The formation probably rests unconformably directly on bedrock at the type section, but conceivably it could overlie other unconsolidated sediments in some places.

The formation was mapped in the Huron area of south-central Indiana (Gray, Jenkins, and Weidman, 1960, p. 20-21), and some of the larger areas underlain by the Prospect Formation are shown on the geologic map of the Indianapolis 1"X 2" Quadrangle (Wier and Gray,1961).

To date no f ossils have been recovered from sediments in Indiana that are positively identifiable with the Prospect Formation.

Age and correlation.--Because the formation is rarely well exposed, the relationship of the Prospect to other unconsolidated deposits is not completely clear. In the type section the formation is capped by a thin layer of silt similar to the loessal silt that caps bedrock soil profiles and Pleistocene deposits of pre-Wisconsin age elsewhere in Indiana. The base of the Prospect Formation rarely is exposed, but in places where it has been examined, it lies unconformably on bedrock. As stratigraphic data do not permit an age determination any closer than post-Paleozoic and pre-Wisconsin, the age of the formation will have to be determined more closely by placing the time of deposition into the proper part of the geomorphic history of the region.

The Prospect Formation is a fluviatile sediment preserved on strath terraces above modern flood-plain levels; therefore deposition must have taken place at a time when base level was higher than it is at present. Three times since the Pliocene Epoch when

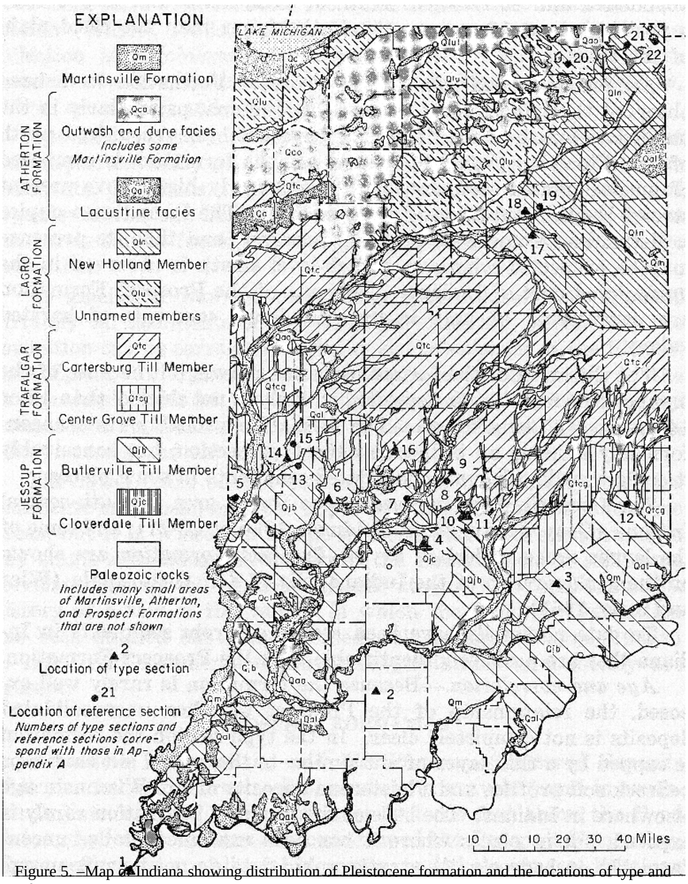


Figure 5. –Map of Indiana showing distribution of Pleistocene formation and the locations of type and reference sections.

this was possible are: (1) very early Pleistocence, while rivers were trenching their valleys beneath the upland level on which the Lafayette Gravel of Pliocene ? Age had been deposited but before they reached the maximum depth of valley cutting, recorded by bedrock valley floors. (2) During some, perhaps all, of the pre-Wisconsin glaciations, when local base level was higher than it is at present,

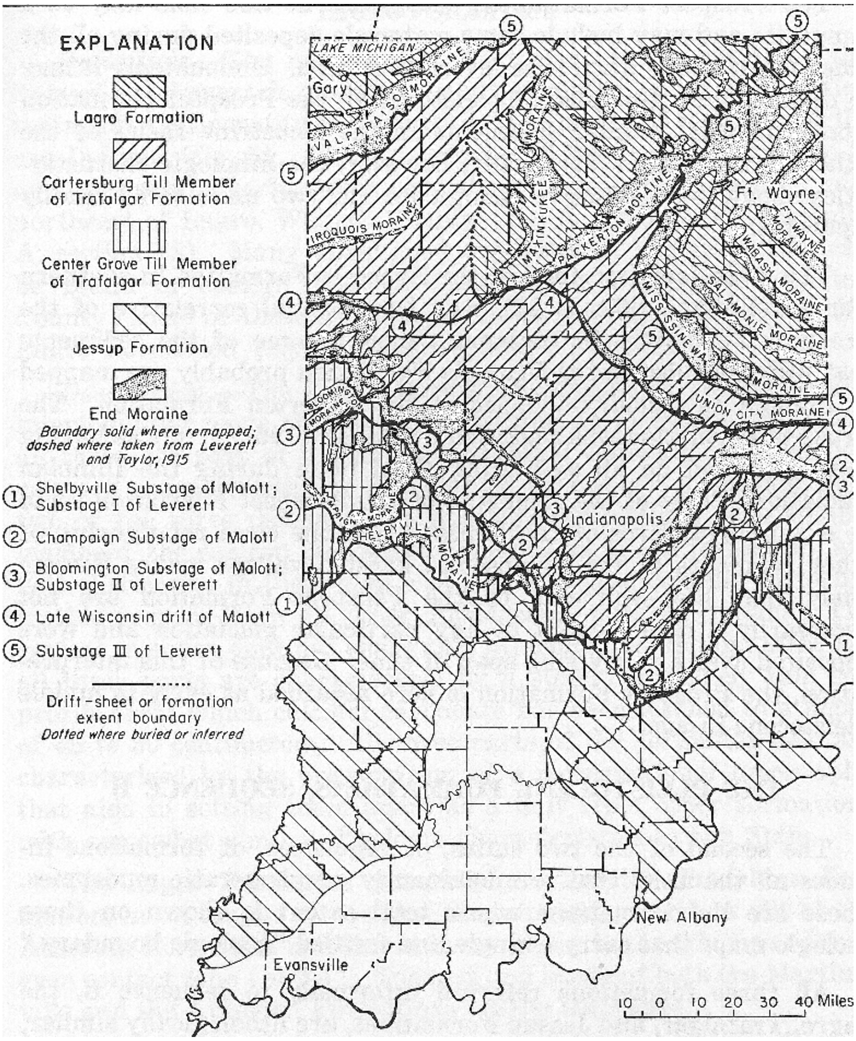


Figure 6.–Map of Indiana showing moraines of Wisconsin age and relationships between Malott's (1922, pl. 3) and Leverett's (1929) substage boundaries and the extent of formations proposed in this report. The Atherton and Martinsville Formations are not shown on this map. Moraine names after Leverette and Taylor (1915).

recorded by gravels of the Atherton Formation deposited in the Wabash, White, and other river valleys. (3) Sangamon time, during part of which time base level, was as much as 10 meters higher than it is at present, as shown by sediments in some of the valleys of southern Indiana (Wayne, 1959a, p. 12).

The Prospect Formation as recognized at this time may be a composite and may include some materials deposited during all the times listed above when base levels were high. Undoubtedly it may be difficult in a few places to distinguish the Prospect Formation from somewhat similar sediments in the lacustrine facies of the Atherton Formation. Generally, however, the lithologic characteristics should be distinctive enough for the two units to be readily separable.

The materials described as the Brussels Formation in southern Illinois (Rubey, 1952, p. 82) may be a partial correlative of the Prospect Formation in Indiana, although some of the sediments that were included in the Brussels Formation probably are mapped in Indiana as lacustrine facies of the Atherton Formation. The Brussels Formation was regarded by Rubey (1952, p. 86) as having been deposited on an aggrading flood plain during the Illinoian glaciation. Some of the remnants of the Prospect Formation could be exact correlatives of the Brussels, but the close relationship of other remnants of the Prospect to karsted valleys makes it seem likely that the sediments of the Prospect Formation are not necessarily a direct result of any particular glaciation and were deposited over a fairly long span of time. Because of this interpretation, the Prospect Formation is here regarded as early to middle Pleistocene in age.

THE PLEISTOCENE FORMATIONS, SEQUENCE B

The second of the two suites, or sequences, of formations includes all the units that are dominantly conglomeratic mudstones. These are the formations whose total extent is shown on those geologic maps that carry a single line entitled "geologic boundary."

All three formations referred informally to sequence B, the Lagro, Trafalgar, and Jessup Formations, are lithologically similar, and if gross lithology alone were to be considered, they might well have been treated as a single unit of formation rank. Some demonstrable variability in lithology of tills does exist, however, and a vertical sequence of mappable units can be established throughout the State by the use of these differences and by the recognition of distinctive marker beds.

As explained on page 28, I have chosen to describe these units, which are of formation and member rank, from youngest to oldest in this report.

LAGRO FORMATION

Definition-.-The name Lagro Formation is proposed for the beds of conglomeratic mudstones and associated lenses of stratified sediments that constitute the surficial sediments of much of northern Indiana (fig. 5). The type section of the Lagro Formation is one of several clearly swept cuts along Lagro Creek about 1 mile northeast of Lagro, Wabash County (fig. 5, location 18; Appendix A, section 18). Many other good exposures of the formation can be found in eastern Wabash County and western Huntington County; some of these are designated as reference sections of the Lagro, Formation (Appendix A, sections 17 and 19).

Description.-The Lagro Formation consists of three laterally intertonguing parts that are here treated as members. Although all three are part of a single depositional unit and have enough common characteristics to be regarded as a single formation, only two of the three members are lithologically similar. The similar members, the eastern and westernmost parts of the formation, are both distinctive in their high clay and low sand content, differing in this respect from all other Pleistocene units in Indiana. The central member does not share this lithologic distinction, although all three parts are characterized by a similar relatively thin soil profile from which calcium carbonate has been leached to a depth of 45 to 80 centimeters. All three parts of the formation also are characterized by the preservation of a constructional topography that aids in setting them apart as a unit from other formations with somewhat similar lithologic characteristics in the State.

The Lagro Formation generally overlies the Trafalgar Formation, but a tongue of nonfossiliferous sand, gravel, or silt of the Atherton Formation is found at many places in the otherwise fairly even contact zone (pl. 3A). Tongues and lenses of both the Martinsville and the Atherton Formations overlie the Lagro.

Almost no fossils have been recovered from the Lagro Formation itself, but fossil wood, pollen, mollusk shells, and mastodon remains have been found in the paludal facies of the Martinsville Formation and in the lacustrine facies of the Atherton Formation in places where these water-laid sediments overlie the Lagro tills.

Distribution.-- The three members of the Lagro Formation are laterally intertonguing, and thus the extent of the entire formation is most readily reviewed in three parts. As all parts of the formation are recognizable by some of the soil characteristics and by the distinctive constructional topography associated with the glacially

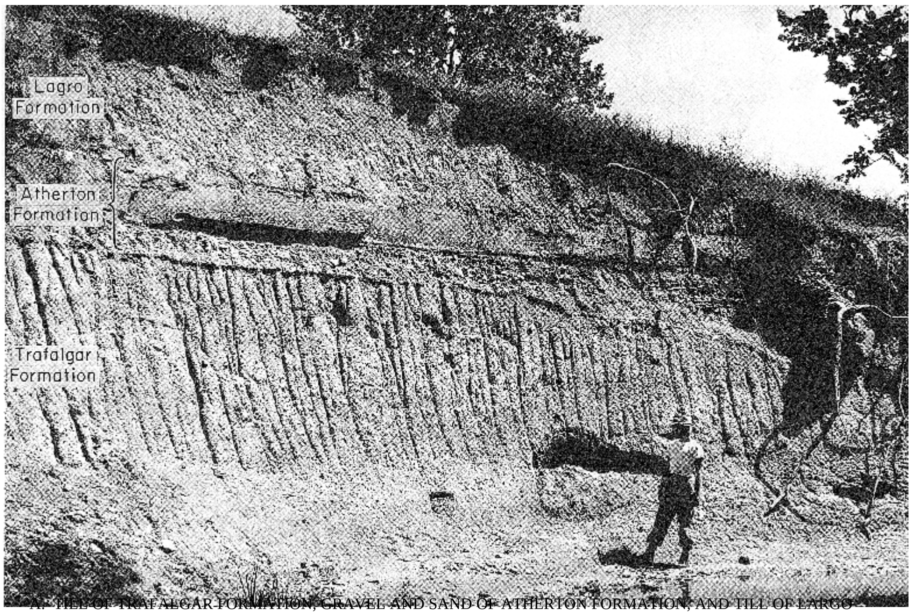
deposited mudstones, these features have been used in part to delineate the extent of the sediments with which they are associated.

The easternmost of the three parts of the Lagro Formation is here designated the New Holland Till Member. The type section is exposed along the bank of Rush Creek half a mile south of New Holland in Wabash County (fig. 5, location 17; Appendix A, section 17). The New Holland Till Member consists dominantly of clay-rich mudstone that is only slightly pebbly (pl. 3A). It is normally calcareous below a depth of about 75 centimeters and commonly exhibits a blocky structure in exposures. The mudstone of the New Holland Till Member is restricted to an area in Indiana east of the distal margin of the Mississinewa Moraine (figs. 5 and 6). The unit varies in thickness, which depends on whether the unit is measured within or between end moraines, but generally it seems to be less than 20 meters thick.

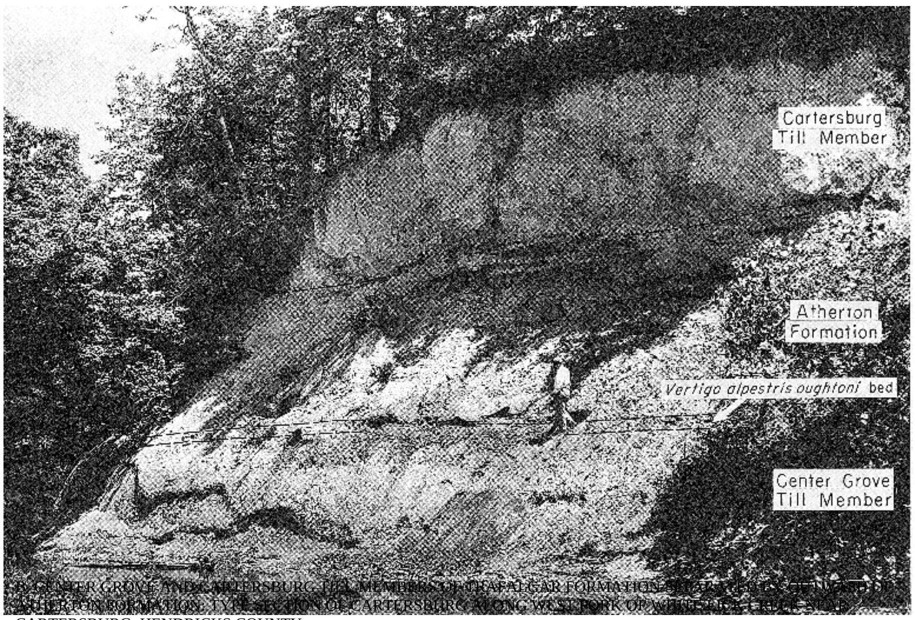
Names are not proposed in this report for either of the other two members of the Lagro Formation. As presently understood, however, the central member (fig. 5) is bounded on the east by the New Holland Till Member, with which it intertongues; the Packerton and Maxinkuckee Moraines (fig. 6) form its boundaries on the south and west. The western most member of the three, a clay-rich mudstone like the New Holland Till Member, is bounded on the south by the south edge of the Valparaiso Moraine (fig. 6), and it is overlapped on the north by lake and dune facies sediments of the Atherton Formation.

Age and correlation.--Deposition of the Lagro Formation took place during the later phases of the Wisconsin glaciation. The eastern and western members of the formation are part of Leverett's (1929, p. 18) "Middle Wisconsin drift," later renamed "Cary drift" by Leighton (1933). Wayne and Thornbury (1951, p. 12-19) referred the mudstones of the New Holland Till Member to the Cary Substage but placed the sediments of the Packerton Moraine area in the Tazewell Substage (table 1). 1 presently consider that the entire Lagro Formation is Cary in age, although it may not be completely equivalent to sediments of that age as defined in Illinois. (See Zumberge, 1960.)

As no plant remains have been found in the sediments of the Lagro Formation, radiocarbon dates are not available to indicate the maximum age of the unit. Deposition had been completed in northeastern Indiana, however, by 13,000 to 14,000 years ago (Appendix B, date W-198). Pollen profiles (Potzger and Wilson, 1941; Guennel, 1950; Moss, 1940; Oliver, 1951) indicate that deposition



A. TILL OF TRAFALGAR FORMATION, GRAVEL AND SAND OF ATHERTON FORMATION, AND TILL OF LARGO FORMATION 3 MILES NORTH OF ANDREWS, HUNTINGTON COUNTY.



B. CENTER GROVE AND CARTERSBURG TILL MEMBERS OF TRAFALGAR FORMATION SEPARATED BY OUTWASH OF ATHERTON FORMATION: TYPE SECTION OF CARTERSBURG ALONG WEST FORK OF WHITE LICK CREEK NEAR CARTERSBURG, HENDRICKS COUNTY.

TRAFALGAR ATHERTON, AND LAGRO FORMATIONS

A. BUTLERVILLE TILL MEMBER OF JESSUP FORMATION SHOWING TWO TILLS WITH INTERCALATED GRAVEL LENS AND FOSSILIFEROUS SILT BED, 4 MILES SOUTH OF MECCA, PARKE COUNTY.

B. JESSUP FORMATION AT CAGLE'S MILL SPILLWAY. TYPE SECTION OF CLOVERDALE TILL MEMBER AND CAGLE LOESS MEMBER, PUTNAM COUNTY.

JESSUP FORMATION

was taking place during the B-1 period of palynologic nomenclature, when the dominant vegetation of central Indiana was a spruce-pine forest.

TRAFALGAR FORMATION

Definition.--The name Trafalgar Formation is here proposed for a unit that is composed mostly of conglomeratic mudstones and that directly underlies the surface in much of central Indiana. The formation as defined here consists of two members and includes all mudstones and associated thin lenses of gravel, sand, silt, and clay from the base of the Lagro Formation down to the top of a distinctive paleosol that caps the underlying Jessup Formation.

The Trafalgar Formation is named from the village of Trafalgar in Johnson County. The type section (fig. 5, location 10; Appendix A, section 10) is exposed along Buckhart Creek about 2 miles east of Trafalgar and 150 meters (500 feet) north of Indiana State Highway 252. A similar sequence of deposits is exposed in each of the cutbanks of Buckhart Creek from this point upstream for about 450 meters (1,500 feet) and along many of the other valleys in this area. (See reference section, Appendix A, section 11.)

The Trafalgar Formation is composed primarily of calcareous conglomeratic mudstone, a compact but uncemented sandy, silty matrix that contains fairly abundant pebbles and cobbles; scattered beds and lenses of silt,,sand, and gravel are included in the formation. Most of the mudstone was deposited by glacial ice and thus is till, but a minor amount of the sediment undoubtedly has been reworked through solifluction. Lithologic variation is not statistically significant (Harrison, 1959, p. 17), but some of the different beds of till in the formation display distinctive features in the field that permit their recognition within limited areas. Among these features that are notable in the Trafalgar Formation are minor differences in color, internal structure, inclusions from underlying sediments, stratigraphic position, and key fossiliferous beds.

The upper surface of the Trafalgar Formation is constructional and has been only slightly modified by erosion since the unit was deposited. Much of the area underlain by the unit is a relatively flat plain into which few streams have cut valleys; thus exposures are sparse except along major drainage lines. The soil profile on moderately well-drained locations shows a youthful profile that has been leached bf carbonates to depths ranging from 80 to 125 centimeters.

TabIe 1-Correlation chart showing terminology used in earlier reports

Formation in this report		Leverett and Taylor (1915) Alden (1918)	Malott (1922) Thornbury (1937)	Leverett (1929)
Martinsville Formation		"Postglacial"		
Atherton Formation	outwash facies	Wisconsin Stage Illinoian Stage: Sand and gravel in plains and channels	Wisconsin Stage Illinoian Stage	
	dune facies	dune sand		
	Ioess facies	loess	loess	
	lacustrine facies	lake clays	lake clays and silts	
Prospect Formation				
Large Formation	New Holland Till Member	Mississinewa Morainic System	Late Wisconsin (Malott) Middle Wisconsin (Thornbury)	Wisconsin drift Substage 3
	unnamed (central) member			Wisconsin drift Substage 2 (in part)
	unnamed (western) member	Kalamazoo (1915) and Valparaiso, (1918) Morainic System		Wisconsin drift Substage 3
Trafalgar Formation	Cartersburg Till Member	Bloomington Morainic System	Bloomington Morainic System	Wisconsin drift Substage 2 (in part)
		Champaign Morainic System	Champaign Morainic system	
	Center Grove Till Member	Shelbyville (or Wisconsin drift border) Morainic System	Shelbyville (or outer border) Morainic System	Wisconsin drift Substage 1
Jessup Formation	Butlerville Till Member	Illinoian and older stages	Illinoian drift	Illinoian drift
	Cloverdale Till Member			

for Pleistocene formations proposed in this report

Leighton (1933) Wayne and Thornbury (1951) Thornbury and Dearie (1956) Wier and Wayne (1953)	Wayne (1956)	Thornbury (1958)	Wayne (1958b) Geol. Soc. America (1959)
Recent Stage, Recent deposits	Recent Stage		
Wisconsin Stage, Taze-well and Cary: Mississinewa and Maumee Terraces dune sand loess lake beds	Undifferentiated glaciofluviatile sediments	Wisconsin (and older) outwash dunes and loess	upper Pleistocene undifferentiated: outwash dunes lake sediments
Cary Substage . . . . Tazewell Substage . . . . Cary Substage	Cary Substage: Mississinewa drift . . . . Saginaw lobe drift . . . . Valparaiso drift	Cary Substage	Wisconsin Stage
Tazewell Substage	"Champaign" drift (Tazewell Substage) . . . . "Shelbyville" drift (Tazewell or Iowan? Substage)	Tazewell Substage: Champaign till stadial . . . . Shelbyville till stadial	Wisconsin Stage
Illinoian Stage (Illinolian drift)	Illinoian Stage . . . . Kansan Stage	Illinoian stage . . . . Kansan Stage	Illinoian Stage . . . . Kansan Stage

The base of the Trafalgar Formation rests on an erosional unconformity that is marked by peaty and (or) fossilif erous silt and sand, part or all of a buried soil profile, or by buried alluvial sediments. Although only two members (named below) are present in central Indiana, there are some indications at Richmond (Gooding, oral communication, 1961), as well as at Wabash, that at least one additional till unit overlies the major unconformity at the base of the Trafalgar Formation.

Throughout central Indiana the Trafalgar Formation is overlain locally by tongues and lentils of the Martinsville and Atherton Formations. North of a line marked by the Mississinewa, Packerton, and Valparaiso Moraines (figs. 5 and 6), it is overlapped by the Lagro Formation and is exposed only along some of the deeper valleys (Appendix A, sections 17, 18, and 19). The formation includes three environmental facies that can be readily recognized and mapped partly because of their distinctive geomorphic expression. These facies consist of blanket till, which constitutes the main body of the formation, end-moraine till, and kame (mixed bouldery gravel and till) facies.

Cartersburg Till Member.--Many exposures have been observed in central Indiana in which the full thickness of the upper member of the Trafalgar Formation, here named the Cartersburg Till Member, can be examined. One of the earliest sections to be recognized and still one of the most complete ones known is along the east bank of White Lick Creek in Hendricks County about 2 miles northwest of Cartersburg. I have selected this cut (pl. 3B), which has been examined during two recent Pleistocene field conferences (Thornbury and Wayne, 1953 and 1957, where it was referred to as the "Clayton Section"), as the type section of the Cartersburg Till Member of the Trafalgar Formation (fig. 5, location 16; Appendix A, section 16).

The Cartersburg consists primarily of conglomeratic sandy mudstone, but the unit includes all sediments from the surficial soil downward to the top of a thin fossiliferous silt bed that caps the underlying member of the Trafalgar Formation.

Petrographically, the Cartersburg Till Member is difficult to distinguish from the underlying member of the formation. (See Harrison, 1959, p. 19.) The character of the soil profile permits identification of the Cartersburg, but in the absence of the fossilif erous silt at the base of the member that serves as a key bed, separation of the two members in the field is difficult.

Soils of the Miami soil catena have formed at the surface on the Cartersburg Till Member. Normally, Miami soils have been leached of carbonates to a depth of about 1 meter or a little less and exhibit a yellowish-brown clayey loam layer from about 25 centimeters to the base of the leached zone.

Center Grove Till Member.--The Center Grove Till Member (lower member) of the Trafalgar Formation is named from exposures in the northwestern part of Johnson County in the vicinity of Center Grove School. (See U. S. Geological Survey Bargersville Quadrangle.) The type section of the Center Grove Till Member is exposed along a tributary of Honey Creek (fig. 5, location 9; Appendix A, section 9) about 2 miles northeast of Center Grove School. Many other exposures of the member can be found along Honey Creek southeast of the school and in the vicinity of the type section for the Trafalgar Formation (Appendix A, reference sections 8 and 11).

The Center Grove Till Member of the Trafalgar Formation is capped generally by a thin layer (commonly 10 to 30 centimeters) of silt through which the modern soil profile extends where the Cartersburg Till Member is absent. This silt cap is a series of thin lenses of fossiliferous gray to brown silt that form a key bed for identification of the top of the member in places where it underlies the Cartersburg.

Because it lies directly on a paleosol in central Indiana, Center Grove till commonly contains larger amounts of wood fragments and bits of weathered material than do some of the other tills. Locally, at least, these inclusions provide a distinctive lithology for the member.

North of a line running roughly from Lafayette through Greenfield and Newcastle, the key bed that caps the Center Grove Till Member has not been found, and thus this member is not with certainty distinguishable from the overlying member. In some exposures, particularly along the Wabash Valley in north-central Indiana, a tongue or lens of the outwash facies of the Atherton Formation separates the two members of the Trafalgar Formation, but in places where this separating unit is absent, differentiation within the Trafalgar Formation is rarely possible on the basis of present knowledge.

Fossils. -- The tills of the Trafalgar Formation are only slightly fossiliferous; scattered fragments of wood are the organic remains most commonly found. The fossiliferous silt, that lies at the top of the Center Grove Till Member, however, commonly contains the remains of snails, leaves, mosses, and pollen as well as wood

fragments. Snails recovered from this bed are primarily species now living in central or northern Ontario and Manitoba (Oughton, 1.948; Wayne 1959a). Species typical of the key bed at the top of the Center Grove are *Vertigo alpestris oughtoni, Columella alticola, Vertigo modesta, and Succinea gelida,* and the bed is referred to here as the *Vertigo alpestris oughtoni* bed (figs. 2 and 7).

In contrast, the fauna recovered from silt beds at the base of the Trafalgar Formation (tongues of the Peoria loess) contains many specie& that are commonly found in the Great Lakes area now, such as *Stenotrema leai, Gastrocopta armifera, Cionella lubrica*, and, of particular note, *Hendersonia occulta*, all of which are rare to absent from the higher fossiliferous bed. The fossiliferous part of the silt is called the upper *Hendersonia occulta* bed.

Age and correlation.--The Trafalgar Formation is in part equivalent to Leverett's (1929) and Leverett and Taylor's (1915) "Early Wisconsin drift" and to Leighton's (1933) "Tazewell Substage." The formation is defined in this report, however, to include all glacially deposited mudstones (tills) and associated lenses of other sediments that lie above the unconformity and distinctive paleosol at the top of the Jessup Formation and beneath and beyond the overlapping Lagro Formation. Thus the Trafalgar Formation is more inclusive than the substage terms proposed by earlier authors to include these sediments (table 1). Although only two members are noted in this report, there may be additional as-yet-unrecognized units in the lower part of the formation. (See Dreimanis, 1958, p. 78-82; 1960, p.116.)

The Center Grove Till Member of the Trafalgar Formation undoubtedly is a correlative part of the sediments of the Tazewell Substage; the Cartersburg, however, may be younger than most of the rest of the Tazewell drift in Illinois. As the Tazewell and Cary Substages have been defined largely on the basis of morainal boundaries, a precise correlation of the upper member of the Trafalgar Formation in Indiana, is, at present, difficult to establish. Wayne and Thornbury (1951, p. 12) regarded all the sediments designated in this report as the Trafalgar Formation to be Tazewell in age; a recent interpretation by Zumberge (1960, p. 1179), however, suggested that some of the Cartersburg Till Member may be Cary in age. Future detailed studies of the stratigraphy of the unconsolidated sediments in Benton, Newton, Jasper,. and White Counties, where exposures are all too scarce, may permit the boundaries of the Cartersburg to be more accurately defined and may provide data needed for a more precise correlation of the unit.

FORMATION AND MEMBER			CHARACTERISTIC SNAIL SPECIES	ENVIRONMENT
Martinsville Formation		k	*Anquispira kochi, Succinea vermeta, Helisoma anceps,Campeloma rufum, Valvata lewisii*	Warm, humid climate; deciduous forest.
		j	*Valvata sincera, Succinea gelida, Gyraulus allissimus*	Cool climate; coniferous forest.
Lagro Formation				
Trafalgar Formation	Cartersburg Till Member	i	*Succinea gelida, Columella alticola, Vertigo alpestris oughtoni, Discus cronkhitei*	Cool to cold, moist climate; probably open park with scattered conifers.
	Center Grove Till Member	h	Fauna poorly known	
		g	*Hendersonia occulta, Succinea gelida, Stenotrema monodon*	Cool, moist climate; spruce forest with birch and willow.
Jessup Formation	Butlerville Till Member	f	*Anquispira alternata, A. kochi, Succinea ovalis*	Warm, humid climate; deciduous forest.
		e	*Succinea gelida, Columella alticola*	Cool to cold, moist climate; open park.
		d	Fauna poorly known	
		c	*Succinea gelida var., Hendersonia occulta, Vertigo elatior*	Cool, moist climate; probably transitional to boreal forest.
	Cloverdale Till Member	b	*Succinea gelida var., Punctum minutissimum*	Cool to cold, moist climate; open park.
		a	*Succinea gelida var., Hendersonia occulta, Strobilops labyrinthica*	Cool, moist climate; boreal forest.

Figure 7.-Stratigraphic position, representative species, and environmental interpretation of fossiliferous beds in the Pleistocene formations in Indiana.

Both recognized members of the Trafalgar Formation, as defined in this report, fall within the Woodfordian Substage (fig. 2) of the classification recently proposed by Frye and Willman (1960). The formation is part of the, "Main Wisconsin" of Dreimanis (1960, p. 109) and the "Classical Wisconsin" of various authors. It correlates with the “Jungwürm” of Woldstedt (1960, p.159). Whether any of the sediments in the lower part of the Trafalgar Formation in central or northern Indiana are Mittelwürm or Altwürm in age (early or middle Wisconsin) is still undetermined, because if they are present, such sediments are overlapped completely by the two upper members of the formation, both of which are late Wisconsin in age.

JESSUP FORMATION

Definition.--The Jessup Formation is the name proposed in this report for a sequence of unconsolidated strata composed dominantly of conglomeratic mudstone that underlies the Trafalgar Formation and that is exposed as the surf ace unit in much of the southern third of Indiana. The formation is named from the village of Jessup in southern Parke County (U. S. Geological Survey Mecca Quadrangle), because many excellent exposures of the formation can be found in the stream banks within a radius of a few miles in all directions. The type section is an exposure along a tributary of Strangers Branch about *5* miles northeast of Jessup (fig. *5,* location 14; Appendix A, section 14).

Description and distribution.--The Jessup Formation consists of several beds of calcareous conglomeratic mudstone and intercalated lenses of clay, silt, sand, gravel, marl, and peat. The formation is extremely variable in thickness, because both upper and lower surfaces of the unit are bounded by erosional unconformities. The formation is divided into two members (described below) in areas where they are separately recognizable. The Jessup Formation is the uppermost geologic unit in much of southern Indiana south of the limit of overlap of the Trafalgar Formation (fig. *5*).

Weathering processes have removed carbonates to a depth of 3 to 4 meters in places where the Jessup Formation is not covered by younger sediments; the upper 20 to 50 centimeters generally consists of a mealy textured loesslike clayey silt. In exposures where the Jessup Formation is overlain by the Trafalgar Formation or by the loess or lacustrine facies of the Atherton Formation, the zone of carbonate removal from the paleosol key bed at the top of the Jessup rarely exceeds 2 meters in thickness (Appendix A,

section 11). In many exposures a distinctive bright orange-brown to strong brown (7.5YR 5/6) color is associated with the paleosol that caps the formation. Oxidation of ferrous compounds generally extends only slightly deeper into the till than the base of the zone from which carbonate rock particles have been leached, but there is noticeable oxidation commonly along joints, a feature not found in either the Trafalgar or Lagro Formation.

The base of the Jessup Formation generally rests on rocks of Paleozoic age in Indiana; thus the contact is one of the most readily recognized in the entire geologic column for the State. In some places, though, a tongue of the Atherton Formation has been observed to be intercalated between the Jessup and the older rocks (Appendix A, section 6).

Butlerville Till Member.--The name proposed here for the upper of two members of the Jessup Formation is the Butlerville Till Member. It consists dominantly of conglomeratic mudstone but includes lenses of gravel, sand, silt, and clay and a few lenses of peat and marl. A distinctive weathered zone, buried where the member is overlain by younger sediments, caps the Butlerville and serves as the key bed for recognizing the top of the Jessup Formation. In some places the paleosol is replaced by peat or marl lenses, and it commonly grades upward into a brown to gray silt bed, whose upper part is fossiliferous, and which is a tongue of the Peoria Loess Member of the Atherton Formation (pl. 4A). The fossiliferous part of this unit is referred to here as the middle *Hendersonia occulta* bed (fig. 2).

The type section of the Butlerville Till Member is exposed in road cuts beside the spillway for the Brush Creek Reservoir 1½ miles northwest of Butlerville (fig. 5, location 3). This section was studied during a field conference held in 1955, and the description in Appendix A, section 3, is modified from the one published in the guidebook for that trip (Murray, 1955, p. 32).

A few exposures of the Butlerville Till Member of the Jessup Formation show that it consists of at least two and possibly three units of till that are separated by thin fossiliferous silt beds (Appendix A, sections 5 and 14). Unfortunately these fossiliferous beds are rarely well exposed, and their nature and extent still are poorly known. The middle till of the three seems to be the most extensive in western Indiana and probably is the one that extends to the southern limit of the member.

The upper till, overlying a fossiliferous silt bed at the top of the middle till, has been recognized in Parke, Vigo, and Wayne

Counties, and the same units probably are present in exposures in Marion County and near Sydney, Ohio. (See La Rocque and Forsyth, 1957.) Only two exposures of the lower till and its associated fossiliferous silt cap bed have been observed (pl. 4A) ; both exposures are in Parke County. This till has a distinctive brownish-gray color, which gives it a "pinkish" cast in contrast to adjacent gray beds.

Cloverdale Till Member.--The name Cloverdale Till Member is proposed here for the lower part of the Jessup Formation. It consists dominantly of sandy conglomeratic mudstone but includes lenses and thin beds of gravel, sand, silt, clay, and low-grade coal. Both the top and bottom of the member are marked by major erosional unconformities.

The type section of the Cloverdale Till Member is exposed in the east end of a diversion spillway that was cut to protect the dam at Cataract Lake on Mill Creek in southwestern Putnam County (fig. 5, location 6). It is an important reference section for the entire Jessup Formation and is the type section for the Cagle Loess Member of the Atherton Formation. It is likely to remain available for study for many years (Appendix A, section 6; pl. 4B).

The member is marked at the top by a distinctive paleosol, from which carbonates have been leached to a depth of 3 to 4 meters, and locally by lentils of weathered gravels, sands, silts, and coallike sediments. Where this "key bed" has been removed by erosion, Cloverdale till generally is difficult to distinguish from overlying Butlerville till. The joints of both members characteristically are marked by oxidation that extends into the mudstone from the fractures; this oxidized zone normally is about 2 to 8 centimeters wide in the Butlerville but is considerably wider, as much as 15 centimeters, in the Cloverdale. Tills of the Cloverdale all seem to be more pebble rich on outcrop than tills of the overlying unit, but mechanical analyses are not available to provide laboratory confirmation of this field observation. The paleosol at the top of the Cloverdale contains noticeable kaolinite, a mineral apparently missing from the paleosol at the top of the Butlerville Till Member (Bhattacharya, 1962, p. 1016).

The Cloverdale Till Member of the Jessup Formation has been recognized only in southern Indiana, and nearly everywhere it is overlain by younger sediments. So far it is known. to be the surface unit only within a small area in northwestern Brown County (figs. 2 and 5), but in a few places in Parke and Ripley Counties the overlying Butlerville Till Member is less than 2 to 3 meters thick,

and the carbonate-free zone of the soil profile on the upper member extends into the lower member. In places such as these, the combined soil profile and the paleosol on the Cloverdale Till Member are leached to a depth of more than 6 meters.

Fossils.-Within generally nonfossiliferous mudstones of the Jessup Formation are at least six separate and distinct silt beds from which fossil snails, wood, and pollen have been recovered. Three of these beds are tongues of the Atherton Formation, two of which are named; the other three, however, are unnamed thin silt lenses or beds moderately rich in organic material, particularly the shells of land snails.

Many exposures of the highest bed in the sequence, the upper *Hendersonia occulta* bed, which is a tongue of the lower part of the Peoria Loess Member of the Atherton Formation, have been recorded in Indiana during the past half century (Leverett and Taylor, 1915; Thornbury, 1937, p. 53-55; Wayne, 1959b, p. 12). Species of snails found in this bed include some from both assemblages of the Peoria farther south. Some of the forms more commonly found are *Hendersonia occulta, Cionella lubrica, Stenotrema leai, Succinea gelida, Pupilla muscorum, Gastrocopta armifera, Vertigo elatior, Vertigo gouldi, Vertigo modesta, Punctum minutissimum, Deroceras laeve, Discus cronkliftei, Carychium exile canadense,* and *Lymnaea parva.* Less commonly found are *Anguispira alternata, Pomatiopsis lapidaria, Vertigo alpestris oughtoni,* and *Columella alticola.*

Within the Butlerville Till Member, two thin intertill silt beds have been recognized, but only a few exposures of each are known. Samples of the upper silt bed collected from Vigo, Parke, and Wayne Counties are virtually indistinguishable faunally from the fauna of the silt bed that marks the top of the Center Grove Till Member of the Trafalgar Formation. The most common species are *Succinea gelida, Vertigo elatior, Vertigo modesta, Columella alticola,* and *Lymnaea parva.*

Only two exposures of a thin fossiliferous silt bed (pl. 4A) lower in the Butlerville Till Member have so far been found; both are in Parke County. Nothing of particularly diagnostic value was noted in the one exposure that has been examined; however, the brownish-gray silt itself is notable, because it has a "pinkish-brown" cast when it is examined in the field beside the gray overlying mudstones. It contains *Succinea gelida, Vallonia albula, Deroceras laeve, Lymnea parva,* and a few specimens of three other species.

A tongue of the Loveland Loess Member of the Atherton Formation, whose fossiliferous part is the middle *Hendersonia occulta* bed, has been found to be exposed in the middle of the Jessup Formation in relatively few places in the State. Fossil snail shells have been recovered from exposures of it in Clay, Parke, and Johnson Counties, but pollen has been recovered from this silt bed and associated peaty materials in exposures in Ripley and Tippecanoe Counties as well as those in Clay, Parke, and Johnson Counties (Englehardt, 1961).

Apparently because the weight of an overriding ice sheet was too great, mollusk remains in the middle *Hendersonia. occulta* bed commonly are badly broken. This position, though, is the lowest from which specimens of *Columella alticola* have yet been recovered in Indiana, and it is the highest silt bed to contain *Succinea gelida* var. Other fairly commonly species are *Hendersonia occulta, Deroceras* cf. *D. laeve, Stenotrema leai, Succinea, ovalis, Vertigo elatior, Carychium exile canadense,* and *Lymnaea parva.*

One thin fossiliferous silt bed has been recognized within the Cloverdale Till Member of the Jessup Formation, and only three exposures of it have been found, all in the same part of Parke County. Similar faunal assemblages were found in all three. The most abundant species are *Punctum minutissimum, Succinea. gelida* var., *Vallonia gracilicosta,* and *Vertigo elatior.*

From a single exposure, the type section of both the Cloverdale Till Member and the Cagle loess, the fossil-rich lower*Hendersonia occulta* bed at the base of the Jessup Formation is known (pl. 4B). Dominant in the list of species from this unit are *Strobilops labyrinthica, Hendersonia occulta, Succinea gelida* var., *Carychium exile canadense, Discus cronkhitei,* and *Oxyloma decampi gouldi.*

Age and correlation.--The Jessup Formation includes all the conglomeratic mudstones of Indiana that are pre-Wisconsin in age. The Butlerville Till Member of the formation is continuous into the type region of the Illinoian Stage in Illinois (Chamberlin, 1896, p. 872-876; Leverett, 1898, p. 173; Leighton and Brophy, 1961; Leverett, 1899) ; the key bed-paleosol and related sediments that marks the top of both this member and of the formation is Sangamon to early Wisconsin in age.

The lower part of the formation, the Cloverdale Till Member, is less well exposed; thus it is not so well known. It has been correlated with deposits of the Kansan Stage (Wayne, 1958a, p. 10). The key bed at the top of the Cloverdale is Yarmouth to early Illinoian in age.

BIOSTRATIGRAPHIC UNITS

Biostratigraphic units are rocks characterized by a particular fossil or fossil assemblage. The boundaries of such units should not necessarily be coincident with lithologic boundaries; both the fossil assemblage and the lithology of the enclosing sediments are products of a particular environment of deposition, however, and their boundaries may coincide. As currently proposed by the American Commission on Stratigraphic Nomenclature (1961, p. 655-657) the fundamental unit in biostratigraphic classification is the zone.

KINDS OF FOSSILS FOUND IN PLEISTOCENE SEDIMENTS

Ice-laid sediments are generally nonfossilif erous, and the Pleistocene glacial deposits of Indiana are no exception. Most of the fossils in the Pleistocene sediments in Indiana come from thin silt beds that lie along unconformities between till units, f rom lacustrine sediments, and from loessal silts. Many kinds of organisms have been preserved as fossils in the Pleistocene formations in Indiana. Unfortunately, most of them are limited in their usefulness to stratigraphy, some because they are too scarce, others because they have received little study and their stratigraphic value is still unknown.

The more spectacular fossils, the vertebrates, are rarely found in continental glacial deposits. Only a few specimens of the large fossil vertebrates, most of them bones or teeth of mastodons, turn up in Indiana each year. Remains of other species are even less frequently discovered. Virtually all vertebrate remains have come from the paludal facies of the Martinsville Formation. Small mammals, which have proved stratigraphically useful in deposits in the Great Plains (Hibbard, 1958), have not been found in the Pleistocene sediments in Indiana.

Fresh-water Pleistocene sediments commonly contain ostracodes. This group of fossils requires microscopic study for identification, however, and little work has been done so far on the stratigraphic distribution of Pleistocene species. Other fossil animal remains that require microscopic examination include larval cases of insects, mites, and cladocera (water fleas), which Frey (1958) found as having considerable stratigraphic and ecologic significance in sediment studies of postglacial lakes.

Wood, seeds, spores, and charophytes are found in many Pleistocene interformational silts and in some tills. Wood requires sectioning and microscopic examination for identification; and as fossil seeds, spores, charophytes, and leaves have not been extensively

studied in North America, their usefulness in stratigraphic work is still not known. At the present time, too little is known about changes that may have occurred in these organisms during the Pleistocene for them to have other than paleoecologic significance.

The use of percentages of pollen types from different depths in postglacial lakes and bogs has been a most fruitful biostratigraphic technique in the zonation of the paludal facies of the Martinsville Formation, because the pollen and spores of many kinds of plants are windborne and much of the pollen and spores is buried in sediments (Guennel, 1950; Potzger, 1941 and 1943; Potzger and Wilson, 1941). The principal disadvantages of this biostratigraphic technique are that pollen requires laboratory studies and that, so far, the effectiveness of the study of pollen has been limited in North America to quiet-water sediments of the Martinsville Formation and its equivalents. A recent study by Englehardt (1961) indicates that some stratigraphic value may be derived fromthe study of pollen in the fossiliferous silts and peats that are buried within the Pleistocene formations, but, so far, the major contribution of such studies has been ecologic.

In view of their abundance, availability for study, and the state of current knowledge regarding them, the most satisfactory fossils in Indiana for use in Pleistocene stratigraphic work are land and fresh-water mollusks. They have been found in nearly all formations of the Indiana Pleistocene and generally can be collected in large numbers by merely washing a bulk sample of the fossiliferous sediment (Wayne, 1959b, p. 13). Unfortunately, nearly identical ecologic conditions near the ice margin prior to, during, and following each glaciation have resulted in the recurrence of relatively similar faunas at successively higher stratigraphic positions. Distinctions between faunal assemblages in the Pleistocene formations in Indiana are more subtle than those recorded for Kansas (Leonard, 1950 and 1952).

Nearly all the species of mollusks that are found as fossils in the Pleistocene sediments in Indiana are still living somewhere today. Not all of them now live in Indiana, however, and many species in the present living fauna of the State have never been recovered from the Pleistocene sediments. As few changes have taken place through speciation, the principle involved in attempting to utilize fossil mollusks in Pleistocene stratigraphic study assumes that the overall species content of the fauna in any given area changes somewhat each time the fauna is destroyed by the changes in temperature and vegetation that accompany a glaciation. Thus the faunal

assemblage at the base of a thick loess deposit is likely to be almost wholly different from the faunal assemblage recoverable from the top of the same loess. In the same way, a fauna that was destroyed by burial beneath ice and till probably differs in several elements from the fauna that repopulated the same region after the ice had melted. Wherever the difference in ecology rather than the evolution of new forms is the dominant factor in the makeup of a fauna, stratigraphic paleontology must be worked out for each limited area. Thus details in one area must be used only with great caution when they are used in correlation in other areas.

In the Martinsville and Atherton Formations, mollusks generally are found scattered throughout the sediments. In contrast, mollusks are almost completely restricted to thin silt beds between much thicker barren till layers in the Jessup, Trafalgar, and Lagro Formations (fig. 2). So far, no fossils of any kind have been reported from the Prospect Formation, but it is possible that some may be found.

VERTICAL DISTRMUTION OF PLEISTOCENE SNAILS

Range zones.--The total vertical range limits of few, if any, of the mollusk species that are abundant as fossils in the glacial deposits in Indiana fall completely within the span of time represented by the Pleistocene sediments in Indiana. A few species do seem to have restricted vertical ranges, however, and when they are found in a deposit that contains certain other species, they make up an assemblage that usually can be placed in its proper stratigraphic position. The most significant of these fossils for Indiana seems to be three forms of *Succinea* that have often been grouped together under the name *Succinea, avara* Say (fig. 8). Fossil species of *Succinea* are admittedly difficult to evaluate, and names are used with the understanding that these are "form" species. (See Leonard and Frye, 1960, p. 12.) There appear to be enough differences, however, to permit recognition of three species that seem to be restricted to certain stratigraphic positions in Indiana.

The species that has been found in the upper part of the Martinsville Formation and is now living in Indiana and that has been referred to as *S. avara* was reclassified recently by Hubricht (1958, p. 61) as S. *vermeta* Say. The *Succinea vermeta* Range Zone in Indiana, here named, is limited to the younger part of the Martinsville (fig. 2). The shell of *S. vermeta is* distinct from the form common to the lower part of the Martinsville and to other upper

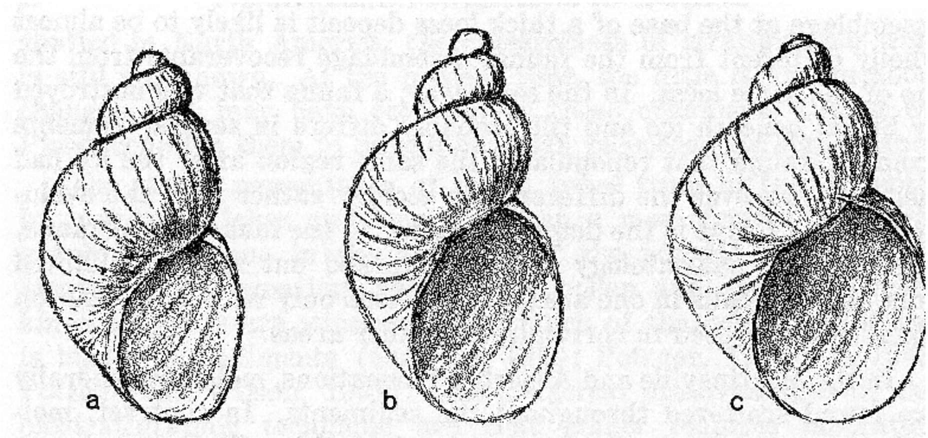


Figure 8.–Variation among forms commonly referred to *Succinea avara* Day: (a) *Succinea gelida* F. C. Baker, var., (X 10); (b) *Succinea gelida* F. C. Baker, (X 10); and (c) *Succinea vermeta* Say, (X 10)

Pleistocene deposits in the State. The species common in sediments of Wisconsin age has a shell that is identical to the species now living along the margins of tundra ponds in the vicinity of the northern limit of wooded country in Manitoba (Wayne, 1959a, p. 93). This species is referred to the form *Succinea gelida* F. C. Baker (Leonard, 1957, p. 19), and the beds that embrace its range in Indiana are designated the *Succinea gelida* Range Zone (fig. 2). A smaller but similar form is found in the lower three fossiliferous beds of the Jessup Formation but seems to be absent from strata younger than Yarmouth. This form can be recognized as different from *S. gelida* but may not be a distinct species. In this report I have referred to it as *S. gelida* var., and the Indiana beds in its range are designated the *Succinea gelida* var. Range Zone (fig. 2). These range zones, used in combination with other species of the assemblages, allow reasonably sound stratigraphic determinations to be made.

Beds.--Hendersonia occulta, (Say) is a readily recognizable species that has been recovered from only three stratigraphic positions in the Pleistocene sediments of Indiana (fig. 7). The type locality of this species is near New Harmony in Posey County, where Thomas Say collected from loess the specimens he described. No living colonies of *H. occulta* have been found in Indiana, but the species is known from suitable habitats in Michigan, Wisconsin, Minnesota, Iowa, and the central Appalachians (van der Schalie, 1939, p. 5).

The sediments in which *Hendersonia occulta is* found are part of the three members of the loess facies of the Atherton Formation,

particularly in exposures where the loess intertongues with the Jessup and Trafalgar Formations and has not been extensively weathered after deposition. For identification purposes in this report, the units that contain *Hendersonia occulta* as a distinctive part of the fauna are designated the lower, middle, and upper *Hendersonia occulta* beds (figs. 2 and 7).

The lower *Hendersonia occulta* bed is in the Cagle Loess Member of the Atherton Formation and lies at the base of the Jessup Formation. In the type section the boundaries of the fossil bed coincide with those of the Cagle loess. It is in the *Succinea gelida* var. Range Zone. The middle *Hendersonia occulta* bed also is in the *Succinea gelida* var. Range Zone and, as the upper part of a tongue of the Loveland Loess Member of the Atherton Formation, is part of the key bed that caps the Cloverdale Till Member of the Jessup Formation. The upper *Hendersonia occulta* bed is in the *Succinea gelida* Range Zone and, as part of a tongue of the Peoria Loess Member of the Atherton Formation, is part of the key bed that caps the Jessup Formation. In places where the Peoria is not overlain by the Trafalgar Formation, *Hendersonia occulta is* present throughout the unit. Say's type of the species undoubtedly was collected from the upper *Hendersonia occulta* bed in exposures of Peoria loess near New Harmony.

Of the remaining fossiliferous units known to exist in the Pleistocene sediments of Indiana, nearly all (specifically, beds designated b, d, e, f, h, and j in figures 2 and 7 and table 2) are still too imperfectly studied for me to select a characteristic species at this time. Bed k (fig. 7) contains much of the modern land and f resh-water snail fauna of Indiana and is in the *Succinea vermeta* Range Zone.

Vertigo alpestris oughtoni is a characteristic species in the thin lenticular silt bed that I have used as a key bed to separate the Center Grove Till Member from the Cartersburg Till Member of the Trafalgar Formation. Even though the species is not restricted to this stratigraphic position (table 2), it is more typically present in bed i (fig. 2) than in any other in Indiana. Therefore the fossiliferous silt that separates the Center Grove from the Cartersburg is designated the *Vertigo alpestris oughtoni* bed.

Table 2-Distribution of species of snails in fossiliferous beds within the Atherton, Jessup, and Trafalgar Formations in Indiana

Species	Fossiliferous beds (figs. 2 and 7)[1]								
	a	b	c	d	e	f	*g*	h	i
Carychium exile canadense (Clapp)	x		x				x		
Columella edentula (Draparnaud)	x		x			x			
Cionella lubrica (Muller).	x		x				x		x
Discus cronkhitei (Newcomb)	x		x				x		x
Euconulus fulvus (Muller)	x	x	x			x	x		x
Gastrocopta armifera (Say)	x	x	x			x	x		x
Hendersonia occulta (Say)	x		x			x	x		
Lyninaea parva Lea	x	x	x		x		x		x
Oxyloma decampi gouldi Pilsbry	x		x				x		
Punctum minutissimum (Lea)	x	x	x		x	x	x		x
Pupilla muscorum (Linne)	x	x					x		x
Retinella electrina (Gould)	x	x	x			x	x		x
Stenotrenia leai (Binney)	x		x		x		x		x
Strobilops labyrinthica (Say)	x		x			x			
Succinea gelida F. C. Baker, var.	x	x	x						
Vallonia excentrica Sterki	x				x				
Vertigo alpestris oughtoni Pilsbry	x	x					x		x
Vertigo elatior Sterki	x	x	x		x	x	x		x
Vertigo gouldi hubrichti Pilsbry	x					x	x		x
Vertigo niodesta (Say)	x	x	x		x		x		x
Deroceras laeve (Muller)		x	x			x	x		x
Succinea grosvernorii Lea		x					x		
Vallonia gracilicosta Reinhardt		x				x			
Valvata tricarinata (Say)		x							
Vertigo gouldi hannai Pilsbry		x				x	x		
Vertigo ovata Say		x				x			x
Columella alticola (Ingersoll)			x		x		x		x
Lymnaea galbana (Say)			x						
Stenotrema hirsutum (Say)			x			x			
Succinea ovalis Say			x			x			
Gastrocopta tappaniana (C. B. Adams)					x				
Succinea *gelida* F. C. Baker					x	x	x		x
Vallonia albula (Sterki)					x		x		x
Vertigo nylanderi Sterki					x		x		
Allogona prolunda (Say)						x			
Anguispira alternata (Say)						x	x		
Anguispira kochi (Pfeiffer)						x			
Discus patulus (Deshayes)						x			
Gastrocopta contracta (Say)						x			
Gastrocopta holzingeri (Sterki)						x			
Gastrocopta pentodon (Say)						x	x		x
Haplotrema concavum (Say)						x			
Hawaiia minuscula (Binney)						x			
Helicodiscus parallelus (Say)						x			
Stenotrema fraternum (Say)..						x			

Table 2-Distribution of species of snails in lossiliferous beds within the Atherton, Jessup, and Trafalgar Formations in Indiana-Continued

Species	Fossiliferous beds (figs. 2 and 7)[1]								
	a	b	e	d	e	f	g	h	i
Stenotrema stenotrema (Pfeiffer)						x			
Vallonia costata (Muller)						x			
Vertigo bollesiana (Morse)						x			
Zonitoides arboreous (Say)							x		
Poinatiopsis lapidaria (Say)							x		
Succinea retusa Lea							x		

[1]The species lists am based on studies of the following number of sample. for each bed:

Bed a - 1 sample
b - 3 samples
c - 3 samples
e - 3 samples
f - 2 samples
g - 6 samples
i - 11 samples
d,h - not studied (1961).

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APPENDIX A. TYPE AND REFERENCE SECTIONS

[Munsell color notations are given where available; all color determinations were made under field moisture conditions. Color descriptions that are not followed by a Munsell value are nonquantitative field notations.]

1. Reference section, Atherton Formation, loess facies. Road-cut exposure along Kentucky State Highway 56 in Union County, Ky., 1 mile east of Shawneetown Ferry landing on the Ohio River. Lat 37˚ 41' N.; long 88˚, 30" W. (Grove Center Quadrangle). Altitude of top of section is about 480 ft. (See also Rubin and Alexander, 1960, p. 139, W-867; Leonard and Frye, 1960, p. 12-13; and Leininger, Droste, and Wayne, 1958, p. 1604.) Measured and sampled April 3, 1958.

	Thickness m	Thickness ft
Atherton Formation:		
Peoria Loess Member:		
Silt; top is brownish gray and contains organic debris; lower part is medium brown, orange mottled, clayey; not calcareous	0.7	2.3
Silt, pale orange-brown, calcareous, very slightly fossiliferous	2.5	8.2
Silt, pale yellowish-brown, massive, calcareous; small concretions at top; slightly fossiliferous near top and base but virtually unfossiliferous through middle; includes a lens of silty fine sand	7.5	24.8
Farmdale Loess Member:		
Silt, light grayish-brown, calcareous, very fossiliferous; contains a layer of shells at top; gullies head in this unit; dated as 22,200 years old (Appendix B, date W-867)	1.0	3.3
Silt, clayey, medium-brown, platy; contains tiny concretions of Mn or Fe; base gradational	1.7	5.6
Loveland Loess Member:		
Clayey silt, orange to yellowish-brown, mottled; large lime concretions at base, but otherwise not calcareous	1.2	3.9
Silt, slightly clayey, yellowish-brown, noncalcareous	0.6	2.1
Cagle Loess Member?:		
Silt, reddish-brown, noncalcareous; weathered sandstone pebbles in lower part	1.7	5.5

2. Type section, Prospect Formation. Road-cut exposure along U. S. Highway 150 at the west edge of the village of Prospect, about 2 miles north of French Lick, Orange County, Ind., in the SW¼:NE¼ sec. 27, T. 2 N., R. 2 W. (French Lick Quadrangle).

	Thickness m	Thickness ft
Prospect Formation:		
Silt, clayey, yellowish-brown	0.6	2.0
Sand, clayey, brownish-red	4.0	13.0
Sand, gravelly, brownish-red; base of unit not exposed	0.9	3.0

3. Type section, Butlerville Till Member of Jessup, Formation. Road- and spillway-cut exposure at Brush Creek Reservoir, 2 miles northwest of

Butlerville, Jennings County, Ind., in the NE¼NE¼ sec. 16, T. 7 N., R. 9 E. (Butlerville Quadrangle). Section modified from Murray, 1955, p. 32-33.

	Thickness m	Thickness ft
Jessup Formation:		
Butlerville Till Member:		
Clay, silty, sandy, light yellowish-gray, mottled, nonealcareous	1.5	5.0
Mudstone, sandy and clayey, brown, noncalcareous.	0.6	2.0
Mudstone, conglomeratic, gray; brown along joint fractures; not calcareous	1.5	5.0
Mudstone, conglomeratic, gray; calcareous throughout but less strongly so at base; brown along joint fractures; contains randomly oriented chunks of dark yellowish-brown noncal careous mudstone. This unit thickens considerably on east side of bridge where it fills a buried bedrock valley, and the sediment contains abundant fossil wood	4.6	15.0
Cloverdale Till Member:		
Mudstone, clayey, dark yellowish-brown, noncaleareous; contains abundant chert pebbles and a few quartzite pebbles	0.3	1.0
Devonian rocks:		
Sand, yeIlowish-white, fine-grained, loose	0.3	1.0
Sandstone, yellowish-gray, thick-bedded	0.6	1.8
Silurian rocks, Laurel Limestone:	(not measured)	

4. Reference section of Atherton and Jessup Formations. Road cuts exposed along Indiana State Highway 45, 1 mile west of Helmsburg, Ind., in the S½SE¼ sec. 28, T. 10 N., R. 2 E. (Morgantown Quadrangle). Section adapted from Thornbury and Wayne, 1957, p. 22-23.

	Thickness m	Thickness ft
Covered to top of terrace	4.9	16.0
Atherton Formation, lacustrine facies:		
Clay, brownish-yellow, blocky, compact, noncalcareous	1.8	6.0
Clay, brown, blocky, compact, plastic, calcareous	0.3	1.0
Clay, pale yellowish-gray, silty, noncalcareous; unit may be a thin layer of loess	0.3	1.0
Jessup Formation, Cloverdale Till Member:		
Silt, dark brownish-gray, clayey, noncalcareous; contains some carbon particles	0.5	1.6
Silt, pale yellowish-gray, clayey, noncalcareous	0.9	3.0
Sand and silt, brown, nonealeareous; cemented with iron oxides; discontinuous	0.1	0.3
Sand, yellowish-gray, clayey, pebbly, noncaleareous	0.5	1.5
Gravel, brownish-yellow; not well sorted; not calcareous	0.4	1.3
Mudstone, brownish-gray, conglomeratic, clayey, noncalcareous	0.03	0.1
Mudstone, brownish-gray, conglomeratic, clayey, sandy, calcareous	1.5	5.0
Mississippian rocks, Borden Group:		
Siltstone, bluish-gray, shaly; base not exposed	0.3	1.0

5. Reference section, Jessup Formation. Cutbank exposure along creek at the north edge of Liggett, Vigo County, Ind., in the SE¼SE¾ see. 14, T. 12 N., R. 10 W. (Terre Haute Quadrangle).

	Thickness m	ft
Jessup Formation:		
Silt, yellowish-brown, clayey, noncalcareous	1.65	5.0
Mudstone, brown, clayey, conglomeratic, noncalcareous	2.00	6.1
Mudstone, gray to brownish-gray, conglomeratic, sandy, cal careous; contains gravelly lenses	1.65	5.0
Silt, pale brownish-yellow, calcareous; upper 3 to 4 em contains humic stains, sparsely fossiliferous; limonitic accumulation at base	0.15	0.5
Mudstone, dark olive-gray, sandy, conglomeratic, hard	1.10	3.7
Sand; contains coal fragments	0.60	2.0
Mudstone, brownish-gray, silty, clayey, conglomeratic, calcareous; upper 30 em brown	1.65	5.0
Pennsylvanian rocks:		
Shale, olive-gray; top surface uneven	2.60	8.0
Siltstone, calcareous	0.30	1.0

6. Type section, Cloverdale Till Member of Jessup Formation and Cagle Loess Member of Atherton Formation. Cut on side of spillway for Cagle's Mill Reservoir, Putnam County, Ind., in the SE¼NW¼ see. 13, T. 12 N., R. 5 W. (Poland Quadrangle).

	Thickness m	ft
Atherton Formation:		
Peoria Loess Member:		
Silt, yellowish-brown, clayey, not calcareous	0.9	3.0
Jessup Formation:		
Butlerville Till Member:		
Mudstone, brown, fractured, nonealeareous; secondary limonite deposition along joints	3.7	12.0
Mudstone, conglomeratic, light-brown, calcareous, clayey	1.6	5.3
Mudstone, conglomeratic, dark-gray, calcareous, clayey	1.8	6.0
Cloverdale Till Member:		
Clay, brown to greenish-gray, nonealcareous, silty to sandy	1.1	3.5
Mudstone, brown, sandy and silty, noncalcareous	2.6	8.5
Mudstone, conglomeratic, reddish-brown, calcareous	0.9	3.0
Mudstone, conglomeratic, brownish-gray, calcareous, silty, sandy; oxidized extensively along joints; contains wood fragments in basal few feet	3.7	12.0
Clay, silty, brownish-gray, laminated, highly calcareous; contains scattered wood fragments throughout; lenticular, pinching out toward west in exposure	0.7	**2.3**
Atherton Formation:		
Cagle Loess Member:		
Silt, grayish-brown; mottled locally; calcareous and abundantly fossiliferous, becoming less so in lower 1.0 ft; wood, peat, and humus common at upper contact; lenticular, pinching out toward west in exposure	0.9	3.0

Pennsylvanian rocks, Mansfield Formation:		
Sandstone, shale, and thin coals, overlain locally by as much as 12 ft of colluvial debris	(not measured)	

7. Reference section in type area, Martinsville Formation. Cutbank along White River along east side of Indiana State Highway 67, 3 miles north of Martinsville, Morgan County, Ind., in the NW cor. see. 16, T. 12 N., R. 1 E. (Martinsville Quadrangle).

	Thickness	
Martinsville Formation, alluvial facies:	m	ft
Sand, silty, yellowish-brown; locally shows stratification laminae 2 to 3 mm thick	1.6	5.1
Silt, sandy and clayey, yellowish-brown to orange-brown; mottled with yellowish gray; massive; stratification obscure; lower part grayer than upper and less mottled; locally gradational into unit below	1.3	4.1
Sand, grayish-yellow, calcareous; contains a few thin (2 to 3 mm) silt lenses, a few particles of granule size, and scattered snail shells	0.6	1.9
Silt, dark-gray; not observably calcareous; contains abundant wood, including a few large (50 cm diameter) logs; base not exposed above water level	0.7	2.2

8. Reference section of Center Grove Till Member of Trafalgar Formation. Cutbank exposure along Honey Creek in the NE¼SE¼SE¼ sec. 15, T. 13 N., R. 3 E. (Bargersville Quadrangle).

	Thickness	
Trafalgar Formation:	m	ft
Cartersburg Till Member:		
Mudstone, slightly conglomeratic, yellowish-gray, calcareous; base undulating	3.0	9.9
Center Grove Till Member:		
Silt, orange-brown to pale greenish-gray, mottled; upper 2 to 3 cm is highly calcareous but porous, as if it is a zone of local secondary deposition of CaCO.; locally fossiliferous; grades laterally into laminated silt and pebbly sand	0.1	0.3
Mudstone, gray, calcareous, laminated; thins to west along face of bluff	1.8	5.9
Sand, coarse, pebbly, gray; locally cemented at top	0.7	2.3
Mudstone, sandy, conglomeratic, gray to brownish-gray, very hard and compact; contains wood fragments and limonite stained laminae in lower part; base not exposed in this section	6.7	22.0

9. Type section, Center Grove Till Member of the Trafalgar Formation. Stream bluff along Turkey Pen Creek, a tributary of Honey Creek, just east of an Illinois Central Railroad trestle in the NW¼SW¼SE¼ see. 2, T. 13 N., R. 3 E. (Bargersville Quadrangle).

Trafalgar Formation:	Thickness m	ft
Cartersburg Till Member:		
Silty clay, brown, nonealcareous; shows some stratification; unit probably represents colluvially moved soil	1.0	3.3
Mudstone, medium yellow-brown, silty, calcareous; no boulders or cobbles noted in the outcrop; basal part of unit is light gray	2.5	8.2
Center Grove Till Member:		
Silt, gray, pebbly; contains wood fragments and snail shells	0.1	0.3
Mudstone, yellowish-gray, calcareous, conglomeratic; boulders common in lower part	5.5	17.0
Jessup Formation:		
Gravel, orange-brown to olive-gray, clayey and sandy, non calcareous; base not exposed	1.0	3.2

10. Type section, Trafalgar Formation. Cutbank exposed along west side of Buckhart Creek about 150 m (500 ft) north of Indiana State Highway 252, 2 miles east of Trafalgar, Johnson County, Ind., in the SE¼NW¼ sec. 8, T. 11 N., R. 4 E. (Franklin Quadrangle).

Trafalgar Formation:	Thickness m	ft
Cartersburg Till Member:		
Silt loam, light-gray; leaf litter at top	0.4	1.3
Mudstone, pale-brown (10YR 6/3) between fractures, which are dark brown (7.5YR 3/2) and clayey; not calcareous	0.5	1.6
Mudstone, silty and pebbly, pale brown (10YR 6/3); limonite deposited along horizontal partings; calcareous	0.8	2.6
Silt, light olive-gray (5Y 6/2), porous, nonealcareous	0.3	1.0
Sand, clayey, dark-brown (10YR 4/3), noncalcareous	0.5	1.6
Silt, yellowish-brown (10YR 5/4), laminated, calcareous	0.5	1.6
Mudstone, silty and conglomeratic; dark grayish brown (2.5Y 4/2) in upper part; dark gray (5Y 4/1) in lower part; cal careous, compact	2.1	6.9
Center Grove Till Member:		
Silt, dark-gray (5Y 4/1) to dark-brown (10YR 3/3), fossiliferous; upper 15 cm contains both plants and mollusk shells; upper 5 cm locally nonealcareous, but remainder of unit calcareous; unit drops about a meter lower at north end of exposure and becomes more sandy; dated 20,300 years B. P. (Appendix B, dates W-597 and W-598)	0.3	1.0
Gravel, sandy and silty, dark-brow-n (7.5YR 3/2), calcareous	0.3	1.0
Mudstone, conglomeratic; dark yellowish brown (10YR 4/4) on surface of exposure where oxidized but dark gray (5YR 4/1) beneath surface; calcareous; lower part of unit contains contorted lenses of strong brown (7.5YR 5/6) noncalcareous mudstone and fragments of wood; dated 20,900 years B. P. (Appendix B, date W-580)	2.0	6.6

Jessup Formation:		
Mudstone, strong brown (7.5YR 5/6), conglomeratic, noncalcareous; maximum exposed on opposite bank of stream.	0.6	1.8

11. Reference section, Trafalgar Formation. Composite section exposed in cutbanks along the creek on the north side of Indiana State Highway 252, 3 miles east of Trafalgar, Johnson County, Ind., in the SE¼ NW¼ sec. 9, T. 11 N., R. 4 E. (Franklin Quadrangle).

	Thickness	
Trafalgar Formation:	m	ft
Cartersburg Till Member:		
Mudstone, brown (7.5YR 4/4), silty and clayey, conglomeratic, noncalleareous	1.2	4.0
Mudstone, yellowish-brown (10YR 5/6); grades downward into light gray (5Y 6/1); silty, conglomeratic, calcareous	4.0	13.0
Center Grove Till Member:		
Silt, grayish-brown (2.5Y 5/2); mottled with strong brown (7.5YR 5/6); calcareous; sandy in lower part; contains fossil shells and wood in upper part	0.4	1.3
Mudstone, light olive-brown (2.5Y 5/4), calcareous, conglomeratic, sandy, silty, hard	1.9	6.2
Jessup Formation:		
Mudstone, dark yellowish-brown (10YR 4/4) to brownish yellow (10YR 6/8), conglomeratic, sandy, clayey, noncalcareous; locally contorted	0.7	2.3
Mudstone, strong brown (7.5YR 5/6) to brownish-yellow (10YR 6/8)-, sandy, conglomeratic, nonealcareous, hard	0.7	2.3
Mudstone, gray (5Y 5/1), silty, pebbly, calcareous; oxidation bands and secondary limonite along joints about 3 cm wide.	1.0	3.3

12. Reference section, Atherton Formation, lacustrine facies. Composite section of strata exposed in cutbanks along Yellow Bank Creek 3 miles northwest of Brookville, Franklin County, Ind., in the NW¼SE¼ see. 34, T. 12 N., R. 13 E. (Brookville Quadrangle).

	Thickness	
Atherton Formation:	m	ft
Silt, yellowish-brown (10YR 4/4); mottled with gray; lower 40 cm calcareous and locally fossiliferous; several thin bands of granule-sized particles present in unit (loess facies)	2.1	6.9
Gravel, poorly sorted and rubbly; locally dark brown; leached clay enriched; elsewhere calcareous	0.6	2.0
Trafalgar Formation:		
Mudstone, silty, conglomeratic, light yellowish-brown, strongly calcareous; base poorly exposed	1.0	3.3
Atherton Formation, lacustrine facies:		
Silt and fine sand ' yellowish-brown, calcareous, weakly laminated; lower part gradational into unit below	1.3	4.3
Sand, gravelly, yellowish-gray, crossbedded, calcareous	3.0	9.9
Clay, gray, calcareous, massive	1.6	5.2

	m	ft
Clay, very slightly silty, gray, laminated; beds 1 to 5 cm thick (pl. 2B)	1.7	5.6
Silt, brown (10YR 5/3), calcareous, fossiliferous, massive, thick-bedded; thickness ranges from 30 cm. to 1.0 m.	1.0	3.3
Silty clay, brown to grayish-brown, calcareous, laminated; beds are I to 3 cm. thick	1.4	4.6
Silt, brown, calcareous, massive; upper 40 cm is highly fossiliferous and exhibits contorted layers; lower part Is sparsely fossiliferous but locally contains large snails, wood, and mosses; base not exposed; maximum thickness observed	1.4	4.6

13. Reference section, Jessup and Atherton Formations. Cutbank exposure along south side of Raccoon Creek 1½ miles southwest of Mansfield, Parke County, Ind., in the center of the SW¼NW¼ sec. 18, T. 14 N., R. 6 W. (Mansfield Quadrangle).

	Thickness m	ft
Jessup Formation:		
Butlerville Till Member:		
Mudstone, conglomeratic; upper part yellowish brown; lower part gray and calcareous except in upper 4 ft; nearly vertical bluff	7.6	25.0
Tongue of the Atherton Formation:		
Gravel and sand; contains two cemented layers, one of which is at top of unit; calcareous	12.2	41.0
Silt, light yellowish-brown, calcareous, massive	0.8	2.5
Silt, light yellowish-brown, calcareous, laminated; base gradational	0.9	2.9
Silt, clayey, light-gray, finely laminated, calcareous; fossil shells at base	1.9	6.2
Jessup Formation:		
Cloverdale Till Member:		
Silt, blackish-brown; not calcareous; contains snail shells in upper 10 cm; may be the tongue of the Loveland Loess Member	0.8	2.6
"Braunkohle," black, stratified, chunky, lenticular; maximum thickness	0.3	1.0
Gravel, brown; mottled with orange brown; not calcareous; top very clayey; base not exposed	1.0	3.2

14. Type section, Jessup Formation. Cutbank exposure along the south side of a small tributary of Strangers Branch 5 miles northeast of Jessup, Ind., in the center of the SE¼ sec. 2, T. 14 N., R. 7 W. (Catlin Quadrangle).

	Thickness m	ft
Jessup Formation:		
Butlerville Till Member:		
Covered	5.0	16.5
Mudstone, yellowish-brown (10YR. 5/6), conglomeratic, calcareous; includes a lens of contorted brownish-yellow gravel	2.0	6.5

Mudstone, silty, slightly conglomeratic; dark grayish brown (10YR 3/2) in lower part; yellow ish-brovrn bands (10YR 5/6) 1 to 2 cm wide along joints in upper part; calcareous.	2.4	7.9
Silt, very dark-gray (10YR 3/1), fossiliferous, calcareous; humus and wood fragments at top	0.05	0.2
Mudstone, silty, conglomeratic, dark grayish-brown (10YR 4/2); brown along fractures; calcareous; contains wood fragments	1.3	4.3
Sand, medium-grained, yellowish-brown (10YR 5/8); inter tongues laterally with upper part of unit beneath; water seeps from base	0.6	2.0
Silt, gray (10YR 5/1), calcareous, stratified; in part laminated; finely divided plant remains along some laminae; locally crossbedded; coarser grained upward	1.3	4.3
Cloverdale Till Member:		
Peat, clayey and silty, black (10YR 2/1), noncalcareous; locally contains wood fragments and snail shells; dated >36,000 years B. P. (Appendix B, date W-669)	0.15	0.5
Silt, sandy, slightly pebbly, dark-gray (5Y 4/1 to 2.5Y 3/2), noncalcareous; base gradational	0.3	1.0
Mudstone, clayey; olive (5Y 4/3) with reddish-brown (5 YR 4/4) mottling at top; orange brown (10YR 4/4) mottled with olive (5Y 4/3) in lower part; not calcareous; sandy at base	0.8	2.6
Mudstone, conglomeratic, brown (10YR 4/4), calcareous, compact and hard	1.1	3.6
Mudstone, conglomeratic; very dark grayish brown (2.5Y 3/2) at top to dark gray (10YR 4/1) at base; calcareous and very compact; brown bands aJong fractures in upper part	4.2	14.7
Silt, gray, calcareous, fossiliferous; contains wood and snails; grades laterally into a sand lens; commonly covered with slumped material from higher units	0.1	0.3
Mudstone, conglomeratic, dark-gray (10YR 4/1), calcaxeous, very compact; base not exposed	0.4	1.3

15. Reference section, Trafalgar and Jessup Formations. Cutbank exposures along a creek 4 miles southeast of Rockville, Parke County, Ind., in the SW¼SW¼ sec. 13, T. 15 N., R. 7 W. (Catlin Quadrangle).

	Thickness m	ft
Trafalgar Formation:		
Center Grove Till Member:		
Silt, clayey, medium yellowish-brown, noncalcareous	1.1	3.6
Mudstone, clayey, silty, conglomeratic, Yellowish-brown, noncalcareous; thin zone of limonitic material at base	0.7	2.3
Mudstone, medium yellowish-brown, conglomeratic, calcareous; upper part soft	2.4	7.9
Mudstone, gray, calcareous, conglomeratic; basal 10 to 20 cm more silty and contains scattered snail shells	1.0	3.3

Jessup Formation:		
Butlerville Till Member:		
Silt, dark grayish-brown, slightly calcareous, fossiliferous; maximum thickness of unit	0.3	1.0
Silt, dark reddish-brown; mottled with gray in lower 30 cm; clayey, slightly conglomeratic, not calcareous; upper surface slightly undulatory	1.3	4.3
Mudstone, brownish-orange, moderately clayey, conglomeratic, not calcareous	0.6	2.0
Mudstone, yellowish-brown; slightly mottled with orange brown; conglomeratic, calcareous, compact	1.0	3.3
Mudstone, medium brownish-gray, calcareous, sandy, conglomeratic, hard	1.8	5.9
Cloverdale Till Member:		
Mudstone, brown, not calcareous, clayey	0.5	1.6
Mudstone, orange-brown, noncalcareous, conglomeratic; lower part of exposure covered with slump; base of unit not exposed	0.4	1.3
Pennsylvanian rocks:		
Shale, light-brown to gray; maximum exposed above creek bed	1.3	4.0

16. Type section, Cartersburg Till Member of the Trafalgar Formation. Cutbank exposure along the southwest side of West Fork of White Lick Creek 2 miles northwest of Cartersburg and 2 miles northeast of Clayton, Hendricks County, Ind., in the SW¼SE¼SW¼ sec. 23, T. 15 N., R, 1 W. (Plainfield Quadrangle).

	Thickness m	ft
Trafalgar Formation:		
Cartersburg Till Member:		
Sand and gravel, brown, locally cemented, lenticular; absent in some places; maximum thickness 7 ft	0.3	1.0
Mudstone, light yellowish-brown, calcareous, conglomeratic	2.4	8.0
Mudstone, bluish-gray, calcareous, conglomeratic; base undulating	1.2	4.0
Silt, laminated to massive, gray; lower 0.5 ft brown; top truncated at contact with till	1.4	4.6
Gravel and sand, grayish-yellow, calcareous; base uneven; interfingers with units 5 and 7	2.4	8.0
Silt, grayish-brown; laminated with clay beds; locally display. inclined bedding	1.0	3.3
Silt, yellowish-gray, very finely sandy; laminated beds of silty clay in upper part; each pair of laminae about 2 cm. thick	0.5	1.7
Center Grove Till Member:		
Silt, medium-gray, calcareous; remains of woody plants at top; snail shells present throughout unit (Appendix B, date W-576)	0.2	0.6
Sand, yellowish-brown, calcareous; locally grades into coarse, rounded gravel; thin zone of Fe2 0. accumulated, at top	1.2	4.0
Mudstone, brownish-gray, calcareous, conglomeratic, sandy and silty, oxidized; base not exposed	2.4	8.0

17. Type section, New Holland Till Member of the Lagro Formation. Cutbank exposure along Rush Creek half a mile south of New Holland, Wabash County, Ind., in the NE¼NE¼ sec. 29, T. 27 N., R. 8 E. (Lagro Quadrangle).

	Thickness m	Thickness ft
Lagro Formation:		
New Holland Till Member:		
Mudstone, conglomeratic; pale yellowish brown in upper part and gray below; clayey, calcareous; contains few pebbles, tough and with blocky fracture; base very even	3.0	9.9
Trafalgar Formation:		
Silt and sand, interbedded, yellowish-gray to orange-brown, laminated, calcareous; lower part involuted	0.6	2.0
Mudstone, yellowish-brown, conglomeratic, silty, clayey, calcareous; contains secondary limonite at top	1.7	5.5
Sand, yellowish-brown, medium- to coarse-grained, lenticular; not present a short distance away	0.3	1.0
Mudstone, dark-gray, clayey, silty, soft; contains a few cobbles	1.5	5.0
Sandstone, coarse-grained, yellowish-brown; cemented with calcium carbonate	0.4	1.0
Gravel, yellowish-brown, coarse, calcareous; base of unit sharp but upper part grades into sand	1.0	3.1
Sand, brownish-yellow, calcareous; contains layers of silt and of pebbles; base gradational	1.5	5.0
Gravel, sandy, light yellowish-brown, calcareous, well-sorted; contains no cobbles	0.4	1.5
Mudstone, light yellowish-brown, silty, sandy, conglomeratic, calcareous	0.6	2.0
Mudstone, medium-gray, silty, sandy, conglomeratic, calcareous; contains a thin silt lens at base; less compact than unit below	2.3	7.5
Mudstone, medium yellowish-gray, silty, sandy, conglomeratic, calcareous, moderately hard and compact; base not exposed	8.2	27.0
Covered	1.2	4.0

18. Type section, Lagro Formation. Cutbank exposure along Lagro Creek about 1 mile northeast of Lagro, Wabash County, Ind., in the SW¼NE¼ sec. 26, T. 28 N., R. 7 E. (Lagro Quadrangle).

	Thickness m	Thickness ft
Lagro Formation:		
New Holland Till Member:		
Mudstone, clayey, dark-brown, noncalcareous	0.75	2.5
Mudstone, clayey, brown, calcareous, very heavy-textured; contains scattered thin lenses of sand	2.4	8.0
Mudstone, clayey, gray, calcareous, very heavy-textured; basal contact zone (5 to 10 cm) is rust colored	4.3	14.0
Trafalgar Formation:		
Mudstone, conglomeratic, yellowish-brown, calcareous	0.75	2.5
Silt and sand, pale yellowish-brown, stratified, calcareous	1.8	6.0

Sand, gray, coarse, calcareous, somewhat clayey and silty; water seeps from this unit	0.3	1.0
Mudstone, gray, calcareous, wet and soft	0.3	1.0
Mudstone, conglomeratic, gray, calcareous, hard; base not exposed	3.3	11.0

19. Reference section, Lagro Formation. Cutbank exposure on west-facing bluff along a branch of Silver Creek about 0.1 mile west of Indiana State Highway 105, Huntington County, Ind., in the SE¼NE¼ sec. 9, T. 28 N., R. 8 E. (Bippus Quadrangle). This section, approximately half a mile south of the exposure illustrated in plate 3A, was measured August 9, 1949.

	Thickness	
Lagro Formation:	In	ft
Mudstone, pale-brown, clayey, heavy-textured; calcareous below soil in top 60 em	3.7	12.0
Mudstone, gray, calcareous; contains lenses of silt as much as 1.5 m thick and lenses of sand	3.1	10.0
Clay, gray, calcareous, heavy-textured	0.15	0.5
Trafalgar Formation:		
Mudstone, gray, conglomeratic, sandy, calcareous, compact; contains thin lenses of sand and silt	4.6	15.0
Mudstone, gray, conglomeratic, sandy, calcareous, very compact, jointed; base not exposed	6.7	22.0

20. Reference section, Martinsville Formation, paludal facies. Ditch bank and core in small peat deposit, from which part of the remains of a mastodon was discovered in 1957 and dug out in 1959 (Wayne, 1960), about 4 miles south of Lagrange, Ind., in the SE¼NE¼NE¼ sec. 18, N., R. 10 E. (Oliver Lake Quadrangle).

	Thickness	
Martinsville Formation, paludal facies:	m	ft
Clay, very silty and mucky, dark blackish-brown; some plant fragments visible	0.30	1.0
Muck, blackish-brown, fine-grained; contains few recognizable plant fragments	0.10	0.3
Peat, dark-brown, fibrous; sphagnum layer; (mastodon bones apparently rested on this layer originally but sank deeper into the next unit below before it became compacted)	0.05	0.1
Peat, dark-brown; fine-grained matrix; shows sedge leaves along bedding; contains seeds, wood fragments, spruce cones, minor amounts of moss, and a few sand grains	0.55	1.8
Peat, dark-brown, very silty; contains scattered pebbles and sand grains; after drying becomes light gray and shrinks only slightly; shows indistinct stratification; only the upper 25 cm exposed-; the lower part examined in a core	1.10	3.6
Lagro Formation:		
Mudstone, conglomeratic, gray, calcareous; hand auger sample seen	(not	determined)

21. Reference section, Martinsville Formation, paludal facies. Bank of an intermittently active marl pit about half a mile north of U. S. Highway 20 and 4 miles west of Angola, Steuben County, Ind., in the NE¼NE¼ sec. 30, T. 37 N., R. 13 E. (Angola West Quadrangle).

	Thickness m	ft
Martinsville Formation, paludal facies:		
Muck, dark-gray	0.15	0.5
Marl, gray; mottled with orange brown in upper part; moderately fossiliferous	1.55	5.0
Marl, yellowisb-white, granular, fossiliferous; base not exposed	0.80	2.1
Marl, granular; apparently similar to unit above but below water level in pit and too "soupy" to sample in a coring tube; not exposed; thickness determined by probing	2.0	6.6
Atherton Formation?:		
Sand, poorly observed	(not determined)	

22. Reference section, Martinsville Formation. Ditch bank exposure about 6 miles east of Pokagon State Park, Steuben County, Ind., in the NE¼SE¼ sec. 2, T. 37 N., R. 14 E. (Angola East Quadrangle). Measured in 1953.

	Thickness m	ft
Martinsville Formation:		
Muck, noncaleareous	0.30	1.0
Clay, grayish-brown, noncaleareous; (alluvial facies)	0.60	2.0
Clay, grayish-brown, calcareous; (alluvial facies)	0.15	0.5
Sand, light-tan, gravelly, highly calcareous; shows minor cross bedding in a few places; maximum thickness; (alluvial facies)	0.60	2.0
Peat, dark-brown, fibrous; contains abundant wood fragments and Picea cones; (paludal facies); dated as 13,020 years B. P. (Appendix B, date W-65)	0.10	0.3
Marl, gray, peaty, clayey and slightly pebbly; mollusks common; (paludal facies)	0.20	0.6
Lagro Formation:		
Mudstone, gray, conglomeratic, calcareous; base not exposed	0.20	0.6

APPENDIX B. INDIANA RADIOCARBON DATES

Date		Years B. P.[1]
Arnold, J. R., and Libby, W. F., 1951, Radiocarbon dates: Science, v. 113, p. 111-120.		
C-364	Dalton, Ill. (p. 115); Tolleston level of Lake Chicago	3,469±230
(no number)	Two Creeks, Wis. (p. 118); average of five samples from peat and wood beneath Valders drift	11,404±350

[1] Before present.

Libby, W. F., 1951, Radiocarbon dates II: Science, v. 114, p. 291-296.

C-500 Cass County, Ind. (p. 293); peat from 22 to 23 ft of depth (pine-oak transition level) . . . . 5,625±310

C-526 Bellevue, Ohio; wood from beach level of Lake Lundy . . . . 8,513±500

Libby, W. F., 1952, Chicago radiocarbon dates III: Science, v. 116, p. 673-681.

C-674 Chicago, Ill. (p. 674); 58th St. at Ellis Ave. on University of Chicago campus; wood from an excavation, beneath 14 ft of stratified sand; Tolleston phase of Lake Chicago . . . . 8,200±480

C-675 Illinois, near Dyer, Ind. (p. 675); wood from alluvial fill along Plum Creek; thought to represent Calumet phase of Lake Chicago . . . . 1,850±480

Libby, W. F., 1954, Chicago radiocarbon dates IV: Science, v. 119, p. 135-140.

C-801 Illinois, near Dyer, Ind. (p. 137); wood from sand ridge regarded as Glenwood phase beach of Lake Chicago . . . . 10,972±350

Libby, W. F., 1954, Chicago radiocarbon dates V: Science, v. 120, p. 733-742.

C-871 Illinois, near Dyer, Ind. (p. 735); same deposit as C-801 but 4 ft deeper in sand; also regarded as Glenwood phase of Lake Chicago . . . . 18,500±500

C-872 Illinois, near Dyer, Ind. (p. 735); same location as C-871 but wood was taken from fine-grained sediments beneath the beach deposit 21,000

Suess, H. E., 1954, U. S. Geological Survey radiocarbon dates 1: Science, v. 120, p. 467-473.

W-33 Cleveland, Ohio (p. 469); wood from position between deposits of Lake Arkona below and Lake Whittlesey above. This phase change in the Great Lakes has been regarded as correlative with the end of the Cary Subage (Flint, 1947, P. 255) and postdates the deposition of the Lagro Formation in Indiana . . . . 13,600±500

W-37 Ohio, south of Dayton (p. 469); wood beneath 16 ft of till at Camden Moraine; probably same position as base of Tratalgar Formation in central Indiana . . . . 20,700±600

W-58 Noble County, Ind. (p. 470); wood from paludal-ficies of Martinsville Formation that was interbedded with gravelly alluvial facies sediments; part of fossil zone (fig. 7). . . . . .12,380±360

W-59 Porter County, Ind. (p. 470); wood from gravelly alluvial facies, of Martinsville Formation along Kankakee River .... 7,990±2OO

W-61 Noble County, Ind. (p. 470); gyttja beneath 3 m of marl (paludal facies of Martinsville Formation); overlying marl contains mollusks typical of fossil zone i (fig. 7) .... 6,720±2OO

W-64 Wabash County, Ind., near Laketon (p. 476); gyttia from base of paludal facies of Martinsville Formation beneath 3.6 m, of marl; overlying gravel facies of the Atherton Formation .... 13,140±4OO

W-65 Steuben County, Ind., near Fremont (p. 470); (see also M-350); woody peat from thin bed of paludal facies of Martinsville Formation overlain by gravelly alluvial facies of the formation and underlain by till of the Lagro Formation. Mollusks typical of fossil zone (fig. 7); (Appendix A, section 22) .... 13,020±4OO

W-92 Oxford, Ohio (p. 469); wood from forest bed beneath 18 m of till, probably at base of Trafalgar Formation .... 19,980±500

Rubin, Meyer, and Suess, H. E., 1955, U. S. Geological Survey radiocarbon dates II: Science, v. 121, p. 481-488.

W-140 Illinois, near Dyer, Ind. (p. 483); same as C-801; peat bed at base of Glenwood phase oi Lake Chicago beach sand, which overlies till .... 12,650±350

W-161 Illinois (p. 483); same location as W-140 but in sand stratigraphically above it .... 12,200±350

W-165 Greencastle, Ind. (p. 483); wood from contact at base of Trafalgar Formation with a silt containing mollusks (fig. 7); (for measured section see Bieber, 1955, p. 207) .... 19,500±8OO

W-198 Ohio, near Metz, Ind., at intersection of Ohio State Highway 49 and Ohio Turnpike (p. 483); small wood fragments in a lens of clayey silt overlying till of Lagro Formation .... 14,300±450

Rubin, Meyer, and Suess, H. E., 1956, U. S. Geological Survey radiocarbon dates III: Science, v. 123, p. 442-448.

W-254 Ohio River, Warrick County, Ind. (p. 446); wood from laminated clay beds underlying about 21 ft of alluvial facies sediments of Martinsville Formation, exposed along north bank of Ohio River 1,000 ft west of Warrick-Spencer county line .... 6,410±160

W-270 Ohio River, Owensboro, Ky. (p. 446); wood from peaty silts underlying about 30 ft of Atherton Formation gravelly sand and marl, exposed along south bank of Ohio River about 1.6 miles east of bridge at Owensboro .... 23,150±500

Rubin, Meyer, and Alexander, Corrinne, 1958, U. S. Geological Survey radiocarbon dates IV: Science, v. 127, p. 1476-1487.

W-325	Delaware County, Ind.; wood from ditch along Buck Creek (p. 1477; for section see Wayne and Thornbury, 1955, p. 23-24); dated bed, containing mollusks characteristic of fossil bed j, is overlain by the alluvial facies of Martinsville Formation containing species of fossil bed k (fig. 7)	9,755±300
W-349	Farm Creek, 111. (p. 1478); wood from top of tongue of Peoria Loess Member of Atherton Formation, which lies beneath Trafalgar Formation.	20,340±750

Rubin, Meyer, and Alexander, Corrinne, 1960, U. S. Geological Survey radiocarbon dates V: Am. Jour. Sci. Radiocarbon Supp., v. 2, p. 129-185.

W-520	Jefferson County, Ky. (p. 147); wood from silt (lacustral facies?) of Atherton Formation at Pleasure Ridge Park, Louisville, Ky	18,530±500
W-576	Hendricks County, Ind. ("Clayton Cut"); wood and twigs from silt between Cartersburg and Center Grove Till Members of Trafalgar Formation (Appendix A,. section 16)	ca. 20,000 (est.)[2]
W-577	Parke County, Ind. (p. 139); wood from peaty fossiliferous silt at base of Trafalgar Formation in the SW¼ SW¼ sec. 15, T. 15 N., R. 7 W	20,500±800
W-578	Marion County, Ind. (p. 139, Trader's Point); wood and twigs from fossiliferous silt. Present corre lation of unit is middle of Butlerville Till Member of Jessup Formation; fossil bed e (fig. 1). (See also W-814.)	>37,000
W-579	Marion County, Ind. (p. 140); wood from tongue of gravel facies of Atherton Formation at base of Trafalgar Formation in stream cut in the SW¼ SW¼ sec. 28, T. 17 N., R. 2 E	20,800±800
W-580	Johnson County, Ind., near Trafalgar (p. 140); wood from base of Trafalgar Formation at type section (Appendix A, section 10)	20,900±800
W-595	Hendricks County, Ind. (p. 140, "Clayton Cut"); wood from Center Grove Till Member of Trafalgar Formation near base of cut. (See section on p. 77.)	22,300±800
W-597	Johnson County, Ind., near Trafalgar (p. 597); wood from silt at top of Center Grove Till Member at type section of Trafalgar Formation (Appendix A, section 10)	20,300±800

[2] Sample inadequate to yield date (Rubin, oral communication, 1955).

W-598	Johnson County, Ind., near Trafalgar (p. 140); wood from top of silt at top of Center Grove Till Member at type section of Trafalgar Formation (Appendix A, section 10)	20,100±800
W-645	Warrick County, Ind. (p. 141); wood from lacustral facies of Atherton Formation exposed in ditch in the NE¼SE¼ sec. 8, T. 7 S., R. 8 W	19,940±300
W-648	Greene County, Ohio (p. 152), Wright-Patterson Air Base southwest of Fairborn; wood from till of Trafalgar Formation	21,600±400
W-663	Parke County, Ind., north of Mansfield (p. 141); wood from contorted peat embedded in base of Trafalgar Formation at Wisconsin glacial boundary (Thornbury and Wayne, 1957, p. 8, 9)	23,300±600
W-666	Vigo County, Ind., near Farmersburg (p. 141); wood exposed in stream bank at base of alluvial facies of Martinsville Formation	4,040±250
W-668	Vigo County, Ind., northwest of Terre Haute (p. 141); wood from base of Trafalgar Formation about a mile north of Wisconsin glacial boundary in creek bank in the NW'/4NE'/4 sec. 9, T. 12 N., R. 10 W	21,400±650
W-669	Parke County, Ind., west of Mansfield (p. 141); wood from peat bed at top of Cloverdale Till Member at type section of Jessup Formation (Appendix A, section 14) in the SE¼SE¼ sec. 2, T. 14 N., R. 7 W	>36,000
W-680	Posey County, Ind., near Mt. Vernon (p. 142); wood in ditch bank cut in Martinsville Formation in east side of sec. 21, T. 6 S., R. 12 W	640±200
W-724	Butler County, Ohio, near Hamilton (p. 152); wood from the upper of two till beds in Trafalgar Formation in the exposure	19,100±300
W-814	Marion County, Ind. (p. 142); Trader's Point section near Zionsville; same as W-578	>38,000
W-832	Posey County, Ind. (p. 142); wood from sediments that probably are part of Martinsville Formation but may resemble lacustral facies of Atherton Formation	7,030±360
W-867	Union County, Ky., near Shawneetown, 111. (p. 139); from highly fossiliferous bed at top of basal unit of Peoria Loess (Appendix A, section 1)	22,200±450
W-871	La Salle County, Ill., Wedron Quarry (p. 139); wood from fossiliferous silt over bedrock, which underlies complex series of beds correlatable with Trafalgar Formation	26,800±700

Olson, E. A., and Broecker, W. S., 1959, Lamont natural radiocarbon measurements V: Am. Jour. Sel. Radiocarbon Supp., v. 1, p. 1-28.

L-414 Wayne County, Ind., Darrah Farm section (p. 12); peaty materials at top of Butlerville Till Member of Jessup Formation; date obtained from humic acids; (for measured section and discussion see Gamble, 1958, p. 18-23, and Wayne and Thornbury, 1955, p. 32) . . . . >41,000

Deevey, E. S., Gralenski, L. J., and Hoffren, Väinö, 1959, Yale natural radiocarbon measurements IV: Am. Jour. Sci. Radio carbon Supp., v. 1, p. 144-172.

Y-450 Butler County, Ohio, near Darrtown (p. 148); spruce log embedded in till; probably correlative with the upper part of the Trafalgar Formation in east-central Indiana . . . . 15,560±230

Crane, H. R., 1956, University of Michigan radiocarbon dates I: Science, v. 124, p. 664-672.

M-66 Orleton Farms, Madison County, Ohio (p. 666); wood from beneath a mastodon skeleton in marl (equals paludal facies of Martinsville Formation). . . . . 9,600±500

M-138 Noble County, Ind. (p. 667); wood associated with Richmond Mastodon, taken from marl and peat that are part of paludal facies of Martinsville Formation. (Note: This sample probably does not date the death of the mastodon; see date M-139.). . . . . 5,300±400

M-350 Steuben County, Ind. (p. 669); same as W-65 . . . . 12,600±600

Crane, H. R., and Griffin, J. B., 1958, University of Michigan radiocarbon dates II: Science, v. 127, p. 1098-1108.

M-139 Noble County, Ind., Cromwell (p. 1099); tusk fragments of Richmond Mastodon, which was embedded in marl and peat of the Martinsville Formation. (See M-138) . . . . 12,630 ±1,000