

CORRELATION OF THE GLACIAL BORDER DRIFT OF NORTH CENTRAL WISCONSIN.*

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ABSTRACT. The glacial Border drift of north central Wisconsin lies north of the Driftless Area and south of the prominent moraine of the Cary substage of the Wisconsin stage. Because of the thinness of the drift, the subdued topography of the area, the acidity of the soils, their high silt and clay content and tough subsoil, the Border drift has been considered to be very old. The writer, however, finds that the silty topsoil is loess and the subsoil is drift, the two being somewhat admixed. Relatively good preservation of drift constituents and shallow depths of leaching of locally occurring carbonates indicate that the Border drift is of Wisconsin age.

INTRODUCTION.

THE field work by the writer was done in the summers of 1940, 1941, and 1942, and consisted of the study of over a thousand soil profiles. This study extended through and included the "C" and underlying horizons, wherever exposures of the substratum were found, and where texture of materials permitted the use of the soil auger at depth. At three localities in the vicinity of Marshfield, Wisconsin, samples were taken with a four-inch post hole auger, with the aid of a mast and pipe extensions, to a maximum depth of 34 feet. At 27 localities, shown as dots in Text Fig. 2, samples were taken from several horizons and mechanically analyzed.

ACKNOWLEDGMENTS.

The writer is especially indebted to Prof. F. T. Thwaites, of the University of Wisconsin, for introducing him to the problem of the Border drift, and for guidance and encouragement in the field and in the laboratory. Mr. E. F. Bean, Wisconsin State Geologist, made available the records and facilities of the Survey, and contributed his personal observations on the Pleistocene of north central Wisconsin. Prof. Emil Truog, and Drs. M. L. Jackson, L. B. Nelson, and R. J. Muckenhirn, of the Soils Department of the University of Wisconsin, provided laboratory facilities and made helpful suggestions. Dr. L. R.

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Wilson, of Coe College, studied pollen from a buried soil sample collected by the writer. Prof. A. R. Whitson, Dr. Frank Lev-erett, and Mr. James Thorp have been kind enough to discuss various aspects of the problem with the writer.

DESCRIPTION OF THE AREA.

The part of north central Wisconsin examined by the writer has an area of about 7,200 square miles. Rib Mountain, the highest point (Text Fig. 3), has an elevation of approximately 1,940 feet, and where Black River crosses the southern bound-ary of Clark County, the elevation is less than 870 feet. The surface is that of a gently rolling plain which slopes south and is somewhat dissected along the Wisconsin and Black Rivers. Pre-Cambrian crystallines form the bed-rock in the northern



Text Fig. 1. Outline map of Wisconsin, showing location of north central Wisconsin.

part, and Cambrian sandstones, siltstones, and shales underlie the southern part. Except for an east-west strip ten miles wide, on the south, the bedrock is covered with a mantle of glacial drift. A prominent moraine of the Cary substage of the Wisconsin stage extends across the northern and eastern parts of the area. Where the moraine attains a width of over five miles, it may be termed a morainal zone. South and west of the moraine, the glacial drift is a veneer which is about ten feet thick and lies on a subdued preglacial bedrock topography. This extra-morainal, thin mantle of glacial drift is the Border

drift. It is not possible to establish a definite boundary between the Border drift area and the Driftless area on the south, because the drift becomes gradually thinner and exhibits no terminal moraine (Text Fig. 7).

Four main types of topography may be distinguished in north central Wisconsin, as follows: (a) the plain and butte topography of the sandstone country in the south and southwest, (b) the mature erosional topography of the upper Wisconsin River valley on the east, (c) the rugged knob and sag topography of the prominent moraine on the east and north (Pl. 1, Fig. 1), and (d) the gently rolling topography of the Border drift (Pl. 1, Fig. 2), lying between the other three.

PREVIOUS STUDIES.

Correlation of the Border drift has proved difficult. T. C. Chamberlin termed this drift "earlier" drift, relative to the recognized Wisconsin moraine. Weidman distinguished, chiefly on the basis of topography, three (Text Fig. 2) and later four Border drifts. In his earlier report (1907), he referred to these drifts by number, without attempting to correlate them with glacial drifts of Iowa and other states. Later, Weidman (1913) suggested correlations of the Border drifts, which, in present day terms (Thwaites, 1939, p. 72), would refer to the Tazewell and Iowan substages of the Wisconsin stage, and the Kansan, and possibly the Nebraskan glacial stages. Leverett spent the summer of 1923 in the area. In 1929, his maps were published by Antevs, showing the Border drift as Illinoian, but his own published maps of the same year classify it as "undifferentiated drift" and "pre-Wisconsin drift." Leverett differed from Weidman in regarding the ridge which extends from Marshfield to Neillsville (Text Fig. 3) as a recessional moraine of the Illinoian glaciation, although he was not certain of this correlation. In 1940, Thwaites discovered that samples of

Plate 1.

Fig. 1. Cut in "red" till in a rugged portion of the prominent Cary Wisconsin moraine, Taylor County. At this place, the till is slightly calcareous below a depth of 20 feet.

Fig. 2. Typical subdued Border drift topography, showing dense forest and a farmer's rock pile of glacial boulders, south of Marshfield.

Fig. 3. Strongly mottled and streaked silty Spencer topsoil lying on brown glacial till, southeast of Neillsville.



Fig. 1

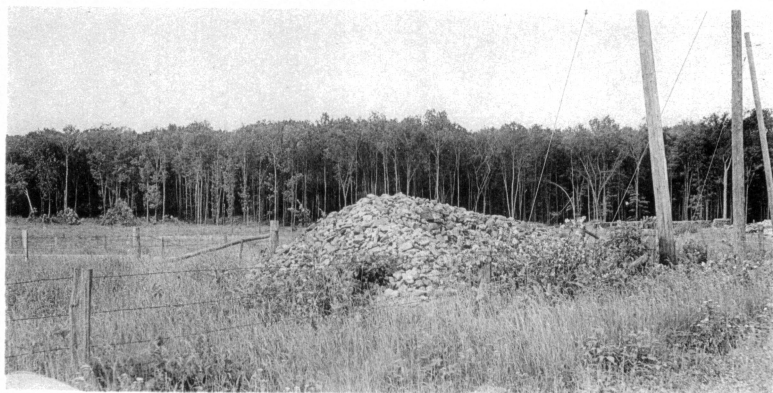


Fig. 2

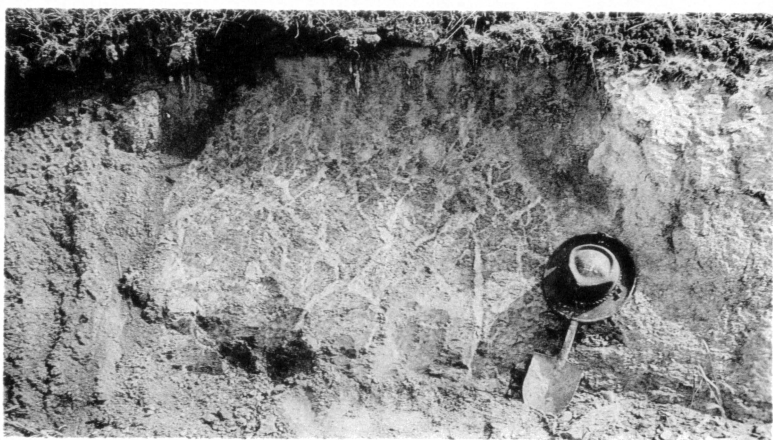
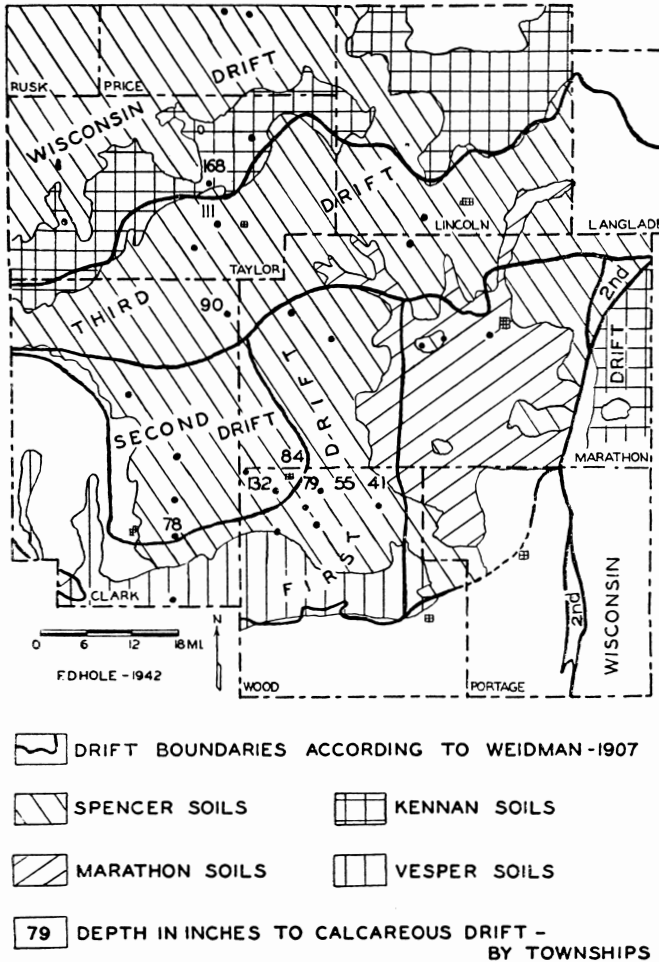


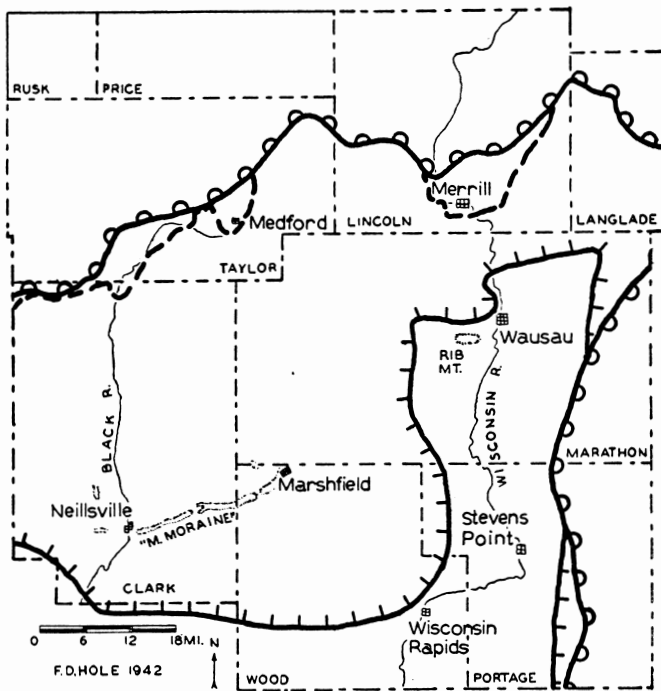
Fig. 3

Border drift taken by Musbach in a well at the Marshfield Agricultural Experiment Station are high in carbonate content. He correlated this fact with the analyses of drift ground waters (Weidman and Schultz, 1915; Bur. Sanitary Engineering, Wis., 1935) of that part of north central Wisconsin, which are much higher in total solids and hardness than would be expected






Text Fig. 2. Sketch map of north central Wisconsin showing glacial drift boundaries according to Weidman (1907), and soils, as mapped by Whitson. Dots represent localities from which samples were taken by the writer for mechanical analysis.

in a region of crystalline rocks. Bean found numerous sandstone outcrops near the crest of the "Marshfield moraine" and concluded that it is essentially a rock ridge with a drift mantle. He suggested that well logs which show great thicknesses of drift in the "moraine" probably report unconsolidated Cambrian sandstone as drift. Bean regarded the silty topsoil as loess, rather than as highly weathered drift. Whitson mapped the Spencer (Colby) and other soils (Text Fig. 2) in the area, and considered them to be very old soils, developed from old

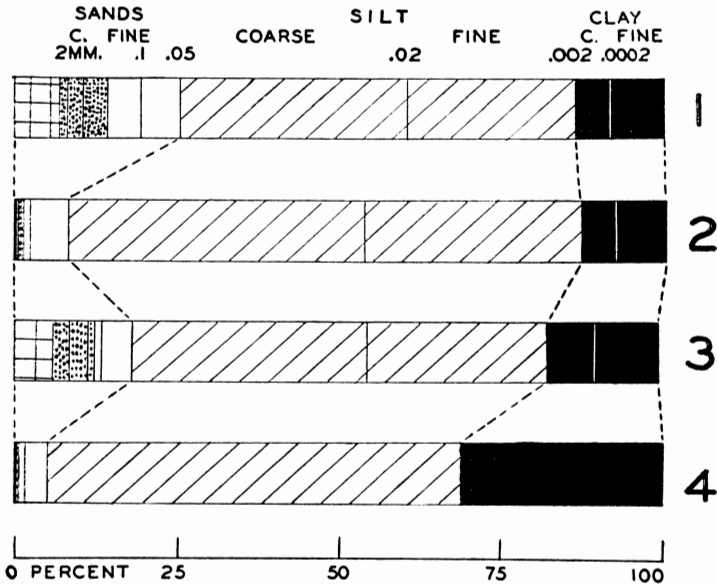


DRIFT BOUNDARIES ACCORDING TO FRANK LEVERETT
1929

-  OUTER BOUNDARY OF MORAINES, SUBSTAGES 3&4, WISCONSIN STAGE.
-  "LIMIT OF WIS. DRIFT OUTSIDE OF ST. CROIX MORAINIC SYSTEM & CORRELATED MORAINES."
-  "LIMIT OF FAIRLY DEFINITE PRE-WISCONSIN.... (DRIFT) ON BORDER OF DRIFTLESS AREA...."

Text Fig. 3. Sketch map of north central Wisconsin, showing drift boundaries according to Leverett, the "Marshfield moraine," and Rib Mountain.

drift and residual materials, and to be covered with a "loess-like blanket" (Whitson, 1918, p. 28). Whitson mapped the Spencer soil both north and south of the prominent Cary Wisconsin moraine. Martin regarded the sandstone mounds northwest of Neillsville as nunataks. Kellogg found that little or no colloids have accumulated in the subsoil of the Spencer and related soils, and concluded that the soils are immature. In the adjoining area of northwestern Wisconsin, Mathiesen



Text Fig. 4. Diagrams of mechanical analyses of silty topsoil of north central Wisconsin, and of a sample of Peorian loess: (1) silty topsoil, representing 22 localities in north central Wisconsin; (2) silty topsoil, representing 1 locality in east central Clark County; (3) silty topsoil, summit, Rib Mt.; (4) Peorian loess, Osceola County, Iowa (Orrben, et al.).

remapped Weidman's three Border drifts as Cary, Iowan, and pre-Iowan in age. Nelson and Muckenhirn investigated fertility and drainage conditions in the Spencer soil area and concluded that the soil is young, and consists of a silty deposit on glacial drift.

SILTY TOPSOIL.

The silty "loess-like blanket" is from two to three feet thick. The mechanical analyses of this material (Text Fig. 4) show that the silty horizon resembles Peorian loess of Iowa (Orrben,

et al.), and is very different from the underlying glacial till of north central Wisconsin (Text Figs. 5 and 6). The stones and sand grains in the silty topsoil may have been pulled up from the substratum by roots of falling trees¹ or by the activity of rodents.²

The Spencer soils were mapped, both north and south of the prominent moraine, wherever the substratum is impervious enough and surface drainage is poor enough to permit mottling to show in the silty topsoil (Pl. 1, Fig. 3). In most places, the substratum is glacial drift. In the vicinity of the Wisconsin River valley, mottling is locally present in the topsoil. No clear evidence has yet been presented of a glacial origin of the subsoil at those places. The Marathon soil was mapped where the silty topsoil is unmottled and lies on pre-Cambrian crystalline bedrock or on one or two feet of drift on bedrock. This is the situation near the Wisconsin River valley (Text Fig. 2). Where silty or sandy topsoil lies on Cambrian sandstone, siltstone, or shale, or on thin drift on Cambrian bedrock, the soils have been termed Vesper. The silty horizon is absent in rough portions of the Cary Wisconsin moraine, where Kennan soils are mapped.

At many places, the contact between the silty topsoil and the glacial drift beneath is a sharp one. The drift has recently been recognized by soil scientists (Muckenhirn and Nelson, 1942) as a "C" horizon of a young soil rather than as a "B₂" horizon of an old soil.

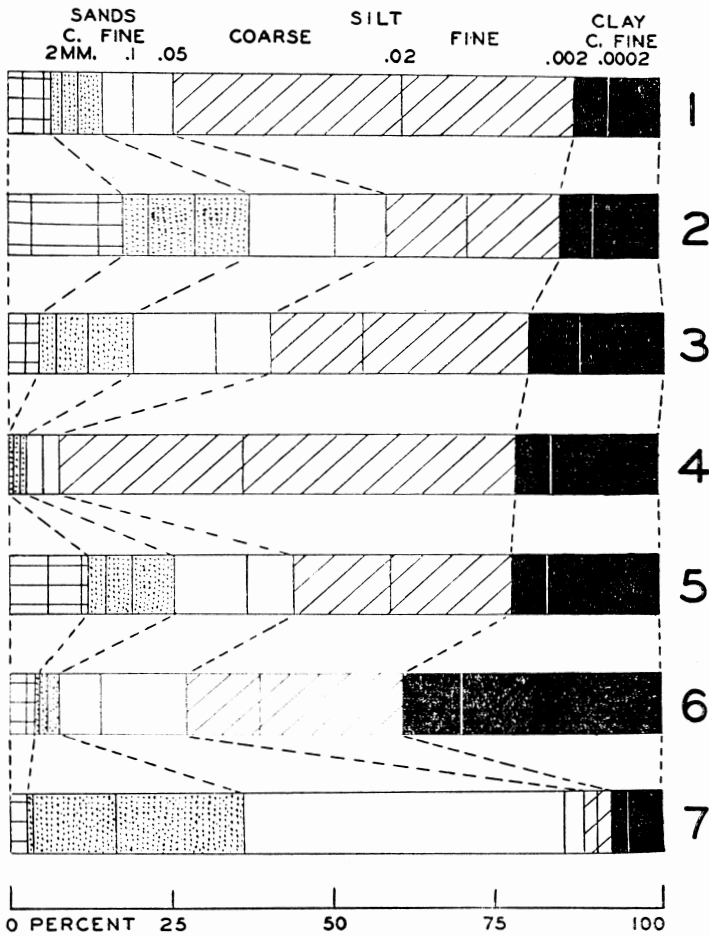
The stones and sands in the silty horizon resemble lithologically and mineralogically the stones and sands of the substratum, whether this consists of Pleistocene or Cambrian or pre-Cambrian materials. Rib Mountain (Text Fig. 3) is a driftless quartzite monadnock. The silty soil which occurs on it is similar in appearance, mechanical composition, and mineralogic composition to the silty horizon on till to the west and north, except that sand and gravel in the soil on Rib Mountain are entirely derived from quartzite.

Preliminary lithologic and mineralogic examination of silt

¹ The area was formerly covered by a mixed conifer and hardwood forest (Pl. I, Fig. 2), and windfalls must have occurred under virgin forest conditions. Many wood lots in the area show a pit and hummock topography which was clearly produced by falling trees.

² In some glaciated states which lie south of Wisconsin, a similar mixing of soil horizons has been ascribed to crayfish, as well.

particles, sands and pebbles in both the silty horizon and the glacial drift shows that minerals are only slightly weathered. The acidity of the soil and deficiency of available plant nutrients is probably a result of conditions prevailing under the virgin conifer-hardwood forest, rather than a result of great age of the soil. The conditions referred to are those which permit podzolic leaching and poor drainage.



Text Fig. 5. Diagrams of mechanical analyses of seven types of materials in north central Wisconsin: (1) silty topsoil, representing 22 localities; (2) glacial till, 24 localities; (3) calcareous till, 3 localities; (4) material on which buried soils rest, 2 localities; (5) subsoil, Wisconsin River valley area of thin or no drift, 2 localities; (6) Cambrian red-brown shale, 2 localities; (7) Cambrian unconsolidated sandstone, 1 locality.

The silty topsoil occurs on slopes, on uplands, and in small valleys.

The evidence cited above substantiates the view held by Bean, Whitson, Thwaites, and others, that the silty horizon is a loess deposit into which sand and gravel have been admixed.

COMPOSITION OF DRIFT.

The drift below the topsoil is largely till, but lenses of sorted materials are numerous. Some of the thicker lenses are the sites of gravel pits, as, for example, those just west of Marshfield.

The chemical nature of the drift is here described chiefly in terms of depths to calcareous drift, as measured in the field. The total chemical analysis of a sample of calcareous "clay" from northeastern Wood County, reported by Weidman (1907, p. 559), was duplicated by the writer when he analyzed a sample of calcareous silty till taken with a post hole auger at a depth of nine feet in the northwest corner³ of the same county. Over three fourths of the carbonate material is calcium carbonate and more than 80 per cent of the total carbonate content of the till is in particles which pass through a 100-mesh sieve. The writer found calcareous drift in 19 sections which lie in a strip of territory three miles wide and extending from the northwest corner of Wood County southeast through Marshfield for a distance of 20 miles.⁴ This strip roughly coincides with a low stream divide where drift is unusually thick. The calcium carbonate equivalent content constitutes about one fifth of the material by weight. Similar calcareous drift is present at a place on the "Marshfield moraine" near Granton,⁵ about half way between Marshfield and Neillsville, and at the North Mound fire tower,⁶ northwest of Neillsville. The calcium carbonate equivalent content of red-brown drift at one locality in northeastern Clark County⁷ is five per cent. At two places⁸ in the Cary moraine in Taylor County, the calcium

³ N.W. $\frac{1}{4}$ N.E. $\frac{1}{4}$ Sec. 6, T. 25 N., R. 2 E.

⁴ The calcareous silty till is exposed in roadside ditches in Secs. 28, 29, 30, 31, 32, 33, T. 25 N., R. 5 E.

⁵ S.E. $\frac{1}{4}$ S.E. $\frac{1}{4}$ N.E. $\frac{1}{4}$ Sec. 10, T. 24 N., R. 3 W.

⁶ At the tower cabin, Sec. 4, T. 26 N., R. 3 W.

⁷ N.W. $\frac{1}{4}$ S.W. $\frac{1}{4}$ S.W. $\frac{1}{4}$ Sec. 23, T. 29 N., R. 1 E.

⁸ S.W. $\frac{1}{4}$ S.W. $\frac{1}{4}$ S.W. $\frac{1}{4}$ Sec. 6, T. 31 N., R. 1 E. and 0.6 mile N. of south line of Sec. 13, T. 32 N., R. 1 E., on Highway No. 13.

carbonate equivalent content is two per cent. Marl is reported from Taylor, Price, and Rusk Counties. The depths to calcareous drift increase from southeast to northwest (Text Fig. 2).

Only very small pieces of limestone were found. The silty, calcareous till in the vicinity of Marshfield contains about .001 per cent by weight of water-worn granules of limestone. Nine tenths of these are pure calcium carbonate limestone, as determined by the Lemberg staining test. They are distinctly different from the rough, calcareous concretions of about the same size which are present locally in the same drift, and which consist of clay, silt, and sand cemented with carbonates. The calcium carbonate equivalent content of these unbanded concretions is 75 per cent. A single small crinoid stem was found in one sample of calcareous silty till.

Decomposed pebbles are present in both the Border drift and the Cary Wisconsin drift. Preliminary studies indicate that undecomposed pebbles, sand grains, and coarse silt particles appear to be as little altered in one part of north central Wisconsin as in another.

Pebble counts made in the Border drift and reported by Bean show that over 25 kinds of rocks are represented. Among them are some striking types of iron formation and Keweenaw conglomerate which must have come from the Lake Superior basin.

The red-brown color of the drift is apparently inherited from the materials which the glacier encountered. There is no evidence that the distribution of red-brown drift is related to topography and drainage conditions. The color is contained in the fine clay portion of the drift. The shade of red-brown is matched both by the red brown of Lake Superior clays, and by that of Cambrian shales south of Marshfield. Gray-brown and gray drift materials also occur in the Border drift area. In some exposures, materials of two colors interpenetrate.

Results of mechanical analyses of several types of materials are shown in Text Fig. 5. The abundance of silt and clay in parts of north central Wisconsin has led some students of the area to believe that the Border drift displays a high degree of chemical alteration. However, the unaltered condition of many mineral particles in the drift suggests mechanical comminution of rocks. A summary of mechanical analyses of ground moraine (Text Fig. 6) from four drift areas, as distinguished by Weidman in 1907 (Text Fig. 2), indicates that the drift of

north central Wisconsin may be divided on the basis of texture into two regions (Text Fig. 7). However, no definite boundary can be drawn between the area of stony till and that of silty till. At present, it appears that the zone of transition between the two approximates the "Third Drift" boundary of Weidman. This division of north central Wisconsin into two zones on the

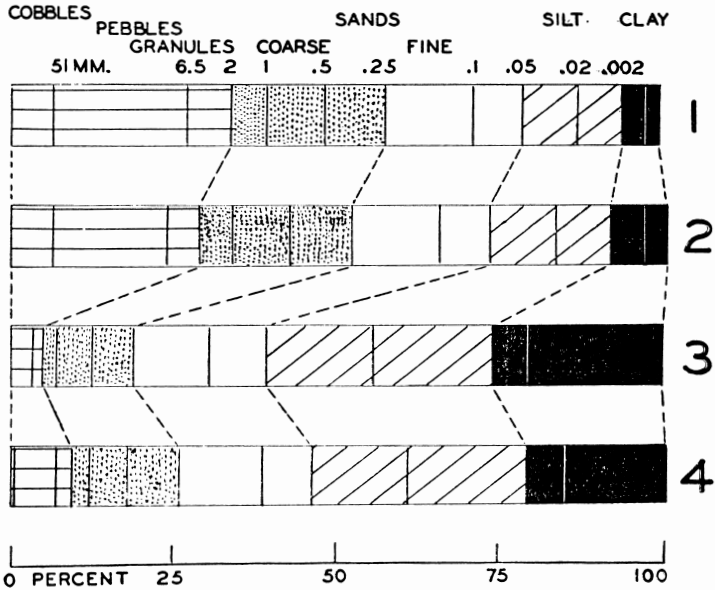


Fig. 6. Diagrams of mechanical analyses of ground moraine in four glacial drift areas of north central Wisconsin, as distinguished by Weidman: (1) Cary Wisconsin drift, representing 3 localities; (2) Weidman's "Third drift," 5 localities; (3) Weidman's "Second drift," 4 localities; (4) Weidman's "First drift," 5 localities.

basis of texture of drift is a generalization to which there are numerous exceptions in the area of silty till, where heterogeneity of drift is outstanding. For example, the till on the "Marshfield moraine" just west of Marshfield⁹ is as stony as till in the Cary moraine in Taylor County.

STRATIGRAPHY OF DRIFT.

No evidence of an earlier, buried till was found. Chamberlin (1883, p. 272) pointed out the danger of confusing buried ice-laid deposits with aqueous and aeolian deposits. At several

⁹ S.W.¼ S.E.¼ S.W.¼ Sec. 13, T. 25 N., R. 2 E.

places on the ridge between Marshfield and Neillville, road cuts expose the contact between till and sandstone bedrock. At the Marshfield Agricultural Experiment Station,¹⁰ and at a place ten miles southeast thereof,¹¹ and at another place ten miles to the northwest,¹² the writer put down holes with a post hole auger to a depth of about 30 feet. Samples were taken at every foot. Observed depths to highly calcareous silty till were three, seven, and eleven feet, respectively, reading from southeast to northwest. This variation appears to be related to topography which changes from flat land to gently rolling country in this interval. At the southeastern locality, 2.5 feet of loess lies on eight feet of highly calcareous gray-brown silty till. Below that, calcareous gray silty till extends to a depth of 30 feet, where disintegrated granite bedrock is encountered. At the Marshfield Experiment Station a black layer, containing 15 per cent of organic matter, some of which is pollen, lies at about 20 feet, and is underlain at a depth of 21 feet by two feet of noncalcareous gray silt. At the northwestern locality, the owner of the farm found peat, which could be burned after drying, at a depth of 20 feet. The writer found only a dull brown, banded layer, containing no pollen, at the contact between the highly calcareous till and the underlying non-calcareous gray silt. The gray silt was penetrated to a depth of five feet. In east central Clark County,¹³ a black layer measuring four inches in thickness is exposed in a six-foot road cut. The black layer has an organic content of five per cent. It underlies three feet of loess and two feet of till, and rests on gray, fine and very fine sand. Thwaites reports¹⁴ that well records from towns in north central Wisconsin show that till lies on bedrock or on gravel, sands, and clays, which do not resemble till.

AGE OF DRIFT.

The Border drift has been considered by some to be an old drift because of its thinness, high silt content, red-brown color, presence of decomposed pebbles, and the subdued topography

¹⁰ N.W.¼ S.W.¼ N.W.¼ Sec. 22, T. 25 N., R. 3 E.

¹¹ S.E. Cor. S.E. ¼ S.W. ¼ Sec. 30, T. 25 N., R. 5 E.

¹² N.W. ¼ N.E. ¼ Sec. 6, T. 25 N., R. 2 E.

¹³ N.E.¼ N.W.¼ N.W.¼ Sec. 34, T. 26 N., R. 1 W.

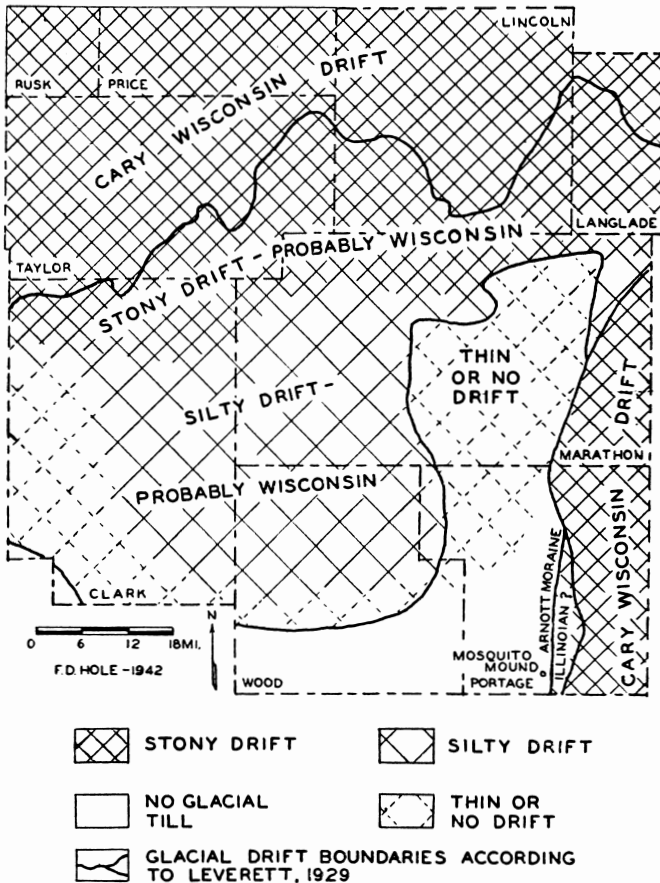
¹⁴ Personal communication.

of the area. Early geologists apparently were greatly impressed by the presence of relatively few decomposed stones in the drift. However, they did not take into account soil profiles, the nature and significance of which were not then well understood. Various types of evidence which suggest that the Border drift is a young drift are: shallow depths of leaching of locally occurring carbonates in the drift, absence of any significant abrupt change in character of drift, bedrock control of topography, absence of a topographic unconformity (Thwaites, 1939, p. 61) between constructional and erosional slopes, presence of a large percentage of unaltered stones, sands and silt in the drift, heterogeneity of the Border drift with respect to both color and composition, presence of a similar loess deposit both north and south of the Cary moraine, and lack of accumulation of colloids in lower horizons of soils developed on the drift. No single type of evidence of the youth of the Border drift can be used alone to fix the age of the drift. This is because the two criteria, topography and leaching, which have been widely used in the correlation of glacial drifts in the middle west, cannot be applied with precision in this area. Standards have not been set up by glacial geologists to permit the use of the remaining types of evidence as the sole basis of a detailed correlation. The writer submits that the Border drift is clearly a Wisconsin drift, but that it is impossible to say which substage it represents.

The depths of leaching (Text Fig. 2) in the Border drift range from three to eleven feet. Two to three feet of loess are included in these measurements. The average depth is five feet, but, as Thwaites has pointed out (1939, p. 65), averages lose value when range of depths is wide. Considerable variation in depth to calcareous till occurs within a few tens of yards in the area of silty till. Porosity of bedrock, texture of till, thickness of loess and colluvium, and topography appear to be the factors that have controlled drainage and depth of leaching. It is apparently not possible to use depths of leaching in drift in north central Wisconsin for purposes of correlation with the certainty with which such data are used in Indiana, Illinois, and Iowa. Descriptions of Lindley, Miami, and Carrington soils by Kellogg show that Illinoian drift is leached to depths of 4.5 to 6 feet in Wisconsin, whereas Cary Wisconsin drift is leached to depths of 2.5 to 4.5 feet. It is possible that long winters have caused depths of leaching to be shallower in north

central Wisconsin than in Iowa, and that local variations in texture, topography, vegetation, original carbonate content of drifts, and thickness of loess mantle have obscured the effect of time. It may be argued that long winters have so inhibited leaching that depths of three or four feet to calcareous till are not inconsistent with a correlation of the Border drift with Illinoian drift in states farther south. It may be argued, at the other extreme, that because the thin Border drift shows, in places, depths of leaching which are as shallow as, or shallower than, those in the thicker Cary drift in north central Wisconsin, it follows that the Border drift is also Cary in age.

The absence of any consistent abrupt change in lithologic



Text Fig. 7. Sketch map of north central Wisconsin, showing correlation of drifts according to the writer.

nature of pebbles, mechanical composition and topography of drift in north central Wisconsin is striking. It is not apparent that the gradual changes from south to north of dominantly silty drift to dominantly stony drift, of thin drift to thick drift, of dominantly gray-brown to dominantly red-brown drift, and of a subdued topography to a rough morainal topography have any significance with respect to age differences of the drift. This leads to the conclusion that it is possible that there really is little or no age difference between the Border drift and the Cary Wisconsin drift. If so, the prominent Cary moraine is a recessional moraine. The presence of pitted outwash just outside this moraine has been noted by Leverett and Thwaites. Thwaites (1926) pointed out the age significance of pitted outwash. Leverett extended the boundary of Wisconsin drift southward (Text Fig. 3) to include such areas in north central Wisconsin.¹⁵ The absence of extensive pitted outwash in the Wisconsin River and Black River valleys south of Lincoln and Taylor counties demands explanation. Post-Cary or late Cary outwash may have been brought down those valleys from northern Wisconsin, and may have obliterated pits made by the melting of buried blocks of Cary ice.

Wilson has reported to the writer that preliminary studies of pollen in samples taken from the buried soil at the Marshfield Experiment Station suggest that the buried soil is post-Kansan in age. The depth of leaching of the silt which underlies the buried soil is two feet at Marshfield and is five feet in a similar buried silt in northwestern Wood County. These leached zones probably represent an inter-glacial period of considerable length. The silt deposits, which were laid down before the Border drift glaciation, may be outwash, loess, or lacustrine deposits, probably related to an undiscovered, buried drift farther north. If the Border drift ice encountered similar silts over a wide area, it is easy to see how the southern Border till came to have a fine texture.

RELATED PROBLEMS.

Three questions which remain unanswered should be discussed briefly. (1) Were some of the rough, craggy sandstone hills in southwestern north central Wisconsin nunataks? (2) Was the Wisconsin River valley glaciated? (3) What was the direction of movement of ice in the Border drift area?

¹⁵ Mathiesen moved the Wisconsin drift boundary southward to include pitted outwash in northwestern Wisconsin.

The first two questions have not been answered satisfactorily because drift is thin or absent in the two areas mentioned, and because in many places it is difficult to establish the glacial transportation of stones. It is known that there is a great variety of pre-Cambrian bedrock in north central Wisconsin, but no exact geologic map has been made of the area, because glacial drift and disintegrated and decomposed residuum obscure the bedrock. A basal Cambrian conglomerate was formerly much more extensive in this region than at present, and a great variety of rocks are represented in it. At present, only unusual types of Keweenaw and iron formation rocks can be recognized with certainty as glacial erratics, which have been brought from outside of north central Wisconsin. Where drift is extremely thin or wanting, a much more careful search for erratics will have to be made, before the problems of the sandstone mounds and the Wisconsin River valley can be solved.

The discussion about the sandstone mounds arises from the difference of opinion among geologists concerning the rapidity of weathering and erosion of the sandstone. Is it possible that the mounds have recragged since glaciation? The following considerations have been offered by various investigators in support of the view that the sandstone mounds were nunataks: no drift is present on the tops and upper slopes of the mounds; the mounds have steep sides with crags and are not rounded as they would be if the glacier had over-ridden them; in many places talus is not abundant around the bases of the mounds; there are numerous unaltered glacial boulders in the drift which surrounds the mounds, which has been regarded as indicating that postglacial time has been too short for steepening of the slopes of the mounds by weathering and mass wasting. The view that the sandstone mounds were not nunataks is supported by the following considerations: crags are known elsewhere in recognized Wisconsin drift, and therefore recragging of sandstone mounds in Wisconsin has been rapid¹⁶; there is a consid-

¹⁶ Thwaites has called the attention of the writer to the following examples: Castle Rock, Rice Co., Minn., which is surrounded by Iowan drift; Liberty Bluff, Marquette Co., Wis., Pine Bluff, east of Baraboo, Wis., and "The Monument," near River Falls, Wis., the first two of which are in areas of recognized Cary drift, and the last of which may be in Iowan drift. At Petenwell Peak and Mauston, Wis., Lake Wisconsin beaches lie buried beneath postglacial sandstone talus. Mathiesen showed that talus slopes in the quartzite Barron Hills of northwestern Wis., have developed since the Cary glaciation.

erable mass of talus in places at the bases of the sandstone mounds; glacial drift may have been present on the mounds and may have slumped off during postglacial recragging.

The following items have been brought forward in support of the idea that the Wisconsin River valley was not glaciated in the Border drift area: drift is thin or absent; supposed drift may be ice-rafted or fluvial deposits, or may be residual Cambrian conglomerate or pre-Cambrian crystalline rock fragments; Rib Mountain and other quartzite hills in the vicinity of Wausau are driftless and may have prevented the glacier from descending the Wisconsin River valley; the Marathon soil of this area is regarded by some investigators as essentially unmottled loess which lies in most places on bedrock and local residuum, and not on till. The case for the glaciation of the Wisconsin River valley has been based on the following points: the boundary of the Border drift surrounding this valley is a retreating erosional feature and not a depositional glacial feature; it is difficult to understand how a glacial lobe could cover uplands on both sides of a deep valley and yet fail to occupy that valley; the fill in the bottom of the Wisconsin River valley is extensive and may have obliterated morainal deposits; some investigators regard the Marathon soil as a well-drained, eroded Spencer soil, and so suggest that the original parent material of the Marathon soil was thin glacial drift. It is possible that the part of the Wisconsin River valley under discussion here is a glaciated valley from which till has been removed by erosion.

A third problem is that of determining the direction of movement of ice in the Border drift area. No striae have been found there.¹⁷ Aërial mosaics and existing soil maps of north central Wisconsin show no "swell and swale pattern" of "annual recessional moraines" (Gwynne), such as is present in north central Iowa. Even the "Marshfield moraine" ridge cannot be regarded as indicating by its trend the shape of a glacial lobe, in view of the mapping by Bean of sandstone outcrops and talus at many places on the ridge. The presence of Keweenaw conglomerate and characteristic iron formation pebbles and of carbonates high in calcium in the Border drift are

¹⁷ Two sets of striae, one reported by Mathiesen and one by Bean, from the Border drift area of Barron Co., Wis., which lies northwest of north central Wisconsin, trend northwest-southeast and northeast-southwest, respectively.

indefinite evidence which does not prove whether the ice came from the northeast, north, or northwest. It is not yet possible to account for the presence near Marshfield of finely divided calcium carbonate through a thickness of ten to twenty feet of silty drift, in a region remote from carbonate rocks, the nearest of which are dolomites. It is also difficult to explain the absence of red-brown color from the calcareous drift and much of the noncalcareous drift in the southern part of the Border drift area. If the ice passed over the iron ranges of the Lake Superior basin, as some of the erratics indicate, it had every opportunity to introduce red materials into the drift, as indeed it did locally in the south and generally in the north, in the Border drift area.

CONCLUSION.

The Border drift is a thin, heterogeneous deposit. Students of the area have recognized that topography of the Border drift area is largely controlled by preglacial land forms, but some have felt justified in correlating the drift on the basis of the similarity of that topography to the subdued topography of areas of thick drift in States to the south. Data have now accumulated concerning the distribution of carbonates in the drift, the presence of a thin loess mantle over much of north central Wisconsin, the immaturity of the soils of the area, the lack of a consistent relationship between color and age of drift, and the unaltered condition of many mineral particles in the drift. The conclusion seems inevitable that the age of the Border drift is not much if any greater than that of the Cary Wisconsin drift to the north. The difference in topography that led some previous investigators to believe otherwise is largely due to bedrock control in areas of thin drift. The Border drift of north central Wisconsin is clearly of Wisconsin age.

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