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by

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IRON-CEMENTED GLACIAL DRIFT IN LOGAN COUNTY, NORTH DAKOTA

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INTRODUCTION

A number of deposits of iron-cemented glacial drift were found by the writer while mapping the surficial geology of southern Logan County, North Dakota, during the summer of 1960. An interpretation as to the origin and significance of these deposits was thought important because of their lithology, induration, alteration, and stratigraphic position below early Wisconsinan drift, and because of the significant occurrence of datable peat underlying one outcrop.

Location and Physiography

The iron-cemented glacial drift was found in seven outcrops in three locations as shown on Fig. 1. All exposures of this drift were found in areas of bedrock controlled erosional topography with local relief of over 150 feet. The underlying Cretaceous Fox Hills formation consists largely of weakly-consolidated iron rich sands. The well-indurated iron-cemented drift forms resistant caps on bedrock highs, and is overlain by thin early Wisconinan till in most outcrops.

METHODS AND RESULTS

Field studies.—A thorough field examination of Logan County revealed only seven outcrops of the iron-cemented drift. Tracing of these deposits under younger drift in two localities was possible, but drill holes in adjacent areas of thicker drift have not been made. Lithologic descriptions and stratigraphic relations were noted in the field, and 100 pounds of samples were brought back to the laboratory for examination.

Laboratory studies.—Twelve thin sections were made from different samples for a microscopic study of the sediment. Stannous chloride and HCl were used to dissolve the iron-cement from the drift for residue analysis.

Description of samples.—The iron-cemented drift is a clastic sediment, probably glacial gravels, with a heavy chemically or biochemically precipitated limonite-goethite cement (hydrous iron oxides). All deposits are massive to weakly stratified, with numerous molds left where the more soluble pebbles have been completely leached out. (See Fig. 2.) The texture is rudaceous to arenaceous with a poor degree of sorting. The entire deposit has been stained and impregnated with precipitated limonite-goethite which then cemented the gravels into a resistant mass.

Laboratory tests showed up to 40% by volume and 55% by weight of the sediment consisted of iron oxides. Permeability and porosity

are moderate to high, and mineral composition is variable. Hand samples and thin sections show various altered and decomposed metamorphic and igneous rock fragments, chert, quartz, and Fox Hills sandstone pebbles. All carbonates have been completely leached out unlike any younger deposits in Logan County.

The thin sections made from this deposit were very similar to those described by Moore (9) in his studies of bog-ores in Ontario. He found in his examination of thin sections that the limonite was in the form of an opaque, reddish-brown mass, heterogeneous, and had no distinguishing features beyond a porous condition. His slides showed numerous angular to rounded quartz fragments, feldspars and some rock fragments with no preferred orientation in the limonite groundmass.

Angular silt-sized grains of quartz similar to those noted by Moore were observed in thin sections "floating" in the iron cement of the Logan County deposits. These were probably carried by local streams or aeolean action blowing sand and silt into the open bog during iron deposition.

Stratigraphic Position and Topographic Expression

The generalized cross-section on Fig. 3 shows the relationship of the iron-cemented drift to the over and underlying sediments in the outcrop areas.

The iron-cemented drift forms a thin, resistant cap on bedrock highs where post-glacial erosion has dissected the area. In one locality the deposit is underlain by 0 to 3 feet of gray to black peaty silt. This silt has numerous carbonized plant remains which were collected and sent to the U. S. Geological Survey in Washington, D. C., for radiocarbon dating. Other C^{14} material was collected from the overlying early Wisconsinan drift in northern Logan County. These samples together with C^{14} material collected from younger drift sheets in Logan County will help decipher the glacial history and correlation of deposits in North Dakota.

Age of the Iron-cemented Drift

The age of the surficial drift west of the Altamont-Max morainal complex in North Dakota has long been in controversy. To avoid confusion this drift is herein informally referred to as the Napoleon drift in Logan County. Numerous exposures are found in northwestern Logan County, North Dakota. Todd (10), Leonard (7), Leverett (8), Alden (1) and others have studied parts of this drift sheet and all have offered possible ages for it. Flint (2), has done the most comprehensive work in correlation of these outlying glacial deposits. Flint states that in South Dakota this drift is Iowan with some possible Tazewell drift included, based on tracing around the west side of the James Lobe from the type area in northeastern Iowa.

Continued tracing on aerial photos north from the South Dakota

border through McIntosh County into Logan County (24 miles) shows the same drift. Lemke and Colton (6) assigned a Tazewell (?) age to the drift, but this assignment is not supported by field evidence in the present writer's opinion.

Field examinations show that the lithologic and topographic expression of this drift in Logan County, and that described by Kay (5), and others, from the type Iowan in Iowa are strikingly similar. The well developed integrated drainage pattern, thin unleached drift, common gravelly knolls, stratigraphic position, and nearly continuous tracing from type area are all factors suggesting Iowan rather than Tazewell deposits. It is the writer's opinion that the Napoleon drift in Logan County is very probably Iowan in age, with erosional remnants of sub-Napoleon drift found in a few locations underlying it. The iron-cemented drift is such a deposit. The radiocarbon datings now in progress should help prove or disprove this tentative age assignment. If the Iowan age is supported by these C^{14} dates, the iron-cemented drift will then be the first proven pre-Iowan (pre-Wisconsinan) glacial deposit from North Dakota.

The deposition of the iron and the leaching of the carbonates probably took place during a major interglacial age.

Possible Origin of Iron-cemented Deposits

The limonite-goethite cementing material in the iron-cemented drift is most characteristic of bog-iron ores. Bog ore is composed principally of these minerals and has been described from northern and eastern Canada, northwestern and northeastern United States, Sweden, and northern Asia. In these areas percolating waters dissolve iron from the glacial drift and bedrock with the aid of carbonic and organic acids. The iron is carried in solution as soluble carbonate, sulphate, or combined with complex organic acids. The iron may then be precipitated chemically or biochemically in marshes, peat bogs, or other shallow surface depressions. (3).

Chemical precipitation takes place either by removal of the solvents by reaction with other materials in solution or by oxidation. It is generally agreed that plants and bacteria are the chief agents in producing the chemical action in the formation of bog-iron (4). The iron complex collects as a thin film on the surface of the water and then sinks or collects along the shore. When the iron becomes oxidized at or near the surface, insoluble limonite forms.

Forms of bog ore deposits.—The common form of bog ore deposits found are horizontally tabular bodies a few feet thick, and red to yellow in color. They are found as both soft or hard-bedded masses, concretions, or as a cement in gravels and sands which the iron-rich solutions have impregnated. The deposits studied by the writer are thought to have been such a porous gravel which has been impregnated by iron rich waters, from which the iron was precipitated.

Iron source.—The iron which was deposited must have been derived either from the existing glacial drift, or from the bedrock Fox Hills sandstone. Most of the iron probably came from the Fox Hills formation which contains many iron-bearing minerals, and is, in many near-by places, hydrostatically higher than the local depressions in which the iron was precipitated. This provided groundwaters an opportunity to remove iron from the Cretaceous sands and drift, and to carry it to depressions where it was precipitated as bog ore. Leonard (7) described a similar deposit he called an iron-cemented "boulder bed" in McKenzie, County, North Dakota, which he attributed to ground water precipitation of iron.

SUMMARY AND CONCLUSIONS

The similarities in mineralogy, topography, structure, and probable origin between the iron cemented material in Logan County and bog-ore deposits reported throughout glaciated areas of North America and other parts of the world, lead this writer to believe that the iron-cementing material was of the same origin. Thin sections of bog ore and the iron-cemented drift support this similarity further.

The tentative age assignment of Iowan for the Napoleon drift in Logan County is presently based on: 1. nearly continuous tracing of this drift from type Iowan in Iowa; 2. stratigraphic position below late Wisconsinan deposits, and above probable highly-weathered iron-cemented sub-Wisconsinan deposits; 3. thickness and lithologic similarities to type Iowan; 4. topographic expression; 5. integrated drainage pattern showing this surface is much older than late-Wisconsinan surfaces to the east in Logan County, but not showing the high degree of weathering that pre-Wisconsinan deposits have.

The significance of the iron-cemented drift located stratigraphically below a drift of probable Iowan age (subject to C^{14} results) is important in the unravelling and regional correlation of the Pleistocene geology of North Dakota. If the age of the Napoleon drift is then Iowan, the underlying iron-cemented drift is pre-Wisconsinan, and is the first proven evidence that North Dakota was glaciated in pre-Wisconsinan time.

Sequence of Events

One possible sequence of events in the formation of the iron-cemented drift deposits in Logan County can be divided into three stages. During the first stage meltwater run-off or increased local precipitation ahead of the first ice advance over this area formed swampy areas on the rough surface of the eroded Cretaceous rocks. Fine silts, clays, and plant debris were deposited in the depressions; this is the peaty basal material found today.

During the second stage the advancing ice overrode the area and deposited thin patchy gravelly drift. When this ice sheet retreated, swampy conditions and a high water table returned. The

rugged pre-glacial topography was little modified by the thin drift deposited. Iron began being dissolved by ground waters from the near-by drift and bedrock sands at higher elevations, and was carried to the lower areas where it was precipitated as bog-iron. The deposition of iron was halted when headward erosion of near-by streams with lower base levels drained the bogs. This increased the downward movement of groundwaters and the ultimate complete leaching of carbonate minerals in the iron-cemented gravels. Molds of these pebbles in the cemented drift are common; these voids are not filled with iron-cement which shows the leaching occurred **after** cementation ceased (due to draining of bogs).

During the third stage of development the early Wisconsinan (Iowan?) glacier advanced over the area and deposited a thin mantle of fresh drift over the leached iron-cemented patches of drift. This is the Napoleon drift sheet. Extensive erosion since that

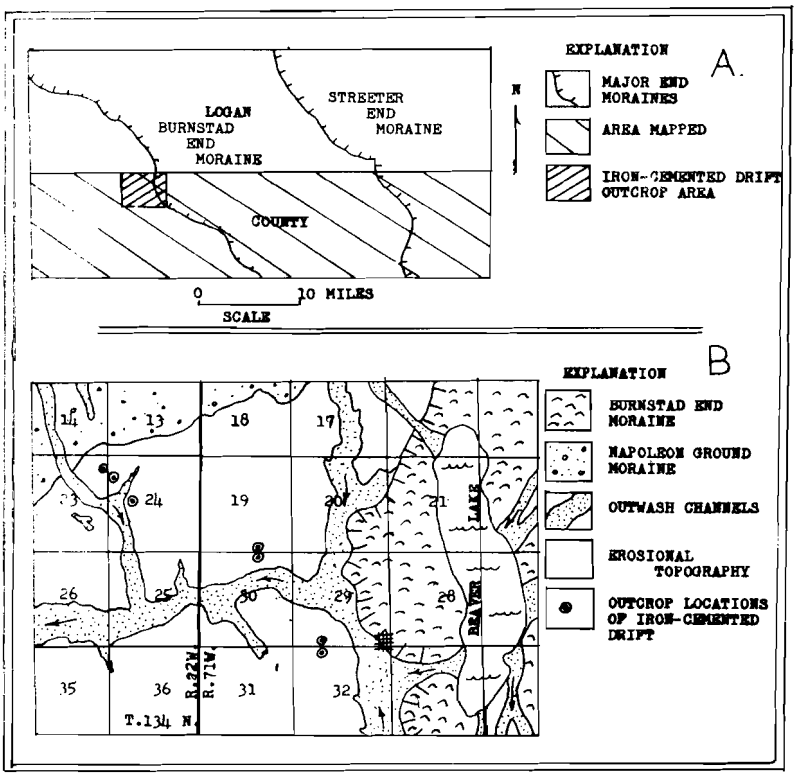

FIGURE 1. (A) Index map of Logan County showing the area where iron-cemented drift crops out. (B) Outcrop area expanded to show glacial geology and outcrop locations.

time has left the more resistant indurated iron-cemented drift capping bedrock highs. Where erosion has not yet progressed as far in adjacent areas to the north and west, any iron-cemented drift patches are still covered. No drill holes are available in near-by areas to prove the existence of additional and more extensive deposits of iron-cemented drift.

FIGURE 2. Photograph of iron-cemented drift sample showing large solution voids due to extensive leaching of carbonates.

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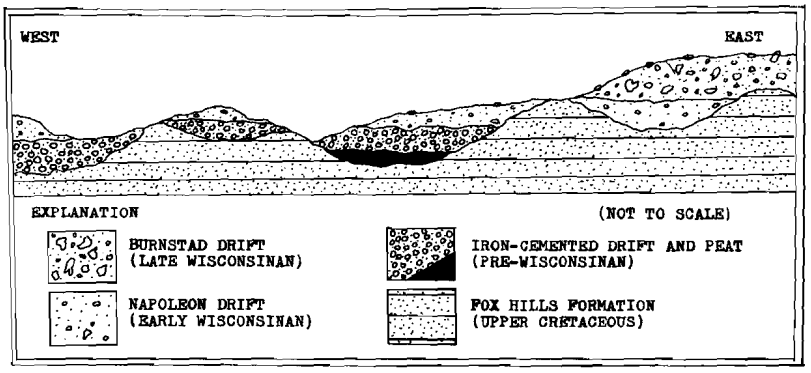

FIGURE 3. Generalized cross-section of iron-cemented drift outcrop area showing its relationship to older and younger sediments.