apparent exchange, depending on the concentrations of iodine and ethyl iodide.

Some thermal exchange has been observed in the methyl iodide–iodine (*11*) and is present in isopropyl iodide–iodine systems; it may also play an important role in the Szilard-Chalmers effect with these systems. It must be noted, however, that several points indicate that thermal exchange is not the sole factor in explaining organic retention in these effects: for example, lower reaction temperatures do eliminate the organic retention, and there is a finite retention at iodine concentrations at which apparent exchange should not be important. Moreover, radioactive products other than the alkyl iodide have been reported. Nevertheless, we believe that the possibility of exchange between alkyl iodide and iodine has been overlooked in these studies; thus the apparent retentions quoted in the literature are probably higher than the true retention, especially when concentrations of I_2 were very low.

E. D. COHEN
C. N. TRUMBORE
Department of Chemistry, University of Delaware, Newark

References

1. L. Szilard and T. A. Chalmers, *Nature* **134**, 462 (1934).
2. For a review, see M. Haissinsky, *Nuclear Chemistry and Its Applications* (Addison-Wesley, Reading, Mass., 1964), chap. 17.
3. W. F. Libby, Jr., *J. Amer. Chem. Soc.* **69**, 2523 (1949).
4. J. E. Willard, *Ann. Rev. Nuclear Sci.* **3**, 183 (1953).
5. P. E. D. Shaw and C. H. Collie, *J. Chem. Soc.* **1949**, 1217 (1949).
6. D. E. Hull, C. H. Schuflett, S. C. Lind, *J. Amer. Chem. Soc.* **56**, 535 (1936).
7. E. Cohen and C. N. Trumbore, *ibid.* **87**, 964 (1965).
8. H. McKay, *Nature* **142**, 997 (1938).
9. W. W. Miller, E. P. Rack, E. J. Burrell, C. N. Trumbore, *ibid.* **23**, 2457 (1955).
10. R. H. Schuler, *J. Chem. Phys.* **22**, 2026 (1954).
11. H. Behrens and A. G. Maddock, *ibid.* **22**, 139 (1954); *Radioisotope Conference* (Butterworths, London, 1954), vol. 2, pp. 30–40.

22 April 1965

Pseudo Superglacial Till

Abstract. *A thin layer of coarse till overlies clay-rich till in northwestern North Dakota. That the thin layer is not a superglacial facies of the underlying clayey till is indicated by (i) geomorphic relations; (ii) contrasted lithologies; (iii) restricted area of exposure; (iv) absence of a similar deposit on a younger clayey till in a comparable topographic environment; (v) presence of a probable paleosol; (vi) an intervening unconformity; and (vii) occurrence of clayey facies of the upper deposit. The deposit is believed to represent a younger till.*

In northwestern North Dakota, a thin layer of silty till rests on a thick deposit of clayey till (Fig. 1). The assemblage resembles a typical complex of superglacial and lodgement tills in which the upper layer represents superglacial (and englacial) drift stranded onto a subglacial deposit during wasting of a single glacier (*1*). This early interpretation, however, encountered difficulties as the regional study progressed and it became increasingly clear that the assemblage was actually the product of two separate glaciations. In this report I describe briefly the evidence for two separate tills in the area of study and, in so doing, emphasize the need for caution in interpretation of superficially similar assemblages elsewhere.

The upper till occupies a lobate area of about 800 square miles (2100 square kilometers) in northwestern North Dakota (Fig 2). It is generally siltier than the underlying till and has a greater concentration of pebbles, cobbles, and boulders. Locally, the upper till includes thin sand seams up to 1 inch (2.5 cm) thick. Over the greater part of the area its thickness varies from a thin veneer to 15 feet (5 m) or more, and probably averages 5 feet (1.52 m). In a few places the thickness is at least 25 feet (8 m) and may be considerably more. The upper till is generally light gray in contrast to the brown till below.

The relative abundance of pebbles of the upper till, other than those of local rock types, is as follows: granitic rocks, about 32 percent; limestone and dolomite, about 44 percent; foliated metamorphic rocks, about 24 percent; and plutonic rocks other than granite, less than 1 percent. Histograms of many pebble samples (*2*) as well as till-pebble isopleth maps showing the regional variations in lithology (*3*) have been published. The source area for the erratics is in the Canadian Shield several hundred miles to the northeast.

The till is distributed over a topography of varied relief. It rests nearly everywhere on the clay-rich till, but locally overlies glaciofluvial sediments. Its surface is generally level to gently undulating, although well-developed moraines are present in several localities. The till is mantled locally by glaciofluvial deposits and regionally by loess. The loess is rarely more than 2 or 3 feet (0.6 to 1 m) thick.

Geomorphic relations in Little Muddy Valley north of Williston strongly suggest that the silty till is younger than the clayey till. The surface of the clayey till is smoothly graded and forms a terrace only lightly veneered with the silty till and loess. In many places in the terrace scarp the clayey till extends down to, and presumably below, stream level. At two localities, 12 and 18 miles (20 and 30 km) north of Williston, the silty till forms pronounced morainal topography below the level of the terrace against whose frontal scarp it abuts. The graded terrace surface could hardly have been fashioned after deposition of the silty till because the morainal topography lies at lower elevations. Nor is it likely that the terrace surface was formed while stagnant ice covered the morainal areas because the terrace is a regional phenomenon, found outside as well as inside the area of silty till. A reasonable interpretation is that the graded surface of the clayey till was subsequently trenched and that a later ice, thicker in the trenches than elsewhere, deposited the pronounced moraines.

The proportions of the erratic pebbles in the silty till differ significantly from those in the underlying clayey till. Histograms of the silty till reveal three prominent peaks representing the granitic rocks, the metamorphic foliate rocks, and limestone and dolomite. The clayey till shows a high peak for limestone and dolomite, a very small peak

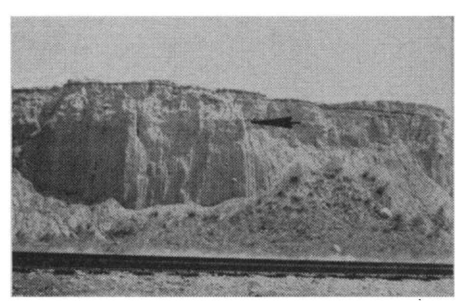

Fig. 1. Thin layer of gray, silty till overlying brown, clayey till in Jones Cut, 5 miles (8 km) southwest of Williston, North Dakota. The arrow indicates the contact. Remnants of a truncated soil are found on top of the lower till.

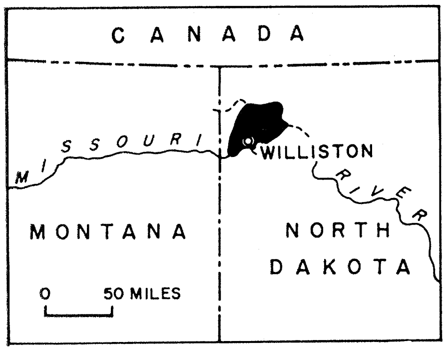

Fig. 2. Location of the pseudo superglacial till (shown in black) in northwestern North Dakota.

for the granitic rocks, and almost none for the metamorphic rocks. Whereas the upper till has only half the quantity of limestone and dolomite contained in the lower till, it has 4½ times the quantity of metamorphic foliate rocks, and nearly ⅗ again as much granite. The contrasts are not due to different degrees of weathering because both tills are unaltered except for oxidation. The contrasts are apparently not due to different rates of attrition of various types of rock under different conditions of transport, because the abundance of pebbles is not related to expectable durability as inferred from the presence or absence of foliation, lineation, and fractures, and by the resistance to breaking under impact. For example, if breakup is assumed to be rapid during reworking of superglacial moraine prior to deposition, the decrease in the percentage of limestone-dolomite might be attributed to more rapid fragmentation of the granite and metamorphic pebbles. If, however, we turn to outwash as the closest analogy to such reworking, we find almost no difference in the relative proportions of the pebbles in outwash and its related till. If, on the other hand, it is assumed that breakup is more rapid in the subglacial transport that provides the clayey till, we are faced with the dilemma of explaining the relatively small content of the easily breakable metamorphic rocks. These same considerations make it seem unlikely that the silty till is the periglacially reworked upper part of the clayey till.

The upper till is largely restricted to a single drainage basin forming a broad south-trending lowland; the clayey till, however, is of regional distribution. The next drainage basin to the west, in Montana, is almost identical in configuration yet the silty till is absent. If the silty till is a superglacial facies of the clayey till, its restriction to a single lobate area presents a difficulty for which there is no ready explanation.

A later clayey till shows no stratification of superglacial and lodgement till even in topographic environments comparable to that in which the silty till occurs. This is true even in the northern part of the lowland in which the silty till is found.

A probable intervening soil was found in exposures in which the silty till overlies the clayey till. All seven members of a visiting party of soil scientists (*4*) were of the opinion that a soil was present, although they varied in their degree of conviction. The soil, where best exposed, seems to have an A-horizon about 1 foot (0.33 m) thick, and a gypsiferous B-horizon 2 to 3 feet (0.66 to 1 m) thick. For the most part, however, the A-horizon is missing.

At one locality, the silty till rests on a level surface truncating the clayey till which is contorted and displays clear evidence of slumping. The contact between the two tills appears to be a simple erosional unconformity, following slumping and crumpling of the lower till. A possible alternative explanation is that the deformation resulted from shoves beneath the ice and that the moving ice beveled the deformed till before deposition of an ablation moraine. The fractures, however, are relatively steep and comparable to those found in modern slumps. Furthermore, a short distance away the beveled surface is underlain by the probable intervening soil mentioned above.

In some areas the upper till is a typical boulder-clay. This argument against a superglacial origin is not stressed, however, because it has not yet been demonstrated that ablation moraine may not, under favored circumstances, accumulate with preservation of most of the fine fraction. It is worthy of mention, however, that there are no significant differences in the pebble analyses of the clay-poor and clay-rich facies of the silty till.

ARTHUR D. HOWARD
Department of Geology, Stanford University, Stanford, California

References and Notes

1. R. F. Flint, *Glacial and Pleistocene Geology* (Wiley, New York, 1957), pp. 120–122.
2. A. D. Howard, *U.S. Geol. Surv. Profess. Paper No. 326* (1960).
3. ———, *Bull. Geol. Soc. Am.* **67**, 1199 (1956).
4. The visiting soil scientists included James Thorp, then regional director of the Division of Soil Survey, Department of Agriculture, and the following Canadian specialists: F. Bentley, W. E. Bowser, J. Clayton, W. Jensen, H. C. Moss, and W. Odynsky.

26 April 1965

Glass-Coated Tungsten Microelectrodes

Abstract. *Unusually rugged microelectrodes for recording the activity of single nerve cells or fibers can be constructed from tapered tungsten wire on which a glass capillary is collapsed and surface bonded. Tip diameter in the range between 1 and 5 microns provides relatively low impedance detection of extracellular potentials.*

In an earlier paper (*1*) it was shown that extracellular spike potentials from nerve cells could best be observed by means of a metal-tipped microelectrode rather than a fluid-filled pipette since the admittance of the metal electrode increases with frequency. Various metal microelectrodes have been described (*2–4*), each with particular attributes such as ease of manufacture, reliability of insulating coat, and sturdiness. The best type of metal electrode for use by neurophysiologists would combine high insulation resistance, stiffness, and good adhesion of the electroplated metal at the fine tip. Such an electrode would allow observation of spike activity near a single nerve fiber with the highest ratio of signal to thermal noise for long periods of time.

The kind of metal which is coated with insulating material makes no difference, since the actual electrical contact is made through the material plated on the tip. Tungsten, as suggested by Hubel (*4*), seems to be at least as stiff as the platinum-iridium alloy or stainless steel used by other investigators. Glass is superior to Hubel's varnish, however, for several reasons: first, it can be examined under the microscope for continuity; and second, when fire-polished, it provides a smooth, hard surface for easy penetration of biological material.

Wolbarsht *et al.* (*5*) thought that Wilska's method (*2*) of collapsing a capillary of glass around the metal electrode was too delicate a technique, and they developed a procedure for pushing a pre-sharpened electrode through a meniscus of molten