accounts for the strong feature seen at 1365 cm^{-1} in various samples.]

The high concentration of impurities in "polywater" samples that exhibit the appropriate infrared spectrum and the failure of the absorption bands to undergo isotope frequency shifts on deuteration make it very unlikely that the spectrum originates from polymerized H_2O units. The evidence presented here is consistent with this assumption and shows that sodium lactate, the primary constituent of sweat, may account for the main features of the infrared spectrum (*17*).

D. L. ROUSSEAU

Bell Telephone Laboratories, Murray Hill, New Jersey 07974

References and Notes

1. E. R. Lippincott, R. R. Stromberg, W. H. Grant, G. L. Cessac, *Science* **164**, 1482 (1969).
2. T. F. Page, Jr., R. J. Jakobsen, E. R. Lippincott, *ibid.* **167**, 51 (1970).
3. D. L. Rousseau and S. P. S. Porto, *ibid.*, p. 1715.
4. A discussion of alternative explanations for the infrared spectrum is given in (*5*).
5. D. L. Rousseau, paper presented at the 44th National Colloid Symposium (1970) (proceedings to be published in *J. Colloid Interface Sci.*).
6. R. E. Davis, personal communication. These data have been reported in *Chem. Eng. News* (29 June 1970), p. 8.
7. E. R. Lippincott, paper presented at the 44th National Colloid Symposium (1970).
8. T. F. Page, Jr., and R. J. Jakobsen, paper presented at the 44th National Colloid Symposium (1970).
9. R. E. Davis, D. L. Rousseau, R. D. Board, *Science*, this issue.
10. B. V. Deryagin and N. V. Churaev, paper presented at the 44th National Colloid Symposium (1970).
11. A report of this presentation by B. V. Deryagin was written by V. Zhvirblis [*Khimiya Zhizn'* (*Russian*) No. 12 (1969), pp. 37-44] [translation (*Joint Publ. Res. Serv. No. 50006*) available from Clearinghouse for Scientific Information, Springfield, Va., 1970].
12. S. Robinson and A. H. Robinson, *Physiol. Rev.* **34**, 202 (1954).
13. J. Couraud, *C. R. Seances Soc. Biol.* **118**, 155 (1935).
14. The band near 3300 cm^{-1} is quite strong in all three of the spectra presented here. However, it may be readily assigned to absorbed H_2O resulting from the deliquescent property of these materials. Results of H_2O-D_2O exchange experiments (*5*) indicate that in "polywater" samples this band is very sensitive to the experimental conditions (temperature and humidity), thereby accounting for some of the differences among various spectra reported in the literature. To confirm that this band in spectrum C (Fig. 1) resulted from adsorbed H_2O, a heater was placed around the sample such that the spectrum could be measured at about 150°C. Heating resulted in the drastic reduction of this band relative to the other bands in the spectrum, thus verifying that it could be attributed to H_2O and was not attributable to sodium lactate.
15. One would expect that other organic acids in sweat would play the most important role in altering the spectrum of "polywater."
16. E. R. Lippincott, personal communication.
17. We may only speculate on the source of the biological contamination in samples prepared in various laboratories. In some instances it may have resulted from accidental handling of the capillaries or of the preparation vessel. Another possibility that we believe to be the more likely source of the biological contamination is the absorption by the capillaries of aerosol particles released by humans. The presence of an aerosol cloud surrounding individuals (not too dissimilar from the cloud surrounding Pigpen in "Peanuts") is a well-known phenomenon encountered in several areas of scientific endeavor. In the space program this aerosol cloud has presented a cleanliness problem; in military applications it has been utilized as a means for the remote detection of people; and in studies of disease control it has been found that bacteria are transmitted in this cloud. The exact nature of the cloud depends on the environmental conditions such as humidity, ventilation, and temperature, and on the specific individual's age, health, and clothing. The condensation of components from this aerosol cloud in the freshly drawn capillaries may be the source of biological contamination in many laboratories.
18. I thank S. Meiboom and M. M. Rochkind for helpful discussions, and C. L. French and D. C. Krupka for sweat samples.

21 August 1970; revised 6 October 1970 ■

Paleolimnology of Late Quaternary Deposits: Seibold Site, North Dakota

Abstract. *A unique late Quaternary lacustrine deposit has been discovered recently on the Missouri Coteau of North Dakota. A diverse, extremely well-preserved biota of more than 160 species has been recovered primarily from an organic mud deposited about 9500 years before the present. The lacustrine body shallowed gradually as the climate became drier.*

In the autumn of 1969, an extremely diverse and unusually well-preserved fossil assemblage was discovered in a late Quaternary lacustrine deposit in southeastern North Dakota (*1*); fish, a frog, beaver, and muskrat form part of this assemblage. We present here our preliminary findings.

Fossils were recovered from an excavation on the floor of an intermittent pond in the SW¼ NW¼ section 21, township 141 north, range 67 west, about 17 km southeast of Woodworth, Stutsman County, North Dakota. This pond, herein called the Seibold Slough (*2*), occupies a subcircular depression, one of hundreds of thousands of similar depressions on the Missouri Coteau. This depression, approximately 100 m in diameter, is completely enclosed by low hills a few meters high. The excavation (about 52 m long by 22½ m wide), as well as other possible excavations within the Seibold Slough, is here designated the Seibold Site (*2*). The area closely surrounding the excavation and slough is in cultivation, but prairie exists where the terrain is undisturbed.

Active glacial ice existed in the general area until about 13,000 years before the present (B.P.) (*3, 4*). With subsequent melting and thinning of the ice, englacial debris was concentrated on the surface, forming a blanket of superglacial till a few tens of meters thick. Insulation by the till allowed stagnant masses of ice to persist for thousands of years; some ice existed at least as late as 9000 years B.P. Both the till and buried ice were distributed irregularly, and when the last ice melted irregular hills and depressions resulted, giving rise to a completely nonintegrated drainage. The Seibold Slough occupies one of these depressions.

The stratigraphic sequence exposed at the site (autumn 1969) is about 4.3 m thick and consists of seven units. All units, except perhaps the lowest, thicken and dip toward the west end of the excavation. The lowest unit (unit 1) is gray, pebbly, sandy to clayey silt. This unit is at least 97 cm thick. We found only rare shells of the snail *Gyraulus parvus* within it. The overlying unit (unit 2) is gray, laminated, sandy to clayey silt. It is up to 40 cm thick and is poorly fossiliferous, having yielded only ostracod shells and fish fragments.

Unit 3 ("fish bed") is green, gray, and brown, laminated, organic mud or "gyttja." It has a maximum thickness of 61 cm at the west end of the excavation. Megascopic laminae are a fraction of a millimeter to 3 mm thick and are distinguishable by color and texture; the lighter laminae are poorer in organic material. Examination of thin sections reveals that each megascopic lamina consists of about 10 to 20 sets of alternating organic-rich and organic-poor laminae. Measurements of 124 sets of these laminae give an average of 9.3 sets per millimeter of sediment. The sediment consists of about 50 to 60 percent organic matter (most of which is translucent and light to dark brown, greenish-brown, or green in thin section), 20 to 30 percent micrite (probably derived mostly from Charophyceae), and minor amounts of terrigenous fine sand, silt, and clay. It is highly fossiliferous and fish are the conspicuous organisms.

Overlying the fish bed is unit 4, light to medium gray, silty, calcareous

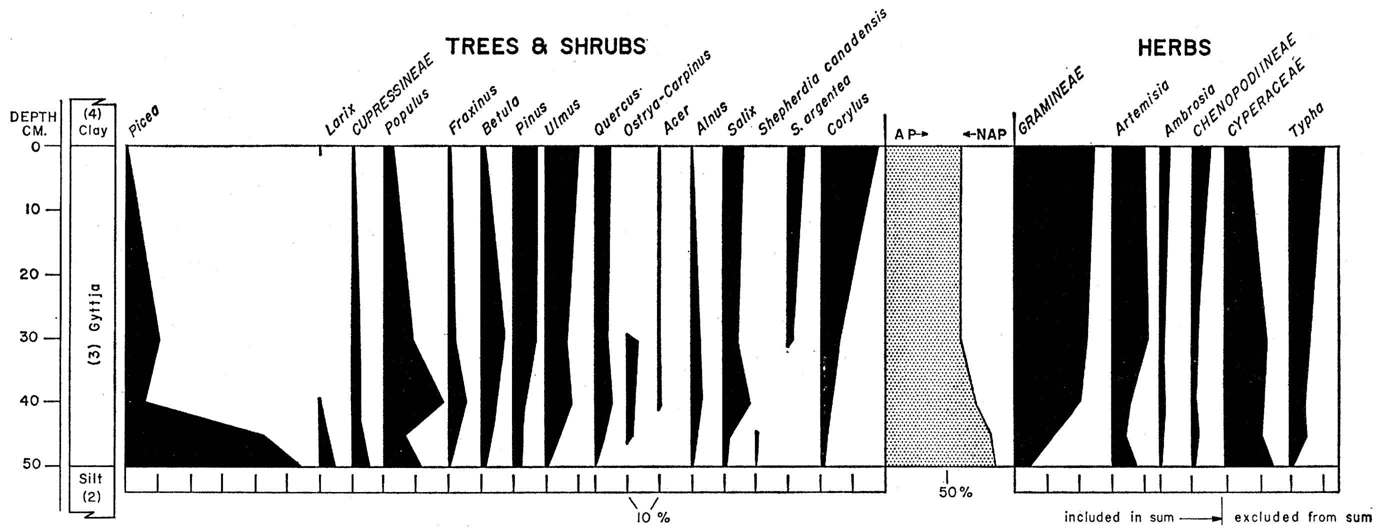

Fig. 1. Pollen diagram of stratigraphic unit 3 (fish bed) near the northwest part of the Seibold Site. Pollen sum is 300 to 400. *AP*, arboreal pollen; *NAP*, nonarboreal pollen.

clay (carbonate content about 35 percent or less); it has a maximum exposed thickness of 71 cm. This unit is quite fossiliferous and contains mollusks, ostracods, insects, and fish fragments.

The three youngest units constitute two facies, a sandy mud facies (units 5 and 7) and a muddy sand facies (unit 6). Unit 5 is dark gray to brown, slightly sandy, silty clay. Mollusks, ostracods, and fish fragments are common. Unit 6, medium and brownish gray muddy sand, is essentially unfossiliferous; it reaches an exposed thickness of 230 cm. Unit 7 is essentially the same lithologically as unit 5 and merges with it toward the northern part of the exposure where the two units reach a combined thickness of 224 cm. Unit 7 differs from unit 5 in containing fewer fossils.

More than 160 species of fossil organisms are presently known from the Seibold Site; most of them occur in the fish bed or unit 3. The general groups, with numbers of species and evidence for each group, are as follows: sponges (1, spicules), bryozoans (1, statoblasts), mollusks (10, shells), cladocerans (1, ephippia), ostracods (18, shells), amphipods (1, body impressions), insects (88, of which 81 are beetles, body parts), mites and ticks (2, body parts), spiders (1, body parts), fish (5, complete skeletons), frogs (1, incomplete skeletons), mammals (2, incomplete skull, gnawed wood, and fecal droppings), aquatic plants (9, mostly body tissue and pollen), trees and shrubs (17, pollen, leaves, twigs, and bark), and grasses and herbs (6, pollen). Most conspicuous are the fish which include *Notropis heterolepis* Eigenmann and Eigenmann, *Hybognathus hankinsoni* Hubbs, *Fundulus diaphanus* Lesuer, *Perca flavescens* Mitchell, and *Eucalia inconstans* (Kirtland) (*5*).

It is noteworthy that the Seibold Site represents the second discovery of fish in North Dakota. Three other fish species were taken from postglacial deposits at the Prophets Mountains Site (*6*), but their stratigraphic occurrence is uncertain. Further study will probably reveal many more taxa, particularly of cladocerans, insects, and plants. Several other groups can also be expected (*7*). Prior to the discovery of the Seibold Site, essentially only mollusks and plants had been recovered from late Quaternary deposits in North Dakota (*6, 8–13*).

Fossil preservation within the fish bed (unit 3) is excellent. Fish generally occur as complete skeletons with otoliths. For certain fishes, abundant scales delineate the configuration of the body; an oily substance is usually present with each fish skeleton. Complete, yellowish, body impressions of amphipods have retained such details as antennae and eyes. Some beetle elytra still exhibit bright metallic colors. Such plants as *Lemna trisulca* occur as what appears to be a film of essentially unaltered, green, plant tissue. Filamentous algae appear to constitute an appreciable percentage of the fish bed lithology; as a result one can peel back dark green layers that have the consistency of heavy tar paper.

A pollen and macrofloral analysis of the fish bed (unit 3) reveals a spruce-dominated assemblage (lower 10 cm) that is replaced by a mixed assemblage of deciduous trees, shrubs, herbs, and grasses (upper 40 cm) (Fig. 1). The spruce decline occurs at the same level as a beaver-gnawed wood sample (I-4537) that was dated at 9750 ± 140 years B.P. This agrees closely with the generally recognized, relatively rapid disappearance of spruce that occurred throughout the eastern United States 11,000 to 10,000 years ago (*14*).

The partial pollen sequence resembles that of other northern prairie sites such as that at nearby Woodworth Pond (*8*), Pickerel Lake in northeastern South Dakota (*15*), and the Belmont and Glenboro sites in southern Manitoba (*16*). Common to all sites is the initial dominance of spruce (*Picea*) with associated small but significant amounts of larch (*Larix*), birch (*Betula*), black ash (*Fraxinus nigra*), juniper (Cupressineae), soapberry (*Shepherdia canadensis*), and, generally, aspen or poplar (*Populus*). These, and other trees and shrubs, constitute more than 80 percent of the pollen sum. At such sites as Woodworth and Belmont, high values of sedge pollen (Cyperaceae) occur at the base of each sampled sequence; this may also be true at the Seibold Site but the lowest sediment has not yet been sampled.

Of the upper mixed assemblage in unit 3, aspen, birch, and elm (*Ulmus*) probably occurred locally; the pollen of oak and pine was probably blown in from elsewhere. Important shrubs were hazel (*Corylus*), alder (*Alnus*), willow (*Salix*), and buffalo berry (*Shepherdia argentea*). In addition to grasses, the prairie herbs included prairie clover

(*Petalostemum*) and wild onion (*Allium*).

Fossil and sedimentological evidence suggest a five-phase history at the Seibold Site.

1) During phase 1, a depression formed as underlying glacial ice melted during the late Wisconsinan (about 12,000 or 11,000 years B.P.). Meltwater flowed into the depression, depositing units 1 and 2 in a cool, oligotrophic lake, here called Paleolake Seibold (*2*). Ostracod evidence (*17*), from the upper part of unit 2, suggests that a permanent stream entered the lake; the maximum temperature of the summer air was about 30°C, and precipitation exceeded evaporation. Fish and other organisms probably entered the lake from the west via a tributary of the Missouri River.

2) During phase 2 (represented by units 3 and 4), latest Wisconsinan and earliest Holocene time or about 10,500 years B.P. and later, a eutrophic lake or permanent pond existed at the Seibold Site and shallowed gradually. Ostracod evidence from unit 3 (fish bed) suggests a maximum water depth of about 6 m during the deposition of that unit. Dissolved solids were lower at the outset of phase 2 than during phase 1 and fluctuated considerably during deposition of the fish bed. Aquatic vegetation was abundant during deposition of most of the fish bed. The lake was flanked by a spruce-dominated forest during the early stage of fish bed deposition and later was surrounded by prairie with tree groves. Ostracod evidence suggests that maximum air temperature during the later stages probably approached 32°C, accompanied by a decrease in precipitation. Continued shallowing of water resulted in the deposition of calcareous unit 4.

3) By phase 3 (early Holocene, about 8500 years B.P. and earlier) all of the ice in the area had melted and a shallow pond, with high concentrations of dissolved solids (represented by unit 5), replaced the lake phases. This phase marked the beginning of Seibold Slough deposition. Branchiate gastropods gave way to pulmonate gastropods.

4) During phase 4 (middle Holocene, about 8500 to 4500 years B.P.) the climate became drier still, and less protective vegetative cover resulted in increased hillslope erosion (represented by sandy unit 6 at the south edge of the basin and by parts of units 5 and 7 near its center). During part of this phase a prolonged dry period is reflected by a complete absence of aquatic gastropods in the sedimentary sequence.

5) Phase 5 (represented by unit 7) was a time (late Holocene, 4500 years B.P. to the present) of reversal to a relatively more moist climate, essentially similar to that of phase 3; it continues as the present-day slough.

ALAN M. CVANCARA, LEE CLAYTON
WILLIAM B. BICKLEY, JR.
ARTHUR F. JACOB
Department of Geology, University of North Dakota, Grand Forks 58201
ALLAN C. ASHWORTH, JOHN A. BROPHY
Department of Geology, North Dakota State University, Fargo 58102
C. T. SHAY
Department of Anthropology, University of Manitoba, Winnipeg 2, Manitoba
L. DENIS DELORME
Canada Department of Energy, Mines and Resources, Western Research Section, Calgary 44, Alberta
GEORGE E. LAMMERS
Manitoba Museum of Man and Nature, Winnipeg 2

References and Notes

1. S. H. Richards (Disease Research Biologist, North Dakota Game and Fish Department) recognized the possible scientific importance of the fossil assemblage and notified the Department of Geology, University of North Dakota. W. B. Bickley, Jr., L. Clayton, A. M. Cvancara, *Proc. N. Dakota Acad. Sci.* **24** (pt. 1) (abstr.) 2 (1970); W. B. Bickley, Jr., and A. M. Cvancara, *Geol. Soc. Amer. Abstr. with Programs* **2**(6), 377 (1970).
2. The Seibold Slough, Seibold Site, and Paleolake Seibold are named after Mr. and Mrs. Vernon Seibold, on whose property the slough is located. They allowed free access to study and collect fossils and sediments and donated several specimens.
3. L. Clayton, in *Glacial Geology of the Missouri Coteau and Adjacent Areas*, L. Clayton and T. F. Freers, Eds. (North Dakota Geological Survey, Grand Forks, 1967), Misc. Ser. 30, pp. 25–46.
4. H. A. Winters, *N. Dakota Geol. Surv. Bull.* **41** (pt. 1), 67 (1963).
5. R. R. Miller and T. M. Cavender (University of Michigan) identified the fish.
6. N. R. Sherrod, *Proc. N. Dakota Acad. Sci.* **17**, 32 (1963).
7. D. G. Frey, *Arch. Hydrobiol.* **2**, whole issue (1964).
8. J. H. McAndrews, R. E. Stewart, Jr., R. C. Bright, in *Glacial Geology of the Missouri Coteau*, L. Clayton and T. F. Freers, Eds. (North Dakota Geological Survey, Grand Forks, 1967), Misc. Ser. 30, p. 101.
9. D. R. Moir, in *Guidebook, Ninth Annual Field Conference Mid-Western Friends of the Pleistocene*, W. M. Laird, R. W. Lemke, M. Hansen, Eds. (North Dakota Geological Survey, Grand Forks, 1958), Misc. Ser. 10, pp. 108–114.
10. L. Clayton, *Proc. N. Dakota Acad. Sci.* **15**, 11 (1961).
11. S. J. Tuthill, *ibid.*, p. 19; thesis, University of North Dakota (1963); in *Glacial Geology of the Missouri Coteau and Adjacent Areas*, L. Clayton and T. F. Freers, Eds. (North Dakota Geological Survey, Grand Forks, 1967), Misc. Ser. 30, pp. 73–82; thesis, University of North Dakota (1969).

→ S. J. Tuthill, L. Clayton, W. M. Laird, *Amer. Midland Natur.* **71**, 344 (1964).

13. G. G. Thompson, *Proc. N. Dakota Acad. Sci.* **16**, 16 (1962).
14. J. G. Ogden, in *Quaternary Paleoecology*, E. J. Cushing and H. E. Wright, Jr., Eds. (Yale Univ. Press, New Haven, 1967), p. 117.
15. W. A. Watts and R. C. Bright, *Bull. Geol. Soc. Amer.* **79**, 885 (1968).
16. J. C. Ritchie and S. Lichti-Federovich, *Can. J. Earth Sci.* **5**, 873 (1968).
17. L. D. Delorme, *ibid.* **6**, 1471 (1969).

22 June 1970; revised 20 August 1970

■

Kinetics of Single-Layer Graphite Oxidation: Evaluation by Electron Microscopy

Abstract. *Etch-decoration reveals that the rate of removal of carbon atoms exposed at monolayer steps on graphite surfaces is very different from the rate of removal, under identical conditions, at multilayer steps. At 1113°K and a pressure of 1.33 newtons per square meter of oxygen, the rate of oxidation (along the layer planes) is less by a factor of nearly 100 than that at multilayer steps.*

For over a century investigators have measured the kinetics of the oxidation of carbon by recording either the rate of change of the mass of the solid (the procedure still widely used for metals and alloys) or the rate of production of gaseous oxides. Within the last decade (*1, 2*) it has proved possible to measure oxidation rates along all the principal crystallographic axes of graphite by following, with optical microscopy, the rate of growth of dislocation etch pits on the (0001) face of single crystals. Anisotropy factors as large as 10^{13} (for the *a*- and *c*-directions) have been shown (*3*) to occur. It is apparent from optical micrographs (see Fig. 1) (*4, 5*) of partially oxidized basal faces that oxidation in directions parallel to the basal planes (that is, in the *c*-plane along either the $\langle 10\bar{1}0 \rangle$ or $\langle 11\bar{2}0 \rangle$ direction involves the uniform recession of multilayers, the step heights being as much as 10 μm. This means that, under steady-state conditions, many thousands of individual basal layers are oxidized cooperatively from their peripheries. The activation energy (*4*) for the recession (*6*) in molecular oxygen in the temperature range 1085° to 1145°K is 268 ± 17 kjoule/mole. We now report a direct method of measuring the rate of recession of individual layers—that is, the lateral movement, by combustion in O_2, of 0.335-nm steps—and