7. R. Bloch, D. H. Walters, W. Kuhn, *J. Gen. Physiol.* **46**, 605 (1963).
8. The enhanced tension in the solvent of a homogeneous ideal solution is

$$\Delta\tau_1 = \frac{RT}{\overline{V}_1}\frac{N_2}{N_1}$$

This can also be written

$$\Delta\tau_1(V_s - N_2\overline{V}_2) = N_2RT$$

which is in the form of an equation of state of N_2 moles of solute molecules occupying a volume of $N_2\overline{V}_2$ in the solution whose volume is V_s; $\Delta\tau_1$, the additional tension in the solvent induced by and opposing the thermal motion of the solute molecules, is analogous to the wall pressure exerted by the container of N_g moles of real gas occupying a volume $N_g\overline{V}_g$ in a container of volume V. The wall pressure, p_w, induced by and opposing the thermal motion of the real gas is

$$p_w(V - N_g\overline{V}_g) = N_gRT$$

which is the equation of state of a real gas for which the pressure exerted by the gas is proportional to its molar concentration,

$$p_g = C_gRT\ \frac{N_gRT}{V}$$

The opposing pressure exerted by the containing wall is greater than p_g by the ratio $V/(V - N_g\overline{V}_g)$. These considerations applied to a solution ensure that the two methods illustrated in Fig. 1a give the same value of Π. In the left cylinder the wall pressure, as measured by p_a, is equal to π and equals $N_2RT/(V_s - N_2\overline{V}_2)$. In the right cylinder the applied tension in the pure solvent below the membrane equals the enhanced solvent tension in the solution, that is,

$$\pi = \tau_a = \Delta\tau_1 = \frac{N_2\ RT}{N_1\ \overline{V}_1}$$

thus assuring that both methods give the same value of π. I would also like to suggest that the concentrations $(N_2/N_1\overline{V}_1)$ and $(N_1/N_1\overline{V}_1)$ be designated as the tensile concentrations of the solute and the solvent, respectively, in the solution.

9. Provocative discussions with Prof. P. F. Scholander since 1960 have led to the thesis formulated in this essay. Discussions with Drs. Y. C. Fung, A. R. Hargens, A. B. Hastings, E. A. Hemmingsen, D. A. Krueger, J. Steen, C. B. Wenger, and A. A. Yayanos have also contributed importantly to my understanding of the phenomenon. My investigations of water relations in plants have been supported, in part, by National Science Foundation grant GB8343 (from the Division of Biomedical Science), grant GA-19604 (from the Office of Polar Programs), and by National Institutes of Health grant NS11704.

Early Man at Holly Oak, Delaware

Paleoenvironmental studies in Delaware suggest alternate times of habitation by early man.

John C. Kraft and Ronald A. Thomas

A reevaluation of an association of early man in northern Delaware with the woolly mammoth (*Mammuthus* or *Elephas* sp.) suggests a time from the early to middle Holocene epoch (8000 to 4000 B.C.) or, alternatively, an extremely early association in the early Wisconsin and late Sangamon ages. Stratigraphic and palynological analyses identify thin sedimentary layers as representing paleoenvironments of the late Holocene epoch and early Wisconsin and Sangamon ages in the northern Delaware region at the boundary between the piedmont and coastal plain geomorphic provinces. These sediments are closely associated with occurrences of abundant Archaic and Paleo-Indian artifacts and a carving of the woolly mammoth. Below, we discuss the probability of association of these artifacts of early American man with the woolly mammoth as well as with the mastodon in either the early to middle Holocene epoch (5,000 to 10,000 years ago) and the very latest Wisconsin age or early Wisconsin and late Sangamon ages (60,000 to 100,000 years ago).

Dr. Kraft is chairperson and professor of geology and a professor of marine geology at the University of Delaware, Newark 19711. Mr. Thomas is head of the section of archeology, Division of Historical and Cultural Affairs, State of Delaware, Dover 19901.

The Holly Oak Pendant

An interesting discovery pertaining to early man in the New World occurred in 1864 when H. T. Cresson and W. L. de Suralt found a number of artifacts associated with some peats near the Holly Oak railroad station in northern Delaware. Among the items found was a pendant carved from a fossil whelk shell, into which was incised the image of a woolly mammoth (Fig. 1). Needless to say, great excitement ensued concerning this evidence of early American man.

Unfortunately, the story of the exact location of discovery of the pendant is somewhat in doubt. One report states that it was found amidst some peat being dug from a "deep" hole on the Delaware River plain opposite the Holly Oak station of the Pennsylvania Railroad (*1*). The farmers are said to have been digging peat for use as fertilizer. Another account (*2*), reports that the Holly Oak pendant was found amidst some peat already spread on a farmer's field near the Holly Oak station of the Wilmington and Baltimore Railroad. The peat was said to have been taken from a "fallen forest layer in one of the adjoining estuaries of the Delaware River."

From 1864 until his death in 1894, Cresson pursued a career as an archeologist and continued to search the northern Delaware piedmont and coastal plain area for further evidences of early man in America. By 1880, he and a few associates had found more than 1000 artifacts, including logs with evidence of cutting, stone sinkers, arrowheads, spearheads, stone knives, hammerstones, splinters of bone, potsherds, stone axes, celts, chips of argillite, quartz, quartzite, flint, jasper, shell beads, a mastodon tooth, human teeth, bone implements, and other remains. Many of these artifacts were ultimately deposited in the Peabody Museum, Yale University, and in the National Museum of Natural History, Smithsonian Institution. Figure 2 shows some of the associated artifacts and human remains. This conglomeration of tools, carvings, bones, teeth, and beads is indeed puzzling. Much of the association appears to be from the Archaic period (8000 to 2000 B.C.). However, the bone implements and the mammoth carved on the Holly Oak pendant suggest a possible Paleo-Indian origin (before 8000 B.C.). Obviously, a great deal of reevaluation needs to be done with regard to the discoveries of Cresson and his associates in northern Delaware.

Cresson's work ranged along the relatively narrow coastal plain adjacent to the fall zone and piedmont of northern Delaware (Fig. 3). Some of the artifacts are reported to have been dug from a rock shelter near the town of Claymont. Many others were found in a layer of peat under the tidal mud that extended under the bed of Naaman's Creek at its confluence with the Delaware River (*3*). Unfortunately, detailed records of the stratigraphy of the sites and of precise locations of the discoveries were not maintained. Interestingly, during the same part of the late 19th century, other discoveries were being made in North America of remains of

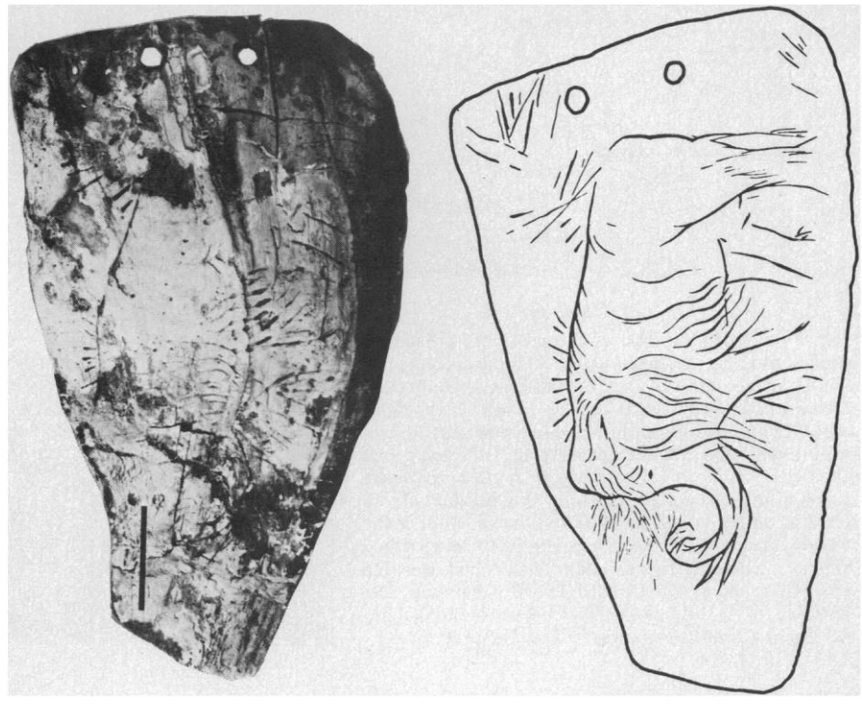

Fig. 1. The Holly Oak pendant. (Left) A carving on a portion of the surface of a large whelk. The two holes bored to hold a thong indicate that the shell was carved as a pendant. Bar, 2 centimeters. [Archaeology Catalog No. 148313 in the collections of the Department of Anthropology of the National Museum of Natural History, Smithsonian Institution. [Courtesy of Dr. Clifford Evans, chairman, Department of Anthropology, National Museum of Natural History, Smithsonian Institution)] (Right) A sketch of the Holly Oak mammoth as carved on the Holly Oak pendant. [Courtesy of Dr. B. J. Meggers, Department of Anthropology, National Museum of Natural History, Smithsonian Institution]

"early man" or "ice age man." These included the discovery of the Lenape stone, bearing the carving of a mammoth pursued by hunters and found in Buckingham Township, Pennsylvania, in 1872. In addition, Charles Abbott, an amateur archeologist, reported a large aboriginal site south of Trenton (*1*). Abbott reported finding crude weapons in river gravels that he interpreted to be of "ice age" origin.

During the later years of the 19th century, many amateur and professional archeologists examined the finds of Cresson and others. Some said that the artifacts were up to 50,000 years old and from a glacial epoch. From the turn of the century into the early part of the 20th century, argument continued as to the age and meaning of the tremendous number of artifacts collected by Cresson. In view of the questionable geological relationships, skeptics began to insist that Cresson had not actually discovered some of the objects he claimed or that the discoveries were spurious or, in some cases, modern in origin. A major criticism raised was that Cresson's discovery of the mammoth carved on the shell occurred in the same year as the discovery by Lartet of a similar carving on a mammoth tusk in the cave of La Madeleine in France (*1*). The Lenape stone is suspect for the same reason. In addition, from 1936 to 1941 an intensive restudy was made of Abbott's discoveries near Trenton. This study with modern techniques and by trained archeologists and geologists suggested that the Abbott's farm occurrence in New Jersey was not of great antiquity (*4*). Continued lack of confirmed evidence of early man in eastern North America led to a general low regard for Cresson's discoveries and to the idea that Paleo-Indian occupancy of eastern North America probably did not begin until the rather late date of 10,000 to 12,000 years ago. A survey of books and publications on ancient man in North America and Paleo-Indian discoveries almost never reveals references

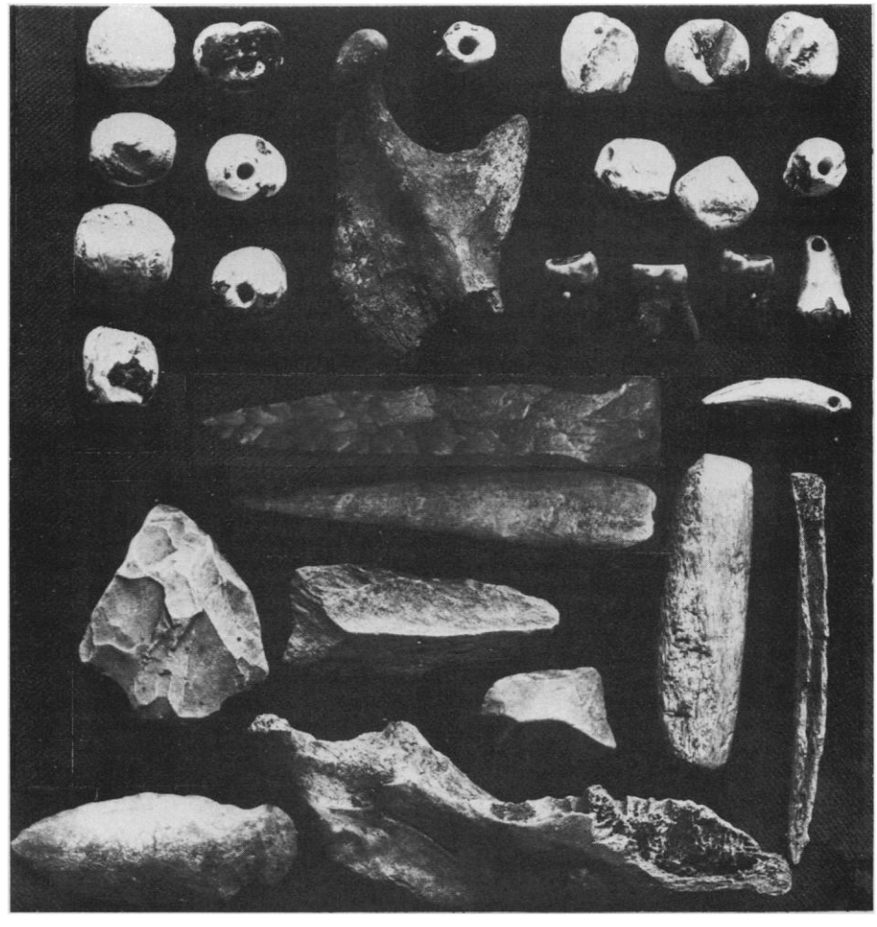

Fig. 2. A series of artifacts from the collection of the Department of Anthropology of the National Museum of Natural History, Smithsonian Institution, shown in association with the Holly Oak pendant. These artifacts are interpreted to be from the Archaic period in part (2000 to 8000 B.C.) and in part from the earlier Paleo-Indian period (before 8000 B.C.). However, the associations are in doubt and detail was not recorded by the collector, Dr. H. T. Cresson. [Courtesy of Dr. Clifford Evans, chairman, Department of Anthropology, National Museum of Natural History, Smithsonian Institution]

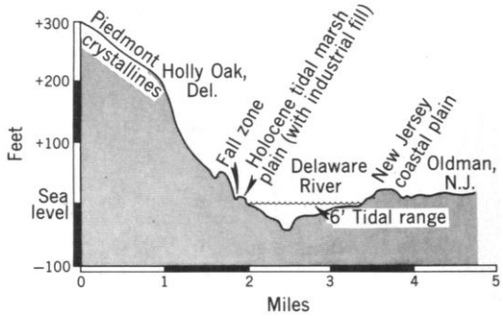

Fig. 3 (above). A profile of the piedmont crystalline province and its junction with the Atlantic coastal plain and Delaware River plain at the fall zone at Holly Oak, Delaware. The first ridges in New Jersey, to the right, are cuesta-like ridges of Mesozoic sediment that dip seaward toward the Atlantic coastal plain and continental shelf geosyncline. Fig. 4 (right). A close-up photograph of the carving on the Holly Oak pendant shows the area with hairs projecting from the shoulder of the woolly mammoth. The carvings appear to be aged in a similar manner to the remainder of the shell. Bar, 0.5 cm. [Courtesy of Dr. Clifford Evans, Chairman, Department of Anthropology, National Museum of Natural History, Smithsonian Institution]

to the Holly Oak pendant and its "mammoth."

Recent studies of the geomorphology and geologic history of the Delaware coastal plain where it borders the piedmont (the fall zone) suggest that sedimentary deposits occur in a time span that lends some credence to the occurrence of Paleo-Indian or Archaic man in the Delaware area at the same time as the woolly mammoth occupation. Accordingly, a new evaluation of the Holly Oak pendant was made. Clifford Evans and his colleagues at the Smithsonian Institution reexamined the carving on the surface of the shell and reached the conclusion that the incisions show the same stages of weathering as the shell surface itself. (Figs. 1 and 4). Most who have examined the Holly Oak specimen "indicated that they think this object is legitimate, and do not see any possibility of even suggesting the remote conception that it is a fake" (*5*). Figure 1 (right) shows a detailed interpretation of the carving on the Holly Oak pendant, constructed by B. J. Meggers of the Smithsonian Institution. It is clear that the Holly Oak pendant is old and bears a carving of a woolly mammoth that was incised at the time of construction of the weathered pendant and near the time of origin of the shell. The question remains: How old is the pendant?

Geomorphic and Geologic Associations

Fortunately, it is possible to make determinations of the geology of the Holly Oak area that clearly define the times of deposition of all sedimentary units. Figure 5 is a geomorphic map of the relatively narrow coastal plain of the tidal Delaware River which lies along the edge of

Table 1. Radiocarbon data from the sediments underlying the coastal plain at Holly Oak, Delaware. Latitude, 39° 46.9′ to 47.0′N; longitude, 75° 28.3′ to 28.5′W.

$-\delta C^{14}$	Age (years) 5,568 = half-life	Age (years) Masca correction	Elevation (meters) from mean low sea level	Sedimentary environment	Material	Isotope Inc. No.
254 ± 3	2,355 ± 85	2,390 to 2,420	+0.3	Tidal marsh	Total organic carbon wood and marsh grass in gray mud	17036
263 ± 8	2,450 ± 85	2,610 to 2,670	−1.2	Tidal marsh	Total organic carbon wood and marsh grass at base of marsh mud	17038
981 ± 3	31,850 ± 1,300	Probably contaminated	−1.2	Alluvial silt	Total organic carbon rotten wood fragments in tan mud	17035
> 993	> 40,000		−1.2	Alluvial silt	Decayed twigs, leaves, and wood fragments from tan mud	17801
> 993	> 40,000		−1.7	Alluvial silt	Decayed twigs, leaves, and wood fragments from tan mud	17802
> 993	> 40,000		−1.8	Alluvial silt	Decayed twigs, leaves, and wood fragments from tan mud	17800
> 993	> 40,000		+0.5	Alluvial silt	Decayed twigs, leaves, and wood fragments from tan mud	17799

the piedmont province in northern Delaware. Three geologic profiles have been constructed (Fig. 6) to show the geology of the coastal plain in the Holly Oak area. As shown on the profiles, the narrow coastal plain of the Delaware River is now at the very edge of the piedmont province. The area includes some colluvial debris washed down from the piedmont surface, a relatively small number of thin fluvial deposits from the piedmont, and, most important, a narrow tidal marsh. The current tidal marsh has encroached across the edge of the piedmont at the fall zone in the Holly Oak area for approximately the past 2700 years. This is a result of the continual late Holocene rise in relative sea level in this area (*6*). The marsh materials are transgressing landward and upward across the piedmont surface.

In some areas (Fig. 6) the late Holocene marsh overlies a tan alluvial silt containing relatively large amounts of twigs, leaves, and other organic debris. It is believed that these alluvial silts are associated with the "peat" mentioned by Cresson. In the borings shown in Fig. 6, the alluvial silts and organic debris are shown to be more than 40,000 years old. One radiocarbon date showed an age of 31,850 years. This led us to our intensive investigation of the geologic structure of the coastal plain at Holly Oak. We now know that the age of 31,850 years is probably spurious and includes intrusions from above (Table 1). Thus far, four dates showing ages greater than 40,000 years have been determined from organic materials in the alluvial silts underlying the coastal plain in the Holly Oak area. As can be seen from Table 1, this deposit varies in elevation from 1.8 meters below mean low sea level to 2.1 meters above mean low sea level.

Waddington and Wright (*7*) of the Limnological Research Center of the University of Minnesota analyzed four samples of the sediment that is more than 40,000 years old. They report that the pollen assemblages (three samples, JCK-74 DH2, Fig. 6) "resemble the uppermost levels at Fernbank, a Sangamon interglacial site in upper New York State (*8*), and at Don Valley, Toronto" (*9*). One of the samples (JCK-74 DH1, Fig. 6) "also resembles the early-Wisconsin interstadial assemblage at St. Pierre, Quebec dated about 60,000 B.P. in age" (*8*). These pollen analyses, radiocarbon dates of greater than 40,000 years, and the elevations near present sea level suggest a date of deposition of the alluvial silts in early Wisconsin and Sangamon age time (about 60,000 to 100,000 years ago). Since Sangamon time, relative sea levels have varied in the Delaware area from 8 meters above present sea level (Sangamon age) to 30 meters below the present level (Holocene epoch), as evidenced by marine coastal stratigraphic units studied in the Rehoboth and Bethany Beach area of coastal Delaware, approximately 160 kilometers south of the Holly Oak area (*6*).

Archaic Period (8000 to 2000 B.C.)

A paleogeographic reconstruction of the Holly Oak area is shown in Fig. 7, which is based on relative sea level data obtained from studies elsewhere in Delaware (*6*). The geomorphic setting for middle Archaic period time is shown. At that time, the alluvial silts more than 40,000 years in age would have had a

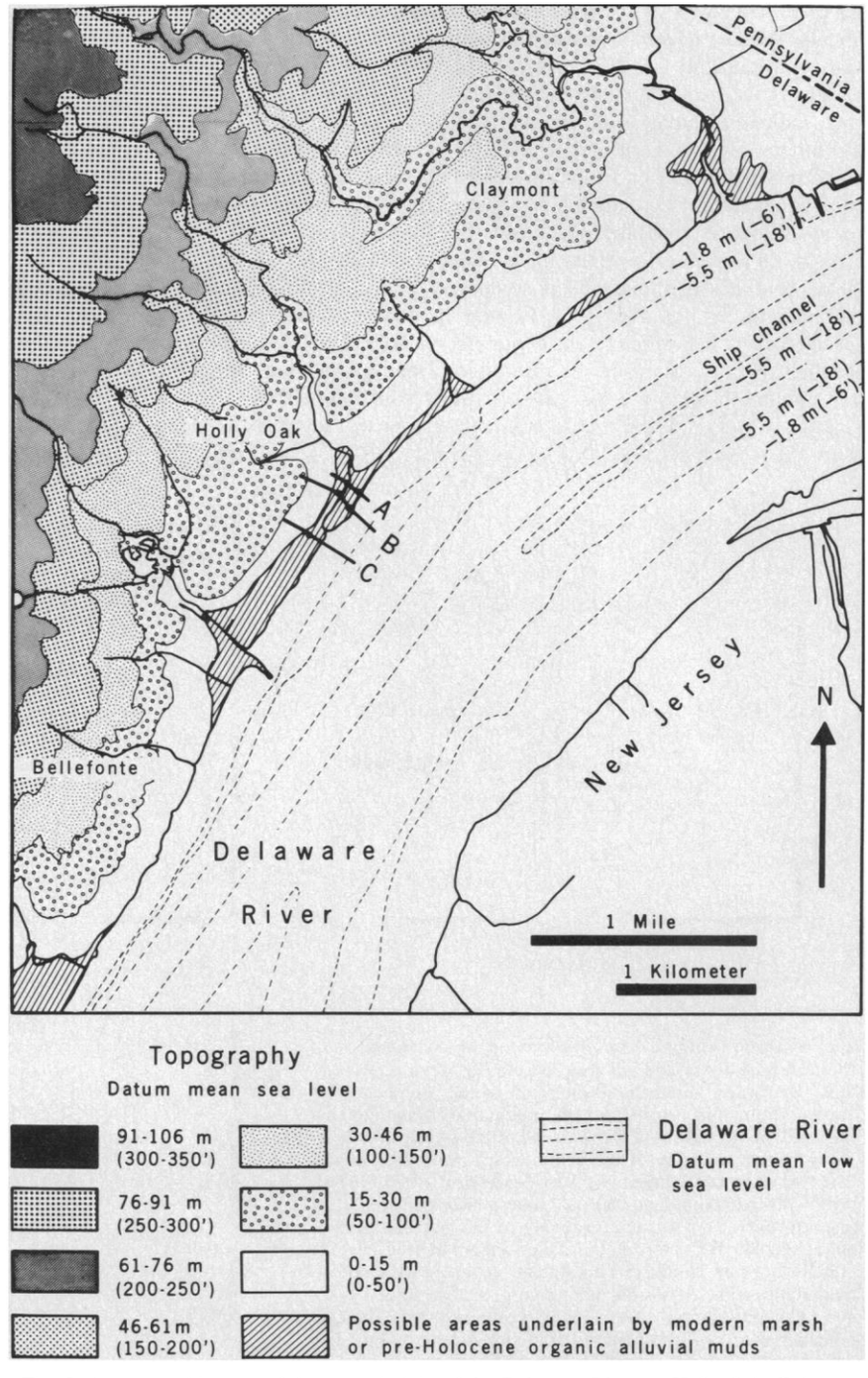

Fig. 5. A topographic map of the coastal plain of the Delaware River at Holly Oak, Delaware, shows the relation of the coastal plain to the piedmont crystalline province. In addition, the lines of sections A, B, and C on Fig. 6 are shown. The possible area underlain by the presently encroaching late Holocene marsh as well as the early Wisconsin and Sangamon age organic alluvial mud is shown.

relatively wide distribution along the narrow coastal plain of the Delaware River at its junction with the piedmont crystalline province. Evidence from elsewhere in Delaware shows that a geomorphic reconstruction of 10,000 years ago and earlier would include a relatively deeply incised ancestral Delaware River valley approximately 30 meters below present sea level. Coastal marshes from Paleo-Indian times have been encountered at 28 to 30 meters below present sea level in the ancestral valleys of the Murderkill River to the south in central Delaware, and the Indian River in southern Delaware. In addition, late Wisconsin freshwater, coastal marsh, and shallow marine sediments have been encountered by others on the continental shelf of eastern North America from Virginia to Massachusetts. Associated with these early Holocene and late Wisconsin indicators of lower sea level are more than 40 occurrences of molars of mastodons and mammoths reported to have been discovered by fishermen on the continental shelf (*10, 11*). Many of the mastodon and mammoth teeth are associated with shallow water and intertidal sediments and peat that are dated from 9,000 to 11,000 years ago and that are now found on the middle and outer continental shelf at water depths of up to 90 meters (*10*).

It is generally accepted that *Mammut americanum* (Kerr), and *Mammuthus* sp. occur in association with coastal environments in earliest Archaic and late Paleo-Indian time on the outer continental shelf. Accordingly, it seems valid to extend this association landward along the estuaries and into the rivers flowing along the coastal plain, for example, the Delaware River at Holly Oak, Delaware.

Paleo-Indian or Earlier?

In view of the poor detail of recorded association of artifact finds with the Holly Oak pendant, there is not enough evidence to determine precisely the age of the Holly Oak pendant. However, a low-lying coastal plain land surface extended along the ancestral Delaware River and adjacent to the piedmont crystalline uplands in Archaic times (4,000 to 10,000 years ago). This land surface included widespread areas of peaty and organic alluvial silts. The silts were deposited as alluvial floodplain deposits at a time more than 40,000 years ago and probably in the early Wisconsin and Sangamon ages (about 60,000 to 100,000 years ago). Possibly the Holly Oak pendant and some of the other artifacts were deposited in this sediment that is more than 40,000 years old and, presumably, of the early Wisconsin and Sangamon ages. Conversely, it is also possible that these artifacts were lost or buried in the land surface of Archaic times as sea level continued to rise and cover the sediment that is more than 40,000 years old. Ultimately, the entire erosional or unconformity surface shown in Figs. 6 and 7 was covered by the modern late Holocene marsh as the late Holocene rise in relative sea level and coastal transgression continued. In view of this, intrusions through late Holocene sediments (Woodland period) and deposits of the Archaic period could lie in close association along this surface.

A precise timing cannot be set for the carving of the Holly Oak pendant. However, we suggest several possibilities.

1) The Holly Oak mammoth may have

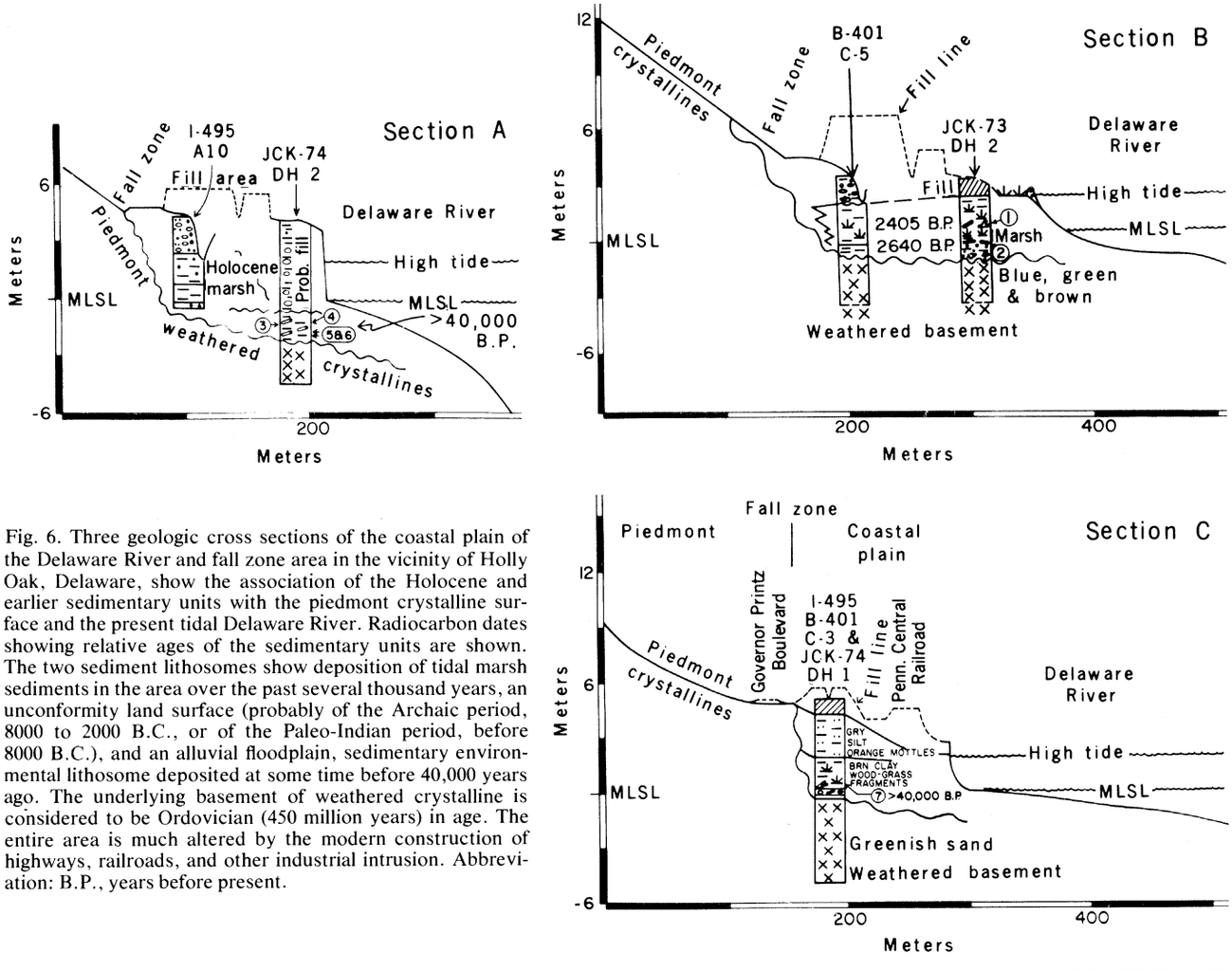

Fig. 6. Three geologic cross sections of the coastal plain of the Delaware River and fall zone area in the vicinity of Holly Oak, Delaware, show the association of the Holocene and earlier sedimentary units with the piedmont crystalline surface and the present tidal Delaware River. Radiocarbon dates showing relative ages of the sedimentary units are shown. The two sediment lithosomes show deposition of tidal marsh sediments in the area over the past several thousand years, an unconformity land surface (probably of the Archaic period, 8000 to 2000 B.C., or of the Paleo-Indian period, before 8000 B.C.), and an alluvial floodplain, sedimentary environmental lithosome deposited at some time before 40,000 years ago. The underlying basement of weathered crystalline is considered to be Ordovician (450 million years) in age. The entire area is much altered by the modern construction of highways, railroads, and other industrial intrusion. Abbreviation: B.P., years before present.

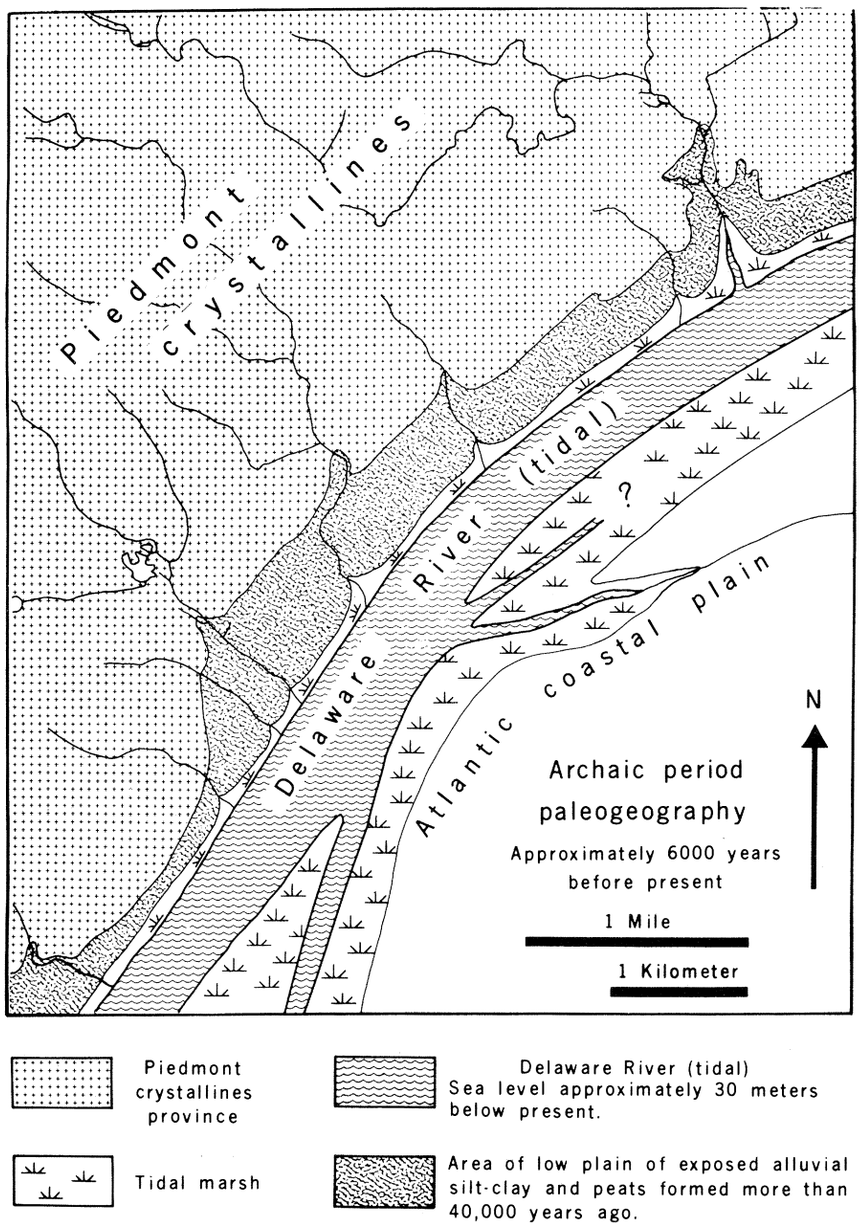

Fig. 7. A paleogeographic reconstruction of the Delaware River coastal plain and associated piedmont crystalline surface in middle Archaic time, approximately 6000 years ago. The extensive area of low plain, including a sedimentary deposit of alluvial silt and clay peats, was formed more than 40,000 years ago. This entire exposed surface was gradually encroached on by middle and late Holocene epoch tidal marsh sediments as the tidal Delaware River rose, in accompaniment to the rise in relative sea level during the Holocene epoch. Accordingly, the possibility exists for the intrusion of Archaic and Woodland period artifacts into the earlier sedimentary unit. The earlier (more than 40,000 years ago) sedimentary unit was probably deposited as a river floodplain of a river flowing between the piedmont crystalline province and the first cuesta of the Atlantic coastal plain in New Jersey. It cannot now be determined whether or not this was an early Wisconsin and Sangamon time ancestor of the Delaware River or some other river flowing in the same path.

been carved by Paleo-Indian peoples or American Indians of the early Archaic period. It is clearly indicated by the times of formation of the geologic units that early man lived in association with the late Pleistocene and early Holocene mastodon and mammoth.

2) It is also possible that the pendant is extremely old and was deposited with the alluvial floodplain sediments more than 40,000 years ago, probably in early Wisconsin or Sangamon age. If so, the case might be made for a truly early American man in earliest Wisconsin or Sangamon times.

3) A third hypothesis could be made, although it is not very tenable. The Holly Oak pendant might have been found in the sediment layers of two and a half millennia ago. This would introduce the possibility of a very late occurrence of the woolly mammoth in eastern North America.

4) It is remotely possible that the pendant was removed from its original place of deposition by later Indians of the Woodland period.

5) Finally, it is possible that the pendant was skillfully manufactured and dropped at the Holly Oak site by Cresson, de Suralt, or an unknown person.

The heavily traveled "fall zone corridor" of Delaware is now covered by Governor Printz Boulevard, Interstate 95, the Penn Central Railroad, a power transmission system, and much industry and "fill." However, a few areas for potential exploration still exist. A renewed effort might still solve the problems of archeologists, anthropologists, and geologists faced with much evidence of early man in northern Delaware: thousands of artifacts, an "old" carving of a mammoth on a shell, early Wisconsin and Sangamon age floodplain deposits; and almost nowhere to excavate. Reexamination of old discoveries, coupled with the application of new concepts in sedimentology-stratigraphy and palynology, has led to an exciting new association of early man with the woolly mammoth in America. Possibly, further work will prove truly ancient (early Wisconsin and Sangamon age) presence of early man. It is probably time to reexamine many of our legends, historical records, and archeologic discoveries in the light of new geoscience techniques.

References and Notes

1. C. A. Weslager, *Delaware's Buried Past* (Rutgers Univ. Press, New Brunswick, N.J., ed. 2, 1968), pp. 30–44.
2. Smithsonian Institution, *Annu. Rep. U.S. Nat. Mus.* (1891), p. 381.
3. H. T. Cresson, *Pap. Peabody Mus. Archaeol. Ethnol. Harv. Univ.* **1** (No. 15), 211 (1892).
4. D. Cross, *Proc. Am. Philos. Soc.* **86**, 315 (1943).
5. C. Evans, personal communication.
6. J. C. Kraft, *Geol. Soc. Am. Bull.* **82**, 2131 (1971).
7. J. C. B. Waddington and H. E. Wright, Jr., personal communication.
8. J. H. McAndrews, paper presented at Friends of the Pleistocene 35th Annual Reunion, Ithaca, N.Y. (1972).
9. J. Terasmae, *Geol. Surv. Can. Dep. Mines Tech. Surv.* **56**, 23 (1960).
10. K. O. Emery, R. L. Wigley, A. S. Bartlett, M. Rubin, E. S. Barghoorn, *Science* **158**, 1301 (1967).
11. K. O. Emery and L. E. Garrison, *ibid.* **157**, 684 (19 → F. C. Whitmore, Jr., K. O. Emery, H. B. S. Cooke, D. J. P. Swift, *ibid.* **156**, 1477 (1967).

12. We thank Dr. H. E. Wright, Jr., and Ms. J. C. B. Waddington for the report on pollen analysis. Credit or quotes regarding this aspect of the work should certainly accrue to them. We also thank Dr. C. Evans and his colleagues from the Museum of Natural History, Smithsonian Institution for the illustrations of the Holly Oak pendant and their professional opinions regarding its authenticity. The University of Delaware Research Foundation (UDRF) supported the majority of the field and laboratory research. The Delaware State Highway Department kindly drilled two exploratory holes for us.