tures containing 30% CO_2–70% O_2 were obtained commercially.

In all the animals the spontaneous rhythm of the cerebral cortex as well as that from the cerebellum was significantly modified by the ingestion of DDT. The amplitude of the cerebellar activity was markedly increased over that seen in normal control animals. Spikelike waves appeared, although electrical fits were not observed. The cerebral rhythms showed similar activity, but definitely after that seen in the cerebellum (Fig. 1 A). Shortly after the administration of the carbon dioxide mixture (Fig. 1 B), but more usually after its removal, there was marked intensification of all electrical activity, and in eight animals seizures were either observed in the cerebellar leads exclusively or appeared in the cerebellum first and then after a short lag period were also seen in the cerebral cortex. The inhalation of the 30% CO_2–70% O_2 mixture sometimes caused a decrease in amplitude and increase in frequency of the electroencephalogram (Fig. 1 C); however, upon its removal, the typical seizure patterns appeared (Fig. 1 D). In four animals where DDT in doses of 500–1000 mg/kg was ingested, the clinical picture described above appeared 4–6 hr later, and the animals usually died within 12–24 hr after DDT feeding.

Previous work (*4*) showed that high concentrations of carbon dioxide in oxygen increased the frequency but lowered the amplitude of the normal cat EEG. Seizures induced electrically or with Metrazole were antagonized when the gas mixture (30% CO_2–70% O_2) was inhaled. Interestingly, it was found that with Metrazole seizures appeared in the thalamus first and then in the cerebrum (*5*). It is noted that, with convulsants potentiated by carbon dioxide, the fits are either confined to or first seen in the cerebellum and then appear in the cerebral cortex (*3*). This seems to explain the observations on the gross behavior of the animals under the influence of the convulsants and also the histopathology found in the cerebellum. Convulsants antagonized by CO_2 do not show fits first in the cerebellum (*4*).

It is not easy to explain why carbon dioxide can act synergistically with DDT and other cerebellar convulsants. We know that the cerebral cortex can have its threshold for stimulation raised by carbon dioxide. It may be that, once the cerebellar convulsant has been introduced, the additional release from cortical inhibition by carbon dioxide is sufficient to permit seizure activity to start subcortically. The fit is then in turn transmitted to the cerebral cortex. As yet no explanation is offered as to why these seizures start when the CO_2 mixture is first applied or shortly after it is removed. The most likely explanation is that a certain critical level of CO_2 must be maintained for a critical period of time and that this combination of circumstances is sometimes realized during induction with CO_2 and sometimes on the way out.

The oral ingestion of DDT causes gross symptoms of cerebellar involvement. This is also seen when electroencephalographic recordings of cerebral and cerebellar activity are made. Shortly after the introduction or removal of 30% CO_2–70% O_2, definite electrical seizures are seen in the cerebellum exclusively or initially, and later appear in the cerebral leads. This potentiating effect of CO_2 with DDT appears in contrast to the antagonistic actions of CO_2 on seizures induced electrically or with Metrazole.

References

1. HAYMAKER, W., GINZLER, A. M., and FERGUSON, R. L. *Am. J. Med. Sci.*, **212**, 423 (1946).
2. CRESCITELLI, F., and GILMAN, A. *Am. J. Physiol.*, **147**, 127 (1946).
3. POLLOCK, G. H., and BAIN, J. A. *Ibid.*, **160**, 195 (1950).
4. POLLOCK, G. H. *J. Neurophysiol.*, **12**, 315 (1949).
5. POLLOCK, G. H., and GYARFAS, K. *Arch. intern. pharmacodynamie*, **89**, 252 (1952).

Manuscript received October 20, 1952.

Recent Changes in Sea Level Along the New England Coast: New Archaeological Evidence

Elso S. Barghoorn

The Biological Laboratories* and *Botanical Museum*, *Harvard University, Cambridge, Massachusetts

Submergence of the Atlantic coast of North America in relation to the tidal plane has long been a problem of interest to geologists, to geographers, to students of plant ecology, and, in more recent years, to archaeologists. Within the past decade archaeological interest has been greatly stimulated by the discovery in New England of extensively submerged aboriginal occupation sites (*1, 2*), and by the striking contrast between past and present tidal conditions in coastal estuaries. Paleobotanical and stratigraphic studies of peat and other plant-bearing sediments found in association with archaeological horizons indicate a progressive encroachment of the sea on shoreline vegetation. These factors, in conjunction with a few recent determinations of the absolute age (*3*) of occupation sites, have focused renewed attention on the problem of coastal stability and its geologic and archaeological implications.

Evidence that has been advanced in the past to demonstrate geologically recent and continuing tidal changes on the Atlantic coast is quite diverse and in part contradictory. Many of the earlier controversies resulted from efforts to prove a priori one theory or another of the geologic consequences resulting from retreat of the Wisconsin ice sheets and subsequent crustal movements of the continental margins. Botanical evidence derived from studies of coastal and estuarine salt marshes and their sedimentary record of peat was variously used to support arguments both for coastal stability and for continued coastal subsidence (*4–6*).

More recently, however, discovery and extensive investigation of the Boylston Street fishweir, a structure excavated at considerable depth in sediments de-

posited in the former Charles River estuary in Boston, show conclusively that submergence of the order of 20 ft has occurred since human occupation of eastern Massachusetts (*7*). Carbon-14 age determinations demonstrate that the time of this human occupation is greater than 3851 (± 390) years and less than 5717 (± 550) years (*3*). By extrapolation of the two dated levels with the present tidal plane and by assuming the weir itself to be 4500 years old, an average rate of submergence of approximately 6 in. per century may be calculated for the period between construction of the fishweir and European settlement of New England in 1620. These calculations, of course, provide no basis for concluding that the rate of submergence has been constant, nor do they prove definitely that submergence has continued to the present.

Virtual proof of currently continuing and significantly rapid submergence of the Massachusetts coast has been secured, however, from recent archaeological discoveries at Saugus, Massachusetts. Here, in the course of restoring the first successful iron works in North America, by the First Iron Works Association in conjunction with the American Iron and Steel Institute, well-preserved colonial wooden structures have been uncovered at levels now daily inundated by high tides. The arrangement of these structures, which include remains of water wheels, a timbered waterway in its original position, and remnants of a dock and wharf, is such that their intended function would be very inefficient if not impossible under present tidal conditions. Associated with the water wheels and wheel pit timbers are abundant and varied artifacts representing diverse products of colonial manufacture. Owing to the completeness and thoroughness with which the excavation and restoration are being made, it has been possible to make repeated observation of the many physical and cultural features currently exposed at the site. It should be noted, however, that present flooding by the diurnal tide, and especially the effect of occasional excessive tides, are sufficiently greater than they were in colonial time as to render excavating and plotting field relations of buried structures in lower parts of the restoration a difficult engineering problem.

Through the interest and collaboration of Roland W. Robbins, in charge of archaeological investigations at Saugus, precise data concerning present tidal relations have been obtained, as well as useful and important historical information.

Critical examination of the field relations exposed in the Saugus excavation indicates that the entire area of early Iron Works development has been affected since 1650 by an increase in the height of tide in the Saugus estuary of approximately 2½–3 feet. There is no evidence of subsurface slumping, or of localized small-scale deformation of the glacial sediments underlying the site, chiefly sands and gravels interbedded with clays, to account for the change in relation to tidal plane. The operation of shoreline processes that might conceivably have induced localized tidal effects (*5*) has evidently not been a causal factor in submergence at Saugus. The area under consideration is nearly 3 miles from the open sea and is located immediately at the terminus of active drainage of the Saugus River. Seaward from the Iron Works site the present drainage is entirely controlled by tidal action and has quite evidently been influenced by tidal currents since colonial settlement.

Not until archaeological investigation has been completed will it be possible to reconstruct in the desired detail a complete interpretation of the interrelationships between and among the several structures that have been unearthed in the Saugus excavations. Colonial developments there were initiated in a topographic and geographic setting that was apparently selected with careful regard both for its physical features and future development. There is no indication in historical records that the Saugus location proved unsatisfactory from the time of its establishment until activities ceased, except for probable exhaustion of raw materials. Present tidal relationships, however, reveal convincingly that certain features of the Saugus Iron Works could not have been effectively developed and efficiently operated if the tidal range effective today had obtained in 1650.

The Saugus site, although very recent in terms of geologic processes, provides an unusual aggregate of evidence on the question whether submergence of the coast of eastern North America is still continuing. Instrumental records of recent change in the tidal level of the Atlantic and Gulf coastal waters have been analyzed in detail by Marmer (*8, 9*). Results of these studies are of especial interest and strongly confirm by physical measurements the same conclusion; viz., that the eastern coast of the continent is slowly subsiding in relation to present sea level.

Evidence drawn from colonial and pre-colonial archaeological investigation is in such close agreement with that from paleobotanical and geologic studies of coastal change that the controversy over coastal submergence seems finally resolved. There remains to be evaluated, however, the more complex problem of relative effect of eustatic rise in sea level and that of crustal movement in the evolution of the New England coast line.

References

1. JOHNSON, F., *et al. Papers Robert S. Peabody Foundation for Archaeology*, **2**, 1 (1942).
2. JOHNSON, F., and RAUP, H. *Ibid.*, **1**, 3 (1947).
3. LIBBY, W. F. *Science*, **114**, 291 (1951).
4. GOLDTHWAITE, J. W. *Proc. Geol. Soc. Am. for 1935*, 79 (1936).
5. JOHNSON, D. W. *The New England-Acadian Shoreline*. New York: Wiley (1925).
6. CHAPMAN, V. J. *Proc. Geologists' Assoc.* (Engl.), **49**, 373 (1938).
7. BARGHOORN, E. S., *et al.* In F. Johnson, Ed., *Papers of the Peabody Foundation for Archaeology*, **4**, 49 (1949).
8. MARMER, H. A. *Geograph. Rev.*, **38**, 652 (1948).
9. ———. *Trans. Am. Geophys. Union*, **30**, 201 (1949).

Manuscript received October 8, 1952.