Reports

Anangula: A Geologic Interpretation of the Oldest Archeologic Site in the Aleutians

Abstract. *Anangula preserves remains of a lamellar flake industry probably between 8000 and 12,000 years old because of a unique combination of geologic factors. The most important are the relation of land and sea in this region in the past, when the sea level was lower than at present, and the relatively slight erosion by the sea today.*

Anangula (called Ananiuliak Island on the U.S. Coast and Geodetic Survey charts) is a small island 7.2 km north-northwest of Nikolski village on Umnak Island in the eastern Aleutians. It is separated from Umnak Island by a water barrier 11 m deep, and in turn from the Alaska Peninsula by several barriers, the deepest of which is about 48 m. Passes west of Umnak are more than 130 m deep. Anangula is protected from storms, except from the northwest, by Umnak Island. Hence, the south and east coasts of Anangula have suffered relatively little postglacial erosion.

Evidence from various parts of the world suggests that sea level stood 8000 years ago at least as low as −20 m (relative to present sea level), 10,000 years ago at −35 m, 12,000 years ago at −45 m, and 14,000 years ago at −60 m (*1*). Thus, as recently as 12,000 or 13,000 years ago, Umnak and Anangula islands formed the west end of the Alaska Peninsula, and an extensive area of the Bering Sea platform (including Bering Strait) was dry land (*2*). A direct land route connected Asia and western Alaska, the eastern Aleutians, and the Alaska Peninsula. Along that route the climate was not very different from the present climate of the land masses that adjoin those now-submerged areas (*3*).

It is apparent that ancient man in this region, if he was sea-oriented, would usually have had his home along the edge of the Bering Sea platform that is now under many meters of water. That he was sea-oriented at Anangula is the most reasonable interpretation. There the occupation site, bordering on a small pond, faced on the sea, where the water is 70 m deep today, and was adjacent to the easternmost pass between the Pacific Ocean and the Bering Sea during the time of occupation. Better sites inland, by a larger lake overlooking the now submerged connection with Umnak Island, were not occupied. Only rarely, then, where unusual topographic conditions existed, would ancient man's home have been high enough to have survived a rise in sea level not just to that of today but to a level 3 m higher, where the sea stood for some centuries about 5500 years ago in the north Pacific (*4*). Storm beaches were built up to 10 m above present sea level in several places around Umnak Island.

The Anangula site, 17 to 20 m above present sea level, is, so far, unique. Laughlin and A. G. May discovered it in 1938 and returned in 1952 (*5*) with others to make detailed studies. It was established that the archeologic site was a manufactory, but its place in time could only be inferred. Except for remains of the flake industry, few traces of the nature and habits of the ancient inhabitants have survived. It is now clear, however, that the site was a large permanent settlement. Black visited it briefly in 1962 (*6*) and recognized a sequence of volcanic-ash horizons and buried soils similar to that around Nikolski, where the results of carbon-14 dating, together with weathering phenomena, relation to raised beaches, and other geologic evidence, permit estimation of the length of time represented by the sequence. Further excavation and study in 1963 (*7*) confirmed the earlier view that the site was one of considerable antiquity.

The ash sequence within the flake site (Fig. 1 shows the upper half of the sequence) rests either on till or on andesitic bedrock. The ash is generally of intermediate composition, but the contained pumice is more acid. Any one of several recently active volcanoes in the vicinity, or several of them, could have provided the ash. Certain distinctive ash horizons of the Nikolski area have been designated by Roman numerals for convenience in field studies. The soil horizons are numerous, and eight distinctive hiatuses are known. The artifacts are confined to one cultural horizon, between ash II and ash III (Fig. 1, bottom), where normally only a relatively weakly developed soil is seen. The period represented by the cultural horizon seems to be at most only a few centuries. One of the heaviest ash falls that has occurred in the area since deglaciation, which was perhaps 17,000 to 20,000 years ago, terminated the occupation.

Dating the site presents a problem. Three dates of charcoal from the one cultural layer, obtained by the carbon-

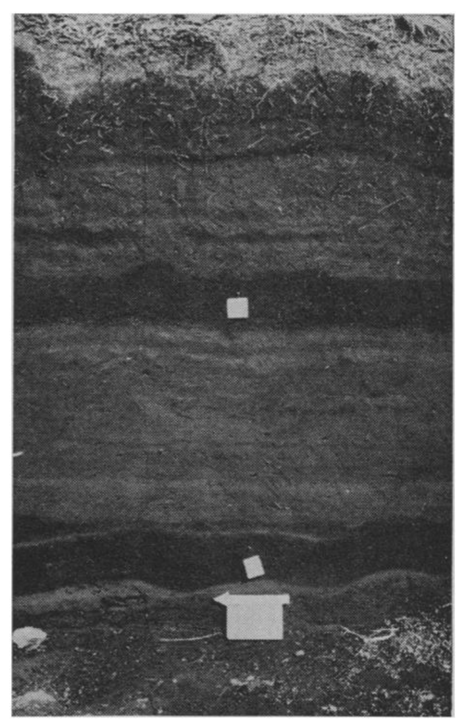

Fig. 1. Upper half of the ash sequence at the flake site on Anangula Island. The arrow indicates the cultural horizon beneath ash III (lower square tag). Ash IV is labeled by the upper square tag. At top is surface vegetation.

Table 1. Dates, obtained by carbon-14 dating, of charcoal from one cultural layer of the Anangula site (*10*).

Laboratory No.	Years ago
I-715	8,425 ± 275
W-1180	7,660 ± 300
I-1046	7,990 ± 230

14 method, are given in Table 1. Living rootlets were present in all samples, and the true ages are probably 10 to 20 percent greater than the ages indicated. Also, geological evidence suggests that the average age obtained by radiocarbon dating is somewhat too young. It is estimated that ash IV, the youngest of the major ashes, is about 5000 years old, for it occurs on the oldest but not the youngest parts of the 10-m storm beach at Nikolski. The age of that beach and of the contemporaneous 3-m beach which borders many parts of the North Pacific today has been estimated, from samples taken at Chaluka (Nikolski), at Cook Inlet, and elsewhere, at about 5500 years (*4*). Field inspection indicates that weathering of ash IV is less advanced than weathering of the ashes below it to the cultural horizon. Moreover, no bone, shell, or wood has survived in the cultural layer at Anangula, yet such materials are well preserved in the dated midden deposits at Chaluka, the earliest of which were laid down about 5000 years ago in ash IV on top of the 10-m beach. If a date of 8000 years ago were of the right order of magnitude for Anangula, and if only 3000 years separated the two sites, one would expect to see artifacts other than those of stone in the Anangula site and to see less soil formation directly below ash IV. The slightly warmer temperature and presumed reduction in precipitation of the Altithermal (about 5500 years ago) would have increased the depth of oxidation in the ashes underlying ash IV, so direct comparison with present-day soils is difficult. Nonetheless, one expects the soil overlying ash III to represent at least 5000 years and perhaps more. Because the soils below the cultural layer are more weakly developed than those above it, it appears, other things being equal, that the cultural layer must have been deposited somewhat earlier than the mid-point between deglaciation and the present. Deglaciation probably accompanied the abrupt rise in sea level that began between 17,000 and 20,000 years ago, as the ice source was on the platform that was submerged south of Umnak Island when the sea rose.

Whether the cultural zone is 8000 or as much as 12,000 years old remains in doubt, but clearly the Anangula site is older than any other site recognized in the Bering Sea–Alaska coastal area. Material from Cape Denbigh is distinctly younger, and that of the Campus site near Fairbanks is slightly younger (*8*). Asiatic affinities are evident, especially in previously unreported angle burins, burin spalls, and core tablets. Also previously unreported are large cores, hammer stones, fragments of a stone dish, and a rubbing stone.

The chance of finding cultural material in this region older than that of Anangula is remote. The rise in sea level caused inundation of most of the earlier home sites, and, in addition, sea-coast erosion during the last 6000 years of high sea levels has been devastating. Sea-cut bedrock platforms, graded to the 3- to 10-m beaches, commonly are 100 to several hundred meters wide. An average rate of lateral erosion of 10 m per century has been estimated for adjacent Unalaska Island (*9*), and this degree of erosion is probably representative of many places in the Aleutians. Consequently, only those coasts protected from rapid erosion can preserve sites of ancient man. Furthermore, a continuous ice sheet over the Alaska Peninsula during the last major glaciation wiped out any existing traces of early man. Since a major source of ice on the Peninsula was in high mountains, the ice sheet survived later on the Peninsula than on the eastern Aleutian Islands, where the main source was cut off by rising sea level.

Along the Bering Sea–Alaska coast, preservation of sites older than Anangula would have required a very special set of conditions. The most logical place to look for such sites is in the eastern Aleutian Islands.

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References and Notes

1. See, for example, R. Fairbridge, in *Physics and Chemistry of the Earth* (Pergamon, New York, 1961), vol. 4, pp. 99–185; E. McFarlan, Jr., *Bull. Geol. Soc. Am.* **72**, 129 (1961).
2. D. M. Hopkins, *Science* **129**, 1519 (1959); W. Haag, *Sci. Am.* **206**, 112 (1962).
3. P. Colinvaux, *Nature* **198**, 690 (1963); thesis, Duke University (1962).
4. H. Powers, *Z. Geomorphol.* **5**, suppl. 3, 36 (1961); T. Karlstrom, *Ann. N.Y. Acad. Sci.* **95**, 290 (1961); F. Byers, Jr., *U.S. Geol. Surv. Bull. 1028-L* (1959), p. 267. Somewhat different conditions existed in the Chukchi Sea north of Bering Strait [G. Moore, *U.S. Geol. Survey Profess. Paper 400-B* (1960), p. 335], but limitations of space prevent discussion of them here.
→ W. S. Laughlin and G. Marsh, *Am. Antiquity* **20**, 27 (1954).
6. Black was accompanied by C. Turner and G. Boyd on a project supported by National Science Foundation grant G-24148 (1962–63).
7. The excavations were made by A. McCartney, M. Yoshizaki, and R. Nelson under the supervision of W. Laughlin, who studied the site in 1962 and 1963. Black examined the excavations and completed the geologic study in 1963 [See W. S. Laughlin, *Science* **142**, 633 (1963)]. The work was supported by National Science Foundation grant GS-136 (1963–64), by the Research Committee of the Graduate School, University of Wisconsin, and by the Wenner-Gren Foundation for Anthropological Research.
8. This is the interpretation of M. Yoshizaki, Director, Department of Archeology, Hakodate City Museum, Hakodate, Hokkaido, Japan.
9. H. Drewes *et al.*, *U.S. Geol. Survey Bull. 1028-S* (1961), p. 665.
10. The U.S. Geological Survey date was based on a smaller-than-normal sample, and dilution with dead carbon was required to provide enough bulk for counting.

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Xenon Tetroxide: Preparation and Some Properties

Abstract. *Xenon tetroxide is a yellow solid at low temperature. It has a vapor pressure of about 25 mm-Hg at 0°C. It is unstable at room temperature. The infrared spectrum of the vapor shows it to have tetrahedral symmetry.*

The existence of a gaseous tetroxide of xenon has recently been established in this laboratory by mass spectrometric analysis of the gas that evolves when sodium perxenate reacts with concentrated sulfuric acid (*1*). This compound has now been prepared in amounts up to 100 mg by reaction of sulfuric acid with sodium or barium perxenate. Some preliminary vapor pressure measurements and a study of the infrared spectrum of the gas have been made.

The perxenate salts, Na_4XeO_6 and Ba_2XeO_6, were prepared by methods described (*2*). The salts were dried in a vacuum desiccator, but may have contained water of hydration. The sulfuric acid was reagent grade, boiled to remove traces of water.

Amounts of salt up to 500 mg were loaded into the glass (Pyrex) side-arm attached to a glass bulb containing about 5 ml of the acid. The bulb was connected by a glass U-tube to a metal vacuum line. The system was evacuated and the salt and acid were mixed