Geology and Submarine Physiography of Amchitka Island Alaska

By HOWARD A. POWERS, ROBERT R. COATS, *and* WILLIS H. NELSON

INVESTIGATIONS OF ALASKAN VOLCANOES

GEOLOGICAL SURVEY BULLETIN 1028-P

Prepared in cooperation with the Departments of the Army, Navy, and Air Force

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1960

UNITED STATES DEPARTMENT OF THE INTERIOR

FRED A. SEATON, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

PREFACE

In October 1945 the War Department (now Department of the Army) requested the Geological Survey to undertake a program of volcano investigations in the Aleutian Islands-Alaska Peninsula area. The first field studies, under the general direction of G. D. Robinson, were made during the years 1946–48. The results of the first year's field, laboratory, and library work were assembled as two administrative reports, and most of these data have been revised for publication in Geological Survey Bulletin 1028. Part of the early work was published in 1950 in Bulletin 974–B, "Volcanic Activity in the Aleutian arc," and in 1951 in Bulletin 989–A, "Geology of Buldir Island, Aleutian Islands, Alaska," both by Robert R. Coats. During the years 1949–54 additional fieldwork was carried out under the direction of H. A. Powers. Unpublished results of the early work and all of the later studies are being incorporated as parts of Bulletin 1028. The geological investigations covered by this report were reconnaissance. The factual information presented is believed to be accurate, but many of the tentative interpretations and conclusions will be modified as the investigations continue and knowledge grows.

The investigations of 1946 were supported almost entirely by the Military Intelligence Division of the Office, Chief of Engineers, U.S. Army. From 1947 to 1955 the Departments of the Army, Navy, and Air Force joined to furnish financial and logistic assistance. The Geological Survey is indebted to the Office, Chief of Engineers, for its early recognition of the value of geologic studies in the Aleutian region, and to the several military departments for their support.

CONTENTS

ILLUSTRATIONS

TABLE

GEOLOGY AND SUBMARINE PHYSIOGRAPHY OF AMCHITKA ISLAND, ALASKA

By Howard A. Powers, Robert R. Coats, and Willis H. Nelson

ABSTRACT

Amchitka Island is the exposed part of a segment of the Aleutian Ridge just west of the southernmost part of the Aleutian arc. It has been disturbed by faulting, differentially uplifted, and dissected by marine, stream, and glacial erosion. The oldest rocks, the Amchitka formation, are volcanic ash, tuff, breccia, and lava flows generally of andesitic composition, apparently erupted and emplaced under the ocean. These rocks were deformed, uplifted, and subjected to erosion before and during deposition of the interbedded conglomerate, basaltic breccia, and tuff of the Banjo Point formation. A meager Banjo Point fauna is Oligocene or possibly early Miocene in age. Rocks of both these formations were intruded by small bodies of quartz diorite.

Flows of feldspathic basalt and andesite, interbedded with marine conglomerate in the lower part and subaerial in the upper part, make up the next younger formation, the Chitka Point formation. In places, rocks of the lower part of the formation were deformed before eruption of the flows of the upper part. The subaerial lava flows were submerged at least 600 feet, and possibly 1,100 feet. Erosion reduced the mass to a surface of low relief, possibly a s ubmarine shoal, now represented by an erosion surface at an altitude of about 1,100 feet. Marine sand and cobble conglomerate, perhaps formed during this erosion, are now exposed at altitudes of up to 600 feet.

Uplift of at least 500 feet and possibly more than 1,100 feet took place differentially and spasmodically during late Tertiary and Quaternary time. A wave-cut platform (perhaps cut during a time of high interglacial sea level) forms a partly dissected plateau between 700 and 900 feet in altitude. A younger abandoned sea cliff, whose base is at an altitude of 240 feet, and a beach deposit, whose top is at 135 feet, are inferred to be structurally dislocated remnants of shoreline features of a late Pleistocene interglacial high sea level, as the fauna of the beach deposit is characteristic of warmer water than now surrounds the island. Movement along faults bounding the Constantine Harbor graben occurred during deposition of late glacial deposits.

Stream-cut ridge and valley topography, modified by glacial action, extends below sea level. The ridges terminate in a line of cliffs at the edge of a plane surface at a depth of about 165 feet. This surface slopes seaward and joins a wide, much flatter bench that extends to the edge of the continental shelf. Both surfaces are interpreted as wave-cut benches associated with shore-

lines of lower late-glacial sea levels. The deeper bench is block faulted in the eastern part, but the minus 165 foot bench is not disturbed by these faults.

Sea cliffs cut by postglacial marine erosion have been abandoned by a relative lowering of sea level of 6 or 8 feet that took place before Aleut settlement more than 4,000 years ago.

INTRODUCTION

Amchitka is the southernmost island of the Rat Island group, which is located west of the center of the Aleutian Island arc. (See fig. 77.) Its rocks contain the record of geologic events during part of Tertiary time, and from its physiography some of the events of Pleistocene time can be inferred.

This report is the result of about 50 days of field reconnaissance by several men during 4 summers. R. R. Coats, geologist, and Will F. Thompson, Jr., recorder, spent 4 days in 1946 and 10 days in 1947 on the east end of the island. In 1949, as a guest aboard the U. S. C. G. S. ship *Explorer*, H. A. Powers was put ashore at several localities around the west end of the island. A larger party, working in two-man teams from the U. S. G. S. motorship *Eider*, made observations in 1951 in some of the larger areas not previously visited. Corps of Engineer topographic maps, scale 1:24,000, were used in the early work, and Coast and Geodetic Survey topographic maps, scale 1:20,000, were available in manuscript stage to the 1951 field party. Dennis P. Cox, Joseph P. Dobell, Richard Q. Lewis, Willis H. Nelson, Richard A. Robie, George L. Snyder, Edward C. Stover, Jr., and Howard A. Powers, in charge, made up this party.

The fossils collected were identified in the laboratory by K. E. Lohman, F. S. MacNeil, R. B. Stewart, F. M. Swain, and Ruth Todd, of the U.S. Geological Survey.

Parts of this work would have been impossible without the cooperation of a great many members of the United States Army, Air Force, Navy, Coast and Geodetic Survey, and Coast Guard. Especial thanks is extended to Lt. Col. R. E. Ware, post engineer, Adak, and Lt. Col. C. E. Johnson, port commander, Adak, in 1946; and to Comdr. H. A. Karo, captain, *Explorer*, in 1949. Credit for the success of difficult small-boat landings and logistic support of the party in 1951 is gratefully placed with Carl Vevelstad, captain, and Charles E. Best, engineer, of the *Eider*.

GEOGRAPHY

Amchitka Island lies between long 178°37′ E. and long 179°29′ E., and between lat 51°21′ N. and lat 51°39′ N.; it is about 35 miles long, in a northwesterly direction, and from 3 to 5 miles wide. Before the Russian occupation in the 16th century, the island apparently supported a relatively large Aleut population. It has long been uninhabited and is not visited regularly by any means of trans-

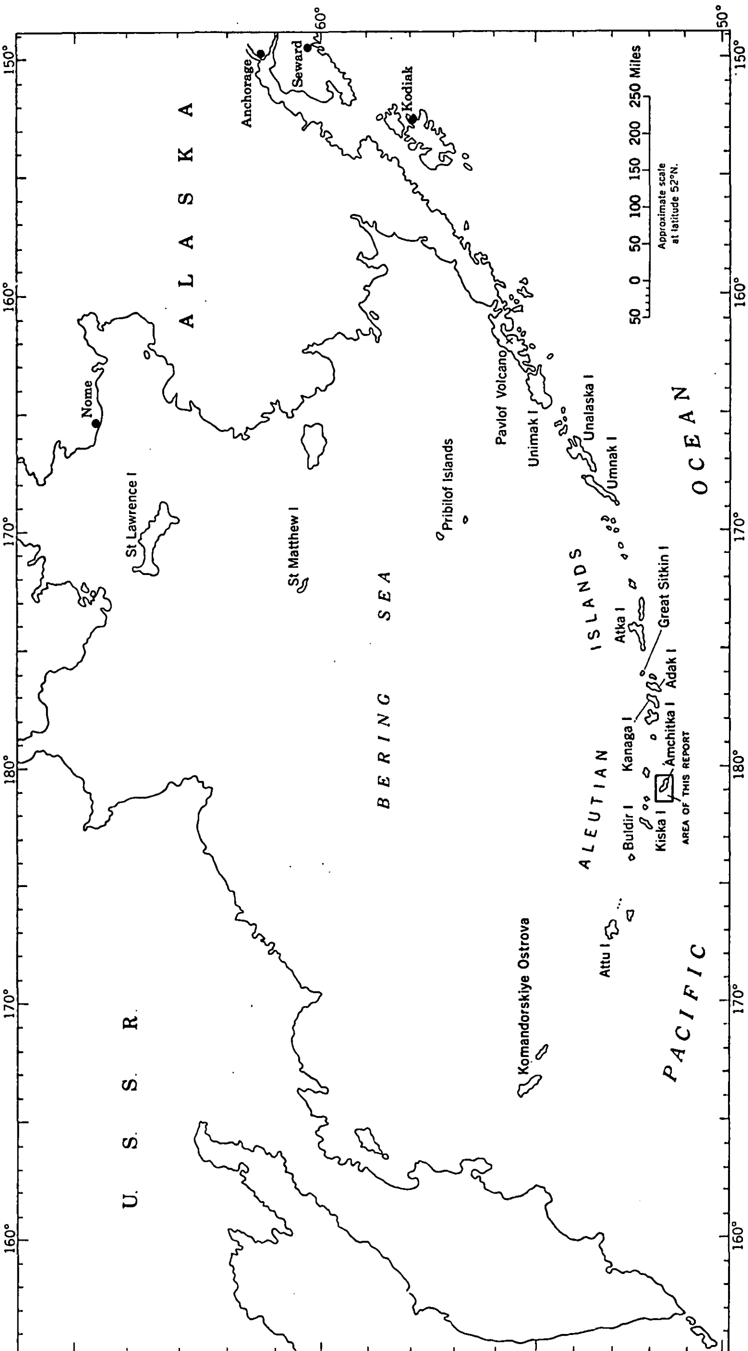

FIGURE 77.—Map of the Alaska Peninsula and Aleutian Islands.

portation. In the summer of 1951, a wharf in Constantine Harbor was in a fair state of repair, and an airstrip was still in existence, both being relics of an extensive military occupation between 1943 and 1950.

The climate is maritime (Arctic Weather Central, 1950); mean annual temperature between 1943 and 1948 at the airbase (225-ft alt) was +40°F, and both daily and seasonal variations were small. Extremes recorded were +15°F and +65°F. During the summer, fog occurred more than 50 percent of the time and complete overcast more than 65 percent. Summer winds averaged about 20 miles per hour, and seldom exceeded 70 miles per hour. In winter months, there was less fog and overcast; winds averaged 25 miles per hour, and frequently exceeded 100 miles per hour. Precipitation averaged 35 inches annually, including snowfall of 70 inches.

Vegetation is an almost complete cover of alpine-zone-type moss, grass, and associated flora, except on the steepest cliff faces and on the wave-swept rock bench above mean tide level. There are no trees.

The island is within the Aleutian Island Wildlife Reservation, and especial protection is afforded the sea otter, which is now present along the coasts in large numbers. Fox and rats, both introduced, were the only land mammals noticed on the island.

PHYSIOGRAPHY

The island contains landforms of varied aspect, ranging from rugged mountains northeast of Windy Island to swampy tableland south and west of Cyril Cove (pl. 69). All the varied topography seems, however, to have been developed from plateaus of low relief, disturbed more or less by block faulting, and modified to greatly different degrees by dissection.

MOUNTAIN SEGMENT

The segment of the island between Chitka Point and Windy Island is mountainous. The divide between drainage to the Pacific Ocean and the Bering Sea is a sinuous ridge with several summits exceeding 1,100 feet in altitude, separated by 4 passes at about 750 feet; an outlying peak (alt 990 ft) south of Chitka Cove is separated from the main mountain ridge by a broad pass with an altitude of about 400 feet. Two prominent long spurs extend southward from the main ridge, and three extend northward; they form divides between major compound amphitheatre valleys that head in the main ridge.

The summits of the ridge, and of parts of the spurs, are gentle slopes eroded across the local rock structure. Each summit flat is small and is bounded by the truncating steep slopes of the amphitheatre valleys. The surfaces are underlain by several feet of colluvium made up largely of angular fragments of local rock that is virtually undecomposed chemically. Clearly these flats are remnants of an erosional surface of very low relief. No features were observed that suggest whether or not the surface has been glaciated, or even whether the cut surface is subaerial or submarine in origin.

The steep headwalls of the amphitheatre valleys are in part rock faces and in part inactive talus covered with vegetation. At the base of the steep slopes is a bench or remnants of a dissected valley floor at an altitude of between 700 and 800 feet in most places; a few slopes extend as low as 400 feet. Most of the bedrock surface exposed in the benches or valley floors is grooved and striated and many outcrops have the form of roches moutonnées. Tarns are present on some of the benches and valley floors. To some extent, the altitude of the benches on which the tarns occur appears to depend upon that of the exhumed top of relatively impermeable rock that underlies more permeable volcanic breccia and flow rock.

HIGH PLATEAU

In the segment of the island northwest of Windy Island, the drainage divide meanders across a partly dissected tableland, most of whose surface is between 700 and 850 feet in altitude; a small knob near the center of the segment extends to slightly above 925 feet. East of the knob, the part of the ridge that is above an altitude of 825 feet is generally undissected. West of the knob, a strip of similarly undissected surface slopes from an altitude of 925 feet to 725 feet where it branches into a north-south strip that includes all the surface above the 700-foot contour. Two separate areas of undissected surface cap the two mesas at the west end of the island.

The high plateau surface is underlain by colluvium of angular rock fragments. On the north mesa of Bird Cape, very well rounded pebbles and cobbles make up about 10 percent of the colluvium, but it is not evident whether they are lag from bedrock conglomerate in the mesa or cobbles related to marine planation of the surface. At lower altitudes, most bedrock surfaces are polished and striated, as they are east of Windy Island.

CHITKA POINT RIDGE

The crest of the island and of the spur extending north to Chitka Point are undissected, rounded surfaces underlain by colluvium of broken country rock of the Chitka Point formation that here is especially closely jointed and locally is abnormally decomposed by the breakdown of abundant pyrite.

A short segment of the island crest that slopes gently southeast from the junction with the Chitka Point spur to the 500-foot contour line is underlain by permeable interbedded sand and cobble gravel of hornblende andesite.

LOWER PLATEAUS

The east half of the island is tableland made up of several segments at different altitudes ranging from about 135 to about 500 feet above sea level. Much of the plateau surface is underlain by a residual mantle of small rock fragments derived from underlying closely jointed sedimentary rock; parts of the surface are on unshattered rock that is grooved and striated and commonly in roche-moutonnée form. Ponds are numerous, both on the plateau tops and the dissected margins. A few ice-scoured knobs appear here and there in all the plateau segments but are most abundant east of Makarius Bay. From the distribution of these patches of scoured rock, it is surmised that the surface of all the plateau has been overridden by glacial ice, but that evidence of the sculpture has been preserved only on surfaces of rather massive rock. Postglacial stream dissection is almost negligible, but stream dissection older than the last glaciation modified each of the plateau segments to a different degree.

PONDS

Many ponds occupy depressions in the surface of bedrock or in alluvium near sea level. A great many others, however, are confined entirely by turf sealed with fine mineral and organic material. Water levels in 2 adjacent ponds separated by a divide about 5 feet wide differed by 1½ feet. In a ditch through the divide, only turf was found to a depth of at least 3 feet below the bottom of the lower pond. The two groups of summit ponds due west of Banjo Point and southwest of Cyril Cove are all of this type. The abundance of ponds thus does not necessarily indicate a large number of closed-contour bedrock depressions. Further, the shape and arrangement of these ponds do not necessarily have a geological significance. The arrangement of ponds in bedrock surface depressions, however, is related to geological features; some are located along the outcrop of less resistant rock, and the alinement of some ponds reflects the outcrop of zones of abundant fracture.

STREAM VALLEYS

Streams are all short and small, and some flow throughout the year. All the streams occupy valleys which are apparently glacially scoured as their broad, shallow, concave profiles appear much too large for the present streams. Most streams enter the ocean in rapids or falls over bedrock; a few are entrenched in short, narrow floors of alluvium near their mouths. The pattern of stream valleys shows many straight-line elements controlled by zones of fracture or, less commonly, by soft beds.

In the western segment of the low plateau, between its west junction with the mountain segment and the 200-foot contour near Banjo Point, the plateau top is moderately dissected by ice-scoured stream valleys, and the margins toward both coasts are deeply indented by valleys. The altitude of these partly dissected plateau tops ranges from 225 feet to 500 feet. In contrast, the plateau top east of Makarius Bay, mostly between 200 and 240 feet in altitude, is not dissected, though the margins are deeply eroded by valleys. Streams across the summit occupy no perceptible valleys, but, at the edge of the plateau, they enter broad, shallow valleys that become broad and deep in a short distance toward the coasts. The same is true of the segment west and south of Cyril Cove whose flat summit is at an altitude of between 125 and 150 feet. Possibly the planed tops were formed after the valleys that indent the margins had been eroded.

INLAND SEA CLIFFS

South of Constantine Harbor, a bedrock knob rises above the 240-foot level of the summit plateau to about 325 feet. The margin of this knob is an almost unbroken cliff 10 to 50 feet high. This cliff is the best example on the island of an inferred elevated sea cliff. Rock outcrops in this knob, the cliff, and the plain have been scoured by ice; the cliff has not been breached by stream erosion.

Several short reaches of cliff fronting the Pacific, south and west of Banjo Point, are indicated as raised sea cliffs on plate 69, although they might be parts of a faultline scarp or they may be neither. These are cited as the least convincing examples of inferred raised sea cliffs. Other probable raised sea cliffs rise from dissected planed surfaces at different places and altitudes.

SHORELINE FEATURES

Most of the littoral zone is a rock bench, perhaps 50 feet wide on the average but in places as much as a quarter of a mile wide, much of which is covered with living seaweed. Seaward, the bench is truncated by a steep cliff that apparently extends as much as 30 feet below water. Landward, the bench terminates against the base of a cliff 50 to several hundred feet high.

The weed-covered part of the bench (wet bench) is a nearly plane surface cut across bedrock structures approximately at mean sea level. Continuity of the wet bench is broken by boulder-floored channels into which waves slosh even at low tide. The shape, dimensions, orientation, and abundance of these channels seem to be determined by zones of fractured rock or by soft beds. Above the general plane of the wet bench (weed-covered surface) knobs, ridges, and platforms rise usually to a height of no greater than about 6 feet, but, rarely, to several tens of feet. Where these features are isolated they are composed of rock more resistant to erosion than that in the bench, but along the landward margin at the base of the cliff where they abound and form a nearly continuous dry bench they are not exclusively of resistant rock.

The landward margin of the rock bench is commonly surmounted by a cobble or boulder beach deposit whose top is 5 to 15 feet above the level of living seaweed. The lower boulder beaches support vegetation only of a sort that becomes established between storms; debris from the military occupation of the island is incorporated in them. The higher beaches and the face of the cliff behind them are covered with a thick turf-and-root mat of long established vegetation. Some of these features are illustrated by the profile off Chitka Point (fig. 78).

The rock bench is absent at the mouths of many stream valleys, and a sand beach terminates an alluvial fill in a few of the wider valley mouths. Storm beaches, with light vegetation, are as much as 15 feet above the level of living seaweed and have a higher, heavily vegetated beach behind them in some places. In a few places the rock bench is missing at the base of a bare rock cliff that exposes massive rock broken by widely spaced joints.

The rock bench approximately at sea level is much wider and more extensively developed along Aleutian shores than along apparently comparable shores at lower latitudes; its development approaches that of the strandflat of high latitudes. It is inferred that rapid disintegration of surface rock by daily freezing and thawing is an important factor here, though not as effective as Nansen's shore erosion by frost in producing the strandflat (Nansen, 1922). In the Aleutian Islands, the effective base of frost erosion may be determined by the position of the ground-water table (Bartrum, 1926).

Long records of daily changes in temperature in the Aleutian Islands are not available, but at sea level perhaps nearly a fifth of the days have light freezing nighttime temperatures and thawing daytime temperatures. Rock of the sea cliffs always contains abundant moisture, even above the water table. Consequently a shallow surface layer of the rock is subjected to disruption by frost action in minute open spaces. Waves at nearly every high tide, and during every storm, wash over the rock surface up to several feet above mean sea level and remove the surface layer as fast as it is loosened. This accelerates the disintegration caused by frost action by keeping a nearly fresh surface constantly exposed to attack in the zone reached by the waves. These two processes form a cut rock bench, most rapidly on permeable rock in which bedding planes and fractures are closely

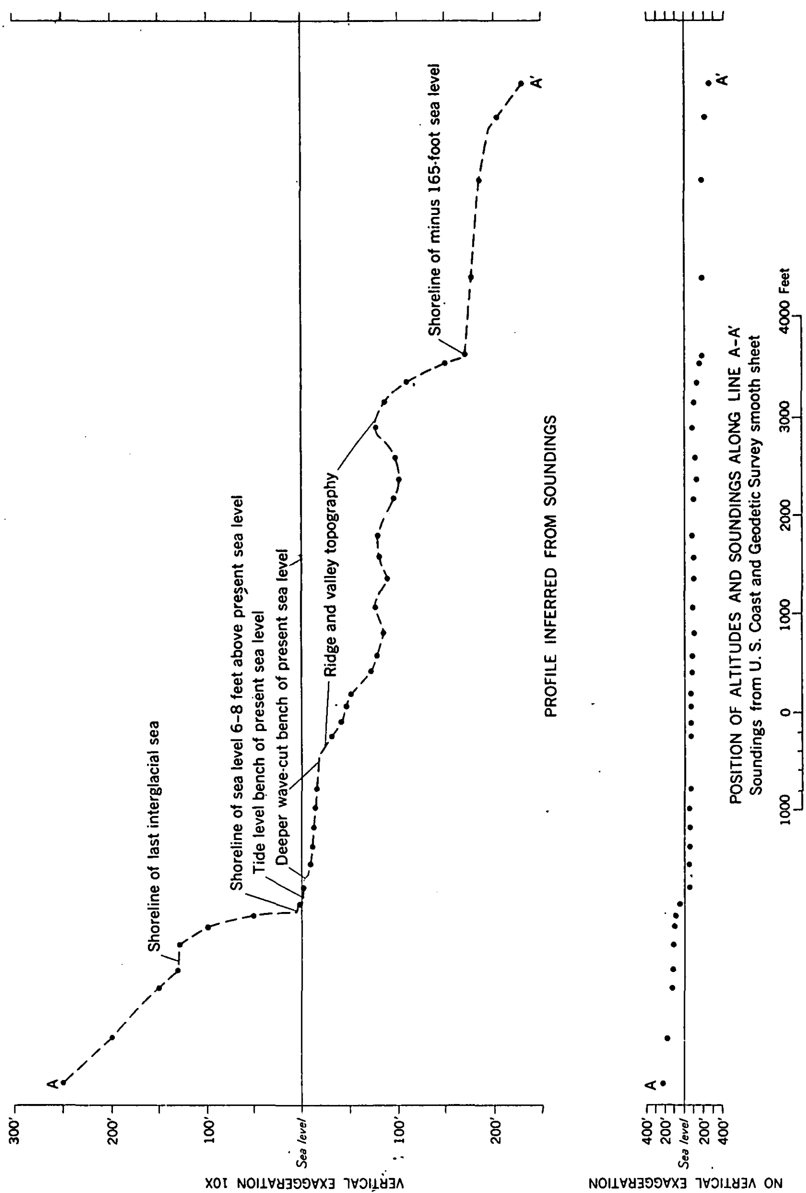

FIGURE 78.—Profile of Chitka Point and offshore area, with inferred origin of features. (See pl. 69 for location of profile.)

spaced, and least rapidly on impermeable rock with widely spaced fractures. The daily freezing cannot take place below the water table, as the ground-water temperature at the shore is influenced strongly by the ocean temperature, which does not reach 32°F. Theoretically, this should fix the position of the bench surface at water-table level, but, practically, the bench is cut below this level by some abrasion as the waves move the loosened material back and forth across the bench. However, the abrasive action is effectively reduced and locally is stopped completely for an unknown length of time after the bench surface is cut below the level of mean tide because a protective mat of seaweed rapidly is established as soon as the water cover is favorable.

Concurrently a different process of erosion is developing a cut bench at a deeper level. Below the water table, where the impact of each wave crest puts the water in fractures under a differential pressure, blocks are loosened and removed by the waves down to a level that is determined in part by local rock structure and in part by wave depth, which is influenced by local offshore configuration. The level appears to be between 12 and 30 feet below sea level. This process seems most effective on massive, impermeable rock with widely spaced joints, and least effective on permeable rock with closely spaced joints and bedding planes. Thus, on coasts cut in jointed gabbro or massive flow lava, a steep cliff extends 15 to 30 feet below sea level, with no tide-level bench, but on coasts cut in closely fractured pillow-lava flows or bedded sedimentary rock a weed-covered bench at low-tide level is truncated at its seaward margin by a submerged cliff that extends down to the deeper wave-quarried bench (fig. 78).

The features of the shoreline that have been described apparently include 2 sets of beach deposits: 1 set is associated with activity at the present sea level, and 1 set is 6 to 8 feet higher and has been undisturbed by wave activity long enough to be covered by a peat-like mat of roots and permanent vegetation. The cliff behind these beaches likewise is protected from present marine erosion. Dwelling sites of Aleut inhabitants commonly found on the crests of the higher, abandoned beach ridges may be as much as 4,000 years old. (Byers, 1959). Similar features of an inactive shoreline are characteristic of the Near Islands (Powers, personal communication, 1950). If the beaches are products of activity at 2 levels of the sea, it follows that the rock bench must include features of 2 sea levels. It is inferred that the knobs and platforms that rise about 6 feet above the seaweed-covered rock flats are remnants of an older tide-level rock bench that is being reduced to a bench in equilibrium with present sea level (fig. 78).

SUBMERGED TOPOGRAPHY

Submerged topography surrounding the island is shown on plate 69 by contour lines at 100-foot intervals to a depth of 400 feet, and by contours at 300-foot intervals starting at 600 feet. More detailed topography to a depth of 400 feet around the east half of the island is shown by supplemental contours at 25-foot intervals. The 25-foot contour is omitted because soundings were too scarce to locate it adequately (heavy growth of kelp prevented operation of the surveying launches). The 50-foot contour is below the bench being cut by present shoreline erosion. However, a profile off Chitka Point (fig. 78), where inshore soundings were made, shows this bench in relation to the local examples of more deeply submerged topographic features. The topography between 50- and 150-foot depths all along the coast suggests ridges and valleys of a stream-dissected slope. This pattern changes abruptly between the 150- and 175-foot contours; the change must be real as there is no coincident change in the number of soundings per unit area. Within this zone of change, the ridges terminate in a steep cliff whose base is at depths ranging from 160 to 180 feet. Examples of these cliffs that have been identified on the charts of detailed soundings are marked on plate 69 with short lengths of dotted lines with a number giving the depth of the base of the cliff. The shape of the 100-foot contour shows that the ridge and valley topography continues all around the island; that of the 200-foot contour shows a slope with very little relief.

The shelf-break (Dietz and Menard, 1951, p. 1996) at the outer edge of the insular shelf (Gates and Gibson, 1956, p. 132), is at a depth of about 325 feet throughout most of its length, though locally short segments are at depths ranging from 300 to 390 feet. Most of the segments of divergent depth are around the east half of the island. The margin of the shelf is not greatly indented, and the shape of depth contours below 325 feet in general suggests fault-block and graben, rather than ridge and valley, topography. The seaward part of the insular shelf between depths of about 290 and 325 feet is a wide bench with very low gradient on the Pacific Ocean side, and locally on the Bering Sea side, of the island. It will be referred to as the shelf-break bench. Details of local topography on this shelf-break bench are shown on plate 69 by symbols showing the altitude of the knobs and the depths of the depressions. Along the inland margin of this bench are several abrupt slopes whose bases are at depths ranging from 265 to 310 feet around the western part of the island, and from 200 to 310 around the eastern part. The tops of these short stretches of abrupt slope are at depths of 180 to 220 feet.

INTERPRETATION OF TOPOGRAPHY

The landmass exposed to erosion, broadly speaking, has the appearance of a fault block elevated and tilted to the southwest. The Bering slope might be a faultline scarp, and the gentle southern insular slope between depths of 400 to 3,000 feet might be the tilted surface of the postulated fault block. The greater encroachment of the Pacific shore onto the block may be due largely to the original asymmetry, but may also be in part to a greater rate of erosion; although Bering Sea storms are frequently as severe as those of the Pacific Ocean, the usual daily waves of the Pacific are stronger.

It is suggested that the high plateau is modified from a marine platform whose inshore edge has been elevated about 800 feet, and that the higher summits are relics of islands shaped by the sea that formed the platform. Plateaus and benches (and cliffs rising from them) at heights of 400 to 500 feet might be relics of features of a second elevated shoreline. If so, they have been displaced relative to each other by faulting.

On this emerged landmass the pattern of stream valleys was established, and a good deal of subaerial erosion was accomplished, before the cutting of a shoreline whose best preserved (but fault-disturbed) remnant now stands at an altitude of 240 feet. It is inferred that the same stream-cut valley and ridge topography extends below present sea level (nicked by the benches and cliffs of the present shoreline) and is almost obliterated by the bench and cliffs of a shoreline now submerged at about 165 feet (fig. 78). Almost no suggestion of ridge and valley topography exists on the deeper shelf-break bench, which is believed to be part of a shoreline dislocated by subsequent faulting and now submerged at depths ranging from 220 to 310 feet. The closed-contour depressions in the shelf-break bench are probably the result of several processes. Those west of Aleut Point, in the pass between Amchitka and Rat Islands, perhaps are due largely to scour by strong currents. Those south of the mountainous part of the island perhaps represent scouring by glacial ice, as each of the larger depressions is offshore from a large amphitheatre that has been glaciated. Those east of the 179th meridian perhaps are in part structural and in part glacial depressions, judging from their shapes and alinement. Evidence of glaciation on the Near Islands platform, which is equivalent in part to the shelf-break bench, is presented by Scruton (1953) and discussed by Gates and Gibson (1956, p. 135).

STRATIGRAPHY

AMCHITKA FORMATION

Water-laid beds of volcanic breccia and some thin-bedded fine-grained tuff, all interbedded with pillow flows of lava, are the oldest recognized rocks of the island and are here named "the Amchitka formation." The material is andesitic and usually porphyritic with phenocrysts of plagioclase, pyroxene, and amphibole. Pyroclastic fragments are angular to subangular; none is well rounded. Beds of both coarse and fine fragments are indurated. All the rock is broken by joints.

These rocks make up the northern part of the western third, and most of the eastern fourth, of the island; small, isolated exposures are found at and west of Cyril Cove. No correlation of individual beds was possible between the two large areas of outcrop. The total thickness of these rocks is perhaps several thousand feet. The formation is overlain, with angular unconformity, by tuff and conglomerate of the Banjo Point formation and lava and conglomerate of the Chitka Point formation. It is invaded by a stock and dikes of quartz diorite, as well as dikes of basalt and andesite.

The geologic age of these rocks is unknown, but they must be at least as old as early Tertiary inasmuch as the overlying Banjo Point rocks are of early middle Tertiary age.

In eastern Amchitka, the most abundant rock of this formation is lapilli tuff and tuff-breccia in beds 10 to 100 feet thick. The fragmental texture is commonly conspicuous, and the fragments range in size from less than a tenth to 3 or 4 inches in greatest dimension. Whole and broken crystals of plagioclase, amphibole, and pyroxene are common, but glassy fragments are most abundant and range in vesicularity from dense obsidian to pumice. The rock is mottled dull yellowish brown and olive green to blue green with flecks and streaks of white. Much of the glass is altered to nontronite, and some of the interstitial space is occupied by zeolites; the rock as a whole is well indurated, though porous in patches. Adjacent to some of the intrusive bodies, and along a few zones rich in pyrite, the rocks are altered to fine anhedral quartz and alkalic plagioclase, calcite, sericite, epidote, chlorite, leucoxene, and iron oxides.

The type section of these rocks is exposed along the south coast from South Bight westward to long 179°18′ E. Beds of coarse tuff-breccia, each more than 100 feet thick, alternate with flows of pillow lava 5 to 20 feet thick and with layers of thin, evenly bedded fine indurated yellow and green tuff 5 to 50 feet thick.

The upper bed of latite-tuff-breccia, exposed over a large area south of Constantine Harbor and all of Kirilof Point, contains abundant angular fragments of dense black obsidian up to 3 or 4 inches across in a mottled brown-green matrix of vesicular pumice fragments and shards. In a few places, bipolar bombs of aphanitic lava (in part hollow) as much as 30 inches long are embedded in the tuff. A core-drill hole south of Constantine Harbor penetrated this bed for 300 feet without passing through it. The glass of the vesicular matrix material is altered to nontronite and has zeolites throughout; heulandite, mordenite, and apophyllite were identified by X-ray examination by Fred Hildebrand of the U.S. Geological Survey. The dense black obsidian is shattered by fractures lined with nontronite and in places with zeolites. Small bodies of the glass, between fractures, contain scattered microphenocrysts of calcic andesine and clinopyroxene. The glass is clear and light brown in thin flakes and sections. The index of refraction of the clearest pieces of glass ranges from 1.520 to 1.523 (±0.001). A sample of the glass, reasonably free of zeolites but not of nontronite, has the chemical composition given in table 1.

TABLE 1.—*Chemical and spectrographic analyses and norms of volcanic rocks from Amchitka Island*

[Analyses by U.S. Geological Survey]

	1	2	3	4
Chemical analyses [Analysts: col. 1, E. J. Tomasi; cols. 2, 3, and 4, L. Kehl]				
SiO_2	59.13	58.84	54.59	58.04
Al_2O_3	15.10	17.94	18.49	18.14
TiO_2	.57	.67	.76	.67
Fe_2O_3	2.14	2.36	2.86	2.92
FeO	2.71	3.41	4.40	3.14
MnO	.12	.12	.15	.13
MgO	1.32	3.33	4.24	3.69
CaO	3.76	7.09	9.05	7.59
Na_2O	3.76	3.55	3.35	3.36
K_2O	3.54	1.67	.92	1.41
H_2O-	1.48	.07	.30	.23
H_2O+	5.75	.73	.82	.52
P_2O_5	.27	.20	.17	.20
CO_2	.01	.01	.15	.01
Cl	.23	[1] nd	nd	nd
F	.07	.04	.03	.03
S	.02	nd	nd	nd
BaO	nd	.04	.03	.03
Total	99.98	100.07	100.31	100.11
Less O	.09	.02	.01	.01
Total	99.89	100.05	100.30	100.10

See footnotes at end of table.

TABLE 1.—*Chemical and spectrographic analyses and norms of volcanic rocks from Amchitka Island*—Continued

	1	2	3	4
Spectrographic analyses [2]				
[Analyst: P. R. Barnett]				
B	0.006	<0.001	<0.001	<0.001
Ba	.20	.06	.04	.04
Co	.001	.002	.003	.002
Cr	.0005	.0040	.0040	.0030
Cu	.003	.009	.009	.008
Ga	.002	.001	.001	.001
Mo	.0005	<.0001	<.0001	<.0001
Li	nd	.0007	.0030	.0010
Ni	<.0005	.002	.002	.002
Pb	.004	<.0001	<.0001	<.0001
Rb	nd	.002	.001	.001
Sc	<.0005	.002	.003	.002
Sr	.08	.10	.06	.09
V	.01	.02	.03	.02
Y	<.001	.004	.004	.003
Yb	<.0001	.0003	.0003	.0002
Zr	.030	.010	.008	.010
Norms				
Q	15.21	12.12	6.69	12.09
or	20.80	9.70	5.24	8.34
ab	29.87	29.87	28.30	28.30
an	14.85	28.08	32.53	30.15
wo	.75	2.55	4.46	2.72
fs	2.45	3.30	4.62	2.51
en	3.30	8.30	10.60	9.20
cc	----	----	.32	----
il	.80	1.30	1.41	1.30
mt	3.20	3.35	4.30	4.18
op	.67	.34	.34	.34
hl	.40	----	----	----
Water	7.23	.80	1.12	.75
CIPW symbol	(I)II.4.2.3″	II.4(5).3″.4	II.″5.3.4″	II.4(5).3.4

[1] nd=not determined.
[2] Looked for but not found: Ag, As, Au, Be, Bi, Cd, Cs, Ge, In, La, Nb, Pt, Sb, Sn, Ta, Th, Tl, U, W, and Zn.

1. Obsidian tuff-breccia, Amchitka formation: sparse phenocrysts of andesine and clinopyroxene. Specimen No. 51-P-27. Lat 51°22′15″ N.; long 179°16′00″ E.
2. Columnar lava, Amchitka formation; rich in phenocrysts of labradorite-andesine, ortho- and clinopyroxene. Specimen No. 51-P-31. Lat 51°27′40″ N.; long 179°09′25″ E.
3. Flow banded lava, Chitka Point formation; rich in phenocrysts of calcic plagioclase, olivine, ortho- and clinopyroxene. Specimen No. 49-P-36. Lat 51°34′50″ N.; long 178°48′45″ E.
4. Scoriaceous lava, Chitka Point formation; rich in phenocrysts of calcic plagioclase, brown hornblende, ortho- and clinopyroxene. Specimen No. 49-P-46. Lat 51°35′55″ N.; long 178°42′40″ E.

In one quarry exposure the bottom of this tuff-breccia is mixed into a mass of microcrystalline lava; laterally this mixed contact changes to a sharp contact of tuff-breccia on pillow lava. In one exposure the pillow lava seems to have burrowed into the tuff-breccia. Two or three other flows of pillow lava, 10 to 20 feet thick, are interbedded with lapilli tuff at other localities, notably at long 179°19′ E. on the south coast.

Banded, richly porphyritic, andesitic rock is exposed in several disconnected outcrops just west of Cyril Cove. The chemical composition of this rock is given in table 1. It could not be determined whether the rock body is a shallow sill or a relatively thick lava flow. The banding, emphasized on weathered surfaces by abrupt changes in color from light to dark gray, apparently is due to slight differences in crystallinity of the groundmass and not to segregation of the phenocryst minerals that make up about half of the rock. Calcic plagioclase is most abundant, then clinopyroxene and hypersthene, and a few large crystals of apatite and opaque oxide. A very few "ghosts" of amphibole crystals are suggested by the shape of patches of opaque dustlike iron oxide.

Along the west shore of Chitka Cove the most abundant rock is light gray mottled with green, porphyritic, and fractured by closely spaced vertical and diagonal joints, and looks like an outcrop of a shallow intrusive body of porphyry. However, the body grades upward into thin-bedded fine-grained thoroughly indurated siltstone about 6 feet thick. Overlying the siltstone, with apparently a depositional contact, is a greenish-gray rock, mottled with light gray, similar in appearance to the lower porphyry. Neither the top of the upper bed nor the base of the lower was seen; each has an exposed thickness exceeding 200 feet.

The lower rock contains rounded crystals of quartz (up to 1 mm in diameter) and aggregates of secondary minerals having the shape of large euhedral crystals of feldspar, amphibole, and clinopyroxene, all in a fine-grained matrix. All constituents except the quartz phenocrysts are altered to calcite, sericite, epidote, alkalic plagioclase, chlorite, fine anhedral quartz, leucoxene, pyrite, and iron oxide. The upper rock contains the same secondary-mineral assemblage but no phenocrysts of quartz and ghosts of only feldspar phenocrysts. It is inferred that these two bodies originally were thick beds of unsorted-crystal vitric tuff whose clastic texture has been destroyed by hydrothermal alteration and recrystallization.

Westward in the larger outcrop the original mineral constituents of the rocks are also altered, but the fragmental texture of lapilli tuff can commonly be seen in spite of the alteration, and the beds are at most a few tens of feet thick. The formation is broken into small fault blocks, tilted at random, with dips of up to 45°.

BANJO POINT FORMATION

Bedded marine sandstone, conglomerate, tuffaceous shale, and some lapilli tuff of basaltic composition make up the stratigraphic unit here named the Banjo Point formation. These rocks occupy the entire width of the island westward from Makarius Bay to about 5 miles west of Banjo Point, and also several square miles of Saint

Makarius Point, and lie on thin-bedded tuff and pillow lava of the Amchitka formation with an angular unconformity of 5° to 10°. On the north coast west of Kirilof Point, sandstone beds of the Banjo Point formation transgress a westward-sloping surface eroded on tuff-breccia. West of Banjo Point, the basaltic tuff and sandstone are separated by a fault contact from hornblende-andesite breccia of the Chitka Point formation; elsewhere they are cut by dikes of similar porphyritic andesite. Everywhere the top of the formation is the present erosion surface. The formation could be as little as 400 feet thick, though it probably was originally much thicker; no marker beds could be traced through the many fault blocks to permit reconstruction of a complete section.

The geologic age of the Banjo Point formation is placed, on the basis of a meager fauna, in the range Oligocene to Miocene. A fauna of 36 species of Foraminifera is contained in two collections, one from Banjo Point and the other from the south coast almost due west of Banjo Point. Eighteen of these species are identified with or closely related to known species (Todd, 1953). The assemblage resembles most nearly the fauna of two formations, the Oligocene Tumey formation of Atwill (1935) in California and the Bastendorff shale of Eocene and Oligocene age in Oregon. Fragments of diatoms, genus *Coscinodiscus* and *Arachnoidiscus*, according to K. E. Lohman, were found in the foraminiferal material but are too fragmentary and corroded to be identified as to species. Some very poor molluscan material from Banjo Point, possibly representing *Lucina*, *Pododesmus*, and a buccinoid gastropod (according to R. B. Stewart) adds nothing to the age determination. A poorly preserved specimen from the south coast at lat 51°24′32″ N.; long 179°9′44″ E., is identified by F. S. MacNeil as *Chlamys* aff. *C. washburnei* Arnold and considered by MacNeil to be of probable middle Tertiary age (late Oligocene or early Miocene). MacNeil states that—

> *Chlamys washburnei* was described from beds on the Yachates River, Oregon, which have been assigned variously to the Pliocene (Arnold [1906, p. 119–120]), middle Miocene(?) (Weaver [1942, p. 86]), and to the early Oligocene (Vokes, personal communication, 1954). It is associated, according to Vokes, with two crinoids, *Isocrinus oregonensis* and *I. nehalemensis*, which Moore and Vokes [1953, p. 116] described from beds correlated with the Keasey formation.

The stratigraphic position of the identified specimen of *Chlamys* with respect to the two collections of Foraminifera is not positively known. Many small fragments of pecten shells occur in beds both below and above the foraminiferal layer at both localities, and there is no geologic evidence to suggest that the Foraminifera and the pecten are not part of the same fauna. No rational choice between

Oligocene and Miocene for the age of the fauna appears possible with the meager data at hand.

Compilation of a complete section of the rocks of the Banjo Point formation was not feasible, but a partial section exposed in the north coast at Banjo Point is considered the type section of the formation.

Eroded present surface.	ft	in
Conglomerate, tuffaceous, unsorted	100+	0
Lapilli tuff, bedded	25	0
Conglomerate	10	0
Sandstone	1	0
Siltstone, tuffaceous, fossiliferous		2
Sandstone		8
Conglomerate	2+	0
Total	138+	10

Base of formation not exposed.

The thick upper unit contains a few large (4-ft diameter) rounded boulders scattered at random in a mass of unsorted lapilli to silt-size fragments of basaltic composition, apparently the product of a nearby volcanic eruption. A few thin, lenticular streaks of sorted material give a very crude bedding, conformable to the surface and to the bedding of the underlying tuff. The contact of the tuffaceous conglomerate on the tuff is abrupt.

The lapilli tuff is poorly sorted but is bedded in units 4 to 12 inches thick, and contains angular lapilli of basaltic scoria in a matrix of vesicular, vitric, similar-appearing material.

The two units of conglomerate contain well-rounded to subrounded cobbles of various sorts of basaltic rock in a matrix of small subrounded to angular fragments of basalt, vitric tuff, and fragments of barnacle and pecten shells. The finer material in these beds is the product of the erosion and transport of volcanic rock rather than of pyroclastic eruption and initial submarine deposition.

The two beds of sandstone are similar and contain subrounded to subangular coarse to medium-grained sand size particles of volcanic material, both crystalline and vitric. They are indurated by limonitic cement.

The tuffaceous siltstone is a compact nonlaminated bed of vitric shards altered to nontronite, rich in carbonized plant fragments. It contains shells of immature mollusks and Foraminifera. The angularity of the shards makes it appear to be a bed of vitric ash initially deposited in water, rather than a product of erosion.

Elsewhere, partial sections of this formation contain beds showing similar lithologic materials present in locally different proportions and arrangement. In 1 exposure on the Pacific shore southwest of Banjo Point is a unit of thin-bedded vitric tuff 80 feet thick; a few hundred yards to the west is a bed, over 30 feet thick, composed entirely of beach-rounded cobbles and boulders up to 2 feet across.

QUARTZ DIORITE

Quartz diorite and related rock form a stock about 2 miles in diameter at the east end of Amchitka that intrudes the Amchitka formation. Dikes of the same sort of rock, too small to map, intrude the Amchitka and the Banjo Point formations. In the east cliff of South Bight, the quartz diorite is cut by a 4-foot dike of hornblende andesite, similar to some lava of the Chitka Point formation. Cobbles of the quartz diorite were not found in any of the preglacial conglomerate.

The age of the stock and dikes of quartz diorite is considered to be middle to late Tertiary, inasmuch as the rock is younger than the Banjo Point formation and older than part, if not all, of the Chitka Point formation.

Much of the rock is medium grained and light to medium gray, and is composed of plagioclase, augite (commonly uralitized), quartz, and orthoclase. The mass ranges from local granodiorite facies to gabbro, but the bulk is quartz diorite.

CHITKA POINT FORMATION

Lava flows and flow breccia of porphyritic andesite, interbedded with marine conglomerate, are here named the Chitka Point formation. The conglomerate is confined to the lower part of the formation; lava flows and breccia emplaced above water form the upper part. These rocks underlie most of the mountainous west half of the island. They lie on the Amchitka formation with angular unconformity, and dikes of porphyritic rock similar to lava of the Chitka Point formation cut the Banjo Point and Amchitka formations. South of Chitka Point they are overlain by a gravel deposit of hornblende andesite. Thickness of the formation probably exceeds 1,000 feet.

The age of the Chitka Point formation is estimated as middle to late Tertiary because it overlies the early Tertiary Amchitka formation and its dikes cut rock of early to middle Teritary age; there is no evidence to rule out the possibility that it might be early Quaternary.

No complete section of the formation was compiled; several incomplete sections (described below) give a picture of its general characteristics. At Chitka Point, the type locality, a thick sheet of poorly sorted, indurated conglomerate contains many carbonized broken fragments of woody material. This wood was unidentifiable as to species, but its presence, together with well-rounded cobbles in the conglomerate, indicates the nearness of land. The conglomerate is interbedded with porphyritic pyroxene andesite lava. This is overlain at a 200-foot altitude on the ridge to the south by a thick lava flow of porphyritic hornblende andesite. Similar-appearing hornblende andesite, with and without plagioclase phenocrysts, is the only rock exposed along the crest of the island for 10 miles to the west. In the north-facing cliff at long 178°48′ E. a 400-foot thickness of hornblende porphyry lava and breccia lying on an eroded surface of the Amchitka formation is capped by almost 100 feet of darker basaltic andesite with plagioclase and pyroxene phenocrysts. Both of these rocks are loose textured, contain open vesicles and interstitial spaces, and appear to have been emplaced on land. Both dip about 15° SW. At long 148°44′ E. on the south coast, a flow of hornblende andesite that dips about 15° SW. lies with angular unconformity on a section of 3 flows of pyroxene andesite interbedded with 2 thin layers of conglomerate that dip 30° N.

The most abundant constituents of the conglomerates are very well-rounded to subrounded cobbles of unaltered porphyritic andesite similar to rocks of the interbedded flows; less abundant, but common, are cobbles and pebbles of the altered rocks from the Amchitka formation containing pyrite crystals. In some restricted localities, particularly on the north coast, all constituents of the conglomerates, as well as of the interbedded lava, are hydrothermally altered.

The most abundant rock type in the Chitka Point formation is porphyritic hornblende-pyroxene andesite. The analysis of one sample is given in table 1. More than half the rock is phenocrysts. About 2 percent is large (up to 5 mm) crystals of brown hornblende with thick reaction rims of calcic plagioclase and opaque oxide. Hypersthene and clinopyroxene crystals up to 1 mm across make up about 15 percent of the rock; zoned phenocrysts of calcic plagioclase make up about 40 percent of the rock. The groundmass is plagioclase crystals in light-brown glass.

The next most abundant rock type, porphyritic andesite, is represented by the analysis in table 1. The sample is from a thick columnar-jointed dark-colored flow. The rock is richly porphyritic. About 1 percent of the rock is now masses of bowlingite, pleochroic in green and yellow, surrounded by thin rims of small pyroxene crystals; the bowlingite was formerly olivine in euhedral 1-mm crystals. Euhedral crystals of pyroxene, both hypersthene and zoned clinopyroxene, make up 10 percent of the rock. Some hypersthene occurs as cores in clinopyroxene. About 25 percent of the rock is phenocrysts of calcic plagioclase, conspicuously zoned with oscillatory zoning and fritted cores. The groundmass is light-brown glass with plagioclase laths and crystallites of opaque oxide.

Less common are two other rock types, one that contains only clinopyroxene as phenocrysts, and one with phenocrysts of green hornblende as the only ferromagnesian constituent; both are rich in plagioclase.

PYRITE-RICH ROCK

Rocks of the Amchitka and Banjo Point formations contain pyrite, up to a third of the volume of the rock, in several localities. Weathered outcrops are conspicuous because of their gossan-red color. In detail, the pyrite-rich rock follows fractures of diverse strike direction, but zones of pyrite enrichment trend within a few degrees of east. These zones are most abundant in the west third of the island, common east of Makarius Bay, and present but not conspicuous in the rest of the island.

In rocks of the Chitka Point formation, pyrite is not common but is present in halos or narrow zones of alteration that suggest fumarolic activity.

One sample of pyrite-rich rock from the south shore of Chitka Cove contains only trace amounts of copper, lead, and zinc; no sulfides other than pyrite were seen in hand-lens inspection of many outcrops.

GRAVEL OF HORNBLENDE ANDESITE

Bedded sand and gravel composed entirely of fragments of hornblende andesite lie on the crest of the island for 6,000 feet southeast of the 600-foot contour south of Chitka Point. The deposit is mostly coarse moderately well sorted sand with several interbeds, 5 to 15 feet thick, of cobble to boulder conglomerate. The material is compact but not indurated. The dip of about 12° SE. is possibly wholly initial. At least 1 of the conglomerate beds is made up of angular to subangular slabs, up to 18 inches in greatest dimension, of porphyritic hornblende andesite. The other conglomerate beds contain well-rounded cobbles and boulders up to 2 feet in diameter, with interstitial coarse sand. Lag deposits of these cobbles and boulders superficially resemble raised boulder-beach deposits where outcrops strike across the crest of the ridge. The formation seems to be a littoral-zone deposit whose thickness probably does not exceed 100 feet.

The relative age of these rocks is not apparent from the available data. They may be entirely younger than the Chitka Point formation, or perhaps correlative with part of it.

TILTED SEDIMENTARY ROCK AT SOUTH BIGHT

Beds of silt, sand, and gravel crop out on the shore at the head of South Bight and at the head of the small unnamed bight across the island to the northeast. Presumably they are continuous between these outcrops, and they may occupy a total area of less than a quarter square mile.

The lowest 200 feet of the beds dip about 12° SE. These are layers, in random sequence, a few inches to 2 feet thick, of carbonaceous sandy silt, fine to medium-size sand, and pebbly sand to sandy fine gravel. A few layers of light-colored siliceous volcanic ash, each less than 2 inches thick, are interbedded. The general color is pale reddish yellow to greenish yellow, and the constituents are compacted but not indurated. Many fragments of partly carbonized wood are scattered through the silt beds, but no other megafossils are exposed, and no microfossils were found in one composite sample containing material from a dozen different beds throughout the section. This series of relatively uniform beds of fine material grades conformably upward into about 150 feet of less well bedded medium-size to coarse sand with irregular layers of well-rounded gravel. The dip of these beds diminishes to 7° or 8° SE. at the top of the section.

The base of these beds is not exposed. Their lateral terminations, both to the northwest and southeast, are poorly exposed but appear to be steep fault contacts against the Amchitka formation. The top is truncated by a nearly horizontal erosion surface about 40 feet above sea level, overlain by fossiliferous beach sediment of Pleistocene age. The deposit apparently is part of a small fault block, tilted and dropped between blocks of resistant rock of the Amchitka formation. The upper layers of coarser material may have been deposited after some of the tilting and faulting had taken place.

INTERGLACIAL BEACH DEPOSIT AT SOUTH BIGHT

At the head of South Bight, about 75 feet of poorly bedded loose fossiliferous coarse sand and gravel lies conformably on the erosion surface that truncates the lower tilted beds of sand and gravel. Inland, this fossiliferous gravel is covered with clifftop dune sand except in a gravel pit back from the north end of the cliff. At the north edge of this excavation, the crudely bedded sand and gravel grade into a gravel beach deposit with seaward-dipping streaks of sand and concentrated shell fragments. The highest exposed beach material, at an altitude of 135 feet, is overlain by spoil from the gravel pit. In the west wall of the excavation, shell-bearing coarse sand and fine gravel are covered by several feet of rounded to angular cobbles and boulders, many of them of mica schist and biotite granite entirely foreign to the bedrock exposed in the Aleutian Islands. Several of these erratic blocks and boulders are scattered on the highest exposed beach material.

Foraminifera, ostracodes, and several mollusks collected from the raised-beach material indicate that it is of Pleistocene age. It is probably interglacial, and perhaps the youngest interglacial age, inasmuch as the deposit has not been removed by erosion.

Foraminifera.—This fauna was reported by J. A. Cushman and Ruth Todd (1947), who compared the collection with that of Timms Point, Calif., and concluded that ". . . the fauna would seem to be either Pleistocene or Pliocene in age, probably the latter." In a letter on this subject (Jan. 7, 1955), Miss Todd said:

I think that most foram workers are now generally agreed on the Pleistocene, not Pliocene, age of the Timms Point material as indicated by the mollusks, and I am sure that at present Pliocene would not be preferred over Pleistocene for this Amchitka deposit. The 1947 report states that—While the fauna is decidedly one of cold waters, it is not by any means arctic, and most of the species found today are in waters to the south of this area. Certain of the species, those of *Quinqueloculina* and *Cibicides*, are known from nearshore deposits and comparatively shallow water. The great abundance of the two species of *Globigerina*, pelagic forms, would indicate that ocean currents from warmer areas, such as the present Japan current, also influenced this area. It would seem probable, therefore, that the fauna was deposited in shallow water, nearshore, and on an exposed coast.

Ostracodes.—Dr. Fred M. Swain examined and reported as follows on ostracodes from the same material that contained the Foraminifera:

Bythocypris sp.
Bairdia cf. *inflata* (Norman)
Cythereis sp. aff. *C. angulata* (G. O. Sars)
Cytheropteron, sp. nov.?
Eucythere? sp. or new genus
New genus aff. *Paracytheridea*

It is difficult to determine the age accurately, but at present I see no reason to believe the deposit is earlier than Pleistocene.

Mollusks.—The mollusks were identified by R. B. Stewart and F. S. MacNeil as follows:

Balanus sp.
Astarte actis (Dall)
Panomya ampla (Dall)
Pecten (Chlamys) n. sp.? aff. *albidus* Dall
Pecten (Chlamys) *beringianus* (Middendorf)
Pecten (Chlamys) *islandicus* (Müller)
Venericardia (*Cyclocardia*) aff. *crassidens* (Broderip and Sowerby)
Epitonium greenlandicum (Perry) n. var. incomplete

This small marine fauna, probably from fairly shallow water, could be of Pleistocene age or possibly uppermost Tertiary. *A. leffingwelli* (Dall) has been reported from no locality younger than the Nome Inter-beach.

GLACIAL DEPOSITS

Till is found at three places and gravel of glacial origin at several others. As a group these deposits are believed to be of glacial origin because in a few places they lie on ice-polished and ice-striated surfaces, they contain fragments of metamorphic rock and mica granite—rock types not found in place in any of the Aleutian Islands, and some of the cobbles and boulders in the till are striated and many are faceted.

A small patch of till was exposed just above a 300-foot altitude on the crest of Amchitka about 1¾ miles west of Banjo Point, but it was later destroyed during road construction. Along the northwest shore of Constantine Harbor, in the upper part of the sea cliff, three thin sheets of bouldery till are separated by irregular lenses of sorted cobbles. The material of the till is mostly local country rock, much of it broken from adjacent outcrops of the thick obsidian tuff breccia, but some is lava from more distant localities and some is quartz diorite of the type now exposed in largest quantity at East Cape. Several of the boulders are of exotic rock types. The till is well cemented probably by secondary minerals weathered from the finely ground andesitic glass that is so abundant in the matrix. A larger body of till inland from the head of Constantine Harbor is composed mostly of fine material with cobbles and boulders, some exotic and a few striated, scattered throughout the mass. The abundant fine matrix material apparently was derived from beds of fine sand and silt that underly the till.

Two deposits in a graben due west of Kirilof Point and two on the island crest southwest of Ivakin Point contain sand and gravel (with some exotic rock types), some poorly sorted and some well sorted. Most of the material in these deposits has been excavated for construction use, leaving few outcrops undisturbed. In 1946, the deposit south of Ivakin Point was 3 to 6 feet thick and consisted of unfossiliferous unbedded gravel containing less than 10 percent sand. Fifty percent of the gravel particles exceeded 1 inch in diameter. A few boulders up to 5 feet in diameter were subangular, and those up to 1 foot were subrounded to rounded, particularly those of quartz diorite, which was very common. These deposits are considered to be of glacial origin because of the presence of the exotic rocks, but it is not known how much of the washing and sorting of the material accompanied the deposition, or how much, if any, may have been caused by marine reworking subsequent to deposition.

Unconsolidated fine sand and silt, in a varvelike arrangement of thin beds, is exposed almost continuously across the island in the graben depression connecting the heads of Makarius Bay and Constantine Harbor. The total thickness of these beds is not known. The highest outcrop against the south wall of the graben is about 75 feet above sea level, and the bottom is not exposed in the deepest cuts. In most exposures these beds are overlain unconformably by gravel or till at a height of 50 to 75 feet.

In a borrow pit 3,000 feet east of the head of Makarius Bay, a 50-foot section of the bedded sand and silt is capped at an altitude of 70 feet by glacial till and a few patches of water-laid sorted sand. At one exposure in this area, a thin lens of pebble conglomerate breaks the orderly, varvelike alternation of beds about 20 feet below the top of the section; this break cannot be traced into other areas.

Another borrow pit, 1,000 feet to the north across the graben, exposes bedded silt and sand overlapping rock of the Banjo Point formation. The loose bedded silt and sand dips about 4° E., and the older bedded rock dips 25° in a S. 20° W. direction. The surface of the older rock, recently exposed by quarrying, shows glacial polishing and striae that plunge about 25° E. on the polished face that dips 30° SE.

In another large borrow pit, 1,000 feet inland from Constantine Harbor along the north wall of the graben, the bedded sand and silt dip as much as 20° E. in a section broken by many minor faults.

The most conspicuous feature of these deposits is the regular interlayering of thin beds of silt and sand. In detail, a coarse layer grades into the overlying fine layer, but the change from fine to overlying coarse is abrupt; the deposit is a series of graded beds rather than alternating beds of coarse and fine material. The graded beds range from ¼ to 1 inch in thickness. The material in the coarser part is fine to very fine sand; that of the finer part is about a half very fine sand, a third silt, and a sixth clay size. The clay-size material, in a laboratory test, remained in suspension in cold water only a few hours. The mineralogy of grains larger than clay size, determined by R. Q. Lewis, is:

50 percent plagioclase grains, rounded edges
30 percent rock aggregate, largely feldspar, magnetite, and chlorite
10 percent chalcedony and other cryptocrystalline material
5 percent quartz, angular-edged fragments
5 percent heavy minerals, in order of abundance, green hornblende, brown hornblende, magnetite, biotite, muscovite, augite, and green chlorite.

No rocks exposed in any of the western Aleutian Islands contain muscovite, and biotite is very rare; all the other constituents could be of local origin. Both types of mica present in the sand probably came from the same source that furnished the cobbles and boulders of schist and mica granite found as erratics in the till and gravel.

Diatoms are the only fossils found in these beds. The following were identified by K. E. Lohman:

[R, rare; F, frequent; C, common]

Arachnoidiscus cf. *A. ehrenbergii* Bailey; R.
cf. *A. longi* Brown, found in beds near Jeremie, Haiti, possibly as old as Eocene; R.
oamaruensis (Schmidt) Brown found in Oligocene near Oamaru, New Zealand, and lower middle Miocene near Nanggoeland, East Java; F.
sp.; F.
Aulacodiscus cf. *A. nigricans* Tempere and Brun, found in Pliocene near Sendai, Japan; R.
sp.; R.
Campylodiscus sp.; C.
Endictya cf. *E. oceanica* Ehrenberg; F.
robusta (Greville) Hanna and Grant; R.
sp.; F.
Grammatophora sp.; R.
Hyalodiscus sp.; R.
Isthmia nervosa Kützing; C.
Melosira cf. *M. sol* (Ehrenberg) Kützing; C.
sp.; F.
Pseudopyxilla baltica (Grunow) Forti; R.
Rhabdonema arcuatum var. *robustum* (Grunow) Hustedt; F.
biquadratum Brun, found in Pliocene near Sendai, Japan, and lower Pliocene Sisquoc formation in Purisima Hills, Calif.; F.
valdelatum Tempere and Brun, found in Pliocene near Sendai, Japan; F.
sp.; F.
Triceratium sp.; F.

This is an amazing assemblage of short-ranging diatoms representing Oligocene, Miocene, Pliocene, and Recent species. The shattered and eroded condition of the individual valves strongly suggests reworking of older beds. The assemblage is almost certainly no older than middle or early Pliocene since it contains two species not known from older rocks. It could be early Pleistocene, with exposures of older diatom-bearing sediments contributing debris and diatoms to the deposits.

The absence of nonmarine diatoms indicates that the original diatom-bearing sediments were deposited under marine conditions. However, it is possible that the present deposit is entirely reworked, and could have been deposited under nonmarine conditions with no contemporaneous diatoms (nonmarine) present.

The age of this deposit probably is Pleistocene since it lies on a glaciated surface and is covered by glacial gravel and till, confirming Lohman's conclusion that a large part of the diatom assemblage is reworked from older sediments. The physical characteristics of the sediments and the geography of the deposit limit the choice of possible conditions under which deposition could have taken place. The thin, even beds must have been deposited in quiet water, undisturbed by wave action or strong currents. The grading within each bed suggests sorting by settling of a sedimentary load dumped periodically into a basin. Probably the deposit was accumulated in a local pond, largely of glacial melt water, and derived almost wholly from ice-transported material.

MANTLE

A mantle, from a few inches to a few feet thick, of broken but undecomposed fragments of the local bedrock is present over most of the island. In places, silt and clay particles fill the interstices in the upper part of the layer of loose fragments. This layer is thickest on bedrock that is transected by closely spaced joints and bedding planes, and thin or absent on rock with widely spaced joints and no bedding planes. It is inferred that frost splitting has been the most active agent in forming this residual mantle.

In a few places, favorable both to undisturbed deposition and preservation, thin beds of very fine volcanic ash give evidence that the island has been showered by material from postglacial eruptions of nearby active volcanoes. On most of the island surfaces such material has been incorporated in the mantle of turf and is not identifiable as bedded ash.

STRUCTURE

REGIONAL

Amchitka, Rat, and Kiska Islands are located along the northeast edge of a segment of the Aleutian Ridge (Gibson and Nichols, 1953, pl. 1) that might be considered, in a general way, as a great fault block tilted southwestward toward the Aleutian Trench. In profile, across the west end of Amchitka, the north face of the block drops 1,500 feet in 7,500 feet (about 1,075 feet per statute mile), and the top surface of the presumed block descends southwestward 3,000 feet in a distance of 80,000 feet (about 200 feet per statute mile), then drops 7,800 feet in 50,000 feet (about 830 feet per statute mile) to the intercept with the Aleutian Bench (Gates and Gibson, 1956, p. 143).

This large tilted block is composed of rocks that are greatly deformed by block faulting (summarized for Amchitka in paragraphs following), so the inferred top surface of the block must be a plane of erosion, perhaps related to the ridge shelf, defined and described by Gates and Gibson (1956, p. 133). This tilted surface that forms the upper part of the south insular slope is crossed by several scarps and canyons that may be the margins of blocks dislocated by cross faults in the supposed large block. Adjacent to Amchitka Island, these features can be traced across the surface of the eastern part of the insular shelf and into the block and graben shapes of the island in the vicinity of Constantine Harbor; similar features to the west cannot be traced across the insular shelf.

LOCAL

On Amchitka Island many lines of topographic features such as elongated pond depressions, straight valleys, and straight canals through the shore bench are prominent on aerial photographs and have been indicated on plate 69. Those lines known or presumed from the geology to represent the outcrop trace of softer layers of interbedded rock are omitted; those shown probably represent traces of fracture zones, joints, and faults. Some of the faults located in outcrop lie on such a line of physiographic features, but many observed faults are not marked by such features.

All the mapped faults and attitudes of disturbed beds seem adequately explained as resulting from normal faulting on planes of moderate to steep dip. In the western part, fault strikes are about equally distributed between northwest, north, and northeast; in the east half of the island, north and northeast directions predominate. In contrast, most of the dikes of the youngest volcanic rock and the zones of pyrite enrichment strike within a few degrees of east, a direction that is not well represented by the mapped lineations or fault strikes.

Faults, both observed and inferred, are most numerous and structural disturbance is the greatest, in the rocks of the Amchitka formation. Glacial deposits are involved in fault movements along the Constantine Harbor graben. At the head of the harbor, in the cliff of both the north and the south shore, are 2 faults that strike N. 80° E. and dip about 75° toward each other. On each fault the graben block has dropped, bringing till into fault contact with tuff-breccia of the Amchitka formation. About 3,000 feet westward from the harbor shore, along the south wall of the graben, a vertical fault cuts fluvioglacial sand and gravel and the north block has dropped at least 30 feet. Overlying the fault, without displacement, is about 2 feet of the uppermost silty till. This movement apparently took place during the last glacial activity. Movement after late interglacial time and before the last glaciation took place along a fault that strikes east of north from South Bight, if the inference is correct that both the raised beach at an altitude of 135 feet at South Bight and the raised marine platform and cliff at 240 feet west of South Bight are features of the shoreline of a late interglacial stand of the sea.

The region is subject to earthquakes, but no physiographic traces of very recent fault movement are to be seen on the ground or on aerial photographs of the island.

At least 2 uplifts separated by 1 submergence, with respect to sea level, are inferred from the stratigraphy. The oldest rocks were all deposited below sea level and consist entirely of unreworked volcanic material. The next younger formation contains rocks deposited in both submarine and subaerial environments, including beds of detrital material derived from erosion of rock of the oldest formation. Subaerial lava flows of the third younger formation that appear to extend below present sea level are covered in part by marine conglomerate that is now as much as 600 feet above sea level.

GEOLOGIC HISTORY

The oldest deposits (the Amchitka formation) are andesitic rocks, products of explosive and effusive submarine volcanic activity, with no land sufficiently near to contribute products of erosion. It is believed that this sea was located on a continental rather than an oceanic segment of the earth's crust, because all the igneous rocks of Amchitka resemble chemically the suites of andesitic rocks distributed around the margin of the Pacific Ocean.

Uplift, with some deformation, brought part of this submarine volcanic deposit above sea level. Products of erosion of this land are interbedded with water-laid tuff and, rarely, a lava flow (the Banjo Point formation of Oligocene or Miocene age). These volcanic rocks are basaltic, but relatively rich in plagioclase. Both the older andesite and the basalt are represented by cobbles in the beds of conglomerate. The assemblage of fossil Foraminifera suggests an environment of disconnected marine lagoons partly sheltered from the open ocean; the abundance of conglomerate suggests shoals and numerous small islands. Tension fractures formed during this time are represented by dikes of basalt that strike generally between northwest and northeast. After an unknown lapse of time, small stocks, sills, and dikes of quartz diorite were emplaced in the rocks of both of the preceding formations.

Eruption of andesitic lava was resumed (the Chitka Point formation) after an unknown lapse of time, and in the region of western Amchitka at least one volcanic pile was built subaerially to a height of more than a thousand feet. Dikes of similar andesitic material trend within a few degrees of east, as do lines of hydrothermal alteration and zones of introduced pyrite. However, most of the alteration and pyritization is found in rock older than the Chitka Point formation, so it is inferred that the east-trending lines of weakness and pyritization are associated with the preceding plutonic activity but persisted through the time of younger Chitka Point volcanism. The age of this youngest volcanic activity on Amchitka is unknown.

The region was next submerged, and marine conglomerate was derived from and deposited on the subaerial Chitka Point formation. (Some of this conglomerate is now found as much as 600 feet above the lowest exposures of subaerial Chitka Point formation at present sea level.)

Erosion reduced the surface of Chitka Point formation to low relief, perhaps a completely submerged wave-cut shoal; it is not known whether the oldest erosion surface (now above 1,100 feet in altitude) on the present island was cut by submarine or by subaerial erosion. The total submergence of these subaerial volcanic rocks, over 800 and perhaps over 1,100 feet, seems to be too great to attribute to a rise of sea level; perhaps all of the submergence should be considered as resulting from structural depression.

Uplift followed this episode of marine planation, and the merging island was benched by shoreline erosion at 2 levels (at the present altitudes of 500 and 800 feet). These shorelines may represent pauses during structural uplift, or possibly fluctuation of sea level in early Pleistocene time. As the island emerged, vigorous stream erosion established the pattern and major dimensions of the present valleys and ridges. The pattern extends below the present sea level, attesting that some stream erosion took place during a time of lower sea level, possibly a time of glacial maximum.

It is inferred that the structural uplift halted before late Pleistocene time and that the shelf-break bench was eroded at a low sea level of a middle Pleistocene glacial maximum, coincident with the erosion of the now-submerged stream pattern. Benches and shoreline cliffs also were eroded at a high sea level of at least the last interglacial stage.

Block faulting occurred on a small scale between the last interglacial and the latest major glacial maximum. In the eastern part of the island, segments of the interglacial shoreline were displaced to altitudes ranging from 135 to 240 feet, and the shelf-break bench was offset from a depth of 325 feet to as much as 390 feet. During the lowered sea level of the last major glacial maximum, shoreline features were cut around the island at a depth of about 165 feet; these features apparently have not been offset by faulting.

Postglacial stream erosion has modified the glaciated topography very little, but marine erosion has made great changes in the shoreline. A good deal of the present sea cliff marks the position of a shoreline cut at a sea level about 6 to 8 feet higher than the present shoreline. At least 4,000 years ago, before early Aleut inhabitants built their dwellings on many of its storm beaches, this shoreline was abandoned by a slight lowering of sea level.

The most recent marine erosion has modified much of the wave-cut bench and beach deposits of the abandoned shoreline and, in favorable localities, has cut a new sea cliff.

The region is still structurally unstable as attested by frequent earthquakes, but no recent earth movement has been sufficient to form visible scarps or offsets in present topography.

REFERENCES CITED

Arctic Weather Central, 1950, Climate, weather, and flying conditions of Alaska and Eastern Siberia: 11th Weather Squadron, Elmendorf Air Force Base, Alaska.

Arnold, Ralph, 1906, The Tertiary and Quaternary pectens of California: U.S. Geol. Survey Prof. Paper 47, 264 p.

Atwill, E. R., 1935, Oligocene Tumey formation of California: Am. Assoc. Petroleum Geologists Bull., v. 19, no. 8, p. 1192–1204.

Bartrum, J. A., 1926, "Abnormal" shore platforms: Jour. Geology, v. 34, p. 793–806.

Byers, F. M., Jr., 1959, Geology of Umnak and Bogoslof Islands, Aleutian Islands, Alaska: U.S. Geol. Survey Bull. 1028–L, p. 267–365.

Coats, R. R., 1956, Reconnaissance geology of some western Aleutian Islands: U.S. Geol. Survey Bull. 1028–E, p. 83–100.

Cushman, J. A., and Todd, Ruth, 1947, A foraminiferal fauna from Amchitka Island, Alaska: Cushman Lab., Contr., v. 23, no. 297, p. 60–72.

Dietz, R. S., and Menard, H. W., 1951, Origin of abrupt change in slope at continental shelf margin: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 1994–2016.

Gates, Olcott, and Gibson, William, 1956, Interpretation of the configuration of the Aleutian Ridge: Geol. Soc. America Bull., v. 67, p. 127–146.

Gibson, William, and Nichols, Haven, 1953, Configuration of the Aleutian Ridge, Rat Islands—Semisopochnoi I. to west of Buldir I.: Geol. Soc. America Bull., v. 64, no. 10, p. 1173–1188.

Moore, R. C., and Vokes, H. E., 1953, Lower Tertiary crinoids from northwestern Oregon: U.S. Geol. Survey Prof. Paper 233–E, p. 113–147.

Nansen, Fridtjof, 1922, The strandflat and isostacy: Christiana, p. 1–313.

Scruton, P. C., 1953, Marine geology of the Near Islands Shelf, Alaska: U.S. Geol. Survey open-file report, p. 1–200.

Todd, Ruth, 1953, Foraminifera from the lower Tertiary of Amchitka Island, Aleutian Islands: Cushman Found. Foram. Research, Contr., v. 4, pt. 1, no. 70, p. 1–7.

Weaver, C. E., 1942, Paleontology of the marine Tertiary formations of Oregon and Washington: Washington Univ. Pub. in Geology, v. 5, pt. 1–3, 789 p.

INDEX

O