Steller's Sea Cow

Amchitka, Alaska

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1036

Steller's Sea Cow (*Hydrodamalis gigas*) of Late Pleistocene Age from Amchitka, Aleutian Islands, Alaska

By FRANK C. WHITMORE, JR., *and* L. M. GARD, JR.

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Description of the first specimen of the extinct Arctic sea cow, Hydrodamalis gigas, *to be found in place in Pleistocene deposits outside the Commander Islands, U.S.S.R.*

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

Cecil D. Andrus, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress Cataloging in Publication Data
Whitmore, Frank C.
Steller's sea cow (Hydrodamalis gigas) of late Pleistocene age from Amchitka, Aleutian Island, Alaska.
(Geological Survey Professional Paper 1036)
Bibliography: p.
Supt. of Docs. no.: I 19.16:1036
1. Hydrodamalis gigas, Fossil. 2. Paleontology—Pleistocene. 3. Paleontology—Alaska—Amchitka Island.
I. Gard, Leonard Meade, 1923- joint author. II. Title: Steller's sea cow... III. Series:
United States Geological Survey Professional Paper 1036
QE882.S6W49 569'.5 77-608068

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 024-001-03001-2

CONTENTS

ILLUSTRATIONS

[Plates follow "References Cited"]

TABLES

STELLER'S SEA COW (*HYDRODAMALIS GIGAS*) OF LATE PLEISTOCENE AGE FROM AMCHITKA, ALEUTIAN ISLANDS, ALASKA

By FRANK C. WHITMORE, JR., and L. M. GARD, JR.

ABSTRACT

A partial skeleton of *Hydrodamalis* has been collected from a Pleistocene interglacial beach deposit, 35 meters above present sea level, on Amchitka, Aleutian Islands, Alaska. This is the first discovery of the genus in place in Pleistocene deposits outside the Commander Islands (Komandorskiye Ostrova), U.S.S.R. Parts of the young but apparently nearly full grown individual were found in a position which suggested that the animal, after death, had been washed into shallow water or up onto a beach. The Pleistocene animal was toothless, as was the modern Steller's sea cow (*Hydrodamalis gigas*), which was exterminated by Russian hunters about 1768. Like the modern form, the Pleistocene sea cow undoubtedly subsisted on kelp. It is indistinguishable from the modern species. A uranium-series date of 127,000±8,000 years on bone from this beast is consistent with a generally accepted age of the last major interglacial stage.

INTRODUCTION

The giant Arctic sirenian *Hydrodamalis gigas* (Zimmermann), popularly known as Steller's sea cow, was discovered in 1741 along the coast of what is now called Bering Island (Beringa Ostrov) in the Commander Islands (Komandorskiye Ostrova), U.S.S.R. (fig. 1). Its discoverer, and the only naturalist who observed it alive, was G. W. Steller, a German who sailed on the second voyage of the Danish explorer Vitus Bering, in the service of the Russian government (Golder, 1925). Steller's description of the animal was published (1751) posthumously and was translated from Latin into English in 1899. A female specimen of *Hydrodamalis*, measured and dissected by Steller (1751, p. 294), was 7.4 m long from the extremity of the upper lip to the extreme right *cornu* of the caudal fork. The animals are estimated to have attained a weight of 10 metric tons (Scheffer, 1972, p. 913).

Steller's sea cow was discovered when Bering's crew was shipwrecked on Bering Island in the course of their return voyage from North America. The starving Russians captured some sea cows with great difficulty, not because they were fierce but simply because their bulk made them hard to haul ashore, and found them to be very good eating. This news was passed by the survivors to subsequent Russian voyagers who, in succeeding years, made the Commander Islands a victualing stop on North Pacific fur-hunting expeditions. Stejneger (1887, p. 1049) stated that from 1743 until 1763 "hardly a winter passed without one or more parties spending eight or nine months in hunting fur-animals there, during which time the crews lived almost exclusively on the meat of the sea-cow." The result was that, by 1768, *Hydrodamalis* was extinct (Sauer, 1802; von Baer, 1840; Brandt, 1846; Stejneger, 1887, Lucas, 1891).

Steller, in 10 months on Bering Island, had ample opportunity to observe the daily activities of *Hydrodamalis* from his hut on the shore. He reported that the animals congregated in herds, feeding incessantly on kelp in shallow water. They were fond of shallow sandy places along the seashore, especially along the mouths of rivers and creeks. "As they feed they move first one foot and then the other, as cattle and sheep do when they graze, and thus with a gentle motion half swim and half walk" (Steller, 1899, p. 198). In his anatomical description, Steller stated that the neck is short but movable: It "has its independent action, a motion observed in the living animal only when it feeds; for it bends its head in the same way as cattle on dry land" (1899, p. 187).

The need for vast amounts of seaweed in shallow water was certainly a limiting factor in the distribution of *Hydrodamalis*, but, even for an animal of such specialized requirements, our knowledge of its range is slight. Only in the Commander Islands is there convincing evidence of the sea cow's existence in historic time, although there has been much speculation on its existence elsewhere in the North Pacific area (Gard and others, 1972, p. 867). A single rib was found on the island of Attu in the Aleutians (Brandt, 1868, p. 294).

During the course of the U.S. Atomic Energy Commission operations on Amchitka, Gard had occasion to talk with Mr. Paul Higdon, then labor foreman for Holmes and Narver, Inc. Higdon had been on Shemya Island (56 km east of Attu) during construction of an airstrip in World War II and remembered a complete skeleton of a large marine mammal being uprooted and pushed aside by construction equipment. Shafer (in Gates and others, 1971, p. 783) reported that the

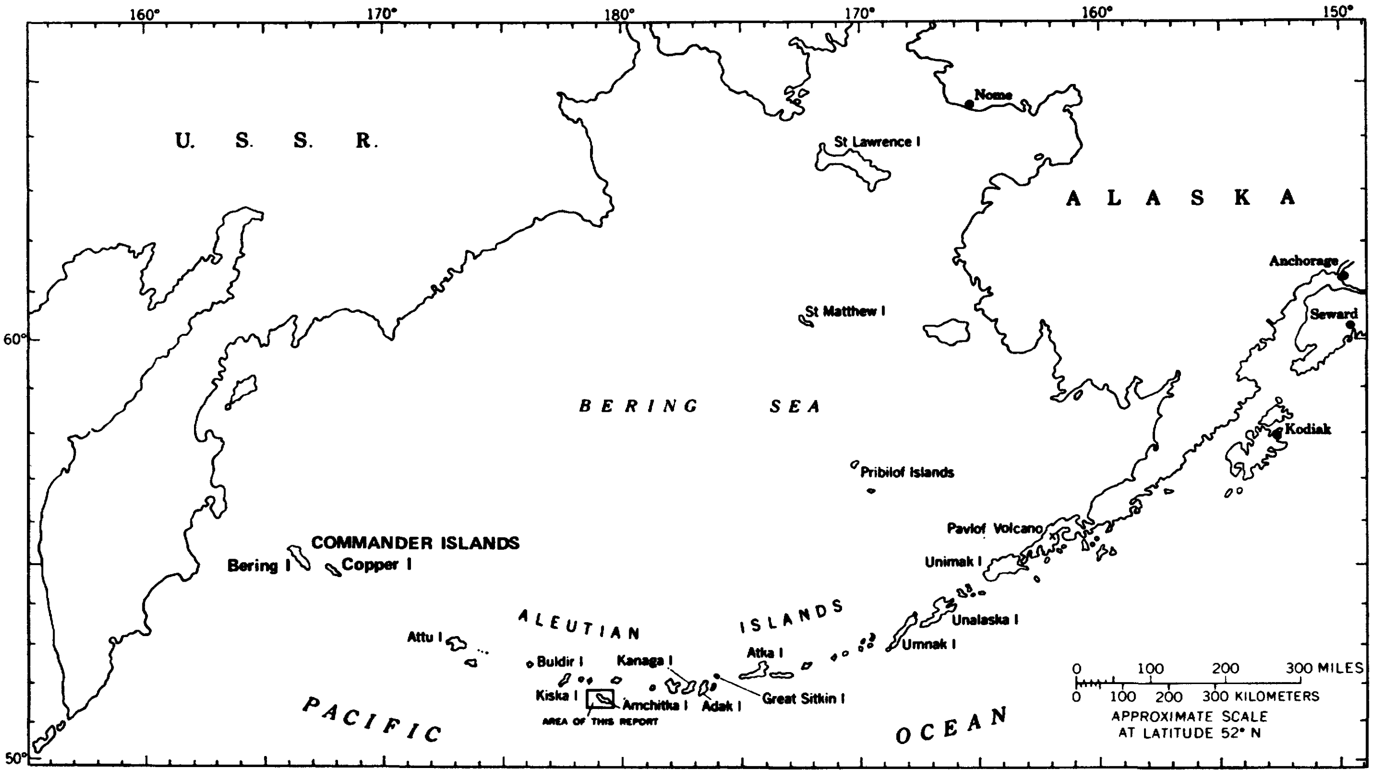

FIGURE 1. — Index map of the Aleutian arc, showing Amchitka and Bering Islands.

bedrock surface of Shemya is a wave-cut platform "most likely of pre-Wisconsinian age" covered by marine deposits, and then glaciated. Perhaps an opportunity to recover the entire skeleton of a sea cow was lost at that time.

Many sea-cow bones were found along the shore of Bering Island (Chelnokov, 1969; Scheffer, 1973). Stejneger (1884) took advantage of this situation to make a collection for the U.S. National Museum. Some bones were collected by Stejneger himself; others were purchased from natives. The composite skeleton now exhibited at the U.S. National Museum of Natural History consists of bones from the Stejneger collection. Among composite skeletons mounted in European museums, one of the best is that at the Naturhistoriska Riksmuseet in Stockholm, Sweden (pl. 1). Sea-cow bones on Bering Island were commonly covered by a layer of earth and gravel; Nordenskjöld (1882, p. 280) reported it to have been 30 to 50 cm thick: "In order to find them, as it would be too troublesome to dig the whole of the grassy bank, one must examine the ground with a pointed iron rod * * *." All the bones were apparently found on a low terrace just above the beach "which may be accounted for by the accumulation of storm-wash under the present conditions or very nearly so" (Dawson, 1894, p. 125). Some bones were found at a considerable distance inland. In the Stejneger papers in the Archives of the Smithsonian Institution are notes by Prof. B. W. Evermann "concerning the Rhytina recently acquired by the Museum," which state that the bones, which were purchased from a "creole" on Bering Island in 1892, lay under about 1 m of sand, three versts (about 3 km) back from the water. Most of the bones in the Stejneger collection at the U.S. National Museum of Natural History are white and hard but not permineralized or replaced. An exception to this is USNM 218376, an *os occipitis* and the first and seventh ribs of the right side, which have a red-ocher color. These specimens are from the anterior part of a skeleton found by Stejneger (1884, p. 61–62) in a sand bank 3.6 m high, 150 m from the sea, and not less than 3–4 m above high tide. The skeleton was on its back. The bones were soft and of a soapy consistency, most of them too soft to be collected. In both softness and red color, these bones resemble some of those discovered on Amchitka, which raises the possibility that there may be sea-cow bones of Pleistocene age on Bering Island in addition to those left by the Russian fur hunters.

Considering the frequency and violence of storms in the Commander Islands, it is not surprising that bones of sea cows butchered in the 18th century should have since been buried under a meter or so of storm-tossed sand. Those buried by the infrequent storms that caused waves to roll far inland could have subsequently been covered by vegetation. The mode of occurrence of the bones led Woodward (1885, p. 457–458) to conclude that specimens collected by Robert Damon for the British Museum (Natural History) were of Pleistocene or early Holocene age: "The specimen now in the British Museum was obtained from compact peat, and all the vertebrae and other bones having cavities in them were full of peat-growth when they arrived, as was also the skull." Without careful field study it is impossible to tell whether sea-cow bones from Bering Island are of Pleistocene or Holocene age, but the historic evidence for extensive killing of sea cows in the 18th century leads to the conclusion that most of the bones date from that period.

The 18th-century range of *Hydrodamalis*, restricted to the Commander Islands, was certainly that of a relict species, perhaps on its way to extinction even without the influence of man. It is logical to assume that the earlier range of *Hydrodamalis* extended eastward along the Aleutian chain. If this was so during the last 10,000 years or so, *Hydrodamalis* would have been ideal prey for the sea-hunting Aleuts (Domning, 1972). However, there is no known archeological evidence that the Aleuts hunted the sea cow. Desautels and others (1969–70), in a report on the archeology of Amchitka, recorded many sea-mammal bones from old Aleut middens but included no *Hydrodamalis*. Six sites (Roger Desautels, written commun., 1971), which revealed occupation over a 2,500-year span, were investigated. Jean S. Aigner (written commun., 1971) reported that there are no known examples of *Hydrodamalis* from any Aleut middens and that a large number of middens had been sampled, some as much as 4,000 years old. Domning (1972) speculated that some middens ancient enough to contain *Hydrodamalis* bones may still exist but that most of them have been covered by the rising sea.

The only occurrence known to us of *Hydrodamalis* bone in a midden was reported by Hall (1971) from a 16th-century Eskimo site at the confluence of the Noatak River and Kangiguksuk Creek in northwestern Alaska (67°58′ N., 161°50′ W.). A rib, which had the distal end sawed off and which was heavily marked with cuts on both sides, was found in floor fill within the house. It is unquestionably associated with the rest of the cultural material at the site (Hall, written commun., 1976). Hall (1971, p. 23) also reported the presence at the site of 133 fragments of fossil mammoth ivory and a bison horn and phalanx, all of Pleistocene age. He pointed out (1971, p. 56) that "mammoth ivory and the bones of extinct animal species are frequently washed out of the permanently frozen banks when the Noatak shifts its course."

The Kangiguksuk site is about 100 km from the ocean. The rib from this site is described in more detail on p. 15.

Hydrodamalis was unknown south of Alaska until 1967, when Jones (1967) reported that a badly eroded cranial fragment had been brought up in a trawl from the bottom of Monterey Bay, Calif., and that it had yielded a C^{14} radiometric age of 18,940±1,100 years B.P. The Monterey specimen is in the lower part of the size range of a series of modern skulls from Bering Island.

Shikama and Domning (1970) reported a rib of *Hydrodamalis* from the late Pliocene of the island of Honshu, Japan. They also mentioned that two specimens of a new species of *Hydrodamalis* have been discovered in the Pliocene of California and that this species is morphologically intermediate between *Metaxytherium jordani* Kellogg of the late Miocene and *Hydrodamalis*. (See also Domning, 1970.).

ACKNOWLEDGMENTS

We thank Daryl P. Domning for many helpful discussions and for reviewing this paper before publication. The photographs of the bones were taken by Robert H. McKinney and Haruo E. Mochizuki, and the drawings for figures 7–10 were made by Richard J. Mjos. Thomas D. Washburn prepared the specimens for study. We are grateful to Dr. Tor Orvig and Mr. Carl Edelstam of the Naturhistoriska Riksmuseet, Stockholm, Sweden, for furnishing photographs of their mounted composite specimen of *Hydrodamalis* and for permission to reproduce them. The drawing on the cover is from a painting by Alfred G. Milotte; permission to use it has been granted by the artist. We thank the U.S. Atomic Energy Commission for logistical support on Amchitka. The Department of Anthropology, Yale Peabody Museum, kindly loaned us a rib of *Hydrodamalis* from an archeological site in northwestern Alaska.

OCCURRENCE AND AGE OF THE AMCHITKA SPECIMENS

STRATIGRAPHIC AND STRUCTURAL RELATIONS

In 1969 Gard discovered a partial skeleton of *Hydrodamalis gigas* 35 m above present sea level in unconsolidated sediments exposed in the sea cliff at the head of South Bight on Amchitka Island (figs. 2, 3). This exposure, first described by Powers, Coats, and Nelson (1960, p. 542) as an emerged Pleistocene interglacial beach deposit, was preserved because it was penecontemporaneously downdropped in a small (800-m wide) east-northeast-trending graben within the Amchitka Formation of early Tertiary age (fig. 4). These beds were conformably deposited on an erosion surface that truncates earlier Pleistocene lacustrine and marine sediments. The earlier semiconsolidated sediments also

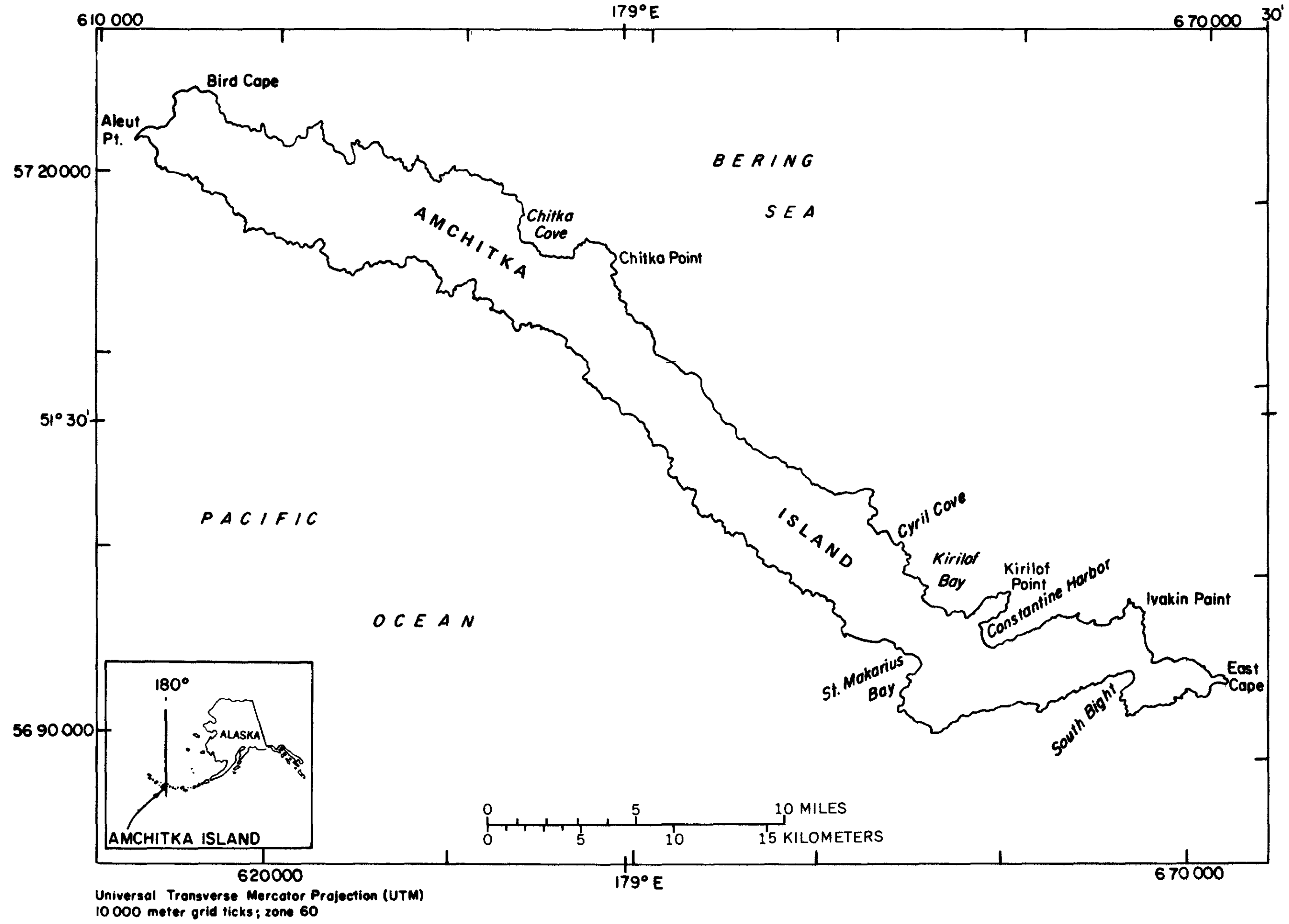

FIGURE 2. — Index map of Amchitka Island.

were trapped in this graben and were tilted and faulted prior to their truncation. The erosion surface, itself tilted and faulted, ranges from 34 m above mean sea level on the north side of the graben to 15 m above mean sea level on the south side of the graben. This surface and the overlying beach deposit are believed to be related to a stillstand of the sea during the South Bight II marine transgression that cut the most extensive terrace on Amchitka Island (Szabo and Gard, 1975). This terrace is as much as 1.5 km wide. The inner edge of the terrace is now 37 to 49 m above sea level.[1]

The beach deposit ranges in thickness from about 6 m on the north side of the graben to about 30 m on the south side of the graben. The deposit was not found on the Bering Sea side of the island and does not appear to extend more than 500–600 m back from the sea cliff.

The deposit consists of loosely consolidated, poorly bedded sand to coarse boulder gravel, which is richly fossiliferous. Some beds near the base of the deposit are composed almost entirely of cross-stratified shell fragments; in a few places, discontinuous beds in the lower part of the deposit are composed entirely of unbroken pecten shells, some of which are articulated. Beds in which the partial skeleton of *Hydrodamalis* was found (fig. 5) are 9 m above the base of the deposit (near the upper middle part) and consist of loose pebbly sand that contains random cobbles and boulders and abundant shell material, including echinoid plates and spines and Foraminifera. Many beds as much as 30 cm thick are composed of well-rounded hornblende-bearing white pumice pebbles, which average 2.5 cm in diameter but which may be as large as 7 cm. The buoyant low-density pumice pebbles probably were derived from eruptions of one of the nearby active volcanoes. Near the base of the deposit, many boulders are coated with calcium carbonate algal secretions, and fragments of these coralline algae (probably *Lithothamnion* sp.), similar to those found on modern Aleutian Islands beaches, are interspersed between the boulders. An isolated rib of *Hy-*

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[1] Altitudes at base of abandoned sea cliffs have been determined from 1968 topographic maps by Holmes and Narver, Inc., scale 1:6,000, contour interval 10 feet. This terrace was erroneously reported as 52 m (Gard and others, 1972, p. 868).

FIGURE 3. — Interglacial beach deposit overlying tilted unconformity (1) in the cliff face at South Bight, Amchitka Island. *Hydrodamalis* (USNM 170761) was found at (2). *Hydrodamalis* rib (USNM 181752) was found at (3), just above unconformity. White bed above (3) is composed of cross-stratified shell fragments. Photograph by R. H. Morris.

drodamalis was found in place near the base of the deposit (fig. 6).

The difference in thickness between the north and south ends of the deposit is the result of contemporaneous southward tilting of the graben block while these beds were being deposited, which caused a discordance of the bedding in the southern part of the deposit and tilting of the erosion surface at the base. At the southern end, the material that forms the generally coarser grained upper part of the section apparently was eroded from the scarp of the more active south-bounding fault. We assume that these boulders, which are as much as 0.6 m in diameter, were deposited in deeper water, where they escaped abrasion, as many are angular or only slightly subrounded.

Although the deposit has been studied in detail, no erosional unconformity is recognized within it.

OTHER FOSSILS

In addition to bones of *Hydrodamalis*, the gravel deposit yielded a partial skull of the Steller sea lion, *Eumetopias jubata* Schreber, the distal half of the radius of a large whale, and a fragment of the tusk of a small walrus.

The presence of a rich invertebrate fauna in the deposit has been known for some time. From 1946 to 1951, U.S. Geological Survey personnel collected a molluscan fauna (Powers and others, 1960). A report on Foraminifera collected by R. R. Coats in a gravel pit 200 m north of the *Hydrodamalis* site was published by Cushman and Todd (1947). In 1969, Allison (1973) collected a large invertebrate fauna from this deposit.

The present authors collected samples of sand that contains Foraminifera during excavation of the sea-cow bones in 1971. These were collected from 0.3 m above the base of the deposit, from the sea-cow horizon, and from 1 m above the sea-cow horizon. Foraminifera in these samples, identified by Ruth Todd (table 1) are all living species and provide no evidence of age. In addition, in 1969, a collection of Foraminifera was made by Gard from about 1 m below the sea-cow horizon and was identified by the late R. L. Pierce, U.S. Geological Survey. According to Todd (written commun., 1971), the 1969 collection (table 1, col. 3) is quite similar to the other three. The 1969 collection and the 1971 collections (taken as a whole) have seven species in common. She noted that the 1947 collection (Cushman and Todd, 1947) is much richer in variety of foraminiferal species and that only six species which she identified in these more recent collections are the same as those in the 1947 list. All these collections of Foraminifera are from the interglacial beach deposit, and all but one are from about the same horizon, although Todd suggested that the fauna collected in 1969 and 1971 might be from shallower water than those in the 1947 collection.

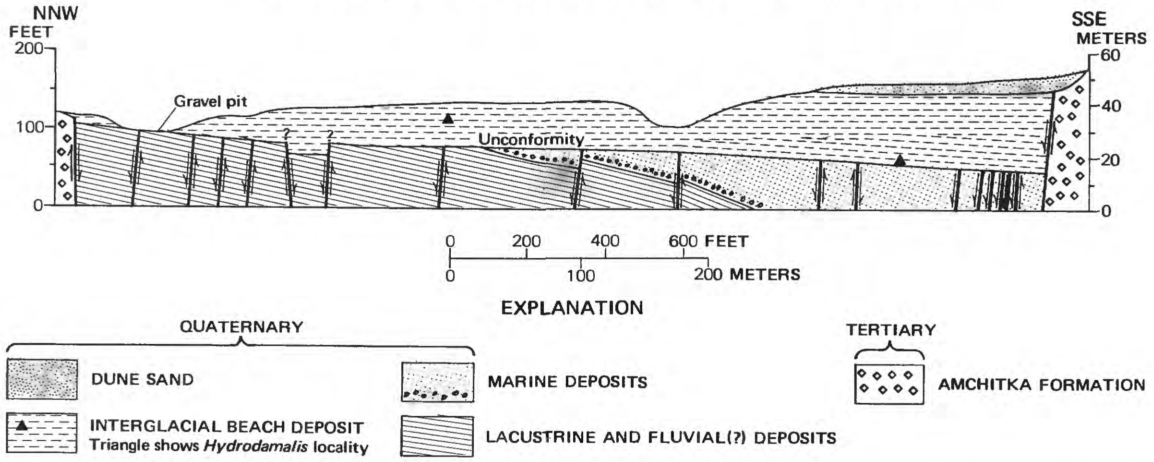

FIGURE 4. — Diagrammatic cross section of South Bight graben, Amchitka Island. Faults mainly generalized. Vertical exaggeration × 2.

FIGURE 5. — Partial mandibles of *Hydrodamalis gigas*, as found on Amchitka Island, upside down in beach sand, anterior end pointing toward lower left corner of photograph. Photograph by F. C. Whitmore, Jr.

ENVIRONMENT

Hydrodamalis apparently lived in an environment much like that of Amchitkan waters today. According to Cushman and Todd (1947, p. 60) "while the [foraminiferal] 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. * * * The great abundance of two species of *Globigerina*, pelagic forms, would indicate that ocean currents from warmer areas, such as the present Japanese Current, also influenced this area." A comprehensive study by Allison (1973) on the paleoecology of the invertebrate megafossils from the deposit indicates that the water temperature at that time was almost the same as it is today. Allison reported that when these mollusks were living, the mean February water temperature was probably about 3.9°C, and the mean August water temperature was 10.0°–11.7°C; these temperatures compare with present-day water temperatures of 3.9°C for February and 10.0°C for August.

Depth of the water in which these fossiliferous beds were deposited could not have been more than 25 m and probably was much less. At least part of the time, this area was within or even slightly above the intertidal zone. A maximum water depth may be assigned by the presence of coralline algae on and between boulders near the base of the deposit. The maximum depth at which sublittoral algae will grow is primarily dependent on the amount of light that will penetrate the water. This, in turn, depends on latitude and water turbidity (Smith, 1938, p. 296). Coralline algae (Rhodophyta) in the North Atlantic Ocean are rarely found at depths below 30 m. At Amchitka Island today, they are found from the intertidal zone to a depth of at least 23 m. The foraminifers *Quinqueloculina* and *Cibicides* are known from nearshore deposits and comparatively shallow water (Cushman and Todd, 1947, p. 60). Allison (1973, p. 42) stated that "the majority of the South Bight fauna lived in shallow (0–23 m(?)) water on the open coast, * * * [and] the environment must have been almost identical to that of South Bight today."

The presence of beds of pumice pebbles indicates that the pumice fragments floated to this area, were rounded by wave action, and stranded on the interglacial beach.

TABLE 1. — *Foraminifera and other fossils associated with* Hydrodamalis *from the South Bight interglacial beach deposit, Amchitka Island*

Fossils / Collections	1971 1 m above *Hydrodamalis* horizon[1]	1971 Upper part of *Hydrodamalis* horizon[1]	1969 1 m below *Hydrodamalis* horizon[2]	1971 15 m above beach, 0.3 m above base of *Hydrodamalis* horizon[1]
Bolivina decussata Brady	×	×	...	...
sp. cf. *B. pseudopicata* Heron-Allen and Earland	...	...	×	...
Buccella frigida (Cushman)	...	...	×	...
Cassidulina californica Cushman and Hughes	×	×	...	...
islandica Norvang	...	×	×	...
teretis Tappan	...	×	×	...
tortuosa Cushman and Hughes	...	×	...	...
Cibicides lobatulus (Walker and Jacob)	×	...	×	×
Elphidiella arctica (Parker and Jones)	...	...	×	...
Elphidium alaskense Cushman and Todd	...	...	×	...
clavatum Cushman	...	×	...	...
frigidum Cushman	×	×	...	×
Globigerina sp. aff. *G. bulloides* d'Orbigny	×	...	×	...
pachyderma (Ehrenberg)	×	×	×	×
Karreriella baccata alaskensis Cushman and Todd	...	...	×	...
Genus rel. *Neoconorbina tabernacularis* (Brady)	...	...	...	×
Oolina borealis Loeblich and Tappan	...	...	...	×
Planulina alaskensis Cushman and Todd	...	×	...	...
Polymorphina kincaidi Cushman and Todd	...	×	...	...
Pyrgo sp. cf. *P. elongata* (d'Orbigny)	...	...	×	...
Quinqueloculina agglutinata Cushman	...	...	×	...
akneriana d'Orbigny	...	×	...	...
seminulum (Linne)	×	×	×	...
Rosalina wrightii (Brady)	...	×	...	...
Rotalia columbiensis (Cushman)	×	×	×	×
Trichohyalis ornatissima (Cushman)	...	...	...	×
Triloculine trigonula (Lamarck)	...	×	...	...
Microscopic gastropods	...	...	×	...
Echinoid spines (very abundant)	...	...	×	...

[1] Identification by Ruth Todd.
[2] Identification by R. L. Pierce.

AGE OF THE DEPOSIT

Uranium-series dating of fossil shells and bone from the interglacial beach deposit at South Bight has yielded an average age of 127,000±8,000 years (Szabo and Gard, 1975). A lengthy stillstand of the sea is indicated by the extensive terrace that was cut on the island. Apparently, when the sea reached its maximum height, it rapidly bevelled the underlying semiconsolidated sediments in the graben. Continued subsidence of the graben allowed the thick beach deposits to accumulate and to be preserved while the sea persisted in cutting the terrace on much harder Tertiary bedrock elsewhere on the island.

Although Allison (1973) presented arguments that this deposit is of Kotzebuan(?) age (pre-Illinoian, according to Hopkins, 1967, p. 50), the radiometric age date of 127,000±8,000 years seems inconsistent with recent fission-track dating of 0.6 m.y. (million years) for ash beds in late Kansan or early Yarmouth deposits in the Western United States (Izett and others, 1970). The radiometric age of the sea-cow bone from the upper middle part of the deposit seems to be reasonably consistent with age dates of the Barbados III sea-level maximum (Mesolella and others, 1969), which has an average radiometric age of 125,000±6,000 years, and with Terrace C in southern California (Szabo and Rosholt, 1969), which has radiometric ages averaging 131,000±15,000 years. These dates are believed by Richmond and Obradovich (1972) to be of late Pleistocene age.

COMPOSITION OF THE COLLECTION

Gard's initial discovery was of bone fragments at the base of a cliff. He traced the bones to their source and collected several vertebral centra and parts of a forelimb. These were identified by G. E. Lewis as belonging to *Hydrodamalis*. Lewis' identification was corroborated by Whitmore, who compared the bones with specimens of Holocene age, which were collected on Bering Island by Leonhard Stejneger in 1882 and

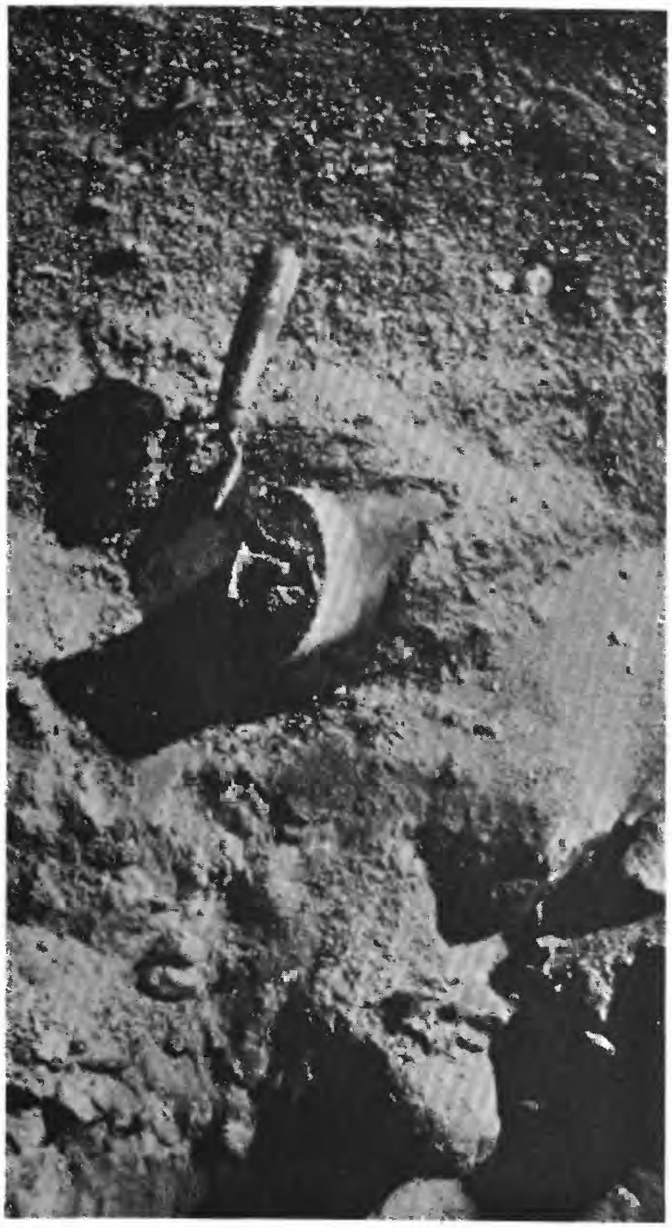

FIGURE 6.—Rib of *Hydrodamalis* (USNM 181752) at base of South Bight II interglacial beach deposit, Amchitka Island. Photograph by F. C. Whitmore, Jr.

1883 and which are now in the collections of the U.S. National Museum of Natural History. In May 1971 Gard and Whitmore uncovered more bones in place in the cliff (fig. 5). The bones found on the cliff face and those uncovered just beneath the surface were hard and well preserved, although not permineralized; they apparently had case hardened upon contact with the air. As we dug farther into the cliff, the bones found were of increasingly poor quality, at first being crumbly, then, about 1 m in from the cliff face, being soft and of a soapy consistency, easily scratched with the fingernail. Stejneger (1884, p. 61–62) found bones similarly preserved on Bering Island.

Altogether, the following bones were collected at the Amchitka locality: The horizontal ramus and a small part of the ascending ramus of the left mandible; the anterior half of the horizontal ramus and the angular region of the right mandible; centra of the last three cervical vertebrae and of the first thoracic vertebra; left scapula; distal half of right humerus and distal end and fragments of proximal end of badly preserved left humerus; left and right radius and ulna; rib fragments; and a chevron bone. About half a meter back in the cliff from the mandibles was a large amorphous mass of soft red material. Perhaps this was all that remained of the skull. All these bones came from a single animal that probably had drifted into shallow water after death and had been quickly buried by sand. The left forelimb, including the scapula but excluding carpals and metacarpals, was in articulation when found; the position of the limbs relative to that of the vertebrae and jaws indicated that the animal was on its back when it was buried.

The epiphyseal cartilage of the long bones was still unossified, and none of the articular ends of the long bones was found. The radius and ulna were not coossified as they are in fully adult specimens of the modern Steller's sea cow, and the mandibular symphysis was only slightly fused. Although the Amchitka specimen was as large as some fully grown Bering Island *Hydrodamalis*, it was a young individual.

These bones were assigned by the U.S. National Museum of Natural History, Department of Paleobiology, the number USNM 170761.

In addition to the bones just described, a single rib of *Hydrodamalis* was found 0.1 m above the base of the interglacial beach deposit, 400 m south of the other specimens (fig. 6). The specimen consists of the distal two-thirds of about a twelfth rib of a very large animal. It was assigned USNM 181752. A small humerus, doubtless from a very young individual, was collected by Gard in August 1972 at the base of the cliff, about 50 m south of the locality of USNM 170761. It was assigned USNM 186807. Also, four fragments of a large sirenian rib were collected at South Bight by Richard C. Allison and deposited in the National Museum by Daryl P. Domning.

DESCRIPTION OF THE AMCHITKA *HYDRODAMALIS*

The bones of the Amchitka specimen will be compared with those of specimens collected on Bering Island by Leonhard Stejneger in 1882 and 1883. Stejneger's specimens, preserved by the U.S. National

Museum of Natural History, are probably the remains of animals killed for food by Russian fur hunters in the 18th century.

MEASUREMENTS

The system of measurements illustrated in figures 7–9 was designed by Daryl P. Domning for his studies of Sirenia and is used here, with only slight modifications, in the interest of uniformity. Because the Amchitka bones are incomplete, Domning's system could not be used throughout.

MANDIBLE

Plate 2, all figures; plate 3, figures 1–4; table 2

The Amchitka mandible was compared with 15 mandibles from Bering Island. Nine measurements were made on each specimen (fig. 7; table 2). All measurements of the Amchitka mandible are within the range of measurements of the Bering Island group. In all but one measurement ("as," which may be correlated with youthful age, or may simply be due to individual variation), the Amchitka specimen is at or near the upper end of the range of measurements. This may signify that the Pleistocene *Hydrodamalis* population was of larger average size than the Bering Island population of historic time, for the Amchitka specimen is immature, whereas the condition of the limb bones of the Bering Island collection indicates that almost all those specimens come from adults. Domning (1970, p. 219) advanced the idea that the 18th-century Bering Island population "was reduced to only about 2,000 animals living in marginal environment in the Bering Sea, their growth stunted so that they never reached the size of their Pliocene ancestors in more favorable habitat to the south."

A notable characteristic of *Hydrodamalis*, in contrast to all other Sirenia, is its lack of teeth. The anterior occluding surface of the rostrum and of the mandible (pl. 2, all figs.; pl. 3, figs. 3, 4) was, as in all modern sirenians, deflected downward and flattened; it served as a grasping device (analogous to the toothless rostrum of ruminant Artiodactyla) with which the animal tore off the kelp on which it grazed. Steller (1899, p. 186) stated, on the basis of his dissection of a specimen of *H. gigas*, that mastication was done by "two strong white bones, or solid tooth masses, one of which is set in the palate and the other is fastened in the inferior maxilla, and corresponds to the first." These bones, Steller said (p. 186), were not fastened in the maxillae and mandibles, but were "held by many papillae and pores." The bones were said to be perforated below and to have many little holes (p. 186) "in which the arteries and nerves are inserted in the same way as in the teeth of other animals."

The "masticatory bones" to which Steller referred were undoubtedly horny plates, of cutaneous origin, covering the palate and the anterior part of the mandible. Brandt (1846, pl. III) illustrated some of these palatal coverings. These plates were certainly hard, and if they were white when dissected out, Steller may have mistaken them for bones.

Owen (1838, p. 41) said of the dugong, "the alveoli in the deflected portion of the lower jaw contained ligamentous processes given off from the internal surface of the thick callous integument covering that part of the jaw: they serve the purpose of fixing more firmly to the bone this dense and horny plate, which is beset externally with short coarse bristles, and is doubtless used in scraping and tearing off the seaweeds and other alimentary substances which may be fixed to the rocks."

The Amchitka mandibles are, in all major respects, identical with the modern ones from Bering Island.

The symphysis of the Amchitka mandible is about 25 percent fused, evidence of the immaturity of the specimen, despite its large size. In profile, the anterior border of the mandible is bluntly rounded (pl. 2, figs. 1, 2), in contrast to the pointed anterior profile of most Bering Island mandibles (pl. 2, figs. 3, 4).

The fossa for the genioglossus muscle (pl. 3, fig. 3; text-fig. 7) always large in *Hydrodamalis*, is especially large in the Amchitka mandible. This muscle functions in protrusion and retraction of the tongue.

The posterior border of the Amchitka mandible is thickened for 80 mm above the mandibular angle; at the angle ("d" in fig. 7 and table 2) it is 14 mm thick. It is thinner for 70 mm above the angle and thicker again (attaining a maximum thickness of 19 mm) for a distance of 80 mm on the uppermost part of the specimen as preserved (pl. 3, fig. 2; table 2). The preserved angular region of the right mandible is broken at the base of the ascending ramus. The posterior thickening of the angular region of the Amchitka specimen is in contrast to this region in adult Bering Island specimens. In the latter, the posterior border of the mandible thins almost to a knife edge ventrally and thickens only slightly at the angle. The posterior thickening of the jaw of the Amchitka specimen resembles more closely that in a young specimen from Bering Island (USNM 218381; table 2) and the Miocene genus *Metaxytherium*. By contrast another immature mandible from Bering Island (USNM 218401; table 2) has only slight thickening (9 mm) at the angle and thus resembles adult mandibles in this respect. Many of the adult Bering Island specimens have a wrinkled surface on the posteromedial side of the ascending ramus (pl. 2, fig. 4). This contrast in configuration of the posterior edge of the mandible probably reflects differences in the areas of insertion of the medial pterygoid and masseter muscles. These mus-

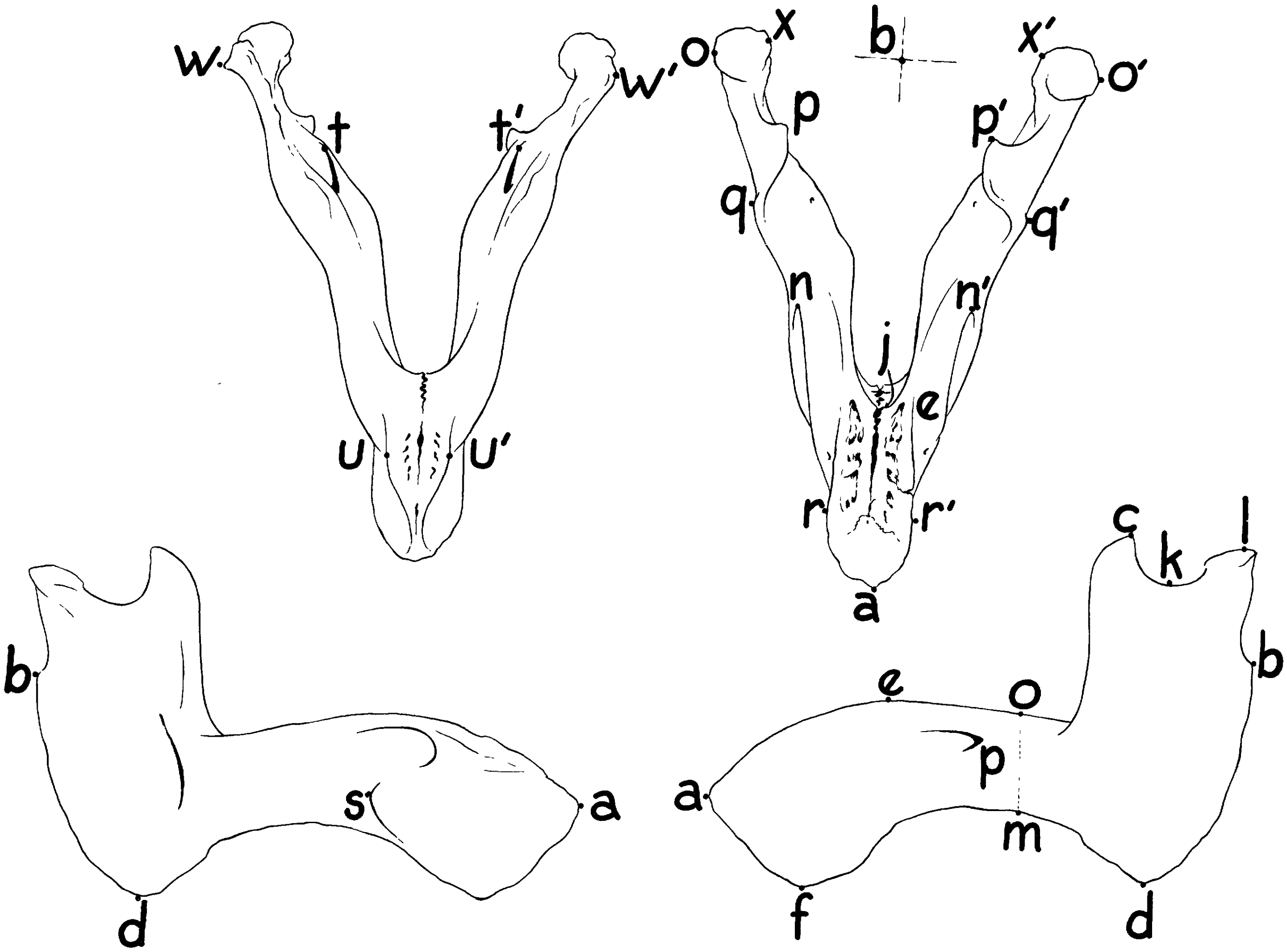

FIGURE 7. — Key to measurements of mandibles of *Hydrodamalis*. (See table 2.)

cles raise the jaw and have great power in keeping the jaws clenched. Despite the immaturity of the Amchitka specimen, the maximum thickness of its posterior mandibular border is greater than that of all but one Bering Island specimen (table 2).

The mental foramen is a prominent opening 10 mm high (pl. 2, fig. 1), situated 235 mm posterior to the anterior end of the mandible and approximately 50 mm anterior to the base of the ascending ramus. The base of the foramen is 63 mm above the ventral side of the mandible; its top is 31 mm below the dorsal side. The groove anterior to the mental foramen is about 65 mm long, widening gradually in an anterior direction. Because of breakage, the posterior extent of the mandibular canal cannot be determined exactly, but enough of the lateral wall of the mandibular foramen is present to show that its position and shape were approximately the same as that of the Bering Island specimens.

VERTEBRAE

Plate 3, figures 5–8; plate 4, figures 1–8; table 3

Only the centra of the last three cervical vertebrae and the first thoracic vertebra were found. They have the dorsoventrally flattened, subrectangular shape characteristic of the Sirenia. Daryl P. Domning (written commun., 1971) has suggested, on the basis of his studies of North Pacific sirenians, that there is a tendency for the width-to-height ratio of cervical centra to decrease in the course of their evolution. This trend is corroborated by comparison of the Amchitka specimen with Holocene specimens from Bering Island. Perhaps this trend can be correlated with increased lateral flexibility of the neck, associated with browsing in shallow water, as described by Steller.

Caution must be exercised, however, in drawing conclusions from measurements of cervical centra in *Hydrodamalis*, for the boundary between the centrum and

TABLE 2. — *Measurements, in millimeters, of mandibles of* Hydrodamalis gigas

[See fig. 7 for key to measurements; leaders (. . .) indicate no measurement was made; entries followed by "e" indicate measurement is estimated]

Measurement	Amchitka specimen	Bering Island specimens (L. Stejneger colln., 1882–83)[1]															
	USNM [2]170761	21255	21260	21262	[3]21266	21269	218371	218377	[2]218381	218399	218400	[2]218401	218402	218403	218408	269064	Mounted composite skeleton, USNM
as	142	160	165	148	144	139	145	175	140	143	124	167	152	166	175	191	165
rr′	71	66	62	67	57	61	72e	68	44e	50	55e	66	58	62	60e	72	64
aj	167	149	150	148	122e	125	123	163	110	145	100	166	141	155	167	159	173
ab	436e	418	425	410e	404	362	428	460	352	382	380e	419	428	430e	438	445	428
ad	361	340	349	345	340	345	355	385	314	312	285	334	354	380	363	374	359
ef	166	157	155	167	120	156	163	136	127	127	130	151	165	141	160	160	135e
df	278	241	243	250	264	248	263	280	236	222	215	240	280	293	284	260	272
mo	90	92	76	86	82	90	86	91	81	67	82	89	95	92	82	103	81
ap	240	209	219	223	197	191e	221	235	200	206	185	215	223	217	237	222	206
Thickness at "a"	14	16	10	8.3	11	11.4	11	12	13	. . .	11	9	12	10	10.5	8	8
Maximum thickness of posterior border	19	16	10.7	17.3	12	11.4	14	12.8	16.5	. . .	13	14	12	13.5	12	20	17

[1] Numbers are from the Division of Mammals, U.S. National Museum of Natural History.

[2] Young specimen: symphysis not completely fused. Number from U.S National Museum of Natural History, Department of Paleobiology.

[3] Note low symphysis.

the transverse process is poorly defined and probably varies in position with age.

In the sixth cervical vertebra, the lower half of the left transverse foramen is present (pl. 3, fig. 7). It is approximately 14 mm wide. Examination of specimens from Bering Island showed the size of the transverse foramen to be variable, even on two sides of the same individual. On the sixth cervical vertebra of USNM 218808, an adult specimen from Bering Island (pl. 3, fig. 8), the left transverse foramen is 11 mm wide, and the right is 14 mm wide. The posterior width of the centrum in this specimen is 135 mm, compared with 140 for the Amchitka specimen (table 3).

The seventh cervical vertebra of the Amchitka specimen has a small facet for rib articulation on its posterior face, on the ventral side of the base of the transverse process (pl. 4, fig. 3). The entire left transverse foramen is present (pl. 4, fig. 2); as in the Bering Island specimens, it is much smaller than the corresponding foramen in the sixth vertebra, being 5.5 mm wide and 2.8 mm high. The first thoracic vertebra has both anterior and posterior demifacets for articulation of the capitulum of the ribs (pl. 4, fig. 6). The anterior demifacet is much smaller than the posterior one.

SCAPULA

Plate 5, figures 1–3; plate 6, figure 3; plate 7, figure 4; table 4

As in all Sirenia, the scapula of the Amchitka *Hydrodamalis* is fan-shaped — that is, very wide in its dorsal (vertebral) part and having a narrow neck just above the glenoid cavity. The result of these dimensions is that the prescapular and postscapular fossae, in which originate the muscles used in rotating the limb, are smaller than in most mammals. By contrast, the vertebral part of the scapula is wide, its posterior part being especially well developed.

The anterior border of the scapula in *Hydrodamalis* is almost straight, with a slight angulation about halfway up its height, in contrast to that of *Metaxytherium* and the modern Sirenia, which is strongly curved. The gently curved edge dorsal to the angulation in *Hydrodamalis* may be the anterior edge of the insertion of the serratus cervicis muscle.

The straight posterodorsal edge of the scapula (fig. 8, tmo) is the origin of the teres major muscle, which flexes the shoulder joint and abducts the arm. A branch of the serratus muscle was inserted on the costal side of the scapula medial to the teres major.

The prescapular fossa is small (fig. 8, ek; table 4), much smaller than in *Metaxytherium* (cf. Kellogg, 1966, pl. 43, figs. 1, 2) and somewhat smaller than in the modern *Dugong dugon* and *Trichechus manatus*. The postscapular fossa is of the same width as the prescapular (fig. 8).

The scapular spine in the Amchitka specimen is restricted to approximately the ventral half of the scapula (pl. 5, fig. 2; pl. 6, fig. 3). Spines in modern specimens from Bering Island occupy, on the average, 60

TABLE 3. — *Measurements, in millimeters, of vertebrae of* Hydrodamalis gigas

[USNM, U.S. National Museum of Natural History; UCMP, University of California, Museum of Paleontology; UCMP measurements by D. P. Domning; leaders (. . .) indicate that no measurement was made; entries followed by "e" indicate that measurement is estimated; an asterisk * indicates front and back reasurements respectively]

	Amchitka specimen	Bering Island specimens			
Bone measurement	[1]USNM 170761	[2]USNM 22182	[2]USNM 218807–218810	UCMP 23050	Mounted composite skeleton, USNM
Fifth cervical					
			(USNM 218807)		
Anteroposterior thickness of centrum	42	31	35	. . .	32
Width of centrum	*140/140	*102/108	*118/118e	. . .	. . .
Height of centrum at middle	78	71	82	. . .	77e
Width/height of centrum	1.79	*1.43/1.52	1.42	. . .	. . .
Sixth cervical					
			(USNM 218808)		
Anteroposterior thickness of centrum	41	36	43	. . .	39e
Width	*130/140	*116/110	*127/135	. . .	120e
Height	80	73	86	. . .	64e
Width/height of centrum	*1.62/1.75	*1.59/1.50	*1.46/1.56	. . .	1.89
Seventh cervical					
			(USNM 218809)		
Anteroposterior thickness of centrum	45	31	41e	. . .	56e
Width	*141/152	*109/110	*136/. . .	*127/123	104e
Height	78	75	83	66	63e
Width/height of centrum	*1.80/1.94	*1.45/1.46	1.63	*1.92/1.86	1.63
First thoracic					
			(USNM 218810)		
Anteroposterior thickness of centrum	46	. . .	59	. . .	58
Width	*145/157	. . .	*147/139	*119/123	104e
Height	78/72	. . .	74/85	74	65e
Width/height of centrum	*1.85/2.18	. . .	*1.98/1.63	*1.60/1.64	1.60

[1] Department of Paleobiology, U.S. National Museum of Natural History.
[2] Division of Mammals, U.S. National Museum of Natural History.

percent of the scapular height. The lower half of the spine (acromion process) of the Amchitka specimen is expanded and heavy, much more so than in the Bering Island specimens. The tip of the acromion process has been broken off; in Holocene specimens from Bering Island (pl. 7, fig. 4) it is less well developed than in *Metaxytherium* (cf. Kellogg, 1966, pl. 43, figs. 1, 2).

The glenoid fossa and coracoid process are absent from the Amchitka specimen because the epiphyseal cartilage was not ossified.

The scapula of the Amchitka specimen is noticeably thicker and heavier, especially in the dorsal part of the blade (pl. 5, fig. 3), than are those in the Stejneger collection at the U.S. National Museum of Natural History. It is slightly narrower relative to its length than is any Bering Island specimen, but in length and width it is within the size range of that collection. In all *Hydrodamalis* specimens observed in this study, the scapula is heavier than in modern Sirenia.

HUMERUS

Plate 4, figures 9, 10; plate 6, figures 4, 5; plate 7, figure 1; plate 8, figure 1; table 4

The distal half of the right humerus of USNM 170761 (pl. 6, figs. 4, 5) was found in a good state of preservation, although it lacks the distal articular surface because the epiphysis had not yet ossified. The left humerus was also present but had deteriorated to such an extent that no measurements or morphologic observations could be made. In addition, the right humerus of a smaller individual (USNM 186807; pl. 4, figs. 9, 10), collected at the foot of the cliff, has open eiphyses and lacks both proximal and distal articular facets. The anterior part of the proximal end of the bone is present, however, allowing measurement of the length of the shaft (245 mm). Although much smaller than USNM 170761, this bone is as heavily constructed.

A prominent feature of the humerus of *Hydrodamalis* is the large shield-shaped deltoid tuberosity (pl. 7, fig.

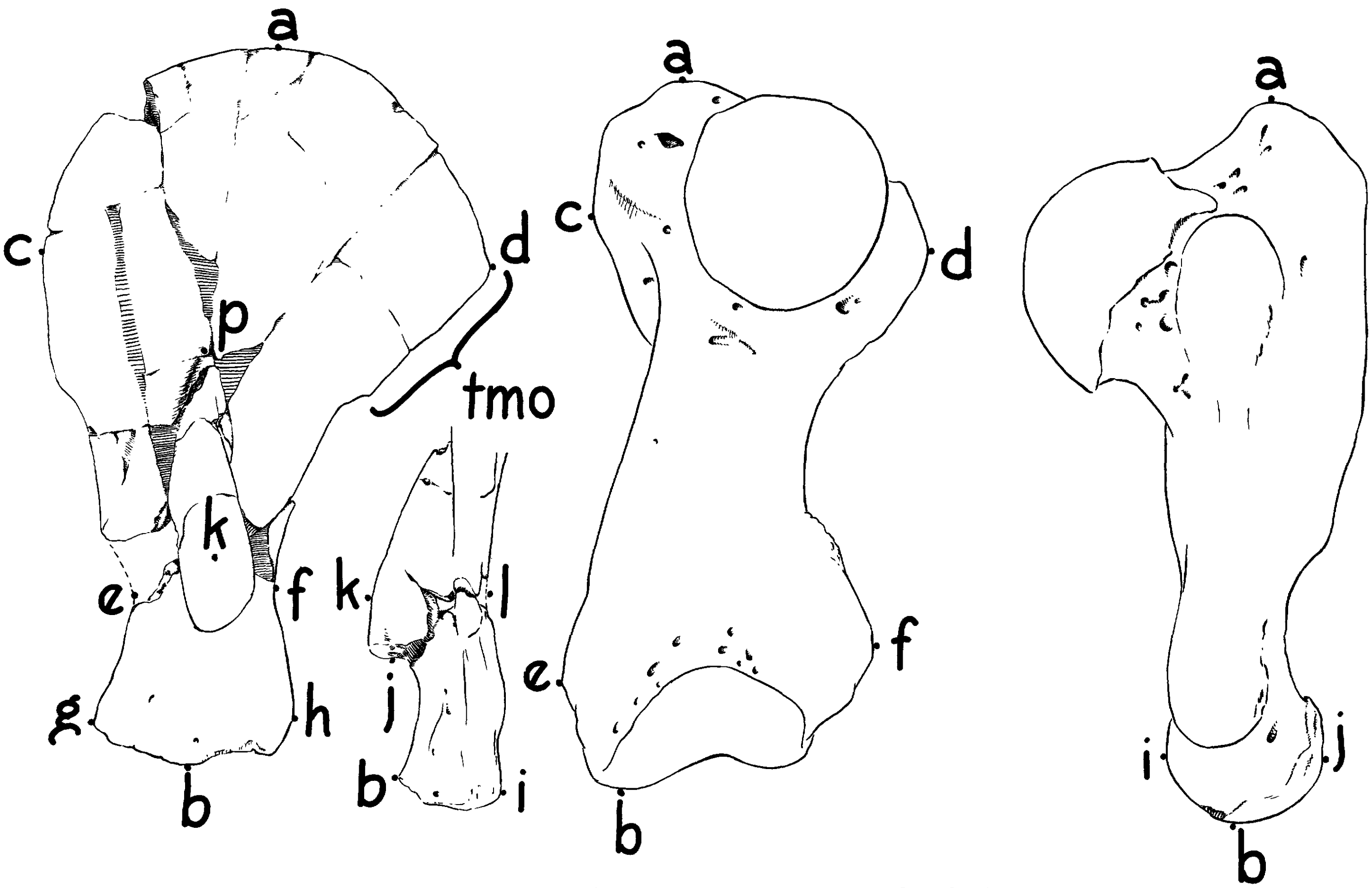

FIGURE 8. — Key to measurements of scapula and humerus of *Hydrodamalis*. (See table 4.)

1). The part of the bone bearing the tuberosity is not present in USNM 170761; in the smaller humerus (USNM 186807), it is rounded and smaller relative to the size of the bone. This is probably due to the immaturity of the individual and possibly also to erosion of the specimen.

RADIUS AND ULNA

Plate 8, figures 2–6; text-figure 9

The forearm bones of both limbs were collected. Those of the right side are well preserved, whereas those of the left were soft and of soapy consistency. The left radius and ulna were collected in a plaster block and subsequently hardened with beeswax; however, they are so badly cracked that measurement was impractical. In all the bones, the epiphyses were open and the articular surfaces were missing.

In adult Holocene specimens from Bering Island (pl. 8, fig. 6), the radius and ulna are strongly fused together at their proximal and distal ends and have scattered small areas of fusion in the middle part of their shafts. By contrast, the radius and ulna of the Amchitka specimen are separate, undoubtedly a function of the youth of the animal (pl. 8, fig. 5).

Near the proximal end of the anterior surface of the radius of the Amchitka specimen is a single tuberosity (pl. 8, figs. 2, 5). In *Dugong*, such a tuberosity serves for insertion of the brachialis muscle (D. P. Domning, written commun., 1973). This tuberosity is double in some observed Holocene specimens from Bering Island (von Nordmann, 1863).

RIBS

Plate 5, figure 4; plate 6, figures 1, 2; text-figure 10

The rib fragments of USNM 170761 are from the anterior region of the thorax. Four pieces show characteristics worth recording. One is a fragment of the proximal end of an anterior rib (probably the first or second), proximally compressed (thickness about 18 mm) and expanding distally to an oval cross section, which measures 70 mm high by 40 mm wide at a distance of 115 mm from the articular surface. The capitulum of this rib is preserved and consists of a small articular surface, spongy in appearance, as would be expected in a young specimen, and measuring 28 mm high by 15 mm wide. The tuberculum has been broken off.

The second fragment is the capitulum of an anterior rib, probably the second or third of the left side. Its articular surface, also spongy (pl. 5, fig. 4), consists of two facets, intersecting at an angle of about 120°, that articulated with the demifacets of two of the thoracic vertebrae. The articular surface has a maximum height of

TABLE 4. — *Measurements, in millimeters, of forelimb of* Hydrodamalis gigas

[See figs. 8 and 9 for key to measurements. Bering Island specimens having the same number are not necessarily from the same individual. USNM, U.S. National Museum of Natural History; Museum numbers of Bering Island specimens are assigned by USNM Division of Mammals; Museum numbers of Amchitka have been assigned by the USNM Department of Paleobiology; leaders (. . .) indicate that no measurement was made; entries followed by "e" indicate that measurement was estimated; (right) or (left) indicates side of skeleton]

Bone measurement	Amchitka specimens	Bering Island specimens				
Scapula	USNM 170761 (left)	USNM 269193 (right)[1]	USNM 218828 (right)	USNM 35638 (right)[2]	USNM 218409 (left)[2]	Mounted composite skeleton, USNM (right)
ab	513	481	570e	574	620	597
cd	338	350	412	414	430	424
ef	104	120	126	130	145	118
ek	60	110	75	120	. . .	117
gh	143	153	214	203	223	195
bi	[3]75	77	125	117	112	120e
bj	108e	102	140	139	177	138
kl	110	118	117	133	139	123
tmo	119	. . .	146	152	154	197
jp	200e	220	196	221	198	207
ap	250	183	240e	230	263	291

Humerus	USNM 170761 (right)	USNM 186807 (right)	USNM 35638 (right)	USNM 35638 (left)	USNM 21251 (left)	Mounted composite skeleton, USNM (left)	Mounted composite skeleton, USNM (right)
ef	183	130	225	211	214	207	185
ij	47	56	81	131	[3]122	113	102
ab	. . .	245	534	521	545	489	454

Radius-ulna	USNM 170761 (right) unfused[4]	USNM 21251 (right) fused	USNM 218380 (right) ulna[2]	USNM 218380 (left) proximal half of ulna[2]	USNM 218371 (right) partial ulna	USNM 218393 (left) fused
ab	. . .	517	294	. . .	. . .	517
ag	. . .	486	. . .	. . .	. . .	. . .
cd	. . .	372	250	. . .	. . .	374
cg	253	324	. . .	. . .	. . .	. . .
gh	70	87	. . .	. . .	. . .	62
ij	121	158	99	107	144	159
mn	62	86	. . .	65	91	99
op	65	76	66	62	72	93
rt	. . .	369	. . .	. . .	. . .	(?)
qr	72	88e	. . .	. . .	. . .	92e
st	73	79e	. . .	. . .	. . .	91e
uv	103	155e	. . .	. . .	. . .	159
wx	63	68	. .	. . .	. . .	69e

Radius-ulna — Continued		USNM 218394 (right) ulna[2]	USNM 218414 (left) fused proximal half[4]	USNM 218415 (left) radius	USNM 218415 (right) radius	Mounted composite skeleton, USNM (left) fused
ab		. . .	. . .	. . .	. . .	506
ag		421	. . .	. . .	. . .	604
cd		. . .	. . .	. . .	. . .	603
cg		345e	. . .	. . .	. . .	316
gh		. . .	. . .	. . .	. . .	150
ij		133e	151	. .	. . .	149
mn		100e	80	. . .	. . .	95
op		65e	73	. . .	. . .	79e
rt		. . .	. . .	409	344	363
qr		. . .	95e	72	73	77e
st		. . .	. . .	63e	81	49
uv		. . .	139	145	139	50
wx		. . .	. . .	57e	73	73

[1] Suprascapular cartilage ossified.

[2] Immature, but epiphyses attached.

[3] Eroded.

[4] Epiphyses missing; measurement less than original length of bone.

55 mm and width of 39 mm. The surviving proximal part of the rib shaft is extremely compressed, being 15 mm thick by approximately 80 mm wide.

The other two rib fragments lack the proximal and distal ends. They do not match the broken ends of the two fragments just described. One has a slight angulation in the form of a low ridge on its convex side; the very gentle curvature of this bone indicates that it is the second or third rib, although it is heavier than such ribs in the Stejneger collection from Bering Island. It is

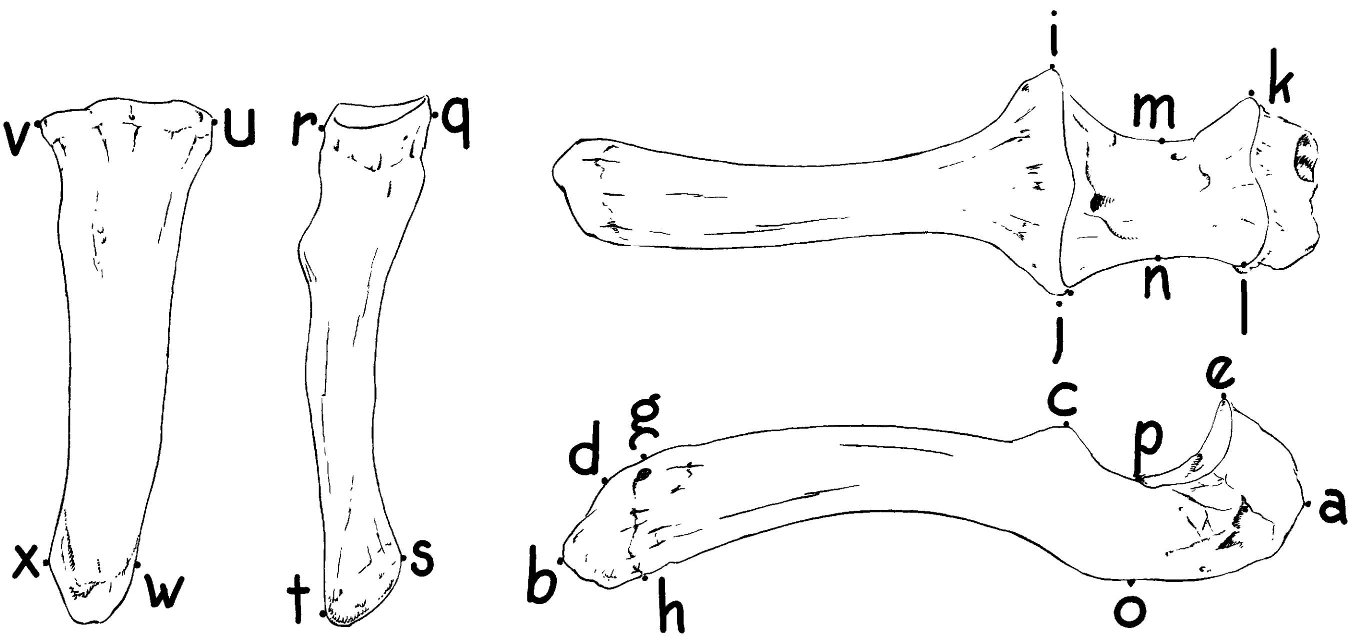

FIGURE 9. — Key to measurements of radius and ulna of *Hydrodamalis.* (See table 4.)

from the right side. The fragment is 170 mm long, 76 mm wide at the angulation, its widest (mesolateral) dimension, and 50 mm thick anteroposteriorly at the same point. The smaller (ventral) end of the rib fragment presents a spongy appearance, indicating that it was near the true end of the bone, where there was a cartilaginous connection with the sternum. At this point the rib is tapering rapidly, having a diameter of 50 mm mesolaterally and 39 mm anteroposteriorly.

The other fragment is probably from the dorsal part of the third rib of the left side. It is more gently curved and heavier than the first fragments and is 150 mm long. At its proximal end, its cross section has the shape of a triangle with rounded angles; the apex points anteriorly. From base to apex, it measures 60 mm; the length of the base is 65 mm. The distal end of the fragment is oval in cross section. It measures 48 mm anteroposteriorly and approximately 60 mm mesolaterally.

A more nearly complete rib fragment (USNM 181752; pl. 6, fig. 1; text-fig. 10) the distal two thirds of approximately the twelfth rib of the left side, was found in place 0.1 m above the base of the deposit 15 m above the beach and about 9 m stratigraphically below the level at which the *Hydrodamalis* skeleton was found. The bone is heavily oxidized, reddish brown, and was very brittle when collected, in contrast to the white color and hardness of bones found near the surface at the top of the cliff (fig. 6). The rib is evenly curved, having been broken distal to the angulation (fig. 10). It is ovoid in cross section; the greatest thickness is anteroposterior. Cross-section measurements are as follows (fig. 10): No. 1, 98×49 mm; No. 2, 84×56 mm; No. 3, 80×57 mm; No. 4, 72×52 mm; No. 5, 62×50 mm. The distal end of the rib has a relatively smooth area running anteroposteriorly and a coarsely pitted area on either side of it. In cross section, where broken at its proximal end, the rib has cancellous tissue in its outer posterior quarter; the rest of the cross section shows pachyostotic bone. This rib is within the size range of modern ribs from Bering Island.

The rib from the Kangiguksuk archeological site (Yale Peabody Mus. No. 233862) is an anterior rib from the left side. The sawed distal end shows it to be pachyostotic except for an area of cancellous bone that runs mediolaterally through the middle of the bone. Such presence of cancellous tissue is typical of young Sirenia; in adult animals the bone is fully pachyostotic, and there is no trace of cancellous tissue.

The distal end of the rib has been sawed off; as preserved, the specimen measures 582 mm along the outside curve. At the sawed distal end it is suboval, being slightly narrower at the outer than at the inner side. In cross section it measures 52 mm transversely and 33 mm anteroposteriorly. At the outer extremity of the curve (approximately at the position of cross-section 3 of fig. 10), the rib measures 46.5 mm transversely and 37 mm anteroposteriorly. At the proximal end of the curve, immediately distal to the tuberculum, it measures 43 mm transversely and 36 mm anteroposteriorly, having been reduced slightly in circumference to form the neck of the rib. The proximal end of the rib, in the area of the capitulum and tuberculum, is anteroposteriorly compressed and gently curved, being concave anteriorly and convex posteriorly. The distance from capitulum to tuberculum is 101 mm; midway in this distance, the rib is 21 mm thick anteroposteriorly and 45 mm dorsoventrally. The capitular articulation is very small, 17 mm dorsoventrally by 18 mm anteroposteriorly. This end of the rib has been worked or gnawed (it is marked by many dorsoventral scratches); probably, the capitulum originally had a somewhat larger articular area. The tuberculum is a low anteroposteriorly compressed ridge.

The Kangiguksuk rib appears to come from a more lightly built animal (possibly because of its youth) than those represented on Bering Island.

CHEVRON BONE

Half a chevron bone, probably from the right side of the animal, was recovered (pl. 7, figs. 2, 3). The chevron bone, named from its shape in cross section, forms the hemal arch below the centra of the caudal vertebrae. Through the V of the hemal arch run the major blood vessels of the tail. There are no chevron bones of *Hydrodamalis* in the collections of the U.S. National Museum, but hemal arches of Holocene *Dugong*, a member of the same family as *Hydrodamalis* (Dugongidae Gray, 1821), are for the most part composed of paired, separate bones in contrast to the condition in the Cetacea, whose hemal arches almost invariably consist of a V-shaped bone, resulting from fusion of the bones of the two sides.

The chevron bone of *Hydrodamalis* from Amchitka measures 66 mm in greatest vertical dimension, 42.5 mm anteroposteriorly on its dorsal side, and 36.5 mm anteroposteriorly at the level where it starts to taper ventrally to a rounded posteriorly slanting edge. The size of the bone indicates that it was associated with one of the posterior caudal vertebrae.

MORPHOLOGIC CONCLUSIONS

The Amchitka skeleton shows no significant morphologic differences from 18th-century specimens from Bering Island. Its mandible is larger than would be expected in the Bering Island population, especially when one considers that it was immature at death; the other Amchitka bones, however, are farther down in the size range of the Bering Island collection. This disparity in ratio between mandible size and dimensions of postcranial bones may be because of the youth of the Amchitka specimen, or it may be because the Pleistocene *Hydrodamalis* had a larger head relative to the body than did members of the 18th-century Bering Island population. D. P. Domning (written commun., 1973) has pointed out that in the transition from *Metaxytherium* to *Hydrodamalis*, body size increased perhaps 100 percent, and skull length, only about 40 percent. Ratios between mandible size and that of postcranial bones in the Bering Island population of *Hydrodamalis*

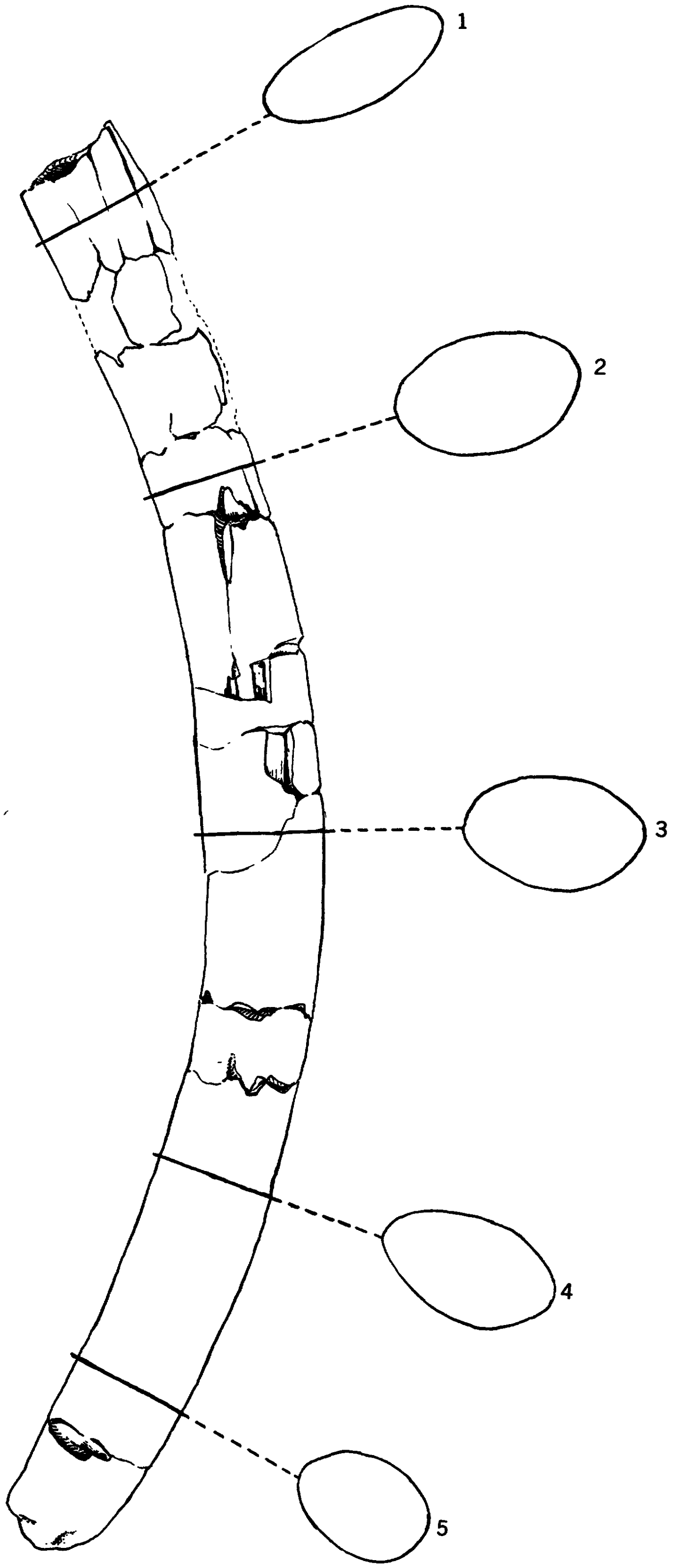

FIGURE 10.—Rib of *Hydrodamalis* (USNM 181752) from base of South Bight II interglacial beach deposit, Amchitka Island. (See also fig. 6.)

(U.S. National Museum collection) are of questionable significance because the collection consists of bones picked up at random; it does not include any associations of bones from one individual.

The only description known to us of a skeleton of a single individual of *H. gigas* from Bering Island was published by von Nordmann (1863). This skeleton, in the zoological museum at Helsinki, Finland, is that of an immature animal, which facilitates comparison with the Amchitka specimen (table 5). In von Nordmann's specimen, the epiphyses of the scapulae, the humerus, the ulna, and the radius had been lost, being separate from the shafts of the bones. The skeleton is 5 m long, as compared with an estimated length of 7.6 m for an adult Bering Island specimen. Von Nordmann's specimen and that from Amchitka appear to have been near enough to the same ontogenetic age that comparisons between them will have some validity; caution is dictated, however, because the size of the adult Pleistocene *Hydrodamalis* is unknown.

As an index of the relation of head size to body size, ratios were established between the length of the jaw and various measurements of postcranial bones in the von Nordmann and Amchitka specimens (table 5). In many of these ratios no significant difference exists between the two specimens; where a difference does exist, the postcranial measurement is smaller relative to jaw length in the Amchitka specimen than in that described by von Nordmann. This relationship fits Domning's hypothesis that body size increased relative to head size in the evolution of the *Metaxytherium-Hydrodamalis* line.

The jaw described by von Nordmann is much shorter than the Amchitka jaw and shorter than the mean of jaws from Bering Island. It is also smaller in other dimensions than are the Bering Island jaws, the exception being the width of the symphysis, in which it measures 65 mm compared with a mean of 61 mm for the Bering Island specimens. With three exceptions, the postcranial bones of the von Nordmann specimen are smaller than the mean for the Bering Island bones. The exceptions are the thickness of the humerus at its lower end and the diameter of the lower ends of the radius and ulna. The small size of these measurements of the Bering Island specimens may result from erosion of the ends of the limb bones, which is evident upon inspection. However, no such cause can account for the fact that, in these measurements, the von Nordmann specimen is larger than the Amchitka specimen, in which the bones concerned are well preserved.

The specimen described by von Nordmann has a larger jaw relative to postcranial bones than do the specimens in the mixed collection from Bering Island, on the basis of mean measurements of bones. In this characteristic, the von Nordmann specimen resembles the Amchitka specimen. The allometry shown by these two animals is probably due in part to their youth. The large size of the Amchitka jaw, however, may indicate,

TABLE 5. — *Comparison of measurements of the Amchitka specimen of* Hydrodamalis gigas *with measurements of an immature specimen from Bering Island, measured by von Nordmann (1863)*

[Measurements given in millimeters. "e" following value indicates estimated]

	Amchitka specimen	von Nordmann specimen
First thoracic vertebra:		
Length of body at base	46	41
Height of body	78	71
Greatest width of vertebral foramen	126e	106
Scapula:		
Length from end of collum to middle of upper border	513	455
Greatest width of upper part	338	377
Width of neck at border of epiphysis	143	152
Thickness of neck in middle	104	85
Greatest height of spine	67	75
Humerus:		
Greatest width, lower end	183	177
Greatest width in middle	86	98
Greatest thickness at lower end	61	82
Greatest thickness in the middle	111	102
Ulna:		
Length of bone without epiphysis	320	320
Greatest width of upper end	121	112
Greatest diameter in middle	60	62
Greatest diameter of lower end	71	78
Radius:		
Length of bone without epiphysis	265	280
Greatest width of upper end	105e	113
Greatest diameter in middle	57	65
Greatest diameter of lower end	66	81
Jaw:		
Length from most posterior border of angle to point of symphysis	395	374
Greatest height of body of jaw at posterior border of foramen maxillare [= mental foramen]	92	84
Grestest height of body of jaw in front of *foramen maxillare*	144	140
Length of symphysis of both jaw halves	143	146
Greatest width of symphysis	71	65
Ratios:		
Jaw length/length, first thoracic vertebra	8.58	9.12
Jaw length/height, first thoracic vertebra	5.06	5.26
Jaw length/scapula length	.77	.80
Jaw length/scapula width	1.13	.99
Jaw length/width of humerus, lower end	2.15	2.11
Jaw length/width of humerus in middle	4.59	3.81
Jaw length/humerus: greatest thickness, lower end	6.47	4.56
Jaw length/humerus: greatest thickness in middle	3.55	3.67
Jaw length/ulna: width of upper end	3.26	3.33
Jaw length/ulna length	1.23	1.16
Jaw length/ulna: diameter of lower end	5.56	4.79
Jaw length/radius length	1.49	1.33

in addition, that the population from which it came consisted of larger individuals than those constituting the 18th-century population on Bering Island.

The larger size of the Amchitka animal indicates that size reduction took place during Pleistocene time within the species *H. gigas.*

One vexing problem of the anatomy of *Hydrodamalis* was unfortunately not solved by the Amchitka find. This problem is the morphology of the wrist and manus. Steller (1899, p. 188) described the anterior extremity of *Hydrodamalis* as terminating "bluntly with tarsus and metatarsus [sic]. There are no traces of fingers, nor are there any of nails or hoofs; but the tarsus and metatarsus are covered with solid fat, many tendons and ligaments, cutis and cuticle, as an amputated human limb is covered with skin. But both the cutis, and especially the cuticle, are much thicker, harder, and drier there, and so the ends of the arms are something like claws, or rather like a horse's hoof; but a horse's hoof is sharper and more pointed, and so better suited to digging." No carpal bones of *Hydrodamalis* have been identified. The skeleton mounted in the Naturhistoriska Riksmuseet in Stockholm (pl. 1) has a bone mounted in the position of a metacarpal, which Domning (in press) has identified as the transverse process of a vertebra.

DISCUSSION

Hydrodamalis gigas, approximately 127,000 years ago, was established on Amchitka Island and was characterized by the same large size and lack of teeth that distinguished the population that became extinct on Bering Island in the 18th century. Remains of three individuals were found within a few hundred meters in the cliffs at South Bight on Amchitka. The South Bight exposure, preserved in a graben bordered and protected by early Tertiary rocks, is a rare occurrence of late Pleistocene interglacial deposits in the Aleutians; the abundance of *Hydrodamalis gigas* in this limited exposure suggests that the species may have been widely distributed in the Aleutians at that time. A former wide distribution of *Hydrodamalis* is supported by other, although scanty, paleontologic evidence — the occurrence of (1) a skull in Monterey Bay, Calif. (Jones, 1967); (2) representatives of the genus in the Pliocene of California (Domning, in press); (3) a rib in the Pliocene of Japan (Šhikama and Domning, 1970); and (4) a rib in an archeological site in northwestern Alaska (Hall, 1971). Further evidence pointing to a low-latitude origin of *Hydrodamalis* is the distribution of fossil as well as modern Sirenia.

The presence of *Hydrodamalis* in the Pliocene and Pleistocene of California emphasizes the question of how the genus, unlike any other representatives of its order, achieved adaptation to life in cold water. Probably this adaptation began in California latitudes; Durham (1950) pointed out that by middle Pliocene time the 20°C marine isotherm, as a result of a cooling trend, had approached its present position near the southern tip of Baja California. Addicott (1969) analyzed the distribution patterns of Tertiary shallow-water molluscan faunas and, although detecting a middle Miocene warming trend, corroborated a decline in the temperature of California coastal water in later Miocene and Pliocene time. Turning to Pleistocene temperatures of the California coast, D. M. Hopkins (written commun., 1972) stated that subarctic mollusk faunas have been collected from the floor of Monterey Bay, "containing, most notably, *Astarte benneti,* a shallow-water mollusk that now ranges from Puget Sound to Point Barrow." As Hopkins pointed out, however, we do not know whether the Arctic mollusks are of the same age as the dredged *Hydrodamalis* skull from Monterey Bay.

It seems certain that the Commander Islands must have had a Quaternary history similar to that of the Aleutians and that *Hydrodamalis* once ranged along the Aleutian chain as well. Whether the sea cow lived in the Aleutians in Holocene time is, however, unknown. If *Hydrodamalis* lived throughout the Aleutians in Holocene time, its presence may have provided incentive for a rapid westward migration of the Aleut, who, like the Russians, would have found that these animals were easily caught and were excellent food. This speculation is supported by Martin's (1973) intriguing proposal of a spectacularly rapid advance of hunting man throughout the Western Hemisphere 11,500 to 10,500 years ago. The Aleuts' westward expansion could account for the disappearance of these animals from the Aleutian Islands (Domning, 1972, p. 188). The Aleuts never reached the Commander Islands (Laughlin, 1967, p. 444), and *Hydrodamalis* survived there until the 18th century. That bones of *Hydrodamalis* have not been found in Aleut middens may be because not enough middens in the Aleutians have been excavated, or perhaps because the bones simply have not been recognized; or it may be that the middens that have been explored postdate the extinction of *Hydrodamalis* in the Aleutians. Aleuts were present on Umnak as much as 8,000 years ago (Laughlin, 1967), and, as Domning speculates, middens where the bones might be found are now mainly below sea level.

The presence of *Hydrodamalis* in the late Pleistocene of Amchitka suggests, despite the presence of icecaps on some, if not all, of the Aleutian Islands, that the water temperature continued to be warm enough during Wisconsinan time to support kelp (which is presently the predominant plant element of Arctic and Antarctic seas, according to Smith, 1938, p. 220) and, in turn, to support the sea cow.

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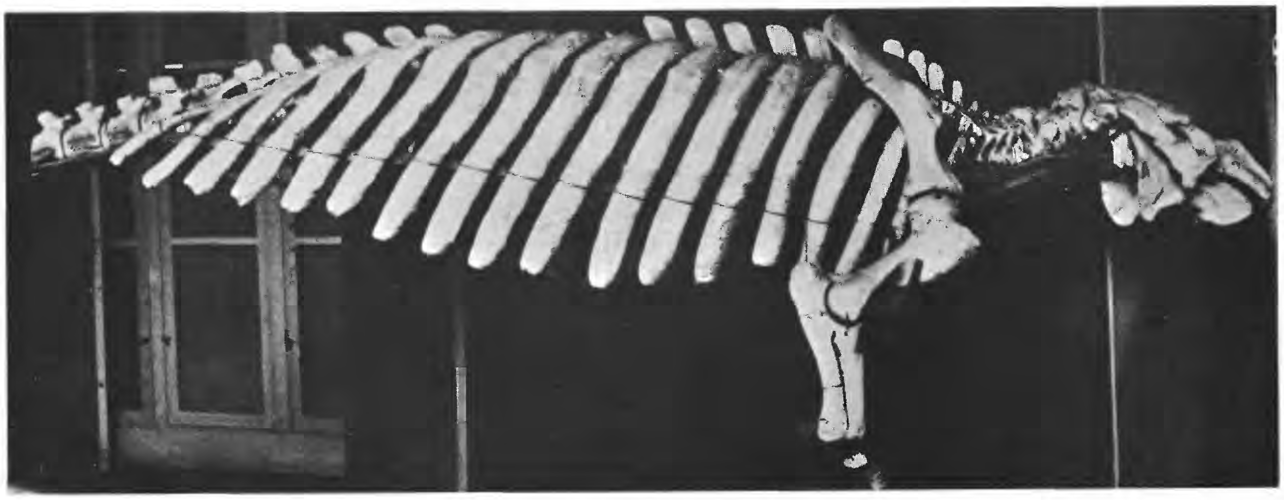
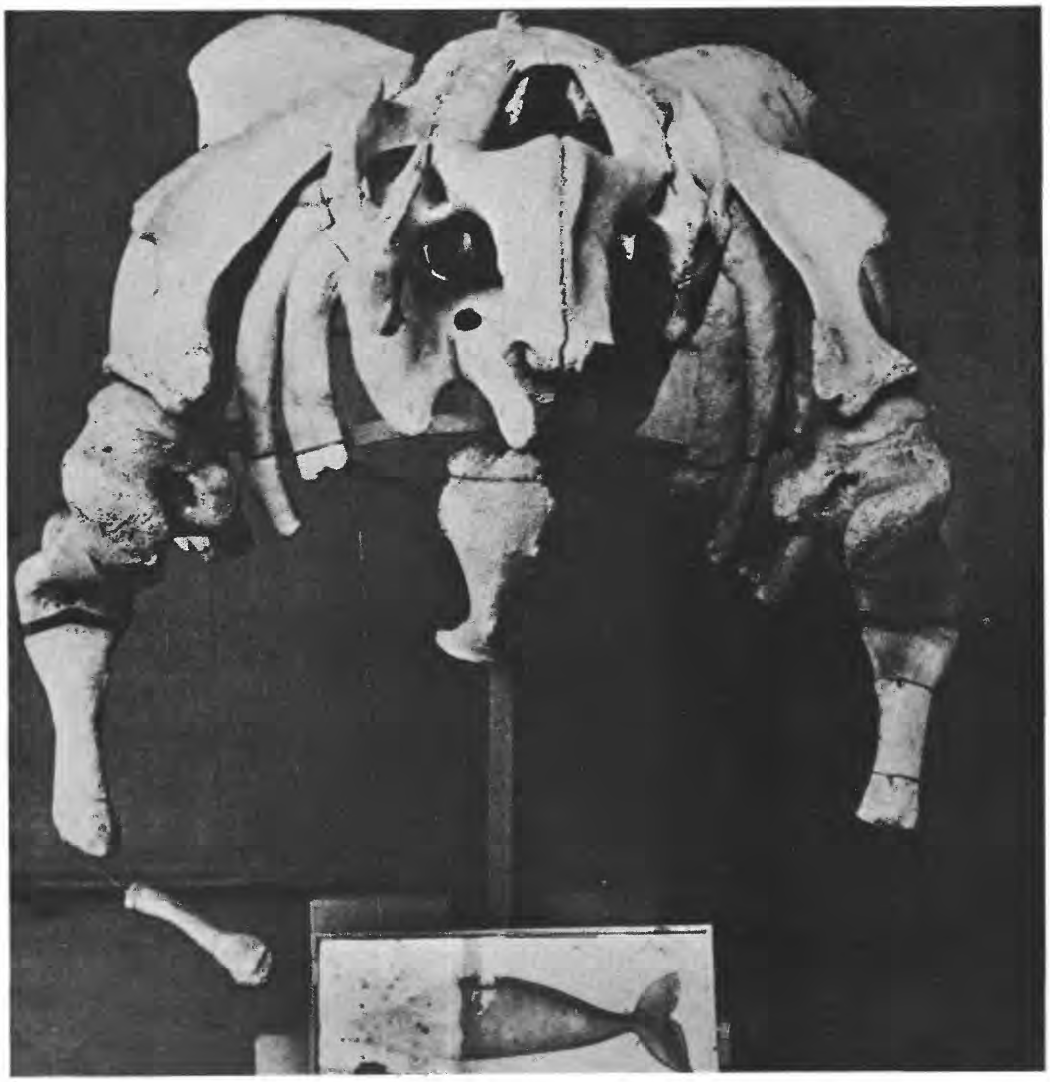
PLATES 1–8

[Contact photographs of the plates in this report are available, at cost, from the U.S. Geological Survey Photographic Library, Box 25046, Denver Federal Center, Denver, Colorado 80225]

PLATE 1

Mounted skeleton of *Hydrodamalis gigas*, Naturhistoriska Riksmuseet, Stockholm, Sweden. The bone mounted as a metacarpal on the right forelimb is actually the transverse process of a vertebra (Domning, in press). Photograph furnished by the Naturhistoriska Riksmuseet, Stockholm, Sweden.





HYDRODAMALIS GIGAS (ZIMMERMANN)

PLATE 2

FIGURES 1–4. *Hydrodamalis gigas.*

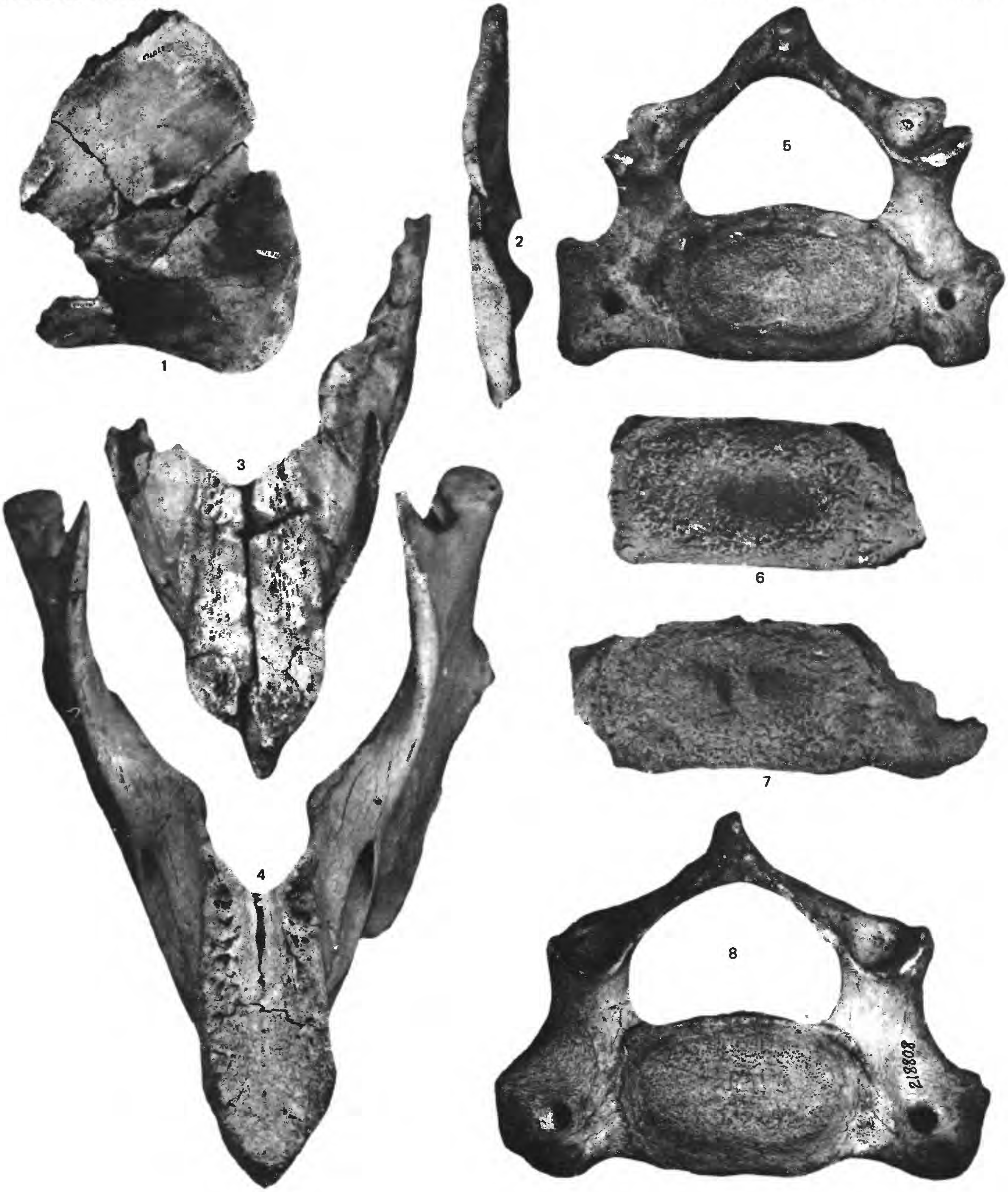
1. Left mandible of Amchitka specimen, USNM 170761. Lateral view, × 0.33.
2. Same. Medial view, × 0.33.
3. Left mandible of Bering Island specimen, USNM 21260. Lateral view, × 0.35.
4. Same. Medial view, × 0.35.

HYDRODAMALIS GIGAS (ZIMMERMANN)

PLATE 3

FIGURES 1–8. *Hydrodamalis gigas.*

1. Posterior part of right mandible of Amchitka specimen, USNM 170761. Medial view, × 0.33.
2. Same. Posterior view, × 0.35.
3. Mandible of Amchitka specimen, USNM 170761. Occlusal view, × 0.38.
4. Mandible of Bering Island specimen, USNM 21262. Occlusal view, × 0.38.
5. Fifth cervical vertebra of Bering Island specimen, USNM 218807. Posterior view, × 0.33.
6. Fifth cervical vertebra of Amchitka specimen, USNM 170761. Anterior view, × 0.34.
7. Sixth cervical vertebra of Amchitka specimen, USNM 170761. Anterior view, × 0.36.
8. Sixth cervical vertebra of Bering Island specimen, USNM 218808. Anterior view, × 0.34.

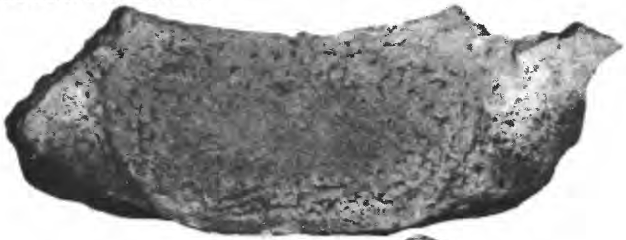


HYDRODAMALIS GIGAS (ZIMMERMANN)

PLATE 4

FIGURES 1–10. *Hydrodamalis gigas.*

1. Sixth cervical vertebra of Amchitka specimen, USNM 170761. Right-lateral view, × 0.34.
2. Seventh cervical vertebra of Amchitka specimen, USNM 170761. Anterior view, × 0.4.
3. Same. Left-lateral view, × 0.37.
4. Seventh cervical vertebra of Bering Island specimen, USNM 218809. Anterior view, × 0.34.
5. First thoracic vertebra of Amchitka specimen, USNM 170761. Anterior view, × 0.34.
6. Same. Left-lateral view, × 0.32.
7. First thoracic vertebra of Bering Island specimen, USNM 218810. Anterior view, × 0.34.
8. Same. Left-lateral view, × 0.36.
9. Right humerus of Amchitka specimen, USNM 186807. Posterior view, × 0.32.
10. Same. Anterior view, × 0.32.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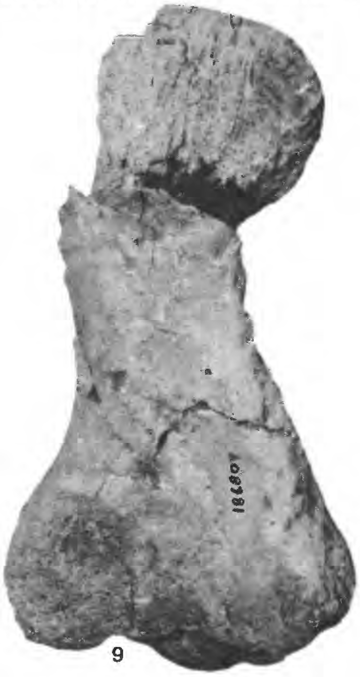

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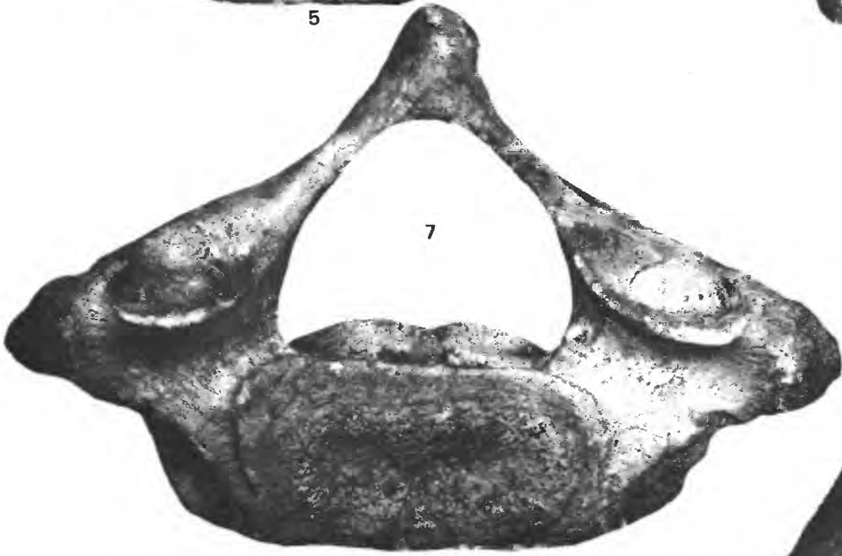
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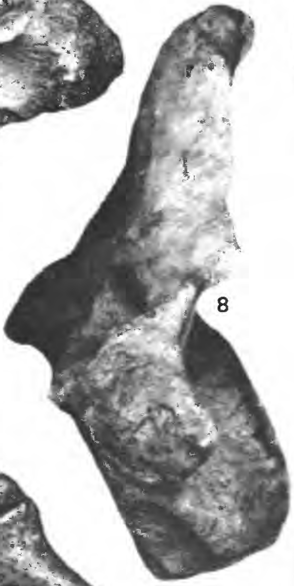
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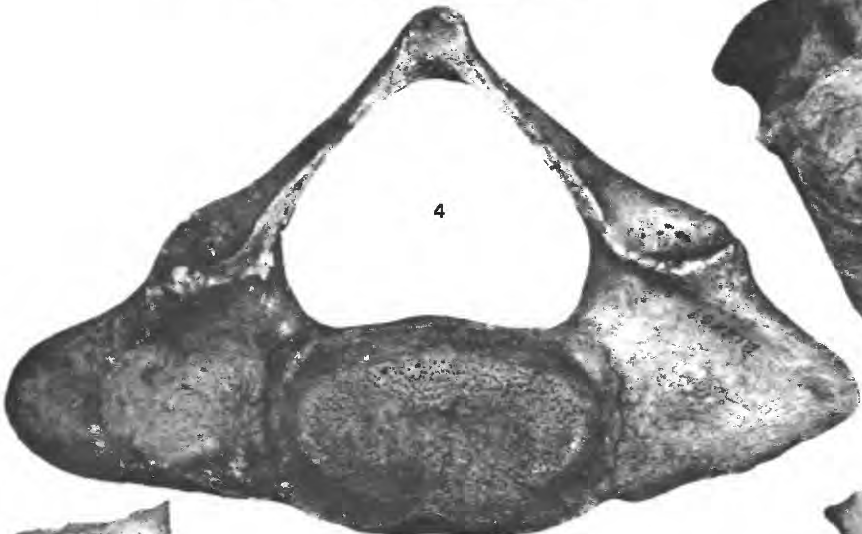
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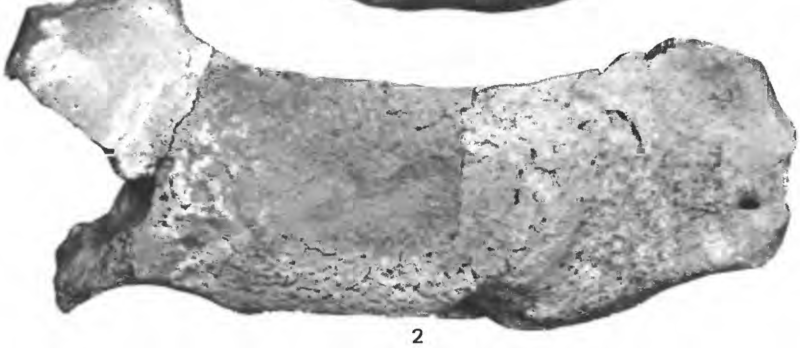
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HYDRODAMALIS GIGAS (ZIMMERMANN)

PLATE 5

FIGURES 1–4. *Hydrodamalis gigas.*

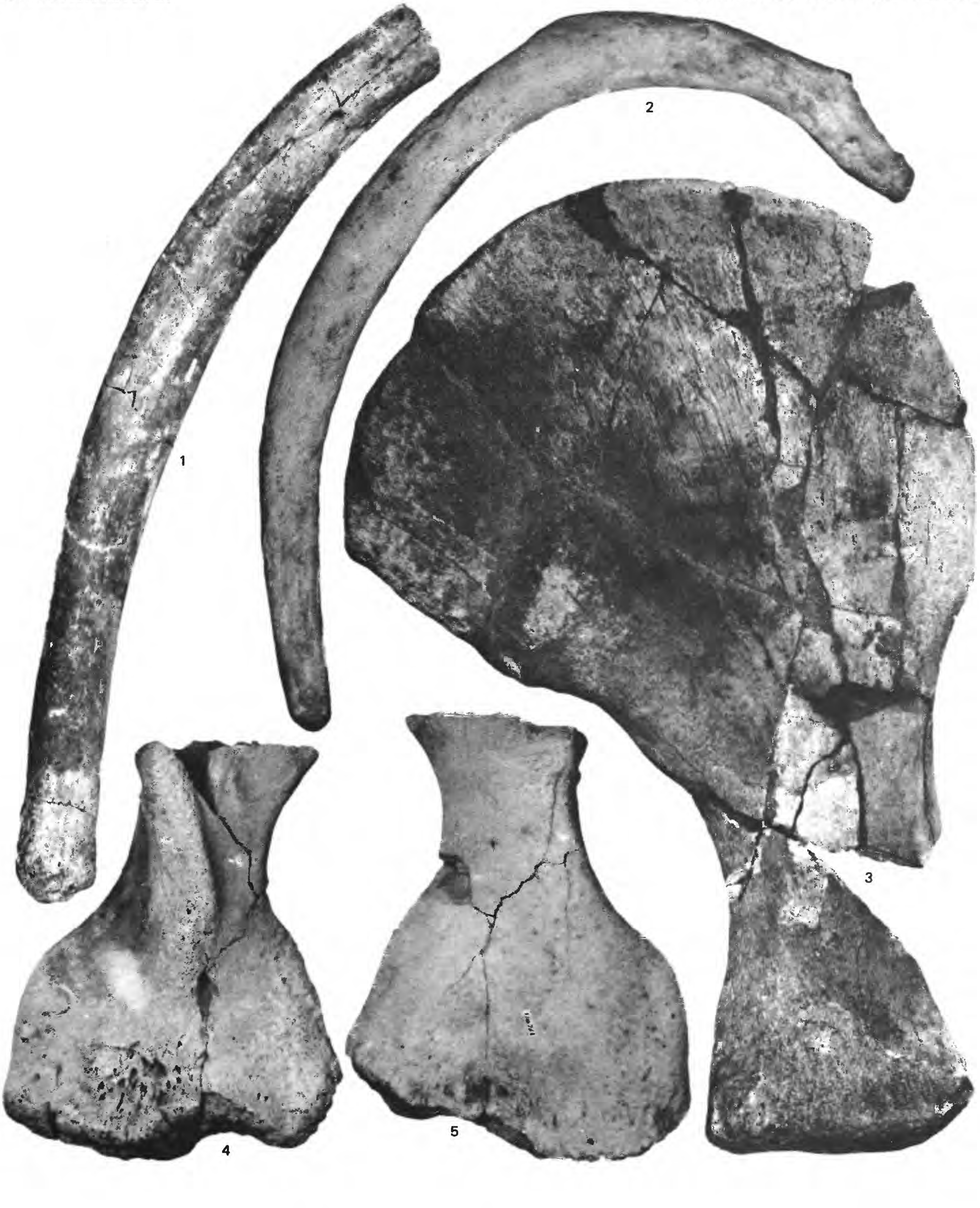
1. Left scapula of Amchitka specimen, USNM 170761. Lateral view, × 0.35.
2. Same. Anterior view, × 0.30.
3. Same. Dorsal view, × 0.39.
4. Proximal end of left anterior rib of Amchitka specimen, USNM 170761. Posterior view, × 1.

HYDRODAMALIS GIGAS (ZIMMERMANN)

PLATE 6

FIGURES 1–5. *Hydrodamalis gigas.*

1. Distal part, approximately twelfth rib of left side, Amchitka specimen, USNM 181752. Posterior view, × 0.28.
2. Approximately twelfth rib of left side, Bering Island specimen, USNM 35638. Posterior view, × 0.19.
3. Left scapula of Amchitka specimen, USNM 170761. Medial view, × 0.36.
4. Distal half of right humerus, Amchitka specimen, USNM 170761. Anterior view, × 0.34.
5. Same. Posterior view, × 0.34.



HYDRODAMALIS GIGAS (ZIMMERMANN)

PLATE 7

FIGURES 1–4. *Hydrodamalis gigas.*

1. Right humerus of Bering Island specimen, USNM 35638. Anterior view, × 0.30.
2. Chevron bone of Amchitka specimen, USNM 170761. Anterior view, × 1.
3. Same. Medial view, × 1.
4. Right scapula of Bering Island specimen, USNM 35638. Lateral view, × 0.30.

HYDRODAMALIS GIGAS (ZIMMERMANN)

PLATE 8

FIGURES 1–6. *Hydrodamalis gigas.*

1. Right humerus of Bering Island specimen, USNM 35638. Posterior view, × 0.27.
2. Right radius of Amchitka specimen, USNM 170761. Lateral view × 0.30.
3. Right ulna of Amchitka specimen, USNM 170761. Anterolateral view, × 0.30.
4. Same. Posterior view, × 0.30.
5. Right radius and ulna of Amchitka specimen, USNM 170761. Lateral view, × 0.30.
6. Right radius and ulna of Bering Island specimen, USNM 21251. Lateral view, × 0.32.

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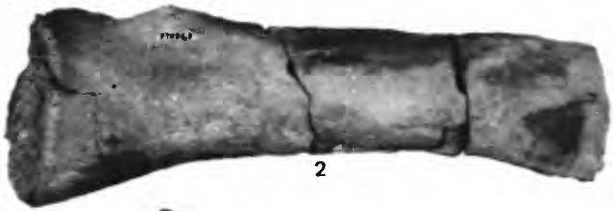

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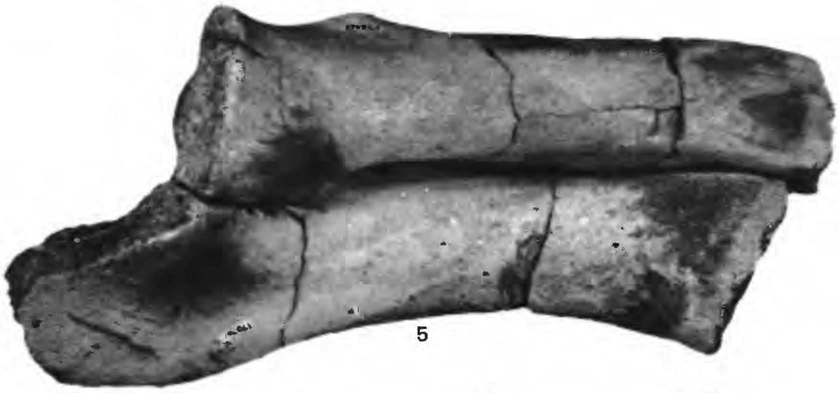

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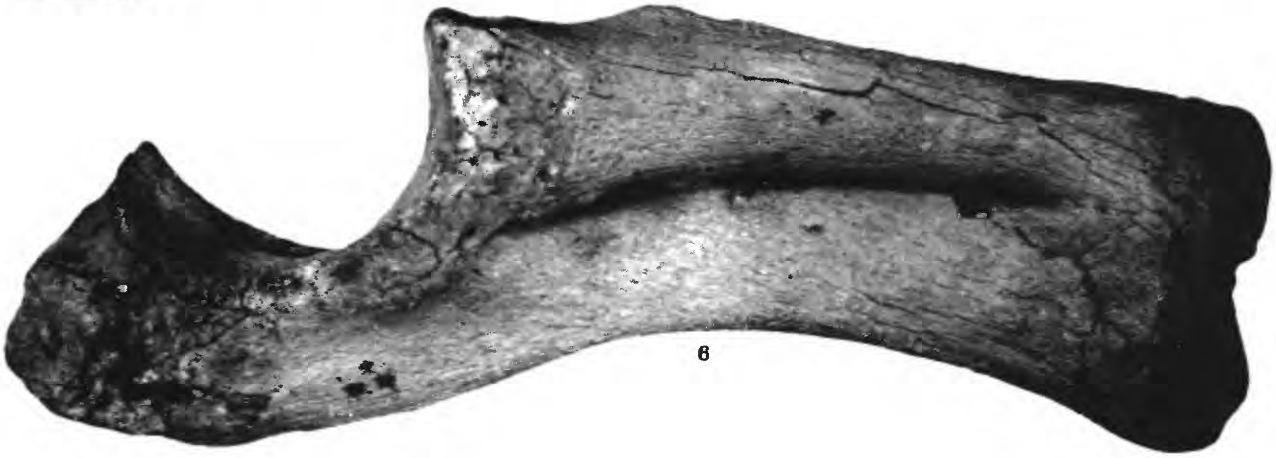

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