1958-II, 1158 (1958); ———, *Biochem. J.* **73**, 701 (1959).
12. A. N. Davison and J. Dobbing, *Biochem. J.* **75**, 565 (1960).
13. D. E. Green and S. Fleischer, *Biochim. Biophys. Acta* **70**, 534 (1963).
14. L. A. Autilio, W. T. Norton, R. D. Terry, *J. Neurochem.* **11**, 17 (1964).
15. G. Rouser, A. J. Baumann, G. Kritchevsky, D. Heller, J. S. O'Brien, *J. Am. Oil Chemists' Soc.* **38**, 544 (1961); J. S. O'Brien, D. L. Fillerup, J. F. Mead, *J. Lipid Res.* **5**, 109 (1964).
16. J. S. O'Brien, D. L. Fillerup, J. F. Mead, *J. Lipid Res.* **5**, 329 (1964).
17. J. S. O'Brien and G. Rouser, *Anal. Biochem.* **7**, 288 (1964).
18. ———, *J. Lipid Res.* **5**, 339 (1964).
19. The details of the analytical procedure, as well as the values for the individual fatty acids, will be presented in a separate report by J. S. O'Brien and E. Lois Sampson (in preparation).
20. W. Koch, *Am. J. Physiol.* **11**, 303 (1904); ———, *Science* **21**, 884 (1905); ———, *Z. Physiol. Chem.* **56**, 496 (1907); ———, *ibid.* **70**, 94 (1910); ———, *J. Am. Chem. Soc.* **31**, 1341 (1909); W. Koch and W. H. Goodson, *Am. J. Physiol.* **15**, 272 (1906); W. Koch and M. L. Koch, *J. Biol. Chem.* **15**, 423 (1913); ———, *ibid.* **31**, 395 (1917); W. Koch and S. A. Mann, *J. Physiol.* **36**, 36 (1907); ———, *J. Am. Chem. Soc.* **31**, 1335 (1909); W. Koch and F. W. Upson, *ibid.*, p. 1355.
21. G. Brante, *Acta Physiol. Scand. Suppl.* **18**, 63 (1949).
22. J. Folch-Pi, in *Biochemistry of the Developing Nervous System*, H. Waelsch, Ed. (Academic Press, New York, 1955), p. 121.
23. J. B. Finean, *Experientia* **9**, 17 (1953).
24. F. A. Vandenheuvel, *J. Am. Oil Chemists' Soc.* **40**, 455 (1963).
25. L. Salem, *Can. J. Biochem. Physiol.* **40**, 1287 (1962).
26. These numbers are, at best, rough estimates and are not intended as absolute values. Variations of intermolecular distances, the degree of hydration of polar groups, and the configuration of interacting groups will have a marked effect on these values.
27. L. Pauling, *The Nature of the Chemical Bond* (Cornell Univ. Press, Ithaca, N.Y., ed. 3, 1960), p. 138.
28. F. Kogl, J. de Gier, I. Mulder, L. M. Van Deenen, *Biochim. Biophys. Acta* **43**, 95 (1960).
29. B. L. Walker and F. A. Kummerow, *Proc. Soc. Exptl. Biol. Med.* **115**, 1099 (1964).
30. For further discussion of this point see L. S. Wolfe, *Can. J. Biochem. Physiol.* **42**, 971 (1964).
31. J. S. O'Brien, *Biochem. Biophys. Res. Commun.* **15**, 484 (1964).
32. B. Gerstl, M. G. Tavaststjerna, R. B. Hayman, J. K. Smith, L. F. Eng, *J. Neurochem.* **10**, 889 (1963).
33. L. Svennerholm, in *Brain Lipids and Lipoproteins and the Leucodystrophies*, J. Folch-Pi and H. Bauer, Eds. (Elsevier, New York, 1963), p. 104.
34. J. D. Robertson, *Progr. Biophys. Biophys. Chem.* **10**, 356 (1960).
35. P. L. Williams, C. P. Wendell-Smith, A. Finch, G. Stevens, *Quart. J. Microscop. Sci.* **105**, 99 (1964).
36. L. G. Elfvin, *J. Ultrastruct. Res.* **5**, 388 (1961).
37. The work reported in this article was supported by the National Institutes of Health, grants HE08429 and NB04136. I wish to thank E. Lois Sampson, V. Shamberger, and S. R. M. Connerton for their assistance in the laboratory.

Quaternary Correlations across Bering Strait

Recent Soviet and American studies cast new light on the history of the Bering land bridge.

D. M. Hopkins, F. S. MacNeil, R. L. Merklin, O. M. Petrov

The broad continental shelf extending beneath the Bering and Chukchi seas from Siberia to Alaska holds great interest for biogeographers. It has been the site, repeatedly, of a land connection, and thus of a migration route for land biota between Asia and North America; and when this land connection has been interrupted, as it is at present, the resulting seaway has been an avenue of migration for marine biota between the North Pacific and the North Atlantic oceans (*1*). Knowledge of the history and past environments of land bridges and seaways in this area must be sought largely through the study of the late Cenozoic sediments exposed along the Alaskan and Siberian shores of the Bering and Chukchi seas and through attempts to establish the synchroneity of individual sets of late Cenozoic sediments on opposite sides of Bering Strait.

The presence of marine sediments of late Cenozoic age in scattered places on the Siberian and Alaskan shores of the Bering and Chukchi seas (Fig. 1) has been known for many years, but, until recently, the more exact dating of these deposits has been very uncertain. Through stratigraphic and paleontologic investigations conducted during the last few years we are beginning to have a better idea of the probable ages of the late Cenozoic marine sediments of Chukotka and Alaska. In this article, and in a companion paper recently published in the *Izvestia* of the Academy of Sciences of the U.S.S.R. (*2*), we compare and attempt to correlate these sequences (Fig. 2). However, the comparison is complicated by several factors.

1) There are strong contrasts at present between the temperatures of coastal waters on the eastern and the western sides of Bering Sea, Bering Strait, and Chukchi Sea, because a strong current of relatively warm water from the North Pacific Ocean flows north along the Alaskan coast and a much weaker and colder return current flows south and west along the coast of Chukotka (*3*). If the correlations proposed in this article are correct, then the temperature contrast, the resulting faunal contrast, and presumably the circulation pattern that causes both, existed whenever Bering Strait was open during Quaternary time and perhaps during late Tertiary time as well.

2) American and Soviet paleontologists have somewhat different concepts of some of the difficult and variable species complexes that characterize arctic and boreal molluscan faunas. Because of this, published faunal lists for Siberian and Alaskan deposits are not strictly comparable. In some cases, different taxa are given the same species name, and in other cases the same taxa are given different names on opposite sides of Bering Strait. These taxonomic problems probably cannot be resolved until an opportunity arises for American and Soviet paleontologists to examine their respective collections together.

3) The late Cenozoic marine sequences have been at least slightly deformed in many areas in both western Alaska and Chukotka. Therefore cor-

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relations cannot be based upon the present altitudes of former shorelines.

4) The late Cenozoic marine beds of western Alaska are interpreted by Hopkins (*1, 4*) as having been deposited during preglacial and interglacial intervals when sea level was approximately as high as it is at present. Although these beds have obviously been deformed in many areas, this interpretation seems reasonable because most of the known occurrences adjoin the inner part of the broad, shallow, Bering-Chukchi continental shelf, hundreds of kilometers from the position in which the shoreline probably lay during worldwide glacial episodes when sea level must have been 100 meters or so lower than it is now (*5*). Furthermore, this interpretation is supported in several places by the nature of local stratigraphic relationships between marine deposits, glacial drift, and unconformities that record episodes of lowered sea level. Moreover, most of the Alaskan marine fossil faunas of late Cenozoic age indicate water temperatures at least as high as those of the present time, and some of them indicate water temperatures considerably higher.

Some of the late Cenozoic marine beds in Chukotka, on the other hand, are interpreted as having been deposited during glacial intervals (*6, 7*), and thus at times when worldwide sea level must have been lower than it is now. This interpretation is based on occurrences of fossiliferous sediments believed to be marine glacial deposits; it is supported by the presence, in some of these deposits, of molluscan faunas indicative of water temperatures considerably lower than those of the present day. The late Cenozoic marine deposits of Chukotka are nearly as remote from the southern margin of the Bering-Chukchi continental shelf as are those of western Alaska. Therefore, crustal disturbances involving large areas of the Bering-Chukchi shelf must have taken place, if parts of the present Chukotkan coast were the sites of marine sedimentation during glacial intervals.

Despite these complications, enough knowledge has now been accumulated to encourage an attempt to correlate the Chukotkan and western Alaskan sequences of marine sediments of late Cenozoic age. However, the correlations suggested here must be considered preliminary; they can serve only as models to be tested by further investigations.

The Chukotkan Sequence

The discussion that follows is based principally upon Petrov's recent account of the stratigraphy of the late Cenozoic deposits of southern Chukotka (*7*) and upon Merklin, Petrov, and Amitrov's description of the fossil faunas (*6*).

The oldest late Cenozoic marine sediments known in Chukotka consist of a sequence of littoral sand and gravel beds constituting the Pestsov Suite (*8*), exposed in the northern foothills of the Zolotoy Mountains (Fig. 1). Molluscan faunas collected during 1964 indicate that the Pestsov Suite is of early Pliocene age. The Pestsov Suite contains a relatively warm-water (south boreal) molluscan fauna consisting of extinct species such as *Taras* cf. *semiasperum* (Philippi) and *Cardita piltunensis* Slodkewitsch, species such as *Glycymeris yessoensis* (Sowerby) that now inhabit more southern and warmer waters, and, in smaller numbers, species such as *Mya arenaria* Linné and *Mytilus edulis* Linné that now reach the Anadyr Gulf. Pollen floras from the Pestsov Suite are dominated by pollen of *Picea, Pinus, Betula,* and *Alnus*, but pollen of *Tsuga, Larix, Abies, Corylus, Fagus, Quercus*, and *Ulmus* is present in sufficient quantities to suggest that trees of these genera, now common in more temperate latitudes, were present in western Chukotka when the Pestsov Suite was being deposited. The area in which the Pestsov Suite is found lies approximately at the present-day boundary between taiga and tundra.

The Koynatkhun Suite, a sequence of preglacial lacustrine and alluvial beds exposed on the east and west shores of Kresta Bay, probably represents the next younger sequence of late Cenozoic sediments in Chukotka. The contact between the Koynatkhun Suite and the Pestsov Suite is not exposed, but the geomorphic relationships, as well as comparisons of pollen floras, suggest that the Koynatkhun Suite is younger than the Pestsov Suite. The Koynatkhun beds contain pollen floras generally suggestive of the modern taiga of eastern Siberia, but pollen of *Tsuga, Abies,* and *Corylus* is present in sufficient quantities to suggest that these trees, now found only in more temperate latitudes, were present when the Koynatkhun Suite was deposited. This suggestion is supported by the occurrence in the Koynatkhun Suite of cones of *Pinus monticola* Douglas, which now grows only in temperate latitudes in North America, along with cones of the Siberian conifers *Picea bilibinii* Vassk., *P. anadyrensis* Kryscht., and *Larix* cf. *siberica* Ldb. A comparison of pollen floras suggests that the Koynatkhun Suite is correlative with the Ermanov Suite of Kamchatka, considered by Soviet geologists to be of late Pliocene age (*9*). The Ermanov Suite includes both marine and nonmarine beds.

The Koynatkhun Suite is unconformably overlain by the Pinakul' Suite, a sequence of bouldery silt (marine glacial deposits?), sand, and clay beds exposed in several places along the south and east coasts of Chukotka, from the east shore of Kresta Bay eastward to the village of Pinakul' at the north entrance to Lavrenty Bay. The Pinakul' Suite contains a fauna consisting entirely of living species, including *Astarte borealis* Schumacher and the *Neptunea communis* (Middendorf) of Merklin and Petrov [= *N. heros* (Gray) of MacNeil]. Several arctic species, such as *Portlandia arctica siliqua* (Reeve), make their first appearances in Chukotka south of Bering Strait in the Pinakul' Suite, but the Pinakul' fauna also includes a few southern boreal forms that no longer occur as far north as Lavrenty Bay. Pollen spectra indicate that tundra vegetation grew at Lavrenty Bay and that a mixture of tundra and forest was present on the eastern shore of Kresta Bay during the accumulation of the Pinakul' Suite. Merklin and Petrov consider the Pinakul' Suite to be of early Quaternary age.

The next younger marine sequence in Chukotka, the Kresta Suite, is widely distributed along the south and east coasts of Chukotka. Beds of the Kresta Suite rest unconformably upon beds of the Pinakul' Suite in several places on the east shore of Kresta Bay. The Kresta Suite consists of a lower sequence of marine beds, a middle sequence interpreted by Petrov as consisting of marine glacial deposits, and an upper sequence of normal marine beds. The marine glacial beds appear to interfinger laterally with drift, representing the most extensive Quaternary glaciation recorded in Chukotka.

The lower and upper members of the Kresta Suite contain faunas composed mostly of mollusks now found in adjoining waters. The faunas are dominated by various species of *Astarte*, but they include *Portlandia* *arctica siliqua* (Reeve), which no longer ranges south of Bering Strait. The middle marine glacial member contains abundant specimens of several arctic mollusks that no longer range south into Bering Sea, including *Portlandia arctica siliqua* (Reeve), *Bathyarca glacialis* (Gray), and *Yoldiella intermedia* (Sars), and thus records extremely cold water conditions. Pollen and spores are rare in the beds of the Kresta Suite; Petrov ascribes their scarcity to sparse vegetation on adjoining land during the time in which the Kresta Suite was being deposited. Merklin and Petrov consider the Kresta Suite to have been deposited before, during, and after a major middle Quaternary glacial episode which they tentatively correlate with the Riss Glaciation of Europe.

Still younger marine deposits, the Val'katlen beds, form a terrace along much of the south and east coasts of Chukotka. In some places the terrace is notched into the deposits of the Kresta Suite, and the Val'katlen beds are covered locally by glacial drift (the Vankarem beds). The Val'katlen beds contain a molluscan fauna nearly identical with the Recent fauna of northwestern Bering Sea. Pollen spectra indicate that tundra vegetation prevailed in Chukotka when these beds were deposited. Merklin and Petrov think the Val'katlen beds were deposited during the Riss-Würm interglacial interval.

A still later episode of marine deposition is recorded in Chukotka by the Amguem beds, principally represented by a marine terrace extending along the straight coast east of Kresta Bay (Fig. 1). The small molluscan faunas found thus far in the Amguem beds do not differ from modern faunas in the adjoining sea. Pollen spectra from river terraces correlated with the Amguem beds record tundra vegetation. Merklin and Petrov think the Amguem beds record an interstadial episode within the Würm Glaciation, because river terraces assigned to this unit are older than end moraines (the Iskatlen' beds) which mark the most recent re-advance of glaciers in the mountains of Chukotka. The marine deposits included in the Amguem beds are the youngest known on Chukotka except for the Recent beaches and barrier bars along the modern coasts.

The Western Alaskan Sequence

Hopkins (*4*) recently described the late Cenozoic marine deposits of Alaska as recording six episodes of preglacial, interglacial, and postglacial high sea level; these he termed the Beringian, the Anvilian, the Kotzebuan, the Pelukian, the Woronzofian, and the Kruzensternian transgressions, ranging in age from late Pliocene or early Pleistocene to Recent. New data suggest that the Beringian deposits represent a long span of time and that they can be more finely subdivided;

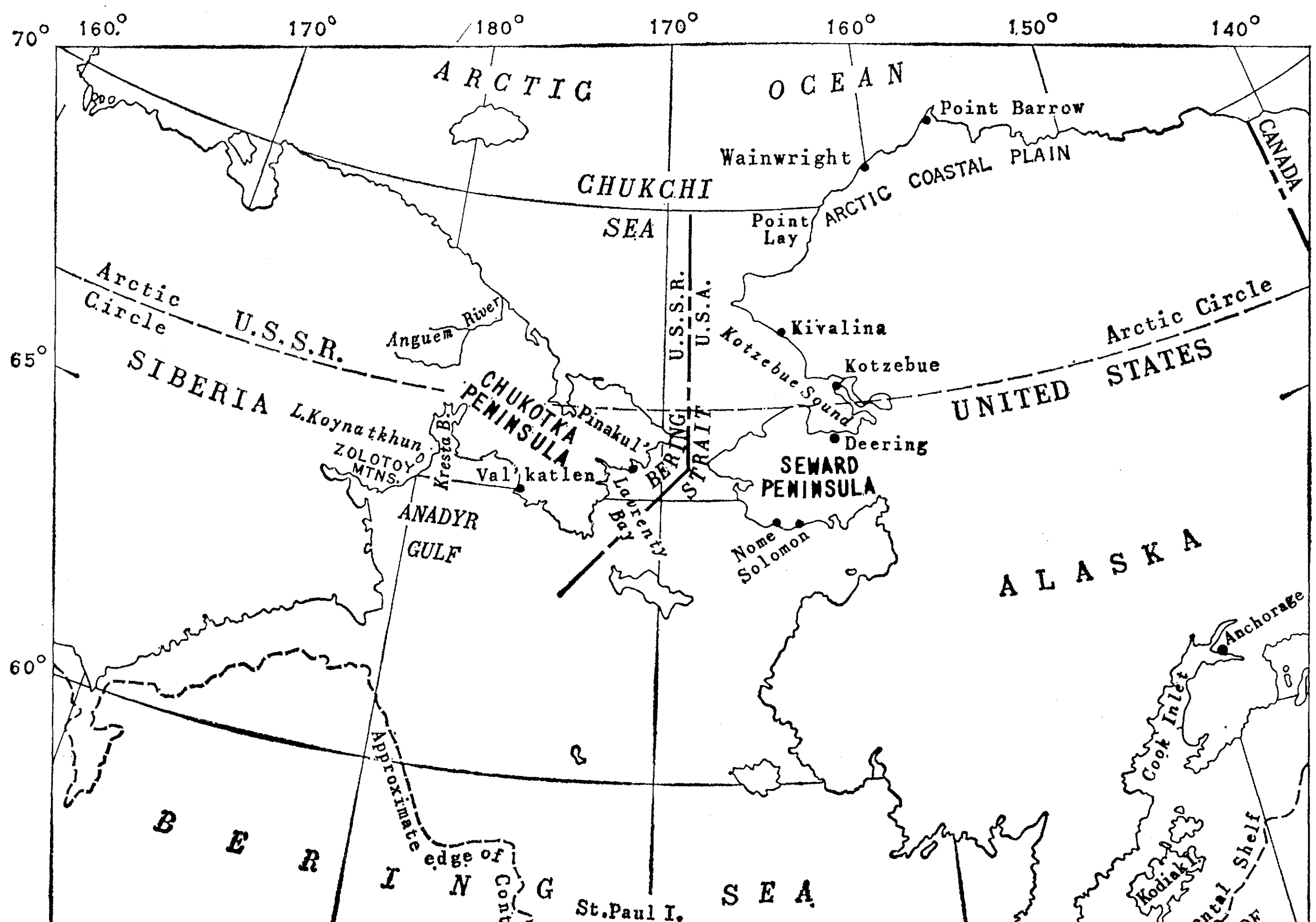

Fig. 1. Eastern Siberia and western Alaska, showing localities mentioned in text.

the comparison of marine sequences in Siberia and western Alaska set forth here also suggests that an additional episode of high sea level is recorded by deposits that are probably younger than the Anvilian and older than the Kotzebuan transgression.

Marine beds of early Pliocene age are widely distributed in southern Alaska and may be present in northeastern Alaska (*10*), but none have been recognized in western Alaska adjacent to the Bering-Chukchi continental shelf. The middle member of the nonmarine Kougarok Gravel of central Seward Peninsula (*11*) contains a rich pollen and wood flora, consisting of a mixture of coniferous and dedicuous trees, that includes representatives of several genera that now reach their northern limits 5° to 15° south of Seward Peninsula. Although the flora of the middle member of the Kougarok Gravel is generally similar in character to the flora of the lower Pliocene Pestsov Suite of Chukotka, comparisons with better studied floras in southern Alaska (*12*) suggest that the Kougarok Gravel is considerably older than early Pliocene.

The oldest late Cenozoic marine deposits known in Alaskan areas adjoining the Bering-Chukchi marine platform consist of beds of fossiliferous sand, pebbly sand, and clay, at Nome (deposits known locally as Submarine Beach) (*13, 14*), and beds containing comparable molluscan faunas at Kivalina (*15*) and Solomon (*4*), and at Tolstoi Point, St. George Island, in the Pribilof Islands (*4, 16*) (Fig. 1). Hopkins designates these beds collectively as the deposits of the Beringian transgression, and designates Submarine Beach at Nome as the type deposits for this transgression (*4*). Fossils of the types most useful for recognizing deposits of the Beringian transgression in areas adjoining the Bering-Chukchi shelf have not yet been found along the Pacific coast of Alaska, but the Beringian faunas of the Bering-Chukchi shelf area have some species in common with, and are most similar in the number of modern forms they contain to, faunas from the uppermost part of the Yakataga Formation and from the upper part of an unnamed sequence of marine beds on Middleton Island in southern Alaska (*17*).

The Beringian molluscan faunas from areas adjoining the Bering-Chukchi shelf have a decidedly modern aspect, and most of the taxa present are closely related to modern species. Nevertheless, many of the mollusks present in these Beringian deposits differ to some degree from their nearest living relatives. The assemblages of small pectinids, especially, are unlike any modern ones, and most of the *Neptunea* and *Astarte* are unlike any living species of these genera. *Patinopecten* (*Fortipecten*) *hallae* (Dall), found at Solomon and Kivalina, belongs to an extinct subgenus whose other representatives are found only in beds of Pliocene age in Japan, Sakhalin, and Kamchatka; the Alaskan species is most closely related to *P.* (*F.*) *kenyoshiensis* (Chinzei), found in middle or upper Pliocene beds in Japan (*18*). *Yoldia koluntunensis* Slodkewitsch, found at Nome, has been previously reported only from the early Pliocene Kakert Suite of Kamchatka (*19*). The Beringian molluscan faunas include a few species that now occur only in warmer, more southern waters.

The Beringian sediments at Nome contain abundant pollen of *Pinus* and *Picea* and sufficient quantities of pollen of *Abies, Tsuga, Larix,* and *Carya* to indicate that these trees were present at Nome when the Beringian sediments were being deposited; Beringian sediments at Kivalina contain abundant pollen of *Pinus* and *Picea* but lack pollen of *Abies, Tsuga, Larix,* and *Carya* (*20*). Both areas now lie in tundra regions, many kilometers beyond the present forest limit in northwestern Alaska.

The Beringian deposits on St. George Island are overlain by lava flows that were erupted at a time when the earth's magnetic field was reversed, followed by lava flows of normal remanent magnetism, and then by younger lava flows of reversed remanent magnetism. Potassium-argon age determinations on seven lava flows in the older paleomagnetically reversed sequence indicate ages ranging from 2.0 to 2.2 million years (*21*). One member of this sequence is a pillow lava representing a flow that entered marine waters and terminated the deposition of the Beringian sediments now exposed near Tolstoi Point, St. George Island.

The Beringian deposits at Nome are covered by drift of the Iron Creek Glaciation, a glacial cycle of early Pleistocene age (*14*). This ancient drift is overlain in turn by marine sediments known locally as Third Beach and Intermediate Beach, which Hopkins (*4*) designates as the type deposits of the Anvilian transgression. Sediments containing similar faunas on the northwestern part of the Arctic coastal plain of Alaska between Wainwright and Point Barrow (*22*) are also referred to the Anvilian transgression, but some of the other deposits that Hopkins previously assigned to the Anvilian transgression (*4*) are now thought to record a later transgression.

The marine faunas of the Anvilian deposits consist mostly of forms now living in adjacent waters, but they include several extinct forms—chiefly species of *Neptunea, Chlamys*, and *Astarte*—and several forms now limited to warmer water (*13, 22*). In both the Anvilian and the Beringian deposits of Alaska the *Neptunea heros* (Gray) lineage is represented by the extinct *N. heros mesleri* (Dall), and the *Astarte borealis* Schumacher lineage, by the extinct *Astarte nortonensis* MacNeil. A specimen of marine sediments recovered from the buckets of a gold-dredge during the process of digging through the Anvilian deposits at Nome contained, in all, 41 identifiable pollen grains, including 17 grains of *Picea* and six grains of *Pinus* (*20*). Hopkins believes that the Anvilian transgression records a high stand of sea level during an early Quaternary interglacial interval, probably following the first continental glaciation. The Anvilian deposits at Nome are covered by drift of the Nome River (Illinoian) Glaciation.

A transgression later than the Anvilian is probably recorded by fossiliferous marine beds at Tolstoi Point and in the Einahnuhto Bluffs on St. Paul Island (*4, 16*), and by certain marine deposits that lie inland from Point Lay and Wainwright on the Arctic coastal plain (*23, 24*). These beds contain molluscan faunas that are much like the modern faunas in adjacent waters. However, the rather variable *Neptunea heros* populations consist mostly of individuals that MacNeil considers typical of the extinct subspecies *N. heros mesleri* (Dall), and the large populations of *Astarte borealis* include individuals that are intermediate between the extinct *A. nortonensis* MacNeil and the modern *A. borealis* Schumacher. Potassium-argon age determinations on lava flows of normal remanent magnetism that lie below and above the fossiliferous marine beds in the Einahnuhto Bluffs indicate that these beds were deposited between 100,000 and 400,000 years ago (*21*). These marine beds and the beds inland from Point Lay and Wainwright on the

Arctic coastal plain were previously assigned by Hopkins (*4*) to the Anvilian transgression because they contain *Neptunea heros mesleri* and because the *Astarte borealis* populations include variants close to *Astarte nortonensis*. However, the otherwise modern aspect of their faunas, the relatively young age indicated by radiometric dating and by their position in the paleomagnetic sequence, and the comparison between the Alaskan and the Chukotkan marine sequences outlined here now lead us to believe that these beds record an interval of high sea level considerably later than the Anvilian transgression.

The next younger marine sequence

Correlation with European sequence: Epoch	Age	Glaciation	Chukotka	Alaska		Correlation with U. S. sequence: Glaciation	Age	Epoch
		Holocene	Barrier, bars, modern flood plains, low terraces along some streams	Barrier, bars, modern flood plains, low terraces along some streams				Recent
Pleistocene	Late	Würm	Iskatlen' beds (end moraines in mountain valleys)	Drift of Naptowne Glaciation in Cook Inlet area	Drift of Salmon Lake Glaciation on Seward Peninsula	Wisconsin	Late	Pleistocene
			Amguem beds: low marine terrace; river terraces	Bootlegger Cove Clay (marine deposits of Woronzofian transgression)				
			Vankarem beds: end moraines and associated glacial deposits	Drift of Knik Glaciation in Cook Inlet area				
		Riss/Würm	Konerginsk beds: alluvial and lacustrine deposits	Marine deposits of Pelukian transgression, including Second Beach at Nome; forest beds and buried soils in upland areas		Sangamon		
			Val'katlen beds: higher marine terrace					
			HIATUS					
	Middle	Riss	Kresta Suite Upper member: boreal mollusks in marine pebbly sand and gravel Middle member: Arctic mollusks in glaciomarine sediments that interfinger laterally with drift of local maximum glaciation	Drift of the Nome River Glaciation; loess in unglaciated areas		Illinoian	Middle	
			Lower member: boreal mollusks in marine sand	Marine sediments of Kotzebuan transgression				
			HIATUS	HIATUS				
	Early		Pinakul' Suite Marine sand and possible glaciomarine bouldery clay and silt	Unnamed marine beds at Einahnuhto Bluffs, St. Paul Island				
			HIATUS	HIATUS				
				Marine deposits of Anvilian transgression, including Third Beach and Intermediate Beach at Nome			Early	
				Drift of the Iron Creek Glaciation				
Pliocene	Late		Köynatkhun Suite Lacustrine and alluvial sediments	Marine deposits of Beringian transgression, including Submarine Beach at Nome				Pliocene
	Middle		HIATUS	HIATUS				
	Early		Pestsov Suite Marine sand and gravel					

Fig. 2. Provisional correlation of Late Cenozoic stratigraphic sequences in Alaska and Chukotka with subdivisions of the late Cenozoic Era in Europe and in the contiguous United States.

recognized in western Alaska consists of deposits of the Kotzebuan transgression found on the shores of Kotzebue Sound (*4, 25*); correlative deposits are probably present on the Arctic coastal plain between Point Lay and Wainwright (*24*). The Kotzebuan deposits are overlain in the Kotzebue Sound area by an end moraine of the Nome River Glaciation; in many places they have been intensely deformed by the overriding glacial ice. The abundant molluscan fauna in the deposits of the Kotzebuan transgression consists exclusively of species that live today in adjacent waters; it is characterized by abundant and varied *Astarte*. *Portlandia arctica* makes its first recorded appearance in western Alaska in the Kotzebuan deposits. No species now limited to warmer waters are represented, but several species represented by fossils in these deposits reach the southern limit of their modern ranges in the Kotzebue Sound area. Two shells from the Kotzebuan sediments have ages, determined by uranium-238–thorium-230 dating, of 175,000 ± 16,000 and 170,000 ± 17,000 years, respectively (*26*). Hopkins (*4, 14*) demonstrates that the Nome River Glaciation corresponds to the Illinoian Glaciation of the northcentral United States; the Kotzebuan transgression evidently records an interval of high sea level during the preceding interglaciation.

A still later marine transgression is represented by the marine deposits of the Pelukian transgression, typified by Second Beach at Nome (*4, 13, 14*). These deposits form low terraces visible on low-lying coasts throughout much of western Alaska; at Nome and in the Kotzebue Sound area they extend inland to ancient wave-cut cliffs carved in drift of the Nome River Glaciation (*14, 25*). Filled canyons formed during the Salmon Lake Glaciation of Seward Peninsula cut through the Pelukian deposits at Nome (*14*).

Molluscan faunas in the Pelukian deposits are closely similar to Recent faunas, but those in the Seward Peninsula-Kotzebue Sound area contain several forms—*Natica janthostoma* Deshayes, *Protothaca adamsi* (Reeve), *Pododesmus macroschisma* (Deshayes), and *Pholadidea penita* (Conrad)—that now range no farther north than the Pribilof Islands. Fossil pollen and wood record a westward advance of the taiga to the area of Nome, Deering, and Kotzebue during the Pelukian transgression. Shells from a single collecting locality in Pelukian deposits at Nome have yielded ages of more than 38,000 years, of 100,000 ± 8000 years, and of 78,000 ± 5000 years, by radiocarbon dating, U^{238}-Th^{230} dating, and U^{238}-Ra^{226} dating, respectively (*14, 26*). The radiometric dating, the evidence of warmer water temperatures and of an advance of the forest beyond its present limits, and the stratigraphic relationships between the deposits of the Pelukian transgression and the drift of the Nome River Glaciation all indicate that the Pelukian transgression represents the high stand of sea level during the Sangamon Interglaciation.

The deposits of the Pelukian transgression are the youngest marine sediments recognized in western Alaska except for those of Hopkins' Kruzensternian transgression, which consists of spits, barrier bars, beaches, and lagoonal sediments deposited within the last few thousand years (*4*). In southern Alaska, however, marine sediments younger than the Pelukian transgression and older than the Kruzensternian transgression are recognized in the Cook Inlet area and near the west end of Kodiak Island. These deposits, designated by Hopkins as the deposits of the Woronzofian transgression (*4*), are typified by the Bootlegger Cove Clay near Point Woronzof in the Anchorage area (*27*) (Fig. 1). They rest on drift of the Knik (early Wisconsin) Glaciation and are covered by drift of the Naptowne (late Wisconsin) Glaciation. The small molluscan faunas recovered thus far from Woronzofian deposits do not differ from the modern faunas in adjacent waters. An age of 33,000 to 48,000 years has been obtained by U^{238}-Th^{230} dating for shells from the Woronzofian deposits near Anchorage (*28*).

Tentative Correlations

Similarities, in stratigraphic relationships, to local glacial deposits indicate that the Amguem beds of Chukotka and the marine sediments of the Woronzofian transgression in southern Alaska are correlative and that both were deposited during an interstade in the last major glaciation, equated in Alaska with the Wisconsin Glaciation and in Chukotka with the Würm Glaciation (Fig. 2). Similar evidence indicates that the Val'katlen beds of Chukotka and the Pelukian deposits of Alaska are correlative; both were deposited during the high stand of sea level of the last interglaciation, equated in Alaska with the Sangamon Interglaciation and in Chukotka with the Riss-Würm Interglaciation.

It is more difficult to decide which, if any, of the late Cenozoic marine deposits of western Alaska correspond to the deposits of the Kresta Suite of Chukotka, but the choice is limited to relatively young deposits in Alaska, because the Kresta Suite contains no extinct molluscan taxa. The Kresta Suite is interpreted by Petrov and Merklin as having been deposited before, during, and after the Maximum Glaciation of Siberia, which is customarily correlated with the Riss Glaciation of Europe (*29*). The topographic expression and the stratigraphic relations of drift of the Maximum Glaciation in northern and northeastern Siberia suggest that this drift is correlative with the drift of the Nome River Glaciation of western Alaska. Thus, the marine glacial deposits constituting the middle part of the Kresta Suite are probably equivalent in age to the drift of the Nome River Glaciation. The upper beds of the Kresta Suite may have been deposited during a waning phase of the Nome River Glaciation, but we cannot exclude the possibility that they correspond to some part of the deposits of the Pelukian transgression. The unconformity between the Kresta Suite and the overlying Val'katlen beds may record a temporary regression of sea level, but it seems more likely to be the result of a tectonic disturbance affecting the area of Anadyr Bay and adjoining parts of the Bering shelf.

The deposits of the Kotzebuan transgression in western Alaska underlie the drift of the Nome River Glaciation and contain a fauna that does not differ from modern faunas. Similarities in faunas and stratigraphic relationships suggest that the deposits of the Kotzebuan transgression are approximately correlative with the lower part of the Kresta Suite. This correlation requires that the Pinakul' Suite of Chukotka be correlated with pre-Kotzebuan deposits in Alaska—that is, with deposits of the Anvilian transgression or with younger, unnamed beds. However, the presence in the Pinakul' Suite of *Astarte borealis* Schumacher and the *Neptunea communis* (Middendorf) of Merklin and Petrov [= *N. heros* (Gray) of MacNeil] precludes a correlation of the Pinakul' Suite with beds as old as the deposits of the Anvilian transgression at Nome, which contain the ancestral *Astarte nortonensis* Mac-

Neil and *Neptunea heros mesleri* (Dall). The Pinakul' Suite is more likely to correspond to the unnamed beds at Tolstoi Point and in the Einahnuhto Bluffs of St. Paul Island and correlative beds inland from Point Lay and Wainwright, which contain *Neptunea* populations transitional between *N. heros mesleri* and *N. heros* and *Astarte* populations intermediate between *A. nortonensis* and *A. borealis*.

Beds correlative with the Anvilian transgression at Nome have not yet been recognized in Chukotka.

No marine deposits are known in Chukotka that are correlative with those deposits of the Beringian transgression that adjoin the Bering-Chukchi continental shelf in western Alaska. These Beringian deposits differ from the Pestsov Suite in that they contain fewer extinct species, fewer warm-water forms, and a higher proportion of modern boreal species. Pollen floras from these deposits contain fewer and less diversified representatives of trees now exotic to the region than do the pollen floras of the Pestsov Suite. Thus, the Beringian deposits of western Alaska appear to be younger than the Pestsov Suite of Chukotka. Similarities in pollen floras suggest that they are approximately correlative with the nonmarine Koynatkhun Suite of Chukotka.

Marine sediments correlative with the Pestsov Suite have not yet been recognized in western Alaskan areas adjoining the Bering-Chukchi continental shelf, though beds of this age are widely distributed along the southern coast of Alaska. The middle member of the nonmarine Kougarok Gravel of central Seward Peninsula contains a pollen flora generally similar to the pollen flora of the Pestsov Suite, but comparisons with better-studied floras in southern Alaska suggest that this member is not younger than late Miocene.

Conclusions and Implications

The south and east coasts of Chukotka and the Bering-Chukchi coasts of Alaska have had somewhat different late Cenozoic histories; as a result, only a few sets of late Cenozoic marine deposits can be confidently correlated from one side of Bering Strait to the other. The Amguem beds, deposited in Chukotka during an interstadial interval in the last major glacial episode, evidently correspond to the deposits of the Woronzofian transgression in southern Alaska, but beds of this age have not yet been recognized along the Alaskan coasts of the Bering and Chukchi seas, perhaps because they lie slightly below present sea level. The Val'katlen beds of Chukotka evidently correspond to the deposits of the Pelukian transgression in western Alaska; both were deposited during the Sangamon (Riss-Würm) Interglaciation. These correlations imply that the Bering Strait was open during the last interglaciation and that it may have been open during at least one interstade within the Wisconsin (Würm) Glaciation. Chukotka and Alaska were evidently joined by land at other times during the last glacial interval.

All of the other late Cenozoic marine deposits known thus far in western Alaska accumulated during nonglacial intervals, when sea level was near its present position, but the middle part of the Kresta Suite, exposed in many places on the shores of Kresta Bay and Anadyr Gulf, Chukotka, accumulated during a glacial interval when sea level must have been 100 meters lower than at present. It is possible that marine glacial deposits are also present in the Pinakul' Suite at Lavrenty Bay, although the presence in these beds of molluscan species now limited to more southern areas tends to refute this interpretation.

The evidence available at present is most reasonably interpreted as indicating that the coast of Chukotka had approximately its present configuration during the time that the Pinakul' Suite was deposited; that the area of Kresta Bay, Anadyr Gulf, and adjoining parts of the Bering shelf began to subside during the time that the Kresta Suite was deposited; and that tectonic disturbances brought these areas to their present level late in, or just after, the Maximum Glaciation, producing the unconformity between the Kresta Suite and the overlying Val'katlen Suite. Earlier cycles of deformation in the Anadyr Bay region may be recorded in the Pestsov Suite and the Koynatkhun Suite.

If these late Cenozoic episodes of deformation affected areas wider than the Anadyr Gulf, they may have resulted in the development of temporary connections between Siberia and Alaska during nonglacial episodes of early or middle Quaternary time, or they may have resulted in the maintenance of a water barrier between the continents during some early and middle Quaternary glaciations.

The successions of late Cenozoic marine molluscan faunas on both the Alaskan and the Siberian coasts of Bering Sea and Chukchi Sea show a progressive modernization, in which warm-water elements disappear and elements of the modern arctic fauna increasingly take their place. Faunas in the middle Quaternary deposits represented by the Kresta Suite of Chukotka and by the deposits of the Kotzebuan transgression in Alaska record a cold-water maximum; the late Quaternary interglacial marine beds were deposited in water that was slightly less cold. The present contrast in the temperatures of waters along the coast of western Alaska and along the coast of Chukotka seems to have existed throughout much of Quaternary time.

References and Notes

1. D. M. Hopkins, *Science* **129**, 1519 (1959).
2. R. Merklin, O. Petrov, D. Hopkins, F. MacNeil, *Izv. Akad. Nauk SSSR* **10**, 45 (1964) (in Russian).
3. L. Zenkevich, *Biology of the Seas of the U.S.S.R.* (Interscience, New York, 1963), pp. 261–269, 818–841.
4. D. M. Hopkins, "Late Cenozoic marine transgressions in Alaska," in *Trudy Inst. Geol. Arktiki* (Leningrad) (in press) (in Russian; translation will be available from Office of Technical Services, U.S. Department of Commerce, and from the American Geological Institute).
5. W. Donn, W. Farrand, M. Ewing, *J. Geol.* **70**, 206 (1962).
6. R. Merklin, O. Petrov, O. Amitrov, "Atlas-guide of mollusks of the Quaternary deposits of the Chukotsk Peninsula," *Publ. Acad. Sci. USSR Comm. for Study of Quaternary Period* (1962) (in Russian; translation available from Office of Technical Services, U.S. Department of Commerce, and from American Geological Institute).
7. O. Petrov, *Bull. Acad. Sci. USSR Comm. on Study of Quaternary Period* **28**, 135 (1963) (in Russian; translation available from Office of Technical Services, U.S. Department of Commerce, and from American Geological Institute).
8. The word *Suite* in Soviet stratigraphic nomenclature corresponds approximately to the word *Formation* in American stratigraphic nomenclature.
9. A. Vas'kovskii, "Short outline of the vegetation, climate, and chronology of the Quaternary Period in the upper reaches of the Kolyma and Indigirka Rivers and on the northern coast of the Sea of Okhotsk," in *Glacial Period in the Territory of the European Part of the USSR and Siberia* (Moscow State Univ., Moscow, 1959), pp. 510–556 (in Russian).
10. F. MacNeil, J. Wolfe, D. Miller, D. Hopkins, *Bull. Am. Assoc. Petrol. Geologists* **45**, 1801 (1961).
11. D. Hopkins, *U. S. Geol. Surv. Bull.* **1141-C**, C29–C34 (1963).
12. J. Wolfe, D. Hopkins, E. Leopold, *U.S. Geol. Survey Profess. Papers* (in press).
13. F. MacNeil, J. Mertie, H. Pilsbry, *J. Paleontol.* **17**, 69 (1943).
14. D. Hopkins, F. MacNeil, E. Leopold, *Intern. Geol. Congr., 21st, Copenhagen* (1960), pt. 4, pp. 46–57.
15. D. Hopkins and F. MacNeil, *U.S. Geol. Surv. Profess. Papers* **400-B**, B339 (1960).
16. T. Barth, *U.S. Geol. Surv. Bull.* **1028-F**, 101 (1956).
17. Unpublished data on mollusks collected in 1963 and 1964 by G. Plafker, U.S. Geological Survey geologist. D. Miller describes the Yakataga Formation in *U.S. Geol. Survey Oil and Gas Invest. Map* **OM-187** (1957), and the Middleton Island Sequence in *J. Geol.* **61**, 17 (1953).

18. K. Chinzei, *Japan. J. Geol. Geography, Trans.* **31**, 63 (1960).
19. A. Ilinya, "Neogene mollusks of Kamchatka," *Trans. All-Union Petrol. Sci. Res. Geol. Exploration Inst.* **202** (1963).
20. Unpublished pollen determinations by E. B. Leopold, U.S. Geological Survey, Denver, Colo.
21. Unpublished paleomagnetic studies by A. V. Cox and unpublished potassium-argon age determinations by G. B. Dalrymple, U.S. Geological Survey, Menlo Park, Calif.
22. F. MacNeil, *U.S. Geol. Surv. Profess. Papers* **294-C**, 99 (1957).
23. R. Chapman and E. Sable, *ibid*, **303-C**, 130 (1960).
24. Unpublished geological data of D. McCulloch; unpublished molluscan determinations by F. MacNeil.
25. D. McCulloch, D. Taylor, M. Rubin, *J. Geol.*, in press.
26. R. Blanchard, thesis, Washington University, St. Louis (1963).
27. R. Miller and E. Dobrovolny, *U.S. Geol. Surv. Bull.* **1093**, 128 (1959); T. Karlstrom, *U.S. Geol. Surv. Profess. Papers* **443** (1964); R. A. M. Schmidt, *Science* **141**, 350 (1963).
28. W. Sackett, thesis, Washington University, St. Louis (1958).
29. V. Saks and S. Strelkov, Eds., "Quaternary deposits of the Soviet Arctic," *Trudy Inst. Geol. Arktiki* **91** (1959) (in Russian; translation available from Defense Research Board of Canada).
30. Publication of this article is authorized by the Director, U.S. Geological Survey. We are grateful to M. C. Blake and Alice Parcel for assistance in Russian-to-English translations.

Soviet Search for Viruses That Cause Chronic Neurologic Diseases in the U.S.S.R.

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Viral infections of the central nervous system are usually thought to produce acute illnesses such as aseptic meningitis, encephalitis, or paralytic poliomyelitis. The one exception known to Western neurologists and virologists has been von Economo encephalitis, a disease of unknown but possibly viral etiology, where Parkinsonism develops after a latent period. Since persistence of virus in human and animal organisms after acute infection of the central nervous system has been disputed and factors precipitating overt disease have not been determined, relatively little is known about the viral pathogens which may take part in chronic forms of neurologic disease.

The recovery of filterable agents from animals with chronic diseases, such as scrapie, Visna, and Aleutian disease of mink, which are characterized by pathological changes suggesting degenerative or demyelinating diseases, has created interest in the role of slow viruses as pathogens of the central nervous systems of animals and man.

Soviet research workers have long been concerned with the relation of virus to the etiology of chronic, progressive, or relapsing diseases of the nervous system. Indeed, they were among the first to search for viruses in tissues of patients suffering from tick-borne encephalitis (formerly called Russian spring-summer encephalitis) in its chronic and progressive form. The viral etiology of other chronic or progressive diseases of the nervous system, such as amyotrophic lateral sclerosis or multiple sclerosis, is generally accepted by scientists in the U.S.S.R.

While visiting several clinical and research institutions in the U.S.S.R. in May and June of 1964 (*1*), we had an opportunity to observe Soviet research on the viral etiology of human chronic neurologic diseases, and we now offer a summary and evaluation of this research.

Possible Viral Etiology of Amyotrophic Lateral Sclerosis

In 1963, Zilber *et al.* reported that intracerebral inoculation of homogenates of medulla and spinal cord from patients that died of amyotrophic lateral sclerosis (ALS) induced a progressive neurologic disease in rhesus monkeys after a latent period of 1 to 3 years. Monkeys inoculated with specimens from three out of six patients developed asymmetrical muscular atrophy of the upper and lower extremities with increased tendon reflexes. The disease progressed over a period of 8 months to 3 years. Homogenates from the brain of affected monkeys and, in one case, homogenates of brains two passages after the initial inoculation, have produced similar disease in other monkeys. However, the inoculum causing disease in monkeys was nonpathogenic for mice and other laboratory animals.

Neuropathologic studies of specimens from man and monkey by Bunina *et al.* at the Neurological Institute of the Academy of Medical Sciences in Moscow indicated that inoculated monkeys had a "clear-cut" loss of ganglion cells of the anterior horns, accompanied by pronounced glial reaction, satellitosis, and neuronophagia. Oxyphilic intracytoplasmic inclusion bodies of 0.5 to 3.5 mμ were found in the nerve cells of the anterior horns. The motor cortex showed focal loss of large pyramidal and Betz cells in the third and fifth layers. There was pallor in parts of the lateral columns corresponding to the location of the pyramidal tracts in sections stained by Spielmeyer's method. The morphologic changes in monkeys were described as being similar to, but less intense than, those observed in patients, presumably because the monkeys were killed before the disease had reached an advanced stage. The Soviet scientists concluded that their experiments "proved

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