cording to Lagaaij (*13*), Oligocene age for the Vicksburg group is also indicated by the first appearance of the bryozoan *Cupuladria canariensis* in the Chickasawhay formation which directly overlies the Vicksburg group. The first appearance of this species, which marks the Oligo-Miocene boundary in Europe as well as in the Gulf Coast and Caribbean regions, is placed somewhere between the top of the *Globigerina ampliapertura* zone and the lower one-third of the *Globorotalia opima opima* zone.

The evidence from the planktonic Foraminifera strongly suggests that the Vicksburg assemblages are closely comparable with the fauna of the *Globigerina oligocaenica* zone of Tanganyika and some Oligocene faunas from northern Europe. The present planktonic Foraminifera are transitional in character between the typical Upper Eocene below and the *G. ampliapertura* zone above and, therefore, indicate their intermediate age, that is, Oligocene. In conclusion, this interpretation reaffirms the existence of the Oligocene in the Gulf Coast region.

TSUNEMASA SAITO
ALLAN W. H. BÉ

Lamont Geological Observatory of Columbia University, Palisades, New York

References and Notes

1. C. J. Maury, *Bull. Am. Paleontol.* **3**, 15 (1902).
2. S. F. MacNeil, *Bull. Am. Assoc. Petrol. Geol.* **28**, 9 (1944); G. E. Murray, *ibid.* **36**, 4 (1952); R. C. Moore, *Introduction to Historical Geology* (McGraw-Hill, New York, ed. 2, 1958), p. 440.
3. F. E. Eames, F. T. Banner, W. H. Blow, W. J. Clark, *Fundamentals of Mid-Tertiary Stratigraphical Correlation* (Cambridge Univ. Press, London, 1962).
4. R. M. Stainforth, *Nature* **187**, 4738 (1960); E. Szöts, *Compt. Rend. Soc. Géol. France* **8**, 236 (1962); W. A. Berggren, *Micropaleontology* **9**, 4 (1963).
5. S. F. MacNeil (*2*) restricted the term Vicksburg group only to the sediments that could be correlated with those ranging from the Marianna to Byram formations, and excluded the subjacent unit, Red Bluff clay, as an independent formation. G. E. Murray (*2*) proposed the Vicksburg (or Vicksburgian) stage to include all the sediments equivalent to those from the Red Bluff clay up to the Byram formation.
6. D. A. J. Batjes, *Mém. Inst. Sci. Nat. Belg.* **143**, 188 (1958).
7. H. M. Bolli, *U.S. Natl. Museum Bull.* **215**, 108 (1957).
8. T. Saito, *Sci. Rept. Tohoku Univ. Second Ser.* **35**, 2 (1963).
9. American Committee on Stratigraphic Nomenclature, *Bull. Am. Assoc. Petrol. Geologists* **45**, 5 (1961).
10. N. N. Subbotina, *Tr. Vses. Nauchn. Issled. Geologorazved. Inst.* **76**, 60 (1953).
11. A. R. Mornhinveg, *J. Paleontol.* **15**, 4 (1941).
12. J. P. Beckmann, *U.S. Natl. Museum Bull.* **215**, 89 (1957).
13. R. Lagaaij, *Palaeontology* **6**, 1 (1963).
14. This report is Lamont Geological Observatory contribution No. 718. Supported by Boese postdoctoral fellowship of Columbia University (1963–1964) and NSF grants GB-155 and G-24472. We thank Miss Angelina Messina, American Museum of Natural History, for permission to study the museum collection to which this material belongs.

2 April 1964

Potassium-Argon and Lead-Alpha Ages of Plutonic Rocks, Bokan Mountain Area, Alaska

Abstract. *Most of the granitic rocks in the Bokan Mountain area, southeastern Alaska, are early Paleozoic (probably Ordovician) judged by potassium-argon and lead-alpha age measurements. The Bokan Mountain Granite, the youngest intrusive unit in the area, belongs to a Mesozoic plutonic episode. These age measurements are the first direct evidence for the emplacement of early Paleozoic granitic intrusive rocks close to the Pacific margin of North America.*

Potassium-argon and lead-alpha age measurements indicate that most of the granitic rocks in the Bokan Mountain area are Paleozoic in age, thus providing the first documentation of Paleozoic intrusive rocks in western North America contiguous to the Pacific Ocean. The results also indicate a possible source for granitic clasts in the middle Paleozoic conglomerates that occur elsewhere in southeastern Alaska.

The Bokan Mountain area, about 189 km² of the southern part of Prince of Wales Island (Fig. 1), is underlain largely by a complex assemblage of granitic rocks ranging from pyroxenite to syenite and peralkaline granite (*1*). Quartz diorite, diorite, granodiorite, and quartz monzonite are the dominant rock types. The granitic rocks intrude metasedimentary and metavolcanic rocks in the northern part of the area; metamorphic rocks also occur as small screens or pendants. Intrusive relationships among the granitic rocks indicate that the more mafic rocks were emplaced earlier than the felsic types. The Bokan Mountain Granite is the youngest intrusive unit in the area. It is a peralkaline granite which forms a boss approximately 8 km² in area that is surrounded by a roughly concentric alteration aureole approximately 3 km wide. Alteration of the quartz monzonite and granodiorite in the aureole is characterized by albitization of plagioclase, chloritization of biotite, and local silicification.

Table 1. Potassium-argon age for plutonic rocks, Bokan Mountain area, Alaska (*10*). The numbers in parentheses indicate the number on Fig. 1.

K_2O (%)	Ar^{40}_{rad} (10^{-10} mole/g)	$\frac{Ar^{40}_{rad}}{Ar^{40}_{total}}$	Age (10^6 yr)
	Riebeckite (1)		
1.72	4.819	0.83	181 ± 8
	Riebeckite (4)		
1.46	4.215	0.82	186 ± 8*
	Hornblende (5)		
0.392	2.792	0.43	431 ± 21
	Biotite (6)		
4.06	24.75	0.96	372 ± 18
	Hornblende (7)		
0.628	4.691	0.57	446 ± 22

Decay constants for K^{40}:
$\lambda_\epsilon = 0.585 \times 10^{-10}$ year^{-1}
$\lambda_\beta = 4.72 \times 10^{-10}$ year^{-1}
Atomic abundance of
$K^{40} = 1.19 \times 10^{-4}$

* Age reported previously by Wasserburg and others (*8*).

According to Buddington and Chapin (*2*) the prebatholithic rocks of southern Prince of Wales Island are Devonian in age. No fossils have been found in the Bokan Mountain metamorphic rocks, and their possible Devonian age is based on correlation with fossiliferous rocks in other parts of Prince of Wales Island.

Criteria for dating (in the field) the granitic rocks in the Bokan Mountain area are meager, but like the other granitic rocks of southeastern Alaska, they were previously assigned a Mesozoic age (*2, 3*). The granitic rocks here intrude metamorphic rocks of possible Devonian age and are cut by dikes of possible Tertiary age (*1*). The Coast Range batholith on the mainland intrudes rocks as young as Middle and Late Jurassic and Early Cretaceous and has been considered to be Late Jurassic to Early Cretaceous in age (*2*). The plutons in the islands west of the Coast Range generally have been considered to be satellitic to the batholith and, by inference, of the same age. Measurement of the lead-alpha ages of zircon suggests a Mesozoic age for granitic rocks in two southeastern Alaska localities (*4*)—near Taku Inlet south of Juneau and near Tolstoi Point in the central part of Prince of Wales Island. Potassium-argon ages of 163 and 186 million years confirm the Late Triassic or Early Jurassic age suggested by field relationships of the Coast Range batholith in two critical areas in western Canada (*5*). In other localities, however, the potassium-argon ages range from early Mesozoic to early Tertiary (*6*).

For the present study, minerals were concentrated from large specimens collected from rock outcrops, except samples 1 and 4, which consist of euhedral riebeckite crystals, 0.6 to 1.8 cm long, weathered from the peralkaline granite. For the potassium-argon analyses (Table 1) the estimated uncertainty in determining the concentration of each nuclide is approximately 2 percent. The plus-or-minus value assigned to each potassium-argon age is the estimated standard deviation of analytical precision, exclusive of possible systematic errors introduced by an uncertainty in the value of the decay constant for electron capture of K^{40}. For the lead-alpha ages the plus-or-minus quantity is an estimate of the analytical uncertainty of the spectrographic and alpha-activity measurements of lead. The plus-or-minus does not include possible errors due to uncertainty of the thorium/uranium ratio in the zircon, to the presence of primary common lead, or to possible gain or loss of parent or daughter isotopes.

The results presented in Tables 1 and 2 clearly show that granitic rocks of two different ages occur in the area. The analyses of two different riebeckite samples indicate a Late Triassic or Early Jurassic age for the Bokan Mountain Granite according to recent compilations of the geological time scale (*7*). Andesitic dikes, probably Tertiary in age (*1*), are the only igneous rocks in the area younger than the Bokan Mountain Granite, but these dikes rarely cut the granite. Also, the crystal structure of riebeckite is similar to that of hornblende which has been shown by many workers to retain argon quantitatively under conditions of moderate metamorphism. Thus, the possible thermal metamorphic effects on the Bokan Mountain Granite probably can be considered negligible. The difference between the argon ages of riebeckite (samples 1 and 4) and the lead-alpha age of zircon (sample 3) is larger than the analytical uncertainties. But the lead-alpha method is only a reconnaissance technique, and a detailed explanation of this discordance will require an isotopic analysis of the zircon.

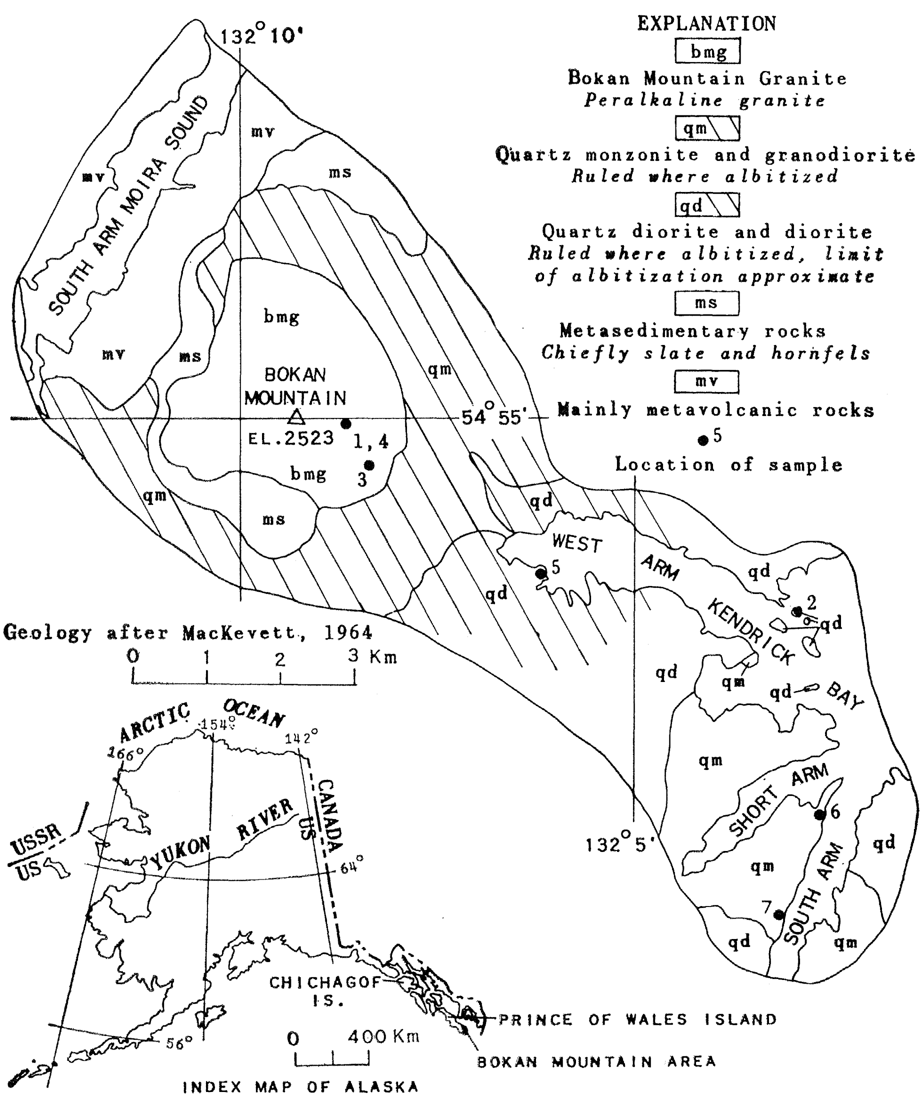

Fig. 1. Generalized geologic map of part of the Bokan Mountain area.

Table 2. Lead-alpha age for plutonic rocks, Bokan Mountain area, Alaska.

No. on Fig. 1	Mineral	Alpha counts (mg^{-1} hr^{-1})	Pb* (ppm)	Calculated age† (10^6 yr)
3	Zircon	319	31.0	240 ± 30
2	Zircon	133	28.4	510 ± 60

* Average of duplicate determination. † Lead-alpha ages (rounded to nearest 10 million years) were calculated from the equations: $t = CPb/\alpha$, where t is the calculated age, in millions of years; C is a constant based upon the thorium-uranium ratio, which was assumed to be 1 in the zircons dated, and has a value of 2485; Pb is the lead content, in parts per million; α is the alpha counts per milligram-hour; and $T = t - \frac{1}{2} kt^2$, where T is the age in millions of years, corrected for decay of uranium and thorium, and k is a decay constant based upon the uranium-thorium ratio and has a value of 1.56×10^{-4}.

The ages of hornblende from samples 5 and 7 indicate an early Paleozoic age, probably Ordovician (*7*), for the quartz diorite and quartz monzonite units. The age for sample 6 is about 15 percent less than the hornblende ages, and may reflect the metamorphic effects of the peralkaline granite pluton. We consider the 446-million-year age for hornblende (sample 7) the best value for the age of the older intrusive rocks, because the sample locality lies outside the alteration aureole surrounding the peralkaline granite. However, the apparent age of sample 5, from a locality within the alteration aureole, agrees, within experimental error, with the age of sample 7. These data suggest that the 446-million-year date may be a realistic estimate of the time of emplacement of the older intrusive rocks. The lead-alpha age of zircon from quartz diorite is slightly higher than the two hornblende dates, but the difference is within analytical uncertainty.

The potassium-argon ages require a revision of the previous assignment to the Devonian age of the metamorphic rocks in the northern part of the Bokan Mountain area. The metamorphic rocks must be Ordovician or older, but their relationship to other Ordovician or pre-Ordovician rocks in southeastern Alaska, such as the Wales Group (*2*), is not known. Our results also require a revision of the ages previously assigned by MacKevett (*1*) to the intrusive rocks of the area. The Bokan Mountain Granite has been considered to be possibly Cretaceous or Tertiary in age, and the other granitic rocks possibly Cretaceous. Our data indicate a Late Triassic or Early Jurassic age for the Bokan Mountain Granite and an early Paleozoic, probably Ordovician, age for the other granitic rocks in the area.

The presence of granitic detritus in Silurian and Devonian conglomerate units in southeastern Alaska has been known since the early 1900's (*2*). The detritus indicates a pre-Silurian plutonic source, but no source had been documented until this study. The older intrusive rocks of the Bokan Mountain area may have been one source of the detritus. Work presently in progress indicates that early Paleozoic granitic rocks occur on Chichagof Island (Fig. 1); probably other areas of early Paleozoic intrusive rocks will be found in southeastern Alaska.

Potassium-argon ages of approximately 350 million years in two areas of western Canada (*5, 9*) are the only additional direct evidence for a Paleozoic granitic event in the North American Cordillera. But both of these areas are more than 800 km east of the Pacific Ocean. Thus, the Bokan Mountain data provide the first direct evidence for the emplacement of early Paleozoic granitic intrusive rocks along the Pacific margin of North America.

MARVIN A. LANPHERE
E. M. MACKEVETT, JR.
U.S. Geological Survey, Menlo Park, California
T. W. STERN
U.S. Geological Survey, Washington, D.C.

References and Notes

1. E. M. MacKevett, Jr., *U.S. Geol. Surv. Bull. No. 1154* (1964).
2. A. F. Buddington and T. Chapin, *U.S. Geol. Surv. Bull. No. 800* (1929).
3. J. T. Dutro, Jr., and T. G. Payne, *Geologic Map of Alaska*, U.S. Geological Survey (1957).
4. J. J. Matzko, H. W. Jaffe, C. L. Waring, *Am. J. Sci.* **256**, 529 (1958).
5. H. Baadsgaard, R. E. Folinsbee, J. Lipson, *Bull. Geol. Soc. Am.* **72**, 689 (1961).
6. J. E. Muller, *Can. Dept. Mines Tech. Surv. Geol. Can. Paper* **61–17**, 98 (1961).
7. J. L. Kulp, *Science* **133**, 1105 (1961); A. Holmes, *Trans. Edinburgh Geol. Soc.* **17**, 183 (1960).
8. G. J. Wasserburg, G. D. Eberlein, M. A. Lanphere, *Geol. Soc. Am. Spec. Paper* **73**, 258 (1962).
9. J. A. Lowdon, *Can. Dept. Mines Tech. Survey Geol. Surv. Canada Paper* **60–17**, 6 (1960).
10. Potassium and argon analyses for sample 4 were made by M. A. Lanphere at the California Institute of Technology, Pasadena, California. All other analyses were made in the Menlo Park, California, and Washington, D.C., laboratories of the U.S. Geological Survey: potassium analyses by H. C. Whitehead and L. B. Schlocker; argon analyses by M. A. Lanphere; alpha-activity measurements by T. W. Stern; and spectrographic lead analyses by C. S. Annell, Harold Westley, H. J. Rose, Jr., and H. W. Worthing.
11. Publication authorized by the director, U.S. Geological Survey.

27 April 1964

Origin of Ice Ages: Pollen Evidence from Arctic Alaska

Abstract. *Pollen analysis of radiocarbon-dated samples from the arctic coastal plain of Alaska shows that vegetation of 14,000 years ago reflected a climate colder than the present, and that there has been a progressive warming, culminating in the present cold arctic climate. The record indicates that the Arctic Ocean has been covered with ice since the time of the Wisconsin glacial maximum, suggesting that the essential condition of the Ewing and Donn hypothesis for the origin of ice ages, that the Arctic Ocean be ice-free up to 11,000 years ago, cannot be met.*

A theory for the origin of ice ages put forward by Ewing and Donn (*1, 2*) requires that the Arctic Ocean be unfrozen as a condition for glacial advance. Livingstone has pointed out (*3*) that, if polar climatic changes were out of step with those of the rest of the world as required by the theory, the vegetation changes in circumarctic lands would be out of step with those to the south of the ice sheets. Livingstone put forward evidence from pollen that vegetation changes in Northern Alaska during the last 8000 years were not out of step with those of temperate regions, but the objection was raised (*4*) that this record did not penetrate the glacial period and thus could not be used to test the hypothesis. A series of samples from the Northern Alaskan coastal plain has now been obtained, which enables the pollen record to be extended to include the glacial period. This record can be used to test the proposition that the Arctic Ocean was ice-free during glacial times.

The samples used in this study were collected (*5*) from Point Barrow and Ikpikpuk on the northern coastal plain of Alaska, and from Umiat and Killik in the arctic foothills (Fig. 1). The materials are from the organic horizons of buried soils, buried peat, or material thawed from ice-wedges. I have analyzed the pollen content of the samples, following procedures described elsewhere (*6*).

In Fig. 2, the samples are arranged according to age (*7*) so that the pollen spectra of successive time intervals can be compared. It is important to note, however, that Fig. 2 is not strictly comparable to a standard pollen diagram, since the ordinate does not represent a continuous section through sediments. The less abundant types of pollen are not included in Fig. 2.

The pollen spectra may be compared with pollen zones found to be applicable to fossil pollen sequences in various parts of Arctic Alaska (*6, 8–10*), and particularly with the pollen zones of a sediment core at Umiat (*11*). The top four samples in Fig. 2 can, on the basis of their alder content, be assigned to zone III. The pollen spectra of these four samples appear similar, if allowance is made for their geographic spread.

It appears that the vegetation and climate of the Arctic coastal region have been rather stable over the last 4000 years. There is a 5000-year gap in the record at this point, followed by a group of four samples (*e* to *h*) with radiocarbon ages of close to 9000 years. These four samples are all from organic soils which may have been buried at about the same time (*12*). The four pollen spectra differ mainly in the content of pollen types, willow (*Salix*) and heaths (*Ericaceae*), which may be expected to be influenced by local factors, and thus to reflect characteristics of the several sites rather than climatic regimens. Changes in the grass-sedge (Gramineae-Cyperaceae) ratio also seem to have little climatic significance in arctic pollen diagrams (*6, 8, 11*). On the basis of the modest birch con-