# The Togiak Basalt, a New Formation in Southwestern Alaska

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CONTRIBUTIONS TO STRATIGRAPHY

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# THE TOGIAK BASALT, A NEW FORMATION IN SOUTHWESTERN ALASKA

By J. M. HOARE and W. L. COONRAD

ABSTRACT

The Togiak Basalt (new) in southwestern Alaska underlies an area of about 450 km' in the lower part of the Togiak River valley. Most of this Quaternary formation is preserved in a graben between northeast-trending faults. It consists of tholeiite and alkali-olivine basalt flows and a prominent volcanic butte—a tuya formed by a subglacial basaltic eruption. The tuya consists of palagonitized glassy tuff and pillow lava capped by glassy subaerial flows of alkali-olivine basalt. The magnetic polarity of the flows on the valley floor is normal. A potassium-argon age determination (0.758±0.2 m.y.) shows that the flows erupted during the present (Brunhes) polarity epoch and are probably 0.55 to 0.7 million years old. The tuya is younger than the flows because it overlies them and erupted while the valley was filled with ice, probably during one of the major glacial events. Radiocarbon dating of glacial deposits indicates major glacial advances about 12,000 years ago and more than 39,000 years ago. The Togiak Basalt is petrologically similar to, and coeval with, late Cenozoic volcanic rocks in many other areas of western Alaska.

## INTRODUCTION

The Togiak Basalt, here named for the Togiak River and Togiak Bay, consists of the volcanic rocks of late Cenozoic age that erupted in the Togiak River valley in the Goodnews Bay and Hagemeister Island quadrangles of southwestern Alaska. The first known reference to these rocks was made in 1898 by J. E. Spurr, who identified them as olivine basalt and assigned them a Tertiary age (Spurr, 1900, p. 140, 231). During later reconnaissance mapping (Hoare and Coonrad, 1961a, b), the basalt was assigned a Pliocene or early Pleistocene age because it was believed to have erupted after the main features of the valley had been cut by the Togiak River but before the valley was glaciated. The volcanic origin of a prominent butte that rises abruptly above the floor of Togiak River valley was also recognized, and the butte was assumed to be of the same age as, and genetically related to, the flows on the valley floor. During recent geologic mapping (Hoare and Coonrad, 1978 a, b), it became evident that the volcanic butte is younger than these flows and that it erupted while the valley was full of glacial ice.

The type section for the Togiak Basalt (figs. 1 and 2) is designated the exposures in the sea cliff east of Togiak Bay (SW1/4 sec. 1, T. 15 S., R. 66 W., Hagemeister Island D–1 quadrangle). The reference section (figs. 1 and 2) is designated the exposures in the steep gully on the northwest side of the prominent volcanic butte and about 1 km southwest of the northwest corner of the butte (SW1/4 sec. 7, T. 12 S., R. 64 W., Goodnews A–4 quadrangle).

Radiometric age-dating and chemical analyses of rocks of the Togiak Basalt obtained during the recent investigation confirm the late Cenozoic age and basaltic composition of the formation.

## DISTRIBUTION, THICKNESS, AND STRATIGRAPHIC RELATIONS

The Togiak Basalt is mostly concealed by overlying glacial deposits. It apparently underlies most of the lower part of the Togiak River valley east of the Togiak River as well as the coastal plain east of Togiak Bay and forms the prominent butte — the Togiak tuya — above the floor of the Togiak River valley. Three or more isolated flow remnants of the Togiak Basalt occur in the Nayorurun River valley (fig. 1), and glacial erratics derived from the massive flows occur on the Walrus Islands at least 30 km south of the seacoast. The elevation of other ice-deposited basalt boulders on the mountains west of Togiak River valley suggests that they were deposited by a glacier at least 500 m thick.

Not included in the formation are two isolated hills near the east mouth of the Togiak River for which the village of Twin Hills is named. The hills consist of mafic and intermediate-composition intrusive and extrusive rocks that resemble an older volcanic unit of probable early Tertiary age, exposed on Hagemeister Island and in the sea cliffs about 15 km southeast of the map area.

The lower flows of the Togiak Basalt are well exposed in the sea cliffs east of Togiak Bay and in cutbanks along the Togiak, Pungokepuk, and Nayorurun Rivers (fig. 1). At most exposures only one or two flows are visible, and it seems likely that the formation is generally less than 20 m thick. North of the Pungokepuk River (fig. 1), where horizontal flows form a low plateau that rises 75 to 100 m above the valley floor, the formation is much thicker. Evidence of the general thinness of the formation is a gravity profile made across the Togiak River valley near the seacoast. There is no appreciable difference between gravity measurements made over the basalt flows in the valley and measurements made over older rocks of Mesozoic age outside the valley.

In the Nayorurun Valley and at two or three localities along the east side of the Togiak Valley where the base of the Togiak Basalt is exposed, the flows rest uncomformably upon deformed sedimentary and volcanic rocks of Mesozoic age. The base of the formation is presumably exposed at one place in the sea cliffs east of Togiak Bay, where a massive flow overlies unconsolidated iron-stained sand and gravel.

## LITHOLOGIC CHARACTER

### LOWER PART

The Togiak Basalt consists largely of undeformed subaerial tholeiite and alkali-olivine basalt flows (table 1) characterized by well-developed columnar jointing and generally 3 m to 10 m thick with vesicular ropy tops. The columns are generally 1 to 2 m in diameter but are smaller in the finer grained flows. Most of the flows are gray, medium-grained, nonporphyritic rock with a loose diktytaxitic texture; some flows are dense fine-grained black rock with small olivine phenocrysts. The flows consist of labradorite, augite, olivine, and accessory magnetite. The fine-grained darker flows also have interstitial glass.

Most, or all, of the medium-grained flows with diktytaxitic texture contain many vertical or near vertical vesicle cylinders (Goff, 1976), 2 to 6 cm in diameter and 10 to 60 cm long, of fine-grained, generally glassy, vesicular basalt. The walls of the vesicular cylinders are sharply defined in the host basalt containing sparse scattered vesicles. There is no gradation between the vesicular texture of the cylinders and the diktytaxitic texture of the host basalt. The fine-grained dark flows do not contain vesicle cylinders.

### UPPER PART (THE TOGIAK TUYA)

In addition to the widespread flows, the Togiak Basalt forms an unusual and prominent butte. The shape, location, composition, and structure of this butte indicate that it was a subglacial volcano. Volcanoes of this type have been recognized in Iceland (Sigvaldason, 1968, Jones, 1969, 1970) and in British Columbia, where Mathews (1947) defined them as "tuyas."

The Togiak tuya, 6 km by 2.5 km, is an isolated rectangular volcano that erupted from or near the Togiak fault near the east side of the Togiak River valley (fig. 1). It is elongate northeastward parallel to the regional structure and to the flow of glacial ice. The sides are steep to precipitous except at the southwest end, where the slope is

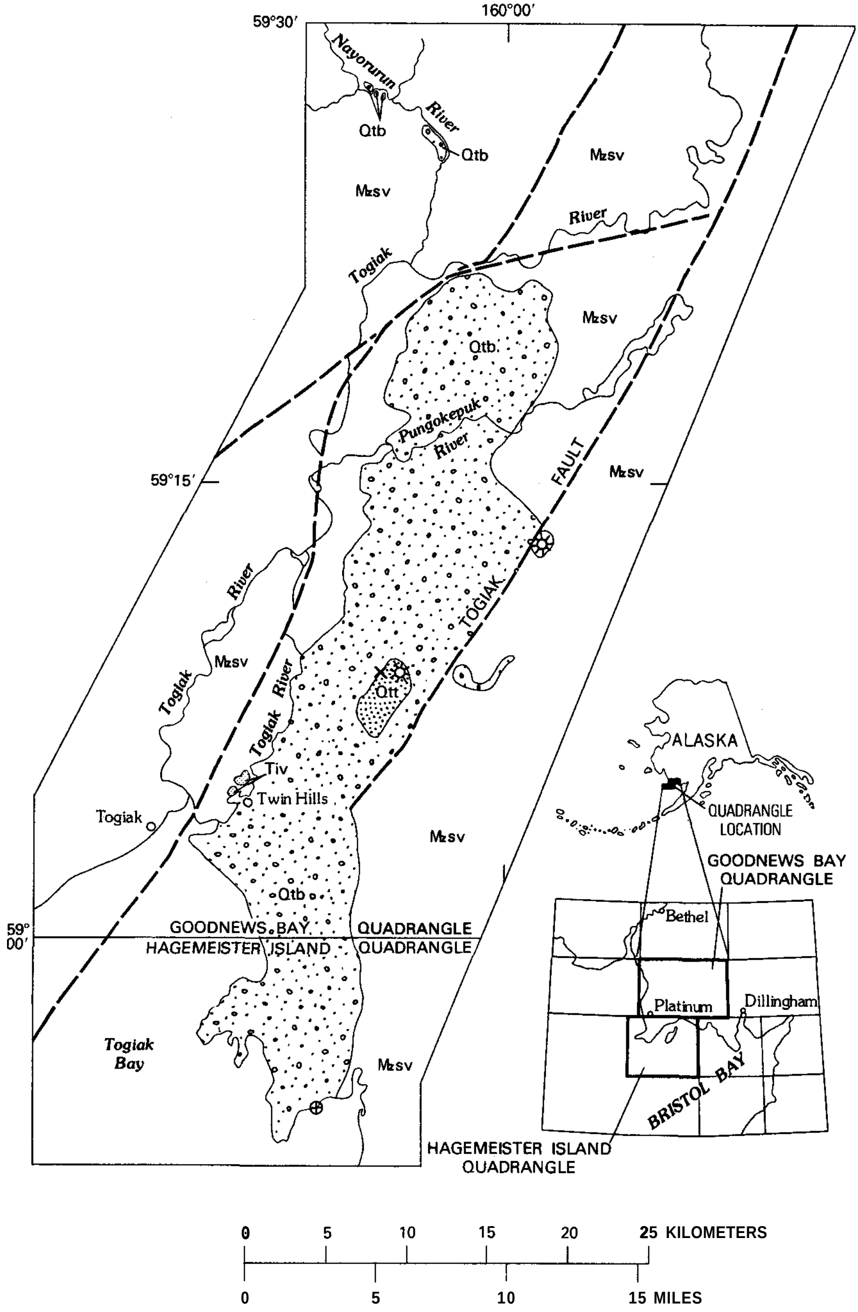


FIGURE 1.— Generalized geologic map of lower part of Togiak River valley, southwestern Alaska, showing location of type and reference sections and distribution of Togiak Basalt. Unconsolidated deposits and plutonic rocks not shown.

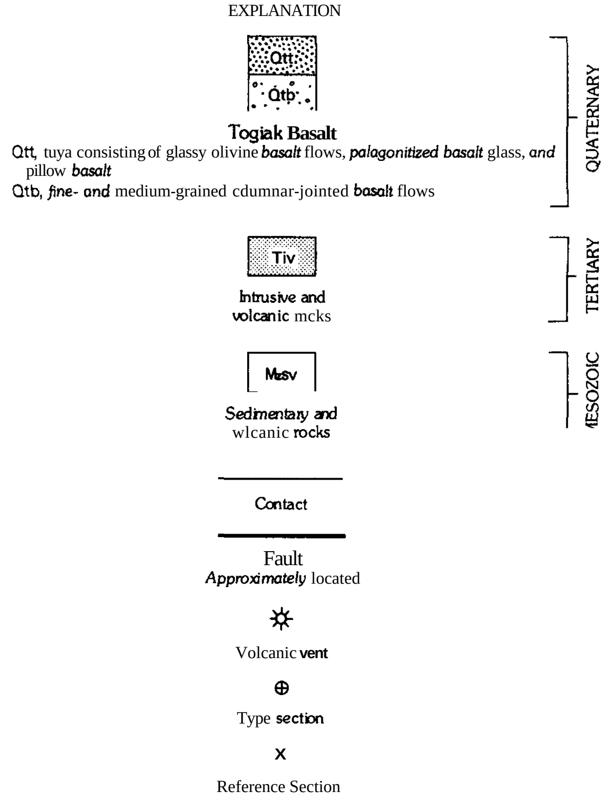


FIGURE 1.—Continued.

TABLE 1.—Chemical analyses of the ***Togiak*** Basalt

[Rapid-rock analysis by method of Shapiro (1975, p. 43–54). Analyst: Hezekiah Smith. From Hoare and Coonrad. 1978a, p. 199]

| Sample | M124635W 1 | M124639W 2 | M124638W 3 |
|---|---|---|---|
| $SiO_2$ | 51.7 | 49.5 | 48.6 |
| $Al_2O_3$ | 15.4 | 14.7 | 14.9 |
| $Fe_2O_3$ | 1.3 | 1.0 | 1.7 |
| FeO | 8.7 | 9.6 | 8.7 |
| MgO | 8.5 | 10.0 | 9.2 |
| CaO | 8.6 | 8.0 | 9.0 |
| $Na_2O$ | 3.7 | 3.8 | 3.5 |
| $K_2O$ | .67 | 1.0 | 1.4 |
| $H_2O^+$ | .24 | .27 | .93 |
| $H_2O^-$ | .06 | .13 | .42 |
| $TiO_2$ | 2.0 | 2.2 | 2.4 |
| $P_2O_5$ | .36 | .42 | .48 |
| MnO | .12 | .13 | .14 |
| $CO_2$ | .03 | .02 | .03 |
| Total | 101 | 101 | 101 |

1. Tholeiite from Row farming sea cliffs an east side of Togiak Bay.
2. Alkali-olivine basalt from valley floor 20 km north of tuya.
3. Alkali-olivine basalt from capping flow on southeast rim of tuya.

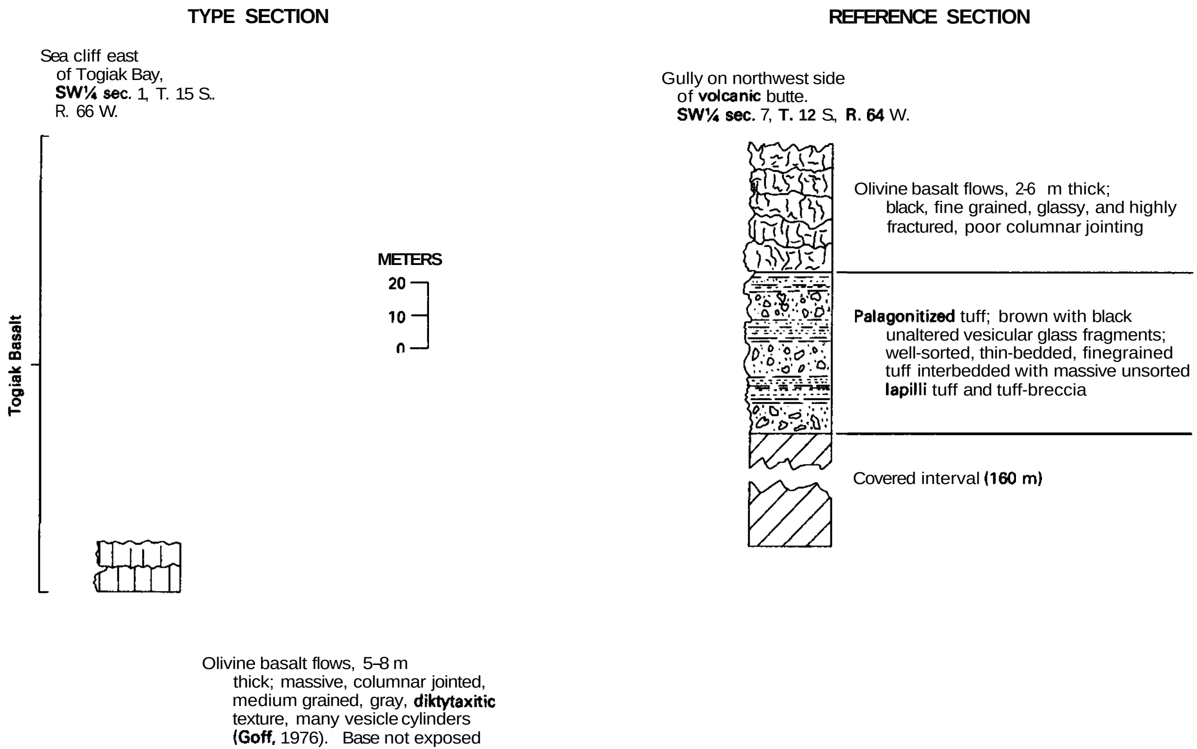


FIGURE 2.—Type and reference sections of the Togiak Basalt.

moderate. The top of the tuya, about 300 m above the valley floor, is a 15-$km^2$ plain that slopes a little more than 1° southwestward. The tuya consists of olivine basalt in the form of glassy tuff (sideromelane), fine-grained subaerial flows, and pillow basalt. The tuff is altered to brown palagonite containing small unaltered black vesicular glass fragments. The structure of the tuff indicates that it probably was erupted from vents forming two cones, both near the northeast end of the tuya. The structural apex of one cone is on or near the northeast rim of the tuya. The summit is capped by 40 to 50 m of the black fine-grained, highly fractured subaerial flows that overlie the palagonitized tuff to the northeast and pillow basalt to the southwest. The only known exposure of pillow basalt is a few meters below the northwest rim and a few hundred meters southwest of a valley that opens northwestward near the center of the tuya. A more complete description of this tuya was published in an earlier paper (Hoare and Coonrad, 1978 a, p. 193–201).

## GEOLOGIC SETTING AND ORIGIN

Most of the Togiak Basalt is in a graben between northeast-trending faults (fig. 1). A high west-facing scarp developed along the Togiak fault defines the east side of the graben; a concealed fault that coincides with the course of the Togiak River defines the west side. The concealed fault is inferred from the observation that the course of Togiak River is alined with the southeast side of Hagemeister Island, a southeast-facing fault scarp (Hoare and Coonrad, 1961b; Hoare, 1961). In addition, contours on the aeromagnetic map of the Goodnews quadrangle (Alaska Division of Geological and Geophysical Surveys, 1973; Griscom, 1978) are offset along a line that coincides with the course of the Togiak River. The upthrown side of the fault is apparently on the west because deformed rocks of Mesozoic (Jurassic?) age underlie the valley west of the river but are overlain by horizontal basalt flows a short distance east of the river. The north end of the graben is probably defined by a fault trending about N. 70" E.

The distribution of the flows and their geologic setting suggest that they probably erupted from vents localized along the faults and were later displaced by the faults. But most of the vents have been destroyed by glacial ice or buried by glacial deposits. Only one cone remnant of preglacial age has been recognized, a highly oxidized, scoriaceous breccia that caps a small shelf projecting out from the east valley wall about 170 m above the valley floor 25 km north of the coast (fig. 1). The location of the cone remnant on the west-facing fault scarp suggests about 170 m of vertical uplift on the Togiak fault since the cone formed. About 9 km south of the cone remnant at the same elevation is a larger shelf underlain by horizontal basalt flows. This shelf curves around the south end of a ridge and extends a short distance up a tributary valley where the flows overlie deformed rocks of Mesozoic (Jurassic?) age.

A second probable center of volcanic activity is the plateau north of the Pungokepuk River. The greater thickness of the flows in this area suggests that they accumulated near a volcanic vent. The top of the plateau is covered with glacial deposits and vegetation and has not been examined on the ground. From the air, several lakes are visible; most are irregular in shape and very shallow. But one small round lake is deep blue and appears to be much deeper. It may be an old crater. The flow remnants in the Nayorurun River valley are at a lower elevation than the basalt plateau. They probably came from a volcano on top of the plateau and flowed up the Nayorurun River valley, where they overlie deformed sedimentary rocks of Mesozoic (Jurassic?) age.

The third and most prominent eruptive center is the site of the Togiak tuya described here.

## AGE AND CORRELATION

The Togiak Basalt is Quaternary in age. The widespread flows on the valley floor erupted after the main surface features of the valley had been eroded. The radiometric age of a flow on the east side of the basalt plateau was determined by the potassium-argon method to be $0.758\pm0.2$ m.y. (J. G. Smith, written commun., 1976). The magnetic polarity of the flows was determined at several places and found to be normal. The polarity of the flows, together with their radiometric age, indicates that they erupted near the beginning of the present (Brunhes) polarity epoch, which began approximately 0.7 m.y. ago (Cox and others, 1966).

The tuya is clearly younger than the flows on the valley floor because it is built upon them. Because the structure and composition of

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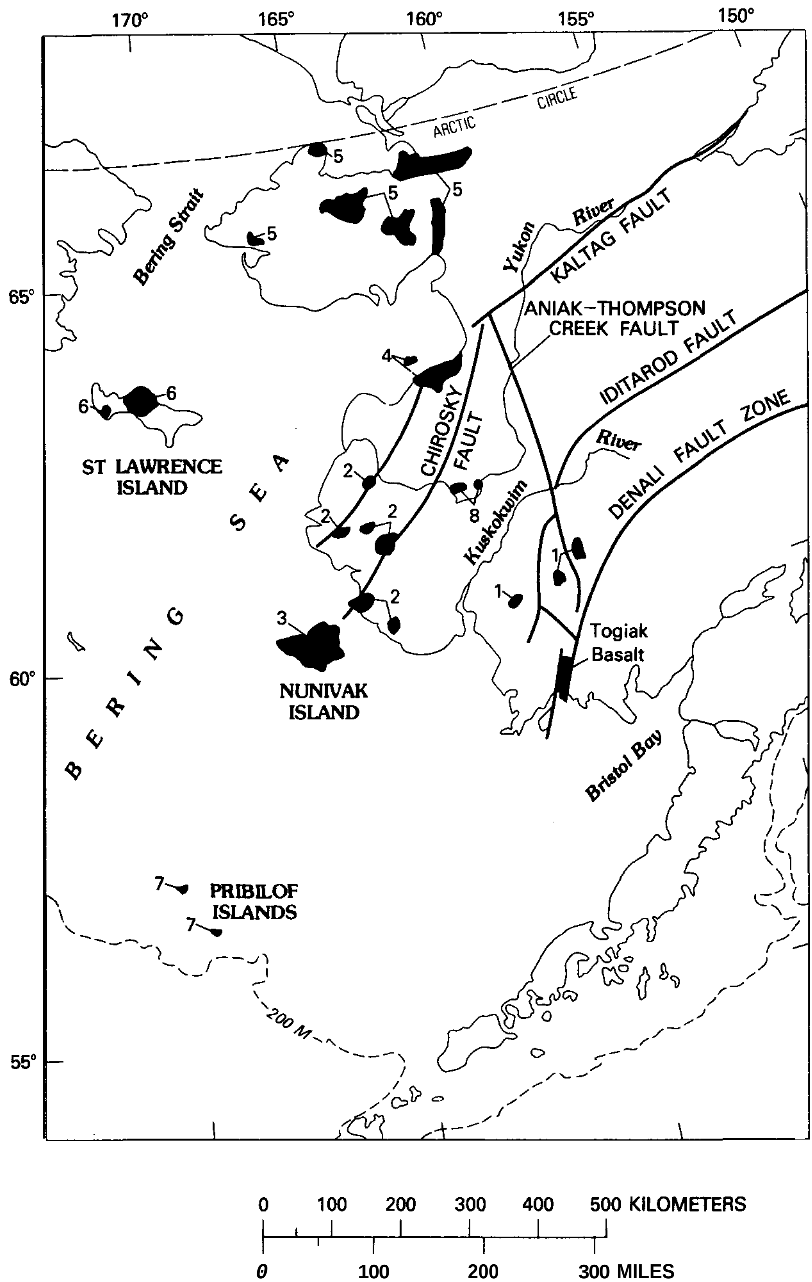
FIGURE 3.—Map showing late Cenozoic basalt in western Alaska and some of the major faults. Localities are: 1, in the valley of the Kwethluk, Kisaralik, and Aniak Rivers in the Bethel quadrangle (Hoare and Coonrad, 1959a; Hoare and Condon, unpub. data, 1970); 2, on Nelson Island and elsewhere on the Yukon-Kuskokwim delta (Coonrad, 1957; Hoare and Condon, 1966, 1968, 1971a); 3, on Nunivak Island (Hoare and others, 1968); 4, in the St. Michael area (Hoare and Condon, 1971b); 5, near Imuruk Lake and elsewhere on Seward Peninsula (Hopkins, 1963; Sainsbury, 1972, 1976); 6, on St. Lawrence Island (Patton and Csejtey, 1971; Hoare and Condon, unpub. data, 1966); 7, Pribilof Islands (Barth, 1956; Cox and others, 1963); 8, Yukon River (Harrington, 1918; Hoare and Coonrad, 1959b). ►

the tuya shows that it erupted beneath a glacier, it must be about the same age as one of the major ice advances. Several radiocarbon age



determinations (M. Rubin, written commun., 1977) made on glacial deposits 80 km southeast of the Togiak River valley indicate that the last two major ice advances occurred about 12,000 years ago and more than 39,000 years ago. It is uncertain when the tuya erupted, but it probably was during the older ice advance, for the northeast end and sides of the tuya have been strongly truncated by glacial ice.

The Togiak Basalt is about the same age and chemical composition as basalt erupted in several other volcanic centers in western Alaska and on the Bering Sea shelf. Most of the other volcanic centers include slightly older basalt and some of them include younger basalt, but all of the centers are late Cenozoic in age. In some of the other volcanic areas, alkali-rich basalt (basanite) occurs in minor amounts, generally <2 percent of the volcanic field.

Late Cenozoic basalt occurs in western Alaska at the localities shown on figure 3.

Numerous radiometric age determinations have been made on these rocks. The oldest age so far recorded, 6 m.y., comes from a sea-level flow at the west end of Nunivak Island (Hoare and others, 1968, p. 385,386). The youngest rocks in two or three eruptive centers are several hundred or a few thousand years old.

Most, if not all, of the late Cenozoic eruptive centers are localized along large faults. It seems likely that they formed during a period of tension and tectonic relaxation following a long period of compressional tectonics that began in early Mesozoic time and continued into early Cenozoic time in western Alaska.

## REFERENCES CITED

Alaska Division of Geological and Geophysical Surveys, 1973, Aeromagnetic map, Goodnews quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-File Report 15, 1 sheet, scale 1:250,000.

Barth, T. F. W., 1956, Geology and petrology of the Pribilof Islands, Alaska: U.S. Geological Survey Bulletin 1028–F, 60 p.

Coonrad, W. L., 1957, Geologic reconnaissance in the Yukon-Kuskokwim delta region, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–223, scale 1:500,000.

Cox, A. V., Hopkins, D. M., and Dalrymple, G. B., 1963, Geomagnetic polarity epochs: Pribilof Islands, Alaska: Geological Society of America Bulletin, v. 77, p. 883–910.

Cox, A. V., Doell, R. R., and Dalrymple, G. B., 1966, Geomagnetic polarity epochs and Pleistocene geochronometry: Nature, v. 198, no. 4885, p. 1049–1051.

Goff, E. F., 1976, Vesicle cylinders formed in vapor-differentiated basalt flows [abs.]: Geological Society of America Bulletin, v. 8, no. 6, p. 887–888.

Griscom, Andrew, 1978, Aeromagnetic map and interpretation of the Goodnews and Hagemeister Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-File Report 78–9–C, 2 sheets, scale 1:250,000, 19 p.

Harrington, G. L., 1918, The Anvik-Andreafsky region, Alaska: U.S. Geological Survey Bulletin 683, 70 p.

Hoare, J. M., 1961, Geology and tectonic setting of lower Kuskokwim-Bristol Bay region, Alaska: American Association of Petroleum Geologists Bulletin, v. 45, no. 5, p. 594–611.
Hoare, J. M., and Condon, W. H., 1966, Geologic map of the Kwiguk and Black quadrangles, western Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–469, scale 1:250,000.
———1968, Geologic map of the Hooper Bay quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–523, scale 1:250,000.
———1971a, Geologic map of the Marshall quadrangle, western Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–668, scale 1:250,000.
———1971b, Geologic map of the St. Michael quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–682, scale 1:250,000.
Hoare, J. M., Condon, W. H., Cox, A. V., and Dalrymple, G. B., 1968, Geology, paleomagnetism, and potassium-argon ages of basalts from Nunivak Island, Alaska: Geological Society of America Memoir 116, p. 377–413.
Hoare, J. M., and Coonrad, W. L., 1959a, Geologic map of the Bethel quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–285, scale 1:250,000.
———1959b, Geologic map of the Russian Mission quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-292, scale 1:250,000.
———1961a, Geologic map of the Goodnews quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–339, scale 1:250,000.
———1961b, Geologic map of the Hagemeister Island quadrangle, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–321, scale 1:250,000.
———1978a, A tuya in Togiak Valley, southwest Alaska: U.S. Geological Survey Journal of Research, v. 6, no. 2, p. 193–201.
———1978b, Geologic map of the Goodnews and Hagemeister Island quadrangles region, southwestern Alaska: U.S. Geological Survey Open-File Report 78–9–B, scale 1:250,000.
Hopkins, D. M., 1963, Geology of the Imuruk Lake area, Seward Peninsula, Alaska: U.S. Geological Survey Bulletin 1141–C, 101 p.
Jones, J. G., 1969, Intraglacial volcanoes of the Laugarvatn region, southwest Iceland—1: Geological Society of London Quarterly Journal, v. 124, p. 197–211.
———1970, Intraglacial volcanoes of the Laugarvatn region, southwest Iceland: Journal of Geology, v. 78, no. 2, p. 127–140.
Mathews, W. H., 1947, "Tuyas," flat-topped volcanoes in northern British Columbia: American Journal of Science, v. 245, no. 9, p. 560–570.
Patton, W. W., Jr., and Csejtey, Béla, Jr., 1971, Preliminary geologic investigations of western St. Lawrence Island, Alaska: U.S. Geological Survey Professional Paper 684–C, 15 p.
Sainsbury, C. L., 1972, Geologic map of the Teller quadrangle, western Seward Peninsula, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–685, scale 1:250,000.
———1976, Geology, ore deposits, and mineral potential of the Seward Peninsula, Alaska: U.S. Bureau of Mines Open-File Report 73–75, 108 p.
Shapiro, Leonard, 1975, Rapid analysis of silicate, carbonate, and phosphate rocks (rev. ed.): U.S. Geological Survey Bulletin 1401, 76 p.
Sigvaldason, G. E., 1968, Structure and products of subaquatic volcanoes in Iceland: Contributions to Mineralogy and Petrology, v. 18, p. 1–16.
Spurr, J. E., 1900, A reconnaissance in southwestern Alaska in 1898: U.S. Geological Survey 20th Annual Report, pt. 7, p. 31–264.