Radiometric Ages of Kodiak Seamount and Giacomini Guyot, Gulf of Alaska: Implications for Circum-Pacific Tectonics

Abstract. *Kodiak Seamount and Giacomini Guyot have been dated at 22.6 ± 1.1 and 19.9 ± 1.0* [2σ *(standard deviation)*] $\times 10^6$ *years, respectively. Concordant whole-rock and plagioclase potassium-argon dates and fission-track apatite ages demonstrate that significant quantities of excess radiogenic* ^{40}Ar *are not present in the dated samples. These seamounts are the northwesternmost edifices of the Pratt-Welker chain, which cuts obliquely across magnetic anomaly patterns in an older northeastern Pacific sea floor. The older of the two dated seamounts is in the Aleutian Trench, apparently about to be subducted. If one assumes that seamounts are generated by plate motion over a fixed hot spot in the mantle, a Pacific-plate motion of 6.6 centimeters per year during early Miocene time may be calculated.*

Kodiak Seamount and Giacomini Guyot are the northwesternmost edifices in the Pratt-Welker chain of seamounts and guyots, located at 56°53′N, 149° 14.9′W and 56°24′N, 146°34′W, respectively (Figs. 1 and 2). Our samples were dredged from the summit area of Giacomini Guyot at a depth of approximately 790 m and from the west flank of Kodiak Seamount at a depth between 3000 and 4000 m. The comparative petrology and geochemistry of these rocks with dredged samples from other North Pacific seamounts have been discussed (*1*).

Alkali basalt was dredged from Giacomini Guyot, and trachyte was dredged from Kodiak Seamount. The analyzed samples were taken from angular blocks recovered from pipe dredge hauls dominated by that particular rock type, rather than by the ice-rafted pebbles, cobbles, and boulders which are frequently dredged from the summit areas of seamounts in the Gulf of Alaska.

The trachyte samples were taken from the core zones of two large "pillow" segments, and the basalt samples were cut from the concave side of an arcuate block rimmed with palagonite. These rocks appear to have erupted in the submarine environment. The samples are vesicular, and vesicles tend to be elongate parallel to the preferred orientation of feldspar laths. Although the dredged blocks display effects of hydration, including palagonitic rinds and the alteration of olivine and pyroxene to iddingsite, the feldspars are virtually unaltered. Groundmass glass is rare to absent.

Plagioclase and apatite were separated from each sample for K-Ar and fission-track dating. Whole-rock K-Ar ages were also determined on samples cut from the centers of the blocks where palagonite was not present. Plagioclase and whole-rock K-Ar dates are concordant within analytical uncertainty for each sample (Table 1), giving mean ages of 22.6 ± 1.1 (2σ) $\times 10^6$ years for the Kodiak trachyte and 19.9 ± 1.0 $\times 10^6$ years for the Giacomini basalt. Apatite fission-track ages are 25.3 ± 4.3 $\times 10^6$ years and 19.3 ± 3.8 $\times 10^6$ years, respectively. The apatite from Giacomini Guyot came from the same sample of basalt, whereas the apatite from Kodiak Seamount was separated from a different but petrographically similar sample of trachyte from the

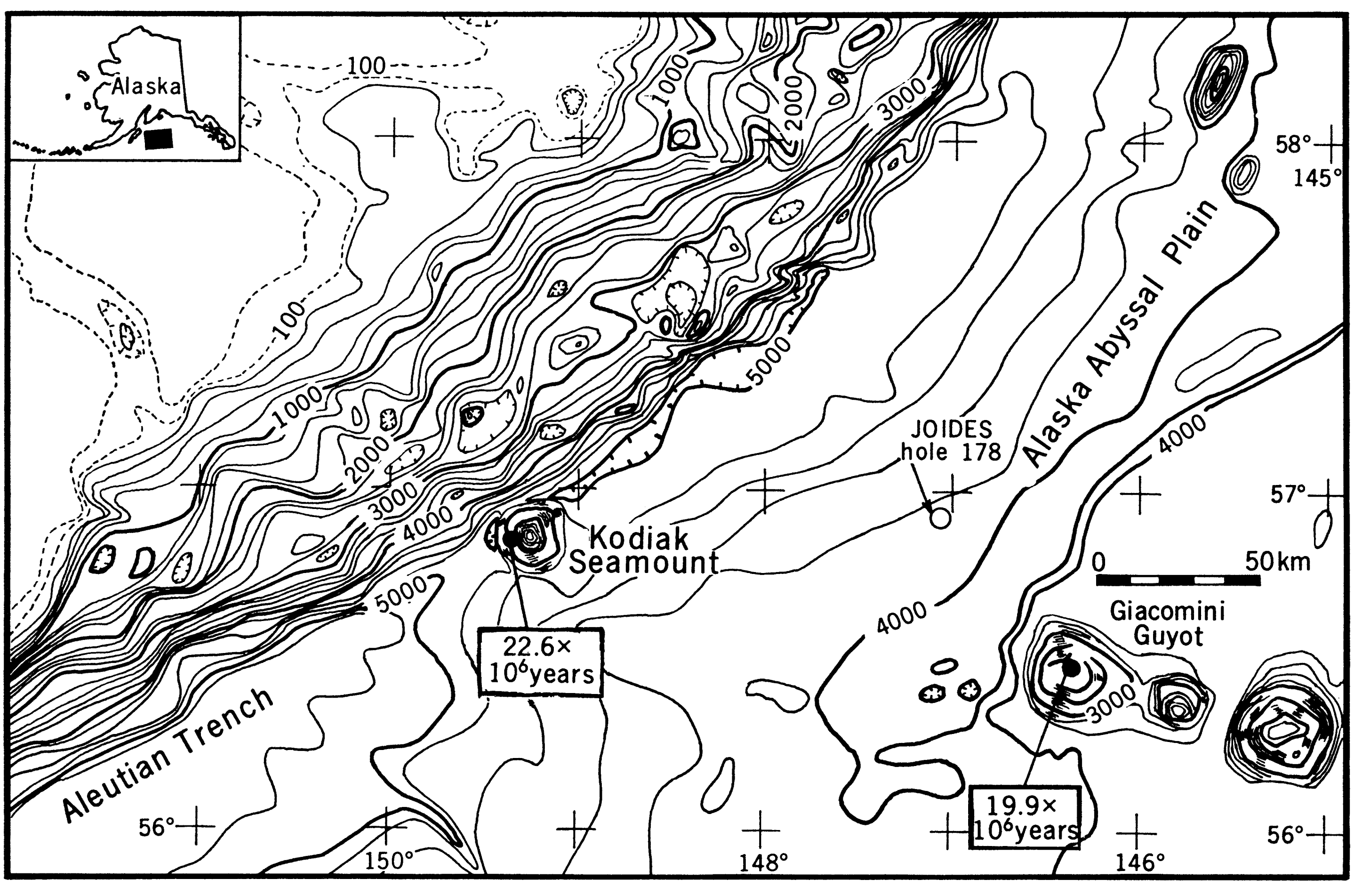

Fig. 1. Radiometric ages and bathymetry of Kodiak Seamount and Giacomini Guyot. Bathymetry from Von Huene (*6*). Depth contours are in meters.

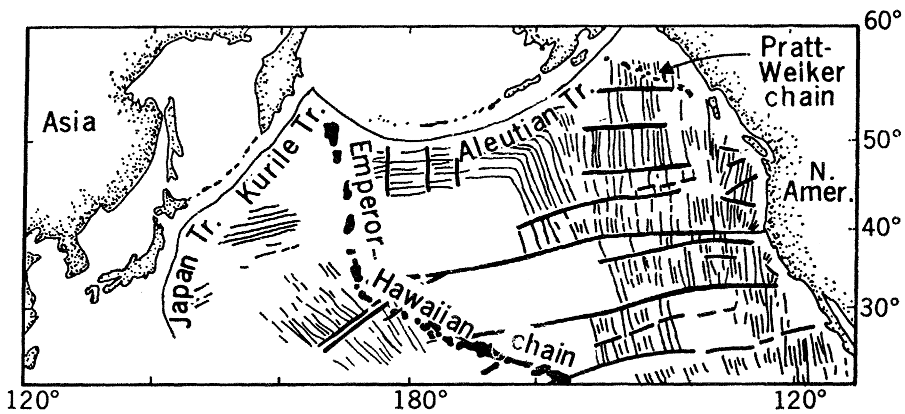

Fig. 2. Magnetic lineations and structural features of the North Pacific from Hayes and Pitman (7), showing the parallelism of the Pratt-Welker and Hawaiian seamount chains. Both chains cut obliquely across the magnetic lineations of the Pacific plate.

same dredge haul. To date, these radiometric ages are the only geochronological data available for samples from the Pratt-Welker chain.

Dalrymple and Moore and subsequent workers (2) have demonstrated the existence of significant amounts of excess ^{40}Ar in modern submarine basalts erupted at depths of 550 m or more. Their work shows that excess ^{40}Ar content is a function of both hydrostatic pressure and cooling rate. Our data offer two independent approaches to the question of excess ^{40}Ar.

1) Excess ^{40}Ar causes overestimates of rock ages, but these are inversely proportional to the ^{40}K content. In spite of the fact that the Kodiak whole rock has more than twice the ^{40}K of its feldspar, and the Giacomini more than six times, in both rocks the whole-rock and feldspar ages are concordant.

2) Fission-track ages are independent of either the ^{40}K or the excess ^{40}Ar content; the fission-track ages of samples from both seamounts are concordant with those from K-Ar dating.

Both of these findings are in agreement with the idea that no excess ^{40}Ar was present in the samples that were analyzed.

Apatite is very susceptible to track loss by heating (3). In most geological materials an apatite fission-track age can be expected to give a minimum age for the sample. Here, where the volcanic rocks have been extruded beneath the ocean and held at ocean-floor temperatures since cooling, little or no annealing is to be expected. If the apatite had been annealed, it would give an apparent age younger than the K-Ar ages. In this case distinguishing between apatite annealing and excess argon would have been difficult. We are confident that the K-Ar ages represent the true ages of the samples, that there is not significant excess argon present, and that there has been no post-eruption heating of the dated samples.

On leg 18 of the JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling (Deep Sea Drilling Project, foraminifera diagnostic of the lowermost Miocene were cored 27 m above basalt in hole 178 (Fig. 1), approximately 60 km north-northwest of Giacomini Guyot (4). According to present radiometric calibrations of foraminiferal chronologies (5), this fauna represents an age of 20 to 21 $\times 10^6$ years before the present. The 27-m interval between the fauna and the top of the basalt consists of typical abyssal pelagic sediments and probably represents a time interval of less than 3 $\times 10^6$ years (4). These data lead to an age estimate of 22 to 23 $\times 10^6$ years for the top of the basalt in hole 178. This age estimate is very similar to our seamount dates and suggests that the sea-floor basalt in the vicinity of hole 178 could have been produced by the same mechanism that produced the seamounts. Moreover, new seismic reflection data show a small hump in the basement near hole 178, possibly suggesting a volcanic edifice (6). Unless there is a major unconformity at the base of the Miocene section, the basalt in hole 178 cannot represent old oceanic crust with an age of 45 to 50 $\times 10^6$ years, as given by the magnetic anomaly data in this area (6, 7). The fact that the postulated volcanic edifice (22 to 23 $\times 10^6$ years) near hole 178 is about 30 km northeast of the main trend of the Pratt-Welker chain is consistent with evidence from earlier studies indicating that deep mantle convection plumes or melting spots have diameters of 150 to 300 km

Table 1. Analytical data for K-Ar and fission-track age determination. We analyzed for potassium with a digital flame photometer (Instrumentation Laboratories, model 343) using the $LiBO_2$ flux fusion technique and mineral calibration standards (10). We determined argon by isotope dilution, using ^{38}Ar tracers, and a mass spectrometer (152.4-cm radius) (Nuclide Corporation) equipped with automated peak stepping and a digital data-acquisition system. The K-Ar dating was done at the Geophysical Institute, University of Alaska; the fission-track dating was done at the U.S. Geological Survey, Denver, Colorado. Plagioclase and whole-rock K-Ar dates are from the same rock sample. Fission-track apatite ages were determined by the population method (11); rad., radiogenic.

Sample	Material dated	K_2O (% by weight)	^{40}Ar (rad.) (%)	^{40}Ar (rad.)/ ^{40}K ($\times 10^{-3}$)	ρs* ($\times 10^5$)	Tracks	ρ† ($\times 10^5$)	Tracks	ϕ‡ ($\times 10^{15}$)	Age§ ($\times 10^6$ years)	$\pm 2\sigma$ ($\times 10^6$ years)
				Kodiak Seamount							
KS-3-56	Plagioclase	1.53	77.6	1.379						23.4	1.2
KS-3-56	Trachyte	3.34	67.5	1.305						22.2	1.1
KS-3-56	Trachyte	3.34	70.8	1.300						22.1	1.1
KS-3-1	Apatite				0.715	298	2.50	1041	1.20	21.0	4.3
KS-3-1	Apatite				0.943	393	2.36	982	1.20	29.3	4.3
				Giacomini Guyot							
GS-58	Plagioclase	0.30	79.6	1.159						19.7	1.0
GS-58	Plagioclase	0.30	43.0	1.207						20.5	1.0
GS-58	Basalt	1.82	83.1	1.162						19.8	1.0
GS-58	Basalt	1.82	86.6	1.165						19.8	1.0
GS-58	Apatite				0.238	99	0.799	200	1.06	19.3	3.8

* Number of spontaneous (fossil) tracks per square centimeter. † Number of induced tracks per square centimeter. ‡ Thermal neutron dose (neutrons per square centimeter). § Decay constants are as follows: $\lambda_\epsilon = 0.585 \times 10^{-10}$ year^{-1}; $\lambda_\beta = 4.72 \times 10^{-10}$ year^{-1}; $^{40}K/K_{total} = 1.19 \times 10^{-4}$ mol/mol; $\lambda_f = 6.85 \times 10^{-17}$ year^{-1}.

(8, 9); resulting volcanic edifices need not always erupt along narrow linear trends comparable in width to that of the seamounts themselves.

Using the mean ages of 22.6 $\times 10^6$ years for Kodiak Seamount and 19.9 $\times 10^6$ years for Giacomini Guyot and their separation of 177.8 km, we calculate a Pacific-plate motion of 6.6 cm/year during early Miocene time. This calculation assumes a hypothesis of seamount generation by plate motion over a fixed hot spot in the mantle (8); it also assumes that the time of construction of each volcanic edifice was short, and, therefore, that dates measured on dredged samples are reasonable estimates for the times of initiation of volcanic activity at each seamount. These assumptions are well documented for the more extensively studied Hawaiian-Emperor chain (9), although the second assumption can be strictly applied only to the tholeiitic, shield-building stage of volcanic activity.

Our data, combined with plate tectonic concepts, suggest that the Pratt-Welker seamount chain consists of a series of volcanoes, all younger than 23 $\times 10^6$ years, cutting obliquely across structural trends shown by magnetic anomaly patterns in an older northeastern Pacific sea floor (Fig. 2). The oldest dated volcanic edifice is in the Aleutian Trench, apparently about to be subducted. Future dating of successive seamounts southeastward along the chain from Giacomini Guyot should show a corresponding decrease in age and provide significant data on Pacific-plate motion during the last 23 $\times 10^6$ years.

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Earthquakes of Strike-Slip Type in Central California: Evidence on the Question of Dilatancy

Abstract. *The travel times of compressional waves from quarry explosions of well-known origin times, measured at the University of California network of seismographic stations for the period 1961 to the present, have been examined for evidence of premonitory changes prior to earthquakes of moderate magnitudes in the region. Velocities to seven station sites are generally constant to within ± 1 percent, with occasional deviations of ± 2 percent. Variations seem to bear no correlation to earthquake occurrence and are probably due to a combination of reading errors and changes in the source location within the quarry.*

Evidence is accumulating in support of premonitory variations in seismic wave velocities in the source regions of earthquakes. Studies in the Soviet Union (*1*) and in New York (*2*) indicate that this premonitory change is seen in the ratio of the compressional and shear velocities, V_P/V_S, which usually has a value of about 1.75. Recent data of Whitcomb *et al.*

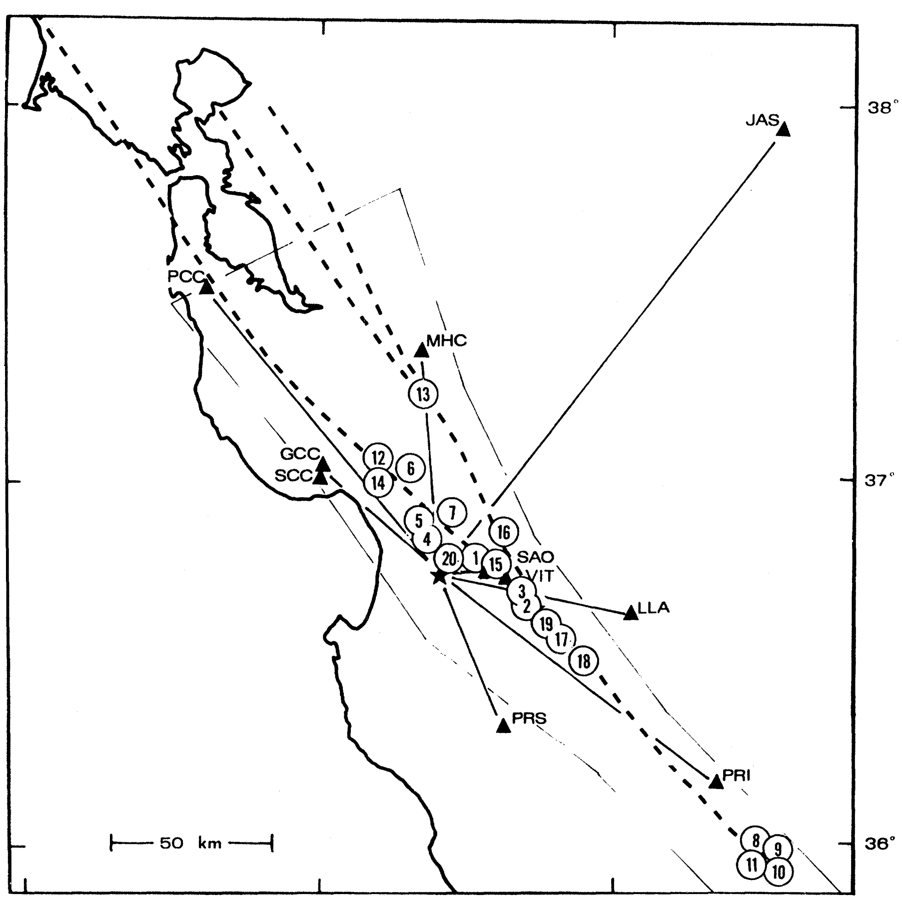

Fig. 1. Map of central California showing the quarry location (star) and seismographic stations (triangles) used in this study. Circled numbers give the locations of all earthquakes since 1960 with $M \geqq 4.5$ within the outlined region.