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THE K-Ar AGE OF THE BLACK POINT DIKE ON OAHU, HAWAII, AND ITS RELATION TO THE YARMOUTH INTERGLACIATION

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THE ISLANDS OF HAWAII, especially Oahu and Lanai, contain an abundant record of Pleistocene eustatic stands of the sea preserved as reef-limestone, beach deposits, wave-cut benches and notches, and marine terraces (Stearns, 1935, 1966, 1974; Ruhe and others, 1965). Evidence for as many as 33 ancient emerged and submerged shorelines has been described (summarized by Stearns, 1978).

One of the best developed of the emerged Hawaiian shorelines is the Kaena shoreline. Kaena time was a warm interval during which corals and coralline algae thrived. As a result, more reef deposits of Kaena age exist in Hawaii, mostly on Oahu, than the total of all previous stands of the sea. These deposits are especially well developed in Lualualei Valley and on the Ewa coral plain. The type locality for the Kaena reef (Stearns, 1935) is at Kaena Point, Oahu, where the reef deposits consist of the Kaena Limestone (Lum and Stearns, 1970; Stearns, 1974), overlain by calcareous beach sand

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and fossiliferous beach conglomerate. At Kaena Point the upper part of the beach conglomerate is covered with talus, but an outcrop in which the top of the beach conglomerate is exposed at 32 m above mean sea level occurs 1.43 km east of Kaena Point. The evidence from these two localities indicates that the Kaena sea stood about 30 m above present sea level (Stearns, 1935; Ruhe and others, 1965).

Thirty-meter terraces are worldwide, and many, including the Kaena, are thought to have formed during the Yarmouth Interglaciation (Stearns, 1974). The stratigraphy on Oahu shows that the Kaena stand was followed by the Waipio -107 m low stand (Illinoian), the Waimanalo $+7.6$ m stand (Sangamon), and the Mamala -107 m low stand (Wisconsinan) of the sea (Stearns, 1974).

On the southeast slope of Diamond Head, Oahu, a dike of nepheline basanite that cuts the Kaena Limestone offers an unusual opportunity to determine a younger limit for the age of the Kaena sea stand and, by correlation, the Yarmouth Interglaciation.

DESCRIPTION OF THE LOCALITY AT BLACK POINT

The dike at Black Point was first described and illustrated by Hitchcock (1906) and subsequently by Wentworth (1926). Later it was mapped by Stearns (1939). Wentworth recognized two limestones, one older and one younger than the dike, and noted that the older limestone did not contain basalt cobbles. The dike crops out for 30 m on the southeast side of Diamond Head, Honolulu, Oahu, and forms a sea cliff 5 m high, 75 m east of Kulamanu Place (Fig. 1). The dike is 1 m wide, strikes northwest, and cuts dense reef Kaena Limestone. On the east side of the dike, cobble conglomerate of the Waimanalo stand of the sea lies unconformably on the Kaena Limestone. In 1977 all except 2 m of the contact of the dike with the limestone was covered by a wall.

The top of the dike is gone, but it lies perhaps only 20 m below the pre-erosion surface and probably was a feeder of a lava flow. It was probably emplaced at the time of eruption of the nearby Black Point Basalt of the Honolulu Volcanic Series (Winchell, 1947).

The Black Point Basalt was briefly described by Cross (1915) and chemically analyzed by Winchell (1947), who classified it as a nepheline basanite. Both the dike and the flow are fresh, porphyritic olivine basanites with 12 to 18 percent olivine phenocrysts as much as 0.5 mm in diameter and 7 to 14 percent of groundmass olivine. Total olivine in the two rocks, however, is nearly identical. Groundmass plagioclase ranges in amount

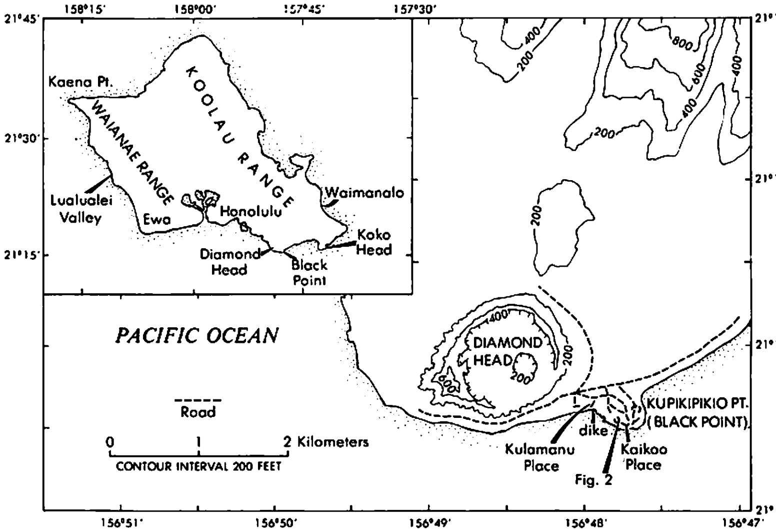

FIGURE 1.—Index map of Oahu, Hawaii, showing location of the Black Point dike, the Black Point Basalt, and the geologic section of Figure 2.

from about 10 to 14 percent. Both rocks contain about 2 to 5 percent nepheline. Winchell (1947) reported 10.5 percent normative and about 6 percent modal nepheline in the flow. The remainder of the minerals comprise clinopyroxene (45 to 50 percent), opaque Fe-Ti oxides (10 to 12 percent), and glass, minor zeolites, and apatite (1 percent). The dike is slightly coarse-grained and contains more modal plagioclase and nepheline and less Fe-Ti oxides and clinopyroxene than the flow. The only alteration noted in either sample was thin rims of iddingsite around fresh olivine cores.

Like the dike, the Black Point Basalt is younger than the Kaena Limestone. The relations are exposed in an abandoned quarry 150 m east of the dike on Kaikoo Place (Fig. 2). In a different locality nearby, a shallow cut at the upper end of Kaikoo Place, Black Point Basalt rests on the Diamond Head Tuff which, in turn, rests on the Kaena Limestone at about 27 m above sea level. A stone wall now conceals the Diamond Head Tuff at this second locality.

K-Ar DATING

Samples of both the flow and dike were crushed and sieved to a size of 0.5 to 1.0 mm. An aliquant of the sized fraction was pulverized to less than

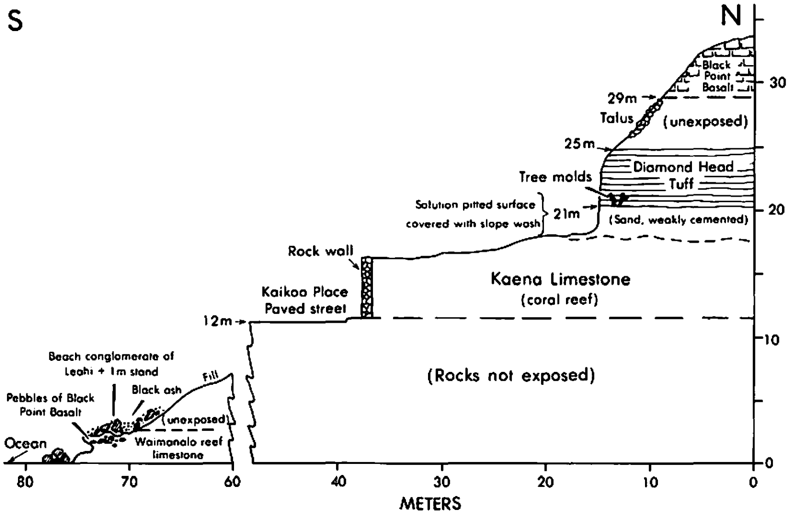

FIGURE 2.—Geologic section at the abandoned quarry on Kaikoo Place, Oahu, showing the relation of Black Point Basalt and Diamond Head Tuff to the Kaena Limestone. After Stearns (1966).

0.074 mm and used for potassium measurements; the remainder was used for the argon analyses. Potassium was determined by flame photometry using lithium metaborate fusion (Ingamells, 1970). Argon analyses were by isotope dilution using a ^{38}Ar tracer. Samples were baked overnight at 280° C prior to fusion in ultra-high vacuum. Mass spectrometry was done with two rare-gas mass spectrometers. One is a conventional 15.24 cm 60° sector, single collector instrument with analog data acquisition. The other is a computerized, 22.86 cm, 90° sector, quintuple-collector mass spectrometer with high-speed digital data acquisition and on-line data reduction. Details of the K-Ar techniques are described by Dalrymple and Lanphere (1969).

The analytical data and calculated ages (Table 1) are consistent with the petrographic evidence that the dike and flow were formed during the same eruptive episode. The reproducibility of the argon measurements on the dike sample is within the analytical precision expected for young rocks with 4 to 5 percent of radiogenic Ar. The two analyses on the flow sample, however, differ by nearly 40 percent, which adds to the uncertainty in the calculated age of the flow. If the second flow analysis is omitted, however, the calculated age of the flow is 0.43 million years, which is in good agreement with the age of 0.41 ± 0.04 obtained for the dike. We consider the age of the dike to represent the best age for both the dike and the flow. The age of 0.48

TABLE 1

K-AR MEASUREMENTS ON WHOLE-ROCK SAMPLES OF THE DIKE AND FLOW AT BLACK POINT, OAHU, HAWAII

SAMPLE	K_2O (WGT. PERCENT)*	ARGON: WEIGHT (grams)	ARGON: $^{40}Ar_{RAD}$ (mol/gram)	ARGON: $\frac{100\ ^{40}Ar_{RAD}}{^{40}Ar_{total}}$	CALCULATED AGE† (10^6 years)
Dike	0.931 ± 0.002	27.580	0.531×10^{-12}	4.5	0.41 ± 0.04
		27.189	0.572	4.1	
Flow	0.879 ± 0.020	19.489	0.539	5.1	0.48 ± 0.08
		19.009	0.746	4.3	

*Mean and standard deviation of four measurements.

†$\lambda_\epsilon = 0.581 \times 10^{-10}\ yr^{-1}$, $\lambda_\beta = 4.962 \times 10^{-10}\ yr^{-1}$, $^{40}K/K = 1.167 \times 10^{-4}$ mol/mol. Errors are estimates of the standard deviations of precision (Cox and Dalrymple, 1967). Calculated ages are weighted means, where weighting is by the inverse of the variance of the individual measurements.

$\pm$ 0.08 m.y. for the flow, however, is not significantly different from the age of the dike at the 95 percent level of confidence.

Our age of 0.41 $\pm$ 0.04 m.y. is somewhat older than the age of 0.305 m.y., recalculated using the decay constants used in this paper, obtained by Gramlich and others (1971) for two samples of the Black Point Basalt.

DISCUSSION

The K-Ar age of 0.41 $\pm$ 0.04 m.y. for the Black Point dike provides an important minimum age for the Kaena stand of the sea and, by correlation, for the Yarmouth Interglaciation. The stratigraphy at Black Point indicates that the Kaena Limestone had been exposed above sea level long enough to have received a layer of slope wash and to have supported the growth of trees before deposition of the Diamond Head Tuff and the subsequent eruption of the Black Point Basalt. If the dike is correlative with the Black Point Basalt, then the Kaena Limestone must have been above sea level when intruded by the dike. Thus, the highest stand of the sea at the end of Kaena time was appreciably more than 0.41 m.y. ago. Veeh (Stearns, 1973, p. 3483) dated a specimen of coral from the Kaena Limestone in Lualualei Valley and found a $^{230}Th/^{234}U$ age of >0.2 m.y. and a $^{234}U/^{238}U$ ratio corresponding to an age of about 0.6 ± 0.1 m.y. These data are in good agreement with the minimum K-Ar age of the Kaena Limestone and suggest that the Yarmouth Interglaciation may have ended about 0.5 m.y. ago.

We would like to point out that a problem first stated by Stearns (1973) is still unresolved. The east half of Oahu is formed by the subareal remnant of Koolau Volcano. The youngest exposed lavas of Koolau Volcano are dated by the K-Ar method at about 2 ± .1 m.y. (McDougall, 1964; Doell and Dalrymple, 1973). After cessation of volcanism, the volcano was incised with valleys more than 2,400 m deep. It then subsided by at least 1,800 m, and the valleys were backfilled with sediments and coral reef deposits. Lum and Stearns (1970) believe that the entire Pleistocene may be recorded by such sediments found in the drill holes at Waimanalo, Oahu.

In contrast, the coast at Black Point is exposed to the full erosional power of the waves, yet the Black Point flow is not deeply eroded. If the vast amount of change in the morphology of Koolau Volcano since its extinction is compared with the slight amount of erosion that has occurred at Black Point during the last 0.4 m.y., then either the K-Ar chronology for Oahu is incorrect or the conditions that allowed the deep erosion of the Koolau Range have not existed during the late Quaternary.

SUMMARY

The Black Point basaltic dike cuts the Kaena Limestone, thought to be of Yarmouth age, on the southeast slope of Diamond Head, Oahu, Hawaii. The dike, a nepheline basanite, has a K-Ar age of 0.41 ± 0.04 million years, and was probably emplaced at the time of eruption of the Black Point Basalt, which has a K-Ar age of 0.48 ± 0.08 m.y. The Kaena Limestone is the most extensive Pleistocene reef deposit formed in Hawaii during any of the high eustatic stands of the sea. The Kaena shoreline was about 30 m above present sea level. The dike was intruded into the limestone after the reef deposits had been exposed above sea level long enough to have been covered with slope wash and trees. Our date is consistent with a uranium series date of 0.6 ± 0.1 m.y. on coral from the Kaena Limestone. The data suggest that the Yarmouth Interglaciation ended about 0.5 m.y. ago.

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