no water escapes to yet undiscovered deeps; and (iii) no heat is being supplied other than that of the incoming water. Since the first assumption is probably incorrect the 104°C is clearly a minimum value. Brewer *et al.* (*8*) made a similar calculation based on changes in water depth rather than volume and estimated a minimum value of the input brine temperature as 113°C. B. Fournier (personal communication) estimates an input temperature of about 120°C based on the SiO_2 content of the brine.
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Magnetic Noise Preceding the August 1971 Summit Eruption of Kilauea Volcano

Abstract. *During the course of an electromagnetic survey about Kilauea Volcano in Hawaii, an unusual amount of low-frequency noise was observed at one recording location. Several weeks later an eruption occurred very close to this site. The high noise level appeared to be associated in some way with the impending eruption.*

During July 1971, we made an electromagnetic survey of the summit area of Kilauea Volcano, Hawaii, to study the internal structure of the volcano.

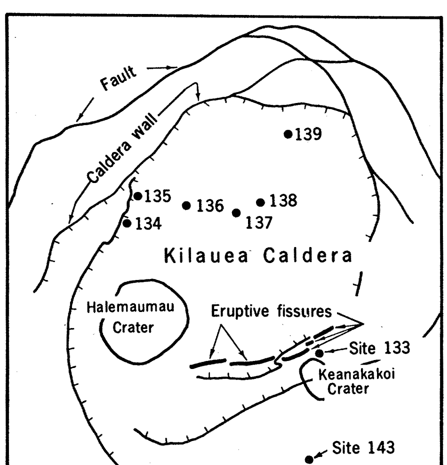

Fig. 1. Map of the summit of Kilauea Volcano showing the location of the eruption of 14 August 1971 and several sites at which electromagnetic field records were made. Other recording sites lie off the map, and site 133 was the only location at which the unusual magnetic noise was recorded. Caldera faults are as indicated by Peterson (*1*).

In so doing, we generated an electromagnetic field by passing current steps through a long grounded wire located several kilometers northwest of Kilauea Caldera. We detected the electromagnetic field by recording the voltage output from a coil of wire lying on the ground. From these measurements, the electrical conductivity distribution of the rocks within the caldera and to the south and west was mapped. Typically, the coil of wire consisted of 26 turns, with a perimeter of 305 m. On the afternoon of 22 July, we attempted to record the electromagnetic field at a site on the north lip of Keanakakoi Crater, a crater which is located only a few hundred meters from the southern rim of Kilauea Caldera (Fig. 1). However, we found that the coil produced relatively large background noise voltages, amounting to several tens of microvolts at frequencies less than 0.1 hz (Fig. 2A). The noise level was higher by at least an order of magnitude than that which had been observed at any of the preceding 32 recording sites (see Fig. 2B for an example), and the attempt to obtain a record was abandoned. At that time, we felt that the high noise level was caused by a faulty recording system.

On the next day, however, the survey was resumed with observations being made successfully at several additional recording sites before we returned to the Keanakakoi site. Again, we recorded a high level of noise characterized by a long period. It was then evident that this noise was characteristic of the site and not an instrument fault. However, no further effort was made to explain the phenomenon.

Twenty-three days later, on 14 August Kilauea Volcano erupted close to the Keanakakoi recording site (*1*). Lava fountained from a series of fissures along a 60°N–70°E trend extending from near the southeastern edge of Halemaumau Crater toward Keanakakoi Crater (Fig. 1). The Keanakakoi recording site (site 133) lies about 150 m from the closest fissure. The next closest recording site (site 143) lies almost 1.5 km south of the fissures. It is difficult to escape the impression that the unusually high noise level at recording site 133 was in some way associated with the impending eruption.

As with any fortuitous observation of this sort, the association cannot be very convincing unless some reasonable explanation can be put forward. One explanation would be that slow movement of magma into the incipient fissure zone would generate magnetic noise because the magma would behave as conductive material moving in the earth's magnetic field. In fact, a relatively high level of seismic activity had been ob-

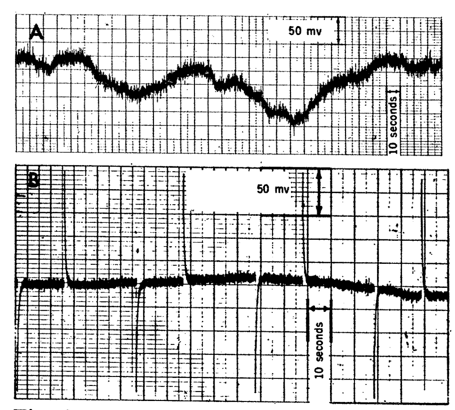

Fig. 2. Sections of records of the voltage produced from a vertical-axis induction loop with an effective area of 151,000 m^2. (A) At recording site 133, on the edge of Keanakakoi Crater. The record was obtained at approximately 1530 hours H.S.T., 22 July 1971, and exhibits an unusually high noise level. (B) At recording site 115, on 16 July 1971. This record shows typical background noise levels. The spikes with alternating polarity are the transient electromagnetic signals transmitted from the grounded-wire source and are not related to the phenomenon being discussed here.

served in the summit area during June and July, such as might accompany the movement of magma (2). An alternate explanation might be that magma intruded near the surface to form a conductive zone in which induction from magnetic micropulsations would take place. Magnetic micropulsations are taking place continuously, being characterized by fluctuations in the earth's magnetic field with amplitudes of a gamma or less, with periods of 10 seconds or longer. These fluctuations induce current flow in the earth in proportion to the conductivity of the earth. The secondary magnetic field resulting from these induced currents is normally directed in the horizontal plane, so that little or no effect would be noticed with a coil lying on the earth, such as we used in our observations. However, when there are strong lateral changes in conductivity, the secondary magnetic field may have a significant vertical component which might be detected (*3*). In either case, the fact that the unusual noise was not detected at recording sites a few kilometers away suggests that the source of the noise was shallow, probably less than a kilometer deep.

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17 December 1971

Buried Caldera of Mauna Kea Volcano, Hawaii

Abstract. *An elliptical caldera (2.1 by 2.8 kilometers) at the summit of Mauna Kea volcano is inferred to lie buried beneath hawaiite lava flows and pyroclastic cones at an altitude of approximately 3850 meters. Stratigraphic relationships indicate that hawaiite eruptions began before a pre-Wisconsin period of ice-cap glaciation and that the crest of the mountain attained its present altitude and gross form during a glaciation of probable Early Wisconsin age.*

Mauna Kea (4205 m) is the highest of five massive shield volcanoes comprising the island of Hawaii, and it last erupted about 4500 years ago as determined by ^{14}C dating (*1*). The bulk of the mountain consists of primitive oceanic basalts of the Hawaiian tholeiite suite, but the top is thinly capped by a carapace of more alkaline lithologies, hawaiite being the predominant rock type. Unlike such recently active Hawaiian volcanoes as Kilauea and Mauna Loa, Mauna Kea possesses no obvious summit caldera. Instead, the crest of the mountain consists of a complex array of cinder cones and lava flows at the apex of three rift zones that trend west, south-southeast, and east-northeast. Geologists have long speculated on the possible existence of a caldera that may lie buried beneath the cap of young lavas and cones that mantle the summit area (*2–4*). Evidence gathered during current studies of the upper slopes of Mauna Kea points to the probable existence of a buried caldera and places limitations on its dimensions and age.

Detailed mapping and study of flow stratigraphy on the upper slopes of the volcano indicate that a relatively abrupt transition occurs from flows of olivine basalt and picrite basalt, which constitute the bulk of the exposed Hamakua Group, to overlying hawaiite lavas of the Laupahoehoe Group (*5*). Except along the three principal rift zones, where hawaiite flows and associated cinder cones comprise an unusually thick section, Laupahoehoe lavas and intercalated sheets of glacial drift seldom exceed 100 m in thickness. Nearly continuous exposures in Pohakuloa and Waikahalulu gulches on the south flank of the mountain show that Hamakua lavas extend high up the slopes of the volcano and that the entire Laupahoehoe section thins progressively downslope, being no more than several flows thick at the south base of the mountain (Figs. 1 and 2). At 3600 m in Pohakuloa Gulch the Laupahoehoe section is at least 110 m thick, but it thins to no more than 10 m at an altitude of 2200 m. Hamakua flows are exposed west of Pohakuloa Gulch in a large kipuka that extends upslope to about 2600 m, and seven other outcrops occur within and near Pohakuloa Gulch between 2800 and 3850 m. Two linear belts of outcrop also are found along Waikahalulu Gulch between 2700 and 3800 m.

Along both gulches the contact between the Hamakua and Laupahoehoe groups slopes south at approximately 230 m/km (*6*). If this contact were projected upward beyond the highest outcrops of Hamakua lavas, it would reach an altitude of nearly 4400 m above the summit of the volcano (Fig. 2). Therefore, the basaltic core of the upper part of the mountain approximates a cone, truncated at about 3800 m and mostly buried by younger lavas. The underlying geometry of the top of the volcano is evident where the topography has not been masked by younger cinder cones. For example, in the reach between Douglas Cone and Puu Waiau, the land surface undergoes a marked and relatively abrupt change of gradient at about 3850 m, passing from 275 m/km downslope to about 90 m/km above. This summit plateau must reflect the basic underlying structure of the crest of the volcano and is compatible with the concept of a former caldera lying buried beneath the cap of late hawaiite eruptives.

Macdonald (*2*) called attention to the concentric alignment of certain

Table 1. Comparison of the dimensions of the inferred caldera of Mauna Kea with those of other Hawaiian volcanoes.

Caldera	Width (km)	Length (km)	Circumference (km)	Area (km^2)
Mauna Kea	2.1	2.8	8.0	4.5
Kilauea	3.1	4.2	12.6	10.7
Mauna Loa	2.6	4.4	15.3	9.3
Kohala (*3*)	3.2	4.8		