alteration mineralogy. The results of these surveys identified several areas around the inferred caldera boundary where anomalous conditions were indicated to be present (Figure 6). Although several alternative explanations for the data are possible, the most reasonable interpretation of the coincident anomalies is that they are arising from at least a low-level heat source within the Waianae caldera system. On the basis of the results obtained, five sites were identified for future exploratory drilling. The U.S. Navy (the present land owner) has taken these recommendations under advisement, but no exploratory drilling is presently planned.

Another identified potential geothermal area on Oahu that has been investigated is the Mokapu Peninsula on the northern edge of the Koolau caldera. Although a detailed geothermal survey was conducted in this area, little evidence of any thermal anomaly was found. Very limited investigations within the Koolau caldera, performed in conjunction with the Mokapu study, identified a few geochemical anomalies that were tentatively attributed to a low-level thermal anomaly. More extensive surveys in this area, as well as in other parts of Oahu, have been forestalled for the present, primarily due to the low probability for finding a high-temperature resource and the high population densities within the more probable development areas.

C. Maui

The island of Maui (Figure 7) is made up of two major volcanic systems. West Maui is the older and smaller of the two, having an age of at least 1.25 million years to about 600,000; post-erosional activity occurred between about 80,000 and 20,000 years before the present. Haleakala volcano (east Maui) is substantially larger and younger than west Maui; the bulk of the Haleakala shield was built between 1.5 and 0.5 million years ago. Post-erosional volcanism on Haleakala has continued up until the present time, the most recent eruptive activity having occurred in 1790 along the lower southwest rift system.

The preliminary geothermal assessment of Maui identified six areas which were indicated to have some potential for a geothermal resource. These potential areas were identified on the basis of groundwater geochemical and temperature data as well as location and age of most recent volcanism. Three of these areas (Lahaina-Kaanapali, Ukumehame-Olowalu Canyon, and Haleakala northwest rift) are presently under intensive investigation and one other (Haleakala southwest rift) is targeted for field surveys in the near future. The presently available results for the areas being surveyed are as follows:

1. Lahaina-Kaanapali

Low-level groundwater chemical anomalies have been identified in two locations east of Kaanapali. Roughly coincident with these are anomalous soil mercury and radon concentrations possibly associated with nearby post-erosional eruptive centers. Geophysical surveys in this area, however, have been less encouraging. Resistivity soundings and self-potential surveys both indicate normal or near normal subsurface conditions. Further, more detailed work using other geochemical and geophysical techniques will be necessary before the apparent conflict in the data from this area can be resolved.

2. Olowalu-Ukumehame

Groundwater geochemical and temperature data strongly suggest that a thermal anomaly is present in or near Ukumehame Canyon; one Maui-type water tunnel near the mouth of the canyon has encountered groundwater with a temperature of 33°C (significantly above the expected ambient groundwater temperature), which also has a substantially altered chemical composition. In addition, geophysical surveys conducted in this area have identified apparent resistivity and self-potential anomalies. Although it is not presently possible to uniquely assign a temperature to the source of the inferred geochemical and geophysical anomalies, the estimated resource temperature may range from about 60°C to as high as 170°C. Geophysical surveys are continuing in this area in an effort to further characterize the nature of the observed anomaly.

3. Haleakala northwest rift

Initial data acquired in this area indicated that both groundwater chemistry and temperature anomalies are present. More recent soil mercury and radon data have tended to substantiate the initial anomalous interpretation, but limited geophysical surveys, as well as more recent groundwater studies, suggest that the earlier geochemical evidence may be the result of other non-geothermal processes associated with the northwest rift zone. Further geochemical and geophysical surveys, as well as detailed hydrologic modelling of this area, are underway in an effort to confirm this preliminary evaluation.

Preliminary data acquired for both the east and southwest rift systems on Haleakala indicate that these rift systems may have a greater potential for a geothermal resource than any of the other identified areas on Maui. This evaluation is based primarily on the geological evidence of eruptive activity along these rift systems; a large proportion of the post-erosional activity on east Maui occurred along the southwest and east rift systems of Haleakala. Although relatively little other geophysical and geochemical data are available for these areas, more detailed field surveys for both the east and southwest rift systems are planned for the near future.

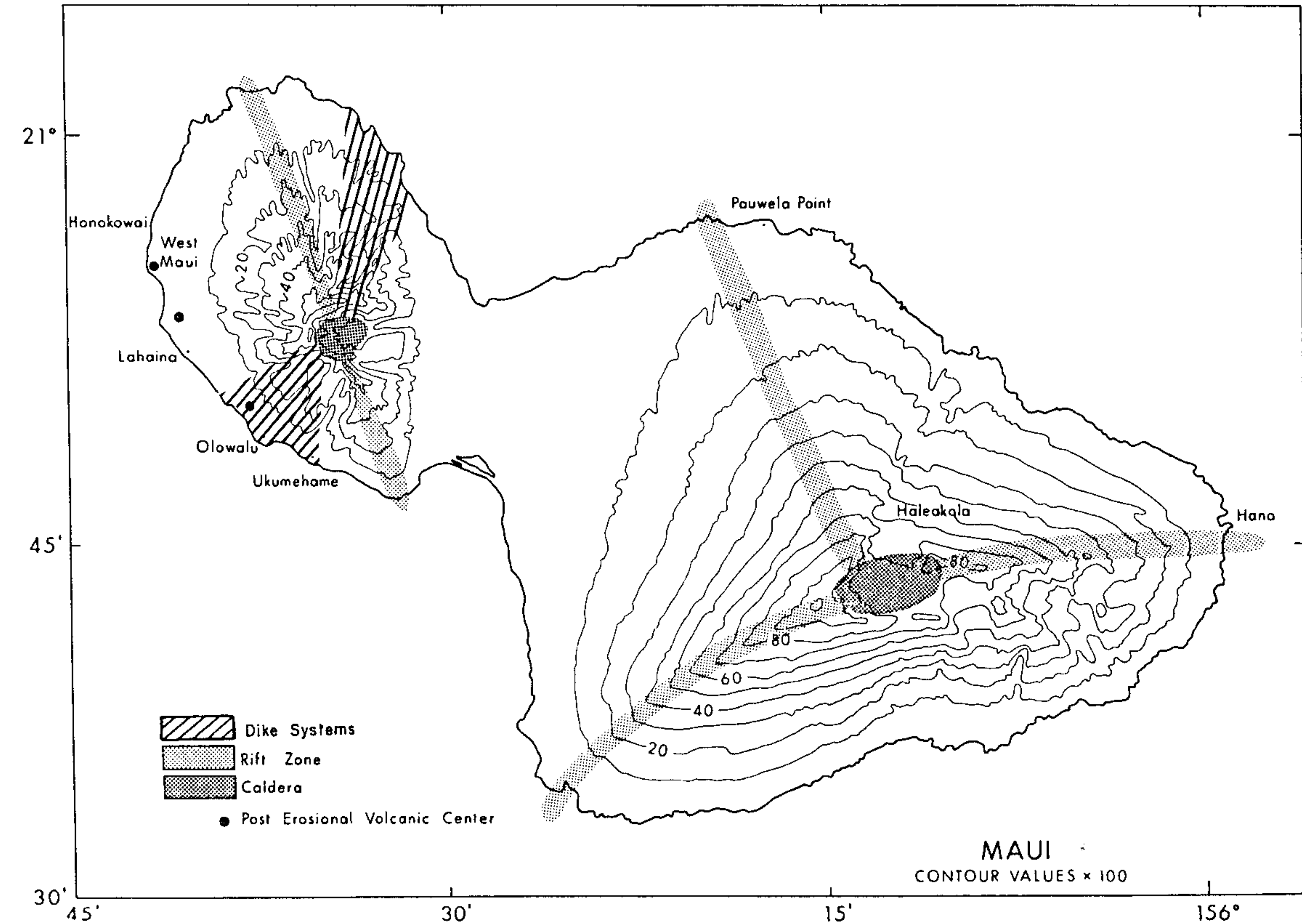
D. Hawaii

The island of Hawaii (Figure 8) is both the youngest and the largest of the Hawaiian chain. The island is made up of five volcanic systems: Kohala is the oldest and is considered extinct; Mauna Kea is the next oldest and is considered dormant; Hualalai, Mauna Loa and, Kilauea have all had eruptive outbreaks during the last two centuries and thus are considered to be still active. The approximate range of ages for each of these volcanic systems are as follows: Kohala, 1.0 million to approximately 0.080 million years before present; Mauna Kea, 1.0 million years to approximately 3,000 years; Hualalai, 750,000 to 180 years; Mauna Loa, 900,000 years to the present; Kilauea, 100,000 years to the present.

The preliminary survey of the geothermal potential of the Big Island identified seven areas which had some evidence for potentially exploitable geothermal resources. Of these seven areas, one, the Kilauea east rift zone, was studied intensively prior to the siting of the University's HGP-A well; three others, Keaau, Kawaihae, and North Kona, are currently being investigated. Based on the data presently in hand, the appraisal of the geothermal potential of each of these areas is as follows:

1. Kilauea east rift

Geophysical and geochemical data acquired for this area during the Hawaii Geothermal Project's exploration program identified several marked anomalies along the surface trace of the rift zone. The HGP-A well penetrated an extremely hot (358°C) reservoir at a depth of approximately 1,900 meters and has thus proven that a resource is present in the lower Puna area (Chen, et al., 1980). Further, more recent geophysical surveys (Zablocki, 1979)



#3 From: Potential Geothermal Resources in Hawaii: A Preliminary Regional Survey or about 1790 (G. Macdonald, pers. comm.) along the southwest rift zone, and thus Haleakala should be considered a dormant, rather than an extinct, volcano.

The structure of Haleakala is similar to that for most other Hawaiian volcanoes (Fig. 19). The major rift zones trend southwest and east from the central caldera complex and the minor rift trends north-northwest from the summit caldera; the minor rift has not been active during the post-erosional phase of activity (Macdonald and Abbott, 1970).

Geophysical surveys

Aeromagnetic surveys have been conducted over the island of Maui (Fig. 20)(Malahoff and Woollard, 1965) and, as was the case with Hawaii, the structural interpretation given (Fig. 21) differs significantly from the surface features observed. It is probable that only those surface features which are crustally controlled correlate well with the magnetic data. One could infer from this fact that the very broad volcanic pipe zone that underlies the West Maui shield has produced the diffuse rift system observed there. This conclusion is partially substantiated by the results of gravity surveys (Fig. 22) (Kinoshita and Okamura, 1965), which also indicate a very broad gravity high beneath West Maui.

There is a similar correspondence between the aeromagnetic and gravity data from Haleakala. Both data sets delineate the major rift system of Haleakala and, whereas the aeromagnetic interpretation indicates two volcanic pipe zones, the gravity surveys indicate a single, very elongate gravity high. The latter interpretation is probably due to the wide spacing of the gravity stations on Haleakala.

At present, neither sufficient seismic nor infrared data are available for Maui or the northern islands to be of use in a geothermal assessment.

Meteorology and hydrology

Although West Maui is not high enough to block the normal trade wind patterns, it does have a significant effect on the local rainfall patterns. The mean annual rainfall on the windward side of West Maui is in excess of 1000 cm/yr (Fig. 23) at the higher altitudes and decreases to about 375 cm/yr on the lower leeward slopes (Taliaferro, 1959). Perennial streams, fed by dike-impounded waters and surface runoff, are common on the southern slopes and often disappear completely during extended periods of dry weather.

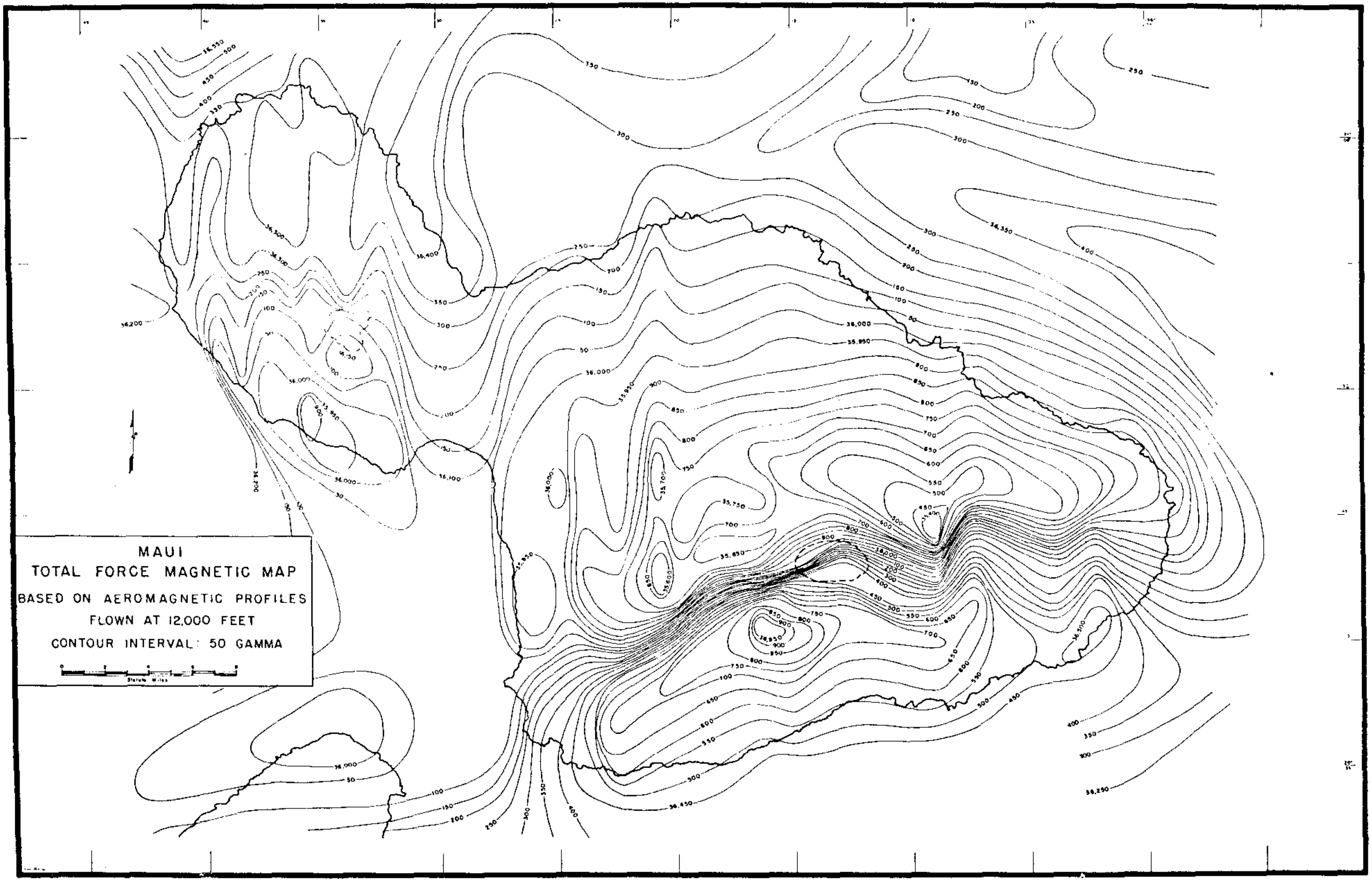


Fig. 20. Total force magnetic map of Maui (from Malahoff and Woollard, 1965).

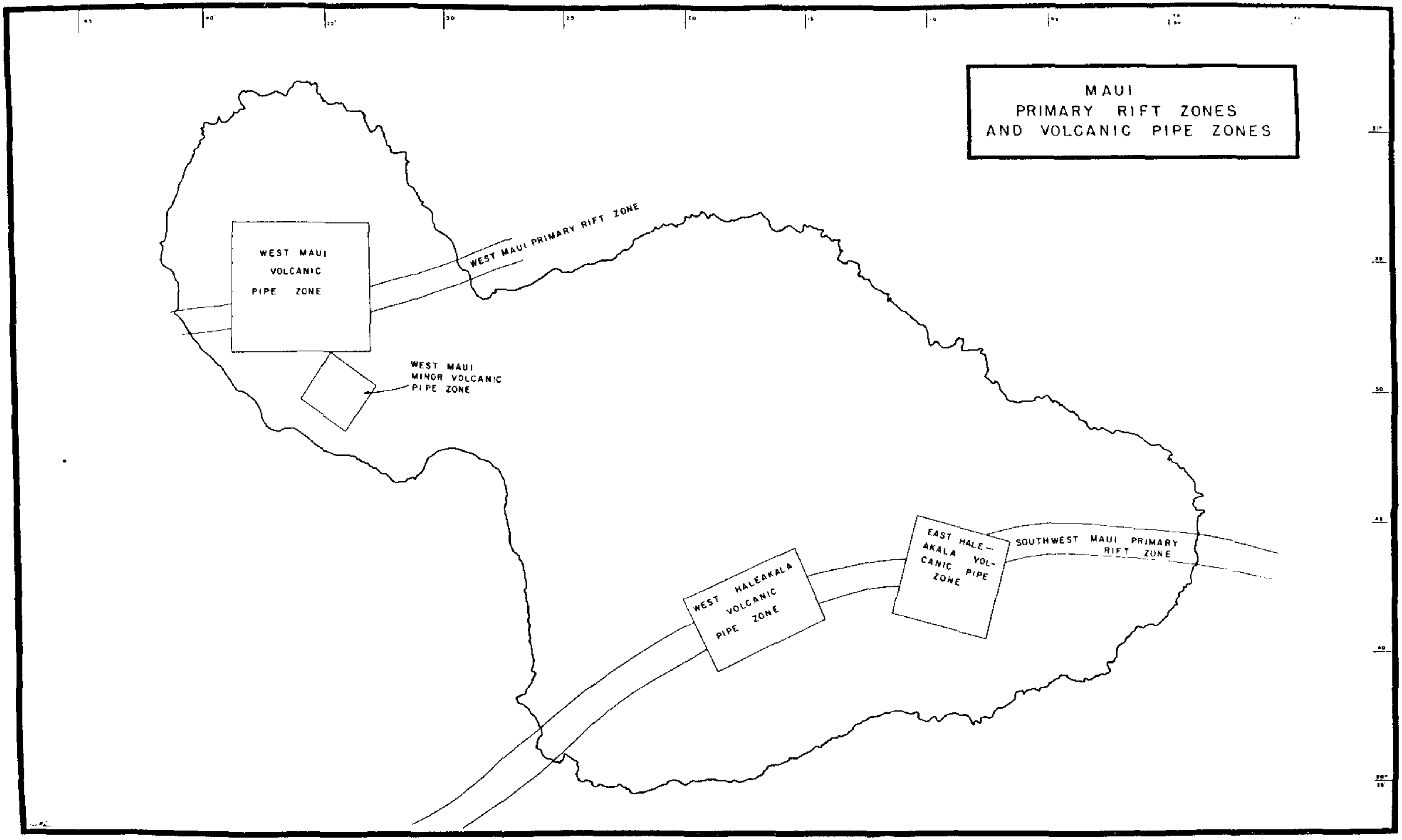
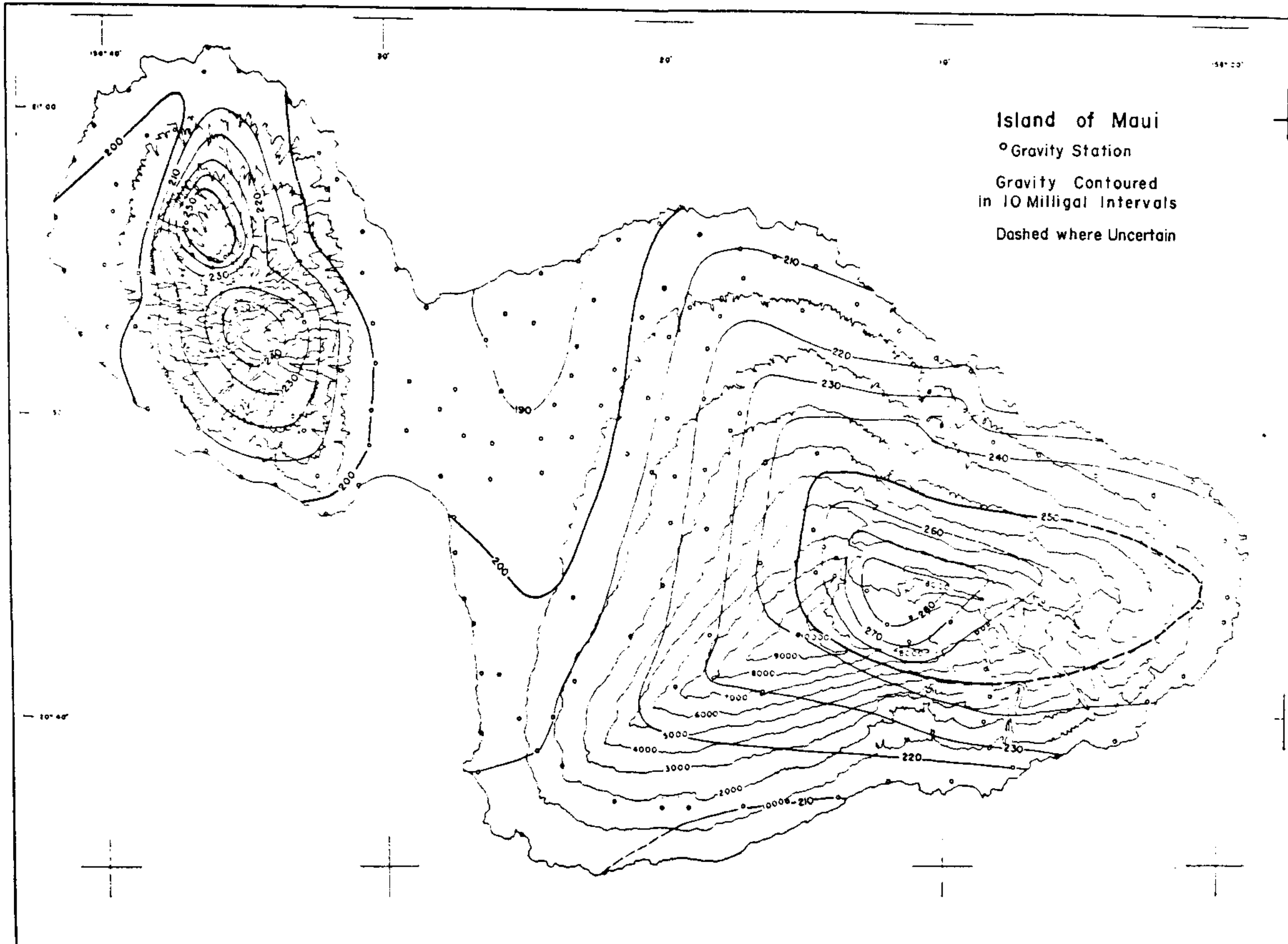


Fig. 21. Primary rift zones and volcanic pipe zones of Maui (from Malahoff and Woollard, 1965).



[illegible] gravity anomaly map of Maui (from Kinoshita and Okamura, 1965).

The hydrology of West Maui is similar to that found on the windward side of Kohala on the island of Hawaii (Fig. 24) (Takasaki, 1978): a thin basal lens of fresh water is found in the nearshore areas, whereas dike-impounded aquifers provide most of the higher elevation groundwaters. Although seawater intrusion into the basal lens is not as ubiquitous as in Kohala, extensive withdrawal from the basal lens can increase the groundwater salinity considerably.

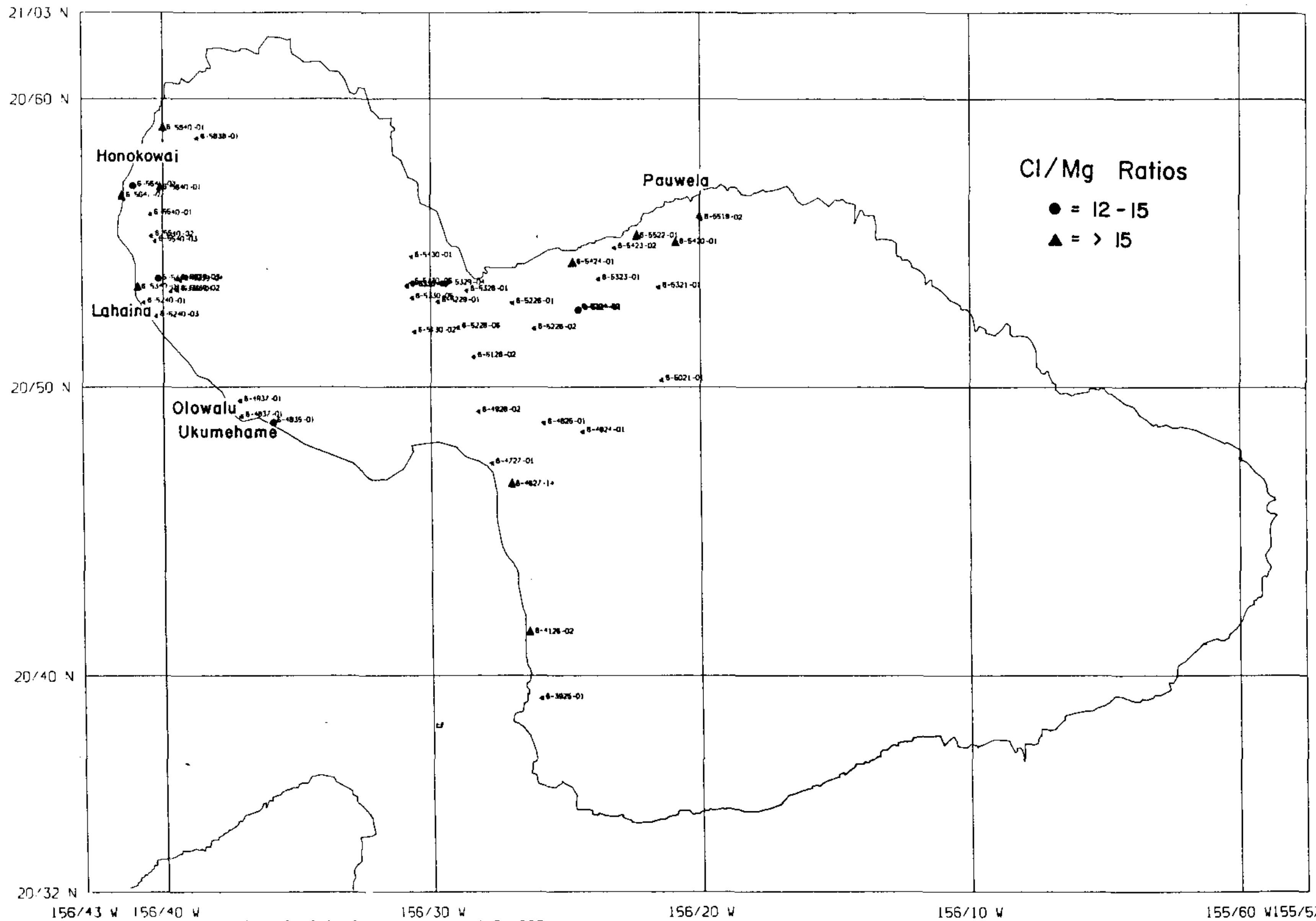
Haleakala received up to several hundred centimeters of rainfall per year on the windward slopes and a few tens of centimeters or less per year on the leeward slopes (Fig. 24). Moderate ash-bed interlayering is found on Haleakala and, where erosion has cut into the windward slopes, ash-bed perched water maintains several perennial streams. Basal water underlies most of the Haleakala shield and is withdrawn from several nearshore areas by inclined shafts skimming water off the top of the basal water lens (Stearns and Macdonald, 1942). The rather confined dike and rift systems on Haleakala have had little apparent impact on the hydrologic flow patterns through the shield.

Geochemistry

Plots of all identified silica anomalies on the island of Maui are presented in Figure 25; all known water sources for the island are shown in Figure 26. Water quality data for all identified silica anomalies on Maui are the Appendix, Table 2. It is apparent (from Fig. 26) that the distribution of groundwater sources for the island is far from uniform: the highest concentration of wells is found in West Maui and in the isthmus betwen the two shields. This uneven distribution of water sources has had the effect of biasing the silica anomaly data toward areas of higher population density on the island.

The silica anomalies located on the leeward side of West Maui can be divided into three sites: Ukumehame-Olowalu, Lahaina, and Honokowai. The Ukumehame-Olowalu anomalies are located within the major rift-dike complex of the West Maui shield. Even though neither the silica nor Cl/Mg ion anomalies are particularly strong in this area, the reported groundwater temperatures are substantially above the expected ambient temperatures. The weak silica and ion ratio anomalies may indicate that thermal waters in this area are highly diluted and that a much hotter resource exists at depth. This location has been chosen for further, more detailed study in the near future.

The Lahaina silica anomalies are located close to the post-erosional (most recent) eruptive centers on West Maui.



MAUI WELL LOCATIONS OF GEOTHERMAL INTEREST, H.I.G. DATA BANK

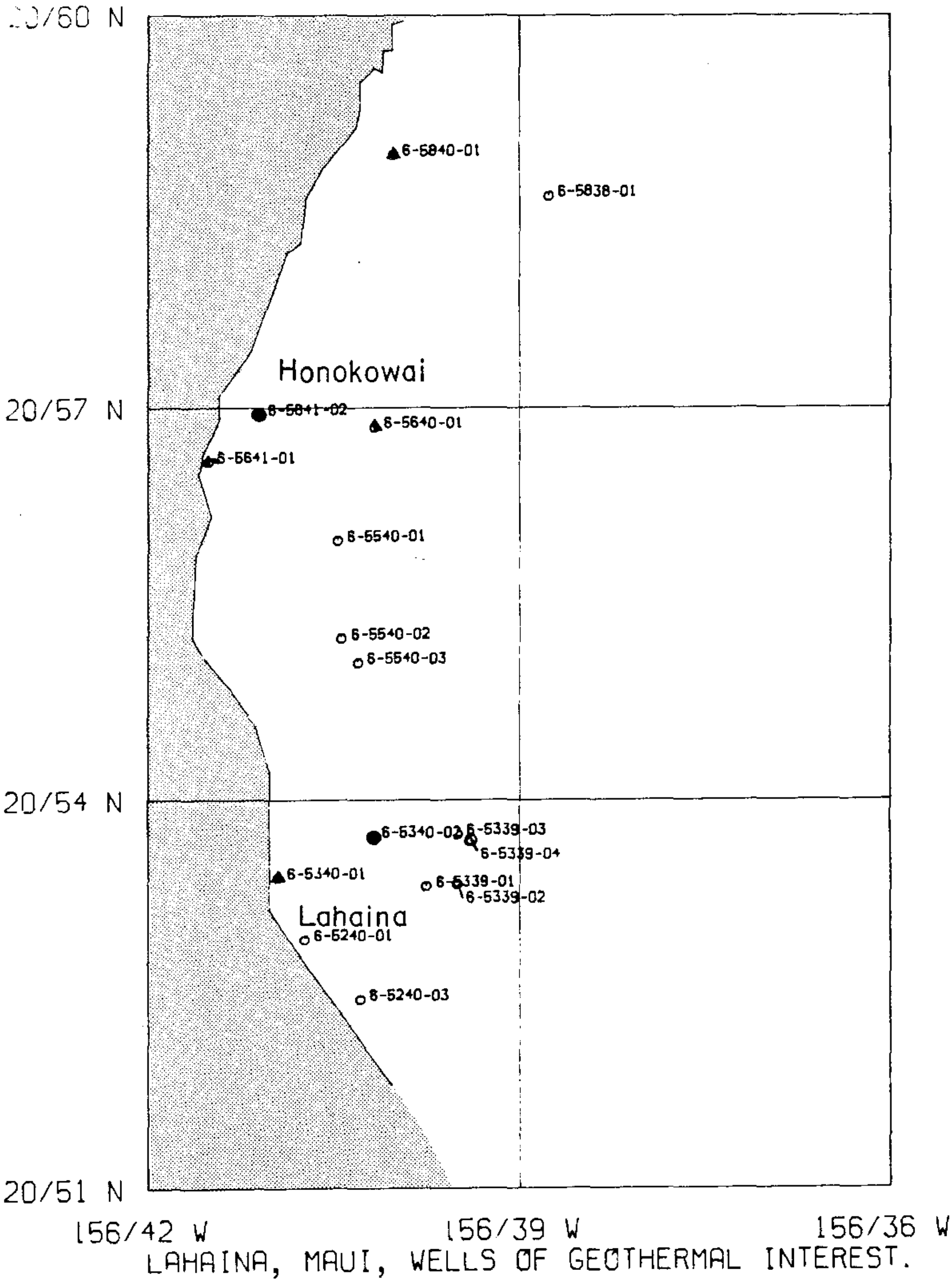


Fig. 25 (continued).

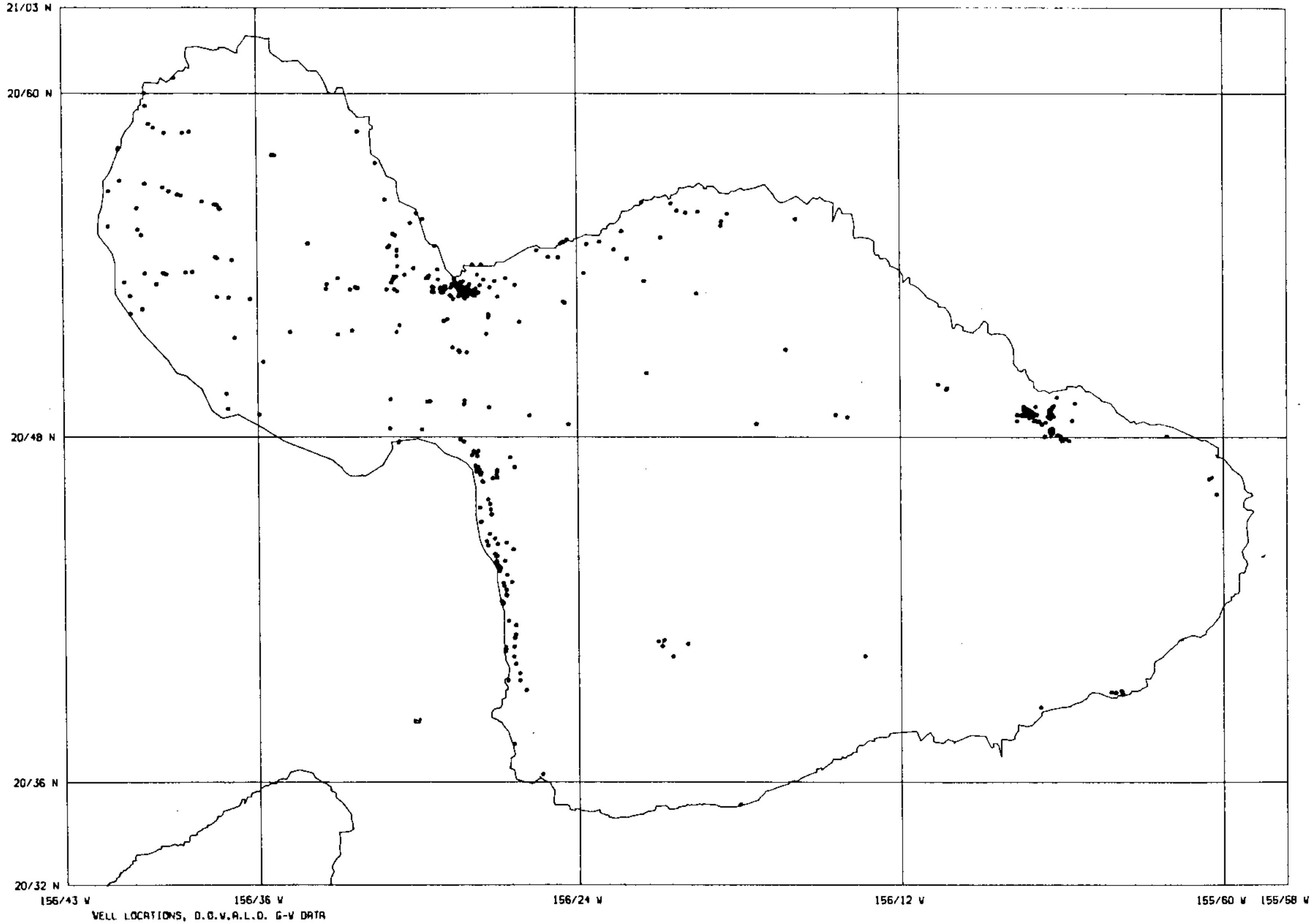


Fig 26. Locations for all water sources on Maui.

The silica anomalies are accompanied by a strong Cl/Mg ion anomaly in well 5340-02 in additional to elevated water temperatures in three other wells (5240-01, 5240-03, 5340-01). From the available data, the Lahaina area appears to have a higher potential for having a thermal reservoir than any other part of West Maui and has also been selected for intensive study in the near future.

The groundwater sources having silica anomalies to the north of Lahaina, in Honokowai, are all located well away from any of the West Maui rift zones or areas of recent activity. Nontheless, several of these water sources exhibit significantly elevated Cl/Mg ion ratios and thus may be associated with a thermal source. Although evidence for a geothermal reservoir is at best marginal, it does warrant resampling of the wells in this area.

The highest incidence of silica anomalies on Maui is found in the isthmus region between the West Maui and Haleakala shields. The absence of any nearby rift system, or any Cl/Mg ratio anomaly, would indicate that the observed silica concentrations are largely a function of groundwater residence time and recharge patterns. This region seems to be a particularly good example of how Cl/Mg ion ratios can be useful in identifying false positive silica anomalies. Further investigations in the isthmus region are not planned for the near future.

The only significant water chemistry anomaly identified on Haleakala is that found in the Pauwela Point area along the north rift. Three wells (5420-01, 5424-01, 5519-02) are associated with relatively strong Cl/Mg ion anomalies and only one, 5423-02, has a significantly elevated water temperature. Several of the anomalous water sources are within a few miles of the north rift; thus there may be thermal fluids in the aquifers from which their water is drawn. Further investigations of this area will be necessary to determine whether the observed anomalies are in fact the result of thermal groundwaters.

The rest of the Haleakala shield has few wells and, as a result, the local hydrology is so poorly understood that an assessment of the thermal potential along the southwest and east rift zones based on water chemistry alone is impossible. Nonetheless, a generalized estimate of the resource potential can be made on the basis of the regional structure and geology. Haleakala is presently in the midst of a post-erosional phase of volcanic activity. Nearly all the eruptive centers during the most recent period of volcanism are located along the southwest and east rift zones; the most recent outbreak took place at an elevation of about 610 m along the southwest rift in approximately 1790. Despite the fact that there are no known surface manifestations of thermal activity along these rifts, it is strongly believed that thermal reservoirs exist beneath both the southwest and east rift systems of Haleakala; both areas should receive more complete regional surveys in the near future.

Summary geothermal assessment

Considerably fewer data are available for Maui than for Hawaii, and thus the preliminary evaluation of Maui's resource potential will have to be correspondingly more tentative. Based on the geochemical and geological information available for Maui, the preliminary assessment for several of the districts on this island is as follows:

Table 2. Summary geothermal assessment for Maui

Area	Low Temperature	High Temperature	Probability for Development
Haleakala Southwest Rift	2	2	4
Haleakala East Rift	2	3	6
Pauwela North Rift	3	4	3
Lahaina	1	3	1
Ukumehame-Olowalu	1	3	2
Honokowai	4	5	2