Gravity Investigations on the Leeward Islands of the Hawaiian Ridge and Johnston Island[1]

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THROUGH THE COURTESY of the U. S. Coast Guard, who allowed the senior author to accompany the U. S. C. G. Cutter "Plaintree" during a base resupply cruise in 1964, it was possible to visit many of the small islands and atolls along the Hawaiian Ridge extending from Nihoa to Midway, as well as Johnston I., to make gravity observations. In all, 133 gravity stations were established on Nihoa, Laysan, Lisianski, Pearl and Hermes Reef, and Midway, and twenty-three stations were established on Johnston I. All the leeward islands in the eastern half of the Hawaiian chain consist of volcanic peaks. On the chain's western end, most of the peaks are capped by coral reefs to form atolls. Although single gravity observations had been made on many of these islands by the Air Force Air Photographic and Charting Service, and some were studied as early as 1948 (Woollard, 1950), the present series of measurements are the first to give a sufficient number of observations for a realistic appraisal of the anomaly field, in terms of both the absolute Bouguer anomaly values and the local gravity gradient.

All observed gravity values were referred to the absolute gravity base at the Hawaii Institute of Geophysics established by Woollard (unpublished), and were adjusted for instrumental drift through Woollard's airport gravity bases at Midway I. and Johnston I. (Woollard and Rose, 1963). The observations were made with a low drift-rate Worden gravimeter having a range of 2000 mgal. The reliability of the values is not uniform and may be no better than ± 2 mgal in the observed gravity values for the central area representing the area of poorest control. Elevations except for those for Nihoa were estimated in most cases by visual observation of sea level and are believed accurate to within ± 2 ft. Elevations for Nihoa were estimated from an elevation contour map with 100-ft contour intervals and could be in error as much as 30 ft. Bouguer anomalies were computed using a density of 2.3 gm/cc in the reductions. The table of principal facts for all stations is reported elsewhere (Hawaii Inst. Geoph., 1965, Table 9).

[1] Hawaii Institute of Geophysics Contribution No. 96.

HAWAIIAN ARCHIPELAGO OBSERVATIONS

The bathymetry surrounding each of the islands is similar, with the land surface falling off rapidly to the northeast and southwest and decreasing over submerged shelf areas elongated parallel to the island chain. In general, the islands have a low elevation and are elongated parallel to the direction of the main oceanic current systems. The exception to this generalization is Nihoa I., which has a maximum elevation of 895 ft and a north shore formed by perpendicular cliffs more than 800 ft high. Based on the observed shapes of the gravity anomalies associated with the volcanic centers on the larger islands at the southeast end of the chain, and the observed magnitudes and gradients observed on these smaller islands, estimates of the location of the center of the gravity highs and the maximum Bouguer anomaly values have been made.

Nihoa

This island covers an area of 156 acres. Rough seas and a landing site rimmed by seacliffs made landings from a small boat hazardous as well as difficult. The rocks are principally olivine basalts occurring as flows or dikes. Because the terrain effect is appreciable and difficult to estimate for stations located along the ridge top near the cliff edge, and as the elevation and meter drift control were weak here, the anomalies may have no better than ± 5 mgal accuracy. The lowest Bouguer anomaly value of $+245$ mgal (Fig. 1) is found at the

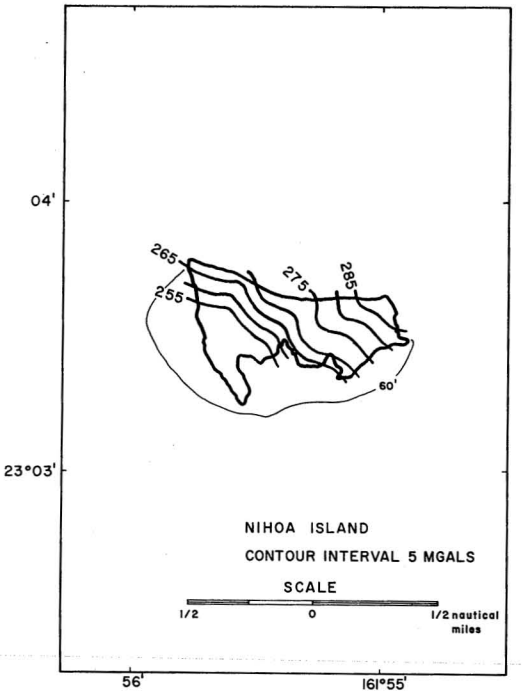

FIG. 1. Bouguer anomaly map of Nihoa I.

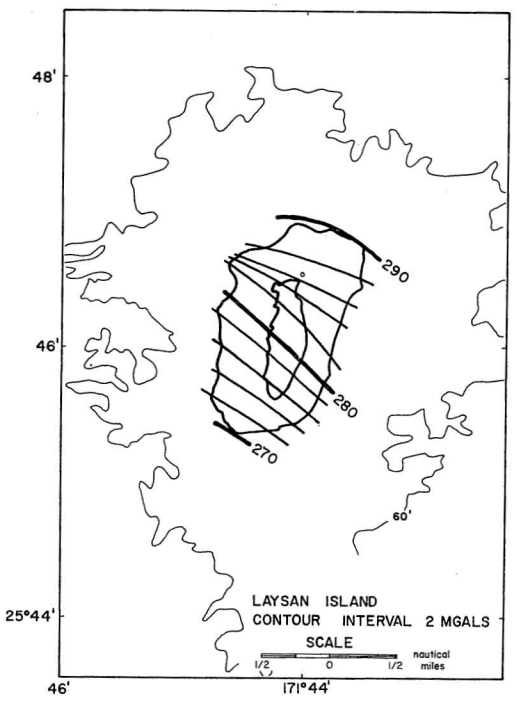

FIG. 2. Bouguer anomaly map of Laysan I.

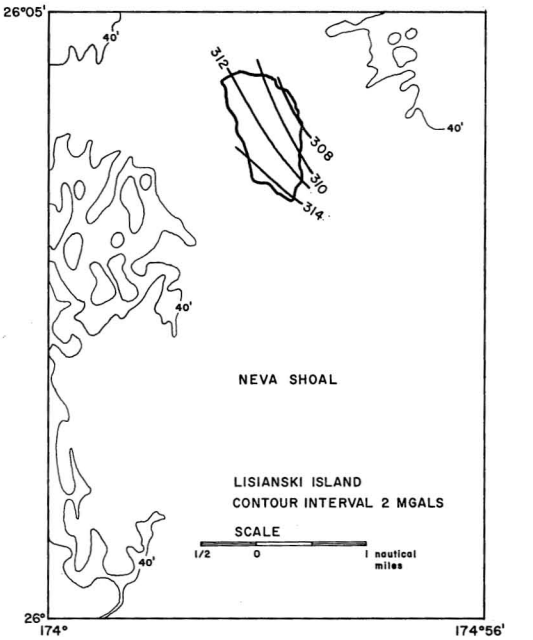

FIG. 3. Bouguer anomaly map of Lisianski I.

southwest corner of the island, and values increase northeasterly to +278 mgal. Based on the observed gravity gradient, the center of the projected gravity high would lie to the north and slightly east of Nihoa and would have an estimated maximum Bouguer anomaly value of +310 mgal.

Laysan

The island is rectangular in shape, trending north-south. The Bouguer anomaly contours (Fig. 2) conform to the shape of the island, with the lowest value of +271 mgal located on the south end and the highest Bouguer anomaly of +290 on the north end. The center of the gravity high appears to lie north and slightly east of the land mass. The gravity gradient on the island averages 10 mgal per mile. Assuming that the gradient remains constant, the center of the high will have a value of about +315 mgal.

Lisianski

This island is about one-half the width and length of Laysan and is elongated in a north-south direction. The Bouguer anomaly contours (Fig. 3) conform to the island's outline. The

lowest Bouguer anomaly value of +308 mgal was found at the northeast tip, and the highest value of +315 mgal at the southwest tip. The gravity gradient averages 10 mgal per mile and increases towards the southwest. The maximum Bouguer anomaly value at the projected center of the gravity high located to the south and west of Lisianski would be approximately +325 mgal.

Pearl and Hermes Reef

This large atoll is comprised of many small islets enclosing a low, coral-filled, shelf area. Only seven of the islets could be occupied, and these are located along the southern edges. A +276 mgal Bouguer anomaly value was obtained on the southeast reef, and values increased to +285 mgal to the southwest. The gravity gradient averages 5 mgal per mile. The contours (Fig. 4) indicate that the high should be found to the north and west of the location of the +285-mgal station, with maximum Bouguer anomaly values possibly as high as +305 mgal.

Midway

Midway I. is a large coral atoll. From magnetic and seismic measurements the coral cap is estimated to be 1000–2500 ft thick (Harry Ladd, personal communication). The contoured Bouguer anomaly map (Fig. 5) shows values ranging from a low of +284 mgal on the south

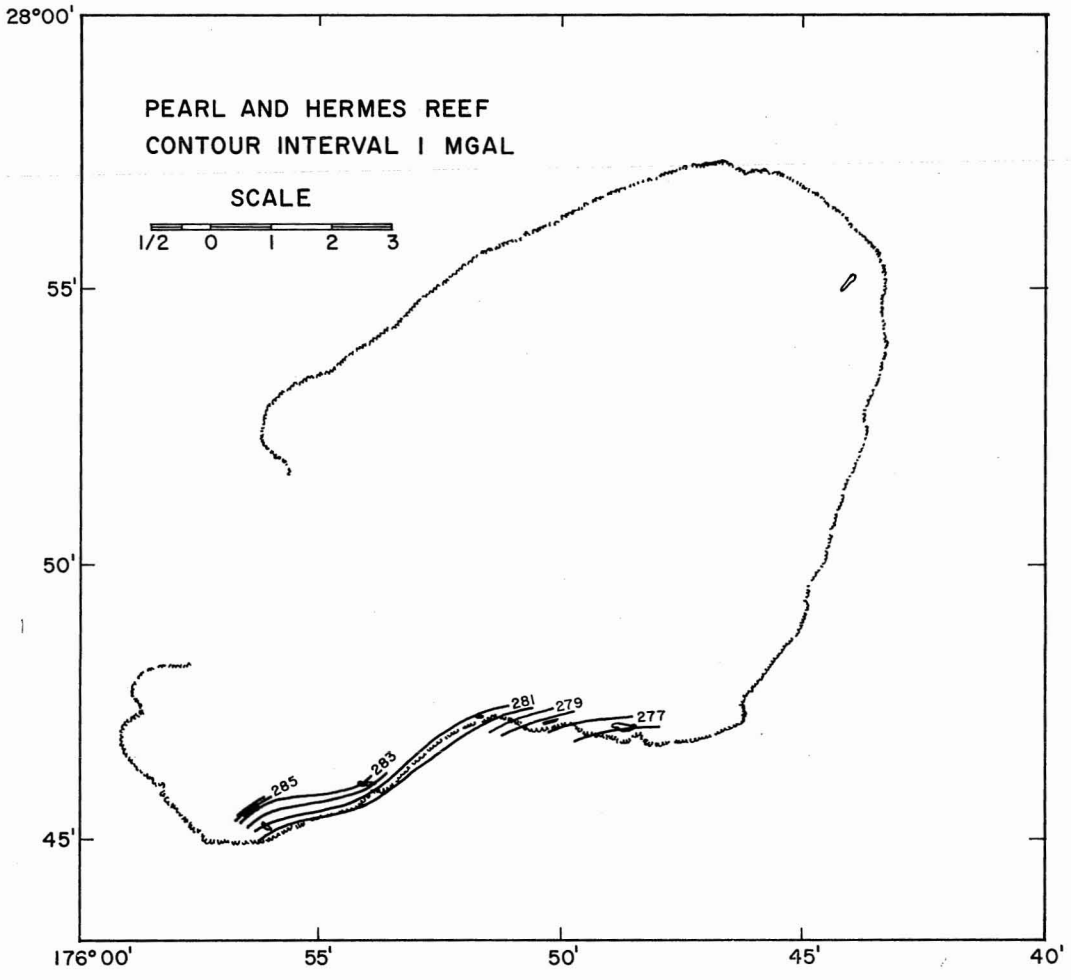

FIG. 4. Bouguer anomaly map of Pearl and Hermes Reef.

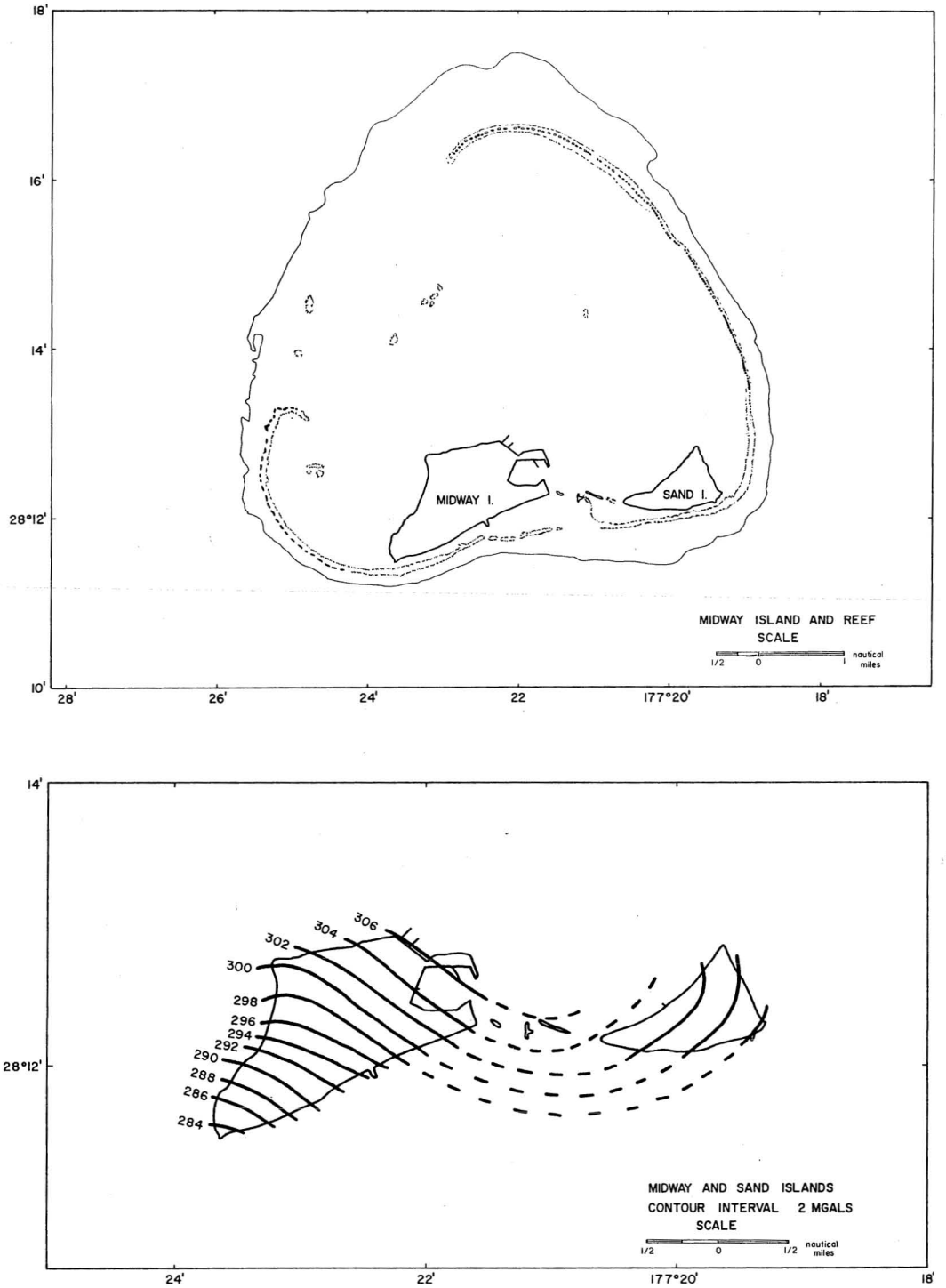

FIG. 5. *Upper,* Midway I. and reef. *Lower,* Bouguer anomaly map of Midway and Sand Is.

of Sand I. to +306 mgal on the north. The gravity gradient on Sand I. averages 10 mgal per mile. The contours indicate a single high with a maximum value of about +320 mgal. The gravity high appears to be positioned midway between Sand I. and Eastern I.

Johnston

Located south of Hawaii, at 16°45′N, 169° 31′W, Johnston I. is not a part of the Hawaiian Ridge but can be considered geologically as the northernmost of the Line Islands. On the basis of bathymetric contours it appears to lie on the northern end of a continuous shoal area extending southeastward from Johnston I. to Palmyra I. North of Johnston the shoal area has a northeast-southwest trend. Johnston I. itself is elongated in a northeast-southwest direction parallel to the barrier reef that exists to the west and northeast of the island.

As seen from Figure 6, the minimum gravity value of +240 mgal is obtained on the southwest end of the island and values increase to +251 mgal towards the northeast. Projecting the gravity gradient of 5 mgal per mile would predict a maximum Bouguer anomaly value of +270 mgal at the center of a gravity high lying to the northeast of the island.

SUMMARY

All islands along the Hawaiian Ridge are characterized by high gravity values with Bouguer values approaching +300 mgal, including those islands represented as atolls having a thick coral cap, such as Midway, where an actual value of +306 mgal was observed. All have pronounced gradients of about 10 mgal per mile that appear to be related to a primary volcanic pipe rather than to the topographic configuration. Despite the geologic indications of greater subsidence toward the northwest along the Hawaiian Ridge there is no indication of any systematic change from southeast to northwest in Bouguer anomaly val-

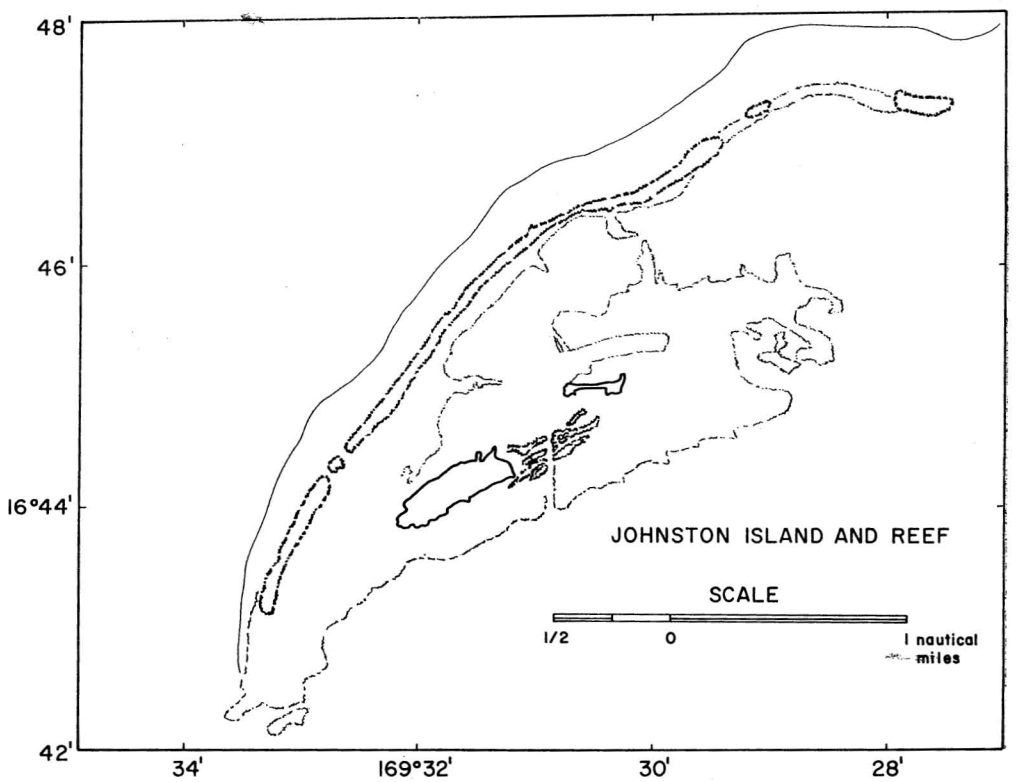

FIG. 6*a*. Johnston I. and reef.

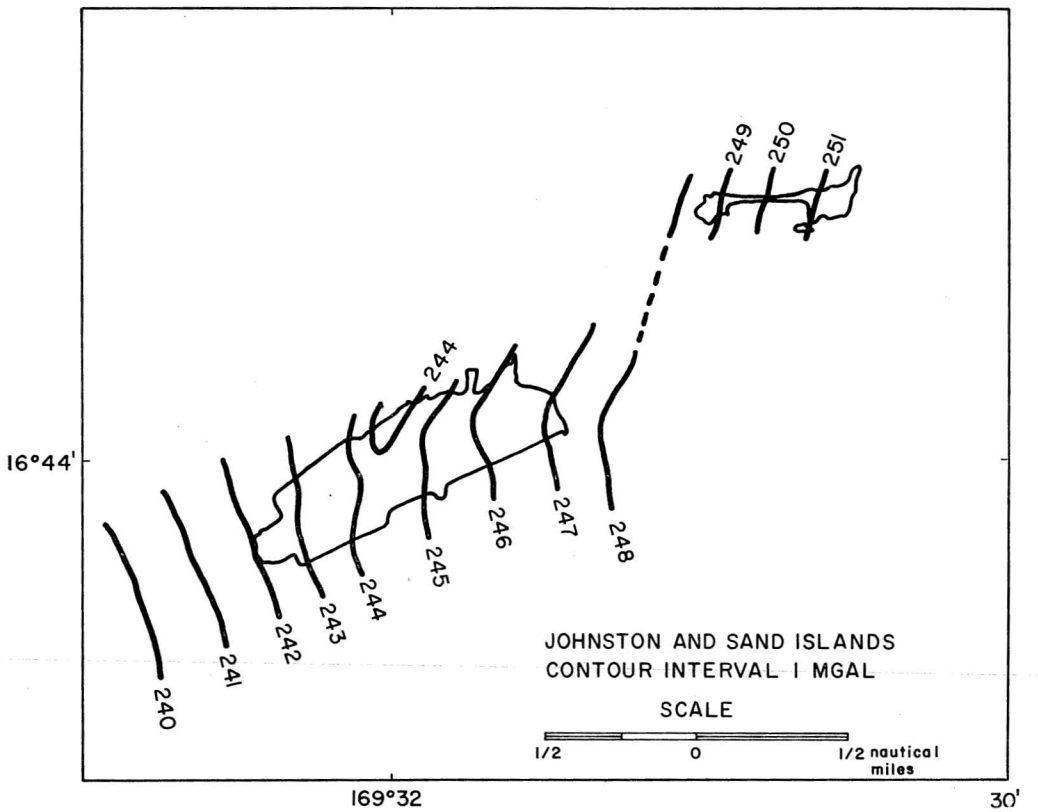

FIG. 6*b*. Bouguer anomaly map of Johnston and Sand Is.

ues observed on the islands of the Hawaiian group.

Johnston I. has absolute Bouguer anomaly values that are somewhat lower than those of the Hawaiian Islands. These values are intermediate between those found on the Hawaiian Ridge and on the remainder of the Line Islands where R. Mason (personal communication) reports absolute anomaly values ranging from +145 to +175 mgal that can be related to the island platform configuration, with no evidence of a feeder pipe contribution in the anomalies.

REFERENCES

HAWAII INSTITUTE OF GEOPHYSICS. 1965. Data from gravity surveys over the Hawaiian Archipelago and other Pacific islands. Hawaii Inst. Geoph. Rept. 65–4, March 1965. 10 tables.

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