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COMBINED GEOPHYSICAL STUDIES AT KILBOURNE HOLE MAAR, NEW MEXICO

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During March 1975, in support of an evaluation of geothermal potential of federal land, the U.S. Geological Survey made gravity, air and ground magnetic, resistivity, audiomagnetotelluric, telluric, and magnetic variation studies in the vicinity of the Kilbourne Hole maar. In this paper I will state our viewpoint, summarize the geophysical findings, and then describe in particular the gravity and magnetic data. The following guidebook papers by Jackson and Bisdorf, Hoover and Tippens, O'Donnell and others, and Towle and Fittermann will describe the other data sets.

Unusually well developed maare of late Pleistocene age occur at Kilbourne and Hunts Holes and elsewhere both locally and regionally. At Kilbourne maar the crater is about 2 km in diameter, 60 m deep, and rimmed with hills of cross bedded, base-surge and air-fall material up to 60 m high on the downwind side of the crater. The maare were described by DeHon (1965). In contrast to DeHon, however, I find neither geological nor geophysical evidence to show that the maare are related to surficial geologic structure.

SUMMARY

Geophysical studies in general seek to test and occasionally to evaluate a presupposed geological model. Here our model comprises about 6 km of horizontal suprabasement sedimentary and volcanic rocks broken by northwest- and northeast-trending Neogene block faults. Near Kilbourne Hole the surface unit is predominantly siltstone and sandstone about 700 m thick (Santa Fe Group) underlain by Tertiary volcanic rocks.

Geologically, we expected the maare to be underlain by a funnel-shaped breccia zone grading downward into a stem of basalt and thence into basalt dikes. The geophysical data do not exactly reject this model but they do not entirely support it.

We find no gravity expression of anomalous rock density nor magnetic expression of igneous rock beneath the maare. We do find anomalously high electrical conductivity. Unfortunately, the conductivity data tell less about the rocks than about the condition of their contained waters. In any case the electrical data indicate that a vertical pipe of some kind extends beneath the craters across major stratigraphic boundaries to a depth of at least 2 km. The water within this zone must be unusually hot, or saline, or contain a large amount of clay related to hydrothermal alteration.

This zone could be a diatreme choked with basalt and large blocks plucked out of underlying sedimentary and volcanic layers. In terms of the magnetic and gravity data, however, the maare are indistinguishable from adjacent sandstone and siltstone of the Santa Fe Group. Although the gravity data are subject to an unusual operational uncertainty, the restrictions provided by the magnetic data are fairly severe. Therefore, for km or so beneath the maare two alternative models are 1) Santa Fe Group sandstone and siltstone having high electrical conductivity because of brecciation, chemical alteration or invasion from below by hot or saline water; or 2) a breccia zone containing exotic fragments which are sufficiently jumbled that magnetic moments cancel, and containing enough increased pore volume to offset the addition to the system of denser rock. The first alternative, which seems to me the more likely, implies that the flux of solid or incandescent material through shallow levels was small in volume and that the erupting material was primarily hot gas.

GRAVITY AND MAGNETIC DATA

A gravity map of the vicinity of the Kilbourne maare, provided by the Mobil Oil Company for public release in this guidebook, is shown in Figure 1. The Bouguer gravity anomaly

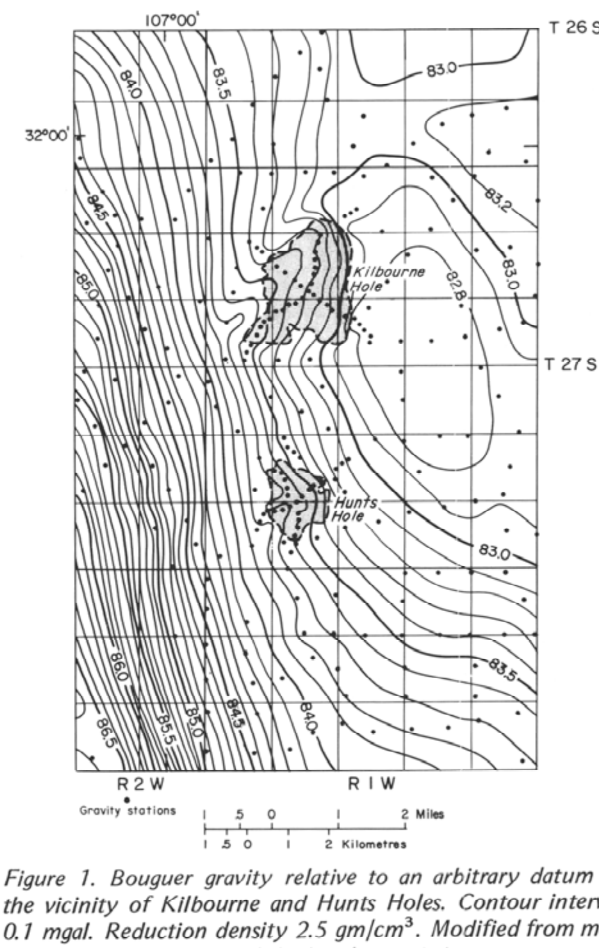

Figure 1. Bouguer gravity relative to an arbitrary datum in the vicinity of Kilbourne and Hunts Holes. Contour interval 0.1 mgal. Reduction density 2.5 gm/cm³. Modified from map by Mobil Oil Co. and published with permission.

relative to an arbitrary datum, based on a reduction density of 2.5 f/cm³, is contoured at an interval of 0.1 mgal. Local terrain corrections were made where required. The main feature in the gravity map is a west-southwest gravity increase toward the upfaulted East Potrillo Mountains (west of the map area).

Detailed gravity traverses (Fig. 1) across Kilbourne and Hunts maare, if taken at face value, indicate local positive gravity anomalies associated with the maare. These anomalies are probably an artifact of the inherent uncertainty in the choice of reduction density. The elevation correction applied to gravity data involves the product of density and elevation. If the density is estimated incorrectly the gravity contours will mimic the topography or its inverse. The problem is especially acute here because topography and the expected geological structure are correlated. The density of surficial rocks in the Kilbourne area probably is about 2.3 gm/cm³ but it could be as high as 2.5 gm/cm³. In Figure 2 I show, for the southwest

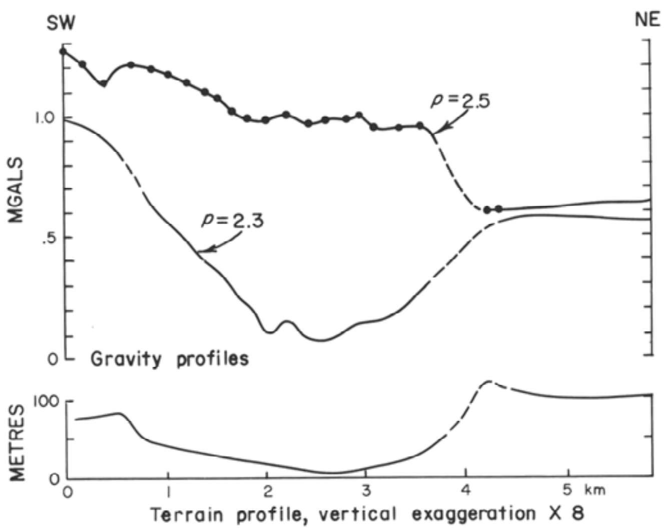

Figure 2. Effect of the elevation correction on Bouguer gravity profiles over Kilbourne maar. Profiles for reduction density ρ = 2.3 and ρ = 2.5 gm/cm³ are shown. Line of profile is generally southwest to northeast across Kilbourne maar. (See Fig. 1)

to-northwest profile across Kilbourne maar, the terrain profile and Bouguer gravity profiles for reduction densities of 2.5 and 2.3 gm/cm³. If the density of 2.3 is approximately correct a small gravity low is associated with the maar. Strictly speaking, the combined effect of topographic relief and uncertainty about the proper reduction density makes it impossible to identify an anomaly over the crater within about ±0.5 mgal.

The small amplitude of the gravity anomaly requires a small underlying density contrast. Assuming an underlying breccia zone in the shape of an inverted cone, and making other assumptions, I estimate from the gravity data a relative porosity increase within the maar of no more than about 2 percent. This is insufficient, in itself, to cause the high electrical conductivity anomalies observed within the maare.

An aeromagnetic map of the Kilbourne Hole region is shown in Figure 3. The complicated pattern in the northwest corner of the map is related to flows and possibly in part to feeder dikes of the Aden basalt field. A strong north-south magnetic grain is evident. A large anomaly is associated with the basalt vent at Black Mountain. The source of the negative anomaly 7 km southwest of Black Mountain is probably about 800 m deep.

No magnetic anomalies are observed over Kilbourne, Hunts, or Potrillo maare. To confirm this, ground magnetometer traverses (not shown) were made across the north and east side of Hunts maar. Anomalies were observed over basalt flows east of the maar but the profile was featureless over the maar itself. The basalt flows thicken westward toward the maar. The absence of flows within the maar, as indicated by the flat magnetic profile, would be expected if the maar-crater were formed by explosive eruption.

ACKNOWLEDGMENT

Mr. Kingsland Arnold of the Mobil Oil Corporation has kindly made his company's gravity data from the Kilbourne Hole area available for inclusion in this series of geophysical studies.

REFERENCE

DeHon, R. A., 1965, Maare of La Mesa, *in* Southwestern New Mexico II: New Mex. Geol. Soc. Guidebook 16, p. 204-209.

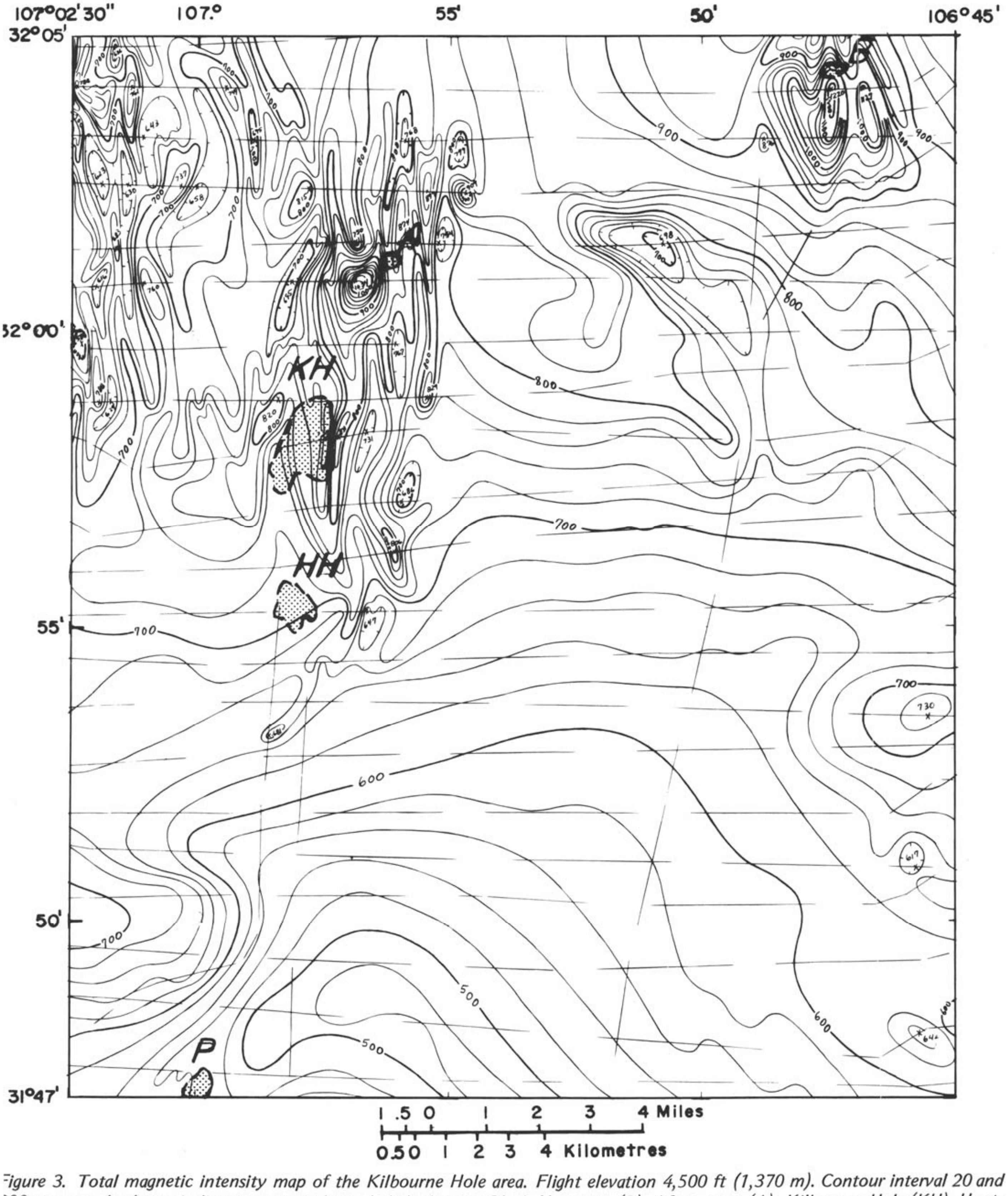

Figure 3. Total magnetic intensity map of the Kilbourne Hole area. Flight elevation 4,500 ft (1,370 m). Contour interval 20 and 100 gammas, hachures indicate magnetic lows. Labels denote: Black Mountain (B), Afton cone (A), Kilbourne Hole (KH), Hunts Hole (HH), Potrillo maar (P).