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SUBJECT: The Geophysical Signature Associated with a Cryptoexplosion Structure - Case 103-7

DATE: July 10, 1970

FROM: J. H. Fox

ABSTRACT

Cryptoexplosion structures are crater-like geologic features whose origins are unknown. Lacking either associated volcanic or meteoritic materials it is not certain whether the forces which created these disturbances were endogenous or exogenous--that is, the result of explosive release of gases from within the earth or of meteorite impact.

Concurrent with the developing interest in astrogeology there has developed a renewed interest in these structures since it is thought likely that the method of their formation may have been similar to the method of formation of some of the craters on the earth's moon and on Mars. An understanding of their origin will contribute to our knowledge of lunar and martian crater formation and will allow us to better plan astrogeologic investigations by astronauts.

This memorandum summarizes the results of a geophysical investigation of one such structure--the Crooked Creek (Missouri) cryptoexplosion structure. Studies of the magnetic and gravity signatures associated with this disturbance resulted in the conclusion that it is related to the tectonics of the region and, therefore, was caused by an endogenous force. The structure is characterized by both a magnetic and a gravity low geophysical signature; shattering of the pre-Cambrian basement rock is indicated. It was found to be situated at the intersection of two major fault zones and this is believed to be more than fortuitous. A structure which best fits the observed data is an inclined inverted cone having a density deficit of -0.13 gm/cm^3 with respect to the surrounding rock and reaching to a depth of at least 2600 meters below the surface of the basement.

The origin of the Crooked Creek cryptoexplosion structure can be best explained by postulating an explosive release of magmatic or phreatic gases which initially derived from a deep-seated source. These gases were guided by the zone of weakness associated with the intersection of the faults. The gases could have penetrated to the surface or could have resulted in a camouflet. The latter postulate has appeal since the geology suggests that the structure may have been formed by doming and subsequent collapse.

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MEMORANDUM FOR FILE

Introduction

Cryptoexplosion structures are isolated crater-like, geologic disturbances whose origins are unknown, both extra-terrestrial (meteorite impact) and terrestrial (volcanic gases or steam) theories receiving about equal support.

Concurrent with the developing interest in astrogeology there has developed a renewed interest in the study of these structures. It is generally believed that the method of their formation may have an affinity with the method of formation of some lunar craters and that the answer to the question of their origin could tell us much about the forces which have operated near the surface of the earth, on the moon and on Mars.

At the 1970 Annual Meeting of the American Geophysical Union several papers given in the planetology sessions addressed this topic. One by C. Ronald Seeger (1970) was especially interesting to me since he reported the results of magnetic and gravity studies of the Versailles and the Middlesboro Basin cryptoexplosion structures in Kentucky. Seeger concluded from his data that the Versailles structure was likely to be of shallow depth and therefore not related to any local or regional tectonic features. He found no relationship between the disturbance and the underlying basement rock from which evidence he concluded that the deforming force probably was exogenous; that is, meteoritic.

In 1953-54 I had occasion to use geophysical methods to study a similar disturbance, the Crooked Creek "cryptovolcanic" structure in Missouri. Since the geologic expressions of most of these disturbances are much alike at the surface of the earth and since, in theory at least, the observed geologic pattern could have been the result of either externally or internally applied forces, their continued study by surface geology and shallow core drilling seemed to offer little hope of resolving the question of their origin. In the approach to the Crooked Creek problem it was assumed that no relationship should exist to the tectonics of the region if the deforming force derived from an extraterrestrial source; that is, one would expect that meteorite impacts would occur randomly and without regard to existing geologic features. If, on the other hand, the deforming force derived from a terrestrial source one would expect that some relationship would exist between the location of the disturbed area and the tectonics of the region.

Data from a magnetic and a gravity survey led me to conclude that the deforming force which caused the Crooked Creek structure was guided by the tectonics of the region and was, therefore, terrestrial in origin. A copy of the results was left in the library of the Missouri Geological Survey and Water Resources, Rolla, Missouri (Fox, 1954). However, the findings were never published in the literature and apparently few students of the problem are aware of this investigation.

It is the purpose of this memorandum to bring the existence of this work to the attention of those interested in the cryptoexplosion problem and to briefly summarize the results. A more detailed paper is planned for publication in the literature later this year.

The Crooked Creek Structure

The cryptoexplosion enigma has been well described in the literature of the past 60 years. Bucher (1963) and Dietz (1963) provide, perhaps, the best and most recent summations of the two principal opposing theories--endogenous or exogenous--which are offered as explaining the origin of the forces which caused these unique geologic features. The geology of the Crooked Creek structure was studied and described by Hendricks (1954) who, largely on the basis of evidence supplied by the orientation of shatter cones, concluded that the deformation was caused by the impact of a meteorite.

In the interest of brevity and on the assumption that the interested reader has a working familiarity with these structures, the literature will not be reviewed here. The Crooked Creek structure, however, has certain unique aspects associated with it that make it an ideal subject for study by geophysical methods and these are worth a brief mention.

Structurally, the disturbance consists of a radially symmetrical region, 3-4 miles in diameter, of intensely deformed Cambrian and Ordovician strata. These tend towards massiveness and are primarily sandstone and dolomites with good lithologic consistency. Thus, there exists in the sediments little or no material of an extraneous nature which would produce local magetic or gravity anomalies. Resting on the northwestern flank of the Ozark Dome (pre-Cambrian) the stratigraphic column involved in the disturbance is reasonably thin with an indicated depth of about 500-600 meters to the base of the Lamotte Sandstone (Cambrian) which rests uncomformably on the pre-Cambrian igneous basement. At least 300 meters of strata were involved in the disturbance since the Bonneterre formation (Upper Cambrian), which normally is found at a depth of about 400 meters in this area, has been identified at the surface close to the center of the structure. No igneous rocks have been found at the surface and no volcanics or meteoritics have been found in this immediate locality.

In Missouri, as in many other regions, it has been shown that the source of magnetic anomalies lies in the igneous complex and is a function of the percent of magnetite contained therein. Thus, the magnetic survey results can be used with considerable confidence to delineate the basement structure. Similarly, the gravimeter readings, when reduced, generally are reflections of basement features although here more care must be applied in assigning density values and density contrasts between the sediments and the igneous basement.

Results

A magnetic map of the vertical component of the magnetic intensity was prepared with a contour interval of 20 gammas (nanotesla) (Figure 1). Three gravity maps were also prepared: (1) a Bouguer gravity map with a contour interval of one milligal (Figure 2), (2) a residual gravity map with a contour interval of 0.5 milligal (Figure 3) and (3) a second-derivative gravity map with a contour interval of 25 x 10^{-15} cgs units (not included in this memorandum).

The approximate limit of the central uplifted area of intense deformation is shown on each map by a circle of one mile diameter. Inside this area the structure is domal with the apical region being slightly depressed to form a shallow basin (Hendricks, 1954). The circle approximates the axial trace of a ring anticline. A ring graben from one to two miles wide surrounds this central uplifted area, the faulted outer border of which constitutes the outer limit of the disturbance.

The Magnetic Survey (Vertical Component) (Figure 1)

The maximum relief in the surveyed area was found to be 482 gammas or approximately 0.9 percent of the total vertical component of the earth's field at this latitude. The region of the disturbance is characterized by an elongated magnetic low superimposed on a broader low associated with what appears to be the southwestern corner of the Cuba graben. To the southeast of the disturbance the extension of the Palmer fault zone shows up clearly in the form of two faulted areas connected by a flexure. In the geologic map of Missouri and in the geologic map of the Steelville Quadrangle (Hendricks, 1954) the Palmer fault is shown to end at the eastern boundary of the disturbance. The magnetic map suggests, however, that it continues for at least a short distance further along the southern edge of the disturbance and may continue beyond to the west.

The northwestern quadrant of the magnetic map is characterized by the presence of a pronounced north-south trend of the

magnetic contours. These are believed to represent the magnetic expression of a subsurface fault which constitutes the western boundary of the Cuba graben in this region. The faulting appears deep-seated and may not have a readily observable surface expression. A northward continuation of this fault intersects the southern terminus of the Cuba fault visible on the surface 15-20 miles to the north and it is suggested that the closely spaced north-south trending magnetic contours reflect an extension of the Cuba fault which in the Crooked Creek area has a deep-seated expression only.

The Gravity Survey

The Bouguer map (Figure 2), reveals the presence of strong regional trends whose magnitudes and directions do not appear to be constant. This is not surprising since clearly defined anomalies, sufficiently intense to prevent being obscured by regional trends, are not common in the Bouguer values obtained in the vicinity of the Ozark dome. Nevertheless, a gravity low is present just north of the center of the Crooked Creek structure. Also, both the Palmer fault and the Cuba fault extension are clearly evident in the gravity contours as excursions from the regionals and confirm the evidence from the magnetic map. From this one concludes that the magnetic and gravity lows associated with the disturbance and the magnetic and gravity reflections of the north-south trending Cuba fault and the east-west trending Palmer fault do indeed exist since the taking and plotting of the magnetic readings is completely objective and the computation of the Bouguer values is practically so.

In gravity work the definition of what constitutes a regional trend depends on the type of structure in which one happens to be interested. Thus, in relatively shallow exploration, we generally consider all effects due to deep-seated masses, which we believe to have no bearing on the particular problem we are studying, to be "regional effects". Obviously, the separation of regional and local effects is subject to personal interpretation. In 1943, the Missouri Geological Survey issued a Gravimetric Map of Missouri which was compiled from data obtained from stations at intervals of one to two miles along the main roads. This map reveals the regional gravimetric trend in the Crooked Creek area fairly well. A residual gravity map (Figure 3), prepared by subtracting this regional trend from the observed Bouguer values, revealed a deep, crescent-shaped, low of about 2-3 milligals to be centered about one-half mile north of the center of the disturbance which, it will be recalled, is 3-4 miles in diameter. This sharp gravity deficit occurs within a broad gravity low which extends to the north and northeast and which seems to be associated with the Cuba graben. The gravity expressions of the Palmer fault and the extension of the Cuba fault are clearly defined, the deep-seated nature of the latter being revealed by the regularity in the trend of the contours. Maximum relief in both the Bouguer and the residual gravity maps is about 13 milligals.

Conclusion

The Crooked Creek structure is characterized by both a magnetic and a gravity low geophysical signature. Shattering of the basement rock is indicated. The structure occurs at the southwestern corner of the Cuba graben; that is, at the intersection of the Palmer and Cuba fault zones. The Cuba fault has not been detected at the surface in this area. However, faulting in the basement consistent in strike and throw which, when extended, joins the Cuba fault is revealed in both the magnetic and the gravity data and the conclusion that this deep-seated faulting is an extension of the Cuba fault seems quite reasonable.

A structure which best fits the geophysical data in the disturbed area is an inverted cone or coal scuttle shaped structure having a density deficit of -0.13 gm/cm^3 with respect to the surrounding rock and reaching to a depth of at least 2600 meters below the surface of the basement. This density contrast represents .05 percent of the assumed density of the enveloping rocks and it is suggested that it is the result of the jumbling and shattering which the rock underwent during the disturbance. The axis of this funnel plunges to the north-northeast with depth and appears to parallel or lie upon the plane of the Palmer fault.

It is difficult to assess the maximum depth to which the disturbed area reaches since as one probes deeper with the magnetometer and the gravimeter the smaller anomalies become overshadowed by larger, more distant regional variations. The data do impose a limiting minimum depth, however, and a shallow basin-like structure is not indicated.

All the evidence is consistent in suggesting that the Crooked Creek structure is related to the tectonics of the region. One is still left with the possibility, however, that this relationship was due to the triggering of incipient zones of weakness by the impact of a meteorite. The magnitude of the faulting suggests that this is a most unlikely explanation. The Palmer fault is easily traced for about 36 miles to the east where it branches, the northern branch linking up with the Ste. Genevieve fault zone. This zone, in turn, continues for another 75 miles into Illinois and, it has been suggested, eventually joins the Rough Creek fault zone in Kentucky. The total length of the fault zone in Missouri alone is about 100 miles. Snyder and Gerdemann (1965) suggest that this zone of weakness may continue westward as far as Kansas. The Cuba fault has been mapped on the surface for more than 35 miles and the results of this study suggest it continues 15 to 20 miles further south to intersect the Palmer fault at the disturbance. The Cuba graben which comprises the northeastern quadrant of these two intersecting fault zones covers an area of more than 300 square miles. When we consider the areal extent of these structural features it is difficult to accept the thesis that a tectonic change of this magnitude resulted from an explosive force which, at the point of release, created such a localized disturbance.

The simplest explanation of the data is that the intersection of the Palmer fault and the Cuba fault zones of weakness provided the locus, the plane of the Palmer fault provided the guidance and subterranean gases provided the explosive force which caused the Crooked Creek disturbance. As for the origin of the gases, note is taken of the Avon region of diatreme activity which exists on the northeastern flank of the Ozark dome (Rust, 1937), (Kidwell, 1947), (Snyder and Gerdemann, 1965). These gases could have penetrated to the existing surface or could have resulted in a camouflet. The latter postulate has appeal since the geology (Hendricks, 1954) suggests that the structure may have been formed by doming and subsequent collapse.

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J. H. Fox

Attachments
References
Figures 1-3

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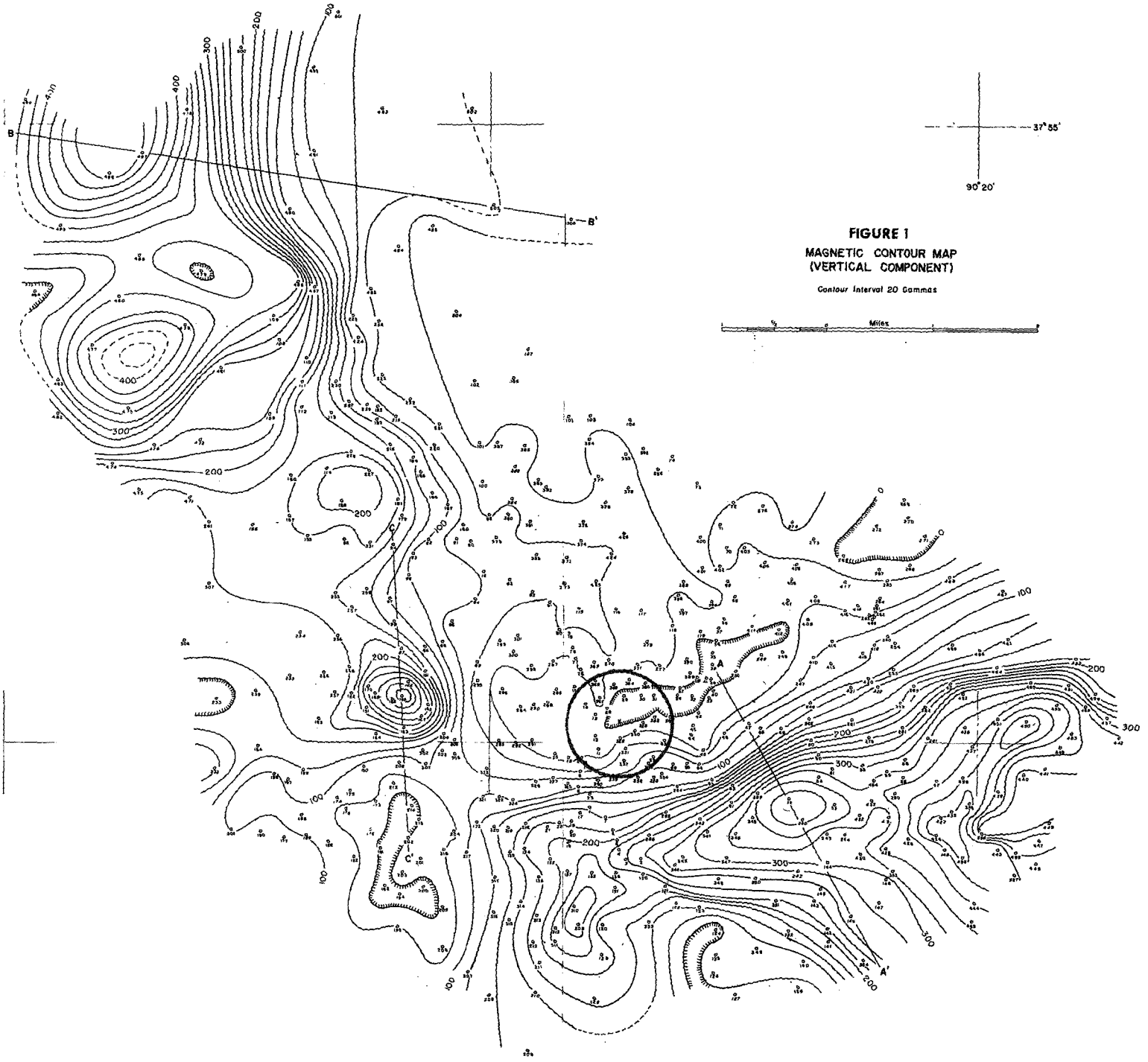

FIGURE 1

MAGNETIC CONTOUR MAP
(VERTICAL COMPONENT)

Contour Interval 20 Gammas

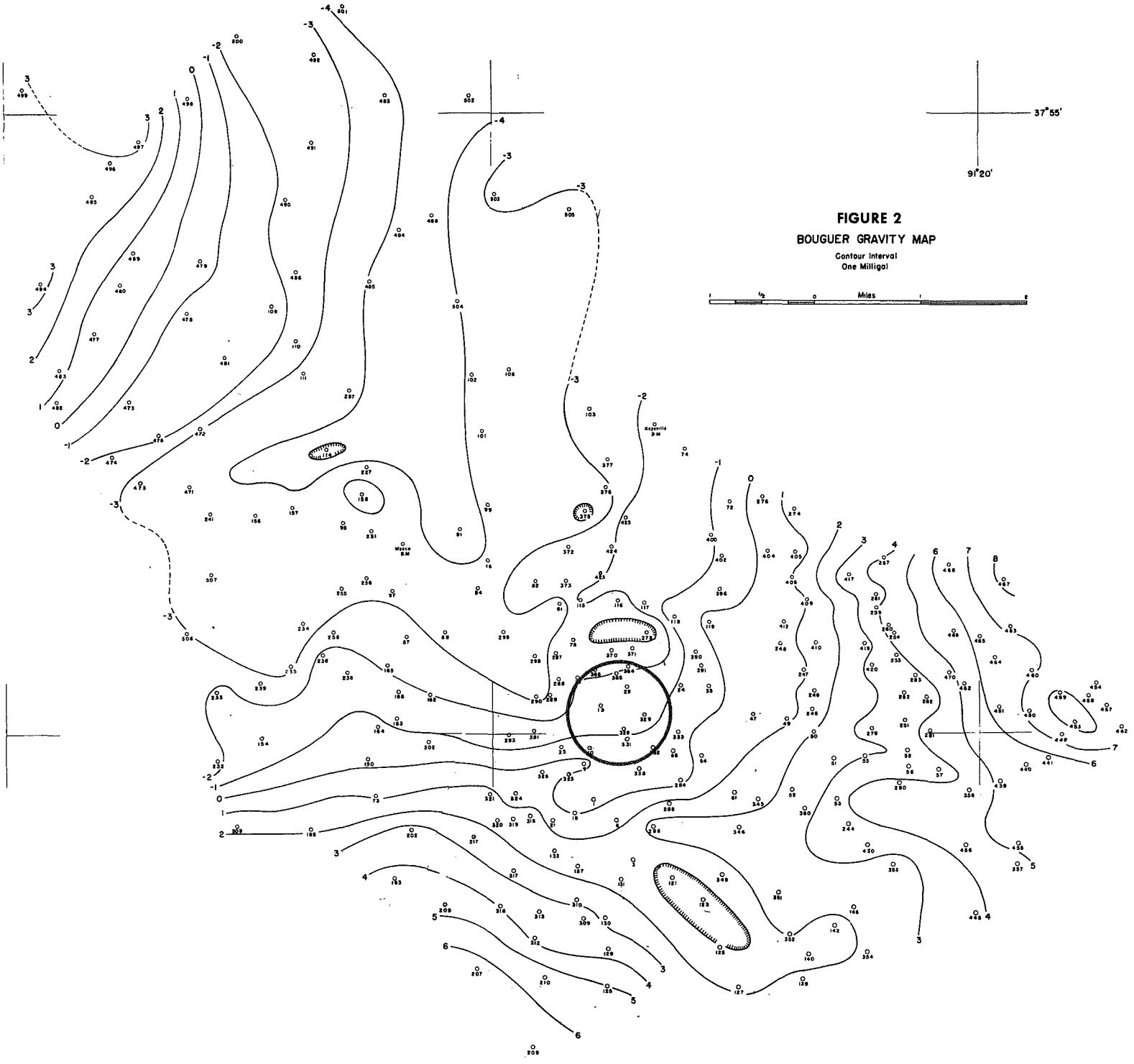

FIGURE 2

BOUGUER GRAVITY MAP

Contour Interval
One Milligal

FIGURE 3

RESIDUAL GRAVITY MAP

Contour Interval 0.5 Milligal

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