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Geophysical Investigations of the Goshute Canyon Wilderness Study Area, Elko and White Pine Counties, Nevada

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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Introduction

A gravity survey was conducted and National Uranium Resource Evaluation (NURE) aeromagnetic data compiled over the Goshute Canyon Wilderness Study Area and vicinity to aid in the assessment of the mineral resource potential of the area. The Federal Land Policy and Management Act (Public law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a geophysical survey of the Goshute Canyon Wilderness Study Area (NV-040-015), Elko and White Pine Counties, Nevada. The gravity data reflect subsurface density distributions, and the magnetic data reflect the distribution of magnetic minerals, mainly magnetite, in the underlying rocks.

In addition, density measurements of 23 rock samples collected in the Wilderness Study Area were made, gridded, and contoured, and the resulting map compared with the gravity measurements. Finally, regional radiometric surveys of the study area were analyzed for possible abnormal concentrations of radioactive minerals.

Gravity and Density Data

Gravity data for the Goshute Canyon Wilderness Study Area were compiled from 512 gravity observations of which 163 were obtained for this study by Harris and Glen (1986). The remaining 349 stations are from the Defense Mapping Agency data base (available from the National Geophysical Data Center, Boulder, CO 80303). Details of the gravity reduction procedure are in Harris and Glen (1986). As a final step to the gravity reduction process, a regional isostatic field was removed assuming an Airy-Heiskanen model for isostatic compensation of topographic loads (Simpson and others, 1983). For the Airy-Heiskanen isostatic model we assumed a sea level crustal thickness of 25 km, a topographic density of 2.67 g/cm^3 and a density contrast of 0.4 g/cm^3 at depth. The resulting isostatic residual gravity map emphasizes the effect of density distributions in the upper crust. An isostatic residual gravity map of the Wilderness Study Area, reduced for a topographic density of 2.67 g/cm^3, is shown in figure 1. To gain a regional perspective of the isostatic residual gravity of Nevada see Saltus, in press.

In addition to a gravity map of the study area (fig. 1) with 5-mGal contours, a local gravity map with 2-mGal contours at a scale of 1:100,000 was made which shows the details of the gravity anomaly over the Goshute Canyon Wilderness Study Area (fig. 2).

Twenty-three rock samples were collected in the Wilderness Study Area at gravity stations. The grain density for these rocks are reported in Table 1. Figure 3 shows a contour map of these density data superimposed on the gravity map shown in figure 1.

Table 1--Rock Densities

Rock Type	Number of Samples	Average grain density in g/cm^3 showing standard deviation
Dolomite	3	2.70±.03
Limestone	15	2.66±.06
Quartzite	3	2.72±.04
Chert	1	2.57
Siltstone	1	2.62
	23	

Aeromagnetic Data

The only available magnetic data in the study area are NURE aeromagnetic profiles flown E-W about 152 m (500 ft) above terrain by helicopter with an approximate spacing of 5 km (Geodata International, 1975). Four flight lines cross the study area (fig. 4), and the two profiles, ML1 and ML2, that go through the central part of the study area are shown in Figures 5a and 5b. Digital tapes of the NURE magnetic data in this part of Nevada were obtained from the Department of Energy and computer processed by Kucks and Hildenbrand (1987) to produce the aeromagnetic maps (figs. 4 and 8). High frequency variations on the original profiles are filtered out on the contour maps, although the longer wave lengths are accurately preserved. This filtering results from the processing, which involves gridding the profile data at 1 km points and upward continuing the resulting data set from the observed 152 m to 305 m above ground. The aeromagnetic maps are poorly controlled, but can be judiciously used, keeping in mind the 5 km separation of profiles as shown by the dashed lines in Figure 4.

Radiometric Data

NURE radiometric data are also available along the flight lines shown in Figure 4. (Geodata International, 1979). The raw data along lines ML1 and ML2 through the study area are shown in Figures 5a and 5b, respectively, and the three profiles marked K, BI, and TL are a measure of the amount of potassium (K), equivalent uranium (^{214}Bi from ^{238}U decay series), and equivalent thorium (^{208}Tl from ^{232}Th decay series) in the ground directly below the helicopter. Radioactive bismuth and thallium are daughter products of uranium and thorium, respectively. Note that the amount of gamma radiation in three distinct spectral windows are displayed with different scales, e.g., for radioactive potassium (K^{40}) of "25 c/s/div" or 25 counts per second per division. To obtain the amount of total potassium from these data involves corrections for the altitude, calibration of the instruments, and the application of overlapping data where both the precise radiation energy levels and the amount of potassium in the rocks have been determined (J. S. Duval, personal commun., 1987). The radiation count is particularly sensitive to the altitude factor, and solid blocks below the profile marked "ALT" indicate areas where the helicopter exceeded specifications on the altitude tolerance, such as just east of point 15 on line ML1 (fig. 5a) where the flight elevation increased to nearly 305 m (1,000 ft) above ground. See Duval (1983) and Geodata International (1979, sec. II) for more complete discussions of the measurements.

Interpretation of Gravity Data

The most prominent feature of the isostatic residual gravity field in the vicinity of the Wilderness Study Area (fig. 1) is a residual gravity high of +12 mGal over the Paleozoic sedimentary rocks of the Cherry Creek Range. This gravity high is flanked on the southeast by a steep gravity gradient terminating in a residual low in Steptoe Valley, with values of about -36 to -40 mGal, and on the west by two gravity lows, both reaching residual values of about -21 mGal. These lows are separated by a gravity saddle with a residual value of about -10 mGal in Butte Valley. The northernmost low is elongated in a N-S direction and parallels the western range front of the Cherry Creek Range, whereas the southern low is more elliptical and marks an area of Tertiary volcanic rocks on both the east and west flanks of Butte Valley (Hose and Blake, 1976, pl. 1).

We have modeled the gravity low over Steptoe Valley along profile A-A' (fig. 1) assuming average densities of 2.0 g/cm^3 for the Cenozoic alluvium, 2.67 g/cm^3 for the Paleozoic clastic rocks and 2.72 g/cm^3 for Paleozoic carbonate rocks. These density values, although higher than the values reported in Table 1, are believed to more accurately represent densities in the Cherry Creek Range based on Nettleton's method (Nettleton, 1939) and are more consistent with reported density values (Daly and others, 1966). Furthermore, the densities reported in Table 1 do not properly account for the positive isostatic residual gravity anomaly over the Cherry Creek Range. The uncertainty in the 2.72-g/cm^3 density-assumption for the Paleozoic carbonate rocks is about ±0.05 g/cm^3 where as the uncertainty in the 2.0-g/cm^3 density-assumption for the alluvium is much greater (±0.2 g/cm^3). Thus the depths to bedrock under Steptoe Valley (maximum of 2800 m) are uncertain to about 35%. Nevertheless, the computed form of the Valley (fig. 6) is probably correct and subject only to the possible effect of lateral density (e.g., facies) changes within the valley fill.

The position of maximum horizontal gravity gradients can be used to estimate locations of sharp vertical density contrasts (Cordell, 1979). However, the position of the maximum horizontal gradient may be displaced from the top edge of the boundary as a function of the depth below the level of observation and the dip of the boundary (Grauch and Cordell, 1987). The position of the maximum horizontal gravity gradient as determined by computer methods (Blakely and Simpson, 1986) is located about 3,000 m into the valley along profile A-A' (fig. 6) and this distance decreases to about 1,500 m about 6 km to the north (fig. 1) as the center of the gravity low and computed center of the bedrock valley configuration migrates closer to the Cherry Creek mountain front. The position of the maximum horizontal gravity gradient well out into the valley indicates that the mountain front buried under the valley is not vertical, but extends at a rather low average angle of less than about 30° as shown in the model (fig. 6). The closer proximity of the maximum gradient to the exposed bedrock suggests that the buried mountain front gradually steepens in that direction and slopes at about 40° to 50° at the northern part of Figure 2.

Gravity profile B-B' across Butte Valley (fig. 1) was modeled assuming an average density of Cenozoic fill of 2.2 g/cm^3, a higher value than that used in Steptoe Valley because of greater abundance of volcanic rocks in the area (Hose and Clark, 1976, pl. 1). The model (fig. 6) gives a computed thickness of 3,500 m in the center of the gravity low, but the uncertainty in computed depths is ±50% which is greater than for Steptoe Valley because of the smaller assumed contrast of -0.47 g/cm^3. The axis of the gravity low is nearly N-S and maintains a constant distance from the Cherry Creek Mountain front for a distance of about 20 km.

Southwest of the Wilderness Study Area, a closed gravity low of about 20 mGals reveals the presence of a depression in the Paleozoic rocks beneath Butte Valley. Volcanic tuff crops out on both sides of the gravity anomaly along the margins of the valley. These observations, along with the aeromagnetic data discussed below, indicate that this feature may be a caldera. The presumed extent of this feature is shown in Figures 1 and 4.

Isostatic residual gravity values are fairly constant within the Cherry Creek Range itself varying from about 0 mGal at both the east and west contacts with Cenozoic alluvium to a maximum of 12 mGal displaced somewhat southwest of the center of the range and inside the study area at point A (figs. 1 and 2). The offset position of the gravity high is consistent with the NW-dipping homoclinal structure of Paleozoic beds, bringing the older and heavier rocks closer to the surface in the SE part of the Range as indicated by the density measurements (fig. 3). In Figure 7, we have included models of both a 2.72 g/cm^3 body (limestone) and a 2.80 g/cm^3 (presumed buried dolomite body) required to increase the computed gravity to match the three gravity observations +8, +11, and +11 mGal near the east end of the profile. The model is consistent with the westerly dip of the beds along this section and the evidence for progressively lower density rocks to the west within the Cherry Creek Range (fig. 3). In any case a 2.80 reduction density for the heavy carbonate rocks lowers the gravity residual level within the Cherry Creek Range to about +7 mGal which is still higher than bedrock values for most of Nevada which average close to zero (Oliver and others, 1981; Saltus, in press).

Interpretation of Aeromagnetic Data

To gain some perspective of magnetic signatures in NE Nevada, the digital aeromagnetic data prepared for the Nevada state map (Hildenbrand and Kucks, 1987) was plotted (fig. 8) and compared with the geologic map of White Pine County (Hose and Blake, 1976, pl. 1). The Ely aeromagnetic map is controlled by 5 km spacing of E-W flight lines, and the data have been processed similarly to those in Figure 4. Our study focused on the character of magnetic signatures over intrusive rocks, particularly those with associated mineral deposits, and evidence of continuity of volcanic rocks under alluvium.

The most pertinant features on the Ely aeromagnetic map in the vicinity of Goshute Canyon are a small but distinct magnetic high of about 100 gammas directly over the exposed Tertiary intrusive rocks with some associated mineralization west of Warm Springs, and a similar but smaller magnetic high over Cambrian rocks which are intruded by Tertiary intrusive rocks about two kilometers west of Cherry Creek. Farther south and west of Ely, a major magnetic high of about 400 gammas is associated with Cretaceous intrusive rocks with apparently associated mineralization, whereas the intrusive body that makes up the Kern Mountains is apparently non-magnetic and non-mineralized. Thus, there are both magnetic and non-magnetic granitic rocks nearby, and there is some correlation in this area between magnetic types and mineralization. To the southeast in the Carlin area, magnetic anomalies associated with mostly buried granitic plutons serve to delineate the Carlin gold trend (Kirchoff-Stein and Hildenbrand, 1986).

The aeromagnetic profiles that cross the Cherry Creek Range through the Goshute Canyon Wilderness Study Area are nearly flat over the whole range (fig. 5), and the resulting aeromagnetic map is similarly flat over the Wilderness Study Area. Thus, we conclude that there is no significant amount of buried magnetic granitic rocks at shallow depths under the Wilderness Study Area similar to those exposed further south in the Cherry Creek Range, although there could be buried non-magnetic granitic rocks similar to those of Kern Mountains. More work needs to be done on determining why some Nevadan granitic rocks are magnetic and others are not.

With regards to the relation of magnetic anomalies to buried volcanic rocks, the correlation of anomalies with the exposed Tertiary and ? older volcanic rocks in the Butte Mountains and along the west flank of the Cherry Creek Range just southwest of the study area is quite good. Moreover, the southwest edge of the magnetic high over the Butte Mountains continues unabated across Butte Valley suggesting that volcanic rocks are continuous under the alluvium (see figs. 4 and 8). By superimposing Figure 1 onto Figure 4, a good correlation is evident between the magnetic high and the elliptical gravity low southeast of the Study Area discussed in the previous section. This correlation is similar to gravity and magnetic anomalies associated with known calderas in other parts of the Basin and Range province (Plouff, 1985, 1986).

Interpretation of Radiometric Data

Based on the aerial gamma-ray spectroscopy data measured in regional surveys as part of the NURE program, the amounts of equivalent potassium, uranium, and thorium are generally lower over the Wilderness Study Area than over areas to both the west and east (figs. 5a and 5b), an observation which is consistant with the carbonate nature of the rocks in the area. Note that the equivalent uranium (BI curve) is only about 5 counts/sec in the study area and is 15-25 counts/sec all the way to the Utah border. The decrease in gamma ray flux over the study area is correlated with an increase in the altitude of the helicopter to about 300 meters above ground over the western part of the Range, but doesn't go above the 5 counts/sec limit even where the 'ALT' curve drops back to 120 meters or less. The ratios TL/K, BI/K (fig 5a) are anomalous because the K has dropped so low where the ALT is greater than 240 meters. The BI/TL ratio (fig. 5a) is more curious and perhaps reflects something about the U/Th ratios in carbonate rocks.

J. S. Duval (written commun., 1985) has concluded from the NURE data that the Goshute Canyon Wilderness Study Area has an overall low radioactivity with values of 0.5 - 2.0% potassium, 1.5 - 3.0 ppm equivalent uranium, and 2.0 - 9.0 ppm equivalent thorium. There are no significant anomalies within the boundaries of the Wilderness Study Area.

References Cited

Blakely, R. J., and Simpson, R. W., 1986, Approximating edges of source bodies from magnetic or gravity anomalies: Geophysics, v. 51, no. 7, p. 1494-1498.

Cordell, L., 1979, Gravimetric expression of graben faulting in Santa Fe County and the Espanola Basin, New Mexico: New Mexico Geological Society Guidebook, 30th Field Conference, p. 59-64.

Daly, R.A., Manger, G.E., and Clark, S.P., 1966, Density of rocks, in Clark, S.P., ed., Handbook of physical constants: Geological Society of America Memoir 97, p. 19-26.

Duval, J. S., 1983, Composite color images of aerial gamma-ray spectometric data: Geophysics, v. 48, no. 6, p. 722-735.

Duval, J. S., in press, Aerial gamma-ray color contour and composite color maps of regional surface concentrations of potassium, uranium, and thorium in Nevada: Nevada Bureau of Mines and Geology, scale 1:1,000,000.

Geodata International, 1979, Aerial radiometric and magnetic survey, Elko National Topographic Map--Nevada, Utah: U.S. Department of Energy, Grand Junction Office, Open-File Report GJBX-159(79).

Grauch, V.J.S., and Cordell, Lindrith, 1986, Limitations of determining density or magnetic boundaries from the horizontal gradient of gravity or pseudogravity data: Geophysics, v. 52, no. 1, p. 118-121.

Harris, R. N., and Glen, J. M., 1986, Principal facts for 163 gravity stations in the Cherry Creek Range and vicinity, Elko and White Pine Counties, Nevada: U.S. Geological Survey Open-File Report 86-559, 13 p.

Hildenbrand, Thomas, 1987, Aeromagnetic maps of Nevada, scale 1:1,000,000: Nevada Bureau of Mines and Geology, Special Map Series.

Hose, R. K., Blake, M. C., Jr., and Smith, R. M. 1976, Geology and mineral resources of White Pine County, Nevada: Nevada Bureau of Mines and Geology, Bulletin 85, 105 p.

Kirchoff-Stein, K.S., and Hildenbrand, T.G., 1986, Composite aeromagnetic map of the Winnemucca 1° by 2° quadrangle, Nevada: U.S. Geological Survey Open-File Report 86-514, scale 1:250,000.

Kucks, R.P., and Hildenbrand, T.G., 1987, Description of magnetic tape containing Nevada state anomaly data: EROS Data Center, Serial number D87-270.

Nettleton, L.L., 1939, Determination of density for reduction of gravimeter observations, Geophysics, vol. 4, p. 176-183.

Oliver, H. W., Saltus, R. W., Mabey, D. R., and Hildenbrand, T. G., 1982, Comparison of Bouguer anomaly and isostatic residual maps of the southwestern Cordillera (Expanded abstract): Society of Exploration Geophysicists, Fifty-second Annual Meeting, Dallas, Texas, October 17-21, 1981, Technical Program Abstracts, p. 306-308, incl. 3 illus.

Plouff, Donald, 1985, Many gravity lows may reflect Cenozoic plutons beneath volcanic terrane of western United States: EOS (Transactions American Geophysical Union), v. 66, no. 46, p. 845.

Plouff, Donald, 1986, Role of magma in localization of basin-range valleys (Abstract): EOS (Transactions, American Geophysical Union), v. 67, no. 44, p. 1226.

Saltus, R. W., 1987, Gravity anomaly maps of Nevada: Nevada Bureau of Mines and Geology, 4 maps, scale 1:1,000,000, 19 p. text.

Simpson, R.W., Jachens, R.C., and Blakely, R.J., 1983, AIRYROOT: A FORTRAN program for calculating the gravitational attraction of an Airy isostatic root out to 166.7 km: U.S. Geological Survey Open-File Report 83-883, 66 p.

White, A. J. R., Clemens, J. D., Holloway, J. R., Silver, L. T., Chappell, B. W., and Wall, V. J., 1986, S-type granites and their probable absence in southwestern North America: Geology, v. 14, p. 115-118.

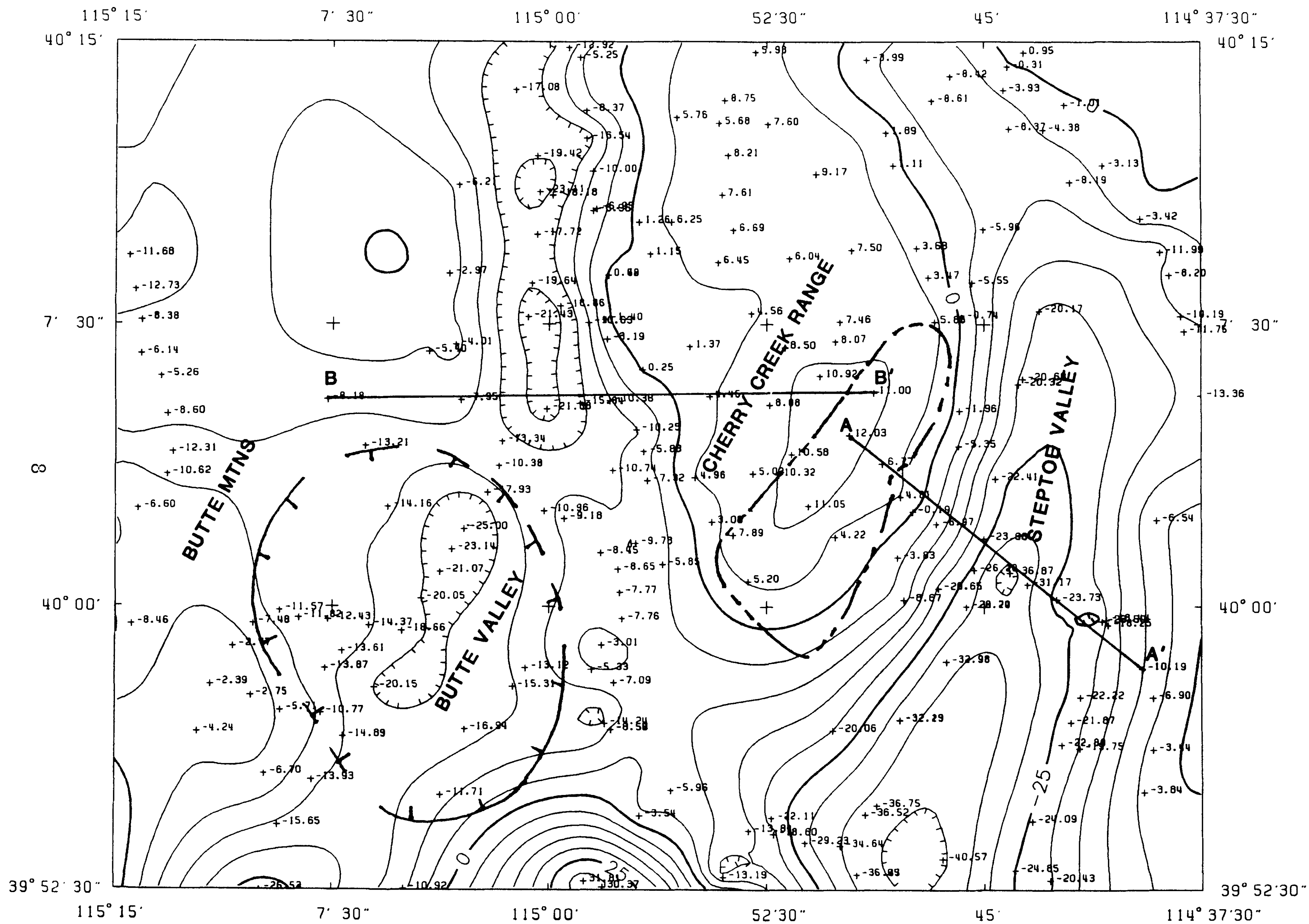

Figure. 1.–Isostatic residual gravity map of Goshute Canyon Wilderness Study Area and Vicinity. Contour interval 5 mGal. + Gravity station locations displayed with isostatic values in hundredths of mGal.
— — — Position of maximum horizontal gradient.
—- - — Boundary of Wilderness Study Area.
Approximate boundary of caldera.

SCALE 1:250000

0 5 10 15 20 KILOMETERS

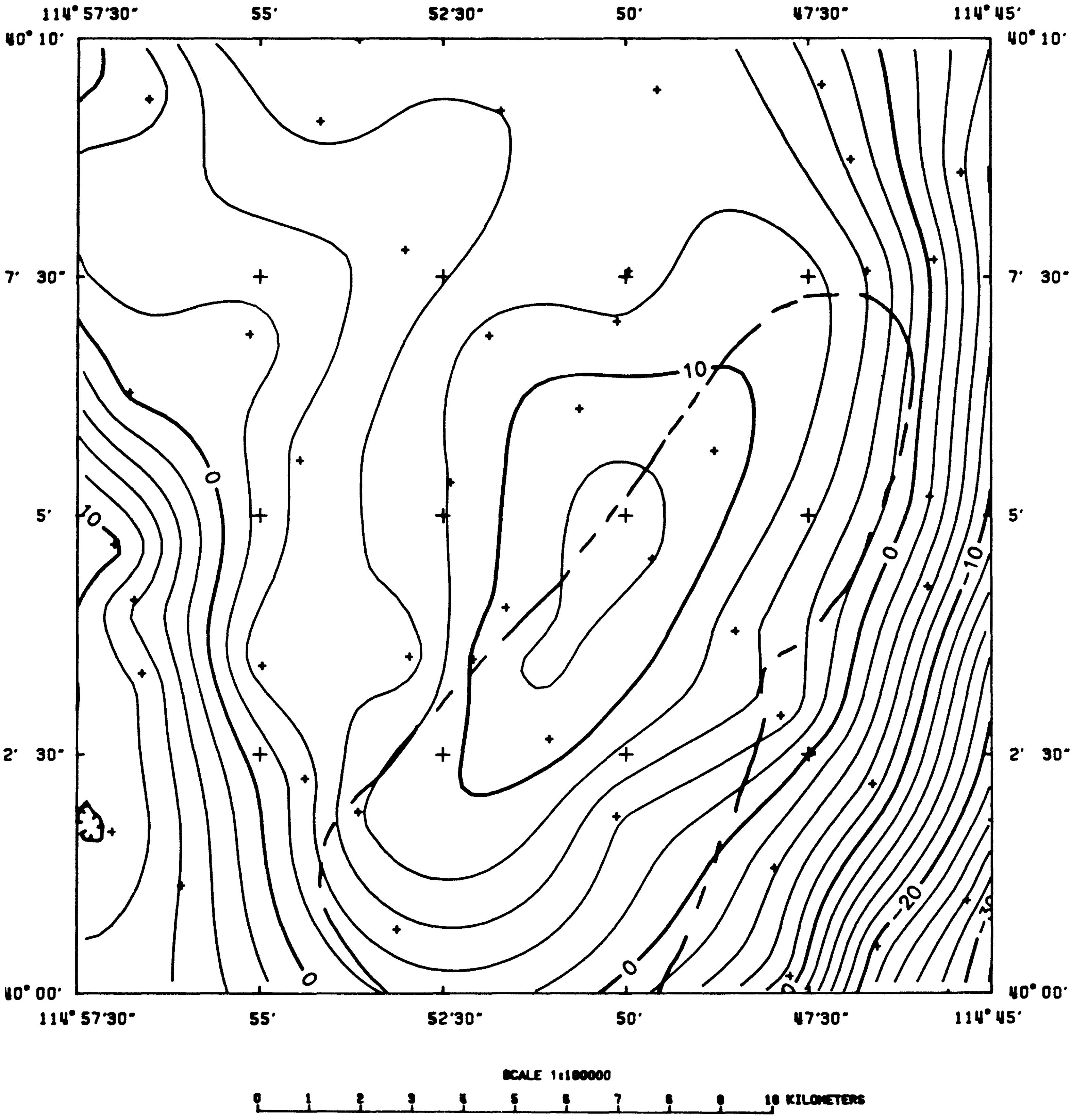

FIGURE 2.–Isostatic residual gravity map of Goshute Canyon Wilderness Study Area, contour interval 2 mGal. —-- — Boundary of Wilderness Study Area.

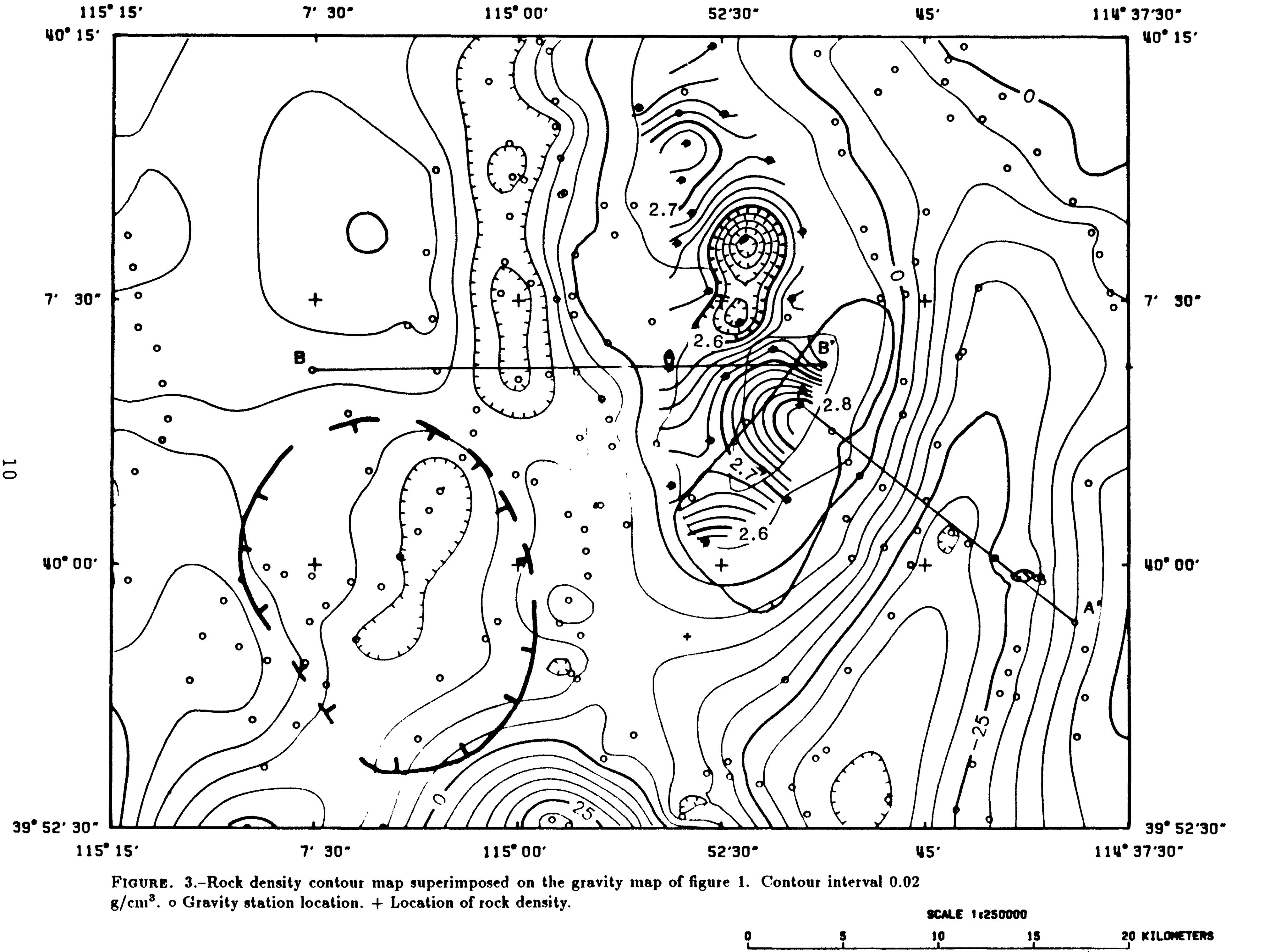

FIGURE. 3.-Rock density contour map superimposed on the gravity map of figure 1. Contour interval 0.02 g/cm³. ∘ Gravity station location. + Location of rock density.

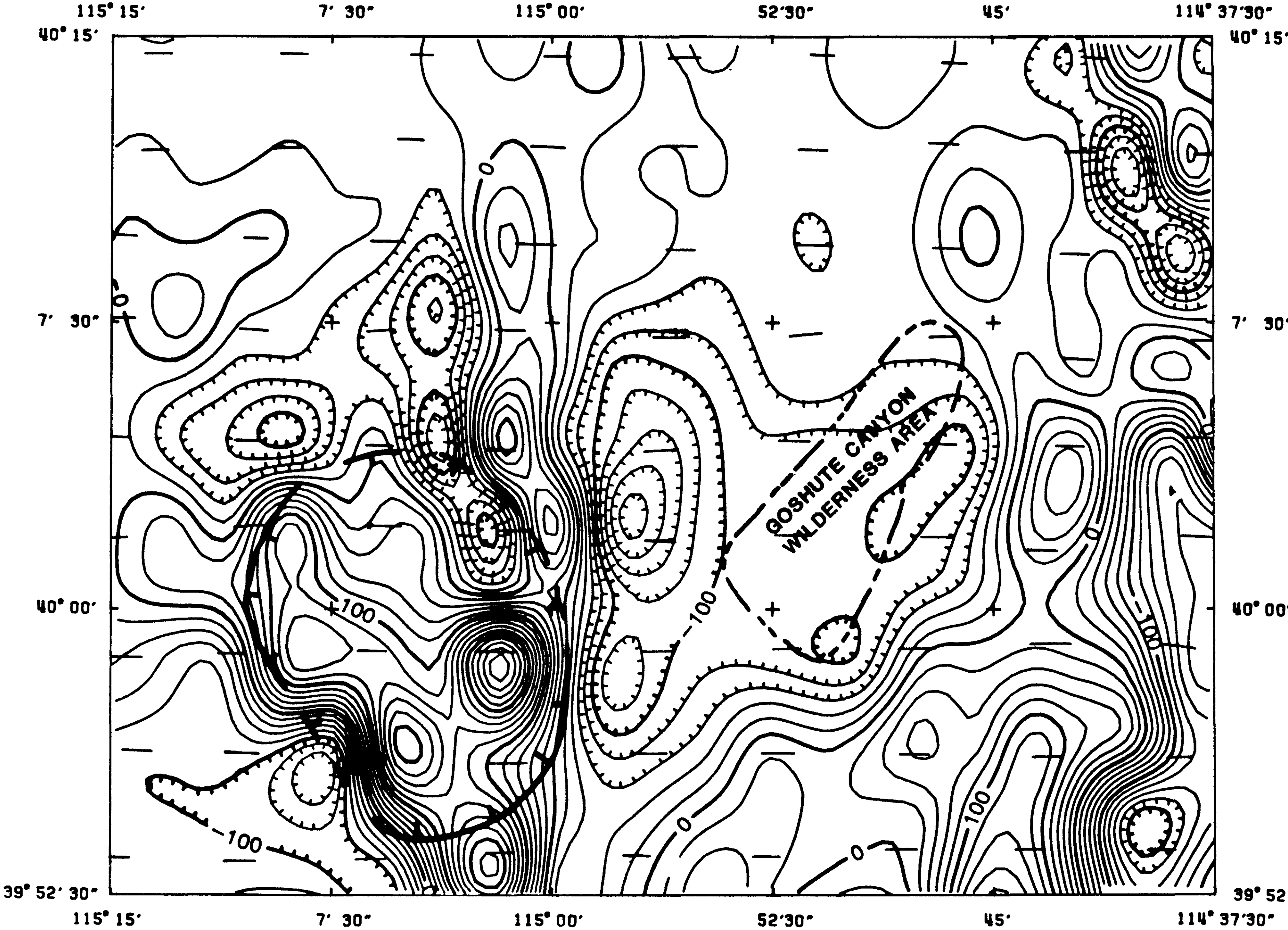

FIGURE. 4.–Aeromagnetic map of Goshute Canyon Wilderness Study Area and vicintiy. Contour interval 20 gammas. Flown at 152 meters above ground and upward continued to 305 meters.

— ⟶ Flight line.

—-- — Boundary of Wilderness Study Area.

Approximate boundary of caldera.

SCALE 1:250000

0 5 10 15 20 KILOMETERS

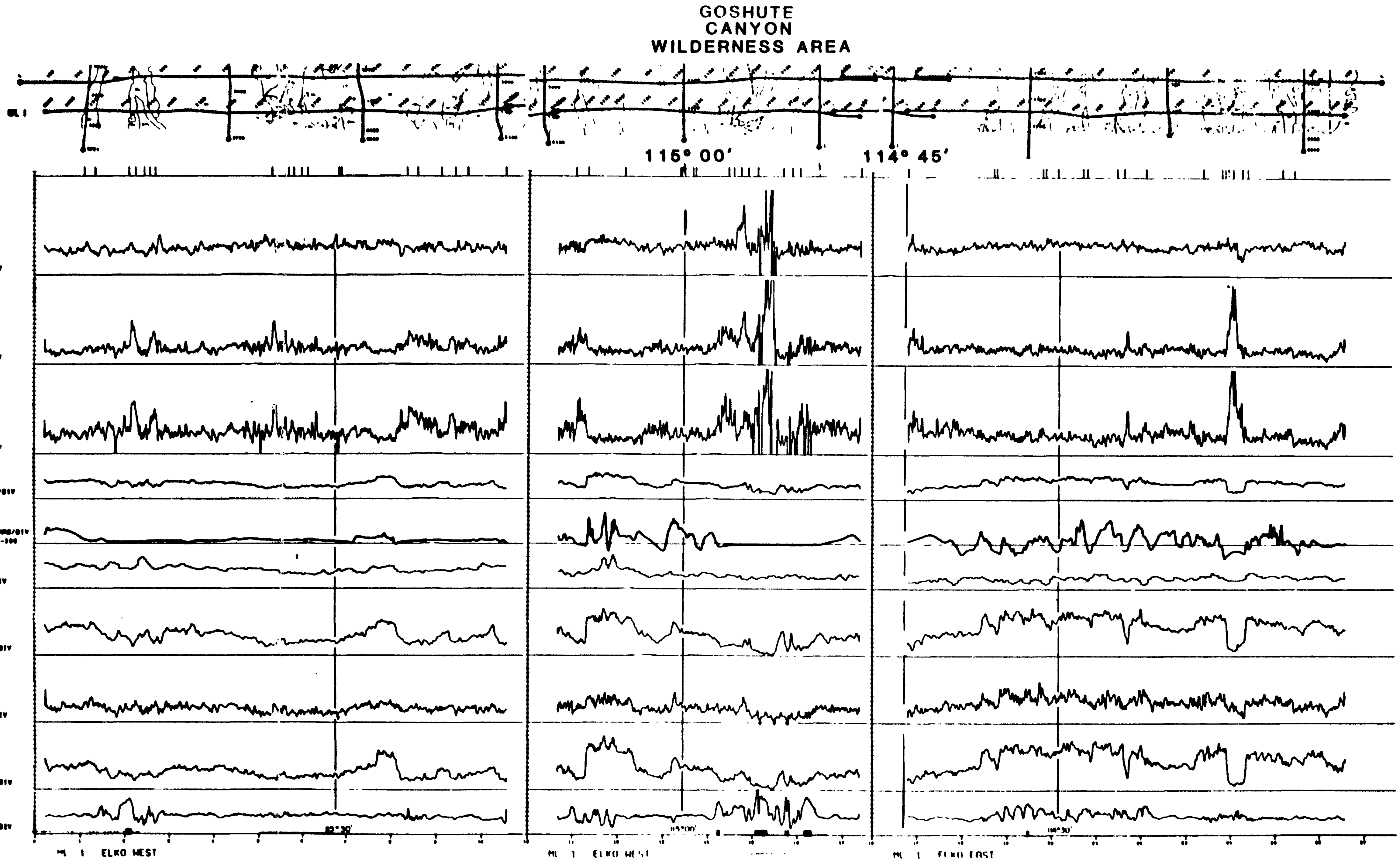

FIGURE 5a.–NURE aeromagnetic and radiation profiles along profile ML1.

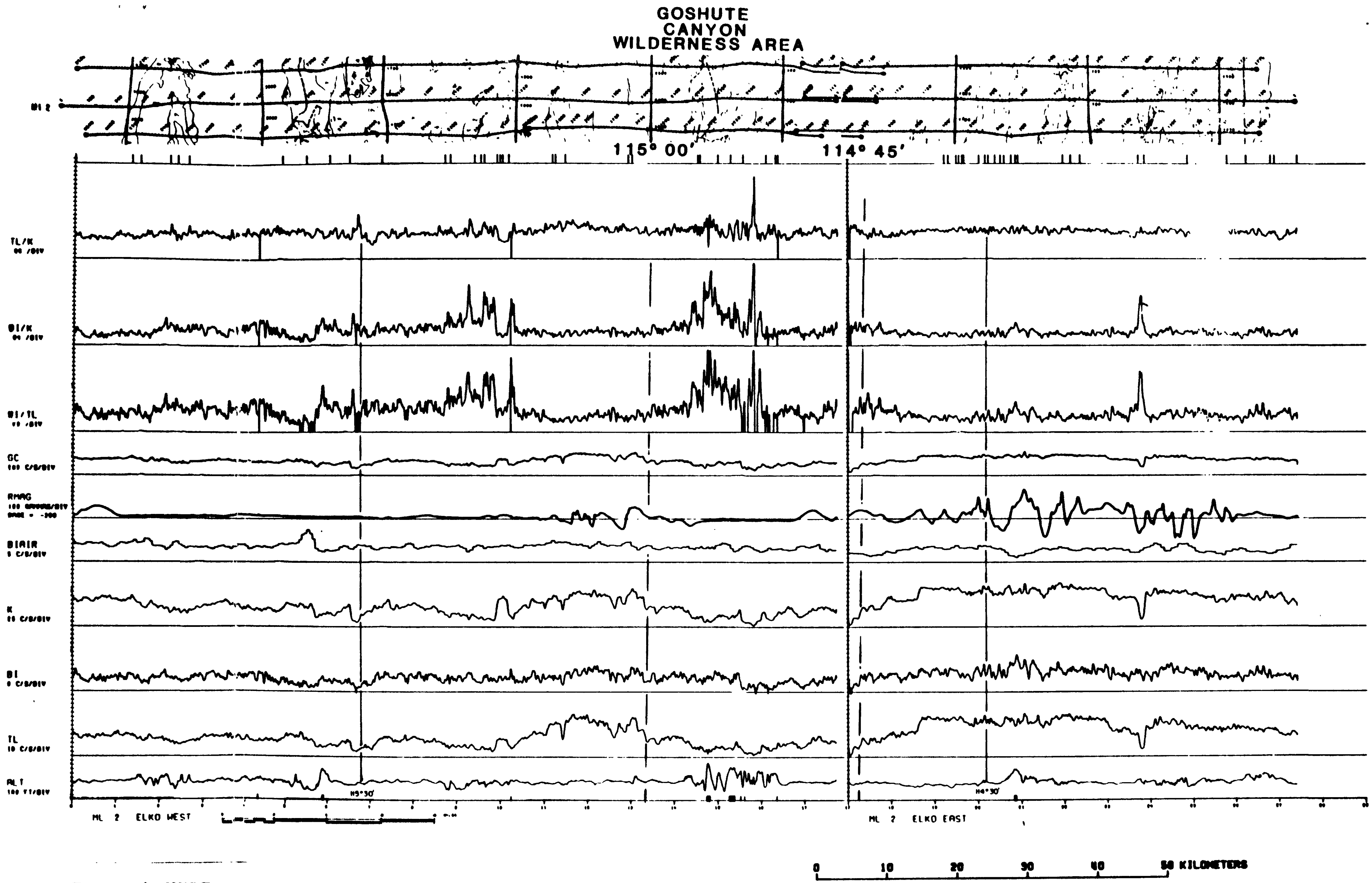

FIGURE. 5b.–NURE aeromagnetic and radiation profiles along profile ML2.

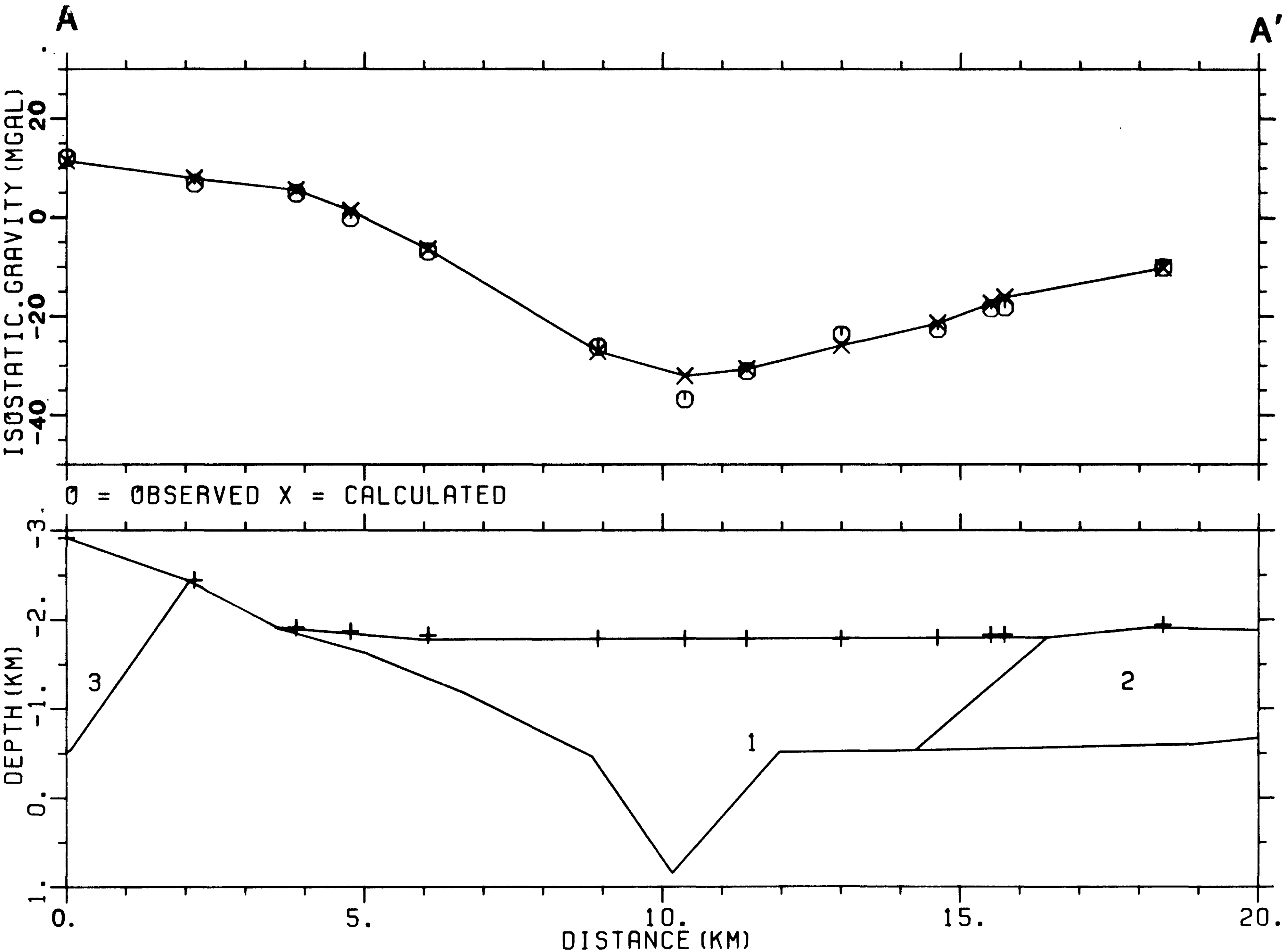

FIGURE. 6.–Gravity analysis along A-A′. Vertical exaggeration 1.5, scale 1:90,000. Density contrast with respect to 2.67 g/cm^3: body 1 = -0.67 g/cm^3; body 2 = -0.37 g/cm^3; body 3 = 0.05 g/cm^3.

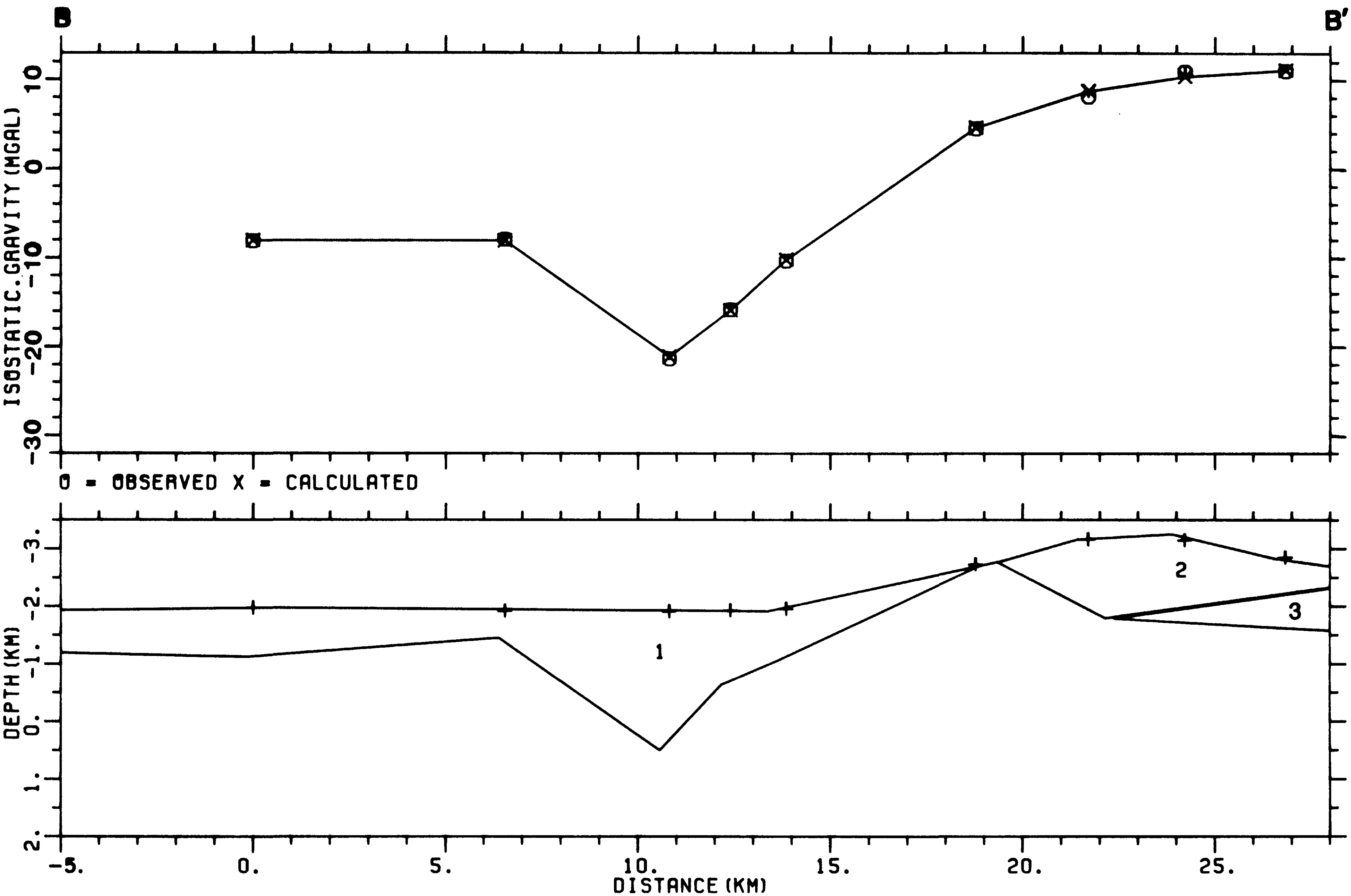

FIGURE. 7.–Gravity analysis along B-B′. Vertical exaggeration 1.5, scale 1:143,000. Density contrast with respect to 2.67 g/cm^3: body 1 = -0.47 g/cm^3; body 2 = 0.05 g/cm^3; body 3 = 0.13 g/cm^3.

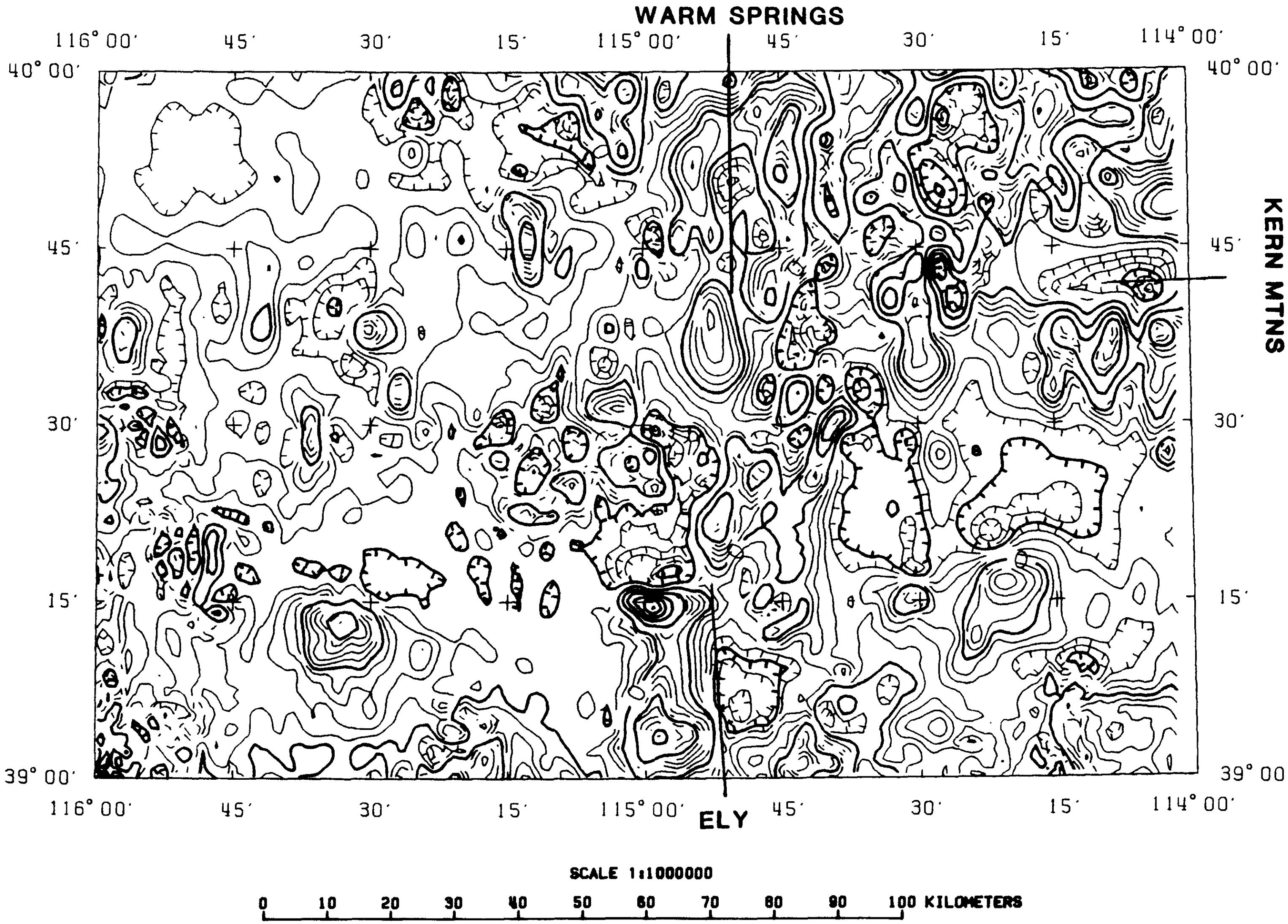

FIGURE. 8.–Preliminary aeromagnetic map of the Ely 1°x2° quadrangle. Contour interval 20 gammas. Flown at 152 meters above ground with a flight line spacing of 3 kilometers and upward continued to 305 meters.