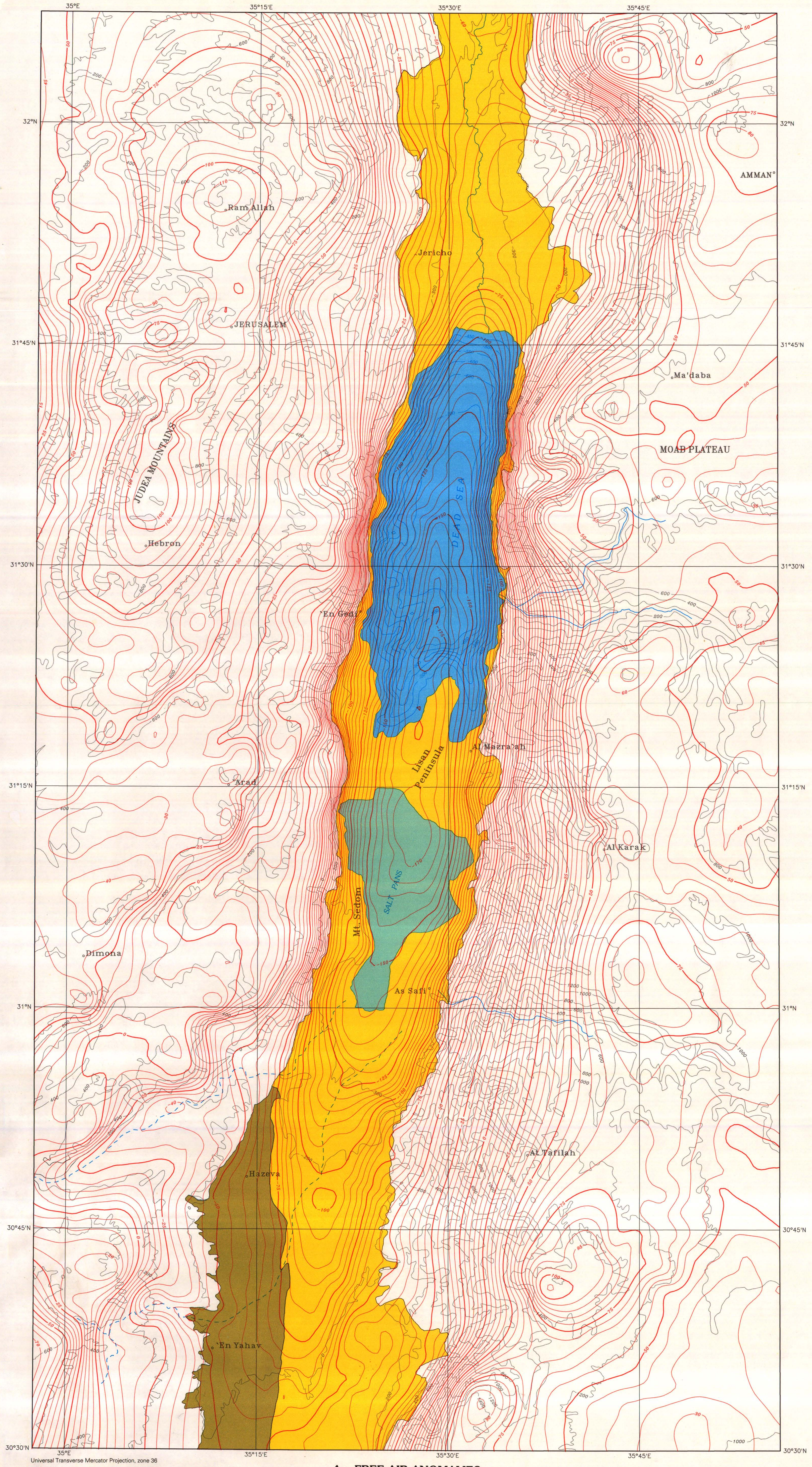
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

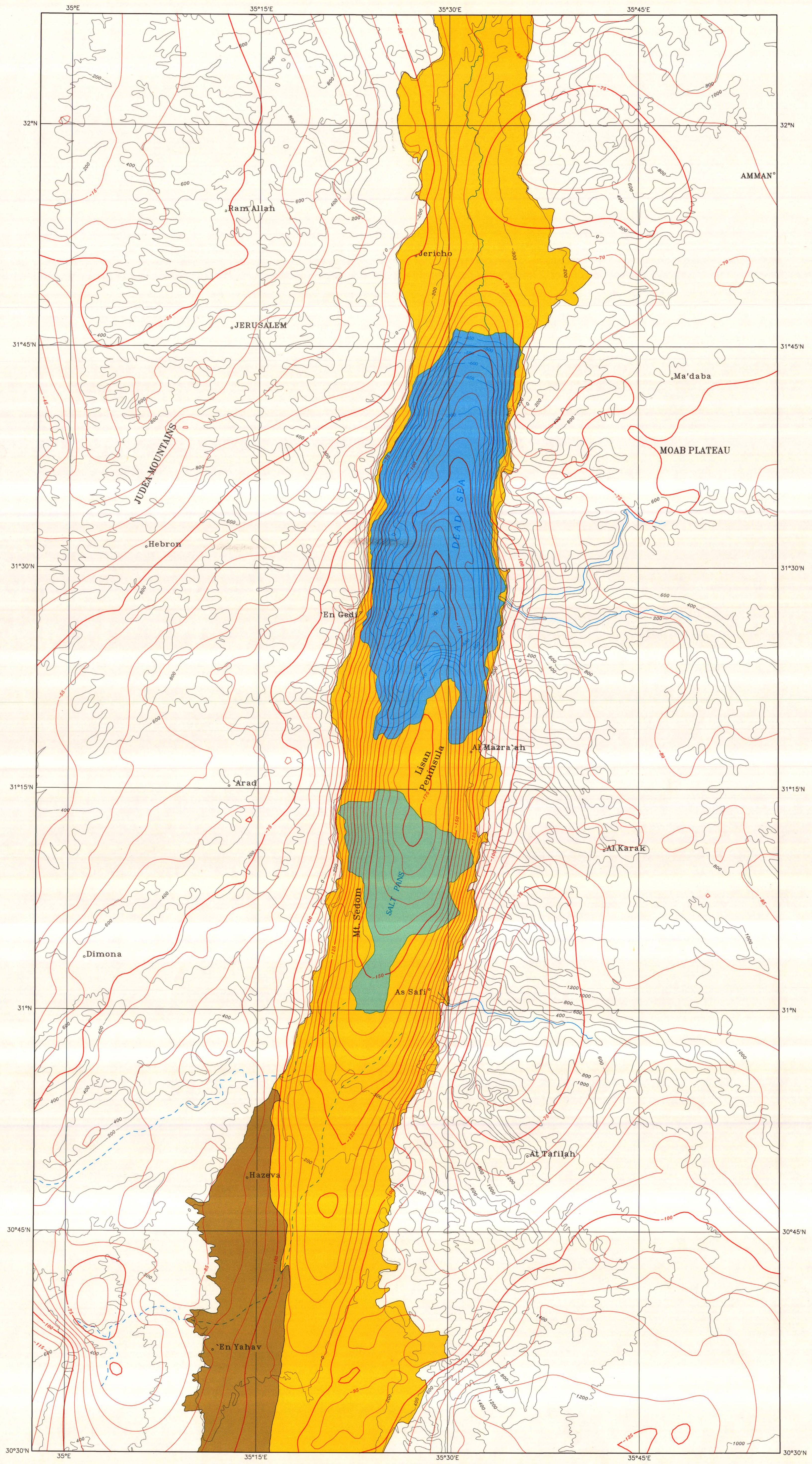
GEOPHYSICAL INVESTIGATIONS
MAP GP–1008



Universal Transverse Mercator Projection, zone 36

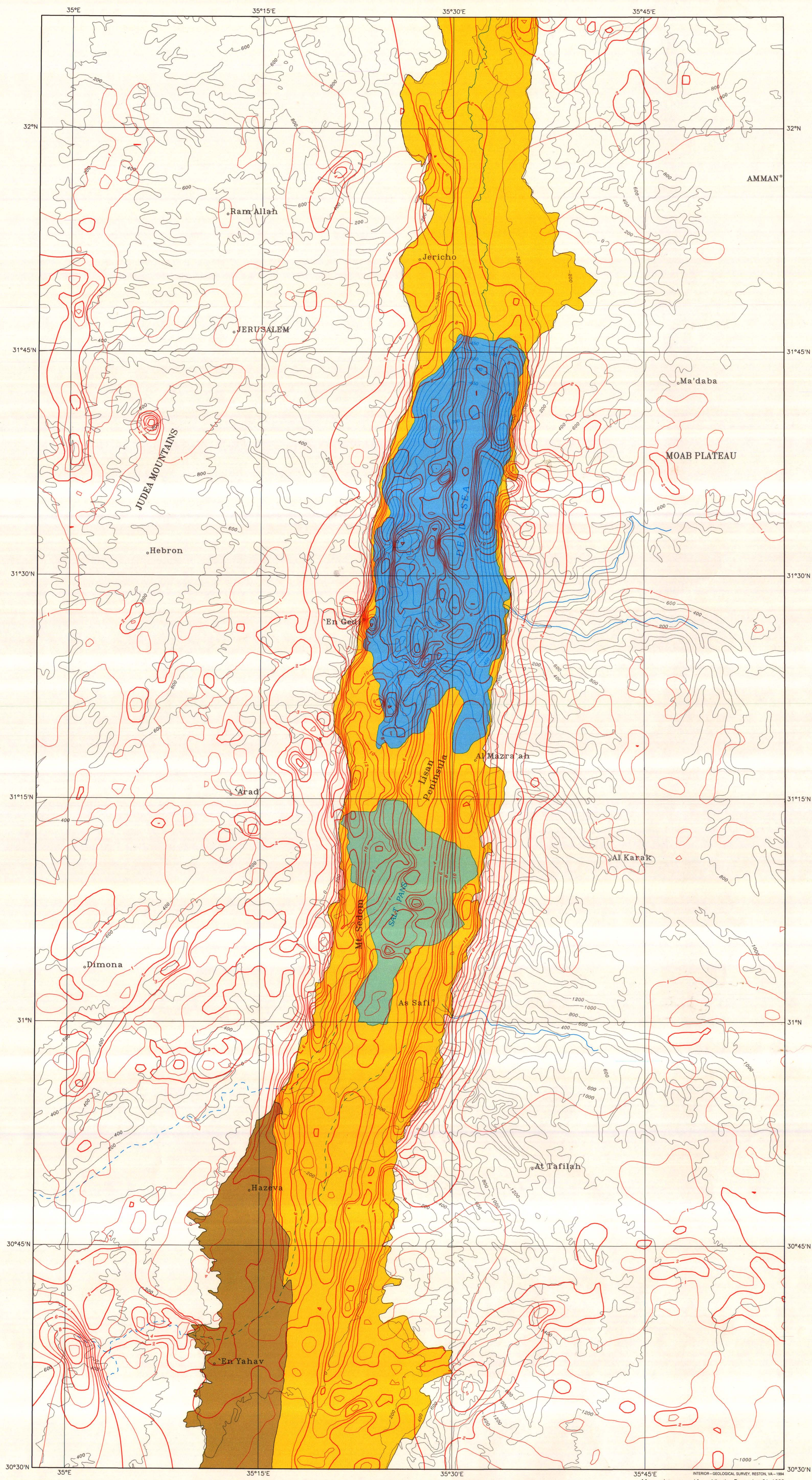
Geographic base map and geology digitized from the Geological Map of Israel, 1965 (reprinted 1983) scale 1:250,000; Picard, L. Y. and Golani, U., northern sheet; Bentor, Y. K., Vroman, A., and Zak,I., southern sheet.

A. FREE AIR ANOMALIES



B. BOUGUER ANOMALIES

Densities used for Bouguer corrections: 2150 kg/m^3 below 250 m b.s.l corresponding to Quaternary sediments within the transform valley and 2550 kg/m^3 above 250 m b.s.l. corresponding to Mesozoic carbonate cover outside the transform valley. The change in density of the Bouguer correction across the elevation contour of -250 m results in a step of 2.65 mGal in the Bouguer anomaly, which is small compared to the amplitude of Bouguer anomalies in the basin. Density of Dead Sea water, 1280 kg/m^3, calculated from its salinity and temperature (Fonofoff and Millard, 1983), was replaced with a density of 2150 kg/m^3. Reference level for map is lake level during the survey, 408.13 m b.s.l.



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C. FIRST DERIVATIVE OF BOUGUER ANOMALIES

The absolute horizontal derivative $((\delta g/\delta x)^2+(\delta g/\delta y)^2)^{1/2}$ emphasizes the short wave-length features in the Bouguer map. Small high amplitude anomalies west of the transform valley are artifacts of the gridding program.

SCALE 1:250 000

5 0 5 10 15 20 25 30 35 40 45 KILOMETERS

5 0 5 10 15 20 25 MILES

GRAVITY MAPS OF THE DEAD SEA BASIN

By
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1994

EXPLANATION

- Quaternary sediments
- Miocene sediments
- Contact
- **Topographic contour**—Contour interval 200 meters
- **Bathymetric contour**—Contour interval 50 meters
- **Gravity contour**—Contour interval on maps ***A*** and ***B*** is 5 mGal; on map ***C*** 1 mGal/km

DATA ACQUISITION, REDUCTION, AND COMPILATION

The Dead Sea basin is located within the Dead Sea transform valley (colored area on the maps). The northern part of the basin is occupied by the Dead Sea, a 300-m- deep lake. In 1988, 300 line km of marine gravity data were collected on the Dead Sea from a 15-m-long utility vessel using the Bell Aerospace BGM-3 marine gravimeter with documented accuracy of better than 1 mGal. This was a unique installation of a modern marine gravimeter for a gravity survey of a lake. Gravity was continuously measured during 3 days and 1 night at an average speed of 5 knots. Gravity was recorded at 1 s intervals and monitored in the field using two COMPAQ 386 computers. Navigation was measured every 1 s by a portable 5.4–5.6 GHz radar- ranging system (Mini-Ranger) of the Israel National Oceanographic and Limnological Institute using the distance from three land stations. The land stations were located at intervals of 10–15 km on the western shore of the lake. The positional accuracy of the system was 3 m. A visual steering program allowed an accurate control of the vessel's course and speed. Water depth was measured using an analog 3.5 KHz DFS- 6000 echo-sounder of the Israel National Oceanographic and Limnological Institute with an accuracy of 0.5 m (in sea water). The elevated salt concentration of Dead Sea water affects both the water density and its acoustic velocity. Four calibrations of the recorded travel time to the lake bottom, made by measuring with a weighted line, gave a water velocity of 1755 m/s which is within 1% of a previous calibration. Additional bathymetry was digitized from single channel profiles (Neev and Hall, 1976), and integrated with our data. The level of the Dead Sea during data acquisition (October 10–13, 1988) was 408.13 m below mean sea level (b.s.l.). A moving average filter with a 200 s Gaussian window was applied to the marine gravity data to remove the accelerations of the vessel. The data were manually edited to remove spurious measurements and were integrated with the navigation data. The drift of the gravimeter was negligible over the short period of the survey. Eötvös correction was applied to compensate for the vessel's speed. The accuracy of the gravity measurements, after adjusting for internal consistency between tie lines, is 1.5 mGal. The marine gravity measurements were tied to a land gravity station, established by the Institute of Petroleum Research and Geophysics (Israel), at the pumping station of the Dead Sea Works Co. on the southwestern shore of the lake. This station was, in turn, tied to two regional stations of the Israeli gravity network.

Free-air gravity values in the western side of the basin were obtained from the archives of the Institute of Petroleum Research and Geophysics (Israel). The values were re-calculated using the 1967 International Gravity Formula to match the marine data and the data from the Kingdom of Jordan. Original field readings in the eastern side of the basin were obtained from the archives of the Natural Resources Agency, Kingdom of Jordan. The readings were converted to gravity values, corrected for meter drift, and edited (North et al., written communication, 1992). The Jordanian data set also included edited gravity values collected by Amoco Oil Co. Merging the marine and the Israeli data with the Jordanian data presented the largest uncertainty in the accuracy of the gravity data set because a reliable tie has never been established between the gravity networks of the two countries. Since a large difference was present between the gravity networks of the two countries, we compared gravity points measured at close geographical proximity across the international border. Five pairs of gravity points, located along the dikes surrounding the Israeli and Jordanian salt pans between lat. 31°7.5′N and 31°10.2′N, are only 450–650 m apart and their elevations are well known. The differences in gravity values between the five pairs of points were between 15.5–17.0 mGal. Gravity gradients were also calculated along short east-west profiles on the Israeli dikes at lat. 31°5.3′N and 31°6′N. The gradients were extrapolated eastward, and compared to two Jordanian gravity points yielding differences of 14.2 and 15.2 mGal. The median value of all the above comparisons was 15.5 mGal, and this value was subtracted from the Israeli and marine data before merging the data sets. Terrain correction was not applied to either data set. The free air and Bouguer maps were gridded using a 500-m cell size then smoothed. The first horizontal derivative field was smoothed using a median filter with a diameter of 2 km and gridded at 0.25′.

INTERPRETATION

The free air gravity anomaly map (*A*) is principally representative of the topography. The anomaly is fairly flat east of the escarpment and decreases approximately 230 mGal toward the basin. A 10–12 mGal/km gravity gradient between lat. 31°00′N and 31°37′N marks the cliff along the western side of the lake. The axis of the Judea Mountains is identifiable in the northwest corner of the map and the northeast-southwest-trending monoclines are identifiable farther south. The maximum peak-to-trough difference in the free air anomaly between the Judea Mountains and the Dead Sea (335 mGal) is 100 mGal larger than that between the Moab Plateau and the Dead Sea, although both flanks are at similar elevations. This indicates the existence of a regional gravity trend decreasing to the east. The trend is clearly observed on a regional-scale Bouguer- gravity profile (ten Brink et al., 1990) and is due to thickening of the crust from 12 km in the Mediterranean Sea to 35 km in the Arabian desert.

Following Folkman (1981), the interpretation of the Bouguer gravity map (*B*) assumes that the anomalies are entirely due to density differences between the basin fill (2150 kg/m^3) and the surrounding Mesozoic sediments (2550 kg/m^3), and to a lesser extent to density differences between the subsided Mesozoic sediments under the basin and the surrounding crust (2670 kg/m^3). The absence of a Bouguer gravity anomaly over the Mt. Sedom salt diapir indicates that the density of evaporites is similar to the rest of the sediments filling the basin. The absence of a Bouguer gravity anomaly within the valley north of the lake argues for the lack of appreciable magmatic intrusion into the crust under the transform valley (ten Brink et al., 1990).

The Bouguer gravity anomaly map (*B*) defines the areal extent of the Dead Sea basin. The north end of the basin is about 5 km north of the Dead Sea. The constant gravity gradient at the northern end precludes the existence of a large normal fault there. A gradient in the Bouguer anomaly at 31°50′N marks the point where the basin becomes considerably shallower and another gradient at 30°40′N marks the southern end of the basin. The basin is associated with a negative Bouguer gravity anomaly of up to 100 mGal below the values in the surrounding area. The minimum anomaly is fairly flat and centered around the Lisan Peninsula. The negative anomaly is confined within the transform valley on the west side, suggesting that the depocenter is significantly narrower than the width of the valley and is located in the eastern part of the basin.

A first derivative map (*C*) emphasizes the short wavelength features of the Bouguer anomaly. It shows a linear "valley" connecting zones of minimum gravity gradient lying between two linear "crests" connecting zones of maximum gravity gradient. The crests align along the eastern and western sides of the basin and are interpreted as the expression of the boundary faults. These crests do not join at the southern and northern ends of the basin implying that there are no fault offsets at these ends. They do, however, become closer to each other indicating that the basin narrows toward its ends. South of lat 30°56′N the western crest deviates from the edge of the basin and follows the contact between the Miocene Hazeva Formation and the Quaternary fill. Seismic data show that the contact overlies a buried fault (ten Brink and Ben-Avraham, 1989). The valley connecting minimum gravity gradient (except north of the Lisan peninsula) probably marks the deepest part of the basin. There are few minor offsets along the valley of low gradient, which may be attributed to subsurface diagonal faults. A two-step decrease from the western crest of maximum gradient to the valley of low gradient between lat 31°00′ and 31°37′ corresponds to eastward-dipping blocks with intermediate depth (Kashai and Crocker, 1987, ten Brink and Ben-Avraham, 1989). Additional analysis, interpretation, and modeling are given by ten Brink et al., (1993).

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