UNITED STATES
DEPARTMENT OF THE INTERIOR
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TECHNICAL LETTER NUMBER 12

CRUSTAL STRUCTURE IN THE VICINITY OF LAS VEGAS, NEVADA, FROM SEISMIC AND GRAVITY OBSERVATIONS*

by

John C. Roller**

DENVER, COLORADO

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Technical Letter
Crustal Studies-12
May 1, 1963

Dr. Charles C. Bates
Chief, VELA UNIFORM Branch
Advanced Research Projects Agency
Department of Defense
Pentagon
Washington 25, D. C.

Dear Dr. Bates:

Transmitted herewith are 10 copies of:

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We intend to submit this report for publication in a review of Geological Survey Research in 1963.

Sincerely,

L. C. Pakiser

L. C. Pakiser, Chief
Branch of Crustal Studies

* Work performed under ARPA Order No. 193-62.

** U. S. Geological Survey, Denver, Colorado.

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Abstract. A seismic-refraction profile indicates that the crust of the earth increases in thickness by as much as 5 km over a horizontal distance of less than 25 km northeast of Las Vegas, Nevada. This feature correlates with a decrease in the Bouguer anomaly and an increase in the average surface altitude.

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Introduction. The U. S. Geological Survey recorded a seismic-refraction profile from a shot point near Kingman, Arizona, northwest across the Las Vegas Valley shear zone (Longwell, 1960) toward the Nevada Test Site (NTS) for a distance of 265 km during June 1962 (Fig. 1). Seismic waves, generated by 4 chemical explosions that ranged in size from 2,000 to 10,000 lbs, were recorded at 24 positions.

Standard seismic-refraction procedures and wide-band recording on both photographic paper and magnetic tape were used in the field (Warrick and others, 1961). Recording positions were spaced approximately 10 km apart along the profile, and at each position six vertical seismometers were spaced 0.5 km apart in a line generally parallel to the line of profile. Two horizontal seismometers (radial and transverse) were placed beside one of the vertical seismometers.

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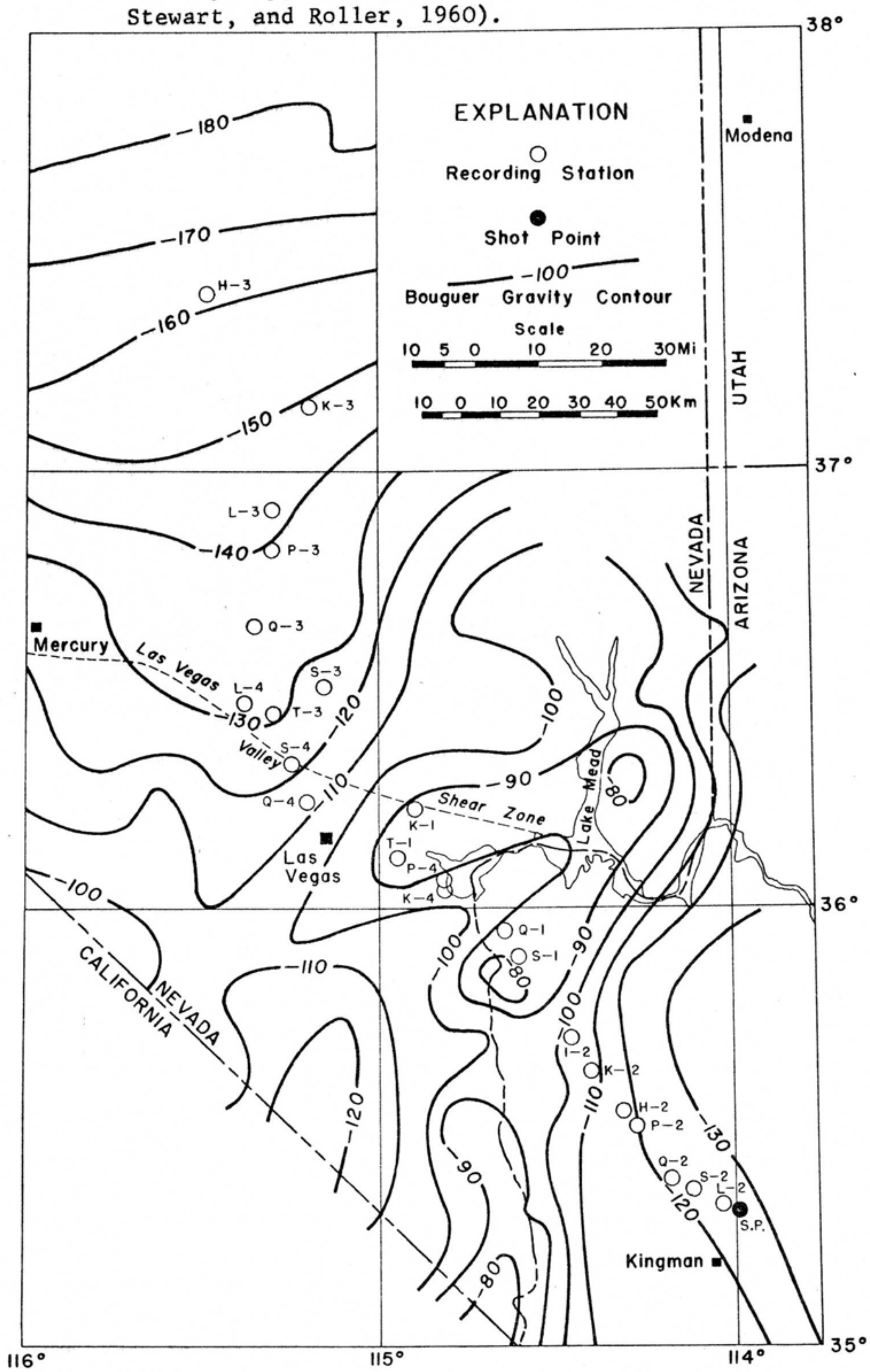
** U. S. Geological Survey, Denver, Colorado.

Figure 1.--Index map showing location of Kingman, Ariz., shotpoint, seismic-recording positions, and generalized Bouguer anomaly map. (Bouguer anomaly map taken from Diment, Stewart, and Roller, 1960).



The area traversed by the seismic profile is characterized by a series of mountain ranges composed mainly of Paleozoic sedimentary rocks and Tertiary volcanic rocks. The ranges are separated by alluvial basins (Bowyer, Pampeyan, and Longwell, 1958). The profile crosses a major shear zone, the Las Vegas Valley shear zone, north of Las Vegas, Nevada (Fig. 1). North of this zone the ranges and many geologic features strike generally north, and the average surface altitude is significantly higher than the area south of the shear zone, where the structural and topographical pattern is more complex (Longwell, 1960).

The generalized Bouguer anomaly map (Fig. 1) shows a relatively flat, although locally complex, pattern immediately south and east of Las Vegas, and a general regional decrease to the north. The Bouguer anomaly contours are based on data from stations on Pre-Tertiary bedrock.

This profile approximately reverses a seismic-refraction profile that was recorded from NTS to Kingman from nuclear explosions in 1957 and 1958 by the U. S. Geological Survey (Diment, Stewart, and Roller, 1961).

Results. Results of observations of the previous profile, from NTS to Kingman, show that the crust is about 28 km thick with an apparent velocity of 6.15 km/sec underlain by the mantle with an apparent velocity of 7.81 km/sec (Diment, Stewart, and Roller, 1961).

These data were based on first-arrival direct waves (P_g) through the crust from NTS to near Boulder City, Nevada, and on first-arrival waves refracted along the mantle from Boulder City to near Kingman. The reversed profile from Kingman toward NTS indicates a thin surface layer with an apparent velocity of 5.2 km/sec overlying a crustal layer with an apparent velocity of 6.1 km/sec (Fig. 2).

The seismic waves that are refracted from the mantle (P_n) south of the Las Vegas Valley shear zone fit a line with an apparent velocity of 7.8 km/sec, and indicate that the crust is 27 km thick. P_n waves that are refracted from the mantle north of the shear zone are delayed 0.55 sec with respect to those south of the shear zone, and indicate a crustal thickness of 32 km. The change in thickness occurs within a horizontal distance of 25 km or less, and may even be a vertical or near-vertical displacement. The P_n arrivals at Q-3 and possibly at P-3 (Fig. 1) that produce the apparent slope in the flexure (Fig. 2) could actually be diffracted waves from a fault-type structure (Heiland, 1956). The delayed arrivals may be related in part to the thickening of Paleozoic sedimentary rocks northwest of Lake Mead. The seismic profile crosses the Las Vegas Valley shear zone in the same general area that the Paleozoic section increases in thickness (Bowyer, Pampeyan, and Longwell, 1958).

The above crustal models were computed assuming flat layers with constant velocities. The velocity in the crust probably increases with

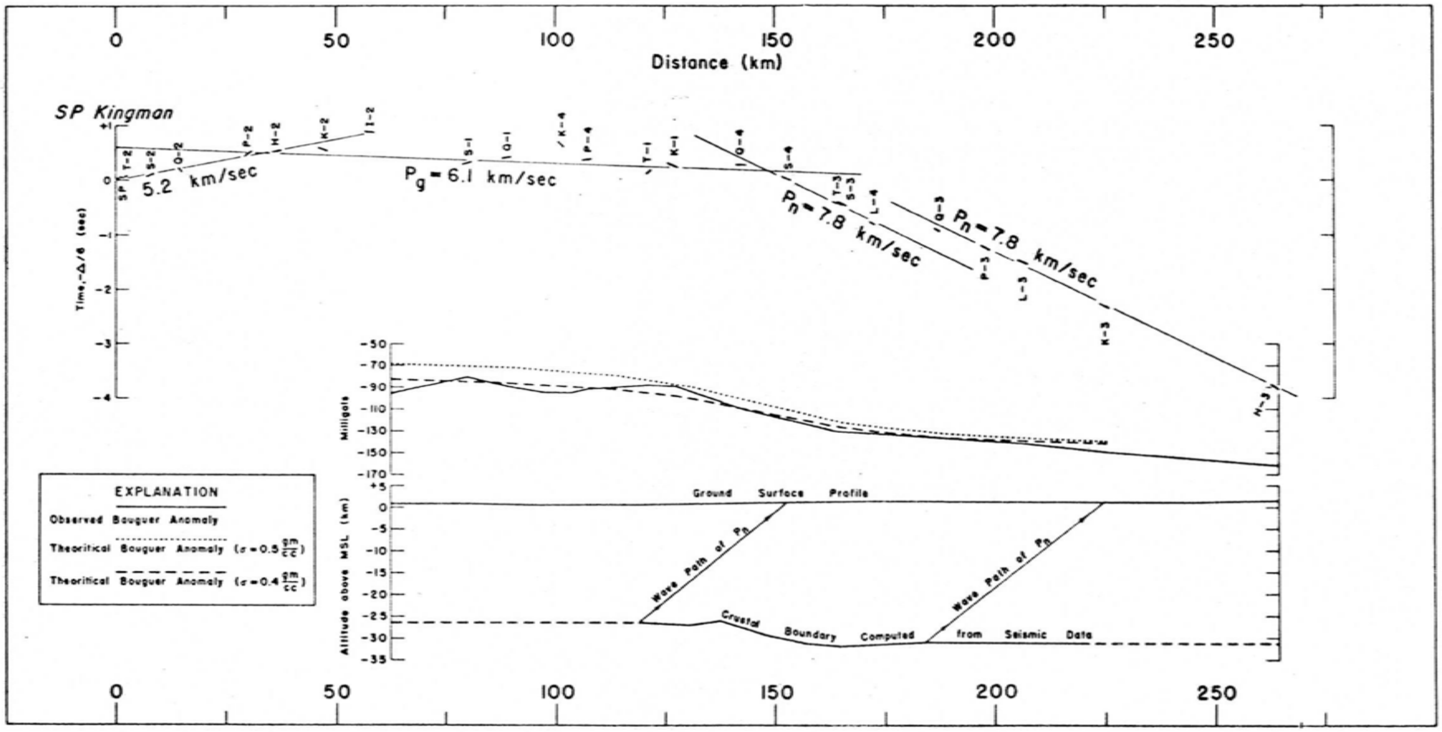


Figure 2.--Traveltimes of first arrivals showing generalized Bouguer anomaly, Bouguer anomaly for the seismic crustal model, and a crustal model computed from seismic refraction data.

depth, as shown by several authors (Berg and others, 1960; Healy, 1963; and Ryall and Stuart, 1963), so these depths are minimums. The relative depths should be correct, however.

The first-arrival times (Fig. 2) that define the 5.2 km/sec line and the 6.1 km/sec line are the uncorrected observed times. Arrival times that define the P_n lines have been corrected for low-velocity material near the surface, either from gravity and seismic data, or by estimating the thickness of these low-velocity sediments from the geologic environment of the recording positions. The seismograms also contain many secondary arrivals, the discussion of which is beyond the scope of this short paper.

The observed Bouguer anomaly profile (Fig. 2) shows a general regional correlation with the crustal cross-section, as computed from a delay-time analysis of the seismic-refraction data (Pakiser and Black, 1957). An area of relatively high Bouguer gravity is observed over the thinner crust and an area of lower gravity is observed over the thicker crust.

Two theoretical Bouguer anomaly curves using assumed density contrasts between the crust and mantle of 0.4 g/cc and 0.5 g/cc were computed (Fig. 2). Assuming a density of 3.3 g/cc for the mantle, which corresponds with a compressional-wave velocity of 7.8 km/sec (Talwani, Sutton, and Worzel, 1959), the density contrast of 0.5 g/cc gives a crustal density of 2.8 g/cc, which corresponds with the observed P_g

velocity of 6.1 km/sec. The density contrast of 0.4 g/cc corresponds with a compressional-wave velocity of 6.5 km/sec and a density of 2.9 g/cc. The theoretical curve using a density contrast of 0.4 fits the observed curve within 10 mgals. This may indicate an increase in crustal velocity with depth.

The most significant difference between the theoretical and the observed Bouguer anomalies is that the gradient on the observed curve is steeper, which indicates that only part of this gradient can be attributed to the crust-mantle boundary, and part must be attributed to density contrasts within the crust. Immediately east of Las Vegas, the trends of the gravity contours deviate northward from the shear zone and generally follow a line between predominantly Paleozoic outcrops to the northwest and Pre-Cambrian outcrops to the southeast.

The surface altitude of the area also shows a general correlation with the seismic and gravity data (Mabey, 1960). South of the shear zone the average altitude is less than 1 km above sea level and the Bouguer anomaly is about -100 mgals. North of the shear zone the altitude above sea level averages about 1-1/2 km and the Bouguer anomaly decreases to -160 mgals at station H-3.

Three major implications can be drawn from these data: major fracture zones may extend to the Mohorovicic discontinuity and probably penetrate the mantle; the Mohorovicic discontinuity is not a flat surface but may include major flexures over relatively short horizontal distances; and in this area there is a regional correlation between thickness of the crust, Bouguer gravity anomaly, and average surface altitude.

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