UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Principal facts for gravity observations in Harold D. Roberts Tunnel, Colorado and the effect of isostasy

by

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INTRODUCTION

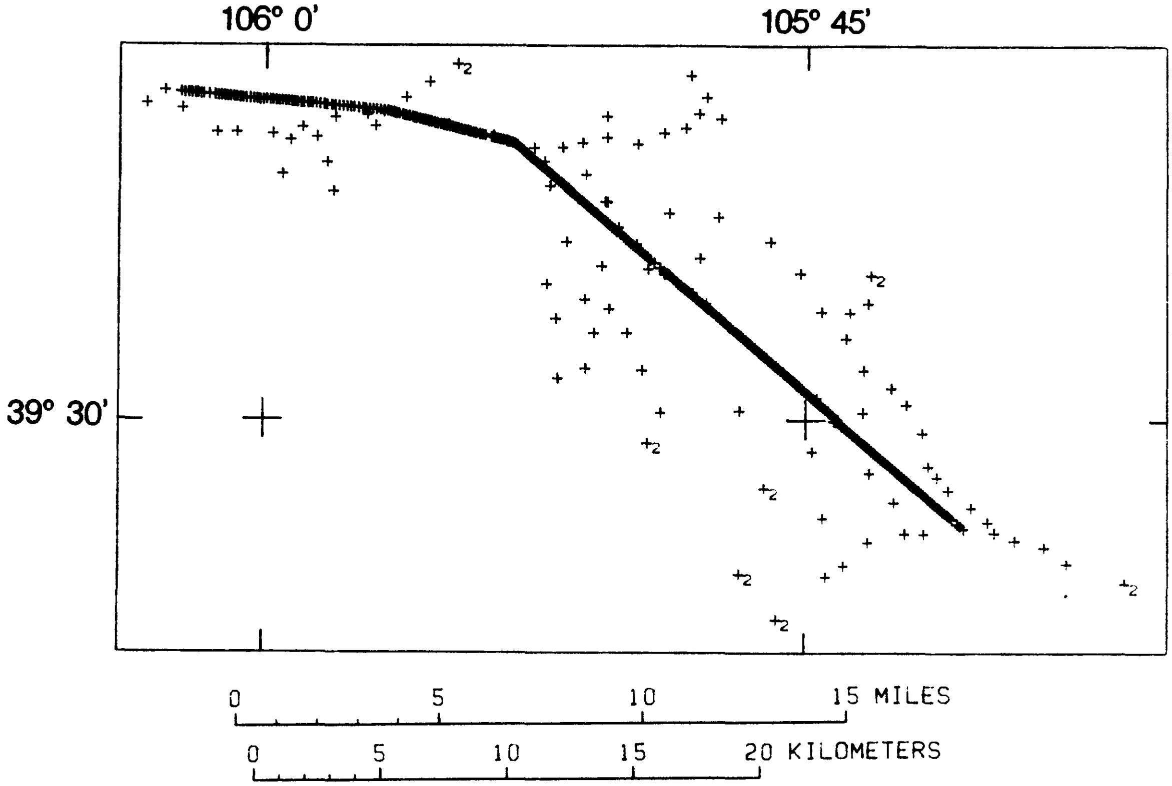
The main purpose of the present report is to publish values of observed gravity collected in the Harold D. Roberts Tunnel, Colorado. A total of 290 gravity stations was established by the U.S. Geological Survey in the tunnel between January 16, 1960 and August 31, 1960. About 100 additional stations were established on the surface near the tunnel (fig. 1), in order to map the regional gravity field. Plouff (1961) discussed the difficulty of using gravity data to calculate the average density of rocks between the tunnel and the ground surface. A few gravity terrain corrections were done at the time of the preliminary study. Terrain corrections needed to calculate the Bouguer gravity anomaly have not been made for the remaining stations.

The work was coordinated with that of Prof. G. P. Woollard of the University of Wisconsin, who wanted to predict the error of closure of the surveyed level potential surface at the point of breakthrough of the tunnel based on gravity measurements. The cooperative effort also was needed to fill an uncovered area of the Rocky Mountains in preparation of a gravity map of the United States. His study began in 1957 with an analysis of gravity stations established in his earlier transcontinental survey. His assistants, Peter Wolf and Monroe Woollard, established gravity stations at each portal, the top and bottom of the shaft, 5 paired stations in and on the surface above the tunnel, and 3 stations above the unexcavated part of the tunnel in 1959. Prof. Woollard supplied an initial absolute gravity value for the primary University of Wisconsin and U.S. Geological Survey base near Dillon. Prof. Woollard presumably made an estimate of the level error at the point of tunnel breakthrough, but I do not know if the results have been published.

OBSERVED GRAVITY

The values of observed gravity for all stations were tied to a network of 20 base stations that were established by the method of 3-step-looping (table 1). The absolute values of observed gravity at base stations RTB 1, RTB 6, RTB13, RTB15, and RTB18 were provided by D. J. Stuart (Stuart and Wahl, 1961), who tied to Woollard (1958) bases at the Denver and Colorado Springs airports with a La Coste and Romberg gravity meter. The gravity readings in and near the tunnel were made with two Worden gravity meters. Worden Gravity Meter W-226 with a constant of 0.4739 mGal/dial unit determined by the manufacturer was used to establish stations RT 1 through RT261 and bases RTB 1 through RTB14 between January 16 and February 19, 1960. Worden Gravity Meter E-340 with a constant of 0.2278 mGal/dial unit determined by the manufacturer was used to establish stations RT262 through RT404 and bases RTB15 through RTB20 between August 12 and August 31, 1960. The gravity data were reduced by using gravity meter constants of 0.4731±0.002 and 0.2273 mGal/dial unit, respectively, based on an unrecorded number of comparisons with values of observed gravity established by D. J. Stuart (written commun., 1960) with a LaCoste and Romberg gravity meter. Future adjustments of the values of observed gravity in the network of stations listed in tables 2 and 3 are facilitated, because base descriptions (table 1) and the base to which each station is referred are included as well as a location code (table 4) that identifies repeatible stations. Values are carried to 0.01 mGal, to avoid rounding errors.

A



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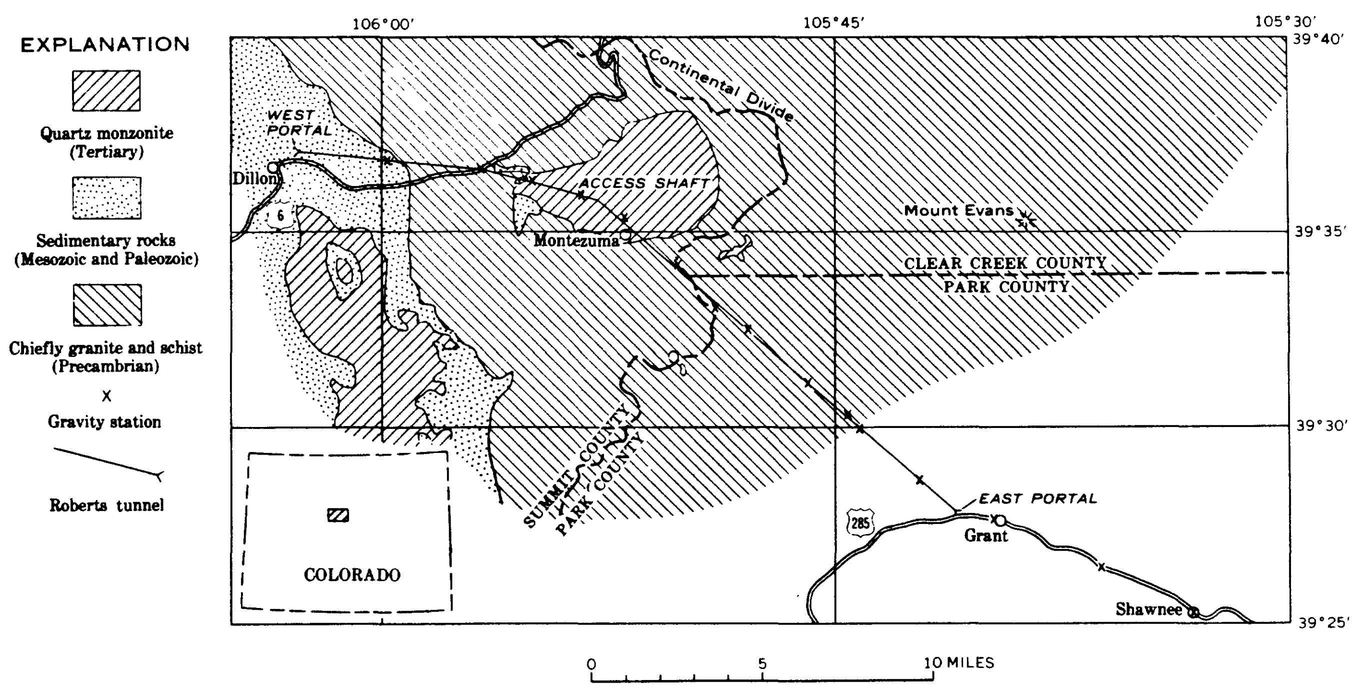

Figure 1.--Index map of study area. A. Location of gravity stations established by the U.S. Geological Survey as part of the present study. Number 2 indicates station from present study with coordinates from DMA File. B. Generalized geologic map (Plouff, 1961).

Assuming that the instrument calibrations are accurate and mis-readings did not occur, the largest expected error of observed gravity is about 0.4 mGal within the network. That value reflects the largest closure adjustment needed in the tunnel. Tide corrections were not made. Repeat readings indicated that distributed drift adjustments with amplitudes not exceeding 0.2 mGal were needed.

The datum for the values of observed gravity in tables 1, 2, and 3 is the International Gravity Standardization Net of 1971 (IGSN 71) described by Morelli (1974). The shift in datum from that of Woollard (1958), which was identified as the "Potsdam datum", was obtained by comparing the original values of "absolute" observed gravity obtained in 1960 with values assigned for the same stations outside the tunnel in the Defense Mapping Agency (DMA) Gravity File of the United States obtained from the Terrestrial Geophysics Data Services (written commun., 1984) of the National Geophysical Data Center in Boulder, Colorado. Generally, one would expect the values based on the IGSN-71 datum to be 14.5±0.2 mGal lower than those based on the Potsdam datum.

Gravity values for stations listed in the present report were found in five contributions to the DMA File. The DMA description of the contributor is quoted in uppercase letters in the following discussion. The datum shift obtained at 7 stations in source 2155 (USGS CRUSTAL STUDIES, 1963) is 14.03±0.02 mGal. The datum shift for 18 stations in source 2646 (D. PLOUFF, ROBERTS TUNNEL, COLORADO, USGS, 1960) is 14.04±0.03 mGal. Datum shifts for stations in source 3494 (G. L. BRINKWORTH, AREA WEST OF DENVER, COLORADO, USGS, 1969) (Brinkworth, 1970) were 13.79±0.01 mGal for 7 stations and 14.66±0.03 mGal for 13 stations. The discrepancy of about 0.9 mGal agrees with the expected error in many contributions to the DMA File, in which the contributor apparently reported values tied to bases listed in 1970 by Jablonski (1974) from the U.S. National Gravity Base Net (Schimmer and Rice, 1969) as though they were tied to the Potsdam datum. It is not known how many, if any, stations that nearly coincide with stations of the present report were independently established in source 3494, because different station numbers were assigned. The datum shift for 33 stations in source 3496 (J. C. BEHRENDT AND P. POPENOE, PARK AREA, COLORADO, USGS, 1970) (Behrendt and Popenoe, 1970) was 14.68±0.03 mGal. The last error mainly reflects the fact that gravity values of Behrendt and Popenoe (1970) contributed to the DMA file realistically were rounded to the nearest 0.1 mGal. About 16 of 23 stations from source 5259 (C. E. CORRY, GRAVITY DATA IN COLORADO * 4964 ETC., CLIMAX MOLYBDENUM) confirm a datum shift of about 14.7 mGal, but different station numbers and wide variations of the remaining 7 matched stations complicate comparisons. A datum shift of subtracting 14.68 mGal from the original values of observed gravity was applied, because this would be most consistent with the large number of nearby stations from Behrendt and Popenoe (1970). Future ties to base stations and other stations listed in the present report could reduce the apparent ambiguities.

LOCATIONS AND ELEVATIONS

Gravity stations outside the tunnel were located on topographic maps of the U.S. Geological Survey (table 3). The maximum expected error for locations of stations outside the tunnel is about 150 ft except for 20 stations, which were located near benchmarks not shown on the published maps. The estimated accuracy of those stations is 250 ft (0.05 mi on a

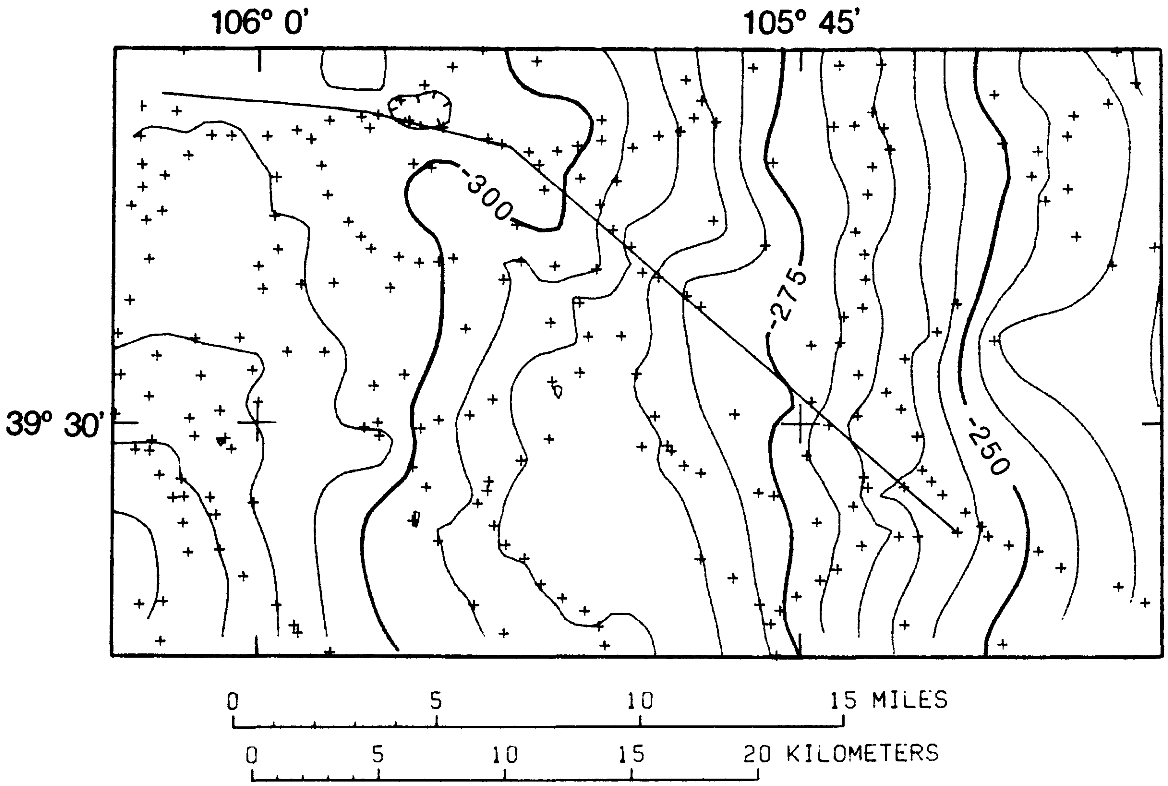

Figure 2.--Bouguer gravity anomaly map. Data from stations outside the tunnel (table 3) are supplemented by other data from the DMA Gravity File. Reduction density, 2.67 g/cm^3. Terrain corrections from station to 166.7 km obtained by using a modification of a computer program by Plouff (1977) with a digital terrain model of average elevations on a 15-second geographic grid. Contour interval, 5 mGal. Solid line indicates tunnel location.

vehicle odometer). About 20 other stations were deleted from the data set, because their locations were uncertain or their elevations were established by altimetry or topographic contour interpolation. Geographic digitization during the present study revealed that the coordinates for several stations are incorrect in the DMA Gravity File. A contour map of the estimated Bouguer gravity anomaly for other stations of the DMA Gravity File (fig. 2) revealed 6 inconsistent values that were deleted. Therefore, locations and elevations of stations in that file first should be confirmed or adjusted by plotting on topographic maps at the largest available scale.

Locations of stations established inside the tunnel were plotted on topographic maps of the U.S. Geological Survey by reference to a horizontal distance system posted at every 100 ft throughout the tunnel and correlation with tunnel bends (29,579 ft and 46,849 ft), the shaft location (45,940 ft), and the intersection with stream crossings and crests at the ground surface shown on the tunnel profile provided by the contractor, Tipton and Kalmbach, Inc. (Quentin Hornback, written commun., 1960). The west portal is at 946 ft and the east portal is at 123,856 ft in tunnel distance coordinates. The maximum expected error of locations is about 150 ft. Elevations of the gravity stations were determined by linearly interpolating among 236 elevation monuments established in the tunnel (Quentin Hornback, written commun., 1960).

TERRAIN CORRECTIONS

Gravity terrain corrections were made for only the few stations evaluated by Plouff (1961). Standard methods of estimating average elevations within compartments bounded by cylindrical sectors (Swick, 1942) were used to estimate terrain corrections from the station to a standard distance of 166.7 km from each of the stations outside the tunnel. No estimates for local terrain corrections were made in the field.

Standard tables or computer programs to determine terrain corrections for the mass of rock above stations in the tunnel were not known at the time of the original compilation. The gravity effect along the axis at the bottom of a vertical cylinder of mass provided a first approximation to the inner terrain correction for stations in the tunnel. The top of the cylinder is at the elevation of the ground surface obtained from tunnel profiles. Two radii of cylinders, 1,936 and 4,199 ft (590 and 1,280 m), were selected, depending on the distance beyond which conventional tables could be used. The latter, more distant radius is suggested for future hand terrain corrections, because the model assumed in the digital terrain correction program (Plouff, 1977), which provides the distant part of the terrain correction, would result in too small a correction near tunnel stations. Terrain corrections for departures of the ground surface from the assumed flat-topped cylinder were calculated by using a formula for the gravity effect of cylindrical sectors. The components of typical tunnel terrain corrections are listed in table 5. In 1960 the process of determining 4 square roots needed for the elevation difference of every sector was a formidable task involving multiple trial-and-error keystrokes on a calculator or logarithms, and, hence, few terrain corrections were attempted for stations located in the tunnel. A two-dimensional model was constructed to determine that the terrain correction for the rock excavated from the 11-ft-diameter tunnel was 0.11 mGal at the level of the gravity meter. Departures of the tunnel profile from the design and the effect of deep water were ignored. The terrain correction would be 0.17 mGal at the edge of the 16-ft-diameter shaft, but only two base stations were read near the shaft.

CALCULATION OF APPARENT DENSITIES

Data used by Plouff (1961) to calculate the apparent density of rocks between the tunnel and the ground surface are in table 6. Outer terrain corrections for tunnel stations were re-calculated by using a digital terrain model (Plouff, 1977). Outer terrain corrections for stations located outside the tunnel, however, were not updated, because the original terrain correction forms with estimates of needed inner "hand" terrain corrections were not found.

DISCUSSION

Values of the free air gravity gradient in this area of anomalous negative gravity (fig. 2) are lower than the standard value assumed for calculating apparent densities, and, consequently, the calculated densities are too high (Plouff, 1961). The need to account for the difficult-to-quantify effect of the anomalous distribution of rock densities beneath and alongside the tunnel exemplifies the principal fallacy in attempting to determine a "best density" for boreholes, horizontal profiles, or regional surveys based on gravity data.

Even the smoothly varying gravity effect of the crustal root that presumably compensates for the mass of rocks above sea level causes a measurable error in the density calculation (table 6). For example, the gravity difference associated with isostatic compensation between the tunnel at distance 64,250 ft (elevation 8,753 ft above sea level) and the surface at station RT359 (elevation 13,180 ft) is 1.40 mGal, and the corresponding adjustment to the density calculation is a decrease of 0.02 g/cm^3. The effect of isostatic compensation was estimated by using the computer program of Simpson and others (1983) to calculate the isostatic effect of an Airy-Heiskanen model (Heiskanen and Moritz, 1967). The parameters assumed for the isostatic model were 25 km for the normal crustal thickness, 2.67 g/cm^3 for the density of the crust, and 3.07 g/cm^3 for the density of the upper mantle. The terrain model consisted of average elevations estimated on a 3-minute geographic grid. The effect of isostatic compensation accounts for about 10 mGal (fig. 3a) of the 50-mGal westward decrease of the Bouguer gravity anomaly (fig. 2) along the tunnel.

The tunnel is near the north end of a 30- to 50-mGal gravity low, which Case (1967, p. 2) interpreted as a reflection of a silicic Tertiary batholith of lower density than adjacent crystalline rocks. Therefore, most of the 40 mGal of gravity relief along the tunnel can be attributed to the underlying Tertiary batholith centered to the west. The Montezuma stock of Tertiary age, which is centered near the shaft (tunnel distance 45,900 ft) and intersects the tunnel for a distance that exceeds 6 km (Robinson and others, 1974), appears to be a cupola of the batholith. The location of the stock correlates with the location of the deepest part of the regional gravity low (figs. 2 and 3b).

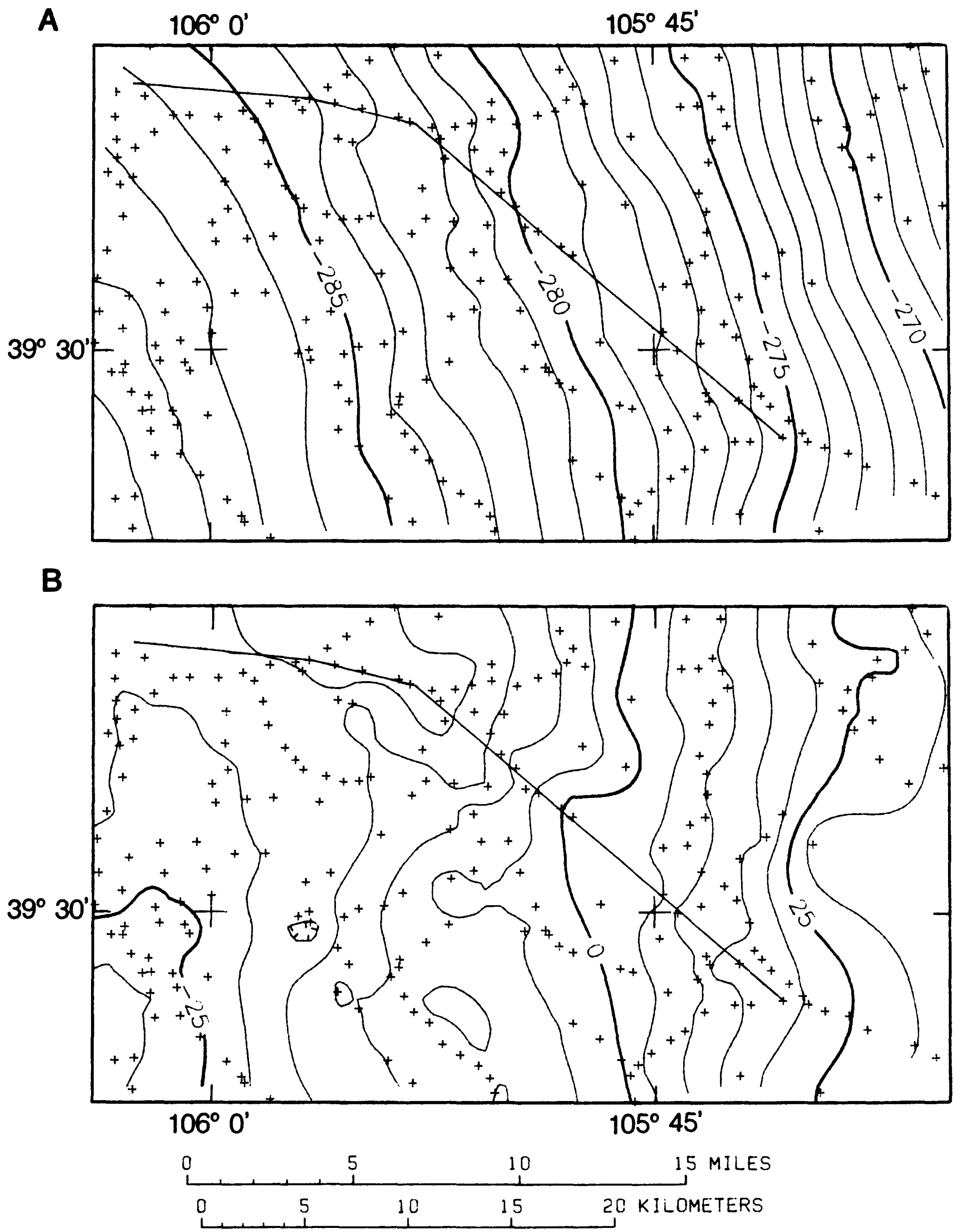

Figure 3.--Effect of isostasy. See text for crustal parameters assumed for the isostatic model. Solid line indicates tunnel location. A. Map of gravity effect of isostatic compensation. Contour interval, 1 mGal. B. Isostatic residual gravity map. Contoured values were obtained by subtracting values of isostatic compensation (fig. 3a) from the Bouguer gravity anomaly (fig. 2). Contour interval, 5 mGal.

ACKNOWLEDGMENTS

My assistant, Alvin J. Vaughan, patiently endured extremely humid conditions with temperatures exceeding 80 degrees F. while stumbling over railroad tracks hidden beneath water and while we hastily clung to walls beneath uninsulated electric wires in response to the unexpected appearance of ore trains from the darkness during 20 miles of tunnel coverage. Later, I was ably assisted by Mr. (Stephen?) Muir while establishing 25 tunnel stations and the gravity stations outside the tunnel, including many mountain tops. Mr. Quentin Hornback, resident geologist in behalf of Tipton and Kalmbach, Inc., was very helpful in providing access to the tunnel and supplying tunnel distances, elevations, and profiles.

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Table 1. --Descriptions, elevations, and values of observed gravity for base stations.

[EL, sea-level elevation at base of tripod. OG, observed gravity in milligals. BM, benchmark. LL, level line. Quad, quadrangle. Quadrangle maps are at a scale of 1:24,000 unless otherwise noted. Vee, corner of intersection whose outward direction is indicated by the bisector of the angle formed between the roads. Compass directions are abbreviated.]

RTB 1 Presumably base station occupied by University of Wisconsin crew. 2 ft E of post. E of SE bridge abutment at Ten Mile Creek. E of BM Z299 of LL-94. About 0.4 mi E of Dillon site.
Dillon 1:62,500 quad. EL 8,832.0 ft OG 979,298.80

RTB 2 75 ft S of and 7.1 ft lower than BM H10 of LL 89. In W Vee. NW edge of road. At U-curve sign near intersection. W of Hoosier Pass.
Mt. Lincoln quad. EL 10,801.3 ft OG 979,139.63

RTB 3 NW of highway. W of and between steel legs for overhead tram, which may no longer exist. SE of E portal of Roberts Tunnel. This station replaced by RTB15 because of frequent vibration at this location.
Mt. Logan quad. EL 8,669.2 ft OG 979,334.89

RTB 4 Top of steps. 17 ft W and 10 ft N of top of access shaft into Roberts Tunnel. 2 ft W of galvanized shed. Replaced by RTB 6 because of frequent vibration at this location.
Keystone quad. EL 9,695.3 ft OG 979,237.25

RTB 5 In Roberts Tunnel. E of access shaft. S edge of tunnel. E of railroad switch. 4 ft E of distance marker "462+50" (46,250 ft).
Keystone quad. EL 8,778.8 ft OG 979,247.37

RTB 6 2 ft NE of Ski Tip Ranch sign. In SE Vee of highway intersection. 42 ft E of and 1 ft higher than BM A300 (USBR) of LL-94.
Keystone quad. EL 9,456 ft OG 979,263.70

RTB 7 At corner of shed. N side of tunnel. Under pipes. Near distance marker "458+50" (45,850 ft).
Keystone quad. EL 8,779.2 ft OG 979,247.94

RTB 8 Inside W portal of Roberts Tunnel. S edge of tunnel. Under sign for distance marker "9+50" (950 ft).
Dillon 1:62,500 quad. EL 8,844.3 ft OG 979,297.24

RTB 9 In Roberts Tunnel. 2 ft N of beam. Near marker "91+00" (9,100 ft).
Dillon 1:62,500 quad. EL 8,832.9 ft OG 979,283.83

RTB10 3 ft W of front door of Breckenridge Masonic building. NE Vee. 200 ft S of and 3.8 ft higher than BM "9577" of LL-89.
Mt. Lincoln quad. EL 9,581.0 ft OG 979,227.57

Table 1.--continued

RTB11	At Alma. 3 ft E of stop sign in SE Vee. SW of and 0.8 ft lower than BM H6 of LL-89. Mt. Lincoln quad.	EL 10,354.5 ft	OG 979,172.84
RTB12	11 ft E of base of front steps to Fairplay Hotel. One block W and one block N from and 1.2 ft higher than BM H4 of LL-89. Leadville 1:125,000 quad	EL 9,945.9 ft	OG 979,208.38
RTB13	Along highway 285. 4 ft W of Bar D Ranch mailbox. E Vee. Como quad.	EL 9,653 ft	OG 979,230.97
RTB14	18 ft W of and 2.8 ft higher than BM 29D of LL-89. On pavement in NE Vee. 4 ft S of stop sign. Jefferson quad.	EL 9,521.4 ft	OG 979,247.48
RTB15	W edge of Grant. W of NW abutment of bridge over West Geneva Creek. 5 ft SW of and 0.7 ft lower than BM M21 of LL-89 (USBR). Mt. Logan quad.	EL 8,587.6 ft	OG 979,342.32
RTB16	2 ft E of and 0.5 ft lower than BM T304 of LL-96. W of rock painted on N face. S of fence corner. Mt. Logan quad.	EL 9,067.4 ft	OG 979,312.34
RTB17	4 ft N of and 0.5 ft lower than BM M26 (USBR). About 5 mi NW of Webster. Jefferson quad.	EL 9,749.8 ft	OG 979,246.63
RTB18	2 ft N of BM S305 of LL-89. At culvert 280 ft E of Shawnee Post Office. Shawnee quad.	EL 8,103.7 ft	OG 979,391.93
RTB19	5 ft NE of and 1.6 ft higher than BM T303 of LL-89. 2 ft E of E guard post. Jefferson quad.	EL 9,777.7 ft	OG 979,252.23
RTB20	W edge of Montezuma. 1 ft W of BM D20 (USGS). Opposite house with red siding to NW. 57 ft in east Vee. Montezuma quad.	EL 10,271 ft	OG 979,207.36

Table 2.--Principal facts for stations established inside Roberts Tunnel. [Posted relative tunnel distances are in units of feet. "BASE" is the base station, to which the gravity station is tied.]

TUNNEL DISTANCE	STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	OBS. GRAV. (MGAL)	BASE
950	RTB 8	39 37.03	106 2.74	8844.3	979,297.24	RTB 1
3100	RT244	39 37.00	106 2.30	8841.4	979,289.39	RTB 9
3500	RT245	39 36.99	106 2.20	8840.9	979,289.10	RTB 9
4000	RT246	39 36.99	106 2.10	8840.1	979,290.14	RTB 9
4400	RT247	39 36.99	106 2.01	8839.0	979,290.95	RTB 9
4800	RT248	39 36.98	106 1.92	8838.7	979,290.78	RTB 9
5200	RT249	39 36.98	106 1.85	8838.2	979,290.28	RTB 9
5600	RT250	39 36.96	106 1.76	8837.5	979,290.50	RTB 9
6000	RT251	39 36.96	106 1.68	8837.0	979,291.04	RTB 9
6710	RT261	39 36.95	106 1.53	8836.0	979,289.81	RTB 9
7500	RT228	39 36.94	106 1.37	8834.9	979,287.82	RTB 9
7900	RT227	39 36.93	106 1.28	8834.5	979,286.78	RTB 9
8300	RT226	39 36.93	106 1.19	8833.9	979,285.79	RTB 9
8690	RT225	39 36.92	106 1.10	8833.4	979,284.61	RTB 9
9100	RTB 9	39 36.91	106 1.02	8832.9	979,283.33	RTB 8
9500	RT221	39 36.91	106 0.94	8832.1	979,282.34	RTB 9
9900	RT222	39 36.90	106 0.85	8831.7	979,281.44	RTB 9
10300	RT223	39 36.90	106 0.77	8831.1	979,280.44	RTB 9
10700	RT224	39 36.89	106 0.68	8830.4	979,279.64	RTB 9
11100	RT252	39 36.88	106 0.60	8829.8	979,279.02	RTB 9
11500	RT253	39 36.87	106 0.51	8829.3	979,278.69	RTB 9
12000	RT254	39 36.87	106 0.40	8828.5	979,278.03	RTB 9
12450	RT260	39 36.86	106 0.30	8827.8	979,277.27	RTB 9
12900	RT259	39 36.86	106 0.21	8827.2	979,276.09	RTB 9
13350	RT258	39 36.84	106 0.13	8826.7	979,274.72	RTB 9
13795	RT257	39 36.84	106 0.03	8826.0	979,273.21	RTB 9
14200	RT256	39 36.85	105 59.94	8825.4	979,271.98	RTB 9
14600	RT236	39 36.84	105 59.85	8824.7	979,270.84	RTB 9
15000	RT237	39 36.84	105 59.77	8824.1	979,269.80	RTB 9
15400	RT238	39 36.83	105 59.68	8823.4	979,268.95	RTB 9
15800	RT239	39 36.82	105 59.59	8822.9	979,268.19	RTB 9
16200	RT240	39 36.82	105 59.51	8822.4	979,267.72	RTB 9
16600	RT241	39 36.81	105 59.42	8821.8	979,267.34	RTB 9
17000	RT243	39 36.81	105 59.34	8821.1	979,267.39	RTB 9
17400	RT242	39 36.80	105 59.25	8820.5	979,267.53	RTB 9
17800	RT235	39 36.80	105 59.17	8820.3	979,267.91	RTB 9
18200	RT229	39 36.79	105 59.09	8819.6	979,268.43	RTB 9
18600	RT230	39 36.78	105 59.00	8819.1	979,269.18	RTB 9
19000	RT231	39 36.78	105 58.92	8818.6	979,269.85	RTB 9
19449	RT234	39 36.77	105 58.81	8818.1	979,269.61	RTB 9
19847	RT233	39 36.77	105 58.73	8817.3	979,269.04	RTB 9
20145	RT232	39 36.77	105 58.67	8817.0	979,268.66	RTB 9
20540	RT187	39 36.76	105 58.58	8816.6	979,268.38	RTB 1
21090	RT186	39 36.75	105 58.47	8815.6	979,268.61	RTB 7
21640	RT185	39 36.74	105 58.35	8814.6	979,269.23	RTB 7
21980	RT184	39 36.74	105 58.28	8814.1	979,269.70	RTB 7
22650	RT183	39 36.73	105 58.14	8813.1	979,270.27	RTB 7
23100	RT182	39 36.72	105 58.05	8812.7	979,270.79	RTB 7

Table 2.--continued

TUNNEL DISTANCE	STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	OBS. GRAV. (MGAL)	BASE
23600	RT181	39 36.71	105 57.94	8811.7	979,271.31	RTB 7
24100	RT180	39 36.71	105 57.83	8811.0	979,271.78	RTB 7
24600	RT179	39 36.70	105 57.72	8810.1	979,272.16	RTB 7
25100	RT178	39 36.69	105 57.62	8809.6	979,272.16	RTB 7
25500	RT177	39 36.69	105 57.53	8809.1	979,271.97	RTB 7
26100	RT188	39 36.68	105 57.40	8808.2	979,271.88	RTB 7
26700	RT189	39 36.67	105 57.28	8807.4	979,272.02	RTB 7
27020	RT191	39 36.66	105 57.21	8807.0	979,272.02	RTB 7
27500	RT192	39 36.65	105 57.10	8806.2	979,271.88	RTB 7
28000	RT193	39 36.65	105 57.00	8805.3	979,271.64	RTB 7
28500	RT194	39 36.64	105 56.90	8804.7	979,271.60	RTB 7
29000	RT195	39 36.63	105 56.79	8803.0	979,271.50	RTB 7
29500	RT196	39 36.62	105 56.68	8802.4	979,271.55	RTB 7
30050	RT197	39 36.61	105 56.58	8802.1	979,271.78	RTB 7
30400	RT198	39 36.59	105 56.50	8801.6	979,271.55	RTB 7
30750	RT199	39 36.58	105 56.42	8801.2	979,271.07	RTB 7
31100	RT190	39 36.56	105 56.35	8800.7	979,270.55	RTB 7
31500	RT200	39 36.55	105 56.27	8800.1	979,269.80	RTB 7
32000	RT201	39 36.53	105 56.16	8799.6	979,269.04	RTB 7
32400	RT202	39 36.51	105 56.08	8798.9	979,268.66	RTB 7
32800	RT203	39 36.50	105 55.99	8798.4	979,268.66	RTB 7
33300	RT204	39 36.48	105 55.89	8797.8	979,268.57	RTB 7
33800	RT205	39 36.46	105 55.79	8797.4	979,268.05	RTB 7
34200	RT206	39 36.44	105 55.70	8797.2	979,267.20	RTB 7
34600	RT207	39 36.42	105 55.62	8795.8	979,266.39	RTB 7
35000	RT208	39 36.41	105 55.54	8795.5	979,265.26	RTB 7
35400	RT209	39 36.39	105 55.46	8794.5	979,263.98	RTB 7
35800	RT210	39 36.38	105 55.38	8794.0	979,262.65	RTB 7
36200	RT211	39 36.36	105 55.29	8793.4	979,261.28	RTB 7
36600	RT212	39 36.35	105 55.22	8792.8	979,259.96	RTB 7
37000	RT169	39 36.33	105 55.13	8792.3	979,258.66	RTB 7
37400	RT170	39 36.32	105 55.05	8791.7	979,257.64	RTB 7
37800	RT171	39 36.30	105 54.97	8791.0	979,256.83	RTB 7
38200	RT172	39 36.28	105 54.88	8790.4	979,255.84	RTB 7
38600	RT173	39 36.27	105 54.80	8790.0	979,255.13	RTB 7
39000	RT174	39 36.25	105 54.72	8789.1	979,254.37	RTB 7
39400	RT175	39 36.24	105 54.64	8788.7	979,253.85	RTB 7
39800	RT176	39 36.22	105 54.55	8788.1	979,253.50	RTB 7
40200	RT213	39 36.20	105 54.47	8787.5	979,253.10	RTB 7
40600	RT214	39 36.19	105 54.38	8787.0	979,252.77	RTB 7
41000	RT215	39 36.17	105 54.31	8786.7	979,252.62	RTB 7
41400	RT216	39 36.15	105 54.22	8785.9	979,252.25	RTB 7
41800	RT217	39 36.14	105 54.14	8785.4	979,251.96	RTB 7
42200	RT218	39 36.12	105 54.05	8784.9	979,251.72	RTB 7
42600	RT219	39 36.11	105 53.97	8784.4	979,251.11	RTB 7
43000	RT220	39 36.09	105 53.89	8783.9	979,250.59	RTB 7
43800	RT168	39 36.06	105 53.72	8782.4	979,249.79	RTB 7
44200	RT167	39 36.04	105 53.64	8781.7	979,249.50	RTB 7
44600	RT166	39 36.03	105 53.55	8781.1	979,249.26	RTB 7
45000	RT165	39 36.01	105 53.47	8780.6	979,248.84	RTB 7

Table 2.--continued

TUNNEL DISTANCE	STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	OBS. GRAV. (MGAL)	BASE
45400	RT164	39 36.00	105 53.39	8779.9	979,248.41	RTB 7
45850	RTB 7	39 35.98	105 53.30	8779.2	979,247.94	RTB 5
46250	RTB 5	39 35.96	105 53.22	8778.8	979,247.37	RTB 4
46600	RT106	39 35.95	105 53.14	8778.1	979,246.80	RTB 5
46900	RT163	39 35.92	105 53.07	8777.8	979,246.09	RTB 5
47300	RT162	39 35.89	105 53.01	8777.3	979,245.24	RTB 5
47700	RT161	39 35.84	105 52.94	8777.2	979,244.20	RTB 5
48100	RT160	39 35.80	105 52.88	8776.6	979,243.21	RTB 5
48500	RT159	39 35.76	105 52.82	8776.0	979,242.40	RTB 5
48900	RT158	39 35.72	105 52.75	8775.3	979,241.79	RTB 5
49300	RT157	39 35.68	105 52.70	8774.5	979,241.22	RTB 5
49600	RT156	39 35.64	105 52.64	8769.8	979,240.79	RTB 5
50000	RT150	39 35.60	105 52.58	8773.7	979,240.42	RTB 5
50400	RT151	39 35.56	105 52.51	8773.3	979,240.18	RTB 5
50800	RT152	39 35.51	105 52.44	8772.7	979,239.71	RTB 5
51200	RT153	39 35.47	105 52.37	8771.7	979,239.33	RTB 5
51600	RT154	39 35.43	105 52.31	8771.1	979,238.85	RTB 5
52000	RT155	39 35.39	105 52.24	8770.4	979,238.14	RTB 5
52400	RT149	39 35.34	105 52.18	8769.8	979,237.48	RTB 5
52800	RT148	39 35.30	105 52.11	8769.4	979,236.58	RTB 5
53200	RT147	39 35.26	105 52.05	8768.9	979,235.50	RTB 5
53600	RT146	39 35.22	105 51.99	8768.4	979,234.27	RTB 5
54000	RT145	39 35.17	105 51.92	8767.9	979,232.94	RTB 5
54400	RT144	39 35.13	105 51.86	8767.3	979,231.52	RTB 5
54800	RT143	39 35.09	105 51.79	8766.8	979,230.15	RTB 5
55200	RT142	39 35.05	105 51.72	8765.9	979,228.68	RTB 5
55600	RT141	39 35.00	105 51.66	8765.2	979,227.31	RTB 5
56000	RT140	39 34.96	105 51.59	8764.7	979,225.94	RTB 5
56400	RT139	39 34.91	105 51.52	8764.0	979,224.57	RTB 5
56400	RT139	39 34.91	105 51.53	8764.0	979,224.57	RTB 5
56800	RT138	39 34.87	105 51.46	8763.5	979,223.24	RTB 5
57200	RT137	39 34.83	105 51.40	8763.1	979,221.92	RTB 5
57600	RT136	39 34.78	105 51.33	8762.4	979,220.55	RTB 5
58000	RT135	39 34.74	105 51.27	8761.9	979,219.13	RTB 5
58400	RT134	39 34.70	105 51.20	8761.4	979,217.56	RTB 5
58800	RT133	39 34.66	105 51.14	8760.9	979,216.05	RTB 5
59200	RT132	39 34.61	105 51.07	8760.4	979,214.63	RTB 5
59600	RT127	39 34.57	105 51.01	8759.8	979,213.12	RTB 5
60000	RT128	39 34.53	105 50.94	8759.3	979,211.49	RTB 5
60400	RT129	39 34.48	105 50.88	8758.3	979,210.00	RTB 5
60800	RT130	39 34.44	105 50.81	8758.0	979,208.65	RTB 5
61200	RT131	39 34.40	105 50.75	8757.5	979,207.44	RTB 5
61600	RT126	39 34.36	105 50.69	8756.7	979,206.21	RTB 5
62000	RT125	39 34.31	105 50.62	8756.3	979,205.07	RTB 5
62400	RT124	39 34.27	105 50.55	8755.9	979,204.03	RTB 5
62800	RT123	39 34.23	105 50.49	8755.1	979,203.32	RTB 5
63200	RT122	39 34.18	105 50.43	8754.4	979,202.71	RTB 5
63600	RT121	39 34.14	105 50.37	8753.8	979,202.17	RTB 5
64000	RT120	39 34.10	105 50.30	8753.5	979,201.76	RTB 5

Table 2.--continued

TUNNEL DISTANCE	STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	OBS. GRAV. (MGAL)	BASE
64500	RT119	39 34.05	105 50.23	8752.8	979,201.41	RTB 5
65000	RT118	39 33.99	105 50.14	8752.1	979,201.29	RTB 5
65500	RT117	39 33.94	105 50.05	8751.3	979,201.31	RTB 5
66000	RT116	39 33.89	105 49.98	8750.4	979,201.24	RTB 5
66400	RT115	39 33.84	105 49.91	8749.8	979,201.24	RTB 5
66800	RT114	39 33.79	105 49.84	8749.5	979,201.29	RTB 5
67200	RT113	39 33.75	105 49.78	8749.0	979,201.20	RTB 5
67600	RT112	39 33.71	105 49.71	8748.3	979,201.24	RTB 5
68000	RT111	39 33.67	105 49.65	8747.7	979,201.34	RTB 5
68400	RT107	39 33.63	105 49.59	8747.1	979,201.43	RTB 5
68800	RT108	39 33.59	105 49.52	8746.4	979,201.46	RTB 5
69200	RT109	39 33.54	105 49.46	8745.6	979,201.46	RTB 5
69600	RT110	39 33.50	105 49.39	8745.0	979,201.53	RTB 5
70150	RT278	39 33.44	105 49.30	8744.5	979,201.64	RTB 3
70800	RT279	39 33.37	105 49.19	8743.7	979,201.81	RTB 3
71800	RT280	39 33.26	105 49.03	8742.5	979,202.31	RTB 3
72400	RT277	39 33.19	105 48.93	8741.7	979,202.47	RTB 3
72900	RT 3	39 33.14	105 48.85	8741.1	979,202.85	RTB 3
73100	RT 4	39 33.12	105 48.81	8740.8	979,203.11	RTB 3
73400	RT 5	39 33.09	105 48.77	8740.5	979,203.42	RTB 3
73800	RT 6	39 33.05	105 48.70	8739.9	979,203.98	RTB 3
74100	RT 7	39 33.01	105 48.65	8739.5	979,204.55	RTB 3
74500	RT 8	39 32.97	105 48.59	8738.9	979,205.36	RTB 3
74900	RT 9	39 32.92	105 48.53	8738.4	979,206.35	RTB 3
75200	RT 10	39 32.89	105 48.47	8737.9	979,207.01	RTB 3
75500	RT 11	39 32.86	105 48.44	8737.5	979,207.74	RTB 3
75800	RT 12	39 32.83	105 48.38	8737.1	979,208.57	RTB 3
76100	RT 13	39 32.80	105 48.34	8736.7	979,209.45	RTB 3
76400	RT 14	39 32.77	105 48.29	8736.0	979,210.37	RTB 3
76700	RT 15	39 32.74	105 48.24	8735.5	979,211.43	RTB 3
77000	RT 16	39 32.71	105 48.19	8735.3	979,212.26	RTB 3
77400	RT 17	39 32.67	105 48.13	8734.6	979,213.59	RTB 3
77800	RT 18	39 32.62	105 48.06	8734.1	979,214.91	RTB 3
78200	RT 19	39 32.58	105 48.01	8733.8	979,216.19	RTB 3
78600	RT 21	39 32.54	105 47.95	8733.5	979,217.70	RTB 3
79000	RT 22	39 32.50	105 47.88	8732.3	979,219.17	RTB 3
79400	RT 29	39 32.46	105 47.82	8731.8	979,220.66	RTB 3
79800	RT 28	39 32.42	105 47.75	8731.1	979,222.65	RTB 3
80200	RT 27	39 32.37	105 47.69	8730.6	979,223.62	RTB 3
80600	RT 26	39 32.33	105 47.62	8730.0	979,225.20	RTB 3
81000	RT 25	39 32.29	105 47.56	8729.4	979,226.83	RTB 3
81500	RT 24	39 32.23	105 47.48	8728.7	979,228.80	RTB 3
82000	RT 23	39 32.19	105 47.40	8728.0	979,231.00	RTB 3
82400	RT 30	39 32.14	105 47.34	8732.3	979,232.82	RTB 3
82800	RT 31	39 32.10	105 47.28	8726.9	979,234.52	RTB 3
83200	RT 32	39 32.06	105 47.22	8726.3	979,236.58	RTB 3
83600	RT 33	39 32.01	105 47.15	8725.8	979,237.86	RTB 3
84000	RT 34	39 31.97	105 47.08	8725.3	979,239.58	RTB 3
84400	RT 35	39 31.92	105 47.01	8724.8	979,241.07	RTB 3
84800	RT 36	39 31.87	105 46.93	8724.3	979,242.66	RTB 3

Table 2.--continued

TUNNEL DISTANCE	STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	OBS. GRAV. (MGAL)	BASE
85200	RT 37	39 31.83	105 46.87	8723.8	979,244.24	RTB 3
85600	RT 38	39 31.79	105 46.80	8723.0	979,245.88	RTB 3
86000	RT 39	39 31.75	105 46.74	8722.6	979,247.18	RTB 3
86400	RT 40	39 31.70	105 46.67	8722.0	979,248.34	RTB 3
86800	RT 41	39 31.66	105 46.61	8721.4	979,249.68	RTB 3
87200	RT 42	39 31.62	105 46.54	8720.9	979,250.70	RTB 3
87600	RT 43	39 31.57	105 46.48	8720.3	979,251.67	RTB 3
88000	RT 44	39 31.53	105 46.41	8719.7	979,252.29	RTB 3
88400	RT 45	39 31.48	105 46.35	8719.2	979,252.71	RTB 3
88800	RT 46	39 31.44	105 46.29	8718.7	979,253.04	RTB 3
89200	RT 54	39 31.40	105 46.22	8718.0	979,253.28	RTB 3
89600	RT 53	39 31.36	105 46.16	8717.4	979,253.42	RTB 3
90000	RT 52	39 31.32	105 46.09	8716.9	979,253.47	RTB 3
90400	RT 51	39 31.27	105 46.03	8716.3	979,253.47	RTB 3
90800	RT 50	39 31.23	105 45.96	8715.7	979,253.47	RTB 3
91200	RT 49	39 31.19	105 45.90	8715.0	979,253.52	RTB 3
91600	RT 48	39 31.15	105 45.83	8714.5	979,253.66	RTB 3
92000	RT 47	39 31.10	105 45.77	8714.0	979,254.04	RTB 3
92400	RT 20	39 31.06	105 45.71	8713.5	979,254.51	RTB 3
92800	RT 55	39 31.02	105 45.63	8712.9	979,255.31	RTB 3
93200	RT 56	39 30.97	105 45.57	8712.3	979,256.36	RTB 3
93600	RT 57	39 30.93	105 45.50	8711.6	979,257.49	RTB 3
94000	RT 58	39 30.89	105 45.44	8711.1	979,258.82	RTB 3
94400	RT105	39 30.84	105 45.37	8710.6	979,260.28	RTB 3
94800	RT 59	39 30.80	105 45.31	8709.9	979,262.03	RTB 3
95200	RT 60	39 30.76	105 45.25	8709.4	979,263.85	RTB 3
95600	RT 61	39 30.72	105 45.18	8708.9	979,265.70	RTB 3
96000	RT 62	39 30.67	105 45.12	8708.4	979,267.54	RTB 3
96400	RT 63	39 30.63	105 45.06	8707.7	979,269.41	RTB 3
97000	RT 64	39 30.57	105 44.97	8706.9	979,272.30	RTB 3
97400	RT 67	39 30.53	105 44.90	8706.2	979,273.62	RTB 3
97800	RT 68	39 30.48	105 44.84	8705.7	979,274.88	RTB 3
98200	RT 69	39 30.44	105 44.77	8705.2	979,275.61	RTB 3
98600	RT 70	39 30.40	105 44.70	8704.7	979,276.06	RTB 3
99000	RT 71	39 30.36	105 44.64	8704.2	979,275.85	RTB 3
99400	RT 72	39 30.31	105 44.58	8703.4	979,275.28	RTB 3
99800	RT 73	39 30.27	105 44.51	8702.8	979,274.81	RTB 3
100200	RT 74	39 30.23	105 44.45	8702.3	979,274.10	RTB 3
100600	RT 75	39 30.19	105 44.38	8701.8	979,273.48	RTB 3
101000	RT 76	39 30.14	105 44.32	8701.3	979,273.06	RTB 3
101400	RT 77	39 30.10	105 44.26	8700.8	979,272.70	RTB 3
101800	RT 78	39 30.05	105 44.19	8700.1	979,272.68	RTB 3
102200	RT 92	39 30.01	105 44.12	8699.5	979,273.10	RTB 3
102600	RT 91	39 29.98	105 44.06	8699.0	979,273.43	RTB 3
103000	RT 90	39 29.93	105 43.99	8698.4	979,274.07	RTB 3
103400	RT 89	39 29.89	105 43.92	8697.8	979,274.71	RTB 3
103800	RT 79	39 29.84	105 43.86	8697.1	979,275.47	RTB 3
104200	RT 80	39 29.80	105 43.79	8696.7	979,276.34	RTB 3
104700	RT 88	39 29.75	105 43.71	8696.0	979,277.41	RTB 3
105200	RT 87	39 29.69	105 43.63	8695.3	979,278.59	RTB 3

Table 2.--continued

TUNNEL DISTANCE	STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	OBS. GRAV. (MGAL)	BASE
105600	RT 86	39 29.65	105 43.57	8694.8	979,279.58	RTB 3
106000	RT 85	39 29.61	105 43.51	8694.2	979,280.48	RTB 3
106400	RT 84	39 29.56	105 43.44	8693.5	979,281.55	RTB 3
106800	RT 83	39 29.52	105 43.38	8693.0	979,282.54	RTB 3
107200	RT 82	39 29.48	105 43.31	8692.2	979,283.75	RTB 3
107600	RT 81	39 29.43	105 43.25	8691.7	979,284.88	RTB 3
108000	RT 65	39 29.39	105 43.18	8691.1	979,285.92	RTB 3
108400	RT 66	39 29.35	105 43.12	8690.6	979,287.11	RTB 3
108800	RT 93	39 29.31	105 43.06	8690.1	979,288.20	RTB 3
109200	RT 94	39 29.26	105 42.99	8689.5	979,289.19	RTB 3
109600	RT 95	39 29.22	105 42.92	8689.0	979,289.66	RTB 3
110000	RT 96	39 29.18	105 42.85	8688.6	979,290.61	RTB 3
110400	RT 97	39 29.14	105 42.79	8687.9	979,291.25	RTB 3
110800	RT 98	39 29.09	105 42.72	8687.3	979,292.12	RTB 3
111200	RT 99	39 29.05	105 42.66	8686.7	979,293.07	RTB 3
111600	RT100	39 29.01	105 42.59	8686.1	979,294.11	RTB 3
112000	RT101	39 28.96	105 42.53	8685.6	979,295.08	RTB 3
112400	RT102	39 28.92	105 42.47	8685.1	979,296.47	RTB 3
112800	RT103	39 28.88	105 42.41	8684.4	979,297.66	RTB 3
113200	RT104	39 28.83	105 42.34	8683.8	979,298.96	RTB 3
113600	RT287	39 28.79	105 42.27	8683.1	979,300.11	RTB 3
114000	RT286	39 28.75	105 42.22	8682.4	979,301.19	RTB 3
114400	RT285	39 28.70	105 42.15	8682.3	979,302.55	RTB 3
114800	RT284	39 28.66	105 42.08	8681.7	979,303.84	RTB 3
115200	RT283	39 28.62	105 42.02	8680.9	979,305.27	RTB 3
115600	RT282	39 28.58	105 41.96	8680.2	979,306.52	RTB 3
116000	RT281	39 28.54	105 41.89	8679.8	979,307.75	RTB 3
116400	RT288	39 28.49	105 41.83	8679.2	979,308.16	RTB 3
116800	RT289	39 28.45	105 41.76	8678.6	979,307.86	RTB 3
117200	RT290	39 28.41	105 41.70	8678.3	979,307.26	RTB 3
117600	RT291	39 28.37	105 41.64	8677.3	979,306.85	RTB 3
118000	RT292	39 28.32	105 41.57	8676.6	979,306.85	RTB 3
118400	RT293	39 28.28	105 41.51	8676.2	979,307.51	RTB 3
118800	RT294	39 28.24	105 41.44	8675.4	979,308.66	RTB 3
119200	RT295	39 28.19	105 41.38	8674.7	979,309.34	RTB 3
119600	RT296	39 28.15	105 41.31	8674.0	979,310.58	RTB 3
120000	RT297	39 28.11	105 41.24	8673.4	979,311.88	RTB 3
120400	RT298	39 28.06	105 41.18	8672.9	979,313.41	RTB 3
120800	RT299	39 28.02	105 41.12	8672.0	979,314.91	RTB 3
121200	RT300	39 27.98	105 41.05	8671.2	979,316.25	RTB 3
121600	RT301	39 27.94	105 40.99	8670.4	979,318.26	RTB 3
122000	RT302	39 27.90	105 40.92	8670.1	979,318.94	RTB 3
123000	RT 2	39 27.79	105 40.76	8668.6	979,324.25	RTB 3
123450	RT 1	39 27.74	105 40.69	8667.9	979,328.46	RTB 3

Table 3.--Principal facts for stations established outside tunnel.
[Station suffix, Q, questionable location. LOC, location code defined in table 4. BASE, the base station, to which the gravity station is tied. Geographic coordinates for 7 stations that lack RT-prefix at end of table are from DMA Gravity Library.]

STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	LOC	OBS. GRAV. (MGAL)	BASE
RTB 1	39 36.76	106 3.24	8832.0	N	979,298.80	RTB 1
RTB 3	39 27.68	105 40.64	8669.2	P	979,334.89	RTB 3
RTB 4	39 35.97	105 53.28	9695.3	P	979,237.25	RTB 6
RTB 6	39 36.58	105 56.69	9346.0	N	979,263.70	RTB 1
RTB15	39 27.59	105 39.78	8588.0	N	979,342.32	RTB 3
RTB16	39 29.73	105 41.77	9067.4	Z	979,312.34	RTB15
RTB20	39 35.01	105 52.09	10271.0	Z	979,207.36	RTB 6
RT263	39 27.42	105 39.22	8565.6	Z	979,344.51	RTB15
RT264	39 27.28	105 38.41	8471.3	Z	979,353.37	RTB15
RT265	39 27.81	105 39.97	8613.0	Z	979,340.27	RTB15
RT266	39 28.13	105 40.43	8705.8	Z	979,334.11	RTB15
RT267	39 28.50	105 41.06	8791.0	Z	979,326.39	RTB15
RT268	39 28.78	105 41.37	8868.0	F	979,322.60	RTB15
RT269	39 29.02	105 41.62	8914.8	Z	979,319.14	RTB15
RT270	39 30.32	105 42.21	9283.3	Z	979,298.79	RTB16
RT271	39 30.68	105 42.62	9616.4	Z	979,281.77	RTB16
RT272	39 31.05	105 43.39	9662.7	B	979,275.52	RTB16
RT273	39 31.73	105 43.88	9728.2	N	979,269.60	RTB16
RT274	39 32.29	105 43.78	9857.0	N	979,262.99	RTB16
RT275	39 32.49	105 43.26	10050.2	N	979,252.98	RTB16
RT303	39 27.40	105 43.29	9029.9	N	979,306.77	RTB17
RT305	39 27.90	105 44.54	9260.6	Z	979,288.13	RTB17
RT311	39 30.15	105 49.02	10512.6	N	979,201.24	RTB17
RT312	39 31.05	105 49.54	11007.1	N	979,171.38	RTB17
RT314	39 31.08	105 51.11	11279.0	G	979,152.69	RTB17
RT318	39 28.65	105 42.12	9971.0	G	979,259.74	RTB15
RT319	39 28.86	105 43.24	10544.0	G	979,219.69	RTB15
RT321	39 26.92	105 37.79	8476.7	Z	979,355.44	RTB15
RT326	39 27.59	105 41.74	8815.8	Z	979,322.43	RTB15
RT327	39 27.59	105 42.27	8914.5	Z	979,314.01	RTB15
RT328	39 26.65	105 44.44	9438.0	Z	979,278.94	RTB15
RT329	39 26.89	105 43.96	9260.2	Z	979,289.38	RTB15
RT335Q	39 36.32	105 54.90	9442.0	D	979,249.48	RTB 6
RT336	39 35.53	105 52.23	10005.0	N	979,221.65	RTB 6
RT337	39 36.46	105 55.83	9389.0	Z	979,259.21	RTB 6
RT338	39 35.82	105 52.52	9855.8	Z	979,229.64	RTB20
RT339	39 36.09	105 53.66	9686.9	N	979,238.11	RTB20
RT342	39 33.82	105 51.62	10560.0	G	979,190.87	RTB20
RT343	39 33.29	105 50.64	11020.7	N	979,166.38	RTB20
RT344	39 31.86	105 49.94	12097.4	N	979,107.58	RTB20
RT345	39 35.84	105 51.74	10198.0	Z	979,210.97	RTB20
RT346	39 35.94	105 51.18	10251.1	N	979,208.41	RTB20
RT347	39 36.05	105 50.51	10408.0	N	979,202.13	RTB20
RT348	39 36.49	105 50.51	10841.0	G	979,178.81	RTB20
RT351	39 35.91	105 49.65	10630.1	N	979,191.96	RTB20
RT352	39 36.15	105 48.93	10867.7	N	979,181.18	RTB20

Table 3.--continued

STATION NAME	LATITUDE (DEG-MIN)	LONGITUDE (DEG-MIN)	ELEVATION (FEET)	LOC	OBS. GRAV. (MGAL)	BASE
RT354	39 36.25	105 48.32	10972.0	G	979,176.91	RTB20
RT355	39 36.55	105 47.95	11097.3	B	979,171.54	RTB20
RT356	39 37.36	105 48.18	12083.0	G	979,117.14	RTB20
RT357	39 36.90	105 47.73	11355.0	G	979,159.48	RTB20
RT358	39 36.45	105 47.33	11903.6	Z	979,127.48	RTB20
RT359	39 34.13	105 50.18	13180.0	H	979, 25.70	RTB20
RT360	39 33.77	105 49.68	13124.0	G	979, 31.27	RTB20
RT361	39 33.23	105 49.36	13266.0	G	979, 23.32	RTB20
RT362	39 33.12	105 48.92	13238.0	G	979, 31.59	RTB20
RT363	39 32.72	105 48.13	12546.0	G	979, 81.98	RTB20
RT364	39 32.49	105 47.74	12470.0	G	979, 85.66	RTB20
RT365	39 33.47	105 47.92	12827.0	G	979, 61.66	RTB20
RT366	39 34.68	105 50.55	12583.0	G	979, 67.71	RTB20
RT367	39 36.53	105 57.15	9311.7	H	979,266.20	RTB 6
RT368	39 36.47	105 58.03	9251.2	B	979,270.11	RTB 6
RT369	39 36.27	105 58.94	9257.2	N	979,271.73	RTB 1
RT370	39 36.12	105 59.76	9101.8	N	979,280.55	RTB 1
RT371	39 36.66	106 2.27	8888.9	N	979,294.23	RTB 1
RT372	39 36.15	106 1.29	8968.0	N	979,288.21	RTB 1
RT373	39 36.15	106 0.74	9022.7	N	979,285.54	RTB 1
RT374	39 36.06	105 58.54	9238.0	F	979,271.39	RTB 1
RT375	39 35.51	105 58.25	9401.0	G	979,258.59	RTB 1
RT376	39 34.89	105 58.07	9563.0	G	979,247.44	RTB 1
RT377	39 36.30	105 56.92	9305.0	N	979,264.20	RTB 1
RT379	39 35.25	105 59.49	9272.0	G	979,268.75	RTB 1
RT381	39 37.22	105 55.41	9778.5	B	979,238.47	RTB 6
RT382	39 36.89	105 56.07	9567.4	B	979,250.86	RTB 6
RT384	39 31.84	105 50.86	11609.0	G	979,136.65	RTB20
RT387	39 33.82	105 45.96	10138.0	G	979,233.39	RTB16
RT388	39 34.35	105 47.41	10694.0	G	979,194.60	RTB16
RT395	39 30.46	105 44.69	10155.0	G	979,240.04	RTB16
RT396	39 29.97	105 44.21	11270.0	G	979,169.07	RTB16
RT397	39 29.32	105 44.82	11338.0	G	979,163.69	RTB16
RT398	39 30.16	105 43.41	10371.0	G	979,235.08	RTB16
RT399	39 30.20	105 46.82	12068.0	G	979,111.16	RTB17
RT401	39 32.16	105 51.91	12367.0	G	979, 85.10	RTB20
RT402	39 32.57	105 51.11	12599.0	G	979, 68.15	RTB20
RT403	39 30.88	105 51.87	12624.0	G	979, 70.59	RTB20
RT404	39 35.25	105 51.09	12053.0	V	979, 98.92	RTB20
2155R380	39 37.60	105 54.65	10031.5	B	979,224.26	RTB 6
26460276	39 33.09	105 43.18	10273.0	N	979,240.48	RTB16
26460313	39 29.51	105 49.39	10315.0	G	979,211.96	RTB17
26460317	39 28.54	105 46.15	9595.1	N	979,265.28	RTB17
26460324	39 26.50	105 36.19	8289.0	N	979,372.30	RTB15
26460332	39 26.70	105 46.85	10216.9	G	979,224.01	RTB19
26460B19	39 25.71	105 45.81	9777.9	N	979,252.23	RTB15

Table 4.--Location description code for stations outside tunnel. [The number indicates the total number of gravity stations for which the code was used in Table 3.]

Code	Number	Explanation
B	6	On level-line bench marks or other permanent marks, including chiselled squares on rocks or cement, incorporated into the U.S. Geological Survey vertical control system. Includes U.S. Coast and Geodetic Survey bench marks.
N	27	Near level-line bench marks described above (code B).
V	1	On vertical angle bench mark in U.S. Geological Survey control system.
H	2	Near vertical angle bench mark (code V).
Z	20	Near level line bench mark surveyed after publication of topographic map. Therefore, horizontal location is uncertain.
D	1	Near assumed location of any of the above marks that was not found or destroyed.
P	2	Near surveyed elevation with or without permanent mark.
F	2	Near a location, at which a spot elevation on a published topographic map is assumed to have been determined by surveying.
G	31	Near a location on a published map at which spot elevations were determined by photogrammetry or near a location where it is not known if the spot elevation was surveyed (code F).
Total	92	

Table 5.--Examples of inner terrain corrections for stations in the tunnel. [H, depth beneath ground surface. Units of terrain corrections are in milligals. Density, 2.67 g/cm^3.]

		Departures from cylinder				Cylinder	
Tunnel distance (ft)	H (ft)	7 to 223 ft	223 to 755 ft	755 to 1,936 ft	1,936 to 4,199 ft	0 to 1,936 ft	0 to 4,199 ft
29,500	583	0.00	0.28	0.98		17.14	
45,850	916	0.00	0.25	2.23	5.30		27.86
51,500	1,309			0.67		30.94	
64,250	4,085	0.00	-0.01	-0.67	-4.55		82.70
72,730	4,435	0.00		-0.74	-5.23		86.14
79,550	3,630	0.00	-0.04	-1.25	-6.48		77.67
98,400	1,390			0.34		32.14	
102,194	2,330	0.00	-0.15	-2.65	-5.82		59.26
114,944	1,290	-0.01	-0.49	-3.42		30.67	

Table 6.--Data used to calculate apparent densities and effect of isostasy. [Pairs of values are listed, in which the first refers to a station on the ground surface near the tunnel and the second refers to an interpolated value at the closest tunnel distance. TC, total terrain correction used in the original compilation. CC, Earth's curvature correction. FA, second order free air correction. DEN, calculated density in g/cm^3; asterisk indicates value corrected from Plouff (1961). D2, calculated density in g/cm^3, using digital terrain correction program for outer part of tunnel terrain correction. ISO, difference of isostatic correction at the two levels, in mGal. RED, reduction in value of apparent density, in g/cm^3, after isostatic correction.]

Station	Elevation (ft)	Observed gravity (mGal)	TC (mGal)	CC (mGal)	FA (mGal	DEN	D2	ISO	RED
RTB 6	9,346.0	979,263.7	7.63	1.6	0.5	2.61	2.64	0.14	0.01
29,500	8,802.4	979,271.5	33.49	1.6	0.4				
RT335	9,442	979,249.5	13.42	1.6	0.4	2.72		0.20	0.01
38,100	8,790.5	979,256.0	45.12	1.7	0.4				
RTB 4	9,695.3	979,237.2	12.14	1.4	0.5	2.70*	2.70	0.28	0.01
45,850	8,779.2	979,247.9	55.92	1.7	0.4				
RT336	10,005.0	979,221.6	9.78	1.5	0.5	2.72	2.76	0.45	0.01
51,500	8,771.2	979,238.9	65.11	1.7	0.4				
RT359	13,180	979,025.7	25.84	0.6	1.0	2.81	2.80	1.40	0.02
64,250	8,753.1	979,201.5	105.45	1.7	0.4				
RT362	13,238	979,031.6	21.18	0.5	1.0	2.79	2.80	1.30	0.01
72,730	8,741.3	979,202.7	110.47	1.7	0.4				
RT364	12,470	979,085.3	17.81	0.8	0.9	2.80	2.81	1.15	0.01
79,550	8,731.5	979,221.3	97.63	1.7	0.4				
RT395	10,155	979,240.0	5.74	1.4	0.6	2.71	2.68	0.45	0.01
98,400	8,704.9	979,275.8	55.93	1.7	0.4				
RT396	11,270	979,169.1	17.30	1.2	0.7	2.78*	2.61	0.66	0.01
102,194	8,699.5	979,273.1	62.93	1.7	0.4				
RT318	9,971	979,259.7	6.65	1.5	0.5	2.68	2.66	0.36	0.01
114,944	8,681.4	979,304.3	39.27	1.6	0.4				