GRAVITY SURVEY OF MT. RAINIER, WASHINGTON

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ABSTRACT

Contrary to expectations, there is no obvious gravity anomaly associated with Mt. Rainier. Small, local anomalies agree with differences in surface geology. The only conspicuous gravity feature is an E-W lineament in the northern portion of the survey: it may be associated with a lateral fault.

Mt. Rainier is the highest (4393 m) volcanic peak of the Cascade Range, that follow almost a great circle from British Columbia to California, parallel to the Pacific Coast at an approximately constant distance of 200 km. (Figure 1).

The geology of Mt. Rainier has recently been studied by Fiske, Hopson and Waters (1963) where, too, the older references are found. The present paper is meant to be a gravity supplement to the above.

The volcano is probably dormant, as may be concluded from occasional minor activities (e.g., Daneš, 1965) as well as from the seismic results by Unger (1969), Unger and Decker (1970) and Unger and Mills (1972). It is therefore conceivable that some anomalous mass distribution may be associated with this mountain, and that a gravity survey may shed light both at some cause of the Cascade volcanism, and at the internal structure of the mountain as well.

For these reasons, the present writer undertook the task of surveying the mountain by means of a Worden gravity meter No. 358.

The field work was interrupted when it was realized that available elevation data were too scarce. That situation changed abruptly with the 1974 publication of the 7½ minute quadrangles of the area by the U. S. Geological Survey. All subbase stations, including the summit station, were then re-occupied in the summer of 1974 and all terrain corrections determined anew.

All calculations were carried out to an accuracy of 0.1 mgal; however, due to variations in surface density and to uncertainties arising from the digitalization of the terrain, the probable error of the final data may be on the order of a few milligals.

In a few cases, single station anomalies in excess of 5 mgal were encountered; those were omitted as probably erroneous.

The first Bouguer gravity map (not reproduced), derived with a standard surface reduction of 2.67 g cm^{-3}, showed a pronounced gravity low of 20-25 mgal, associated with the mountain. The gravity values were then recalculated, so as to give the minimum correlation with topography, and the resulting density turned out to be 2.3 g cm^{-3}. That gravity map is shown on Figure 2. (Due to this change, contours of Figure 2 do not match those of Figure 1.)

Whether the density of 2.3 g cm^{-3} is realistic, or too low, is an open question. It may, however, be significant that Stricklin (1974) found the same low value in the Lemei Rock-Steamboat Mountain area some 80 km farther south.

If we assume that the mountain is composed of andesitic lava flows and layers of water saturated cinders, both of the same matrix density of 2.7 g cm^{-3}, but the andesites of zero porosity, and the cinders of porosity, p; and if n is the proportion by volume of cinders to that of the total, then the average density

$$\rho_{average} = \rho_{matrix}(1 - np) + \rho_{water} \cdot np$$

and therefore

$$np = \frac{\rho_{matrix} - \rho_{average}}{\rho_{matrix} - \rho_{water}} = \frac{2.7 - 2.3}{2.7 - 1.0} = 0.235$$

Since neither n, nor p may be greater than one; and since, moreover, porosities greater than 50% are unlikely, we may conclude that the porosity is likely to be within the limits of 23.5% and 50%, and that

the cinders then make from 100% to 47% of the total, respectively. A reasonable mean value within those limits would then call for 33% of andesite and 67% of cinders with porosity of 35%.

Another way of expressing the same result is that the "mean porosity of the mountain" is 23.5% (In all the above calculations, the contribution of glacier ice has been neglected. It is unlikely that it would alter the result in a noticeable way.)

While all the above results are high, they may not be unreasonable.

With the new surface reduction density, any kind of gravity anomaly associated with the mountain proper has disappeared. (The absence of a major gravity anomaly compares well with the more-or-less negative results of Battis, 1973.)

What persists are:

1. A broad minimum along the eastern edge of the survey; probably associated with a buried acidic batholith. (Koníček, 1974-a, 1974-b.)
2. Small, scattered local anomalies, both high and low, best noticeable in the SW portion of the map. Those correlate well with outcrops of various rock types, as reported by Fiske, et al. (1963), provided we adopt the following qualitative density scale:

$$\rho_{\text{old basalt}} > \left\{ \begin{array}{l} \rho_{\text{young basalt}}, \\ \rho_{\text{plug andesite}} \\ \rho_{\text{granodiorite}} \\ \rho_{\text{rhyolite}} \end{array} \right\} > \rho_{\text{ash flow}} > \rho_{\text{sediment}}$$

Since that density scale is quite reasonable, and the magnitudes of the anomalies compare fairly with estimated thicknesses of formations, the geological meaning of those anomalies is probably deciphered.

3. A weak indication of a gravity high of about 5 mgal at the summit, station number 436. (This station represents an average of a line of several closely spaced points.) This anomaly, too, may be explained as due to the high density density central plug (2.7 g cm^{-3}) inside the low density cinder cone (2.3 g cm^{-3}) of diameter of 0.7 km, extending to the granodioritic block 2 km below the summit. All those data are in good agreement with the geological evidence by Fiske et al. (1963), but due to the large terrain correction, the result should be accepted with caution.

4. The E-W striking trends in the northern part of the map. The gravity low from Stat. No. 177 toward No. 524 is real beyond much doubt. In the eastern portion, it coincides with the White River Valley, but continues toward the west with no apparent topographic counterparts. The gravity high trend farther north is only partly defined, but probably also real. While the feature may be interpreted in many different ways, it is at least possible that it is a signature of a lateral fault or fault zone.

The correlation between the major Cascade volcanoes and the abrupt offsets in gravity trends, possibly representing deep seated lateral faults, has been noticed by Daneš (1969) and, for Mt. Rainier, has been indicated on Figure 1. The rest can be better noticed on the

new gravity map of Washington (Bonini, Hughes and Daneš, 1974). The relation between the offsets and volcanoes is not yet clear, and additional work on this subject is planned for the future.

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Figure 2. Bouguer Gravity Map, Mount Rainier National Park, Washington, U.S.A. (Station reduction density, 2.3 g cm^{-3}; contour interval, 5 mgal; datum, sea level; scale, 1:62,500*.)

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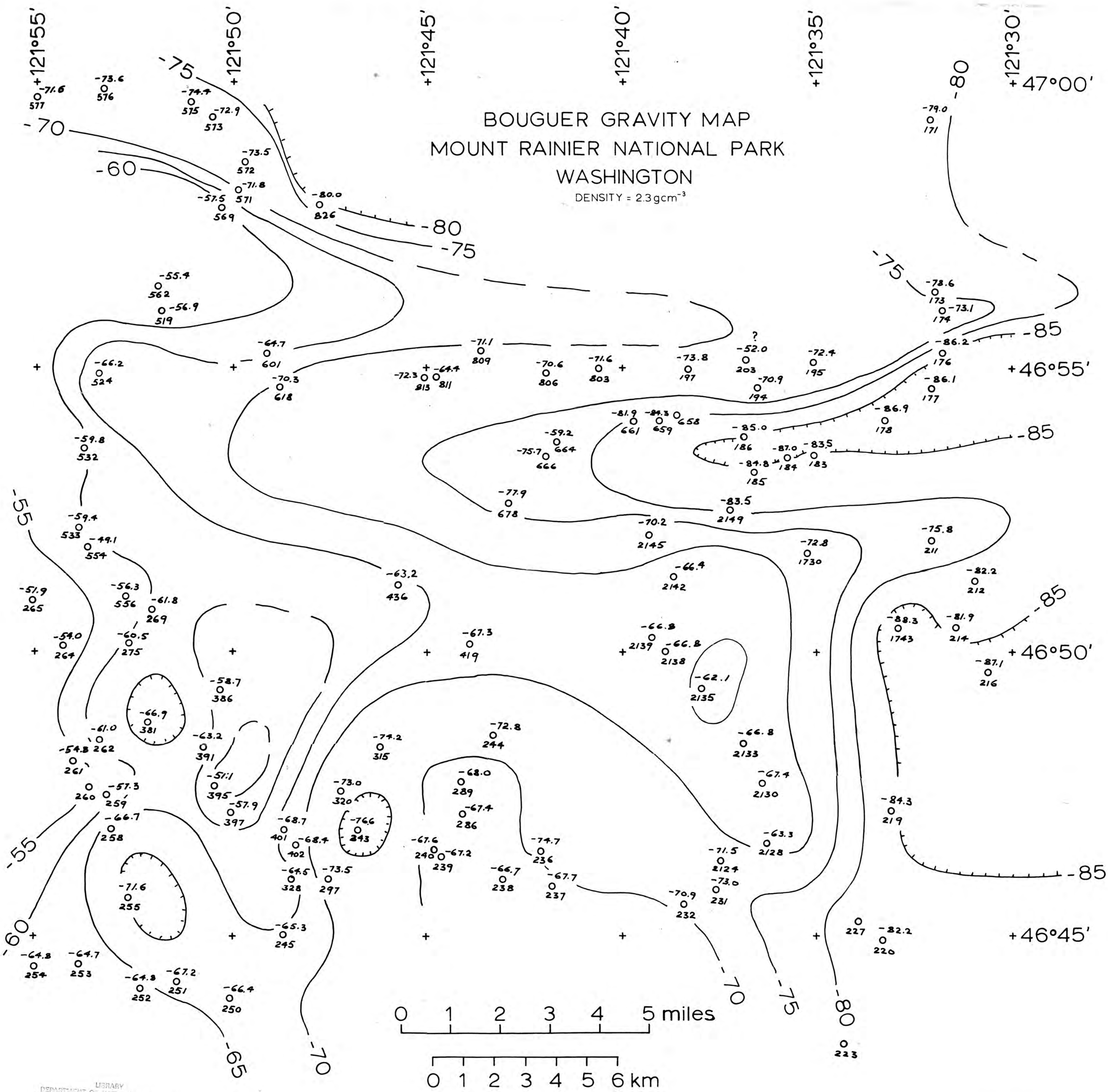
*(The numerical scale should be there <u>only</u> if the map is reproduced full scale. If it is reduced, then the scale should be changed, or omitted.



Z.F. Danes, 1975