STRUCTURE OF CRATER FLAT AND YUCCA MOUNTAIN, SOUTHEASTERN NEVADA, AS INFERRED FROM GRAVITY DATA

by

H.W. Oliver[1] and K.F. Fox[2]

DRAFT

[1]U.S. Geological Survey, MS 989
345 Middlefield Road
Menlo Park, California 94025
415/329-5301

[2]U.S. Geological Survey, MS 602
Denver Federal Center, Box 25046
Denver, Colorado 80225
303/236-0213

ABSTRACT

"PRELIMINARY DRAFT"

Existing gravity data in the vicinity of Yucca Mountain and Crater Flat have been examined to determine if these data only support the caldera model[1] or if other geologic models such as a high-angle graben or detachment fault model are possible. The west to east isostatic gravity profile reduced for a density of 2.0 g/cm^3 shows a gravity low of about 20 mGal centered only 2 km from the eastern edge of Crater Flat relative to a gravity high over the eastern boundary of Yucca Mountain. In the western part of Crater Flat, isostatic anomalies rise about 50 mGal across the Flat reaching a maximum gradient of 9 mGal/km about 3 km east of the Bare Mountain range-front fault.

Computer modeling of these data indicate that a model that consists of a detachment fault that dips to the west at 12° under Yucca Mountain and intersects a 27° east-dipping Bare Mountain fault fits the observed gravity data generally as well as the caldera model.

INTRODUCTION

Crater Flat is inferred to be either 1) a buried caldera which is presumed to be the source of the Crater Flat Tuff[1], 2) a filled graben bounded by high-angle, planar faults, or 3) a structural depression formed at the intersection of the Bare Mountain fault and a postulated west-dipping low-angle detachment fault or faults below Yucca Mountain, one of which forms the contact between Tertiary rocks and subjacent Paleozoic rocks[2,3,4]. Previous modeling of gravity data indicate that the data are consistent with the caldera hypothesis[1]. In this paper, we present an alternative gravity model that is consistent with the detachment hypothesis.

GEOLOGIC SETTING

PRELIMINARY DRAFT

Crater Flat is an intermontane basin, elliptical in plan, approximately 8 km in east-west dimension and 22 km in north-south dimension, flanked on the west by Bare Mountain, and on the east by Yucca Mountain (fig. 1). Bare Mountain is a craggy, dissected edifice rising abruptly to a summit 900 m above the floor of Crater Flat, and is composed of steeply inclined Late Proterozoic and Paleozoic basement rocks which are mostly carbonates (fig. 2). Yucca Mountain, in contrast, steps gradually up through a succession of low, north-trending ridges to a flat, eastwardly tilted summit area near the Prow, 800 m above Crater Flat.

Yucca Mountain is composed of a stratiform sequence of variously welded ash-flow tuffs with minor interlayers of bedded tuff. These rocks are comprised of the Paintbrush Tuff, erupted approximately 13 m.y. ago from a source area to the northwest, which concurrently or subsequently collapsed to form the Claim Canyon-Oasis Valley caldera located to the north of Yucca Mountain[5]. At Yucca Mountain, the Paintbrush Tuff overlies the tuff of Calico Hills, and it in turn overlies another thick sequence of variously welded ash-flow tuffs, referred to as the Crater Flat Tuff, which erupted approximately 13.5 m.y. ago[5]. D. Snyder and W. Carr proposed that the source of this tuff lies in the subsurface below Crater Flat[1].

The sequence of tuffs at Yucca Mountain is cut by a series of west-dipping, north- to northeast-trending normal faults. Individual fault blocks are tilted eastward 5 to 30 degrees. The dip of these blocks steepens in the hanging wall near the block-bounding faults. Conversely, the dip commonly rolls over to moderate west dips within the footwall. This roll-over structure suggests that the block-bounding faults are listric to a low-angle, west-dipping fault or faults at depth[6].

Crater Flat itself is veneered by surficial deposits and studded with youthful basaltic cinder cones and lava flows, but westward continuations of the ash-flow tuffs exposed to the east at Yucca Mountain have been intersected in the subsurface at two drill holes (VH-1 and VH-2)[1]. A major east-dipping, dip-slip fault (the Bare Mountain fault) forms a structural

FIGURE CAPTIONS

Figure 1. Isostatic gravity map of the Beatty 1/2° by 1° quadrangle overprinted on a simplified geologic base. Gravity contour interval is 10 mGal and the reduction density is 2.67 g/cm^3. An Airy-Heiskanen isostatic model was used for which the sea level thickness of the crust is 25 km, and the difference in density between the crust and upper mantle is 0.4 g/cm^3. The gravity map is controlled by over 2000 gravity stations[7,8].

Figure 2.—Detachment model of subsurface structure under Yucca Mountain area along A-A' (fig. 1). Numbers within units are the densities in g/cm^3 assumed in the mode. No vertical exaggeration. The geologic symbols are as follows: Q - Quaternary alluvium, Tvpt - Paintbrush and Timber Mountain tuffs, Tvcf - Crater Flat tuff and older volcanic rocks, P_zc - Paleozoic carbonates, P_zm - Early Paleozoic schist and gneiss.

Note: these figure captions and figures are placed here instead of at the end because they are cited on p. 2 and we need to put the references in order (see 7,8 above in Fig. 1 caption) for camera ready copy.

boundary between Bare Mountain and Crater Flat. There is no comparable eastern boundary. Rather, the family of fault-bounded ridges forming Yucca Mountain obliquely intersects and sinks below the east side of Crater Flat.

GRAVITY DATA

Regional gravity data have been obtained with 3 to 5 km station spacing in southeastern Nevada since about 1960 in connection with Weapons Testing within the Nevada Test Site (NTS), ground water studies of Las Vegas basin, and most recently in connection with nuclear-waste disposal studies at several possible underground storage sites including Yucca Mountain. A Bouguer gravity map of the Death Valley 1° by 2° quadrangle was released in 1980[9], and a preliminary, page-size isostatic gravity map of the Yucca Mountain area was published in 1984[1]. More recently, a 1:100,000-scale isostatic gravity map of the NTS covering the area northeast of Yucca Mountain and based on about 16,000 gravity stations was published in 1990[8,10]. A current plot of available data as well as a summary of major gravity results are available[11,12].

An isostatic gravity map of Yucca Mountain and vicinity to a radial distance of 30 to 40 km is shown in Figure 1. The 5 mGal gravity contours are reduced for a density of 2.67 g/cm^3 and are overprinted on a simplified geologic base. The gravity contours show a range of about -40 mGal northeast of Yucca Mountain to over +30 mGal in the Funeral Mountains in the southwestern part of the map. Gravity lows occur over low density sediments in Death Valley, the Armargosa Desert, Crater Flat, and Frenchman Flat. Pronounced gravity highs are present over the high-density metasedimentary rocks that make up the Funeral Mountains, Bare Mountain, and the Specter Range. Yucca Mountain, itself, is characterized by a northwest dipping gravity gradient with the -20 mGal contour striking NNE through the center of the Mountain.

The observed residual gravity profile along A-A' (fig. 1) is shown in Figure 2 and is the same profile modeled by D. Snyder and W. Carr[1]. The gravity data have been reduced using a density of 2.0 g/cm^3, which is appropriate for Yucca Mountain[1]. The regional effects of deep isostatic compensation for the topography have been removed using the Airy-Heiskanen model[13] with a normal crustal thickness of 25 km, a density contrast between the crust and upper mantle of 0.4 g/cm^3, and a regional topographic density of 2.67 g/cm^3.

Gravity residuals (fig. 2) of about +5 mGal over Bare Mountain decrease quite rapidly over Crater Flat to a minimum value of about -45 mGal near the eastern edge of the Flat. Farther east, gravity values rise to a relative maximum of -25 mGal about 5 km east of the crest of Yucca Mountain and then drop back to about -30 mGal over Jackass Flats. The gradual eastward rise in gravity in the vicinity of the Yucca Mountain crest is not affected by local topography, indicating that the 2.0 g/cm^3 reduction density is correct for this area.

The main purpose of the model (fig. 2) is to see if the new tectonic concepts of detachment faulting for the fundamental structure under Yucca Mountain summarized above (see Geologic Setting section) could fit the gravity data. We started with an east-dipping detachment fault under Bare Mountain and adjusted the eastward dip of the fault to approximate the eastward decrease in "Regional gravity" shown in Figure 2. Then we broke the Bare Mountain normal fault into two sections: (1) the Range front section (marked R in fig. 2), and the main section which is displaced 2 1/2 km east of the Range front. The location of the main section is required by the position of the maximum gradient of 9 mGal/km marked "M" on the gravity profile. The assumed density contrast across the Bare Mountain normal fault is 2.6 g/cm^3-1.8 g/cm^3 or 0.8 g/cm^3 near the surface and decreases to 2.6 g/cm^3-2.2 g/cm^3 or 0.4 g/cm^3 below a depth of about one km. To explain the westward decrease in residual gravity across Yucca Mountain (YM), a west dipping detachment fault under the Mountain has been postulated with a density contrast of 0.4 g/cm^3. Using a two-dimensional computer program[14], and the densities listed in Table 1, it was determined that a dip angle of 27° for

Table 1. Densities[1] used in the detachment fault model (fig. 2).

Symbol	Unit	Density (g/cm^3)
Q	Quaternary alluvium	1.8
Tvpt	Paintbrush and Timber Mountain tuffs	2.0
Tcf	Crater Flat tuff and older volcanic rocks	2.2
Pzc	Paleozoic carbonate rocks	2.6
Pzm	Early Paleozoic metamorphic and gneisses	2.7

the Bare Mountain normal fault and 12° for the YM detachment fault are consistent with the gravity data. These angles are much less than the corresponding 70° and 60° angles required for the caldera model of Snyder and Carr (1984, fig. 5), and these modeled faults are within reach of other subsurface methods such as magneto-telluric, seismic refraction, and drilling.

The calculated gravity profile based on the detachment model does fit the observed profile slightly better than the caldera model in the western part of Crater Flat and the eastern part of Yucca Mountain.

CONCLUSIONS

The Paleozoic-Tertiary contact below Yucca Mountain was modeled as a planar contact dipping 12° to the west, that intersects the subsurface projection of the Bare Mountain fault 4 km below the axis of Crater Flat. The Bare Mountain fault dips 27° eastward, passing below Yucca Mountain at a depth of 6.5 km. This geometry is consistent with the detachment model, as originally proposed by R.B. Scott[2] and in more detail by K.F. Fox and others[15]. However, the distribution of gravity stations may be too sparse to resolve possible steps in the east-dipping Paleozoic-Tertiary contact under Crater Flat. Thus available gravity data may not distinguish between the caldera model of Snyder and Carr (1984) and the detachment model. However, other more expensive methods such as seismic refraction/reflection, magnetotelluric, and drilling could help resolve this issue.

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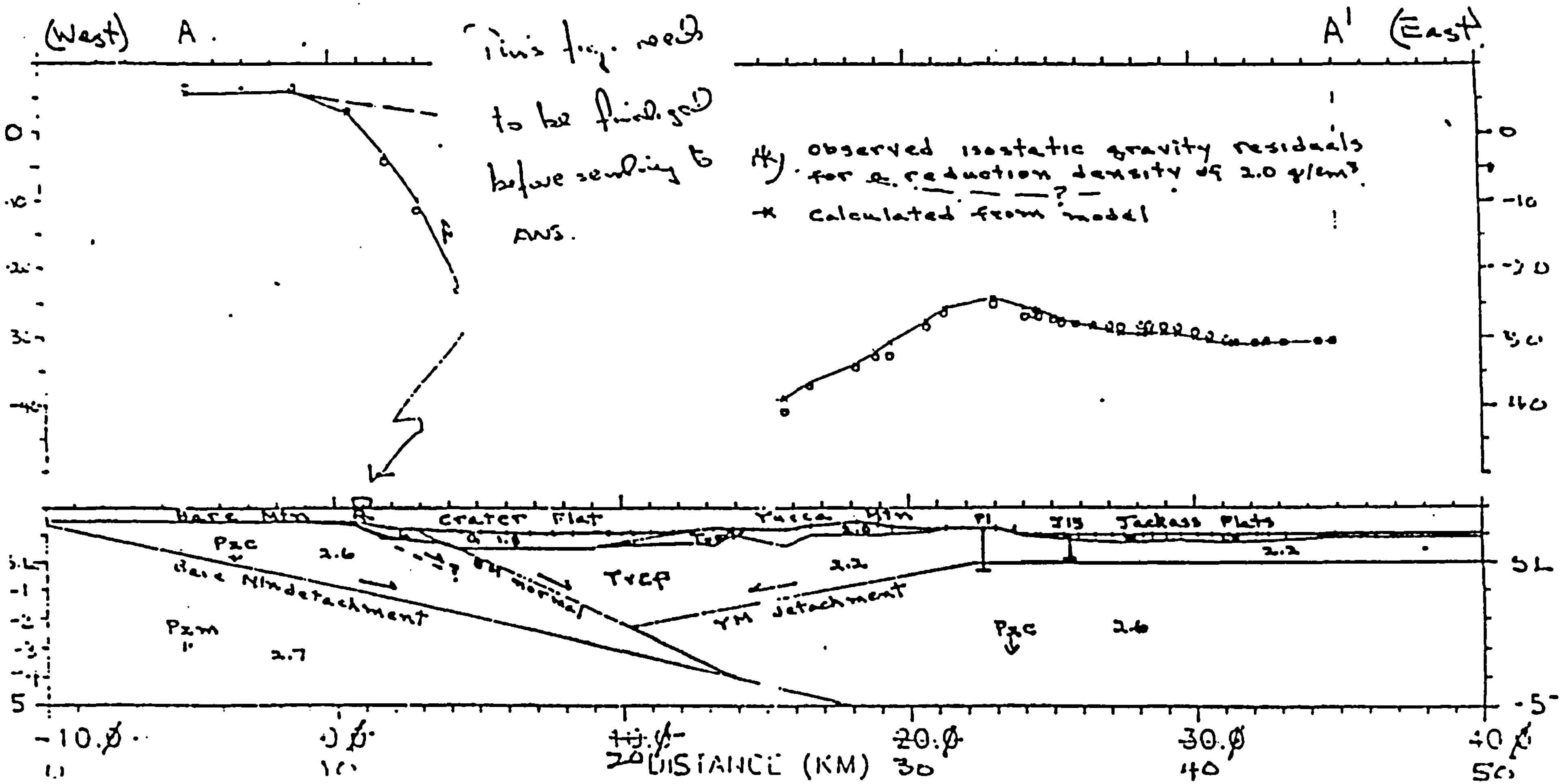

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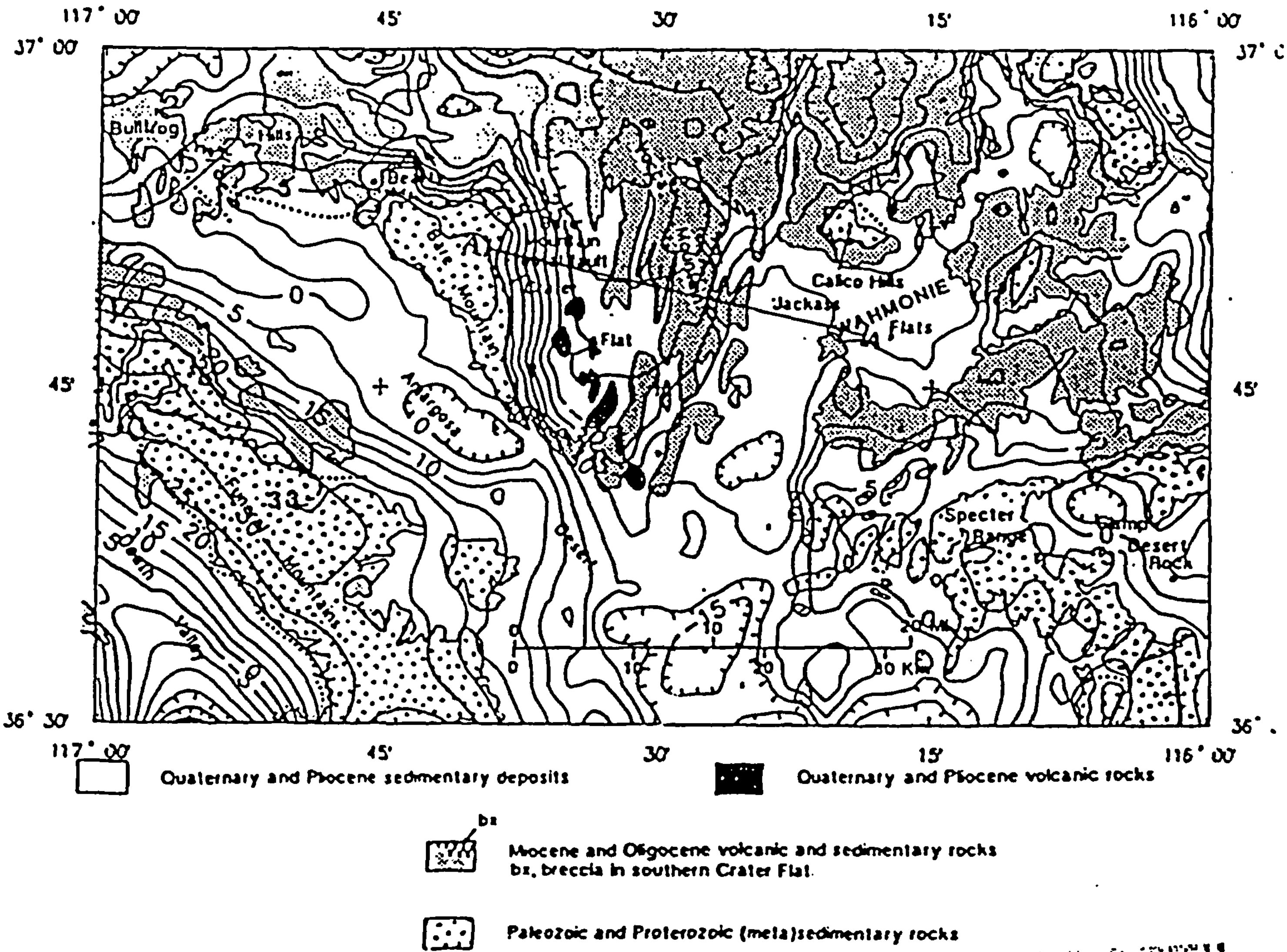

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