# Gravity and seismicity of Jaisalmer region, Rajasthan

**N. Krishna Brahmam**

National Geophysical Research Institute, Hyderabad 500 007, India

**An attempt is made to explain the causes of the earthquake which occurred on 8 November 1991 in the Jaisalmer region on the basis of the Bouguer gravity anomaly map. The gravity data indicate a thickness of about 4 km for the sediments of the Sheo (Barmer) Basin. The gravity highs encountered in the region cannot be explained as mere reflections of basement ridges. A considerable part of the gravity highs seems to be caused by uplift of dense lower crustal (or upper mantle) rocks. It is suggested that the seismicity reported in this region is due to the reactivation of the zones of weakness created presumably by the emplacement at shallow depths of denser lower crustal or upper mantle material.**

## Introduction

An earthquake of magnitude 6.3 on the Richter scale, with its epicentre located in the sparsely populated desert area of Jaisalmer occurred on 8th November 1991. This earthquake is of special significance, for there has been no recorded seismic event in the Jaisalmer region so far (Table 1). As the gravity maps are useful in understanding the geological structure, and faults are possibly responsible for seismicity[1], the present work deals with an analysis of the Bouguer gravity anomaly map of the Jaisalmer area (Figure 1) in order to infer the existence of active faults (Figure 2) and to suggest the probable crustal structure (Figure 3) in that region.

## Geological setting

The extensive arid plain of Rajasthan lying west of Jodhpur forms the great Thar desert. A summary of the geological evolution and hydrocarbon prospects of Rajasthan Basin (based mostly on the work by the ONGC) has been published by Datta[2] together with a small scale gravity map of that region. The basement is made up of mostly the Malani suite of rhyolites and granites, the Aravalli metamorphics and the Jalor/Siwana granites. The total sedimentary thickness of the Shahgarh Depression is likely to be of the order of 10,000 m or more. There are eight sedimentary cycles from the Upper Proterozoic sediments to Indus Alluvium of the Quaternary age in the evolution of the Jaisalmer Basin[2]. The final phase of uplift of the axial belt is believed to have started during the Oligocene times.

There are four phases of Malani igneous activity in Sankara, Jaisalmer[3]. The first phase is represented by rhyolites and rhyolite porphyry flows, the second phase comprises coarse-grained biotite-granite intruding into the Jalore-type granites, the third phase includes both extrusives and intrusive rocks of acid and intermediate composition, and the fourth phase is represented by the intrusive basic rocks. The emplacement of ultramafic rocks and gabbro-diorite in the axial zone of the Delhi fold belt, and the acid effusives in the Trans-Aravalli region (Malani rhyolites) are the manifestations of the extensive anorogenic magmatism resulting from abortive rifting around 850 m.y. ago[4]. The mafic and alkaline rocks of the Malani volcanic province belong to two younger magmatic events[5] (a) a Mesozoic event (ca. 125 m.y.) related to opening of several sedimentary basins in western Rajasthan, and (b) a Paleocene event related to collision of Indian plate with the Asian. In the early Jurassic, epeirogenic movements led to subsidence and formation of Kachchh and Sanchor Basins in the south and the Jaisalmer Basin in the central part[5]. These movements continued till the Upper Cretaceous when subsidence and attendant fracturing transformed the Barmer Basin into a graben. The intermediate alkaline rocks of Tavidar (in the eastern margin of Sanchor

Table 1. Seismicity in the Jaisalmer area[8]

| Date | Latitude (deg) | Longitude (deg) | Place | Magnitude | Source |
|---|---|---|---|---|---|
| 25.7 1907 | 26.0 | 72 0 | Malani | VI | Historical |
| 26 5 1959 | 27.2 | 70 2 | Feyzabad | — | International Seismological Summary, UK |
| 8 11 1991 | 26 28 | 70 58 | Jaisalmer | 5 6 | (22 km) USGS 5 7 |

ISS International Seismological Summary, UK; USGS United States Geological Survey, USA

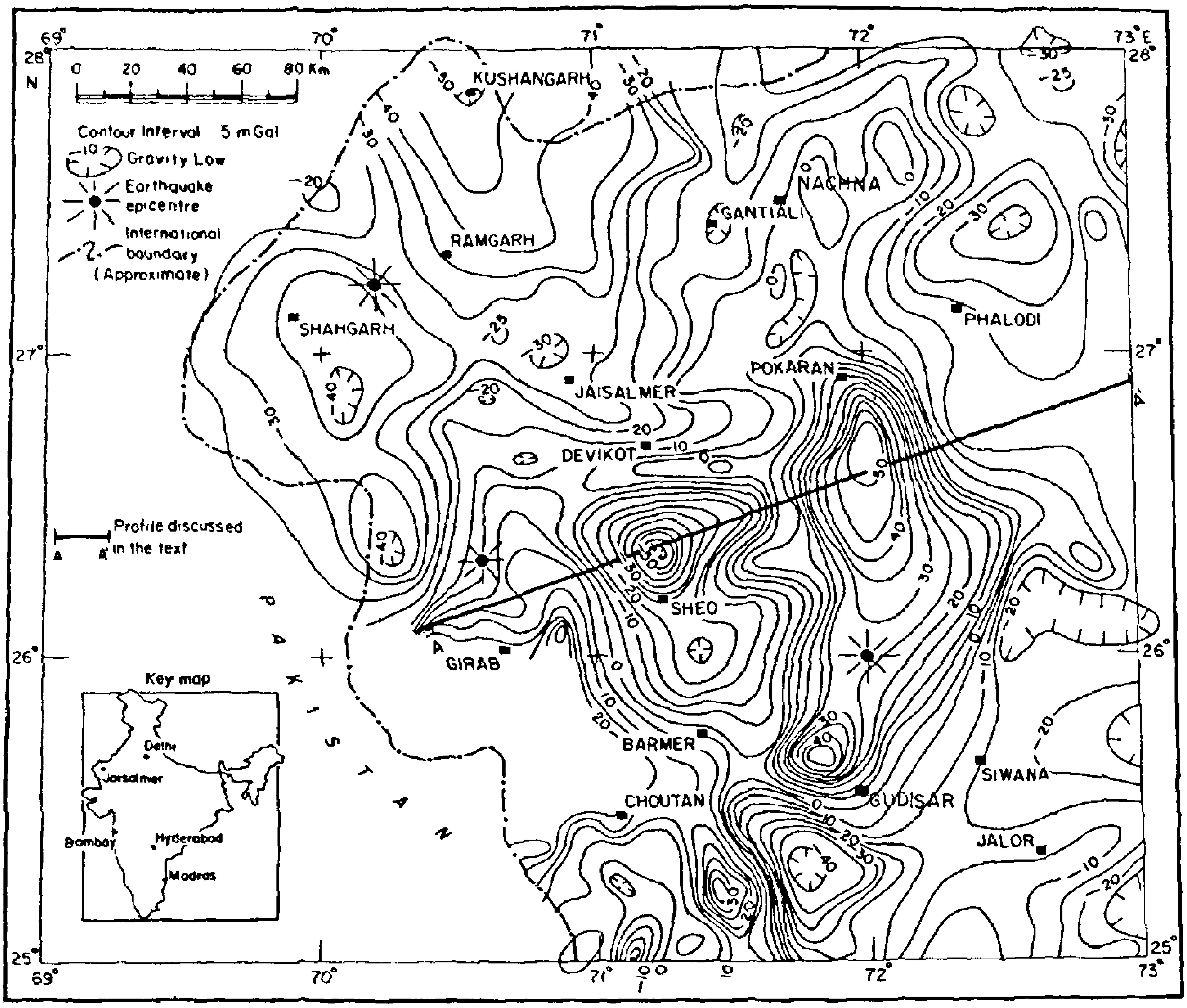


Figure 1. Bouguer gravity anomaly map of a part of western Rajasthan.

Basin), Sarnu-Dandali (in the eastern margin of Barmer graben) and Pokaran (in the eastern margin of Jaisalmer Basin) are related to these early to middle Cretaceous movements and located at the faulted crests of epeirogenically domed crustal swells[6].

## Interpretation of gravity map

The Devikot-Pokaran-Nachna gravity high, trending northeast-southwest, has been interpreted as a basement ridge[2]. It is suggested that a major fault (Fategarh Fault) immediately to its south delimits the Jaisalmer Basin to the southeast from the Barmer Basin to the northwest. Another basement ridge passing through Radhanpur (23.82°: 71.6°) and Barmer has been suggested by the workers of ONGC[7]. Possibly the Cambay graben in Gujarat is connected with the Rajasthan Shelf through the Sanchor and Barmer grabens. The geological history of the Jaisalmer Basin is similar to that of Indus Shelf and the axial belt. The other three basins are closely related to the evolution of the western part of the Indian Shield.

In many cases the gravity maps reflect lateral variations in crustal and possibly upper-mantle densities. The gravity highs are generally correlated with basement highs or ridges. However, in certain cases the gravity highs can be explained only partly by basement highs. In the present case the exposed Malani suite of rhyolites and granites is well within the regional gravity high, but is within zones of relatively lower gravity within the high. Thus, the gravity high axis east of Pokaran (Figures 1 and 2) does not exactly pass through the axis of the exposed Malani suite of rocks. It is therefore, concluded that the Jaisalmer gravity

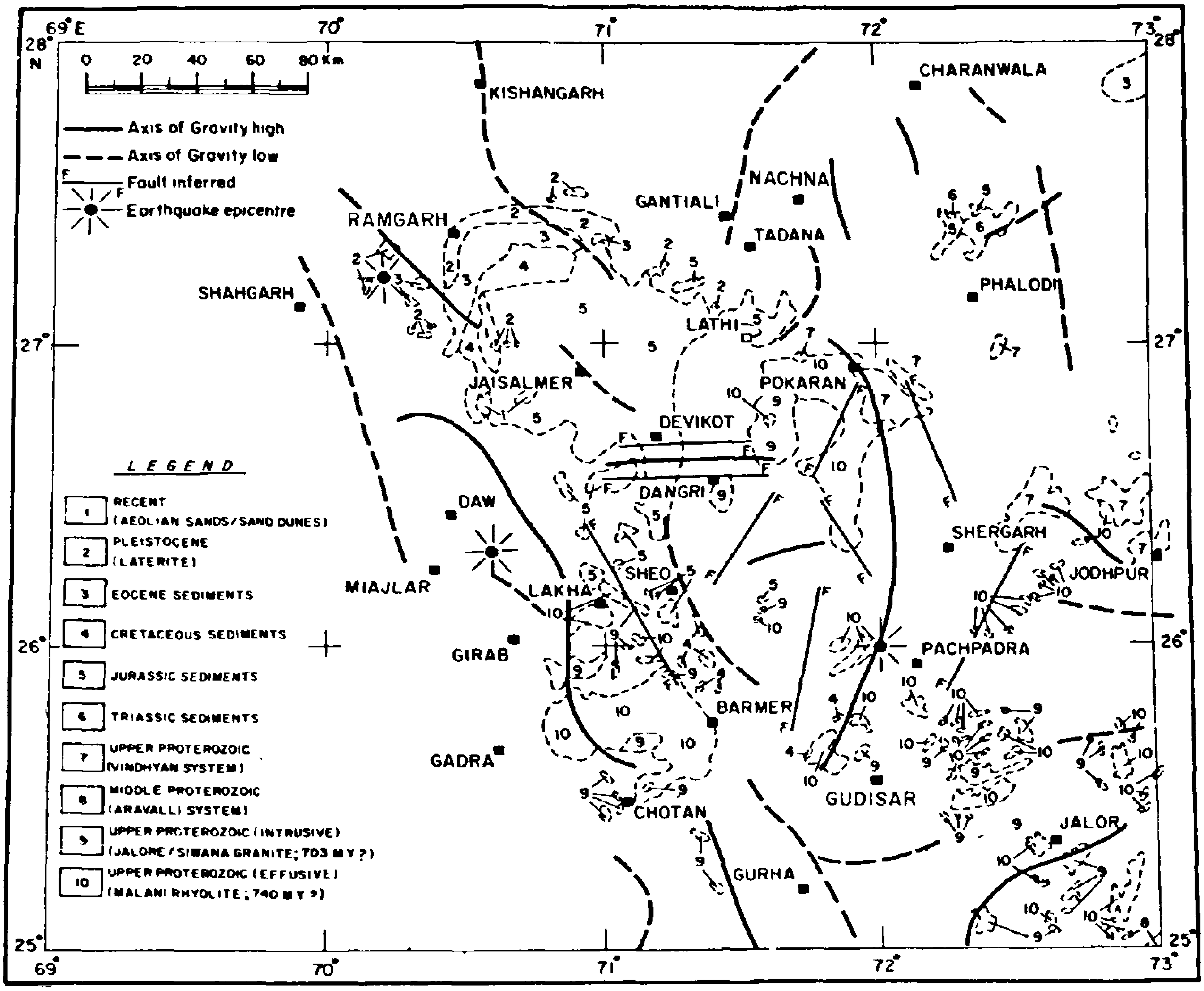


**Figure 2.** Map of part of western Rajasthan showing (**a**) simplified geology (**b**) Axis of the gravity high and gravity lows (**c**) Epicentres of earthquakes, and (**d**) Faults inferred from the gravity.

highs are not necessarily associated with the basement highs. A considerable part of the gravity highs is caused by uplift of dense lower crustal (or upper mantle) rocks. Interestingly the intrusive Siwana and Jalor granites are not characterized by prominent gravity lows. Assuming density values of 2.67, 2.27 and 2.97 g/cc for the basement, sediments and lower crustal rocks respectively, quantitative interpretation of a gravity profile (A–A′), shown in Figures 2 and 3 indicates a maximum thickness of about 3.8 km for the sediments to explain the gravity low about 15 km north of Sheo (Figure 3). The gravity high can be explained by the presence of high density material whose top is at a depth of about 5 km. The dimensions of the bodies suggested in Figure 3 are valid for the values of densities assumed.

## Seismicity

Some conjectures relating to zones of weakness have earlier been made, such as—the alignment of rhyolite hills from east of Jodhpur to the west of Barmer is parallel to the Aravalli axis and represents a line of weakness or crack that developed in the continental block during the late Proterozoic upliftment of the Aravalli chain[5]. Figure 2 shows, among other things, the epicentres of known seismic events in the region. Dearth of seismic observatories precludes exact determination of the location of the epicentres. However, the three seismic events seem to fall near the proximity of gravity highs (Figure 2). The epicentre of the earthquake of July 1907 was located in the proximity of the

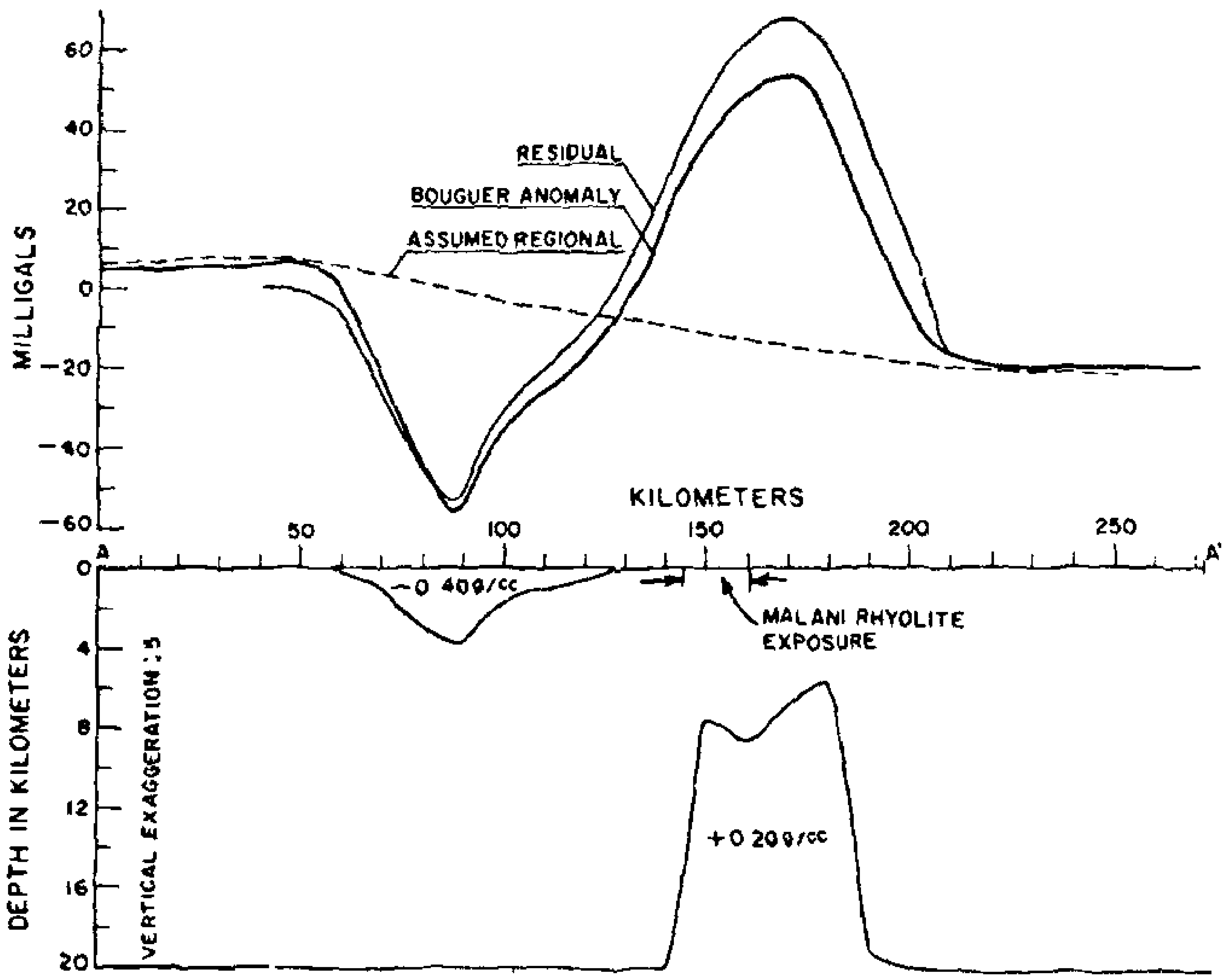


**Figure 3.** Gravity profile A-A' showing two-dimensional models, providing explanation for the gravity anomalies.

axis of the Pokaran-Gudisar gravity high. The epicentre of the earthquake of May 26, 1959 was on the flank of the Jaisalmer-Mari gravity high, whose southwestern flank is down-faulted to the southwest along a series of NW-SE trending en-echelon stepfaults[2]. The epicentre of the November 8, 1991 earthquake seems to be located on the flank of Choutan-Girab gravity high. Its focal depth, according to the USGS, is about 22 km. The USGS assigns a magnitude of M5.6 for this earthquake. Two alternative fault plane solutions were offered by the USGS for the Jaisalmer earthquake of November, 1991. The first fault (NP1) strikes N56° (dip 43°) while the second fault (NP2) strikes N289° (dip 61°). The epicentre location by the USGS is 26.32° N and 70.60° E and the depth of focus is 22 km. The strike of the gravity anomalies in that area seems to support the second fault. It is suggested that the reactivation of faults associated with the uplift of the dense lower crustal (or upper mantle) rocks indicated by the gravity is responsible for the seismicity in this region.

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