TECHNICAL PAPER No. 6

Survey of India

THE ARAVALLI RANGE AND ITS EXTENSIONS

By

Mr. B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (India)
Director, Geodetic and Training Circle, Survey of India

PUBLISHED BY ORDER OF
THE SURVEYOR GENERAL OF INDIA

November 1952

Price Two Rupees and Eight Annas or Four Shillings and Three Pence.

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1. **Introduction.**—The Arāvalli mountains at the present moment stretch across Rājputāna from Gujarāt to Delhi in a north-easterly direction. They came into existence by an upheaval of orogenic nature at the close of the Dhārwār era and dominated the geography of India in Palaeozoic and Mesozoic periods. The geologists believe that they were then a mighty range extending far beyond their present confines—northwards into Garhwāl and southwards into Deccan and Laccadives. This geological suggestion is well illustrated by the chart of Crustal Warp Lines(1), which shows the various hidden upwarps in continuation of the visible Arāvallis.

In the present Himālayas, evidence of Arāvallis exist with their original strike intact and there is considerable geological evidence regarding the continuation of the Arāvalli range under the Gangetic alluvium, till it is seen to meet the Himālayas between Chakrāta and Naini Tāl(2).

A similar continuation of the Arāvallis is believed to exist between Delhi and Lahore. An evidence of this is provided by a few isolated outliers of Arāvalli rock series at Kirana and Sāngla between the Jhelum and the Chenāb rivers. The geologists believe this to be the prolongation of the Arāvallis to the interior of the plains of the Punjab(3).

Attempts have been made at various times to prove the existence of these ridges by geodetic evidence, as such buried features in the alluvium play a very important role in the flow of subsoil water. The object of this paper is to discuss the light shed by the geodetic data on the compensation of the present-day Arāvalli range and its hidden extensions (if any) under the Indo-Gangetic alluvium.

2. **Compensation of the Arāvallis**—As mentioned before, the Arāvalli belt in Rājputāna is the result of crustal movements in Purānā era. It is a highly worn-out range and comes under the category of the so-called "relict mountains". It was a mountain chain of folded sediments of ancient seas and although it appears now a minor feature, it was once very lofty. Ever since pre-Cambrian times, it has been subject to denudation except for some upheaval forces in Mesozoic era. The main range and its subsequent rejuvenation are believed to be due to pressures approximately in north-west to south-east direction. On geological evidence, the Arāvallis appear to have been peneplaned in pre-Cretaceous times.

It is of interest to examine the part played by isostasy during the prolonged continuous removal of debris from the Arāvalli Range till it has attained its present attenuated height of 4,000 feet or so. The Arāvalli rocks are highly metamorphosed being composed of quartzites, slates, shales,

(1) Survey of India, Geodetic Report 1939, Chart VII.
(2) Records of the Geological Survey of India, Vol. LXVI, p. 467.
(3) Records of the Geological Survey of India, Vol. XLIII, Part III, 1913, p. 229.

phyllites and gneisses. Their density would be of the order of 2·74, but in the early days they may be reckoned to be composed of sediments of density 2·5 (say). A modest estimate of their primeval height may be taken as 25,000 feet. Assuming that denudation is compensated by undertow in the intermediate layer with density 3 which produces a secondary elevation of the surface, the lowering of the range by 20,000 feet would require denudation of a thickness of 24 miles of rock. In other words the granitic and the bulk of the intermediate layer would have been eroded away.

Actually, the Bouguer anomalies in this area are nearly zero and are by no means correlated with the height. At Ajmer (Latitude 26° 28′ 18″, Longitude 74° 38′ 42″), the Bouguer anomaly is even positive amounting to 18 mgals and at Mount Abu near the southerly extremity of the range, the anomaly is only −8 mgals. Hayford gravity anomalies[1] are strongly positive amounting to 40 mgals or so, indicating under compensation.

Pendulum stations on which the anomaly charts are based are, however, spread too wide and thinly to be useful for detailed quantitative analysis. It is hoped to put in a closer mesh of gravimeter stations in this region in the near future to delineate in detail its departures from isostatic equilibrium.

It is of interest to point out that the Compensated Geoid[2] is in accord with the gravity results and is elevated in this region and the indications are that the portion of the sea in extension of the Arāvallis is also a region of positive isostatic anomalies.

It appears then, that prolonged denudation rather than isostasy has played the dominant role in the lowering of the Arāvalli mountains and that they are being supported now by the strength of the earth's crust.

3. **Delhi–Lahore Ridge.**—Quite a number of igneous outcrops are known to occur in the districts of Shāhpur and Sargodha. These hills are composed of quartzites slates and lavas of Arāvalli age and rise from the arid expanse of the Punjab alluvium in four separate groups at Kirana, Chiniot, Sāngla and Shāhkot. The nearest point of the visible Arāvalli range is about 250 miles away, the intervening portion being filled with the Gangetic alluvium. The strike of these hills is north-west to south-east, which is at right angles to the Arāvalli strike.

A series of traverses was carried out by the Punjab Irrigation Research Institute in 1933 with the Torsion Balance and the results are exhibited in Plate II of Research Publication Vol. VI, No. 1. The presence of this ridge along the line Chiniot–Sargodha–Shāhpur is clearly indicated.

Chart I shows the gravity anomalies in this region and Chart II the gravity profiles along sections AB and CD. The increase of gravity as the ridge is crossed is very pronounced.

The above conclusion regarding the presence of a submerged barrier is reinforced by consideration of the plumb-line deflections in this area, which are also shown on Chart I. It is significant that they change their direction near Lyallpur. The geodetic evidence regarding the existence of this ridge may thus be regarded as pretty definite.

Taking the average density of the Arāvallis to be 2·74 and of alluvium to be 1·8, it would appear that there is hardly any alluvium between Chiniot and Sargodha but that between Sargodha and Shāhpur maximum thickness of the alluvium is of the order of 4,000 feet.

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(1) Survey of India, Technical Report, Part III, 1951, Chart XXIII.
(2) Ibid Chart XIX.

The comparative shallowness of the soil in the region from Chiniot to Sargodha cannot but reflect on the sensitivity of the water-table and it is doubtlessly responsible for the exceptionally rapid rise of water-table in tracts above this ridge.

4. **Delhi–Dehra Dūn Ridge.**—The earliest attempts to prove the existence of this ridge from geodetic data were made by R. D. Oldham[1] in a memoir entitled "The Structure of the Himālayas and of the Gangetic Plain as elucidated by geodetic observations in India". Making use of available geodetic data, he arrived at seemingly final conclusions regarding the compensation of the Himālaya mountains and the form of the entire Gangetic trough. This memoir aroused a considerable storm in geodetic circles and two disclaimers were issued, one by Cowie[2] and the other by Burrard[3]. It was contended that his claims bordered on the fantastic and that his attempts to lower the standard of geodetic accuracy were to be deplored.

Amongst other important matters, Oldham also utilized the evidence of plumb-line deflections at three stations (Sarkāra, Lat. 29° 16′, Long. 78° 32′, Datairi, Lat. 28° 44′, Long. 77° 39′ and Bostān, Lat. 28° 31′, Long. 77° 31′), to see if the Arāvalli range continued northwards under the alluvium. He sums up as follows on page 97 of his memoir :

"The geological structure has suggested the possibility of an original extension of the Arāvalli range into what is now the Himālayan region, the geodetic observations have supported this suggestion and converted what was only a bare possibility into something more than probability".

Burrard pointed out that Mr. Oldham's handling and interpretation of geodetic results was quite erroneous ; two of the deflections he quoted furnished no evidence on the point while the evidence of the third was adverse. Oldham had remarked that "the northern deflections at Datairi and Bostān occur on the line of the main range of Arāvalli". This does not make sense, because if they occurred on this line, the Arāvallis will not produce deflections either north or south. The source of the observed deflections is obviously not to be sought in the postulated ridge.

The deflection data in this region is meagre and very old. Only meridian deflections are available and in the absence of prime vertical deflections, any conclusion drawn would be problematic. No further deflection observations have been taken in this area since Oldham's time but all available deflection data has now been synthesized in the form of geoidal charts as the information from stray deflections is generally difficult to piece together. Such geoids generally provide a much clearer picture regarding underground variations of density than plumb-line deflections.

The generalized chart of the Compensated Geoid whose undulations are supposed to depict variations from isostatic equilibrium shows that the geoid is depressed by 10 feet between Delhi and Dehra Dūn and so the deflection data does not lend support to the existence of a hidden ridge.

In the last decade, Glennie[4] has produced crustal warp line charts for India based on the so-called Δg_{B} anomalies ; these clearly indicate

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(1) Memoirs of the Geological Survey of India, Vol. XLII, 1917, Part II, p. 1.

(2) Survey of India, Professional Paper No. 18. A criticism of Mr. R. D. Oldham's memoir "The Structure of the Himālayas and of the Gangetic Plain" by Cowie.

(3) Geographical Journal, Vol. LII, 1918, p. 237 "A critical examination of Mr. R. D. Oldham's recent treatise on Himālayan structure" by Burrard.

(4) Survey of India, Geodetic Report 1930, Chart VII.

an extension of the Arāvalli system to the Himālayas. His normal warp anomalies seem prima facie to have some justification but are really quite empirical and are designed to fit in gravity results into approximate agreement with the geological suggestions of ridges and other structural features in India. They are burdened with a welter of unknown factors and their derivation involves among other things, Hayford compensation being taken as usual in outer zones and being neglected in inner zones up to an arbitrary radius of 120,000 feet. The sphere of application of such unorthodox anomalies is necessarily restricted. They serve a useful purpose in small local areas where the objective is to establish some sort of a correlation between local geology and gravity anomalies. Being reckoned from imprecisely defined standards, they are, however, inappropriate when extended to such a vast country as India and can lead their user far astray in his conclusions as the inconsistencies inherent in them assume tremendous proportions.

Lately it has been possible to observe a number of gravimetric stations with the Frost gravimeter in this region to enable reliable isostatic anomaly contours being drawn.

Chart III gives the Hayford gravity anomalies at intervals of 10 mgals. The gravity anomalies from Meerut to Dehra Dūn are negative and if these are to be attributed solely to lighter sediments their thickness near Roorkee would be of the order of 10,000 feet. To avoid the criticism that Hayford's hypothesis of compensation is rather artificial, the anomalies have also been resolved on the Airy hypothesis assuming the thickness of the earth's crust to be 30 kms. The resulting contours are shown on Chart IV. Comparing it with Chart III, it will be seen that the Hayford and Airy anomalies are exactly identical at Delhi and Dehra Dūn. In between, the Airy anomalies are even more negative than Hayford's.

The gravity data thus runs counter to the existence of a shallow concealed ridge of dense rocks between Delhi and Roorkee and it rather appears as if the rocks of the Arāvalli range NE. of Delhi were depressed as a downwarp in front of the Himālayas. Actually although in the Himālayas there are folds and other structures with an Arāvalli alignment their lithology is not the same as that of the Delhi Arāvalli rocks of the Arāvalli range in general.

Both gravity and deflection data do not support the ridge theory and presumably this extension of the Arāvalli range sagged as a foredeep to form the rocky basin of the Indo-Gangetic depression at the time when the Himālayan flexures were in operation.

The gravity contours show that the shape of the trough from Delhi to Dehra Dūn is asymmetrical; the greatest downwarping being near the northern edge at the foot of the Himālayas. This is evidenced by the closed ring near Roorkee where the thickness of the sedimentary cover appears to be maximum. This is in accord with the fact that the northern margin of the trough is under considerable tectonic strain due to overthrusting and dislocation.

The gradient of gravity along this line increases as we approach the mountains. The maximum gradient is about 7 mgals per mile.

5. **Southward Extension of the Arāvallis.**—Lt.-Col. R. B. Seymour Sewell* has brought forth the interesting suggestion that the great submarine ridge which extends due south from the west coast of India and on which are situated the Laccadive, Maldive and Chagos archipelagoes, is

* Memoirs Asiatic Society Bengal, Vol. IX, No. 7, p. 429–442 (1935).

possibly a continuation of the Arāvallis range. It is conceivable that this part of the Arāvallis was submerged when the faulting along the western coast of India took place.

This, however, will remain a speculation until submarine gravity observations are taken in the Arabian sea. The meagre gravity data available so far seems to indicate that the region of positive isostatic anomalies does not extend to the south of Bombay and that the anomalies round the Laccadive and Maldive Islands are strongly negative.

6. **Conclusion.**—The Arāvalli mountains were *the Mountain Range* in India in bygone ages. Heavy denudation has reduced them to insignificant proportions now and it appears from geodetic evidence that in their present condition they are being supported by the strength of the earth's crust rather than by the mechanism of isostatic equilibrium.

The prolongation of the Arāvalli range under the Gangetic alluvium is a matter of much speculation amongst the geologists. No bore hole data exists and there is very little geological information about the thickness of the alluvium. The indications are that its floor is not plain but is corrugated by buried ridges, which play a vital role in ground water hydrology. Two such ridges have been considered in this paper.

Strong support is forthcoming from geodetic evidence regarding Delhi–Punjab ridge. The extension of the Arāvallis to the Himālayas is still widely believed and it has been backed by imperfect understanding of geodetic principles and by purely empirical approach. But gravity data is in agreement with the geoid in discounting the hypothesis of a submerged shallow ridge between Delhi and the Himālayas.

G. & T.C.—P.O.—J.S. 375—25-11-52—200 bks.

Chart I

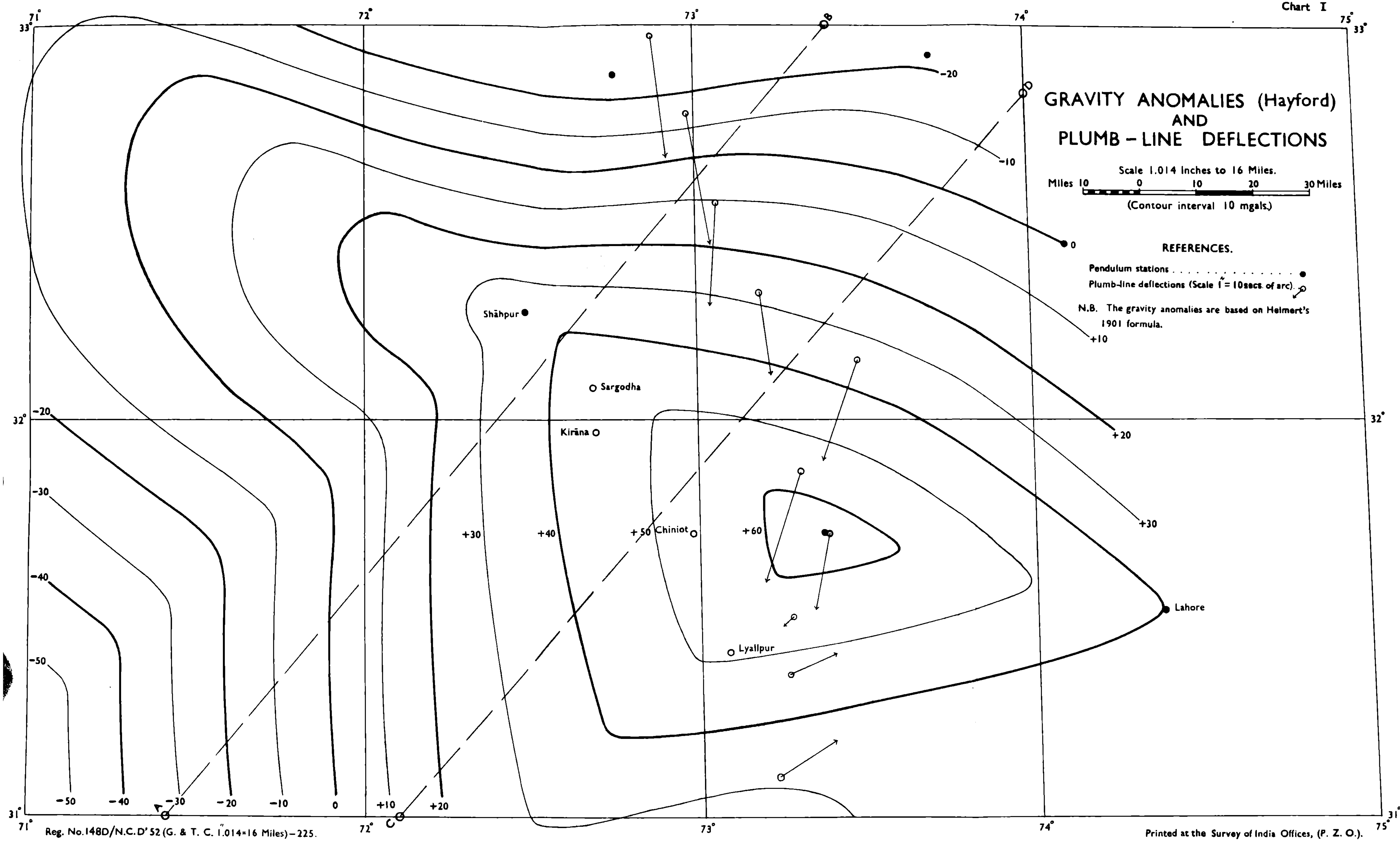

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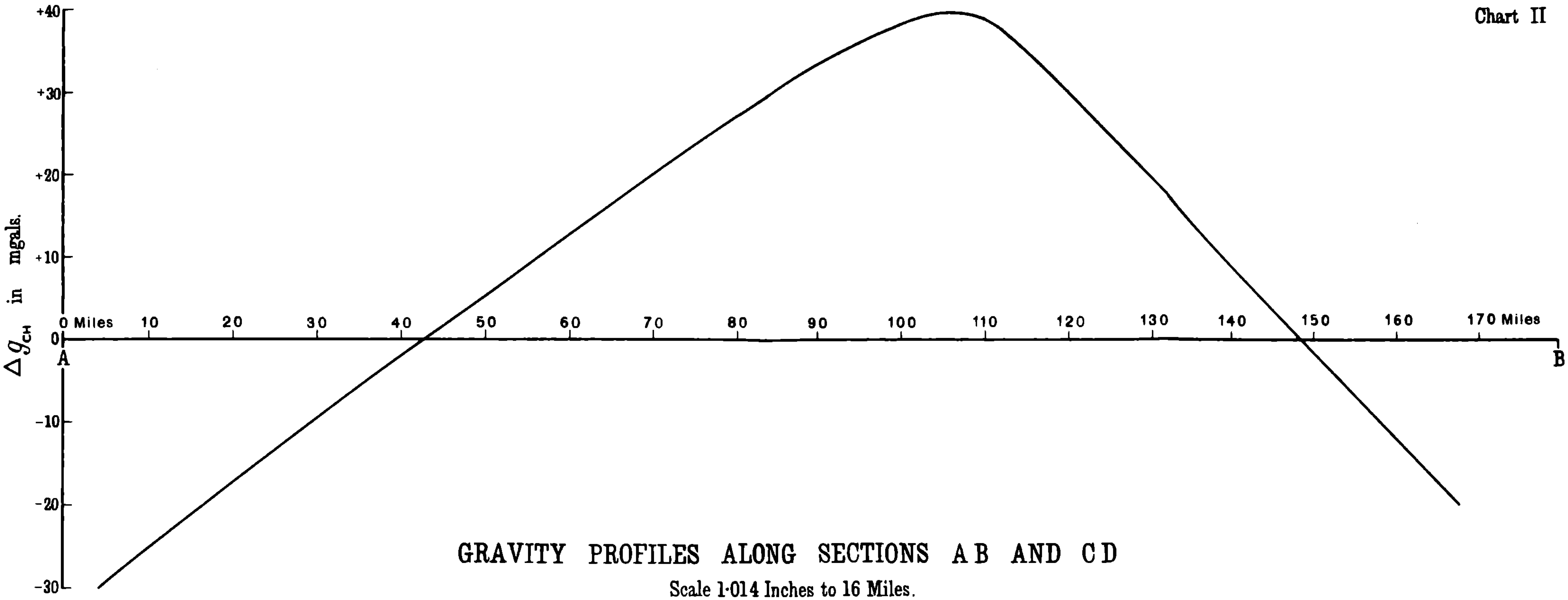
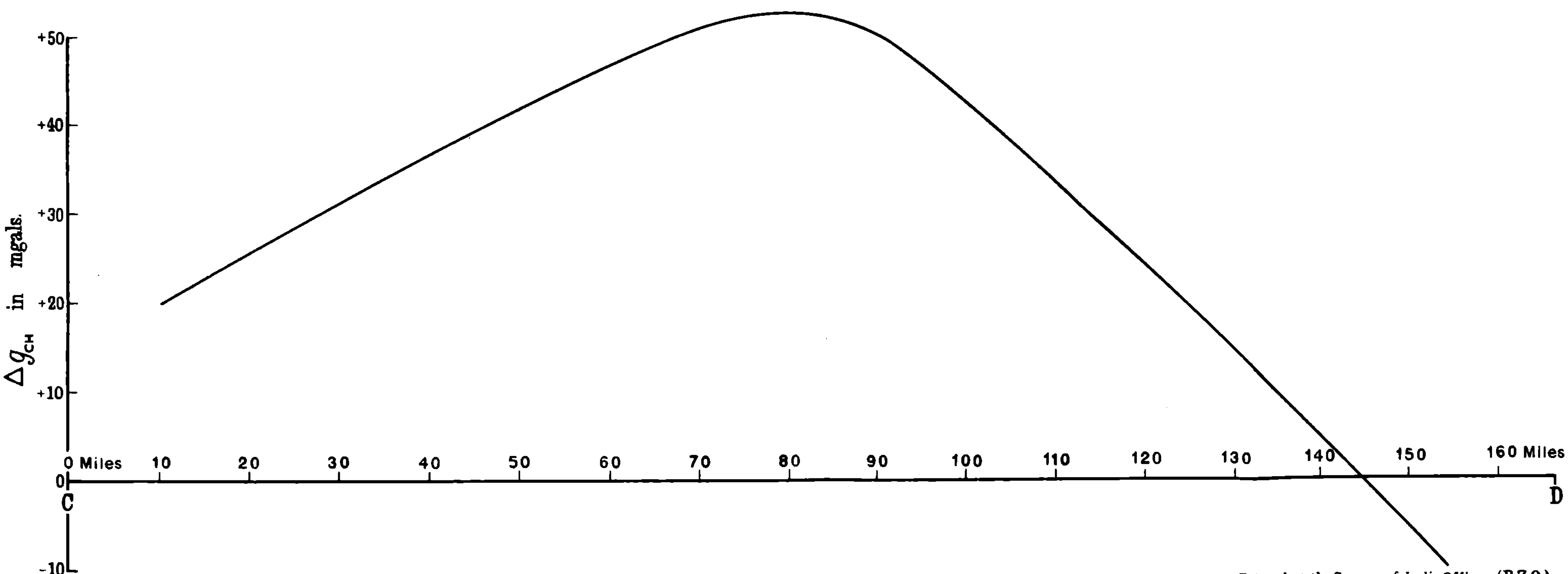
Chart II



GRAVITY PROFILES ALONG SECTIONS A B AND C D

Scale 1·014 Inches to 16 Miles.



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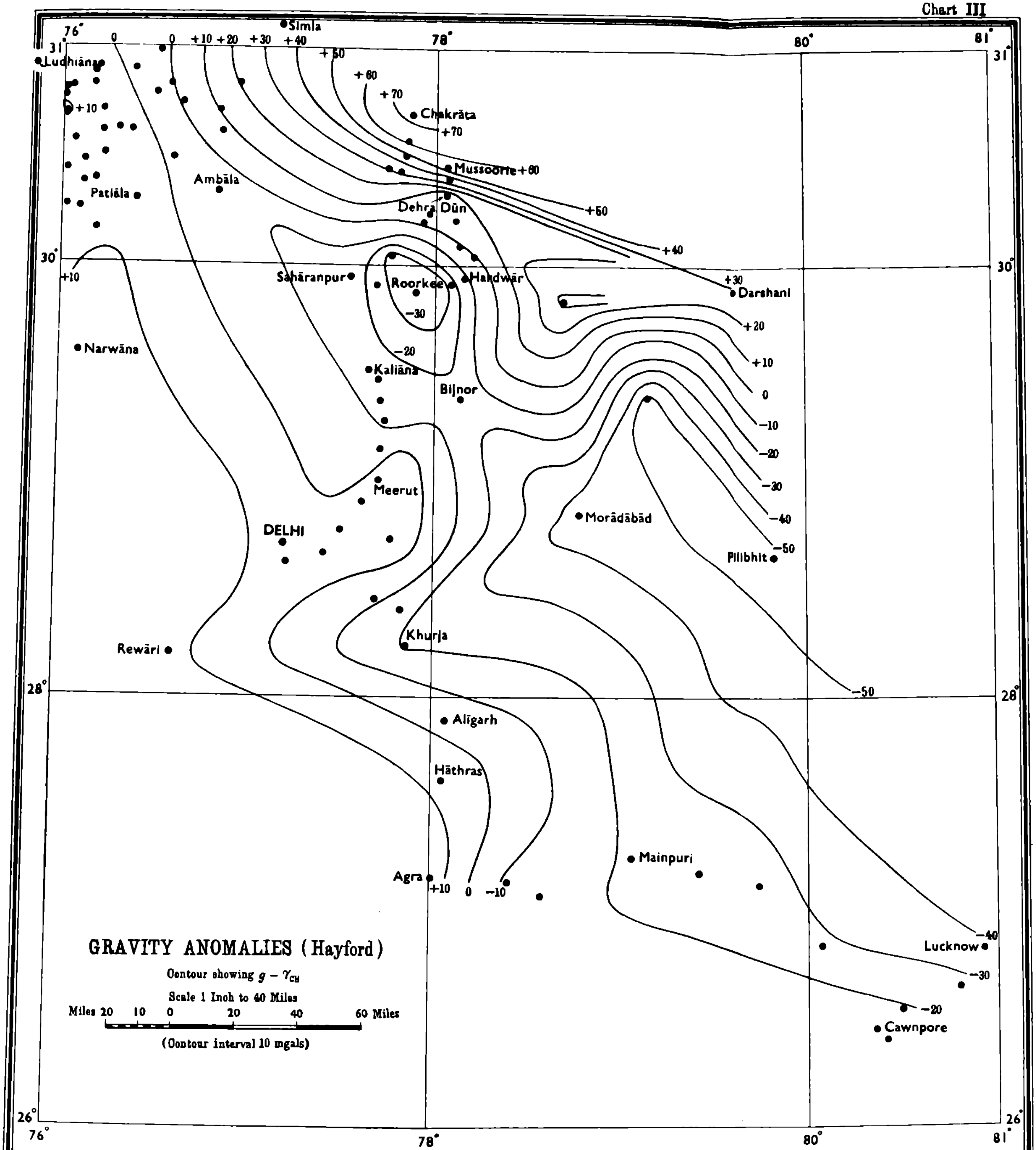

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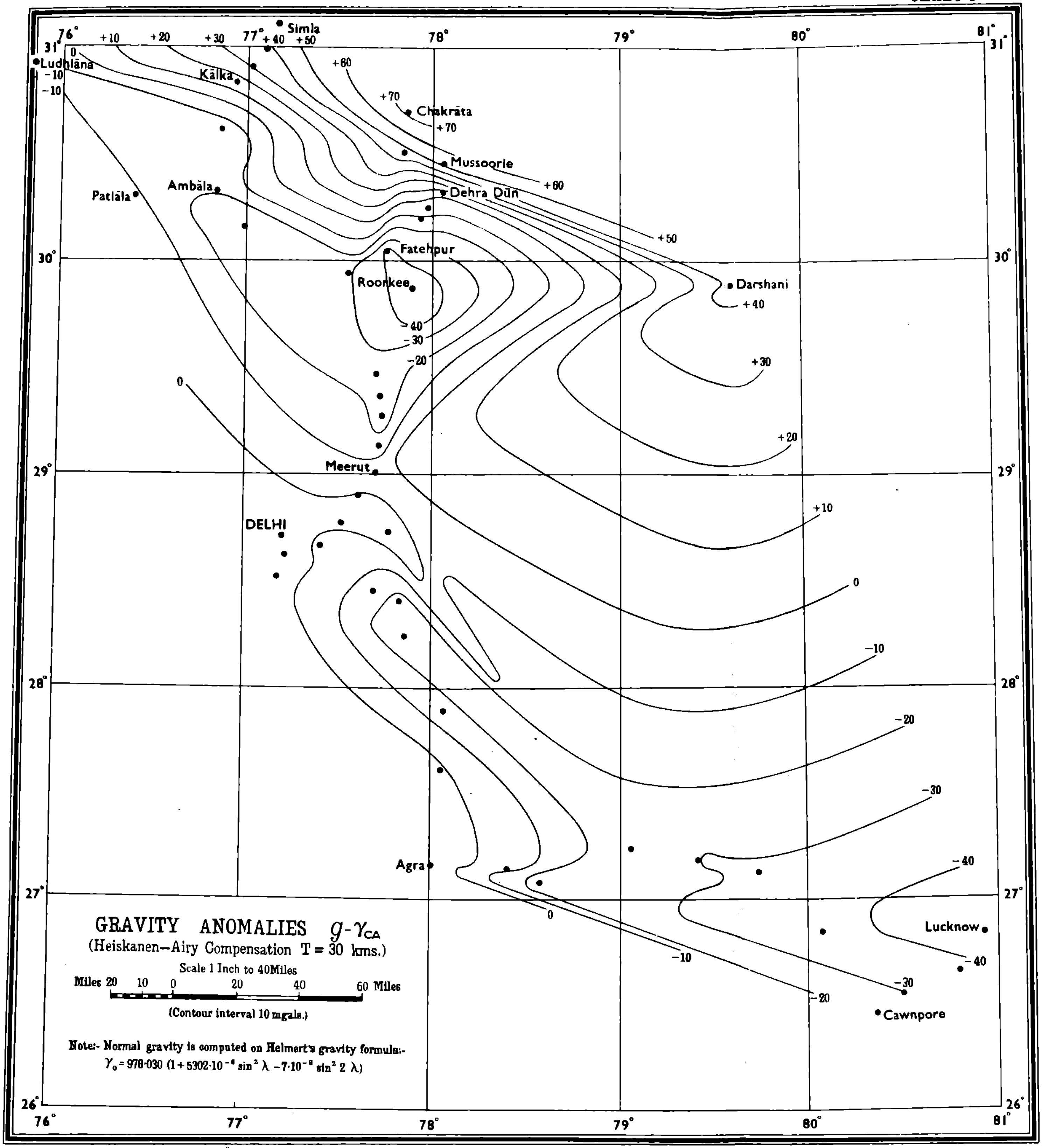

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