Are the Himalayas Compensated?*

By D. N. Wadia.

THE rise of the Himalayas from the floor of the ancient *Mediterranean* sea, a Sea which stretched across the earth from the Central Europe to Western China, is an epic of the geological history of Asia. All the relevant facts of this event are well dated and documented in the rock-records of these mountains laid bare in the valleys and defiles. Paradoxical as it may seem, mountains denote the weaker belts of the earth's surface, belts that have been depressed below the sea for long ages and have received enormously thick deposits of marine sediments belonging to long cycles of geological ages. It is these overloaded and consequently weakened zones of the earth's circumference which respond most to the lateral and tangential earth-pressures which follow the cessation of the sinking process and become folded and elevated into mountain-chains during periods of great compression. Hence has arisen the well-known principle of geology that where areas of the earth have sunk deepest, they also rise highest. These sunken and loaded belts are called *geosynclines* in geology. During the process of compression (by tangential forces) of these sunken and loaded zones into mountains, they are narrowed to almost a quarter of their original width. The Himalaya system of mountains represents the largest individual geosyncline on the face of the earth, containing over 30,000 of sediments—strata representative of all geological ages from the Carboniferous to the Eocene. Their uplift from the mediterranean sea-bed was not a single act, but there were three distinct and widely separated phases of elevation. The earliest was in the beginning of the Tertiary era of geological history, while the latest was in Sub-recent times, a date which, measured in terms of geological antiquity, is almost as recent as yesterday. There are evidences that all earth-movement has not entirely disappeared, for something like 5,000–8,000 feet of uplift has taken place in the Western Himalaya since Man appeared on earth.

With regard to the static relations of the Himalayas and their physical adjustment with the interior of the earth, it may be mentioned that geodesy does not regard mountains as mere unadjusted excrescences on the surface of the earth. If Central Asia, with the high-standing Tibetian plateau supporting the Himalayan chain, were extra masses of rock piled on the circumference of a homogeneous earth uniform to the core, the waters of the Indian Ocean would be pulled up a considerable distance towards the Himalayas, extending much beyond the present heads of the Arabian Sea and the Bay of Bengal. The fact that the sea-level is not appreciably affected shows that the continents and mountainous portions of the earth's body, in relation to the hollows of the great oceans, are in some sort of adjustment with their bases and are commonly believed to be supported on a dense semi-plastic substratum by a process of flotation, somewhat as ice-caps are supported on the surface of the polar seas. This theory of support of mountains by flotation on a dense medium gives a rational explanation of the existence of what is commonly termed "mountain compensation", and also accounts for the stability of some abnormally abrupt geographical features, *e.g.*, the great Andian chain rising 20,000 feet in altitude above the sea-level, right in front of a sub-marine depression which plunges down 26,000 feet below that level.

That the earth is not homogeneous and uniformly rigid to the core is borne out by the phenomena of earthquakes, vulcanicity, tides, etc. To small periodic forces, *e.g.*, earthquake waves, the average rigidity of the earth's crust as a whole is twice that of steel. But to prolonged extensive pressures, such as those exerted at the root of the Himalayas or by continental ice-sheets, such as that of Greenland (a mass of over a million square miles having a thickness of 3,000 feet), the earth behaves as a plastic body and the surface sinks under the load, rising again when a diminution of the load takes place.

Below the cold rigid crust the earth seems to have but little strength, to judge from these proofs of its mobility. Early in his work (1830), Everest recognized that the Himalayas would exercise a disturbing effect by their gravitative attraction in the triangulation of India, which necessitated the accurate measurement of the arc of the meridian from Cape Comorin to the foot of the Himalaya near Mussoorie.

Plumb-line and pendulum observations at Dehra Dun have shown that "topographical deflection", *i.e.*, deflection from the normal, due to the gravitative pull exerted by the calculated visible mass of the Himalayas, is 86 feet, but the true observed deflection of a plumb-line is only 31″. For Murree, in the Kashmir Sub-Himalaya, the figures are 45″ and 12″ respectively, while at Katiana, which is only 50 miles south of the foot of the Himalaya, the observed deflection is only 1″, whereas it ought to be 58″. These observations suggest that the excess rock material lying above the main surface of the earth, constituting the Himalayas, is compensated for by a defect of density in the rock layers underlying the mountains. In other words, this theory (Isostasy) postulates that there is an adjustment between surface geographical features and an arrangement of density in the earth's interior, so that above each region of less density in the sub-crust there will be a surface bulge, while over tracts of greater subterranean density there will be hollows or depressions—the former will be the continents, plateaus and mountains; the latter will be basins of the oceans and seas. This hypothesis, which first originated in India as a highly suggestive speculation of Archdeacon Prat, has had a great vogue in America.

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Movements of gravity and deviations from the vertical, as carried out by the Geodetic Survey of India during the last two decades, give some support to the main facts of Isostasy by indicating that the principal relief features of India are in a large measure compensated, though many discrepancies still remain to be explained.

To what extent are the Himalayas compensated? Observations at a number of stations in the midst of the Himalayas enable us to say that there is a defect of compensation in the outer foot-hills, known as the Sub-Himalayan, zone; in other words, this area is undercompensated and one of surface overload. This defect increases in amount until, according to Oldham, " at some 50 miles from the edge of the hills it reaches an equivalent to an overload of about 2,000 feet of rock ". In the interior of the Himalayas in the central ranges there is, on the other hand, over-compensation, that is, mountain material is in defect, due perhaps to excessive erosion by rain and rivers, while the underground density at the root of the mountains is of a high order.

If these facts ultimately prove to be well-established, the question of the origin of mountain ranges would appear to be largely dependent on the provision of an underground belt of rocks of excessive specific gravity. The primary factor in mountain-building would thus be not the formation of a deep geosynclinal trough with its pile of sediments, but the changes in underground mechanics bringing about movements in the denser basaltic layers under the sub-crust.

It appears from a consideration of isostatic facts and the data from gravity investigations that, on the whole, India is an area of defective density of mass. Gravity in India is in deficit in spite of all the height, bulk and weight the Himalayas have given to it, and it needs a thick stratum of rock, somewhere about 600 feet thick, spread over the entire surface of the country to counterbalance this deficit of mass.

The Sex Ratio.*

"THE subject of the numerical proportions of the sexes in a population is of such obvious interest to the naturalist, the sociologist, the economist amongst others, that it is not surprising to find that to it considerable attention has been paid, but so complicated are the problems that cluster round it that even yet our understanding of the significance of the sex ratio is still very incomplete." Darwin (1871) wrote: " I formerly thought that when a tendency to produce the two sexes in equal numbers was an advantage to the species it would follow from natural selection, but I now see that the whole problem is so intricate that it is safer to leave its solution for the future. " Prof. Crew, in view of the recent developments in cyto-genetics, which have removed many of the difficulties that surrounded the subject in Darwin's time, has re-examined the problem in great detail. In the case of the human beings, after analysing the figures available, he finds that " to be born is a more dangerous adventure for the male than for the female, and that there is a sexually selective mortality which not only operates at all ages after birth to the disadvantage of the male, but which acts and possibly equally strongly pre-natally as well. The expectation of life at all ages is greater in the case of the female of the species, and the true recipe for longevity is to be born a girl. " After dealing with the application of the metabolic theory and the alternative sex-linked lethal theory to man he examines at some length the application of these theories to other animals, such as mammals, birds and insects, and concludes that " It is thus possible to look upon the inequality in capacity for continued life between the sexes as being partly of the nature of an evolutionary oversight due to a lag in the development of a harmonious relationship between the mechanisms of mutation and heterogamety. But this disharmony has been repaired by the invention of a supplementary device which can provide a compensatory primary sex ratio, high in those species with male heterogamety, low in those in which the heterogametic sex is the female. "

In his Address, Prof. Crew has presented evidence to show that three possible causes of sex differences in mortality have to be considered: (1) " sex-linked lethals, (2) sex limitation of defects and derangements, and (3) sex-dimorphic physiological and endocrinological differences. " He is of the opinion that probably " sex-linked lethals play only a minor part and that the defects and derangements that have come to be manifested only or more completely in the male owing to his relative unimportance in respect of propagation, constitute the major cause ". In the Address he tries to reconcile the views of the geneticists and of the physiologists and is of the opinion that the problem of the human sex ratio must be studied not only by the statisticians but also by the experimental biologists both in the laboratory and in the open country.

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* Summary of the Presidential Address of Prof. F. A. E. Crew, D.Sc. Zoology Section, British Association for the Advancement of Science, Nottingham, 1937.