The Paulin Aneroid.

THE Swedish engineer, G. Paulin, has recently applied the null reading principle to the aneroid barometer. The action of the instrument will readily be understood from the illustration (Fig. 1). The diaphragm *a*, the total range of motion of which is restricted by means of stops to about $\frac{1}{40}$ mm., actuates the frame *j*, to the upper ends of which are attached phosphor bronze strips, bent at an angle and fastened at their lower ends to the base. To the angles of the

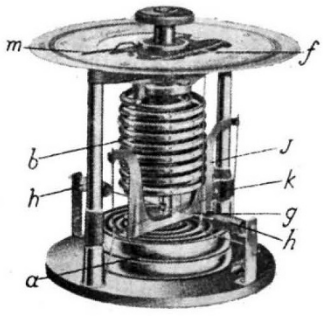

FIG. 1.

latter strips are attached two horizontal strips *k*, which are pinned above and below a transverse torsion strip *g*, held by springs *h*, and carrying the *null* pointer *f*. It will be seen that a rise or fall of the diaphragm alters the angles of the bent strips and imparts a twist to the torsion strip *g* through the horizontal strips *k*.

The *scale* pointer *m* is carried by a central threaded spindle, passing through a nut attached to the upper end of the spiral spring *b*. The lower end of this spring is coupled to the diaphragm. Varying air pressure on the diaphragm is thus equilibrated, and the diaphragm thereby restored to its null position by the measured rotation of the central spindle.

The writer has recently had an opportunity of testing this type of barometer on an experimental survey in the Eastern Highlands of Scotland, in the course of which checks on the aneroid readings were obtained at frequent intervals by means of trigonometrically fixed heights. Normal surveying practice was followed by reading a stationary barometer at intervals during the field traverses to allow for diurnal and weather changes of pressure, and the effect of varying temperature of the air column was allowed for, on the usual isothermal assumption, in reducing the field readings.

The makers claim that friction errors are eliminated, and this claim would appear to be substantiated. The reading is always consistently definite and is not affected by tapping.

The extent of the first climb in the early morning was invariably *exaggerated* by the instrument to the order of $1\frac{1}{2}$ per cent. This error is not due to hysteresis, since it is in the wrong sense. Neither is it due to want of sympathy between the makers' graduation formula and the local meteorological and geographical conditions, for an independent computation from the International formula reveals no greater difference on this score than 0·1 per cent. The only alternative which suggests itself is faulty temperature compensation of the particular instruments under trial. Temperature fell considerably during the climb, and it is likely that insufficient time was allowed before starting to enable the traverse barometer to take up the outdoor temperature. It is indeed difficult to see how the mechanism described in the makers' catalogue can be compensated. On the other hand, the writer has been shown the results of National Physical Laboratory tests on other barometers of this type, which indicate remarkably good temperature compensation. Possibly the difficulty has been overcome in later models, at any rate in selected specimens.

Minor variations in altitude were recorded to within one or two feet of truth, and in all cases where the temperature remained sensibly constant the traverse closed to within two or three feet, even after a sudden drop of a thousand feet.

This instrument would appear to mark a step forward in the design of surveying barometers, although more extended field trials are necessary before this can be stated with assurance. M. H.

Isostasy.

By GEORGE R. PUTNAM, U.S. Department of Commerce, Washington, D.C.

THE condition of equilibrium in the crust of the earth is maintained by under-surface compensation of some sort, between the extremes of no compensation (a rigid crust) and complete local compensation (a plastic crust). Common knowledge shows that the materials of the crust are too weak for rigid support of the relief, and are too strong for complete local isostasy. What, then, is the most probable arrangement of the actual isostatic compensation ?

Gravity measurements furnish the principal evidence. Of the methods for their discussion, the reductions of Bouguer and Hayford correspond to the above two extremes. The large Bouguer anomalies prove that the crust is not rigid. In papers printed in the May 1928 issue of the *Proceedings of the National Academy of Sciences*, I have shown that the Hayford hypothesis of complete local compensation is untenable, and leads to significant error.

The Hayford method assumes that the isostatic compensation is "complete under every separate portion of the earth's surface," however small. This hypothesis was not claimed to be completely true, but this notable work has been built around local compensation, as complete as mathematically practicable. Hayford and Bowie allude to any error due to this assumption as a negligible matter. The Hayford reduction divides the area about the station into very small compartments, and assumes complete local compensation for each. The first zone is a cylindrical column 2 metres in radius and extending downward 113,700 metres (71 miles), and this column is assumed to be in perfect equilibrium, free to move without resistance from surrounding materials. This cannot represent a condition possible in Nature. Such compensation could be true only with materials wholly plastic, and no remaining surface relief.

The errors in the Hayford residuals show as overcompensation for stations above the average level, and as under-compensation for stations below ; they are appreciable or large for mountainous stations, but negligible in fairly level regions. They are similar to the 'free air' reduction errors, although much smaller. The proofs given depend mainly on comparisons of pairs of adjacent gravity stations differing materially in elevation. The evidence shows that regional compensation cannot be ignored in gravity reductions.

I also used this strong method by pairs, for a measure of the horizontal extent of regional compensation, and find evidence that this is appreciable to about 160 kilometres (100 miles) from the station.

Another basic hypothesis of the Hayford reduction is that the densities so vary with the elevation that the mass in a unit column is constant. This cannot be true even approximately, in mountainous regions, for small unit areas. The correct conception is that of limited regional compensation horizontally, which is the same as incomplete compensation vertically, or partial lack of local compensation, for features of moderate extent.

All this affects the discussion of the so-called Airy and Pratt theories. With regional isostasy there will be horizontally extended compensation beneath mountains, instead of individual downward protuberances. Probably the depth of compensation varies appreciably, and the topographic relief must be explained by more than one kind and direction of force.

To bring the gravity measurements within the possibility of mathematical treatment general assumptions cannot be avoided, but these must be physically reasonable, and be such as to result in minimum residuals.

In the papers to which reference has been made, two regional isostatic methods of reduction of gravity observations are given. One, a more accurate method now first proposed, uses a practicable regional system of reduction by averaging the elevation for moderate areas about the station, thus avoiding the local compensation error. It yields results nearer the truth than the Hayford method, and requires less labour. A more correct, but less readily computable, conception, would substitute a warped surface for a levelled area about the station.

The second method, the 'average elevation isostatic reduction,' was devised and used by me in 1895; it averages the surface elevation within 100 miles of the station, and applies a compensation for this average elevation. This is a simple method, although approximate, as it neglects curvature. On a reasonable conception of isostasy, it eliminates or greatly reduces the extreme residuals in mountainous regions. This method is of special significance in the general problem, as it proves isostasy without using the Hayford assumptions. It is not based on any assumption as to the thickness or vertical density arrangement of the compensation, providing it is at a considerable depth, and hence an unlimited number of combinations of these elements will satisfy the condition of isostasy. This reduction is a regional treatment of compensation, and the area used conforms well to that found, by more exact methods, to be regionally compensated. It confirms the previous conclusion that regional isostasy cannot be ignored.

In 1894, gravity measurements across North America were made by me for the Coast and Geodetic Survey, at stations which had been carefully selected to test the condition of the earth's crust. I applied this average elevation reduction to these and other determinations, representing extreme and diversified conditions. This work, on a basis of isostasy, eliminated the larger residuals which all preceding methods had failed to do, and it was the first consistent proof of isostasy.

The first observational evidence of crustal equilibrium came from British trigonometric and gravimetric surveys in India. The first definite proposal of this theory was made by Airy seventy-three years ago, and English scientists have continued to make valuable contributions to the theory of isostasy.

University and Educational Intelligence.

CAMBRIDGE.—The governing body of Emmanuel College offers to a research student commencing residence at the University in October next, a studentship of the annual value of £150, tenable for two years. Preference will be given to a candidate who has already completed at least one but not more than two years of research. Applications should reach the Master of Emmanuel (The Master's Lodge, Emmanuel College, Cambridge, England) not later than June 30.

THE Geological Department of the University of Melbourne has been provided with a new building at the cost of £21,000, by a grant from the Government of Victoria. On the occasion of the opening of the new building by Lord Somers, the Governor of Victoria, a pamphlet has been issued summarising the history of the Department and giving a list of positions obtained by its graduates, and of the 123 papers issued in connexion with the School during the past twenty-three years. The pamphlet refers to the early history of the school under its founder, Sir Frederick McCoy, from 1854 until 1899, Prof. Gregory during the next five years, and Prof. Skeats since 1904. It has been conducted in recent years in a joint building with metallurgy erected in 1905. The growth in the number of students has rendered necessary the provision of the present large and well-equipped building. The staff of the Department includes Dr. Summers as associate professor and Mr. Frederick Chapman, of the Victorian National Museum and now acting as Palæontologist to the Australian Federal Government, as lecturer in palæontology.

STUDLEY COLLEGE, Warwickshire, is appealing to the public, and especially to those having agricultural interests, for £20,000 to enable it to continue its work of providing courses of instruction for women in horticulture, agriculture, dairying, and poultry-husbandry. Originating as a hostel at Reading in 1898, the College moved in 1903 to Warwickshire, where it became a teaching centre for gardening and dairying. It now provides a three-years' diploma course in horticulture; two-years' courses in horticulture, in agriculture, in dairying, and in poultry-husbandry; one-year and shorter courses in the above subjects and instruction in carpentry, bee-keeping, fruit-bottling, and floral decoration. The fees for tuition and residence amount to 110 guineas and upwards per annum. The College is always full, and the demand made upon it for trained workers is greater than it can supply with its present accommodation, which is limited to sixty resident students. Of the twelve hundred women who have passed out from it, many are now managing their own land or earning salaries not only in Great Britain but also in Australia, New Zealand, Uganda, Kenya, South Africa, Canada, India, and Ceylon, where they are growing crops of all kinds, including cotton, lemons, oranges, coffee, and tobacco. In 1911 the College obtained a lease of Studley Castle estate, comprising the castle, farm buildings (now needing repair and enlargement), and 340 acres of land. This lease is now drawing to a close and £15,000 must be raised before July 1 to complete the purchase of the freehold. Towards this the Treasury has promised a grant of £5000, former students have pledged themselves to find £1000, and the present students and staff are contributing £300. The College is recognised by the Ministry of Agriculture and Fisheries, from which it receives an annual grant of £1000. The appeal is signed by the Marchioness of Londonderry as president. Donations may be sent to the honorary treasurer, Mr. H. Keeling, 26 Eccleston Street, London, S.W.1.