complete. It is fortunate that it should be so, for the work itself is most worth-while, and through it we should attain, not merely scientific ends, but the moral virtues of fellowship and intelligent cooperation. As for the expense, it ought not to be necessary to mention such a thing.

I referred just now to the resources of the country, and I suppose some of you are wondering just what those include. Is our great undertaking to include simply the sources of food or shelter or clothing? Or if we include the flowers, is it only because they can be eaten by cows, or because innocent people will sometimes buy them, and so give them commercial status? I do not so understand it. We live in a great and wonderful environment, to which we may react in a thousand ways. Broadly speaking, happiness comes through the harmonious exercise of our faculties. To be blind where we might see, callous where we might feel, dumb where we might speak—these are the great futilities, in the presence of which material wealth is of small account. Thus we must hold that our resources are only limited to those things which we can appreciate with our senses, and get some good by so doing. Wealth of this kind is so abundant that there is more than enough for all. No one can use more than a small part of it, but many minds and hearts, with a common purpose, may approach a grand synthesis which some genius will clarify and define. This is the manner of intellectual progress.

In this country of ours we are facing a somewhat new situation. Thanks to science, material wealth has increased enormously. With the spread of democratic ideals, life has become easier, the hours of labor shorter. People have time and money as they never had before. What are they doing with them? We have only to look around to see resources wasted, and time—the precious hours and minutes of human life—squandered on inanities. We do know how to work, the whole world admits that, but we do not know how to play. Now with the pressure of a complicated civilization and the dominance of machinery, our working hours are more and more standardized as to their content and the manner of our operations. We are necessarily slaves to the system or to the machine. This is no great evil, so long as it occupies only part of our time, and we have still enough in which to dream, and invent, and discover. But if the free time, the so-called leisure time, is deprived of worthy activities, not only is life reduced to its lowest terms, but the very springs of progress are dried up. Thus the appreciation of nature, including human nature, becomes a high social duty, through which personal happiness and national progress may be attained.

And, after all, even in those dark valleys of sorrow and loneliness which we all have to cross, there comes the sense of the unity and permanence of this wonderful universe, in which loss is followed by gain, apparent death by resurrection; and we, atoms that we are, are partners in the firm which shall never be dissolved or go into bankruptcy. Vital activity is our business, and through it, in all its varied forms, we may realize the purpose of existence. Putting the thought in verse, we may perhaps express ourselves in this wise:

The world is full of sorrow, and sad the heart of man,
Put on the bright and merry tune, and dance it if you can,
And let it be a token, that in ages yet to be
The flowers will blossom in the fields, the glory of the sea
Will never fade or pass away, nor will the changing sky
Its lovely pageant fail to show, as hours of daylight die.

So banish man-made ugliness,
Let vulgar notions fade,
And learn to know the loveliness
Of that which heaven made!

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NOTES ON THE AIRY OR "ROOTS OF MOUNTAINS" THEORY

THE Pratt theory of isostasy calls for a uniform thickness of the crust or, at least, it is supposed that the crust extends to a uniform depth below sea level.

The Airy theory, on the other hand, postulates a varying thickness. This is practically identical with what is generally called the "Roots of Mountains" theory and we shall therefore speak of the two as the "Roots" theory.

In the Pratt theory the major, and perhaps other, changes in elevation must be due to changes in the density of the materials of the crust below the affected surface. The changes in density may be uniform throughout the crust, they may be greater at one depth than at others, or they may affect only a part of the crust. Although we may prove the Pratt idea by geodetic and other evidence which might be available, it is possible that we shall never be able to determine the exact distribution, with the depth, of the changes in density resulting in the formation of a mountain system or a synclinorium.

Isostasy seems to have been proved. Just how the densities of the crust are arranged to give the equilibrium, found to exist, and how the equilibrium is maintained are interesting problems still unsolved.

In this short paper let us lay aside the Pratt idea and give our attention only to the Airy or Roots theory. I am assuming the rôle of an advocate of the Pratt idea and consequently am setting forth some of the weaknesses of the Roots theory.

The Roots theory calls for the crushing of the crustal material to form mountains and islands. To account for the elevation of a plateau, such as the one to the east of the Rocky Mountains in North America, there must have been an uplift due to the thickening of the crust. This could only have been due to pressure from the sides and must have been accomplished without distortion of the outer strata which, through erosion, can now be seen and examined.

I do not recall having seen, in the literature on the subject, just how a synclinorium is formed under the Roots theory, but it must be due to the reverse of the process involved to cause a major uplift if the isostatic equilibrium is to be maintained.

The conception of the Roots theory is due to the belief that the nucleus of the earth is losing heat and contracting, while the crust, maintaining its temperature, collapses on the nucleus. The theory calls for a constancy of the crustal temperature. Another essential feature of the theory is that there are no decided changes in density of crustal material.

A condition of the earth made necessary by this theory is that the subcrustal materials must be very weak in order to permit the buckled crust to extend downward into it. The crust, on the other hand, must have very weak material along certain belts where the breaking, crushing or plastic yielding takes place to form the mountains. The remainder of the crust must be strong enough to carry the thrusts for thousands of miles to the yielding belts, overcoming the frictional resistance to the crust moving over the subcrustal matter. The crust must be weak enough to undergo the distortion incident to the concentration of the crushing or buckling within narrow zones of moderate length as compared with the earth's circumference.

These seem, at least, to be some of the conditions which must be present in the crustal and subcrustal material, in order that the Roots theory may function. Let us analyze just a few phases of the problem involved in the processes which must be operating under the Roots theory.

Seismologists and students of the earth and ocean tides, as well as those engaged in a study of the variation of latitude, tell us that the earth as a whole is as rigid as steel to the short-time stresses with which they deal. It is necessary, therefore, to give up any ideas that the subcrustal materials are highly plastic to short time stresses.

But, in spite of its high rigidity shown under the short time stresses, we know that the crust of the earth is in isostatic balance to a remarkable degree of perfection. In order that this may be true, the ability of the subcrustal materials to resist the gravitational stresses set up by the shifting of materials over the earth's surface must be exceedingly small. Evidences of tremendous erosion are everywhere present on land areas, yet the existence of the isostatic equilibrium is established by geodetic data.

Such a low residual rigidity of subcrustal material is needed by the Pratt as well as by the Roots theory. The first requires a horizontal movement below the crust to restore the isostatic balance, while the second must have a pushing down of the crustal material into the subcrustal space with horizontal movement of displaced matter. But this weakness which must exist makes it certain that the subcrustal matter acts hydrostatically under any stress differences which tend to disturb its equilibrium.

The Roots theory calls for a crushing of the crustal material or for at least a giving way of the material plastically along certain belts, with the consequent elevation of the crustal surface and the depression into the subcrustal space of a protuberance several times the surface change in elevation. The relation of the elevation of the surface and the depth of the roots depends upon the relation of the crustal and subcrustal densities. This formation of mountains and roots requires a crustal material, along the crumpled line or zone, of great plasticity or of low strength. The distortion must be due to either plastic flow or crushing. But the subcrustal materials must be even weaker than those of the affected part of the crust.

Under these conditions is it possible that the root can maintain itself against the hydrostatic pressure of the subcrustal matter exerted against the sides and bottom of the root?

Let us consider the root or roots of the Himalayan Mountains. The average elevation of the Himalayas is not far from three miles. The root must be extensive enough to counterbalance this mountain mass. If the subcrustal material is assumed to be ten per cent. denser than that of the crustal matter forming the root, the downward extension must be about thirty miles. The stress exerted by the plastic subcrustal material on the tip of the root must be equivalent to that exerted under gravity by a column of rock three miles in height. Even though the root may have been formed, and it must have been of very weak material to have been formed, surely it could not be maintained against such enormous stress differences acting since the time the Himalayas were raised.

The condition of stresses under the Himalayas, by this theory, must exist under all mountain systems but only to degrees proportionate to their average elevations.

In applying the Roots theory to the elevation of a plateau, we run into the difficulty of having the crust so weak as to permit of great uniform thickening and at the same time so strong as to cause that thickening. It may be conceivable that the crust is strong enough to cause a thickening in a local zone, but how can material that has once carried a thrust great enough to thicken the crust several miles under the local zone be weak enough to undergo collapse and thickening itself under continuing horizontal forces? Or, if a local zone has been thickened on the side of the affected crust from which the thrust comes, how can that collapsed zone transmit further thrust to regions beyond it? Even though all this were possible, how can we account for the thickening of the crust represented by the elevation above sea level and the length of the roots, with at least the surface strata horizontal and apparently undisturbed, except for change in elevation? I can not recall having seen any explanation of how the plateau would be raised under the Roots theory, but the difficulties appear to be unsurmountable.

A theory advanced to account for the elevation of the earth's surface must also provide an explanation for a lowering of the surface. There have been synclinoria formed where were once high lands. The only process involved must be one of stretching. But would the stretching occur in the thick crust under a mountain or in the thin crust under an ocean?

It does not seem possible for a synclinorium to be formed under the Roots theory, for it has no provision for a change in the density of crustal materials. Without that provision we run into great difficulties.

If the crust is thick under the mountain systems, then under the deep portion of the oceans it must be thin. Under the portions of the oceans of average depth, it must be thinner than under the mountains. All this must be so in order that the Roots theory may be of universal application.

The theory calls for a very plastic subcrustal material, with a stronger material in the crust. Can we assume that the crustal material under the oceans, not more than half the thickness of that under the continents, is so much stronger that it can carry the forces without yielding or fracturing to the margins or interior of the continental areas and form mountains?

Considered as an engineering structure, placed in a testing machine, we should expect the failure to come under the deepest portions of the oceans where the crust must be thinnest.

How, for instance, could the Japanese Islands have been formed by horizontal thrusts from the continent outward, or by thrusts originating under the Pacific, in view of the fact that one of the deepest ocean troughs lies parallel to and not far from the Japanese archipelago on the Pacific side? The statement of the problem at once indicates the answer. It could not have been done in the manner indicated. The Roots theory seems to fail here if the crust under the deep is in isostatic equilibrium. Let us hope that gravity observations may be made over this and other deeps in the near future.

It is not practicable to use the Roots theory with any satisfaction in making the isostatic reductions of gravity stations or computing deflections of the vertical. This theory has, as a fundamental principle, constancy of density in the crust. The density may vary with the depth, but no change in the density of crustal material is supposed to occur during the process of the formation of the mountains and their roots. In order to use the theory some approximation to the differences of crustal and subcrustal densities would be needed. The difference in elevation between the highest mountain and the deepest point of the oceans is about ten miles. The difference in the thickness of the crust under these two places necessary to maintain isostatic equilibrium would have to be eighty miles with none of the crust under the ocean deep if the difference between crustal and subcrustal densities is ten per cent. In making the estimate of eighty miles rather than one hundred miles the mass of the water is considered.

The depth of compensation derived for the area of the United States from gravity data in mountainous regions is sixty miles. When the data for the whole area were used, the derived depth was found to be about forty miles. The depth for the United States from deflection data in mountain regions was about sixty miles and from data for the entire area the depth was about seventy miles.[1]

Taking these depths in connection with the Roots theory means that, if mountains have thick crust below them, the deeps of the oceans have below them no crust whatever. That is, the material would not be the same as found under continents. It would have to be the same in density as the subcrustal matter under the continents. Of course, subcrustal matter brought up to the bottom of the ocean might change its rigidity and strength from its normal condition, due to decrease in pressure and to lower temperature.

We can not now say, positively, that the geodetic data disprove the Roots theory, but certainly we shall have to formulate that theory in a somewhat different

[1] It is probable that the depth to which crustal material extends is somewhat greater than the computed depth of compensation. This idea is discussed on p. 39 of Special Publication No. 99 of the U. S. Coast and Geodetic Survey.

way from that usually outlined in order that a definite test may be made. As the theory is generally understood, analysis seems to indicate great weakness in it.

The hypothesis formulated by Wegener is closely related to the Roots theory. Isostasy is an essential part of it—but not the Pratt isostasy. According to this hypothesis, material of which continents and islands are formed, called *sial,* floats in a highly plastic material called *sima.*

The hypothesis has many strong advocates and as many equally strong opponents. It would take too much space even to outline the views of the two groups.

This much may be said, however: The mechanics of the hypothesis are weak to the point of being impossible. The sial, according to Wegener, was all grouped together in one body in the geologic past; then, under the exceedingly small stress differences caused by the tidal forces of the sun and moon, the mass broke into pieces and formed separate continents and islands. This may or may not have been possible. But when the drifting continents had their forward margins crumpled up into mountain systems by the resistance of the sima in which the masses of sial were moving, under small forces, there seems to be much mystery involved in the process.

The biological necessity for all the land movements postulated by Wegener may be present, and his theory may account adequately for the distribution of plants and animals. His theory would have had fewer opponents if he had left out the mountain-forming part of it.

Perhaps it will be found, upon analysis, that the meteorological conditions near the interior area of the unified mass of sial were not favorable to the growth of plants and animals whose remains, deposited in geological periods prior to the splitting up, have been found in parts of the drifting fragments which were far inland when the masses were together. It would seem that the central area of the combined sial would have been very arid and thus not suitable for much of the plant and animal life existing then.

The changes of density needed in the Pratt theory of isostasy may appear to many to be improbable, but if it is granted the mechanical details involved in uplift and down-warping of the earth's surface seem to be reasonable. Vertically acting forces as the predominant ones, with horizontal movements within the crust near the surface as secondary, seem to the writer to explain surface changes better than the regionally acting forces. But the former requires changes in density of crustal materials to maintain isostatic equilibrium.

WILLIAM BOWIE

U. S. COAST AND GEODETIC SURVEY

IRA OSBORN BAKER[1]

IN noting the death of Ira Osborn Baker, which occurred November 8, 1925, it is fitting that the senate of the University of Illinois place on its records a statement in recognition of the long and distinguished service which Professor Baker rendered to the university.

Starting as assistant in civil engineering and physics immediately upon graduation with the class of 1874 (the third class to be sent out by the university), in 1878 he was made instructor and was also put in temporary charge of civil engineering upon the resignation of the professor of civil engineering. In 1879 he was promoted to assistant professor in charge of civil engineering, and in 1880 to professor of civil engineering. With the establishment of departmental organizations in the university in 1892, Professor Baker became head of the department of civil engineering and continued in charge of the department until 1915 when he relinquished the administrative duties, but continued full teaching work. He again carried the administrative work of the department from 1920 to 1922. He was made professor emeritus in 1922, but continued to give service to the university in various ways until his death. During all these years he labored diligently and effectively in the upbuilding of the university. He exercised an important influence on university affairs in the accrediting of high schools, in the work of committees and in various other ways, especially during the earlier and formative period of the university. His greatest contribution was toward the development of the college of engineering and the department of civil engineering. Here through his teaching ability and his high ideals in instruction and in the aims and meaning of education and his insight into the needs of the profession of engineering, he aided greatly in giving early reputation to the college of engineering and in making its standing far higher than the number of students and the financial resources of the institution warranted. He early developed one of the first college laboratories for investigating the properties of cements, mortars and concretes, and a few years later one for highway materials. The designing, construction and equipment of the astronomical observatory were under his charge. Through his text-books and writings he carried his teaching to many engineering schools, even instructing the practicing engineer of the office and field all over the country. He was a leader in professional engineering activities and educational movements. Forty years ago he formed the Illinois Society of Engineers, an organization that

[1] Minute presented to the president and senate of the University of Illinois by a committee consisting of M. S. Ketchum, A. P. Carman and A. N. Talbot.