should begin constructing planning organizations on a large enough scale to function as a social brain and not a mere ganglion, in order to ensure that any first step which we may be able to take directly after the war will be a step in the right direction.

But again, do not let us attempt any ideal or complete plan, any grandiose scheme for which the world is not ripe. That was one of the causes of the League's failure; it was an attempt to impose an ambitious ready-made plan of world citizenship, for which public opinion was insufficiently prepared. Rousseau and the Encyclopedists had been preparing opinion for a radical change in society for half of the eighteenth century; without that preparation, the French Revolution would have been a fiasco. In 1918, the idea of supernational organization had not penetrated beyond a limited circle of intellectuals, and even they had not had time to work out the idea in detail, before Wilson sought to impose it in reality. To-day we have at least had twenty years of discussion, together with some bitter if salutary experiences. If the leaders of thought in the various nations can now work out a less pretentious but more workable plan, and at the same time can prepare public opinion for the idea of a dual citizenship, national and world, this war may be the occasion for taking a small but decisive step away from war and towards a world organization of humanity.

THE GRAVITY ANOMALY AN IMPORTANT FACTOR IN EARTH SCIENCE

By Dr. WILLIAM BOWIE

U. S. COAST AND GEODETIC SURVEY, RETIRED

THE difference between the observed and the theoretical value of gravity, called the gravity anomaly, is receiving much attention by students of the earth who are striving to discover the causes of the changes that have occurred in the configuration of the surface of the earth during the past 2,000,000,000 years. Why are there oceans and continents, mountain systems and broad lowlands, earthquakes and volcanoes? What is the shape of the sea-level surface? How far down do the hard crystalline rocks extend? Is the rock below the outer shell lacking in rigidity and strength? These are some of the problems which were discussed by several hundred delegates to the seventh general assembly of the International Union of Geodesy and Geophysics, held in Washington early in September of last year.

In most countries there are governmental and private agencies and educational institutions in which geodesists and geophysicists are studying the earth with a view to the solutions of the problems enumerated above. These problems are also receiving the attention of many geologists, especially those who are searching for minerals and petroleum.

There are many phases to the sciences of geodesy and geophysics and it would require several large volumes to cover them in a comprehensive way. In this paper I shall confine my comments to one phase only of the earth sciences, the gravity anomaly.

In deriving the formula for theoretical gravity the sea-level surface of the earth is supposed to be a spheroid, with its shorter axis coinciding with the polar axis of the earth. This assumption has been found to be close to the truth. The sea-level surface deviates not more than one or two hundred meters from the spheroid or mathematical surface. The geoid or sea-level surface is above the spheroid for continental areas and below it for oceanic areas. This is as it should be, for the spheroid is an average of the geoid.

The constants of the gravity formula are derived from observed values of gravity in many countries and at different latitudes. Different groups of stations will furnish different sets of constants.

The International Geodetic Association has adopted the following formula which is based on a large number of stations located in many countries: $\gamma_0 = 978.049 (1 + 0.0052884 \sin^2 \phi - 0.0000059 \sin^2 2\phi)$ gals, in which γ_0 is the value of gravity at sea level and ϕ is the latitude of the station.

Further gravity measurements will make it possible to obtain constants that should be of more universal application. But it is believed that with the data now available it may be possible to derive constants for the theoretical formula that will enable the student of earth science to more correctly interpret the significance of the gravity anomaly than he can now do.

In order to derive a gravity anomaly, a number of corrections must be applied to the observed value of gravity, and then the corrected value is compared with the value given by the theoretical formula for the latitude of the station and at sea level. The difference is the anomaly.

Various corrections must be applied. Owing to the irregular surface of the earth, topography and isostasy must be taken into account. Corrections must be applied to the observed values of gravity to eliminate the effect of the topographic masses above sea level and of the deficiency of mass in the ocean basins.

Since it has been proven that the topographic features are compensated by deficiencies of density under land and by excesses of density under the water areas, and that these deficiencies and excesses extend to moderate depths below sea level, corrections for the compensation must be applied to observed values of gravity. An elevation correction must be applied to each station that is above or below sea level. A change in elevation of the point of observation of 10 feet causes a change in gravity of one part in one million. A small correction should be applied for the difference in level between geoid and spheroid. It is not known definitely how far down the compensation extends, nor whether the depth is the same for different parts of the earth. For the United States the depth, if uniform, is about 60 miles. But the effect of the compensation for 50 or 70 miles is not far from what it is for 60 miles. Nor does the compensation effect differ greatly for the irregular depth and for the uniform one.

In making the computations of the effect of the topography and the compensation some density must be assigned to the rocks that appear above sea level. The density most generally employed is 2.67. This value is also used in computing the deficiency in mass of oceans. It is assumed that all rock below sea level has the same density all around the earth for any one layer except as modified by the isostatic compensation. This applies to the rocks under the oceans, though for them the first horizontal layer may have its upper surface one or more miles below sea level.

For our present purposes it may be assumed that the corrections applied to the observed values of gravity are close to the truth for elevation of the station, for the deviation of the geoid from the spheroid and for topography. We may assume also that the errors of observation are not large and that they are of the accidental nature.

Still we find anomalies of relatively large dimensions for individual stations and we find regions of some extent where all or nearly all the anomalies will have the same sign. We find that sea stations have an average anomaly of about plus 30 milligal (30 parts in one million). In the waters of the East Indies and the West Indies and along the east coast of Japan there are narrow strips where all the stations have large negative anomalies. In the United States stations located on recent geological formations have negative anomalies in most cases, and the largest negative anomalies found are in those areas. The largest positive anomalies are at stations located near outcropping pre-Cambrian rock. The anomalies at stations located on volcanic islands are usually positive and in many cases large.

It is generally believed that the large anomalies at land stations are due to the presence near the stations of rock having densities much greater or smaller than that assumed for normal surface rock. Where anomalies of one sign persist over a large area the crustal material may be out of equilibrium or the isostatic compensation may be much closer to or much deeper than is supposed, or the compensation may not be directly below the topographic features.

The persistence of positive anomalies for sea stations may be due to errors in the derived constants of the theoretical formula. If isostasy represents the true condition of the earth, as we think it must, there is difficulty in believing that the positive anomalies of ocean areas indicate a departure from equilibrium of the crust below the oceans. These oceanic areas are not subject to the disturbances due to erosion and sedimentation that occur on land, and there is no indication that the rotation of the earth will distort the globe into a tri-axial form. The anomalies seem to be due to some other cause, and I am inclined to the opinion that it is partly the way in which the constants of the theoretical formula are derived.

There are areas of the earth in which there are few if any disturbing elements. These areas are the portions of the oceans having nearly uniform depths over wide extents and flat parts of the continents on which there are no thick deposits of recent and unconsolidated sedimentary matter. These continental areas are the interior plains, some of considerable elevation.

The densities of the crust under the areas indicated above should be quite regular and normal and for computing the compensation effect the depth of compensation need not be known with great accuracy. Assuming that the topography is compensated, the attractive effect of the topography would be almost exactly equal to that of the compensation, as it is a well-known principle that the attraction of a layer of matter of uniform thickness and of large horizontal dimensions will be the same for different distances of the attracted particle above the center of the layer or if the mass remains the same the layer may have different thicknesses without changing its attractive effect. It is seen that the effects of the topography and the compensation will almost balance in areas that are nearly level and in which recent sedimentary matter is absent. In consequence of these considerations the isostatic gravity anomalies should be free from errors due to assuming an erroneous depth of compensation and should not be seriously affected by errors in the assumed distribution of densities of the crust below sea level.

If we derive the constants of the gravity formula from values secured at stations located on the plains and plateaus of continents and over those portions of the oceans where the depths are fairly uniform for great distances, and if we assume, as seems reasonable, that for these areas the crust is in equilibrium, would we not be able to use the new formula with effectiveness to show the extent to which the crust under other areas deviates from equilibrium and to arrive at a fair estimation of the real deviation of crustal densities from the normal?

As mentioned earlier, the isostatic anomalies at stations located on thick beds of recent sedimentary rock tend to be negative in sign. This is notably the case in the Indo-Gangetic plain of India, along the coast of Virginia, along the eastern coast of Puget Sound, near the coast of Southern California and in many other places. Similarly, near areas where there are outcropping pre-Cambrian rock, of limited horizontal extent, the anomalies tend to be positive. We wish to be able to evaluate the gravity anomalies in terms of abnormal masses near the stations, and it would seem that this can be done if the constants of the gravity formula are obtained from data secured at stations that are least likely to be affected by local abnormalities of densities of surface and upper crustal matter.

It should be said that in deriving such a gravity formula the observed values of gravity should be referred to the spheroid. This would reduce the ocean values and increase those on land, thus bringing the anomalies into closer agreement. I believe that the stations at sea and on the continents as here recommended for the derivation of a new formula will be found to be in substantial accord. This can not be the case when unselected land stations are used.

During the assembly of the International Union of Geodesy and Geophysics, held recently at Washington, the writer discussed this matter of a new gravity formula with Dr. W. A. Heiskanen, the director of the Isostatic Institute of the International Geodetic Association, and he agreed to derive a new formula along the lines discussed herein. The results of Dr. Heiskanen's efforts will be awaited with interest.

OBITUARY

CHARLES ZELENY

CHARLES ZELENY, professor of zoology at the University of Illinois, died at his home in Urbana on December 21, 1939. He was born at Hutchinson, Minn., on September 17, 1878, and spent his early boyhood days there. Later his parents moved to Minneapolis, and when he was ready for college, he entered the University of Minnesota, where he graduated in 1898. He remained as a graduate student at Minnesota until 1901, at which time he was granted the M.S. degree. The next year he was a graduate student at Columbia University, working with T. H. Morgan and E. B. Wilson, and the following year he worked at the Naples Zoological Station. Returning to America in 1903, he entered Chicago University, where he obtained the Ph.D. in 1904. He went to Indiana University as an instructor in the summer of 1904. Here he advanced rapidly and held the rank of associate professor at the time of his call to the University of Illinois in 1909. Beginning at Illinois as an assistant professor, he was promoted the next year to the rank of associate professor and in 1915 to a professorship. Upon the retirement of Professor H. B. Ward in 1933, he was made head of the Department of Zoology and chairman of the Division of Biological Sciences. Because of ill health, he had retired from his executive duties in 1938.

On May 29, 1911, he married Ida Benedicta Ellingson, of St. Morris, Wis. Mrs. Zeleny and a son, Charles, Jr., survive.

Dr. Zeleny's family is unique in that three of his brothers are scientists of note. Anthony Zeleny, now retired, was professor of physics at the University of Minnesota; John Zeleny is professor of physics at Yale; and Frank Zeleny is an engineer with the Burlington Railway.

As is true with every great man, chronological facts such as those enumerated tell but little of the life of Charles Zeleny. They are cold, external. It was the writer's good fortune to have been a student in Dr. Zeleny's first class in embryology taught at the Biological Station in the summer of 1904. For the next three years, our associations were intimate. We worked together, ate at the same table, played together and tramped through the woods and fields together. The fact that one was teacher, the other student entered but little into our thinking. The friendship formed in those early years remained to the end. As a friend he was true, somewhat reserved, seldom talked of his own personal affairs, possessed a subtle, sometimes mischievous, wit, appreciated by those who knew him best. Seldom did he complain about anything. Bitterness, if present, was kept hidden.

As a teacher he was kind, helpful, encouraging, stimulating. As a zoologist his papers in the fields of regeneration, experimental embryology and genetics speak for themselves. They rank among the best contributions of his time. Originality in thinking stands out prominently in all his work.

In recognition of his attainments, he was elected vice-president of section F of the American Association for the Advancement of Science in 1932, and president of the American Society of Zoologists in 1933.

Dr. Zeleny's death at the early age of 61 years is