第四卷·地质力学(1)

Volume Ⅳ Geomechanics (1)

李四光全集

The Complete Works of Li Siguang

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50年代在北京地质学院作学术报告

编者说明

本卷收入作者有关地质力学方法方面的著作共24篇，其中有10篇为中英两种文字写成。英文部分均为建国前所著，先后发表在《中国地质学会志》、英国的《地质杂志》和《自然杂志》等刊物上；中文部分除《地质力学之基础与方法》一文于1945年5月曾由重庆大学地质系印发，后于1947年1月由中华书局作为《中国科学社丛书》之一出版外，其余均集自1979年科学出版社出版的《地质力学方法》一书。

在本次整理过程中，对原文一些篇目的标点符号、表格、注释和参考文献进行了统一处理，有些图例重新作了清绘，部分图幅有所缩小。此外，还订正了一些错别字，书中均未一一出注说明。

目　录

The Fundamental Cause of Evolution of the Earth's Surface Features[①]

In the days when the uniformitarians triumphantly fought against the catastrophists, it was apparently thought by the leaders of the rising school that the ebb and flow of the oceanic water had been going on indefinitely all over the surface of our planet for an untold length of time. Beyond this, little was then recognized of the adjustment between land and sea. With the advancement of our knowledge regarding continental structure. and with the establishment of the principle of isostasy, the fundamental difference between the true ocean and the epicontinental waters of the past ages became, however, more and more obvious. Indeed, the world presents to the geologist of today a very different picture from that which appeared to the older school of men who toiled in the north-western corner of Europe. It seems that we have to admit, in the light of our present knowledge, that geosynclines and mountain ranges are but a particuiar phase—a minor phase— of continental structure; or in other words, orogenic movement is but a critical

① 原载《中国地质学会志》第5卷，第3—4期，第209—262页，1926年。——编者注

manifestation of a more widespread movement of the continents. If this conception be anything approaching the truth, it will be difficult to see how the grander tectonic movements in the geological past could be attributed to local causes.

What, then, are the processes leading to, and the forces involved in such secular changes? We are reminded from time to time by prominent men of the geological science that efforts have not been spared in attacking this baffling problem; at the same time, we cannot but admit that most geologists seem to have lost sight of the forest because of the trees. They are however, not to blame for turning away from such a highly theoretical discussion, for any theory evolved must be brought to the test of the carefully observed facts.

Eduard Suess, the illustrious master of the geological science, entered probably more profoundly into this problem than any other geologist before his time. After reviewing an enormous mass of geological literature he asserts, more than once, the sweeping movement of the Eurasian Continent against the Indo-African block. This assertion is not based on any hypothesis, but is the direct outcome of the analyses of the structures of the Iranian and Himalayan Ranges and the successive Arcs of Eastern Asia. His method is largely, if not entirely, inductive. In spite of his supreme command of geological fact and his great synthetic power, Suess seems to have failed, even in his last days, to locate the ultimate cause or the force required to stage such gigan ticmovements. But his failure in this respect does not throw any doubt upon his authority and insight,

for it is in his monumental work, Das Antlitz der Erde', that one finds, for the first time, penetrative remarks that reach the final barricade of our problem.

Since Suess' time numerous attempts have been made. Among them there are those revolutionary theories advanced by F. B. Taylor, A. Wegener and J. Joly that have shocked many a geologist who chooses to remain the faithful apostle of what is generally believed to be orthodox geology. Whatever attitude the orthodox may take towards the ultimate implication of those daring theories, certain fundamental facts on which they are based seem to be too valuable an asset for us to ignore.

It was a matter of mere chance that the writer had fortunately discovered Taylor's paper (Taylor 1910) in our limited library; and it was a pleasant surprise to find that so much had already been written of the more obvious things that were gradually taking shape in his own mind. One regrets that such an important paper should have been buried in the masses of geological literature without attracting the attention that it deserves. Taylor has not only digested and mastered the vast stock of tectonic facts available to Suess, but proceeds to discuss the probable mistake that Suess has made concerning the direction of the Alpine Movement. As we shall see later, neither Suess nor Taylor is entirely right. Using the same method as Suess did, Taylor shows us how the continent of Europe together with that of Asia crept towards the south, and thereby heaved up the girdle of mountain ranges across Eurasia in the Tertiary times. He shows us again how the North American

Continent was torn away from Greenland by a south-westerly drift and how Australia was pushed to the northeast of its original site. In fact he produces evidence to prove that the land-masses of the whole world tended or actually did rush up towards the equator during the mid-Tertiary Movement. Taylor's estimation of the amount of actual displacement due to that movement may have been exaggerated, but it seems that he has certainly succeeded in indicating the trend of the events.

Again following Suess' argument for eustatic movement, Taylor deduced that the same oceanic oscillation as expressed in terms of its oblateness must apply to the continental sheaths. Thus he writes regarding the figure of the continents: "Whatever the cause may have been, its distributive characters appear to be precisely the same as those which belong to an incroase of oblateness of the oceanic figure."

Because Taylor was apparently unconcerned with the ultimate cause of the change of the earth's figure, and because he did not undertake to review the geological changes in the remote past, he discusses at first the probable shifting of the earth's centre of gravity towards the south pole by an incipient creeping of north polar land towards the lower latitudes. And he says: "This would leave the remaining north pole lands under slightly greater strain than before··· Such a change would, of course, increase the chances of further movements from the north pole and decrease those from the south pole." Then, in the last few lines of his paper, he simply turns to some form of

tidal forces as the only possible agency to change the degree of oblateness either in oceanic oscillation or in the deformation of the lithosphere. These broad remarks do not seem to afford us an intelligible solution of the outstanding problem.

We may now turn for a moment to the famous theory of "Continental Drift" formulated by Dr. Wegener (Wegener, 1920). In his stimulating essay, Wegener endeavours to show how the configuration of the continental blocks and their disiurbed borders as witnessed by the world to-day and the distribution of certain faunas and floras as well as climatic changes in times past by presupposing two sets of movements that had been going on on the part of the continents. The first set of these movements is supposed to be a westward drift of the continental blocks; and the second set is a movement which is so aptly characterized as "pole-flight". The harmonious relation between the eastern and western coast-lines of the Atlantic is certainly suggestive of a westward drift of the Americas; and that relationship appears to have served as an initial basis on which Wegener developed his elaborate theory. The subject of pole-flight was discussed in the earlier works of Kreichgauer and Taylor, but it might not have drawn so wide an attention had it not been for Wegener's elaboration.

As to the causation of these continental movements, Dr. Wegener argues that the centre of gravity of the continental mass at any point on the globe lies at a higher level than does its centre of bouyancy. Since the surfaces on which these centres of forces lie generally make a small angle with each other

except at the poles and equator, there will be a small resultant urging the continental blocks towards the equator. But at the poles and the equator the resultant will be zero.

Regarding the alleged westward drift of the continents, Wegener seems to maintain that it might have been due to the tidal pull or more probably to the coupled effect of pole-flight and the earth's rotation as is manifested in the development of the trade wind. If we admit pole-flight as a fact, it seems hardly possible to deny its correlated, westward movement. Unfortunately Dr. Wegener's parabolical suggestion is too brief to allow us a thorough understanding as to the consequences involved.

The fundamental difficulty that we encounter in Wegener's theory is not so much connected with the directions of continental movements, but rather with its dynamic basis. Is it possibe that forces so inadequate① as postulated by Wegener could have administered so extensive movements of the continent assumed in the Drift theory? If those forces have been the cause of continental deformation or transfiguration. Should we not expect a ceaseless deformation of strata from the earliest time down to the present day? But geological history clearly shows that the manifestation of orogenic forces has been decidedly periodic. It seems then that we have to look for a different source of force to account for the phenemenon of pole-flight.

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① Jeffreys, H. The Earth etc. p. 261.

The most disputable point in Wegener's theory is perhaps his unconditional claim of extensive pole-wandering. This controversial problem has been most ably and thoroughly discussed by Professor Leo A. .Cotton who seems to have decided in its favour on the condition that the nature and constitution of the earth's interior are such as "to behave like a highly viscous solid for stress of secular duration" (Cotton, 1923). Granting this postulate, it would still seem necessary to enquire into the mode of deformation of such a viscous solid before we can arrive at any notion as to the nature of its dynamic effect. Enquiry of that kind would obviously involve some grave assumption which, if at all avoidable, might be well deferred in explaining things that could be explained otherwise. Pending further advancement of geophysics, it would appear to be on the safe side to consider the problem from a geological point of view. No matter how and to what extent the poles may have migrated, their course must be dictated by the existing structure of the surface layer of the globe.

True, many important regions in the world have not yet been thoroughly explored from a geological point of view; but sufficient data are now available to afford us a general view of the successive spatial distribution of the larger geological formations and of the harmonious nature of the tectonic axes that run through the several continents. We see in the illustrative palæogeographic maps of Schuchert that the Canadian Shield and the Appalachian and Cordilleran Geosynclines were already in existence at the opening of the Palæozoic Era. We

find with Suess that the Amphitheatre of Irkutsk has remained as such since an equally ancient date. The belts of formations in Asia of the succeeding periods simply arrange themsolves, speaking broadly, around this ancient nucleus of the Asiatic Continent. In a word, the more important facial features over the whole globe seem to have developed in a definite order and along definite lines. If the earth's axis of rotation with reference to its integral parts has altered to any extent during the geological periods, might we not expect that the consequent redistribution of stress and strain would have effected some far reaching change in its superficial configuration, and thereby produced a less harmonious or more diversified relation of the tectonic features than we find them to-day? This broad generalization is necessarily vague. But it will be rendered more intelligible when we come to discuss the directions of the more powerful crustal movements known in the geological history.

Even the phenomena of climatic changes in the geological periods do not necessarily require any appreciable alteration of the position of the poles. In fact it could be qualitatively deduced that the cyclic change of climate may well be a mechanical consequence of the alteration of the earth's rotational speed. As this problem does not fall within the scope of the present paper, there is no object to bring it into our discussion.

Still more revolutionary is the theory recently advanced by Professor Joly whose rigor of argument has thrown a strange light upon a field hitherto unexplored (Joly, 1924). After re-

viewing the fact of isostasy as interpreted from the results of recent geodetic survey and the analyses of seismic waves, Joly pictures, as does Wegener, the earth-crust as consisting of two layers: the upper or the continental blocks probably having a thickness of 25 to 35 kilometres of lighter material, are merely floating, so to speak, on a denser substratum of a basaltic composition. This substratum with a known content of radioactive substance forms the oceanic floor and underlies the continental masses. If it be assumed that such a highly heated substratum is on the verge of melting, then it only requires a certain amount of latent heat to develop fluidity. That heat can be readily stored up under the continents, for the latter themselves also contain a sufficient amount of radioactive substance to prevent the escape of heat developed underneath.

Starting with a solid basaltic substratum, Joly calculates some 25 to 35 millions of years to render it into a liquid state not only underneath the continents but also below a cortain depth of the oceanic floor. Here the tidal force intervenes. As a result, the continents are pulled westward and change their sites. Then follows a period of cooling through a system of convection from the oceanic floor. A bodily contraction of the crust would ensue, and a crumbling or orogenic movement would take place in the continents.

Thus Joly provides for the tidal force a periodic manifestation for which Wegener's theory falls short.

As it stands, Joly's theory seems unassailable. But as soon as we examine the structure of the continents in detail,

we are brought to face some disappointments. True, we have some evidence to show the westward drift of the American Continents in the structure of the Cordilleran Mountains, and also perhaps of the African Continent in the great meridional rifts. But what of the gigantic mass of Eurasia? Why should the most imposing mountain chains on these continents arrange themselves essentially in the east-west direction and subsidiarily as bordering arcs? Professor Joly probably answers these questions by saying that these ranges represent the former geosynclines, and therefore would be more readily affected, according to the principle of isostatic compensation, by the molten magma underneath. But we would further ask: Why the geosynclines were there? Such a questioning does not seem to have entered into Joly's theme. Furthermore, if each period of orogenic movement experienced by the earth-crust involves an entire change of the sites of the continents, why, then, such stupendous movements have not left more traces upon all continents of the type and magnitude of the Great Rift Valley of Africa or the compressed border of the American Continents?

To these questionings we seem to encounter difficulty with Joly to find adequate answers. Nevertheless there is no reason why we should underestimate the importance of the factor of radioactivity in determining the physical state of the "underworld" so admirably brought out by Professor Joly.

Other theories have been advocated of late by men representing distinct schools of thinkers. Their fundamental con-

ceptions seem to be linked up, in one way or another, with the sarlier suggestions made by James Hall, James D. Dana and Joseph Le Conte. Some would stress upon geosynclinal expansion and consequent under-thrusting of the submerged inland mass towards its border-lands (Hobbs, 1921). Others would believe segmentary foundering of the oceanic base (Chamberlain, 1925) to be the primary cause which gave rise to "suboceanic spreading" and lateral pressure against the "inert mass" of the continent①. Each of these theories certainly affords us an explanation of a certain phase of the geotectonic phenomena, and may indeed express a partial truth; but they fail to account for those important facts recently pointed out by Dr. Grabau (Grabau, 1924).

Realizing the involved nature of our problem, it seems necessary, before entoring on the geological discussion, to consider, even though briefly, the probable behaviour of the earth under forces of secular origin. Elaborate treatment of the subject evidently belongs to the domain of geophysics, and cannot therefore be undertaken here.

Let us note at the outset that when an ellipsoid like the earth is rotating about its shortest axis, a guiding force directed perpendicularly towards the axis must be applied on every revolving element which at the same time tends to fly a way from the axis with an equal but opposite force. And it is a fa-

① Willis, B. Research in China, Vol. 2. Systematic Geology, Chapt. VII, pp. 125—133.