Science in South Africa.[1]

By General the Right Hon. JAN CHRISTIAAN SMUTS, P.C.

THE Wegener hypothesis purports to explain the origin, the past and the present of all the continents and oceans of this globe. But for us in South Africa it has a special interest in its account of the origin and distribution of continents in the southern hemisphere. Whether this account is correct or not, the hypothesis has the great merit of focussing attention on many great problems which call for explanation; and it has the further merit of associating these problems and making them parts and aspects of a great common scheme, instead of merely leaving them, as disjointed unconnected items, scattered haphazard over the various special sciences.

For us in this part of the world, the most interesting feature of the scheme is that in it Africa assumes a central position among the continents; it becomes, in fact, the great "divide" among the continents of the southern hemisphere; it appears as the mother-continent from which South America on one side, and Madagascar, India, Australasia and their surrounding areas on the other, have split off and drifted away, have calved off, so to speak. The evidence for all this is strong; but it may well be that the evidence is yet insufficient to account for the whole Wegener hypothesis. It may not be strong enough to prove the actual disruption and separation of the continents in the past which is the essence of the hypothesis. But even so it may be right in assigning to the African continent a central determining position in respect of many of the great unsolved problems of geographical distribution, and in making that position the key which science will have to use in ever-increasing measure if it wishes to unlock the door to future advances. The value of a hypothesis often depends not so much on its correctness as on its fruitfulness. For the present I am prepared to look upon Wegener's hypothesis as a fruitful point of view more than a solution, as a suggestive line of thought and research along which useful work may be done in the future.

One important line of research which it suggests to us is the east/west aspect in addition to the hitherto prevalent north/south line of orientation. Hitherto it is the European affiliations which have guided our thought and our research; we have looked to the north for explanations as well as our origins. In future, on the lines of Wegener's speculations, we shall look more to east and west—to our affiliations with South America, India, and Madagascar and Australasia, for the great connexions which can explain the problems of our past and present. We shall look upon southern Africa as the centre of the southern hemisphere and correlate all the relevant scientific problems of this hemisphere from that new point of view. This new aspect will establish new contacts, and it is generally such new contacts which prove fruitful and creative for scientific progress.

Let me first take the case of geology, a science in which a very high standard of success and excellence has been achieved in South Africa. A great amount of attention has been devoted to the question of the correlation of our geological formations with those of Europe, and although many unsolved problems still remain, the main outlines of the correspondence of our formations with those of the northern hemisphere have been successfully worked out. A good deal has been done, yet quite insufficient to correlate our formations with those of South America, India or Australasia. Yet it is evident that the subject is one of profound interest, both from a scientific and a practical point of view. Several of our formations at the Cape seem to be continued or paralleled by identical or similar formations in India and South America. A proper correlation of the geological systems may lead to most interesting results, and may also throw great light on the past of the three continents. We may thereby be enabled to explain just why they are practically the sole producers of the world's diamonds; why the diamond-fields of South-West Africa are situated on one edge of the Atlantic and those of Brazil on the other; why the coal-fields of these three countries and of Australia are confined to the eastern halves of each of these land masses; and why the curious and ancient banded-ironstones are so widely spread in South Africa, Brazil, peninsular India and Western Australia, though absent from Europe. The results of such a comparative study for the southern hemisphere might be most valuable and might settle many of the problems which still agitate science as to the past of the earth.

It is when we come to the biological sciences, however, that such a comparative study promises the most fruitful results. Here there is a number of momentous problems still awaiting solution. Consider, for example, the problems affecting our botany. We have two distinct floras in South Africa; one, the South African flora which covers most of sub-tropical Africa and is clearly of tropical origin; the other, a temperate flora, found only in the south-west of the Cape Province on the seaward side of the first great mountain barrier, with outliers extending to the north along the mountain systems into the tropics. The two floras are apparently quite different and distinct and are engaged in a mortal conflict with each other, in which the temperate or Cape flora is slowly losing ground. This Cape flora forms indeed a problem of profound and baffling interest. What is its origin, and what its relation to the South African flora? The South African flora is, as I have said, clearly of tropical origin, and consists largely of subtropical derivations and modifications of the tropical forms found farther north in the equatorial regions. Can its origin be traced further back? In the answer to this question we meet again with what I may call the European fallacy, or the fallacy of the European origin. The current idea among botanists is that northern Europe is the source and the north temperate flora of Europe is the origin of both our South African and Cape floras. The north temperate flora of Europe is supposed to have been driven south by the onset of the last great Ice Age in Europe and, in the much cooler climate of the tropics at that time, to have migrated southward along the eastern mountain systems of Africa until southern Africa was reached.

[1] From the presidential address to the South African Association for the Advancement of Science, delivered at Oudtshoorn, Cape Province, on July 6.

This common view of the European origin of our floras will, however, require very careful reconsideration from the viewpoint which I am suggesting here. The correlation of our floras with the other floras of the southern hemisphere may profoundly affect this question of origins, and may throw much fresh light not only on the origin of our floras in Southern Africa, but even on so momentous a question as the origin of the flowering plants and on geographical distribution generally. Even according to our present knowledge, the African floras do not seem to fit in well with the current view of their origin. Apart from the Cape flora in the extreme south, and the Mediterranean temperate flora in the extreme north, the African flora—better known as the Tropical African flora or the Palæotropical African flora—covers the rest of the continent. In this flora an element predominates which is peculiar to this part of the world, but is more or less closely related to the floras of India, Madagascar, Australasia and South America. In other words, the special affiliations of the Tropical African flora are in the southern hemisphere. Similarly the Cape flora has peculiar affiliations with the floras of certain countries in the southern hemisphere. The current view of the northern origin may therefore not be the last word so far as botany is concerned.

On this question we have the following two interesting facts. First, the fact already mentioned that the chief types of the African flora have their affiliations in the southern and not in the northern hemisphere. Secondly, the fact that the chief types of the present Cape flora, such as the Proteaceæ, Rutaceæ, and Restiaceæ, to-day occupy the areas that correspond to the former Gondwanaland, that is to say, exactly the same area which was covered by the Glossopteris flora in Mesozoic times. It is alleged that some fossil types of Proteaceæ have been found in Central Europe in lower Cretaceous deposits, but these finds are disputed. These two facts would seem to point to the conclusion that the two African floras are probably of southern origin and have not been derived from the northern or European flora. Nay, more, the suggestion of Seward that the Mesozoic flora of Europe, which is markedly dissimilar from that of its Palæozoic flora, may have had a southern origin in Gondwanaland, opens up very interesting possibilities. Indeed, in the palæobotany of the southern hemisphere we are only at the beginnings; and who knows whether further discoveries in this largely virgin field of research may not yet give point and substance to Darwin's surmise that the existence far back in the long ages of an extremely isolated Southern Continent is somehow to be linked with the mysterious origin of flowering plants.

Some of the greatest problems of botany, of geographical distribution, and of the past of the earth will have to wait for their solution until palæobotany has made much further advances in South Africa and the southern hemisphere generally. In this connexion a great opportunity lies before science in South Africa. I trust a step will be taken by the establishment of a chair of palæobotany at one or other of our South African universities. It will be a small step, but its significance will be great and its results may be far-reaching.

So far I have only referred to the evidence of palæobotany. But the evidence of our southern palæontology generally is all in the same direction. Still more so is the evidence of the present botanical distribution throughout the southern hemisphere. The present distribution is not only strong presumptive evidence in favour either of a great Southern Continent or great land connexions in the south in the past, but also in favour of the independent origin of the African flora. Dr. Otto Stapf, whose knowledge of African grasses is unrivalled, goes even further in his masterly "Gräsenflora Süd-Afrikas," and would seem to suggest that very special importance is to be attached to the unique character of the Cape flora as distinguished from the African flora. The Cape flora points not only to a southern origin but to an origin even farther south than the ancient Gondwanaland is commonly supposed to have extended. May we not venture the suggestion that the Cape temperate flora is the survival of an Antarctic and sub-Antarctic flora which has perished in the climatic changes of the past? That, at any rate, would account for its marked differences from our sub-tropical South African flora.

Enough has been said to show how important it is that there should be a regular comparative study of the scientific problems of the countries which lie in the southern hemisphere, with South Africa as the centre of the whole group. Such a comparative study promises rich results and will probably give a new direction and a fresh impetus to many branches of scientific work. For this purpose it seems to me not only advisable to devote more attention to palæobotany at our universities, but also essential that South African students and workers should visit other countries of our hemisphere and familiarise themselves with the scientific conditions and problems which obtain there.

Let us now pass on from biological questions to the problems of South African climate and meteorology, which I need scarcely point out are of supreme importance not only in an economic but also in a scientific sense. Here, too, we shall find that the present has its roots deep in the far-off past.

Great ice-ages are known to have occurred far back at the beginnings of geological time before the present sedimentary formations were laid down. To pass to the other extreme, Europe during the Permo-Carboniferous period, when the coal measures were mostly laid down, possessed the climate of a sub-tropical rain-forest, and at a much later date the magnolia and similar tropical plants flourished in Greenland and Spitsbergen. At that time, Europe was mostly covered by shallow seas and its tropical climate was balanced by a cold dry climate which existed in the contemporaneous Gondwanaland of the southern hemisphere. The Glossopteris flora of the latter was the vegetation of a cold dry climate; and the glaciation of many parts of Gondwanaland, of which evidence is visible over a large part of South Africa, shows that great ice-masses must have covered its high table-land. Much other evidence points to the fact that the ancient Africa which formed the centre of Gondwanaland was on the whole a cold and arid country.

Gondwanaland must have been an unpleasant country to live in, not only because of its climate but also because of the vast geological disturbances which were gradually tearing it to pieces. Even if the tearing asunder and drifting apart of the ancient continent according to Wegener did not take place, there must have been submergence and disappearance under the sea of great land connexions between the countries of the southern hemisphere. Other indisputable evidence of the severe and long-continued convulsions of Africa during the Tertiary times exists. The vast cracks and fissures which rent it from south to north exist to-day still in the chains of great lakes and "rift-valleys," which extend across Africa from the Zambezi to the Red Sea, the Dead Sea and the deep valley of the Jordan. Farther north the crust of the earth folded up slowly like a crumpled scroll, and as a result the huge mountain chains of the Atlas and the Alps, the Taurus and the Himalayas were formed. Volcanoes burst forth in Africa in many places along the lines of weakness, while in the south the diamond pipes were formed. During this prolonged period of change the climate of southern Africa also must have changed considerably, for instead of the cold of Mesozoic Gondwanaland, we find so far south as Kerguelen Island the remains of araucarias which must have flourished there in Tertiary times.

These far-off climatic conditions of the ancient Africa have for us of to-day only a mild scientific interest. But the remarkable changes in terrestrial climate which set in at the end of the Tertiary period are on a different footing and have produced effects which are still felt by us in the present era. A marked elevation took place in the lands of the southern hemisphere, and South Africa ended considerably farther south and nearer to the Antarctic than to-day. Then the snow began to fall and the ice to form on Scandinavia, and the glaciers and ice-fields to extend south into Central Europe. Similar conditions ensued in North America and Antarctica. The last Great Ice-Age had begun, with effects which were felt right across the equator into subtropical southern Africa. The increasing cold in the Antarctic and the subantarctic islands wiped out the entire south temperate flora with the single considerable exception of its most northern outlier in the South-West Cape, where it still survives as a unique relic of the past. The combined effects of the two northern and southern cold areas were reflected in moister conditions and greater rainfall in southern Africa during the Pleistocene than we have to-day.

Throughout the half a million to a million years which cover this period, the land level of northern Europe kept oscillating, and the Scandinavian ice-mantle was growing or dwindling, with mild or even warm interglacial periods between. It was in the last two interglacial phases that man appeared in Europe, not yet *Homo sapiens*, but earlier species of mankind. To locate ourselves properly in the frame of the geological picture we have to envisage ourselves as living in a new and mild interglacial period; we have to remember that Scandinavia is once more rising at the present rate of perhaps a metre or more per century, and that in another ten thousand years or more Europe will possibly be once more in the grip of a great ice-age. South Africa is also rising at a rate which has not yet been determined but is appreciable, our climate will gradually become cooler, until we shall again have more moist and rainy conditions than to-day; and the voices of the Schwarzes will no longer be heard crying in the wilderness which will have passed away. We may regret that we shall not live to see that day, but that regret will be tempered by the further thought that hitherto each interglacial phase has seen the passing away of a lower species of the human genus to make way for a higher one, and that in all probability our present human races will before the next phase have had to disappear and make way for the higher species of humans which it is hoped will occupy the next age.

The factors which affect large divisions and periodicities of climate and rainfall are still a matter of controversy amongst scientists. But there can be little doubt that the formation of the great Scandinavian ice-field, partly at any rate through land elevation at the end of the Pliocene, had the most profound effect on the climate and the history of Europe and Asia during the present geological period. A great anti-cyclonic storm centre was thereupon established, which displaced the rain-bearing cyclonic belts and thereby produced the most far-reaching changes, which were felt even across the equator of the old world.

The Great Ice-Age in Europe appears to have synchronised with a period of greater rainfall in Africa, including South Africa. The remains of great rivers and lakes in all parts of southern Africa, and the gravel terraces in certain regions which are now waterless deserts, bear witness to the higher rainfall during the Pleistocene and to the consequent accumulation of surplus waters in the sub-continent. The Swedish geologist de Geer has by methods of remarkable ingenuity and accuracy determined that the ice-body finally retreated from Sweden about twelve thousand years ago, and this result agrees very well with the corresponding estimates obtained in North America. We may therefore take it that during the last ten thousand or twelve thousand years South Africa has been experiencing a lessening rainfall; the run-off of the rivers to the ocean has not been properly compensated for by rain. There has thus been a progressive desiccation of the land, and the arid or semi-desert conditions of to-day have probably been in existence for some thousands of years. That is the opinion of Passarge ("Die Kalahari," c. 37), who made a closer study of this question in the Kalahari region than any other worker. At the same time it has to be admitted that we are still ignorant of or in doubt about a number of matters bearing on the past rainfall of southern Africa, and important problems still await the attention of our scientific workers in this regard. Prof. Schwarz's writings have focussed much popular attention on some of these questions, but in scientific circles the matter as a whole has not yet received the attention it deserves. It is to be hoped that this omission will soon be repaired, for there can be no question either of the scientific interest or the practical economic importance of the subject as a whole.

Meteorology ought to occupy a foremost place in our activities as a State and as a country for scientific investigation. The comparative smallness and seasonal uncertainties of our rainfall make this a matter of the greatest economic importance, while our central position in the southern hemisphere carries with it peculiar advantages and responsibilities for meteorological observation and research. Yet very little pure research has so far been done. In his letter to the recent

Drought Investigation Commission, Dr. G. C. Simpson, Director of the Meteorological Office, London, makes the following grave charge against us:

> Of the large land surfaces, the meteorological conditions of Africa are probably the least known; for except from Egypt we receive practically no meteorological information from this great continent, and South Africa is probably the largest area having a settled civilised Government which publishes little or no meteorological information officially.

and he goes on to make the following recommendation:

> The most hopeful method of attack on the problem of seasonal forecasts is to compare and correlate the records of various meteorological factors; thus one of the first steps to the attainment of your object will be the formation of a strong meteorological service to gather data of satisfactory reliability from Africa itself, and probably, in connection with other countries in the Southern hemisphere, from the Antarctic continent. I do not think that one country alone should undertake to place meteorological observatories on the Antarctic continent. There should be international co-operation of the countries interested, and the aim should be to establish one or more observatories which can be kept in constant activity along a well-planned programme for an indefinite time.

Here, then, is a very valuable suggestion for us to act on. The Argentine Government has already made a start by maintaining two meteorological stations in the Antarctic, one on the South Orkneys and one in South Georgia. If the Union of South Africa and Australia could agree each to maintain an Antarctic station opposite or to the south-west of their respective territories, and the work of the four Antarctic stations could be co-ordinated, the results might be of the utmost value.

The discussion of our climate and meteorology leads me to mention the subject of astronomy and to refer for a moment to some of the outstanding contributions which have been made to it in South Africa. Here, too, our favourable situation in the southern hemisphere and our meteorological conditions, unrivalled for astronomical research, have enabled South Africa to play an honourable part in the advancement of science. Here it was that in the middle of the eighteenth century the Abbé Lacaille made the first scientific catalogue of Southern Stars. Here, too, it was that early in the nineteenth century our second Astronomer-Royal, Henderson, made the first determination of the distance of a fixed star from the earth, in the case of α-Centauri. Here it was that Sir David Gill made the classic determination of the mean distance of the sun from the earth, a determination the accuracy of which has received only additional confirmation from subsequent determinations.

The Cape is also the birthplace of many other lines of astronomical research. It was at the Cape Observatory that celestial photography had its real beginning. Previous to 1882 it was more an amusement in, than an auxiliary to, astronomy. But in that year Gill, while photographing the great comet, was struck with the power of the photographic plate to picture the faintest stars. Forthwith he conceived the idea of photographing the whole heavens, and thus the most efficient and far-reaching arm in stellar research had its beginnings. From that day photography became the most powerful weapon in the astronomical armoury. The epoch-making departure thus happily initiated will now be further followed up in South Africa with the great resources of the United States of America. We wish the Yale Observatory at Johannesburg under Dr. Schlesinger, and the coming Princeton Observatory at Bloemfontein under Dr. Hussey, all possible success in the important tasks they have set themselves.

Let me mention a second line of astronomical research where South Africa was responsible for taking the initiative. For many years it was the home of variable star research. The first observatory in the southern hemisphere for this special branch of astronomy was built at Lovedale in 1891 by Senator A. W. Roberts. It was at this observatory that he made the first estimates of stellar densities, as well as the earliest determinations of close binary systems and their evolution. This pioneer work has led to most important developments in astronomy which are now rapidly revolutionising our views as to the origin and evolution of the material universe. On all these grounds the record of South Africa in astronomical research is indeed one of outstanding distinction; and there is no reason why this record should not be maintained for the future in this land of clear skies, of equitable climate, of peaceful days and cloudless nights, where an endless attraction and a rich promise are continually held out to the lover of the heavens.

I now pass on to the last science which I shall refer to as one to which South Africa should, from its central position, be able to make a great contribution in the future: I refer to human palæontology. Three finds of outstanding importance have in recent years signalled South Africa as a great field of research into the human past. The first was the discovery of the Boskop skull, which traced the Strandlooper and Hottentot peoples of South Africa to their prehistoric ancestry. The second was the discovery of *Homo rhodesiensis* at Broken Hill, which Prof. Elliot Smith is reported to have declared one of the most significant finds ever made in human palæontology because by that discovery Africa for the first time realised our firm expectation of providing extinct types of the human family that present problems of exceptional interest. Finally, we have *Australopithecus africanus*, which largely breaks new ground in palæontology.

In *Australopithecus africanus* we have a transitional form between the ape and the human; we have a creature which is still indisputably an ape, but with certain facial features and a brain development which take it some way towards the human. Looking upon the human and the ape forms as the two extremes which will have to be bridged by palæontology, we note that this can be effected in either of the two ways. We may find fossil forms carrying the human further back into its human or prehuman past, or we may find fossil forms carrying the ape form forward towards some intermediate point on the road towards the human. The Broken Hill skull has done the first, and the Taungs skull has done the second. Together they form an outstanding contribution to the elucidation of a most difficult but most fascinating problem of anthropological science.

It is a remarkable fact that *Homo rhodesiensis,* although apparently a more primitive and simian type than *Homo neanderthalensis,* was found still unfossilised, and among animal remains which belong to still living Rhodesian species. The deduction has been made that *Homo rhodesiensis* was living quite out of his proper geological horizon, and was surviving in South Africa long ages after his compeers in Europe had passed away. In fact he was probably still flourishing in the south when his European "contemporaries" had been dead for thousands of years. But there is really nothing singular in such an idea. After all, such a situation is typical of South Africa in more respects than one. Our Bushmen are nothing but living fossils whose "contemporaries" disappeared from Europe many thousands of years ago. The interest of South Africa as a field for anthropological research is partly just this, that it is possibly ten thousand years behind the times, as measured by the standards of European cultures. In this respect our anthropology does not stand alone, for in botany also we have true "living fossils" like the cycads. In South Africa, therefore, certain biological problems can still be studied from life which in Europe can only be deduced with difficulty from the fossil records of the past.

That is by no means, however, the only or the best claim that South Africa can put forward as a fitting place for palæontological study and research. Discoveries already made point to the possibility that South Africa may yet figure as the cradle of mankind, or shall I rather say one of the cradles? As we have seen, it is not only one of the oldest land surfaces but also, since the end of the Mesozoic period, it has generally enjoyed a fairly habitable though, on the whole, dry climate. While in Tertiary and Pleistocene times most of Europe and much of Asia and North America were intermittently under ice or shallow seas, southern Africa was very much as it is to-day. No wonder, therefore, that it should contain some of the most ancient fossil records of the human race, and that among its living races it should include what are "fossils" in other continents. Its little Bushmen are unique; its little pigmy population that hide in the tropical and subtropical parts are the representatives of the long-vanished human past. Going a little further back, we find in Africa the home of the great anthropoid apes which are nearest to us in the affinities of life. Here then we are clearly near to the great origins. These and other considerations point to the vast importance of Africa from a palæontological point of view, if not to the possibility that here may yet be found some intimate connexion with the far-off beginnings of the human race. The scope for scientific work in South Africa in this department of knowledge is therefore immense.

Science has in South Africa a splendid field of labour: other nations may well envy us the rich ores of this great "scientific divide" which is our heritage. I trust that South African science will rise to the height of its great opportunities, and that this sub-continent will yet earn for itself that scientific leadership of the southern hemisphere to which its central position and its great scientific assets and opportunities entitle it.

The Crystalline Structure of Inorganic Salts.[1]

By Prof. W. L. BRAGG, F.R.S., Langworthy Professor of Physics, University of Manchester.

THE examination of crystalline bodies by means of X-rays has enabled us to discover the positions of the atoms in the crystal. In the earlier period of X-ray analysis it was only possible to do this when the atoms were arranged according to a simple pattern of high symmetry. Experience has increased the range of substances to which the new methods can be applied, and we can now assign structures to relatively complex crystals, basing the proposed structure on the manner in which the crystal diffracts the radiation.

The study of the crystalline structure of organic and inorganic compounds has revealed certain broad distinctions between these two classes of crystals. The crystalline arrangement throws new light on those differences in the structure of the molecule which have made it convenient to distinguish organic from inorganic chemistry. No exact line can be drawn between the two classes of crystals, and yet the main features are sufficiently different to make the classification useful. The organic crystal appears to be composed of definite molecules. Inside each molecule the atoms are bound together by forces so local, and so rigid, that an addition to one part of the molecule scarcely affects the rest; these molecules are then massed together by comparatively weak forces into a crystalline structure. The form of the inorganic crystal suggests that the bonds between atom and atom are not limited to certain directions; the molecule is more fluid, and an addition to one part profoundly disturbs the relationship of all the rest. It must be this molecular fluidity which makes it so hard to apply the ideas of stereochemistry to inorganic compounds although they have been so successful in explaining the organic compounds.

Our powers of X-ray analysis are as yet very incomplete and it is difficult to find the positions of the atoms in complex structures. The complexity of a structure depends on the number of parameters, or degrees of freedom permitted by the symmetry, which fix the positions of the atoms in its pattern. At the present time any structure with more than half-a-dozen of these independent parameters presents a difficult problem. Crystals with two or three parameters are comparatively simple. For several reasons the inorganic salts can be analysed more completely than organic compounds. In the first place, the number of atoms in the inorganic molecule is generally smaller than that in the organic molecule, and owing to the power of readjustment in the former class of compound which has already been mentioned, the atoms often take up a symmetrical arrangement and this symmetry makes the X-ray investigation more easy. Every requirement of symmetry which must be satisfied by the atom reduces the number of variable

[1] Discourse delivered at the Royal Institution on Friday, May 1.