

Some Problems of Polar Geography.<sup>1</sup>

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## THE TASKS OF EXPLORATION.

THE existence of an Antarctic continent is still based on circumstantial evidence, and until more than some 5000 miles of its coastline, or only about 35 per cent. of the total length, are known, direct evidence of Antarctica will be lacking. It is not a little remarkable that all the exploration of the twentieth century has merely modified the probable outline of that continent as it was predicted by Sir John Murray in 1886. He had little but the reports of Ross, d'Urville, Wilkes, a few sealers, and the *Challenger* to go on, and, mainly on circumstantial evidence, he built his Antarctic continent. The one considerable change in that map has been the curtailment of the Weddell Sea and the removal of its southern extremity some four degrees north of Murray's position in lat. 82° S.

Most of the Antarctic 'lands,' and certainly nearly all those that may be classed as key positions to the coastline of Antarctica, date from last century, some of them from a hundred years ago. Coats Land, Wilhelm Land, and Oates Land are among the few exceptions. Enderby Land, the one certain or nearly certain land in more than 3000 miles of hypothetical coastline, has never been seen or seriously searched for since Biscoe found it in 1831. It should be the base of an expedition that is prepared to work westwards. Heavy ice congestion so far found by all vessels that have tried to push south between Enderby Land and Coats Land, suggests that this stretch of coastline will have to be put in by sledge journeys along the edge of the ice cap. The western shores of the Weddell Sea are another ice-girt region which no ship has been able to penetrate, a region of dangerous ice pressure. Here, too, the advance must be by land journey, but it should be relatively simple, since accessible bases are known in Oscar Land and adjoining parts of Graham Land. Lastly, there is the great gap south of the Pacific between Charcot and Edward Lands, which leaves ample scope for an attack from both ends. A minor problem in the outline of Antarctica for an expedition based on Edward Land is the determination of the eastern side of the Ross Sea and the elucidation of Amundsen's sighting of land to the south of Edward Land, the appearance of land which he called Carmen Land.

Even more important, however, than the discovery of the 'missing' stretches of the Antarctic coastline is the explanation of the structure of the continent and its former connexions with other lands of the southern hemisphere.

Graham Land and Victoria Land are both regions of lofty mountain ranges, but apparently of contrasted structure and diverse origin. The ranges of Graham Land, often called the Antarctic Andes,

in stratigraphy and structure as well as in their eruptive rocks, bear so close a resemblance to the Cordilleras of South America that there can be no reasonable doubt that they were at one time connected and are in fact disunited parts of the same foldings. Nor does it appear doubtful, any longer, that the line of former continuity can be traced by a submerged ridge on which stand relics of the chain: in the South Orkneys, the volcanic South Sandwich Group and South Georgia, extending in a great arc between Trinity Land and Tierra del Fuego and sweeping well to the east of Drake Strait. There is no doubt of this line of connexion, but we are still uncertain if South Georgia, and even more so, if the Falklands are really fragments of the arc or relics of a lost South Atlantic Land.

The Antarctic Andes, or Southern Antilles, have been traced south-eastward but lost sight of at Alexander Island and Charcot Land, which in all probability are parts of the same formation. The great problem of the Antarctic is what happens to these ranges. On the opposite, or New Zealand, side of the Antarctic, the great fault ranges of Victoria Land show little if any resemblance in structure and origin to the Antarctic Andes. A great horst capped with horizontal layers of sandstone, probably of Permian-Carboniferous age, is associated with much evidence of volcanic activity, and seems to rise from a great peneplain of crystalline rocks which underlie the whole of that side of the Antarctic ice-sheet.

The structure of the Victoria Land edge of the Ross Sea is reminiscent of Tasmania and eastern Australia, and the suggestion of former continuity across the Southern Ocean receives further support from our knowledge of submarine relief between Antarctica and Australia.

The relationships between Antarctica and South Africa are still very obscure, since the African quadrant of the Antarctic, both by land and by sea, remains one of the least explored parts.

One suggestion is that the horst of Victoria Land is continuous with the Antarctic Andes. Certainly the direction of the Maud Mountains to the south of the Ross Sea supports this view, and evidence of great faults bounding the Andes may show that those ranges after all are not entirely different in nature from the ranges of Victoria Land. A second suggestion is that the Antarctic Andes reappear in the Ross Sea in the old crystalline rocks of King Edward Land—which as yet are but little known—and that these were once continuous with the folds of New Zealand. If this be true, the ranges of Victoria Land and the Maud Mountains probably swing across to Coats Land and may cause those vague shadowy shapes that a few of us who have seen Coats Land believe to exist in its far interior. Nothing is known at first hand of the structure of Coats Land, but rock fragments dredged in the Weddell Sea, and presumably

<sup>1</sup> From the presidential address to Section E (Geography) of the British Association delivered at Leeds on Sept. 1.

derived from Coats Land, suggest a closer relation with Victoria than with Graham Land.

In any case, it looks probable that our knowledge of Antarctica confirms the growing belief that the Pacific basin is girdled by a ring of fold mountains marking the course of a system of geosynclines. The remains of the borderlands of this Pacific geosyncline may possibly be found in small islands in that mysterious ice-bound region to the north of Edward Land which no ship has been able to penetrate.

Much has yet to be done in explaining the peculiar Antarctic blizzards which rank among the fiercest winds on the face of the globe. Dr. G. C. Simpson has given an explanation of these in the Ross Sea, but are the blizzards of Wilkes and Coats Lands, which occur under different topographical conditions, amenable to the same explanation, or has Prof. W. H. Hobbs found the solution in his theory of strophic winds associated with glacial anticyclones, a theory which he applies also to Greenland, where he is at present investigating it?

A further important meteorological problem, with strong geographical bearings, is the alimentation of the ice-sheet. We know that it is wasting by the calving of icebergs, by surface ablation, and other processes, and that it has shrunk considerably since its Pleistocene maximum, but we are at a loss to explain satisfactorily how the precipitation in the heart of an anticyclone can ever have been sufficient to allow such an ice-sheet to grow. There is every reason to believe that during the great Ice Age, ice-sheets did not develop over the Arctic islands of Canada or over most of Siberia. The temperatures were low, but moisture was insufficient. Yet in the southern hemisphere the ice grew in the heart of a vast high-pressure area.

Still another problem is that of oscillation of climate as expressed by varying amounts of sea-ice and variations in the intensity of currents. R. C. Mossman and others have shown that there is a correlation between certain Antarctic records and those from places in the northern hemisphere. There seems to be every likelihood that before long general weather forecasts of real value will be possible for some months ahead. At Buenos Aires, for example, the high correlation coefficient of +0.88 is reached when the summer rainfall there is correlated with the temperature of the South Orkneys for the winter that began three and a half years earlier. In fact, statistical correlation indicates that a very cold winter at the South Orkneys will be followed after an interval of three and a half years by a drought over the Argentine cereal belt; a very mild winter, after the same interval of time, by bountiful rains.

Lastly, there is great need of oceanographical work in high southern latitudes. This branch of research has been overlooked by most expeditions in their hurry to reach their southern bases. The employment of echo-sounding should, however, make it both easier and more accurate.

No pioneer problems of equal magnitude await the explorer in north polar regions. There is small likelihood that any new land of importance remains

to be discovered. There is certainly no 'polar continent.' However, there are gaps to be filled. Nicholas Land, found by the Russians to the north of the Taimir peninsula in 1913, has still to be investigated. Its full extent and its relation to other Arctic islands are unknown. North-west of it the Arctic Ocean has never been penetrated except by the drifting *St. Anna* in 1912-14. We hope that Russian investigators of the coast of Siberia will include Nicholas Land within their scope of work.

Another problem of importance and far-reaching influence is the mysterious fluctuation in the extent of Arctic sea-ice. The fluctuations appear to be cyclic rather than progressive, but so far defy satisfactory explanation. Dr. C. E. P. Brooks has recently pointed out the influence of the amount of ice in the Labrador and East Greenland currents on pressure distribution and consequent amount of precipitation in the British Isles. Here at least is one direct link between the Arctic and the most important factor in our climate. But until we know more about Arctic climatic conditions and the distribution of ice in the Arctic basin, we are not likely to find the cause of these fluctuations.

Facts so far available point to a rotary surface movement with overflows from an overcharged Arctic basin, by the Greenland Sea and other less important outlets. This movement may account for the tendency of ice-bound vessels in the Arctic basin to take a peripheral drift. It may also explain the relatively smooth and unrafted ice reported from the vicinity of the Pole. Again, the heavy ice to the north of Greenland may be due simply to the heaping and rafting against the land of the pack that has been swept past the overflow of the East Greenland current. It cannot, however, be said that this circulation is proved.

Fluctuations in the amount of ice in the overflow currents may well be due to variations in the strength of these currents. These variations may be associated with departures from the normal in the amount of water poured into the Arctic basin from the great Siberian and American rivers, which in its turn depends on causes far removed from Arctic regions. The complexity of the problem is almost baffling, but even before the chain of cause and effect is traced, useful work could be done in looking for correlations.

#### METHODS OF EXPLORATION.

In recent years the aeroplane has appeared in the Arctic, and Amundsen and Nobile have used the airship. It was inevitable that aviation should be tried in high latitudes, if for no other reason than its spectacular daring, but so far its success has not been marked. That, however, does not necessarily imply that aviation is never to be a serious help in polar exploration. Amundsen's flight in the *Norge* gave a probable confirmation of what had already been deduced from indirect evidence. He found no land where none was expected. He saw nothing but ice-covered sea. Moreover, a rapid flight over snow-covered land, even if the eye could distinguish that surface from ice-covered sea, would tell little

of importance. Byrd's flight to the Pole and back was of even less value to exploration, for on his track there was no possibility of land. The kind of exploration that is now required entails patient observation and accurate measurement. A quick-moving machine cannot help in this, and there is always the probability of mist to hamper the value and imperil the success of aviation in the polar summer. Amundsen himself admits that owing to "a tremendous sea of fog, in some places of extraordinary density" in the Beaufort Sea, he may have passed over islands of low altitude without seeing them. So that on the only part of its course where land can possibly exist, the flight of the *Norge* has left us where we were, and the field is clear for the next explorer.

Even for reconnaissance the aeroplane has doubtful value. So much depends on ground organisation, which never can be perfect in polar regions, and there is the even greater difficulty of satisfactory landing-places. In one respect, however, the aeroplane can be successfully used in polar work, that is in aerial survey of difficult country that lies within reach of a base accessible by sea transport and provided with a good landing-place. In the Antarctic, where I have pointed out the pioneer explorer still has ample scope, long-distance flights may be of some value. The ice-cap offers the prospect of better landing than the pack-ice. Yet in view of its great expanse there is even less chance of retreating on foot after a forced descent.

#### SETTLEMENT OF POLAR LANDS.

During recent years, territorial claims have been made to all parts of Arctic regions that were not formerly subject to sovereignty, and even in the Antarctic great dependencies have appeared. This is an expression of the growing belief that polar regions are not merely desert wastes but have some economic resources of value to man.

There is no reason to suppose that the domestication of reindeer, starting with Siberian stock and gradually introducing the American caribou, will be anything but successful in most parts of the Canadian tundra, in the rich pasture lands of western Greenland, and the more restricted areas of Spitsbergen. All these regions have supported vast numbers of reindeer in the past, and should do so again if excessive hunting is curbed, wise game laws instituted, and the wolf exterminated, as Canada is endeavouring to do.

Alaska is said to have pasturage for 4,000,000 reindeer. Basing his estimate on this figure, Stefansson calculates that the Arctic tundras as a whole are capable of supporting about 100,000,000 reindeer and perhaps five times as many musk-ox. This is probably an over-sanguine estimate, for it must be remembered that the Alaskan herds are mainly in the more fertile valleys of the south and south-west, which have few, if any, equals in fertility in the tundras farther north; but even if we reduce the numbers considerably, say by so much as 50 per cent., there remains a possible food production from the waste Arctic lands equivalent to some 1,000,000,000 sheep, or more than ten

times the total number of sheep that Australia now supports.

This would, of course, take many years to accomplish, and naturally will not occur until the temperate lands of the world are more fully occupied than at present. But gradually as world population multiplies and food production has to be increased, the lands that are not fit for cereal growth will command attention by their possibilities for pasturage. It is a geographical axiom that the herder must always give way to the tiller of the soil with his more intensive occupation. With the extension of dry farming, there seems little likelihood of any considerable areas of temperate lands in the long run being left to pastoral pursuits. But the Arctic tundras are entirely unsuited for agriculture by unfitness of soil and shortness of summer for ripening the grain. Their advantage as pasture land is that the farmer can never displace the herdsman. As the world's supply of beef decreases, the supply of venison and musk-ox flesh will come more into demand.

Up to the present, the tide of human migration has flowed and ebbed on Arctic shores and has been mainly a seasonal movement, marked even in the permanent residents by a great degree of nomadism. But eventually the tide of white settlement will definitely set northward, even to the Arctic seas, and in its flood destroy the present inhabitants.

It is no more presumptuous to forecast a scattered population of reindeer and musk-ox farmers in the 'barren lands' of Arctic Canada, the tundras of Siberia, and even in Greenland and Spitsbergen too, a hundred years hence, than it was a hundred years ago to suggest sheep farmers in the plains of Australia or wheat fields in the Peace Valley of Canada. Every land beyond the frontiers of settlement has been a 'never-never land' to unadventurous and unimaginative folk living in sheltered homes. But in most cases the prediction has been falsified.

The problem is one of considerable importance in the future of human settlement for two reasons. First, because there is no real evidence that the white races are suited for the tropics; that is to say, for permanent racial transference as apart from visits. All the evidence that is conclusive points the other way and suggests that only by a slow process of natural selection can the white races ever find a sure footing in the tropics. Long before that is achieved, the coloured races will have effectively occupied the warm lands. This means that the white races must turn, as in effect they have been turning for several centuries, polewards in their search for new homes. Secondly, the possibility of polar settlements affects, as I have tried to show, the future food production of vast areas which at present enter little into the economic life of the crowded populations of food-importing communities.

The only example of real Arctic colonisation that exists is that of the old Norse colonies in south-western Greenland founded in the tenth century. At their height the two colonies must have contained between 2000 and 3000 people, men, women,

and children, scattered in about 280 farms, where they kept cattle, goats, sheep, and horses, perhaps raised a few poor crops of little account, and hunted bears, reindeer, and seals. There is no need to recall the history of these settlements, how trade with Europe gradually ceased and how the Norsemen had entirely disappeared when late in the sixteenth century communications with Greenland were reopened.

Recent Danish researches at Herjolfsnes, near Cape Farewell, have discredited the old belief that the colonies disappeared either by Eskimo extermination or by fusion with the Eskimo races. It now seems clear, at least as regards Oesterbygd, that the Norse race maintained its racial purity and did not 'go native'. The general reluctance of the Nordic races to mix with widely divergent stock was as noticeable then as it has been in later centuries. Examination of skeletons in the churchyard of Herjolfsnes reveals the interesting facts that while clothes and ornaments, in graves of the fifteenth century, show little trace of Eskimo influence, the skeletons all show signs of rickets or other malformations and stunted growth, but no sign of racial mixture with the Eskimo. There is also a very high proportion of remains of infants and young people. Evidently, therefore, the Norse colonies, at least Oesterbygd, perished by exhaustion. Even if the climate were changing for the worst during the existence of these colonies—and such a change is by no means proved—there is no reason to suppose that the habitual meat diet failed. The cessation of communications with Europe cannot have affected the diet of the colonists to any great extent. The *King's Mirror*, describing conditions when the colonies were prosperous, notes that most of the settlers did not know what bread was. And what else could they get from Europe to vary their meat diet?

The conclusion is, therefore, that the Norse colonists in Greenland died out for want of new blood, or, in other words, that they were not acclimatised to their Arctic home. From this it might be argued that even the Nordics can never colonise the Arctic. Certainly no other race from

temperate climates is likely to try, since the Nordics alone show that distaste for gregariousness and that capacity for enduring solitude which are essential qualities for the task. We may even grant them a greater measure of physical enterprise and love of wandering than other people.

The Greenland experiment is not, however, a sure criterion of Nordic unsuitability for the Arctic. The pastoral settlement, which is suggested, will be a slow colonisation, in which natural selection will have some say. Those suited will remain, others will move away or perish. But the colonists will not be cut off from the world: they will be in close touch with it. New blood will continually flow in their veins, so that the unchecked course of natural selection which operated in the old isolated Norse colonies and killed out the more nervous and imaginative type, a type that is least adapted to the Arctic, will not have free play. There is no reason why the race should become impoverished by the elimination of its most progressive element. Even though a diet solely of meat has proved wholesome enough in the case of Eskimo and some explorers, it will not be necessary for the Arctic colonists to subsist on it entirely: transport facilities will bring every variety of food to their doors. If the Norsemen suffered from insufficiency of certain ingredients in their diet, a similar fate will not be the lot of the colonists of the future. If they died out by lack of new blood and continual inbreeding, the Arctic settlers of the future will be able to avoid that disaster.

Such is the legitimate forecast, as I see it, of the outer rim of the Arctic of the future with its prosperous, though scattered, colonists of pastoral interests, and its fur farms here and there supplying high-priced Arctic furs in limited numbers. But the settlement must wait until the pressure of population on the world's resources is even greater than it is to-day. The remoter parts, those without rich tundra and the ice-covered seas and lands, must remain deserts, visited only by roving hunters and occasional explorers. In short, I see a shrinking of the Arctic wildernesses, but never their disappearance.

### The Structure of Silicates.<sup>1</sup>

By Prof. W. L. BRAGG, F.R.S.

AT a time when the fundamental conceptions of the structure of matter are being changed so rapidly, when every six months witnesses the birth of a new analytical method of dealing with the very foundations of our physical science, the study of the crystal patterns of silicates must seem a trivial matter. Yet similar studies have played their part in the extraordinary development of physics in the last decade, and I hope that the refinement of our methods of analysis, such as is represented by the present examples, will in turn prove to be of use.

The results of the particular investigations which I propose to describe are interesting in themselves

because the silicates form so large a proportion of the earth's solid crust, and certain artificial forms are so largely used for technical purposes. I think, however, that it is right to stress another aspect of this study. We are trying to improve the technique of the X-ray examination of solid bodies, to increase the resolving power of our instruments so that we can see finer detail and deal with more complicated structures. It is at present a tedious and difficult task to discover how the atoms are arranged in these bodies; even when some experience in handling them has been obtained, one has to devote much time and concentration to each particular case. Yet every solution makes the next problem easier to attack, and when we look

<sup>1</sup> Discourse delivered at the Royal Institution on Friday, May 20.