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SOME PROBLEMS OF MINERAL GENESIS IN SOUTH AFRICA[1]

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On the day upon which the Mineralogical Society of America convenes for its second annual meeting, the writer sails from England for Cape Town to undertake, as a member of the Shaler Memorial Expedition to South Africa, a tour of several months duration among the more interesting geological and mineralogical regions of that country. He trusts that it will appear fitting to the members of the Society that under these circumstances his address to you should deal with some of the problems of mineral occurrence and genesis of which he has read in the South African literature and some of which he may hope to study in the field. Travelling through so vast a country for a limited time, a visitor can scarcely hope to add much to the detailed observations of the resident students of these problems. But he can at least bring to bear upon them a new point of view and may reasonably expect to clarify his own interpretation of described phenomena after visiting the localities, even though he may not add largely to the store of observed facts.

THE DIAMOND

The unique opportunities for the study of the origin of the diamond offered by the deep mines of the Cape Colony have been so well availed of by the geologists of South Africa that we may regard the problem as solved, at least for that region. Wagner's book sums up so admirably all the available evidence that there need be no hesitation in accepting as proved the igneous origin of the diamond as an accessory constituent of kimberlite. Some related questions still remain, however, which seem to invite further consideration although they are on the whole largely geological and to a high degree speculative in their nature.

[1] Presidential Address, presented at the second annual meeting of the Mineralogical Society of America, Amherst, Mass., December 29, 1921.

First. What is the mechanism by which the pipes now filled with kimberlite were opened? It has been adequately shown that groups of pipes are more or less aligned along fissures in some cases; and that individual pipes change their form in depth and become more or less fissure-like in cross section. Yet some pipes are quite isolated and preserve the verticality of their walls to great depths. The mechanical process by which these vertical holes have been produced, penetrating rocks of utmost variation of texture and resistance for thousands of feet without essential change of form or size has not, I think, been elucidated.

May it not be possible to learn from a critical study of the actual walls and minute features of these reexcavated volcanic vents more of the nature of the agents which were there active? Was the hole punched out by an explosion which actually drove before it a solid column of rock? Was it rather an attack by solvent gases acting under great pressure and removing the obstructing column of rock by chemical attack combined with spalling off of the superheated surfaces exposed to their action? Or was the removal of the rock due to a stoping action effected by projectiles in the solid state which ground or bored their way upward? Anything that might be learned as to these processes from the diamond pipes, the only volcanic conduits which have been or are likely to be laid open by mining operations and thus made subject to minute examination, will have an application as wide as the whole field of volcanology.

Second. What causes produce the wide variation in amount and characters of the diamonds in different pipes? While the rock contents of the pipes as a whole present a remarkable similarity over wide areas, the accessory constituents, especially the diamond, vary widely from one pipe to another. The expert is said to be able to tell with some degree of accuracy from which of the known pipes a given parcel of stones or even an individual diamond was taken. He judges by crystal habit, prevailing color, average size and a number of other characters. On the basis of such a judgment it is confidently asserted that the diamonds of the coast placers of the former German Southwest Africa could not have been derived from any known pipe. The amount of diamond necessary in the blue ground for economic working varies in the active mines from about one part in ten millions to one in forty millions of rock. The amount is thus at most minute. The explanation of the apparent total absence of diamonds in many pipes and of these local variations in character of the stones is probably to be found in the delicate equilibrium existing between the molten magma and the carbon in solution. Goldschmidt and Fersmann showed in their study of diamond crystals that the forms of growth and of solution were markedly different; that few crystals had escaped solution etching; and that a crystal might even have been growing on certain faces in the same magmatic solution that was dissolving material from other faces. The control of the saturated condition of the solution is thus sensitive but its nature is quite unknown. It may well be temperature or pressure; or the presence of other dissolved substances. The latter would be most likely to cause variation of color or other physical characters of the diamond crystals. And for the absence of diamond from so many pipes at least two explanations may be suggested. Carbon may never have been present in the magma of a particular locality. It seems more likely that it is always present but may be held in solution by peculiar chemical or physical conditions through the cooling period in which diamond can form and thus remains in solid solution in the rock. The ultimate source of the carbon is of course problematic. The sporadic distribution of diamond in the pipes might be explained by postulating local digestion in the magma of older, carbon-containing rocks. But it seems more probable that it is derived from the dissociation of carbon oxide gases in the magma, the carbon separating under favorable conditions as diamond.

Third. Some relations of the kimberlite magma. The wide distribution of kimberlite-filled pipes demands consideration. First found near what is now Kimberley and in the neighboring Orange Free State, later discoveries extended the area of their occurrence first to Pretoria in the Transvaal and then by a vast expansion north and west to southern portion of the Belgian Congo and to (German) Southwest Africa. Pipes of analogous character, except for the absence of diamonds, were also found not only in the vicinity of those developed as diamond mines but also over an extensive area to the south in Cape Colony. The pipes are thus distributed very irregularly over an area of roughly a million and a half square miles. Wherever found they are characterized by a general similarity of the rock filling. It is a basic magma rich in magnesia and lime, rather high in titanium and low in alkalies, yielding such minerals as olivine, diallage, mellilite and perofskite, generally largely altered to serpentine. The age of the pipes is not definitely known but they seem always to be later than the Karroo (Permian) and at least as late as Cretaceous. Are we not justified in believing that these hundreds of volcanic vents are related to a common and coextensive magma horizon? The speculation is particularly interesting if viewed in connection with two other widely distributed groups of igneous rocks in neighboring areas. The Karroo dolerites recently described most graphically by Du Toit are of basaltic type. They were intruded in a complex of sills and dikes or poured out as lava flows over an area of at least two hundred thousand square miles lying on the whole to the southeast of the diamondiferous pipes but overlapping them in part. On the other hand, to the north east in the region of the Rift Valley are the lava flows and great volcanoes of Central Africa dating from Tertiary times to the present. Covering a region comparable in extent to those already considered they exhibit a third type of magma, highly alkaline and low in magnesia and lime. Differing thus in age, in character of materials and in mode of extrusion, these groups of rocks seem to offer an exceptional problem in regional differentiation of igneous magma on a gigantic scale.

GOLD

An outstanding feature of the widespread gold deposits of South Africa is their almost universal association with quartzites or quartzitic conglomerates, the "banket" of the African miner. This association is found in rocks of several geological periods and over a vast area extending northwards from the Rand at least as far as the Belgian Congo on the Rhodesian boundary. This mode of occurrence is the more noteworthy in that it is not characteristic of any other important gold region and a vigorous controversy has arisen as to the mode of emplacement of the gold in the deposits. The evidence collected by a host of skillful observers and marshalled in behalf of one or another of two principal theories is conflicting.

The placer theory, whether the conglomerates be regarded as marine or as delta or flood-plain deposits, has the obvious advantage of simplicity. But when an effort is made to discover among recent deposits or on the shores of the present seas placers which at all resemble the gold reefs of South Africa, the result is conspicuously unfavorable. The kind of sorting action leading to coarse pebble accumulation on beaches is not likely to produce at the same time and place concentration of heavy minerals like gold and its associates. Delta or flood-plain deposits are characteristically discontinuous; it is difficult to conceive of the formation under those conditions of the mile-wide stretches of "banket" with its constancy of thickness, pebble character and gold content. The abundant pyrite of the cement and the absence of gold in the pebbles are alike difficult to explain on any placer hypothesis. If it is argued that exceptional conditions of sedimentation may be assumed for particular deposits, it is to be remembered that essentially identical deposits have here been formed in several geological epochs and in widely separated regions, so that the inherent probability of exceptional conditions becomes vastly diminished.

The alternative theory regards the gold as introduced into the sedimentary beds posterior to their formation by solutions of deep-seated origin. According to this theory the conglomerates are the seat of gold deposition because, as the most permeable rocks, they offered the easiest passage to invading gold-bearing solutions.

The writer's judgment leans strongly towards the second hypothesis, possibly in part because of his having spent two seasons in intensive study, with others, of the copper-bearing conglomerates of Lake Superior. There a conglomerate horizon singularly comparable to those of the Rand has become the seat of deposition of metallic copper which replaces the cement of the pebbles and in part even the pebbles themselves. In this case of course there is no possibility of explaining the presence of the copper by contemporaneous deposition or indeed by any other agent than copper-bearing solutions. The degree to which copper has been uniformly introduced into large areas of conglomerate without material alteration of the pebbles as a whole; and the remarkable selective action through which one bed has been saturated with copper and another, near at hand and apparently quite as favorable to the permeation of solutions, has been entirely unaffected; these and other features offer striking analogies to conditions described in the Rand and other African gold deposits.

Certain other considerations, some of which may be mentioned, lead in the same direction. Developments in the Rand mines have revealed numerous large diabase intrusions which might well have functioned as sources of ore-bearing solutions.

There are good reasons for believing that in the neighborhood of the gold deposits deeper seated intrusions exist, as yet unrevealed, which as proved in the case of the Bushveld laccolite, might profoundly modify overlying rocks both by contact metamorphism and by the action of post-magmatic solutions. The presence in some of the gold districts of typical gold-quartz veins offers sure proof that gold-bearing solutions were active. Time does not suffice to even summarize various other lines of evidence bearing on this problem, certainly one of the most interesting offered by the South African field.

COPPER

Until recently the copper deposits of South Africa have been of minor importance. With the exploration of the Katanga region in southern Belgian Congo, however, a copper-bearing formation apparently of the first importance has been revealed. The district in which the copper ores occur is very extensive but their nature is as yet imperfectly understood. They consist of beds of sandstone or of silicified dolomite, of the same age, probably, as the gold-bearing Rand formation, in which at the surface copper carbonates and silicates replace the original rock minerals. There are indications that as depth is gained the rich oxidized ores are giving place to sulfides of copper or to cupriferous pyrite. The copper ores contain a considerable percentage of cobalt as well as some gold and platinum; and one deposit at least is rather a gold than a copper ore. All descriptions seem to indicate that the Katanga ores are replacement deposits; the analogy with the better-known gold deposits is striking and it would seem that this field would perhaps be a critical one for the correct solution of the problem of the nature of the gold banket.

NICKEL and PLATINUM

At Insizwa in southeastern Cape Colony, in a thick sill of diabase belonging to the Karroo igneous series, a basal differentiate of nickel-bearing pyrrhotite has been discovered which seems to reproduce many of the features of the Sudbury copper-nickel deposit. In view of the conflicting testimony as to the true nature of the Sudbury ores it seems probable that the smaller and presumably less complex African deposit may give valuable evidence bearing on the formation of magmatic sulfide deposits.

Very recently an occurrence of platinum has been discovered in the same general region. The platinum is reported to occur in the free state in diabase, from weathered portions of which as well as in derived gravels the metal may be obtained by panning. It is hoped that this novel and interesting locality will prove accessible to our party.

CHROMITE

The extensive deposits of chromite at Selukwe in Rhodesia have for some years practically supplied the world with this mineral. As described by Zealley the chromite occurs in lenses and disseminated throughout the enclosing rocks which are largely talc-schist, talc-carbonate schist and silicified serpentine with a very subordinate amount of serpentine. The peridotite from which these rocks have been derived is intruded by an extensive mass of granite which extends in ultra-acid dikes into the chromite deposits. The association of chromite with talc on so large a scale is the novel feature of these deposits. The chromite is believed to be an original magmatic crystallization from the peridotite. It would be interesting to consider the question whether the presence of the intrusive granite may be responsible for the abnormal metamorphism of the peridotite.

CORUNDUM

Corundum has been found in deposits scattered over wide areas of the Northeastern Transvaal within the past few years. It occurs partly in well formed crystals up to 15 cm (six inches) or more in length, partly in granular masses, associated with white plagioclase feldspar. The corundum rock is described under the name of plumasite in a recent report of the Union Geological Survey by Hall. He finds that it occurs always as a contact layer about large xenoliths of an older ultrabasic rock series which have been engulfed in an intrusive granite. The corundum rock is regarded as a reaction product between the two materials. The field is large and many mines are being opened although the main production is from eluvial deposits. Hall's descriptions reveal a wide variety of local developments and the further study of this region should largely advance our understanding of the puzzling paragenesis of corundum contact deposits.

ASBESTOS

Blue asbestos or crocidolite and its derivative, the ornamental stone termed Tiger's-eye, have long been associated in the popular mind with the diamond as the typical South African minerals. Recent discoveries in the Transvaal of asbestos of a different, but related type, have led to a thorough examination of all the South African asbestos deposits and the report on them by Hall contains much that excites the interest of the mineralogist. Crocidolite is well known to be the fibrous form of a soda-iron amphibole; the newly discovered Transvaal mineral to which the name of amosite has been given is a white magnesia-iron amphibole. It occurs as does crocidolite in cross-fiber, bedded veins in siliceous, hematitic sediments. The fibers reach the unusual length of 25 cm (ten inches) or more, and in its physical properties it closely simulates chrysotile asbestos. The amosite-bearing beds lie just above the great dolomite of the Transvaal system and within the influence of the Bushveld complex. It is believed by Hall that the solutions which transformed the silica and iron oxide of the sediment into asbestos emanated from the intrusive rock, possibly obtaining magnesia as they traversed the dolomite. It appears to be a remarkable case of complete and markedly selective metasomatic replacement on a large scale. The crocidolite veins of Griqualand are believed to owe their formation to a similar process, sodium-rich solutions emanating from an assumed underlying intrusive being the transforming agent. Nowhere, perhaps, so well as in these asbestos localities is an opportunity offered for the study of the mechanics of cross-fiber vein formation. Microscopic study of the replacement phenomena should also be rewarding.

THE BUSHVELD COMPLEX

Study in the field of the great laccolitic intrusion of the Bushveld in the northern Transvaal is the principal aim of the Shaler Memorial Expedition. Dr. Molengraaff first recognized the nature of this intrusive body twenty years ago. He now returns to renew its study, for notwithstanding the many workers who have been interested in this region in the interval, there still remain many unsolved questions concerning it. These are chiefly of a petrographic or structural character. The processes of differentiation in this great intrusive body; the origin especially of the alkaline rocks; the structure of the mass as a whole; the sequence of lavas and intrusives and the structure of the Pilandsberg and its relation to the greater laccolite; the age of the laccolitic intrusion; these are some of the unsolved or but imperfectly solved problems from a petrographic viewpoint.

The mineralogist is attracted by the many types of alkaline rocks including pegmatites containing unusual minerals which have as yet been but imperfectly described; by the ore deposits of a number of metals which are satellitic to the laccolite; and by the various phases of contact metamorphism exhibited about its borders. The metals include particularly tin in characteristic cassiterite pegmatite and in quartz veins and pipes in the red granite; magmatic deposits of magnetite and chromite in the norite; and veins of copper, silver, cobalt and gold. The asbestos deposits have been already referred to.

I have attempted to present some of the problems that appear to the bibliographic student of South African mineralogy and petrology as possible subjects for profitable research. The field is large and varied and the writer will deem himself fortunate if he finds it possible to actually visit even a small part of the deposits here briefly pictured.

In conclusion let me add a word of appreciation of the energy and thoroughness displayed in the work of the South African geologists. They have described and elucidated with striking effectiveness the major elements of the earth features and mineral resources of their vast territory.

SECOND ANNUAL MEETING OF THE MINERALOGICAL SOCIETY OF AMERICA

The second annual meeting of the Mineralogical Society of America was held at Amherst, Massachusetts, in conjunction with the thirty-fourth annual meeting of the Geological Society of America. Both the President and Vice President having previously announced their inability to be present, the Council designated Dr. Edgar T. Wherry as chairman of the meeting. The meetings were held in the Biological Lecture Room of Amherst College, the morning session being called to order at 9:30 A. M. Thursday, December 29th, 1921.