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GRAPHICS OF ORE-ORIGIN.

BY CHARLES R. KEYES.

In the main ore deposits are precipitated in aqueous solutions. Solution, transportation and deposition of ore-materials are distinctly processes operating through the medium of subterranean waters. The sources of the ore-minerals, the courses they follow through the geologic formations, and the immediate causes of their localization, are factors of prime importance in the consideration of ore-genesis. Obscure as is the migration and changes of ore-materials it is possible, as will be seen presently, to represent graphically the general courses.

As recently pointed out the various phases of primary ore-genesis may be all reduced to four principal groups: (1) extraction from sea-water; (2) inclusion of metallic minerals as accessories in the igneous rocks themselves and the subsequent liberation and segregation of the ore-materials through weathering-processes; (3) production of metalliferous bodies in connection with rock-masses in a molten state, either through magmatic secretion or by expulsion of the volatile compounds of the metals during the progress of magma-cooling; and (4) derivation of metallic particles from extra-terrestrial sources, and their later segregation through the action of percolating surface-waters. Of these several groups contention regarding the first mentioned is now obsolete; the conceptions concerning the second and third enter into nearly all of the recent discussions of the subject; the idea of the last receives yet only incidental attention, but is likely to prove the most important of all.

On the theory of meteoritic agglomeration, the original and often the immediate source of ore-materials cannot be in nature so largely magmatic as it is vadose. Qualified in some ways and strenghtened in others, the general arguments of Forchhammer, Sandberger, Winslow, Van Hise and Bain assume a new interest and an added value. The main shortcoming, if such it really be, is merely in ascribing a sole or principal origin of the ore-materials to rock-weathering, when a somewhat broader interpretation of the facts seems necessary.

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It is not difficult to fancy the manner in which metallic substances of meteoritic origin may become incorporated with ore-materials generally. After reaching the surface of the earth, both cosmic dust and the larger meteorites must mingle with the soil, more or less quickly oxidize, and enter, by means of the circulating groundwaters, or otherwise, the deep-seated zone, in the same way as any of the heavier mineral particles liberated from the surface rocks through decomposition are supposed to do. The processes involved are essentially the same as for the changes and movements of rock-forming ore-materials. The distinction to be made is that, instead of the ore-materials being derived from the breaking down of the rocks of the lithosphere, a very large proportion is regarded as coming from extra-terrestrial sources.

Although there is probably no such universal sea of groundwater as that pictured by Van Hise, there is yet no reason for not believing that surface-water readily penetrates to the deep-region, even to the zone of rock-flowage. The lithosphere thus represents merely the flotsam and jetsam of the globe, through which the heavier materials may migrate, generally inward as individual particles, but occasionally or spasmodically outward, in connection with volcanic flows.

In the course of the inward migration of ore-materials temporary orebodies are often localized, in the vadose zone, chiefly. How much of these materials are of recent extra-terrestrial origin and what proportion is the product of rock-decay, is at the present time difficult to estimate. The meteoritic contribution has received as yet insufficient attention. That it may be much more important than has been suspected hitherto is clearly shown by recent observations in desert regions. That this is the main source of vadose ore-materials now seems not unlikely. It is probable that most of the diffused metallic content of the sedimentary rocks is in reality immediately derived from meteoritic sources; for its derivation from the country-rock of mining districts, especially in tracts far removed from volcanic activity, has never been a very satisfactory explanation.

As commonly regarded a mineral vein consists of (1) the deeper primary portion below groundwater level, and (2), above the latter a limited weathered part known as the gossan. The lower part is composed of sulphides and the upper portion of oxides. Of late, between the two, at groundwater level, there has come to be recognized a third zone, that of secondary sulphide enrichment. According to this simple conception the movement of ore-materials liberated by weathering and passed into solution is merely slowly down the course of the vein.

The circulation of ore-matter seems to be very much more complex than this and the immediate sources of the ore-materials are widely different from a mere settling down along a vein. The ordinary circulation of metalliferous groundwaters is graphically indicated by the subjoined cut (Fig. 1).

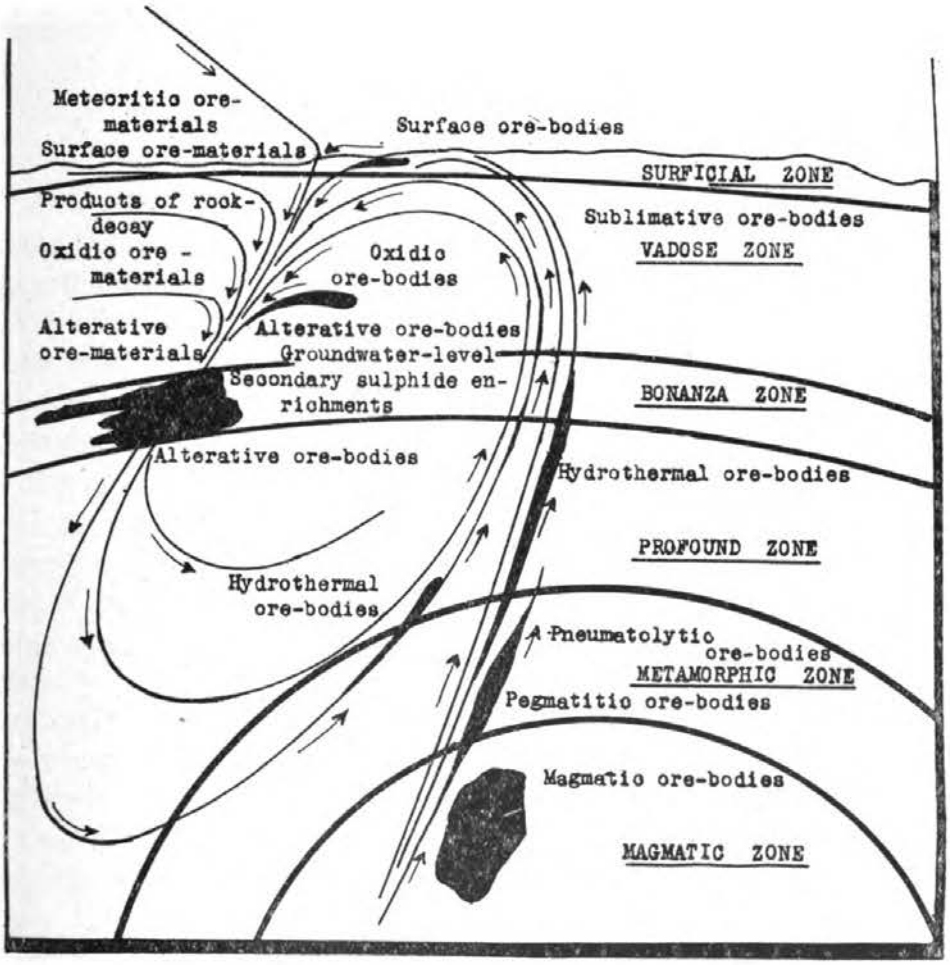

Fig. 1. Graphics of Ore Origin.

In the diagram the courses of the various circulations are represented as merging at a single point or along a given line. The latter may be an old mineral vein or it may be a recently formed fault-plane. In either case the currents reach ground-water-level where their burdens of oxidic ores are mainly reduced to sulphidic form, and dropped, forming the bonanza zone or layer of secondary sulphide enrichment. A minor part goes on downward into the profound zone. The proportions of metallic substances derived from each source are not easy at this time to accur-

ately evaluate. Meteoritic sources supply much larger amounts than it has been customary to suppose. The part liberated by secular decay of rock-masses is probably the largest. By the oxidation of small masses of sulphide ores there is an appreciable contribution. Through the constant working over of the bonanza layer the ores are kept localized and concentrated.

At any rate, deposition of ores derived from the vadose zone is very much more important than is usually assumed.