THE RELATION OF ECONOMIC GEOLOGY TO MINING.

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Geology as a science is usually treated under such recognized subdivisions as physiographic geology, stratigraphic geology, historic geology, and dynamic geology. These sub-divisions are merely useful as a mean of reaching a comprehensive conception of the subject as a whole; and doubtless the arrangement, while arbitrary, is essential and fruitful in results. Culled in part from all of these subdivisions there is a branch of geology which bears directly upon mining undertakings, and is today considered as one of the practical tools of the mining engineer. It discriminates between geology as a whole, and the study of the mode of occurrence of those metals and minerals which have industrial and commercial uses; and treats for purely material ends of the genesis, history, occurrence, structure, and alterations of minerals. I refer to Economic Geology.

Mining engineering is recognized as the science of winning the valuable constituents locked within the outer part of the earth; and just as the exact sphere of the mining engineer is to evolve a productive mine from an intelligently selected tract of mineral ground or prospect, so does the special sphere of the economic geologist consist in investigating the structural geology of the district, the genesis of the ore deposits, and in tracing thereby the unseen structure of the vein, its occurrence, its flexures and displacements, the likely zones of ore enrichments, etc.; and thus does the field of the economic geologist encroach upon and finally merge into that of the mining engineer. The economic geologist must have an intimate knowledge of mining engineering, or the mining engineer must be cognizant of the principals of economic geology and skilled in their application, else in these days their respective spheres of activity are materially limited.

When any particular mineral property is first examined with the object of exploiting it for its supposed mineral wealth, the ele

mentary problems are geologic in nature. The first consideration is, before anything else, to know if the geologic conditions indicate the probability of the presence of valuable mineral; secondly, is the ore deposit formal in character, that is, does it show promise of producing ore in commercial quantities and grades. Once such matters as these have been satisfactorily determined, the mining engineer outlines his campaign of prospecting, exploration, and development; yet even here the economic geologist may well be better prepared to indicate where to prospect and explore, while the mining engineer decides how.

Situated here in Mexico in the midst of a region bountifully favored with mineral riches, and actively engaged, as we are, during a decade, remarkable for its progress in bringing geology and mining into practical relations, we are liable to get out of focus and fail altogether to appreciate that the occurrence of mineral wealth is really due to infrequent and comparatively rare causes; and, *hence, that corresponding hypotheses, by the nature of things, are* crystalizing but gradually into laws and a theory of ore deposits. Although the status of our knowledge regarding the formation of ore deposits has not yet reached a stage where it can be classed as an exact science, nevertheless, investigations by specialists throughout the mining world, and the correlation of their observations and deductions justify the acceptance of many of the modern theories and their utilization for practical ends in mining operations.

It is generally accepted, I believe, that ore deposition is one of the many manifestations of expiring vulcanism. It was not so many years ago, however, that this was a mooted point; and from 1880 to 1892 European and American geologists, though admitting that veins were found closely associated in nature with eruptive rocks, were more concerned in demonstrating whether this relation was really genetic or simply fortuitous. No engineer today fails to feel a thrill of satisfaction, on entering an unfamiliar district, in finding *evidences of dynamic activities on a grand scale such as are evidenc-* ed at El Oro, Matehuala, Charcas, Mazapil, Taviche, Guanajuato, Catorce, Pachuca, etc., and so far as this goes, it is certainly a favorable element in any district.

There is a tendency within the last few years, not only to recognize a simple association, genetic in character, between ore deposits and eruptive rocks, but to suggest a direct magmatic origin for ore deposits in general; and within the year the hypothesis has been

seriously presented from sources commanding respect that many veins are segregations of minerals differentiated from cooling magma, and formed within the same as the final step in the process of cooling. This certainly would remove not a few factors difficult to adjust into a consistent relation concerning the circulation of deep-flowing solutions in the zone of flowage. On the other hand, to an interested observer, it seems hardly possible that a direct magmatic segregation can be predicated of a large and important class of deposits throughout the Mexican Cordilleran regions which have considerable evidence of having been formed at depths of but a few hundred meters below the surface. I have in mind the numerous veins primarily argentiferous, containing a small amount of gold in a fine state, associated with more or less of the sulphides of the bases, lacking altogether magnetite and specularite, as well as all of the various silicates characteristic of the dee-deposited ores such as garnet, hornblende, tourmaline, biotite, apatite, chlorite, spinal, etc. That the solutions which built up these deposits were not meteoric, or even vadose, but rather of direct magmatic sources—the juvenile waters of Suess—seams feasible; indeed, these particular argentiferous deposits appear to be geologically very recent, are in the midst of young eruptives, while in the immediate vicinity may be found such evidences of expiring vulcanism as active hot springs, and occasionally issuing steam and gases; and that with magmatic or juvenill waters as a source of the deposits the function of time and mass action are consistent seems reasonable from the results obtained by Gautier in his experiments with gases and water in igneous rocks. There are other veins, however, to which a direct magmatic segregation of the economic minerals from a cooling magma may with more reason seem to apply, such as for instance some mineralized dikes the walls of which are indefinite or perhaps altogether wanting, while the metallic minerals slowly and gradually diminish to nothing on either side; also, certain gold deposits, rare in Mexico, which are entirely unaccompanied by walls, associated with a slight amount or no metallic minerals, have a gangue of country rock or its altered product of hard amorphous quartz, and without any apparent fissure or even joint plane.

A prerequisite to an intimate acquaintance with any district is a certain familiarity with its physiography, and its orographic history; thus enabling suggestive correlations to be made with other districts in the same geologic division. The structure of a

district and the probable dynamic causes of the same merit keen scrutiny, inasmuch as in this manner the trend of the main fissuring may be indicated, permitting a classification into principal and secondary fractures.

Mexico is climatically divided into pronounced arid zones where the oxidization of the veins often reach great depth, and zones characterized by a vigorous wet-season during which the heavy drainage wears away the incipient oxidization of outcrops effected during the rainless months. With this latter in mind, together with a careful reference to the relative age of the district's topography, the extent of the degradation and oxidization of outcrops may be clearly indicated.

Intense dynamic action and eruptive rocks in abundance strongly suggest fissure-zones of considerable depth, as well as of lateral persistency. Mass chemical action such as alteration and replacement of rock, and particulary the presence of metallic mineral impregnations (not necessarily commercial minerals) indicate a vigorous, extensive, and significant activity of mineralizing solutions. Factors such as these awaken favorable impressions of a district, leading to, and justly so, more formal and far reaching preliminary mining operations than otherwise might be ventured upon.

A pronounced weathered-zone, whether enriched or impoverished, and a secondary zone of enrichment of the sulphides, are recognized as often having a pertinent bearing on the ores near the underground water level and in the regions of primary sulphides. There may be therefore, a marked chemical and physical change in the ore as depth is approached, effecting for the better or the worse, as the case may be, the tenor of the ore, and conceivably its amendability to reduction processes adapted to the state of the ore in the upper parts of the mine. We expect that the gold assays encountered throughout the weathered portion of silver-bearing veins and lodes to fall off somewhat as depth is attained; while in copper deposits this surface concentration of gold may practically disappear on reaching the sulphide zone, as seen in the copper mines of Jimenez, Matehuala, Mazapil and Ameca. This latter district a quarter of a century ago, was operated for the free gold occurring along the oxidized outcrops, assaying from 6 to 20 grams per ton; but at an insignificant depth (the district is in the belt of heavy rains) copper sulphides came in carrying a gram or less of gold—today Ameca is chiefly known because of its copper mines.

The metamorphic deposits of copper ores along, or near the contact of sedimentary and intrusive plutonic rocks were viewed only a few years ago with indifference, if not doubt, by miners, and were little understood by engineers. Deposits of this class were formed at medium to great depths below the ancient surface; and, where exposed at the present surface because of the erosion of the overlying strata, is quite likely, particularly in Mexico, to still retain intact practically all its original vertical dimension. Silver and gold in slight quantity accompany these deposits, while medium and low grade copper ores occur as a rule in great tonnage. These contact metamorphic deposits are today recognized as of probable persistency both laterally and vertically, and likely to develop into an enterprise of no little magnitude.

It behooves the investigator of mineral veins to endeavor to distinguish deposits from aqueous solutions of a deep-seated origin, from those formed at relatively shallow depths. Emmons calls attention to the 'almost unbroken series of deposits' from those of pegmatitic and contact metamorphic conditions formed in the deeper zones of high temperature to the characteristic deposits forming actually about the vents of active mineral springs. A great many of the ore deposits of Mexico I believe to be of comparatively shallow origin, that is, formed from two hundred to fifteen hundred meters below the surface of the ground at the time of their deposition. It is often possible to discriminate between type deposits of shallow and of deep-stated formation through data furnished from surrounding strata, physical aspect of the veins and walls, and associated gangue minerals; and thus the case might occur of an ore deposit of shallow formation which has been extensively eroded, leaving intact today but a greatly reduced vertical component. Such a condition appears to apply to certain ore deposits in the southern part of Puebla, and in Oaxaca and Guerrero, in which 'case only the roots of the original veins would remain below the outcrops. In circumstances of this nature, though commercial ore might be forthcoming, the conservative engineer, on appreciating the probable geologic conditions, would tend to invest additional time and capital to prospecting and exploration before presuming to undertake costly permanent adits and shafts, or to erect expensive equipment or reduction works.

It has been the intention in this paper to touch upon the broader phases and only in a suggestive way, of the relation of econo-

mic geology to mining—the subjects merits a volume—; setting forth the influence such geologic problems may have in the determination as to whether or not any particular district or property shall be attacked by capital and mining skill, and, when affirmatively decided, its further prerogative in prospecting and exploration operations. The scope of economic geology cannot by any means be limited with these broader and elementary investigations; indeed, in anything, it comes into a more intimate relation with mining as the mine workings reach out into depth. The location of faults and post-mineral movements, and their effect on the vein system; the chemical and physical influence of different country rocks on the ore deposits; the manner of occurrence of lenses and ore-chimneys: the recognition of the leads in limestone between ore-chambers; the determination of the zone of secondary enrichment as well as of those of oxidization and primary sulphides; and numerous other underground natural manifestations have not been brought within the shadow of this paper, yet the manner in which these signs are interpreted may alone signify failure or success for the mining operator.

Some twenty years ago the mining geologist was hardly tolerated by the busy manager, and was viewed with no little good natured amusement by the miner. The advancement in the application of geology to mining undertakings and operations has been such that today the economic geologist is one of the most valuable functionaries on the executive staff of the larger mining companies. He is gradually falling heir to many of the duties heretofore performed by the mining engineer, while the activities of the latter have to do more with operations of a mechanical nature—and the end is not yet reached.

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