THE SEARCH FOR ORE DEPOSITS*

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INTRODUCTION

It would seem that an exposition on the search for ore deposits, to a large degree at least, must be subjective. No one person's experience can have covered the entire mining field in one lifetime, nor could the gaps have been filled by the literature which is incomplete and to some extent biased. My own experience has been largely restricted to the Southwest and Mexico.

HISTORY OF DEVELOPMENT

The wide interest in the theory of mineral deposition prior to 1900 is difficult to comprehend unless one reads particularly "The Genesis of Ore Deposits" published by AIMME in 1901. Papers were contributed and discussed by such stalwarts as Posepney, LeConte, Van Hise, Vogt, Kemp, S. F. Emmons, Lindgren, Weed and Richard. One gets the impression that the broader aspects of ore deposit theory, although still in some dispute, had been outlined by that time and that intensive studies had already been made of ore deposits especially in Europe and the United States. This is reviewed in the book by Crook (1933) "The History of the Theory of Ore Deposits." The increasing mining activity in western United States during the last quarter of the 19th century motivated much of that interest.

To get a reliable estimate on the success of the application of geology to ore finding before 1900 would seem to be nearly impossible. The theory of oxidation and of enrichment was on a good basis. Such ore finding as was done by engineers and geologists must have been largely based on this theory and structural work, or just cutting up the ground. Most of the burden of new discovery, however, as we know, was assumed by the prospector. He depended on the "friendly appearance of the rock," his meager knowledge of minerals, his pan and burro. So far as a broad theory of ore genesis goes engineers and geologists were about as well off as they are today although we have greatly progressed in environmental and depositional theory.

After 1900 there was an increased awareness of the need for surface and underground maps. The U. S. Geological Survey was responsible for a burst of surface mapping and report writing which, when the limitations of time, transport, and personnel are considered, was remarkable for its quality and bulk. This type of work with improving quality has continued

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to the present day. During the first two decades of the century the basic problems in ore finding though largely empirically based were pretty well outlined. Particularly, a good understanding was had of the meaning of outcrops, the habits of ore bodies in veins and in limestone, and of fault problems. Excellent mapping was being done at Butte, Cananea, Homestake and at many other places.

The "porphyry copper" bulk low-grade deposits became of great interest about, or just before, 1910, for they were a new concept and soon became of potent economic importance. Their exploitation, particularly, was made possible by the burst of technical and engineering know-how as the Twentieth century progressed. Many engineers and geologists became skilled in reading "porphyry copper" outcrops. Special investigations were made such as the one led by A. Locke and participated in by Alan Bateman and some half dozen others. Many, especially W. H. Emmons, continued to work on the geochemistry of enrichment and L. C. Graton headed up a team for the study of this subject.

This was about the picture of development up to the depression of 1921 in metals. World War I had, of course, greatly stimulated mining. The Twenties, after a slow start, saw mining booming again. Few if any new "porphyry coppers" were found but progress continued about as it had previously. Great ore deposit discoveries were made in Africa, Canada, and Australia.

The Thirties, of course, witnessed a deep depression in all mining except that of gold. Many idle or nearly idle technical men returned to college and there was a flood of publications on mining geology and exploration. AIMME published two important volumes on ore deposits. The introspections of many in this period appears to have stimulated application in the next two decades. In certain areas application had or continued to have good success as in Montana, Utah, the Tri-state area, and in New Mexico.

The period from World War II to date has seen intense activity all over the world aimed at finding mineral reserves. This activity climaxed in the development of vast uranium reserves and many new porphyry copper deposits. Applied geochemistry and geophysics were found to be effective in many situations. In general during this period geology and the new techniques finally got good recognition.

PROFESSIONAL RELATIONSHIPS

The professional relationship of operators and mining engineers with geologists was very poor as late as World War II. There was the general awareness of the possibilities of, and need for, geological work in ore finding — which was becoming more difficult — but the reluctance of operators and engineers to give up prerogatives and responsibilities, and the lack of depth of skill on the part of the geologists, usually prevented adequate communication and cooperation. The common expression was

"Who ever heard of an ore body found by a geologist!" By World War II, however, the effectiveness of good geology in many districts was finally recognized.

The field of mining geology itself up to this time was pretty much of a down-to-earth practice with close rapport between the laboratory and the field. Many of the more basic relationships were becoming known. Most of these were empirical, but, nevertheless, effective. This relationship continued in such new explorations as that for uranium, but in general there began to develop a great schism between application and the "science of ore deposition." The laboratory investigations were greatly stimulated by the rapid rise of general science. In this field, however, effective application still remained largely empirical. Even to date it has not seemed possible to make practical use of most of the laboratory advances in microscopy, isotopes, character of ore fluids, etc. The exception may be applied "geochemistry" but this has had largely to do with sampling and analytical techniques.

Applied geophysics seemed to possess great possibilities in the Twenties and Thirties when a good deal of consideration was given to it. For a century at least "magnetics" had been of critical importance in the search for iron ore. In the shield areas such techniques as the equipotential method had been successful. Unfortunately, in the younger, only partially eroded orogenic areas such as the Western Cordillera, where the ore bodies were hidden at greater depths, the magnetic techniques only were of much use. For other methods the "inverse cube law" stood in the way of penetration much greater than 100 feet unless the target had a mass much greater than usual. The techniques were furthermore not very advanced, too much was claimed for them by charlatans as well as sincere advocates. Besides, professional jealousy seemed to have prevented an essential cooperation between geophysicists and geologists. The methods seem better suited for broad scale preliminary studies and for work supplementary to geology.

This schism between geophysicists and geologists is slowly narrowing and there are examples of close cooperation. The techniques are better and the limitations of the various methods are better known.

DISTRIBUTION OF MINING ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS

The policies of the Federal Government the past three decades have greatly narrowed the professional opportunities for mining engineers, geologists, and geophysicists. Our foreign policy of anti-colonialism, promotion of socialism, and conscious or unconscious appeasement of communism has forced capital and opportunity for professional employment out of many countries. To some extent, it must be granted, forces are now operating that appear beyond the U. S. or any other control.

Domestically, the post-war inflation plus unbalanced, excessive-labor-cost inflation has reduced many types of underground mining to near the vanishing point. So far, luckily, a boom in iron, copper, uranium, and silver has partially offset the above negative factors.

The larger mining companies now have their own geological staffs. This soaked up some of the losses in foreign fields and until recently in uranium exploration. It has resulted in less demand for consulting work, at least in geology.

The U. S. Geological Survey has been greatly expanded. It has continued field mapping and has gone into many specializations such as mapping the moon, geochemistry, etc. The well-justified demand for Federal work in hydrology has greatly increased and is being met. In ore deposits the chief difficulty with Federal work has been that the results are often published too late to be of much use in given mining districts. The Forest Service employs many geologists and engineers. The State Surveys, geological and mineral, and other bureaus, have done excellent work and employ many professionals.

The universities and colleges employ more and more engineers and geologists in teaching and research. Some of this research is now supported by the Federal Government. Then there is the Moho project, oceanic research, etc.

CURRENT EXPLORATION ACTIVITIES

The search for new mines and districts falls into three distinct categories: (1) the appraisal of submittals; (2) the exploration in old districts; and (3) planned regional exploration. In the Western Cordillers at least the majority of the new discoveries, except perhaps in uranium, have been made by investigating submittals. The next most productive may have been by invasions into new and old, often operating, mining districts.

Planned regional exploration at first thought would seem to offer the best chance for new ore discoveries, especially because of the availability of such new tools as is provided by aircraft, visual inspection, photographs, etc. Regional structure study seems to have large possibilities. So far, however, I believe, at least in Western Cordillers planned regional study has had little success with the possible exception of the Carlin, Nevada, gold discovery. We may expect too much from an approach that is at a disadvantage in provinces that have been intensely prospected for a hundred years or more.

The high hopes for the discovery of deposits concealed by gravel and clay in inter-mountain valleys must be greatly qualified not only because of the difficulty inherent in the search itself, but also because of the economic problems faced. We may hope to find more edges of important deposits. The edge of alteration zones often is significant. Some tools of geophysics, especially magnetics, resistivity, and induced potential are of proved broad scale and even detailed value.

The economic problem here includes at least three aspects: (1) The thicker the barren overburden the greater the stripping cost if we are considering bulk open cast mining; (2) the fact that many of the valleys are irrigation areas dependent on sedimentary reservoirs for their water supply. This water reserve usually cannot be greatly disturbed. Or where it may be, pumping is a great added expense. (3) Even if mining can be done below an overburden, in general costs will be higher and so the grade will need to be better and/or the deposit larger.

MINING AND DISTRICT EXPLORATION PROBLEMS

In the area of mine and district exploration for ore bodies the methods used vary greatly with the geological environment. For this discussion we may divide the possible terrains into the following: veins, limestone replacement, porphyry copper and other bulk mining types, syngenetic deposits, uranium environments, and the ferrous metals.

The development of veins has been facilitated by: alteration studies including outcrop and wall; relation of outcrops to terrain and structure; structure per se; ore shoot habits; geometry and the solving of fault problems. Genetic studies have made valuable contributions in classification, etc. Large scale maps often are essential.

The limestone replacement type of deposit generally requires detailed large scale structural, alteration, and outcrop mapping for good results. The Mexican mano type of limestone replacement, however, for many years resisted rationalization except for the empirical, neo-philosophical type such as was made effective by Prescott (1946).

The "porphyry copper" group of bulk-type low-grade deposits has been largely developed from old districts that had a history of copper production from veins or replacement deposits. A few have been found by outcrop diagnosis and one or more by geophysics. One in the Southwest probably was found by "geochemistry" and at least two by geomagnetic work. The "porphyry" copper type of deposit is often amenable to quick recognition by outcrop inspection. Rough to detailed geology is useful for it can save drilling footage and point out good or poor probability for ore extensions. It seems difficult for many to grasp the needed outcrop technique.

Not much need be said about the syngenetic copper, manganese, potash, and iron deposits. The exploration techniques used approach those of coal, but an understanding of regional geology — say, reef formation in potash precipitation, pre-Cambrian source rock for enriched iron ore, etc. — is often useful.

The uranium deposits are in a field in which I have had very limited experience. The exploration problem is in many cases one of finding old carbonaceous trash-filled stream channels or pockets.

OUTSTANDING TOOLS IN EXPLORATION

The presently most effective tools available for exploration besides the bona fide drilling and other mechanical ones are as follows:

In geology: alterations including gossans, structure, mapping of various kinds, genetic concepts, aerial photography, and geochemistry.

In geophysics particularly: magnetic, equipotential, self potential, resistivity, induced potential, and gravity methods. Aerial sensing includes magnetics, gravity, radiometric, and mercury vapor techniques.

GENERAL COMMENTS AND CONCLUSIONS

As I look back on four decades in mining geology I am impressed by the magnitude of the changes that have taken place. Many have said that change is often mistaken for progress and to some extent this has been true especially during the last decade. Much of the change, however, has resulted in real improvement.

As geologists we must admit that in spite of the advanced scientific studies in the laboratory we still have no defensible theory of origin, especially for the hydrothermal ore deposits.

Then it seems to me that many geologists are clining to dogma that was declaimed as principle in the first few decades of our century. The so-called principles, however, often rest on assumptions and lack of evidence.

On the negative side also is the fact that modern geologists because of present conditions can seldom experience the discipline gained by mapping miles of underground workings and that of tying the geologic work to the facts of mine economics.

All to the good is the better scientific training geologists are getting. The old theory that mathematics, chemistry and physics were not essential for geologists — presumably scientists — is "for the birds." This is eminently desirable and necessary. We also see much more cooperation between the operation and exploration staffs. Although there is still a place apparently for bold individual initiative, even for the lone explorer, nevertheless the need for teams of specialists is more and more evident.

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REFERENCES

Crook, T.
1933 History of the Theory of Ore Deposits: Thomas Murby and Co., London.
Genesis of Ore-Deposits, 1901, AIMME, New York, New York.

Prescott, Basil
1946 Limestone Replacements Refute Theories of Origin: Eng. and Min. Jour., vol. 147, p. 86-89.