

THIRTY-YEAR EVOLUTION OF PORPHYRY COPPER EXPLORATION IN SOUTHWEST USA¹

PART 1. TECHNIQUES AND PHILOSOPHIES

by

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More or less 30 years ago there was a gradual but profound change in mineral exploration—particularly in porphyry copper exploration.

Functioning for the first time in organized, systematized groups outside of their home districts, mining geologists themselves became regional prospectors.

In order to explain that last statement, I feel that I must go back, not just 30 years, but into the last century, even earlier, for a number of comparisons, because the contrast in exploration procedures is distinct; and by no means are the distinctions all due to new technological capabilities.

Through very early Biblical times, and the Cypriots, Romans, and Conquistadores, to name a few, the prospector-miners were slaves. That's low-cost operation at its lowest, particularly because the families of the slaves had to feed them.

The Queen of Sheba is a good example of ingenuity. She operated a lode gold mine. The slaves who rotated her hand ore grinders were blinded. Even if they did find nuggets, they couldn't escape. She certainly needed no time-motion analyst to explain the meaning of operational efficiency. Her biggest headache probably was maintaining a monopoly on the slave market because her labor turn-over must have been high due to early insanity among the workers.

The first "free" prospectors in history were the California '49ers. They were free, that is, to blister in summer, freeze in winter and starve year-round. On average they barely made wages. But they came from all over the world and they didn't return home when the placer gold deposits were soon worked out. Some became ranchers, store owners, blacksmiths, and the like, and most prospered; but some took their California gold pans, spread out over the West, learned to detect other heavy minerals and metals, and taught

themselves and their successors a few characteristics of ore deposits. These men became the prospectors, and a very few of them became the discoverers of bonanzas, the real founders of the burgeoning mining business of the West.

However, most of them ruined themselves with hard, useless work because they lacked education—even the rudiments of business, engineering, or geology—partly because it was not available, but mostly because they were too rough-hewn to have bothered with it anyway. Consequently, they tended to regard almost any mineral showing as a probable ore-body; they simply did not recognize the tremendous odds against success; they were imbued with the Western tradition of toughness; and they were sustained by that marvelous incentive for human endeavor: the dream of instant wealth. Altogether, the thousands of miles of hand-driven workings on worthless mineral showings is staggering to contemplate.

They found many thousands of mineral deposits. But with the exception of those few bonanzas, the instant wealth didn't materialize.

Most of the prospectors realized rather early they could not convert the discoveries of seemingly fairly good mineral showings into instant wealth either by themselves or in hard-working small groups. To some of the discoverers it became evident that the making of mines required talents and resources they lacked: First, an understanding of geology such that a discovery could be evaluated without blindly undertaking a terrible amount of fruitless hard work; second, an appreciation of mining engineering, management, marketing, etc; and most important, a supply of money and knowledge of its use.

The bonanza discoveries, of course, early attracted money along with engineering and management talent. When the ore was rich, however, the mine operators could and did make many expensive exploration blunders—unnoticed. So, recognition by anyone of a need for knowledge of the geology of mineral deposits evolved very slowly.

The earliest individuals doing "mining"

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geological work of a special kind—for example, men like Becker and Hague of the Survey who published classics respectively on the Eureka and Comstock Lode districts of Nevada in 1882 and '83—were only scientific observers and describers, educated in Europe—and they worked only on the known bonanza deposits.

The same can be said for the next generation of geniuses, such as Ransome and Lindgren. They were marvelous scientific observers; they were not discoverers; but they were teachers, inasmuch as their publications and their fame improved and speeded the movement of the knowledge of mineral ore occurrences from European universities to eastern United States and on to the West.

Rather tardily, mining geology became available in the West. The more progressive mining companies began to hire men with education in the science of mineralization. Their exploration judgment gradually began to replace the whims of the mine shifters, the superintendents, the surveyors, the astrologers, and the like.

Anaconda formed the first and justly famous geological department. Other companies, large and medium sized, imitated Anaconda because of its reputed great success in ore finding. These new departments in other companies also found ore. The very important point here is that these departments of mining geology and their increasing knowledge of ore occurrence primarily functioned to find ore in company-owned mines, properties and districts. With the exception of checking out some prospects brought to their attention, no mining geologists really were prospecting for new districts in a regional sense—at least, they were not getting far from home base.

The rapidly improving knowledge about mineralization was still not directly available to the prospectors. As time went on they still did not understand, themselves, really how to evaluate a newly discovered mineral showing, or for that matter, how to check out an old prospect in light of new economic conditions.

So—a technique evolved which had innumerable variations and ramifications and which I can only crudely describe here.

I term it the "walking through the door" technique. After digging around a bit on a new discovery—or possibly opening up the workings of an old prospect acquired with his second cousin's life savings—the prospector collected a few samples and specimens and went in search of the right office door to walk through. This might be the office of a nearby small mine manager, or the friend of a friend

who knew a fellow who . . . , etc., or a lawyer, or a promoter who knew a mining vice president. Briefly, he had to get through a door behind which was the right combination of money and exploration-mining talent. This usually meant a medium-to-large company.

If he walked through that right door, it only meant that his mineral showing would get a proper evaluation, hopefully favorable and with a follow-up. If not, there were other mining company doors. Otherwise, there were doors such as stockbrokers'. In those days money from stock sales seldom involved much in the way of preliminary evaluation of a prospect; blatant misrepresentation was common; but money from valid stock sales did find and develop many orebodies.

The implication is not intended that the men with exploration and mining talent and the money managers were hiding behind their doors doing nothing but wait for bonanzas to walk in. They were quite busy with their own mines. Rather, and this is the whole point, the prospectors and promoters were keeping the mining companies sufficiently supplied with "outside" prospects worth the gambles of exploration and development. As a result the supply of base metals was being augmented enough to keep up with the demands of the growing industrial revolution. The mining geologists not only lacked the time, it wasn't even necessary for them to become real regional prospectors outside of their home mines and districts.

This system worked even though it grew accidentally; it was unorganized and haphazard, and it was unfair to the prospectors. It worked because the successive generations of prospectors had those recurring visions of the rainbow's end. Even if the rudiments of knowledge about mineral occurrences—and their vagaries—had been available to the prospectors of, say, 70 and 100 years ago, they wouldn't have listened because, if I may repeat myself for emphasis, all of those men were motivated by the delusive incentive of instant wealth.

The walking-through-the-door system was still functioning—willy-nilly, but effectively—when I got out of college. And in one form or another it will always be part of the business.

The first organized exploration program in history was undertaken, I believe, when World War II was looming and the U.S. military was shocked (and probably indignant) to learn that God had not provided instant domestic orebodies of quite all the minerals and metals the generals wanted for a new war. No brilliant exploration ideas seem to be immediately at hand, so the government reacted by

legislating instructions to the U.S. Bureau of Mines to find orebodies of seven strategic metals and minerals. For at least two reasons this was a dirty trick on the Bureau: First, they didn't really have good reasons to know where and how to explore for new supplies of these strategic items; and second, being very conscientious mining engineers, they thought they were supposed to know.

The Survey was fitted into some advisory capacity to the side and provided considerable help, so I understand, particularly when another law enhanced the problems by adding six more short-supply items.

A massive bureaucratic effort was made in which there was a great rejuvenation of interest in prospects and properties, practically all of which had already been turned down as too risky by private companies, usually by several, but, mind you, always on the basis of non-wartime economics . . . A new "through the door" procedure developed. It became a mad dash, not a walk, because the exploration money was not only free, it was wrapped in patriotism. Despite this frenetic atmosphere, the basics of the old system still prevailed. The prospector, or mineral property owner, or small-mine owner still had to get the attention of the experts behind the door. This time the door was government. The experts were more concerned with the collection and accuracy of details, but somewhat less concerned with exploration risks.

Despite the Bureau's mandate, which could have invited some pretty wild exploration, prospects and properties were checked thoroughly. Many drilling risks were taken, but only with care and thought. A few tons of ore were found here and there, but only one real discovery—San Manuel—resulted from the entire program, and that was too late to benefit the war effort. B. S. Butler of the University of Arizona and earlier USGS fame, and Nels Peterson, USGS, were the instigators of that discovery.

Considering their sincere efforts, the men conducting that major wartime exploration project deserved more luck. If viewed strictly from a commercial standpoint the program failed. The profit from ore found was small as compared with the program's cost. But, of course, it was not really supposed to be a commercial success. From philosophic and scientific aspects, however, I believe it was successful. It had only a few new geologic concepts for original impetus, but the published results eventually were of great value to future workers.

The big changes in exploration, particular-

ly porphyry copper exploration in the Southwest, took place after World War II. The results of the Bureau and Survey programs had an effect; but the changes were not directly related to the war's end or to dramatic economic changes, or, since Ralph Nader hadn't arrived yet, to any great public outcry that something had to be done about something.

Rather, the realization gradually evolved in the minds of a few that, at least in the case of porphyry copper, it was possible that neither the prospectors nor the earlier geologists had really known how to find any but the rather obvious ore districts. The San Manuel discovery probably had some effect on this line of thought. This meant that (1) some other porphyry copper orebodies could be around somewhere and (2) the mining geologists had to re-do the copper prospecting job themselves.

There were other factors related to the changing copper exploration philosophy, and I'll get to those momentarily. First, though, let me indulge in a bit of narrative because I was involved somewhat myself. If you haven't already, you will note some difficulty in my being objective about a philosophy which is mostly subjective anyway.

E. N. Pennebaker, as consulting geologist for Consolidated Coppermines Corp., originated and conducted the first systematic program of regional prospecting for porphyry copper orebodies in the Southwest. It was begun in '48 and continued until '52 when the company was beginning to fold.

Penny had a staff of four to six young but excellent geologists. Ray Ludden, now manager of western exploration for Phelps Dodge, was one of the group. Their specific objective was to find new porphyry copper alteration zones. They used the state map to spot Laramide intrusives and they combed the Mines Handbook for leads like FeO-cemented gravels and for fringe manganese deposits like Bisbee and Ely. They jeeped and walked all over the place. They found about a dozen porphyry copper deposits not known as such theretofore, although a couple were near known porphyry districts. After finding an alteration zone, they would map in detail with particular attention to leached capping interpretation.

They drilled several holes in each of four, which I'll identify as Safford, Kelvin, Patagonia, and Yerington. I believe they penetrated ore-grade material in all four and they had one drill hole in the middle of what is now Kennecott's big Safford orebody. That's a pretty good record considering that they were constrained with the need for a +1.0% Cu orebody at a 0.6% cutoff. The copper price

didn't jump quite soon enough for them, that's all. They were mining geologists who became the first organized group that didn't wait for a porphyry copper prospect to walk through the office door.

While working at Silver Bell and then in southern Peru in the late '40s on some of those copper deposits, particularly Toquepala, Harold Courtright and I began to realize that green copper-stained outcrops could be seriously misleading in terms of copper sulfide ore occurrence. (By cutting myself in on this, I'm stretching things a bit because, as I suppose some of you know, I'm color blind—green copper stain comes through as a nice clean gray—so, I wasn't mapping the stuff anyway.) I did, however, contribute in various ways. I can assure you there was no great flash of insight involved. In fact, there were many complicated aspects of Toquepala geology: We were busy disagreeing about a lot of these other things, and I don't believe we began to think much about the copper-stain business until later when I had had a chance conversation with Juan Oviedo, the original owner of Toquepala. It then became evident that Cerro de Pasco had almost walked away from Toquepala without testing the sulfide zone. Apparently they thought the copper-stained outcrops were the guide to ore. What I want to emphasize is that, if Cerro had walked away, Southern Peru might today still be a rugged, discouraging desert with 2 or 3 billion tons of untested copper ore.

A steep-walled canyon cut the middle of the Toquepala deposit. A few small patches of weak copper-staining occurred high on the canyon walls in the fringe zones of alteration. Cerro had driven about eight adits, 250 m each, beneath these surface copper showings. They cut no sulfides and their adit assays were sometimes as high as 0.1% Cu. They were prepared to move out their camp. So, in desperation rather than with knowledge, Oviedo sank a shaft in the bottom of the canyon. Within 15 m his shaft encountered disseminated chalcocite averaging 4.0% Cu. Cerro stopped packing and started drilling.

Actually, Harold and I were rather slow to catch on. But we began to discuss the possibility that porphyry copper sulfide ore easily could occur in many other places without the need for directly overlying copper-stained outcrops.

The idea was simple, but a lot of other geologists had not caught on either. I worked with Blanchard for several weeks in '47 and I've talked with Locke and Tunell. I believe they all thought of the technique of leached outcrop interpretation, which they originated,

as being useful in finding more ore in already discovered districts. It seems rather incredible, but I don't believe they considered it as being a means of discovering entirely new, separate deposits or districts by re-prospecting large regions. None of their publications state this as a possibility.

Anyway, Courtright and I thought the idea was important enough to warrant re-prospecting the Southwest United States and many other regions.

American Smelting didn't exactly respond with alacrity to my report describing how this prospecting should be done. While working on the Flux mine in the Patagonia Mountains, however, Courtright recognized porphyry copper alteration without copper stain, and I was sent to check it out early in '51.

That's where we ran headlong into our old friend Pennebaker and his crew. We had worked for Penny in the 30s and 40s at Ely, and we knew Ray Ludden and others of his crew. Also, Phil Jenney, representing Coppermines' partner, American Metals, used to show up frequently. We all stayed at the same motel and, as you can imagine, altogether there was quite a bit of socializing while we were stealing secrets from each other.

Of course, it was immediately evident that, although arrived at independently, our basic exploration ideas and Pennebaker's were about the same, only he was three years ahead of us.

Anyway, between Patagonia and the border there were plenty of porphyry copper alteration zones and breccia pipes for everyone. A number of holes were drilled, but there was no significant chalcocite enrichment. We all pulled out. Too bad none of us had the instincts of real estate operators. In terms of one kind of exploration philosophy and how it changed, everyone then was using about 18¢ copper when making projections into the dim, distant future of, say 1960 or '65.

I've dealt with the leached-capping-without-copper-stain idea rather at length because, although a simple geological idea, it had been overlooked. It got some drilling programs started. In turn, that activity got other groups interested. And so on.

Also, though, at about that time important new geophysical, geochemical, and other techniques were appearing and adding significantly to the changes in exploration. A change more important than the advent of new techniques, however, was taking place.

The evolution of exploration philosophies

has been primarily a matter of changes in the methods of managing exploration. For a very long time the average mining community was isolated, and even the large operations all began in isolation. In those circumstances the local mining engineer-mine manager was king. He had to know how to do almost anything and he did. All problems arrived in front of him immediately, and his solutions were fast and usually good.

As the isolation problem became uncommon and as the whole mining business became large, complex and, for the individual, specialized, the concept that the mine engineer-operator still should be the real decision maker prevailed for a remarkably long time.

At this point I'll bring up Kennecott—not because I know more about that company than the rumor mill normally provides—but because for such a long time they completely ignored exploration. It wasn't a technique, a philosophy or a problem. Once in awhile a manager would point to an area on a map, some holes would be drilled, 10,648,321.4 tons of ore would be added to reserves and—so what is unusual?

In the late 30s the manager of one of their operations, and a nice guy nonetheless, gave me some friendly advice. I was working for a neighboring company; he knew me only slightly; but he could tell I was taking my job too seriously. He said "A geologist might be all right, but I prefer a churn drill."

In those days Kennecott could afford managers like that, but the breed flourished in many companies where it was ill-afforded.

As I remember it, sometime in the late 40s a well-known geologist named Anthony Gray (African experience mostly, I think) persuaded the Kennecott board to undertake a massive exploration program. That in itself was a full 180-degree turn, but the hard-to-believe part was the corporate managerial arrangement.

Bear Creek was set up as an exploration entity having no connection with the system of operating mine management.

Gray had retired, and I have no knowledge of his effect on policy beyond my understanding that he accomplished the establishment of Bear Creek. Jim Boyd, a mining administrator of established talent, but a far cry from the old-time mine operator boss, ran the show; and the size of his money supply was hard to believe.

I have never learned of any especial geological idea or combination of exploration tech-

niques that motivated the formation of Bear Creek. So, my own thought is that Kennecott decided first to collect a big bunch of talented geologists, and the exploration ideas then were bound to evolve. They did.

Bear Creek people soon were all over the place. In many ways they influenced nearly all facets of porphyry copper exploration. For example, besides many geophysicists, geochemists, and photogeologists, they had field geologists specializing in regional reconnaissance, and others in detailed mapping, and scientists combining specialized field and sophisticated laboratory studies; they had mining engineers, mineralogists, geological researchers, statisticians, economists, computer programmers, drilling specialists, and so on.

I'm not necessarily expressing approval of all of the Bear Creek setup and procedures; but I do emphasize that their influence on the administration and methods adopted by other exploration organizations was pronounced.

Many exploration groups moved into the Southwest in the 50s and 60s. Some just intended to determine, briefly, what was going on. Most stayed to do a lot of reconnaissance work; and, because an array of technical improvements and new developments were just coming out in geophysics, geochemistry, and photogeology, they continued with projects. The detailed list is long under each of these headings of techniques; so a new group could quickly become involved in various combinations of these techniques—and many did just that.

Most groups concluded, too, that because they were covering new ground they should properly do their own geological mapping to back up whatever geophysical or other survey they might be conducting.

Thus, field work of many types was conducted over large tracts.

Despite the title of my talk I've no intention of commenting upon or even listing all of the activities and variations that could be considered as new or specialized exploration techniques used around here. There isn't time really to deal with the popular ones, let alone all of those which, in my opinion, either did not apply, or were overused. But I must mention a few factors that spurred and maintained exploration in the Southwest.

First, the real price of copper stayed ahead of all predictions, even if we average in a couple of episodes like the past year and a half.

Second, both the quality and quantity of publications on ore deposits and related geology in general and porphyry copper-molybdenum in particular increased remarkably in the past 20 years. Certain universities (the University of Arizona up with the top) and the USGS contributed most; some trade journals came out with surprisingly useful papers, and even private industry cut loose with some remarkable material on rare occasions.

Third, as the mining geologists became prospectors they learned that, despite the great amount of geological work of all kinds in the Southwest over the past 100 years, and particularly the last 30, there are still more uncertainties and complexities, though of different kinds, than 30 years ago. What appeals to me is that so many of these "new complexities" have relationships to exploration possibilities.

Of course, the high percentage of postmineral cover rocks in the Basin and Range province is always attractive to explorationists for many reasons.

Fourth, my friend who will be talking about case histories here tonight is certain not to deal properly with an episode which I believe had a most important effect on the exploration business.

Discovery always involves many people. Dave Lowell's Kalamazoo affair, however, was as close to being a one-man show as anything I know of. He demonstrated that the best of geological work may be subject to new or improved interpretations. This, however, requires logical thought, thoroughness, and time. Nowadays we have to hurry most of the time. I believe Dave showed us, however, that one of the keys to discovery is to know when to slow down and be thoughtful and thorough.

I'm constrained to add a precaution which you may find surprising. Certain lines of geological thought attain prominence as having possible value to exploration for one reason or another. Really, though, they are intellectual games, mostly. Please understand, I enjoy playing some of these games myself, but when exploration is involved a sharp distinction should be drawn between practical and impractical.

A couple of examples:

1. I am personally convinced that "lineaments," alignments, structural zones, or whatever the name, were important localizers of some porphyry copper deposits. But these structural conditions are very obscure in most

cases and should be postulated only with care. A few years ago lines were being drawn all over the Southwest—the matter had become an intellectual game, and, as such, its real exploration value became obscured—almost valueless.

2. Plate tectonics is a wonderful subject of new scientific thought. But a tremendous amount of world-wide field work must be redone to improve its authenticity. Pictures of hydrothermal systems appear on sections of subduction zones. That alone is all right. But if there is a statement or an implication that up-to-date knowledge of plate tectonics will give me the longitude and latitude of a brand-new porphyry copper deposit in a year or two, I know we are playing intellectual games again.

All of us must use care in distinguishing the intellectual games from the practical aspects of geologic thought and conversation.

As an example of practicality, I would like to present my concept that the first real prospecting event occurred during pre-history. In case some of you are not up to date, pre-history is that gray area in time between recorded history and what I usually term "PB," or Post-Baboon. That terminology is easily confused with the newly accepted scientific initials "BP," or Before Present. I understand there is a group which maintains there is no time gap between Before Present and Post-Baboon.

Anyway—upon being pushed out of a tree an angry post-baboon-pre-person hurriedly picked up a chunk of yellow rock and threw it at her husband. It was heavy and knocked him cold. This so fascinated the pre-person (post-baboon, that is) that she took the summer off and went prospecting for another, bigger chunk of gold so she could really finish him off. I believe she was committed because a tribe of environmentalists discovered her prospecting license had expired.