Bureau of Mines Heavy Metals Program
Technical Progress Report

March 1968

Gold Resources in the Oxidized Ores and Carbonaceous Material in the Sedimentary Beds of Northeastern Nevada

U.S. DEPARTMENT OF THE INTERIOR

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by

Roland W. Merwin

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PREFACE

As a participant in the Interior Department's Heavy Metals Program, it is the Bureau of Mines' responsibility to develop new or improved mining and metallurgical systems and techniques that can be applied to new or existing resources. As part of its metallurgical investigations, under the program, the Bureau in 1966 began research into improved methods for extracting gold from refractory and submarginal ores. One phase of this work being conducted at the Reno, Nev., Metallurgy Research Center, was devoted to the carbonaceous ores of Nevada.

The research began with the isolation and identification of the carbon compounds in these ores; then techniques were developed to disrupt the mechanism that keeps the gold tied up with the carbon. Carbonaceous gold ores treated by conventional cyanide processes usually have recoveries of from 20-35 percent. The Bureau's objective was to develop a treatment method that would economically increase these recoveries to 90-95 percent. By mid-1967, researchers at Reno were nearing this objective. By late 1967, laboratory tests of this technique indicated that a breakthrough had been made, and invention reports were filed.

Now that a promising metallurgical technique had been developed, it was essential to determine the extent of the carbonaceous resources on which the new method could be used. Consequently, in December, 1967, an extensive survey of the carbonaceous resources in Nevada was started. This study has now been completed and its findings are presented in this Technical Progress Report.

It is the conclusion of this study that substantial resources of gold exist in the carbonaceous material and that this gold will become accessible with the Bureau's newly developed technique, if the process can be successfully scaled up for commercial application.

Since foreign patenting is under consideration and the U. S. patent application is in progress, the Bureau is unable to reveal specific details of the process at this time. Pilot-scale tests of the process are underway at the Reno Metallurgy Research Center. When the patents have been filed, it is the Bureau's plan to demonstrate and reveal the entire process. This disclosure should be made within the next few months.

Walter R. Hibbard, Jr.

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Director, Bureau of Mines

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ABSTRACT

Sedimentary beds of northeastern Nevada associated with the Roberts Mountain thrust fault system were investigated by the Bureau of Mines, under the Department of the Interior's Heavy Metals Program, to assess the commercial potential of gold-bearing deposits in the area. Available data on the extent and gold content of these deposits was evaluated economically in the light of present mining and milling technology. Special consideration was given to recovery of gold under economic conditions, by a method now under development, from refractory carbonaceous materials known to constitute a major portion of the region's gold-bearing deposits.

INTRODUCTION

The Department of the Interior's Heavy Metals Program, which began in mid-1966, aims at stimulating the domestic production of heavy metals that are in short supply, including gold, silver, platinum metals, mercury, tin, bismuth, antimony, and tantalum. Initial program emphasis has been on gold, industrial consumption of which in the past few years has exceeded production by three to four times. Projections for industrial uses alone for the next few decades indicate a continuing widening of the gap between supply and demand unless active measures are taken to increase production.

The program is conducted by the Geological Survey and the Bureau of Mines, both agencies having been authorized new funding to support expanded research and investigation. The immediate objective of the program is to stimulate increased gold production by private industry within the present price structure of $35.00 per ounce. It is the Bureau of Mines responsibility to contribute to this goal by developing new or improved mining and metallurgical systems and techiques that can be applied to either existing resources or new resources that may be discovered through the Geological Survey's exploration efforts. Two of the important areas in which research is being conducted by the Bureau of Mines are improved recovery of gold from scrap, and the treatment of carbonaceous ores.

The present Nevada resource study was stimulated by encouraging metallurgical research on the carbonaceous ores conducted by the Bureau of Mines Reno Metallurgy Research Center.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance given and information supplied for this report by the U. S. Geological Survey, Menlo Park, Calif.; Newmont Exploration Ltd.; the Carlin Gold Mining Co., the Homestake Mining Co., the American Exploration and Mining Co., the London Extension Mining., and Harry Treeweek, former manager, Gold Acres mine.

BACKGROUND

The gold-bearing sedimentary beds of northeastern Nevada constitute a newly recognized auriferous province presently covering an area of 8,000 square miles, with possible extension into southern Nevada and central Idaho. The favorable geology and the importance of the area as a potential gold producer was first brought to the attention of industry in 1961 by the Geological Survey. Subsequent exploration resulted in the discovery of a major deposit at Carlin, Nev., currently the second largest producer of gold in the United States. Another major deposit, at Cortez, Nev., was in an advanced stage of development in early 1968 and is expected to begin producing before the end of the year. Industry is very optimistic about future discoveries in the region. The general consensus ofinformed personnel in both industry and government is that this area offers one of the most favorable opportunities in the United States for the discovery of significant new gold deposits of a size and grade that would warrant exploitation under present economic conditions.

The gold deposits, regionally associated with the Roberts Mountain thrust fault system, are in windows where uplift and subsequent erosion have exposed lower-plate sedimentary beds of Silurian age. Gold was deposited as submicroscopic particles in permeable carbonaceous horizons of silty dolomitic limestones during a period in which the carbonate minerals were largely replaced by microcrystalline quartz. Subsequent supergene action, weathering, and oxidation removed the carbonaceous material from the upper and surface portions of the deposits and effectively masked all indication of the existing gold depostion.

The lack of gossan, and the fact that the gold particles are so fine, delayed recognition of this type of gold deposit.

Orebodies occur as irregular stratiform masses and in multiple horizons. Strikes and dips conform to the present attitudes of the original bedding. Thicknesses may exceed 100 feet, and strike

lengths, several hundred feet. (At the Carlin mines, assemblages of orebodies occur along a strike length of over 7,000 feet.) Mineralization is considered to be of the low-temperature epithermal type; however, no vertical limitation of the deposition has been noted in any of the known deposits.

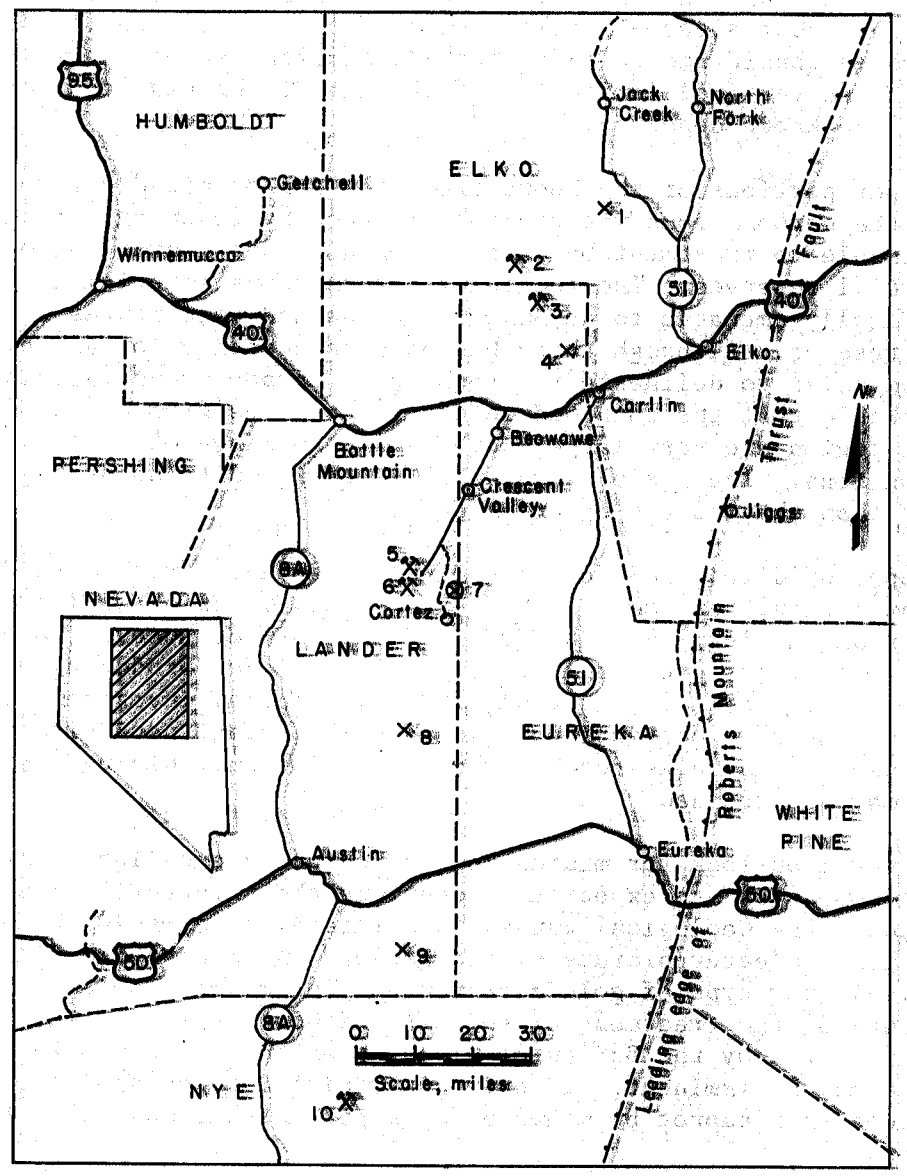
The upper portions of the known orebodies are oxidized ore zone from which the carbonaceous material was removed by leaching. Such ore is amenable to treatment by cyanidation and constitutes the present commercial reserves. The remaining carbonaceous material is not economically amenable to any known process and constitutes a submarginal reserve. Although there has been no incentive for any of the companies to delineate the tonnage of carbonaceous material, it is probable that the combined inferred resources from all deposits in the region are very large, perhaps in the range of 30 to 100 million tons. The grade of material is believed to be as high or higher than that of the upper oxide ore.

The upper oxidized ore zones are mined by open-pit methods and treated by cyanidation, but some of the carbonaceous material will require underground mining. Even before it can be mined, however, a satisfactory treatment process must be developed. For producing both oxide and carbonaceous material, the high capital investment for construction of a conventional mine and mill plant necessitates the development of a large reserve tonnage so low unit mining and milling costs may be attained.

The general outlook for mining in the region is excellent. Major mining companies are expected to continue their intensive exploration programs. The Geological Survey is maintaining teams in the area to obtain a clearer picture of the geology and mineralization of this relatively new type of gold occurrence. The major problem confronting operators is the treatment of the carbonaceous ores. Recent metallurgical research by the Bureau of Mines shows that solution to this problem may be imminent. Underground mining methods applicable to resources that cannot be mined by open-pit methods must also be devised.

LOCATION

Significant gold deposits in sedimentary beds of Silurian age occur at various location over an extended area in northeastern Nevada 40 miles wide and 200 miles long. The area is centered 40 miles west of, and parallel to, the leading edge of the Roberts Mountain thrust fault system. It extends from a point 50 miles north of Elko, Nev.,



L E G E N D

- Mine
- Explor. area
- Developing

1. Various
2. Bootstrap
3. Carlin
4. Gold Quarry
5. London Ext.
6. Gold Acres
7. Cortez (AMEX)
8. Homestaker
9. Various
10. Northumberland

FIGURE 1.—Location map.

near the Idaho border, southwesterly through Elko, Eureka, and Lander Counties. The geological setting is favorable for additional deposits for the extension of this area into central Idaho and southern Nevada. The general locations of known deposits and exploration and development programs are shown in figure 1.

PREVIOUS AND PRESENT MINING ACTIVITY

The history of gold production in this area begins in 1935 when the Gold Acres mine, 30 miles southwest of Beowawe, Nev., was brought into production on a small scale. Ore was mined from small underground stopes and surface pits and operations ceased in 1941. At that time the deposit was not recognized as being of the sedimentary type because the rock was intensely altered.

From 1939 to 1942, Northumberland Mining Co., operated the Northumberland mine, an open pit and cyanide mill about 25 miles north of Belmont, Nev., in Nye County. The ore deposition was sedimentary and had many of the characteristics of the more northerly deposits. The oxidized ores were amenable to cyanidation but the carbonaceous portions proved to be refractory and dampened any further interest in that particular area at that time. In 1966, however, exploration was revived and, reports indicated that the area might prove to be an extension of the better known deposits to the north.

In 1942, London Extension Mining Co. built a mill immediately adjoining the Gold Acres property and operated an open-pit mine and cyanide mill until 1961. Geological studies by the Nevada Bureau of Mines identified the true nature of the deposit but the property did not attract much interest, probably because from the start the operation was plagued by the carbonaceous material, layers of which occurred within the oxidized ores. Extensive investigations in a number of laboratories failed to develop an economic treatment method for the carbonaceous material, although the oxidized ores were amenable to cyanidation. Eventually the oxidized ores were exhausted and operations suspended, leaving a substantial tonnage of carbonaceous material, some of which can be seen in the face of the open pit.

From 1957 to 1959, a local group worked the Bootstrap mine, a small open-pit operation about 10 miles northwest of the Carlin deposit. The ore, coarsely crushed and leached in tanks, was of the oxidized type and the general geology and mineralization were similar to that of the other sedimentary deposits of the district. Engineers from

several large mining companies examined the property, but because of its apparent small size and a lack of knowledge of the geology of this type of deposit, interest in the area once again slackened off.

These four mines produced $11,725,000 from 2,835,000 tons of ore for an average yield of $4.14 per ton milled, which was profitable during this period of low capital and low operating costs.

Publication in early 1961 of a Geological Survey paper by Roberts, (4) [1/], created the first real interest in exploration for major gold deposits in this area by large mining companies. A number of large exploration groups entered the field; but because of the complexity of the geology and the difficulty of recognizing rock types and structures, most of these groups soon withdrew.

However, Newmont Mining Corp. persisted and found the first ore in what is now the Carlin operation in September 1962. This discovery was followed by a crash drilling program and 11 million tons of ore averaging 0.32 ounces of gold per ton was developed in a little over a year. Virtually all of this ore was the oxidized type that could be mined by open-pit methods. Mill construction began in June 1964 and the first gold was produced in May 1965. The main ore body was found on previously unclaimed public land and the ore cropped out at the surface with substantial gold values. Up to December 31, 1967, the Carlin operation has milled 2,120,942 tons of ore valued at $25,426,555. The average value was $11.99 per ton.

Following discovery of the Carlin deposit, most of the major mining companies reentered the area with extensive exploration programs. The Geological Survey also assigned specialized groups to obtain additonal information on the geology of the area. Results in general have been encouraging.

Concurrently with development of the Carlin mine, Newmont acquired land in the Gold Quarry area, about 10 miles southeast of the Carlin mine, and initiated a drilling program which continued on a relatively limited scale through 1967.

Guided by results of geochemical investigations by the Geological Survey (Circular 534 - Gold Geochemical Anomaly in the Cortez District Nevada), drilling in the Cortez area by a group headed by American Exploration and Mining Company (Amex) began in 1966. On March 9, 1968,

1/ Underlined figures in parenthesis refer to items in the Bibliography.

it was officially announced that the joint venture, named Cortez Gold Mines, would bring into operation by late 1968 a mine and mill with a throughput of 1500 tons of ore per day. Gold output (of the property) would be over 400 troy ounces per day. Measured ore reserves were stated as approximately 3.4 million tons containing 0.29 ounces of gold per ton. Total capital investment of the joint venture was estimated at $9 million and it will employ over 100 persons.

Beside Amex (wholly owned subsidiary of Placer Development Limited), others in the joint venture are the Bunker Hill Company, Vernon R. Taylor, Jr. and Webb Resources, Inc. The new mining operation will be managed by Amex.

In addition to Amex, a large number of other responsible exploration groups have been active in the region. Among them, the Homestake Mining Company has been conducting intensive exploration in a number of areas south of Cortez. The Union Pacific Railroad Company obtained control of the London Extension claims and surrounding property and initiated a drilling program in an area in which gold-bearing carbonaceous material was encountered relatively close to the surface during the operations of the London Extension mine from 1941 to 1961.

GEOLOGY

The gold deposits are regionally associated with the Roberts Mountain thrust fault. This is a low angle fault system of major magnitude trending from southwest to northeast Nevada with an inferred extension into central Idaho (figure 2). Clastic volcanic rocks of early and middle Paleozoic age (western assemblage) have ridden easterly and southerly over correlative carbonate rocks (eastern assemblage) with a movement in excess of 100 miles. Local post-thrust uplift and doming caused the upper plate rocks to be removed by erosion, so that carbonate rocks of the lower plate were exposed in windows. Known windows in northeastern Nevada were delineated by Roberts (4), who pointed out that the principal mining districts are located in and around eroded windows of lower plate carbonate rocks, and that the alignment of windows indicated zones of structural weakness along which igneous rocks and related ore-bearing fluids have penetrated (fig. 3).

The mechanism of doming, post-thrust faulting, and erosion that created these windows is illustrated in figure 4, which shows the gen-

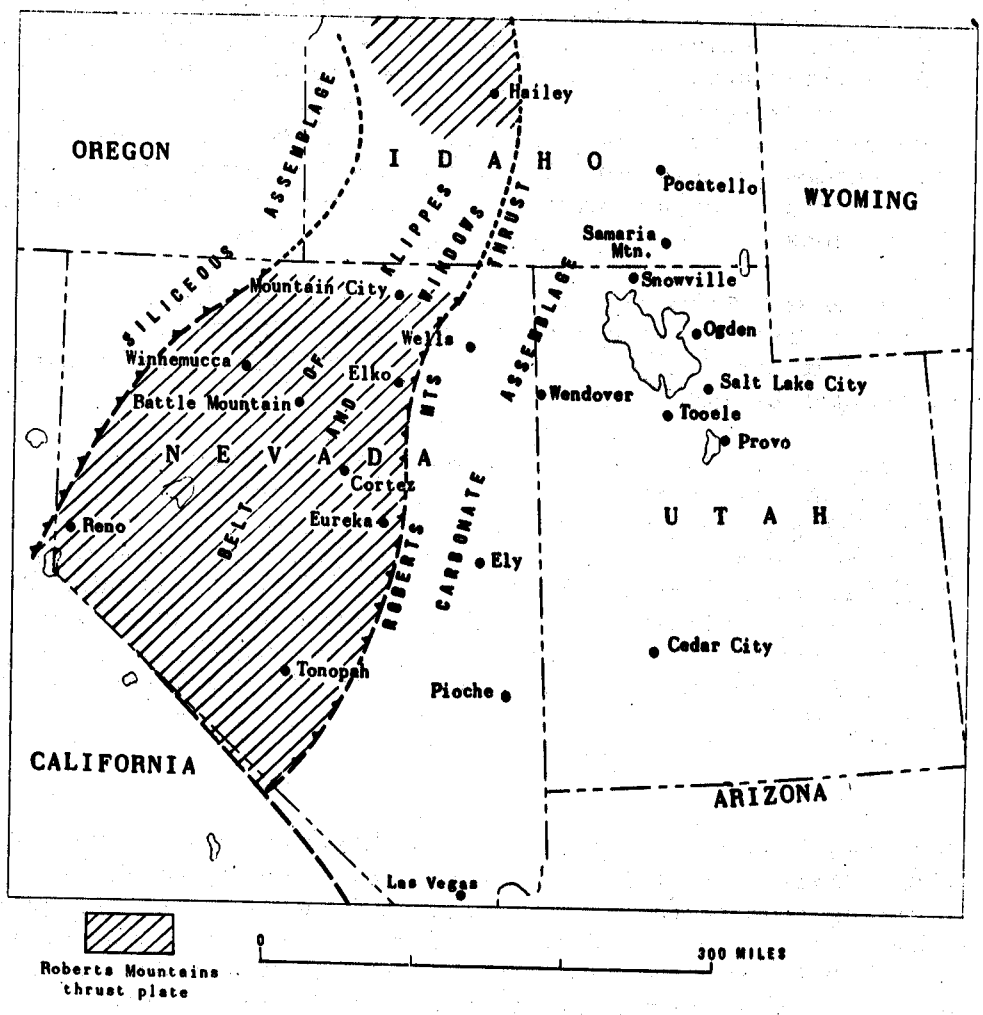


FIGURE 2. Map showing distribution of Paleozoic rocks in Roberts Mountains thru plate after Mississippian thrusting. (After Roberts (5))

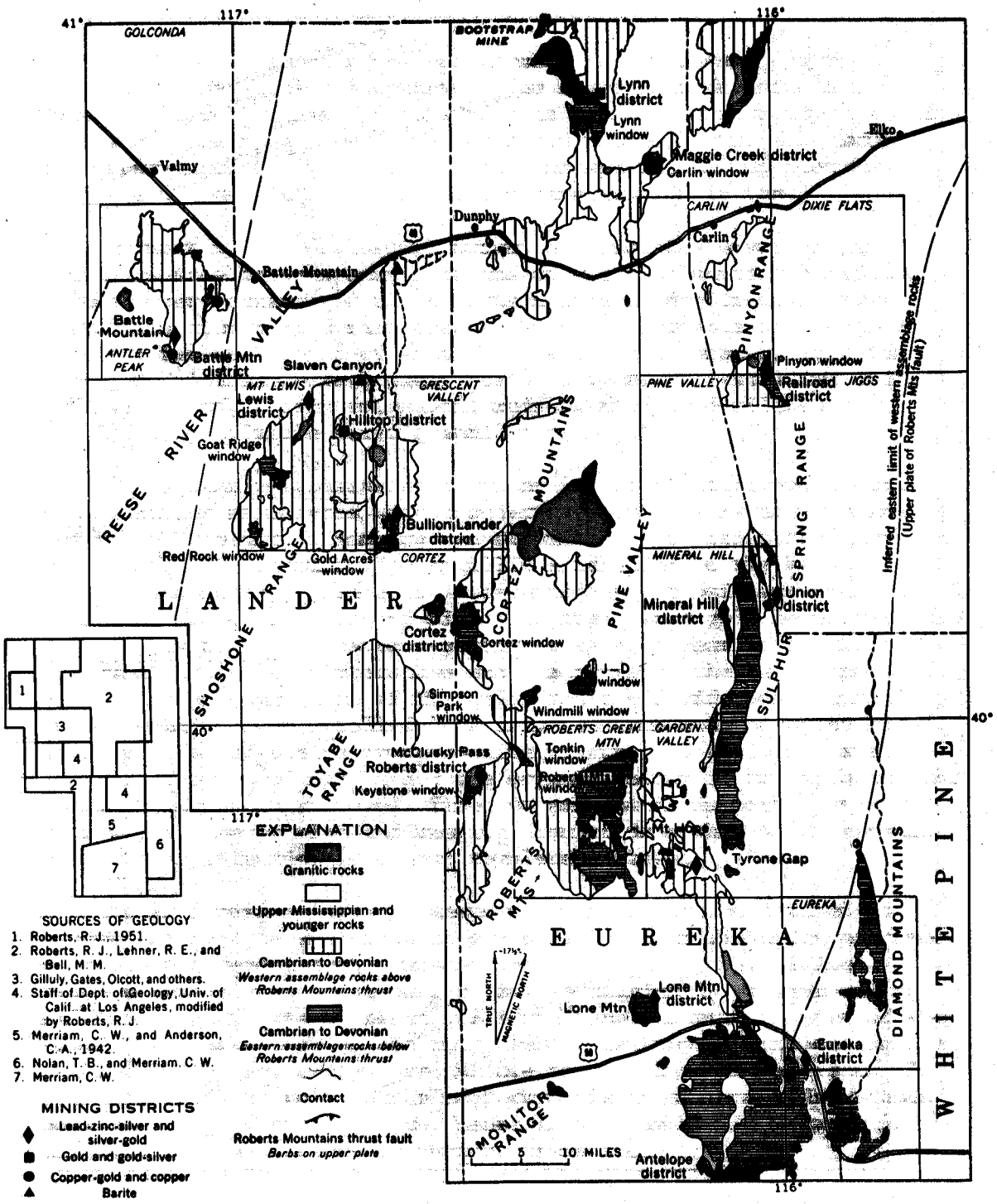


FIGURE 3.- Map showing distribution of Paleozoic facies, granitic rocks, and principal mining districts in northeastern Nevada. (After Roberts (4))

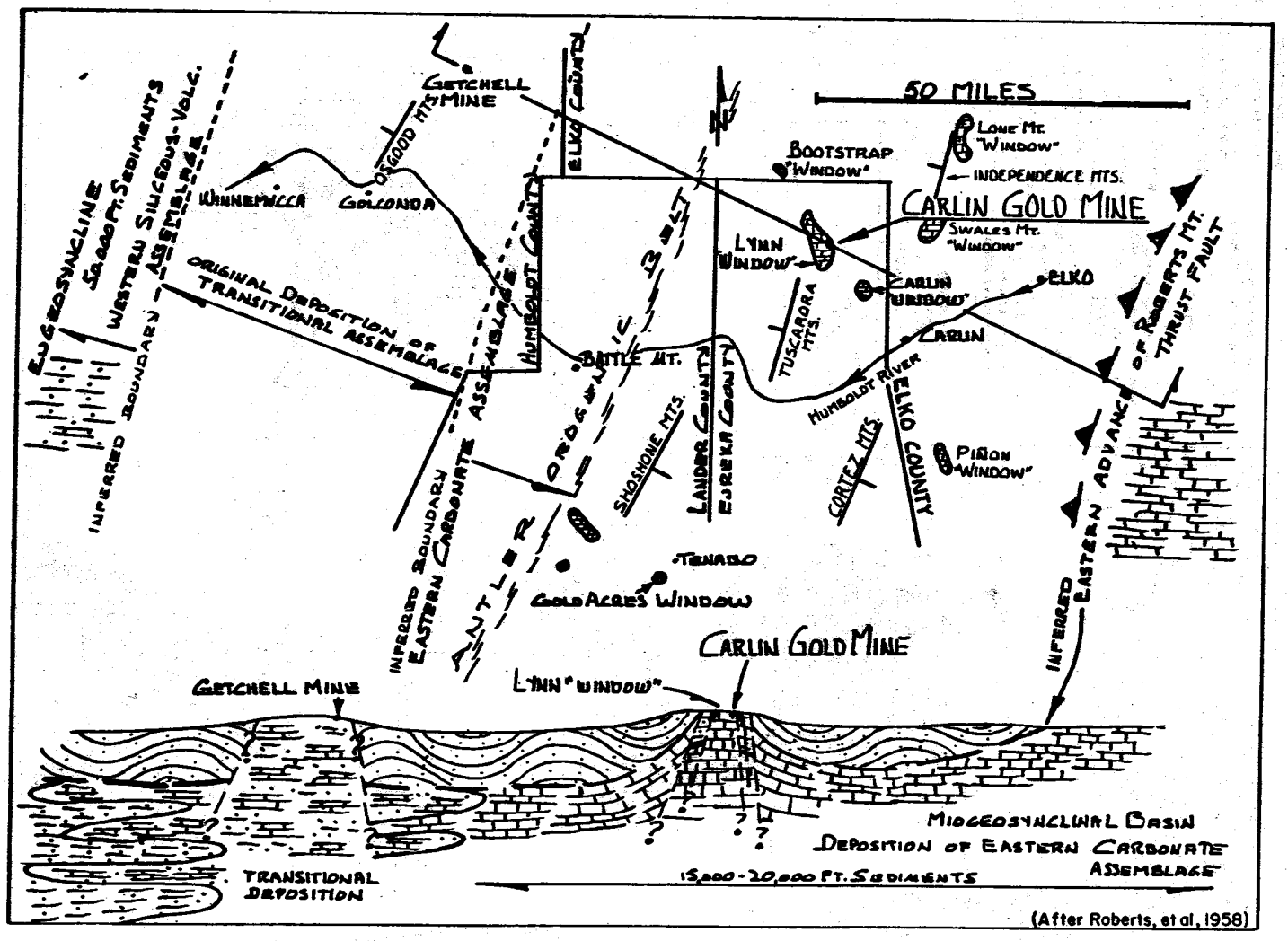


FIGURE 4. Generalized location map of part of northern Nevada showing site of Carlin Gold mine (upper), and generalized geologic cross section through the mine. (After Hardie (1))

eralized section through the Carlin mine (Lynn window) and the location of other nearby windows. The known gold deposits are located entirely within windows of this type in sedimentary horizons of lower plate rocks that were favorable for leaching, alteration, and deposition, and where local faulting and fracturing provided adequate channels for leaching and mineralizing solutions.

Further work by the Geological Survey and industry demonstrated that permeable carbonaceous horizons of silty dolomitic limestones in the upper portions of the Roberts Mountain formation, a lower plate formation of Silurian age, provided a favorable host environment for the deposition of gold by a replacement process in which carbonate minerals were largely replaced by microcrystalline quartz and chalcedony to form epigenetic beds of chert and siliceous sinter along multiple stratigraphic horizons.

Gold deposition is considered to be of low temperature and epithermal character associated with a moderate amount of pyrite and trace amounts or realgar, cinnabar, and stibnite. Deposition resulted in extensive silicification and argillic alteration of the beds. The actual deposition of the gold is regarded as a subsidiary phase in the sequence of leaching and silicification, with gold being deposited in the form of submicroscopic particles as gold-bearing fluids were diffused into minute interstices and fractures of the less permeable beds. The precipitation of the gold from the auriferous solutions is believed to be controlled by a large surface area provided by micro-pore structure, microcystalline quartz, and illitic clays and the presence of pyrite and the organic matter in the carbonaceous beds. The gold is extremely fine; 90 percent is in particles less than 0.2 micron in size and ranging down to less than 0.005 micron. Silver mineralization is almost completely absent.

Subsequent supergene action, weathering and oxidation leached and removed the pyrite and carbonaceous material from the upper portions of the known deposits. It masked the presence of the original trace minerals, and the amount of pyrite originally present was not sufficient to create a gossan. The practical effect, in view of the submicroscopic nature of the gold, was to destroy any indication of a mineral deposit, even where the ore crops out on the surface. The gold was too fine to create placer deposits in streams below eroded portions of gold-bearing beds, hence they could not be located by the conventional stream-bed panning techniques.

However, at depths dependent upon topography and bed permeability, and which may vary considerably, the original unoxidized mineralization is encountered, with orebodies containing pyrite and carbonaceous

material occurring in bed layers that may alternate with beds of well-oxidized ore and barren beds of unaltered cabonaceous rocks that were originally too impervious for leaching, alteration, and gold deposition. Near the surface the impervious beds may have responded to supergene leaching and oxidation to some degree.

ORE DEPOSITS

Orebodies occur as irregular stratiform masses at multiple horizons in beds that retain their original thin-bedded platy character. They vary greatly as to dimension and grade within short intervals, both laterally and vertically and grade control by visual means during mining would not be possible. The general pattern of ore deposits can be predicted by wide spaced drilling but mining requires closely spaced sample control for delineation of ore. The thickness of the individual lenses may range from a few feet to more than 100 feet, with lengths of from tens to hundreds of feet.

Strikes and dips conform to the present attitude of the original beds. These beds have been affected by local faulting and folding and have dips ranging from fairly flat to steeply inclined. Strike lengths of assemblages of orebodies vary from property to property, but in the Carlin deposit the length is over 7,000 feet. Down dip lengths of orebody assemblages have not been determined at any of the properties, but at Carlin the deposition appears to have been followed downward about 1,000 feet along the dip, with no definite bottom in sight.

Locally, the individual bodies may finger out, or the assemblage may be cut by faulting. Economically, the ore assemblages may be bottomed by the allowable stripping ratio in the case of open-pit mining.

Figures 5 and 6 show the general plan and two generalized sections of the Carlin deposit and illustrate the nature of this type of deposition. Although not enough detail is included to show the true stratiform occurrence of the individual orebodies, the sections serve to illustrate the typical problems that relate to stripping ratios and gradation of the oxidized ore into unoxidized carbonaceous material below the level of supergene oxidation and leaching. They also demonstrate that substantial orebodies can crop out, as in the case of three known deposits, and escape detection because of a lack of any indication of mineralization.

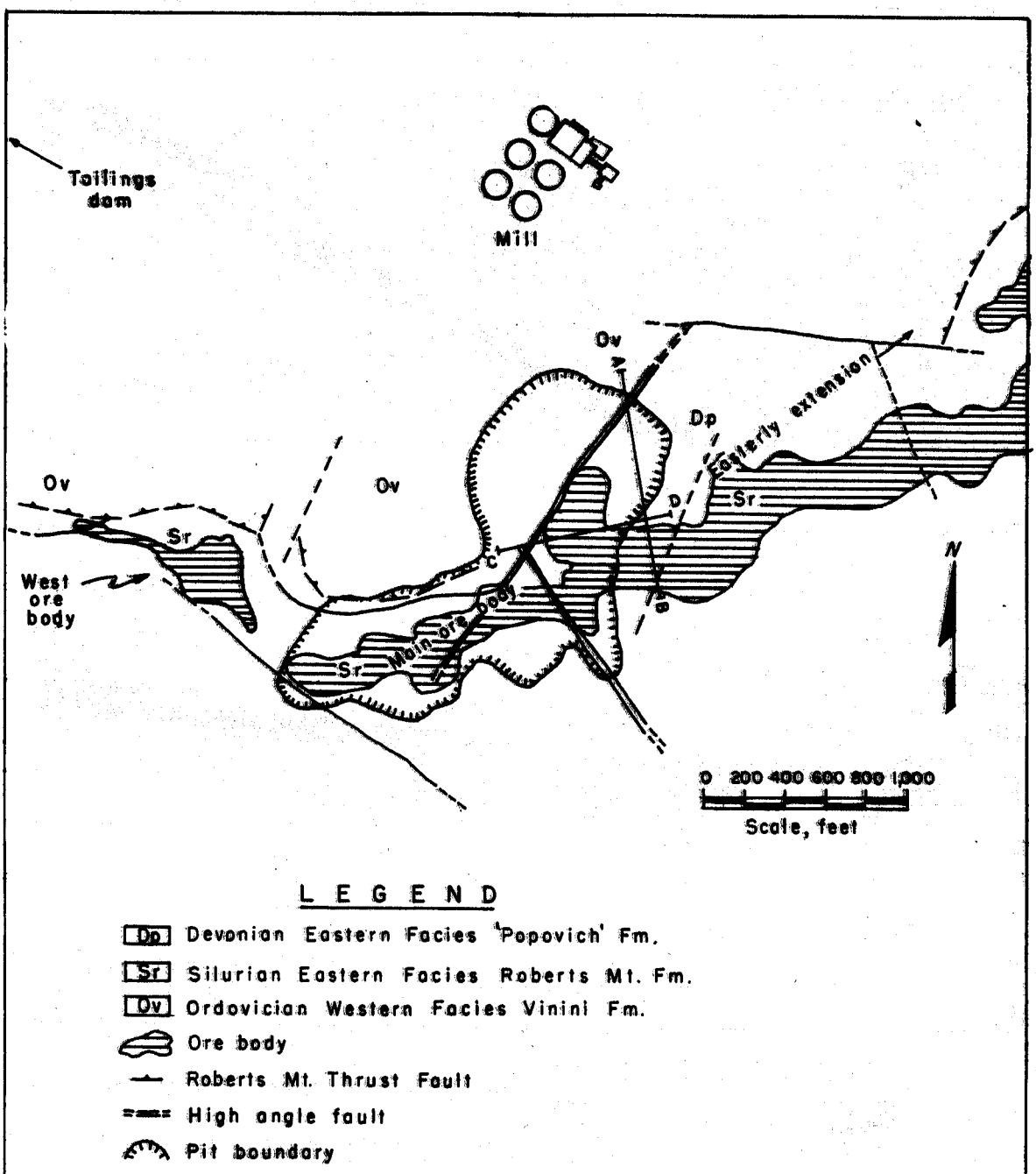
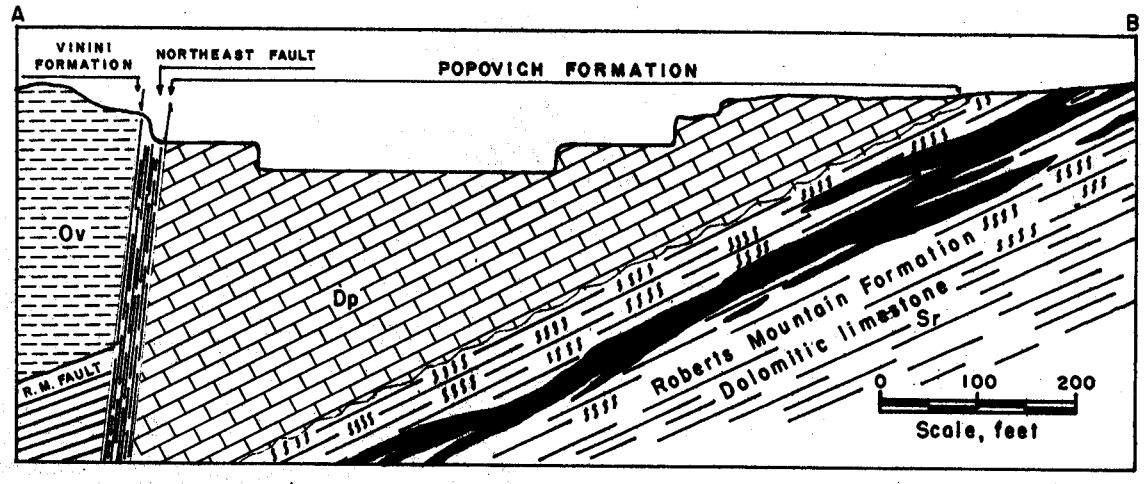
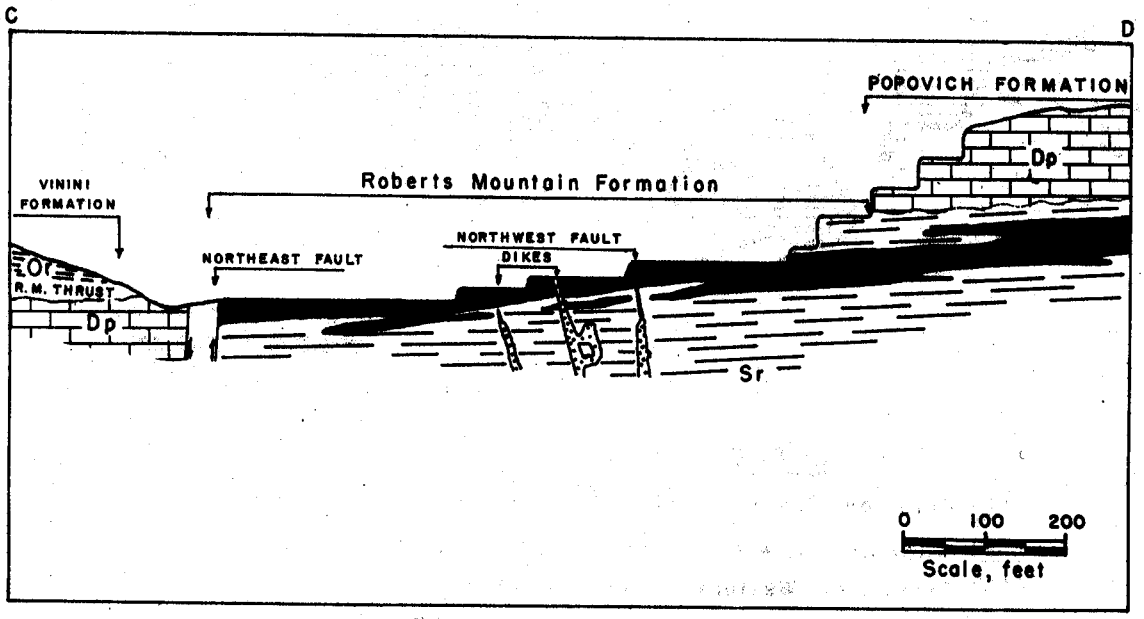


FIGURE 5.- Schematic Map of Carlin Mine.
(After Hausen (2))





LEGEND

Ore zone

Dp	Devonian Eastern Facies 'Popovich' Fm.
Sr	Silurian Eastern Facies Roberts Mt. Fm.
Ov	Ordovician Western Facies Vinini Fm.

FIGURE 6.- Cross sections of Carlin ore body.
(A-B above, C-D below) - Ref. Fig. 5.
(After Hausen (2))

ORE RESERVES

The known oxide ore reserves in the region are substantial. From published figures and information supplied by informed personnel, it is estimated that the proven and reasonably assured reserves of this type of ore amount to about 15 million tons, mostly amenable to open-pit mining. The grade of this ore will average 0.30 ounce of gold per ton.

In view of the recent recognition of this type of deposition, the rapidly advancing developments in geological knowledge and exploration techniques, and the intense exploration efforts on the part of industry, it is reasonable to expect that the reserves of oxidized ores will be substantially increased in the future. The responsible exploration groups are basing their substantial efforts on this expectation.

Reserves of carbonaceous gold-bearing material in the region are largely inferred because the refractory nature of the ore has discouraged drilling to determine their extent. However, it is the consensus of informed personnel in both government and industry that the tonnage will prove to be much greater than that of the oxidized ores. Some of this material will be exploitable by open-pit mining methods but the greater part will require development of suitable underground mining systems.

Compilation of data from various sources indicates a reasonably assured reserve of 20 to 30 million tons of auriferous gold-bearing material in deposits that will range in grade from 0.20 to over 1.00 ounce per ton. Inferences based on recent geological studies of the occurrence of these types of deposits indicate that the reserve of gold-bearing carbonaceous material in the region could total 100 million tons or more if projections are made below present drilling depths. There is no way to estimate the grade of this deeper material, but there is some indication that it may be of better grade than that from the upper zones.

MINING METHODS

Except for minor quantities of ore extracted by random open stoping and small glory holes at the Gold Acres mine, all of the sedimentary gold deposits in the region have so far been mined by open-pit methods, which are inexpensive because both the ore and the overburden have been relatively soft. This mining cost probably is no more than $0.20 per ton of material moved, including overhead.

The low unit-cost for mining has allowed high stripping ratios in the design of the open pits, with the inclusion of virtually all the known oxidized ores. The stratiform nature of the orebodies necessitates the removal of considerable tonnages of waste concurrent with mining. This tonnage must therefore be estimated in calculating the overall stripping ratio. Also, at depth the oxidized ore will be interbedded with carbonaceous material, thus adversely affecting the overall stripping ratio as applied to amenable ore. The net effect is that most pit designs will almost invariably leave under the "high-wall" of the pit beds of amenable ore that could only be recovered by underground mining methods.

No serious thought has been given to mining ores that cannot be handled by open-pit methods, although large reserves are known to exist. Most of these reserves are carbonaceous and if the metallurgy is solved, a satisfactory mining method will have to be developed to recover this material, some of which is of excellent grade.

Development of a satisfactory low-cost underground mining method for these deposits presents a challenge, as the ore bodies are stratiformed in inclined sedimentary beds, irregular as to shape, variable as to grade within short distances, and with incompetent ore and wall rock.

Geological evidence indicates that the deeper deposits may be less affected by post-mineral oxidation and weathering. If so, the competency of the rocks may be considerably better than is presently indicated in near-surface mine workings. Such a condition would increase considerably the probability of mining the deeper deposits economically.

METALLURGY

Gold ores from the sedimentary beds of northeastern Nevada fall almost entirely into two major classifications, oxidized and carbonaceous.

Oxidized ores are those from which the original carbonaceous or organic constituents have been removed by supergene leaching, weathering, and oxidation. They are amenable to treatment by cyanidation at low cost and with virtually no cyanide consumption by chemical reaction. Due to the high porosity of the rock and the submicroscopic nature of the gold, the dissolution of the gold is rapid, with high recovery, and without the need for fine grinding. One small operation simply crushed the ore to a 2-inch size, leached the material in tanks for 72 hours, and obtained a 75-percent recovery. The Carlin operation grinds the ore to below 35 mesh and dissolves 90 percent of the gold in the grinding circuit. From almost any standpoint the oxidized ores can be considered ideal to treat.

Carbonaceous materials are those from which the original carbonaceous or organic constituents have not been completely removed. Up to this time no method of treatment has been developed which is both metallurgically and economically satisfactory. These ores are extremely reactive with gold-bearing cyanide solutions, absorbing the gold ion almost as fast as the gold is dissolved. Furthermore, the carbonaceous constituents have a high absorption capacity because the admixture of even small portion of carbonaceous material with the oxidized ore in the cyanide circuit will "strip" the gold from the plant solutions in the grinding and agitation circuits, resulting in a partial or complete loss of gold recovery. Inasmuch as thin beds of carbonaceous material frequently occur within thick layers of oxidized ores this can create serious milling problems.

The carbon problem is not limited to the gold-bearing carbonaceous materials themselves; beds of original unaltered carbonaceous dolomitic limestone, which are not gold-bearing, may be found within the ore-bearing zones. At several properties, these barren carbonaceous materials absorb gold in the same manner as gold-bearing carbonaceous beds. Unless this material can be eliminated from the mill feed by selective mining, otherwise favorable oxidized ores will not be mined in some instances.

The original nature of the carbonaceous or organic constituents has not yet been clearly established, and their present nature and occurrence have been affected by weathering, leaching, and other chemical reactions. This has resulted in varying degrees of metallurgical reactivity, not only regionally but within the various deposits. A study of the metallurgy of carbonaceous material requires the selection of a proper suite of samples so as to be able to determine not only the general treatment requirements but the delineation of the particular problems that will exist in the region and/or deposits.

It has been found that roasting will oxidize the carbonaceous materials and render them non-reactive, but the temperature must be controlled within narrow limits and the treatment is expensive. At higher temperatures, the illitic clays in the ores, which by the very nature of the original gold deposition are in close contact with at least part of the submicroscopic gold particles, will fuse, and enclose the gold particles, sealing off the substantial part of the gold from contact with the cyanide leach solutions.

Several other methods for treating gold-bearing carbonaceous materials have been investigated over the past 25 years, including procedures which have proved successful with carbonaceous materials from other areas of the world, but they have not proved satisfactory in this case. It is evident that a major metallurgical breakthrough will be required if a satisfactory method is to be developed.

Researchers at the Bureau of Mines Reno Metallurgy Research Center, Reno, Nevada, have been conducting intensive investigations on the reasons for poor extraction of gold by cyanide treatment of carbonaceous ores. Using improved methods developed there, small laboratory scale experiments of aqueous chemical treatment and subsequent cyanidation show nearly complete recovery of gold. A series of experiments will be conducted simulating plant conditions to check out this procedure and its amenability to cyanide plants. Preliminary economic analysis by Bureau of Mines and mining company metallurgists indicates this is an attractive concept. Consideration of the chemical principles involved shows that this method of treatment of carbonaceous ores is promising and could be considered a breakthrough.

Metallurgically, three other minor types of ore occurrences have been noted, although so far as is known they will not be of economic importance. One type is where later silicification has enclosed gold particles, rendering them unamenable to cyanidation at any economic grind. In another, gold is associated with pyrite, and in a newly noted type, gold occurs with arsenic at depth.

ECONOMIC CONSIDERATIONS

Industry has not released information about feasibility studies, capital expenditures, or operating costs at existing facilities. However, an economic evaluation can be made, based on data accumulated from other localities by the Bureau of Mines, and taking into account known local conditions. Each property will have widely varying conditions and problems, so the estimates must be considered as general in nature.

Studies were made of a hypothetical open-pit operation with a stripping ratio of 4 to 1, with treatment in a conventional countercurrent cyanide mill. Two sizes of operations were considered with milling rates of 1,000 and 2,500 tons per day. Studies indicated that the smaller operation would not be attractive when employing conventional treatment processes unless the ore was relatively high grade.

Capital expenditures, including pre-production costs such as stripping, were estimated at $4,400 per ton of daily mill capacity for the larger operation. About two-thirds of this cost would be for the treatment plant and related facilities. For the smaller operation, capital expenditures were estimated to be not less than $5,500 per ton of daily mill capacity, and they could be higher.

Direct operating costs for the large operation, before allowances for depreciation, depletion, and Federal income taxes were estimated at $3.60 per ton of ore milled. For the smaller operation, these costs were estimated at $4.50 per ton milled. Unit costs for mining (per ton of material moved, combined ore and waste), would be about the same for the two sizes of operations.

However, the lower milling rate for the smaller operation would increase the millings costs by about 25 percent, while the general overhead costs for the smaller operation would increase by 45 to 50 percent.

On the cash flow basis, using standard rates for depreciation, depletion, and income taxes, the larger operation would have a pay-out period of about 2.4 years based on a milling rate of 900,000 tons per year and a recovery of $10.00 per ton. If the recovery is reduced to $7.00 per ton, the pay-out period would increase to 4.9 years.

For the smaller operation, the pay-out period would be 4.1 years, based on a milling rate of 360,000 tons per year and a recovery of $10.00 per ton. If the recovery is reduced to $7.00 per ton, the pay-out period would increase to 7.5 years.

The correspondingly longer pay-out periods associated with smaller operations, or those using lower-grade ores, would discourage investment. Major mining groups like to develop properties that have a pay-out period of no more than 5 years, and preferably less.

Lower unit-costs for treating oxidized ores could be achieved by a breakthrough in metallurgy that would allow for lower capital cost for a treatment plant, one that could be operated with less labor, and one that would require less maintenance. Suggested avenues of attack include research on heap leaching, in-situ leaching, and resin-in-pulp treatment.

Similarly, development of a low-cost method for treating auriferous carbonaceous materials would result in making available substantially increased tonnages of ore. The next economic barrier that will face industry in this region will be the design of suitable mining methods for the deeper deposits that cannot be mined by open-pit methods. These deposits probably will be mainly of the carbonaceous type.

OUTLOOK

Northeastern Nevada is one of the most favorable areas in the United States for the discovery of significant new gold deposits of a size and value to warrant exploration under present economic conditions. Factors favorable to new discoveries include the large area to be explored, and the favorable geological conditions for additional deposits.

One of the best indications of the potential importance of the area is the intense exploration activity by responsible mining companies and the secrecy surrounding their operations.

The obscure nature of the deposition, with a complete absence of surface mineralization, not only explains why such an important discovery as Carlin was overlooked for years but points out the difficulties experienced in exploration. Except for geochemical work at Cortez, geochemical and geophysical methods do not appear to have been of much help in the exploration, and emphasis has been placed on detailed mapping and the application of experience gained by highly skilled geologists who have continuously studied the special problems of the area. However, as the understanding of geochemical and geophysical relationships are better developed it is logical to expect that the usefulness of methods directed to them will increase.

Investigations underway by the Geological Survey and the various exploration groups should lead to a better understanding of the mode of occurrence of these deposits. Many important subjects being considered by these organizations, including the general geology of the area, the structural relationships associated with deposition, and the mechanism of gold deposition. In this latter respect, there are indications that the gold mineralization in presently known favorable beds will extend to much greater depths than previously postulated by the apparent low temperature type of mineralization. There is also some expectation that deeper stratigraphic horizons in the Silurian formations will prove productive.

The presently known deposits have proved to be, after discovery, of the most obvious nature, occurring within known well-defined windows, with the ore cropping out at the surface in beds that are now recognized as having definite alteration characteristics. As exploration continues, it is reasonable to expect that less obvious deposits will be discovered in windows that have not been opened to surface by erosion, and in less well-defined windows where the ore does not crop out, where the alteration effects are less pronounced or are masked by extreme weathering, or where post-mineral faulting has down-dropped the favorable sediments so that they are not exposed. There is a good possibility that favorable windows may lie beneath alluvium fill. In the case of the Cortez deposits, a large part of the ore zone extends below the valley alluvium, although the upper part is exposed. There is the further possibility that horizons favorable for deposition will be found to exist in the upper strata of the Silurian formation down dip along the flanks of the anticlinal structure formed by doming, too deep for exposure by present erosion.

The long-range future of the area will undoubtedly depend primarily upon the development of an economic treatment process for the gold-bearing carbonaceous material.

All indications are that the inferred tonnages and gold contents will greatly exceed those of the near-surface oxide ores. Informed personnel in industry state that they can conceive of no greater stimulation to the exploration effort in the area than a breakthrough in the metallurgy of treating the carbonaceous material.

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DEPARTMENT of the INTERIOR

ITEM 37

news release

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PROMISING NEW GOLD PROCESS UNDER PILOT-SCALE TESTING

Pilot-scale tests are under way on a metallurgical process which possibly could increase markedly the mineable gold reserves of the United States, the Interior Department's Bureau of Mines announced today.

Work on the promising process is being conducted at the Bureau's Reno (Nev.) Metallurgy Research Center, according to J. Cordell Moore, Assistant Secretary of the Interior for Mineral Resources. He said the development results from intensive efforts by the Department to find and make economically recoverable new resources of gold and other "heavy metals" such as platinum, silver, tantalum and tin--all of which represent immediate or near-future supply problems.

"If the pilot-scale tests indicate commercial feasibility, this will be a major technical breakthrough," Moore said.

The new process has been tested in laboratory experiments. It provides "nearly complete recovery of gold" from carbonaceous ores for which there is--to date--no known commercial method of treatment. The method is described as "an aqueous chemical treatment" of the ore before it is processed conventionally. Further details on the process will be made public, the Bureau announced, after the matter of foreign patent rights has been settled.

Deposits of carbonaceous ores occur in several areas of the West, including Nevada, Idaho and California.

"In Nevada alone," said Moore, "success with the Bureau's process could increase gold-producing potential severalfold, yielding enough to supply domestic industrial requirements for six or seven years at the present consumption level." By making possible economic treatment of so-called "carbonaceous" gold ores, it could boost the value of mineable ores in Nevada from a current $175 million to possibly more than $1 billion, at the price of $35 per ounce.

The gold content of the carbonaceous ores in Nevada is estimated at 10 to 30 million ounces, compared to the Nation's present known mineable reserves of 9.4 million ounces, obtainable from what are called oxidized ores, the Assistant Secretary said.

A detailed description of Nevada's gold ores and their potential for augmenting the Nation's supply of gold is given in a technical progress report of the Bureau of Mines made public by Assistant Secretary Moore. He said it is the first definitive economic appraisal of the State's potential gold resources to be prepared by the Bureau under the heavy metals program.

The report lists "known reserves" of 15 million tons of oxidized ore, now being mined and actively delineated. These ores, which can be economically processed with conventional techniques, average about a third of an ounce of gold per ton, for a total value of about $175 million.

The Carlin mine in Eureka county, Nev., developing the oxidized material, has produced $25 million in gold from 2 million tons of ore in its first three years of operation. It is now the second largest gold producer in the Nation. Another Nevada mine at Cortez, Lander county, about 40 miles southwest of Carlin, will start production this year.

Current mining activity in the area was stimulated by the Interior Department's Geological Survey, which pointed out the area's potential as a gold producer in 1961. The Geological Survey and the Bureau of Mines are working closely together in the Department's heavy metals program, Moore said.

The larger deposits of carbonaceous ores in Nevada have a gold content equal to or greater than that of the oxidized ores. Carbonaceous ores are estimated at more than 30 million tons and perhaps as much as 100 million tons "if projections were made below present drilling depths." Extraction of the deeper ores would, of course, require improved underground mining technology to keep costs comparable to those experienced with the surface mining methods currently used.

The new report, "Gold Resources in the Oxidized Ores and Carbonaceous Materials in the Sedimentary Beds of Northeastern Nevada" was written by Roland W. Merwin, mining engineer in the Bureau's San Francisco office. It also covers the history of gold mining in the area, the geology of the deposits, and mining and milling methods in current use.

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