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STERLING MINE JOINT VENTURE
ANATOMY OF A SMALL UNDERGROUND MINE & HEAP LEACH

February 1982

by I.S. Parrish*, G. Austin† & D.W. Kappes‡

INTRODUCTION

The Sterling gold mine is typical of the many small heap leach operations active in Nevada. The ore is composed of micron-sized gold particles unevenly disseminated in iron-stained sedimentary rocks overlying a major thrust plate. The gold is recovered from a heap leach by cyanide solution which is then passed through activated carbon. The carbon is later stripped by a caustic medium. The Sterling mine merits study as its history illustrates that small tonnage, moderate grade underground mines can be profitably worked.

LOCATION

As illustrated in Figure 1, the Sterling mine is located in western Nye County some 10 miles (16 kilometers) southeast of Beatty, Nevada. Physiographically, it is on the eastern flank of Bare Mountain adjacent to Crater Flat and the Nevada Test Site. Topography of the mountain is rugged with relief of as much as 2,000 feet (600 meters). The adjacent valley is gravel filled, broad and flat. The ore body is within the mountain, allowing access via the deeply eroded canyons. The main recovery plant is located on the relatively flat valley floor. The climate is arid and summer temperatures exceed 110°F (45°C).

HISTORY

Beatty has been an active mining area since the turn of the century. Most production has come from the bullfrog district west of Beatty. Prospectors of the time combed the Bare Mountain area and the so-called Panama shaft on the Sterling property dates from the 1910-1920 period; production there was negligible. Some ore was found in siliceous fillings of limestone caverns and in narrow quartz veins in dolomite. Gold has also been reported from other mines on Bare Mountain, such as Gold Ace and the Telluride.

Of more economic importance was the fluorspar production from the Diamond Queen, or Goldspar pit, adjacent to the Sterling mine. Most of production here occurred between 1958 and 1967.

In early 1973, John Livermore and Petter Galli of the Cordex Syndicate (Cordilleran Exploration), staked the Sterling claims to cover the Panama shaft and all the land extending from it north to the Goldspar group. After initial mapping and geochemistry, they drilled holes numbered 1 through 37, some of which encountered gold mineralization. The claims were optioned by one of the present authors, Greg Austin, for SAGA Exploration. Austin drilled 14 more holes establishing an apparent ore trend and drove a short adit to expose the ore. In 1979, Dan Kappes began to study the possibility of heap leaching the Sterling ore. Derry, Michener & Booth, Inc., and E & B Explorations, Inc., of Vancouver joined with SAGA in January of 1980 to provide financing and technical assistance via the Sterling Mines Joint Venture for development of the possible ore zone.

The adit was rehabilitated and underground advance began in April of 1980. Ore was stacked on a pilot pad and leaching began July 1, 1980. During the fall of 1981, the payback of all capital expenses was achieved. Drilling has extended the ore zone so that several years of additional production and profits are anticipated.

The success of the Sterling Joint Venture is, in part, due to the division of responsibilities amongst qualified professionals. The mining and everyday operation of the Sterling Mine is the responsibility of SAGA Explorations of Winnemucca, Nevada. They maintain a work crew of about 30 people under the direction of Jim Bossley, Mine Manager. The geology and exploration is directed by Derry, Michener & Booth, Inc., of Golden, Colorado. DMB has one full-time

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geologist at the site and provides additional geologists as needed. DMB also provides long range engineering input. Miller-Kappes, Inc., of Reno, Nevada, designed and carries responsibility for the recovery system. A representative spends about one week a month on the property and is on-call at all times. E & B Explorations, Inc., of Vancouver, in addition to providing the bulk of the financing, lends overall direction to the Joint Venture.

GEOLOGY

General

Bare Mountain is underlain by sedimentary rocks that range in age from Late Precambrian to Upper Mississippian. Paleozoic and later Cretaceous deformations have folded and faulted the sequence so that stragigraphic correlation is difficult. In addition, tertiary volcanic activity and associated faulting and subsidence complicate the geology.

The Bare Mountain area lies within the Walker "Lane," or lineament, which is 30 miles (48 kilometers) wide and strikes northwest across western Nevada (Figure 2).

The geology of the area is best described by Cornwall and Kleinhampl (1961) on the 15 minute Bare Mountain Quadrangle map and in the Nevada Bureau of Mines & Geology Bulletin No. 77, on Geology and Mineral Deposits of Southern Nye County (Cornwall, 1972).

Local

The rocks in the area of the Sterling mine are a series of light colored (gray, tan, orange) dolomites, siltstones and quartzites. The ore occurs principally in red siltstones of the Wood Canyon formation of the lower Cambrian age overlying gray dolomite of the Bonanza King formation. Earlier maps indicate the host unit to the Johnnie formation; however, the most recent studies (Cornwall, 1972) show the unit as Wood Canyon formation.

It should be noted that very small, but important gold concentrations are found in the Bonanza King dolomite and also that narrow dolomitic beds are present in the Wood Canyon formation. Also, although ore is predominantly found in red siltstones, gold has been mined from tan, gray, green and even white siltstones. The ore lies above the contact at a thickness of up to 35 feet (10.5 meters). Locally, gold mineralization extends as much as 15 feet (5 meters) below the contact into the dolomite of the footwall. In many instances a massive quartzite bed is present a meter or so above the ore.

The Wood Canyon/Bonanza King contact is thought to be a thrust contact because of the stratigraphic relation of the younger Bonanza King unit beneath the older Wood Canyon. The thrust relation is not at all certain as the stratigraphic correlation is tenuous and although in some places the contact itself appears sheared and broken, in others it is normal and undisturbed.

In the vicinity of the mine, the rocks are folded into a syncline. This fold can be traced in the mine workings and from drill hole data. It has a northeast trend and plunges gently to the south.

Ore Geology

Although several ore pockets have been located, only two have been worked. One, the main zone, has been the focus of activity, and the second near-surface enrichment has only received cursory attention up to this time.

The main zone is a shoestring body (Figure 3) that ranges from 50 feet (15.5 meters) to 150 feet (46 meters) width, up to 35 feet (10.5 meters) in height and is known to extend at least 2,000 feet (600 meters) in length. In longitudinal section, the zone plunges gently (10°) to the southwest, but rolls and pitches so that the development decline is flat in places and locally rises. In cross section, the ore body is roughly canoe or keel shaped, being thickest near or at its middle and thinning to both sides (Figure 4). The top of the body is generally flat. Note, however, that the cross section in any one area may be tabular, tilted or have abrupt, faulted edges.

The grade of the ore ranges up to several ounces over five feet (1.5 meters), but averages 0.25 ounces Au/ton. Silver content is negligible with a gold:silver ratio of about 30:1. There is little or no copper, lead or zinc. A very minor amount of stibnite and galena have been found. The alteration minerals of volumetric consequences are the iron secondaries (hematite, limonite and goethite), the clays and sericite. Pyrite is also present in small amounts and it is assumed that pyrite is the source of the iron.

The gold is present as flakes and particles to 4 microns in size, found with hematite and rimming calcite grains.

Although little work has been done on gold found outside of the main zone, the occurrences suggest similar controls and habits.

OPERATION

SAGA Explorations operates the Sterling mine. Jim Bosley is Mine Manager. He has a crew of about 30 people including 8 miners, 1 surveyor, 1 foreman, 2 assayers, 2 truck drivers, 1 clerk, 5 laborers, 2 samplers, 2 shift bosses and 5 mechanics.

The surface plant, excluding the recovery plant which will be discussed in detail later on, consist of an office trailer, an assay trailer, warehouse and machine shop trailers, a Deutz 50 KVA generator and a 600 cfm compressor. Rolling stock, excluding pickups, includes a 22 ton dump truck, a 7,200 gallon, (27,250 liter) water tanker, two 4 yard (3 m^3) front-end loaders (a Cat and a Terex), a Case 1⅛ crawler loader and a small 8 foot (2.4 meters) Basic grader.

Water is a major concern. The Sterling at present buys its water from the town of Beatty. An average of 9,000 gal/day (34,065 liters/day) in the winter and 15,000 gal/day (56, 775 liters/day) in the summer is trucked to the mine site. About 20% is stored in a tank above the workings for use underground and the remainder is used at the recovery plant.

The mine is worked on a 2-shift basis. Underground equipment includes a Secoma hydraulic drill ATHE 12, 2 Elmac 5250 loaders, 3 Elmac trucks (two DIOs and one D5), pneumatic drills, etc. The Secoma is an entirely hydraulic unit. Elmac units were chosen because of their parts standardization (interchangeable engines, transmissions and drive-trains). Split-set rock bolts installed on 4 foot (1.2 meters) centers have proven to be the most suitable for ground support especially when augmented by wire screening. The rock bolts are installed using jack-legs. Ventilation is provided through two vent raises. Two fans, one 6 foot (1.8 meters) diameter 50 hp and one 36 inch (0.9 m) diameter 50 hp, have been installed.

The general mining method has been modified room and pillar with an occasional shrinkage stope. The mine was developed via an 8 foot (2.4 meters) x 10 foot (3 meters) decline. This drive was positioned so that as to lie in the lower central part of the ore body. As drill data was sparse the drive has not always been ideally located, nonetheless, it is essentially a central footwall drift. From this drift crosscuts were driven to the edges of the ore body at approximately 75 foot (23 meters) intervals. The crosscuts leave the main drift at nearly right angles and were driven so as to keep the footwall ore contact in the lowest part of the face.

Directional and control of the headings was supplied by visual and sample data, by previous drill hole data and in some cases, by long hole information. Samples were taken of every face. Vertical rib samples were also taken of both walls at 5 foot (1.5 meters) intervals.

The samples were analyzed on-site at a company owned and operated atomic adsorption unit.

The ore zone plunges steeply south from a point midway along its length. At this point the central drift was halted and east and west fringe drifts were driven at the edges of the ore body. These drifts connected the crosscuts and divided the body into “rooms.” Stoping of these “rooms” by slashing has begun. The first stope recovered a higher grade section between crosscuts 3 and 4 west (Figure 5). A 25 hp Joy slusher was required to bring the ore down to the central haulage drift.

A second stope was started between crosscuts 8 and 11 east in low grade ore (Figure 6). Slashing here has shown that the wall rocks can be supported by rock bolts and screening and that 60% of the ore can be retrieved on a first pass with rubber tired LHD equipment. Further stoping is underway with present plans calling for making the western fringe drift the main haulage. Mining will proceed from south to north and from east to west. Future work will include driving below the ore pillars and eventual recovery of the pillars through finger raises.

The broken and sheared siltstone ore drills and breaks easily. The Secoma drill can complete 1.5 rounds per shift, with about 28 holes in each face. Break is about 9 feet (2.7 meters) per round. The broken ore is transferred into an Elmac truck for haulage to surface. During the development phase, rate of production was 100 tons/day. This will be increased to 250 tons per day during the stoping phase.

On Surface, the ore is crushed to 3-inch (7.6 centimeters) size in a 24-inch x 36-inch (6.1 centimeters x 91.4 centimeters) jaw crusher prior to being trucked to the pads for leaching.

HEAP LEACH DESIGN

Initial test work on fine-crushed ore indicated that there would be no percolation or chemical problems. The ore was competent enough that the heaps could be driven on by trucks and end loaders while being constructed, with only minor effects on solution flow. Very soft unsilicified ore yields 90% recovery in two weeks of laboratory leach testing, while the bulk of the ore is moderately silicified and yields 70-75% of its fire-assayable gold in six weeks of field leaching, when crushed to 2-inches (5 centimeters).

To confirm the lab test data, and to provide early reassurance to the investors, a mini-production heap of the first 3,000 tons of ore was stacked ten feet (3 meters) high in two 5 foot (1.5 meters) lifts and leached using a temporary carbon column recovery circuit. Recoveries from this heap verified lab tests and heap size has gradually been increased to the present 15 foot (4.6 meters) to 17 foot (1.5 meters) height.

The current production heaps are located on a large alluvial fan about three-fourths (1.2 kilometers) of a mile below the mine. To prepare a leach area, vegetation is removed and contours are smoothed by cutting and minor filling using a bulldozer. A thin layer of gravel is spread to cover rough areas of the prepared surface and then a 30 mil thick PVC pad is installed by the mine crew.

This pad is covered with 6-inches (15 cm) of gravel screened to ¾-inch (2 cm), which is made in an on-site screening plant from alluvial fan material. To insure good drainage, 4 inch (10 centimeters) diameter perforated polyethylene pipe is installed parallel to drainage, on 8 foot (2.4 meters) centers within the gravel cover. This pipe is manufactured in 200 foot (61 meter) long rolls, making installation very simple.

HEAP CONSTRUCTION

The ore heaps are built on the pads in modules of about 12,000 tons each and are predominantly left on the pads. New heaps abut directly against older heaps so as to cover the old heap side slopes. Eventually, the leaching area will appear to be one large continuous heap.

The ore is stacked on the 15 foot (4.6 meters) high heaps in three 5 foot (1.5 meters) high layers, to minimize segregation. A ramp of waste rock is built behind the heap up to the height of the layer constructed. Trucks drive up onto the top of the layer and dump their loads and a bulldozer pushes the material over the leading edge of the heap. When a layer is completed it is thoroughly ripped, and thereafter no truck traffic is allowed upon it. Once the third layer is completed, leaching is begun.

HEAP LEACH DESIGN

Solutions are sprayed onto the heaps 10 to 16 hours per day (during dayshift and evenings) at a rate of 70 gallons per minute (265 liters/minute), or approximately 0.003 gallons per minute per square foot (0.0209 ml/s per square meter). Because of the high assay grade of the ore and the hot, sunny climate, care is taken to ensure good sideslope irrigation. Solution is applied using Bagdad wigglers with 3/16-inch (5 millimeters) I.D. tygon tubing, spaced on 9 foot (2.7 meters) centers. Senniger wobbler No. 8 sprinklers, spaced on 27 foot (8.2 meter) centers are now being tried successfully on the top surfaces, though Bagdad wigglers will be maintained on the side slopes. Addition of 0.12 gallons (500 milliliters) per day of Barochem S-35 to the barren ponds has almost eliminated scaling of the sprinkler heads.

The leach solutions contain 0.5 to 1.0 grams sodium cyanide per liter. Sodium hydroxide is available for pH control, but the rock appears naturally alkaline and is seldom added.

Water for the operation is hauled 23 miles (37 kilometers) in a 7,200 gallon (27,250 liter) tank truck from the town of Beatty. Evaporation rate on hot summer days is 30 percent of solution sprayed, or about 10,000 gallons (37,850 liters). An additional 5,000 gallons (18,925 liters) per day is required to saturate the ore. The water is high in fluoride and chlorides. These are not affecting the leaching or carbon adsorption behavior, but they are the apparent cause of very high corrosion rates on anodes within the stripping plant.

Pregnant solutions exiting a new heap run 60 milligrams per liter (ppm) gold or higher and remain above 3 ppm during most of the time it takes to reach 70% recovery. Each of the 12,000 ton heap leach modules drains to a separate pond and countercurrent leaching of older heaps is planned to begin in late 1981. This will permit very high recovery while maintaining flow rates through the recovery plant.

GOLD RECOVERY

The gold recovery plant encompasses several unique features, including the following:

- Up-flow, non-fluidized columns
- Permanent residence of the carbon in the columns throughout adsorption, desorption and acid washing cycles
- Plastic (PVC) pipe construction in the gold stripping circuit
- Priming of all centrifugal pumps with a Mayno positive displacement pump

The complete plant is housed in a 40 foot (12.1 meters) semi-trailer. Included within the trailer are four 36 inch (0.9 meters) diameter insulated carbon columns, a power supply and electrolytic cell, two pregnant solution pumps (one for normal operations and a second for occasional fluidization of the carbon), a totally enclosed acid wash system, and a sink with a counter for handling electrolytic cell cathodes. Immediately adjacent to the trailer is an 800 gallon (3,028 liter) insulated tank for strip solution storage, heated with 21 kilowattss of electrolytic immersion heaters. The cost of the system was $50,000.

COLUMN OPERATION

Each of the four columns is 36 inches (0.9 meters) in diameter, 7 ½ feet (2.3 meters) high, and contains 1,000 pounds (455 killigrams) of 6 x 12 mesh Calgon type PCB carbon. The four columns are arranged in two parallel sets of two columns each. 60 to 80 gallons per minute (275-365 liters/minute) flow upward through the first column in the in the set at the rate of 8 to 12 gallons per minute per square foot (335-505 liters/minute per square meter). A special fluidization pump is used to raise the flow-rate to 17 gallons per minute per square foot (867 liters/minute per square meter) once every few days. Inflow solutions commonly contain in excess of 20 parts per million gold and exit the second column to the barren pond with levels of 0.2 to 0.5 parts per million of gold.

GOLD STRIPPING

Once gold levels in barren solution climb to above 0.5 parts per million, a column set is taken off-line by switching valves and the alternate set is placed on-line. Gold is then stripped from the carbon in the off-line set using hot alkaline alcohol solution (83°C, 20% ethanol, 1% NaOH) at a flowrate of 8 gallons per minute (30 liter/minute). Addition of sodium carbonate to the strip solution appears to greatly speed up the process and to significantly reduce corrosion. It is also important to calculate alcohol additions on the assumption that the carbon will absorb 12% of its weight in alcohol. The strip cycle is about 12 hours and is preceded by a 2-hour carbon preheating period in which solution is pumped through the carbon then back into the heating tank. Strip solutions sometimes attain peak gold contents exceeding 5,000 parts per million.

The electrolytic cell is a rectangular 30 gallon (114 liter) polypropylene tank containing eight stainless steel anodes on 3.5 inch (9 centimeters) centers and seven steel wool cathodes measuring 18 x 18 inches (46 centimeters x 46 centimeters). Solution flows up then down between alternate anodes and the cathodes are made to provide ¼-inch (0.6 cm) of free solution flowspace between the cathode and the anode.

The cell is run at 400-600 amps and up to 9 volts (with no anode corrosion, voltage is usually about 4). Current efficiency for the first several hours of the strip is 40% – 70% and gold recovery per pass is 75%.

Regardless of the current density, anode corrosion is severe. This is attributed to the buildup of chlorides and fluorides on the carbon from the field heap solution, and could possibly be alleviated by a deionizing water wash prior to stripping. Mild steel anodes are unusable after one strip cycle. Type 316 stainless anodes have to be cleaned after each cycle and replaced every four cycles. A titanium anode is being tried.

MELTING

The wet cathodes from the electrolytic cell are immediately transferred to a Denver No. 4 titling hearth furnace. The iron is fluxed off using sodium nitrate. The product of this single stage melt is a dore button assaying 950 fine or better.

ACID WASHING

Following stripping, the carbon in the columns is fluidized with heap solution and then acid washed in a closed-pumping cycle with dilute HCL until the pH stabilizes below 2.0. The acid wash solution is then neutralized with NaOH prior to being discharged to the barren pond. The columns are again fluidized until the effluent is clear and then they are ready to be placed back on line. After eight months of continuous operation during which the carbon has never been removed from the columns, they are showing only minor signs of channeling and activity loss.

CONCLUSION

The Sterling ore body was not exposed on the surface. It is too small and linear to be amenable to open cast mining. Yet, as a result of prudent exploration, efficient underground development and the application of low cost heap leaching technology, the ore body has begun to yield a profit to its owners. The Sterling story is a testimony to the fact that small scale mining is alive and well in the United States.

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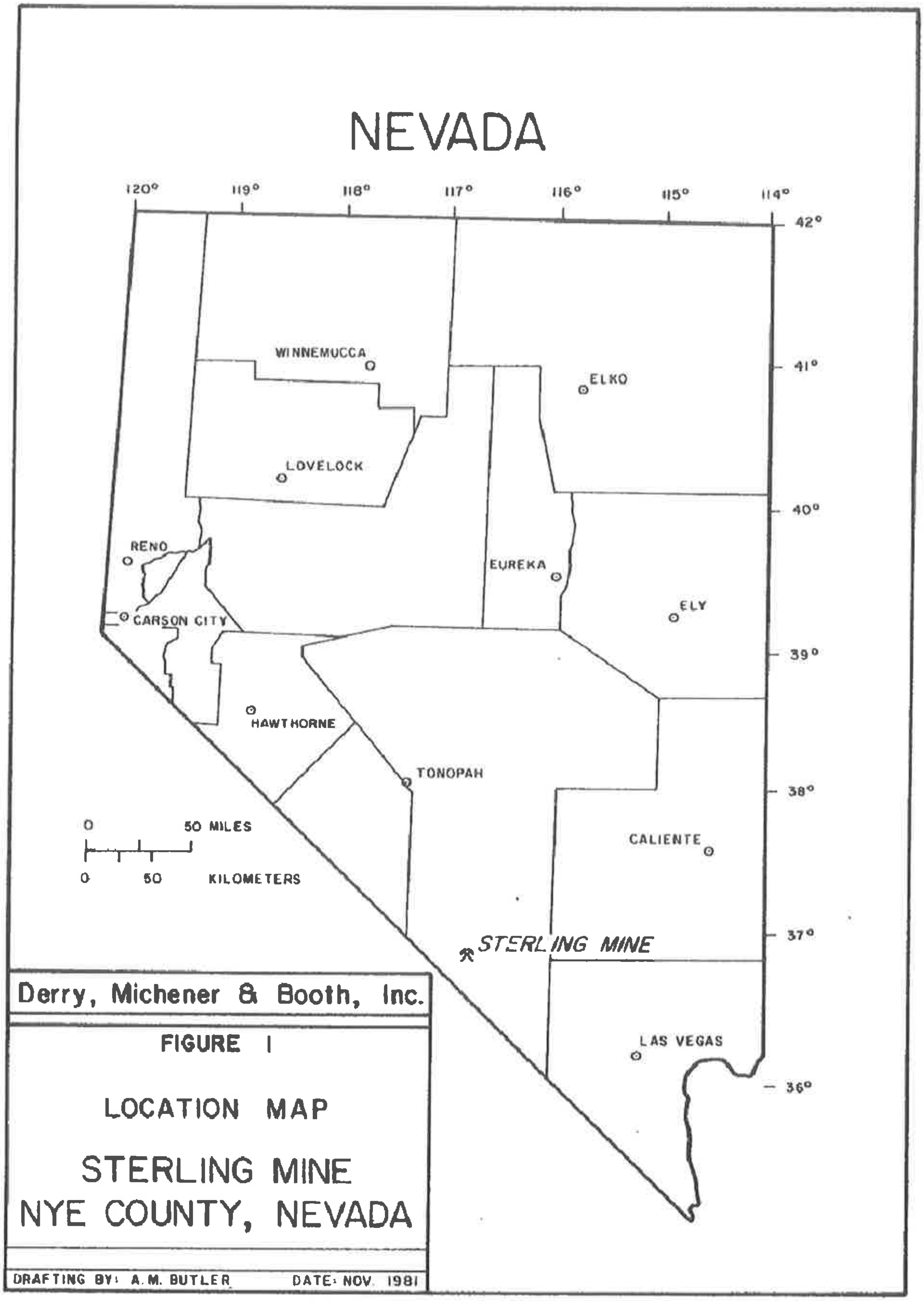
Cornwall, H.R., and Kleinhampl, F.J., 1961, Geology of the Bare Mountain quadrangle, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ-157.


NEVADA
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
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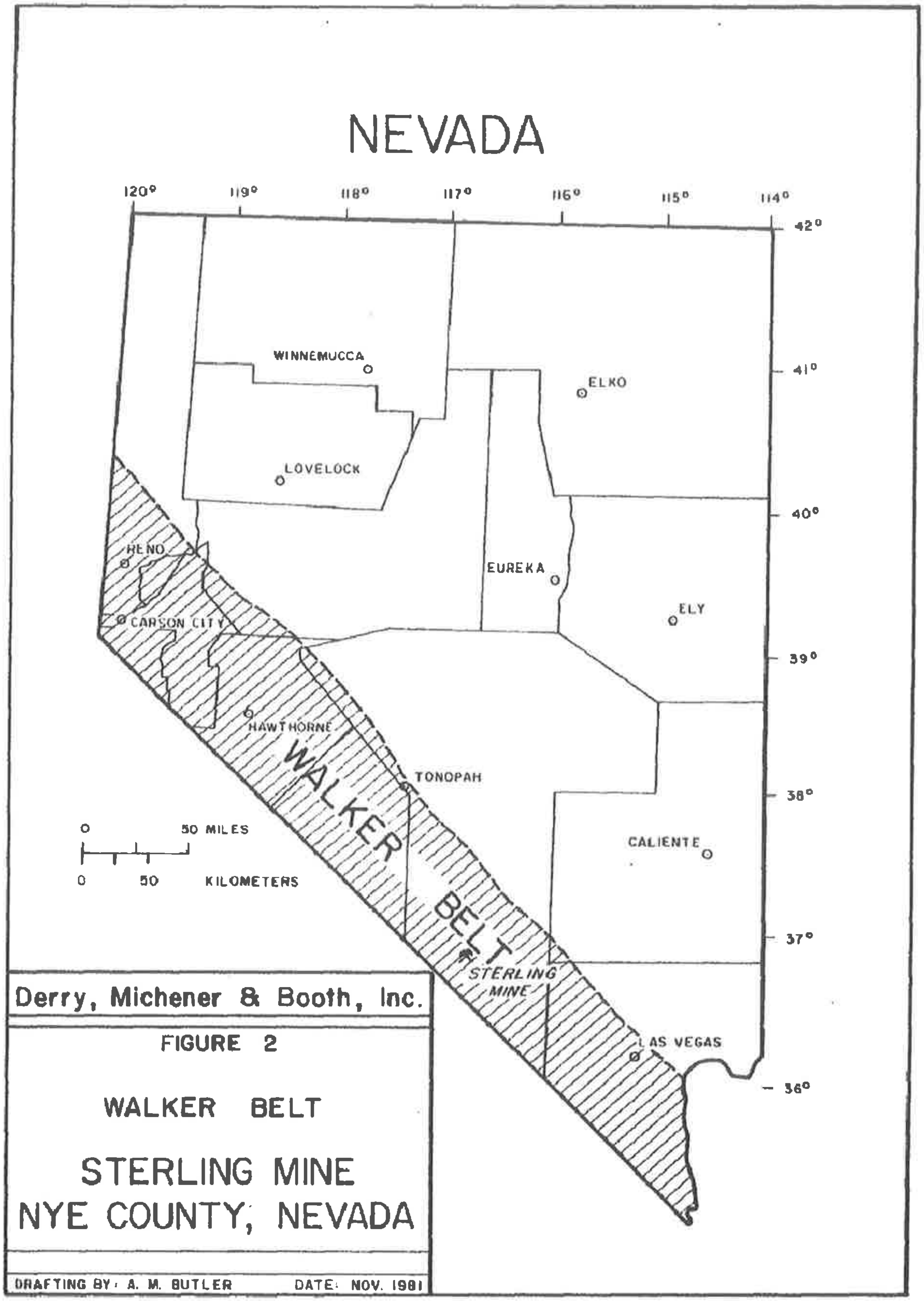
37°
36°
WINNEMUCCA
ELKO
LOVELOCK
RENO
EUREKA
ELY
CARSON CITY
HAWTHORNE
TONOPAH
CALIENTE
STERLING MINE
LAS VEGAS
0
50 MILES
0
50
KILOMETERS
Derry, Michener & Booth, Inc.
FIGURE 1
LOCATION MAP
STERLING MINE
NYE COUNTY, NEVADA
DRAFTING BY: A.M. BUTLER
DATE: NOV. 1981



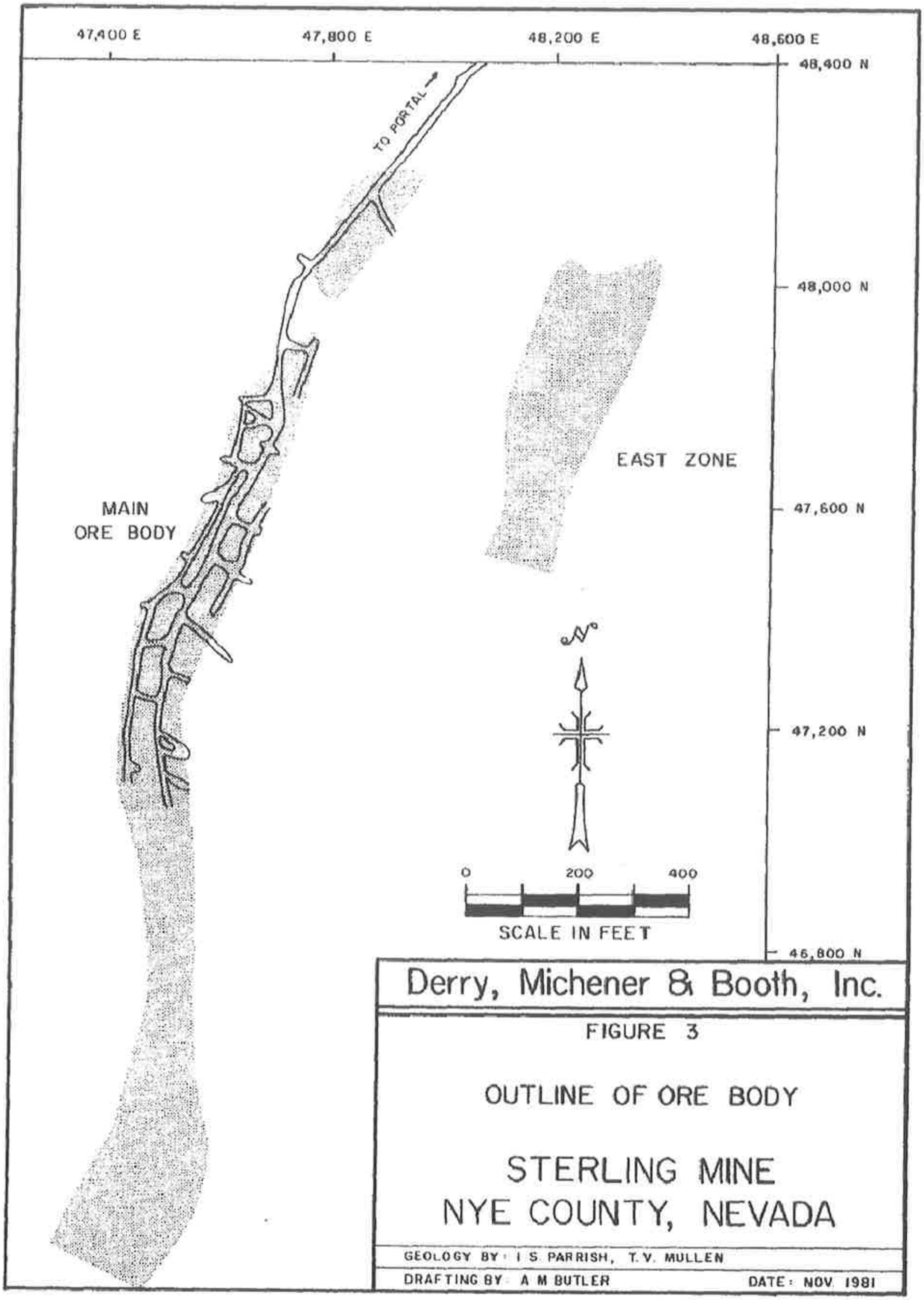
Derry, Michener & Booth, Inc.

FIGURE 2

WALKER BELT

STERLING MINE
NYE COUNTY, NEVADA

DRAFTING BY: A. M. BUTLER DATE: NOV. 1981


47,400 E
47,800 E
48,200 E
48,600 E
48,400 N
48,000 N
47,600 N
47,200 N
46,800 N
TO PORTAL
MAIN
ORE BODY
EAST ZONE
0
200
400
SCALE IN FEET
Derry, Michener & Booth, Inc.
FIGURE 3
OUTLINE OF ORE BODY
STERLING MINE
NYE COUNTY, NEVADA
GEOLOGY BY: I S. PARRISH, T.V. MULLEN
DRAFTING BY: A M BUTLER
DATE: NOV. 1981

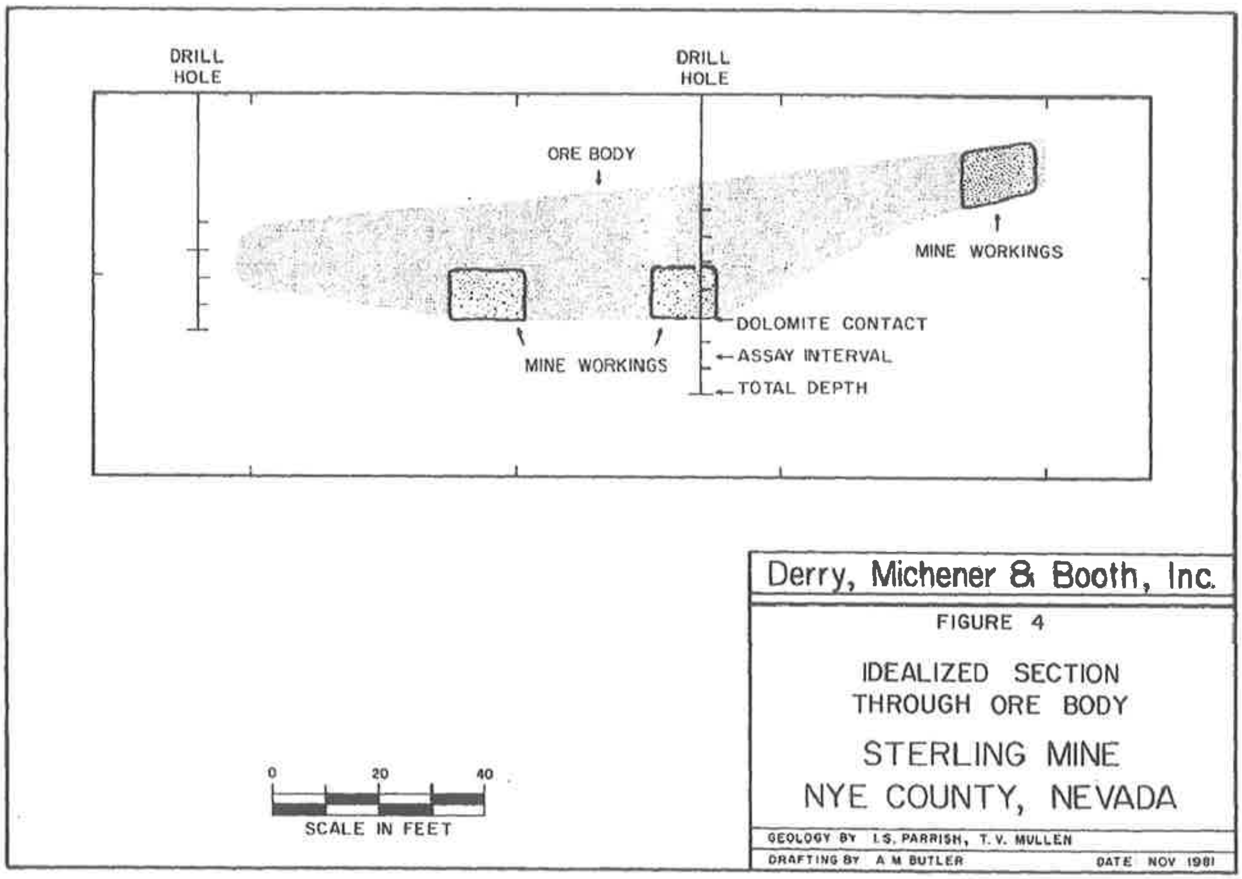
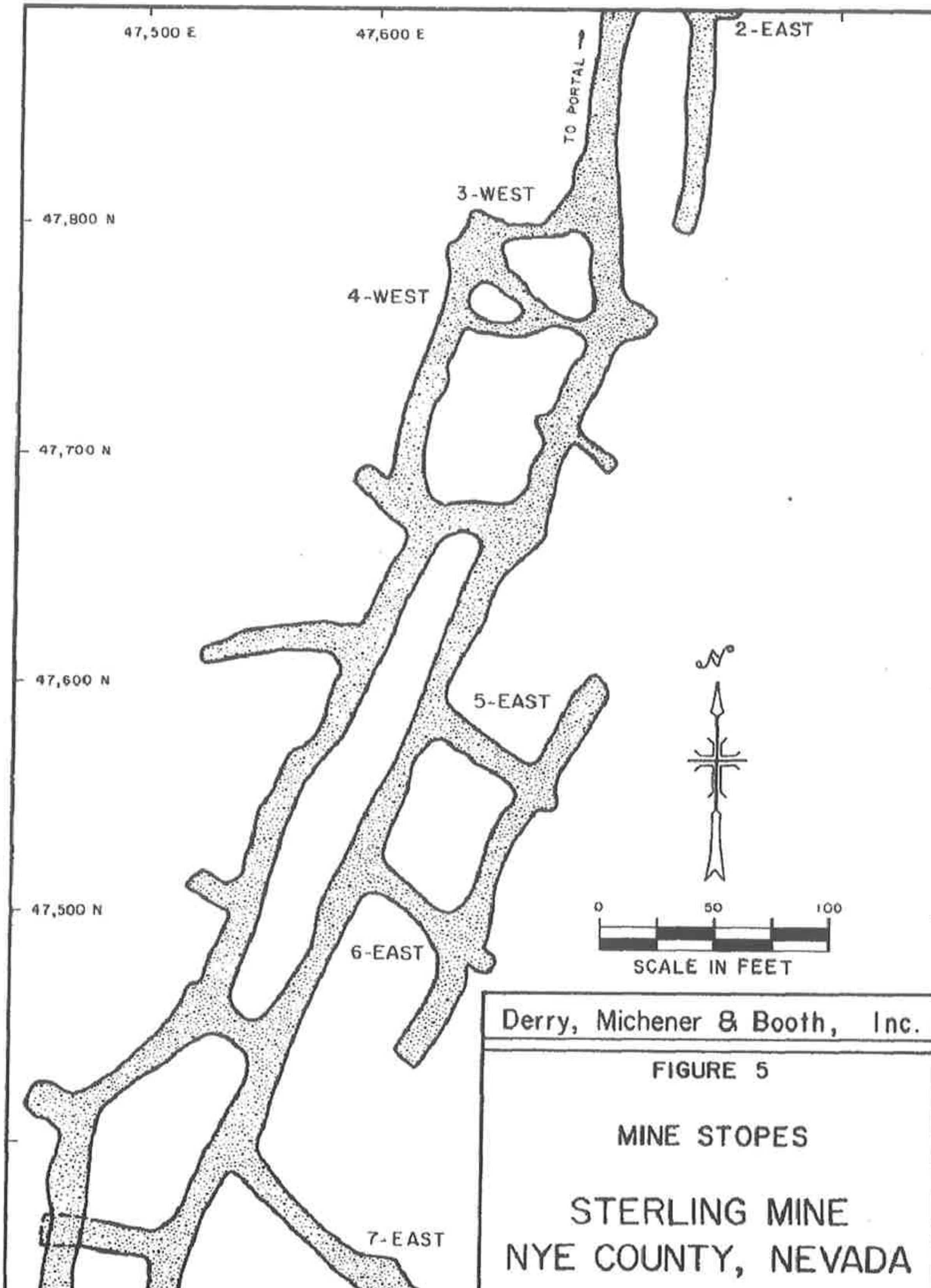
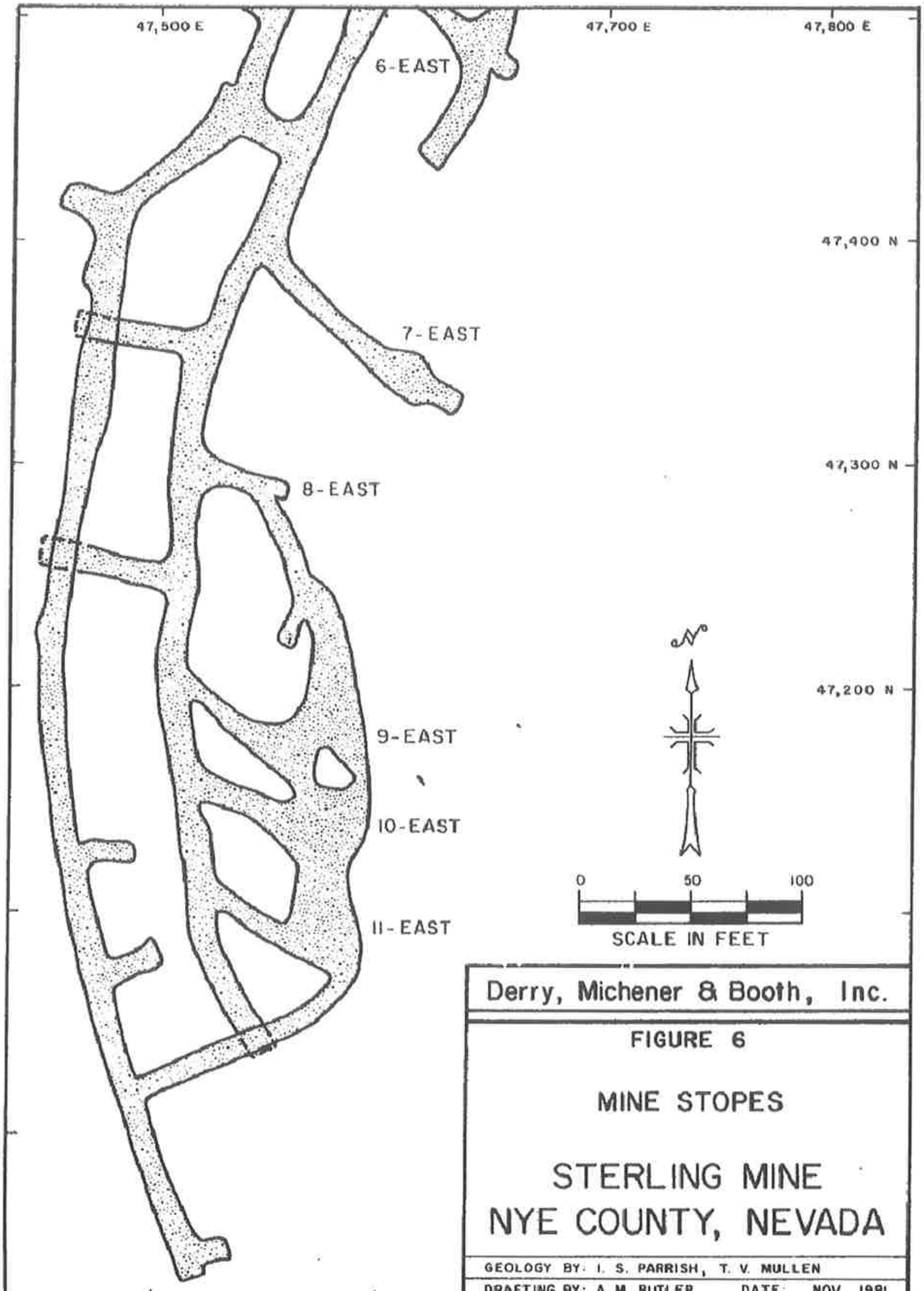


FIGURE 4

IDEALIZED SECTION THROUGH ORE BODY

STERLING MINE
NYE COUNTY, NEVADA


47,500 E
47,600 E
TO PORTAL
2-EAST
3-WEST
47,800 N
4-WEST
47,700 N
47,600 N
5-EAST
47,500 N
6-EAST
7-EAST
0
50
100
SCALE IN FEET
Derry, Michener & Booth, Inc.
FIGURE 5
MINE STOPES
STERLING MINE
NYE COUNTY, NEVADA
GEOLOGY BY: I. S. PARRISH, T. V. MULLEN
DRAFTING BY: A. M. BUTLER
DATE: NOV. 1981


47,500 E
47,700 E
47,800 E
47,400 N
47,300 N
47,200 N
6-EAST
7-EAST
8-EAST
9-EAST
10-EAST
11-EAST
N
0
50
100
SCALE IN FEET
Derry, Michener & Booth, Inc.
FIGURE 6
MINE STOPES
STERLING MINE
NYE COUNTY, NEVADA
GEOLOGY BY: I. S. PARRISH, T. V. MULLEN
DRAFTING BY: A. M. BUTLER DATE: NOV. 1981

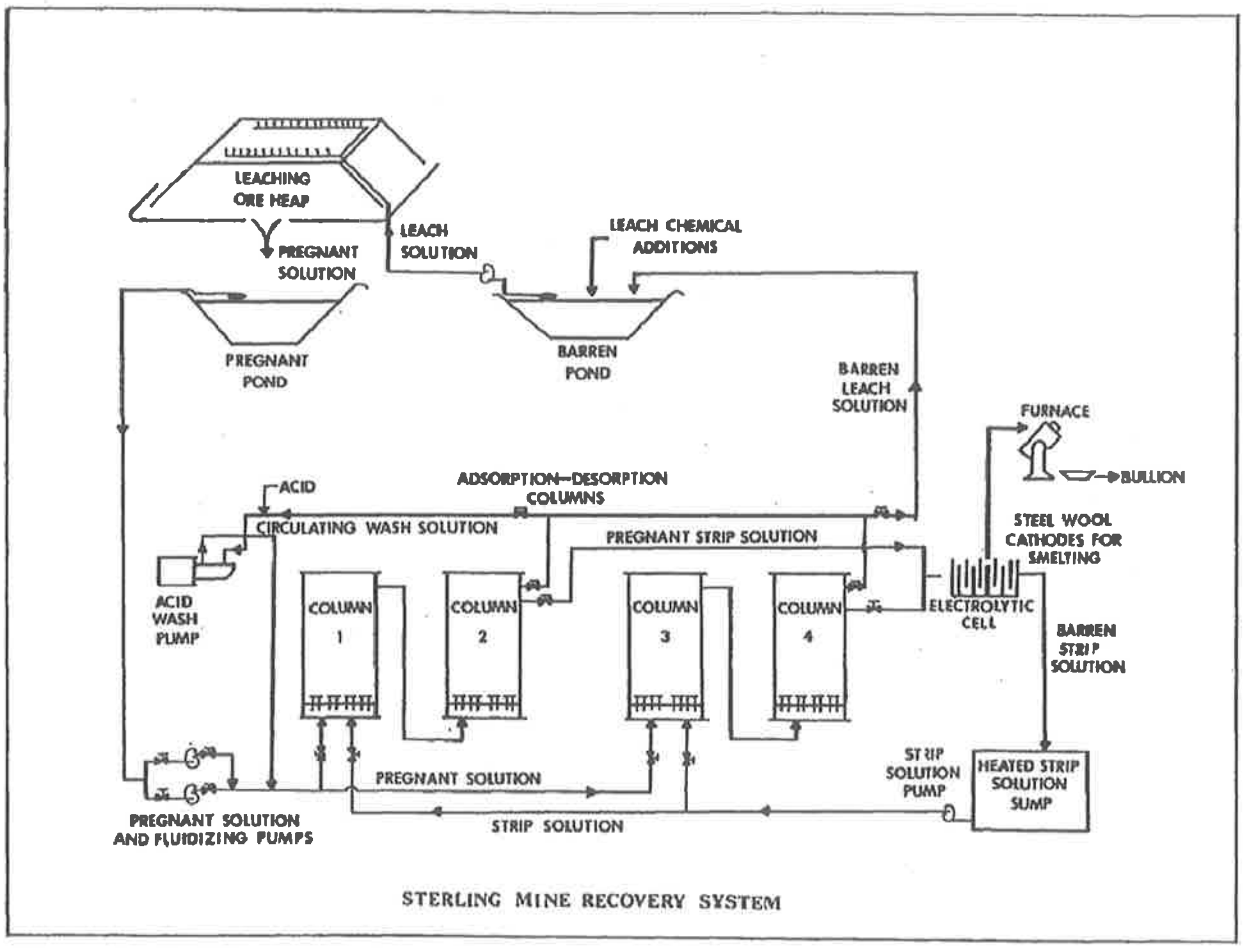


Figure 7. Sterling Mine Recovery System.

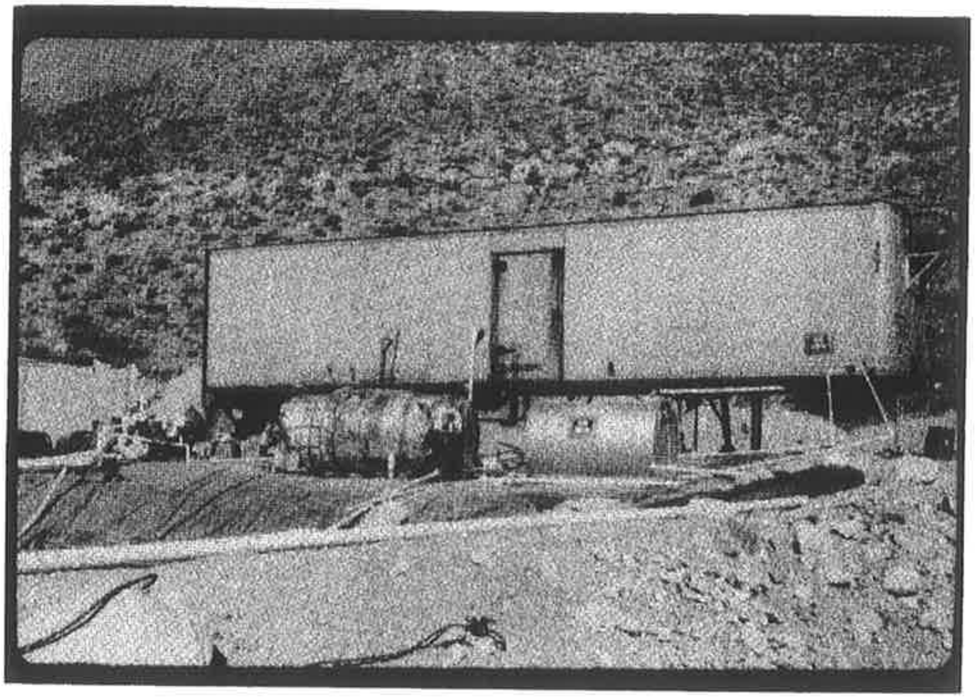


Figure 8. The heap leach system is designed for quick-leaching, high-grade gold ores at the rate of 300 tons of ore per day. Each 12,000 ton heap leach drains to a separate pregnant pond, which allows countercurrent leaching to extract the last traces of gold from the ore.

Figure 9. Heaps of 12,000 tons each are built, 15 feet high, atop gravel-covered PVC pads. Lots of land is available on the alluvial fan below the mine.

Figure 10. Heaps are built in three 5-foot lifts. The heap in the background will remain under leach for at least two months. The first layer of the adjacent heap is under construction in the foreground.

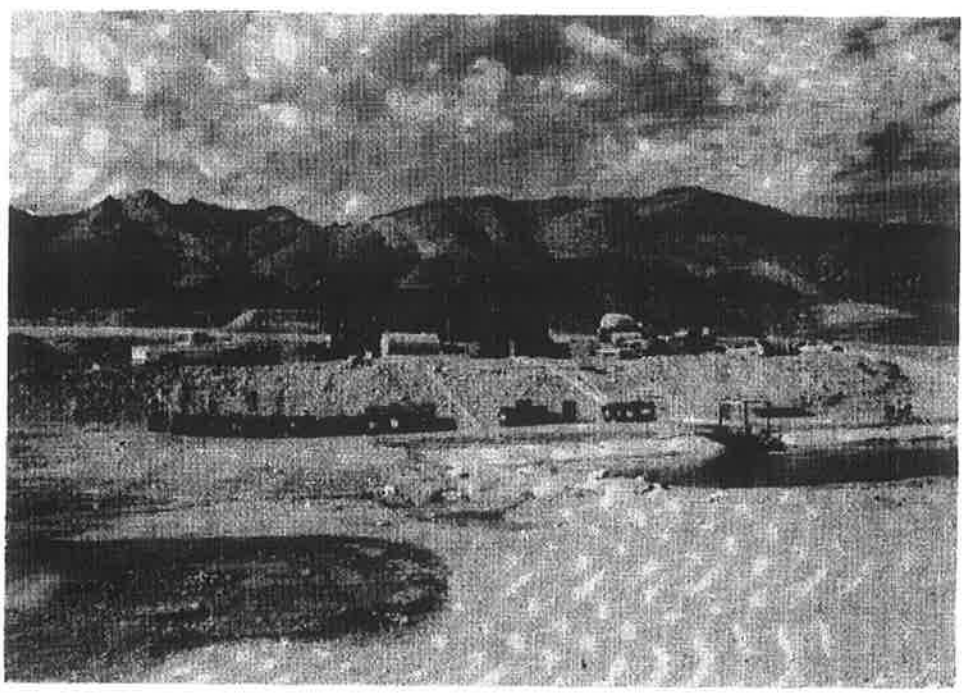


Figure 11. Individual pregnant ponds are below the heaps. From there, solution is pumped through the recovery trailer, and is then discharged to the barren pond in the right foreground. Solid caustic soda and cyanide are manually added to the barren pond before solution is recycled to the heaps.

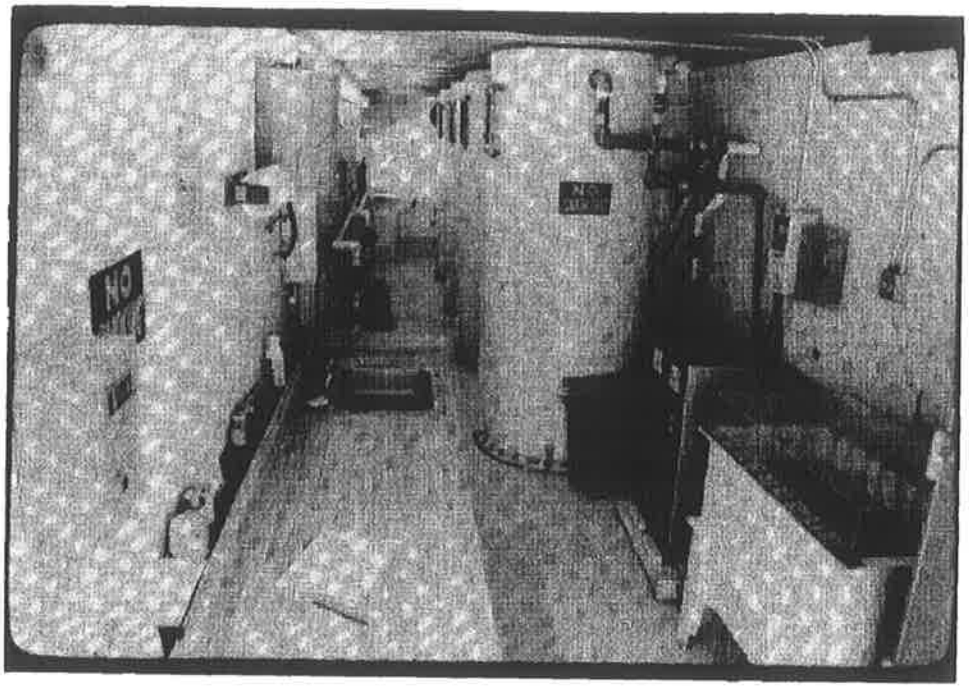


Figure 12. The recovery trailer contains four recovery columns holding 1000 pounds carbon, each. All construction was done in Reno, and then the system was transported 700 miles to the project site. Key features include insulated adsorption/stripping columns and a rectifier/electrolytic cell system for in-place recovery of gold.