FIELD NOTES FROM THE ARIZONA BUREAU OF MINES

Vol. 7 No. 2 — Earth Sciences and Mineral Resources in Arizona — Summer 1977

We're Changing Our Name!

Summer 1977 FIELDNOTES will be the last publication from the Arizona Bureau of Mines. On August 27, 1977, our name will change, our organizational format will be revised, and our duties updated.

Governor Raul Castro signed House Bill 2060 on May 26, which changes the Arizona Bureau of Mines into the Bureau of Geology and Mineral Technology, and revises the original 1915 charter. The main points of HB 2060 are:

New name: Bureau of Geology and Mineral Technology

The Bureau's new name better describes the actual function of this agency. As the Arizona Bureau of Mines, our geological survey and research functions were not easily recognized by those to whom we could be of service.

Division of the University of Arizona

Under the new charter, the Bureau is a division of the University reporting directly to President Schaefer. Previously, the Bureau had been a department, but in theory reported directly to the Board of Regents; in practice, though, the Bureau had been under the direction of the University President since 1918.

Director's qualifications changed

The Bureau's Director, under the 1915 laws, "must" be a mining engineer. House Bill 2060 changed this to include geologists and geological and metallurgical engineers, and to require registration by the Arizona Board of Technical Registration.

Two separate branches created

The dual roles of the Bureau were emphasized by the official creation of a Geological Survey Branch and a Mineral Technology Branch. An assistant director is to be appointed to head each branch: a registered geologist or geological engineer will head the Geological Survey Branch, and a registered mining or metallurgical engineer will head the Mineral Technology Branch. In addition, the assistant director in charge of the Geological Survey will officially become the State Geologist.

Goals and duties updated

The Bureau's goals were redefined in keeping with other state geological surveys. In brief, our duties now include:

1. The investigation, description, and interpretation of the geology of the State, including natural hazards and mineral resources.
2. Conducting research into the exploration, mining, and processing functions of mineral resource production.
3. Publishing the results of our research and investigations.
4. Providing lectures, displays, and exhibits to the public.
5. Maintaining a central repository, or library, of geological and mineral technological publications, and making it available to the public.
6. Maintaining a well cutting and core repository.

We already supply all of these services, although our 1915 charter did not make specific allowance for them.

According to that charter, though, our duties included the maintenance of a "mine rescue car" and the teaching of first aid and safety classes. The State Mine Inspector's office, since its inception, has carried out the safety functions, and we have not been able to locate or identify a mine rescue car during the 62 years of our existence.

Bureau Studies Olivine Resources On San Carlos Apache Reservation

by John S. Vuich and Richard T. Moore

This article is extracted from a recently completed report compiled by the ABM in cooperation with the University of Arizona Office of Arid Lands Studies. The project was undertaken at the request of the San Carlos Apache Tribe.

The objectives of the study were fourfold:

1. Evaluate the source materials, an olivine-rich basalt flow on Peridot Mesa.
2. Suggest efficient methods of mining and beneficiation.
3. Determine the types of products that might be marketed.
4. Investigate the extent of the market that might exist for the potential products.

This abbreviated report includes most of the geologic description and product evaluation/market survey contained in the original report. Missing here are the lab procedure description and analysis tables, the glossary of terms, and the recommended methods for mining and beneficiation. The complete report may be seen in the library of the Bureau's Geological Survey Branch or at the Office of Arid Lands Studies, both located at 845 North Park Avenue, Tucson.

John S. Vuich, Assistant Geologist, and Richard T. Moore, Principal Geologist, are with the Arizona Bureau of Mines, Geological Survey Branch.

Geology

General Geologic Statement

The olivine-bearing volcanic flow is basaltic in composition. Virtually all olivine on Peridot Mesa is contained in this single flow. Subsequent eruptions of scoria spatter and scoriaceous flows

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Also in this issue

Water and the Mineral Industry:

The Arizona Water Commission Looks Ahead

The Arizona Water Commission released Phase II of the Arizona State Water Plan in February, 1977. Titled "Alternative Futures," it follows "Inventory of Resources and Uses," Phase I, which was released in 1975 (see FIELDNOTES, June 1976). The following article is Chapter V – Mineral Industry, and is being reprinted from "Alternative Futures" with the permission of the Water Commission.

For purposes of projecting alternative levels of water use, the future of the mineral industry is separated from the municipal and other industrial sectors because of the size and importance of this industry in Arizona. The future of the industry, particularly the copper mining and processing sectors, will have considerable influence on water planning efforts.

Mineral Production

In 1910, Arizona achieved the distinction of being the nation's leading copper-producing state. Subsequently, Arizona production has represented a steadily increasing percentage of the total U.S. copper production. By 1960, the State's share had reached nearly 50 percent of the total, and in 1975 the State accounted for 57 percent of national production.

In 1974, the gross value of the State's production of minerals was $1.56 billion, with copper representing 85 percent of the total. The copper mines also produce most of the State's gold, silver, molybdenum and zinc as byproducts. With the value of these minerals added, copper mining produces 92 percent of the total value of mineral production in the State.

The copper industry is second only to manufacturing as a source of State income. In most areas where the mines are located, the mineral industry represents the major source of income. The communities of Ajo, Morenci, Clifton, Bagdad, Superior, Globe, Miami, Hayden, San Manuel and Winkleman are almost totally supported by the mining industry. The City of Tucson's economy is materially benefitted by mines in Pima County that account for about 38 percent of the State's total mineral production.

While sand and gravel production provides only 3 percent of the State's mineral industry revenue, it accounted for about 20 percent of the industry's water withdrawals in 1970. Unlike copper, almost all of Arizona's sand and gravel production is used within the State. The production level of the sand and gravel industry for purposes of this report was assumed to be dependent on the State's population and the rate at which it grows.

Factors influencing copper production

Arizona uses only a small part of the copper mined in the State. Most of the output is marketed directly to semifabricators which produce a variety of products for industrial use. The five economic sectors using semifabricated copper are electrical and electronic products (52 percent), construction (18 percent), industrial machinery (13 percent), transportation (9 percent), and ordnance (3 percent).

Copper production is primarily influenced by the level of national and international economic activity. Demand for this basic industrial commodity responds to both positive and negative changes in the general level of business activity. For example, the recession of 1974-75 resulted in Arizona copper production declining more than 114,000 tons from the 1973 level.

The ability of the State's copper companies to remain competitive in the domestic and international copper market will have significant impact on future production. In this report, the potential for dislocations brought about by changing domestic and international market conditions has been handled by the assumption that future prices will be at a level which will enable the State's industry to maintain its relative position as a producer of copper. It is further assumed that production will not be abnormally affected by higher energy costs, lower-grade ores, environmental controls, or water availability and cost, although it is recognized that each could have a substantial impact on the cost of producing copper in Arizona and could affect future production levels.

Future production levels

The locations of most potential copper-producing areas in the State are well known although the extent of copper reserves are not well defined. Considerable amounts of time, effort and money are required to define reserve ore bodies. Mining companies generally do not divulge the information which they have developed. Consequently, no unimpeachable basis is available for pinpointing future development. However, the U.S. Bureau of Mines has estimated that Arizona has approximately 85 percent of the nation's copper reserves.

Three projections for copper production are shown on Figure 10. The forecasts are for the most part based on information and data supplied by the U.S. Bureau of Mines. The alternative suggest a wide range of possibilities in future copper use. The high projection is consistent with a national forecast based on historic trends. In this forecast, Arizona maintains a fixed percentage of the production required to satisfy the national demand and its copper production increases from 918,000 tons in 1970 to 1,660,000 tons in 1990 and 5,100,000 tons in 2020, an increase of 455 percent in 50 years.

The medium projection is based on low national demand with Arizona's production satisfying a constant percentage of the national demand. The resultant production level for 1990 is 1,480,000 tons and for 2020 is 3,700,000 tons. This represents an increase of about 300 percent in 50 years.

The low projection is based on a fixed per capita use rate and the OBERS Series E population projections for the entire country (an increase of about 46 percent from 1970 to 2020). Arizona's estimated production level in this projection is 1,155,000 tons in 1990 and 1,410,000 tons in 2020, or an increase during the 50-year period of 54 percent.

Water Use

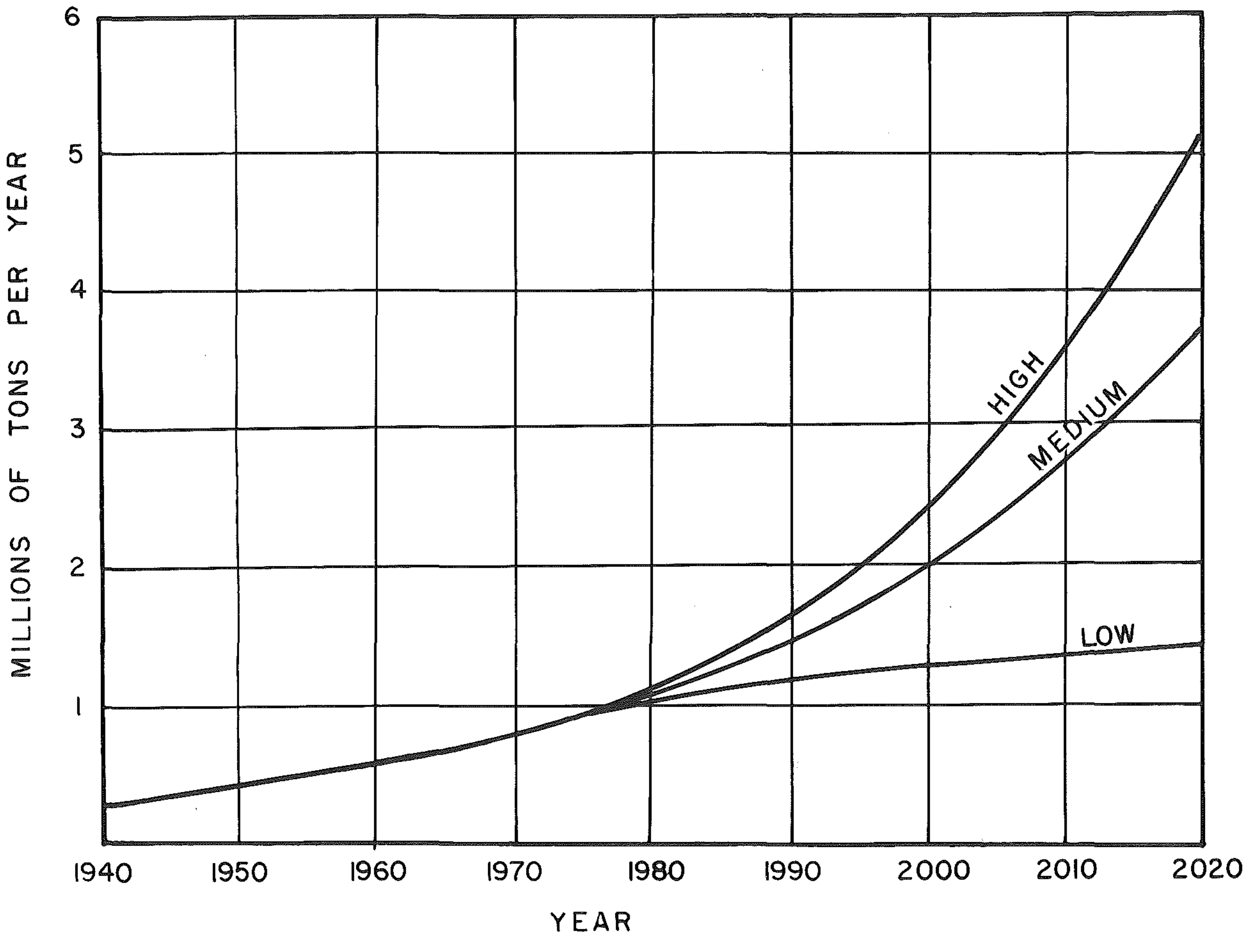
The principal water-using functions of the mineral industry in Arizona are involved in the mining and processing of copper, coal, cement and sand and gravel. Of these, the copper mining and associated operations accounted for over 70 percent of the water used in 1970, while sand and gravel operations used about 20 percent. Projections show that the copper industry will represent an even greater percentage of the water used in the future by the mineral industry.

Water is used at copper mines for dust control, smelter cooling, power plant cooling, acid plant cooling, and as a solvent or transporting agent in the crushing, classifier, concentrator, thickener, leaching, precipitation and reducing processes. The percentage of copper produced by the leaching process has

FIGURE 10

HISTORIC AND PROJECTED COPPER PRODUCTION IN ARIZONA

Chart by Arizona Water Commission



increased in recent years and stringent emission controls at the smelters may require a greater use of leaching and other hydrometallurgical processes in the future.

Projections of water use for copper production are based on estimated water depletions per ton of ore processed. Because of increasing costs and decreasing availability of water supplies, the amount of water required per ton of ore is expected to decline as the mining companies improve water use efficiencies. Water use is projected to decline from over 200 gallons per ton of ore processed in 1970 to slightly over 100 gallons per ton in 2020. Unfortunately, this improvement will be offset by the need to handle larger quantities of material as the industry is forced to resort to the mining of lower-grade ores. As a result, little or no reduction in depletions is expected to occur in terms of water per ton of copper actually produced. Figure 11 shows projected depletions per ton of ore processed and per ton of copper produced. The values are based on the projected ore grades in the mid-range projection of production.

The depletions per ton of copper displayed in Figure 11 were used to estimate copper industry depletions for each alternative in each future time frame. The projected water use rates do not provide for irrigation to revegetate mined areas which could substantially increase the water requirement. This potential requirement was omitted because there is little to indicate that such actions will be required or what amount of water would be associated with the action.

As opposed to the three levels of water use for the copper industry, only one level of water use for sand and gravel operations is projected in this report because the difference between the high and low projections is small. Water use values for sand and gravel represent a present level of 350 gallons per ton dropping to a 2020 level of 200 gallons per ton. Total statewide water use is projected to be 30,000 acre feet in 1980, and 40,000 acre feet in 1990 and thereafter.

Coal mining requires water for dust control, revegetation of mined areas and, in certain cases, for coal slurry pipelines used to transport coal to areas of use. Commercial deposits of coal are located in the northeastern part of the State in Apache and Navajo Counties. Currently, the State's largest operation is located at the Black Mesa Mine in Navajo County which produces coal for the Navajo Electric Generating Station at Page and the Mohave Generating Plant in Nevada across the Colorado River from Bullhead City. A slurry pipeline is used to transport the coal to the Mohave plant while a railroad is used for transportation to the Navajo plant. Water depletion associated with coal mining in these areas is projected to increase from about 3,000 acre feet per year in 1980 to 5,000 acre feet per year in 2020. This assumes no additional export of water through coal slurry pipelines. While different levels of coal production would require different levels of water use, the potential range of use is insignificant in terms of total depletions by the mineral industry. However, situations of local significance could arise in Apache and Navajo Counties and the more detailed investigations planned for the future should be structured to consider these two counties closely. For this reason, only one level of water depletions for coal production was used in this analysis.

Figure 12 shows the estimated water depletions for the entire mineral industry through the year 2020. The values on the graph were derived using the copper production levels shown on Figure 10, and the unit depletion values per ton of copper presented on Figure 11 and adding the estimated depletion for coal mining and sand and gravel operations. On a statewide basis, the high projection indicates that mineral industry water depletion in the year 2020 will rise from 131,000 acre feet per year in 1970 to 841,000 acre feet per year in 2020. This represents a 50-year increase of 540 percent. Medium and low projections for 2020 indicate depletion increases of 375 and 100 percent to levels of 622,000 and 265,000 acre feet per year, respectively. Although copper production is the dominant factor in mineral industry water requirements, the increases in water requirements are not nearly so dramatic as the projected increases in production. This, of course, is due to the increased water use efficiencies projected for the copper mining industry.

Table 6 shows the estimated mineral industry depletions for the State and each county in the years 1990 and 2020 for each level of production. The county values were disaggregated from the State totals on the basis of the requirements of existing mines; mines being developed, expanded and planned; and of expected population growth patterns. The values for Maricopa, Apache, Coconino, Yuma and Santa Cruz Counties reflect expected increases in sand and gravel operations. The values for Navajo County indicate water depletions for coal mining and sand and gravel operations.

The State's principal copper deposits are located in Pima, Yavapai, Mohave, Gila, Pinal, Cochise, Graham, Greenlee and Santa Cruz Counties. Ideally, projections of relative production in each county would involve an analysis of the relative ore grades in each area. Reliable data, however, are not available. In the absence of such data, depletion amounts were estimated on the basis of water use by existing mines and the anticipated requirements of mines currently being developed and planned for operations in the near future.

The role of Graham County in mineral production should increase substantially as two mining companies are in the preliminary stages of developing new copper mines. New mines are being developed in Pinal County and a major mine expansion is in progress in Yavapai County. Pima County is expected to remain as the State's leading county for mineral production but the county's relative production percentage is expected to drop as other areas develop. Within a 50-year time frame, some mines will close as the economically recoverable ore is exhausted. The probability of old mines closing and new mines opening in another county is high. Should this happen it would result in considerable error in the projection for any particular county.

In terms of water depletions for mineral production, no

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FIGURE 11

PROJECTED
WATER REQUIREMENTS FOR COPPER PRODUCTION

Chart by Arizona Water Commission

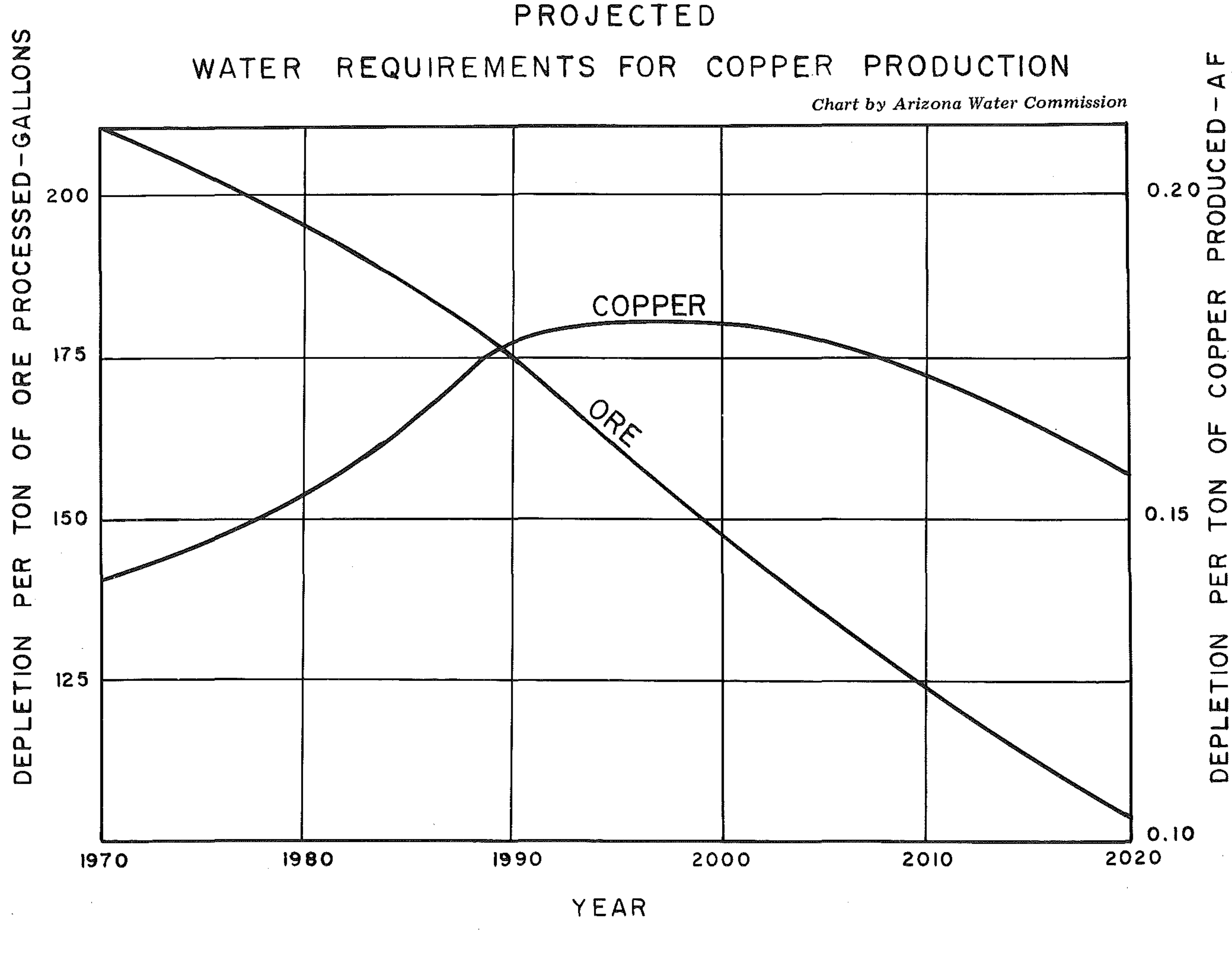
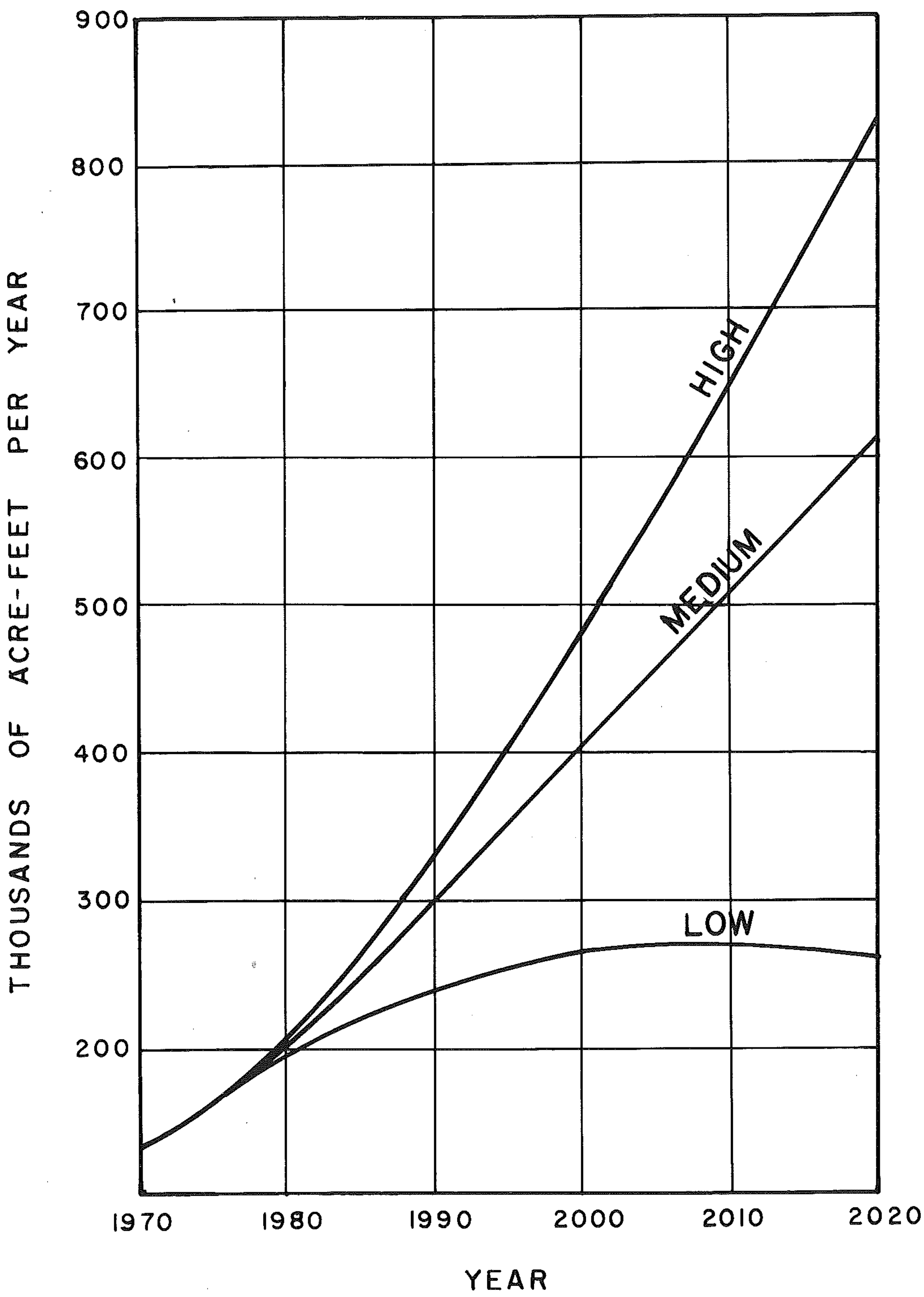


FIGURE 12

PROJECTED WATER DEPLETIONS FOR MINERAL PRODUCTION

Chart by Arizona Water Commission



Olivine Resources Study *Continued from page 1*

contain small amounts of olivine. A semicircular dike system on Peridot Hill appears to be the source of both the main basalt flow and the scoria eruptions. All scoria flows are confined to the area immediately surrounding Peridot Hill. They drape over the earlier basalt flow and underlying sedimentary rocks. The original extent of the basalt flow was probably twice the present exposed surface area. Small erosional remnants of this flow cap portions of mesas and ledges immediately to the north, south, and east of Peridot Mesa (Geologic Map, Fig. 1). A reconnaissance of the surrounding region did not reveal other olivine-bearing rocks of any significance; therefore, the Peridot Mesa flow is considered to be the only volcanic rock worth exploiting.

Olivine Formation

The origin and history of the olivine material began in a molten-rock chamber. Olivine was one of the first substances to crystallize and collect in this molten rock mixture, probably as a layer of granular, crystalline matter. A subsequent fissure-eruption of this molten mixture broke the olivine layer into small fragments which outpoured with the eruption. As the molten rock flowed on a surface of sedimentary rocks, the olivine fragments tumbled and rolled with it, gradually settling to the bottom while much of the flow was still viscous. Later eruptions were scoriaceous and local in extent. Figure 2 shows the sequential development of Peridot Mesa with a dike representing the basalt-filled fissure from which the eruptions issued.

Peridot Mesa Description

Sedimentary rocks underlying Peridot Mesa consist of water-lain (?) tuffs, tuffaceous siltstones, sandstones, and conglomerates. These rocks are essentially flat-lying bedded sediments upon which the Peridot Mesa flow rests. The upper beds contain small quantities of olivine bombs (Lausen, 1927) from pre-flow eruptions.

On Peridot Mesa, the average basalt flow thickness is estimated to vary from 10 feet to 60 feet. Local channel-fill sections are thicker. Headward erosion of Peridot Canyon drainage has conveniently removed some of the flow surface in the vicinity of the Main Pit workings. Here the flow has been eroded to approximately 5 feet in thickness. Remant-flow margins thin northeasterly in the outlying mesa outcrops. Rock structures on Peridot Mesa such as flow wrinkles and lava-lobe shapes suggest that the general flow trend was northeasterly. Figure 3 is a diagram of typical features seen in cross section of the olivine-bearing basalt flow.

The basalt flow is in contact with lakebed sedimentary rocks. Bottom surfaces of the volcanic rock are generally marked by a scoriaceous flow-breccia. The irregular nature of this cindery breccia zone often contains blocks of underlying sedimentary rocks and inclusions of olivine. Above the flow-breccia is the olivine zone.

Physical Characteristics and Distribution of Olivine

Some general features were noted concerning the olivine size and distribution within the flow. Much of the olivine is granular in texture, analogous to a mixture of fine-sized gravel and coarse-grained sand. The small masses of granular olivine are varied in their size and shape, depending on their cohesiveness and the forces to which they were subjected during transportation and settling within the flow. Some blocks are rounded and others are angular or oblong (Figure 4). The blocks are commonly 2-6 inches across while some larger masses up to 18 inches in diameter were noted. In any given section, the larger olivine lumps congregated by settling near and at the bottom of the lava flow. Upper portions of the olivine zone contain progressively fewer olivine blocks and their respective diameters are commonly less than 3 inches. The overall olivine content and block size decreases northeasterly as the olivine zone thins toward the flow margins. In the central area of Peridot Mesa, from the Main Pit location to the North Pit, the olivine zone thickness is estimated to vary from 1.5 to 5 feet and contain upwards from 60 to 70 percent olivine. Barren basalt above the olivine zone is from 5 to 10 feet or more in thickness. Along the north margins of Peridot Mesa, and along the basalt flow exposed in the cliffs above the San Carlos River's east bank, the olivine zone locally increases in thickness to 15 feet. Here, however, the olivine content is even lower, being less than 10 percent, and the granular masses are commonly less than 4 inches in diameter. Basalt overburden above these olivine zones has increased to 20-30 feet. Although all the exposures of the original flow margins examined contained some olivine blocks, these minimum zones were estimated to have an overall content of only 2 percent olivine occurring in granular masses of from 1 to 2 inches in diameter.

Mineral Reserves

From observed quantities and distribution of olivine it is estimated that 80 percent of the original olivine volume remains on Peridot Mesa and in the erosional remnants of the basalt flow. We would also conclude that all presently exploitable olivine resources lie on

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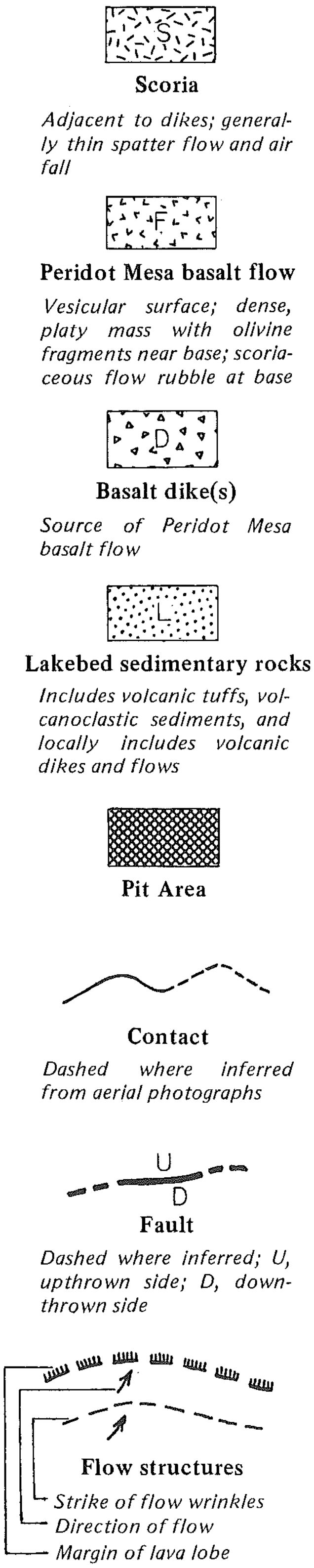
GEOLOGIC MAP

EXPLANATION



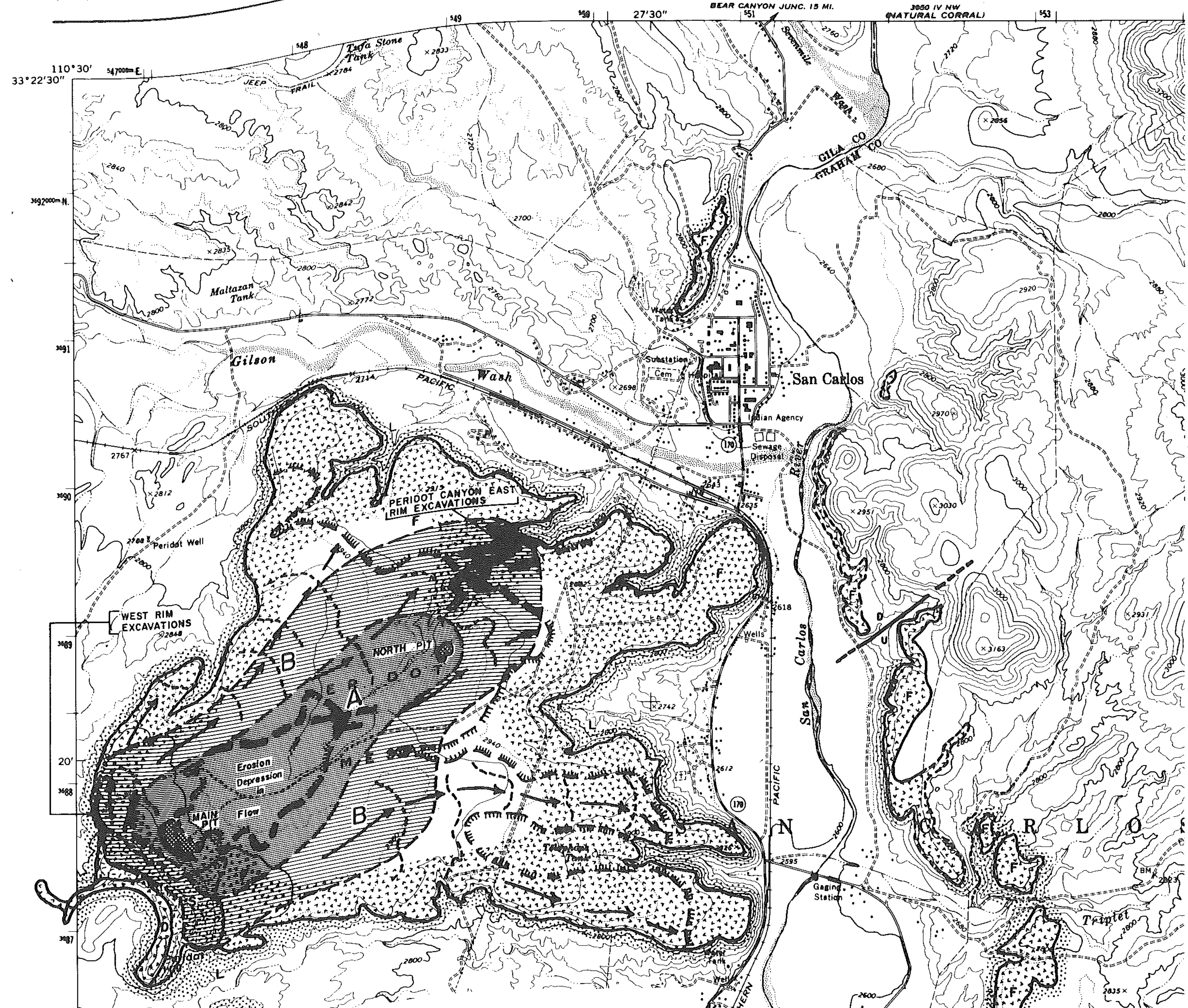


TABLE I. Numbers represent possible ore reserves as indicated by geology and examined, widely-scattered exposures. Lack of detailed subsurface data precludes certainty of actual location and extent.

AREA	OVERBURDEN THICKNESS (Barren basalt rock above mineralized zone)	OVERBURDEN (millions of short tons)	AVERAGE ORE ZONE (OLIVINE ZONE) THICKNESS AND ESTIMATED AVERAGE OLIVINE CONTENT	ORE ZONE (millions of short tons)	OLIVINE IN ORE ZONE (millions of short tons)	BASALT IN ORE ZONE (millions of short tons)
A 440 acres	2-5 feet; 3 feet average	5.5	3 feet; 50% olivine	5.5	3.0	2.5
B 690 acres	3-25 feet; 10 feet average	27.6	5 feet; 30% olivine	13.7	4.7	9.0
COMBINED TOTAL 1130 acres		33.1		19.2	7.7	11.5

SAN CARLOS QUADRANGLE

Continued from page 6

Peridot Mesa (Mineral Reserves Table – Geologic Map, Fig. 1). In order to maintain a reasonable stripping ratio of overburden to ore from 0.5:1 to 2:1, it appears that the olivine zone should maintain a minimum olivine content by volume of 30 percent. This figure is based on olivine distribution and flow geometry. Mining methods and market/product valuations certainly would be a basis for revision of this olivine content estimate. The Mineral Reserves Table (Table 1) is our best estimate of the probable extent of the 30 percent olivine zone. Our best estimate of the area of a higher-grade ore zone containing 50 percent olivine is shown within the 30 percent zone.

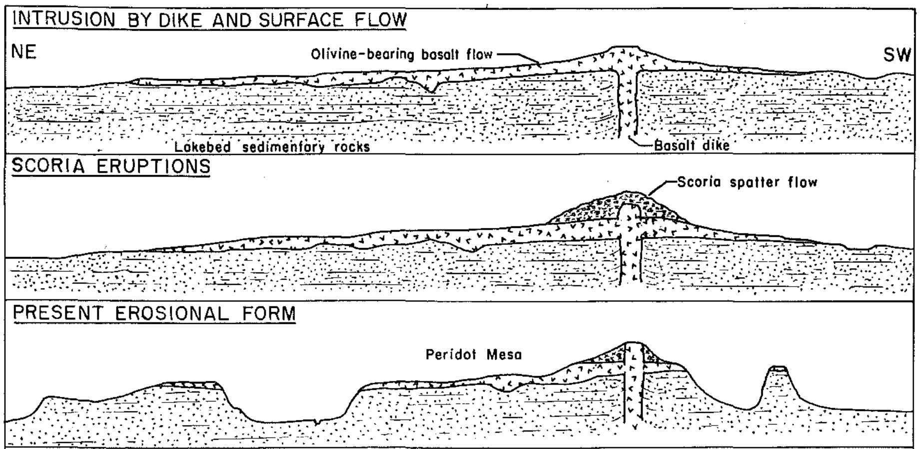


Figure 2 Generalized cross-section of Peridot Mesa area. Northeast — southwest section; view is easterly. Historical development is interpretive. Not to scale.

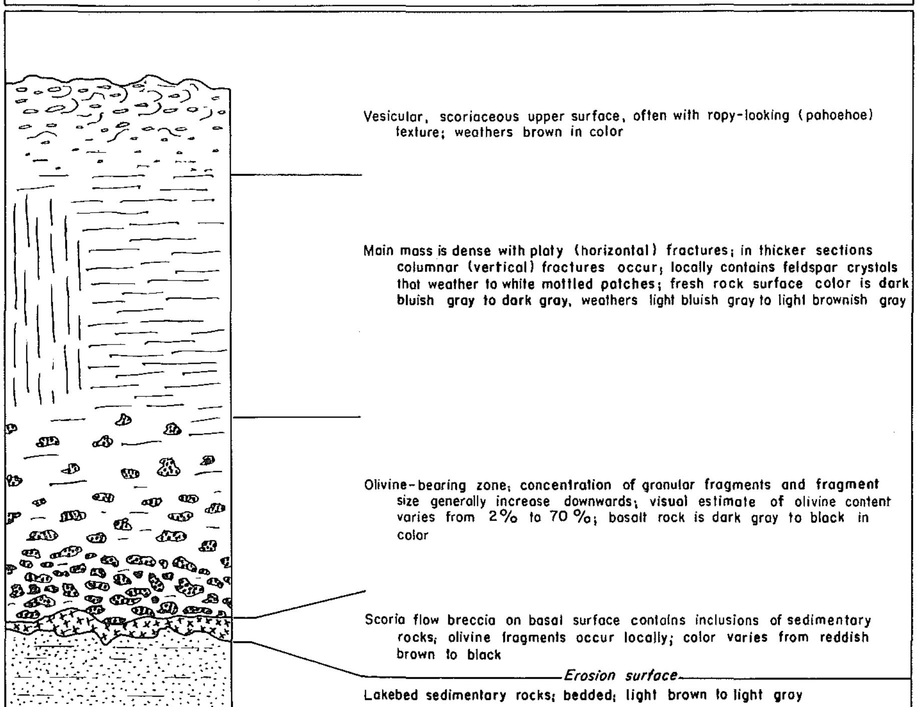


Figure 3 Generalized column through the Peridot Mesa basalt flow. Not to scale

An example of a shallow olivine zone with an approximate stripping ratio of 0.5:1 lies along the West Rim excavations, and at the North Pit the ratio is approximately 1:1. Deeper olivine zones with a stripping ratio of 2:1 and locally 5:1 are exposed along the east rim excavations of Peridot Canyon. The Main Pit workings lie partly in an erosional depression at the head of Peridot Canyon drainage. This is an example of how erosion has partially removed the basalt overlying the olivine zone, and thus contributed to the inconsistency of overburden thicknesses.

Based on field observations and assumptions defined on the olivine reserves chart (Mineral Reserves Table 1), it is estimated that approximately 1,100 acres of Peridot Mesa contain over 19 million tons of "ore" in which there is nearly 8 million tons of olivine and over 11 million tons of basalt. Above this "ore zone" lie over 33 million tons of essentially barren basalt at an average stripping ratio of 1.7:1.

Product Evaluation and Market Survey

Gem Peridot

Gem peridot has been produced from Peridot Mesa for many years and is a logical product for first consideration in any evaluation and market survey.

The olivine on Peridot Mesa, as previously indicated, occurs as nodules and irregularly shaped masses of granular material. The value of the olivine as a gem stone is dependent upon the size, clarity, and shadings of color of the individual granules. Granules under approximately ¼ inch in diameter, or having internal fracture planes; granules which are cloudy or contain inclusions; and granules of excessive darkness or paleness of color all are of little value.

In past years, the individual operators sold their peridot production in various grades, depending upon size, and prices ranged from $1.50 to $8.00 per pound. More recently, however, the tendency has been to sell unsorted material (other than the initial sorting at mine site) at an intermediate price of from $4.00 to $4.50 per pound. With the increase in this practice, there has been a tendency among some of the operators to dilute their product with considerable worthless material because it is not easily detected under casual examination in the ungraded material. The result of this rather questionable practice has been to make a number of the buyers interviewed quite critical, and this could eventually work to the disadvantage of all the operators.

Apparently, no records are currently being kept on the amount of peridot being produced and it was not possible to determine this accurately through questioning of the operators. On the basis of what could be observed, however, we crudely estimate that between 1,600 and 2,400 pounds per month of rough peridot is being marketed from the Mesa. Of this, probably less than 7 percent actually remains as salable material after processing into faceted and tumble-polished gem stones, and by far the major portion of the finished stones are in the lower-priced tumble-polished category.

Tracing the trail of raw peridot from the mine to the principal "brokers" is a difficult task – the business is very competitive and few of the traders and dealers are willing to discuss their individual arrangements. An overall picture of the market process, however, has been pieced together from numerous sources.

In general, two categories of buyers

Fig. 4. Detail features of olivine zone, North Pit. Olivine blocks are "salt and pepper" granular masses; the basalt is dark and partially vesicular. Lens cap is 2.5 inches in diameter.

can be identified. The first is the individual who may be either an amateur gem and mineral collector or a small dealer who is engaged in resale to amateur collectors, gem cutters, and lapidaryists. The second category is the larger dealer, or broker, who buys in somewhat larger quantities from several different sources and then resells the material into the commercial market.

Buyers in the first group generally deal directly with the operators, either at the mines or at the operators' homes. Although there is considerable overlap in the method of operation of the various buyers, the broker more often operates out of a fixed business establishment and acquires the major portion of his peridot from operators and other, smaller buyers who come to his establishment with bulk material for sale. At this point in the market process, prices are rather well established in the $4.00 to $4.50 per pound bracket. An exception to this is the case where an intermediate buyer may do some additional sorting to produce a higher quality material, which of course then demands a higher price.

The next step involves the first really careful sorting to which the major portion of the peridot will have been subjected. The broker sorts the material into the poorer quality fraction, which is useful only for tumbling and the production of baroque jewelry, and into the much smaller fraction of high-quality stones which are set aside for faceting. The greater proportion of the faceting-grade material is shipped to any of several foreign countries for faceting. These are, in the order of quality of workmanship, primarily Germany, Korea, Hong Kong, Taiwan, Burma, and India; the exception to this, of course, is the peridot that is faceted in this country by the many amateur lapidaryists.

The market in faceted stones operates in either one of two principal fashions. Many of the major gem wholesalers, for instance those quartered in Los Angeles and New York, do not deal in uncut peridot. They buy directly from the gem cutters in Germany, Korea, etc., and the quality of the material they demand, of course, depends on their reputation and the size of their business. Typically these dealers pay from $7.50 to $15.00 per carat for faceted peridot, depending upon the size and quality of the stones. The second procedure that is followed by the major brokers who deal almost exclusively in peridot is to send shipments of 15 to 20 thousand stones at a time to various of the gem cutters with whom they do business for cutting and shipment back. In this case, the cutters are paid a previously agreed-upon price for cutting services only, as the broker already owns the peridot. Prices arrived at by these arrangements are extremely competitive and it was impossible to get any factual data on them. A problem that does occur with this method, however, was discovered; that is, in a shipment of 20 thousand stones for cutting often only 10 or 15 thousand stones might be returned, and usually no explanation is given. Some of the material may not have been facetable, or there is the obvious possibility that the material was retained by the cutters strictly for their own resale. Another problem sometimes encountered is the faceting of stones with fractures or other imperfections. When this happens, the owner is still charged the cutting fee but he does not receive a stone of salable quality.

Peridot that goes into the tumble-polished circuit may be either treated in the brokers' own shops or shipped overseas for polishing, drilling, and transhipment back. Such material wholesales at between $.50 and $.75 per carat, polished and drilled, and therefore must be considered a low-priced commodity.

Typical wholesale prices for various other peridot gem forms are as follows: 16" strands of tumbled and drilled stones range from $10 to $15 each; faceted stones of good quality will sell for from as little as $1.75 each for a 4-millimeter round-cut up to as much as $30 each for a fair to good 10 by 8 millimeter oval.

The major portion of world production of gem peridot, in terms of value, has been produced from Sri Lanka (Ceylon) and Egypt. Of secondary importance are Burma, Australia, Brazil, and the United States. Lesser quantities, although of commercial importance, have been obtained from India, Rhodesia, Namibiya (South-West Africa), Tanzania (Tanganyika), South Africa, Chile, Colombia, Uruguay-Paraguay, Canada, and Mexico. In the United States, Arizona and New Mexico are the principal areas of production. Although considerable world supplies would seem to be available for exploitation, it was the general consensus of the jewelers interviewed that the world market is capable of absorbing any reasonable amount of peridot that can be produced from the San Carlos Indian Reservation.

Commercial Products

Field examination of the olivine deposits on Peridot Mesa and extensive conversations with the Tribal members currently mining peridot on the mesa indicate that less than 1 percent of the olivine is of gem quality. However, inasmuch as it is necessary to handle all of the olivine in order to sort out that of gem quality, it was felt that it would be very desirable to develop, if possible, a market for the other 99 percent of the material to help cover the expenses of handling. With this is mind, a study was made of the commercial uses of olivine.

Our study indicates that relatively few commercial uses for olivine have been developed. Olivine sand is used principally as a refractory material in fire brick and foundry sand, and in the manufacture of magnesium phosphate as a fertilizer. Because of the lack of readily available supplies of phosphate material in the Arizona area, the use of olivine from Peridot Mesa in fertilizer is discounted at this time.

The use of olivine as a refractory is based on several of its physical and chemical properties. For instance, olivine is a high refractory material with a sinter point of between 2,850° and 2,900°F. and a fusion point in excess of 3,000°F. This property of the material gives rise to numerous uses in the refractory industry, such as block olivine for furnace linings, crushed olivine mixed with a binder for refractory brick manufacturer, ladle linings, patching compounds, and ramming mixes. Another use of olivine with a direct relation to its refractoryness, and potentially the most important in the terms of tonnage used, is in the field of foundry molding sands. Considerable research effort, both in this country and in Europe, has been applied in an effort to delineate the advantages and limitations of a manufactured olivine foundry sand.

Several foundries in the Tucson and Phoenix area use olivine sand as a foundry sand, and the bulk of this material is imported from Washington State.

Tests performed in the Arizona Bureau of Mines laboratories indicate that material derived from Peridot Mesa can be treated, and a probably usable foundry sand produced.

Although varying somewhat from the screen analyses of material currently being marketed in Arizona as foundry sand, it is quite probable that material of this general consistency could be used successfully. The actual determination of this, however, can only be made by submitting samples to several of the current users of olivine foundry sand for their experimentation. Currently, olivine foundry sand used in Arizona is being quoted at $5.60 per hundred pounds, sacked.

If a commercially acceptable product is made, there would seem to be no reason why it could not compete successfully in the southern California market area.

A second potential application of olivine, which to our knowledge has not been used commercially in this country, is as a decorative material in precast architectural concrete shapes.

This potential was discussed with two producers of precast shapes in the Phoenix area. We estimate that at a price of $60 per ton in 100-pound sacks, the olivine could be competitive with decorative aggregates that are now being used.

Recommendations

After evaluating the role the San Carlos Tribal Government should take in the mining, beneficiation, and marketing of olivine, based on the information so far developed, we would make the following recommendations:

1. A Tribal industry based on the production of peridot is feasible. It should, however, be established as an addition to the existing operations and not be designed to take them over.
2. The industry should be established first to produce rough gem peridot only, and not be expanded into the production of commercial olivine products until markets for them can be assured.
3. The Tribal industry should consist primarily of producing raw, graded peridot on a wholesale basis. Although the production of tumble-polished material is a valid goal, the Tribe should not become involved in the production of domestically cut or faceted stones.

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Water and the Mineral Industry *Continued from page 4*

significant problems are indicated for Maricopa, Apache, Coconino, Navajo, Yuma, and Santa Cruz Counties. The combined 2020 high projection for these six counties, as shown on Table 6, is only 20,000 acre feet per year or less than one percent of the currently developed dependable supply. However, some of the remaining counties can anticipate intense competition from the mining industry for the available water supplies. Mineral industry depletions in Pima County were estimated to be 53,000 acre feet in 1970. In both the high and medium projection, depletions would double by 1990 and, in the low projection, depletions would increase by approximately 50 percent by that year. As the current dependable supply is only 72,000 acre feet per year, Pima County faces a demand from this one industry well in excess of its dependable supply. The high projection for 2020 indicates that demand could be more than three times the supply currently available to all of Pima County on a dependable basis.

In Yavapai County, depletions in the mineral industry might increase to a level almost 10 times current use. Much of the future water use will be in the Bagdad area with supplies imported from Mohave County. A project is now under construction which will convey water from the Big Sandy Valley to Bagdad, and the mining company has requested a contract for 20,000 acre feet per year of Colorado River water. In general, the water supply situation in Yavapai County is relatively unclear, but the relationships between the projections and what is known about water supply indicate a potential problem and a need for additional study.

The absolute increase between the 1970 level of depletions by the mineral industry and the 2020 high projection for Pinal County is 188,000 acre feet of water. While the Pinal County relationship between projected demand by the industry and current dependable supply is more severe than in Pima County, competition for the supply will be less pronounced as urban requirements are expected to be considerably lower.

In Gila County the mineral industry is forecast to continue as the principal water user. By 1990 more than 80 percent of total county water depletion is projected to be by the mineral industry and by 2020 this will have increased to more than 90 percent. There is very little competition between mineral uses and agricultural uses in Gila County but only because agricultural usage is so small. In Greenlee County the mineral industry is forecast to realize large increases in water use causing severe water deficiencies. The high projection results in the mineral industry alone depleting an amount of water three times the current total dependable supply. Even the demand under the low projection would create severe competition for the limited supply available. It is clear that if Greenlee and Gila County are going to realize mineral industry development as projected in Table 6, additional water supplies will have to be made available through exchange with water users in other counties.

The mineral industry in Graham County is projected to emerge as a large water user as new mines are developed. Even though the high projection indicates total water use less than dependable water supplies, the mineral industry is faced with a number of complex physical and legal issues in developing supplies to meet the future demands because most water available to Graham County is water from the Gila River decreed to other users.

In Cochise County, mining and mineral processing will continue as a major nonagricultural water user. However, it is not anticipated that the water supply situation for nonagricultural users will be as severe as in other central Arizona counties.

On a statewide basis, maximum increases of mineral industry water depletions for the year 2020 are projected at over six times current depletions while the low projections for that year indicate a doubling of depletions.

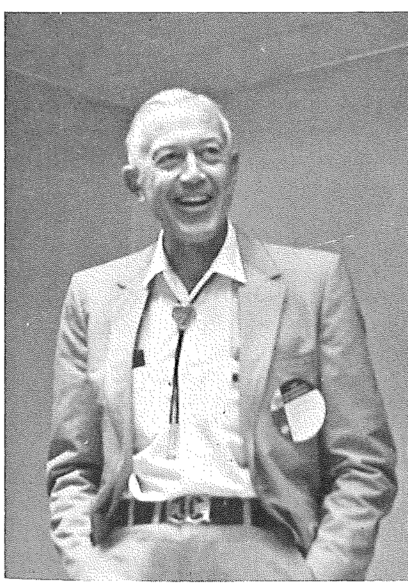
Geologist S.B. Keith Retires From Arizona Bureau of Mines

After nearly eleven years as a geologist with the Arizona Bureau of Mines, Stanton B. Keith is retiring on June 30, 1977 and moving to Silver City, New Mexico.

Mr. Keith has authored many of the Bureau's publications since 1966; he compiled the Bureau's two metallic mineral occurrence maps, authored chapters in bulletin 180, *Mineral and Water Resources of Arizona,* and co-authored bulletin 182, *Coal, Oil, Natural Gas, Helium, and Uranium in Arizona.* His most recent contributions include bulletin 183, *Geologic Guidebook 3 – Highways of Arizona, Arizona Highways 85, 86, and 386,* and the first four bulletins in the Bureau's series of indices of mining properties by county: bulletins 187 (Cochise), 189 (Pima), 191 (Santa Cruz), and 192 (Yuma), the latter to be issued later this summer.

Before joining the Bureau, Mr. Keith had acquired broad experience in geologic, mineral exploration, mining, and administrative work covering a wide field of mineral products. A graduate of Amherst College and Harvard University, he worked for mining companies in South America, Mexico, and the United States. He also held administrative positions in various government agencies in Washington, D.C.

In his new location, Mr. Keith expects to keep busy with private consulting work.



Stanton B. Keith

GEOTHERMAL PIPELINE

W. Richard Hahman Sr.

Geologist Dick Hahman has been hired by the Bureau to serve as Principal Investigator for the Bureau's geothermal energy project, which is funded by U.S. Energy Research and Development Agency. Dick received his B.S. from American University in Washington, D.C., and his M.S. from West Virginia University in Morgantown, W.V. Before joining the Bureau, Dick was a consulting geologist in metals and coal for his own firm, Explorations Unlimited. He is a member of A.I.M.E., G.S.A., S.E.G., A.P.G.S., A.S.M.O.A., and the Arizona Geological Society.

On May 1, 1977, a new area of investigation was added to the Geological Survey Branch of the Bureau of Geology and Mineral Technology (formerly the Arizona Bureau of Mines): geothermal energy. On that day the University of Arizona, Geosciences Department, the Bureau of Geology and Mineral Technology, Geological Survey Branch and the U.S. Energy Research and Development Administration, Division of Geothermal Energy entered into an agreement to investigate geothermal energy in the state of Arizona.

The main emphasis of the current program will be on locating sources for hot water convection systems, (temperatures to 150°C) and hot, dry, crystalline rock. The term "hot crystalline rock" means a temperature that may be in excess of 200°C, while "dry" means that, because of its low permeability, the rock will not produce fluid.

The purpose of these above mentioned systems would be to furnish space and process heating. Of course, hot dry rock and hot water systems in excess of 150°C would be considered for the generation of electricity.

Hot dry rock is more abundant than wet, hydrothermal systems and therefore has greater potential for utilization as a source of energy. Experiments are currently underway at the Los Alamos Scientific Laboratory of the University of California at Los Alamos, New Mexico, to determine the proper treatment of hot dry rocks for the recovery of heat, in this instance for the possible generation of electricity. Two wells have been drilled into hot, dry granitic rock; one is 0.785 km deep, the other 1.98 km deep. Large hydraulic fractures have been successfully induced upon the granitic rocks at these depths.

The hoped-for successful operation will involved charging the fracture with cool water through one well and removing hot water through the other well. The hot water will be pumped to a generator and then back down to the "heat chamber" through the first well. It is also hoped that thermal-stress cracking, caused by shrinking of the rock during the cooling process, will expose fresh hot rock to the system thereby extending the life of the project.

The following projects have been initiated by the Geological Survey Branch in conjunction with the geothermal study in Arizona. A Landsat lineament map of Arizona, scale 1:1,000,000, will be constructed, with emphasis on Quaternary fractures, and with optical Fourier analysis and text. Another project will be a geophysical study of the Basin and Range physiographic province of Arizona with respect to geothermal models, depth to "basement" in valleys, and structural analysis.

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Geothermal Pipeline *Continued from page 11*

A third project will be the study of over 10,000 chemical analyses of ground water in Arizona for high and low temperature geothermal reserves. The content of SiO_2 and Na-K-Ca, geochemical geothermometers, in the water can indicate the probable temperature of the geothermal reservoir. An infrared imagery study of the rock in the Safford area with respect to geothermal rock alteration is also under consideration. The hoped-for results of this study would be the locating of favorable areas for geothermal reserves. This study will probably be authorized after further evaluation of infrared imagery techniques. Site-specific geological evaluation and water sampling programs will commence this summer, probably in July.

In addition to the above programs, the Geological Survey Branch of the Bureau of Geology and Mineral Technology is compiling a special library on geothermal energy. These texts and papers will be for public use, on the premises. Also, U.S.G.S. and U.S. ERDA's Divison of Geothermal Energy will supply our library with open-file maps and reports concerning geothermal energy in Arizona. Both of the above federal agencies have compiled valuable information concerning the geothermal energy potential of the state. This material will also be available for public inspection and use.

Geothermal Pipeline will become a regular feature in FIELDNOTES. We hope our updates on the development of geothermal energy in Arizona will help private industry and the public keep abreast of the state and federal geothermal energy programs.

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New Small Geologic Map of Arizona

The Arizona Bureau of Mines recently published a colored geologic map of Arizona at the scale of approximately 1:2,500,000. Selected cross sections of the state are printed in black and white on the reverse of the map.

Listed as Number 14 on the Bureau's "List of Available Publications," the map is available folded, or folded and prepunched for a 3-hole binder, at a cost of 25¢ per map. The Bureau charges a postage and handling fee for all mail orders: a 25¢ minimum charge per order, or 10% of the total.

Uranium Favorability Circular Published by Bureau

Research done under a grant from the U.S. Geological Survey has been published as Bureau of Geology and Mineral Technology Circular 19, "A Survey of Uranium Favorability of Paleozoic Rocks in the Mogollon Rim and Slope Region – East Central Arizona," by Dr. H. Wesley Peirce et al.

In addition to addressing the specific subject, this circular provides a review and analysis of the general geologic history of a large segment of Arizona.

Although the original report has been available in xeroxed form since early 1976, Circular 19 has undergone some editing and also incorporates a liberal supply of photographs.

Enhanced uranium favorability is associated with carbonized plant debris contained in certain conglomerates that occur near the Pennsylvanian-Permian boundary. The zone of general favorability has been traced not only in outcrop but into the plateau subsurface as well. The conglomerates are believed worthy of additional research not only because they are an interesting phenomenon but because they afford possible insight into some classic, late Paleozoic stratigraphic problems.

Circular 19 costs $1.75 per copy. For single-copy mail orders, please include 25¢ for postage and handling charges; for multiple orders, 10 percent of the amount of the order.

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State of Arizona
Governor .... Hon. Raul Castro
University of Arizona
President .... John P. Schaefer
Arizona Bureau of Mines
Director .... William H. Dresher
Editor .... Judi Goodpaster

ARIZONA BUREAU OF MINES
THE UNIVERSITY OF ARIZONA
845 NORTH PARK AVE.
TUCSON, ARIZONA 85719

INE 1852

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