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Copper Deposits of the White Mesa Mining District,

Coconino County, Arizona.

by

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ILLUSTRATIONS

Copper Deposits of the White Mesa Mining District,

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Summary. The White Mesa Copper Mining District is an area of approximately 10.5 square miles near the western margin of the Kaibito Plateau in unsurveyed T 37 N, Rs 9 and 10 E, Coconino County, Arizona. It is 112 miles northeast of Flagstaff, Arizona, the nearest rail head, from which it is accessible by paved and secondary road, and is at an elevation of about 6400 feet. Inadequate water supply and isolation from supply centers and smelters are factors which have inhibited development and which may be expected to handicap mining operations in the district.

Sporadic attempts to develop the reserves of the district have been unsuccessful, and production has been minor. At present, three companies are interested in development, and are engaged in, or have recently attempted, prospecting.

The copper deposits occur in the upper portion of the nearly horizontal, highly crossbedded, gray Navajo sandstone (Jurassic ?). Occasional large tabular bodies and numerous small pods of copper ore occur through an interval of at least 150 feet in the upper part of the formation. The deposits are disseminations of malachite, copper silicates, and minor quantities of copper pitch and sulfides in sandstone, the copper minerals serving as cementing and grain-coating materials. Grade varies up to 15% copper but it is doubtful if many of the deposits will average much higher than 1%. The larger bodies, some of which contain several hundreds of thousands of tons, may be expected to average less than 1%. The deposits show a well-defined fissure control. Origin may have been telethermal or meteoric, but there is no decisive evidence bearing on this point.

The mineralization is too sporadic to permit accurate estimation of ore reserves in the absence of extensive underground exploration or mining operations. The following preliminary figures are therefore only indicative of the general magnitude of the deposits. Approximately 2,250,000 tons of ore averaging about 1% Cu are indicated in ore bodies that are exposed or penetrated by drill holes. Only a few thousand tons of this total can be classed as "measured ore" on the basis of available data, but 615,000 tons are reasonably assured. The remaining 1,650,000 tons probably exist in extensions, indicated by geologic evidence, of the known ore bodies. In addition, 14,000,000 tons is the inferred order of magnitude of an aggregate tonnage of mineralized sandstone that may exist in "blind" ore bodies concealed in undissected uplands.

Consideration of the average grade and size of the known deposits suggests that large-scale development of these reserves under present conditions will be a marginal enterprise, even under favorable operating conditions. The additional problems imposed by inadequate transportation facilities and water supply enforce a pessimistic outlook. The relatively large inferred reserve of concealed ore cannot be regarded as a mitigating factor because it is problematical whether concealed ore bodies can be discovered and developed at reasonable costs.

It is recommended that further attempts to prospect or to develop the copper reserves of the district be prefaced by a careful analysis of mining and concentrating costs based on minimum tonnage estimates. Only in the event that such a survey indicates economic feasibility, should additional steps in development be undertaken.

Introduction

The sandstone copper deposits here described are near the northwestern margin of the Kaibito Plateau in the western Navajo Reservation, Coconino County, Arizona. The area, known as the White Mesa Mining District, is in unsurveyed T. 37 N., Rs. 9 and 10 E. It consists of 9 patented and 28 unpatented/ claims, two mining and prospecting leases, an abandoned millsite lease, and a campsite lease. Sporadic attempts to mine the small deposits of high grade ore in the district have been futile. Recently, comprehensive prospecting programs by three companies have been initiated in a determined effort to ascertain the feasibility of developing, on a large scale, the low-grade copper reserves in the district.

The area of approximately 10.5 square miles which encompasses the claims and leases is about 112 miles northeast of Flagstaff, Arizona, from which it is accessible by U. S. Highway 89 to Gap Trading Post, and from there by dirt road twenty-six miles to the Copper Mine Trading Post in the northwestern portion of the district. The mean altitude is about

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/ In the southwestern part of the area some maps show two additional claims, the corners of which were not found in the field.

6,400 feet, and the local relief is approximately 420 feet. Annual precipitation is less than 10 inches, and surface and ground water are scarce in and adjacent to the district. This deficiency of water, isolation from supply centers, and lack of adequate transportation routes are important factors which have inhibited development of reserves in the district.

Only one report bearing on the geology of the White Mesa Mining District has been published, a brief and general account by J. M. Hill.[1] However, a number of confidential reports have been prepared by geologists and engineers employed by companies interested in the area, and several of these have been examined during the course of the recent Geological Survey investigations. Company prospecting data have likewise been consulted freely, and grateful acknowledgment of the courtesies of the Shattuck-Denn, Coronado, and Mardun organizations in making these available, is here expressed.

Field work by the Geological Survey was begun late in March and was completed early in July, 1943. The investigation was part of a program designed to determine the status of marginal copper deposits and was undertaken by the Geological Survey at the request of the War Production Board. C. B. Read was in charge of the White Mesa project, and was assisted by H. H. Sullwold during the entire period of study. R. D. Sample joined the party on May 23, and aided in the later stages of the work.

[1] Hill, J. M. Copper deposits of the White Mesa district, Arizona; U. S. Geol. Survey. Bull. 540, pp. 159-163, 1914.

Development and Production

Mining operations in the White Mesa District were first attempted by Mormon settlers who, in the latter part of the past century, located the mining claims and opened many of the known copper bodies. An unknown, but relatively small tonnage of high-grade ore was recovered during this early period of discovery and initial development.

In 1917 operations on the Little Dick and Copper World claims were attempted by the Navajo Copper Company. Two open cuts were developed, and 290,000 pounds of copper, as well as a small quantity of silver, are reported to have been recovered. The operations were not profitable, and were discontinued in 1918.

The Coconino Copper and Chemical Company began operations in the western part of the district in 1939 and suspended them in 1940. Their activities were mainly on the Copper World and Dutchman Claims. Complete records of production are not available. However, in 1940 they treated 4,534 tons of 3.13% ore from which 797,878 pounds of copper sulfate were produced and shipped.

The Mardun Company, which was formed in 1941, milled 3000-3500 tons of ore which yielded about 150 tons of concentrates estimated to contain from 15 to 20 percent copper. This company operated on a mining lease obtained from the Navajo Indian Service. In 1943 an option on the Mardun lease was acquired by the Coronado Copper and Zinc Company. An intensive prospecting program begun by the Mardun organization has been continued in an effort to locate large low-grade ore bodies on the property. It is reported that the Mardun Company drilled 17,000 feet of test holes with an average depth of 24 feet or less. Records of a number of these have been examined, but others are lost. Known locations are shown on the map, Plate II B.

The recent activities of the Coronado Company suggest that the assay logs of these tests show unduly high copper content. In order to avoid confusion the data are therefore witheld until the matter is clarified by shaft-sinking and drilling now in progress. At present the engineers of the organization are pessimistic regarding the possibility of discovering large orebodies on the lease.

In 1926 the Shattuck-Denn Mining Corporation acquired tax titles on the nine patented claims in the White Mesa District. More recently they obtained options on the unpatented claims and in 1942 undertook a drilling and prospecting program in Old Fort Hill area. About 4700 feet of core holes were drilled and assayed. Locations of these holes and summaries of mineralized sandstone encountered are shown on the map, Plate II.

Geology

Most of the Kaibito Plateau, in the area studied, is surfaced by nearly horizontal, highly crossbedded, gray Navajo sandstone of Jurassic(?) age. About 1525 feet of clastic sediments assigned to this unit were measured in an incomplete section at Echo Cliffs immediately west of the district where the Navajo is underlain by Triassic clastic sediments and Permian limestone. To the east, red clastic sediments assigned to the Carmel formation rest on the Navajo.

The major structural feature of the western Kaibito Plateau is Echo Cliffs monocline which trends north-northwest to north along the margin of the table land. The steep dips on this flexure flatten gradually eastward into the plateau, but the regional dip continues east to southeast. Oblique normal faults locally complicate the Echo Cliffs monocline and extend north-eastward into the plateau, where they are difficult to trace because of the homogenous nature of the Navajo sandstone which forms both walls at the surface.

Geologic features of the White Mesa District.- The White Mesa Mining District occupies an area some 10 miles east of the Echo Cliffs monocline. Nearly horizontal Navajo sandstone, overlain by a veneer of dune sand, is the surface rock throughout the district. Approximately 420 feet of the unit, constituting the upper portion of the formation, are exposed in the area.

The fracture pattern of the White Mesa District is shown in Plates I and II. Fault fissures trend north-northwest and east-southeast in the western part of the district. Most of these show a slip down to the west or northwest. Sheeted zones traversed by parallel to subparallel faults and joints are marginal to the major fissures. A set of master joints, trending northeast, intersects these fractures, forming a complex system. In the central and eastern portion of the district northeast-trending master joints constitute the dominant fissures. Reefs of silicified breccia and gouge characterize the faults. Veinlets of chalcedony and, more rarely, calcite occur in the fault zones and walls. The major joints also commonly show extensive silicification.

Mineral Deposits.

The copper deposits of the White Mesa district vary from large low-grade tabular bodies to small irregular pods and veins of higher grade ore. Most of the well-exposed bodies are along or near zones of south, southeast, or northeast-trending joint or fault fissures which constitute the dominant structural control of ore deposition. The deposits have a very limited vertical extent and few show thicknesses which exceed 50 feet. The majority are similarly limited horizontally. Grade varies widely but is predominantly low, and for the district as a whole will not exceed 1%. Inferred reserves of this low-grade ore are large, but the cost of exploring the deposits will probably be high due to the large area which must be prospected.

Mineralogy.--Malachite is the most important copper mineral in the district and is usually associated with "chrysocolla."[1] These two minerals are disseminated through the sandstone in which they partially fill pore spaces, form coatings on grains, and occasionally occur as veinlets.

Copper pitch occurs in the wall rock of fissures where it frequently forms a halo around disseminations of chalcocite or bornite. The small quantity of both oxides and sulfides make their economic consideration negligible.

Gangue, in addition to sand grains comprising the sandstone, is mainly chalcedony which occurs in anastomosing stringers associated with the higher grades of ore. Veinlets of calcite are rare. Limonite is commonly disseminated in the sandstone as variable but rarely extensive halos around the copper bodies.

Distribution.--Large, low-grade copper deposits are mainly restricted to the northwestern portion of the district in the area between the Ida M. Smyth and Eastern Star faults. The most notable of these are the Little Dick and its possible Grand Pacific extension, the Copper World, and the California deposits. Series of closely spaced small bodies occur on the Dutchman claim, and in the area of the Coronado lease on

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[1] The exact composition of the copper silicates has not been determined. Clays, which are the common cementing minerals in the Navajo sandstone, have been combined with soluble copper compounds forming copper carbonate disseminated in clay, silicates, and oxides, Cf. Clark, F. W., The data of Geochemistry: U. S. Geol. Survey Bull. 770, pp. 670-680, 1924.

and near Copper Hill and Old Fort Hill. A rather large, but very low grade, body is exposed on the Queen Claim, and smaller ones occur on the Sunset and Ray Claims.

Throughout the district there are numerous small copper bodies. The distribution of the various exposed deposits and of their indicated or inferred extensions is shown on the map, Plate I.

Form and Character.—The copper deposits are very irregular and pockety. As indicated above, the larger, low-grade, tabular deposits are exemplified by the Little Dick, Grand Pacific, Copper World, and California bodies where weak mineralization occurs in large areas of sandstone. Drill-hole records show that these may exceed 80 feet in thickness. Such bodies are traversed by numerous joint fissures, the walls of which frequently show stronger mineralization than does the intervening sandstone. The small, higher grade bodies often occur as disseminations in the walls of fissures, and are usually vein or pod-like in character. Few have been observed to extend as continuous deposits for a greater horizontal distance than 50 feet. It is probable that their maximum vertical dimensions are approximately the same as those of the tabular bodies.

Control.—The majority of copper deposits examined are associated with joints, but relatively few are adjacent to fault fissures. In the western part of the district fissuring is dominantly south-southeast although locally it trends nearly east. Farther east most of the fissures associated with copper deposits are northeast-trending. Copper mineralization is commonly, although not invariably, strongest in the walls of the joint fissures but continues, with decreasing intensity, for a variable distance away from the apparent feeders. Joints which are strongly silicified appear to have constituted partial barriers to copper-bearing solutions and to have caused the waters to spread widely along bedding planes.

The White Mesa copper deposits are epigenetic and are products of precipitation from dilute copper-bearing solutions which entered the Navajo sandstone along fissures and spread along permeable laminae away from these fractures. It is not clear, however, whether the solutions were meteoric or telethermal.

There has been some modification of the original form and composition of the copper deposits. Downward-moving surface waters have undoubtedly resulted in the oxidation of the copper sulfides which were probably important primary minerals in the deposits. Such waters have also caused rather wide dissemination of originally more restricted deposits as a result of leaching and reprecipitation. "Sweating" of the sandstone has apparently resulted in concentration of soluble copper minerals near the present topographic surfaces.

Reserves

The status of mining development in the White Mesa Mining District does not permit highly accurate estimates of copper reserves. The ensuing discussion is an attempt to indicate the general magnitude of these reserves and their approximate range in grade as determined in the course of surface mapping. Drilling and assay data are available only in the western part of the district and have been freely used to supplement outcrop data.

In terms of the classification of ore reserves recently adopted jointly by the Geological Survey and Bureau of Mines,[1] reserves of ore in the known ore bodies of the White Mesa district are herein classed as <u>indicated ore</u>, and possible reserves that may exist in concealed ore bodies are classed as <u>inferred ore</u>. A significant portion of the indicated ore, in parts of ore bodies bounded by very moderate extensions from observed faces of ore in open cuts, shallow shafts, or short adits, is reasonably assured. The remainder of ore in this class, although regarded with less assurance, is believed to exist in farther extensions of the ore bodies. Outlines of these blocks (Plates I and II) are based on geologic evidence with little or no prospecting control. If further refinements in classification were justified a small fraction of the indicated ore might be regarded as <u>measured</u>, and a similarly small fraction around the fringes of the assumed outlines might be regarded as <u>inferred ore</u>. In this report, however, <u>inferred ore</u> includes only those possible reserves which may be present, although not exposed, in undissected mesas and buttes. Estimates of this class of reserves have been calculated by applying the ratio of volumes of sediments to volumes of ore as measured in adjacent outcrops. They are not, in any sense, accurate estimates, but they do provide a reasonable indication of the general order of magnitude of completely hidden (and still undiscovered) reserves.

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[1] Eng. & Min. Jour., vol. 144, No. 6, p. 94, June 1943.

TABULATION OF ORE RESERVES

WHITE MESA MINING DISTRICT

Indicated Ore

	Reasonably assured	In probable extensions	Totals
Grading 1 to 4% (in scattered small bodies).	80,000	180,000	260,000 tons
Grading 0.3 to 1% Cu (in a few large and many small bodies).	535,000	1,465,000	2,000,000 tons
	615,000	1,645,000	2,260,000 tons

Inferred Ore

	In concealed orebodies	
In area west of Eastern Star fault	7,250,000	
In area east of Eastern Star fault	6,750,000	
	14,000,000	14,000,000 tons

TOTAL INDICATED AND INFERRED RESERVES............ 16,260,000 tons

Variations in grade are further illustrated in the following table of typical average assays from various parts of the district:

Description	Samples	oz. Au.	oz. Ag.	% Cu	Remarks
Little Dick claim					
In and along walls of open cut	16	.001	.32	1.23	
40' NE and NW of N. end open cut	2	.001	.18	1.15	25 channel samples
South central part of claim	3		.15	.70	1.12% Cu
West central part of claim	1		.14	.59	
NW corner of claim	3		.20	1.05	
Grand Pacific claim					
West central part of claim	6		.23	1.02	12 channel samples
Central part	3		.18	.82	.82% Cu
South central part	3		.21	.44	
California claim					18 channel samples
Central part of claim	8		.14	.98	.82%
West part	10		.13	.69	
Nannie E claim					
North end	6		.18	.54	
Copper World claim					16 samples-channel
North part open cut	10	.001	.44	.69	.71% Cu
South part	6	.001	.26	.74	
Ida L. Symth claim					
NW corner claim	4	.001	.22	.55	
SE corner	1	.001	.14	1.57	
NE corner	1	.001	.16	1.02	
Eli claim					
North central part of claim	4	.001	.32	.80	
Gopher claim					
SW Central part of claim	1	.001	.20	1.35	

The area west of the Eastern Star fault contains most of the larger ore bodies and is believed to offer the best chances for mining development. Most of the large, low-grade copper deposits occur in this part of the district where they lie north of the Ida M. Smyth fault. The Little Dick-Grand Pacific, California, and Copper World bodies together account for 323,000 tons of measurabl or indicated and 1,130,000 T of inferred low grade ore in the estimates given. The Copper Hill area on the Lardun lease affords some promise as does the Dutchman Claim. It is considered possible that about 10% of the uplands in this part of the district are mineralized to an average depth of 50 feet giving 7,250,000 tons of implied ore which probably cannot be found economically.

Numerous small pods of high-grade ore occur in the eastern part of the district. There are a few large bodies, however. Approximately 1% of the uplands east of the Eastern Star fault are believed to be mineralized through an observed interval of 150 feet. The resultant 6,750,000 tons of implied ore will be costly to find and probably cannot be recovered economically.

Outlook

Possibilities for large copper-mining operations in the White Mesa Mining District are not high in the immediate future. The summation of reserves indicates a large probable and possible tonnage of ore which, at first glance, might be considered attractive to mining companies. The grade, however, is low and will average less than one percent copper. There is little to suggest that numerous large deposits of this low-grade material will be found and abundant reason to believe that most of the bodies will contain not more than a few thousands of tons. Deposits such as the Little Dick, Copper World, and California are clearly in the minority.

Exploration for reserves in the area will be costly because of the large areas which must be drilled on close centers in order to block out known ore bodies or to find inferred ones. Open-pit mining operations will require the removal of large tonnages of barren or very low-grade sandstone in order to search out and recover ore pods which may characterize the supposed large tabular deposits. Furthermore such operations can not long be restricted to a narrowly circumscribed portion of the district. Costs of constructing roads, trucking ore to mills, and moving mining machinery from one location to another will therefore be considerable.

The White Mesa Mining District is 112 miles from the rail head at Flagstaff, Arizona, and approximately 175 miles from the nearest smelter at Clarkdale, Arizona. Beneficiation will be necessary to obtain, in significant tonnages, a product which can be profitably shipped. The White Mesa ore will leach well but the present water supply of the district is inadequate for such an operation, and conditions are unfavorable for any large increase by additional drilling. Although it would be physically possible to obtain surface water from Colorado River at Lee's Ferry or from Navajo Creek, about twenty miles north or northeast of the district and at far lower elevation, costs of installing and maintaining a pumping system would probably be prohibitive.

A dry milling process which is reported to yield a 20 percent concentrate with a rather high efficiency has been developed by the Mardun Company. As the process is still in the experimental stages, however, there are no data on costs and recovery in large milling operations. It is possible that this process may offer a solution to concentrating problems in the district.

It is suggested that any large-scale attempt to develop the copper reserves in the district be prefaced by a careful analysis of mining and concentrating costs based on the mining of many scattered small bodies which will average not higher and probably less than one percent copper. Efforts to block out ore should be initiated only in the event that such an economic survey points to the possibility of development based on minimum rather than maximum tonnage expectations.

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