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TENTATIVE CORRELATION OF THE SEDIMENTARY ROCKS AT CANANEA, SONORA, MEXICO WITH THE SECTION AT BISBEE, ARIZONA *

By Roland B. Mulchay and J. Rubén Velasco

INTRODUCTION

The copper deposits and rocks of the Cananea District have been described by many geologists and engineers as noted in the accompanying bibliography. Cananea has long been recognized as a remarkable field for geologic study. In the past, however, the emphasis in Cananea publications has been upon the mineralization and widely varied rock types of the district. Only the most general correlations have been attempted to compare Cananea sedimentary rocks with other known sedimentary sections in northwestern Mexico and southwestern United States. The present paper describes the Cananea sediments in somewhat greater detail than has been done before, and attempts to fit the Cananea sedimentary section more closely into the geologic timetable. The lack of well preserved fossil remains has made it difficult to date the sediments accurately in geologic time, but based upon the detailed sections developed at Bisbee and other parts of Southern Arizona, it is possible to make tentative correlations between the Cananea sediments and the southeastern Arizona sections based largely upon lithology and general position in the geologic column. It appears that sedimentation at Cananea and Bisbee may have been closely similar during Paleozoic time. Even such generalized correlations may be subject to considerable modifications in the future. The present study has led to the recognition of still other problems of age and mineralization relationships in the Cananea District.

LOCATION, PHYSICAL FEATURES, HISTORY

Cananea is located in the north central part of the State of Sonora, Mexico, at Latitude 30°57'N, Longitude 110°18'W, at an elevation of 5270 ft. (1606 mts.). It is approximately 135 miles northeast of Hermosillo, the state capital, and about 25 miles south of the international boundary. The town is 40 miles by road southwest of the twin towns of Naco, Arizona and Naco, Sonora, and some 50 miles by road from Bisbee, Arizona. Cananea is served by the Nogales-Naco branch of the Sud-Pacifico de Mexico Railroad,

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and the Lamsa Airline gives Cananea air connections with Chihuahua and Mexico.

The San Pedro River, which flows northward to the Gila River in Arizona and eventually reaches the Gulf of California at its northern end, and the Sonora River, which flows southerly and west past Hermosillo to reach the Gulf of California, both have their headwaters in the Cananea Mountains. The shorter Magdalena River, which flows westerly to the Gulf, also has its start on the west slopes of the Cananea range. Elenita Mt., the highest point in the district, has an elevation of 8140 ft. (2481 mts.). The Cananea Mountains, which rise from surrounding gently sloping gravel plains, extend in a series of north-south to northwest-southeast trending spurs and ridges. The mineralized area occupies a broad belt across the southern and central part of the range, and has a length of about six miles and a maximum width of about two miles. Elevations vary from around 5300 ft. at the Cananea Duluth Mine at the southeast end of the district to between 6000 and 7000 ft. at the west end of the mineralized area at the Puertocitos-Elenita Mines. The main production has been derived from the intensely mineralized and altered area of Capote Basin in the central part of the district and the immediately surrounding area to the southeast. The district has produced over 2,000,000,000 pounds of copper, substantial molybdenum, and minor amounts of lead, zinc, silver and gold. Total production through 1949 is estimated to have had a value of over $300,000,000 dollars.

Although the Cananea mineralization had been known for many years, the modern history of the camp dates from 1900 when large scale development was started by Col. W.C.Greene. The growth of Cananea largely parallels that at Nacozari, another large copper district about 60 miles to the southeast. Although the development of the district until the second World War was based upon exploitation of high-grade ores, the installation of a large concentrator in the early 1940's made extraction of low-grade ores possible, and operations have since been based upon mining and processing ores containing less than 1.0% copper from open pit and underground workings. Operations based upon such low-grade material are, of course, dependent upon continued high copper prices, and exploration for new high-grade ore bodies is actively continued throughout the main mineralized areas.

GENERAL GEOLOGY

Study of the involved rock pattern at Cananea has indicated a complex geologic history for the district, and widespread alteration and mineralization have masked many of the salient features of age of rocks and mineralization. Interpretations of the geology have changed widely during the many years of study as additional evidence has become available, and further work will probably provide information which will modify current beliefs.

At Cananea a conformable series of sediments of probable Paleozoic age were deposited upon an unknown basement. Following Paleozoic time there was an extended period of erosion, as has been described in many districts in the southwestern United States. At Cananea there is no present evidence of further sedimentation after the Paleozoic. The eroded limestone surface developed at the end of the Paleozoic was eventually covered with a great thickness of extrusive volcanic rocks. The entire series of sediments and volcanics was later intruded by a variety of deep seated igneous rocks.

These included the Cananea granite, the Cuitaca granodiorite, the El Torre syenite, the Tinaja diorite, the Campana diabase and gabbro, and the Colorada quartz porphyry. Mineralization, probably in several surges, was deposited in economic amounts, and locally enriched, chiefly in the sediments, volcanic rocks, and the quartz porphyry. Garnetization of the upper limestone beds occurred on a district wide scale, and the intimate relations of the garnetization and some of the mineralization suggest that at least part of the tremendous development of garnet, mainly andradite, was caused by hydrothermal solutions rather than by limited contact metamorphic effects. Intense sericitization developed in the volcanic rocks and the quartz porphyry was directly related to strong and widespread mineralization.

Cananea is lacking in prominent vein structures and most of the economic mineral deposits have been mined as primary and secondarily enriched ore bodies localized in steep dipping breccia pipe structures, in disseminated deposits in the volcanic rocks and quartz porphyries, and from replacements in the sediments. Recent faulting also has been of minor importance, although there has been some movement along northeast trending faults, and some prominent northeast striking shear zones without important movement have been developed. Faulting of early age, probably prior to the deposition of the volcanic rocks, may have been responsible for the present position of some of the intrusive rock masses. In the Capote Mine on the 3rd and 4th levels the northwest striking Ricketts fault zone, with an apparent offset of as much as 800 ft., has been sealed by a dike-like mass of Cananea granite which gradually increases in size with depth. In the lower levels of the mine the granite forms a large southeast plunging mass in a general way following the course of the Ricketts zone. Although the granite is not known southeast of the Capote-Oversight Mine areas, and the Ricketts fault does not appear in the volcanics southeast of Capote Basin, a series of prominent plugs of Colorada quartz porphyry cut the volcanics along the assumed general trend of the Ricketts zone to the southeast. These porphyritic intrusives may be the upward expression of a batholithic mass of granite, deeply buried below the volcanic rocks in the southeast end of the district.

Much of the copper mineralization mined during the past twenty-five years appears to have been closely associated with the quartz porphyry intrusives, and detailed study of the contact phases of these intrusive bodies has been useful in the enlargement of many of the known low-grade areas of mineralization. So called "rock breccia" areas around the margins of the quartz porphyries have proven favorable loci for mineralization which has been deposited within these areas of intimate mixture of quartz porphyry and volcanic rocks. Within these contact zones breccia pipes, some of which do not reach surface, have formed feeders for bodies of low-grade mineralization composed of numerous small seams and disseminations, often enriched with secondary chalcocite.

The ore deposits of the district have been described by Mr. V.D. Perry, and the rocks have been described by Mr. Wilbur Valentine. The high-grade ore minerals of the La Colorada ore body were investigated by Mr. V.C.Kelley. For the purposes of this paper no further description of the ore deposits will be attempted, although the ore occurrences in the "rock breccias", in breccias without surface expression, and in the several types of breccia pipe

structures present at Cananea are intriguing subjects, and worthy of much additional discussion and description.

STRATIGRAPHY

CAPOTE QUARTZITE

The lowest member of the sedimentary series, and the oldest known rock in the district, is the Capote quartzite. Formerly believed to have been deposited upon the Cananea granite as a basement rock, underground work at the Capote Mine has shown that the Cananea granite is intrusive into the sedimentary series, and the original basement rock below the quartzite is unknown. The composition of the quartzite in the lower exposed beds suggests that the sediments were derived from a granitic rock, but the basement of pre-Cambrian Pinal schist and granite, found below the Bolsa quartzite at Bisbee, is unknown at Cananea. In common with the other sediments of the Capote Basin area of the district, where the largest exposures of the sedimentary rocks are found, the quartzite has a general northwest strike and northeast dip. It is generally well bedded, and is now chiefly composed of quartz and sericite with considerable pyrite. The thickness of the formation is obscured by fault contacts and a considerable part of the lower quartzite series may have been intruded by the Cananea granite, but there is a stratigraphic thickness of at least 400 ft. exposed northwest of the Capote Mine. Valentine believes there may have been as much as 800 ft. of quartzite present.

At Bisbee the lowest member of the sedimentary series, the Bolsa quartzite which rests on pre-Cambrian Pinal schist, is given a thickness of 430 ft. by Ransome, and is assigned to middle Cambrian age. In the Swisshelm Mts., north of Douglas, Arizona, the basal quartzite member of the Paleozoic series has a thickness of about 300 ft., and in part at least has been intruded by granite at or near the base.

ESPERANZA LIMESTONE

Immediately above the Capote quartzite, and with no break in sedimentation, there are a series of very thin bedded, very highly altered and mineralized limestones. Though these beds have been developed underground for about three thousand feet on strike, no trace of original, unaltered limestone has been found. The beds vary from one inch to twelve inches in thickness, and are completely replaced along bedding by chlorite, epidote, little garnet, heavy pyrite, magnetite, hematite, locally gypsum, and some copper and zinc mineralization. In particular areas the iron content, chiefly as pyrite, is very high, and throughout the series there are small, isolated pods and lenses of later chalcopyrite with little bornite and chalcocite. The upper part of the old and very high-grade Capote orebody, mined during the early days of the camp, is believed to have been a secondarily enriched body of relatively high-grade copper ore deposited in the Esperanza beds. This mineralization appears to have been introduced through the Capote breccia pipe, which successively in the Capote lower levels cuts quartzite and granite. Ore within the breccia pipe itself on the lower levels was comparatively low grade.

The thin bedded, highly altered Esperanza series has a thickness of 300 ft., plus, and appears to be conformable with the underlying Capote quartzite. The upper contact grades gradually into thicker bedded white to gray limestones without apparent unconformity.

The Abrigo limestone at Bisbee, which succeeds the Bolsa quartzite in the sedimentary column, was given a thickness of 770 ft. by Ransome. The series there is composed of very thin bedded, shaley, flaggy limestones, and is assigned to the middle Cambrian. In the Swisshelm Mts. similar limestones lying above the basal quartzite member have a thickness of 400 - 600 ft.

CRYSTALLINE LIMESTONE

Succeeding the Esperanza beds, and with a gradational zone between them, there is a thickness of from 300 to 350 ft. of gray white to dark gray crystalline limestones, locally entirely marbleized. The darker bands are largely in the lower part of the series. Average analyses of these limestones show they now contain up to 12% MgO. While the series is locally well altered with weak development of chlorite and epidote near some intrusive rocks, the Crystalline beds can be traced laterally for over 2000 ft. underground and extend at surface as an irregular band, interrupted by faulting, from the Veta Mine northwest to the Elisa Mine. Beds vary from a few inches to about three feet in thickness, and are conformable with the remainder of the sedimentary series. The strike is northwesterly, and dips vary from 25 to 45° to the northeast. Locally there is little mineralization along bedding and in narrow fissures which cut bedding, but in general this horizon has not been favored by mineralizing solutions, and no important ore bodies have been found in the series.

The only fragmentary fossil remains discovered to date in Cananea have been found in the crystalline limestones. Poorly preserved fossils from the lower part of the series, microscopic spirifers and crinoids which could not be identified, resemble Devonian forms. Somewhat better specimens from the upper beds of the series were discovered in 1925 by Dr. G. J. Mitchell, formerly chief geologist at Cananea, and were identified by Dr. G.H. Girty as Missippippian fauna. The fossils included cup corals and a spirifer of the Rockymontanus group.

Sedimentation appears to have been continuous, passing from the underlying thin bedded limestones, tentatively assigned to Cambrian age on basis of lithology and position in the section, through the Crystalline limestones and into the succeeding beds above. On the basis of the few fossil remains discovered to date, it appears reasonable to place the lower part of the Crystalline limestone series in the Devonian with the upper beds representing a gradational phase into the lower Carboniferous. The thickness of the Devonian might be assumed to be from 200 to 250 ft. with the upper 50-100 ft. of the Crystalline series to be included with the lower Mississippian.

At Bisbee sedimentation from the underlying Cambrian Abrigo limestones to the Mississippian Escabrosa appears to have been continuous, but there is no fossil record of sedimentation of Ordovician or Silurian age. The Devonian Martin limestone, between the Abrigo and the Escabrosa, has a

thickness of 340 ft. as determined by Ransome. The contact with the overlying Escabrosa is not clearly marked, and is termed gradational. This is also true in the Swisshelm Mts. where about 400 ft. of gray limestones can probably be assigned to the Devonian with gradational upper and lower boundaries.

CHIVATERA ZONE

At the approximate upper boundary of the Crystalline limestones, a horizon particularly favorable for mineralization has been developed in several mines, and has contained economic amounts of copper-zinc-silver mineralization. This zone has been called the Chivatera mineral zone, and lies between the massive garnetized horizons of the Puertecitos limestones and the underlying Crystalline series. Locally the mineralization replaces some of the upper Crystalline beds. The zone has a thickness of 50-100 ft. but may disappear completely at the ends of the mineralized lenses. The mineralization roughly follows bedding on dip, and within the mineralized areas the limestone is entirely altered to chlorite and epidote with irregular chalcopyrite, sphalerite, pyrite, little chalcocite and bornite, and little calcite and quartz. There is some evidence of mineral zoning in the Chivatera replacements with an increase in copper minerals at the expense of sphalerite with depth. While the Chivatera zone is not continuous, it has been extensively developed across the district in the Veta 5, Chivatera, Hueco and Campana Mines. The position of the zone immediately above the upper Crystalline beds, which contain poorly preserved Mississippian forms, suggests that this horizon also should be placed in the lower Carboniferous.

At Bisbee, the lower Carboniferous Escabrosa limestone has proved a very favorable horizon for mineralization. Many important ore shoots, extending from the surface exposures of the original Copper Queen orebody on the west, through the Junction mine and other ore shoots localized around the Sacramento Hill porphyry, to the pipe-like Campbell ore body on the east, have contributed their major copper content from replacements in the gently east dipping Escabrosa beds.

PUERTECITOS LIMESTONE

Above the Crystalline limestones and the Chivatera zone begins a series of conformable, relatively thick bedded limestones from one to four feet in thickness which have been nearly entirely garnetized. Formerly the entire limestone section at Cananea was known as the Puertecitos limestone, the name having been taken from the garnetized limestones of the Puertecitos area where considerable mining of isolated ore lenses was done in the early days of the camp. For the present usage, the name "Puertecitos limestone" will be reserved for the garnetized beds which form the uppermost beds of the sedimentary series.

Bedding in this series appears to be conformable with the rest of the sediments, although the attitude is much less evident than in the Esperanza and Crystalline divisions. The upper limit of the limestones is an old erosion surface upon which large thicknesses of volcanic rocks have been deposited. Extending eastward and to the southeast from Capote Basin the most recent volcanic rocks, the Mesa tuff series, cap the garnetized limestones,

and within strongly mineralized areas the volcanic rocks have also been replaced by extensive garnet masses. The garnetized limestones have a minimum thickness of 1000 ft., and where capped to the southeast by the Mesa tuff the thickness is probably not less than 2000 ft.

While the age of these limestones cannot be closely determined, the thickness of the series which has undergone similar change to almost massive andradite garnet suggests that the entire series was a chemically very similar unit as are the Carboniferous Escabrosa and Naco limestones of Southeastern Arizona. There, too, the upper limit of the Naco Pennsylvanian limestones is an old erosion surface. On this basis it appears reasonable to assign the garnetized limestones to the Carboniferous, and to include the Chivatera zone and the upper beds of the Crystalline limestone in the Carboniferous without further differentiation.

At Bisbee the Mississippian Escabrosa limestone has a thickness of 600-800 ft., and the Naco limestones, truncated by an old erosion surface, were measured as 1500 to 2000 ft. in thickness. In the Swisshelm Mts. the Escabrosa was estimated to have a thickness of 350 ft., and the Naco, only partly exposed, was estimated at 350 ft. plus.

COMPARISON OF THE CANANEA SECTION WITH THE BISBEE AND SWISSHELM MOUNTAINS SECTIONS

The following summary shows a comparison of the sedimentary section at Cananea with the sections at Bisbee, Arizona, and the Swisshelm Mountains, north of Douglas, Arizona:

	Cananea	Bisbee	Swisshelm Mountains
Tertiary (?)	Volcanic rocks	- -	Volcanic rocks
Mesozoic	- - -	Cretaceous Bisbee Group 5000 ft.	- - -
	Unconformity	Unconformity	Unconformity
Paleozoic Carboniferous	Puertecitos Ls 2000 ft. plus Chivatera Zone 50-100 ft. Upper Crystalline Ls 50-100	Naco Ls 2000 ft. plus Escabrosa Ls 600-800 ft.	Naco Ls 350 ft. plus Escabrosa Ls 350 ft.
Devonian	Lower Crystalline Ls 200-250 ft. Gradational upper & lower boundaries	Martin Ls 340 ft.	Martin Ls 400 ft. plus or minus
Cambrian	Esperanza zone 300 ft.	Abrigo Ls 770 ft.	Abrigo Ls 400-600 ft.
	Capote Quartzite 400 ft. plus	Bolsa Quartzite 430 ft.	Bolsa Quartzite 300 ft. plus
Pre-Cambrian	Unknown basement	Pinal schist & granite	Basement - granite (?)

On the basis of lithologic similarity and the few available fragmentary fossils found in the Crystalline limestones, the Cananea sedimentary section can be tentatively correlated with the Paleozoic section in Arizona. While it must be admitted that there are many sources of doubt as to particular boundaries in the conformable series of sediments, the general comparisons appear reasonable. Further investigation may make possible more accurate dating of the Crystalline limestones with consequent more secure placement of the remainder of the series.

GENERAL GEOLOGY IN SURROUNDING AREA

VOLCANIC ROCKS AND SEDIMENTS

Surrounding the Cananea Mts. there are wide gently sloping mesas of recent unconsolidated conglomerates which reach a thickness of at least 1100 ft. at Del Rio, north of Cananea. These gravels cover a pediment of the latest Mesa volcanic rocks which lap on to the lower eastern slopes of the Cananea range. The conglomerates are comparable in age to the relatively recent Gila conglomerate series of Arizona.

To the northeast in the San José Mts., just south of the international boundary, several thousand feet of folded Cretaceous sediments, which correspond to the Cretaceous beds at Bisbee, are exposed. Toward Cananea, southwest of the San José exposures, nearly vertical beds of Cretaceous quartzites and shales are found near the Sauz Arroyo road crossing on the Cananea-Naco road. These sediments are succeeded to the south and southeast by extrusive tuffs and agglomerates. The volcanic rocks can be followed southeasterly into the Ajo Mts. which lie about 15 miles east of Cananea. It is probable that these volcanics at the northerly end of the Ajos Mts. can be correlated with the most recent Mesa tuff volcanics at Cananea.

In the Ajos Mts. basal quartzites are reported to rest on pre-Cambrian Pinal schist, and to be succeeded by Paleozoic limestones above. Cretaceous limestones are also recognized in the Ajos, although generalized relationships have not been established. Northeast of the Ajos, N.L. Taliaferro has described a considerable thickness of upper Cretaceous sediments with some thin interbedded ash beds. These sediments are reported to be of Upper Cretaceous age and later than the Comanche Cretaceous beds at Bisbee.

South of the Cananea Mts., some 25 miles at San Antonio Ranch, there are wide exposures of shales of probable Cretaceous age; the area between Cananea and San Antonio is largely covered with volcanic rocks.

The problem of the age of the volcanic rocks at Cananea is an interesting one, but one which at present cannot be fully resolved. The Mesozoic sediments found around the Cananea area apparently were deposited through almost the entire Cretaceous period. While sediments of this age may have been deposited at Cananea, none are now in evidence, and if deposited, must have been completely stripped by erosion. It seems unlikely that the great thicknesses of extrusive Cananea volcanic rocks could have been formed during a period in which there was nearby sedimentation such as appears to have extended through most of the Cretaceous. The earliest of the Cananea volcanic rocks, on this basis, must, therefore, not be older than late Cretaceous.

As three thick volcanic series, the Elenita, Henrietta and Mesa, have been recognized at Cananea, all separated by erosional gaps, it appears that volcanic activity must have extended over a considerable time. The intrusion of the deep seated igneous rocks and the mineralization which followed may have occurred, therefore, somewhat later in geologic history than has been previously believed.

ACKNOWLEDGMENTS

The writers wish to acknowledge the assistance which has been obtained from geologic data acquired over the years by various members of the Company geologic staffs and consultants. Particular recognition must be accorded Mr. Reno H. Sales, Mr. V.D. Perry, Mr. Wilbur Valentine, and other more recent members of the staff who have contributed to the general knowledge of the district. Dr. A. Stoyanow, of the University of Arizona, kindly looked at the few new fragmentary fossils found. Mr. Albert Mendelsohn, President of The Cananea Consolidated Copper Company, has kindly given permission for publication of the paper, and it is appreciated that only the active support of Mr. Mendelsohn and the Company has made possible the continuation of detailed geologic work in the district.

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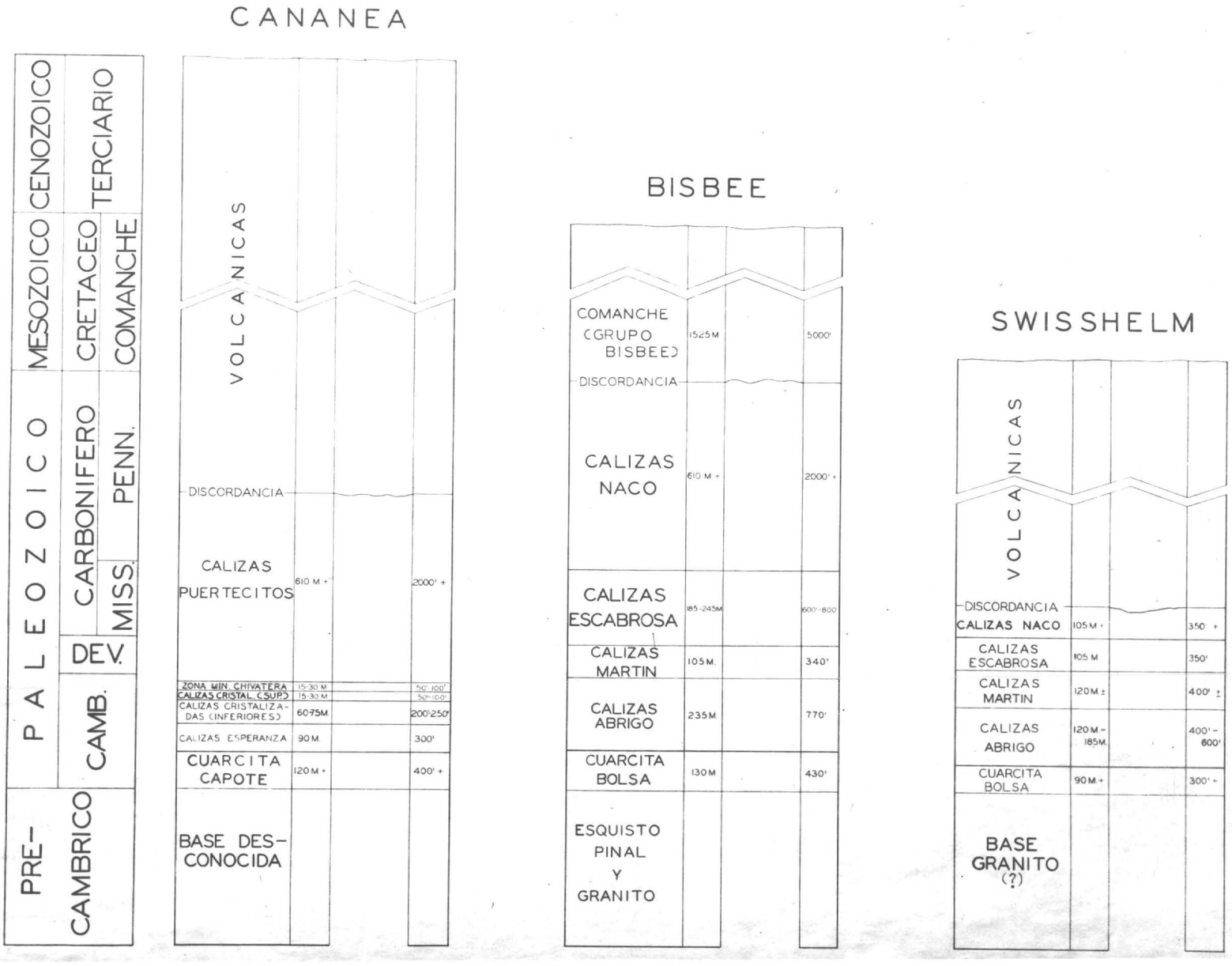

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THE CANANEA CONSOLIDATED COPPER COMPANY, S. A.

CANANEA, SONORA, MEXICO.

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July 25, 1952

Mr. E. J. Kennedy, Jr., Sec.,
Tech. Publications Committee, AIME,
29 W. 39th Street, New York 18, N. Y.

Dear Mr. Kennedy:

Enclosed are three photostatic copies of a generalized geologic column to accompany the paper "Tentative Correlation of the Sedimentary Rocks at Cananea, Sonora, Mexico with the Section at Bisbee, Arizona" by Mulchay and Velasco.

We have a chance to send out the copies this morning, and will not, therefore, attempt to reduce them further in size. The original of the drawing is approximately 25 1/2 x 33 in., or about three times as large as an ordinary letter size sheet.

With best regards

Yours very truly,

Roland B. Mulchay

Roland B. Mulchay

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