UNITED STATES DEPARTMENT OF THE INTERIOR

U. S. GEOLOGICAL SURVEY

COPPER AND URANIUM MINERALIZATION IN THE COYOTE MINING DISTRICT MORA COUNTY, NEW MEXICO

By

Donald Carl Laub, 1922-

May, 1954

This report or illustration is based on work done on behalf of the U. S. Atomic Energy Commission.

U. S. GEOLOGICAL SURVEY
OPEN FILE REPORT
This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

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ABSTRACT

Sedimentary copper-uranium deposits lie along the eastern flank of the Sangre de Cristo Range in the Coyote mining district, Mora County, New Mexico. The oldest rocks in the district are pre-Cambrian granites, pegmatites and metasediments. These are unconformably overlain by marine limestones and shales of Pennsylvanian age and fluviatile sediments of Pennsylvanian-Permian(?) age. Tertiary basalt flows are extensive to the east and cover Pennsylvanian and Permian rocks locally.

The copper-uranium mineralization occurred in a belt of thrusting and transverse faulting associated with the uplift of the Ancestral Rockies, but there is no visible evidence to relate the ore deposits to faults. The uranium deposition seems to have been controlled by channels containing carbonized plant remains in the coarser sandstone lenses of the Sangre de Cristo formation.

There are two major types of ore deposits in the Coyote district. One consists of copper-replaced pyrite nodules and plant remains in black carbonaceous shales, the other consists of uranium in cross bedded sandstones. Copper is most abundant in the lower 1,500 feet of the Sangre de Cristo formation.

The most important copper mineral is chalcocite with minor amounts of chalcopyrite, bornite, covellite, pyrite, malachite, and azurite. The uranium minerals are metatyuyamunite and an undetermined black radioactive mineral associated with chalcopyrite.

The uranium occurs in stream channels approximately ~~1,500~~ 2,000 feet stratigraphically above the top of the Magdalena group (as mapped).

The copper-uranium ~~is of epigenetic origin and~~ was probably derived from nearby pre-Cambrian highlands which contain abundant copper mines, granitic intrusions, and uranium bearing pegmatites. ~~Atmospheric~~ Meteoric waters containing copper sulfate and a solu~~a~~ble uranium compound transported the minerals to their present site and upon encountering carbonaceous material were precipitated out.

ACKNOWLEDGMENTS

This paper concerns work done by the U. S. Geological Survey on behalf of the U. S. Atomic Engergy Commission and is open-filed with the permission of the Commission.

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INTRODUCTION

In the Coyote district, Mora County, New Mexico, a copper-bearing black shale of Pennsylvanian-Permian age was found to contain uranium. The abnormal radioactivity of the shale was first reported by George O. Bachman and Charles B. Read, (1951). A reconnaissance map on a 1"-1000' scale and a preliminary report on the area were completed by H. D. Zeller and E. H. Baltz, Jr., (1952). In the summer and fall of 1953 C. M. Tschanz, J. W. Fuller, and D. C. Laub made a detailed geologic map of selected areas at a scale of 1"-200'. The areas showing highest radioactivity were trenched at intervals along the mineralized horizons. The trenches were mapped and sampled in detail. No uranium ores have been produced from these deposits up to the date of this report.

Purpose and scope

The purpose of this study is to determine the paragenesis of the copper-uranium minerals and their relation to the enclosing host rock, to determine the factors that control the ore deposition, and to draw conclusions concerning the origin of the copper-uranium mineralization. Mineralogical studies were made of selected rock and mineral specimens by means of thin sections, polished sections, X-ray analyses, differential thermal analyses, heavy mineral separation, and autoradiographs.

Field work consisted of measuring a complete section of the Sangre de Cristo formation, observation of sedimentary structures to determine their possible relationship to copper-uranium deposition, preparation of detailed sketch maps of cut and fill structures containing uranium, and radiometric traverses of the complete area.

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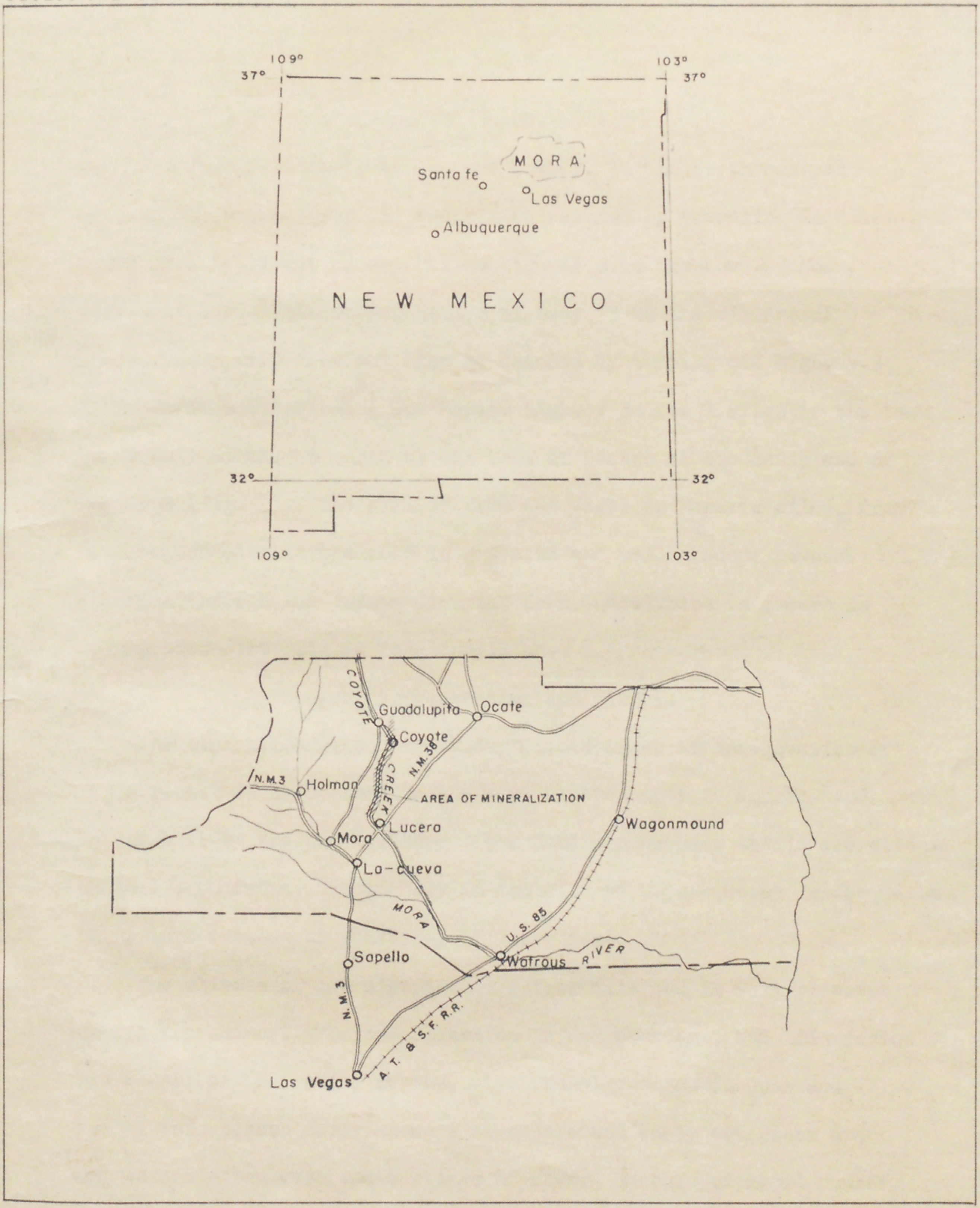

FIG. 1

INDEX MAP
OF
MORA COUNTY, NEW MEXICO

0 10 20 30 MI.
SCALE

Location and Accessibility

The Coyote district is in Mora County, in the north central part of New Mexico (fig. 1) and can be reached by traveling 28 miles north from Las Vegas on New Mexico highway 3 to the town of Mora, thence 14 miles east on New Mexico highway 35 to the village of Guadalupita. The area may also be reached by turning off highway 3 at La Cueva and following New Mexico highway 38 for 7 miles to the town of Rainville, thence north to the town of Lucero at the south end of the area (fig. 1). The highway from Las Vegas to Mora is oiled, from Mora to Guadalupita the road is graveled and well graded; however, the road through the Coyote district from Guadalupita to Lucero is an ungraded dirt road in poor condition.

Topography, vegetation and climate

The mineralized area lies along Coyote Creek at an elevation of 7,200 feet. It is bounded on the west by the Southern Rockies and on the east by the Great Plains. The Southern Rockies attain elevations up to 13,000 feet. Immediately to the east of Coyote Creek is the Ocate Mesa, that reaches an elevation of 7,600 feet.

The climate of the district is rather mild and is very pleasant during the summer. The precipitation is not abundant, but this region has a well defined rainy season, which usually comes in June and July. During this season daily showers at middle and early afternoon are common and often wash out sections of road. Because of rapid runoff, erosion is extremely rapid and deep gullies are characteristic. The temperature in the late fall and winter is sufficiently low for snow to cover the higher parts of the range, but snow seldom stays in Coyote Valley.

The upper slopes support abundant stands of pinyon and ponderosa pine. At lower elevations Juniper and scrub oak are dominant. Short grasses cover the floor of Coyote Valley and the adjacent slopes.

GEOLOGY

Stratigraphy

General statement

The rocks in the district comprise four main groups: (1) metamorphic and igneous rocks of pre-Cambrian age; (2) arkose, sandstone, siltstone, limestone and shale of Pennsylvanian and Permian age; (3) basalt flows of late Tertiary or Quaternary age; (4) alluvial deposits of Pleistocene and Recent age. The uplift of the Sangre de Cristo Range to the west deformed the Pennsylvanian and Permian rocks in the Coyote district. The Magdalena group and the Sangre de Cristo formation have been steeply tilted and faulted to form north trending hogbacks along the east flank of the Sangre de Cristo Range. The Permian and younger rocks to the east of the area are relatively undeformed and are capped by basalt flows of late Tertiary or Quaternary age. (See fig. 2).

Pre-Cambrian igneous and metamorphic rocks

Igneous and metamorphic rocks are exposed immediately to the west of the area and make up the core of the range. The predominant metamorphic rocks near the area are quartzites, with mica schists and

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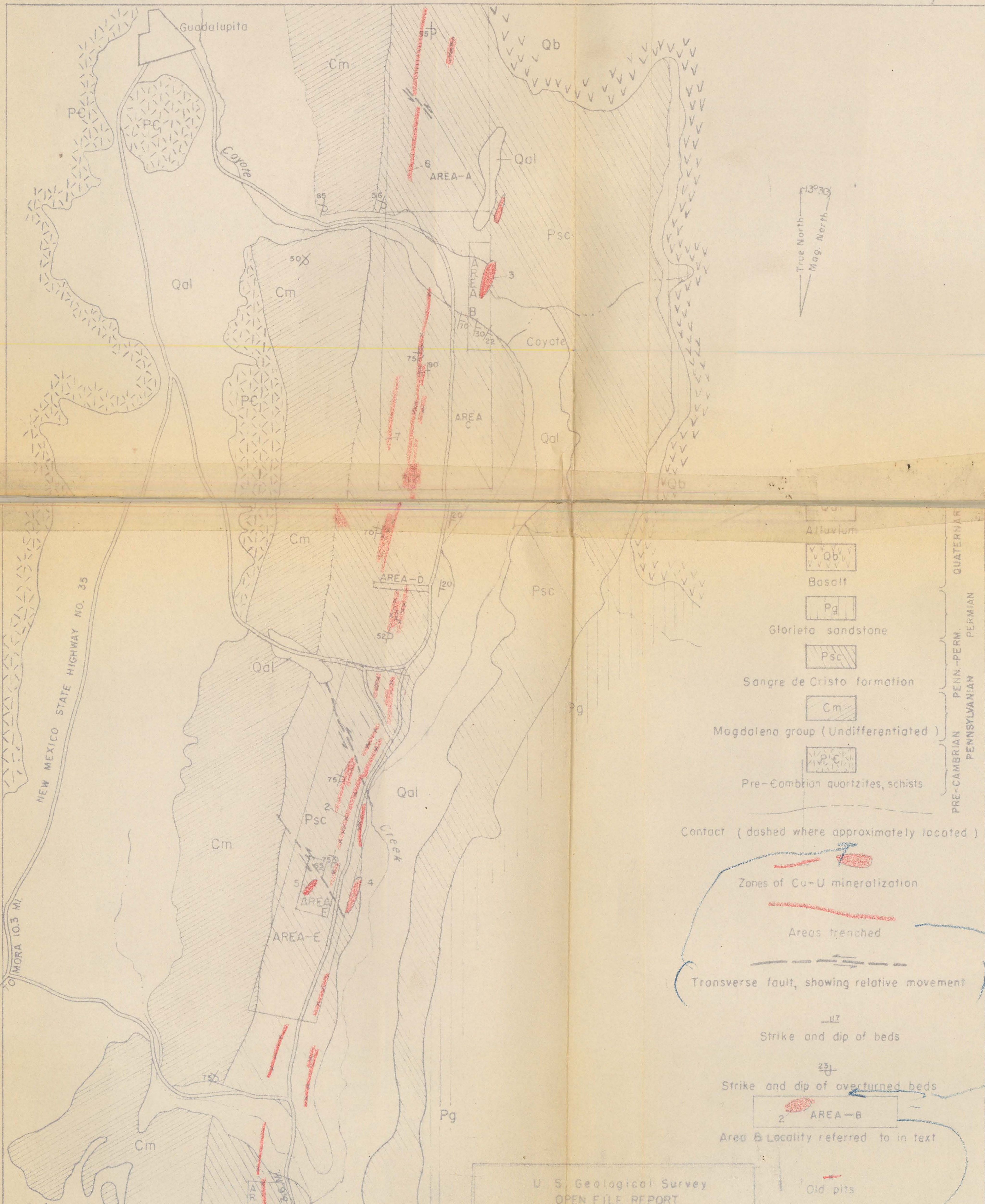

FIG. 2

GEOLOGIC MAP OF
PART OF COYOTE DISTRICT
MORA COUNTY, NEW MEXICO

0 1,000 2,000 3,000 4,000 5,000 6,000 ft.

SCALE $\frac{1}{24,000}$

Adapted from figure 2 TEMR 435
Modified by D.C. Laub & C.M. Tschanz

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gneisses more abundant further west. These rocks are cut by granite stocks and pegmatites.

Several copper deposits of probable pre-Cambrian age (Lindgren, 1910, p. 112) occur along the eastern flank of the range. The copper occurs in fissure veins in the schist and gneisses. Small amounts of uranium were found in the granite pegmatites by L. R. Page (1950, pp. 22-30) in the Petaco district and at the Pidlite mica mine near Mora. A similar uranium bearing pegmatite in Gallinas Canyon was visited in April, 1954 by the writer and C. M. Tschanz of the U. S. Geological Survey.

The uranium is closely associated with magnetite, pyrite, and biotite in a granite pegmatite cutting pre-Cambrian gneiss.

Pennsylvanian system

Magdalena Group

General features. — The Magdalena group 12 miles west of Guadalupita, as described by Bachman, (1953) consists of four units. The basal unit, equivalent to the Sandia formation, is about 3,800 feet thick and is dominantly composed of sandstone and arkose together with interbedded shale and minor amounts of limestone. The succeeding unit consists of about 1,000 feet of bituminous and slightly calcareous, friable and fissile shale. Above that is a unit that consists of 2,800 feet of interbedded arkose, sandstone, shale and limestone. The uppermost unit consists of brown to brownish red sandstone, arkose and shale interbedded with gray marine limestone. It is about 3,000 feet thick. It is apparent that the Pennsylvanian strata here are more than 10,000 feet thick and that they are dominantly marine.

The Magdalena group near the town of Mora, however, is only 3,540 feet thick. Bachman (1953) believes part of the Magdalena group is cut out by faulting west of the Coyote district.

The contact of the Magdalena group with the overlying Sangre de Cristo formation was drawn at the top of a fossiliferous marine limestone which formed a convenient marker bed. The horizon also coincides approximately with a color change from yellow-brown arkoses of the Magdalena group to the dominantly pink arkoses which characterize the Sangre de Cristo formation.

Fossils. — A suite of invertebrate fossils collected from the limestone bed chosen as the top of the Magdalena group was identified by Mackenzie Gordon, Jr. and Helen Duncan of the U. S. Geological Survey. The fossils included:

Meekella striatocostata

Dictyoclostus sp.

Linoproductus sp.

Composita subtillata (Hall)

Pteria sp.

Allorisma sp.

Worthenia sp.

Algae

Caninoid corals

Clisiophyllid corals

Fistulipora sp. massive form

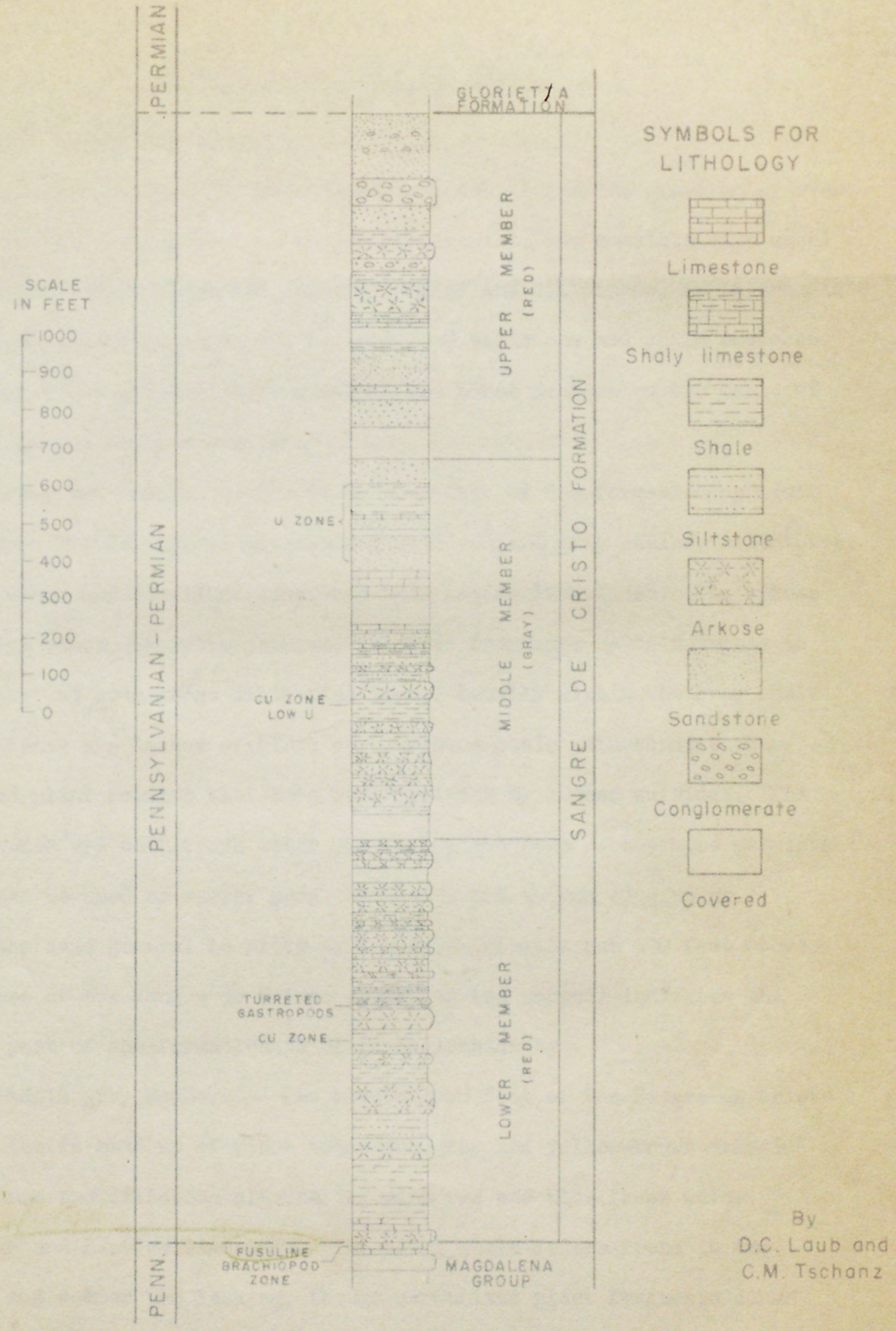
Polypora sp.

Rhapdomesan sp.

Sponge, species undetermined

The *Worthenia* was identified by Ellis Yochelson and Brooks Knight.

Age. -- The fossils indicate that the upper part of the Magdalena group is of post-Morrowan Lower or Middle Pennsylvanian age. The assemblage of corals, bryozoans, brachiopods and mollusks is typical of marine calcareous deposits formed in relatively shallow epeiric seas.



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C.M. Tschanz

FIG. 3 GRAPHIC SECTION OF SANGRE DE CRISTO FORMATION SHOWING ORE HORIZONS

Pennsylvanian and Permian system

Sangre de Cristo formation

General features. -- The Sangre de Cristo formation conformably overlies the Magdalena group in the Coyote district, and consists of a basal arkose series with interbedded red and gray shales and siltstones, an intermediate gray sandy, limy sequence and an upper red sandstone and shale sequence. The writer has divided the formation into three members on the basis of lithology and color change (fig. 3).

Lower red member. -- The lower 1000 feet of the formation consists of coarse angular arkose alternating with red and gray shales, siltstones, fresh water nodular limestones, and thin marine limestones. The arkose contains large quartzite pebbles, feldspar fragments up to 2 inches in diameter and some large silicified logs. Locally within the gray shale unit, there are lenses of black carbonaceous shale with abundant carbonized plant remains that have been replaced by copper sulfides. The limestones are both fresh water and marine and some of the more persistent ones can be used as marker beds. A brachiopod (Linoproductus sp.) from the same general locality as the other fossils but 500 feet above the base of the Sangre de Cristo formation (as mapped) indicates the lower part of the formation is of Pennsylvanian age.

Middle gray member. -- The middle 1000 feet of the Sangre de Cristo formation is made up of fine- to medium-gray and yellow-brown arkosic sandstone and siltstone alternating with red and blue fresh water nodular and massive limestone. The black shale lenses found in the lower red member are lacking, though carbonized plant fragments occur sparsely in sandstones and siltstones which show excellent crossbedding and cut and fill structures characteristic of channel deposits.

Upper red member. -- The upper 1000 feet of the formation is made up of red fine-grained arkosic sandstones, siltstones and shales, alternating with red ferruginous limestones. A white friable sandstone containing large quartzite boulders was chosen as the top of the Sangre de Cristo formation.

Conditions of deposition. -- The Sangre de Cristo formation was probably deposited under both subaerial and subaqueous conditions. The red beds in the lower part containing silicified logs attest to deposition above sea level, while the interbedded red and gray shale and marine limestone suggests a fluctuating strand line. The association of shales and sandstones with abundant plant remains and carbonaceous flakes interfingering with nodular limestone in one direction and typically marine shale and limestone in the opposite direction attest to deposition in lagoons or deltas on the littoral zone. As a result of these alternating conditions vertical sections show abrupt variations in texture and lithology.

Permian system

Glorietta formation

The Glorietta formation overlies the Sangre de Cristo formation in this area. The formation is approximately 266 feet thick and forms the escarpment along the east side of Coyote Creek. The formation is made up of a red-brown fine- to medium-grained massive crossbedded sandstone. Bachman (1953) believes the Glorietta sandstone is a beach deposit reworked as the sea transgressed northward.

Tertiary and Quaternary system

Basalt flows

To the east of Coyote district on Ocate mesa are basalt flows of two periods of volcanism, both of late Tertiary or Quaternary age. The ~~earlier~~ later period of volcanism produced 5 volcanic cones on Ocate Mesa. The closest of these is less than a mile from Coyote Creek. Lava flows associated with the cones cover all older rocks and in Coyote Valley form the capping of small isolated mesas. According to Bachman (1953) the later flows are not present in the Coyote district, but are confined to the Ocate mesa.

Quaternary system

Alluvium

Alluvium of Quaternary age forms a thin cover in Coyote Valley and in places partly conceals the middle gray member of the Sangre de Cristo formation.

Structure

Folds

The Coyote district is in an area of deformation partly due to folding and partly due to faulting which marks the east edge of the Sangre de Cristo Range. As a result of this deformation, increasing in intensity from east to west, the beds strike near north, and change from relatively flat dips beneath Ocate Mesa, near the east edge of the area, to vertical along Coyote Creek. Farther west on the flanks of the Sangre de Cristo uplift, the beds are overturned and dip west at angles of 50 to 80 degrees (fig. 2).

Faults

The area is cut by several northwest striking transverse faults with lateral displacements up to 500 feet. The larger faults are in the northern part of the area and the relative movement was to shift the north side to the west (fig. 2). A few minor faults in the southern half of the area strike northeast; the displacements on these faults are opposite that of the northwest trending faults. The major northwest trending faults are interpreted as tears in or below structural blocks that moved eastward along steep reverse faults related to the uplift of the pre-Cambrian rocks to the west.

Geologic History

During Pennsylvanian and early Permian time the Ocate-Guadalupita area was part of an active geosyncline called The Rowe-Mora trough. The Rowe-Mora trough was flanked on either side by rising geanticlines of pre-Cambrian rocks which were part of the Ancestral Rockies. According to Bachman (1953) the axis of the geosyncline was about 12 miles west of the Coyote district. The rising positive areas furnished great volumes of coarse arkose to the basin that was occupied by the sea during most of Magdalena time. Marine sedimentation recurred intermittently during the deposition of the Sangre de Cristo but most of the sediments were deposited under subaerial conditions. Both the Magdalena and Sangre de Cristo sediments onlap onto the pre-Cambrian. The overlying Glorietta sandstone is probably a beach sand reworked as the sea transgressed northward.

In early Tertiary time regional compression, during part of the Laramide orogeny, buckled the site of the Sangre de Cristo mountain into an anticlinorium. Pre-Cambrian rocks rode eastward over the Pennsylvanian rocks on the east flank of the rising mountains along steep reverse faults. The rocks within and east of the zone of thrust faults were steeply tilted or overturned to form a series of hog backs in which the Coyote district is located. The narrow upturned belt follows the east flank of the mountains from Las Vegas, New Mexico north into Colorado. The sediments further east were gently folded to form the Sabinosa syncline and Ocate anticline. The axes of these are 3 miles and 6 miles to the east respectively. (See Bachman, 1953).

ORE DEPOSITS

General features

The copper-uranium deposits of the Coyote district are in the Sangre de Cristo formation and are associated with carbonized plant remains which consist of fossil logs, branches, leaf-like material and unidentifiable plant remains. Copper is most abundant in the lower red member, whereas uranium is most abundant in the lower part of the middle gray member. The mineralization is spotty and erratic in distribution and although the copper and uranium generally occur together, visibly identifiable copper minerals are not a reliable guide to uranium, for beds containing considerable copper may show little or no radioactivity, and beds with negligible copper content may contain appreciable amounts of uranium.

Mineralogy

The copper ore consists of chalcocite, chalcopyrite, covellite, bornite, malachite and azurite. The malachite and azurite are products of weathering of chalcocite which is the principal ore mineral. The copper mineralization occurs in three types of sediments: (1) replacing calcareous and kaolinic cement, and feldspars in arkose, (2) replacing carbonized plant remains and pyrite nodules in black carbonaceous shales, and (3), filling joints and cavities in limestone.

In the middle gray member the only visible sulfide is chalcopyrite occuring in small grains disseminated throughout certain arkosic sandstone lenses.

The only identified uranium mineral in the sandstones is metatyuyamunite; however, Zeller and Baltz (1953) reported pitchblende in a chalcocite nodule from the black shales.

The uranium mineralization occurs in three different environments: (1) in channels and lenses containing fine to coarse grained arkosic sandstones, (2) in a yellow-brown micaceous siltstone, and(3) in black shales associated with copper. Semi quantitative spectrographic analysis of the pink micaceous sandstones by the Denver laboratory of the U. S. Geological Survey shows abundant iron, copper, manganese, titanium, uranium, vanadium, lead, barium, and a very high rare earth content.

Copper deposits

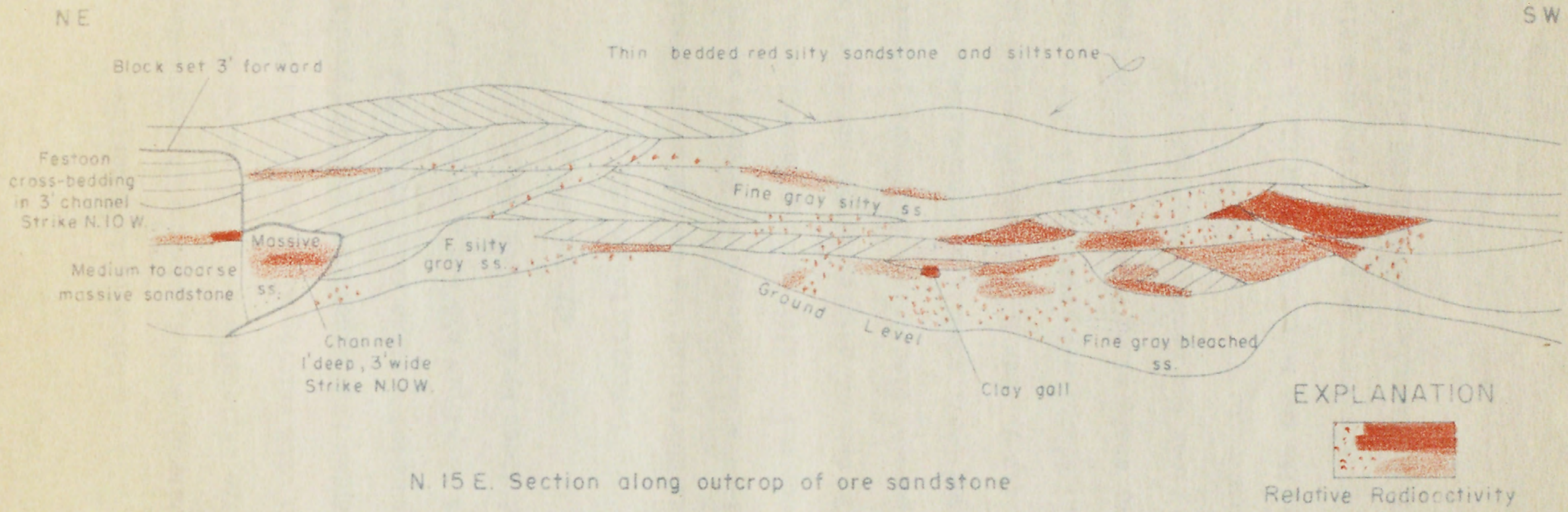
Deposits in arkose

At locality 1, Area G, chalcocite replaces the calcareous and kaolinic cementing material in arkose (plate II, fig. 7). The quartz grains are unaltered but some feldspars are replaced by chalcocite.

The mineralized arkose is usually adjacent to a black copper bearing shale.

Deposits in black shales

The black carbonaceous shales in the lower red member contain the most abundant copper deposits. In polished section the chalcocite appears to have replaced pyrite nodules. Plate II, fig. 8 shows pyrite stringers radiating outward from the center of a nodule. The chalcocite veinlets cut across the pyrite stringers and have replaced much of the pyrite. Plate III, fig. 9 shows a chalcocite replaced nodule containing a thin concentric ring of pyrite near the center, upper ~~right~~ left corner of photograph. These nodules were probably originally all pyrite which was later replaced by chalcocite. In some of the larger pieces of chalcocite replaced wood, in the black shales, pyrite is present. In many of the copper replaced plants, however, there is no visible indication of pyrite being present. The wood has been completely replaced by chalcocite and minor amounts of chalcopyrite, bornite and covellite. Plates III and IV, figs. 10 and 11 show a cross section of longitudinal section respectively of such an occurrence. The replaced wood contains 95 percent chalcocite, 3 percent bornite and covellite, and 2 percent chalcopyrite. The well defined and relatively undeformed cell structure indicate the wood was replaced before compaction of the enclosing shale due to burial.



N. 15 E. Section along outcrop of ore sandstone

By D.C. Laub and C.M. Tschanz

FIG. 4

AREA B - BLAS MEDINA PROPERTY
COYOTE MINING DISTRICT, MORA COUNTY, NEW MEXICO

0 5 10 FEET
Horizontal & Vertical Scale

Deposits in limestone

At locality 2, Area E, chalcocite occurs associated with nodular limestone. The chalcocite is in the center of limestone nodules and is associated with calcite along joints and in small cavities. The limestone nodules have a peculiar acicular growth of secondary calcite surrounding a dense green core. The calcite coating is generally red to purple and has a satiny luster but in some places it is colored green by malachite stain.

URANIUM DEPOSITS

Deposits in arkosic sandstones

The rocks containing the most abundant uranium minerals are gray to pink, well-cemented, micaceous, arkosic sandstones and siltstones.

The copper and uranium bearing sandstone at Locality 1, Area B consists of 30 percent quartz, 15 percent mica, both muscovite and biotite, 20 percent plagioclase feldspar, 30 percent orthoclase and microcline, and small amounts of nontronite.

At Locality 3, Area B, the uranium occurs in northwest trending channels (fig. 4). The coarser lenses within the channels contain clay galls and clay seams along bedding planes and have a radioactive count from 2 to 40 times the normal background, however, no uranium minerals were identified.

Chalcopyrite and an unidentified black radioactive mineral?in interlocking grains occur in some of the channels (plate IV and V, fig. 12 and 13). The black mineral ~~(?)~~ also surrounds orange-yellow altered feldspars. Microchemical tests of the black mineral gave positive reactions for uranium, iron, and copper.

At Locality 4, Area E, the uranium occurs as visible metatyuyamunite in the coarser lenses in channels. The uranium is closely associated with vanadium and black micaceous clay galls. The vanadium occurs along bedding planes and surrounding the uranium mineralization. At some places near joints and along bedding planes, the arkosic sandstone has a pink cast. When this is noticeable the radioactivity is high. The pink color is due to a ferric iron mineral that coats quartz grains and pervades altered feldspars, and indicates oxidation has taken place.

Near the central part of the lower red member at Locality 5, Area F, the visible uranium occurs in a thin fine-grained, arkosic and micaceous sandstone lens surrounded by gray- to black micaceous shale and siltstone. There is no indication of cut and fill structure here but the mineralized lens was probably a bar or spit that served as a depository for plant debris that later caused the uranium to be precipitated. Visible metatyuyamunite in the heavy mineral concentrates, coats mica, fills vugs in quartz grains and occurs as small individual grains.

Deposits in siltstone

At Localities 6 and 7, in Area A and C, the uranium is associated with an olive-brown siltstone from 2 to 5 feet thick. The siltstone does not contain visible copper or uranium minerals and the radioactivity is low but the zone is fairly continuous for at least 6,000 feet along the strike. The siltstone lies below a thin blue fossiliferous marine limestone. The siltstone contains small brachiopod casts and many carbonized plant fragments and leaf imprints. Stringers of black carbonaceous material, when present, show higher radioactivity than the mineralized siltstone.

Deposits in black shales

The black shales containing copper also contain some uranium, however, the grade of the uranium is much lower than the occurrences in arkosic sandstones or siltstones.

Ore Control

Stratigraphic control

The deposition of uranium appears to be controlled by several factors. The principal control is filled channel scours in arkose and sandstone. Within the channels small lenses of coarse sandstone containing carbonized plant fragments control uranium deposition.

Vanadium is present along bedding planes and also surrounds the uranium bearing sandstone. Clay galls are associated with the uranium and vanadium and when the clay galls are black rather than gray-green the radioactivity is higher in the enclosing sandstones. Some clay galls show all stages of alteration from gray-green to black. Where the sandstone has a pink-to red cast due to ferric iron the radioactivity is higher than in the typically gray-pink sandstone. In the mineralized channels slightly flattened pieces of sand filled wood are present and usually count less than the enclosing sandstone. Where the sandstone and fossil wood is colored yellow-brown due to an iron mineral stain, the uranium content is insignificant.

Structural control

The mineralized zones throughout the area are offset by numerous transverse faults. Despite the proximity of some deposits to zones of faulting, there is little evidence for a genetic relationship between them. In zones of closely spaced faults the arkose is sheared, bleached, and in some cases argillized, indicating that solutions moved along the faults, but there is no conclusive evidence to relate the argillization to the copper and uranium mineralization and no concentration of metals along faults have been found in the district.

Possible origin of the copper and uranium

The origin of the copper-uranium in the Coyote district appears similar to that proposed by Lindgren (1933, pp. 408-409) for the sedimentary copper deposits and is quoted as follows:

> "The epigenetic character of the copper deposits in sandstone is proved beyond reasonable doubt. The replacement of coal, carbonaceous shale and calcareous or kaolinic sandstone cement by chalcocite is also proved. The gangue minerals are few and quartz is conspicuously absent. Barite in small amounts is rather common. Irregularity in dissemination is typical, though the ores often follow certain horizons persistently. The independence of the occurrence of igneous rocks is marked. The occurrences are mainly on the flanks of older continental areas containing pre-Cambrian copper deposits; the sandstones were rapidly laid down as arkoses, indicating a long epoch of rock decay, the products of which were swept away during the following arid epoch. Considering the evidence as a whole, the sedimentary deposits must have contained finely divided copper ores in part from solutions derived from the land area, in part as cupriferous detritus. When atmospheric waters charged with salt and gypsum searched these beds they must have taken this copper into solution and concentrated it at certain horizons where reducing substances like coaly vegetable matter were

available. In most cases the solution probably contained copper as sulfate, though where much salt was present it might well have been transformed into chloride. Ascending thermal solutions of meteoric origin may have formed some deposits. Magmatic agencies seem in most cases to be definitely excluded.

Pyrite, bornite and chalcopyrite often appear as nodules or in the fossil wood the chalcocite often replacing earlier sulfides."

The pre-Cambrian rocks contain several [large] copper mines [near] the Coyote district and are described by Lindgren, Graton and Gordon (1910, p. 112-114). The pre-Cambrain granites could have been the source of uranium. The average uranium content of granitic rocks according to Rankama and Sahama (1950, p. 638) is 4 grams per metric ton. Uranium is also present in the pre-Cambrian pegmatites in the Petaca district, 30 miles NW., the Pidlite mica mine [near] Mora, and in Gallinas Canyon 20 miles southeast of the area.

The Sangre de Cristo formation seems to be made up of first cycle sediments derived from the pre-Cambrian highlands, which bordered the Rowe-Mora trough on the east and west. It is possible that the copper and uranium could have been carried in as detrital grains and later leached and redistributed by ground water, but the present evidence seems to indicate that mineralization was later than the sediments and that streams draining the pre-Cambrian highlands carried traces of copper sulfate and a soluable uranium compound which were precipitated out as copper sulfides and metatyuyamunite under the reducing conditions encountered in bodies of carbonaceous material which had accumulated along sand bars and in meanders of the old stream channels.

CONCLUSIONS

On the basis of field work in the summer and fall of 1953 and examination of heavy mineral concentrates, autoradiographs, and polished and thin sections, the following conclusions are made.

1. Most of the copper occurs as chalcocite in the black shale of the lower red member of the Sangre de Cristo formation and in general has little or no uranium associated with it.
2. Chalcocite replaces calcareous and kaolinic cement in arkose adjacent to black shales, and also replaces feldspars within the arkose.
3. The most favorable loci for uranium deposition are in small stream channels filled with coarse sandstone containing carbonized plant fragments.
4. The sediments associated with the uranium mineralization show a high rare-earth content indicating the uranium was probably derived from a pegmatitic terrain.
5. The copper and uranium are probably of epigenetic origin. It is believed that they were derived from the pre-Cambrian rocks to the west and were carried to the present site in solution by ground waters where they were precipitated upon coming in contact with carbonized plant remains. Ground water may have later redistributed the copper and uranium minerals to some extent.
6. The occurrence of uranium in the Coyote district in association with copper deposits of the red bed type, leads to the conclusion

that other areas known to contain red bed copper deposits should be examined. Many of the copper deposits of the red bed type occur in the Permian-Triassic sediments derived from the Ancestral Rockies and related uplifts that occurred in Pennsylvanian time.

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Figure 5. View looking north along vertical beds in Lower member of the Sangre de Cristo formation.

Figure 6. View looking south at Glorietta sandstone. Note rapid change in dip.

Plate I

Figure 7 X-100. Thin section showing chalcocite-cc replacing calcareous cement and feldspars-f in arkose.

Figure 8 X-100. Polished section of chalcocite-cc replacing pyrite-py in nodule.

Plate II

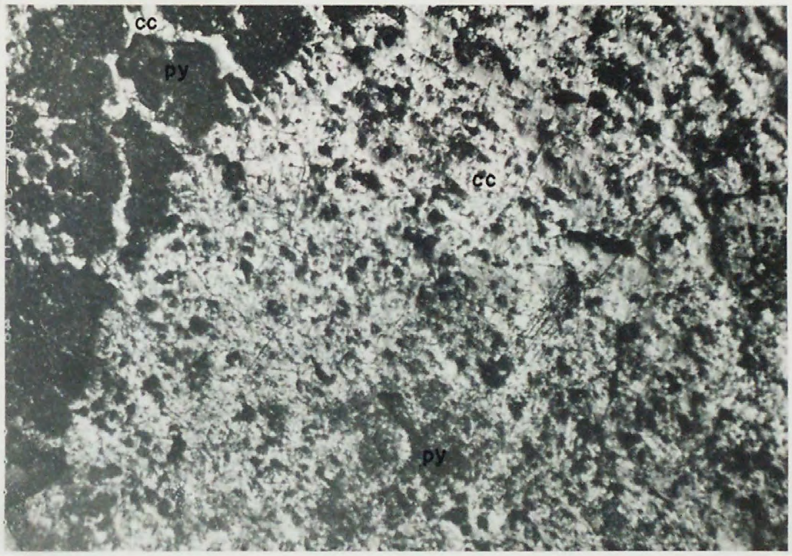

Figure 9 X-100. Polished section of chalcocite-cc replacing pyrite. Note concentric ring of pyrite in upper left corner.

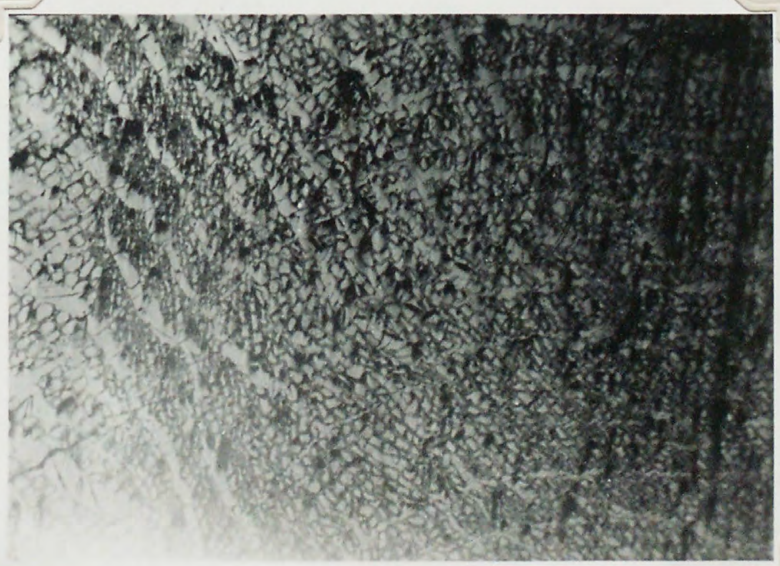

Figure 10 X-100. Cross section of fossil branch completely replaced by chalcocite. Note well defined cell structure.

Plate III

Figure 11 X-100. Longitudinal section of copper replaced wood showing cell structure.

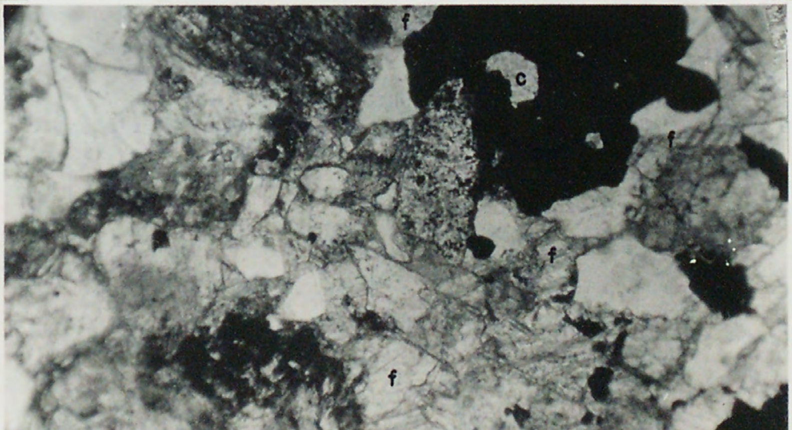

Figure 12 X-100. Thin section of arkosic sandstone containing chalcopyrite and black radioactive iron oxide in interlocking grains. Chalcopyrite replacing calcite-c and feldspars-f.

Plate IV

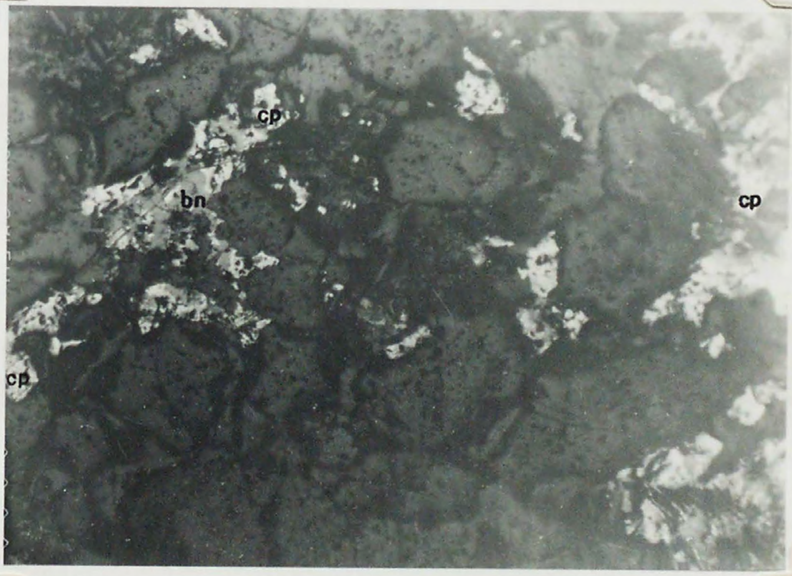

Figure 13 X-100. Polished section from area A showing bornite-bn replacing chalcopyrite-cp in arkosic sandstone.

Plate V