Cu-Ag deposits of the red-bed type at Negra Huanusha in Central Peru

Autor(en): **Kobe, Huldrych W.**

Objekttyp: **Article**

Zeitschrift: **Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie**

Band (Jahr): **40 (1960)**

Heft 1

PDF erstellt am: **25.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-31144

Cu-Ag deposits of the Red-Bed type at Negra Huanusha in Central Peru[1])

By *Huldrych W. Kobe* (La Oroya, Peru)

With 8 plates

Contents

Introduction and summary

During a survey of the Negra Huanusha region in Central Peru, a suite of Cu-Ag ore deposits of the Red-Bed type was studied. These deposits are an unique feature in the Peruvian Andes, although similar

[1]) Published with permission of Cerro de Pasco Corp.

occurrences have been reported to exist some 150—200 km SE of Negra Huanusha in the Huancayo area.

The structure of the area is marked by a flat westerly-plunging anticline comprising of rocks of the Permian Mitu-formation, which is surrounded on the N, W and to the S by Mesozoic limestones (Paria-formation), while the center of the anticline to the E is formed by the Paleozoic Excelsior schists. The Mitu-formation consists of red, coarse to fine-grained arkosic sandstones and fragmental arkoses with layers and lenses of red mudstone.

It has been proved by chemical and petrographical methods that the ore deposits s. str. are characterized by a bleaching of the red arkose to a light bluish- or greenish-gray color. Such bodies of bleached rock are lenticular and may have a length from a few to over 200 m and a width from 20 cm to over 2 m. Disseminated carbonaceous plant remains are abundant in most of the deposits. The disseminated Cu-ore is chalcocite with a smaller amount of bornite and covellite, and only accessory silver-sulfides and native silver. Alteration products are malachite, rarer azurite and rarely Cu-sulfate. The partial replacement of wood by Cu-sulfides is a most striking feature.

Although this type of deposits is very similar to the U-V-Cu deposits described from the Colorado Plateau, Uranium is lacking at Negra Huanusha, and Vanadium could be detected only in minor amounts (but could not be recognized mineralographically).

As no particular studies (which need large laboratory equipment) could be made, and also because the deposits are not explored to such an extent that the structure could clearly be observed, genetic relationships can be guessed only in comparison with statements in the voluminous literature.

It is thought therefore, that the host rock was deposited in a large river-plain with inclusion of abundant plant remains restricted to a few places. Later on, Cu, Ag, etc. was brought in by groundwaters (either leached from eroded earlier deposits or added to by hydrothermal solutions) and deposited, where a recuding atmosphere was present, i. e. in the vicinity of decaying wood, probably where H_2S was produced by anerobic bacteria. Volcanic activity may also have played a minor role — as indicated by andesitic fragments in the arkose.

The deposits have little economic importance because of their small size and irregular lenticular nature, although they have been worked in various locations, lately by the Cerro de Pasco Corp. as a silica-flux ore for the Cu-smelter in La Oroya.

Location (see plate V)

The Negra Huanusha region lies in the Central Andes of Peru at the NE border of the Pampa (at about 4300 m altitude) at the source of the Palcamayo River which flows toward the Montaña and the eastern lowlands. The area lies between the towns of La Oroya, Junin and Acobamba, being connected with them by a road between Tilarnioc (on the Oroya-Cerro de Pasco railway) and Palcamayo-Acobamba (on the eastern slope).

General geology and tectonic relationships (see plate VI)

The general structure of this restricted area is characterized by a flat westerly-plunging anticline. A small intrusive body is located near the anticlinal axis, intruding the Mitu-formation in the W. Towards the E, the Mitu-formation thins out on both sides of the Excelsior-formation (N and S), and is absent in the sequence for an appreciable distance (HARRISON, 1940).

Unconformities are evident between the Excelsior- and Mitu-formations and also between Mitu- and Paria-formations respectively. This is noted especially in the variation of strike between the various formations (see map, locations E of points O and P, and along the contact between locations K and the Anita-Mine in the W).

The *Excelsior-formation* (Paleozoic) consists mainly of sericite-chlorite schists with quartz veinlets. Occasional larger areas are represented by coarse conglomerates (N of point Q). Magnetite in well-developed octahedrons is present in an area E of point ZB, where also amphibolites accompany the chlorite schists.

The *Mitu-formation* (Permian) consists primarily of fine-grained red sandstone or arkose with a few beds of red mudstone. One particular rock type, which is main host for ore-mineralization consists of sandstone with numerous smaller mud lenses parallel to the bedding.

At the locations marked by a letter (see map, indicating mostly old workings), the red sandstone is bleached to a gray color, which in many places shows a greenish tint due to the malachite content. These bleached zones often contain carbonaceous plant remains. They are very irregular, mostly lenticular with doubtful downward extension.

Along the contact with Paria-limestone in the N, the sandstone may often be black or dark gray without any visible traces of copper or coal. In the S, where the Mitu-formation is thinning out, a red-violet porphyrite occurs, which is not shown separately on the map.

The *Paria-formation* (Mesozoic) consists of white limestone containing only rare undeterminable fossils.

The *intrusive stock* in the W consists of a quartzdiorite-porphyrite. Most contacts are covered by abundant talus, but near the NW-end of the stock a small contact zone against Paria-limestone can be observed. The intrusive therefore is at least younger than Triassic.

Mineral deposits

Three types of ore-occurrences are present in the mapped area. (For distribution see plate VI.) Two of them are rather similar, while the third has a different appearance.

Type 1a) It occurs always in the red sandstone formation. The ore-deposits are characterized by the bleaching of the red to a clear-gray sandstone, mostly with a greenish tint due to the presence of malachite. These bleached bodies often have an irregular form, but may sometimes follow the bedding of the sandstone. In a few places, they are in connection with narrow mylonite zones and faults (Negra Huanusha proper). The gray sandstone may contain disseminated chalcocite with bornite and covellite. Near the surface these copper minerals may be changed partly into malachite. Generally these copper sulfide occurrences are accompanied by carbonaceous plant remains.

Type 1b) It also occurs always in the red sandstone formation. Here little bleaching is observed, and the copper ores are agglomerated in spots and patches. It is noted under the microscope that only these occurrences contain hematite-magnetite besides the copper sulfides. (Locations O and P show this type of ore deposit.)

Type 2) This type of deposits is observed at various places at the upper limit of the red sandstone, mostly within the lowest part of Paria limestone. The contact between the two formations, Mitu and Paria respectively, is sometimes formed by a mylonite zone (0—8 m) with black argillaceous planes. This mylonite is the host rock for a copper mineralization, fine disseminated chalcocite often changed to malachite and azurite.

As this type is not well exposed, it could not be studied adequately and will not be described in the following pages.

Macroscopic features

Bedding: The sandstone is in general fairly massive and homogeneous, but in places may be bedded or layered (coarser- and finer-grained).

The layered zones are often bent and distorted. At two principal older mining locations, Negra Huanusha proper and mining sites xx-Z, numerous measurements on bedding and faulting planes were made. Average values for Negra Huanusha proper and mining site xx-Z are N 44° E/34° N and N 60° E/ 36° N respectively for the bedding.

Faults and joints: These are abundant and less regularly distributed, but at least one distinct concentration in each place can be seen fairly easily, at Negra Huanusha proper around N 32° E/80° S, and at location xx-Z around N 28° E/74° S.

Cross-bedding: It is noted in various places, mostly with very small angles between two adjacent series of layers. In the place shown on photo 2, small-scale cross-bedding is noted, but with bigger deviation in the direction of adjacent layer series.

Layered texture: Layered parts although common, are not as abundant as the homogeneous sandstone and the units mixed with so-called "clay galls" (mud lenses). All the three types are shown on photo 1.

Mud cracks and fossil raindrops (?): They are frequently seen where larger areas of bedding planes of mudstone are exposed. One typical occurrence at Negra Huanusha proper is shown on photo 3.

Ripple marks: They have been observed in one very restricted area only, and there it is very doubtful, whether they are real ripples or merely due to recent weathering of the surface of the sandstone.

All the above features indicate the climate and properties of deposition of the formation. These observed facts are typical of deposition of the sand by rivers in a flat river-plain, which occasionally may have been inundated for short periods by a very shallow sheet of water. Arid climate is indicated not only by the mudcracks and fossil raindrops (?), which have been preserved so well, but also by the red color of the whole formation, which is rather typical of the Permian Red Beds the world over.

Bleaching: It occurs especially (but not exclusively), in connection with deposits of plant remains, and is present in nearly all the marked locations on the map. Bleaching is present in all of the textural types of sandstone. In most cases the bleached beds only contain some Cu-mineralization. The bleaching is not necessarily restricted to one distinct layer or bed, but may deviate from the bedding plane. This is represented on the diagram, plate VII (mining site xx-Z). The bleaching and with it the Cu-mineralization occurs in lenses and only occasionally is restricted to a distinct bed for any appreciable distance. It is observed, however, that one narrow zone (specially marked on the map) contains several of the richest deposits arranged in one horizon.

Carbonaceous fossil plant remains: They are abundant, especially within bleached beds. In some instances the coal has already been washed out, leaving only brown limonitic prints. In other places bigger branches are present. They are generally fractured with malachite filling transversal cracks (photo 4). Most of the plants are badly preserved, only a few are probably good enough for determination.

After G. C. AMSTUTZ (1956) who sent a series of them to Prof. JONGMANS in Holland, this specialist determined types of Voltzia and other coniferae, which are typical of Middle Permian age (compared with plants in the so-called "Kupferschiefer" in Germany).

There exists also a note by G. STEINMANN (1930), who reported Voltzia Recubariensis Mass. from the same region and therefore considered the formation to be of Triassic age. So far as can be seen, other types of plants are present also which from comparisons with pictures in paleobotany-books seem to belong to the Walchia group. Ullmannia is also likely to be present.

The relatively bad preservation of the plant remains and their deposition in the observed manner also points to a deposition along river banks, and not by burial in situ.

Microscopic features

Photo 5 represents one type of sandstone by low magnification. It is a fairly coarse-grained sandstone with "clay-galls" or mud lenses along the bedding plane. Black spots indicate the Cu-mineralization, which is more abundant within the coarse-grained part. Photos 8 and 9 represent the type of rock generally found in the Mitu-formation at Negra Huanusha, the constituents being quartz, plagioclase, microcline, sericite-muscovite, calcite, some chlorite and numerous rounded volcanic rock-debris of andesitic composition. Calcite is the only fracture-filling mineral. It occurs in simple flat rhombohedrons.

The rock must be called a fragmental arkose.

It may occur (with the same mineralogical composition) in fine-grained and fairly coarse-grained varieties. The red color derives primarily from hematitic and limonitic material, which is disseminated between the above minerals, but in the first instance forms the groundmass of the andesitic rock fragments.

Bleached areas are the result of partial conversion of $Fe^{\cdots}$ to $Fe^{\cdot\cdot}$, or due to massive removal of Fe as a whole.

Carbonaceous material is restricted to the bigger plant remains or may be disseminated in small specks between the other minerals, but never occurs as the matrix of the rock. The plant remains have been called silicified, but this is very rarely the case. It is found that the coal is accompanied by calcite and not by quartz. Calcite may be coarse-grained together with the sulfide concentrations or may fill cracks through the coal as seen on photos 6 and 7.

There is little or no matrix between the mineral grains. They show direct contacts or have some clayey minerals between them.

Ore-mineralization

The copper minerals so far reported from the deposits around Negra Huanusha are chalcocite, bornite, covellite, malachite and azurite. G. C. AMSTUTZ (1956) mentions also cuprite, and a coppersulfate has been found at the C_5-adit at mining site xx-Z. The Cu-minerals need not be in direct contact with carbonaceous matter, although the heaviest deposition is around or within the coal (see photos 6, 7, 12 and 13). Bornite occurs mostly, where larger concentrations of sulfides are present, it is rarely seen disseminated through the arkose. It is always intergrown with chalcocite, either in a graphic-like intergrowth or else surrounded by chalcocite. This combination bornite-chalcocite often enters the cells and fills the cell-interiors. In places each cell may have a bornite center and a chalcocite rim.

Chalcocite is also present in single patches without any trace of bornite (see photo 10). It seems, that primarily clayey material has been replaced, but also calcite and perhaps some parts of groundmass of volcanic debris. Instead of chalcocite covellite occasionally occurs within coal fragments (see photo 13). It also partly replaces chalcocite in the disseminated type.

With this type of mineralization silver minerals occur. They are also around coal remains, and may occur as fine, short veinlets through the arkose. Silver-sulfosalts, stromeyerite or polybasite and also native silver occur together with chalcocite.

Type 1b deposits contain the chalcocite in spots and nodules disseminated in the slightly bleached red sandstone, but concentrated in a few places. They occur mostly in a coarse-grained reddish gray arkose. Under the microscope the nodules are seen to be composed of silicates (mostly quartz) in a matrix of chalcocite, which contains abundant hematite-prisms. In some places magnetite remains disseminated throughout the section, but only rarely within the nodules. Chalcocite sometimes replaces the hematite laths (see photo 11). It has been also noted, that hematite often replaces magnetite.

In this type of deposits, coal is usually absent, or present in very minor quantities.

Chemical composition of the ore

5 types of rocks from the deposit at Negra Huanusha were analyzed spectrographically for Cu, U, V, and chemically quantitatively for Cu only.

Sample description

1. Normal fine-grained red arkose.
2. Layered, coarse-grained red-gray arkose.
3. Somewhat layered, fine-grained greenish bleached arkose.
4. Bluish-gray mud-sandstone conglomerate with visible rich chalcocite dissemination.
5. Pieces of bleached sandstone with coal remains and malachite stain on the surface.

Assay results

	Sample Nr.				
	1	2	3	4	5
10%	—	—	—	Cu	Cu
1—10%	—	—	Cu	—	—
0.1—1%	—	—	—	—	—
0.01—0.1%	Cu, V	Cu, V	V	V	V
0,01%	—	—	—	—	—
Sought for but not detected	U	U	U	U	U
Cu quantitatively (%)	0.02	0.02	0.29	2.95	3.67

This indicates clearly, that only the bleached host rock contains a certain amount of Cu, that V is present in an equal amount in all of the samples, while U is completely missing.

Chemical assay over a two-years period (during 1954—1956) on ore shipped to the La Oroya smelter gives the following averages for Cu, Ag and Au (by suppression of one sample extraordinarily high in Ag and Au):

Cu: 3.21% Ag: 2.92 oz/t Au: 0.006 oz/t

The iron content of a composite of all samples collected during the survey at Negra Huanusha proper and at mining site xx-Z is: Fe 2.3%.

The arithmetical average for diversified unsoluble substances for the same samples is:

SiO_2: 61.6% Al_2O_3: 16.1%

This gives a quite accurate picture of the ore to be expected from the Negra Huanusha region deposits.

Hypothesis of deposition for the Negra Huanusha deposits

Although it is very difficult to give any explanation that could be regarded as definite, because of the lack of more intense exploration on the deposits, the author's opinion is given below.

a) Sedimentation of the host rock: The red sandstone, arkose and mudstone were deposited in a flat river plain, which might have been inundated for short periods by a shallow sheet of water. The climate was arid as indicated by the good preservation of mudcracks and fossil raindrops (?) and by the red color of the whole formation. Perhaps also wind-transport may have been active. There was probably also contemporaneous volcanic activity, indicated by the volcanic fragments in the arkose. It will be very difficult to find any signs of marine influence in this region, as supposed by G. C. AMSTUTZ (1956). Wood and other vegetable remains were deposited by the rivers along their borders, buried and subsequently carbonized with time and also by the pressure of overlying younger beds.

b) Origin and deposition of the ore: The appearance of the Negra Huanusha deposits would justify the hypothesis, that the copper and related silver and vanadium were brought in by circulating groundwaters. There exists some scope however concerning the origin of these ions. They might have derived from eroded older ore-deposits or have been otherwise supplied by hydro-(epi-)thermal solutions. Also volcanic activity may have played a certain role, but in general it is apparent that volcanic rocks have only a negligible Cu-content. Cu, Ag, V, etc. ions were transported in the groundwaters in equilibrium with SO_4, Cl etc. anions. Around the decaying wood in the early stages of carbonization, the sulfates were reduced to sulfides. Also the iron in the rock itself must have been reduced in this way. It is thought, that the reducing action of anerobic bacteria living on and from the decaying wood produced H_2S which could escape and exert its reducing action in the whole environment, thus forming the bleached zones. There must have been a somewhat different reaction in the deposits of type 1b.

Magnetite is very probably a sedimentary deposit in these arkoses. It may have derived from the underlying eroded Excelsior schists, where it is still observed in perfect octahedrons near the contact Excelsior-

Mitu. The magnetite is mostly changed to hematite. Chalcocite could then be precipitated in this reducing environment from the Cu-sulfate-bearing groundwaters. The aggregation of iron-compounds in lense-shaped bodies may be due to an accumulation of them in placer deposits in the former river beds. Hematite, however, may also have derived from the Excelsior-formation by erosion of such specularite veinlets as observed at present below Tarma, in the Chanchamayo area.

It is obvious, that the Cu-minerals chalcocite and the silversulfides and especially the native metals silver and copper are typical of an environment of supergene enrichment. Malachite, azurite and Cu-sulfates are products of secondary alteration near the surface.

With the above data, the author believes, that these deposits have been formed post-syngenetically (this means, that the Cu and the other elements were precipitated as sulfides after the deposition of the host rock, but still in a stage, in which groundwaters could circulate through the not very deeply buried formation, and when the decaying wood was in the first stages of carbonization — when it had itself a certain reducing power — allowing bacteria to act as reducing agents through formation of H_2S). The problem of the origin of the primary metal ions will not be solved satisfactorily, as long as modern methods (such as the Sulfur isotope-method in combination with others) cannot be applied.

Acknowledgements

The author is grateful to U. Petersen and J. D. Hamilton, chief geologist and assistant chief geologist respectively, for their interest in this work, and to Cerro de Pasco Corporation for the permission to publish the results of this survey at Negra Huanusha.

Zusammenfassung

Während einer geologischen Feldaufnahme des *Negra-Huanusha*-Gebietes in Zentral-Peru wurde eine Reihe von Cu-Ag Lagerstätten studiert. Diese Lagerstätten sind in ihrer Art einzigartig in den peruanischen Anden, obschon ähnliche Vorkommen 150—200 km südöstlich von *Negra Huanusha* in der weiteren Umgebung von Huancayo zur Kenntnis des Autors gebracht wurden.

Das strukturelle Hauptmerkmal der Gegend ist eine flach gegen W einfallende Antiklinale, welche von der permischen Mitu-Formation gebildet wird. Sie ist im W umgeben von mesozoischen Kalken, während ihr Kern im E durch die paläozoischen Excelsior-Schiefer ausgefüllt wird.

Die Mitu-Formation besteht aus roten, fein- bis grobkörnigen Arkose-Sandsteinen bis zu „fragmental arkoses" und enthält Lagen und Linsen von rotem Mergel.

Durch petrographische und chemische Untersuchungen wurde gefunden, daß die Lagerstätten im engeren Sinne durch eine hellbläulich- oder grünlichgraue Ausbleichung der roten Gesteine ausgezeichnet sind. Die gebleichten Formationen sind linsenförmig und weisen Erstreckungen bis zu 200 m und Mächtigkeiten bis über 2 m auf. Sie enthalten meistens kohlige Pflanzenreste. Das feinverteilte Erz ist größtenteils Kupferglanz mit zurücktretendem Buntkupfer und Kupferindig, akzessorischen Silbersulfiden und metallischem Silber. Verwitterungsprodukte sind Malachit und Azurit sowie selten Kupfersulfat. Ein Hauptmerkmal dieser Lagerstätten ist die teilweise Ersetzung der Kohle durch Kupfersulfide.

Obschon dieser Lagerstättentyp sehr ähnlich den bekannten Vorkommen von U-V-Cu im Colorado-Plateau ist, fehlt Uranium in *Negra Huanusha*, und Vanadium konnte nur in kleinen Mengen nachgewiesen (aber noch keinem bestimmten Mineral zugeschrieben) werden.

Indem keine speziellen Studien (welche umfangreiche Apparaturen benötigen) gemacht werden konnten und auch die Lagerstätten nicht in so systematischer Weise untersucht sind (wegen teils ungenügenden Aufschlußverhältnissen), konnten Detailstrukturen nicht beobachtet und genetische Schlußfolgerungen nur im Vergleich mit umfangreicher Literatur gezogen werden.

Die genetische Abfolge der Vorgänge, die zur Bildung dieser Lagerstätten geführt haben, ist folgendermaßen gedacht:

Das Muttergestein wurde in einer weiten, flachen Flußebene sedimentiert unter Einschluß von reichlichem Pflanzenmaterial an bestimmten Plätzen. Später wurde Cu, Ag etc. durch Grundwasser transportiert (herausgelöst aus älteren Lagerstätten oder von hydrothermalen Lösungen herbeigebracht) und dort abgesetzt, wo eine reduzierende Umgebung vorhanden war (in der Umgebung von verkohlendem Holz, wo wahrscheinlich durch anärobische Bakterien H_2S produziert wurde). Vulkanischer Einfluß mag auch eine gewisse Rolle gespielt haben — was durch andesitische Fragmente in der Arkose angedeutet ist. Durch Anwendung der Sulfur-Isotopen-Methode (eventuell in Kombination mit anderen) könnten wohl genauere Daten über das Alter und die Herkunft der Vererzung erbracht werden.

Bibliography

(Only the papers which were available to the author for reference have been mentioned!)

AMSTUTZ, G. C. (1956): A note on a peculiar association of copper with fossil plants in Central Peru. Soc. Geol. Peru, Anales pt. 1, Tomo 30.

ARKHANGELSKY, A. D. and ROZHKOVA, E. V. (1932): Accumulation of copper in sedimentary rocks. Bull. Soc. Nat. Moscow (N. S. 40, Sect. Geol. 10, No. 2, p. 295—307).

BASTIN, E. S. (1933): The chalcocite and native copper types of ore deposits. Econ. Geol. Vol. 20, No. 8.

BATES, R. C. (1959): An application of statistical analysis to exploration for Uranium on the Colorado Plateau. Econ. Geol. Vol. 54, No. 3.

BRUMMER, J. J. (1958): Supergene Cu-U deposits in Northern Nova Scotia. Econ. Geol. Vol. 53, No. 3.

BUTLER, R. D. (1938): A „Red-Bed" type Cu-occurrence, Wyoming Co, Pennsylvania. Econ. Geol. Vol. 33, No. 6.

COLEMAN, R. G. (1957): Mineralogical evidence on the temperature of formation of the Colorado Plateau U-deposits. Econ. Geol. Vol. 52, No. 1.

DAVIDSON, E. S. (1959): Geology of the Rainy Day U-Mine, Garfield County, Utah. Econ. Geol. Vol. 54, No. 3.

FATH, A. E. (1915): Copper deposits in the Red-Beds of SW Oklahoma. Econ. Geol. Vol. 10, No. 2.

FINCH, J. W. (1928): Sedimentary metalliferous deposits of the Red-Beds. Trans. AIME, Vol. 76, p. 378—384.

FINCH, W. I. (1955): Preliminary geologic map showing the distribution of U-deposits and principal ore-bearing formations of the Colorado Plateau region. US Geol. Survey, Min. Invest. Field Stud. Map MF 16.

FINNELL, T. L. (1957): Structural control of Uranium-ore at the Monument No. 2 Mine, Apache County, Arizona. Econ. Geol. Vol. 52, No. 1.

FISCHER, R. P. (1937): Sedimentary deposits of Cu, V, U, and Ag in SW USA. Econ. Geol. Vol. 32, No. 7.

— (1950): Uranium-bearing sandstone deposits of the Colorado Plateau. Econ. Geol. Vol. 45, No. 1.

— (1956): U-V-Cu deposits of the Colorado Plateau region. Proc. Int. Conf. on Peacef. U. of Atom. Energy, Vol. 6, Geol. of U and Th. UNO N. York, p. 605—614.

GARRELLS, R. M. (1955): Some thermodynamic relations among the U-oxides and their relation to the oxidation states of the U-ores of the Colorado Plateau. Am. Min. Vol. 40, No. 11/12.

GARRELLS, R. M., HOSTETLER, P. B., CHRIST, C. L., WEEKS, A. D. (1957): Stability of U, V, Cu and Mo-minerals in natural waters at low temperatures and pressures (Abstract). Geol. Soc. Am. Bull. Vol. 68, No. 12/2.

GRUNER, J. W. (1956): Concentration of U in sediments by multiple migration accretion. Econ. Geol. Vol. 51, No. 6.

HARRISON, J. V. (1940): Nota preliminar sobre la Geologia de los Andes Centrales del Peru. Soc. Geol. Peru, Bull. Tomo X.

ISACHSEN, Y. W., MITCHAM, T. W., WOOD, H. B. (1955): Age and sedimentary environments of U host rocks, Colorado Plateau. Econ. Geol. Vol. 50, No. 2.

JENSEN, M. L. (1957): The significance of S^{32}/S^{34} ratios on the origin of sulfides in U-deposits of the Colorado Plateau (Abstract). Geol. Soc. Am. Bull. Vol. 68, No. 12/2.

— (1958): Sulfur isotopes and the origin of sandstone-type U-deposits. Econ. Geol. Vol. 53, No. 5.

JOHNSON jr. H. S. and THORDARSON, W. (1959): The Elk Ridge-White Canyon channel system, San Juan County, Utah: Its effect on Uranium distribution. Econ. Geol. Vol. 54, No. 1.

JOUBIN, F. R. (1955): Discussion of "Widespread occurrence and character of uranitite in the Triassic and Jurassic sediments of the Colorado Plateau", by A. Rosenzweig et al. Econ. Geol. Vol. 50, No. 2.

KOEBERLIN, F. R. (1938): Discussion about "Sedimentary deposits of Cu, V, U and Ag in SW USA" by R. P. Fischer. Econ. Geol. Vol. 33, No. 4.
LINDGREN, W. (1933): Mineral deposits. New York.
LOUIS, H. (1896): Discussion of "Copper ores in the Permian of Texas", by E. J. Schmitz. Trans. AIME, Vol. 26, p. 1051—1052.
MASTERS, J. A. (1955): Geology of the Uranium deposits of the Lukachukai Mountains area, NE Arizona. Econ. Geol. Vol. 50, No. 2.
MCCAULEY, J. F. (1958): Discussion of "Supergene Cu-U deposits in Nova Scotia", by J. J. Brummer. Econ. Geol. Vol. 53, No. 8.
MCKEE, E. D. (1951): Sedimentary basins of Arizona and adjoining areas. Geol. Soc. Am. Bull. Vol. 62, p. 481—506.
MCKELVEY, V. E. and NELSON, J. M. (1950): Characteristics of marine U-bearing sedimentary rocks. Econ. Geol. Vol. 45, No. 1.
MILLER, L. J. (1955): U ore controls of the Happy Jack deposit, White Canyon, San Juan County, Utah. Econ. Geol. Vol. 50, No. 2.
MILLER, D. S. and KULP, J. L. (1958): Isotopic study of some Colorado Plateau ores. Econ. Geol. Vol. 53, No. 3.
MITCHAM, T. W. and EVENSON, C. G. (1955): Uranium ore guides, Monument Valley district, Arizona. Econ. Geol. Vol. 50, No. 2.
MOORE, G. W. (1954): Extraction of U from aqueous solution by coal and some other materials. Econ. Geol. Vol. 49, No. 6.
PAPENFUS, E. B. (1931): "Red Bed" copper deposits in Nova Scotia and New Brunswick. Econ. Geol. Vol. 26, No. 3.
PAVONI, N. (1957): Geologie der Zürcher Molasse zwischen Albiskamm und Pfannenstiel. Vierteljahrsschr. Nat. Ges. Zürich, Jg. 102, Abhandlung No. 5.
POOLE, F. G. and WILLIAMS, G. A. (1956): Directions of the sediment constituting the Triassic and associated formations of the Colorado Plateau. Proc. Int. Conf. on Peacef. U. of Atom. Energy, Vol. 6, Geol. of U and Th. UNO, New York, p. 326—330.
RICHARD, L. M. (1915): Copper deposits in the "Red Beds" of Texas. Econ. Geol. Vol. 10, No. 7.
ROGERS, A. F. (1916): Origin of copper ores of the "Red Beds" type. Econ. Geol. Vol. 11, No. 4.
ROLKER, C. M. (1881): The silver sandstone district of Utah. Trans. AIME Vol. 9, p. 21—33.
ROSENZWEIG, A., GRUNER, J. W., GARDINER, L. (1954): Widespread occurrence and character of uraninite in the Triassic and Jurassic sediments of the Colorado Plateau. Econ. Geol. Vol. 49, No. 4.
SCHMITZ, E. J. (1896): Copper ores in the Permian of Texas. Trans AIME, Vol. 26, p. 97—108.
SCHNEIDERHÖHN, H. (1955): Erzlagerstätten. Stuttgart.
SCHOUTEN, C. (1946): The role of sulphur bacteria in the formation of the so-called sedimentary copper ores and pyritic ore bodies. Econ. Geol. Vol. 41, No. 5.
SHAWE, D. R., ARCHBOLD, N. L., SIMMONS, G. C. (1959): Geology and U-V-deposits of the Slick Rock district, San Miguel and Dolores Counties, Colorado. Econ. Geol. Vol. 54, No. 3.
SOULÉ, J. H. (1956): Reconnaissance of the "Red Bed" copper deposits in SE Colorado and New Mexico. US Dept. of Int. Bur. of Min. Inf. Circ. 7740.

STEINMANN, G. (1930): Geologia del Peru. Heidelberg.

TARR, W. A. (1910): Copper in the "Red Beds" of Oklahoma. Econ. Geol. Vol. 5, No. 3.

THIEL, G. A. (1930): Experiments bearing on the biochemical reduction of sulfate-waters. Econ. Geol. Vol. 25, No. 3.

TOUWAIDE, M. E. (1930): Origin of the Boleo Cu-deposits, Lower California, Mexico. Econ. Geol. Vol. 25, No. 2.

TRASK, P. D. (1925): The origin of the ore of the Mansfelder Kupferschiefer, Germany (a review of the current literature). Econ. Geol. Vol. 20, No. 8.

TURNER, H. W. (1903): The copper deposits of the Sierra Oscura, New Mexico. Trans. AIME, Vol. 33, p. 678—681.

— (1916): Discussion of "Origin of copper ores of the 'Red Bed' type", by A. F. Rogers. Econ. Geol. Vol. 11, No. 6.

VAN HISE, C. R. (1900): Some principles controlling the deposition of ores. Trans. AIME, Vol. 30, p. 27—177.

VICKERS, R. C. (1957): Alteration of sandstone as a guide to U-deposits and their origin, Northern Black Hills, South Dakota. Econ. Geol. Vol. 52, No. 6.

WHERRY, E. T. (1908): The Newark copper deposits of SE Pennsylvania. Econ. Geol. Vol. 3, No. 8.

WIESE jr., R. G. (1957): An occurrence of mineralized organic material in Nova Scotia. Econ. Geol. Vol. 52, No. 1.

WRIGHT, R. J. (1955): Ore controls in sandstone U deposits of the Colorado Plateau. Econ. Geol. Vol. 50, No. 2.

Received: november 10th 1959.

PLATES I—VIII

Photo 1. Homogeneous and layered beds of sandstone, with one bed containing argillaceous lenses ("clay galls"). Negra Huanusha proper, pt. 10-A.

Photo 2. Small-scale crossbedding in red sandstone. About 200 m W of triangulation pt. G-7, mining site xx-Z.

PLATE I

Photo 1

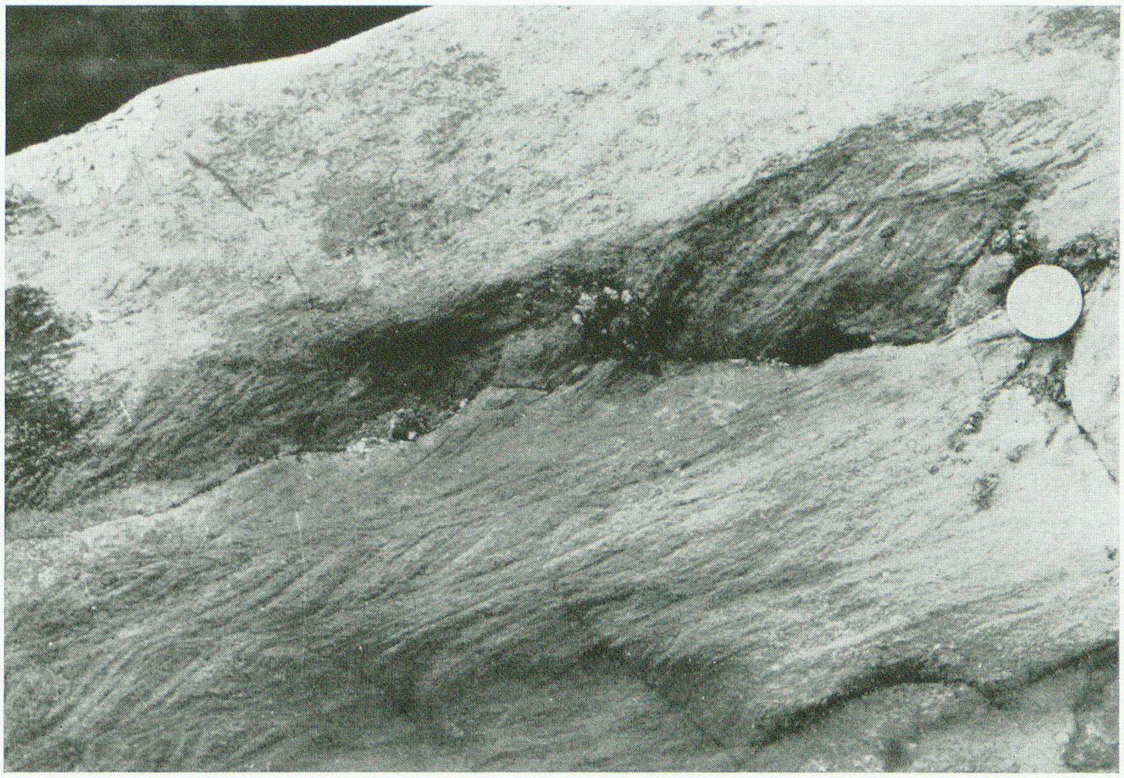


Photo 2

Photo 3. Mudcracks and "fossil raindrops" (?) on the surface of a red argillaceous bed. Negra Huanusha proper.

Photo 4. Bleached sandstone with abundant carbonaceous plant remains on bedding plane. Most of them show malachite deposition on the surface and along numerous cracks. Negra Huanusha proper.

PLATE II

Photo 3

Photo 4

Photo 5. Thin section of a Cu-rich arkosic sandstone with argillaceous lenses ("clay galls"). Black spots are sulfides. Negra Huanusha proper, main adit, pt. A plus 34 m. Enlargement 7×, without Nicols.

Photo 6 and 7. Two sections through the same small stem, which show very clearly the deposition of Cu-sulfides around the coal. With the sulfides is coarser calcite, which fills also cracks through the coal. Negra Huanusha proper, main adit, pt. A plus 34 m. Enlargement 20×. (Photo taken without microscope; Micro-Tessar lens.)

PLATE III

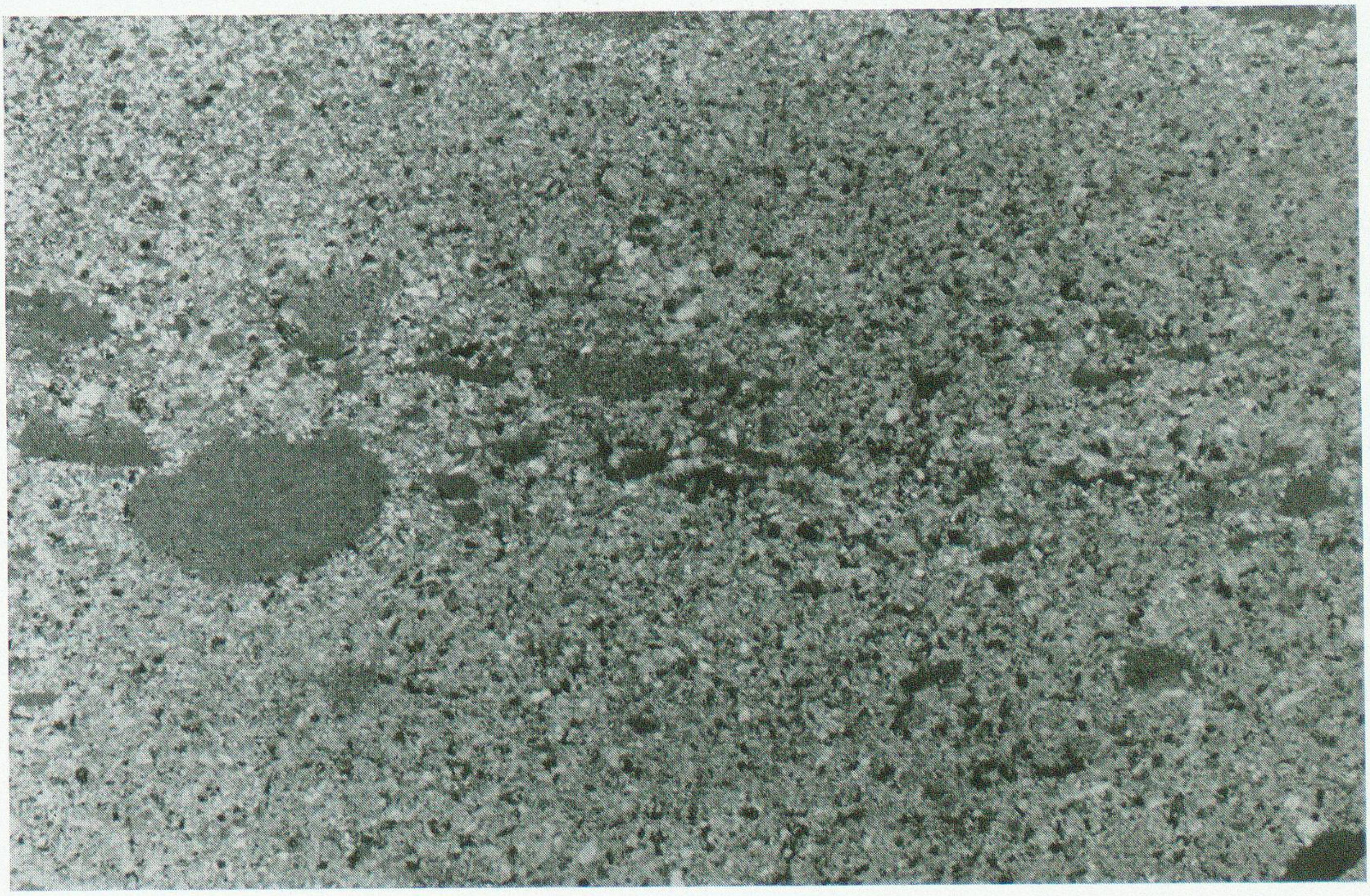


Photo 5

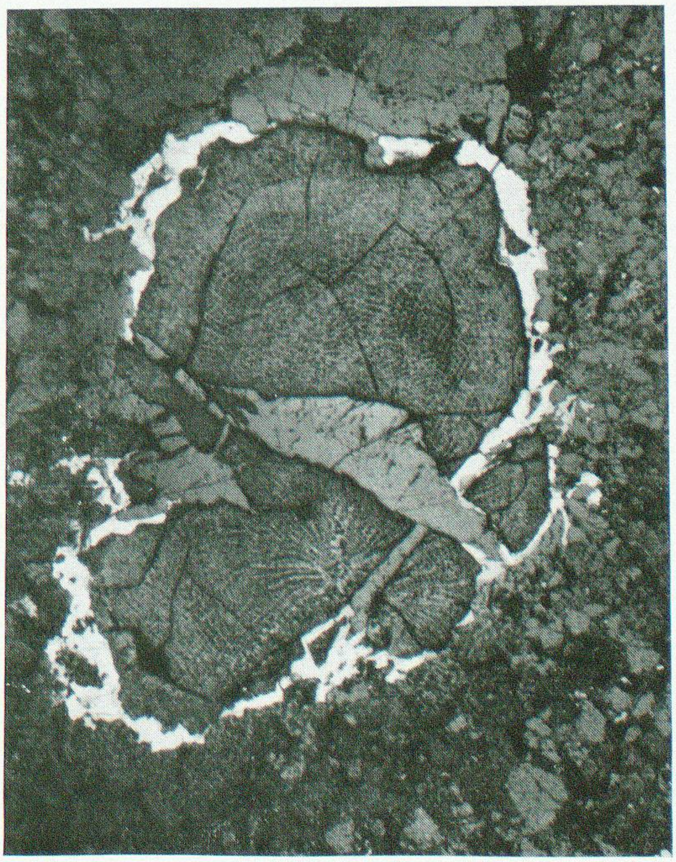


Photo 6

Photo 7

Photo 8 and 9. Fragmental arkose with the following constituents: quartz (q), plagioclase (p), calcite (c), sericite (s), volcanic rock fragments (v). Negra Huanusha proper, sample 1170/2. Enlargement 90×, photo 8 with // Nicols, photo 9 with X Nicols.

Photo 10. Disseminated sulfides in arkosic sandstone. Negra Huanusha proper, main adit, pt. A plus 34 m. Enlargement 90×, // Nicols.

Photo 11. In a sulfide nodule, as occurring at locations O and P, chalcocite makes the fillmass between silicates and hematite. The latter may be partly replaced by chalcocite. Enlargement 360×, oil immersion, // Nicols.

Photo 12. Chalcocite and bornite in graphic intergrowth, chalcocite replacing bornite. Negra Huanusha proper, main adit, pt. A plus 34 m. Enlargement 360×, oil immersion, // Nicols.

Photo 13. Covellite, replacing wood and disseminated among silicates in the nearest vicinity. Note cleavage in covellite. Negra Huanusha proper, main adit, pt. A plus 34 m. Enlargement 90×, // Nicols.

PLATE IV

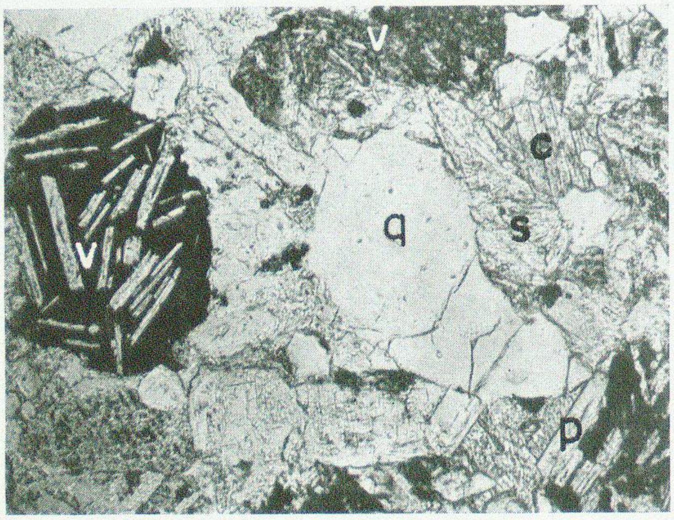


Photo 8

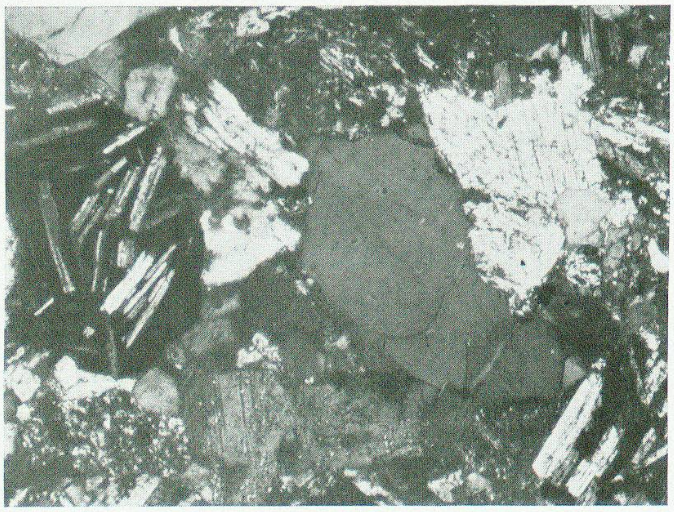


Photo 9

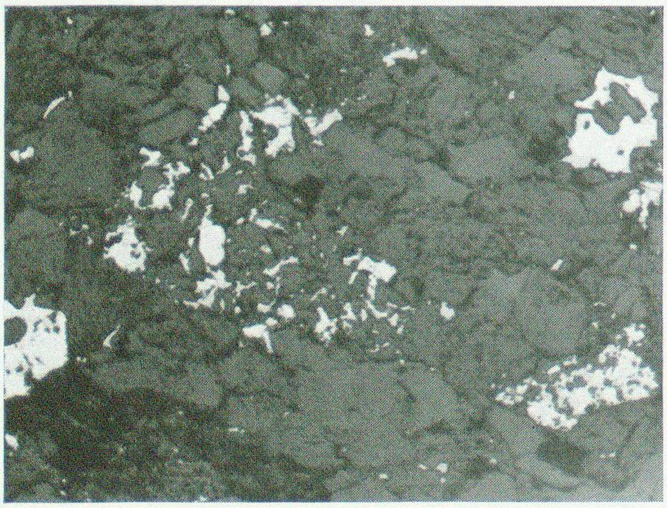


Photo 10

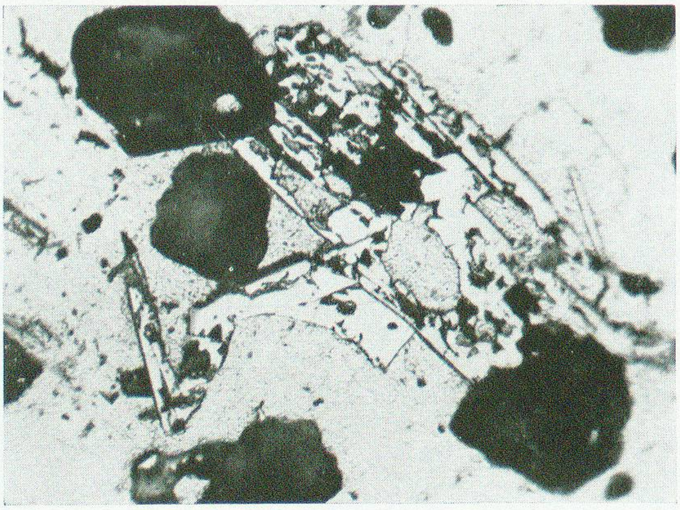


Photo 11

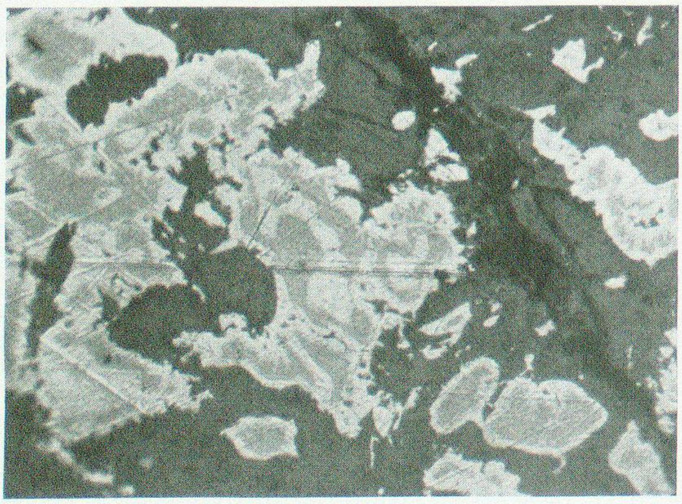


Photo 12

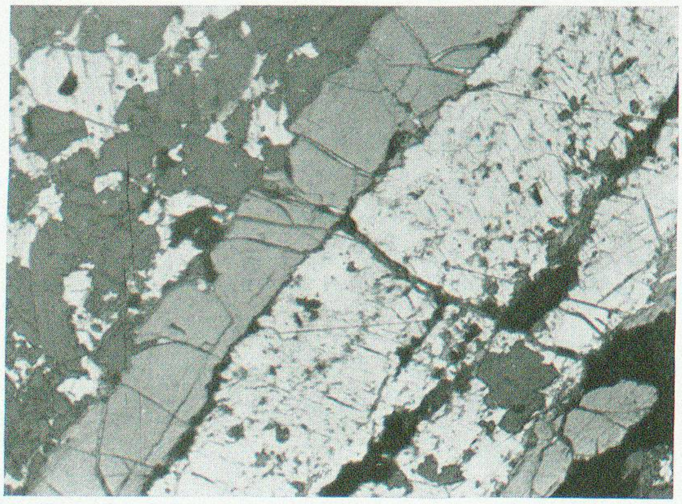


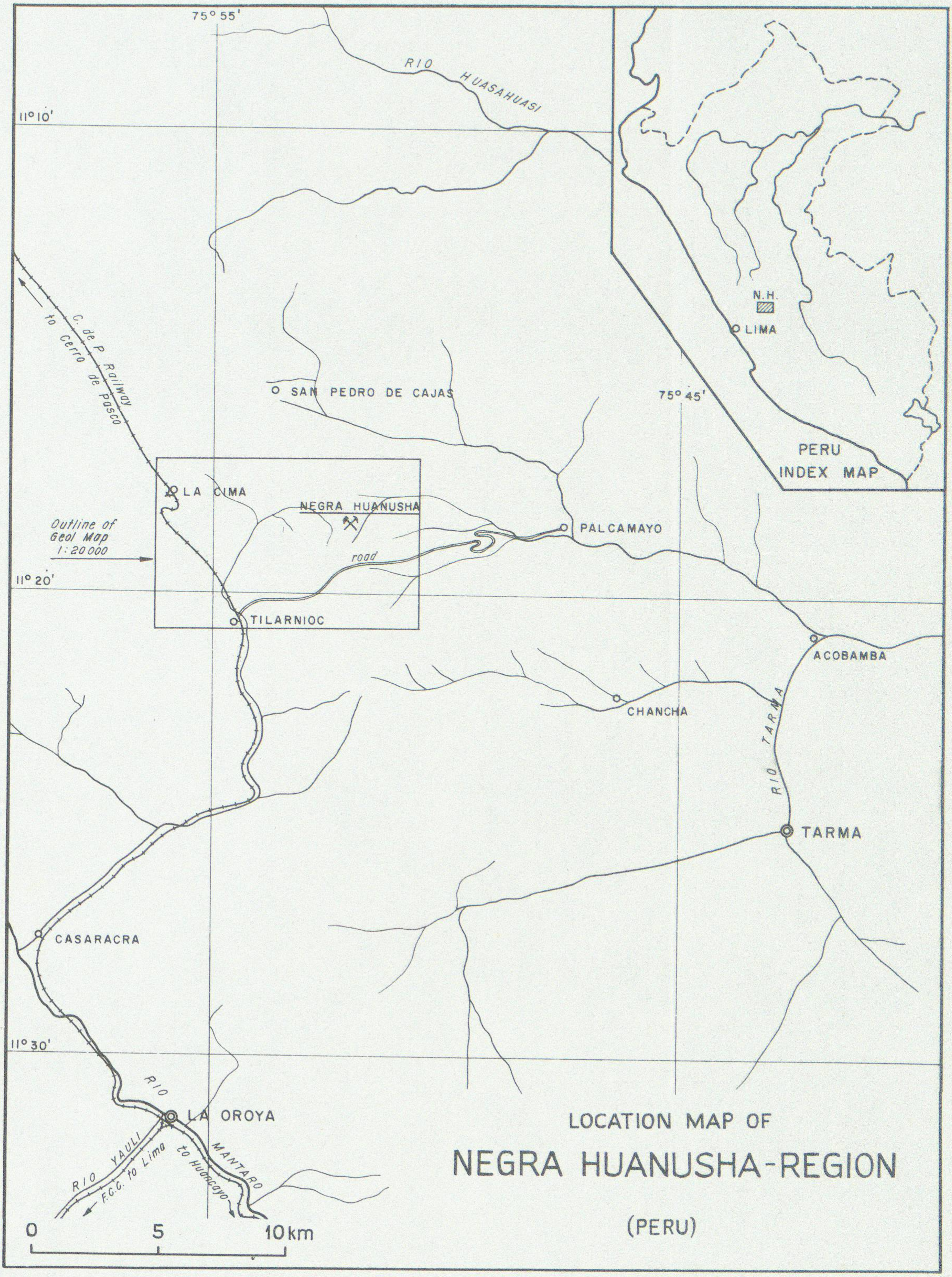
Photo 13

Leere Seite
Blank page
Page vide

PLATE V

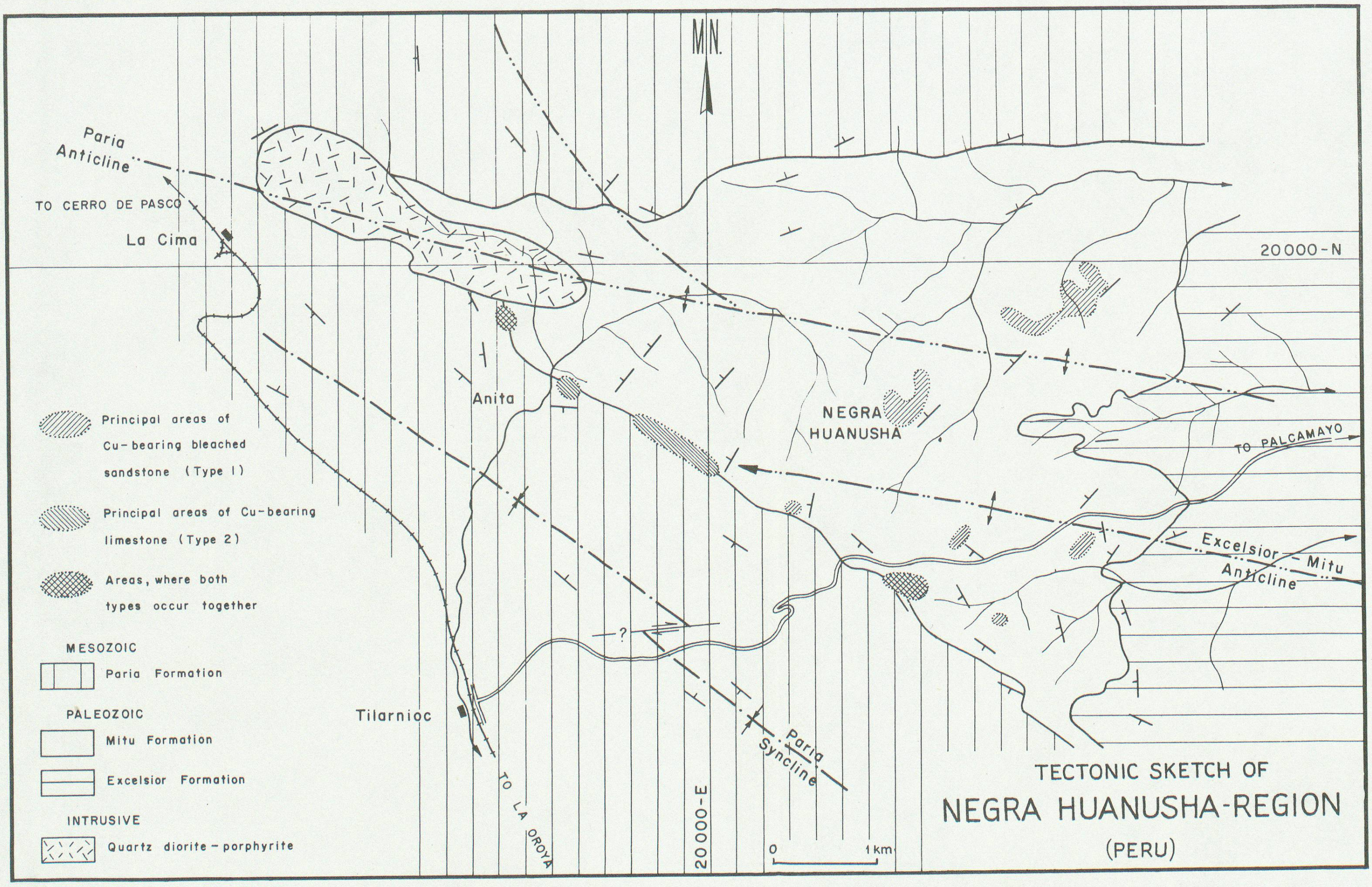
Schweiz. Min. Petr. Mitt.
Band 40, Heft 1, 1960

H. W. KOBE: Cu-Ag deposits of the Red-Bed type at Negra Huanusha in Central Peru



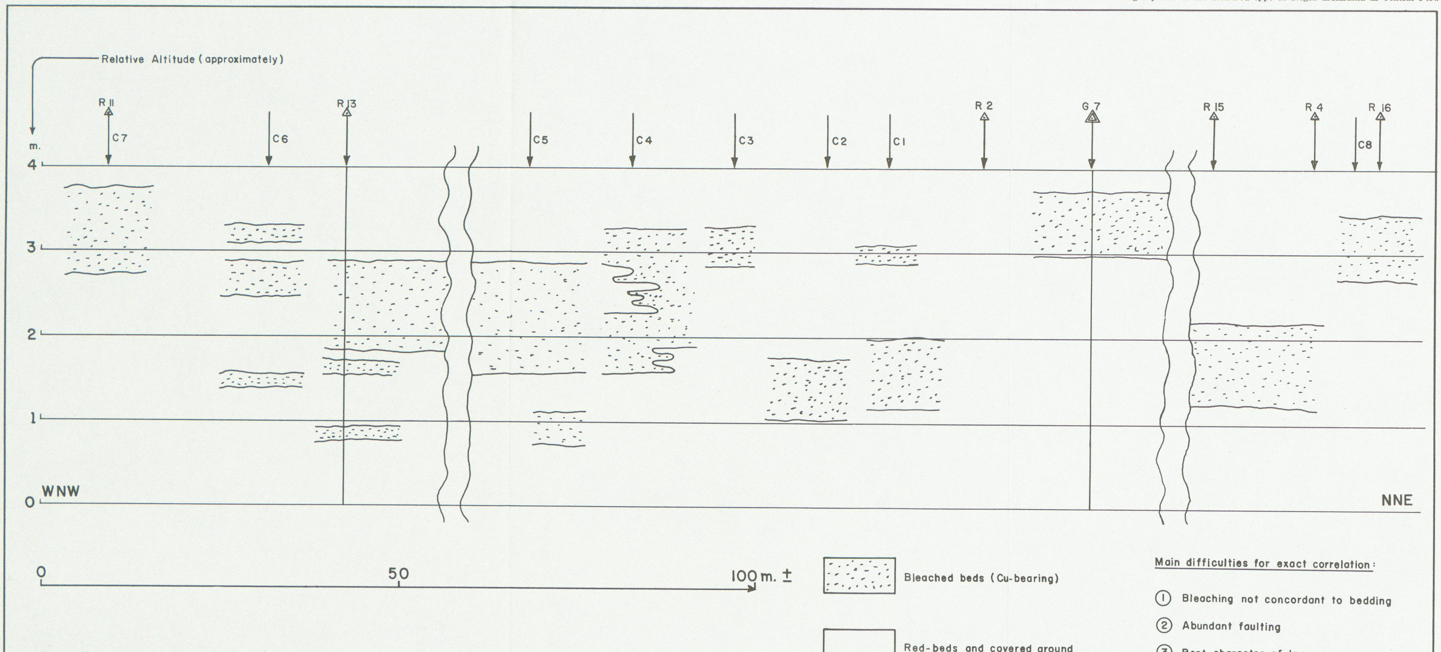
Leere Seite
Blank page
Page vide

Schweiz. Min. Petr. Mitt., Band 40, Heft 1, 1960



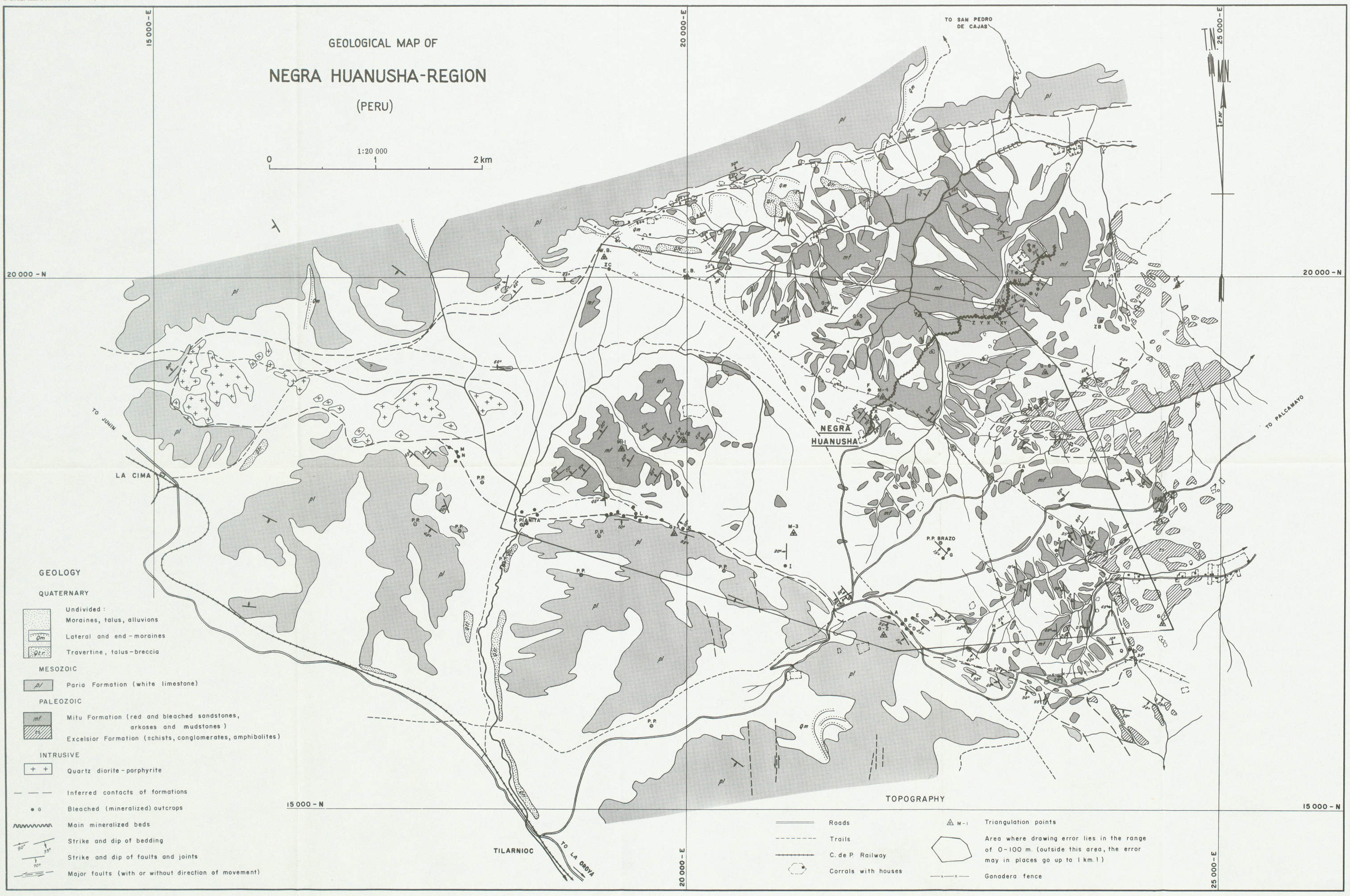
TECTONIC SKETCH OF
NEGRA HUANUSHA-REGION
(PERU)

Leere Seite
Blank page
Page vide



Tentative correlation of bleached beds at mining site Negra Huanusha xx-Z (=Prehistoric Ruins).

Leere Seite
Blank page
Page vide


GEOLOGICAL MAP OF
NEGRA HUANUSHA-REGION
(PERU)
1:20 000
0
1
2 km
15 000-E
20 000-E
25 000-E
20 000-N
15 000-N
T.N.
M.N.
TO SAN PEDRO DE CAJAS
TO JUNIN
TO PALCAMAYO
TO LA OROYA
LA CIMA
TILARNIOC
NEGRA HUANUSHA
P.P. BRAZO
M-3
GEOLOGY
QUATERNARY
Undivided:
Moraines, talus, alluvions
Lateral and end-moraines
Travertine, talus-breccia
MESOZOIC
Paria Formation (white limestone)
PALEOZOIC
Mitu Formation (red and bleached sandstones, arkoses and mudstones)
Excelsior Formation (schists, conglomerates, amphibolites)
INTRUSIVE
Quartz diorite-porphyrite
Inferred contacts of formations
Bleached (mineralized) outcrops
Main mineralized beds
Strike and dip of bedding
Strike and dip of faults and joints
Major faults (with or without direction of movement)
TOPOGRAPHY
Roads
Trails
C. de P. Railway
Corrals with houses
Triangulation points
Area where drawing error lies in the range of 0-100 m. (outside this area, the error may in places go up to 1 km.!)
Ganadera fence