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COPPER ORE OCCURRENCES AT BUDDHA KHOLA IN SOUTH-CENTRAL NEPAL (ASIA)

With 3 figures in the text and 3 plates

Buth Khola or Buddha Khola is located in south-central Nepal (Latitude 27° 49′ North, Longitude 84° 27′ East) about 55 airline miles west of Kathmandu. (Figure 1.) It is a tributary of the Seti River, which flows into the Gandaki, one of the main branches of the Ganga. The prospect is 12 level miles from the nearest road at the western end of the Rapti Valley (Narayangarh), or about 50 miles from the nearest port (Calcutta). (Figure 2.)

The Buddha Khola prospect was discovered in March, 1958, by O' Rourke, Suwal, and Rimal. Boulders of copper-bearing quartz were found in the Seti River near Sarang Ghat. These boulders were traced to their source, which proved to be a swarm of large veins. The veins were mapped and the known limit of the belt was extended to Labdi Khola (Fig. 1), where a large vein was found in place. The preliminary map was completed and the sorounding area was explored for new deposits.

O'Rourke, Suwal and Rimal (1959) described the geologic setting as follows:

»The ore deposits are contained in a sequence of slate, dolomite and quartzite that trend north-west and dip steeply to the north-east. The beds are highly folded and faulted. Most of the folds are isoclinal and appear to be related to thrust faults. The age of the rocks is not known, because of the lack of fossils. One of Hagen's maps indicates that they lie within the Nawakot Nappe System, which is dated as Triassic, but they include iron-formation, and the presence of this distinctive rock-type indicates that they may be Paleozoic, because the iron-formation of Pulchoki has been dated lower Paleozoic by conclusive fossil evidence. Several iron-deposits discovered in the last few years form a belt stretching from Buddha Khola to Pulchoki, a distance of about 64 miles. Some observers have noticed that examples of copper mineralization also are numerous in this same belt, but no genetic connection is obvious because the iron deposits are sedimentary, whereas the copper is hydrothermal.

The copper-cobalt deposits are lenticular quartz veins enclosed in slate and limestones. They range in size up to 40 ft. thick and 500 ft. long. The vein belt is known to be at least three miles long. Some of the veins contain irregular fragments of dolomite, which seem to be inclusions. One of the dolomite beds has been mineralized by replacement, some of the slate contains considerable pyrite, and some of the quarzite and one bed of iron formation are slightly mineralized, but the largest portion of the ore is in the veins.

The veins are composed of chalcopyrite and pyrite in a gangue of quartz. Erythrite was found in several stopes, but no primary cobalt mineral was seen, either in hand specimen or under the ore microscope. The sulphides weather to limonite, sulphur, malachite, chrysocolle and white sulphates. Covellite is found lining cavities and fractures in the largest stopes. The ore minerals are scattered unevenly throughout the veins, but the richest values are generally found in vugs or irregular masses. The old workings indicate that ore bodies of respectable size were mined in some of the veins«. Figure 3.

From the 5th to the 10th January, 1960, one of the authors (B. Z a l o k a r) had the opportunity to visit and inspect the copper ore occurrences and the current exploration drilling. The trip was arranged and sponsored by M/s Kamani Engineering Corporation Ltd. The author

Fig. 1

was in a position to observe both the old mining workings and the conspicuous outcrops. The deposit belongs to a type of copper deposits characterized by a very lean mineralization. There was no proper »gossan« outcrops. The main gangue mineral is quartz. The outcrops are slightly limonitized and stained by secondary copper minerals, mainly malachite. The present diamond drilling showed the core to be very poor, containinig on an average 0,2–0,4% of copper. The veins are well exposed, they are resistant and stand up high above the adjacent slate. Fourteen channel samples analysed by the U. S. Bureau of Mines showed an average of 0,4% of copper. Numerous patches of a 5% ore were left in the ancient mine workings. The ancient miners mined only the richer pockets, the largest beeing 75 × 30 × 25 ft.

MINERAGRAPHIC STUDIES

By mineragraphic studies the following paragenesis was proved: *quartz, siderite, chlorite, chalcedony, pyrite, »intermediary product« (pyrrhotite), chalcopyrite, valleriite, gudmundite, bornite, Ni or Bi-telluride, chalcocite,* as hypogene minerals and *goethite, microcrystalline pyrite, lepidocrocite, malachite, covellite* and *chalcocite* as hipergene minerals.

Quartz is the main gangue mineral of the deposit. It is heterogranular, the dimensions of the grains varying from 20 microns up to 1,5 millimetres. It displays mainly the so-called mortar structure; sutured textures or cataclastic structures are rare. The larger grains are cracked or even crushed, often optically anomalous and turbid, owing to mineral dust.

Siderite is coarse-grained, predominatly isometric, exibiting distinctive cleavages. (Phot. 1) The alteration to limonite commenced along the cleavage planes, but usually along the cleavages siderite is replaced by chalcedony and quartz.

Chlorite (green) is not scarce, but it occurs in very small quantities. Usually it is found in quartz beside opaque minerals.

Chalcedony is the youngest mineral. As already mentioned, it replaces siderite along the cleavages and cracks. It is of a radially-fibrous texture, the fibres producing minute bunches of an divergent arrangement with fan-like extinction.

Pyrite is the main ore mineral. In quartz, there are minute idiomorphic crystals or small rounded masses, (Phot. 2 and 3) which are oxidized on the rim zones to *goethite*. If occurring in larger masses, pyrite is coarse-grained and allotriomorphic. The rim zones of pyrite in allotriomorphic aggregates are replaced by chalcopyrite, thus uncovering the structure of the pyrite aggregates. Sporadically the replacement of pyrite is noticed along cracks and cleavages. Some grains of pyrite are strongly cataclased; the network of the cracks is cemented by chalcopyrite. A wormlike replacement of pyrite by chalcopyrite was also noticed. Some isolated pyrite grains are cemented by masses of quartz. Pyrite is replaced by gudmundite and bornite.

There is some *»intermediary product«* found around the quartz masses forming discontinuous wreaths. (Phot. 4) It occurs with microcrystalline or cryptocrystalline pyrite masses. Further on, it is distinctly anisotropic, occurring as *pseudomorphoses on pyrrhotite*. The »intermediary product« and the cryptocrystalline pyrite are the result of the alteration of the pyrrhotite in the surfacial zones of the ore deposit. Sporadically, the »intermediary product« was noticed in chalcopyrite, in the form of minute agglomerations.

Cryptocrystalline pyrite is a product of the alteration of the pyrrhotite. It occurs regularly along with the »intermediary product«. (Phot. 4). Sporadically, it is developed in the so called »bird eye« structure.

Chalcopyrite is coarse-grained when present in larger masses, but usually it occurs in small masses in quartz and siderite, replacing them. It is markedly twinned. The lamellae are appreciably larger. Sporadically, the replacement of siderite by chalcopyrite is very intensive, only in places some resistant siderite rhombohedron is left. In one place the

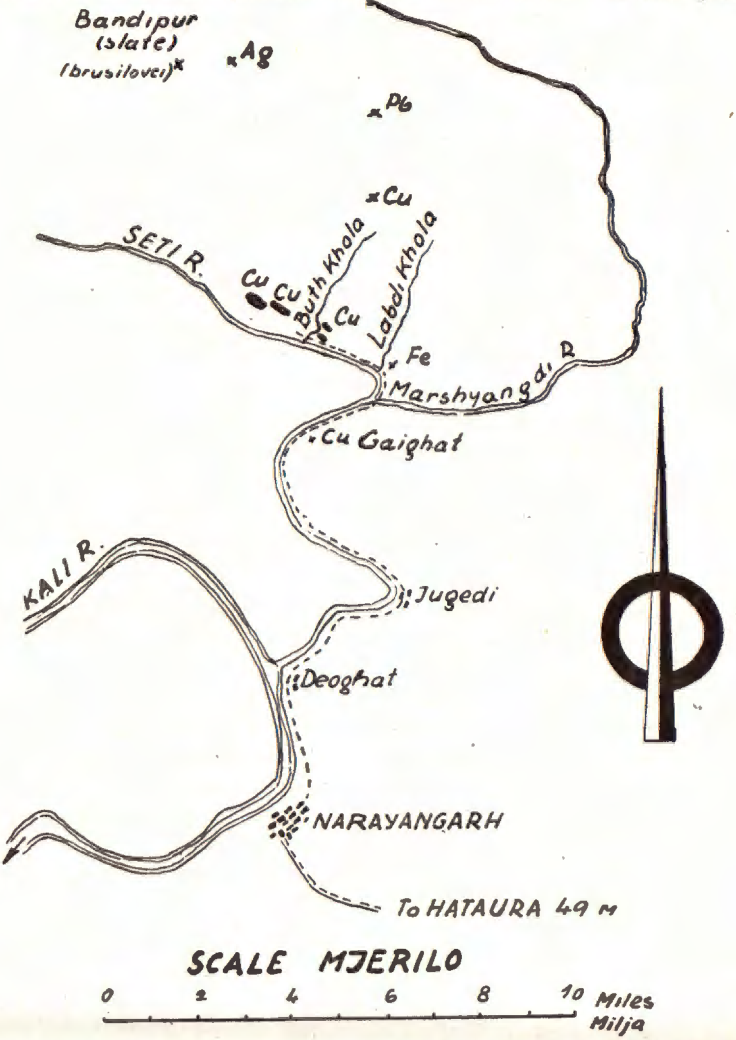

Fig. 2. Copper area Buth Khola, Nepal. – Sl. 2. Bakronosno područje Buth Khola.

contact between siderite and pyrite is replaced by chalcopyrite, separating them in this way. There is chalcopyrite in the cracks and pores of quartz, but sometimes it replaces quartz in a sievelike manner. (Phot. 2). Many of the small chalcopyrite masses are weathered along the fine network of cracks or on the rim zones to hipergene minerals, especially *iron hydroxides*.

Valleriite ($Cu_3Fe_4S_7$) was noticed in one ore section in the form of lamellae, small starlets or irregular bodies in chalcopyrite. In places the lamellae of valleriite are crossed by an angle, which is characteristic for the tetrahedron planes. Valleriite shows an exceptionally strong reflective pleochroism and remarkable anisotropic effects.

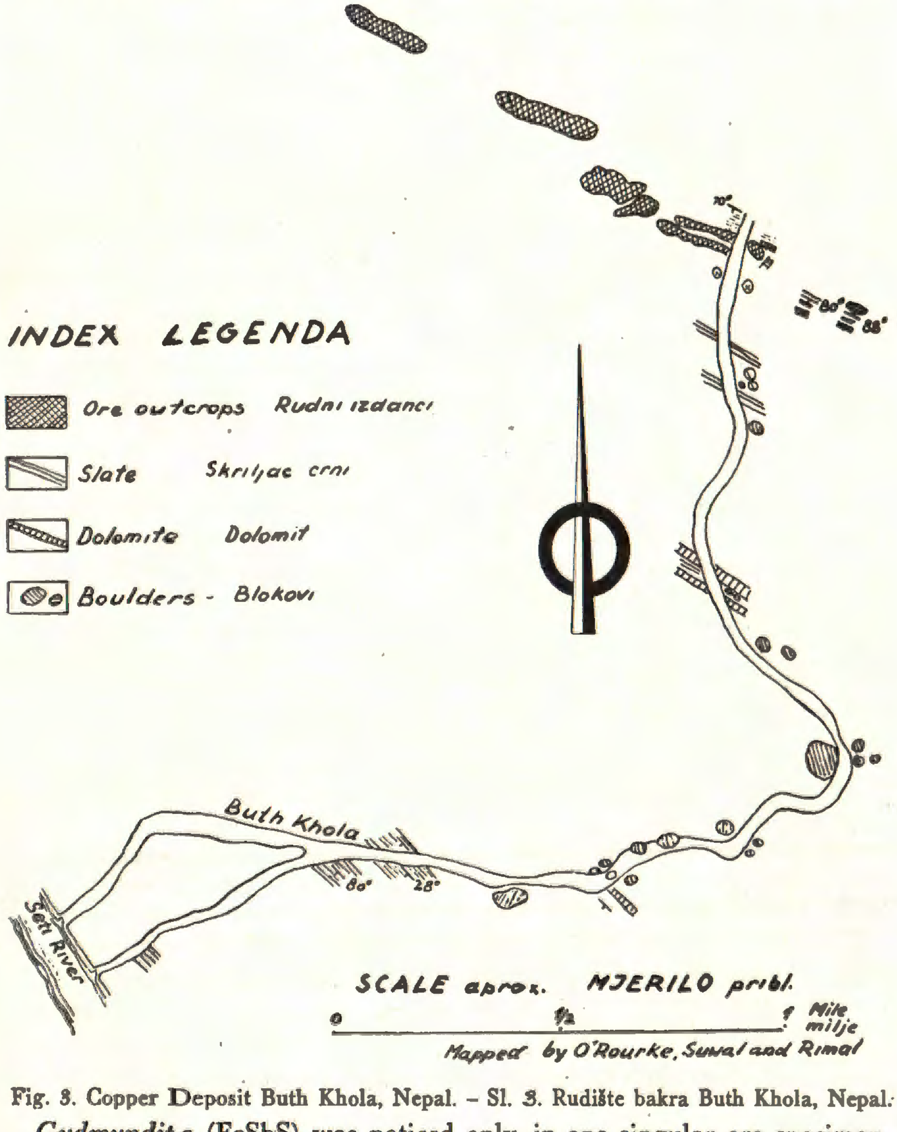

Fig. 3. Copper Deposit Buth Khola, Nepal. – Sl. 3. Rudište bakra Buth Khola, Nepal.

Gudmundite (FeSbS) was noticed only in one singular ore specimen. (Phot. 1). It appears as small-grained aggregates of polygonal grains, the dimensions of the grains ranging from 30 to 60 microns. Sporadically, there are also coarser grains, which are twinned. Gudmundite exhibits a marked reflective pleochroism: creamy-yellow to slightly pinkish, especially when twinned. In cedar oil the rosy colour is more evident, particularly if gudmundite is in contact with pyrite or chalcopyrite. The anisotropic effects are very distinct and coloured. The relief of gudmundite is much lower than that of pyrite, and slightly higher than the relief of chalcopyrite and bornite. It replaces pyrite, being replaced by chalcopyrite and bornite. (Phot. 6).

Bornite is very scarce in the individual grains, and it occurs with a small amount of exsoluted chalcopyrite. Something more frequent is a kind of bornite which exhibits distinctive exsolution lamellae of chalcopyrite parallel to (100) of bornite. In such specimens the optical properties of both minerals are distinctive, and especially noticeable in the oil immersion. Characteristic is the appeareance of an abnormally coloured chalcopyrite, which displays under small magnification a dull-yellow tone with a slightly pinkish-brown undertone. Under great magnification and especially in the corners of the mineral, it could easily be seen that this is not a homogenous mineral, but that it contains quantities of exsolutions of minute lamellae, discs and drops of chalcopyrite in bornite plessite. The dimensions of these lamellae, discs and drops are just above the lowest limit of visibility. In the rim zones of some larger masses, normal exsolutions of thinn chalcopyrite lamellae in bornite are noticeable. In one and the same bornite mass there are portions which are in a state of exsolution, but the dimensions of these exsoluted bodies are on the limit between the submicroscopic and microscopic range of visibility; then there are portions with hardly noticeable drop-like chalcopyrite exsolutions, and consequently portions with normal chalcopyrite exsolution lamellae. In some bornite masses the chalcopyrite exsolutions occur along the cracks.

Especially interesting is a rather frequent exsolution texture. (Phot. 5). Owing to the exceptionally small dimensions of this exsoluted bodies it is difficult to state definitely about their nature, but most probably those are alterations of anomalous bornite to *chalcocite* and *chalcopyrite* or the so-called *»Kupferkieslamellen* according to P. Ramdohr, 1955«. These are spindle-like, slightly bent, flame-like bodies which penetrate into bornite and are frequently associated with Cu_2S. In our particular case an exceptionally anisotropic mineral – presumable *valleriite* is also present. In some mineral masses light grains, probably some *nickel* or *bismute telluride,* are noticeable.

Goethite, lepidocrocite, malachite, covellite, chalcocite are the products of weathering of the hypogene minerals in the oxidized zone of the ore deposit.

SEQUENCE OF MINERALIZATION

Hypogene phase:

$FeS_2 \rightarrow SiO_2$ + chlorite $\rightarrow FeS \rightarrow FeCO_3 \rightarrow FeSbS + (CuFeS_2 + Cu_3Fe_4S_7) + (Cu_5FeS_4 + Cu_2S + Cu_3Fe_4S_7 + Ni[Bi?]$ — tellurides)

Hypergene phase:

»Intermediary product« + microcristalline pyrite → goethite + lepidocrocite + malachite + covellite + chalcocite.

GENETIC TYPE OF ORE DEPOSIT

The appearance of coarse-grained pyrite, coarse-grained and partially optically anomalous quartz, furthermore chalcopyrite with exsolution of valleriite, furthermore pyrrhotite, anomalous and structurelly unstable bornite, furthermore gudmundite, suggests that the deposit belongs to a relatively high-temperature hydrothermal type; of the kata to the mezothermal stage.

REFERENCES

O' Rourke, Suval & Rimal (1959): Report (manuscript).
Ramdohr, P. (1955): Die Erzmineralien und ihre Verwachsungen, Berlin.

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POJAVA BAKARNE RUDE KOD BUDH KHOLA U JUŽNOM DIJELU NEPALA U AZIJI

Pojava bakarne rude otkrivena je god. 1958. od O' Rourke, Suval i Rimala oko 55 milja zapadno od glavnog grada Katmandu.

Rudna pojava se nalazi u škriljavcima i vapnencima, vjerojatno paleozojske starosti. To su lećaste žice kvarca duge oko 500 stopa i debele do 40 stopa, u pojasu dugom oko 3 milje. Golim okom se vide pirit i halkopirit i njihovi razgradni produkti: limonit, malahit, hrizokola i razni sulfati, katkad i kovelin. Rudni minerali su neravnomjerno razdijeljeni u žicama, većinom kao gnijezda i nepravilne mase. Ima dosta tragova starih rudarskih radova.

God 1960 izvršio je B. Zalokar prospekciju rudnih pojava i tom prilikom sakupio rudne uzorke za mikroskopsko ispitivanje. Mikroskopska analiza je utvrdila ovu paragenezu:

HIPOGENI MINERALI:

kvarc, siderit, klorit, kalcedon, pirit, halkopirit, valeriit, gudmundit, anomalni bornit, Ni ili Bi (?) telurid, halkozin.

HIPERGENI MINERALI

»međuprodukt kao pseudomorfoza po pirotinu«, mikrokristalasti ili kriptokristalasti pirit, getit, lepidokrokit, malahit, kovelin, halkozin.

REDOSLJED MINERALIZACIJE

pirit → kvarc + klorit → pirotin → siderit → gudmundit + (halkopirit + valeriit) + (bornit + halkozin + valeriit + halkopirit + Ni/Bi) telurid.

GENETSKI TIP

Pojava krupnozrnatog pirita, krupnozrnatog i parcijalno optički anomalnog kvarca, zatim halkopirita s izdvajanjima valeriita, pa pirotina, anomalnog bornita s izdvajanjima halkopirita, valeriita, halkozina, lamelarnog halkopirita (»Kupferkieslamellen«), te pojava gudmundita ukazuju da se radi o hidrotermalnom ležištu i to o višetemperiranom katatermalnom do mezotermalnom ležištu.

PLATE — TABLA I

Phot 1. Coarse-grained siderite (grey), predominatly isometric, exibiting distinct cleavages. Gudmundite (white) replaces siderite.

Krupnozrnati siderit (siv), pretežno izometričan s vrlo jasno razvijenom kalavosti. Gudmundit (bijelo) potiskuje siderit.

Phot. 2. Allotriomorphic granular pyrite (py). Chalcopyrite (chpy) replaces pyrite and quartz. Quartz (black) is gangue mineral. Pyrite is locally cataclased.

Alotriomorfno zrnati pirit (py). Halkopirit (chpy) potiskuje pirit i kvarc. Kvarc je mineral jalovine (crno). Pirit je lokalno kataklaziran.

Phot 3. Idiomorphically developed pyrite (py) crystals in quartz (black). Chalcopyrite (h) replaces quartz.

Idiomorfno razvijeni kristali pirita (py) u kvarcu (crno). Halkopirit (chpy) potiskuje kvarc.

Phot. 4. Along the rim zones of quartz (black) occurs an »intermediary product as pseudomorphosis on pyrrhotite« (i. p.) Small masses of microcrystalline pyrite (py) associated with an intermediary product. Chalcopyrite (h) includes quartz and an intermediary product.

Po rubovima mase kvarca nalazi se intermedijarni produkt (i. p.) kao pseudomorfoza po pirotinu, a uz njega malo mikrokristalastog pirita (py). Halkopirit (h) uklapa kvarc i interprodukt.

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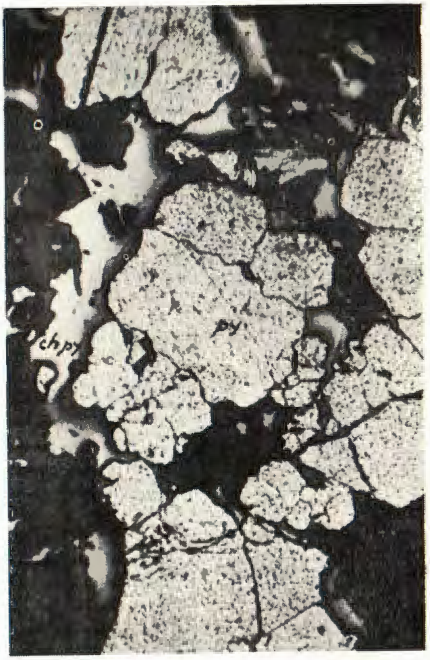

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PLATE — TABLA II

Phot. 5. In siderite (black) a mass of anomalous bornite with drops and bent lamellae of chalcocite and »Kupferkieslamellen«. In the upper part a mass of normal bornite (b).

U sideritu masa bornita sa izdvajanjima lamela, kapljica i tjelešaca halkozina i »Kupferkieslamellen«. U gornjem dijelu slike jedna masica normalnog bornita (b).

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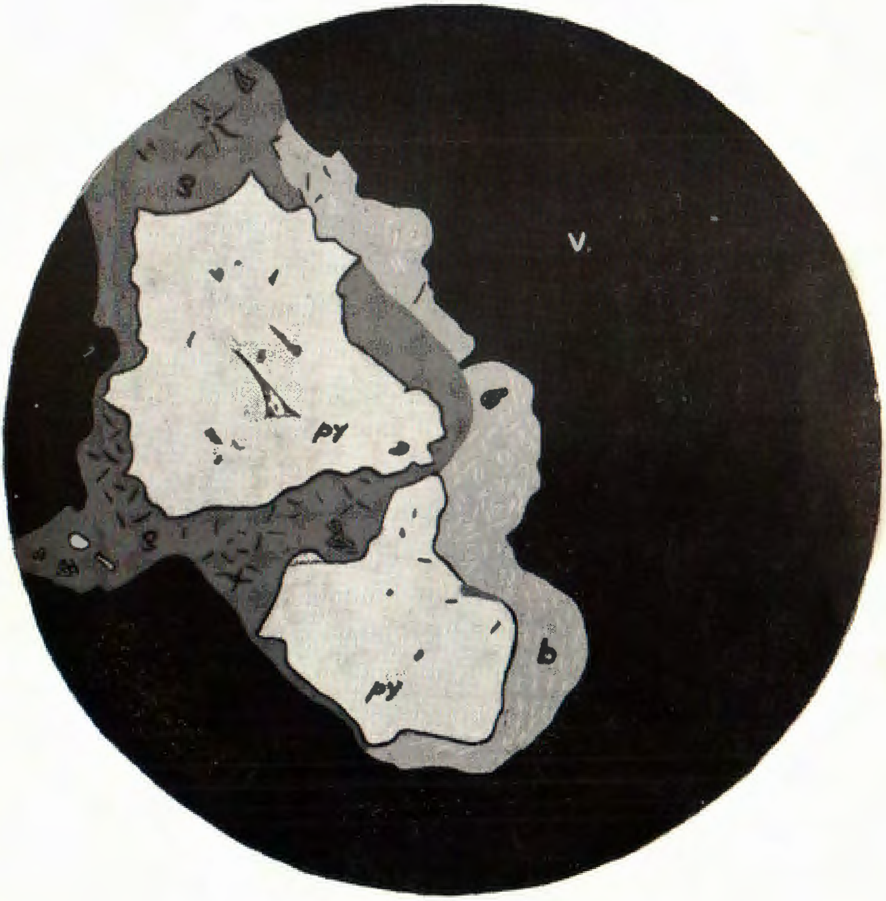
PLATE — TABLA III

Phot. 6. Buddha Khola, Ore section No. 5, magnified 450 ×, oil immersion. Fine-grained gudmundite (g) and bornite with chalcopyrite exsolution lamellae (b) arround pyrite (py). (v) gangue minerals.

Sitno zrnati gudmundit i bornit s halkopiritskim lamelama izdvajanja (b) oko pirita (py). Minerali jalovina (v).



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