TUNGSTEN BEARING QUARTZ VEINS AROUND CHHENDAPATHAR, BANKURA DISTRICT, WEST BENGAL, INDIA—THEIR MINERAGRAPHY AND GENESIS

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Abstract

Tungsten bearing quartz veins around Chhendapathar (22° 45′ 21″ N.; 86° 45′ 22″ E.), Bankura district, West Bengal, India, have been studied in detail. The ore veins crop out in pelitic schists surrounding Chhendapathar granite. The country rocks exhibit pronounced effects of retrogression. The deposits are fissure filling veins ranging from paper-thin to several metres in width. Greenish white muscovite-schists containing profuse tourmaline have developed along the margin of the veins. Wolframite and scheelite are the important tungsten minerals. Other ore minerals are molybdenite, bismuthinite, magnetite, ilmenite, pyrite, arsenopyrite, pyrrhotite and chalcopyrite. The gangue minerals include quartz, tourmaline, muscovite and pink mica. Supergene minerals are WO_3-ochre, haematite, goethite and malachite. Textural relations and mineral paragenesis of the ore veins have been discussed. Zonal structure in scheelite (not reported before) has been described. Important replacement textures, comprising pseudo-tetragonal replacement of scheelite by wolfram, vein replacement of wolfram by scheelite, pseudographic replacement of pyrrhotite by arsenopyrite have been observed. The high temperature mineral assemblage points to hypothermal nature of the veins. At a lower temperature mesothermal mineralization was responsible for the formation of chalcopyrite, sericite and part of the scheelite. Bent cleavages in wolfram twisted needles of tourmaline and deformation lamellae in quartz indicate that the area has been subjected to deformative stress during the consolidation of the veins. This has caused development of new *S*-planes and puckers in country rocks and widespread retrogression. On the whole, however, crystallization has outlasted deformation in these ore veins.

1. Introduction

Swarms of quartz veins carrying tungsten minerals crop out in Chhendapathar (22° 45′ 21″ N.; 86° 45′ 22″ E.) and neighbouring villages of Bankura district, West Bengal, India. First published report on the occurrence of wolfram is due to Clegg (1945). The veins supplied forty-five tons of wolfram in the period 1942-43 (Braun and Dey, 1955). Deb (1956) made microscopic studies of the specimens of ore from the vein and reported replacement of wolfram and magnetite by scheelite and martite respectively. In the present work the author has attempted a detailed mineragraphic study of the veins. Besides already reported wolfram, scheelite, magnetite and martite, a good number of ore minerals comprising ilmenite, molybdenite, bismuthinite, arsenopyrite, pyrrhotite, pyrite, chalcopyrite and supergene minerals have subsequently been observed. This paper is confined to brief description of the geology of the area, modes of occurrence, mineral assemblage, optical characters and etch reactions of the minerals as well as the textural relations, mineral paragenesis and origin of the ore veins. Zonal structure in scheelite, replacement of scheelite by wolfram, pseudographic replacement of pyrrhotite by arsenopyrite are some new observations in these ore veins.

2. Geology

The area is an eastern continuation of the Archaean terrain of Chotanagpur, Singhbhum, Manbhum and Dalbhum. Two major rock units, namely metamorphics and granites, constitute the area. The metamorphics include rocks of igneous and sedimentary origin. The paraschists are mainly pelitic rocks with subordinate intercalations of arenaceous and calcareous types. Orthotypes include epidiorites, amphibolites and ultrabasic rocks. The granite gneiss has more or less an elliptical outcrop restricted to the south-west part of the area. Another small outcrop of granite is found near Kharakocha (22° 52′ N.; 86° 34′ 20″ E.). Occasional small outcrops of granite can be found up to Chhendapathar (22° 45′ 21″ N.; 86° 34′ 20″ E.) from Kharakocha (22° 52′ N.; 86° 34′ 20″ E.) in NW.–SE. belt of the country. Generally one would expect concentration of ore veins around a granite which has not been deeply eroded. The small outcrops of granite indicate a favourable geological setting of the area for mineralization.

Following zonal concept of variation of metamorphism four mineral isograds (biotite, garnet, staurolite-kyanite and sillimanite) have been delimited in the area (Chakravarty, 1955) by observing the first appearance of index minerals. The distribution of the metamorphic zones shows a broad concordance with the structural plan of the region. Highest grade rocks occur at the core of plunging foliation anticlines of the area. Thus intensity of metamorphism appears to be closely related to tectonic depth modified to some extent by the metasomatic effects around granite and granodiorite bodies. Analysis of megascopic and microscopic structures indicates at least two periods of deformation in the terrain.

Majority of the ore veins bearing tungsten mineral are exposed in a mica-schist country around Chhendapathar granite. Contrasting with Kuilapal granite mass, the Chhendapathar granite is not gneissic. It is commonly a pegmatoid biotite-granite. Local varieties are muscovite-granite and leuco-granite (Pl. XVI, fig. 1). Emplacement of the small granite plutons and these ore veins occurred at the culmination of the second deformation. Crystallization has outlasted deformation in these granite bodies. Local fault zones in granite-country only exhibit strong effects of post-crystalline deformation.

The garnetiferous mica-schists in which majority of the ore veins are located show pronounced retrograde changes. Staurolite and garnets have been changed to clots of sericite and limonite. Kyanites and sillimanites have been changed to shimmer-aggregates of sericite. Biotites have been altered into hydrobiotite and chlorite. Deformation lamellae in quartz, fractured and bent muscovites showing translation lamellae and highly contorted mica-schists point to a good degree of shattering of the area. Common striation lineations on sheared rocks, presence of siliceous breccia and lateroid masses indicate that the area is in a discolation zone. The mineralizing fluids have been emplaced following weak zones in the country rock.

3. Mode of occurrence of the ore bodies

Most of the deposits are fissure-filling veins which consist mainly of massive white and blue-grey quartz with wolfram, light coloured mica and other minerals. These are located within pelitic schists near granite margin. Contacts between vein and wall rock are often sharp. In some instances the wall rock has been replaced by quartz so that fragments of mica-schists are found along marginal portion of the veins. Veins range from paper-thin to several metres in width. Minerals are unevenly distributed in the veins without any delicate crustification; but rough banded arrangement formed by successive crystallization of minerals has been noted in some veins. Mica, wolfram and, rarely, tourmaline are commonly attached to the walls of the veins with a central filling of massive quartz. Frequently an ore body has honeycombed structures filled with limonite, malachite and drussy quartz.

In general, the mineralization is sporadic. Rich concentrations are rarely found. Sufficient quantity of ore can be recovered from the eluvial deposits accumulated at the foot-region of the reefs.

4. Wall rock alteration

Tourmaline and greenish white muscovite commonly occur in the wall rocks, where tungsten veins are located in pelitic schists (Pl. XVI, fig. 2). In many cases tourmaline does not occur in the veins but they are abundant in thin sections of the wall rocks. These wall rocks megascopically display a greenish white colour and a phyllitic sheen. On some of these, striation lineations are abundant. In most cases the alteration of the wall rock, as indicated by change of colour and texture, can be detected only within three feet from the veins.

5. Mineralogy of the veins

Wolframite is the only tungsten mineral that occurs in important amounts in a good number of veins of the area. Besides, scheelite occurs in small quantities in most of the veins. Other ore minerals include molybdenite, bismuthinite, ilmenite, pyrite, arsenopyrite, pyrrhotite and chalcopyrite.

The gangue minerals include quartz tourmaline, muscovite and pink mica (lepidolite).

Supergene minerals are WO_3-ochre, haematite, goethite and malachite.

Ore Minerals :

Wolframite occurs as coarse to thin bladed crystals embedded in quartz. Against quartz it commonly shows crystal faces. Films of WO_3-ochre, pale yellow in colour, are frequently found along the cleavages and cracks in wolfram.

In incident light the mineral is greyish white. In oil, the colour is grey with a brownish tint. Reflectivity in air is 17 (using Berek's photometer, green filter). Reflection pleochroism is weak grey to brownish grey. The mineral shows oblique extinctions. Internal reflection is deep red. Two sets of distinct cleavage are seen. The mineral is veined and replaced by scheelite (Pl. XVI, fig. 3) and sulphides (Pl. XVIII, fig. 1). Rarely wolfram veins interstitial scheelite (Pl. XVIII, fig. 4). The mineral is negative to all standard reagents including H.F.

A small portion of the finely powdered sample was fused with Na_2Co_3; and the fused mass was dissolved in HCl. On adding granules of Zn to the solution a fine blue colour appeared.

Scheelite occurs as grey-white and yellow-white patches associated with wolfram. It shows bluish white fluorescence when examined in ultraviolet light. In transmitted light scheelite is colourless to pale yellow and exhibits a high relief. Birefringence is 0·016. Uniaxial positive.

In incident light, scheelite is dark grey. Reflectivity in oil is 2·9 (Berek's photometer, green filter). Anisotropism is distinct but highly masked by abundant white internal reflection. Scheelite frequently occurs along grain boundaries of wolfram and quartz and forms vein in wolfram (Pl. XVI, fig. 3).

Scheelite is negative to all standard reagents. Etch-test with HF developed beautiful zonal structure (Pl. XVI, fig. 4). No published literature describes zonal structure in scheelite. Whether this zonal structure is imbibed by replacement of a zoned and twinned cassiterite is not certain. Locally it resembles growth twins.

Molybdenite usually occurs in aggregates of fine flakes in wolfram quartz and other sulphides. Locally they form rim around scheelite (Pl. XVII, fig. 3).

The mineral polishes rather well notwithstanding its low hardness. Reflectivity varies widely, being 30 along the basal section and 15 in the direction C' (E). It is white to dark grey in reflected light. In oil, it has distinct bluish tinge and the reflectivity is much lowered.

Anistropism is strong, and there is no internal reflection. The mineral is negative to all standard reagents.

Parallel displacement along 0001 is frequent (Pl. XVII, fig. 1).

Bismuthinite :

A few radial fibrous flakes and granules of bismuthinite are found embedded in quartz. Strong reflection pleochroism from bluish grey-white to yellowish white is characteristic. Also it shows pronounced anisotropic colours.

Etch reactions :

Positive	: HNO_3 stains black.
———	: HCl fumes tarnish.
Negative	: KCN, $FeCl_3$, KOH.

Certain spots in bismuthinite are found to exhibit very pronounced reflectivity (near that of native silver). These portions may be droplets of native bismuth in bismuthinite (Pl. XVII, fig. 4).

Magnetite is frequent in some of the ore veins. They occur generally interstitially to wolfram. The colour is pale rose brown and the mineral is isotropic. Streaks of martite are present along the octrahedral planes as well as in the grain boundaries.

Etch reactions :

Positive	: HCl—mineral darkens and the fumes around the drop tarnish. Solution turns yellow.
———	: HF—turns the mineral sooty black. Corrodes the grain.
Negative	: HNO_3, KCN, KOH, $FeCl_3$, $HgCl_2$, etc.

Arsenopyrite :

The colour of the mineral is white with a creamy tint. Reflectivity in air is 51 (Berek's photometer, green light).

Etch reactions :

Positive	: HNO_3, Aq. regia, KCN, $HgCl_2$.
Negative	: HCl, $FeCl_3$, KOH.

Pyrite :

This occurs as cube-shaped grains associated with other sulphides. Yellowish white grain shows high reflectivity in incident light. Isotropic.

Etch reactions :

Positive	: HNO_3 stains slightly, fumes tarnish.
Negative	: HCl, Aq. regia, KCN, KOH.

Pyrrhotite is pinkish cream in reflected light. Reflection pleochroism is very distinctly brownish creamy (*E*) to reddish.

Etch reactions :

Positive	: HNO_3, HCl, KOH, HF, KOH turns brown.
Negative	: KCN, $FeCl_3$, $HgCl_2$.

Pyrrhotite is found constantly associated with arsenopyrite. Sometimes the two minerals form pseudographic texture (Pl. XVIII, fig. 1) due to partial replacement of pyrrhotite by arsenopyrite.

Chalcopyrite together with scheelite and other sulphides form veins in wolfram. Small grains are also found embedded in quartz. Brass yellow grains show a high reflectivity in incident light. Anistropism is distinct in shades of greenish-yellow.

Etch reactions :

Positive : HNO_3, Aq. regia, fumes tarnish.
Negative : HCl, KCN, $FeCl_2$, KOH, $HgCl_2$.

Ilmenite is abundant in some of the veins. It is brownish pink in reflected light. Reflectivity, determined by Berek's photometer using green filter, is 18 (in air). The grains are strongly anisotropic. Frequently they have been oxidized to haematite along cleavages, cracks and grain boundaries. Ilmenite forms vein in wolfram (Pl. XVI, fig. 6).

The mineral is negative to all standard reagents except HF which corrodes and blackens the mineral after a prolonged treatment.

Minute grains of a few ore minerals, other than those described above, have been found during examination in reflected light with high power objectives. Due to insufficiency of material, exhaustive study could not be carried out, and their identification remains provisional. They have not been mentioned in the present paper.

Gangue Minerals:

Chief gangue mineral of the tungsten ores is massive quartz. It is commonly milky white but in some veins it displays a blue-grey colour. In transmitted light the massive quartz is found to be composed of coarse anehedrons often full of dusty inclusions. Strain shadow in quartz is universal. Quartz has a long period of crystallization, therefore we find most of the hypothermal and mesothermal minerals embedded in massive quartz.

Silvery muscovite is common in the veins. Pink mica lepidolite has been found in some of the veins. Biotite is absent. A small amount of sericite is observed in many thin sections. It is a late mineral occurring in fracture and grain boundaries of other minerals.

Supergene Minerals:

Supergene alteration of scheelite and wolframite to tungstite is frequent. WO_3-ochre occurs as fine grained powder veining and replacing wolfram. It is easily distinguished by its softness and greenish yellow colour.

Haematite of secondary origin is found along cleavages, cracks and grain boundaries of ilmenite. It is bluish white in reflected light, and is strongly anisotropic. It is negative to all standard reagents.

Geothite occurs along the borders of haematite and wolframite (Pl. XVI, fig. 5). It is grey in reflected light, and shows a distinct reflection pleochroism. Anisotropism is strong in shades of grey. Internal reflection is reddish brown more distinct in oil.

Etch reactions :

Positive : $SnCl_2$ (Sat) + HCl (0·2W) stains yellow brown.
——— : HCl fumes tarnish.
Negative : HNO_3, H_2O_2, HF, H_2SO_4, etc.

Malachite is frequent in these veins either as aggregate of small crystals or simply as green stains on quartz. It is a supergene alteration product of chalcopyrite.

6. Textural relations and mineral paragensis of the ore veins

The veins exhibit a consistent structural relation between the minerals. As already noted, mica, wolfram and tourmaline are attached to the walls of the veins with a central filling of massive quartz. Wolfram also occurs as isolated, or clusters of, crystals in massive quartz. Green and silvery muscovite is found as a thin selvage along the vein walls. Mica and tourmaline commenced crystallization early in the sequence. A very fine sericitic mica is found to vein wolfram, quartz and other minerals. This belongs to a late period of deposition. Quartz had a long period of crystallization, and all the hypothermal and mesothermal minerals are embedded in, and replaced by, quartz.

Wolfram-scheelite relation is especially interesting in these ore veins. Scheelite occurs as interstitial to wolfram. Also it has veined and replaced wolfram abundantly (Pl. XVI, fig. 3). In rare instances, wolfram has sent out parallel tongues in the interstitial scheelite (Pl. XVIII, fig. 2). Ramdohr (1950, pp. 756-757) comments that in normal temperature and concentration conditions, the replacement of wolfram by scheelite is more evident. But the reverse relation has been reported from Omaruru and San Ajuria where wolframite has formed after scheelite in pseudotetragonal network. Both the relations are found in these ore veins. From the textural relation it is concluded that scheelite had a very long period of deposition. It commenced to crystallize slightly earlier than, or broadly simultaneously with, wolfram, but it continued to vein and replace the hypothermal minerals and part of the mesothermal, and deposited even after the sulphides.

Molybdenite appears to be the earliest of the sulphides. It is found embedded in arsenopyrite, and also in quartz (Pl. XVII, fig. 1). It has also been replaced and veined by scheelite (Pl. XVII, fig. 2). Relation of ilmenite and magnetite with other minerals is not definite but they often vein wolfram. Also bismuthinite, which is found embedded in quartz in minute flakes, cannot be assigned any definite position in the paragenetic table.

Other important sulphide minerals are arsenopyrite, pyrrhotite, pyrite, the period of crystallization of which broadly overlapped. Locally arsenopyrite and pyrrhotite form pseudographic texture (Pl. XVIII, fig. 1) due to partial replacement of pyrrhotite by arsenopyrite. Chalcopyrite commenced crystallization late in the sequence and formed veinlets in other minerals together with scheelite. Sericite formed later along the fractures and grain boundaries of other minerals.

WO_3-ochre, haematite and goethite are the supergene minerals which formed due to weathering, leaching, oxidation, hydration and carbonation of the primary minerals.

The paragenesis of the ore minerals are given in Table 1.

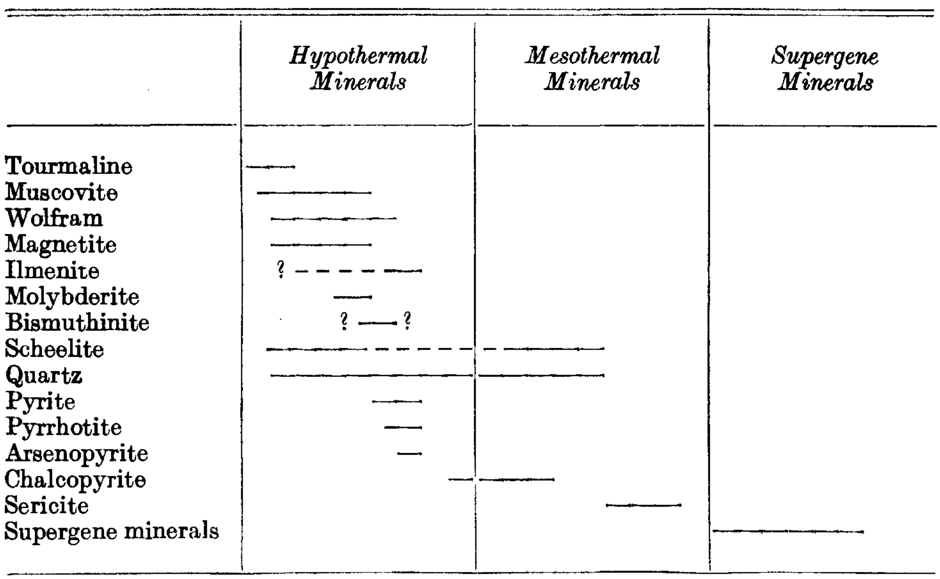
The absence of cassiterite in the above table is striking because tin and tungsten minerals are commonly associated in nature. A single crystal of cassiterite was obtained from marginal portion of a vein during prospecting work by Messrs. Gauripur Industries. Deep and extensive mining is likely to reveal more grains of cassiterite. As the single observed occurrence near the contact of vein with wall rock indicates, the cassiterite may have started to crystallize broadly simultaneously with wolframite. But tin-bearing components became exhausted much earlier.

7. Origin of the veins

Association of tin and tungsten with granitic rocks is universal. The pegmatoid Chhendapathar granite is the source of the mineralizing fluids in the present area. The high temperature mineral assemblage—tourmaline, wolframite, molybdenite, bismuthirite—point to hypothermal nature of the vein. But at a lower temperature mesothermal mineralization was responsible for the formation of sericite, chalcopyrite and part of scheelite.

From experimental observations (Smith, 1949), tourmaline has been found to be stable in water solutions which have a low alkalinity but it is unstable in strongly acidic and strongly alkaline solution. Common presence of tourmaline in veins and wall rock indicates that the mineralizing fluids were mildly alkaline in nature. At lower temperature fluids may have turned acidic, which explains the absence of any carbonate in the gangue.

TABLE I



Occurrence of tungsten copper and lead-zinc silver minerals indicates a space-zoning around the granite outcrops of the area (Chakravarty, 1955). High temperature tungsten and copper minerals occur more near the granite margin and lead-zinc-silver minerals occur further out. Complex structural set-up of the area has controlled and modified this zonal arrangement by providing favourable channels for emplacement of the mineralizing fluids. Still, granite outcrops in the area appear to be the focal points of metasomatic introductions and mineralization (Chakravarty, 1955).

The ore veins, as also the country rocks, have been subjected to deformative stress during the consolidation of the veins. This is indicated by bent cleavages in wolfram, twisted tourmaline needles and deformation lamellae in quartz. This effect may be correlated with the development of new S-planes and puckers in country rocks and widespread retrogression. On the whole, however, crystallization has outlasted deformation in these veins.

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2


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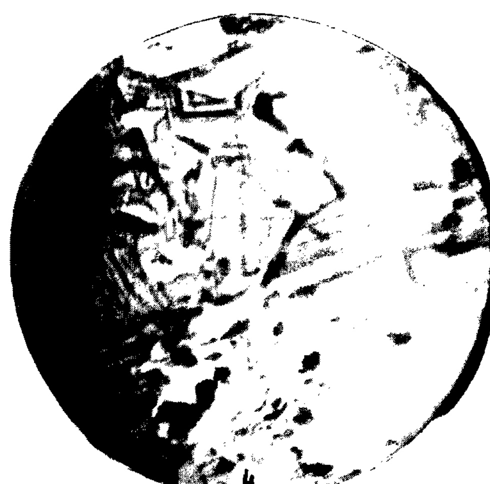
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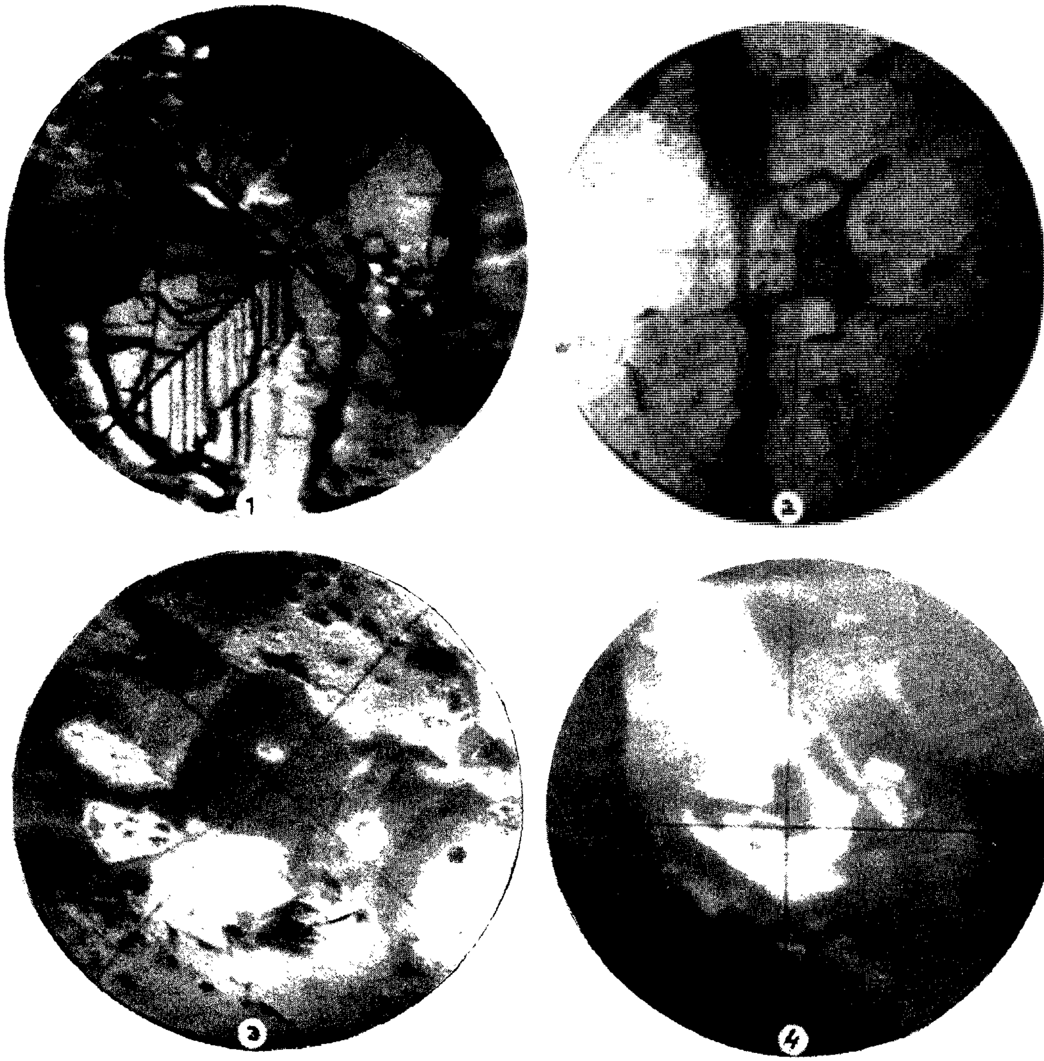
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Plate XVI

FIG. 1. Photomicrograph of a thin section of Chhendapathar granite showing quartz, plagioclase and epidote. (×30.)

FIG. 2. Wall rock of the ore veins containing muscovite and profuse prisms and needles of tourmaline in a base of greenish white mica. (Thin section ×30.)

FIG. 3. Wolfram (black) veined and replaced by scheelite. (Thin section ×30.)

FIG. 4. Zonal structure in scheelite (grey) developed after etching with HF. Wolfram (white) is not affected. (Polished section ×80.)

FIG. 5. Goethite (showing beautiful wavy bands) occur along the border of haematite (beneath the band) and replaces wolfram (white). (Polished section ×80.)

FIG. 6. Ilmenite forms vein in wolfram. Secondary haematite has developed along cleavages, cracks and grain boundary of ilmenite. (Polished section ×80.)

Plate XVII

FIG. 1. Molybdenite is embedded in arsenopyrite and exhibits parallel displacement along (0001). (Polished section ×320.)

FIG. 2. Scheelite (dark grey) invading molybdenite (flaky, light grey), the base is wolfram. (Polished section ×160.)

FIG. 3. Scheelite (grey) showing parallel bright-white internal reflection is embedded in wolfram. A fine rim of molybdenite occurs as an interspace between wolfram and molybdenite. (Polished section ×320.)

FIG. 4. Bismuthinite embedded in quartz. Very highly reflecting spots may be droplets of native bismuth in bismuthinite. (Polished section ×650.)

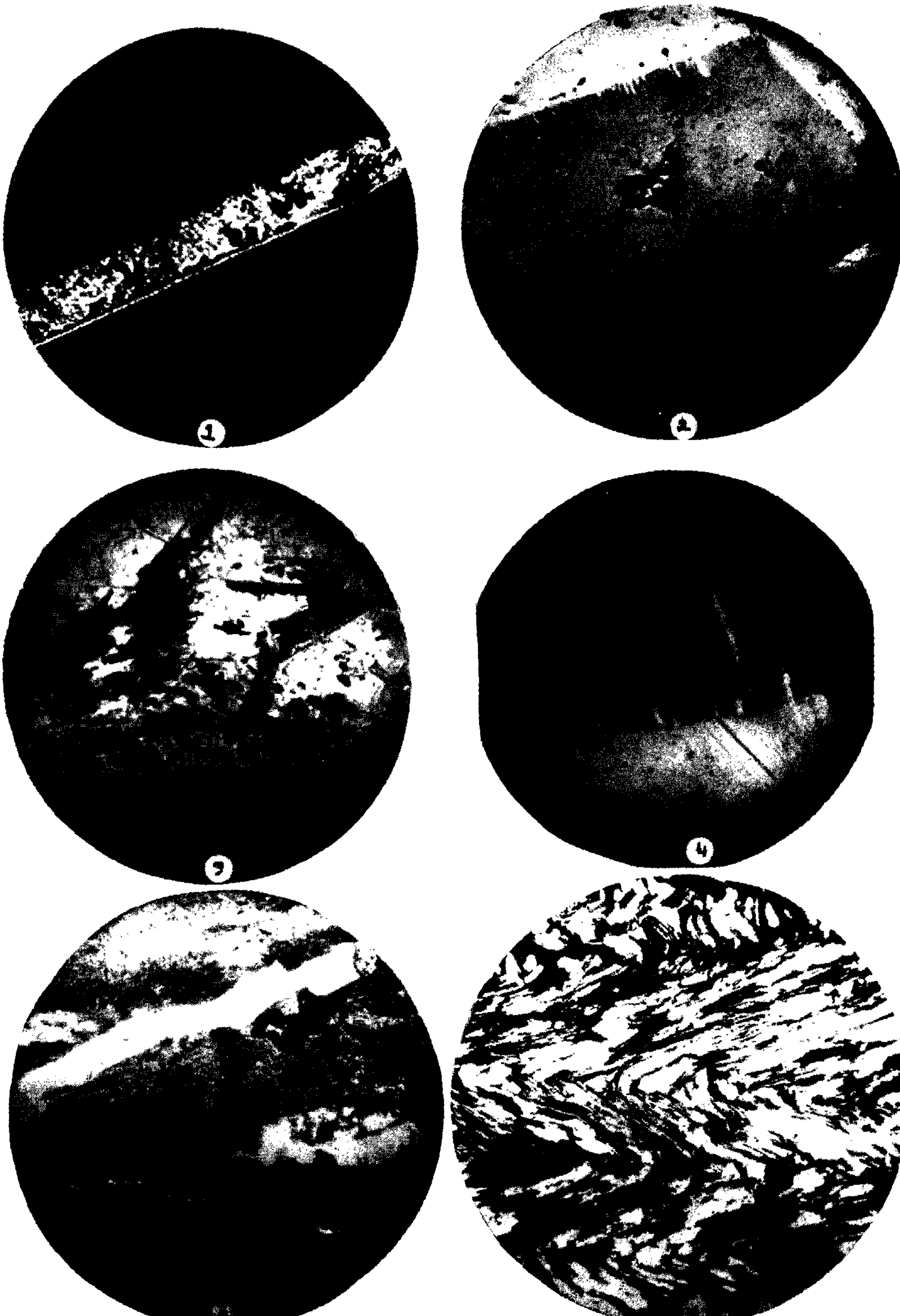

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Plate XVIII

FIG. 1. Pseudographic texture due to partial replacement of pyrrhotite (black due to etching with KOH) by arsenopyrite (bright white). The sulphide band and scheelite (black) follow the cleavage in wolfram. (Polished section ×320.)

FIG. 2. Wolfram sends parallel tongues in interstitial scheelite. (Polished section ×320.)

FIG. 3. Bent needles of tourmaline in the tungsten mineral bearing quartz vein. (Thin section ×60.)

FIG. 4. Wolfram sending pencil-like projection in scheelite. (Polished section ×320.)

FIG. 5. Folded sericite aggregate in the schists which is pseudomorphous after some aluminous mineral. (Thin section ×64.)

FIG. 6. Acutely folded quartz-muscovite schist. (Thin section ×64.)