THE NABABEEP NEAR WEST TUNGSTEN MINE, SOUTH AFRICA

P. G. SÖHNGE, *O'okiep Copper Company, Ltd., Nababeep, South Africa*

ABSTRACT

A number of ferberite-wolframite deposits in the Namaqualand copper district are restricted to several bands of sedimentary schist separated by paragneiss. These Archaean formations are intruded by Pre-Cambrian granite which was the source of the tungsten-bearing solutions. This paper deals briefly with the main features that influenced mineralization in the Nababeep Near West mine and with the mineralogy of the ore.

INTRODUCTION

Nababeep is situated about 300 miles north of Cape Town in the well dissected escarpment belt of Little Namaqualand separating the interior plateau from the Atlantic coastal plain. The copper deposits of this district have been mined since 1850 and with the discovery of the spectacular alluvial diamond deposits at Alexander Bay in 1927 attention was drawn to the rarer minerals, e.g., beryl, scheelite, tantalite, euxenite, bismuth, spodumene, in the pegmatite area 50 miles north of Nababeep. The revival of the tungsten market in 1933 gave further impetus to the search for scheelite which was subsequently found in numerous small vein deposits in metamorphosed basic eruptives along the Orange river over a distance of 200 miles.

Wolframite was discovered at Narrap in the copper district in 1938; the first successful mine was developed at Klein Kliphoog in 1941. In the same year six other mines started production, the largest of which was the Near West mine at Nababeep. At the end of World War II five had closed down while the Klein Kliphoog and Nababeep Near West mines suspended operations in 1949. The total production of the seven mines amounted to approximately 1,800 tons of concentrates, of which the Near West contributed 885 by treating 77,000 tons of ore averaging 0.92 per cent WO_3. No previous literature on these deposits has been published.

GENERAL GEOLOGY

The rocks of the copper district comprise a conformable succession of gneisses, granulites, quartzites and schists, correlated with the Archaean Kaaien series, intruded by granite of early Pre-Cambrian age. The Archaean formations are highly metamorphosed sedimentary beds largely transformed into rocks of granitic appearance, but retaining a more or less clear banding that represents the original stratification. Between Springbok and Nababeep the metasediments are folded into a major closed anticline whose limbs dip about 30° north and south while the two ends plunge down at about 10°. A minor elliptical dome appears immediately north of O'okiep. From Rooipoort to Steyerkraal in the north stretches a regional syncline with moderately inclined south limb and nearly vertical north limb. To the west these formations are capped unconformably by the early Cambrian Nama quartzite and shale. The subdivisions of the Kaaien series as established in the copper district are shown on the accompanying sketch map (Fig. 1).

Porphyritic Rietberg granite intrudes the gneisses and metasediments in the form of sills, dykes and irregular stocks regarded as offshoots from a buried batholith that caused the regional granitization of the ancient formations. Although the contact between granite and country rock is commonly sharp the latter is distorted only locally in minor degree; it is inferred that intrusion did not take place with strong directed force, but that the granite magma was largely generated by melting in situ accompanied by metasomatic transformation of the bedded formations. This mode of origin accounts for the development of transitional rock types that resemble granite but may have just escaped melting. Subsequently irregular noritoid dykes were injected into the metamorphic terrain and with these are associated all the important copper deposits. Oblique and transverse faults striking N.W., N. and N.E. are present in great numbers; their bearing on tungsten mineralization is locally important.

The Ore-Bearing Formations

All the more important tungsten deposits are located in the Wolfram schist, a marker stage about 400 feet thick, which separates the underlying Nababeep gneiss from the Concordia gneiss above. The lower part of this stage consists of varied granulites, siliceous hornfels, and gneiss; the upper 200 feet in the Nababeep area is dominantly banded sillimanite-quartz-biotite-garnet schist alternating with sills of leuco-granite, either intrusive or of metasomatic origin. In the Near West mine are a few lenticular interbeds of dark augite-amphibole schist containing variable amounts of quartz, labradorite-bytownite, biotite and garnet. While the larger part of the Wolfram stage appears to be highly metamorphosed shale the sillimanite-rich layers probably originated from kaolinic clay and the augite-amphibole schist from dolomitic marl. East of Nababeep the Wolfram stage is progressively changed to granulite, gneiss, and granitic rock so that only a few bands of schist, each a few feet thick are preserved at Klein Kliphoog and Concordia. South of the Springbok anticline the schist is very largely metamorphosed to quartz-feldspar granulite and only a few thin beds have been found at the Tweedam mine and in the Carolusberg area. In the east between these two belts

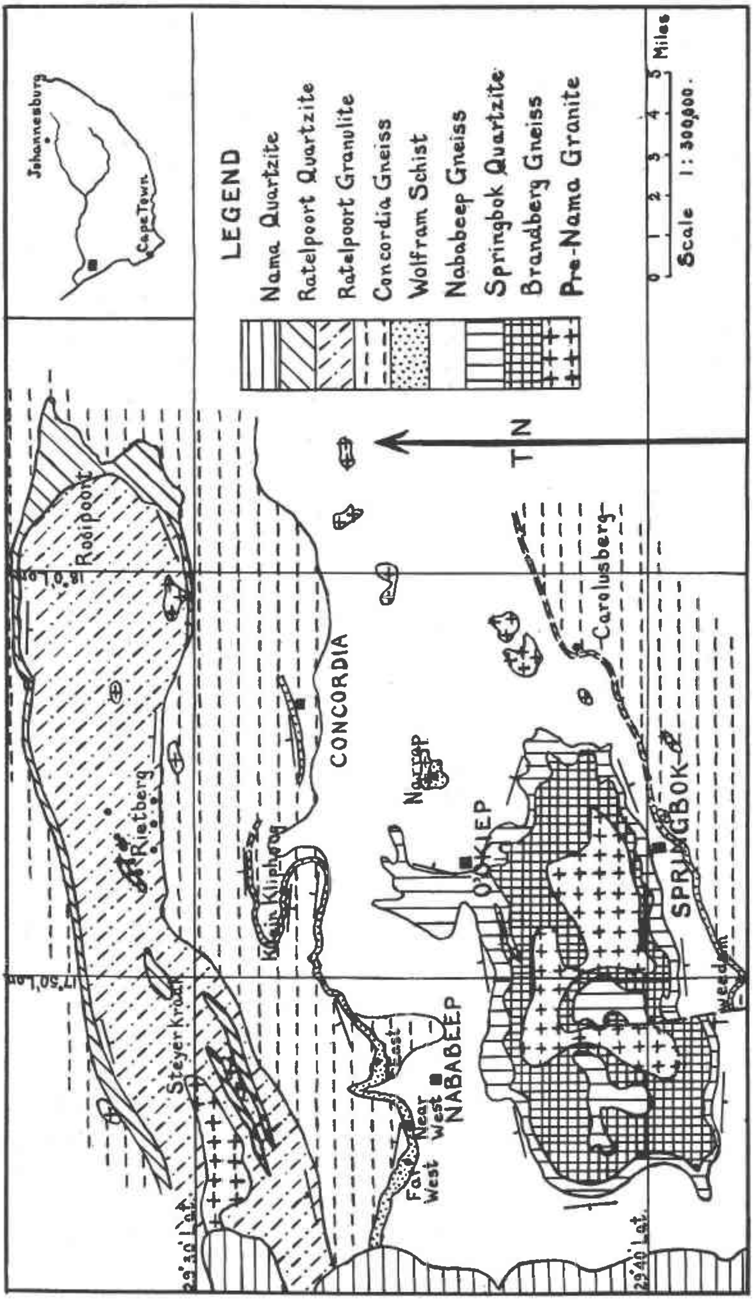

FIG. 1. Generalized plan showing regional geology and location of tungsten mines in the Namaqualand copper district.

of mineralization is the Narrap mine in a faulted outlier of the schist which here forms a band about 50 feet thick. There is no clear relation between the degree of metamorphism of the Wolfram stage and the proximity of intrusive granite, but the change is more complete where quartz-feldspar gneiss (Concordia type) appears concordantly within and below the schist. It is suggested that local fusion occurred at this horizon whence granite magma was injected over short distances and concurrent transformation of schist to metamorphic granite and granulite was intensified.

About 2,000 feet stratigraphically above the Wolfram stage are the Ratelpoort beds, now consisting mainly of red and gray granulite with occasional interbeds of gneiss, biotite-sillimanite schist and metaquartzite in which are located many wolfram prospects, only one of which—the Rietberg mine—produced a notable tonnage of concentrates.

And, lastly, two small showings of tungsten ore are found in the upper schist and quartzite of the Springbok stage, some 1,500 feet below the Wolfram schist. One of these yielded scheelite as well as wolframite.

Structure

The strike of the Wolfram schist swings from N 70° E at the east end of the mine through E-W, to N 70° W at the west end, the northward dip changing from 40° near the surface, through an average of 20° in the main section, to about 10° on the lower levels. The ore body, essentially conformable to the bedding of the host, lies therefore in a gentle synclinal cross-structure plunging to the north. East of the mine the schist swings sharply south due in part to drag along a major shear fault trending north while a group of anorthosite intrusions practically obliterate the Wolfram stage to the south; Concordia gneiss appears to have become mobilized here, replacing some of the schist. These disturbances have created a tight anticlinal cross-structure along which mineralization is interrupted, but farther east, where a second gentle cross-syncline is developed, payable reefs reappear.

Superimposed on the major synclinal structure in the mine are many minor rumples with a width of a few tens of feet and amplitude of 1–3 feet. While those in the upper part of the mine have probably developed by differential slip along the bedding during regional folding, some of the rumples in the deeper section are clearly associated with an oblique shear fault. Individual rumples generally die out within a distance of about 100 feet. Still smaller folds have been caused by injection of the vein quartz forming pods of ore.

There are only three major fractures in the mine. The first strikes N 40° W, dips steeply SW, and is exposed along the inclined shaft; pegmatitic granite forms an irregular dyke-sill intrusion in the distorted zone. The second shear fault, also containing pegmatitic granite, strikes N 45° E, dips nearly vertically and reaches from 9 level half-way up to 8 level before changing into a sharp fold that fades westward into a group

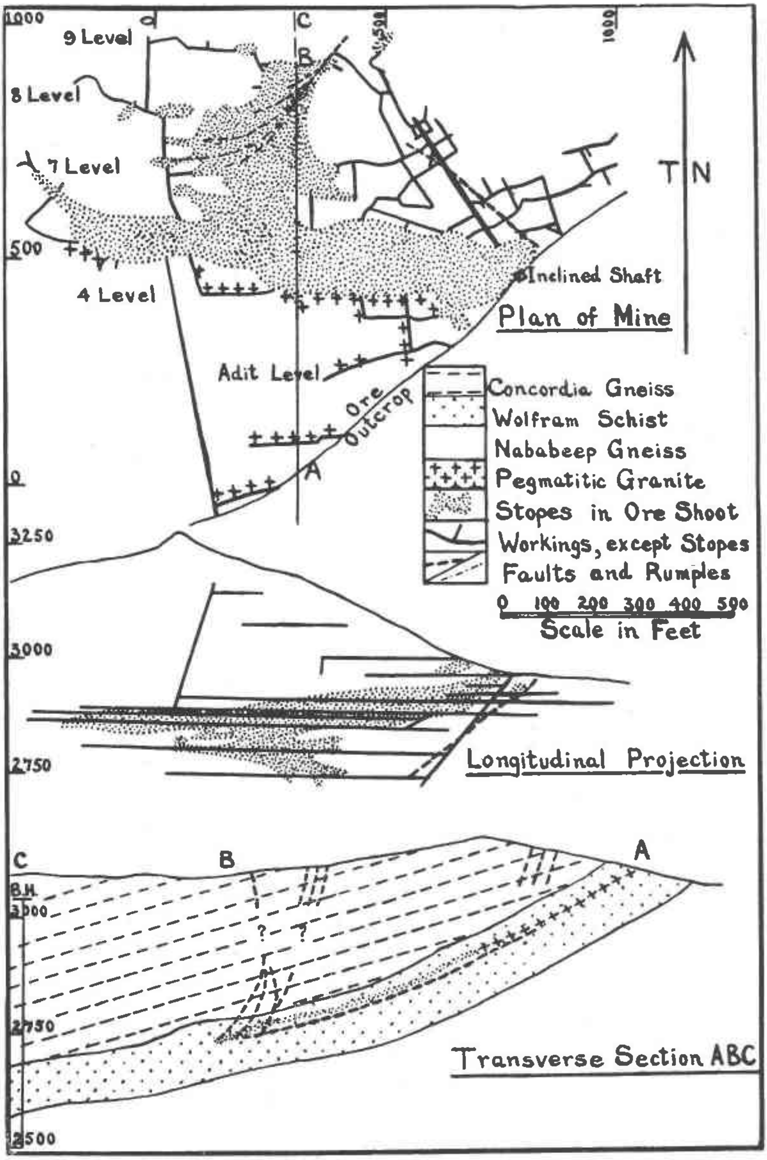

FIG. 2. Plan and sections of the Nababeep Near West tungsten mine.

of rumples; a gentle anticline also diverges from the fault on the south side. The third important fracture is a bedding thrust exposed throughout the mine about 5–20 feet below the ore zone. The schist has been ground up by the movement and is replaced by quartz and pyrite over a width up to 12 inches. Minor fractures striking due north and filled with quartz are most prominent below 7 level.

The Ore Shoot

In plan the ore body has a mushroom shape, the deeper part representing the stem and the upper part the curved top. Its length measures 1,000 feet, average breadth down dip 150 feet, with the stem portion extending down an additional 350 feet. The reef zone consists of a series of quartz veins parallel to the bedding through a stratigraphic distance of 10–20 feet in the upper half of the main band of schist. Individual veins swell out from an average width of 1½ feet to as much as 5 feet. The stoping width ranges from 3 feet to 12 feet.

By drawing contour plans of variations in dip and total thickness of minable reefs the following relations have been established:—(*a*) The richest and thickest reefs were localized in the upper east wing where dips are considerably steeper than the average and where irregular minor folding is evident. (*b*) In the central and western sections of the shoot a similar relation holds, though less clearly defined because changes in dip are less abrupt. (*c*) Below 7 level the richer ore is restricted to the medial part of the body as it rapidly narrows toward the distorted zone merging with the shear fault. (*d*) The anticlinal rumples, especially below 7 level, are loci of better grade reef, whereas synclinal rumples are commonly barren. Stoping toward the west was eventually all but confined to such rumples emerging from the shear fault.

Other factors in the localization of ore deserve mention:—(*a*) The degree of silicification of the schist and its conversion into hornfels prior to mineralization determined the extent to which the ore solutions could find their way into the host rock. The western boundary of the shoot is where the soft schist changes laterally to siliceous garnet hornfels which resulted from the formation of numerous sills of quartz-feldspar granite in that area. Similar silicification partly accounts for the lower eastern ore limit which is, however, an economic boundary for the reefs, though poorer, continue toward the shaft. (*b*) The bedding fault prepared the ground above for mineralization. (*c*) The NE shear fault on 9 level appears to have been the focus whence the ore solutions spread out upward along the bedding, guided in part by minor fractures striking north and by the anticlinal rumples already described. (*d*) The upper margin of the payable ore on 4 and 5 levels roughly coincides with the appearance of sericitized quartz-feldspar pegmatite merging with the quartz veins. The pegmatite constitutes low-grade ore.

Rock Alteration

Extensive *silicification* occurred during and after the formation of dykes and sills of pegmatitic granite. The sillimanite of such schist was largely altered to sericite which, with biotite, was progressively replaced by quartz, leaving only shadows of the digested minerals. Early *pyritization* was more restricted, though generally accompanying the silicification; the widespread late pyrite was deposited more by filling than by replacement of the host rock. *Pegmatitic recrystallization* of the schist alongside the quartz veins caused the formation of lenses of coarse-grained sillimanite, biotite and garnet up to 10 feet away from reef. Some of them contain ferberite crystals unaccompanied by quartz. *Sericitization and chloritization* on a moderate scale followed; biotite progressively lost its brown color to become a white to greenish nearly opaque substance, probably a mixture of chlorite, sericite, ilmenite and leucoxene. Pyrophyllite may accompany the sericite replacing sillimanite. Where ore entered along cracks in garnet and sillimanite fine chlorite was locally developed. Microcline was also sericitized.

The Quartz-Ferberite Veins

Form. There is a general change from thick, persistent veins, traceable over several hundred feet along strike, in the upper workings to lenses and pods of quartz separated by barren schist in the lower. The larger veins have structurally regular walls, whereas the schist wrapping around the pods is distorted and progressively replaced by quartz. The vein-forming solutions evidently entered the host rock under great pressure; once entry had been gained replacement of schist proceeded simultaneously from several bedding planes so that the final ore vein was much wider than that formed by the initial injection. The veinlets branching off the larger pods are commonly highly irregular, some showing forms resembling ptygmatic folds; as no crumpling is to be seen in the schist the snake-like vein pattern must have developed by alternate replacement along two or more cleavage planes.

Texture. Most of the quartz veins display ribbon texture, the banding being more or less parallel to the foliation of the schist. Where the latter has been distorted the ribbons show similar folding. Where the schist broke into thicker slabs of less regular shape relics in various stages of conversion into quartz cause a streaky to mottled texture between ribboning and slabby breccia. The veins hold up to 10 per cent garnet, biotite, chlorite and sillimanite, garnet tending to be concentrated along the contact. Segregations of ferberite and the accompanying sulphides commonly show a sub-parallel arrangement, especially near the margins of the veins, while locally individual ferberite crystals display such preferred orientation. The growth of the ore minerals was clearly influenced by the ribbon texture and by parallel cracks formed during metallization. In the upper levels the quartz merges with streaky sericitized pegmatite.

MINERALOGY:

Apatite, associated with pyrite, is an unusual constituent in some veins of fine-grained quartz and was probably derived from the schist in which it is a common accessory.

Bismuth and *bismuthinite* appear along cleavage traces in biotite, sericite, sillimanite and molybdenite and as corroding blebs and veinlets inside pyrite, ferberite, garnet and quartz. Together they constitute about 0.1 per cent of the ore.

Calcite is a rare associate of pyrite and chlorite.

Chalcopyrite in minor amount was deposited with early disseminated pyrite and again with the comparatively late bismuth minerals.

Chlorite with very low birefringence developed as a widespread alteration product during the replacement of schist by quartz and in microscopic amounts during metallization.

Ferberite forms tabular crystals, up to 2 inches in length, typically clustered in lenses parallel to the walls of the reef. Under the microscope ferberite may be seen as dust-size particles replacing sillimanite and biotite or as coarser grains intergrown with garnet and quartz. The mineral has $FeWO_4:MnWO_4=91:9$.

Fluorite is a rare constituent accompanying late scheelite.

Garnet grains form deep red aggregates up to 2 inches in diameter in the reefs. The average refractive index (1.793) and specific gravity (4.02) show little variation between garnet in the schist and that in the reef and roughly indicate a composition of almandine$_{60}$ pyrope$_{30}$ grossularite$_{10}$.

Jacobsite (?) or magnetite forms a grating in many ferberite crystals, especially near cracks, and also little blebs and veinlets distributed at random. Due to its very fine grain the mineral could not be identified with certainty. It may be a product of exsolution or of oxidation.

Microcline in curved crystals is largely sericitized in the pegmatitic reef of the upper levels.

Molybdenite, generally concentrated in streaks along the reef contact, forms corroded relics in ferberite and pyrite. Replacement of biotite is indicated by a semi-opaque fringe of molybdenite dust separating the solid crystals from the gangue.

Pyrite developed as an early fine-grained dissemination during wall rock silicification and crystallized again after deposition of ferberite and molybdenite to which it is adapted. Finally some pyrite filled numerous minute cracks in the reefs, developing euhedral forms where cavities existed. Such pyrite in the bedding fault suggests that this channel was open to the end of mineralization.

Quartz, the dominant gangue mineral, ranges from fine in partly replaced schist to very coarse and vitreous in the wider reefs, the color shading from bluish gray to grayish white. The interlocking grains have sutured boundaries and commonly show undulatory extinction, locally accompanied by clearer granulation. Late euhedral quartz is found in little vugs in the bedding fault.

Scheelite is sporadically present in small amount, fringing ferberite crystals and in occasional vugs where it is accompanied by fluorite. The augite-hornblende schist contains layers of scattered, tiny scheelite grains.

Sericite as tiny nests and veinlets in quartz and garnet is probably derived from the alteration of biotite and sillimanite. Partial chemical analysis by A. Knoetze established the presence of sufficient potash and soda to verify its identity, but some pyrophyllite may be mixed with it.

Sillimanite relics are found in the vein quartz in accessory amount, but the white prisms are most conspicuous in the pegmatized wall rock.

Sphalerite is contained in chalcopyrite as minute specks.

Zircon is an accessory doubtlessly inherited from the replaced schist.

The simplified paragenetic sequence is:

Pegmatitic Stage: Zircon and apatite (inherited), sillimanite, garnet, microcline, quartz.

Hydrothermal Stage:

(*a*) Quartz, sericite, chlorite, calcite, pyrite.

(*b*) Quartz, molybdenite, ferberite, scheelite (?), pyrite, bismuthinite, bismuth, chalcopyrite, sphalerite, scheelite-fluorite, jacobsite (?).

At the surface the ore zone has undergone moderate leaching and oxidation. *Bismutite* forms a greenish yellow impregnation particularly in sericitized pegmatite. Chalcopyrite has changed to sooty *chalcocite* and *covellite* besides causing green copper staining. Pyrite is oxidized to dark brown transported *limonite,* while ferberite shows all stages of alteration to reddish brown limonite with cellular boxwork. Sericitized microcline is largely changed to kaolinite.

Ore Genesis

The regional setting of the tungsten mines of the Namaqualand copper district in several belts of schist and granulite separated by unmineralized paragneiss proves that the ore solutions entered and moved within the schist with far greater facility than in the gneisses. Where the upper part of the Wolfram stage is mainly schist the vein deposits are of the hypothermal type (e.g., Nababeep Far West and Near West, Narrap), but where the host rocks were thoroughly metamorphosed to granulite alternating with Concordia gneiss the veins are pegmatitic, ranging from pure quartz to pure microcline (Nababeep East, Klein Kliphoog, Rietberg, Tweedam). The type of ore was therefore conditioned by the grade of metamorphism, including granitization, which can only mean that the ore solutions were brought into circulation by the buried granite batholith that caused the widespread granitization and is indicated by the smaller intrusions exposed at the present surface. Analysis of the detailed structure in the Nababeep Near West mine shows how pre-existing folds and fractures have guided the ascending vein-forming fluid and localized the formation of ore shoots.