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HYDROTHERMAL TIN-TUNGSTEN MINERALIZATION IN THE BRANDBERG WEST-GOANTAGAB AREA OF THE DAMARA OROGEN, SOUTH WEST AFRICA/NAMIBIA

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1. INTRODUCTION

This report is a slightly modified version of a paper presented at "Geocongress '86" (Pirajno and Jacob, 1986). More detailed discussions of metallogeny and mineralization are presented elsewhere (Pirajno and Jacob, in press.; Pirajno *et al.*, in press).

The evolution of the Pan-African Damara Orogen reflects the dynamics of a triple junction which probably included episodes of opening and closing of a proto-South Atlantic Ocean, and possibly of a narrow oceanic arm within the intracontinental branch. These processes resulted in sedimentation, deformation, metamorphism and magmatism (Miller, 1983). At a much later stage, during the Jurassic and Cretaceous periods, anorogenic within-plate magmatism occurred in response to the re-opening of the South Atlantic during the break-up of Gondwana. Products of this activity include lavas of the Karoo Sequence, and a number of ring-type alkali complexes, whose north-east alignments along the structural grain of the intracontinental branch may be related to transform directions (Marsh, 1973).

The Damara Orogen contains numerous Sn, Sn-W and W deposits, which can-be grouped geographically into 3 major clusters or "belts" (Pirajno, 1986; Pirajno and Jacob, in press). The northernmost of these is in the Brandberg West-Goantagab area, which is located in the northern coastal arm, within the Southern Kaoko Zone of Miller's (1983) tectono-stratigraphic subdivisions of the orogen. This area occupies the lower Ugab River region, north-west of the Brandberg alkaline granite intrusion, and extends in an east-north-east direction for some 80 km (Fig. 1). The lithologies consist of N-trending, folded turbidite-facies metasediments (metagreywacke and metapelite) and thin marble bands which may be correlated with formations of the Swakop Group (Miller, 1983).

2. MINERALIZATION

The mineralization is characterised by a number of Sn-W and Sn (+ minor Ag and base metals) hydrothermal deposits in quartz-vein systems and Fe-rich, replacement bodies, all of which post-date Damara-age fabrics in the host rocks. Several of the deposits are spatially associated with circular structures identifiable on LANDSAT imagery. Sn and Sn-Ta-bearing pegmatites also occur in the area (Fig. 1), but are not considered in this paper.

The simplified geology in the Brandberg West-Goantagab area, and the distribution of the deposits and circular structures are shown in Fig. 1. This report is based on studies conducted on four key deposits (Brandberg West, Frans, Gamigab and Goantagab), whose principal characteristics are described below.

2.1 Brandberg West

The non-operational Brandberg West open-pit mine and surrounding mineralized areas are located near the intersection of two ring structures and a NNW-trending fracture (Pirajno *et al.*, in press) (Fig. 2). Sn-W and base-metal sulphide mineralization (mainly chalcopyrite and pyrite) is predominantly hosted in quartz veins, forming a sheeted and anastomosing system, extending for about 4 km in a north-east direction. The vein system is emplaced in hornfelsed quartz-biotite schist and quartzite of the Zebraputz Formation and schists of the Brak River Formation. In the mine area many of the veins dissipate against the marble unit of the Brandberg West Formation, which they penetrate locally. The quartz veins have variable strikes, lengths and thicknesses, and they can be grouped into 5 sets. One set may be of Damara age (quartz + tourmaline), whereas the other four sets are post- tectonic (Petzel, 1986). Only the post-tectonic vein sets are mineralized.

Hydrothermal alteration-mineralization is varied and complex and appears to be related to at least 3 pulses of orebearing fluids. An early greisen stage produced quartz + muscovite ± cassiterite ± wolframite. This stage was followed by deposition of quartz + sericite + fluorite ± cassiterite. The final hydrothermal stage resulted in the crystallization of hematite ± cassiterite ± sulphides ± graphite.

The greisen stage of wall-rock alteration was fracture-controlled and produced quartz-muscovite-tourmaline assemblages in the schists. This alteration generally is developed close to the vein margin and is seen throughout the pit. The quartz-sericite alteration, which followed the greisen stage, is best developed in the northern part of the pit and the eastern part. The final pulses of hydrothermal activity are represented by carbonate veinlets.

An important feature at Brandberg West is the presence of a quartz-albitite plug which intruded the Zebraputz Formation schist post-tectonically about 2 km north-west of the pit locality. The albitite consists of a felted mass of albite with anhedral quartz grains, and

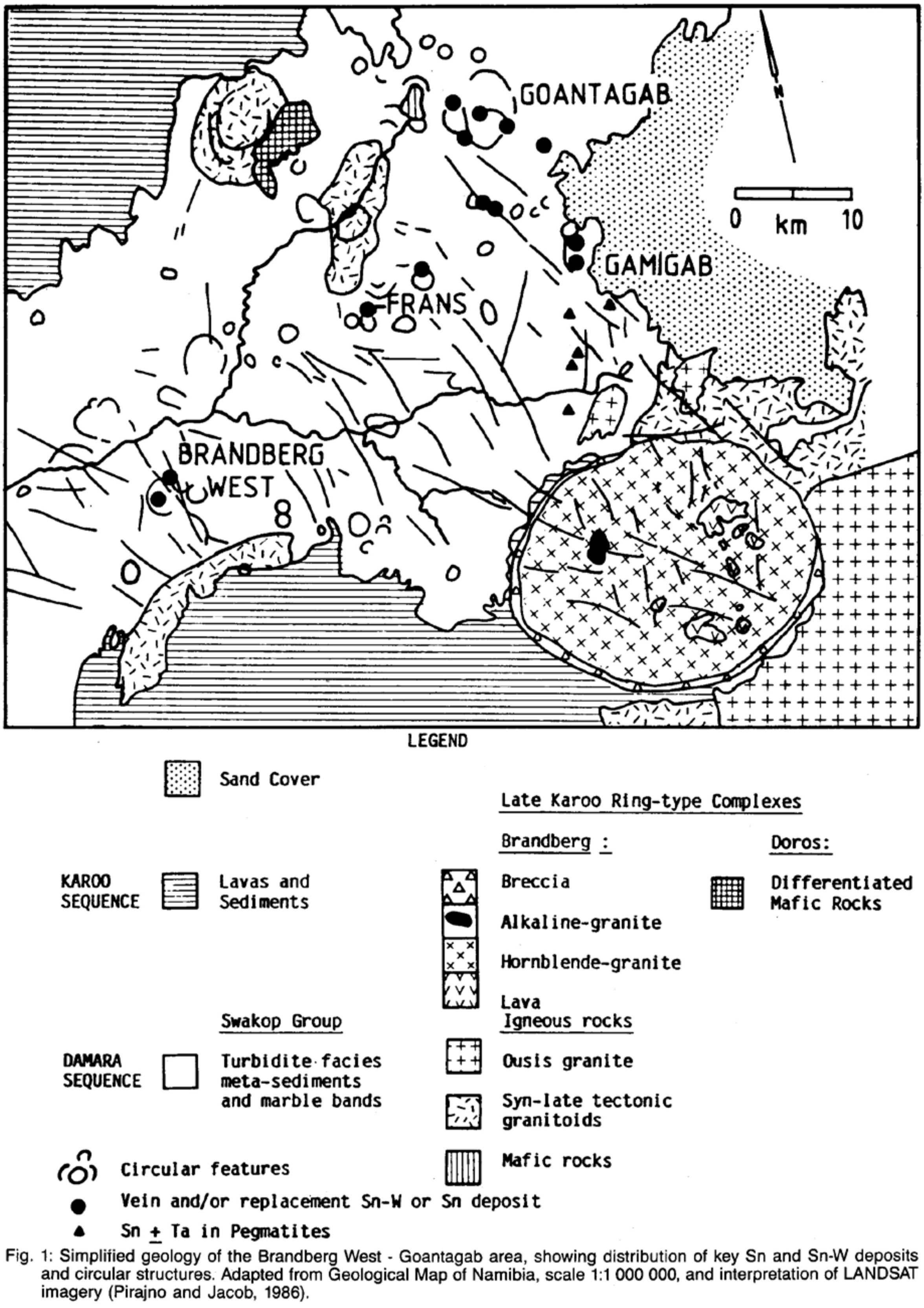

Fig. 1: Simplified geology of the Brandberg West - Goantagab area, showing distribution of key Sn and Sn-W deposits and circular structures. Adapted from Geological Map of Namibia, scale 1:1 000 000, and interpretation of LANDSAT imagery (Pirajno and Jacob, 1986).

has abundant carbonate-filled miarolitic cavities suggesting high CO_2 activity.

2.2 Frans Prospect

This prospect is situated within a small ring structure on the eastern limb of a tight isoclinal fold. Mineralization occurs in quartz veins emplaced mainly in biotite schist. There are 3 major veins sets trending north, north-north-east and north-east. These form a zone about 3 km long. The veins are intensely fractured and contain cassiterite, wolframite, pyrite and chalcopyrite. Wall-rock alteration is much less both in extent and intensity than at Brandberg West. Tourmalinization, hematitization and sericitization accompany the mineralization from the vein margins outward. Marbles in the area exhibit ferruginization (hematite and siderite) in proximity to the mineralized veins.

2.3 Gamigab

At Gamigab, cassiterite mineralization is hosted in an E-trending quartz-vein system emplaced into quartz-biotite schists and spatially associated with ferruginized and brecciated marbles. Hydrothermal alteration of the schist wall rocks has produced tourmaline, hematite, graphite and late, cross-cutting carbonate veinlets. The vein material is fractured and infilled with cassiterite and hematite. Sulphides are present in minor amounts.

The schists are overlain by marbles, which are intruded to a certain extent by quartz veins. Important features of the marble are locally intense brecciation and hydrothermal alteration. Small replacement bodies of quartz-hematite are associated with the breccias. The breccia zones are locally extensively ferruginized and they are surrounded by haloes of ferruginized, non-brecciated marble.

Small outcrops of amygdaloidal lava and a volcanic breccia plug, of probable Karoo age, occur along a northerly trend about 500 m north-east of the main prospect trenches. The breccia contains carbonate material indicating a high CO_2 content of the original magma. The country rock marbles exhibit intense ferruginization at this locality.

The relationship of the mineralization to brecciation, hydrothermal alteration, structure and igneous activity are being investigated by Walraven (MSc., in prep.).

2.4 Goantagab

The area at Goantagab is underlain by metasediments of the Ugab and Khomas Subgroups. The main host rocks of Sn mineralization here are correlates of the Karibib Formation, which comprises a lower marble

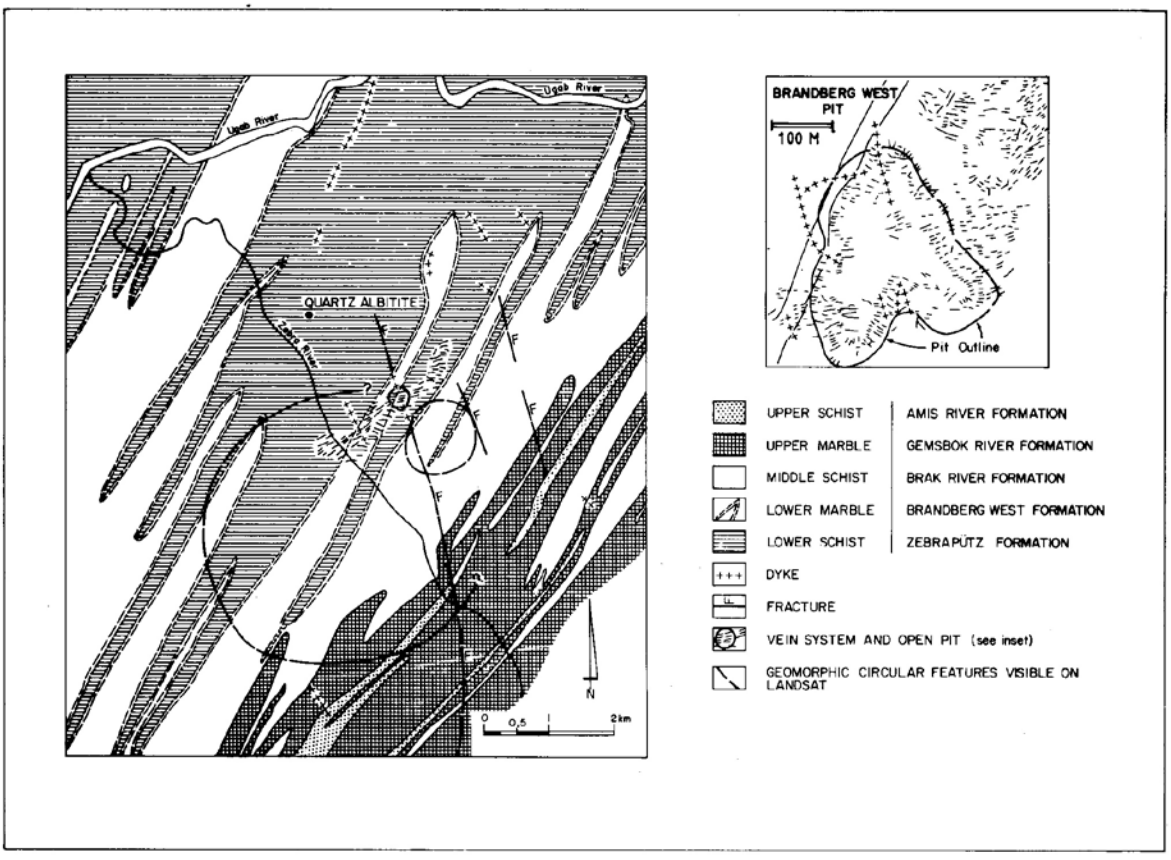

Fig. 2: Geology of the area around Brandberg West, showing trends of vein system (from Petzel, 1986 and Jeppe, 1952). Stratigraphic nomenclature is from Jeppe (1952) on the left, and from Miller *et al.* (1983) on the right.

unit, a schist unit and an upper marble unit (Fig. 3). The rocks exhibit a regional north-north-east strike, but at Goantagab they are folded into a number of upright, open antiforms and tight synforms. At least 3 episodes of deformation have been recognised in the rocks (Petzel, 1986). The F_2 episode is responsible for the fold pattern and for the transposition of bedding into the NNW-trending axial-plane foliation. Regional metamophism of low- to medium grade has affected the rocks, which are mainly biotite-sericite schists and tremolite marbles. The schists contain post-tectonic porphyroblasts of biotite which may be related to the hydrothermal mineralizing event.

The hydrothermal mineralization occurs in the form of quartz veins in the mica schists and as replacement bodies in the marbles. The quartz veins appear to have been feeders of the overlying replacement bodies.

The numerous quartz veins in the schists here constitute two main systems. One system of essentially barren veins trends approximately east-north-east and the other, which is mineralized, trends north-north-east. In some places the mineralized veins are grouped to form lode deposits. The schists have been brecciated locally by hydraulic fracturing. The lower marble unit contains a single set of N-trending quartz veins along which some mineralization is developed. Transposition structures have exerted a control over this set. The quartz veins consist mainly of more than one generation of quartz, as indicated by the brecciation of early quartz and sealing of fractures by a later influx of silica. Commonly the veins also contain tourmaline, sericite, chlorite, calcite, sulphides (pyrite, pyrrhotite, sphalerite and galena) and cassiterite. The lodes exhibit a certain degree of mineral zoning in that pyrite is more abundant in the upper levels near the schist-marble contact whereas pyrrhotite becomes more abundant at depth.

The wallrocks of the veins have been intensely altered during the hydrothermal activity and a mineral zonation is present in the alteration halo. The main types of alteration include tourmalinization and silicification close to the veins followed outwards by sericitization. Pyrite ± pyrrhotite commonly occurs with the sericite and graphite is present in the tourmaline zone. Carbonatization resulted in the formation of veins and megacrysts of carbonate. This alteration, together with chloritization and ferruginization, is a late process and overprints the earlier tourmalinization. Carbonate veining cuts the mineralized quartz veins. In common with the other localities, the width of the alteration zones is not always related to vein width.

The marble units of the Karibib Formation are hosts to replacement bodies of Sn mineralization. These bodies are preferentially located along the contact between the schists and overlying marbles. However, they also extend into the marble and occupy zones of weakness created by the partial transposition of the rocks into the NNW-trending F_2 axial-plane foliation. The replacement bodies are located preferentially in zones of brecciation that have formed both along the lithological contacts and the transposition zones. The breccia fragments of marble show varying degrees of replacement.

The deposits consist of bodies of mainly hematite and hydrated Fe-oxides together with smaller amounts of carbonate and quartz. Cassiterite is disseminated through the bodies but its distribution is irregular. It is associated with carbonate and, locally, with chlorite and fine tourmaline. In places the hematite-rich bodies are associated with Si-Fe rich replacement veins and the cassiterite occurs as discrete grains within these as well as in the hematite bodies. A zonation is evident in places, from massive quartz-poor hematite + carbonate + cassiterite in the centre, to more quartz-rich zones, to peripheral ferruginized marbles.

The marbles have played an important role in the formation of the replacement bodies. On the one hand they have provided a physical trap for the hydrothermal solutions that passed through the underlying schist. The contact is more highly fractured than elsewhere and permitted the accumulation of fluids. On the other hand the marbles were more reactive than the schists and replacement occurred preferentially within this unit. The common calcite veining, and brecciation of the quartz veins and replacement bodies, is indicative of CO_2 degassing from a source at depth, as yet uncertain.

3. CONCLUSIONS

The investigations to date indicate that multiple hydrothermal systems were active in the area. The nature of the mineralization suggests that the systems were linked to underlying igneous intrusions, whose emplacement and attendant volatile degassing may have led to the development of circular structures, vein deposits and breccias.

Differences in the geological features of individual deposits are attributed to different levels of exposure of the hydrothermal systems with respect to the underlying intrusions. These features indicate that the Brandberg West mineralization was formed relatively close to its parent source. The Frans, Gamigab and Goantagab deposits were formed at relatively greater distances from their respective parent intrusions.

On the basis of the post-tectonic character of the mineralization, the hydrothermal alteration of a dyke at Brandberg West and the spatial association with igneous rocks of probable Karoo age, we suggest that the mineralization may be related to Karoo/post-Karoo magmatic activity.

4. ACKNOWLEDGEMENTS

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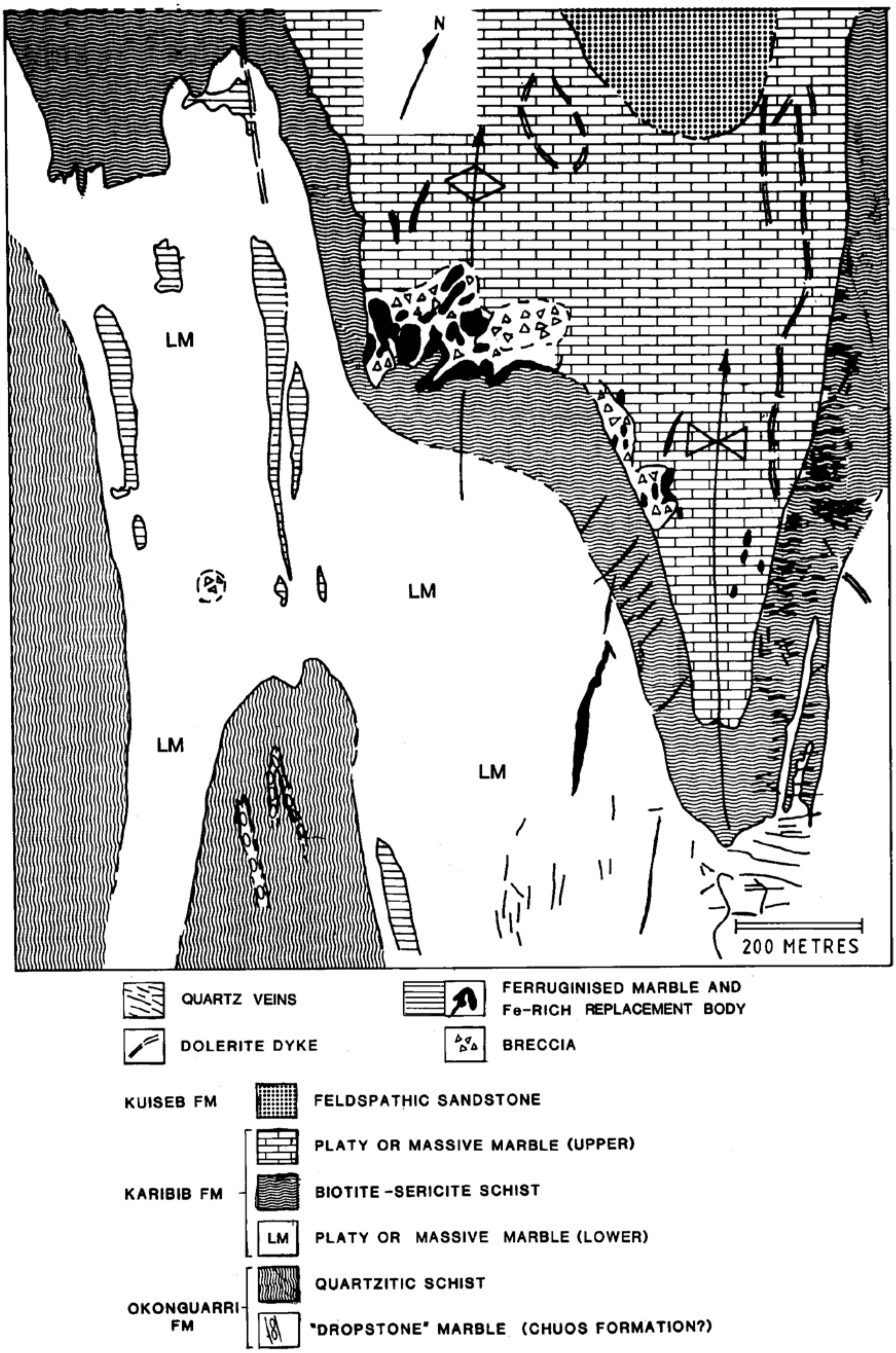

Fig. 3: Simplified geology and distribution of vein and replacement-type Sn deposits at Goantagab.

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