

MICROLITES AND ASSOCIATED OXIDE MINERALS FROM NAIPA PEGMATITES – ALTO LIGONHA – ZAM- BEZIA - MOZAMBIQUE

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Keywords: Alto Ligonha pegmatite district, LCT- pegmatite, U-Pb-Ba-Bi-Sb-microlite

Naipa granitic pegmatites of LCT type, located in Alto Ligonha Pegmatite District, Monapo-Mocuba belt, Zambezia Pegmatite Province (Mozambique), are mined for tantalum and gemstones (topaz, OH-herderite; tourmaline and beryl). They are structurally complex, concentrically zoned, intruding chlorite and amphibole phyllites and gneisses. Internal units include wall zone (Mn-almandine line-rock), several intermediate zones (K feldspar, albite, muscovite, spodumene) and a quartz±lepidolite core

or a nuclear quartz+cleavelandite unit with miarolitic pockets. Pegmatites seem to be genetically related to Pan-African biotite-amphibolic granites (zircon hosted in lepidolite was dated 482 ± 10 MA - U/Pb). In the Northern Sector of Naipa mine, the internal zones are better defined, while in the Southern domain, at least four stages of hydrothermal alteration mask the primary structures in the outer and inner intermediate zones. Two dilatation episodes produced pegmatite veinlets, well expressed in the Southern Sector (Fig.1).

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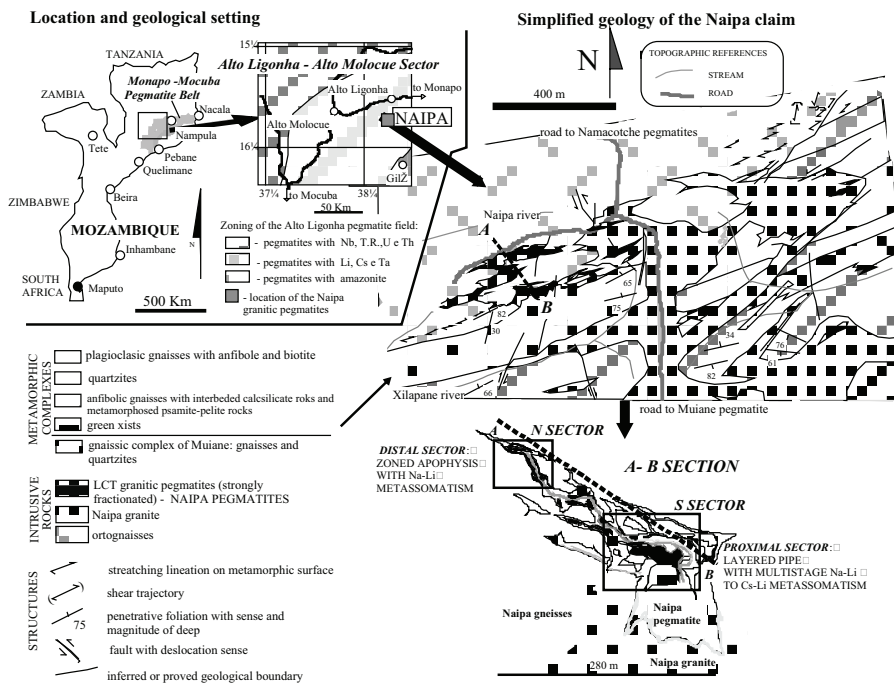


Figure 1 – Geological setting of Naipa pegmatites.

Currently high-Ta microlite concentrates are mined from lepidolite+quartz and cleavelandite comb-structured units of late but primary paragenetic stages. Lower Ta, Mn-columbite-tantalite + microlite are

more regularly obtained from *subsolidus* late units, with layered albite + lepidolite, and replacement phyllosilicates such as cookeite, lepidolite, smectite, halloysite and kaolinite (Fig. 2).



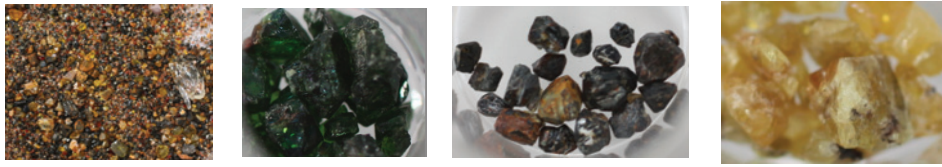


Figure 2 – Some aspects of microlite mining in Naipa claim: A - South Sector (N front) of Naipa pegmatite approximately at the same location referred in the South Profile of fig. 1 – multistage replacement units where the above mentioned “mixed red” and “dark” microlite concentrates are collected; B - Mixed red concentrate (impure), Mn-columbite + Mn-tantalite + microlite (includes Sn-microlite) + cassiterite, $Ta_2O_5 = 22\%-31\%$, S SECTOR, albite+lepidolite replacement with spodumene ± rose beryl; C - Green concentrate, microlite (includes Sb or Bi rich microlite and rarely Sb-tantalite), $Ta_2O_5 > 73\%$, N SECTOR, lepidolite+quartz core unit with cleavelandite ± herderite ± topaz; D - Dark concentrate, yellowish microlite with hydrothermal brown-black U ± Pb phases, $Ta_2O_5 = 33\%-45\%$, S SECTOR, albitised±lepidolitic decomposed units; E - Honey yellow or “dry-grass” concentrate, microlite rich (including some Mn-columbite), $Ta_2O_5 = 40\%-51\%$, S and SW SECTORS, desilicated albite – microcline unit with Cs-beryl ± bertrandite. Scale bar = 2 mm.

Phase discrimination and petrology of microlite from different units and from the main stages of mineralization, was performed by reflected light microscopy and in Scanning Electron Microscope SEM (Fig. 3). Paragenetic relations were refined using atomic number contrast in SEM - back-scattered electron mode (BE) (Fig. 3).

Discriminated crystal domains where analysed by electron microprobe –

Hyperprobe Jeol JXA-8500F, operating at 20Kv and 20nA (detection limits $<0.03\%$ for major oxides) – LNEG equipment, S. Mamede de Infesta, Portugal. Some of the results are shown in table 1.

Calculated contents of atoms per formula unit (apfu) of oxide minerals suggest several levels of organization for the crystal-chemical fractionation trends of Naipa Nb-tantalates. The main patterns are illustrated in figure 4.

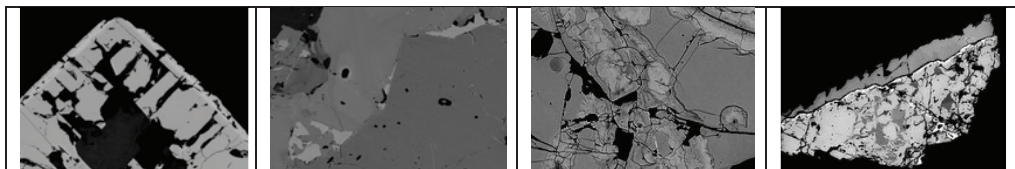


Fig. 3. SEM - back-scattered electron imagery of microlite polished sections. A - Sb – rich overgrowth after high-Ta, Na, F microlite; B - Ti-Sn ixiolite rimmed by cassiterite + Sn-microlite (medium grey) + microlite; C - botryoidal U-microlite of late replacement along fractures, formed after normal microlite; D - Bi-rich microlite rim pre-dating Ba-microlite and post-dating normal microlite with fracture controlled U-Pb microlite of late replacement, along fractures. Scale bar = 0.5mm.

Table 1 – Selected compositions of microlites and associated oxide minerals – obtained by electron microprobe in some large homogeneous domains of idiomorphic crystals from the most representative populations of Naipa Ta concentrates: m. – microlite; tant. – tantalite; col. – columbite; ixiol. – ixiolite.

	Green m.	Creamy white m.	Dark brown m.	Brown m.	Orange m.	Red m.	Sb tant.	Col. tant.	Ixiol.	Mn tant.
Nb ₂ O ₅	2.12	3.70	2.01	3.57	3.71	5.91	3.39	55.99	28.20	2.75
Ta ₂ O ₅	76.41	62.49	64.69	75.02	69.00	65.51	56.71	22.01	40.67	81.91
FeO	0.04	0.12	0.21	0.00	0.03	1.38	0.03	10.51	10.18	0.67
MnO	0.07	0.52	0.34	0.60	0.04	11.16	0.00	9.39	4.80	13.93
MgO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.23	0.00
PbO	0.09	1.87	0.79	0.52	0.00	0.00	0.12	0.00	0.00	0.00
CaO	9.62	0.03	1.83	4.23	13.52	0.18	0.00	0.00	0.00	0.00
BaO	0.00	4.64	0.24	0.20	0.03	0.00	0.00	0.00	0.00	0.00
Na ₂ O	6.80	0.33	0.00	0.28	5.31	0.00	0.00	0.00	0.00	0.00
Cs ₂ O	0.00	0.15	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
SnO ₂	0.06	0.05	0.00	0.11	2.46	16.51	0.43	0.07	3.73	0.00
UO ₂	0.07	8.98	13.01	7.03	0.02	0.00	0.00	0.05	0.03	0.04
TiO ₂	0.07	0.23	0.07	0.03	1.95	0.45	0.04	0.80	5.35	0.07
WO ₃	0.03	0.10	0.00	0.00	0.25	0.00	0.35	0.27	2.70	0.55
Sb ₂ O ₃	0.15	0.13	0.65	0.08	0.00	0.04	38.07	0.01	0.00	0.03
Sc ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	2.21	0.00
Bi ₂ O ₃	1.58	0.00	0.00	0.48	0.01	0.00	0.61	0.00	0.00	0.00
F	4.19	0.19	0.36	1.46	4.06	0.00	0.00	0.00	0.00	0.00
Total	99.54	83.45	84.06	93.16	98.68	101.1	99.73	99.56	98.69	100.88

Fractionation trends in columbite/tantalite - tapiolite quadrilateral (fig. 4A) show a generalized primary evolution of Naipa Nb-Ta oxide minerals to the high Ta domains of microlite compositions, plotted at the upper portion of the diagram.

Mn-tantalite is rare and Sb-tantalite, accidental. During pegmatite fractionation high Ta cationic level, typical of microlite is achieved by diversely departed trends. In fact, Ta apfu contents tend to concentrate at $0.78 < \text{Ta}/(\text{Ta}+\text{Nb}) < 1.0$ interval (fig. 4A), occupying almost all Mn/(Mn+Fe) variability, which reflects the diversity of microlites and to a less extend, the presence of Mn-tantalite and Sb-tantalite containers.

The diversity of microlites is incremented after several cycles of replacement through hydrothermal alteration. Sb partitions between Sb-rich microlite and Sb-tantalite mainly in green microlite primary depositional environments. The same occurs with Bi in Bi-rich microlite and Bi-tantalite. In columbite/tantalite – tapiolite quadrilateral, general primary fractionation of Nb-tantalates (trends 4 in Fig.4A) is distinguishable from late subsolidus evolution and inner crystal-chemical evolutions observed at the level of individual crystal growth. At this level, oscillatory fractionation is persistent, although, when Fe and Mn apfu are still significant in microlite, a trend towards Fe pole is clearly perceptible (trends 2 in Fig. 4A). Oxides, located outside microlite compositions, fractionate to Mn-tantalite terms with parallel tendencies departing from earlier Nb contents, which are typical of each unit individualized inside de pegmatite bodies (trends 1 in Fig. 4A). Late hydrothermal alteration of microlites, in terms of Nb/Ta and Fe/Mn variability, determinates a peculiar arc-like tendency towards the lower Ta contents in U-rich members (trends 3 in Fig. 4A).

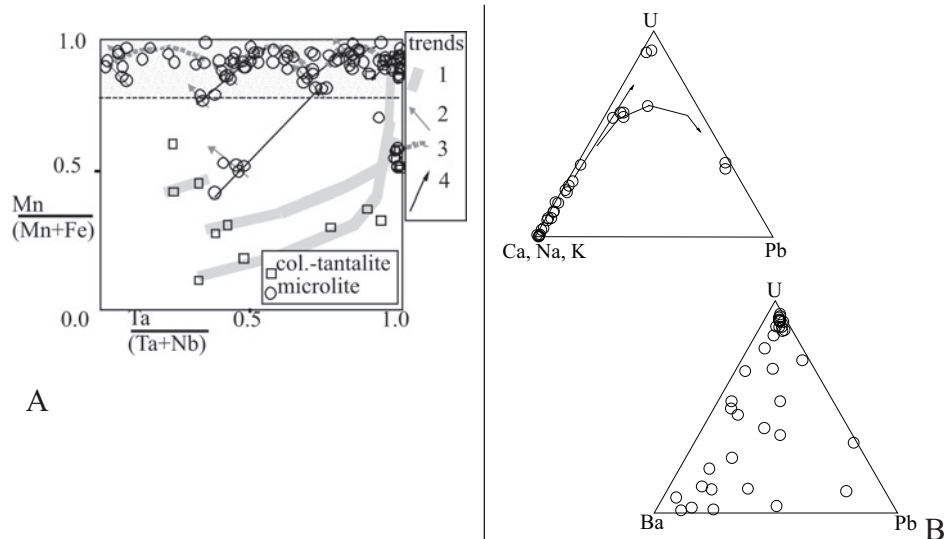


Fig. 4 – Fractionation trends in terms of apfu for Nb-tantalates from microlite-rich assemblages. A – columbite/tantalite – tapiolite quadrilateral; B- plotting of A-site contents of microlites. Note: trends described in text.

U-microlite and rarely Pb and Ba-microlite formed in relation to low temperature hydrolyse-solution followed by precipitation/recrystallization of primary assemblages and are strongly confined to the proximity of primary microlite-rich units (fig. 4B). In some cases they clearly form as replacement products of earlier microlite crystals.

Microlites of LCT pegmatites from Naipa claim have experienced multiple stages of fluid interactions. The only microlite clearly primary in the paragenetic sequence is emerald green high-Bi – high-Sb population, which crystallized at the same stage as OH-herderite, topaz, Cs-beryl (morganite gem type), Hf-rich zircon and Mn-rich F-apatite and F-elbaite, in lepidolite ± quartz ± cleavelandite-rich units at the proximity of the quartz core.

Acknowledgements

This work received support from Programa de Financiamento Plurianual de Unidades de Investigação from FCT,

financed by European Union (FEDER) and national budget of the Portuguese Republic. The fieldwork was possible with the contribution and support of The National Directorate of Geology and Mining from Mozambique and the EuroExport Mining Company (Nampula, Mozambique) to which we are duly acknowledged.

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