Formation of Mn-skarn Ores at Thapsana Mines, Paros Island, Attico-Cycladic Metallogenetic Massif, Greece

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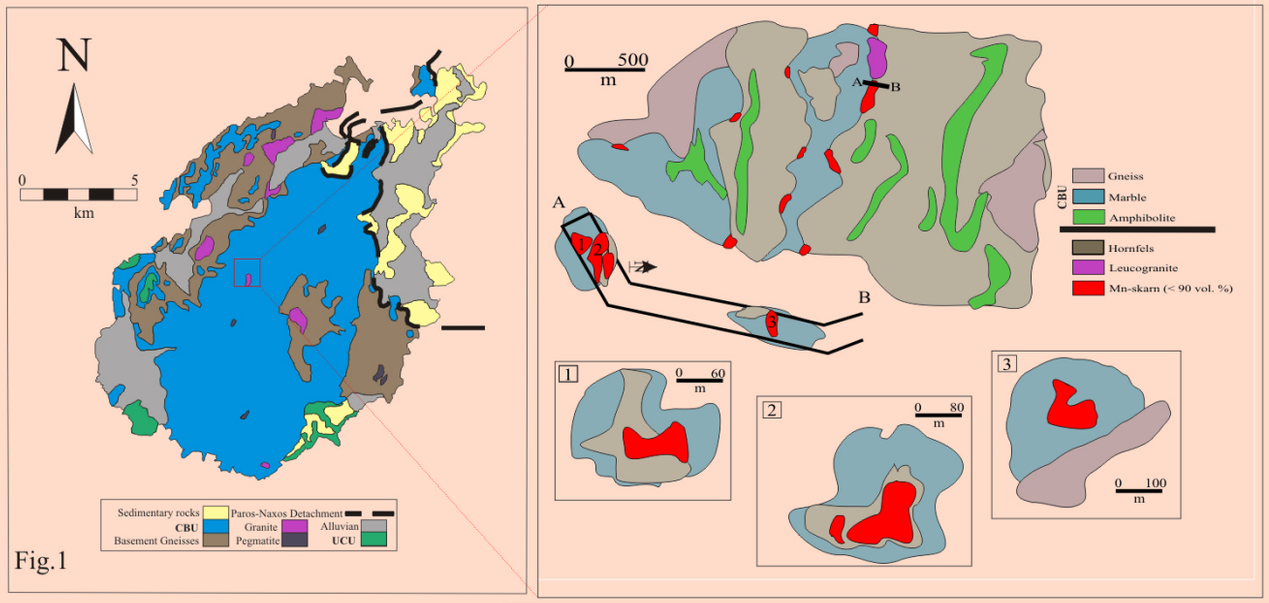
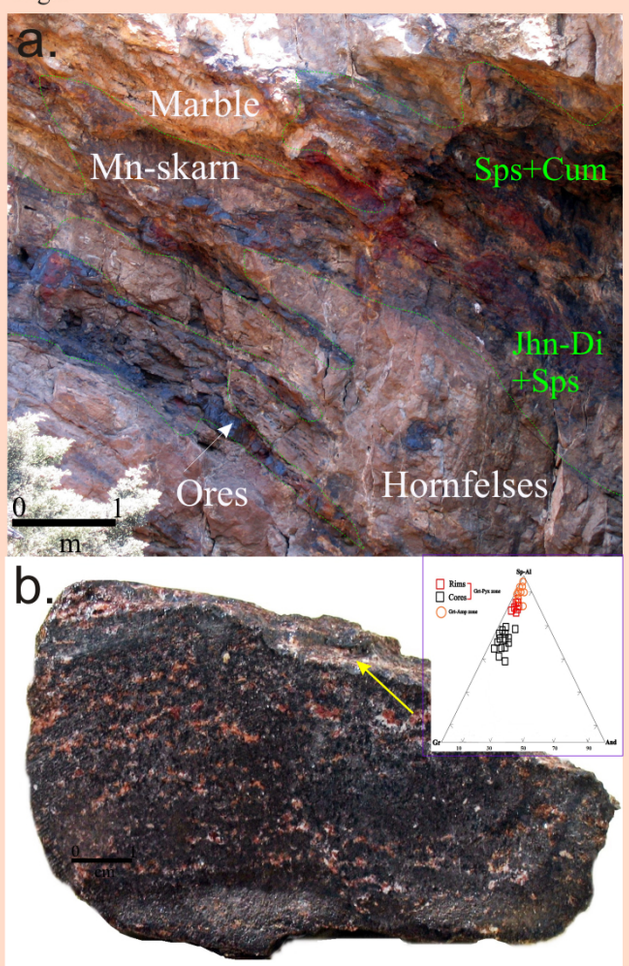


Fig.1

Fig.2



1. Introduction

Mn-skarn ore deposits are relatively infrequent worldwide. A typical example of a Mn-skarn in the Attico-Cycladic Metallogenetic Massif is located at the mining area of Thapsana, Paros Island. The skarn occurs adjacent to the Thapsana, highly sericitized, biotite-garnet-tourmaline-lepidolite leucogranite apophyses of the Paros granitoid and related pegmatites and aplites dated 11,5-12,4±0,2 Ma (K-Ar biotite and muscovite, Durr et al., 1978; Altherr et al., 1982) and 17,1 Ma (K-Ar and Rb-Sr, Durr et al., 1978; Altherr et al., 1982), respectively. According to Baltatzis (1996), the other granitoids body of Paros (Naousa, Kamares, Leykes, Paroikia, Taxiarches, Logovathra and Tripiti) dated 7-15Ma. The Mn-skarns orebodies occur as lenses and NE-trending veins hosted in the Cyclades Blueschist Unit (CBU) marbles and intercalated calcic schists.

2. Petrography, Mineral Chemistry and Isotopes Chemistry

They comprise two discontinuous paragenetic zones (with widths of ? 10 m): The first zone that contains rhodonite, vesuvianite, Mn-enriched salite to johannsenite-diopside and euhedral spessartine with cores enriched in grossular component ($Sps_{\sim 75}Grs_{\sim 15}$), placed close to the Thapsana leucogranite, and the second zone of fine grain assemblages grossular ($Sps_{\sim 85}Grs_{\sim 5}$), actinolite to Mn-cummingtonite (with Mn ~ 0.8 apfu) and phlogopite (with Mn ~ 0.6 apfu) more distal from the leucogranite and replaced the minerals of the first skarn zone. The Mn-skarns are crosscut by later WNW- to W-trending veins filled with Ca-K-Mg-bearing hollandite, pyrolusite, manganite, rhodonite and rhodochrosite, carbonates, hydroxylapatite and johnbaumite.

The Mn-ores occur as massive aggregates or disseminated comprising jacobsite, hausmannite, Mn- enriched magnetite, braunite and hollandite (with crystals of ? 2cm). Occasionally jacobsite and hausmanite display oriented intergrowths and related with the first skarn zone. The ore paragenesis also includes secondary pyrolusite, manganite, rhodonite, rhodochrosite, cryptomelane, manjiroite, vernadite and supergene Fe-oxides which related with the second skarn zone. Geothermo-oxygen-barometry suggests that the main zones of the Mn-skarns at Thapsana have been formed at temperatures ranging from ~ 440º to ~ 510ºC, pressures of 0.11 to 0.12 GPa and $\log fO_2$ values just below the magnetite-hematite buffer. Almost constant average isotopic compositions obtained from the Mn-ores (n = 10) of $\delta^{44}Ca_{BSE}$ and $\delta^{26}Mg_{DSM-3}$ of 0.5 ± 0.05 and -0.6 ± 0.1 and $\delta^{18}O$ and δD of 7.2 ± 0.5 and -92 ± 2 per mil, suggest a magmatic source for the metasomatic ore fluids related to the Thapsana leucogranite which have also interacted and isotopically equilibrated with the host CBU marbles.

References

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3. Conclusions

Our concluding remarks based on the synthesis and analysis of geologicalmineralogical, and isotopic data in Thapsana Mn-skarns and ores can be summarized as follows:

- Three metasomatic zones were recognized, a Jhn-Sps zone proximal to the leucogranite, a Sps-Cum zone, more distal and a rhodonite and subordinate vesuvianite adjusted to the CBU marbles.
- Garnet are almost pure spessartine ($Sps_{\sim 80 \text{ to } 85}$), with minor andradite component ($Adr_{\sim ?10}$) for the Jhn-Sps zone, and almost pure spessartine ($Sps_{\sim 75 \text{ to } 80}$), with minor grossular component ($Grs_{\sim ?15}$) for the Sps-Cum zone. Clinopyroxenes from the Jhn-Sps zone are zoned with almost pure Johannsenite ($Jhn_{\sim 80 \text{ to } 90}Di_{\sim ?13}$) at their cores, and Johannsenite-Diopside solid solutions ($Jhn_{\sim 60 \text{ to } 70}Di_{\sim ?30}$). Amphiboles from the Sps-Cum zone are classified as magnesio-mangani-hornblende passing towards cummingtonite.
- The minimum estimated pressure during the Mn-skarn formation at Thapsana was from 0.11 to 0.12 GPa, at temperatures ranging from ~ 440º to ~ 510ºC.
- Stable isotopic compositions suggest a magmatic source for the metasomatic ore fluids related to the Thapsana leucogranite. The mineralizing fluids have interacted and isotopically equilibrated with the host CBU marbles, schists and amphibolites.

Figure captions

Fig. 1. Simplified map of Paros (modified after Papanikolaou, 1980). In the red box is the Mn-skarn of Thapsana.

Fig. 2. a) A view of the relation of skarn zones with marbles and hornfelses. b) A hand specimen of rich spessartine from Mn-skarn. Representative photomicrographs of SEM-EDS of Mn-ore and silicate minerals and the relations between their (c., d., e., Abbreviations: Mn-Cpx: manganoan clinopyroxene of Johannsenite-Diopside series, Cum: Cummingtonite, Sps: Spessartine, Jcb: Jacobsite, Hsm: Hausmannite, Hol: Hollandite). f.,g.) Characteristic photomicrographs of polarising microscope of silicate minerals and the relatives between their.