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Evidence of Nb-Ta mobility in high temperature F-rich fluids evidenced by the La Bosse quartz-Nb-ferberite stockwork (Echassières, French Massif Central).

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In the Echassières district (northern French Massif Central), the 310 Ma Beauvoir granite (a P-rich peraluminous RMG) overprints a quartz-ferberite stockwork. The 900 m-deep GPF1 scientific hole shows that the stockwork is split into two parts by the gently dipping Beauvoir intrusion: the upper section ($\sim$ 100m thick) occurs in the La Bosse quarry, , and the lower section ($\geq$ 60 m thick) below the granite floor. The root of the stockwork (hypothetic La Bosse granite) has not been reached.

The stockwork comprises flat-lying quartz veins ($\leq$ 0.6 m thick) concordant to the regional schistosity of surrounding micaschists, and steep N10-N50°E quartz veins ($\leq$ 0.2 m thick). The two sets result from hydraulic fracturing, and consistently display crack seal features. A family of aplites and aplo-pegmatites dikes follow the same set of fractures, being either later (with partial dissolution of pre-existing quartz veins) or earlier, than the quartz veins. There is no alteration, nor associated mineral other than ferberite, at the La Bosse quarry, whereas micaceous selvages are observed in the lower section.

Ferberite display a trend of ferberite enrichment with increasing depth (0.71 to 0.95 Fb mole%). In the La Bosse quarry, three ferberite habitus are present: acicular, lanceolate and prismatic. Acicular crystals are typically nicely zoned, with alternating Nb-rich (4.95$\pm$0.94 % Nb2O5) and Nb-poor (1.57$\pm$0.38 % Nb2O5) growth bands. Ta (up to 0.30 Ta2O5), Ti and Sn are also enriched in the Nb-rich bands. Nb and Ta incorporation into the ferberite is in the form of columbite, as either true solid solution or nanoinclusions. Lanceolate crystals have a similarly zoned acicular core and a Nb-poor rim (1.08$\pm$0.66 % Nb2O5). Prismatic crystals are unzoned and Nb-poor (0.67$\pm$0.20 % Nb2O5). In the lower part of the stockwork, the Nb contents are lower (2.17 % Nb2O5 in the Nb-rich bands, 1.36 % in the Nb-poor bands, 0.08 % in the unzoned cortex, 0.15 % in the unzoned prisms).

Thus the unusual Nb content of the La Bosse ferberites is correlated to the apparently very distal setting of this quartz system relatively to the parent granite, in contrast with most quartz-W systems in the French Massif Central (Aïssa et al. 1987).

When invaded by aplites or aplopegmatites, the ferberite-bearing quartz veins are dissolved, but the ferberites remain apparently unaffected – they are not dissolved by the granite melt. Yet, the acicular and lanceolate crystals have lost their Nb-zoning and display uniform homogenised Nb content.

The emplacement of the Beauvoir granite was associated with late magmatic exsolution of an Al- and F-rich, silica undersaturated, hydrothermal fluid that percolated upwards in the surrounding schists (Cuney et al. 1992). When interacting with the quartz veins of the La Bosse stockwork, this fluid precipitated topazites. Again, included ferberites remain apparently unaffected. However, they display microscopic vuggy cavities, successively filled by a Nb-rich ferberite (up to 8.91% Nb2O5) with significant Ta content (up to 0.35 % Ta2O5), a wolframo-ixiolite and a Ta-rich columbite. Later Li-phengite was precipitated from the same magmatic fluid, and was associated with hubnerite enrichment of pre-existing ferberites along Li-phengite-bearing microcracks (down to 0.20 mole % Fb).

Ta and Nb are known for their poor solubility in hydrothermal fluids, but the Nb and Ta enrichments observed in the wolframite of La Bosse stockwork show that they can be transported to some extent by F-rich fluids.

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