

Mineralised pegmatites of the Damara Belt, Namibia: fluid inclusion and geochemical characteristics with implications for post-collisional mineralisation

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Namibia is renowned for its abundant mineral resources, a large proportion of which are hosted in the metasedimentary lithologies of the Damara Belt, the northeast-trending inland branch of the Neoproterozoic Pan-African Damara Orogen. Deposit types include late- to post-tectonic (~ 523 - 506 Ma) LCT (Li-Be, Sn-, and miarolitic gem-tourmaline-bearing) pegmatites, and uraniferous pegmatitic sheeted leucogranites (SLGs), which have an NYF affinity. Fluid inclusion studies reveal that although mineralization differs between the different types of pegmatites located at different geographic locations, and by extension, different stratigraphic levels, the fluid inclusion assemblages present in these pegmatites are similar; thus different types of pegmatites are indistinguishable from each other based on their fluid inclusion assemblages. Fluid inclusion petrography indicates that although fluid inclusions are abundant in the pegmatites, no primary fluid inclusions are present, and rather those studied are pseudosecondary and secondary. These are aqueo-carbonic (\pm NaCl), carbonic, and aqueous. It is proposed that all of the pegmatites studied share a similar late-stage evolution, with fluids becoming less carbonic and less saline with the progression of crystallisation. Oxygen isotope ratios allow the discrimination of different pegmatites into two groups, Group A (Sn-, Li-Sn-, and gem-tourmaline-bearing LCT pegmatites), and Group B (Li-Be-bearing LCT, and U-bearing NYF pegmatites). Group A pegmatites have O-isotope ratios ranging from 11 to 13 ‰ suggesting that they have an I-type affinity. These values are, however, elevated above those of typical I-type granites the derivation of these pegmatites from a non-pelitic/S-type metaigneous source. Group B pegmatites have higher $\delta^{18}\text{O}$ ratios ($\delta^{18}\text{O} = 15 - 16 \text{ ‰}$), indicative of their S-type affinity, and their derivation from metapelitic source rocks. Trends in the trace element concentrations of both Group A and Group B pegmatites are very similar to each other, making the two groups indistinguishable from each other on this basis. The Damaran pegmatites also share similar geochemical trends with their country rocks. There is, however, no direct field evidence to suggest that the pegmatites were derived from the *in situ* anatexis of the country rocks. It is more likely that anatexis occurred some distance away from where the pegmatites were ultimately emplaced, and that the melts migrated and were finally emplaced in pre-existing structures, possibly formed during Damaran deformation. O-isotope and Ti-in-quartz geothermometry indicate that Damaran pegmatites can be subdivided into two groups based on their crystallisation temperatures. LCT pegmatites crystallised at temperatures ranging from ~ 450 - 550 °C, while the NYF pegmatites crystallised at higher temperatures, ranging from 630 - 670 °C. It is important to note that the subdivision of pegmatites in Groups A and B based on their O-isotope systematics does not correspond with their subdivision into the LCT and NYF pegmatite families according to their crystallisation temperatures. In addition to clarifying aspects of the emplacement and evolution of the Damaran pegmatites, this study points out that there are several discrepancies in the current classification schemes of pegmatites. It shows that in addition to the problems encountered when trying to distinguish between LCT and NYF pegmatites based on their mineralogy, they also cannot truly be distinguished from each other using their geochemical and isotopic characteristics, or their tectonic settings. It is tentatively proposed that crystallisation temperature be considered as an alternative or additional characteristic in the classification of pegmatites, and that it be considered on a regional scale rather than only in the evaluation of the highly evolved end-members of a pegmatite swarm.

Petrographic textures of primary phosphates from pegmatites of the Conselheiro Pena district, Minas Gerais, Brazil: transformation sequence and genetic implications

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In Brazil occurs one of the most important pegmatite provinces in the world, the Eastern Brazilian Pegmatite Province (EBPP), which is located at the eastern side of the São Francisco craton. The Conselheiro Pena pegmatitic district forms part of the EBPP where two intrusions crosscut the basement rocks and its cover: the Galiléia and Urucum magmatic suites which belong to the G1 and G2 supersuites, respectively. Pegmatites intrude the garnet-, biotite-, and sillimanite-bearing schists of the São Tomé Formation (Rio Doce group, Late Proterozoic).

In 2008 and 2010, we visited several pegmatites located in the Conselheiro Pena district, between Galiléia and Mendes Pimentel, in order to investigate the petrography of phosphate minerals and their relationships with associated silicates. According to their macroscopic features and their mineralogy, three kinds of phosphate masses were found. The aims of the present paper are (i) to describe in detail the petrographic texture affecting these primary phosphate minerals in order to explain their crystallization sequence and the physico-chemical conditions prevailing during the magmatic stage of the pegmatite, and (ii) to better understand how the hydrothermal stages affected the phosphate masses throughout the chemical and petrological study of secondary species, which crystallize during these stages.

During the magmatic stage, phosphate associations developed three kinds of primary textures, which may occur in the same pegmatite: association I is constituted by dendritic triphylite, forming intergrowths with silicates (spessartine or albite); association II forms blocky nodules; and association III shows exsolution lamellae of triphylite in massive beusite. These primary textures and the Fe/Fe+Mn+Mg ratio of primary triphylite allow one to establish the crystallization sequence of the primary phases in pegmatites of Conselheiro Pena district. The relationships between primary intergrowths of association I, involving spessartine and triphylite, will also be discussed.

After these magmatic stages, the primary associations are affected by hydrothermal stages and form secondary phosphate minerals. Their petrographic relationships lead us to the crystallization sequence of these secondary phases. It clearly appears that the hydrothermal stages don't affect one whole pegmatite in the same way: in the same pegmatite, some masses may be completely oxidized while other masses remain almost unaltered. Moreover, the nodular phosphate masses evolved like a relatively closed system since secondary species, which crystallized during low temperature hydrothermal stage, strongly depend on the cations which are locally available in the sample zone.