Evolution of a peraluminous REE enriched garnet granite towards a world class HREE enriched ion-exchange deposit, Penco, Chile

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In the Coastal Cordillera of Penco, Chile, a peraluminious dioritic magma intruded around 310 Ma ago into metapelites, resulting in partial melting with the subsequent formation of a garnet-rich granite (S-type). The garnet (almandine) granite exposed to extensive meteorization in the area lead to a heavy rare earth element (HREE) enriched ion-exchange deposit. Three fractionation steps from the light rare earth element (LREE) dominated source mineralogy towards the final HREE ion-exchange deposit could be detected. 1.) A dioritic magma provided monazite, xenotime, ilmenite and apatite as REE source minerals. During partial disolution and anatexis, modeling of the REE-pattern composition suggests that mainly ilmenite and xenotime dissolution provide the REE's sequestred by the neo-formed garnets. The garnets contain abundant inclusions of these REE source minerals as well as quartz and zircon, suggesting that a subsequent density fractionation in the anatexic magma, enriched the garnets (average 20%) in the magma chamber. Although the concentrations of the REE in the garnets are relatively low (0.23 wt.% ∑REE), but due to the important amount of this mineral and the tendency to sequester HREE and Y, the concentration of it in parts of the magma chamber is the first step towards forming a HREE deposit, which expose about 15% of the REE in this easyly meteorizable mineral. 2.) A later hydrothermal alteration event adds Ca, Al, Fe-rich solutions, which promote the alteration of monazite towards allanite with the formation of relictive thorite as inclusion in the allanite. This hydrothermal alteration event makes tabout 70% of the LREE available to meteorization, as allanite weathers easier than monazite. 3.) Weathering processes of the magmatic and hydrothermal mineralogy produced an enrichment of mainly HREE in a depth of 10-20 m in the weathering profile, where illite is the dominant cation exchanger. Sequential extraction data also suggest that the LREE are fixed mainly in secondary phosphate minerals in the saprolite, leading to an additional fracionation towards the HREE's fixed in the ion-exchangeable fraction.