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Phase relations and prograde evolution of REE minerals from diagenetic to amphibolite facies conditions in pelites from the Central Alps, with implications to geochronology

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Amongst the REE-minerals, two phosphates (monazite and xenotime) and the REE-epidote (allanite) are known to yield high-precision ages by U-Th-Pb dating. In order to correlate such ages with P-T conditions, a number of contributions have made efforts to constrain the stability, phase relations and chemistry of REE-minerals in metamorphic rocks. However, few studies have investigated the REE-minerals and the reactions forming REE-phases at low metamorphic grade, i.e. (sub)greenschist facies conditions. We report on the REE distribution in samples from the Central Alps, taken along a well established metamorphic field gradient, between the Helvetic Prealps and the northern part of the Lepontine dome. We chose samples of Al-rich, Ca-poor metapelitic composition, for which carefully documented petrographic data exist, recording a progressively increasing metamorphic grade, from diagenetic to lower amphibolite facies conditions. Our strategy has been to characterize texturally and chemically the REE-bearing minerals, document their assemblages, and deduce the mineral reactions which had occurred along the metamorphic gradient.

In diagenetic to low-grade metamorphic rocks, LREE are contained in monazite, which occurs variably as minute grains (<5 μm, present in most samples) or roundish and/or irregular grains ($\sim$25-50 μm). Chemical U-Th-Pb ages (EMP data Jeol-8200, Univ. Bern) reveal that irregular and roundish monazite grains are inherited (mainly Hercynian ages), whereas the minute grains are newly formed (Pb below detection limit), with growth occurring at diagenetic to low grade metamorphic conditions. With the appearance of chloritoid, monazite vanishes, and LREE are taken up in idiomorphic allanite grains (10-30 μm); these are found in intergranular positions or as inclusions in chloritoid porphyroblasts. With increasing metamorphic grade, up to the “chloritoid-out” zone boundary, allanite grains increase in size (up to 500 μm) and very commonly acquire rims of epidote. In samples showing evidence of faint late-stage hydrothermal alteration, very local replacement of allanite grains has been observed, with monazite (<2 μm) and tiny REE-carbonate grains occurring at their periphery. In higher-grade metapelites (St-Ky-Gt-Bt grade), allanite is in part replaced by monazite+xenotime, which are associated with plagioclase, biotite and/or staurolite. In these samples, allanite is observed as inclusions in garnet, whereas monazite occurs in the matrix only. Xenotime is present in all of the samples studied. At diagenetic and low metamorphic conditions, it occurs as minute grains in intergranular position or as overgrowth of zircon; it is considered to be diagenetic. In the higher-grade metamorphic rocks it is assumed to be metamorphic, since it is found in association with monazite replacing allanite.

This study demonstrates that newly formed REE-minerals can be found from diagenetic up to amphibolite facies conditions. The evolution of the REE-phases appears to be correlated with the succession of major silicate assemblages. This study thus demonstrates potential for novel geochronology, since all of the samples display REE-minerals for which ages can potentially be determined and related to the P-T conditions of their formation.