# Chronological constraints for Variscan *vs* Alpine eclogite facies metamorphism in the basement units of the Eastern Alps

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## Introduction

The pre-Alpine basement of the Austroalpine nappes, the highest tectonic unit in the Alps, is mainly composed of old continental crust, with a mean age (Nd DM model ages) of *c.* 1.6 ± 0.1 Ga. Polymetamorphic paragneisses, micaschists and orthogneisses are the main constituents, with only minor intercalations of amphibolites and metacarbonates. The rocks exhibit strongly varying Alpine (Cretaceous) structural and thermal overprint, reaching from lowest greenschist to higher amphibolite facies grade. Eclogitized metagabbros and metabasalts, remnants of former oceanic crust material, outcrop as isolated pods and lenses in both low as well as higher grade Alpine gneiss-micaschist host rocks of these nappes. New isotopic data are reported for eclogites and their host rocks from two such different areas in the Eastern Alps: a) the Ötztal block to the west (southwest of Innsbruck) and b) the Saualpe-Koralpe region to the east (southwest of Graz), to constrain (I) the timing of the magmatic crystallization of the eclogite protoliths as well as their geotectonic setting and (II) the timing of the high-P event.

## Data presentation

*Ötztal basement.* Within the amphibolite-eclogite zone of the central Ötztal basement unit, relictic gabbro occurrences (Miller, 1970; 1992 pers. comm.) document the derivation of some of these eclogites from gabbroid protoliths. Two types of gabbros are discerned: olivine-rich gabbros and coarse-grained, olivine-free (cpx-pl) gabbros. Two ol-gabbros and one cpx-pl-gabbro yielded near-concordant Sm-Nd isochrons for clinopyroxene-plagioclase pairs of 521 ± 10 and 530 ± 2 Ma. In all cases, the whole-rock data point plots slightly off the two-point mineral isochrons. Initial isotopic compositions range from +5 to +8 ε for Nd and at 0.7024 to 0.7029 for Sr.

Within the eclogites, three types are discerned on the basis of mineralogical, geochemical and isotopic data: kyanite-bearing eclogites, Fe-rich eclogites and quartz-eclogites. These types are interpreted as being the metamorphic products of gabbroid, ferro-gabbroid and MORB-type basaltic parents, respectively (Miller and Thöni, 1994). Minimum PT conditions for the high-P event are estimated at 20 kb/660°C. Mineral isochrons, including garnet, omphacite, zoisite and whole-rock from two ky-eclogites and five Fe-eclogites yielded Sm-Nd ages of between 373 ± 20 and 342 ± 3 Ma. In addition, nine Fe-eclogite whole-rocks with strongly varying and partly very high Sm/Nd ratios define a regression age of 362 ± 29 Ma (MSWD = 15.7). Garnets from sillimanite-andalusite-bearing paragneisses to the southwest of the eclogite zone give somewhat younger Sm-Nd ages of between 343 ± 1 and 331 ± 3 Ma (Hoinkes *et al.*, 1994).

*Saualpe-Koralpe region* Eclogites in the Saualpe and Koralpe type-localities occur as numerous small pods within coarse-grained micaschists and/or highly deformed gneisses (so called plattengneiss). Cpx-pl-gabbros and N-MORB-type basalts are recognized as the eclogite protoliths in this case as well (Miller *et al.*, 1988). PT conditions at the peak of the eclogite metamorphism are given as 18 kb/600°C (Miller, 1990). Isolated gabbro relics from the southern Koralpe that show stepwise eclogitization on the outcrop to hand-specimen scale yielded Sm-Nd isochrons for plagioclase, clinopyroxene and whole rock of between 261 ± 10 and 295 ± 11 Ma (Thöni and Jagoutz, 1992; Thöni, unpubl. data). Initial isotopic compositions range at +8 to +9 ε for Nd and 0.7025 to 7028 for Sr. The analysed minerals from eclogites (garnet, omphacite, zoisite, amphibole) from both the Saualpe and the Koralpe, on the other hand, show a wide range of Sm-Nd ages of between 150 and less than 60 Ma. Rb-Sr ages for phengites of some of these assemblages range between 84 and 102 Ma. Contrary to the metabasites, garnets from the coarse-grained eclogite host rocks (micaschists) yield well-defined, concordant Sm-Nd ages of

between 88.5 ± 2 and 91 ± 1 Ma. Garnet porphyroclasts from pegmatite mylonites of the Koralpe plattengneiss, however, have preserved their magmatic ages of 260 Ma, despite Alpine overprinting temperatures of *c.* 600°C.

### Discussion and conclusions

The 530–520 Ma cpx-pl Sm-Nd ages of the Ötztal gabbros are interpreted to date magmatic crystallisation of the eclogite protoliths. Geochemical and initial isotopic compositions support production of MORB-type oceanic crust. A Cambrian island arc–marginal basin situation may be discussed as one possible geotectonic setting for these magmatic rocks. Subduction and high-P metamorphism in the central Ötztal Alps is, however, much younger. Garnet Sm-Nd ages bracket the most probable time span for this Variscan high-P event at *c.* 350–360 Ma. The somewhat younger, 330–340 Ma Sm-Nd garnet ages from the sillimanite-andalusite-bearing gneisses document a late stage of pressure release and exhumation. Tentatively, a common Variscan subduction-exhumation history for the gneiss-eclogite associaton in the Ötztal basement may be constructed.

Contrary to previous models, the data from the Saualpe and Koralpe region support an eclogite-forming event related with the Alpine orogeny. The MORB-type eclogite precursors were derived from the upper mantle in a Permian to U. Carboniferous (300–260 Ma) rift situation, probably representing the nucleation of the Alpine Tethys (to be distinguished from the younger Piemontais-Pennine ocean!). Convergence processes of N. Adria and the European plate during Jurassic-Cretaceous times resulted in subduction and high-P metamorphism of the southern Austroalpine units. The exact timing of the high-P event is difficult to assess, due to imperfect reselling of the Sm-Nd system during eclogitization. A maximum and a minimum age may, however, be derived from the Sm-Nd and Rb-Sr data which give 150 and 90 Ma, respectively. Exhumation and cooling was accomplished at *c.* 70 ± 10 Ma.

### References

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