Subduction of a rifted passive continental margin: the Pohorje case of Eastern Alps - constraints from geochronology and geochemistry

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Outline

- Introduction
- The geological background and problems
- Sample locations
- Research methods and results
- Discussion and Conclusions
Introduction

Eastern Alps: the result of the convergence of two independent Alpidic collisional orogenic belts

consisted of:

**Austroalpine nappe stack**
(can be divided into a strongly imbricated **Lower Austroalpine nappe complex** with several internal nappes, a thick **Middle Austroalpine nappe complex** that is mainly composed of polymetamorphic basement rocks, and the **Upper Austroalpine nappe complex**)

**Two windows** **Tauern window** and **Rechnitz window**, enable a look onto Penninic and Helvetic rocks flysch sediments underlies the thrust plane at the base of the Austroalpine nappe stack.
The geological background and problems

EGU comprises a succession of metamorphic rocks with continental affinity.

includes various paragneisses, rare marble and quartzites and intercalated eclogites, rare metagabbro and pegmatites
The geological background and problems

**Simplified tectonostratigraphy** (ca. 100 km N-S section)

**Koralpe-Saulaupe Complex:**
- Protolith age is unknown
- Permian HT/LP metamorphism
- Few late Permian metagabbros
- Many Late Permian-Triassic pegmatites
- Cretaceous HP/UHP metamorphism

**Plankogel Complex:**
- Protolith age is ???
- Permian HT/LP metamorphism
- Permian-Triassic mafic rocks
- Some Late Permian pegmatites only in the S
- Cretaceous amphibolite-facies metamorphism

**Wölz-Speik Complex:**
- Protolith age is Early Paleozoic
- Permian metamorphism??
- Many Late Permian pegmatites
- Cretaceous amphibolite-facies metamorphism

Diagram showing the geological structures with labels for the Koralpe-Saulaupe, Plankogel, and Wölz-Speik Complexes, indicating their stratigraphic relationships and metamorphic events.
Sample location

modified from Mioč and Žnidarčič 1977
Sample location

Biotite-gneiss

Grt-Ms-gneisses

Granitic augen gneiss

Map modified after Kirst et al. 2010
Research methods and results

**Zircon U-Pb Ages**

Representative CL images of zircon crystals used for LA-ICP-MS dating from the Pohorje Mt.

**Aim:** To determine the age of magmatic or metamorphic events

**Magmatic age**
- Subhedral-euhedral oscillatory zoning
- High Th/U ratios of (0.12–1.30) >0.1

**Metamorphic age**
- Rounded
- Slightly oscillatory zoning
- Low Th/U ratios (0.005–0.009) <0.01

Inherited cores in which exhibit more clearly oscillatory zoning

**SK1**
- 268 ± 4 Ma
- 262 ± 4 Ma
- 257 ± 2 Ma
- 260 ± 2 Ma

**SK2**
- 264 ± 4 Ma
- 266 ± 3 Ma
- 263 ± 3 Ma
- 245 ± 4 Ma

**SK10**
- 89 ± 1 Ma
- 265 ± 3 Ma
- 281 ± 4 Ma
- 91 ± 2 Ma

**SK12**
- 95 ± 2 Ma
- 562 ± 7 Ma
- 336 ± 6 Ma
- 98 ± 2 Ma

89 ± 1 Ma
Why is difference in zircon between augengneiss and leucogneisses (beside their different locations)?

**Augengneiss** are hosted within amphibolite facies metamorphic rocks with no preserved fabrics of HP/UHP metamorphism (e.g., no retrogressed eclogites); metamorphic temperatures remained < ca. 650 °C.

**Leucogneisses** are hosted within an UHP environment (diamond-bearing country rocks: ≥3.5 GPa and 800–850 °C, Janák et al., 2015, Journal of Metamorphic Geology)

Likely solution: Two separate tectonic units with different metamorphic history?
Section 2 of Kurst et al., 2010
Research methods and results

Zircon Hf isotope data

To retrospect and discuss magmatic origin

$^{176}\text{Hf}/^{177}\text{Hf}(t)$ values on magmatic zircon grains range between 0.282703 and 0.282868 (t = 255 Ma)

$\varepsilon\text{Hf}(t)$ values between -6.4 and -1.7 and crustal model ages ($T_{DM}^C$) of 1392 to 1617 Ma

$^{176}\text{Hf}/^{177}\text{Hf}$ values on zircons from the leucogneisses of 0.282385–0.282562 (t = 90 Ma)

$\varepsilon\text{Hf}(t)$ values of -13.7 to -7.9 and yield Hf crustal model ages ($T_{DM}^C$) of 969–1195 Ma

These data suggesting a predominantly Proterozoic crustal source.
Research methods and results

Geochemistry data

To constrain the origin of gneisses

- Enrichment in LILEs; e.g., Rb, Sr, and K
- Depletion in HFSE, negative anomalies for P, Nb, Ba
- the paragneiss display lower normalized light REE
- The REE all characterized by a fractionation between light and heavy REEs
- have small negative Eu anomalies (probably resulting from plagioclase fractional)

Chondrite-normalized REE patterns of zircon grains reveal that they are strongly depleted in light REEs relative to heavy REEs, and that they exhibit pronounced positive Ce, Sm and negative Eu anomalies

Th/U ratio allow distinction of magmatic and metamorphic zircons
Research methods and results

Augengneiss samples

- Na₂O/K₂O ratios less than 1
- MnO (4.60–6.14 wt.%)
- calc-alkaline
- granodiorite
- metaluminous

Leucogneiss samples

- high Na₂O/K₂O ratio
- MnO (0.05–0.10 wt.%)
- high-K calc-alkaline
- granite
- peraluminous
Augengneisses plot mostly in the field of A-type granite. The εHf(t) values of zircons are negative (-6.4 to -1.7). The zircon U–Pb ages of the orthogneisses are 255 ± 2.2 Ma and 260 ± 0.81 Ma. High (La/Lu)_N ratios, strong negative Eu anomalies. Augengneisses formed in a rift and lithospheric thinning setting in the Permian.
Discussion and Conclusions

Permian granitic to granodioritic intrusions was dated at 255–260 Ma and are derived from partial melting of lower continental crust in a rift zone.

An intracontinental subduction zone formed within the Austroalpine continental crust at the site of a Permian rift.

The segment of the EGU is part of the distal Permian rift zone, which finally led to the opening of the Meliata Ocean during Middle Triassic times. The stretched continental crust was subducted to mantle depth and then rapidly exhumed by upward motion due to buoyancy during early Late Cretaceous times.

We propose a new model for accretion of lower Middle/Lower Central Austroalpine and Lower Austroalpine by continuous downward motion of the Meliata oceanic slab.