# Ages and deformation of felsic dikes within granulites and gneisses of the Gruf Complex, Central Alps.

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Magmatic leucosomes and dikes in metamorphic terranes provide an opportunity to correlate accessory phase crystallization ages with the timing of deformation and metamorphic events as well as larger scale magmatic intrusions.

The Gruf Complex consists of migmatitic gneisses plus scarce charnockites and UHT sapphirine granulites We identified several mineralogically distinct types of leucosomes and dikes: 1) foliation-defining, biotite-bearing leucosomes that are commonly folded; 2) medium-grained hornblende- and/or biotite-bearing granite pods crosscutting these leucosomes; 3) biotite-bearing pegmatite dikes, boudinaged or crosscutting the main foliation; 4) pegmatitic muscovite-, garnet-, beryll-bearing dikes, crosscutting all other rock types. Field observations indicate changing melt composition during and after regional metamorphism and associated deformation. Zircons from these dikes were dated by LA-ICP-MS to constrain deformation and metamorphism.

All analyzed samples contain oscillatory-zoned zircons with ages of 250–300 Ma. A leucosome within a brecciated metaperidotite enclave contains equant, sector-zoned 32.2±0.2 Ma zircons. Most dike sample zircons have rims of 28–30 Ma. An undeformed muscovite-bearing pegmatite dike crystallized at 25.6±0.3 Ma. Another muscovite-bearing pegmatite dike lacks zircon domains <28 Ma, probably due to insufficient Zr in the melt.

Apparent zircon saturation temperatures ($T_{Zrs}$) for dike and leucosome samples are 680–890°C and uncorrelated with age. We attribute the wide $T_{Zrs}$-range to inherited zircon that did not dissolve in the melt. The pegmatite without <28 Ma zircon has a $T_{Zrs}$ of 730°C suggesting its parental magma formed by partial melting of material similar to the deformed dikes, but did not exceed 730°C.

Coclusions: partial melting in the migmatites is coeval with the 30–32 Ma Bergell intrusion and main deformation. Dike emplacement and deformation continued until c. 24 Ma, coinciding with intrusion of the Novate granite and cooling of the granulites below the $T_c$ of rutile at c. 500°C. The presence of 32 Ma zircons in all dikes indicates remelting of older leucosomes and dikes as the mechanism to produce the more fractionated pegmatites.

# The copper isotope composition of bulk Earth: A new paradox?

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It is estimated that two thirds of terrestrial Cu is held in the core [1]; hence, to constrain the bulk Earth Cu isotope composition, $\delta^{65}Cu$ estimates for both mantle (BSE) and core are required. By analysing a representative suite (n ~ 50) of basaltic samples and their differentiates, we have investigated the behaviour of Cu isotopes during mantle melting and magmatic differentiation, and established a robust $\delta^{65}Cu$ value for BSE. Our results show that, during fractional crystallisation, Cu isotopes can be fractionated to both lighter and heavier compositions, depending on crystallising phase. However, during partial melting, there is no resolvable fractionation. This implies that primitive basaltic melts are a good proxy for the Cu isotope composition of the mantle. Such analyses give an average $\delta^{65}Cu_{BSE}$ value of 0.07 ± 0.12 ‰ (2sd; relative to the standard NIST 976).

To estimate the Cu isotope composition of the Earth's core, we performed a series of piston-cylinder experiments to determine the $Cu_{metal/silicate}$ isotope fractionation factor. These show that metal is preferentially enriched in the heavier Cu isotope, which agrees with emprical data from silicate-bearing iron meteorites [2]. Using these data to estimate a $\delta^{65}Cu_{CORE}$ value, we calculate the Cu isotope composition of bulk Earth to be $\delta^{65}Cu_{BE} \approx 0.16$‰. The "paradox" is as such: bulk Earth has a heavier Cu isotope composition than most (if not all) of the thus-far analysed chondritic meteorite groups [3, 4].

Assuming chondrites = bulk Earth, to explain this "missing $^{63}Cu$", we tentatively propose two possibilities:

1) Isotopically light Cu entered the Earth's core as a sulphide phase, or is stored in a thus-far unsampled part of the mantle, again in sulphides.
2) The light Cu isotope was preferentially lost as a result volatile processes during Earth's accretion.

Alternatively, the current $\delta^{65}Cu$ chondrite dataset does not represent bulk Earth, and further analyses are required.

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