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Lost in subduction: nitrogen mobility in fluids indicates its low recycling efficiency in cold slabs

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Nitrogen is a critical element for life on Earth: it dominates the planet's atmosphere and is present in the deep geological cycle. Recent studies suggest that most of the Earth's nitrogen is sequestered in the solid Earth rather than in the atmosphere, and the connection between the surficial and deep nitrogen cycles occurs in the oceans via sedimentation and subduction [1-3]. Understanding the Earth's geological nitrogen cycle requires knowledge of how nitrogen behaves during the dehydration of subducting crust.

Here we present 21 new experiments in the pressure and temperature range of 2-2.7 GPa and 300-800 °C to investigate the partitioning of nitrogen between muscovite mica and a fluid phase in the subsolidus regime of subduction zones. $D_{N(mica/fluid)}$ ranges within 0.1-0.2 with no observed dependence on temperature and pressure as D_N shows a very weak negative trend with respect to P/T. The low D_N in the subsolidus regime strongly contrasts with the D_N known from experiments that investigated the suprasolidus regime of subduction zones, with $D_{N(melt/fluid)}$ of 0.1-0.3 (0.95-2.28 GPa/750-925 °C [1]), 0.1-0.4 (2-4 GPa/1050-1300 °C, [2]), and 0.2-0.7 (2-4 GPa/800-1200 °C [3]), all of which showed strong positive dependency with P/T. Accordingly, loss of nitrogen to subduction fluids is higher in cold subduction zones after >600 °C (antigorite breakdown) where the slab surface stays subsolidus beyond the volcanic arc.

Comparing cold vs. hot subduction, more N would be lost to subduction fluids at subsolidus conditions (Figure 1). However, at the depth of arc magma formation (~3.5 GPa), N contents of subducting slabs from hot- and cold subduction zones are nearly identical (~12 vs. ~13 µg g^{-1}). Hence, the emergence of cold subduction at the beginning of the Phanerozoic probably had little effect on the efficiency of N recycling to the deep mantle.

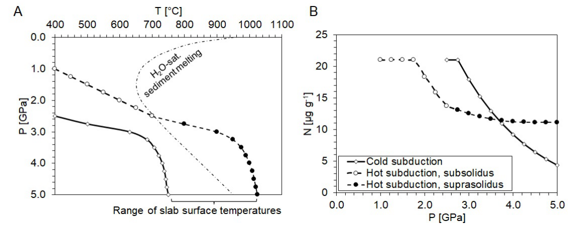

Figure 1: Slab top geotherms (A) and relative residual slab N content (B) for cold- and hot subduction zones starting with an average slab N mass fraction of ~21 µg g^{-1} [3].

[1] Jackson et al., (2021). *EPSL*, 553, 116615. [2] Mallik et al., (2018). *EPSL*. 482, 556-566. [3] Förster et al., (2019). *Chem. Geol.*, 525, 334-342.