Significance of enigmatic blue ice moraine gypsum, Sør Rodane, East Antarctica

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During the international GEA-II expedition (2011/12) to Sør Rondane (East Antarctica), large aggregates of crystalline gypsum were found within blue-ice moraines on the south side of the Sør Rondane Mountains at an elevation of ca. 2000 m and ca. 250 km inland of the present coastline. Gypsum aggregates reach one meter in diameter with individual crystal length up to 20 cm. Apparently, the gypsum grows in-situ and as a result of sublimation of the blue ice on the gravel of the moraine. Individual cobbles and sand are incorporated into the gypsum aggregates. The gypsum does not show signs of transport. In thin section, the gypsum shows an irregular growth zoning and in part bent cleavage planes. Abundant primary fluid inclusions are present parallel to the growth zoning as well as parallel to cleavage plains. This type of gypsum formation is enigmatic and has never been described before. It might indicate an important and thus far unknown process, characterising a special way of interaction between the lithosphere and the cryosphere. Preliminary Sr-isotope data indicate relatively high values and suggest crustal affinities.

A preliminary set of sulfate sulfur ($\delta^{34}S_{SO4}$) and oxygen ($\delta^{18}O_{SO4}$) isotope data reveals values ranging from +7.0 and +29.6 ‰ ($\delta^{34}S_{SO4}$) and between -16.7 and +0.3 ‰ ($\delta^{18}O_{SO4}$). Samples display a positive correlation between $\delta^{34}S$ and $\delta^{18}O$. Thus, Sulfur isotope values are highly variable and offer different conclusions with respect to potential sulfate sources. None of the gypsum samples displays a sulfur isotopic composition reflecting a pure seawater sulfate (i.e. sea spray) origin. Two samples yielded $\delta^{34}S_{SO4}$ values of +7.0 and +9.0 ‰, most others are distinctly more positive than modern seawater sulfate (i.e., above +21.0 ‰), with a maximum value of +29.6 ‰. In general, the sulfur isotope values more positive than modern seawater sulfate suggest bacterial sulfate reduction. The low $\delta^{34}S_{SO4}$ values are comparable to values measured previously for continental sulfate and are similar to a single pyrite sample from a black schist sample, ca. 150 km to the W, Steingarden area (this study). The oxygen isotopic composition for the blue ice gypsum samples is also characterized by rather variable including strongly negative $\delta^{18}O_{SO4}$ values. Negative sulfate oxygen isotope values possibly reflect an ^{18}O depleted continental source such as Antarctic glacial waters that could have fostered the oxidative weathering of sulfide sulfur. The observed variability could reflect different stages of bacterial sulfate reduction.

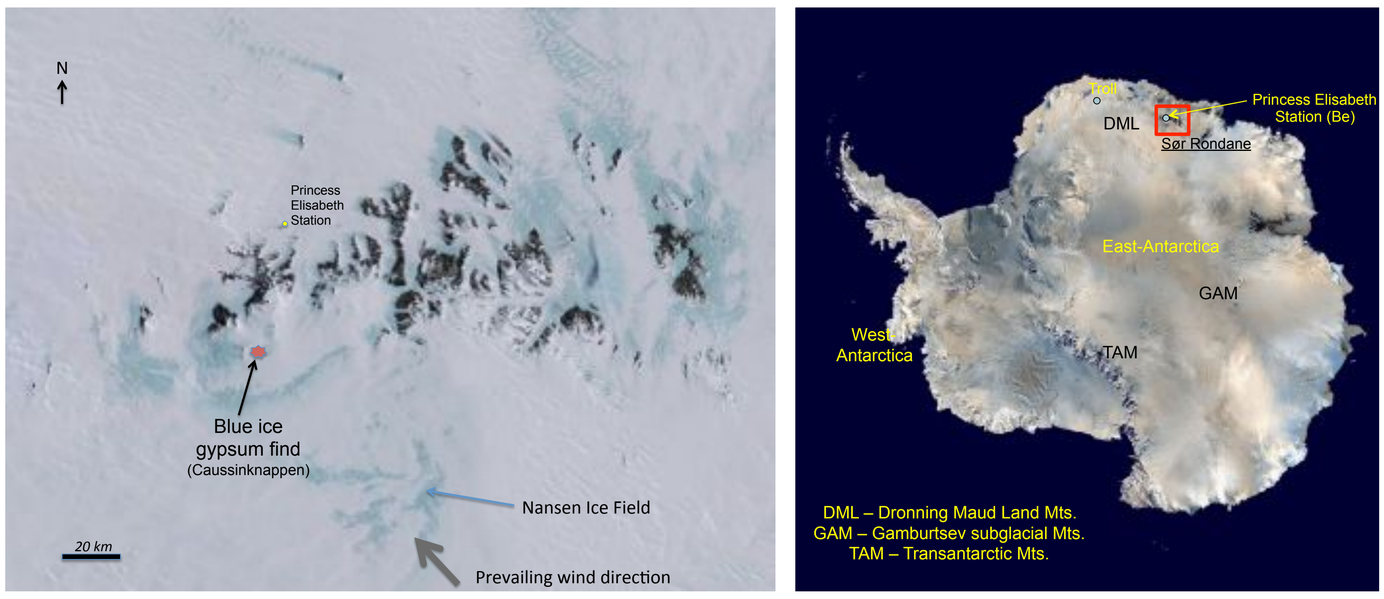

Fig. 1: Satellite image of Sør Rondane, East Antarctica, indicating extensive blue ice areas to the S and E of the mountain range. Blue ice gypsum localities are found on the S-side of the Sør Rondane Mountains at Caussinknappen and on the lee-side of the Nansen blue ice field at an elevation of ca. 2200 m.

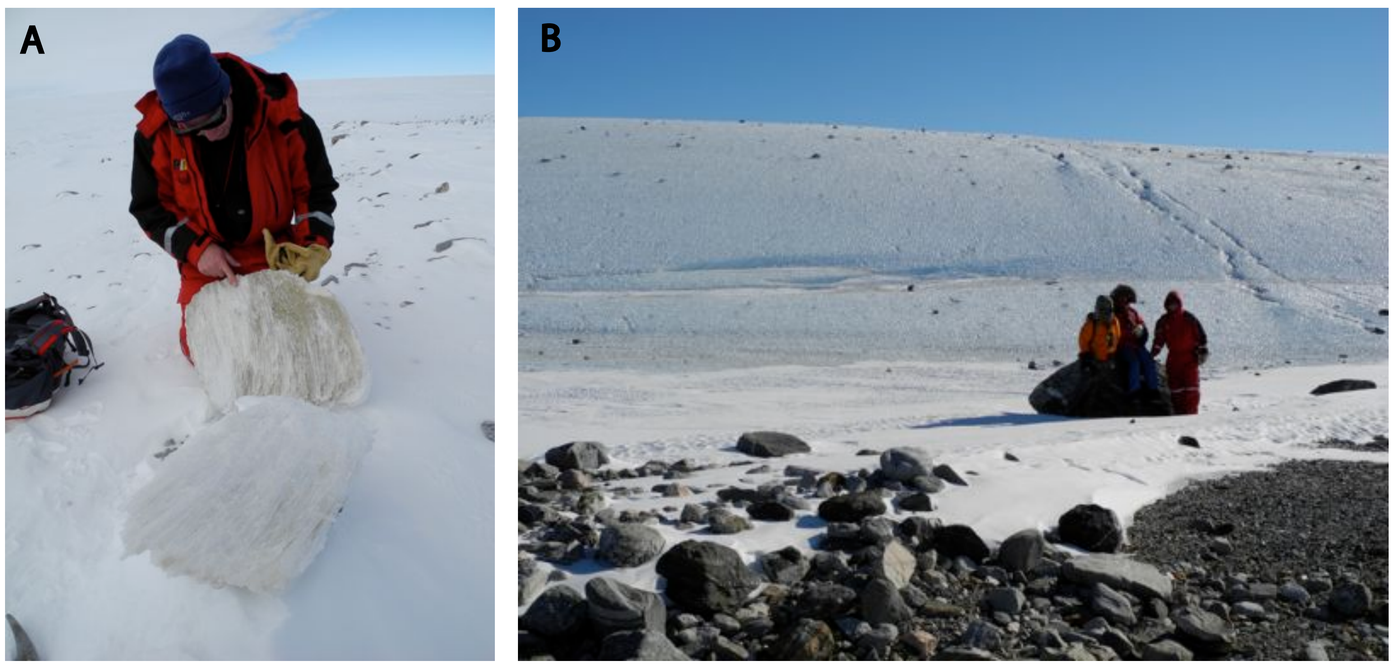

Fig. 2: A) Occurrence of coarse crystalline gypsum on the blue ice moraines, south-western Sør Rondane Mountains. The thin snow layer represents new summer snow and is underlain by blue ice. **B)** Typical blue ice moraine on the southside of the mountain range, view S. Blue ice transports large boulders that are assembled in a blue ice moraine (forground).

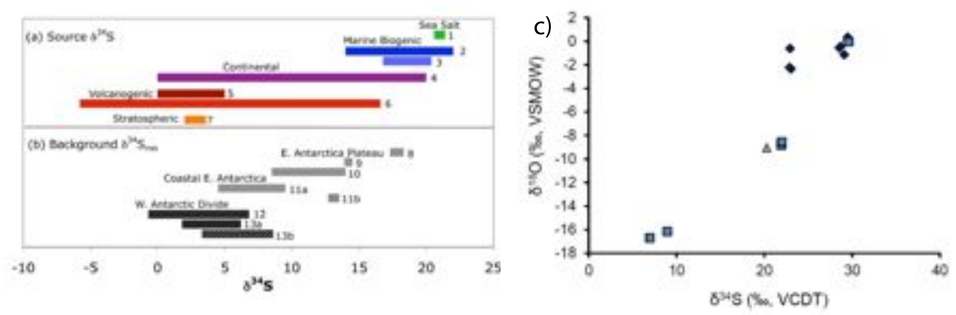

Fig. 5: Sulfur isotopic composition ($\delta^{34}S$) of different sulfur sources (a) and measured background non-sea-salt sulfur isotope values from Antarctic ice cores (b) (from Kunasek et al., 2010); c) Preliminary sulfur and oxygen isotope values for blue ice gypsum from Sør Rondane

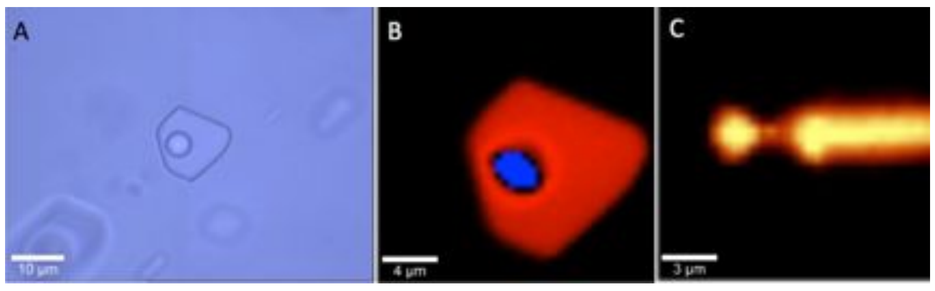

Fig. 6: A) Typical fluid inclusion in blue ice gypsum, consisting of a liquid and a gaseous phase; **B)** Raman spectrum of the fluid phase red (H_2O) and the gaseous phase blue (N_2); **C)** Raman map: liquid phase (vertical section through the FI, demonstrates excellent confocal depth resolution).

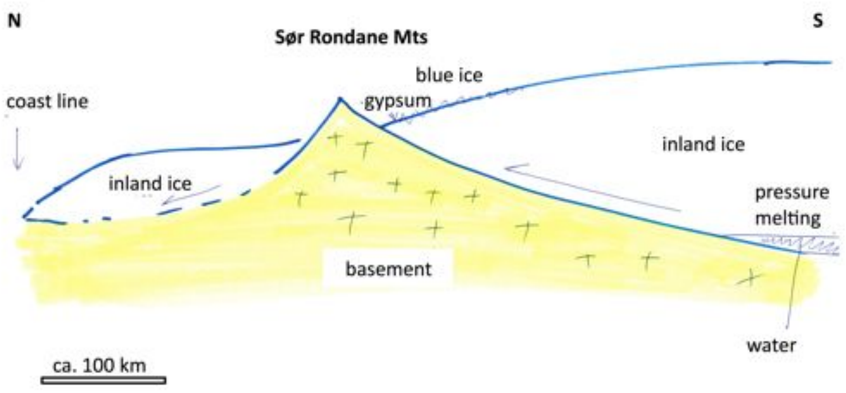

Fig. 7: Working hypothesis: Old ice exhumes along the southern side of the Sør Rondane Mts., ice sublimates, and Ca and SO_4 iones conentrate in sediment traps within blue ice moraines. Underneath thick ice, water forms from pressure melting. This might leach the basement for Ca, which is dominated by tonalitic gneisses. SO_4 is sufficiently available in the cryosphere.

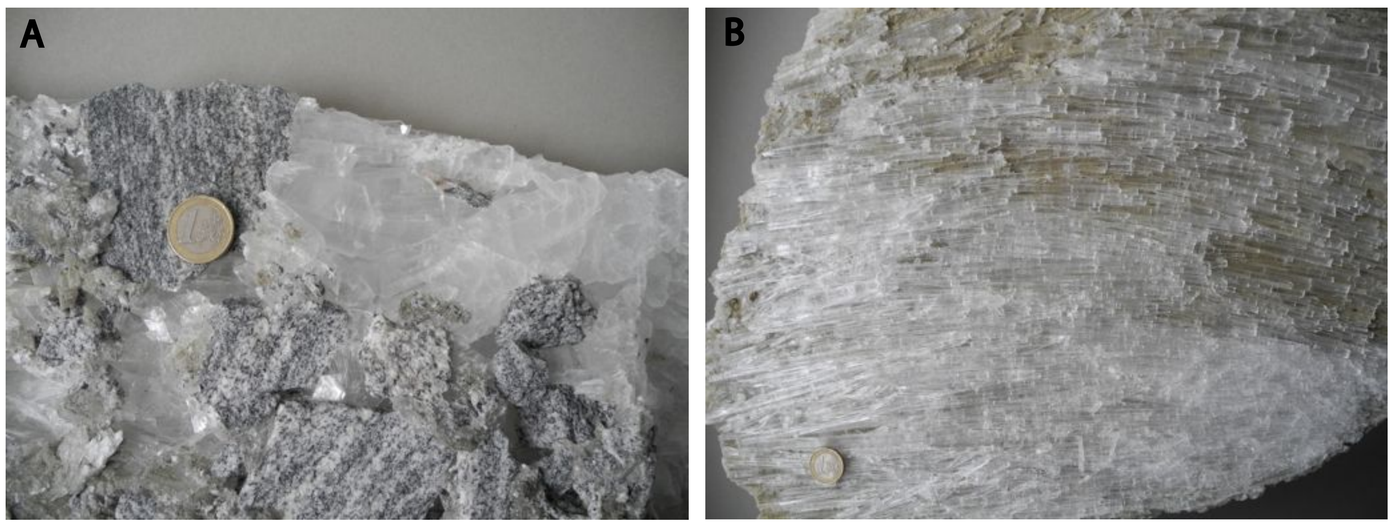

Fig. 3: A) Gypsum apprently overgrows moraine gravel of meta-tonalite gneiss. Meta-tonalite is the dominant lithology of SW Sør Rondane **B)** Gipsum crystals (selenite) are very clear but bent; in between individual grain abundant sand is commonly found (yellow).

Fig. 4:
A) Thins section, gypsum apprently overgrows moraine sand, note bent cleavage planes;
B) Cross section, gypsum sample;