

Introduction

The Balsfjord Series is located in the central part of Troms–Finnmark County, northern Norway, and is part of the upper allochthon of the Scandinavian Caledonides. It consists of an Ordovician–Silurian metasedimentary sequence lying on top of the mostly gabbroic Lyngen Magmatic Complex (LMC). The unit exhibits an inverted metamorphic gradient, where the metamorphic conditions increase from the base to the top, from very low grade in the southeast to medium grade in the west and northwest. The Balsfjord Series is sandwiched between two high-grade units, the Nakkedal + Tromsø Nappe Complex in the hanging wall and the Nordmannvik Nappe as the top part of the Reisa Nappe Complex (RNC) in the footwall.

One of the main motivations in this project is to resolve the Caledonian deformation history in the Balsfjord Series, ideally leading to a regional tectonic model explaining the tectonostratigraphic and metamorphic relationships between the abovementioned units.

Geological History and Area

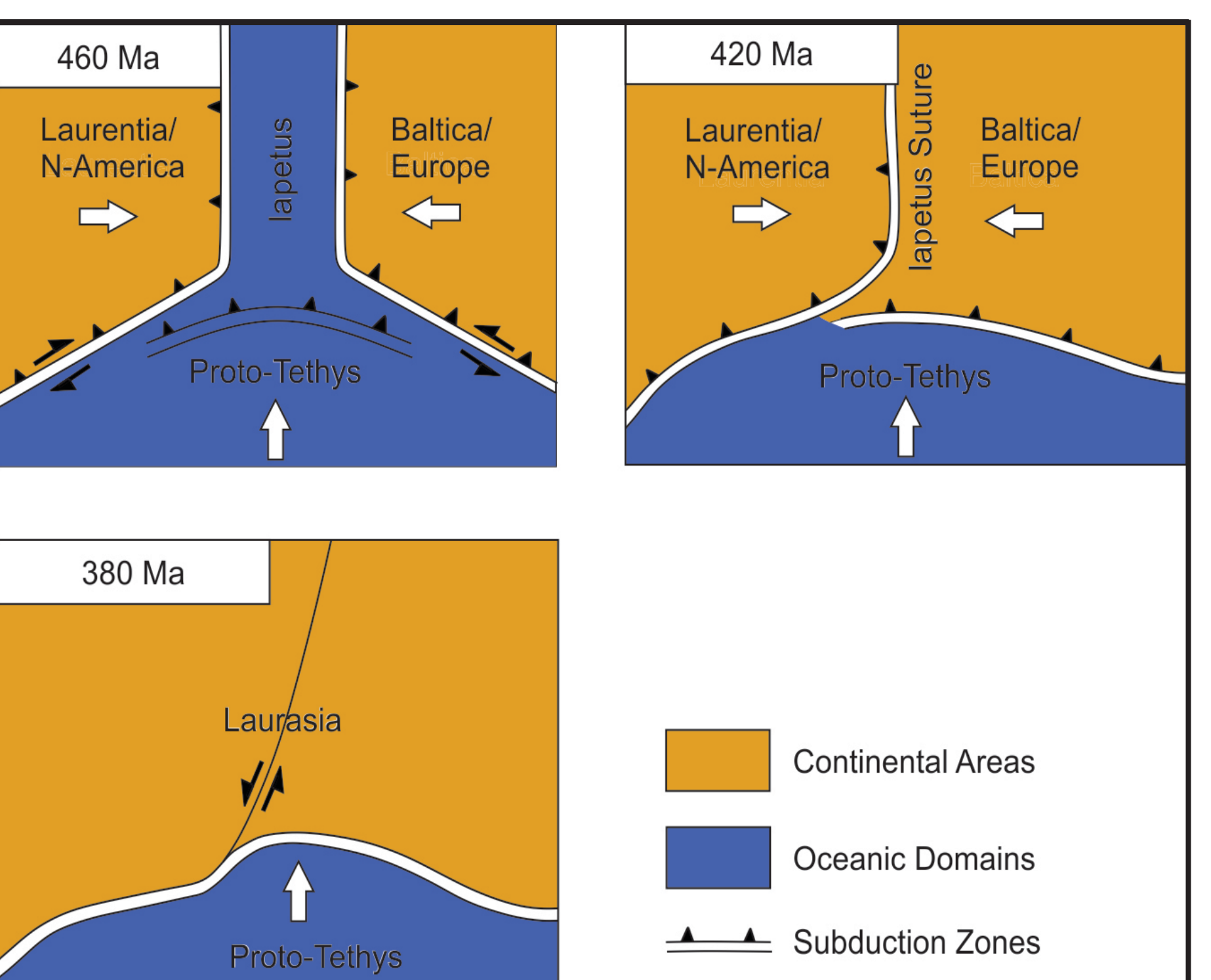


Fig. 1: Left: Schematic Reconstruction modified from Ziegler (1985) of the ancient collision between Laurentia and Baltica approximately 420 Ma ago resulting in the formation of the Caledonian mountain range. Right: Map of Scandinavia with rectangle marking the working area of the project around the city of Tromsø

Results

The Balsfjord Series features two main discernible folding phases. The earlier phase (D1) displays tight to isoclinal folds with flat lying axial surfaces parallel to the penetrative foliation. Observed fold axes are parallel with the stretching lineation. These folds are best preserved in the northwestern, upper part of the unit and are syn-metamorphic in certain areas, as they fold original bedding (transposed foliation). A later folding phase (D2) is represented by mainly open folds with inclined to steep axial surfaces. Their fold axes are gently plunging with a predominant NE–SW orientation.

Geological Map and Structural Geology

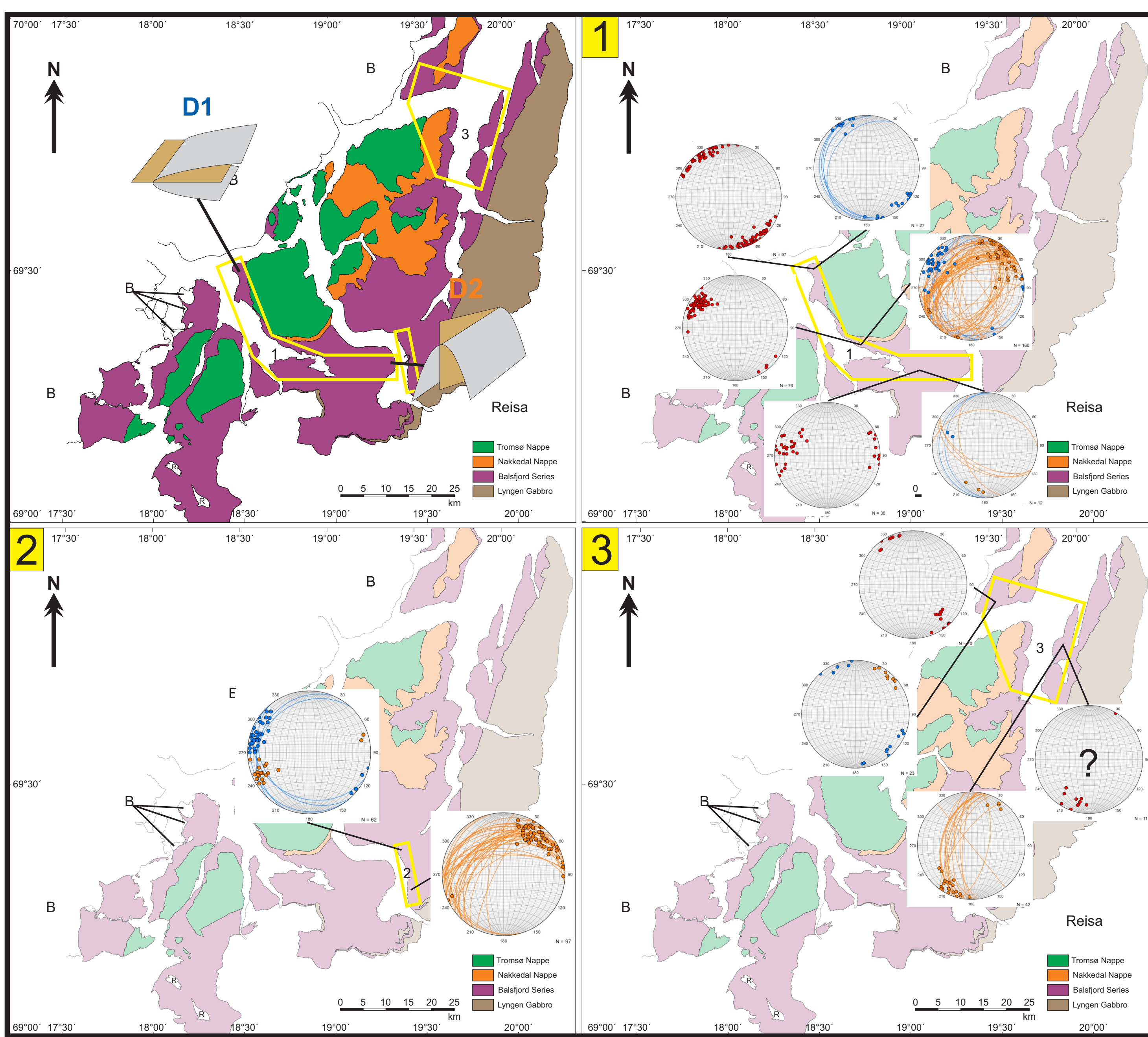


Fig. 2: Top Left: Geological Map modified from Augland et al. (2014) of the investigated area with idealized models of the two deformational events (D1 and D2) at the locations where they are most prominent. The area is subdivided into three zones that are compared by their structural properties (Schmidt Net). Red dots are flat lying Stretching Lineations (SL), blue Great Circles symbolize Fold Axial Planes (FAP) and blue dots represent Fold Axes (FA).
1: In Zone 1 in the NW the SL show an average NW-SE direction, albeit some spread. Note, that this is parallel to the orientation of the FA that are linked to flat lying W-dipping FAP (D1). Going further SE in the area we see the SL are more concentrated in the NW and there no longer any N-S measurements. Looking at the folding, a new population emerges (D2) with NE-SW directed FA and steeply dipping FAP. Finally, at the very south it is evident the SL have reoriented even more and are now organised almost E-W with some even being WSW-ENE. Analysis of the folding here needs more data but there are first signs of both D1 and D2 being active here as well.
2: Zone 2 lies further to the E of Zone 1. D2 is very dominant in the southern part but there is no sign of D1. Moving further north D1 picks up again and coexists with D2. SL were difficult to verify in this zone.
3: Starting in the W of Zone 3, the SL have the same orientation as the SL in the NW of Zone 1. Measured FA indicate the existence of both D1 and D2, albeit D1 being more dominant. Looking at the E side of the zone across the fjord we can see SL in a NE-SW orientation. Judging by their orientation this may actually be FA or crenulations. More fieldwork needs to give clarification on this matter. The FAP are typical for D2 and are exceptionally steep.

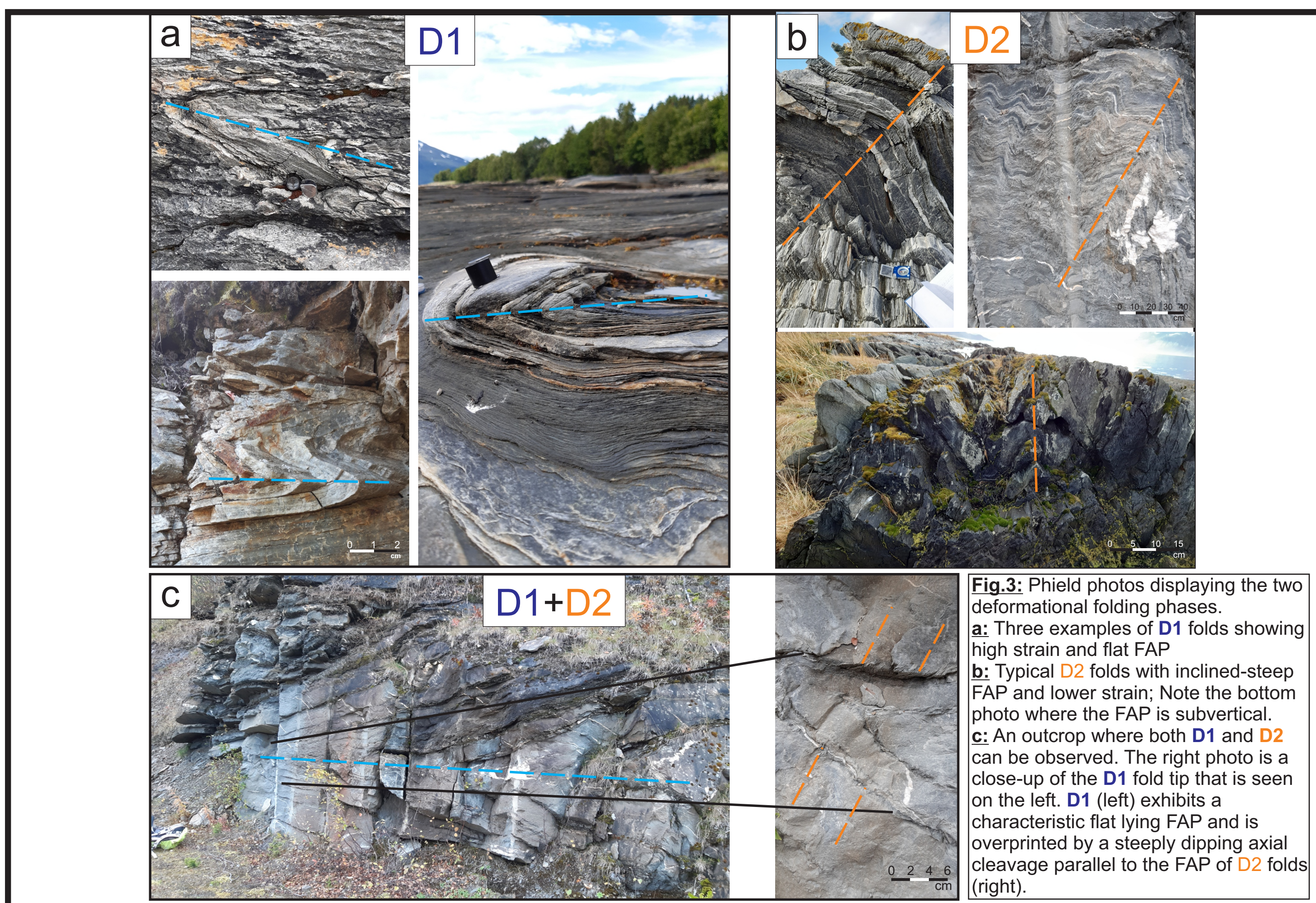


Fig. 3: Field photos displaying the two deformational folding phases.
a: Three examples of D1 folds showing high strain and flat FAP
b: Typical D2 folds with inclined-steep FAP and lower strain; Note the bottom photo where the FAP is subvertical.
c: An outcrop where both D1 and D2 can be observed. The right photo is a close-up of the D1 fold tip that is seen on the left. D1 (left) exhibits a characteristic flat lying FAP and is overprinted by a steeply dipping axial cleavage parallel to the FAP of D2 folds (right).

Metamorphism and Age Dating

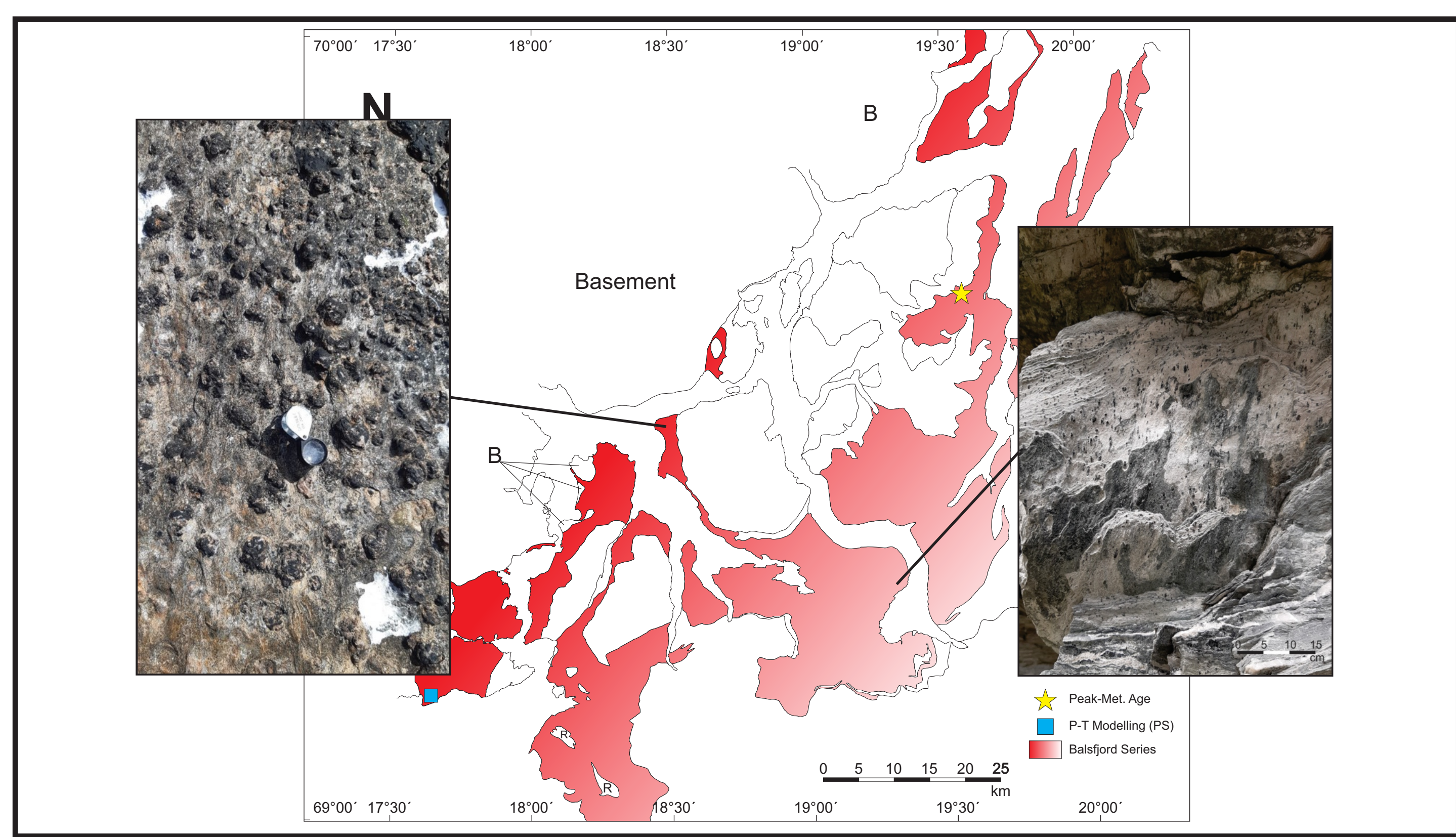


Fig. 4: A map showing the Balsfjord-Series and its inverted heterogeneous metamorphic grade. The lower part of the unit in the SE displays distinctly low grade rocks like chloritic schists without biotite (right) and features characteristic metapelites like garnet-mica schists in the upper NW-W part (left). This increase in metamorphic grade appears to be tied to tectonic contacts. The higher grade Balsfjord Series is usually found in close proximity to the nappe contact with the Tromsø Nappe, whereas the lower grade parts are situated closer to the Lyngen Gabbro in the E. First results on constraining the conditions and timing of the peak metamorphism of the Balsfjord-Series can be observed in Fig. 5. The analysed localities where the respective samples were taken are marked (yellow star and blue rectangle).

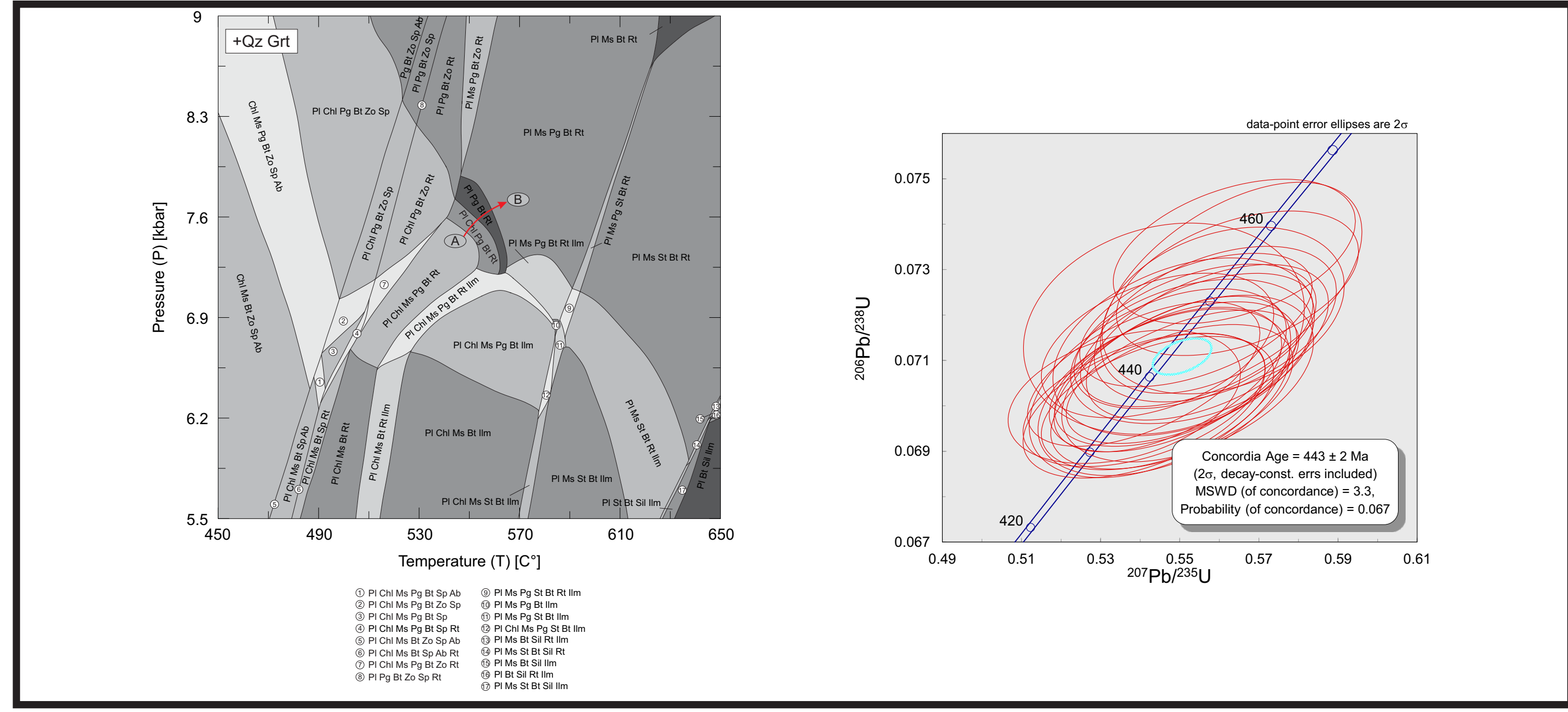


Fig. 5: Left: P-T Pseudosection calculated in Perple_X (Connolly, 2005) in the NCKFMASH system modelling a metapelitic sample (garnet-micaschist) of the Balsfjord-Series. The location of the sample is marked on Fig. 4 (blue rectangle). A and B represent garnet growth P-T conditions where A is the garnet core and B is the garnet rim. The P-T conditions for the core and rim are quite similar and lie at around 550 °C and 7.5 kbar. Right: U-Pb dating of the peak metamorphism in a garnet-micaschist with monazites that are assumed to have grown during peak metamorphism. The location of the sample is in the E of the Balsfjord-Series (yellow star in Fig. 4).

Interpretations and Conclusions

- The two folding events (D1 and D2) are interpreted to be genetically related but slightly diachronous. The earlier folding phase D1 was likely generated during nappe thrusting and peak metamorphism of the Balsfjord Series (443 Ma). The subsequent open folding D2 is explained as a result of continued shearing and shortening of the weaker metapelitic Balsfjord Series against the more rigid gabbroic part of the Lyngen Gabbro in the E during late stages of the Caledonian nappe thrusting.
- Dating of the peak metamorphism of the overlying Tromsø-Nakkedal complex has yielded ages of around 450 Ma (Fassmer et al. 2020, Augland et al. 2014) and 439 Ma for the underlying Reisa Nappe complex (Faber et al. 2019).
- Both of these units show high metamorphic grades with the lower-grade Balsfjord-Series being sandwiched in between. The recent dating of its metamorphism (443 Ma) reveals a tectonic continuity between these units and that the final exhumation of the Tromsø-Nakkedal Complex took place during prograde metamorphism of the underlying Balsfjord Series.

References

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