Early Devonian sinistral strike-slip in the Caledonian basement of Oscar II Land advocates for escape tectonics as a major mechanism for Svalbard terranes assembly

Grzegorz Ziemniak, Jarosław Majka, Maciej Manecki, Katarzyna Walczak, Pauline Jeanneret, Stanisław Mazur, Karolina Kośmińska

AGH

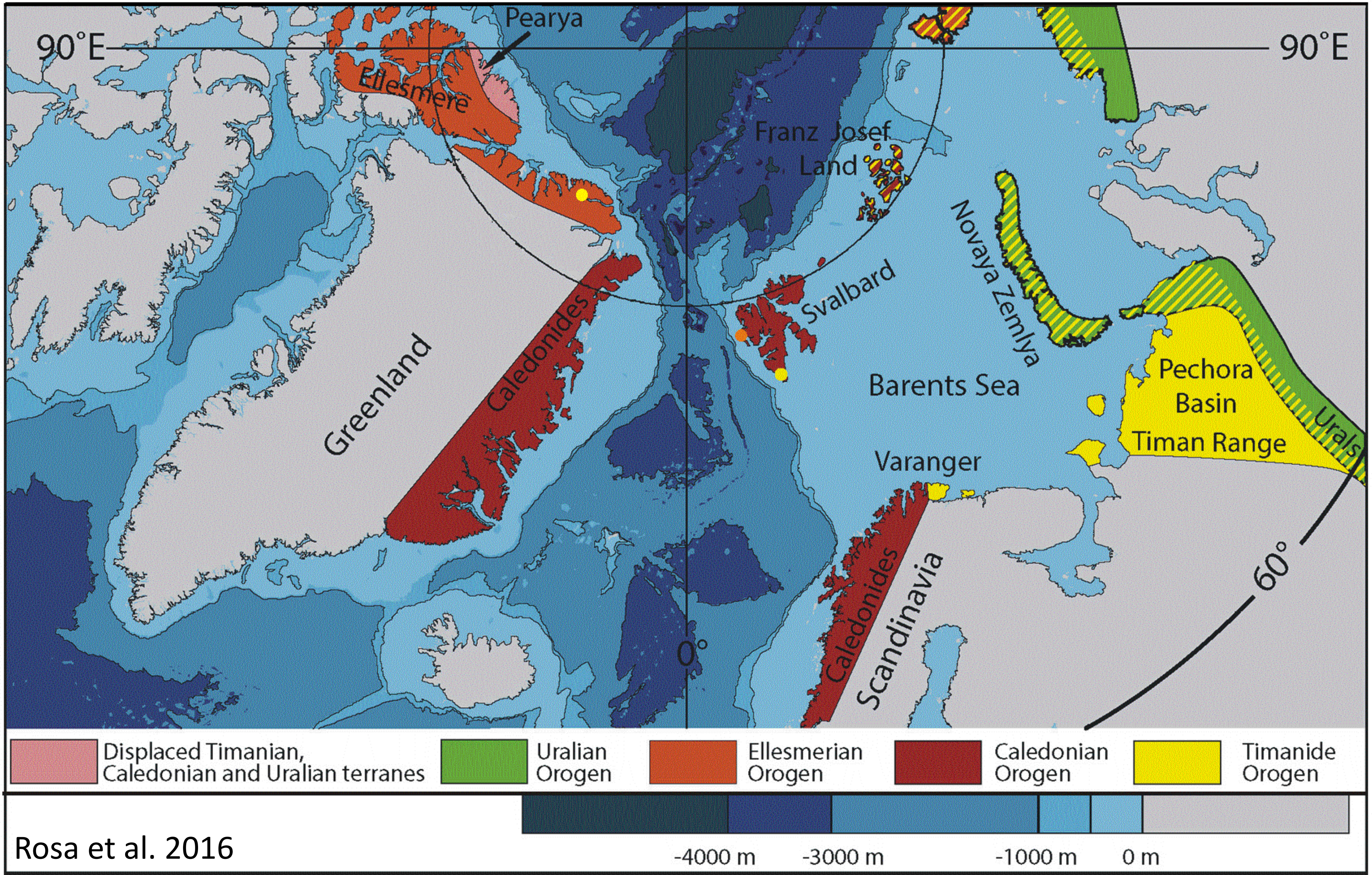
UPPSALA UNIVERSITET

PAN POLISH ACADEMY OF SCIENCES

UBFC

OROGEN DYNAMICS TEAM

Svalbard – the key to high Arctic



Rosa et al. 2016

Tectonothermal events:

*Late-Grenvillian
~950 Ma
*Torellian-Timanian
~570-640 Ma
*Caledonian
~420-480 Ma
*Ellesmerian
~360 Ma
*Eurekan
~40 Ma

Svalbard Basement Provinces

Eastern Province

North-western Province

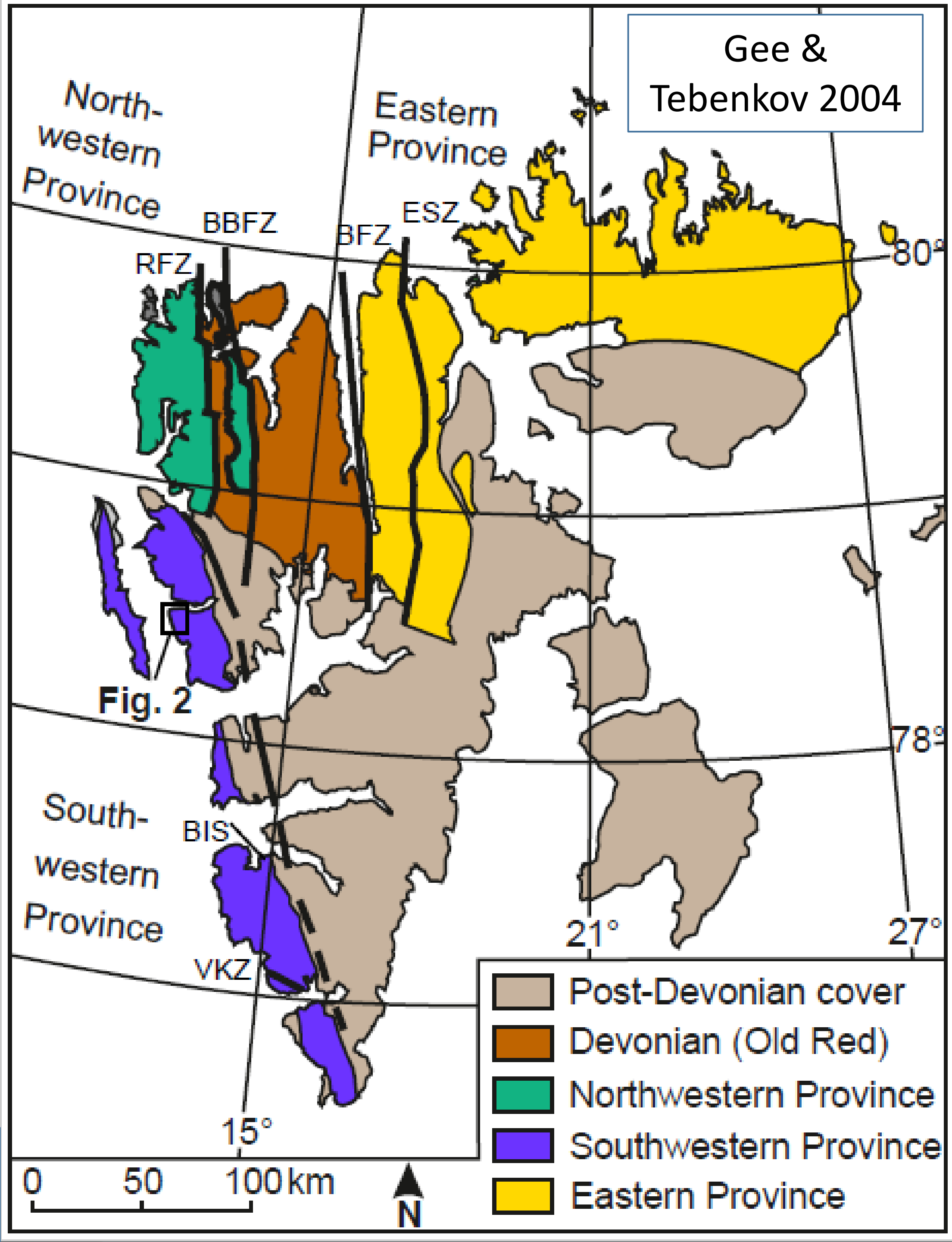
------Laurentian margin

South-western Province

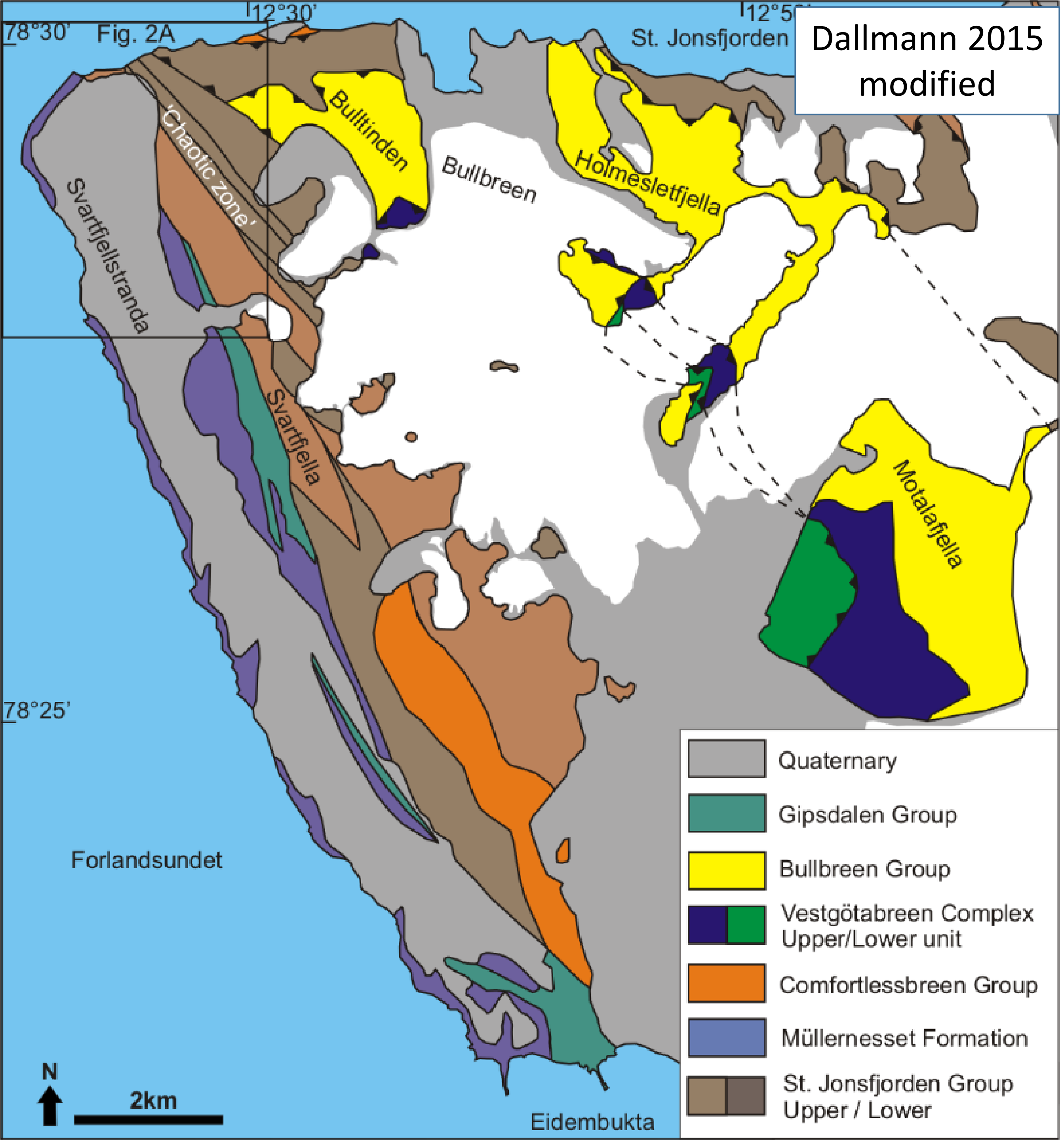
-------Pearya Terrane

-------Timanides

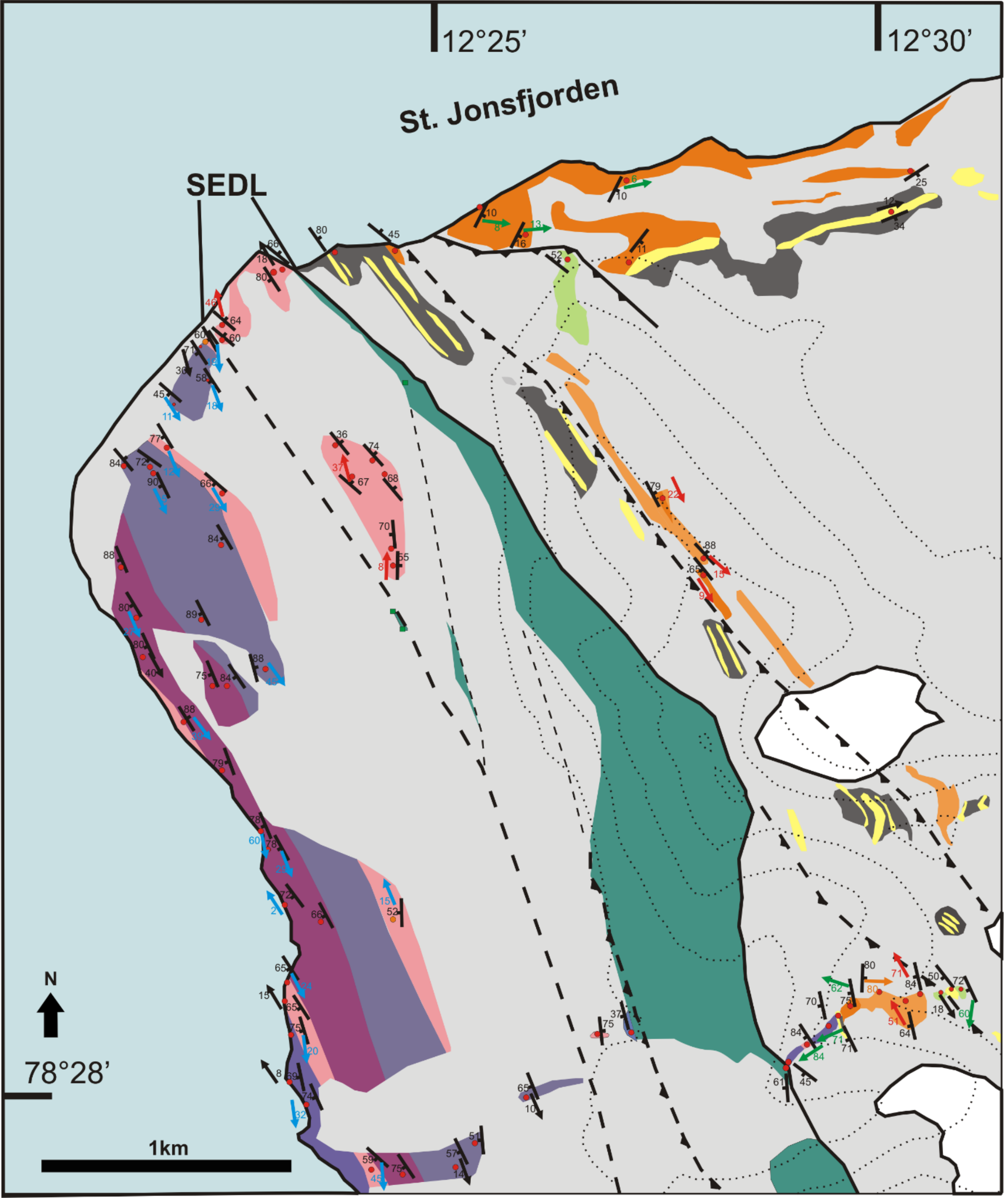
-------Laurentian margin



BBFZ-Breibogen-Bockfjorden Fault Zone; BFZ - Billefjorden Fault Zone; BIS – Berzeliuseggene Unit; ESZ – Eolusletta Shear Zone; RFZ –


Dallmann 2015 modified
12°30'
78°30'
Fig. 2A
St. Jonsfjorden
Bulltinden
Bullbreen
Holmesletfjella
'Chaotic zone'
Svartfjellstranda
Svartfjella
Motalafjella
78°25'
Forlandsundet
Eidembukta
N
2km
Quaternary
Gipsdalen Group
Bullbreen Group
Vestgötabreen Complex
Upper/Lower unit
Comfortlessbreen Group
Müllernesset Formation
St. Jonsfjorden Group
Upper / Lower

Oscar II Land



Quaternary

Carboniferous (undifferentiated)

Oscar II Land Basement (late Neoproterozoic)

Marbles

Dolomites

Chlorite-rich phyllites

Calcareous phyllites

Calcareous phyllites with clasts

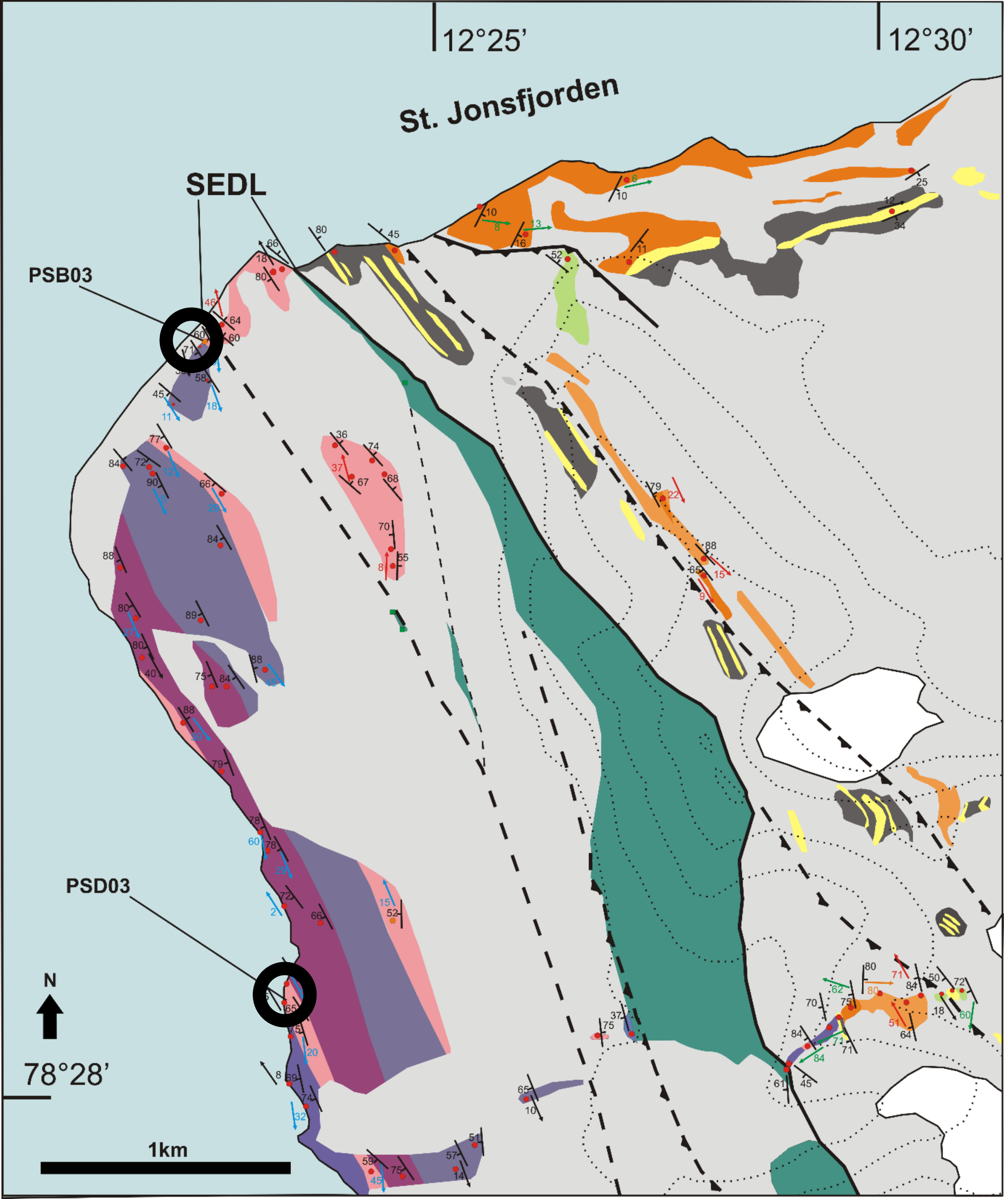
Müllernesset Formation (late Mesoproterozoic - - early Neoproterozoic)

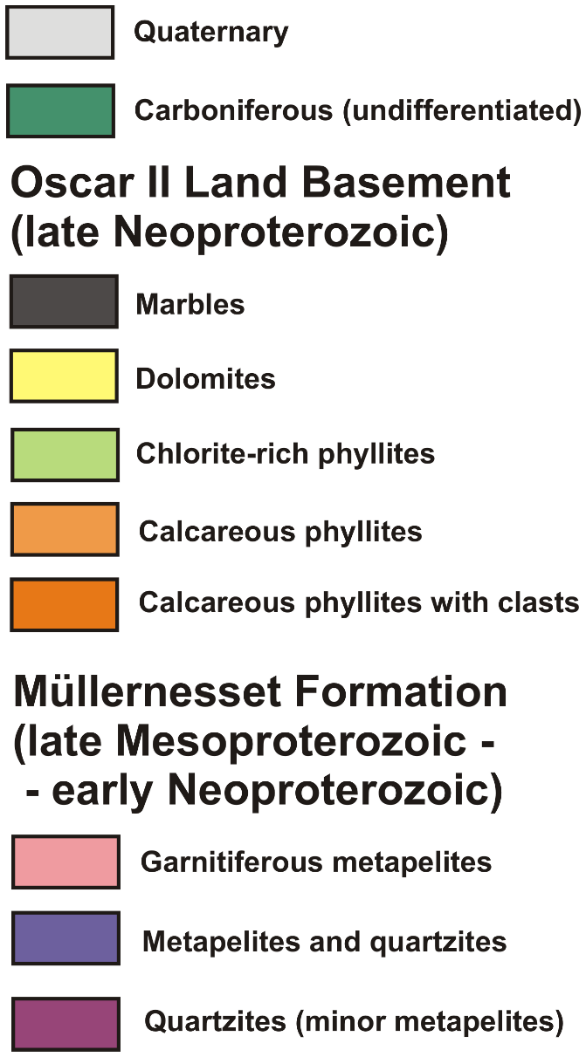
Garnitiferous metapelites

Metapelites and quartzites

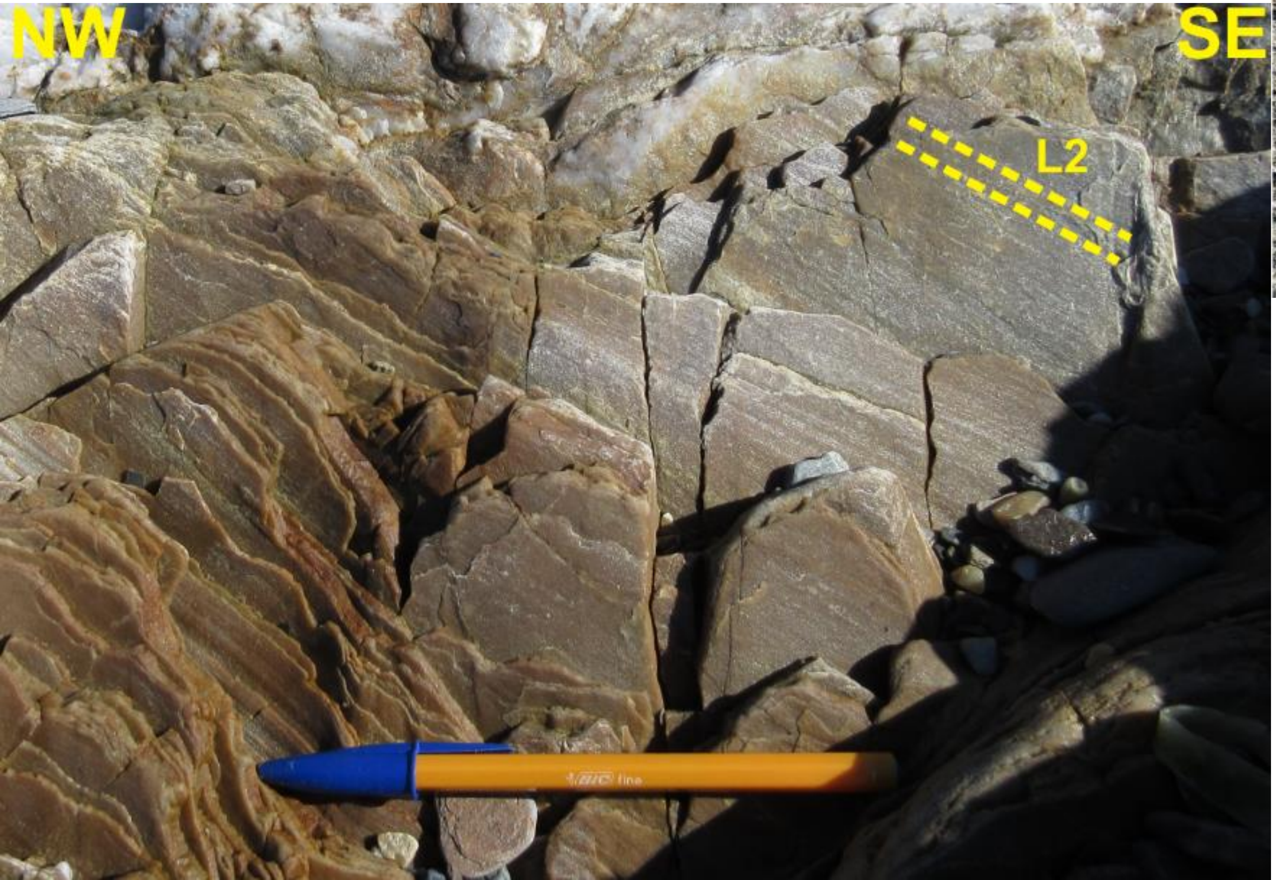
Quartzites (minor metapelites)

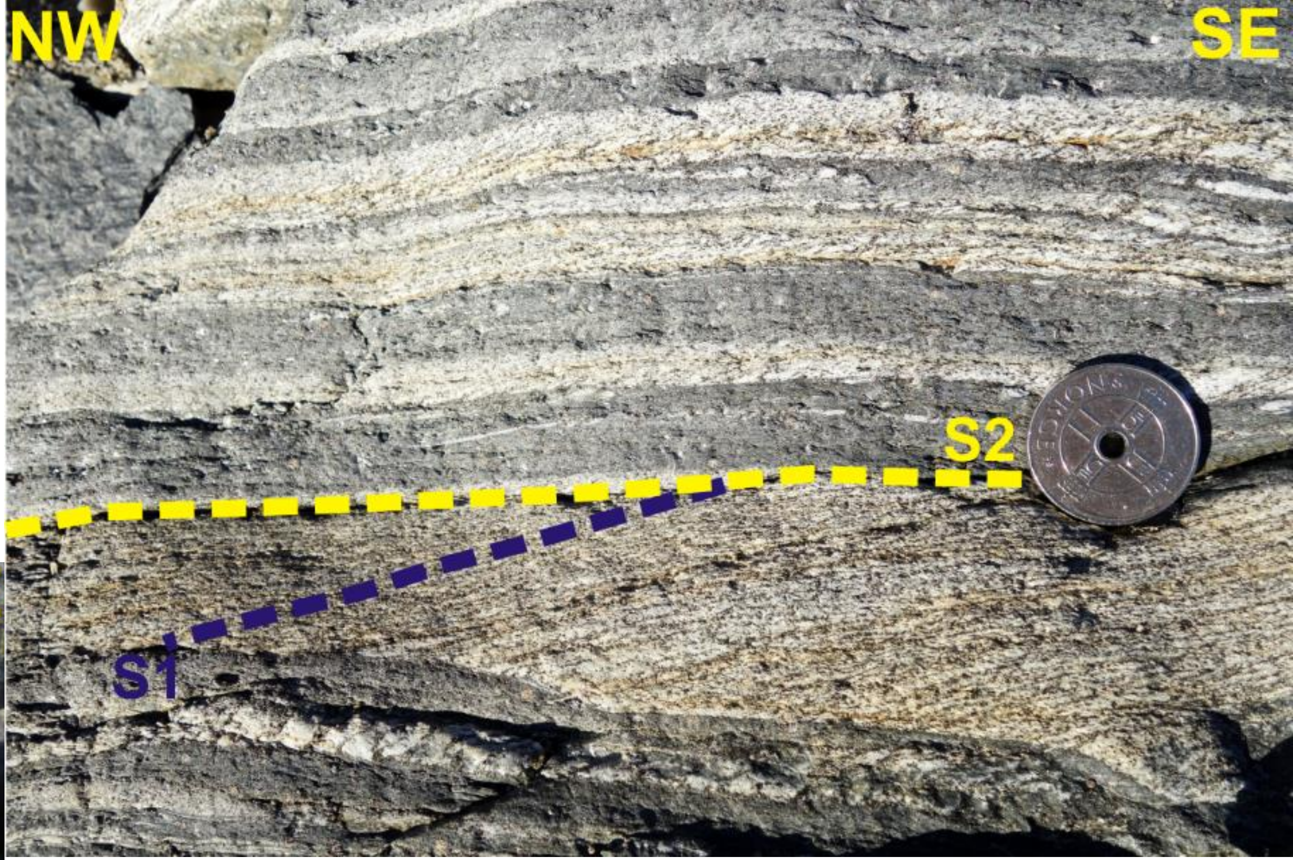
Oscar II Land





Metapelites and metapsammites of the Müllernesset Formation

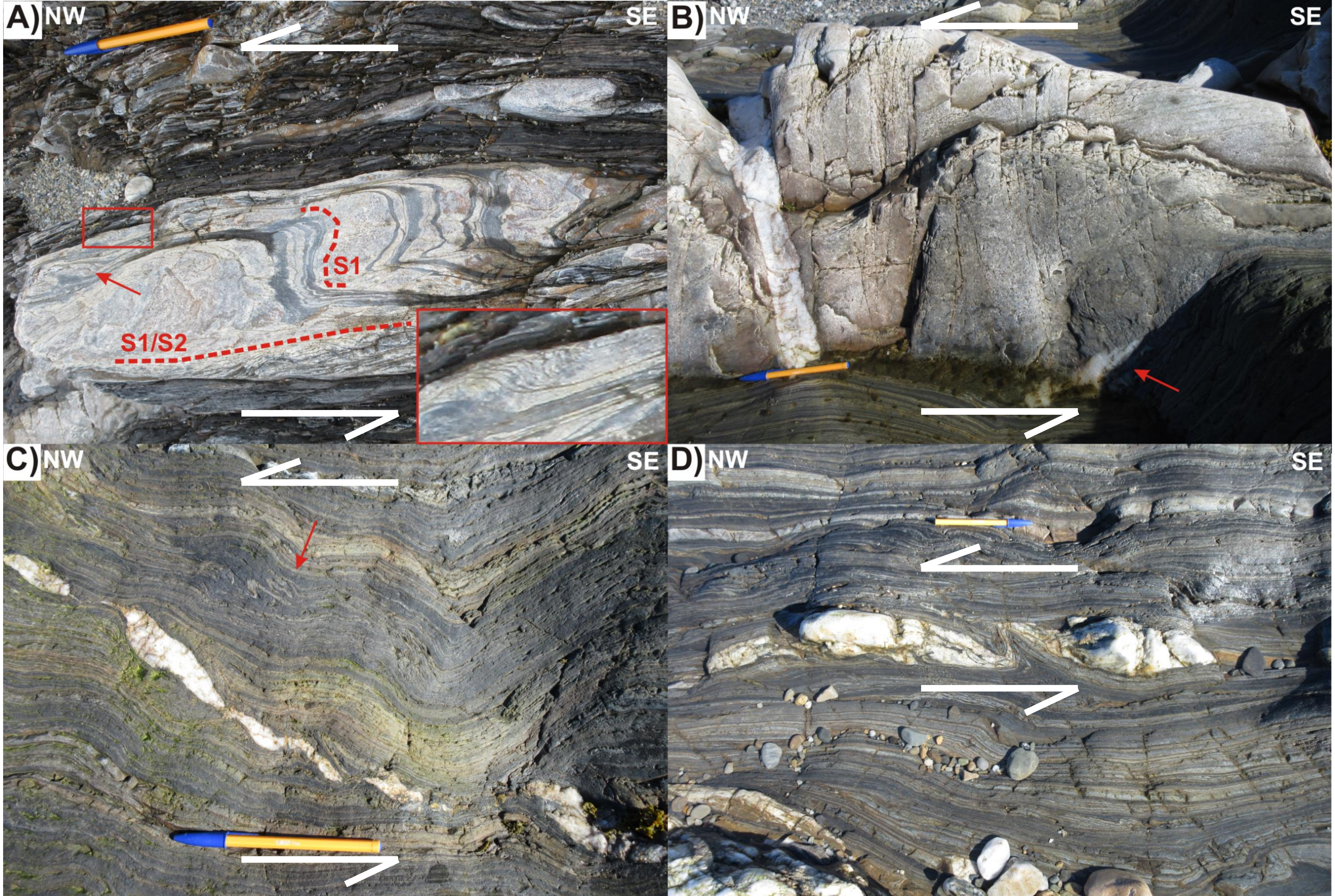




S2 Mylonitic foliation

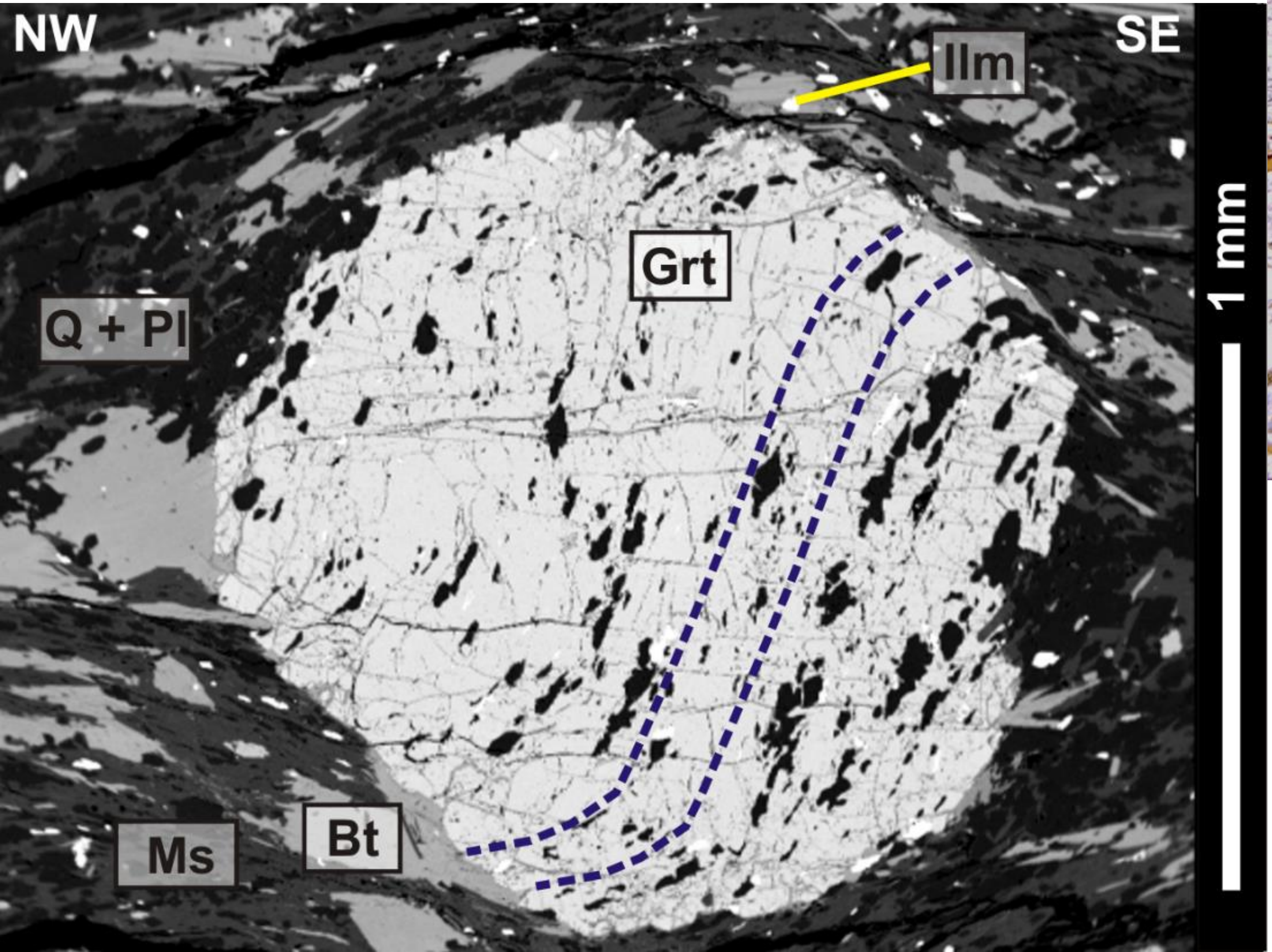
L2 stretching lineation

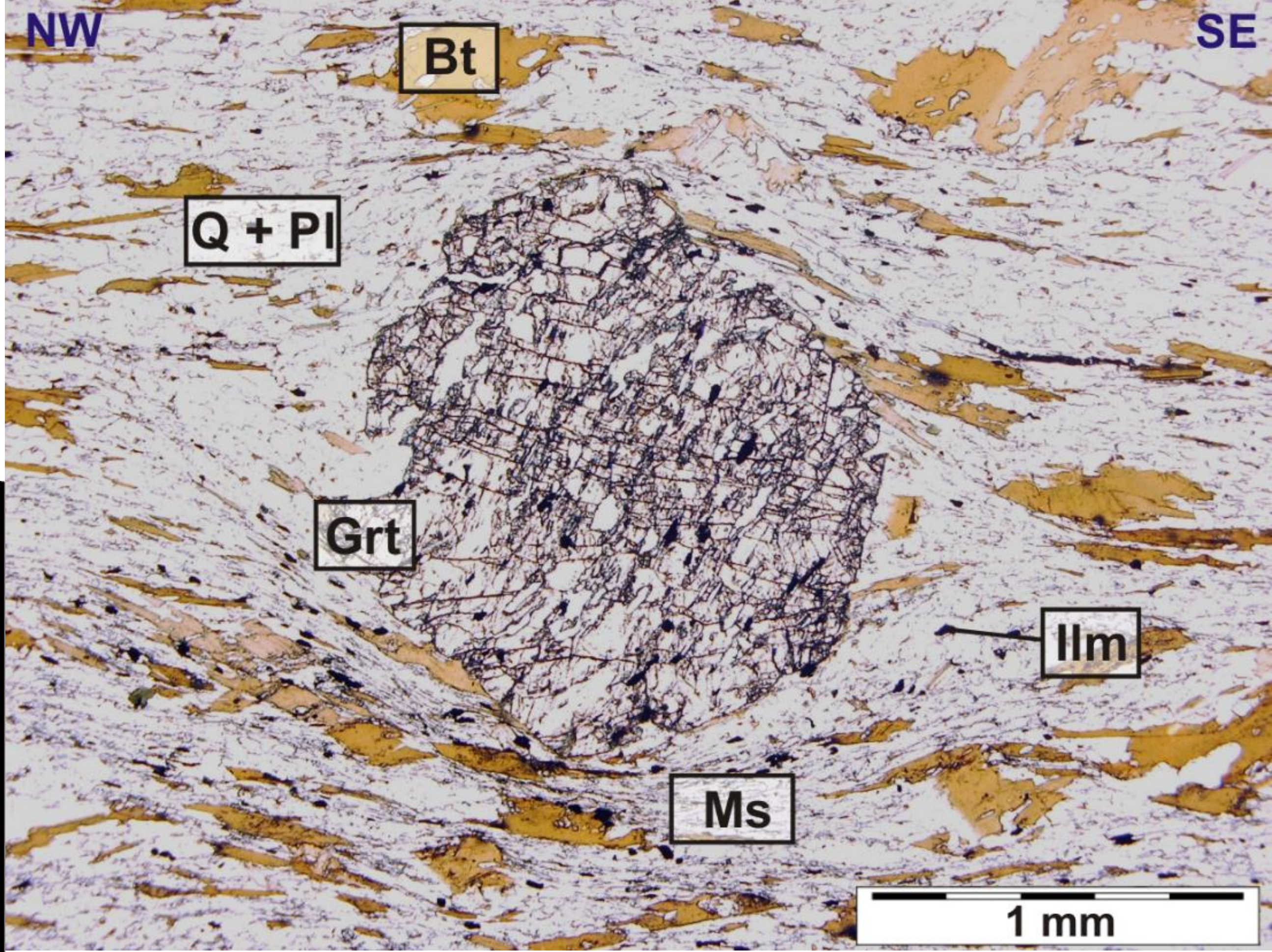
Left-lateral kinematic indicators


A)
NW
SE
S1
S1/S2
B)
NW
SE
C)
NW
SE
D)
NW
SE

M1 paragenesis

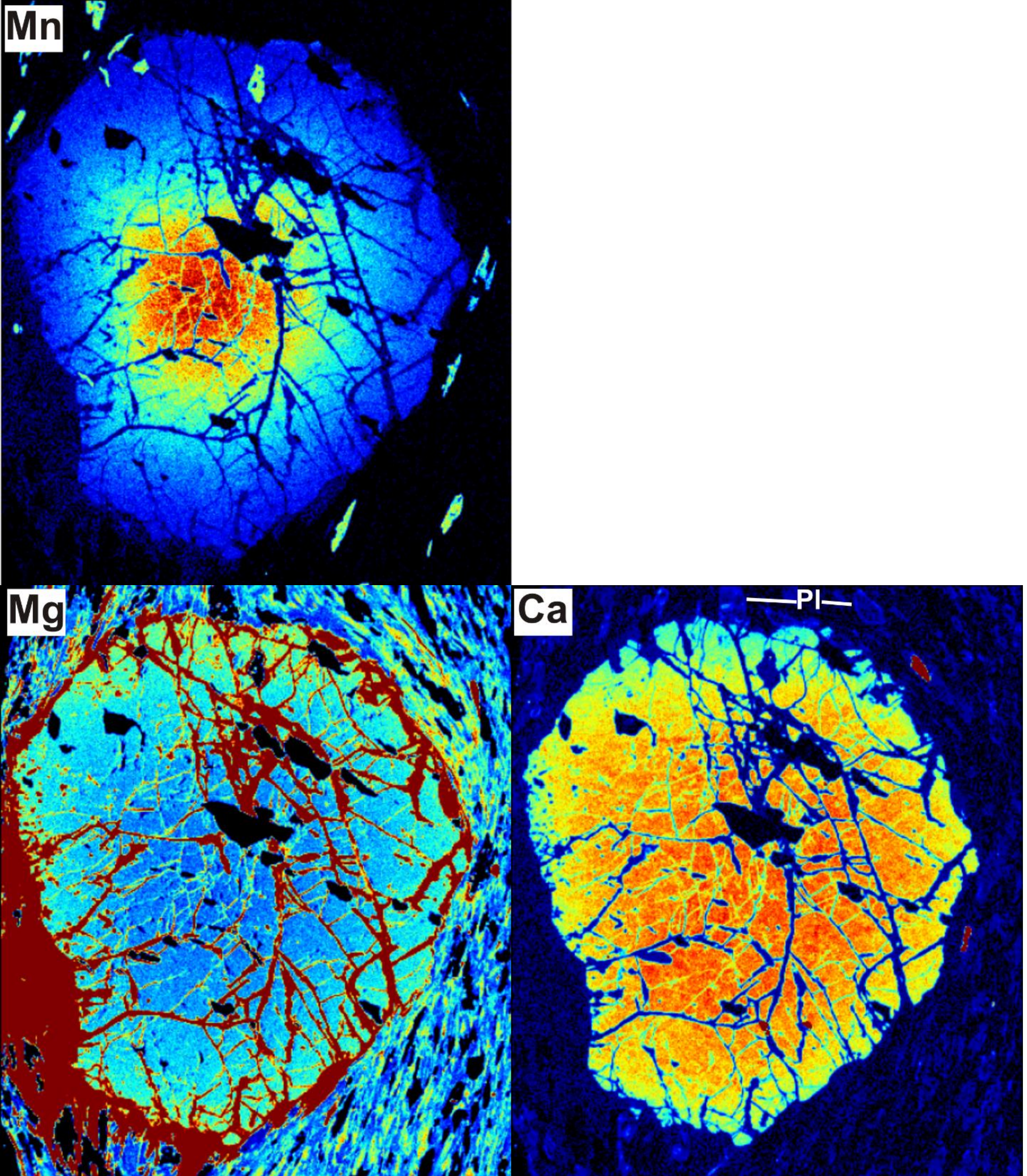
Grt + Bt + Ms + Pl + Q + Ilm + Aln + Ap





S – shape inclusion trails in Grt & Bt

Allanite included in Grt & Bt



M1 paragenesis - chemistry

Garnet core: Alm_{62} Grs_{18} Sps_{17} Prp_{3}

Garnet rim: Alm_{84} Grs_{10} Prp_{6} Sps_{1}

Plagioclase core: Xab = 0.99

Plagioclase rim: Xab = 0.91

White mica: Si 3.18 - 3.13 a.p.f.u.

Mg 0.11 - 0.14 a.p.f.u.

Biotite: Ti 0.10 - 0.12 a.p.f.u.

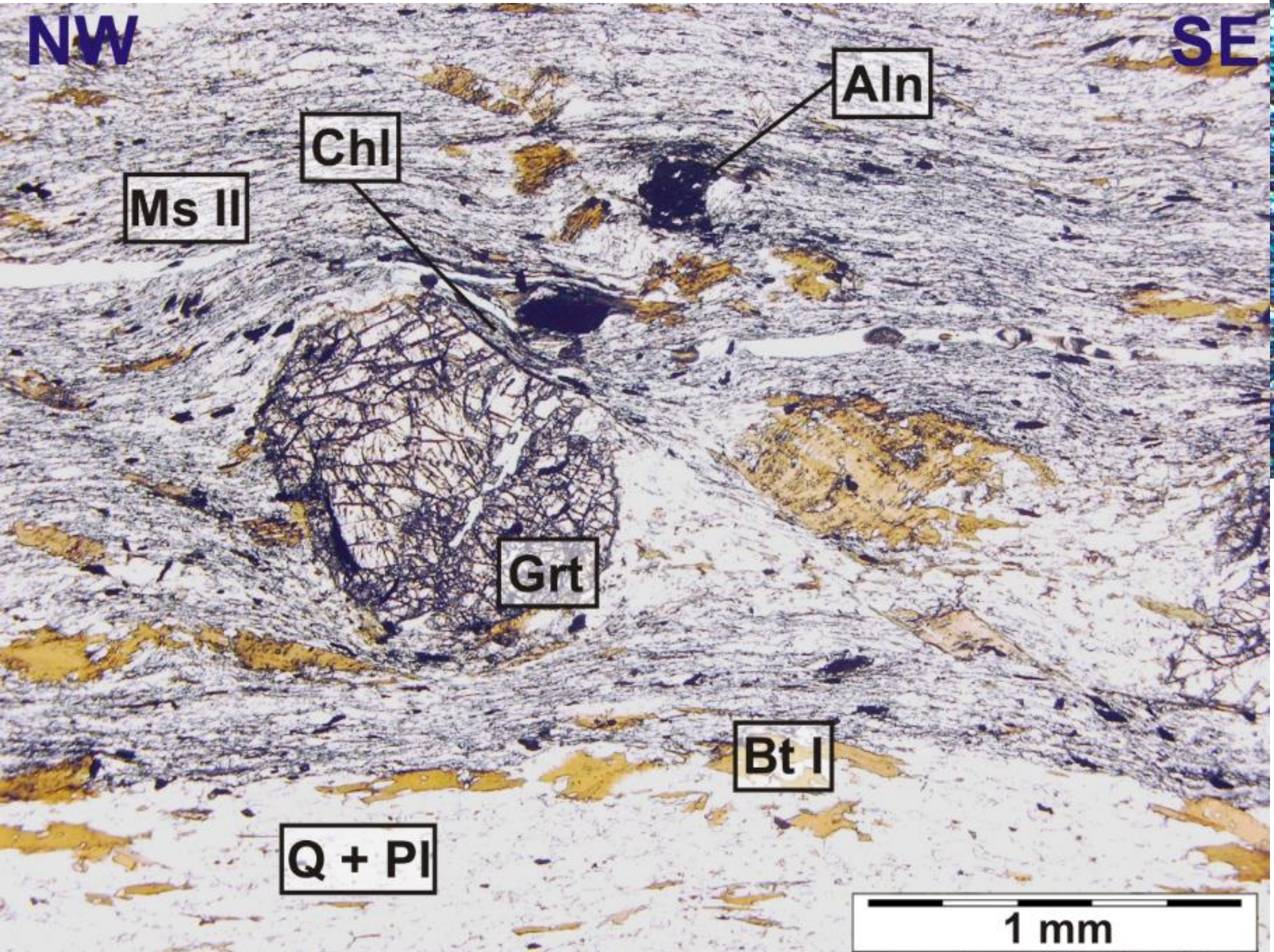
PT estimates (Ca-Fe exchange in garnet Wu et al. 2019)

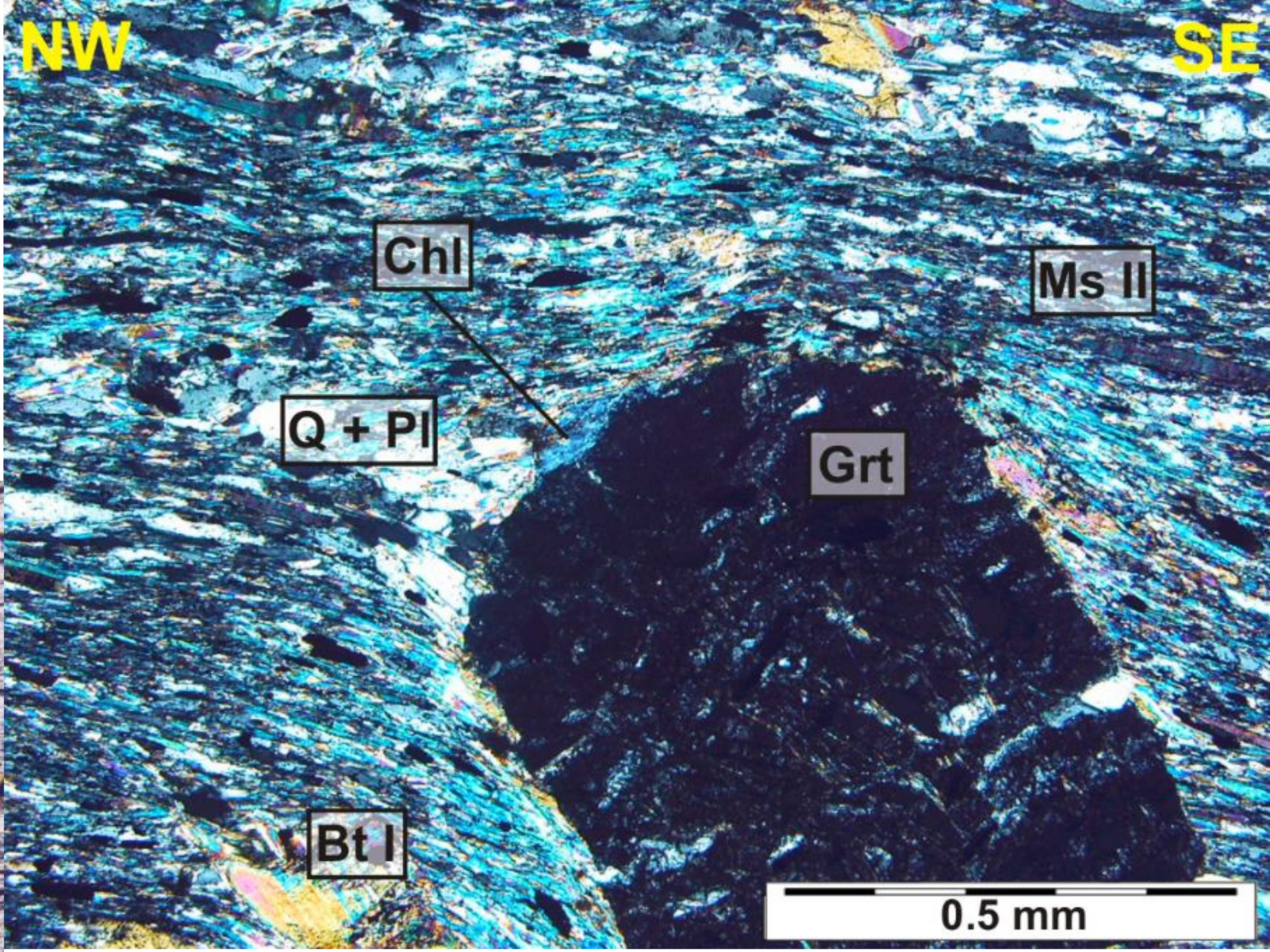
Garnet core: 480 - 520 °C; 6.6 - 7.1 kbar

Garnet rim: 530 - 560 °C; 5.0 - 5.8 Kbar

M2 paragenesis

Bt + Ms + Chl + Q + Ilm + Mnz



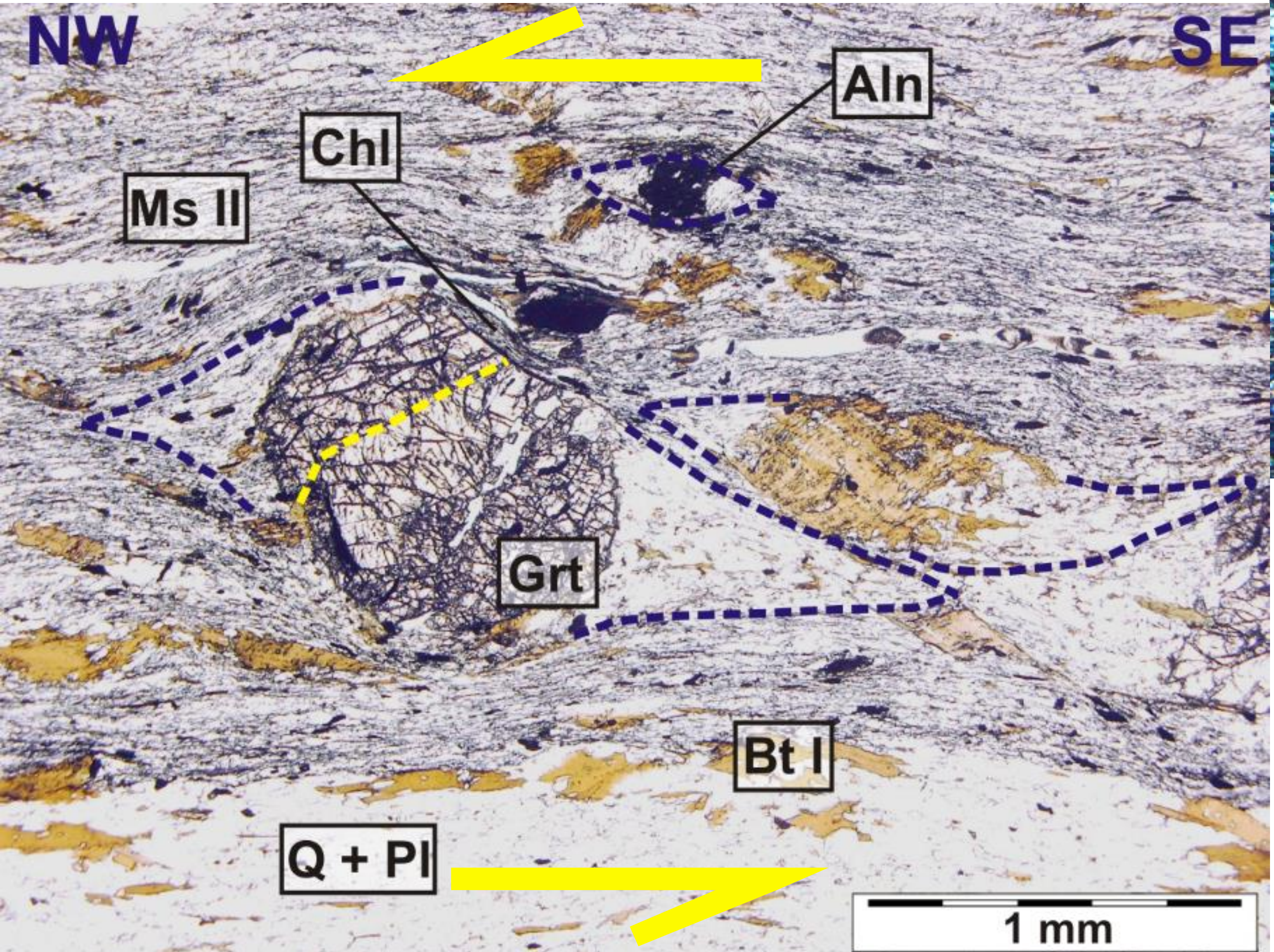


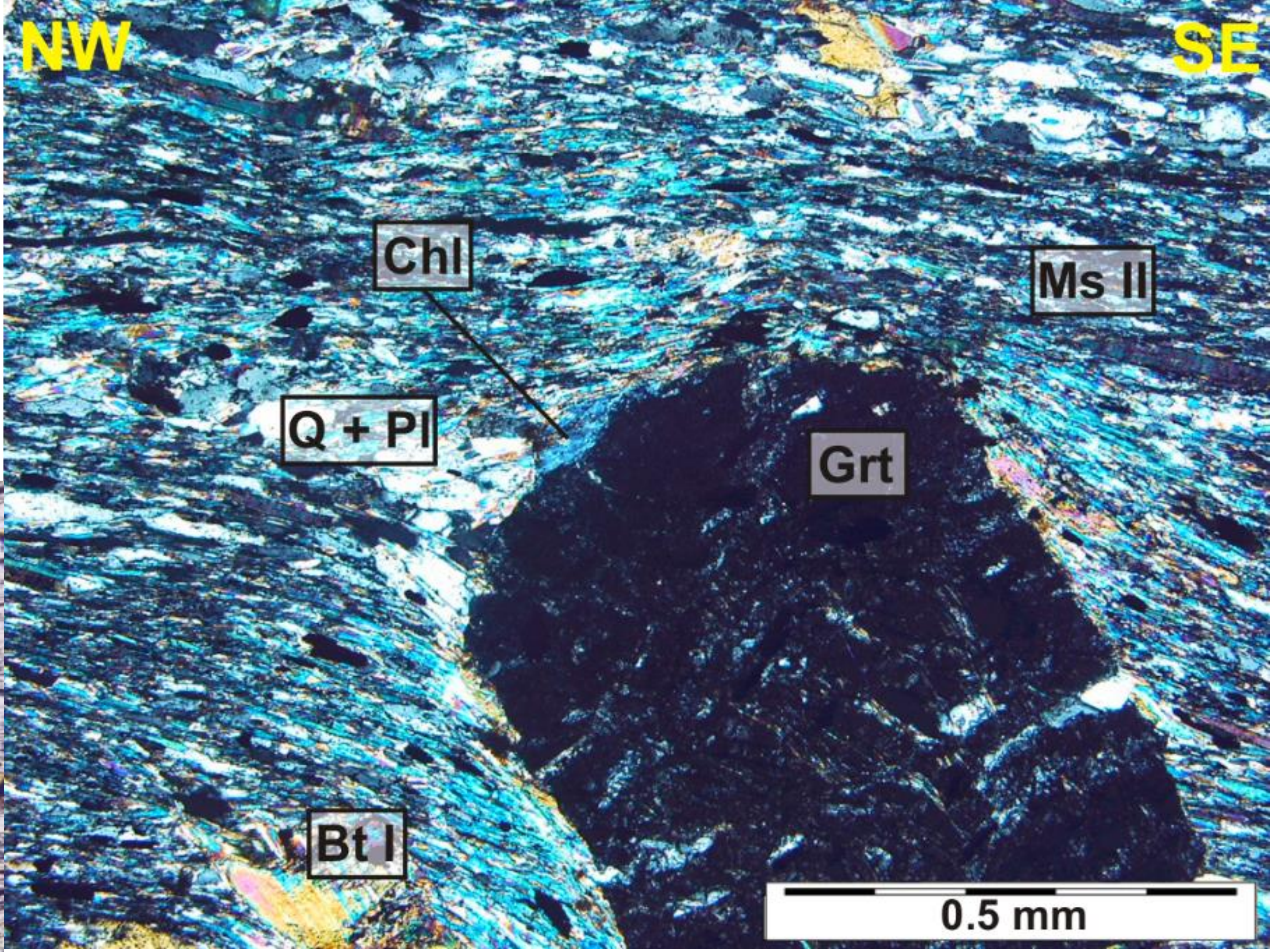
Decreased grain size of the matrix

Chl replacing Grt and Bt

M2 paragenesis

Bt + Ms + Chl + Q + Ilm + Mnz



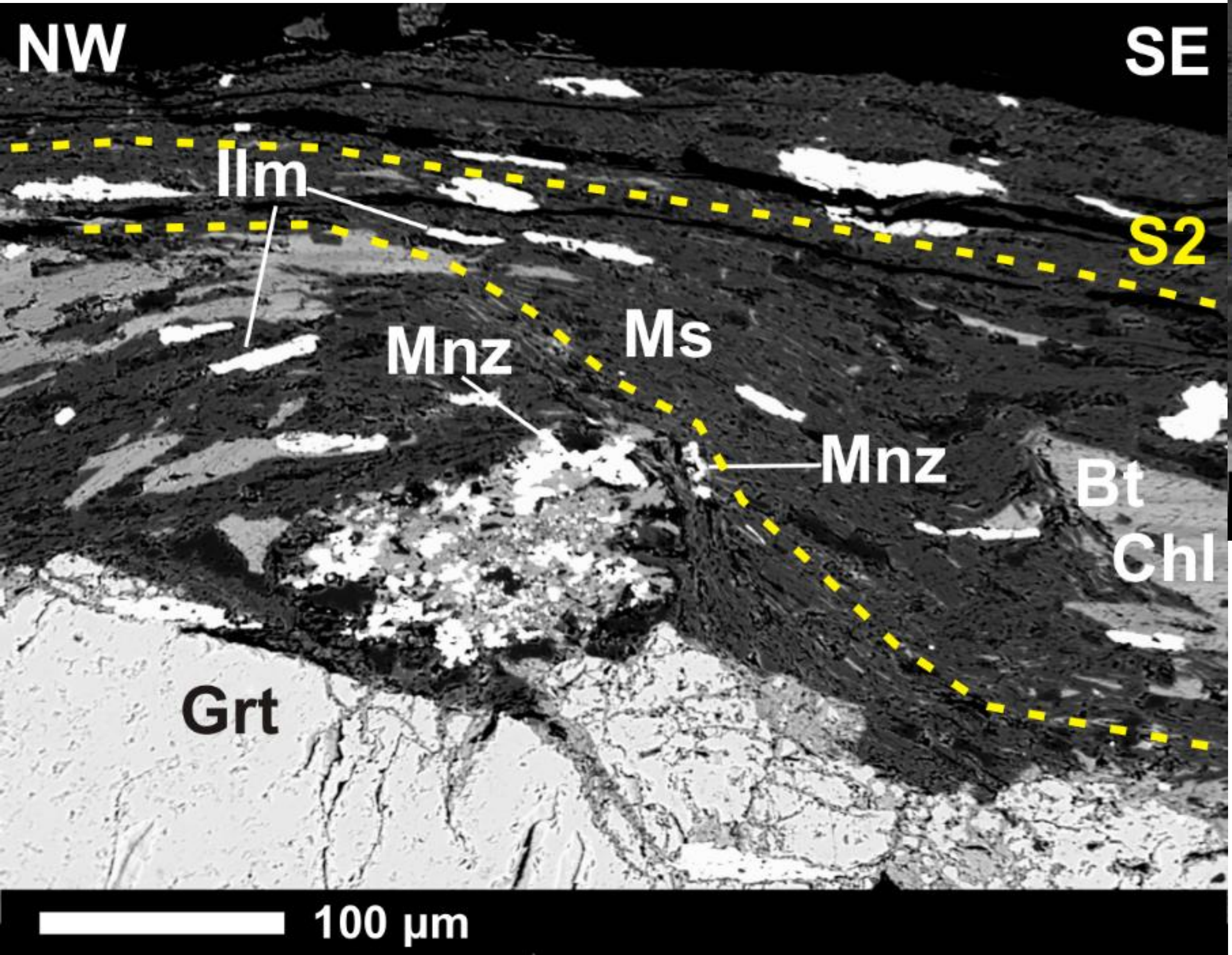


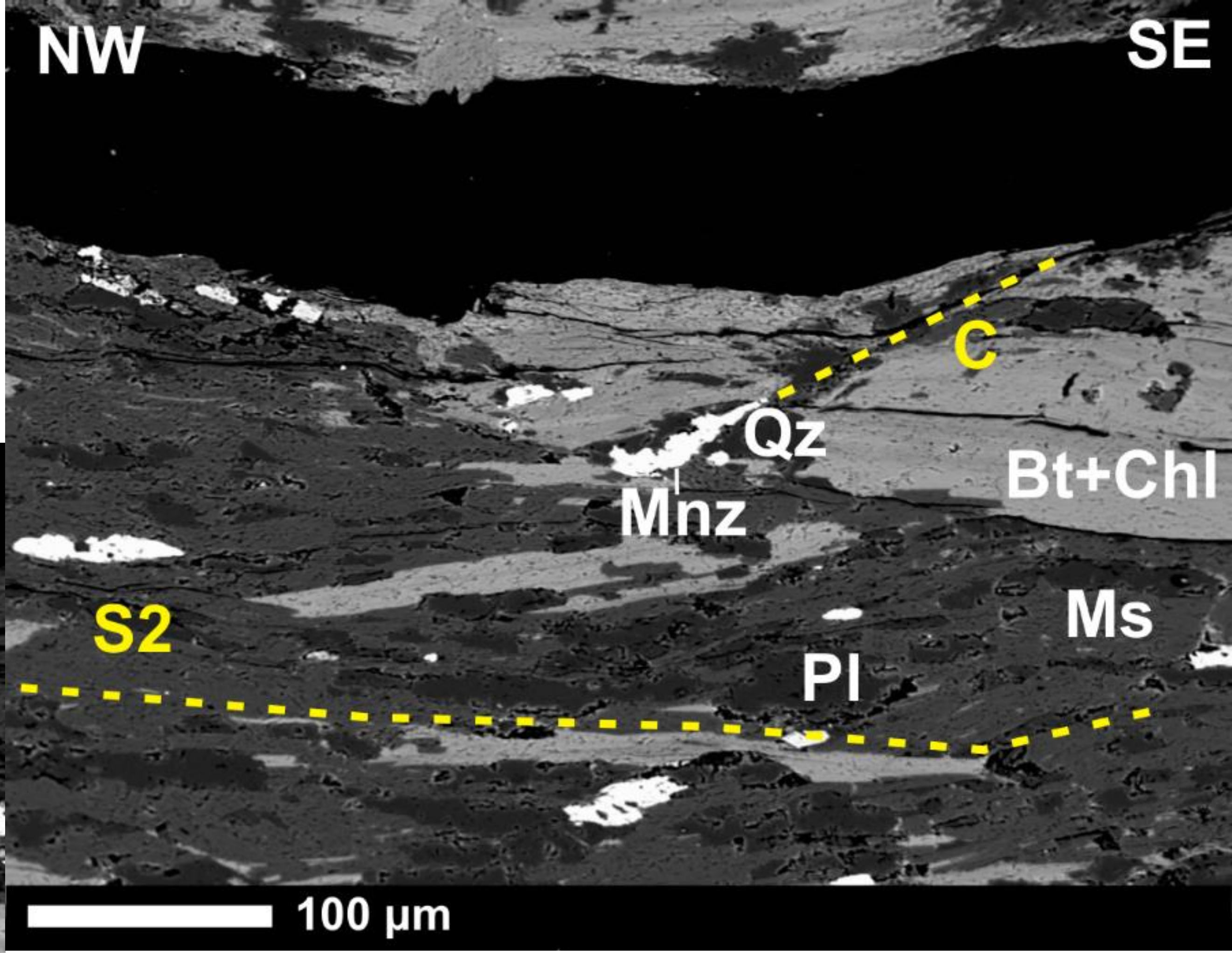
Decreased grain size of the matrix

Chl replacing Grt and Bt

Sinistral kinematic indicators

Monazite position



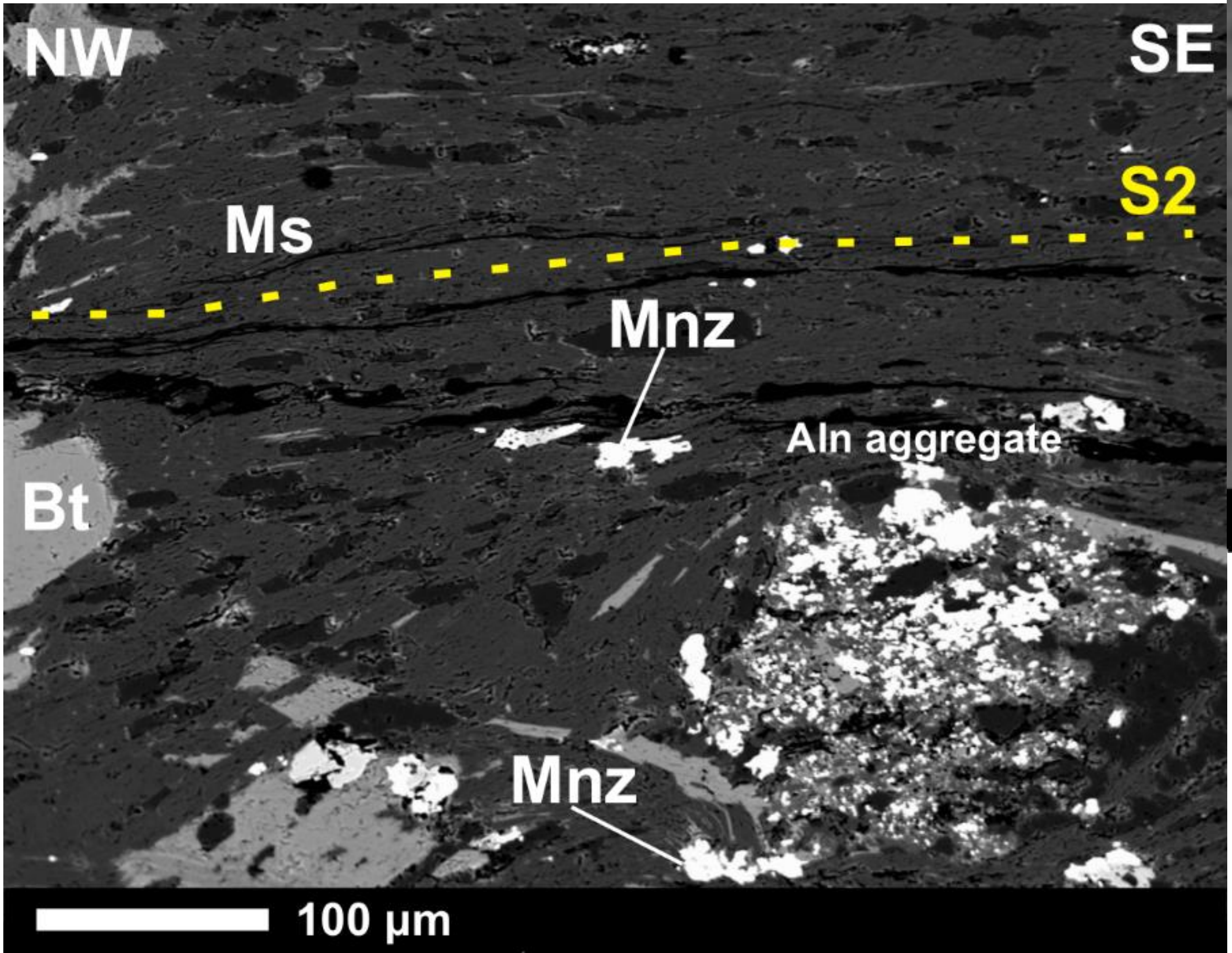


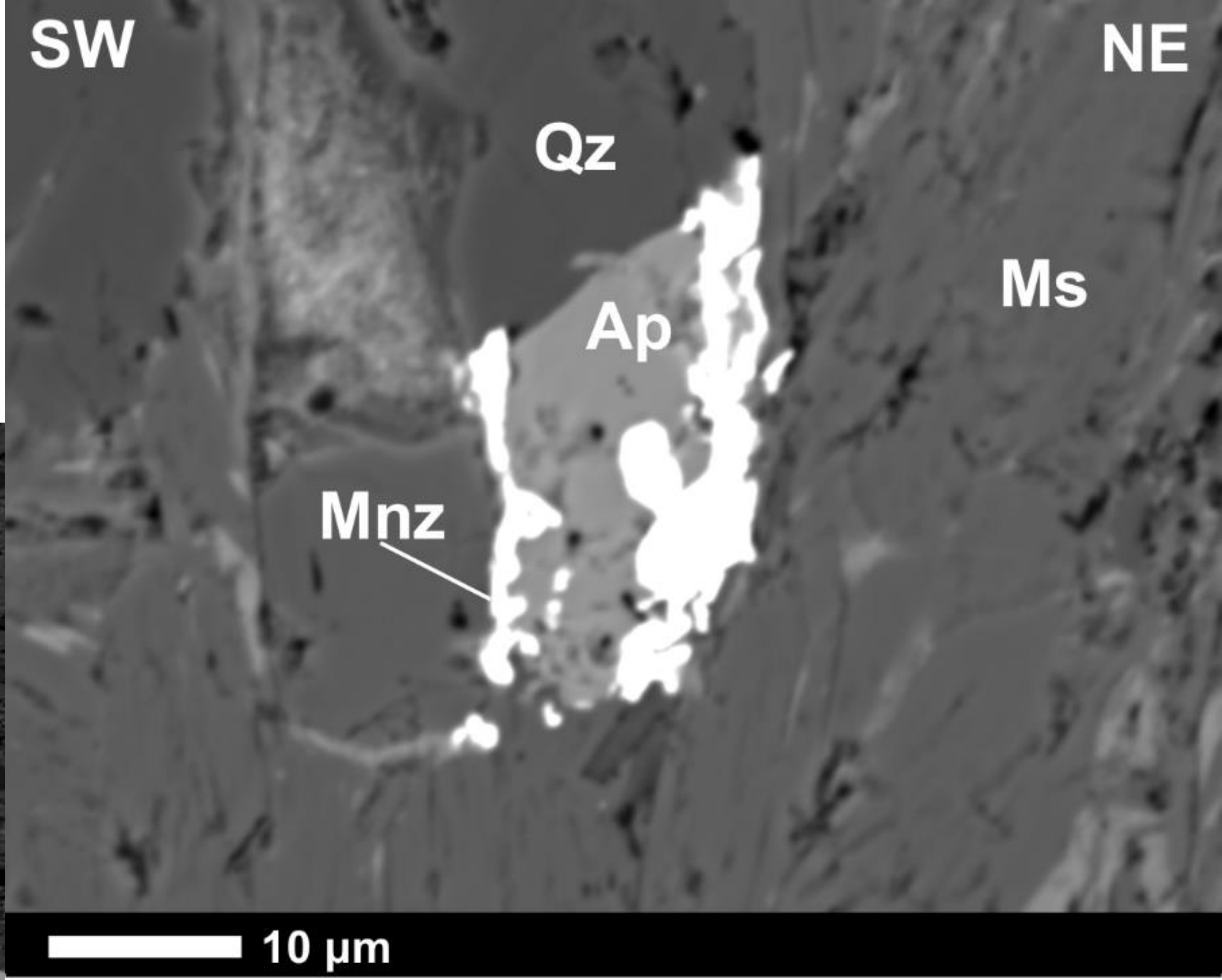
Monazite grows within S2 foliation

Monazite grows within shear bands

Monazite is a retrograde mineral

Monazite precursors

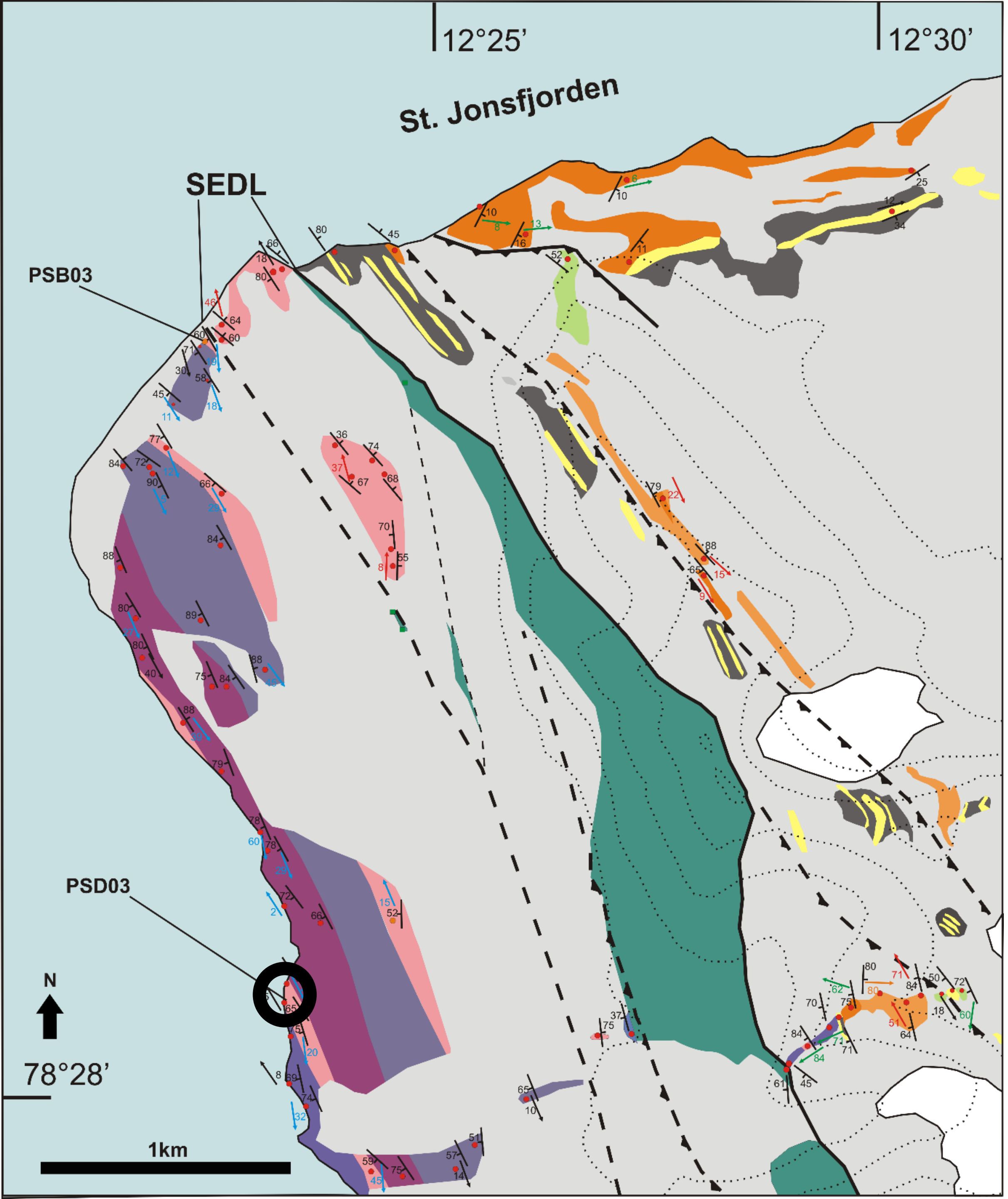




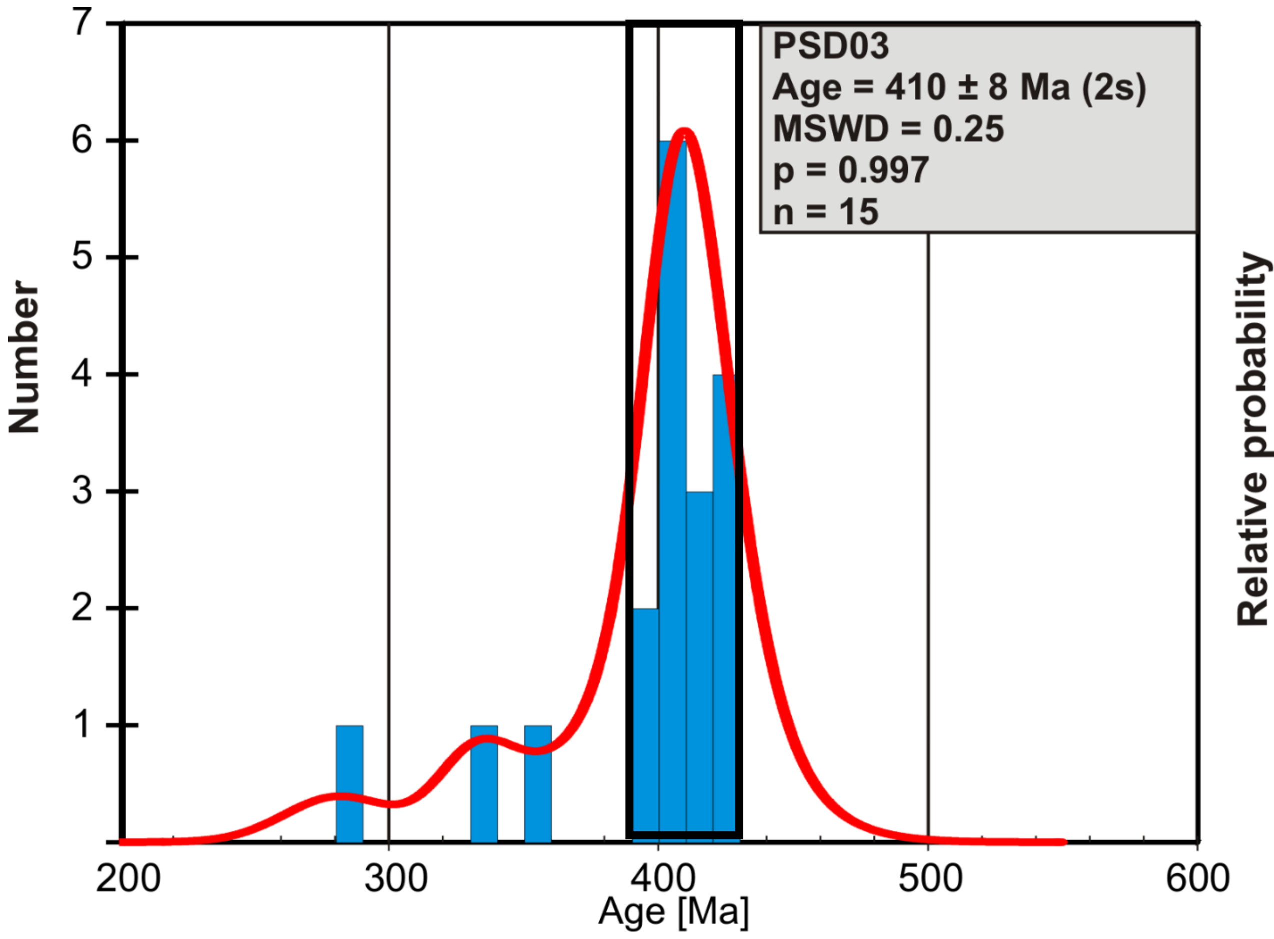
Allanite replaced by monazite

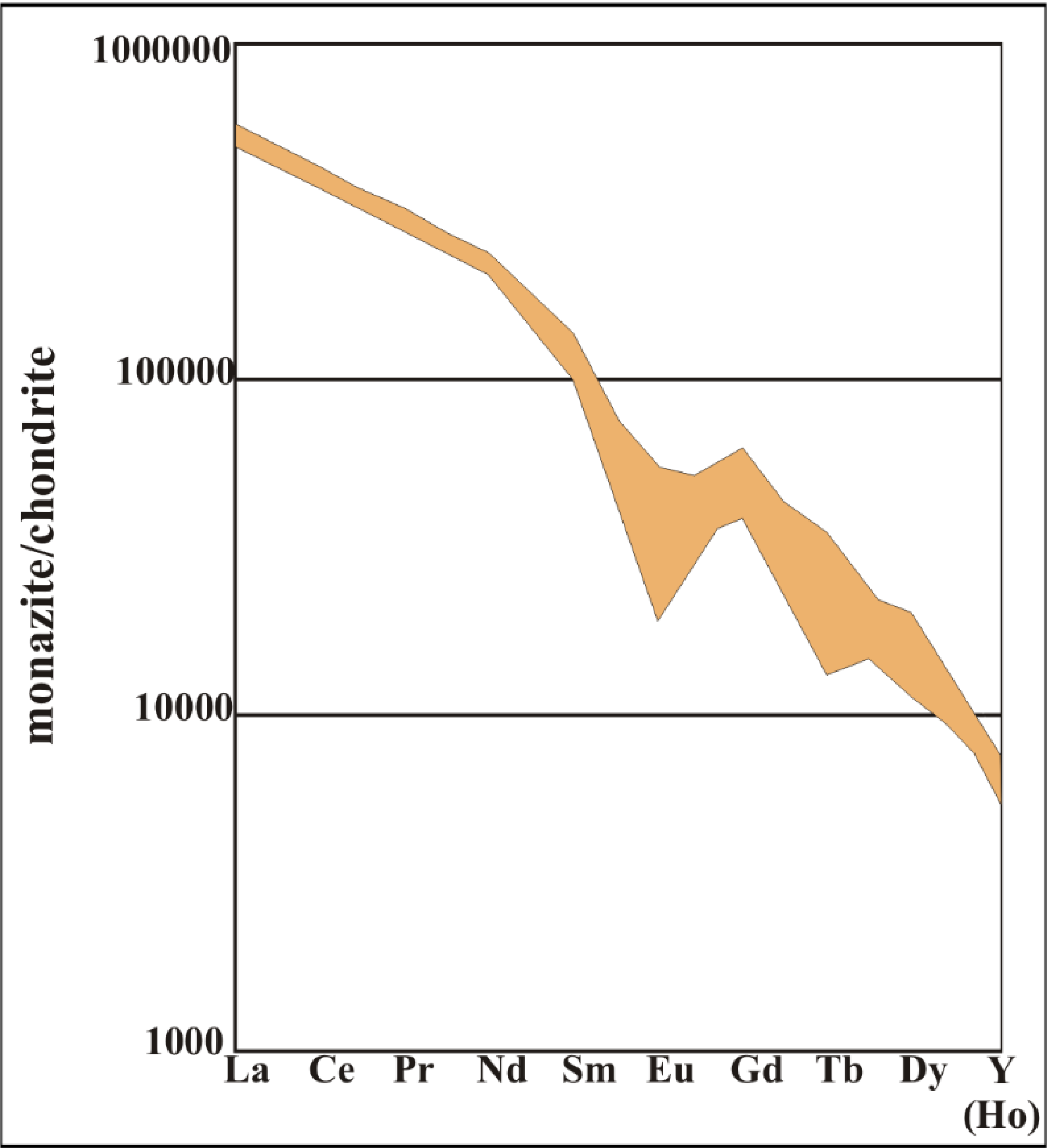
Apatite replaced by monazite

Temperature of monazite growth: 500-420°C

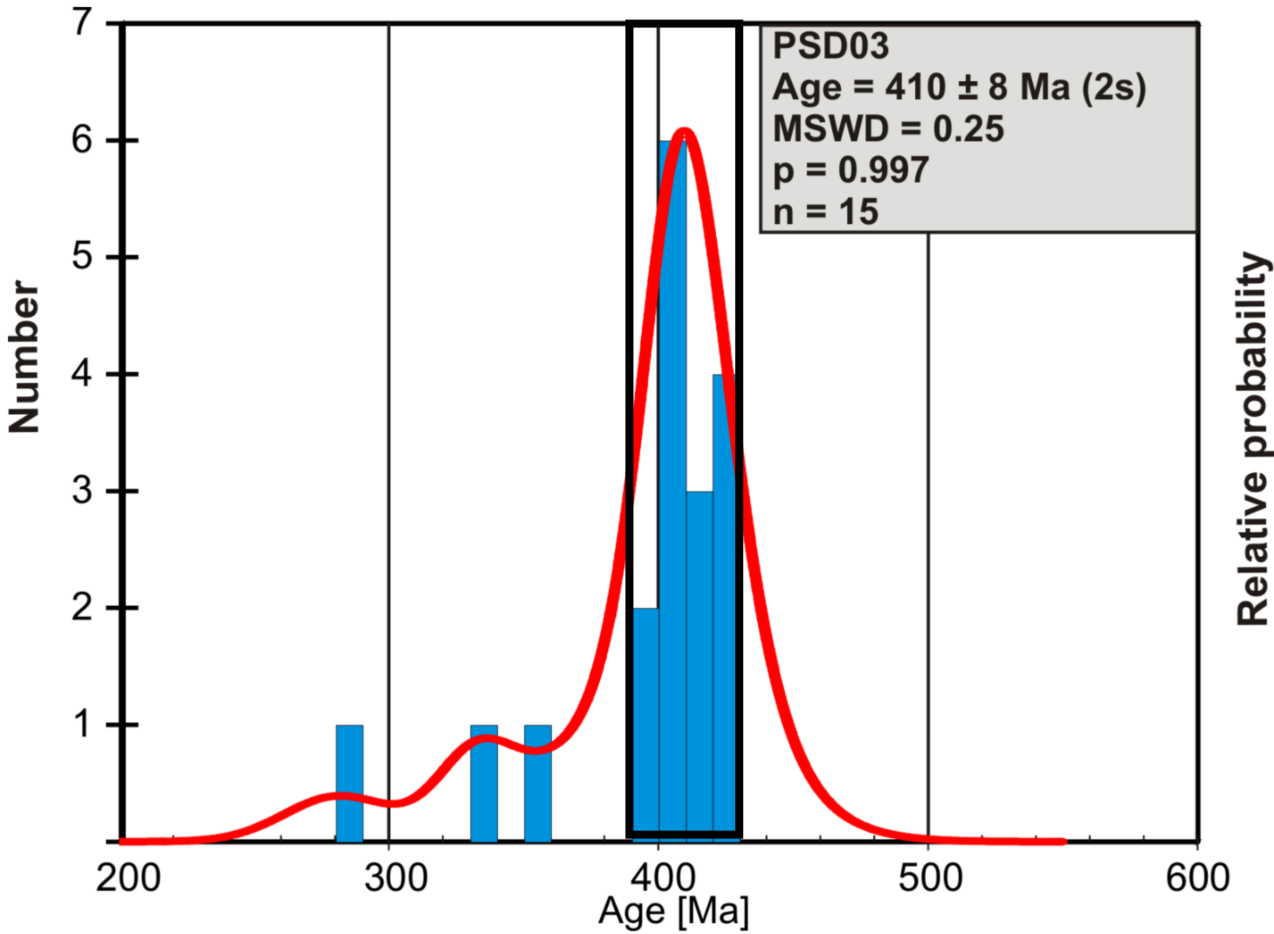


Th-U-total Pb dating of monazite

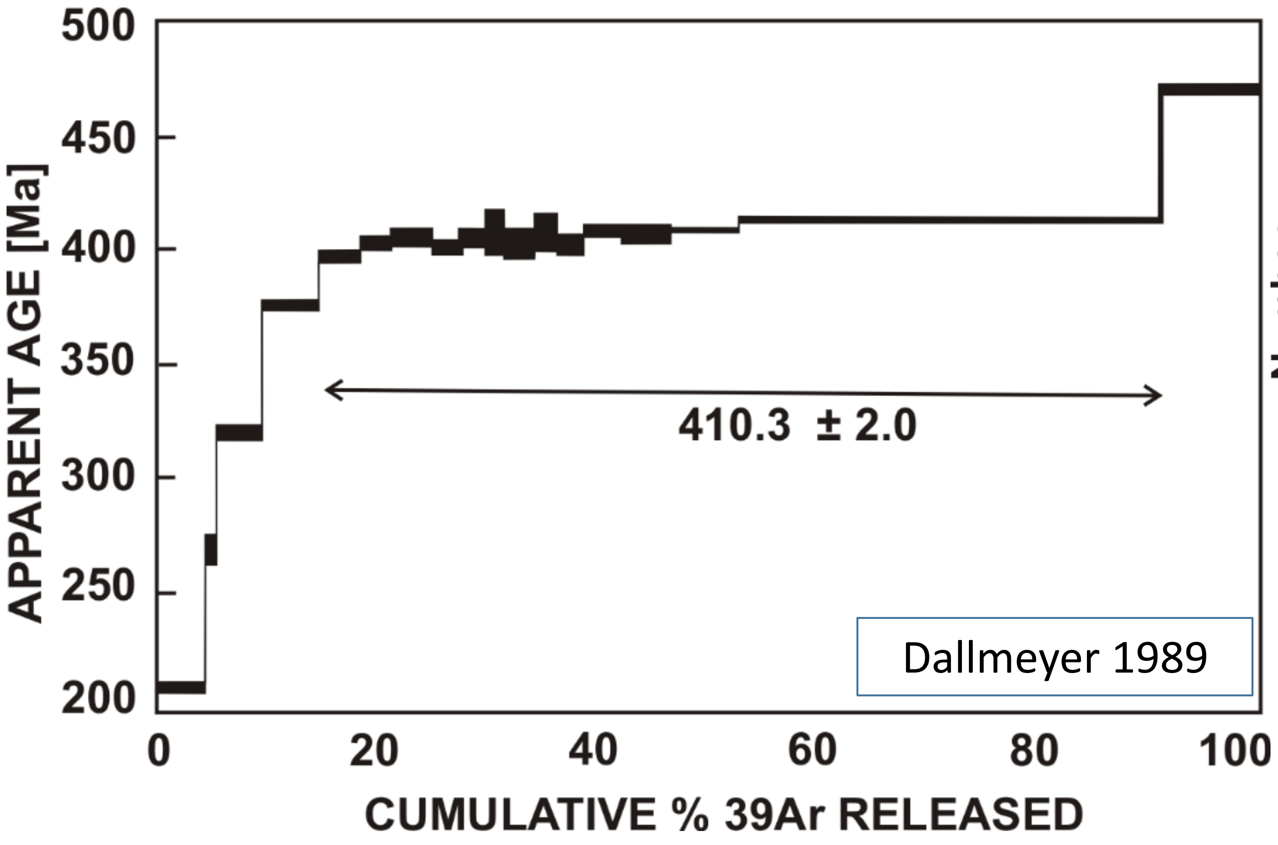




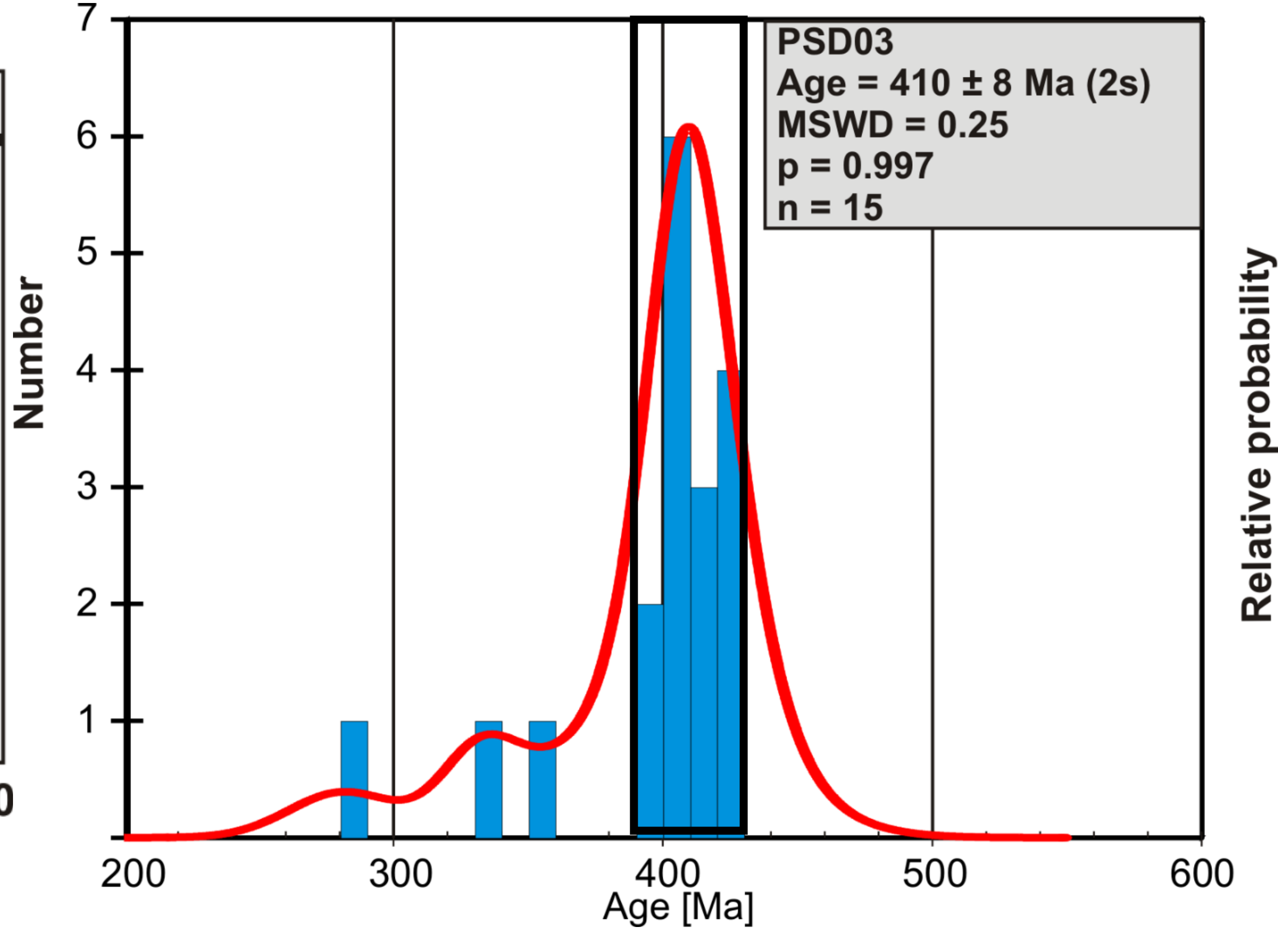
Th-U-total Pb dating of monazite

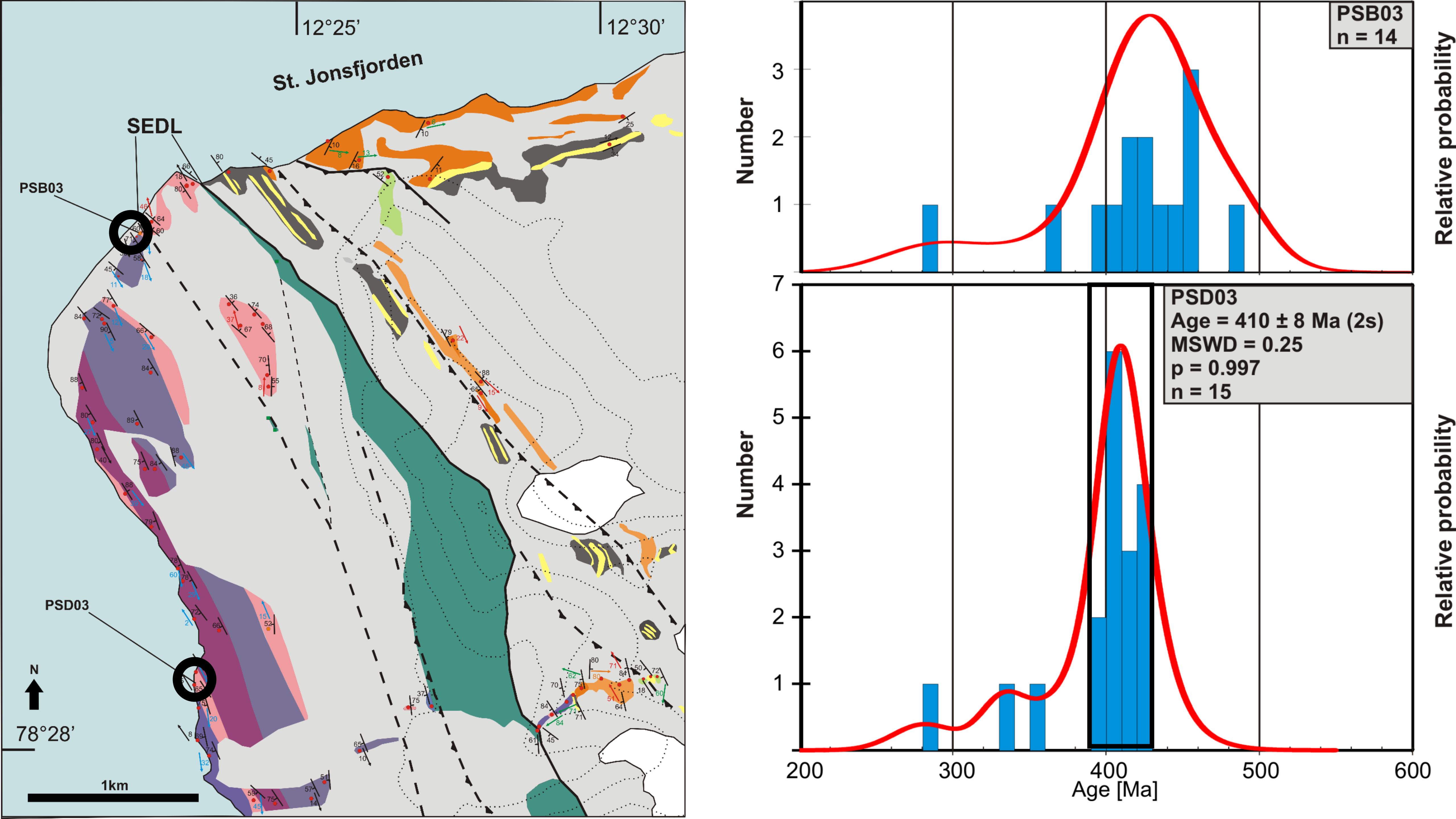


$^{40}Ar/^{39}Ar$ white mica step heating

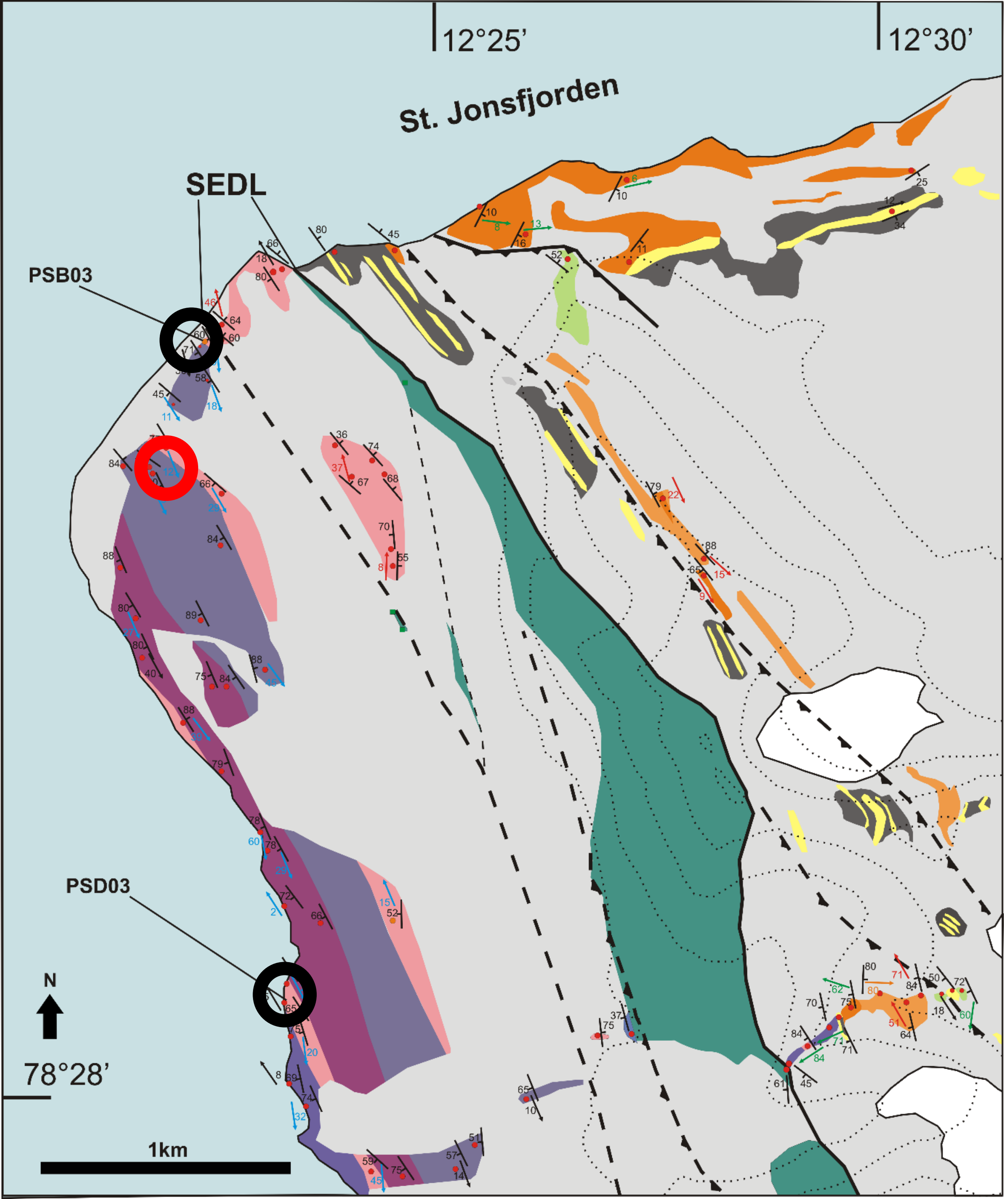


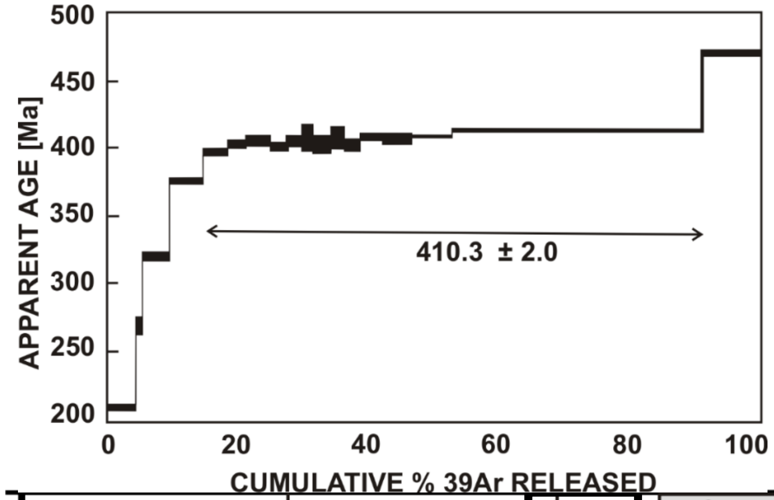
Th-U-total Pb dating of monazite



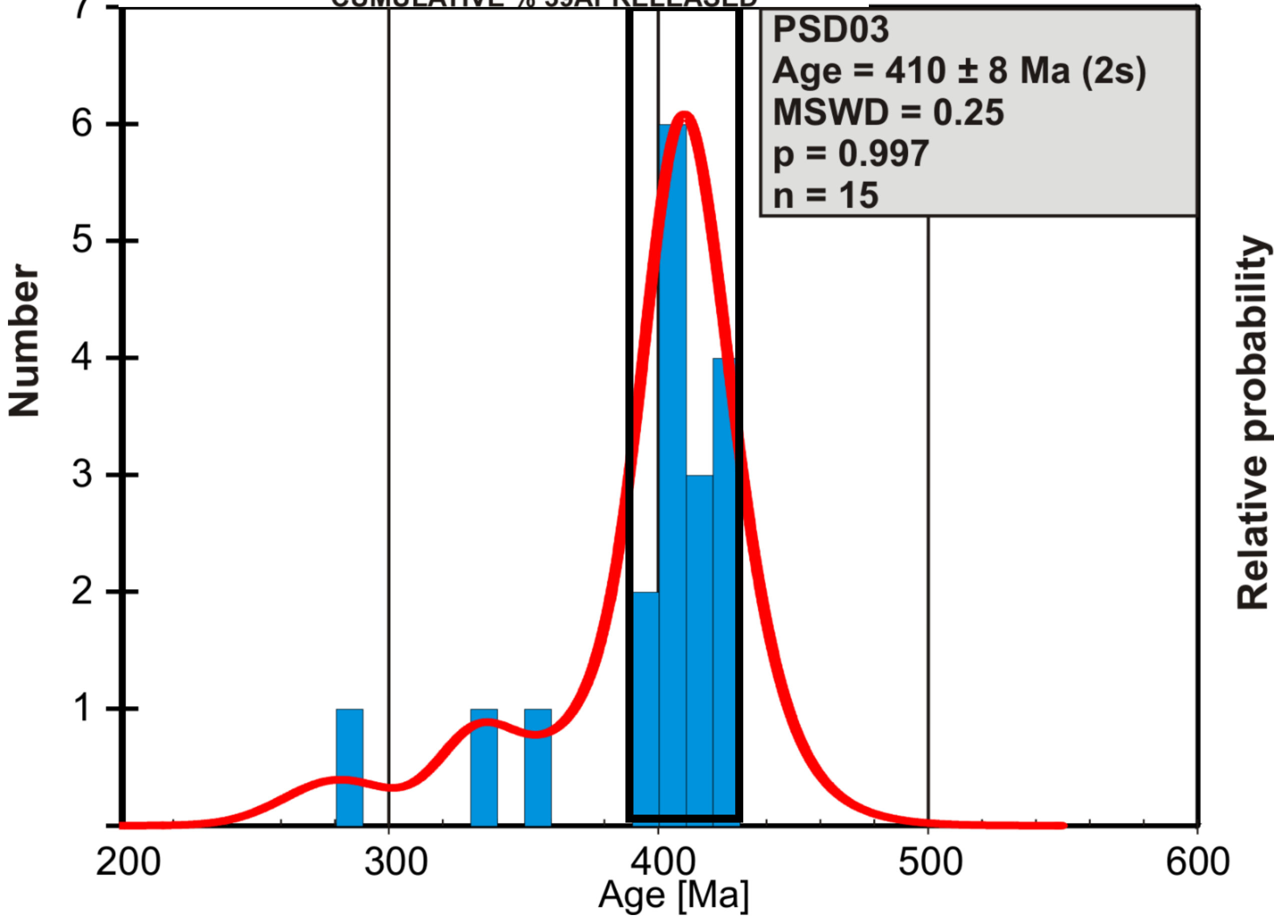


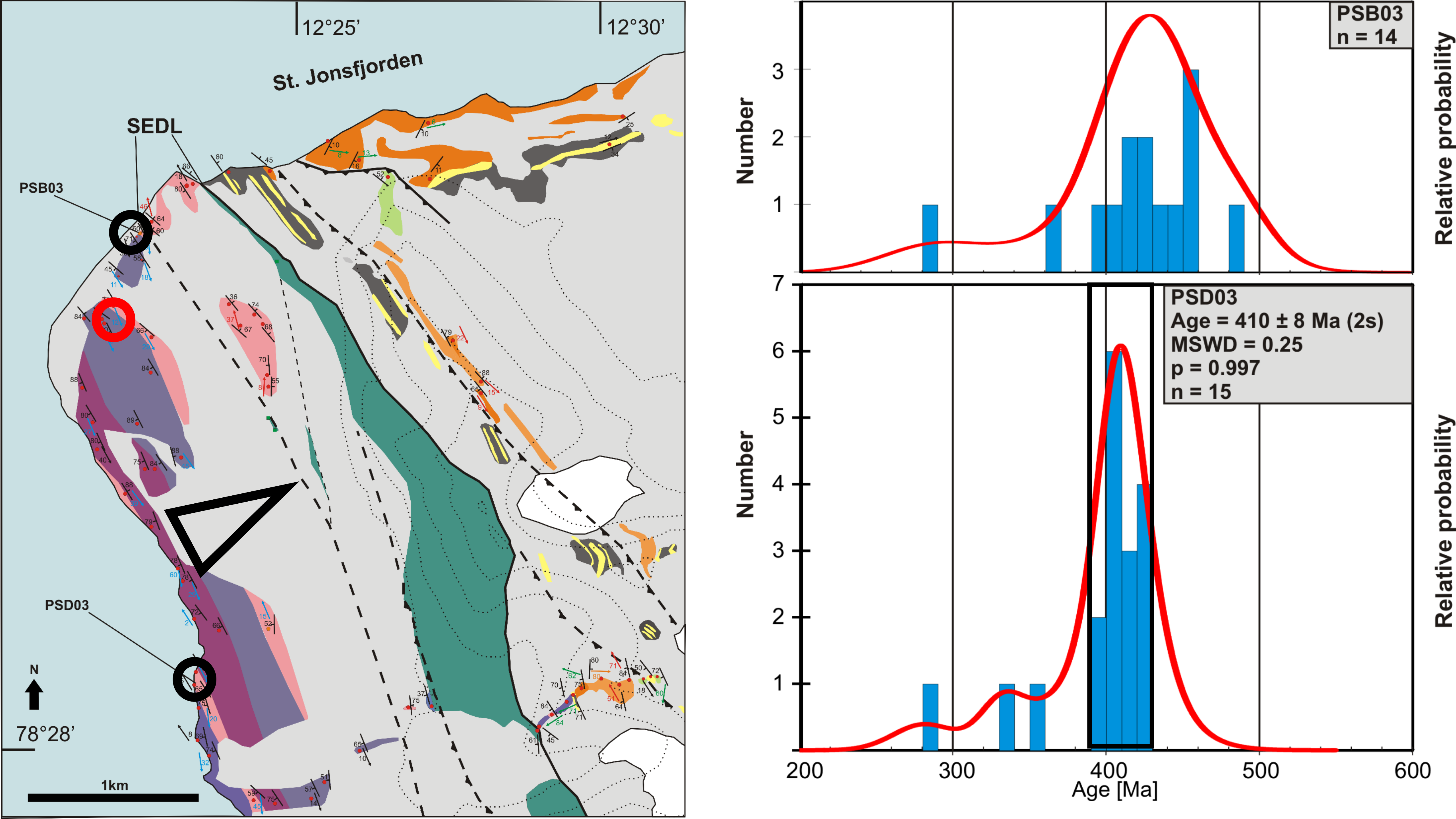
12°25'
12°30'
St. Jonsfjorden
SEDL
PSB03
PSD03
N
78°28'
1km
PSB03
n = 14
Number
Relative probability
PSD03
Age = 410 ± 8 Ma (2s)
MSWD = 0.25
p = 0.997
n = 15
Number
Relative probability
200
300
400
500
600
Age [Ma]



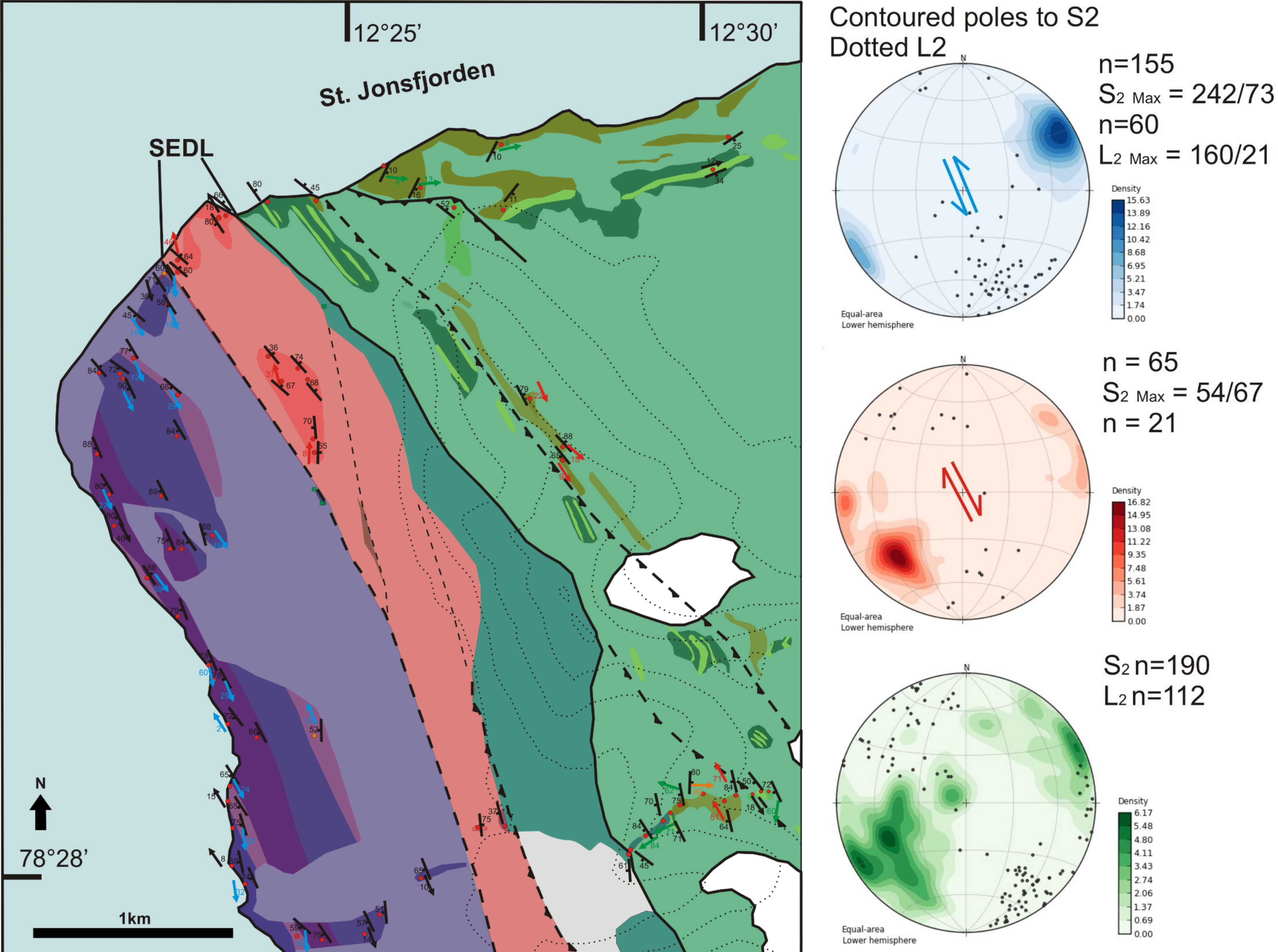


Dallmeyer
1989





12°25'
12°30'
St. Jonsfjorden
SEDL
PSB03
PSD03
N
78°28'
1km
PSB03
n = 14
PSD03
Age = 410 ± 8 Ma (2s)
MSWD = 0.25
p = 0.997
n = 15
Number
Relative probability
Age [Ma]


12°25'
12°30'
St. Jonsfjorden
SEDL
N
78°28'
1km
Contoured poles to S2
Dotted L2
n=155
S2 Max = 242/73
n=60
L2 Max = 160/21
Density
15.63
13.89
12.16
10.42
8.68
6.95
5.21
3.47
1.74
0.00
Equal-area
Lower hemisphere
n = 65
S2 Max = 54/67
n = 21
Density
16.82
14.95
13.08
11.22
9.35
7.48
5.61
3.74
1.87
0.00
Equal-area
Lower hemisphere
S2 n=190
L2 n=112
Density
6.17
5.48
4.80
4.11
3.43
2.74
2.06
1.37
0.69
0.00
Equal-area
Lower hemisphere

S2 mylonitic foliation in the western part of the Müllerneset Formation is dipping steeply to the SW and is associated with stretching muscovite and biotite bearing L2 plunging shallowly to the SSE. Kinematic indicators predominantly display a left-lateral sense of shear.

Th-U-total Pb dating monazite yielded 410 ± 8 Ma, which represents the timing of M2 retrogressive event, identical with the 410 ± 2 Ma $^{40}Ar/^{39}Ar$ cooling age of white mica reported by Dallmeyer (1989).

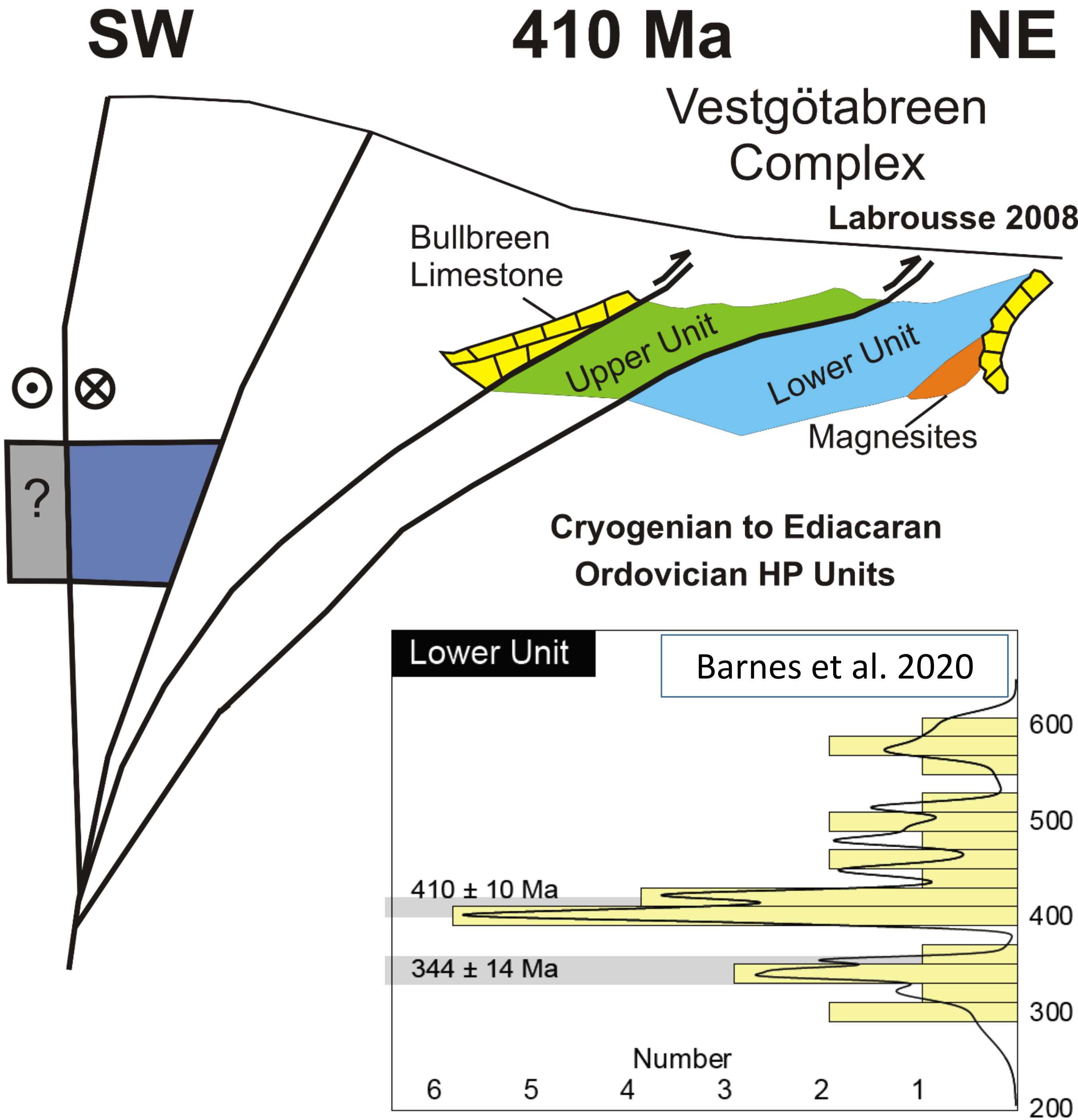
Geochronological evidence combined with structural observations suggests that the Müllerneset Formation in the Early Devonian was tectonically exhumed on the NW-SE trending left-lateral strike- to oblique-slip shear zone.

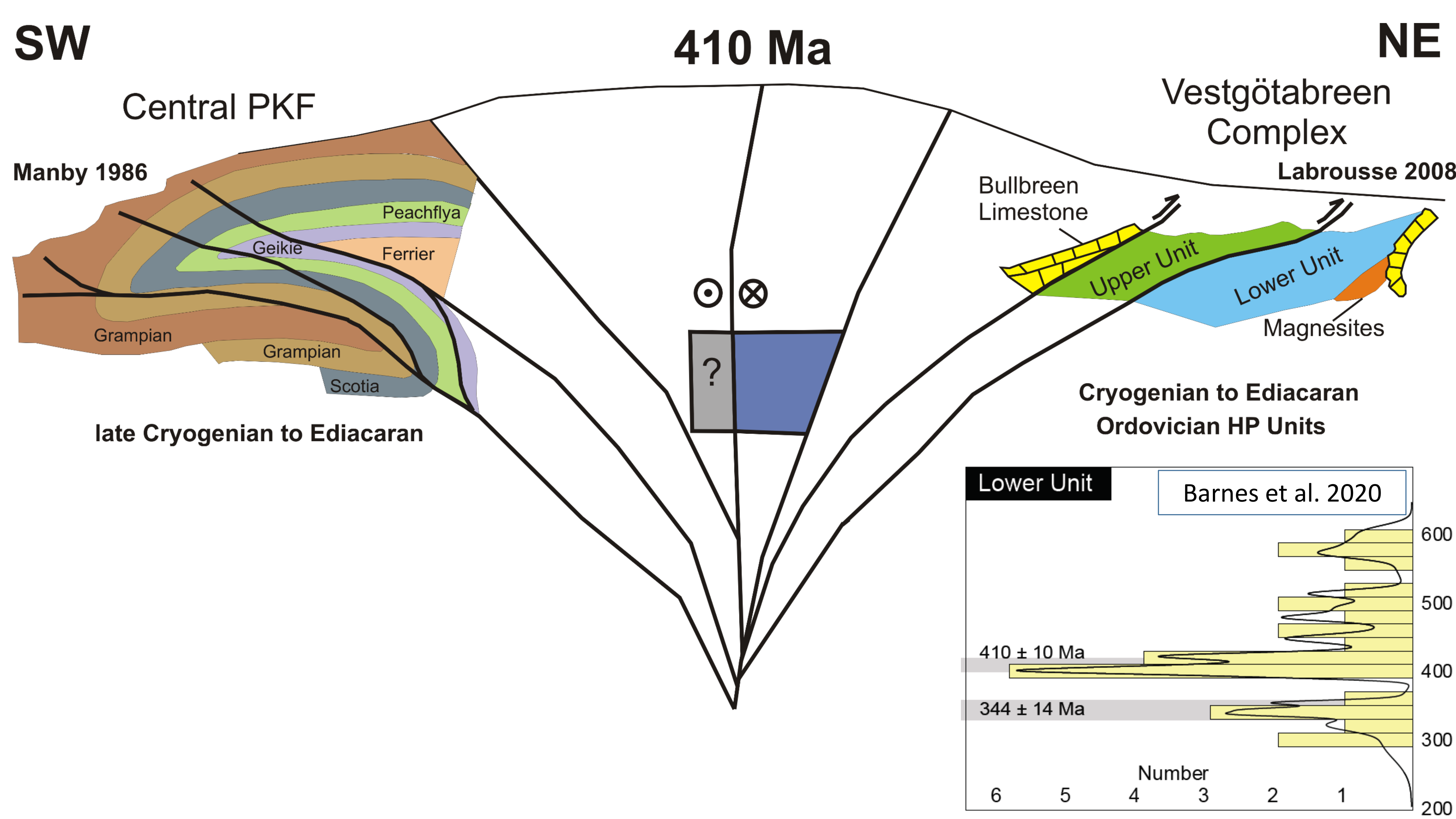
Timing of the left-lateral shearing in the Müllerneset Formation is coeval with the greenschist facies overprint recorded by Th-U-total Pb dating of monazite in the Ordovician HP Vestgötabreen Complex.

Left-lateral shearing in the Müllerneset Formation and NE directed thrusting in the Vestgötabreen Complex may be explained by strain partitiong during oblique (NW-SE) compresion.

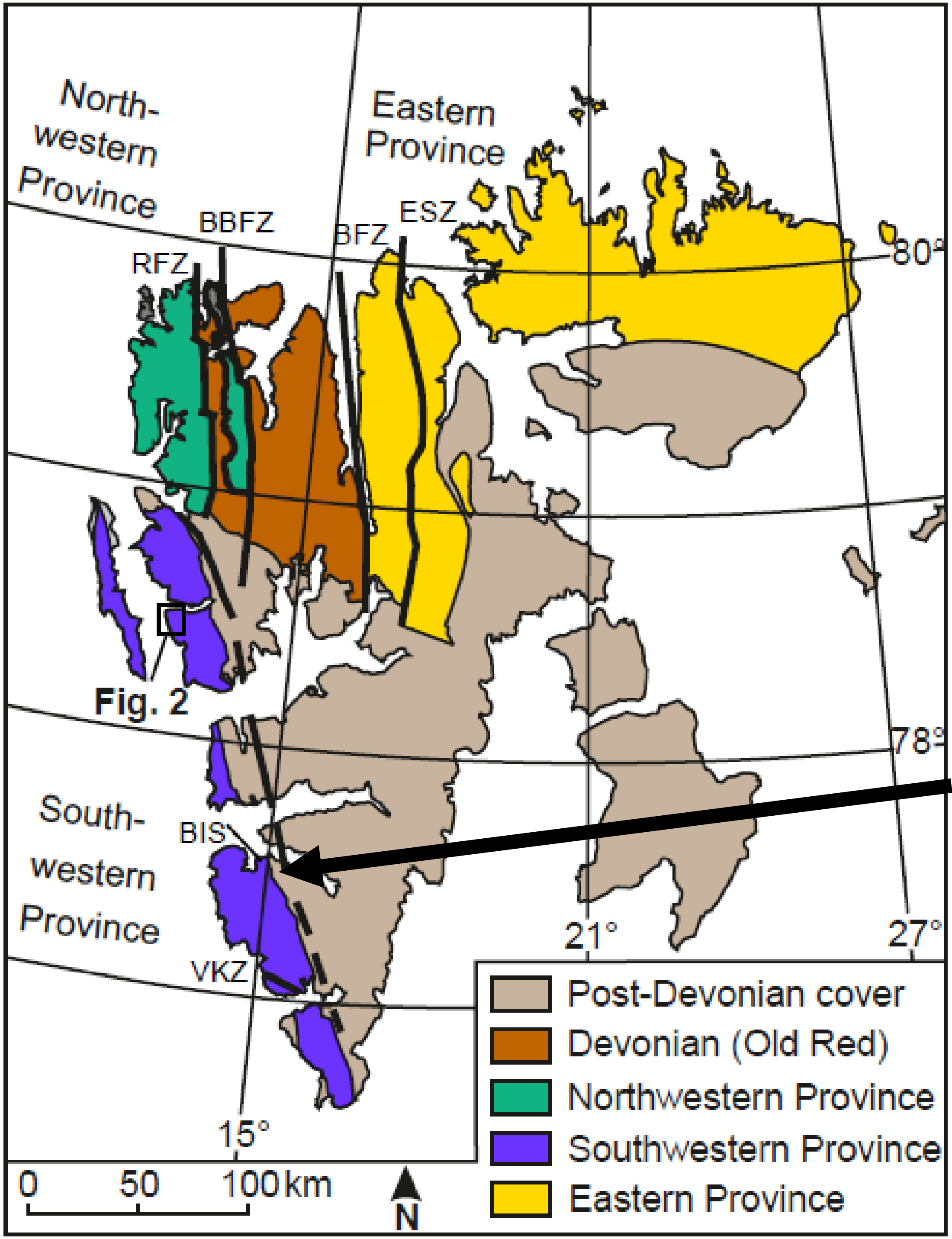
The opposite block is not exposed (Forlandsundet Graben). The most likely candidate is basement of Prins Karls Forland (PKF).

No geochronological data are available there.

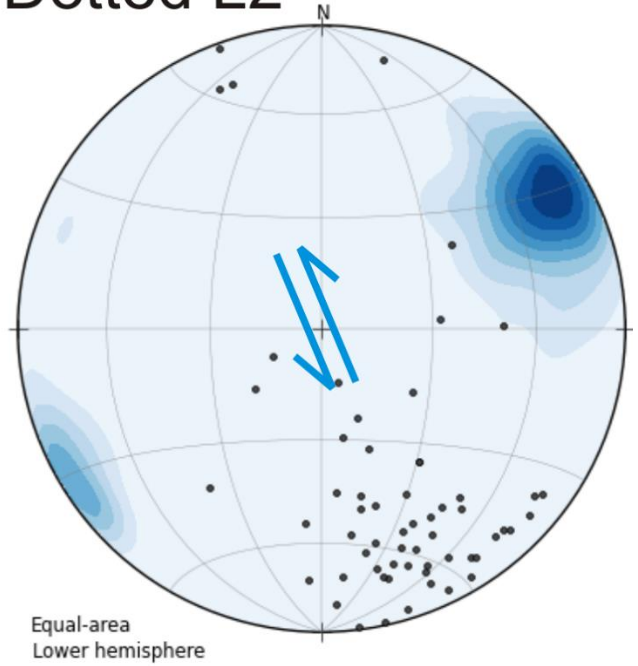




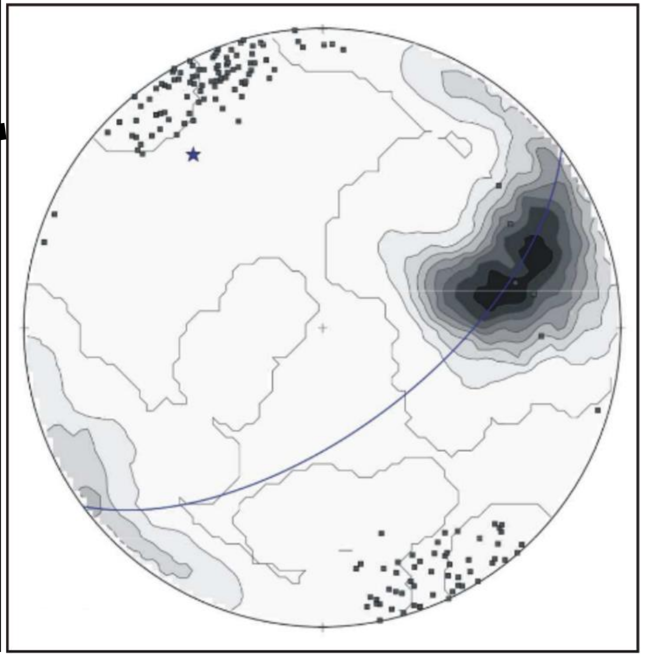
SW
410 Ma
NE
Central PKF
Manby 1986
Peachflya
Geikie
Ferrier
Grampian
Grampian
Scotia
late Cryogenian to Ediacaran
?
Vestgötabreen
Complex
Labrousse 2008
Bullbreen
Limestone
Upper Unit
Lower Unit
Magnesites
Cryogenian to Ediacaran
Ordovician HP Units
Lower Unit
Barnes et al. 2020
410 ± 10 Ma
344 ± 14 Ma
600
500
400
300
200
Number
6
5
4
3
2
1



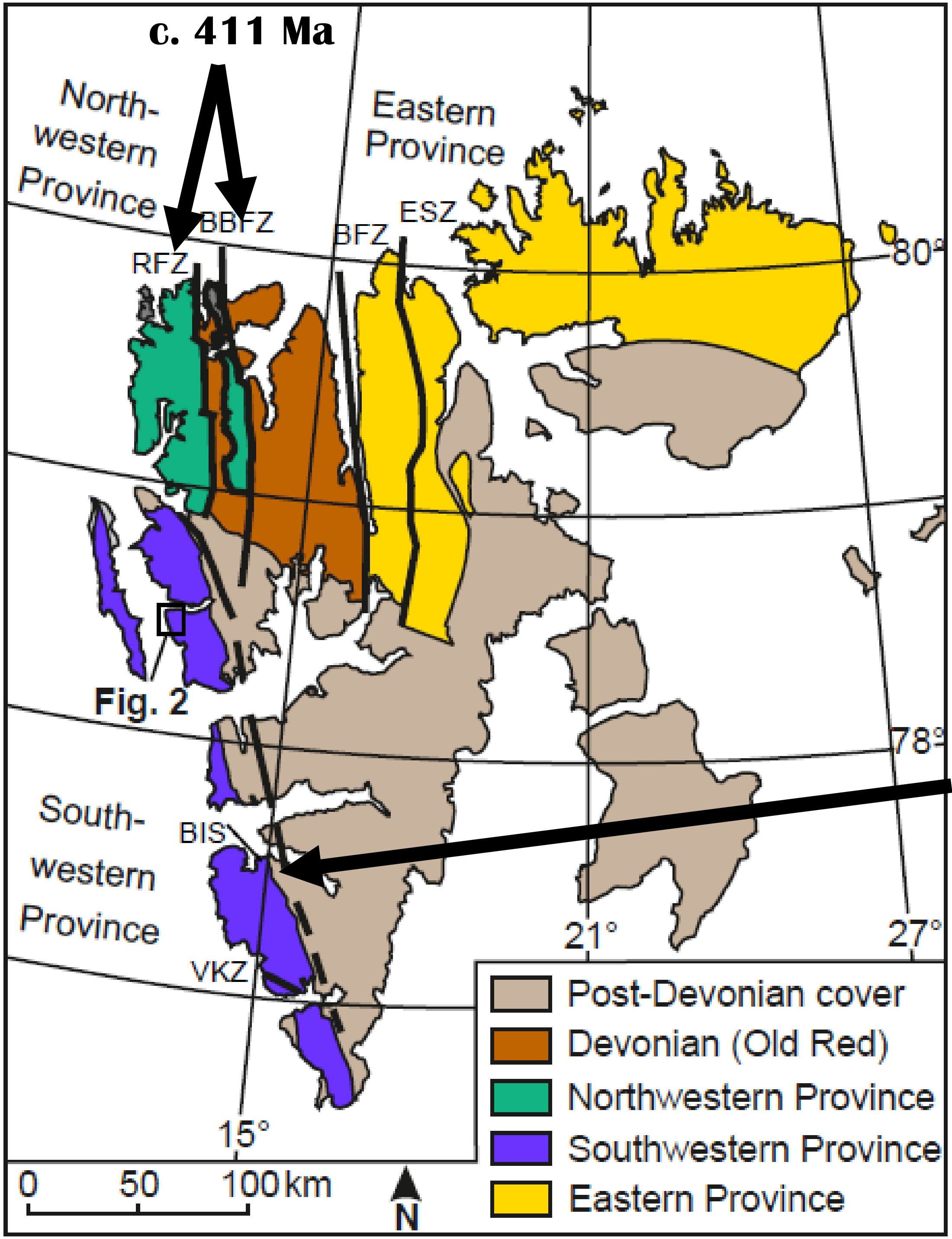
Contoured poles to S2
Dotted L2



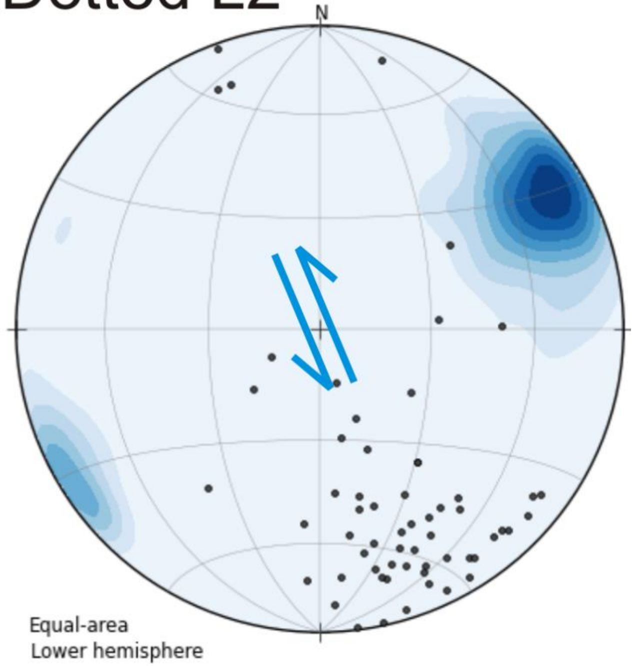
Müllerneset Formation monazite U-Th total Pb 410 ± 8 Ma



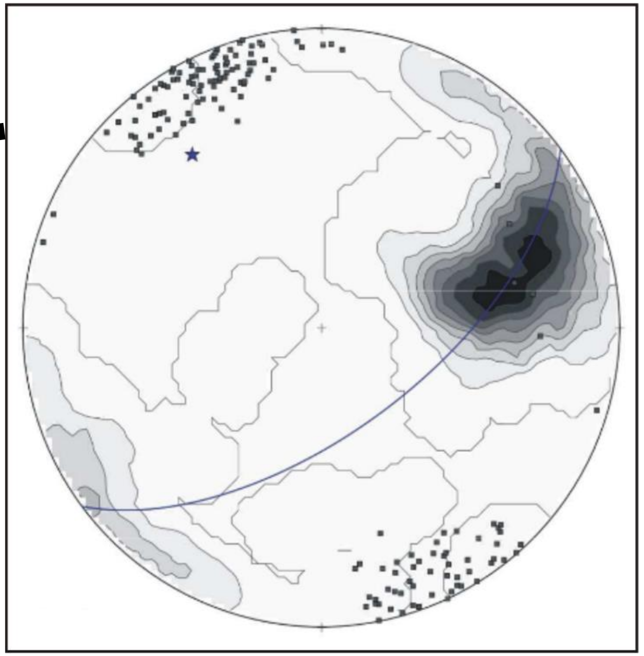
Berzeliuseggene unit Total fusion $^{40}Ar/^{39}Ar$ white mica 410 ± 18 Ma Majka et al. 2014 Faehnrich et al. 2020



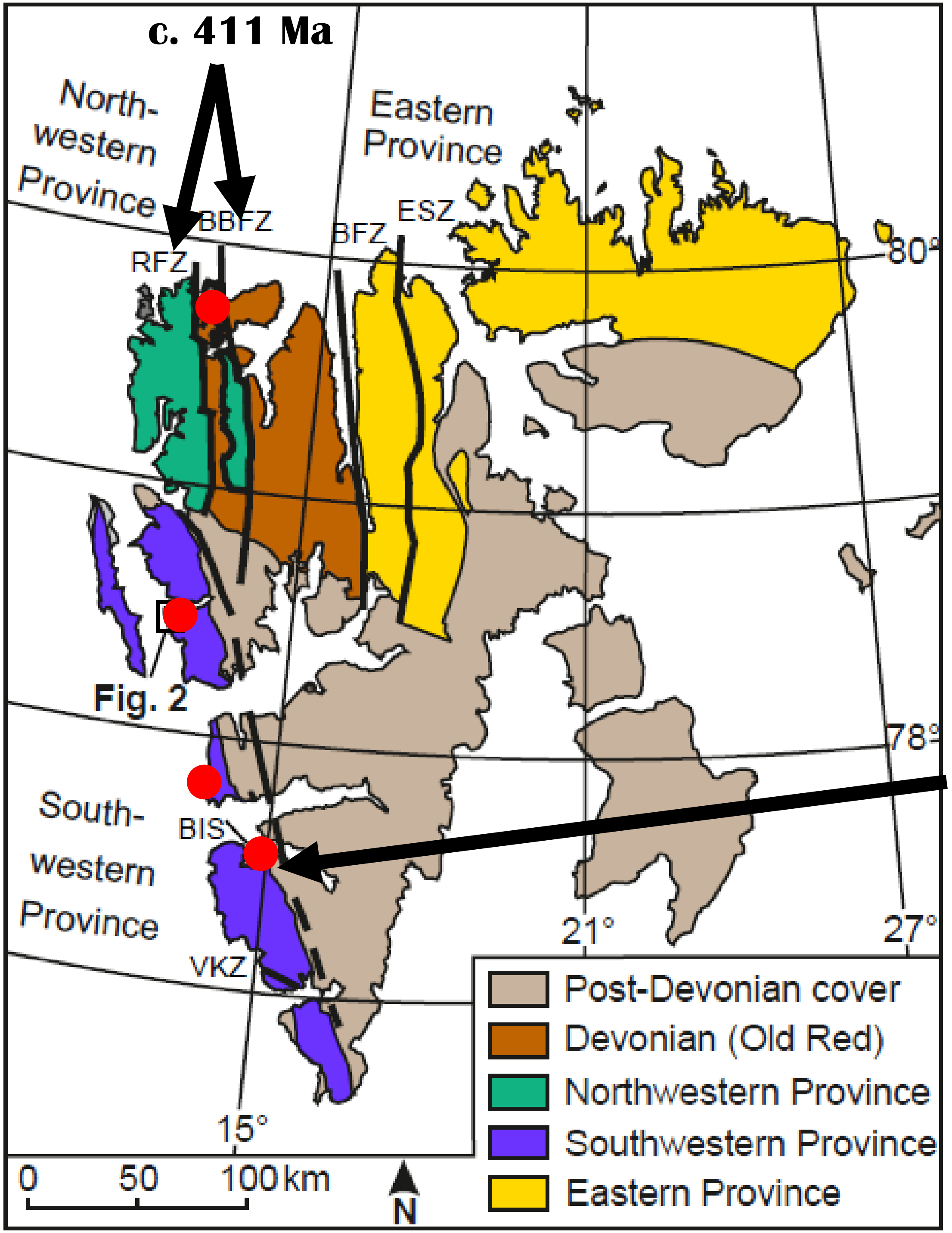
Contoured poles to S2
Dotted L2



Müllerneset Formation monazite U-Th total Pb 410 ± 8 Ma



Berzeliuseggene unit Total fusion $^{40}Ar/^{39}Ar$ white mica 410 ± 18 Ma Majka et al. 2014 Faehnrich et al. 2020

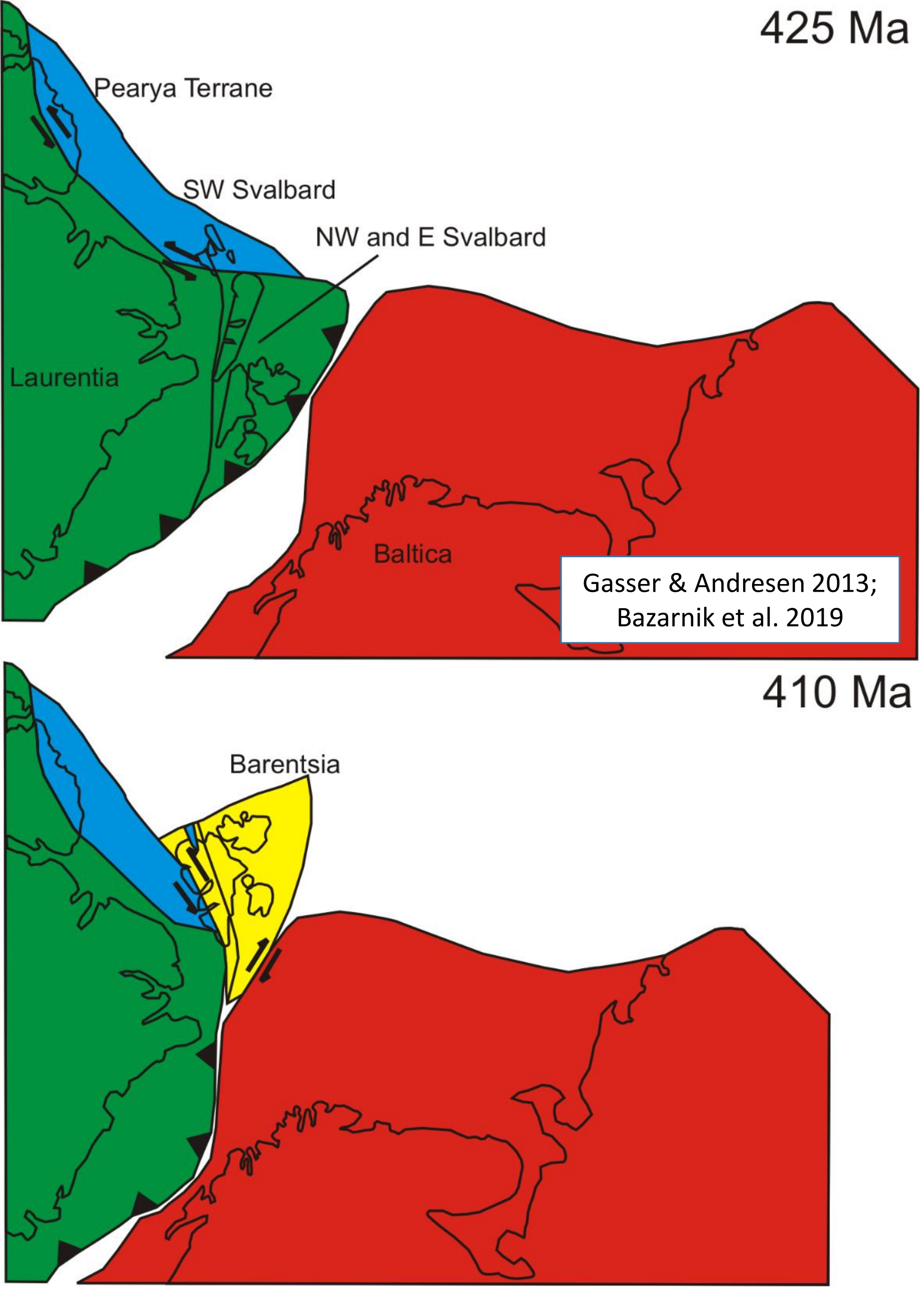


Left-lateral shearing in the Müllerneset Formation is coeval with shear zone exposed in the Berzeliuseggene Unit and shear zones in the NW Basement Province of Svalbard.

They all display the same left-lateral sense of shear and have Ordovician HP units on their W(SW) or E(NE) side.

It suggests that the Ordovician HP units that potentially represent the same Pearya Terrane affinity (Trettin 1987) were dismembered in Early Devonian by an anastomosing set of shear zones along the Western coast of Svalbard.

Ordovician HP localities

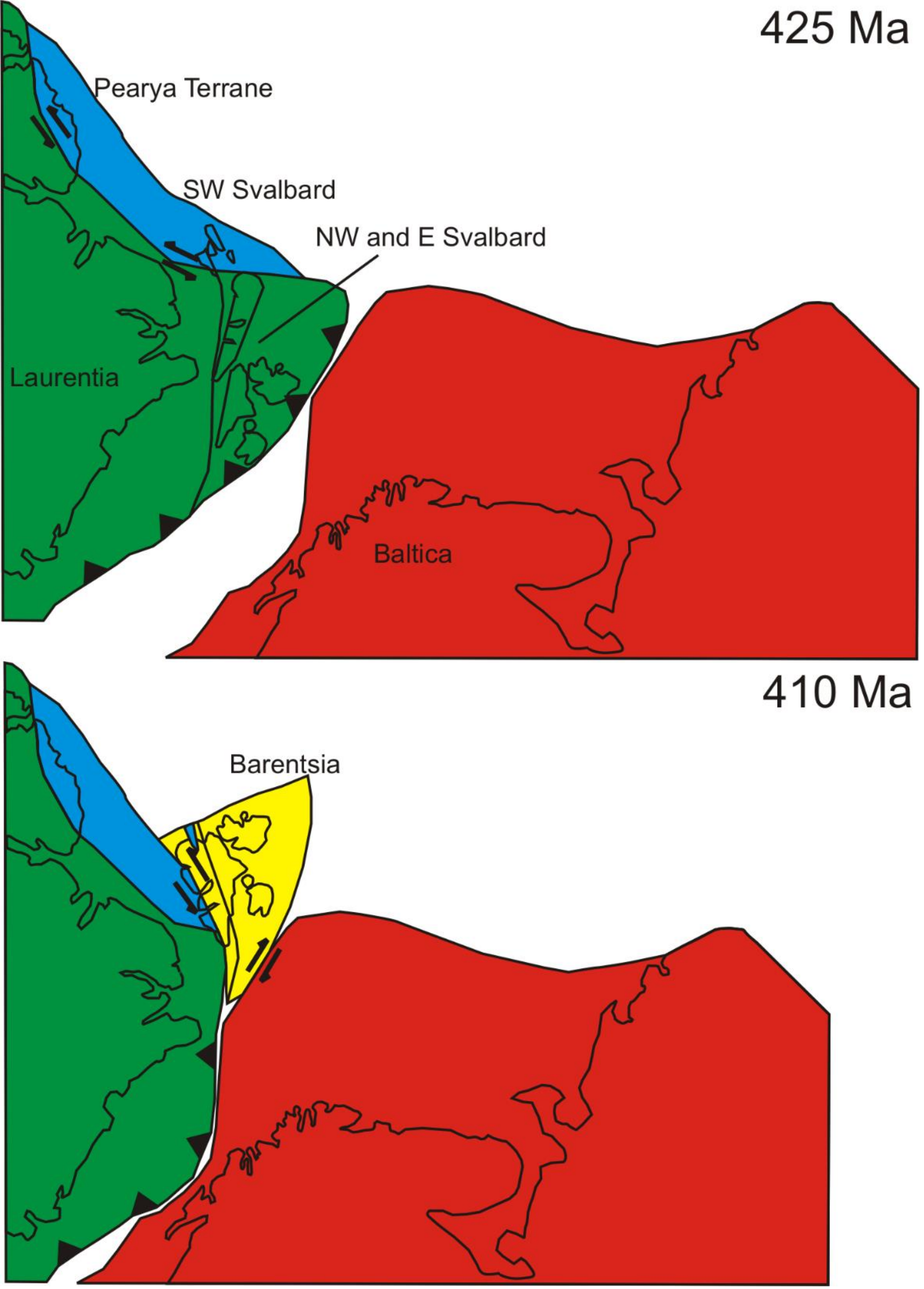


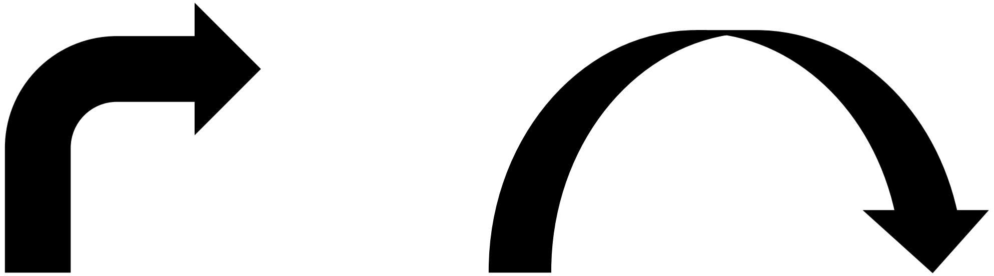
Schematic sketch of late-Caledonian assembly of Svalbard.

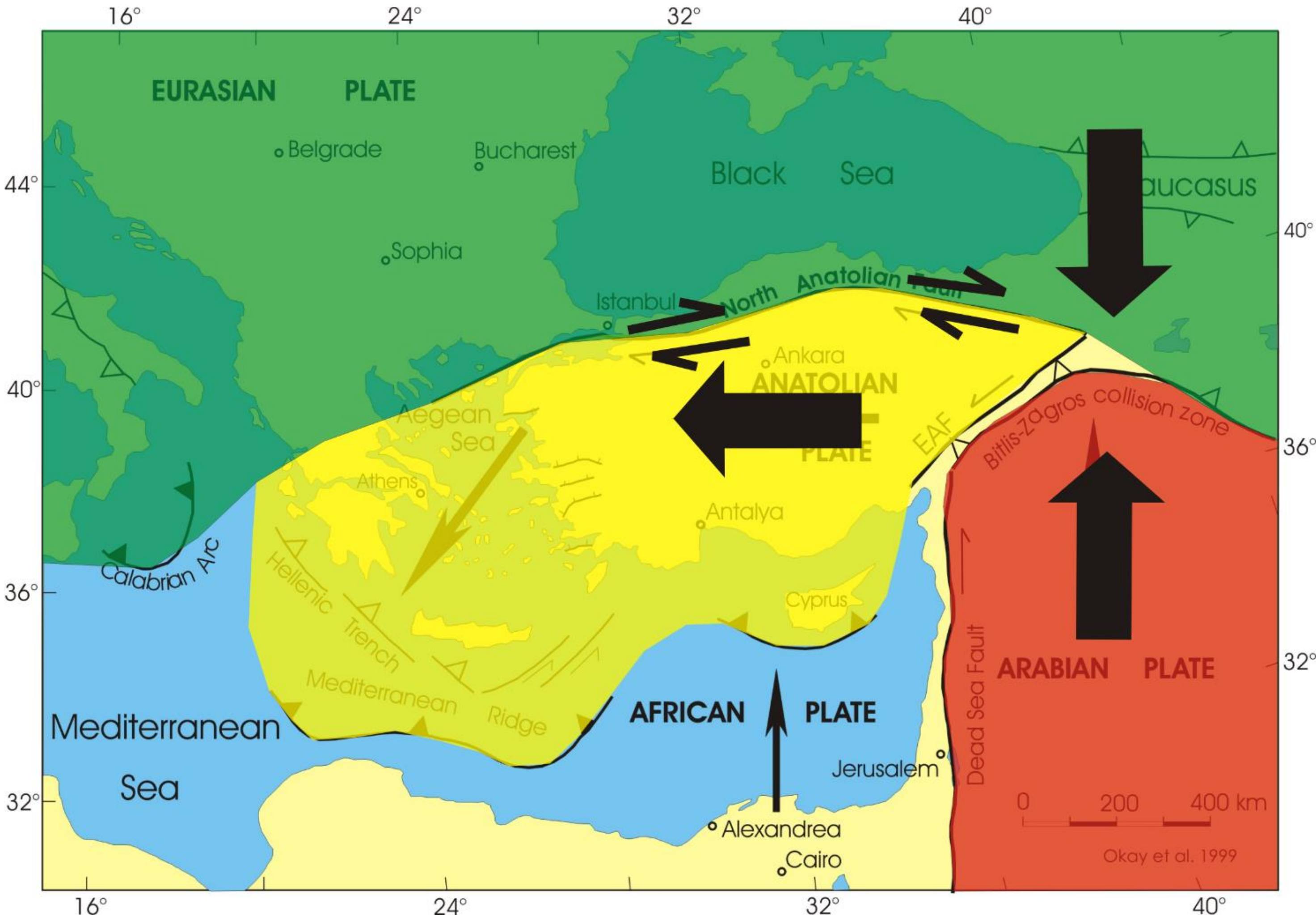
In late Silurian the Pearya Terrane and SW Svalbard are being accreted to the northern Laurentian margin along the Northwest Passage (Colpron & Nelson 2009). At the time Northwestern and Eastern basement provinces of Svalbard were still a part of Laurentian Plate.

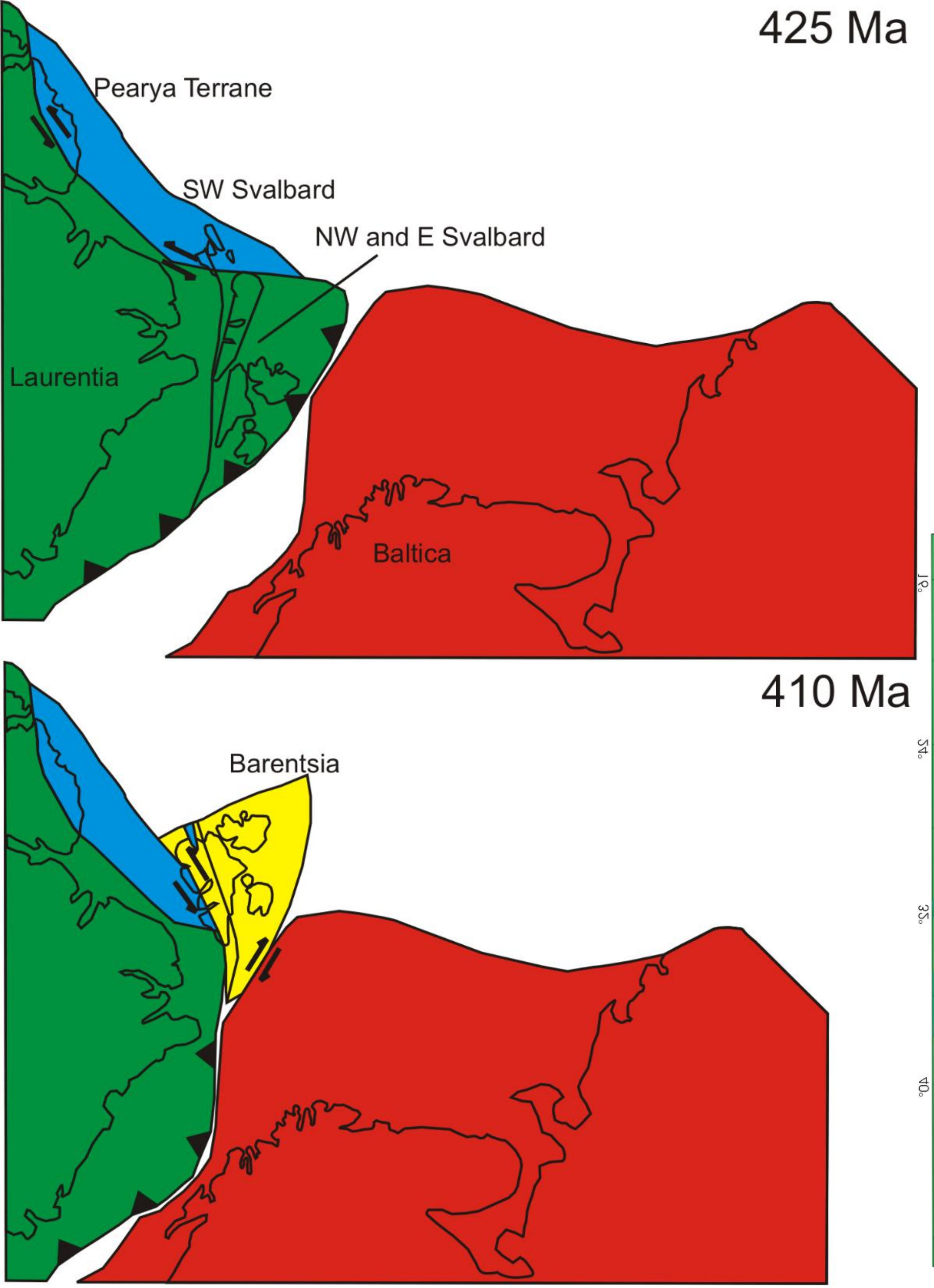
In the latest Silurian to Early Devonian part of Laurentian Plate (Barentsia, Gudlaugsson et al. 1998) is separated from Laurentia along a set of anastomosing left-lateral shear zones. The Southwestern and Northwestern basement provinces of Svalbard are formed as a collage of peri-Laurenitian and peri-Peryan terranes.

The modern analogue of the escape of the Barentsian Plate is formation of the Anatolian Plate.

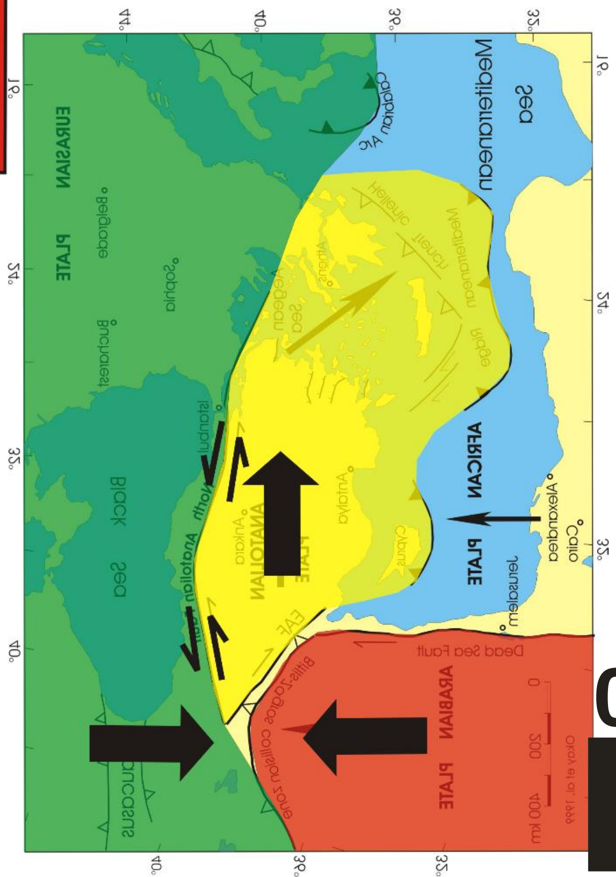

425 Ma
Pearya Terrane
SW Svalbard
NW and E Svalbard
Laurentia
Baltica
410 Ma
Barentsia




16°
24°
32°
40°
44°
40°
36°
32°
EURASIAN PLATE
Belgrade
Bucharest
Black Sea
Caucasus
Sophia
Istanbul
North Anatolian Fault
Ankara
ANATOLIAN PLATE
Aegean Sea
Athens
Antalya
EAF
Bitlis-Zagros collision zone
Calabrian Arc
Hellenic Trench
Mediterranean Ridge
Cyprus
Mediterranean Sea
AFRICAN PLATE
Jerusalem
Alexandrea
Cairo
Dead Sea Fault
ARABIAN PLATE
0 200 400 km
Okay et al. 1999



Analogies between the deformation in the Caledonian basement of Svalbard and the one in Anatolia Plate has been discussed by Liberis & Manby 1999, based on observations in the Eastern Basement Province of Svalbard.



Thank you