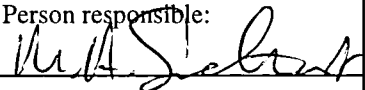


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Structural and plate tectonic evolution of the
SW Barents Sea: A perspective from Area A;
Sørvestsnaget Basin

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Authors: Jon Mosar			Client: Norsk Hydro E&P		
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Summary: The project derived a preferred plate model for the North Atlantic-Arctic ocean from Tertiary to Recent with special emphasis on the Tertiary extension in the SW Barents passive transform margin. Relative drift of adjacent continental blocks is seen as a key driver to the timing and kinematics of tectonism along the Barents Sea passive margin. Therefore detailed plate reconstructions help constrain the tectonic and structural history of the area. The project provides a series of key plate reconstruction time slices that can be used to describe gross palaeogeography and illustrate key phases and changes in the relationship of the adjacent plates.					
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FIGURE CAPTIONS

Figure 1 and 1bis: Regional overview-map with major plates and smaller elements of continental crust. Hovgaard Ryggen and Jan Mayen are blocks underlain by continental crust. The continent ocean boundaries (COB) are indicated in red; they indicate the transition zone from continental to oceanic lithosphere (crust). Mid-ocean ridges are shown in blue including the extinct Ægir ridge. Belgica Basin represents the continental crust offshore NE Greenland. The Vøring Basin and the Trøndelag Platform are the extended offshore continental crust of the Mid-Norway passive margin. Faults and structures in the Svalbard region, the Barents Sea and the offshore Norway are from the NPD data base and represent the major tectonic features. Magnetic anomalies are indicated in green with the anomaly number. Conjugate passive margins (PM) and transform margins are indicated.

Figure 2: Location of the present COB for Greenland and Europe and position of the magnetic anomalies from the Bedrock map of Norway and adjacent ocean areas (Sigmond, E.M.O., Geological Survey of Norway, Trondheim, 1992) overlain on the Magnetic anomaly map of Norway and adjacent ocean areas (Olesen, O., J. Gellein, H. Håbrekke, O. Kihle, J.R. Skilbrei, and M.A. Smethurst, Geological Survey of Norway, Trondheim, 1997).

Figure 3: Location of the COB for Greenland and Europe and position of the magnetic anomalies from the Bedrock map of Norway and adjacent ocean areas (Sigmond, E.M.O., Geological Survey of Norway, Trondheim, 1992) overlain on the Gravity anomaly map of Norway and adjacent ocean areas (Skilbrei, J.R., O. Kihle, O. Olesen, J. Gellein, A. Sindre, D. Solheim, and B. Nyland, Geological Survey of Norway, Trondheim, 2001).

Figure 4: Plate reconstruction at anomaly 24 (53.3Ma) showing the positions of Greenland, the Iceland hotspot. The mid-ocean ridge (existing and incipient) is shown together with the location of the COB for Greenland and Europe. The different structure of the Mid-Norway passive margin and the North Sea (Viking Graben) are shown.

Figure 5: as in fig. 4 but highlighted are the major plate boundaries at anomaly 24.

Figure 6: Pre-drift reconstruction of the Greenland-Norway plates at anomaly 24 showing the large overlap of the NE Greenland offshore extended continental crust with the Barents Sea shelf in the Sørvestsnaget Basin area. Jurassic fault system is from Norsk Hydro data base.

Figure 7: Revised reconstruction of the pre-drift fit at anomaly 24 between NE Greenland and Barents Sea/Norway. The hatched areas show the zone of future strike-slip motion, both transpressive and transtensive and zones of smaller basin development. Hatched lines indicate the major rift/fault boundaries. Hovegaard Ryggen is attached to S Svalbard and will only rift away during Burdigalian times (20Ma). The large amount of extension that need to be accommodated between the NE tip of the offshore extended continental crust of Greenland and the Sørvestsnaget Basin cannot be accommodated on the European shelf (Barents Sea). It has therefore been transferred to the Greenland plate using the Trolle Land Fault Zone and its offshore extension. Kronprins Christian Land has been cut off from N Greenland and transferred slightly

to the NE. Green arrows indicate periods of important sedimentary input. The potential extension of Late Paleozoic salt is indicated in the Belgica Basin area as well as in the Sørsvetsnaget Basin area.

Figure 8: Reconstruction at anomaly 21 Lutetian. The hatched areas show the zone of future strike-slip motion, both transpressive and transtensive and zones of smaller basin development. Hatched lines indicate the major rift/fault boundaries. The Trolle Land fault zone is extended offshore to match with the northern edge of the Belgica Basin and the northern extension of the Paleozoic salt

Figure 9: Reconstruction at anomaly 18 Bartonian. This is the time of maximum convergence between Svalbard and Greenland. The hatched areas show the zone of future strike-slip motion, both transpressive and transtensive and zones of smaller basin development. Hatched lines indicate the major rift/fault boundaries. The major normal and strike-slip faults on the NE Greenland extended shelf are drawn to match their “symmetric”/conjugate faults on the Barents Sea shelf .

Figure 10: Reconstruction at anomaly 13 Rupelian. The hatched areas show the zone of future strike-slip motion, both transpressive and transtensive and zones of smaller basin development. Hatched lines indicate the major rift/fault boundaries. An incipient new ridge is developing in the Boreas Basin and the opening direction in the Lofoten and Greenland Basins is going to change from NW to more W directed.

Figure 11: Reconstruction at anomaly 7 Chattian. The hatched areas show the zone of future strike-slip motion, both transpressive and transtensive and zones of smaller basin development. Hatched lines indicate the major rift/fault boundaries. The transform zone between Greenland and Svalbard is going to develop into a new plate boundary of the passive margin type with small zones of transform faults. The overlap of the future COB is shown. The ridge jump has occurred and has moved the new spreading center closer to the Barents Sea shelf. Hovegaard Ryggen is about to be detached from Svalbard.

Figure 12: Reconstruction at anomaly 6 Burdigalian. Svalbard and Greenland are finally separating and new ocean floor forms between the two plates. The Eurasia Basin and North Atlantic connection are opening. The hatched areas show the zone of future strike-slip motion, both transpressive and transtensive and zones of smaller basin development. Hatched lines indicate the major rift/fault boundaries.

Figure 13: Reconstruction at anomaly 5 Tortonian. Svalbard and Greenland continue separating. The Eurasia Basin and North Atlantic connection has grown to substantial width. The Hovegaard Ryggen continental sliver pertains now to the Greenland/North America plate. The hatched areas show the zone of future strike-slip motion, both transpressive and transtensive and zones of smaller basin development. Hatched lines indicate the major rift/fault boundaries.

Figure 14: Track of selected locations from North America (60°N, 295°E), Greenland (69.2°N, 330°E) and Eurasia (60°N, 10°E) for the last 130 Million years according to the hotspot model. Major changes in direction of all plates occur at 80.4 Ma from a N directed motion towards a NW directed displacement. Between 32.5 and 20.5 Ma an important change occurs in the motion direction of Europe from NW to NE

Figure 15: Present-day simplified geological map of the North Atlantic showing relevant plate and structural features with track of 3 selected points: two on the European plate – Svalbard/Prins Karls Forland (lat 78.5/long 11) and Area A (lat 72/long 17); and one on Greenland - Kronprins Christian Land (lat 81.5/long 348) for the last 130 Ma according to the hotspot model in a present day

Figure 16: Track of 3 selected points: two on the European plate – Svalbard/Prins Karls Forland (lat 78.5/long 11) and Area A (lat 72/long 17); and one on Greenland - Kronprins Christian Land (lat 81.5/long 348) for the last 130 Ma according to the hotspot model. (see Excel files for complete data set).

Figure 17: Velocity Graph of absolute velocities for 3 selected points: two on the European plate – Svalbard/Prins Karls Forland (lat 78.5/long 11) and Area A (lat 72/long 17); and one on Greenland - Kronprins Christian Land (lat 81.5/long 348) for the last 130 Ma according to the hotspot model. See detailed discussion in text. (see Excel files for complete data set).

Figure 18-24: Enlarged plate reconstructions (figures 7-13) showing location of the Jurassic and Tertiary faults/basins from Norsk Hydro in the Area A zone.

1. ABSTRACT

The project derived a preferred plate model for the North Atlantic-Arctic ocean from Tertiary to Recent with special emphasis on the Tertiary extension in the SW Barents passive transform margin. Relative drift of adjacent continental blocks is seen as a key driver to the timing and kinematics of tectonism along the Barents Sea passive margin. Therefore detailed plate reconstructions help constrain the tectonic and structural history of the area. The project provides a series of key plate reconstruction time slices that can be used to describe gross palaeogeography and illustrate key phases and changes in the relationship of the adjacent plates.

2. GENERAL COMMENTS

- The plate Model has been generated using Gmap software (Torsvik and Smethurst, 1999; Torsvik et al., 2001). The basic rotation poles used for the reconstructions of the opening of the North Atlantic in the Tertiary are based, mainly, on new best fit calculations for the magnetic anomalies in the Greenland and Lofoten Basins (W. Roest personal communication) and are discussed in a paper by Torsvik et al. (2001). The magnetic anomalies are those “classically” used and are shown in the map by Sigmond et al. (Sigmond, 1992). These data are in good agreement with the magnetic anomaly lineaments shown on the recent magnetic anomaly map of the North Atlantic (Olesen et al., 1997). Substantial uncertainty, however, exists concerning the age and location of magnetic anomalies in the Boreas Basin, between Greenland and Svalbard.
- All Maps used in this report are polar stereographic (equal angle) projections!
- In all reconstructions Europe is fixed and the other plates move according to the rotation parameters (Euler poles) obtained from fitting magnetic anomalies.
- For purposes of completeness and in order to facilitate the general overview of the plate models presented here, the maps have been made large enough to include parts of the Eurasian Basin, Lomonossov Ridge, the Canadian Arctic Islands, the Jan Mayen Transform Zone, the Vøring Basin, the Trøndelag Platform, the Ægir Basin and the Iceland Basin. It is however beyond the scope of this project to discuss the detailed evolution of these regions. Many problems related to the evolution of the Jan Mayen microcontinent and the Canadian Arctic Islands are still debated and a discussion is beyond the scope of this report. *The reconstructions relative to these areas shown in this report remain subject to uncertainties and discussion.* More detailed views related to Area A are also included in the report.
- OBS! No retrodeformation was applied to the extensional and compressive structures on Svalbard and Greenland and the faults shown on the reconstructions are in their Present location.

3. PLATE MODELS, PLATE MOTION AND DRIFT VELOCITIES

Different types of plate models can be used to make reconstructions at different times:

- relative displacement models with Europe fixed and Greenland-North America moving towards Europe. Magnetic anomaly data, globally applicable from mid-Jurassic times (ca. 175 Ma) in the Atlantic realm and from 53.3 Ma on (anomaly 24) in the North Atlantic, provide relative fits between continents;
- absolute displacement models with all plates moving in an absolute framework based on the hotspot reference model. The hotspot reference frame has been used to make global reconstruction and establish absolute position of continents through time. A fundamental assumption is that the hotspots are stationary, or move at insignificant speeds, relative to plate-tectonic velocities. Given the similarity between the Early Tertiary hotspot and paleomagnetic reconstructions and recent analysis from the Indian Ocean, it can be shown that the hotspot reconstructions for 130 Ma to present-day by Müller (1993) represent viable first-order approximations to use in drift-rate calculations.

Paleomagnetic data yield paleolatitudinal and rotational constraints for continents throughout geological history. Conversely, from Cretaceous times (ca. 130 Ma), hotspot reconstructions provide paleolongitudinal control, absent in paleomagnetic data, for plate positions.

3.1 Plate Reconstructions

We have used in our reconstructions relative fits with Europe fixed, based on the existing magnetic anomalies and best fits. The reconstructions discussed cover the Tertiary period with a focus on the plate motion between Greenland and Europe. The rotation poles used for the reconstructions presented are given in the table below and the overall discussion of the plate model and the quality of the data are discussed in Torsvik et al. (2001) added as a separate paper with this report. The reconstructions have been generated with GMAP2001 (Torsvik and Smethurst, 1999).

Age (Ma)	Mag. Anom	Period	Latitude	Longitude	Angle	reference
10.3	A5	E. Tortonian	70.2	117.6	2.3	Torsvik et al 2001
19.6	A6	Burdigalian	68.8	132.3	4.8	Id.
25	A7	Chattian	68.7	131.3	6	Id.
33.3	A13	Rupelian	68	129.9	7.6	Id.
39.3	A18	Bartonian	59.81	129.63	8.26	New pole
42.54	A20*	L. Lutetian	48.92	134.88	8.1	Wold 1992#
47.1	A21	E. Lutetian	53.7	128.9	9.2	Torsvik et al 2001
53.4	A24	E. Ypresian	51.5	122.6	11.4	Id.

*Rotation parameters to rotate Greenland back to Europe (with Europe fixed; Angle – clockwise; # from the online ODSN data base on plate reconstructions); * reconstruction not shown because of loose fit of magnetic anomalies.*

3.2 Iceland hotspot and hotspot reference frame

The synthetic hotspot track for the Iceland hotspot (relative to Greenland) assumes a stationary hotspot, presently located at 64°N and 16°W, and was calculated from the 'global' hotspot model of Müller et al. (1993) and magnetic anomaly fits. This track is quite similar to that of Lawver and Müller (1994) and implies that the Iceland hotspot was located beneath West-Central Greenland at c. 60 Ma and subsequently at the East Greenland Margin at c. 40 Ma. We note that the shape and extent of the Iceland plume relative to genesis of the pre-break-up volcanics is still controversial: the dispersed localities of the early volcanism around the North Atlantic must be taken into account when we attempt to envision and reconstruct the Cretaceous through Tertiary NW movement of Greenland over an isolated pole. We underscore that imprecise knowledge of the Iceland plume shape does not affect the reconstructions presented in this study, since data from the Iceland plume are never used as direct input for the reconstructions.

3.3 Drift curves - velocity curves from real displacements

In order to evaluate the velocity of a plate one can consider a point on a given plate and calculate its displacement in time with respect to a reference frame. One can alternatively choose between the global hotspot reference frame to calculate absolute velocities of any given point on a plate, or a relative reference frame, where one plate is fixed and the other moves (mostly based on magnetic anomalies), or else use the virtual geomagnetic poles based on apparent polar wander paths and calculate latitudinal displacements.

- virtual geomagnetic poles: unfortunately the virtual geomagnetic pole curve is not, at present, of good enough quality and precision to be used for precise and detailed reconstructions and velocity measurements for the Mesozoic and Cenozoic time periods.
- absolute displacement based on the hotspot reference frame are discussed for 3 different points: two points on the European plate – Svalbard/Prins Karls Forland (lat 78.5/long 11) and Area A (lat 72/long 17); and one on Greenland - Kronprins Christian Land (lat 81.5/long 348). The curves for absolute displacement of these points are shown in figures 15 and 16. The velocity analyses is shown in figure 17. A similar behavior, showing increases and decreases in velocity, for both the European and the Greenland plate, are recorded during most of the Cretaceous. Beginning in Maastrichtian, that is prior to separation in Tertiary the curves show a distinct evolution of the velocities. While the velocities generally decrease towards the Middle Oligocene, the points on Europe show a faster decrease than the point on Greenland. The period of minimal velocity in the Oligocene is not quite coincident on Europe and on Greenland.

Relative motion of Greenland with Europe fixed is not further discussed herein, but is discussed in Torsvik et al. (2001).

4. PLATE-TECTONICS RELATED TO TECTONIC EVENTS IN THE NORTH ATLANTIC

4.1 Major general geodynamic/plate tectonic events in the Atlantic realm

The evolution of the North Atlantic ocean is of course related to the evolution of the neighboring oceanic realms such as the Labrador Sea and the polar Eurasia Basin. It forms the successful attempt of the Atlantic Ocean to propagate to the North. Some of the major

events of opening of the Atlantic are related to major changes in plate tectonics and are briefly described hereafter.

- The opening of the Atlantic: the drifting of the Central Atlantic started around 180 Ma and is associated with an overall eastwards drift of the African plate (in a reference frame with Europe fixed). It is from this time on that the African plate has a motion to the E-SE. The Alpine Tethys opens during this period and expands until 130-120Ma.
- 130 Ma Hauterivian: This is a period of major changes in plate motion and the development of important Cretaceous basins on several plates linked to the developing Atlantic Ocean. This period coincides with the rift-drift transition (beginning of formation of oceanic crust) in the South Atlantic, and there is a strong rotational component to the movement of Africa. Overall, and until 85Ma, plate motion in the North Atlantic realm is to the North.
- Around 83 Ma a dramatic change in plate motion occurs and all plates in the North Atlantic realm now move towards the NW. This event is coincident with intra-oceanic subduction in the NeoTethys in front of the northward moving Indian continent (the rapid northward movement and convergence with Asia began also around 85 Ma). From the Around 83 Ma a strong inversion (folding) is recorded mainly in North Africa and the Peri-Arabic domain (with an ophiolite obduction). The collision of Iberia with Europe (France) and the consumption of the Valais ocean and the Bay of Biscay ocean in a short-lived subduction probably generated inversion along the Africa margin facing Iberia at the time. This is also the time (85-80 Ma) of rift-drift transition between W-Africa and Amazonia. It is also the period (or slightly before) that the Labrador Sea starts to open.

4.2 Detailed evolution of the North Atlantic realm: Barents Sea Margin and Svalbard-Greenland

A more detailed description of the different opening stages of the North Atlantic realm in relation with the southern edge of the Barents Sea and Svalbard is given below. In these reconstructions. The Hovegaard Ryggen is considered to be a sliver of continental crust that pertained to SE Svalbard until Burdigalian times and only subsequently drifted away from Svalbard. Shown on the different maps are the location of Area A and the position of the Tertiary and Jurassic faults in the investigated area (fault data set provided by Norsk Hydro).

- Anomaly 24 – 53.9 Ma – Ypresian (Early Eocene): The overall situation including the Labrador Sea and the northern Central Atlantic are shown in figures 4 and 5. This is the time when Greenland is about to separate from Norway. The conjugate passive margins are in a best fitting position, except for the NE part of the offshore of Greenland and its counterpart on the Barents Sea Shelf (figure 6). There is an excess overlap of extended continental crust of some 240km that has to be accounted for. Such a large amount of shortening cannot be realized on the European plate (as the information from deep seismic do not show faults with sufficient extensional offset). There the extension/shortening has to be transferred to the Greenland plate (figure 7). This includes cutting off Kronprins Christian Land and moving it towards the NW along the Trolle Land fault zone.

- Anomaly 21 – 47.1 Ma – Lutetian (Middle Eocene). While oceanization is in progress in the future Lofoten and Greenland Basins, a best fit pre-breakup situation is achieved between NE Greenland and the Barents Sea shelf. Maximum extension is achieved on the European and Greenland plate (figure 8).
- Anomaly 18 – 39.4 Ma – Bartonian (late Middle Eocene). The Boreas basin is now opening (oceanic crust forming) (figure 9). The convergence of Greenland and Svalbard at its climax during this period. The mid-ocean ridge in the Lofoten – Greenland Basin is now at the S edge of Area A. North of the Sørvestnaget Basin a passive margin develops, whereas W of Area A a transform margin develops. The Labrador Sea has stopped spreading at or just prior to anomaly 18 since the youngest magnetic anomaly known in the Labrador Sea is anomaly 20. North America and Greenland now behave as a single plate.
- Anomaly 13 – 33.3 Ma – Rupelian (Early Oligocene). Greenland and Svalbard start again moving away from each other. The transform edge of the northern Boreas Basin is still located to the SW of the Hovegaard Ryggen continental sliver (figure 10). The ridge in this basin is facing the Hovegaard Ryggen continental sliver inducing probably important uplift which is corroborated by the discovery of continental spores and pollens in this area. The mid-ocean ridge in the Lofoten – Greenland Basin is now at the N edge of Area A. Following Anomaly 13 there is a change in plate motion and in a reference grid with Europe fixed, Greenland is now moving more westerly than before (where the motion direction was more NW). In a global hotspot reference frame this is the time when Europe starts moving to the NE (figure 14 and 15). It's the beginning of the final separation of Europe and Greenland in the Svalbard area.
- Anomaly 7 – 25 Ma – Chattian (Late Oligocene). Subsequent to the displacement of the major strike-slip to the E of the Hovegaard Ryggen a new mid-ocean ridge developed in the Boreas Basin (ridge jump!) in direction of the Barents Sea shelf (figure 11). This leaves the northern Boreas Basin with an abandoned ridge and its "old" magnetic anomalies. Hovegaard Ryggen is also now moving along the strike-slip fault to the NW. This is also the time when the Iceland hotspot is "captured" under the North Atlantic mid-ocean ridge (absolute plate motion has moved the ridge system over the hotspot)
- Anomaly 6 – 19.6 Ma – Burdigalian (Early Miocene). The transform margin between Greenland and Svalbard has now changed to a passive margin edge (figure 12). And new ocean floor develops between the Svalbard and Greenland conjugate margins (with smaller transform edges). This is the period of final separation between Greenland and Svalbard (Europe).
- Anomaly 5 – 10.3 Ma – Tortonian (Late Miocene). The mid-ocean ridge in the Boreas Basin has changed its position to form a more ribbon-like structure. The connection between the North Atlantic and the Arctic Eurasia Basin is now fully open (figure 13).

5. TECTONIC EVENTS IN THE NORTH ATLANTIC

A series of tectonic events in the North Atlantic domain are related to the formation of the Boreas, Lofoten and Greenland Basins and the development of the associated passive margins and strike slip/transform margins. Many events related to the extension can be seen in the sedimentary record in the basins along the Barents Sea-Atlantic Ocean region. Other events, both extensional and compressional, are seen on Svalbard in the Tertiary Basins but also in the fold-and-thrust belt and in their counterparts in Greenland.

From structural studies on Svalbard the following major events can be discriminated:

- 61-56 Ma L. Paleocene: phase 1 – convergence
- 56-52 Ma phase 2 - extension
- 52-48 Ma phase 2 - strike –slip
- 47-39 Ma M. Eocene phase 3 – convergence
- 37 - .. L. Eocene phase 4 – extension

The events are largely coincident with important changes occurring in the oceanic domain which are linked to the plate dynamics and which are described before.

6. KEY REFERENCES TO THE UNDERSTANDING OF THE SEPARATION BETWEEN GREENLAND AND SVALBARD

In the following is a list of relevant references suitable for a quick and overall update on the tectonics, plate-tectonics and geodynamic evolution of the Svalbard – Greenland area.

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6.3 Regional maps used

- Olesen, O., J. Gellein, Håbrekke, H., Kihle, O., Skilbrei, J.R. & Smethurst, M.A., 1997: Magnetic anomaly map of Norway and adjacent ocean areas, Geological Survey of Norway, Trondheim.
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- Skilbrei, J.R., Kihle, O., Olesen, O., Gellein, J., Sindre, A., Solheim, D. & Nyland, B., 2001: Gravity anomaly map of Norway and adjacent ocean areas, Geological Survey of Norway, Trondheim.

6.4 Other references cited in this report

- Lawver, L. A., & Müller, R. D., 1994: Iceland hotspot track: *Geology*, v. 22, 311-314.
- Müller, R. D., Royer, J. Y., & Lawver, L. A., 1993: Revised plate motions relative to the hotspots from combined Atlantic and Indian Ocean hotspot tracks: *Geology*, v. 21, 275-278.
- Torsvik, T. H., & Smethurst, M. A., 1999: Plate tectonic modeling: virtual reality with GMAP. *Computers & Geosciences*, v. 25, 395-402.

TABLES

On computer diskette in Excel spreadsheet format

APPENDIX

Initial Work plan - Deliverables

- ☐ Document discussing and defining the most appropriate plate model for the investigated area. Evidence for the preferred plate-model will be presented together with a critical assessment of existing-alternative models.
- ☐ Relative drift curves for adjacent plates through time and estimates of finite extension at different times will be given.
- ☐ Plate reconstruction time slices showing the key stages in the plate development will be related to global plate dynamics and major changes in global plate kinematics/dynamics.
- ☐ Short report documenting the different aspects.
- ☐ Visit to present work and integrate the ideas with existing work on seismics and stratigraphy-sedimentology
- ☐ Final Report: Plate reconstruction, velocity/extension plots and discussion of model

Figure 1

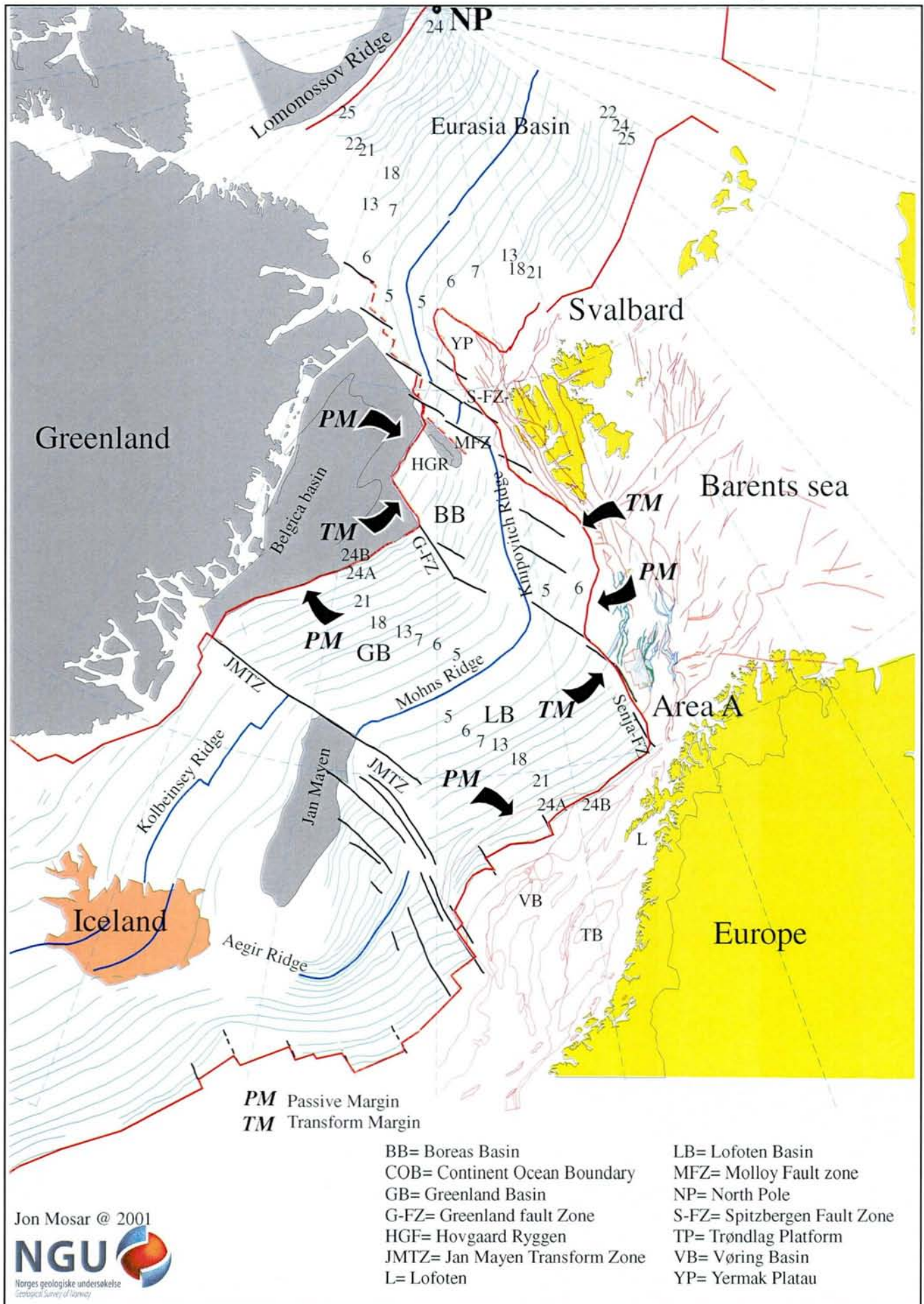
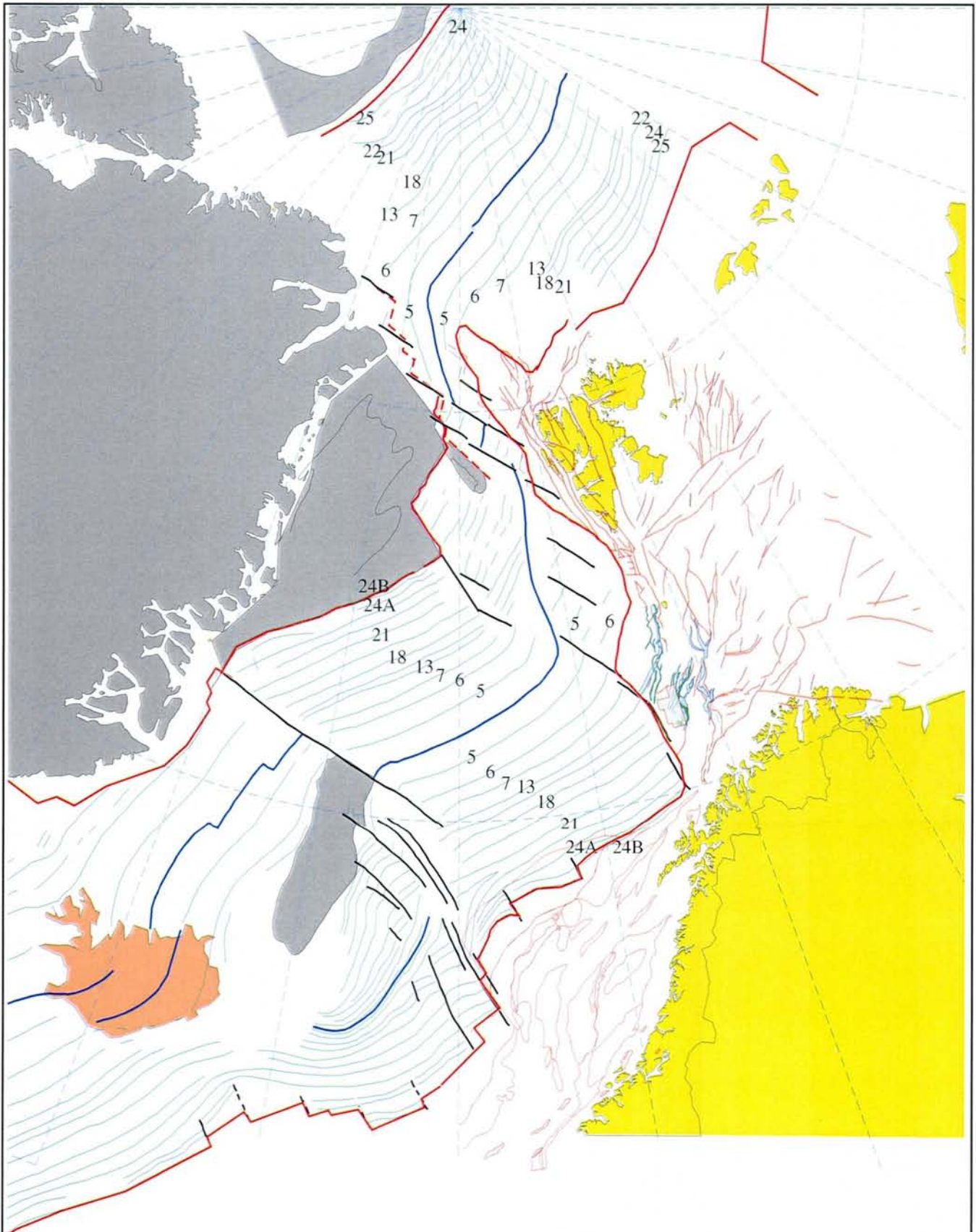


Figure 1bis

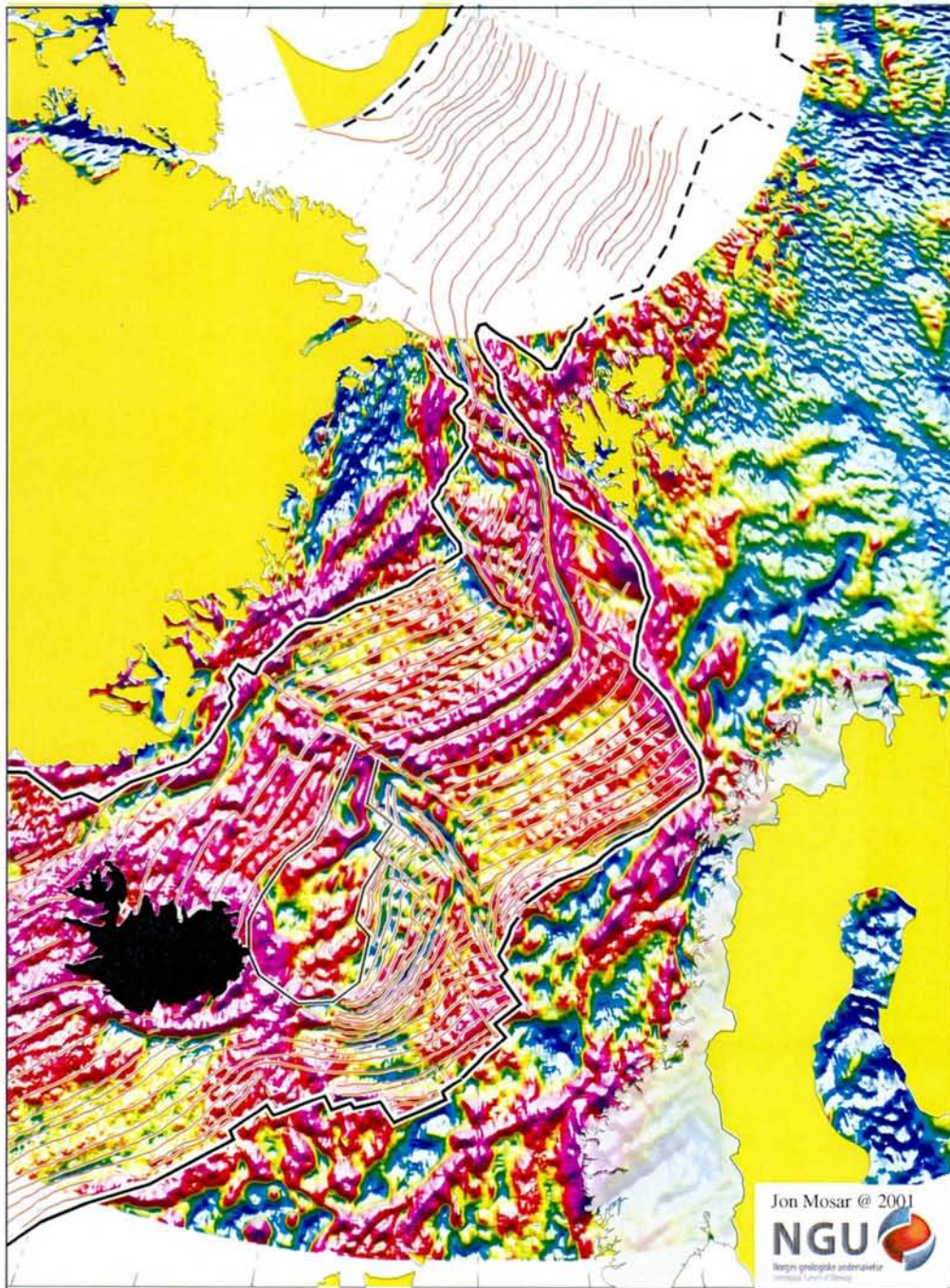




Magnetic Anomaly Map

Olesen, O., Gellin, J., Håbrekke, H., Kihle, O., Skilbrei, J. R., and Smethurst, M. A., 1997, Magnetic anomaly map of Norway and adjacent ocean areas: Geological Survey of Norway, scale 1:3 million

Figure 2



Gravity Anomaly Map

Skilbrei, J. R., Kihle, O., Olesen, O., Gellein, J., Sindre, A., Solheim, D., and Nyland, B., 2001, Gravity anomaly map of Norway and adjacent ocean areas: Geological Survey of Norway, scale 1:3 million

Figure 3

Figure 4

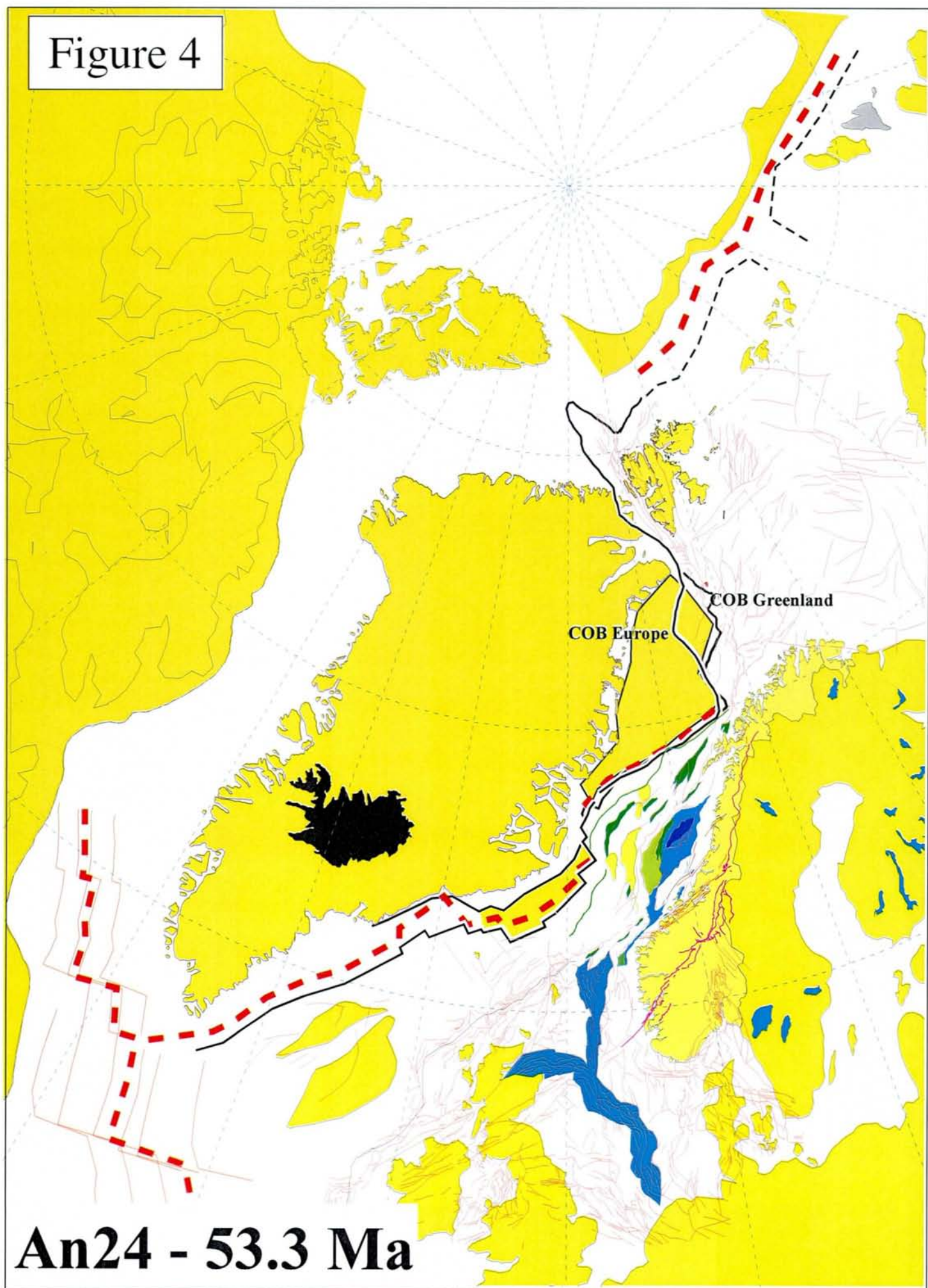
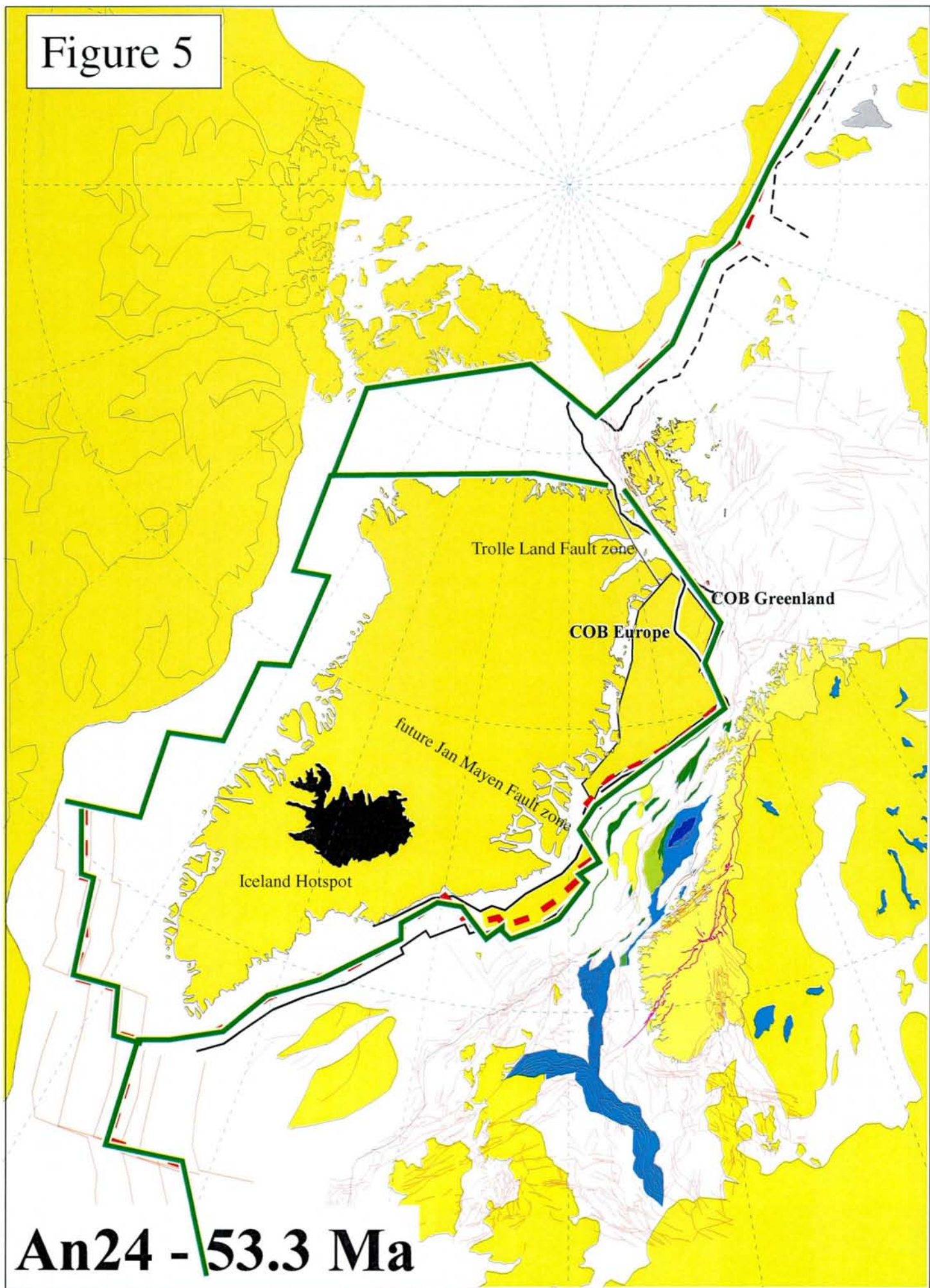
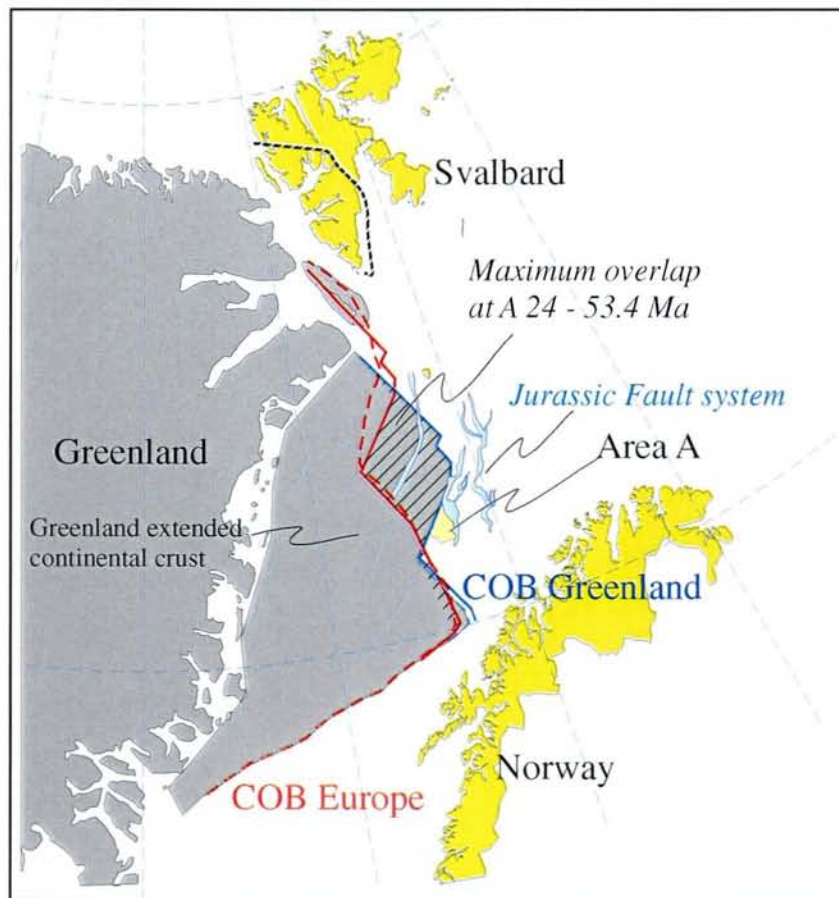


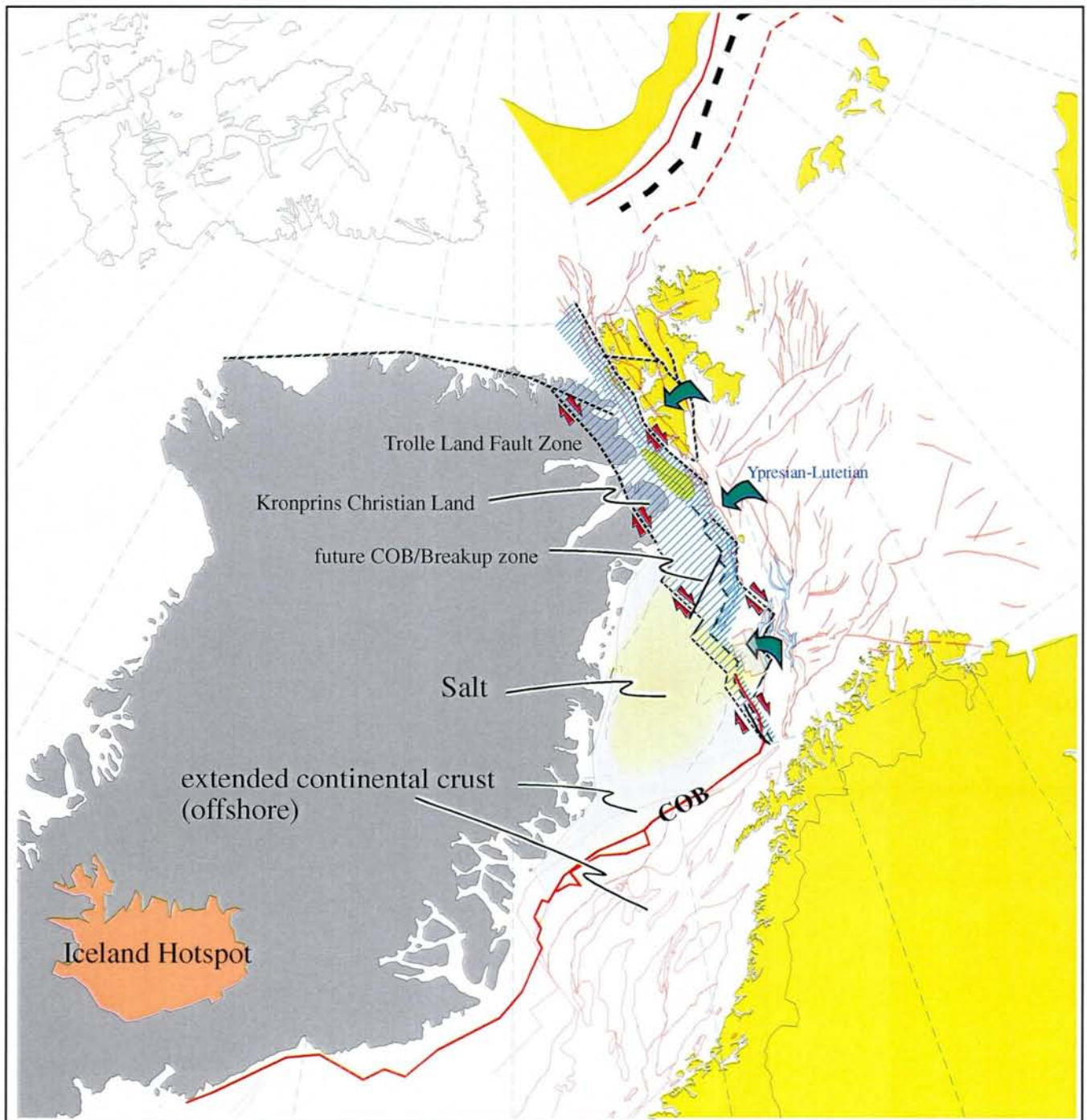
Figure 5





Anomaly 24 fit (Europe fixed; polar equal angle projection).
 Overlap of Greenland extended continental crust onto Barents
 Sea domain. Total overlap of some 240km.

Figure 6

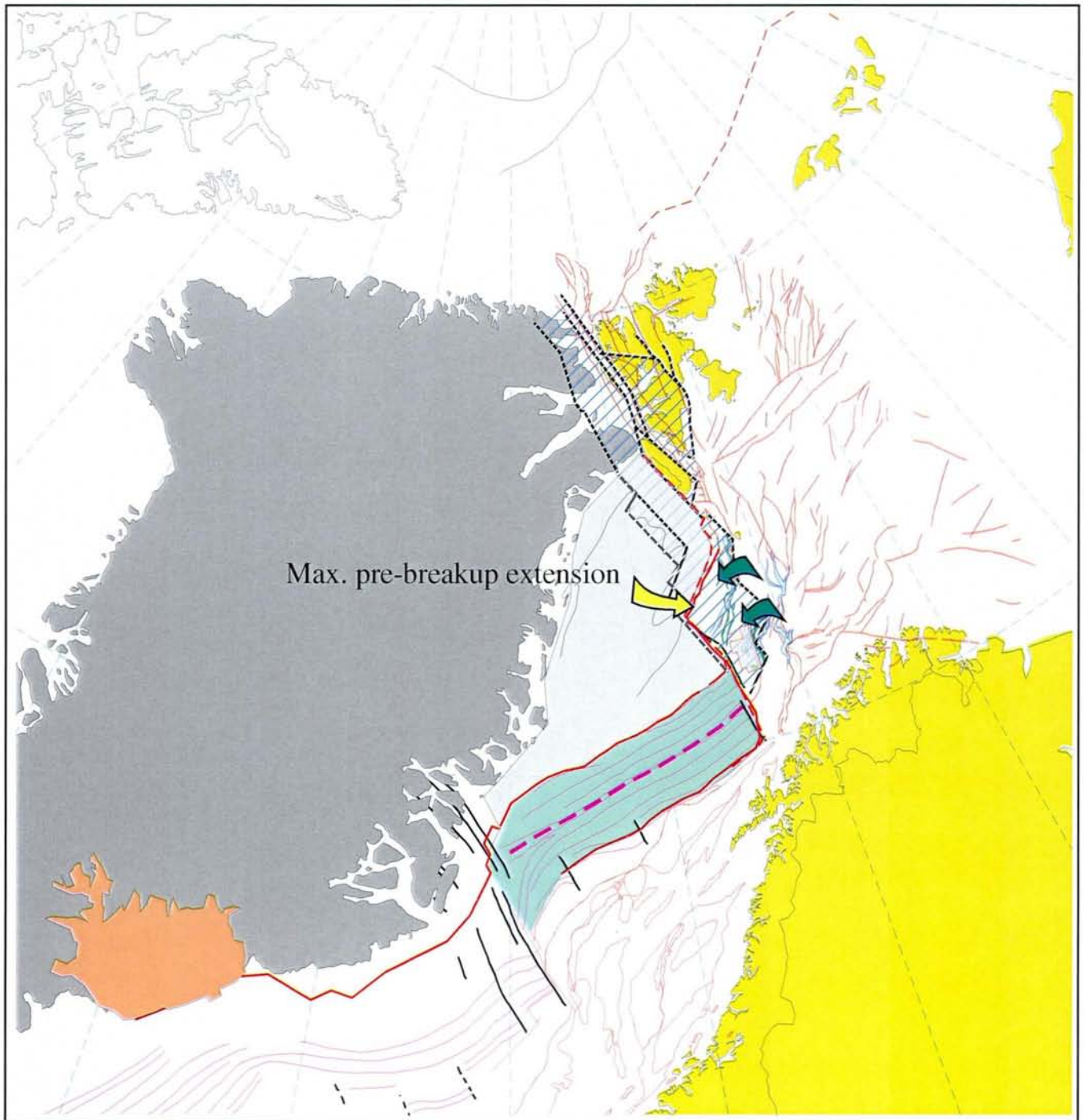


Anomaly 24 - 53.9 Ma Ypresian

Jon Mosar 2001 **NGU**

-  Zones of normal and/or strike-slip faults
-  Shear/Transform zone (with transpression and/or -tension)
-  Sediment infill

Figure 7

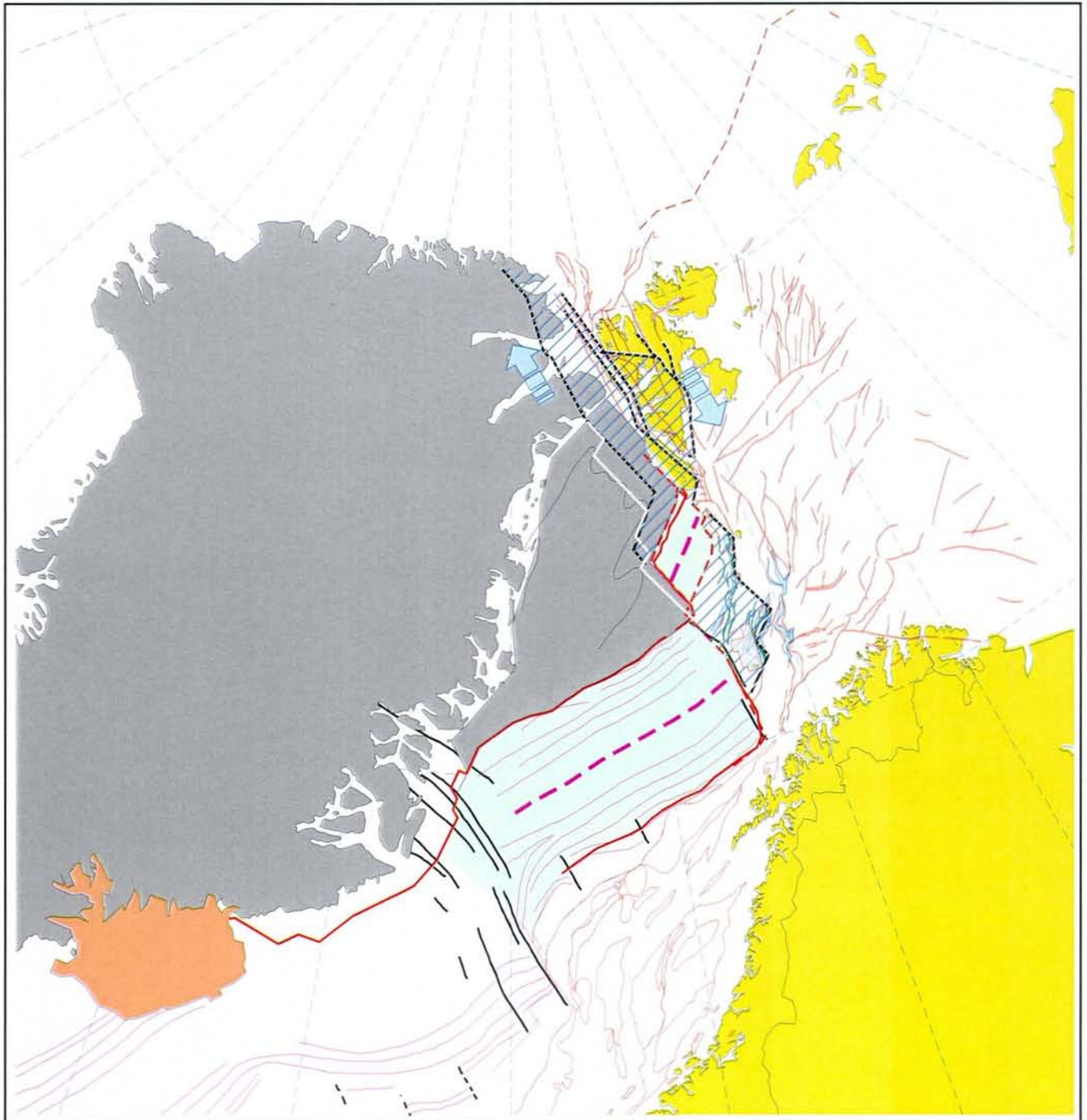


Anomaly 21 - 47.1 Ma Lutetian

Jon Mosar 2001 **NGU**

-  Zones of normal and/or strike-slip faults
-  Shear/Transform zone (with transpression and /or -tension)
-  Sediment infill

Figure 8

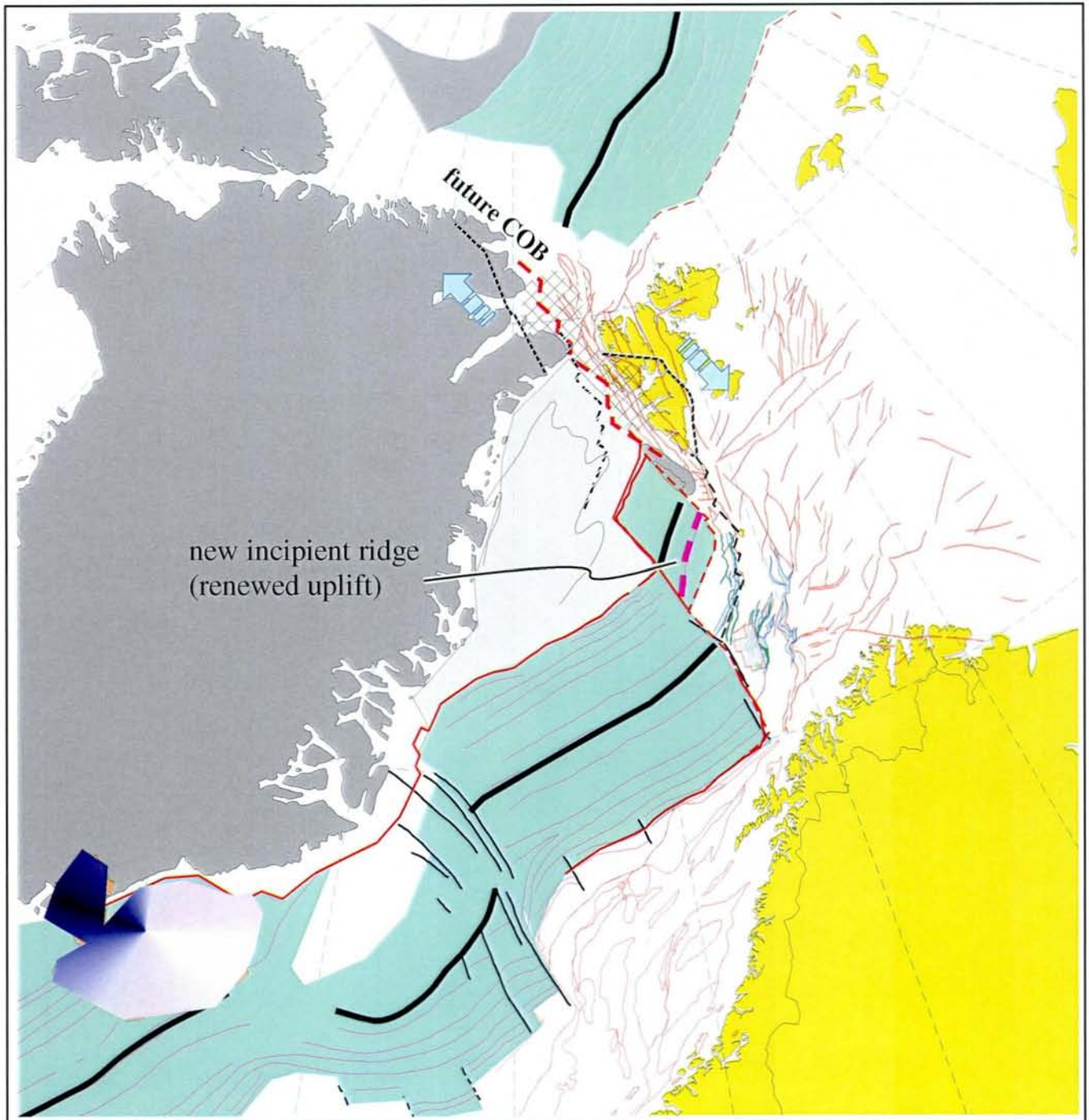


Anomaly 18 - 39.4 Ma Bartonian

Jon Mosar 2001 **NGU**

-  Zones of normal and/or strike-slip faults
-  Shear/Transform zone (with transpression and /or -tension)
-  Sediment infill

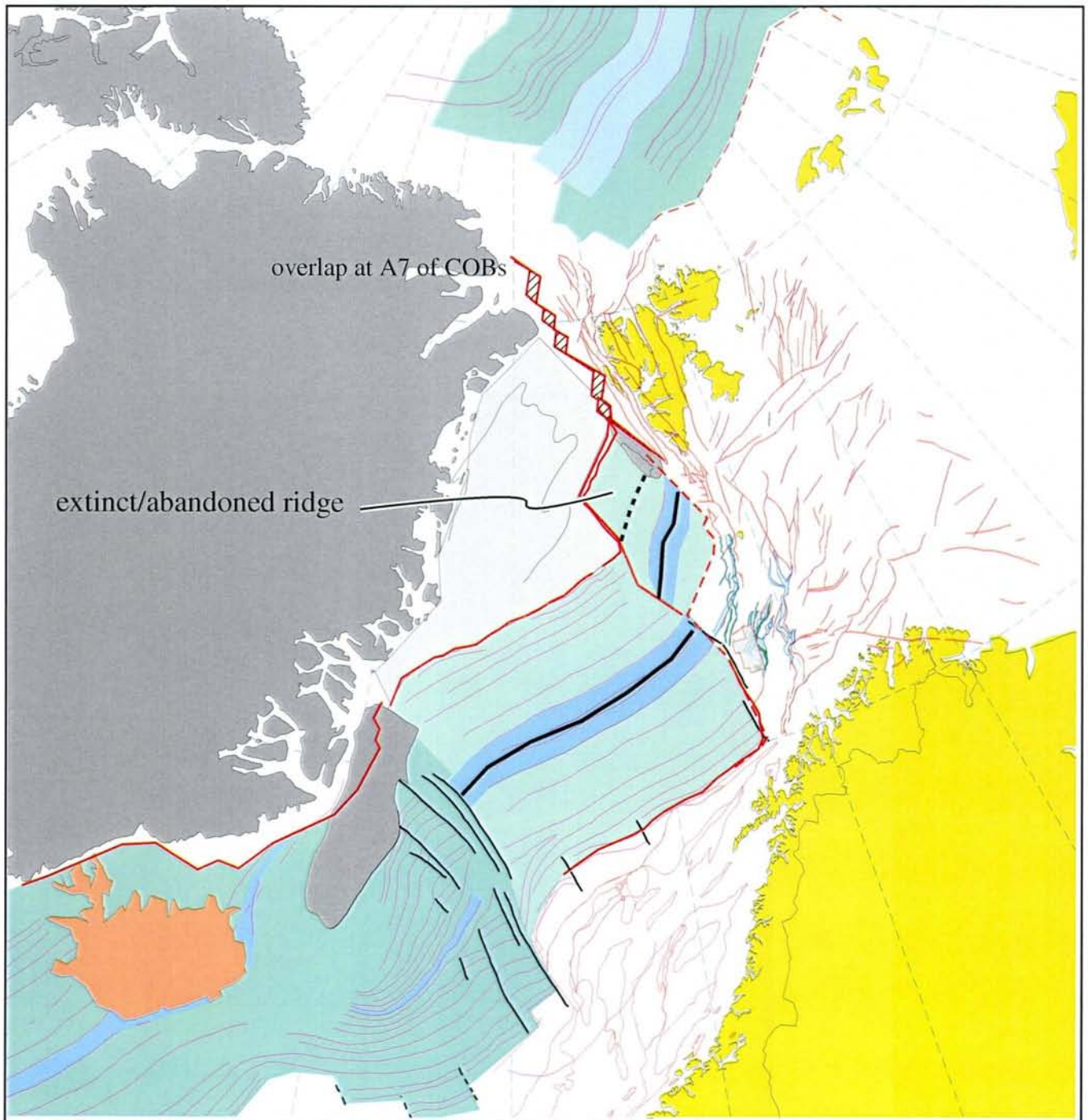
Figure 9



Anomaly 13 - 33.3 Ma Rupelian

Jon Mosar 2001 **NGU**

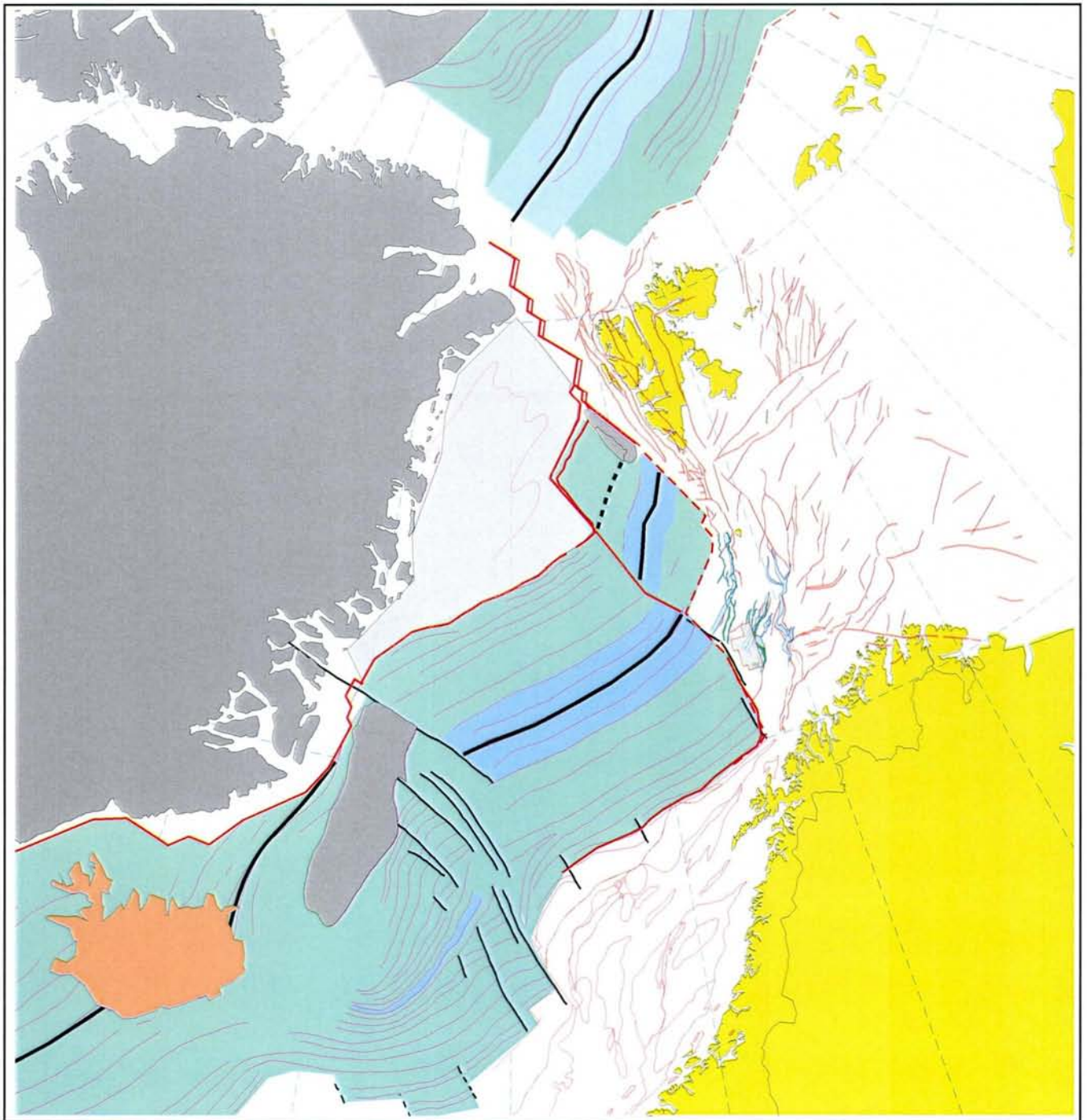
Figure 10



Anomaly 7 - 25 Ma Chattian

Jon Mosar 2001 NGU 

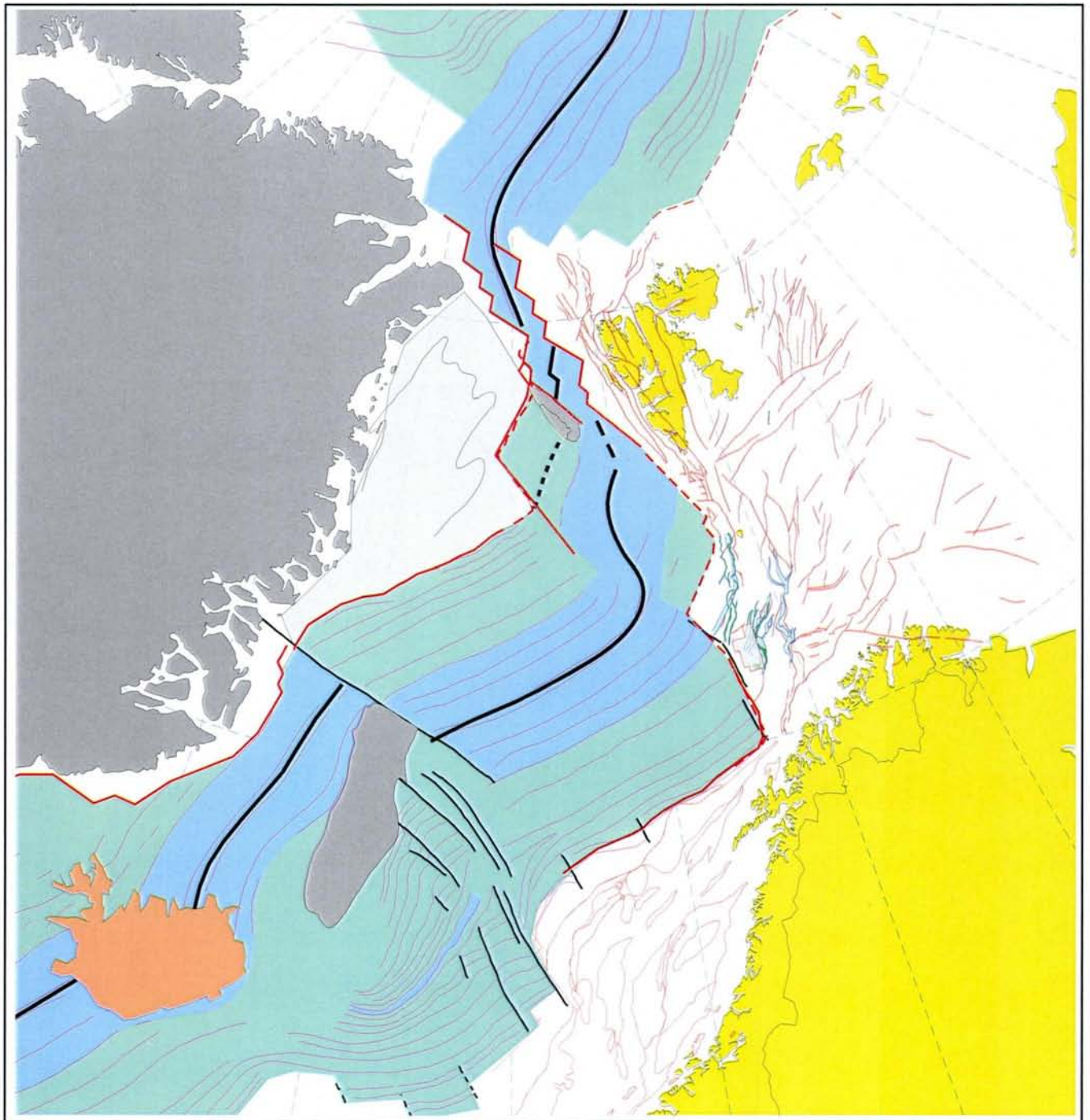
Figure 11



Anomaly 6 - 19.6 Ma Burdigalian

Jon Mosar 2001 NGU 

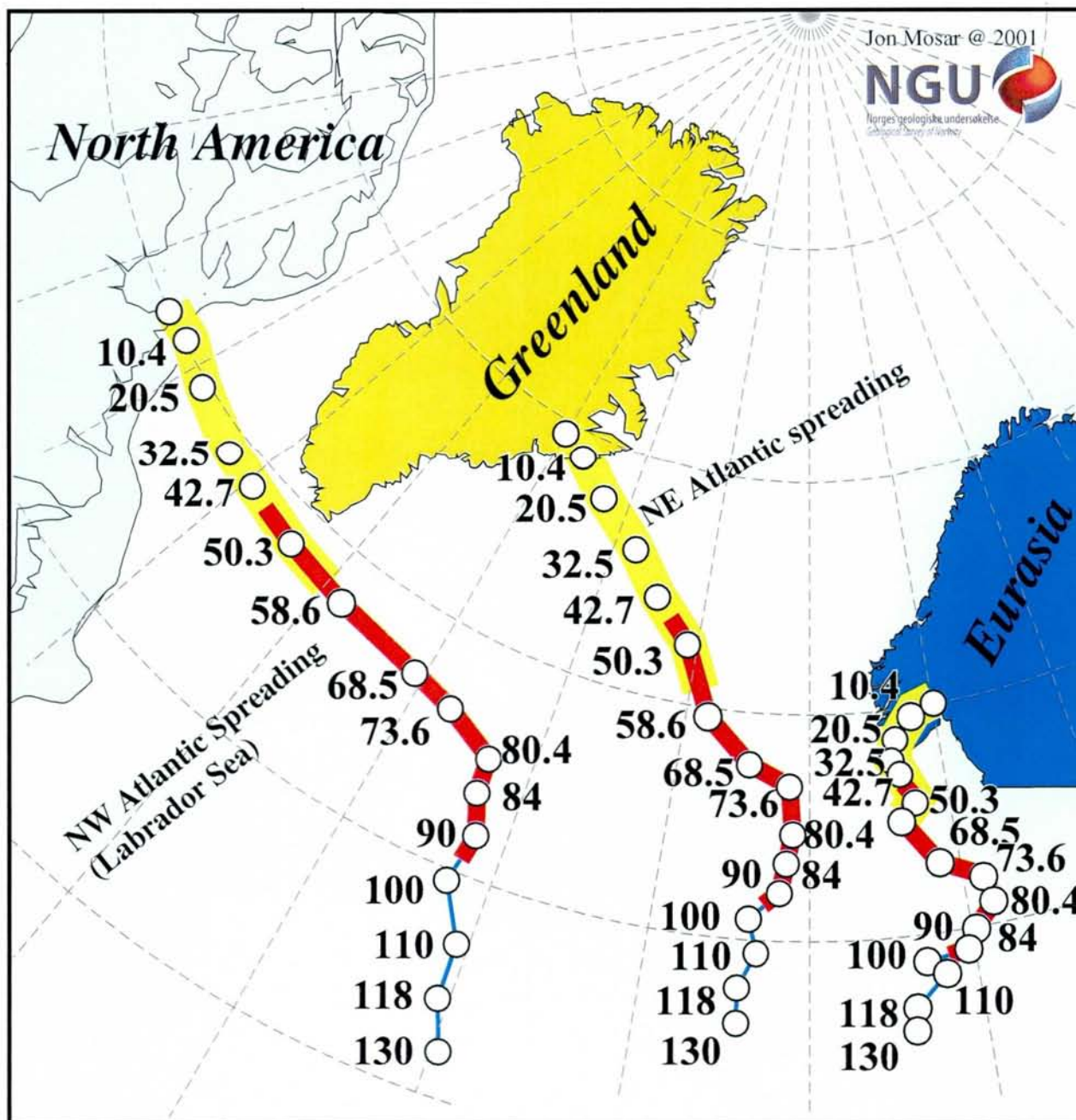
Figure 12



Anomaly 5 - 10.3 Ma E. Tortonian

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Figure 13



Absolute track of
 Greenland 69.3N, 330E
 North America, 60N, 295E
 Eurasia 60N, 10E

Figure 14

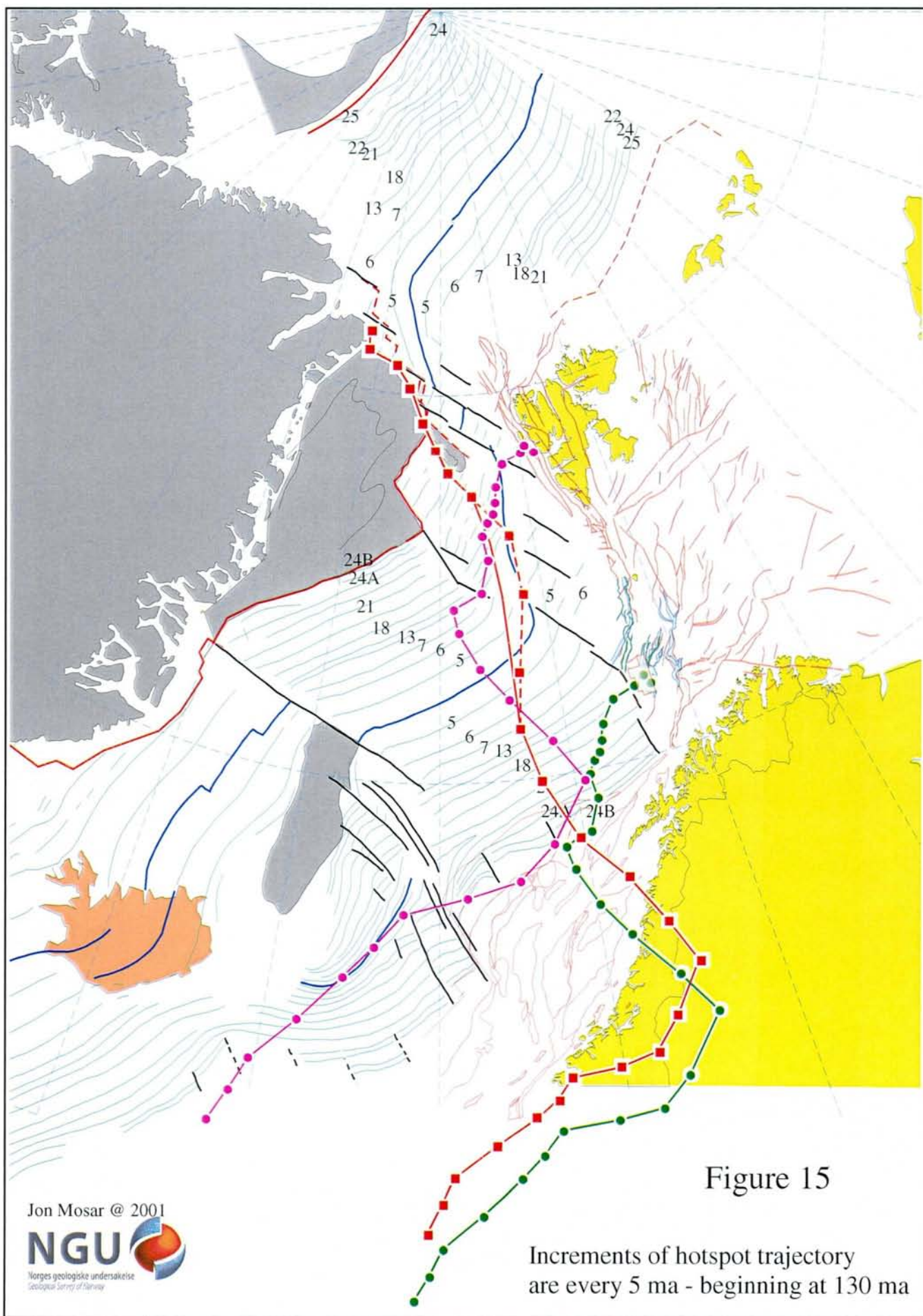


Figure 15

Increments of hotspot trajectory
are every 5 ma - beginning at 130 ma

Figure 16

Absolute displacement

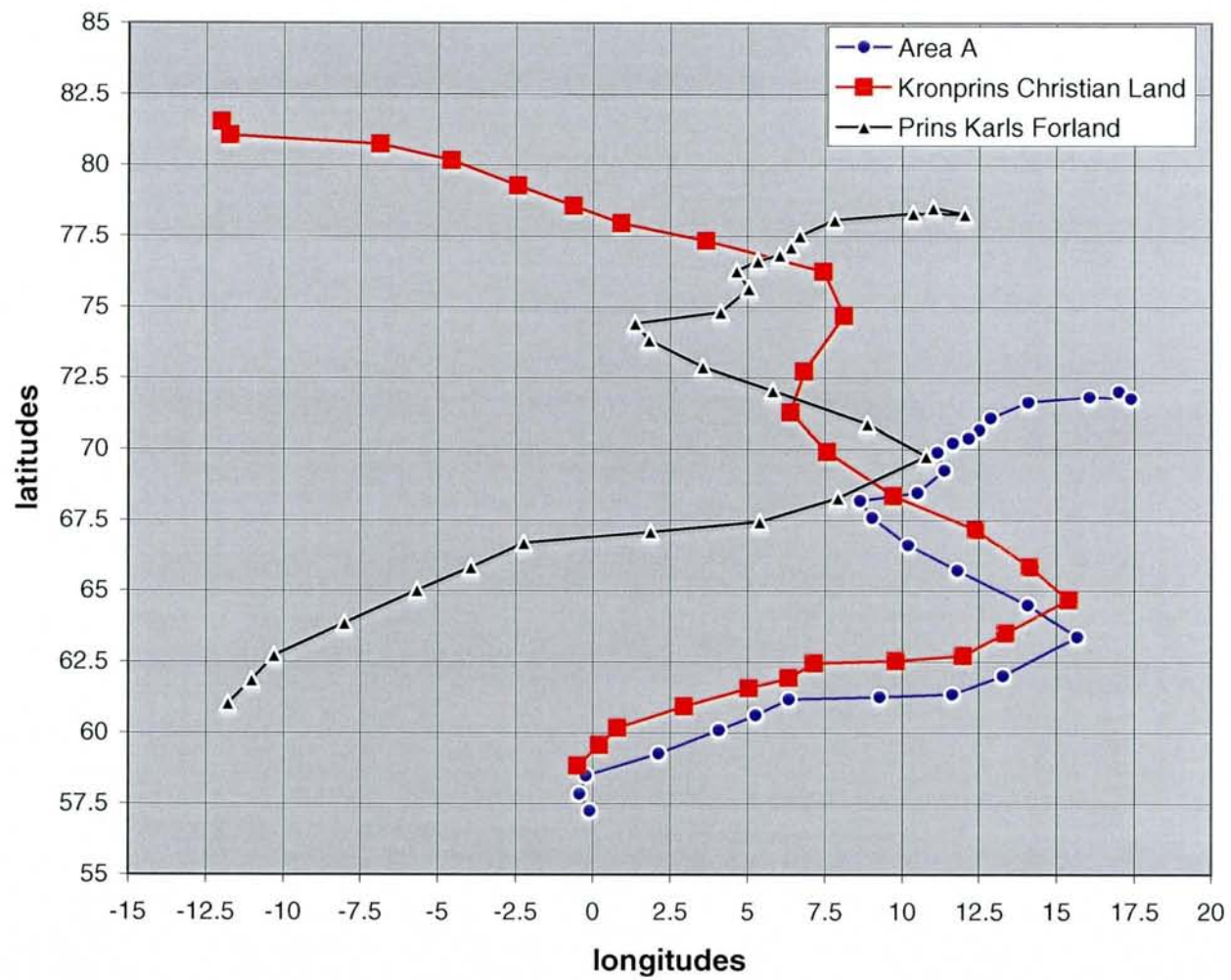


Figure 17

Absolute Velocities (cm/year)

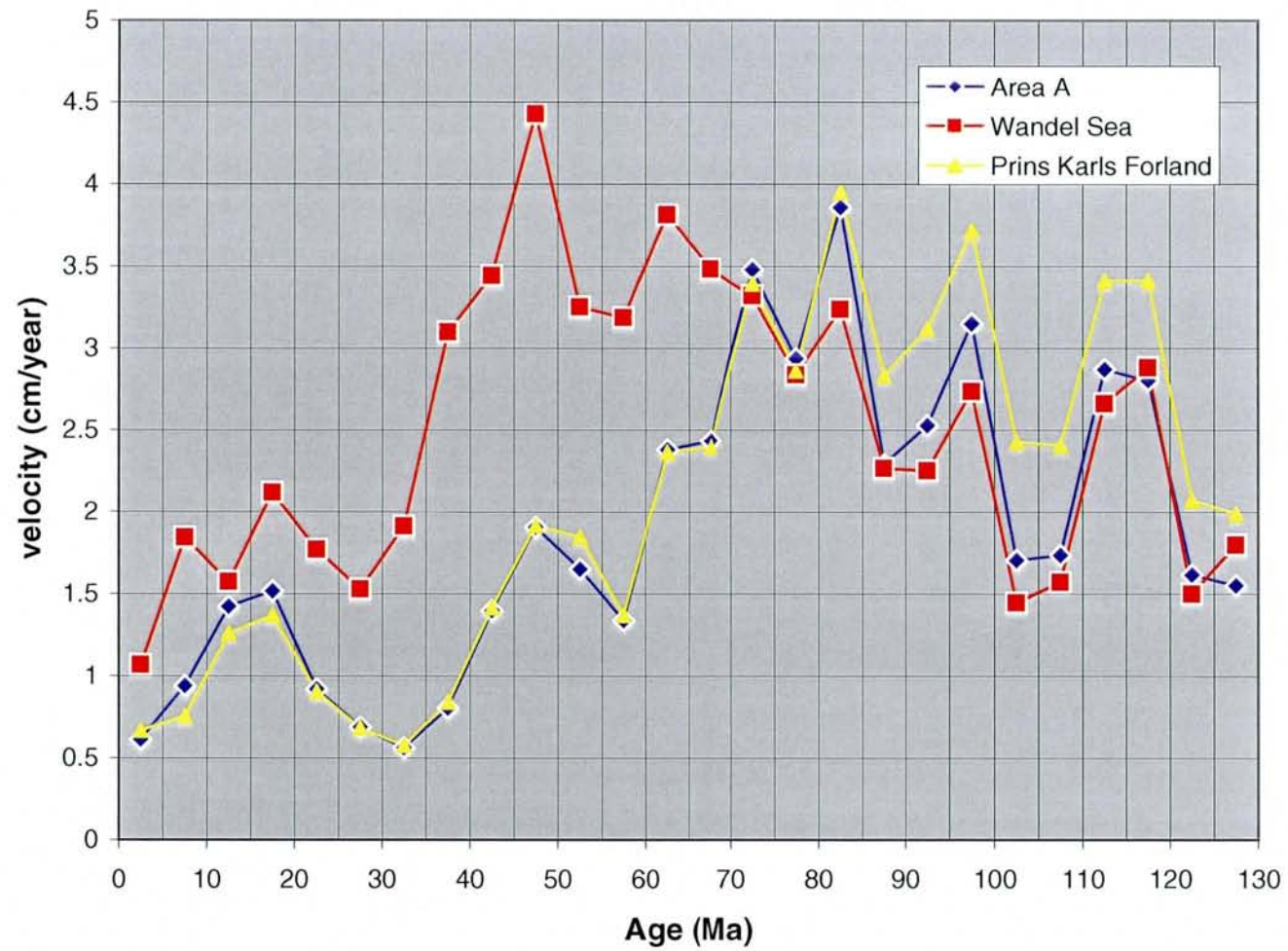
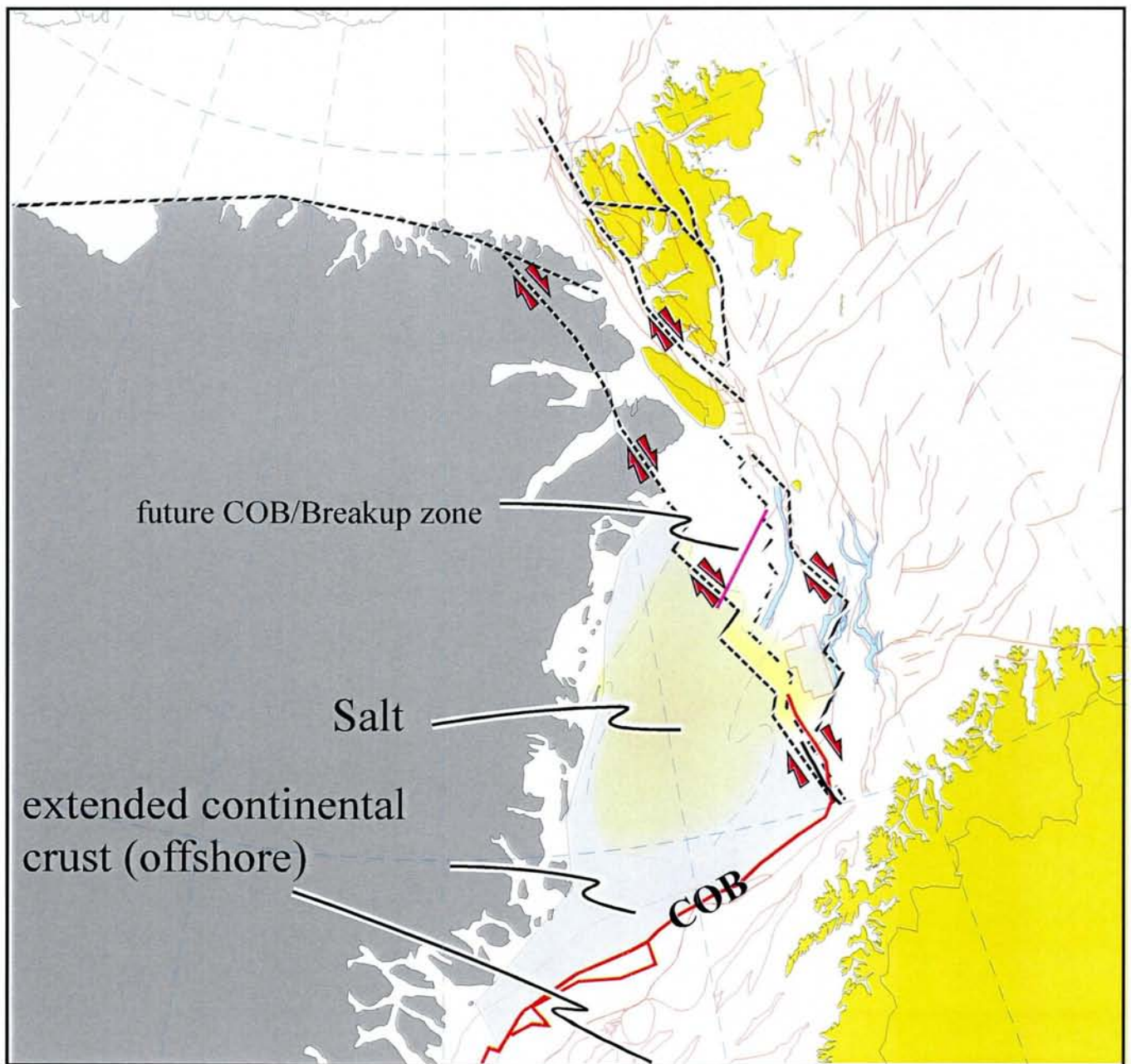
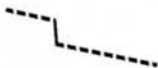


Table with absolute velocities and displacements and lat/long positions

			Area A	lat72/long17			Kronpr. Christian Land Greenland/Wandel Sea				lat81.5/long348		Svalbard/Pr. Karls For		lat78.5/long11	
	age		km	cm/year	Plat	Plon	km	cm/year	Plat	Plon	km	cm/year	Plat	Plon		
0	0				72	17			81.5	-12					78.5	11
5	2.5	0	30.6812	0.613624	71.75	17.4	53.39962	1.067992	81.02	-11.74	33.31559	0.666312	78.28	12.03		
10	7.5	5	46.89288	0.937858	71.8	16.06	92.20079	1.844016	80.72	-6.86	37.76291	0.755258	78.31	10.36		
15	12.5	10	71.18478	1.423695	71.61	14.11	78.71024	1.574205	80.13	-4.57	62.95478	1.259096	78.08	7.82		
20	17.5	15	75.88125	1.517625	71.05	12.89	105.9395	2.118791	79.25	-2.42	68.58826	1.371765	77.51	6.7		
25	22.5	20	46.0318	0.920636	70.65	12.52	88.60584	1.772117	78.54	-0.62	45.18717	0.903743	77.11	6.41		
30	27.5	25	34.35758	0.687152	70.37	12.17	76.46443	1.529289	77.93	0.93	34.0378	0.680756	76.82	6.05		
35	32.5	30	28.07519	0.561504	70.19	11.66	95.65439	1.913088	77.3	3.68	28.86476	0.577295	76.61	5.34		
40	37.5	35	40.15291	0.803058	69.87	11.15	154.9284	3.098568	76.21	7.47	41.94642	0.838928	76.27	4.66		
45	42.5	40	69.90663	1.398133	69.24	11.38	172.1313	3.442626	74.67	8.13	70.77951	1.41559	75.64	5.05		
50	47.5	45	95.28075	1.905615	68.45	10.51	221.366	4.427319	72.71	6.85	95.78764	1.915753	74.81	4.14		
55	52.5	50	82.5602	1.651204	68.17	8.65	162.6055	3.252109	71.26	6.41	92.43179	1.848636	74.42	1.37		
60	57.5	55	66.96678	1.339336	67.58	9.04	159.3022	3.186043	69.88	7.58	68.55246	1.371049	73.82	1.82		
65	62.5	60	119.0256	2.380512	66.61	10.21	190.6443	3.812887	68.34	9.73	118.2451	2.364902	72.88	3.57		
70	67.5	65	121.7468	2.434935	65.72	11.8	174.0409	3.480817	67.15	12.41	119.8867	2.397734	72.04	5.82		
75	72.5	70	173.9025	3.47805	64.49	14.09	165.9795	3.319591	65.83	14.17	169.6162	3.392324	70.87	8.87		
80	77.5	75	146.8492	2.936983	63.37	15.66	141.9464	2.838927	64.67	15.41	143.0089	2.860178	69.75	10.77		
85	82.5	80	193.0093	3.860186	62.01	13.29	161.9469	3.238938	63.51	13.38	197.5477	3.950953	68.29	7.92		
90	87.5	85	114.4443	2.288886	61.34	11.64	113.3668	2.267335	62.71	11.98	141.5828	2.831655	67.45	5.39		
95	92.5	90	126.4492	2.528984	61.25	9.28	112.6756	2.253512	62.54	9.81	155.9537	3.119074	67.09	1.88		
100	97.5	95	157.4433	3.148866	61.17	6.35	136.8157	2.736314	62.45	7.16	185.8562	3.717123	66.68	-2.24		
105	102.5	100	85.33195	1.706639	60.6	5.28	72.29837	1.445967	61.92	6.35	121.3307	2.426615	65.83	-3.95		
110	107.5	105	86.83478	1.736696	60.08	4.1	78.61407	1.572281	61.56	5.06	120.3182	2.406363	65.02	-5.67		
115	112.5	110	143.6573	2.873146	59.25	2.14	133.0559	2.661117	60.91	2.97	170.4975	3.40995	63.86	-8.01		
120	117.5	115	140.139	2.802779	58.48	-0.21	144.0999	2.881997	60.16	0.82	170.5241	3.410482	62.73	-10.3		
125	122.5	120	80.84017	1.616803	57.83	-0.42	75.10923	1.502185	59.55	0.23	103.5206	2.070412	61.86	-11.03		
130	127.5	125	77.58755	1.551751	57.24	-0.09	90.00954	1.800191	58.83	-0.48	99.48554	1.989711	61.04	-11.8		

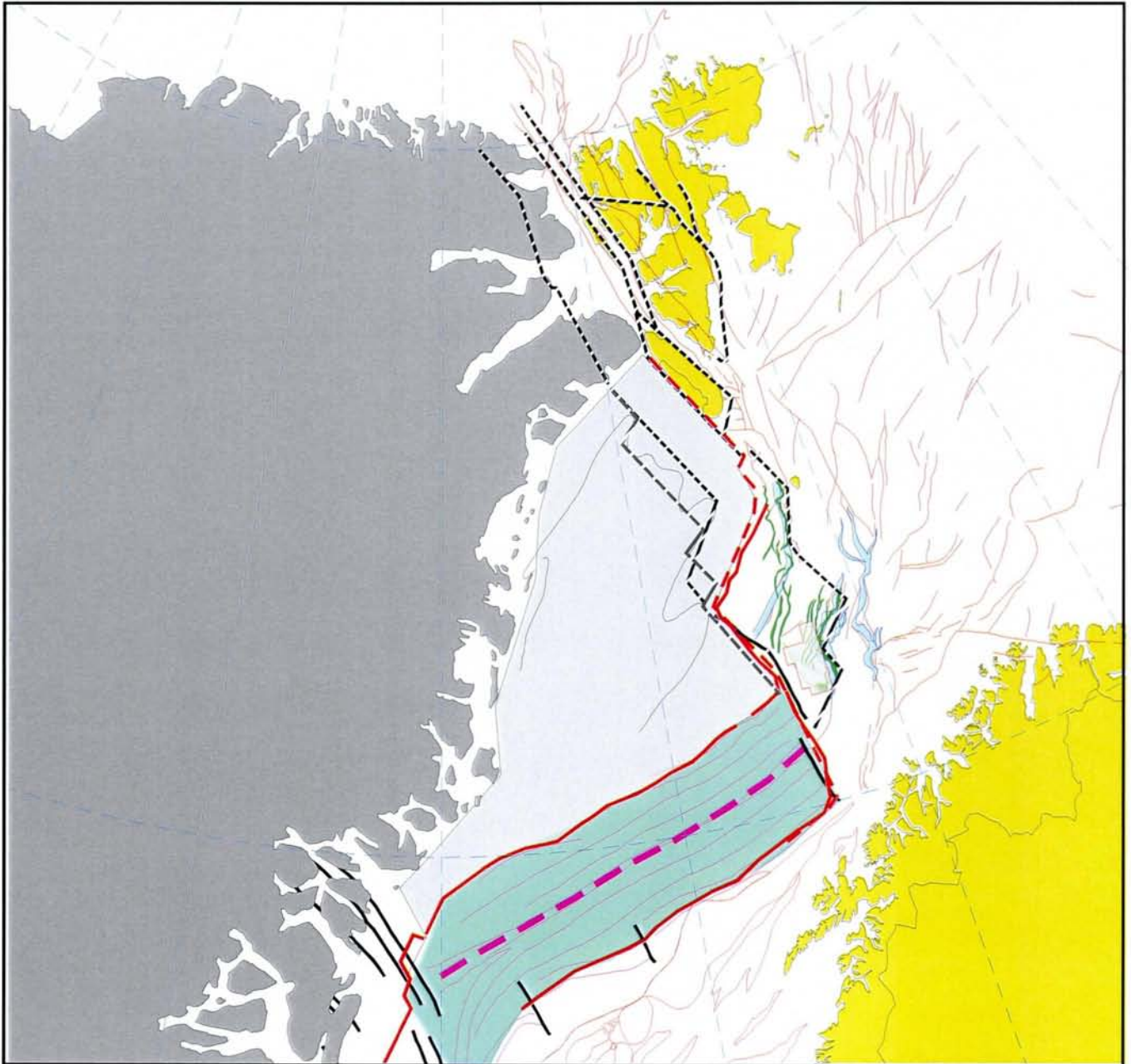


Jon Mosar 2001 **NGU** 

 Zones of normal and/or strike-slip faults

Anomaly 24 - 53.9 Ma Ypresian

Figure 18

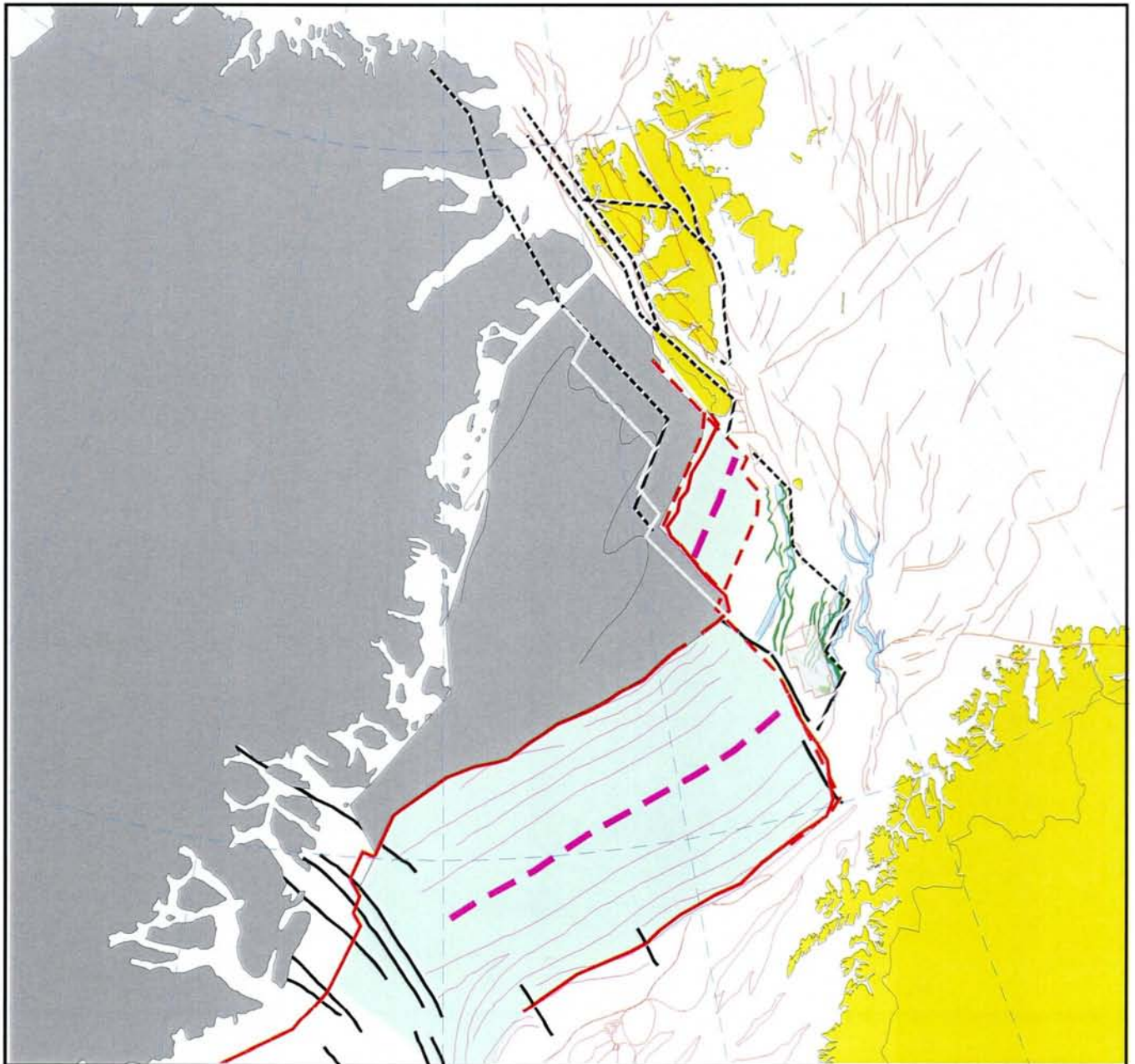


Jon Mosar 2001 **NGU** 

 Zones of normal and/or strike-slip faults

Anomaly 21 - 47.1 Ma Lutetian

Figure 19

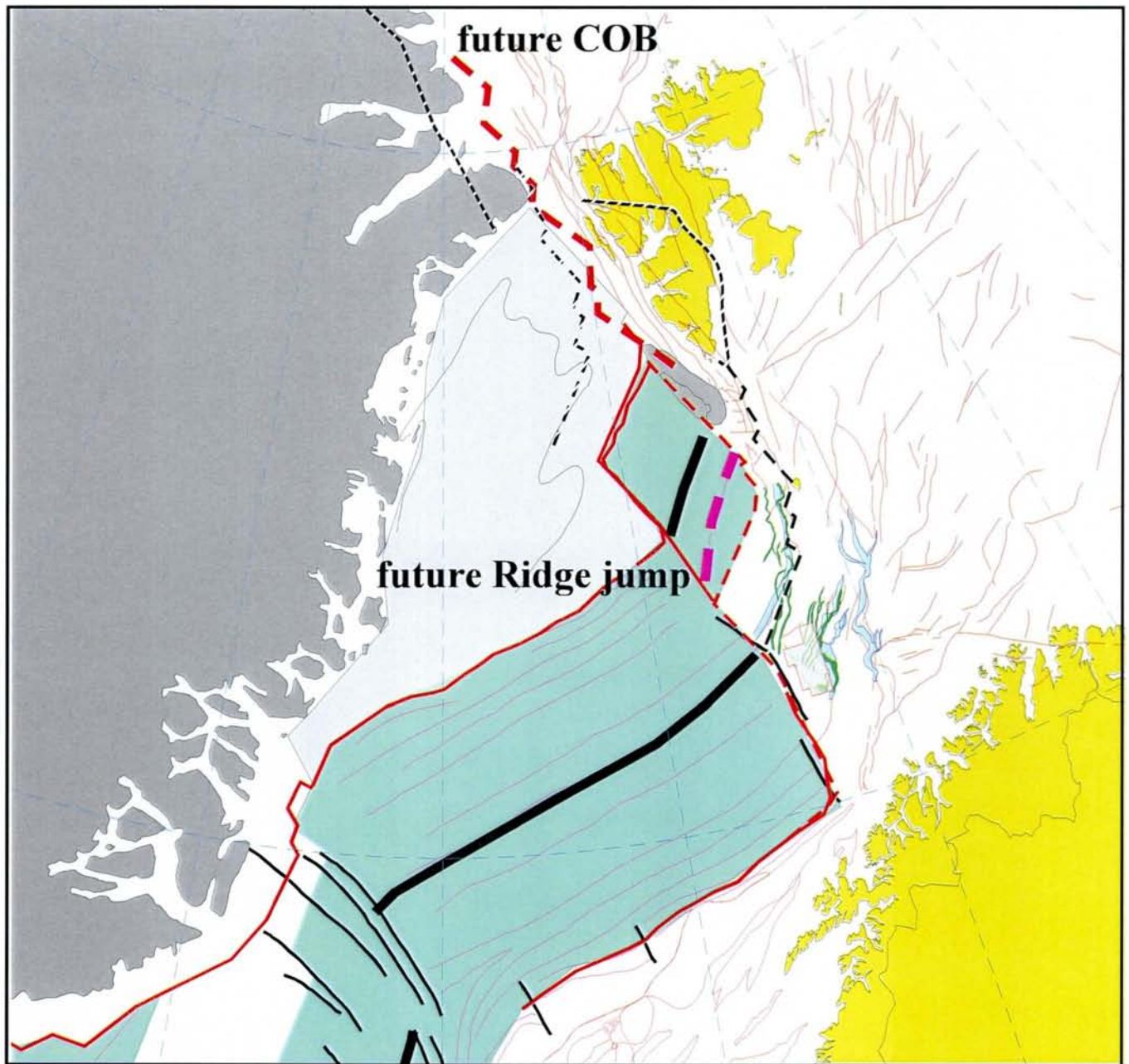


Jon Mosar 2001 **NGU** 

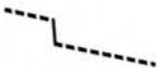
 Zones of normal and/or strike-slip faults

Anomaly 18 - 39.4 Ma Bartonian

Figure 20

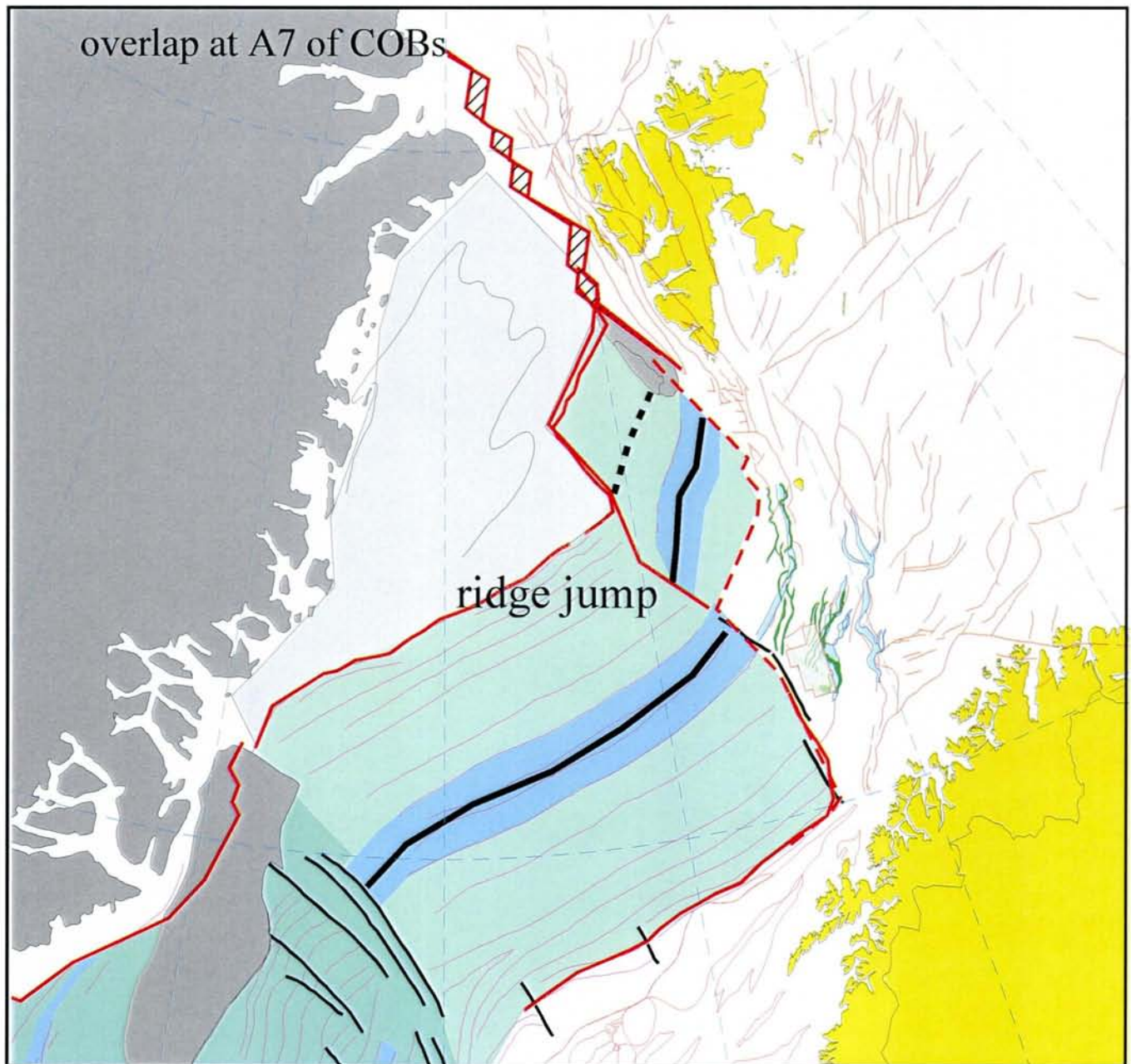


Jon Mosar 2001 **NGU** 

 Zones of normal and/or strike-slip faults

Anomaly 13 - 33.3 Ma Rupelian

Figure 21

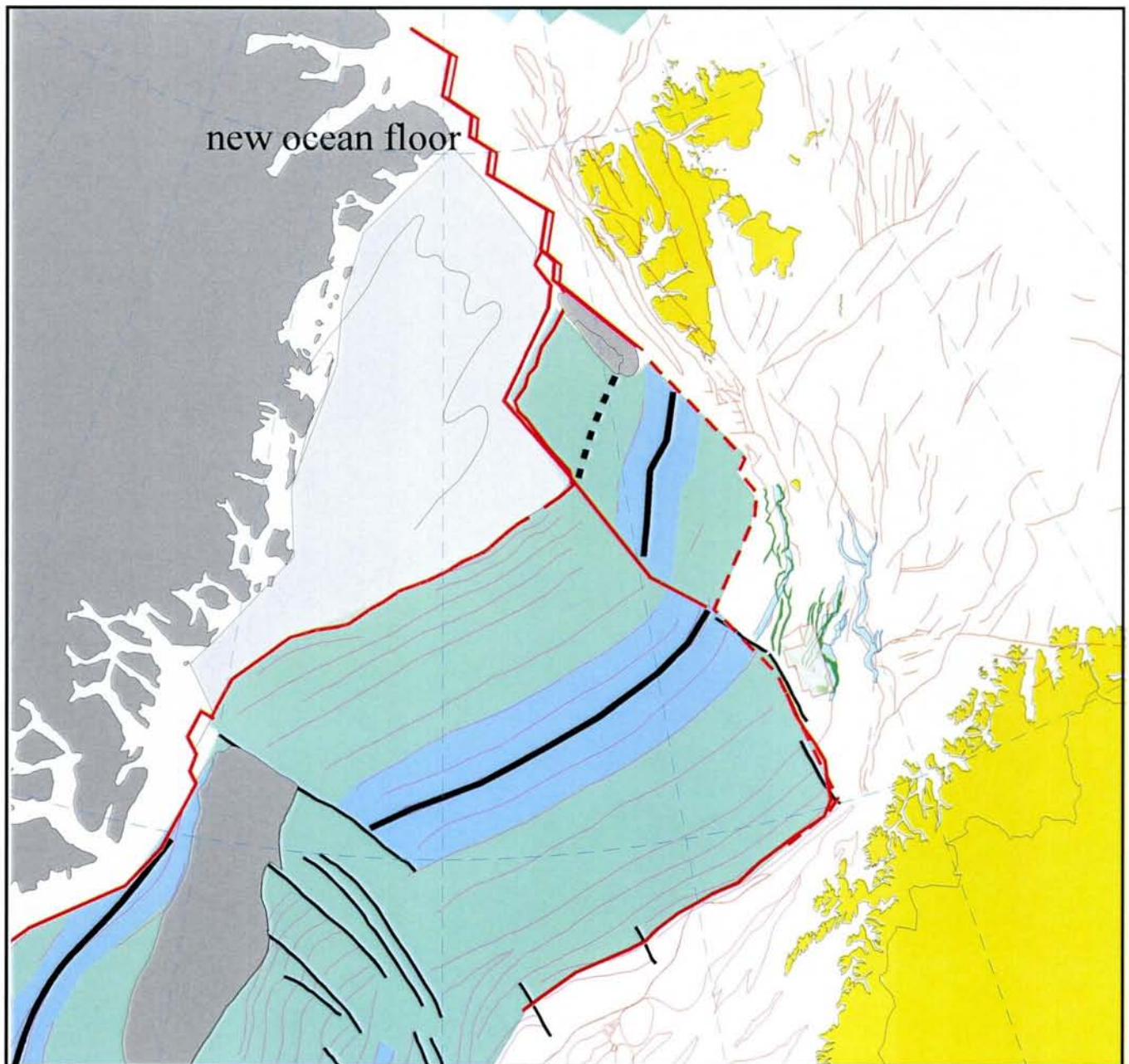


Jon Mosar 2001 **NGU** 

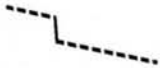
 Zones of normal and/or strike-slip faults

Anomaly 7 - 25 Ma Chattian

Figure 22

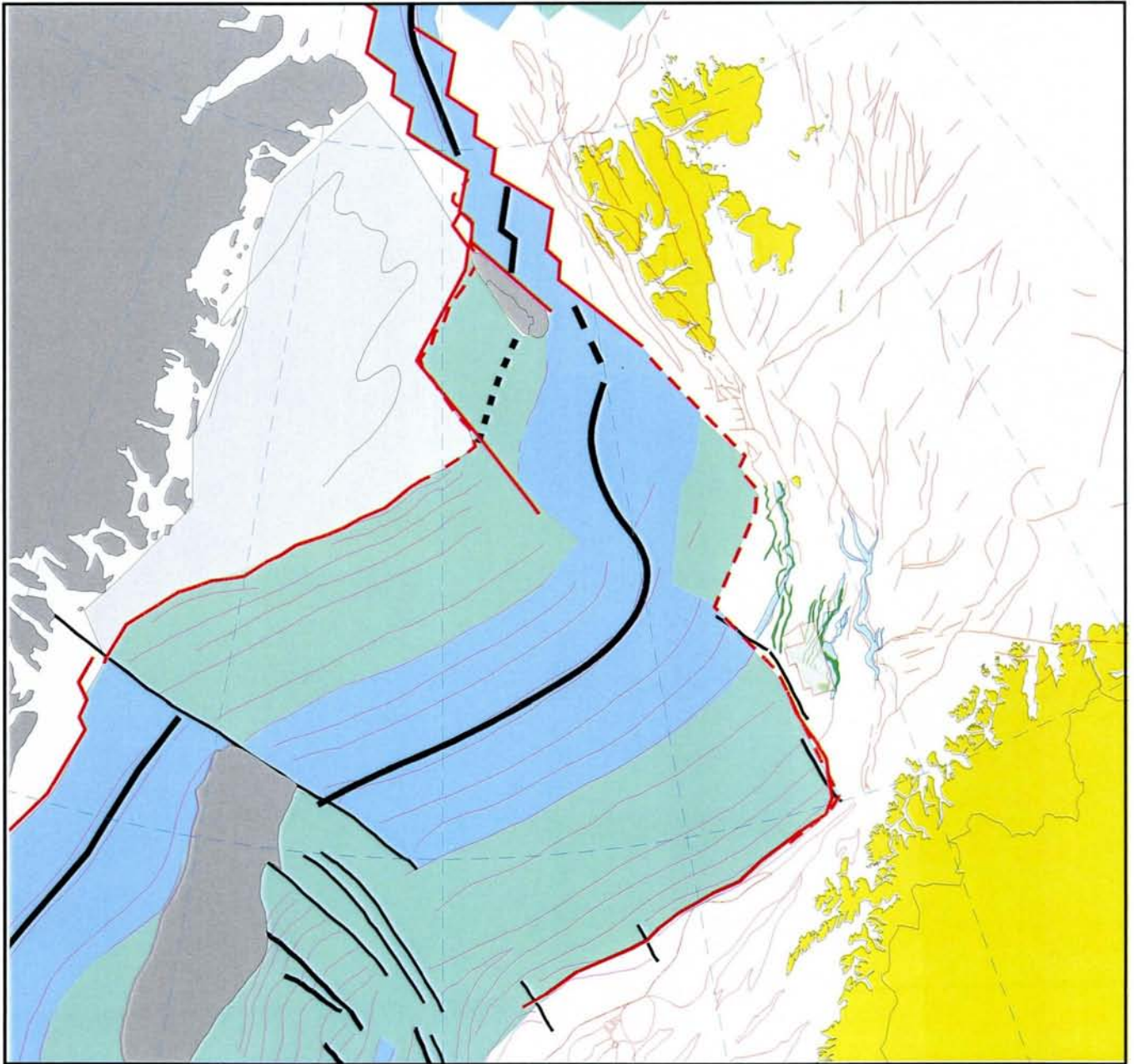


Jon Mosar 2001 **NGU** 

 Zones of normal and/or strike-slip faults

Anomaly 6 - 19.6 Ma Burdigalian

Figure 23



Jon Mosar 2001 **NGU** 

 Zones of normal and/or strike-slip faults

Anomaly 5 - 10.3 Ma E. Tortonian

Figure 24