Structure and evolution of the Jan Mayen Microcontinent

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Introduction

The Jan Mayen Ridge (JMR) is a 150-km-long and 10–30 km wide seafloor expression in N-S direction in the centre of the North Atlantic and part of the Jan Mayen Microcontinent (JMMC).

Previous studies show:

- The eastern flank of the JMR was formed during the breakup of the Norway Basin along today's Aegir Ridge, prior to magnetic anomaly C23 (~50 Ma).
- Rifting gradually propagated northward, likely from Chron C21 (~46 Ma) onward. Fan-shaped magnetic anomalies in the Norway Basin suggest that the JMMC must have rotated counter-clockwise.
- The JMR is likely underlain by continental crust. Lava flows have been observed within the sediments in the Jan Mayen Basin (JMB). While a relatively uniform upper crust was observed throughout the JMMC, the thickness of the lower continental crust varies significantly from up to 15 km below the JMR down to almost zero thickness towards the western part of the JMB.

The character of the lower crust, the geometry of the continent ocean transition (COT), and the development of the conjugate East Greenland – JMMC margins during Oligocene are still disputed.

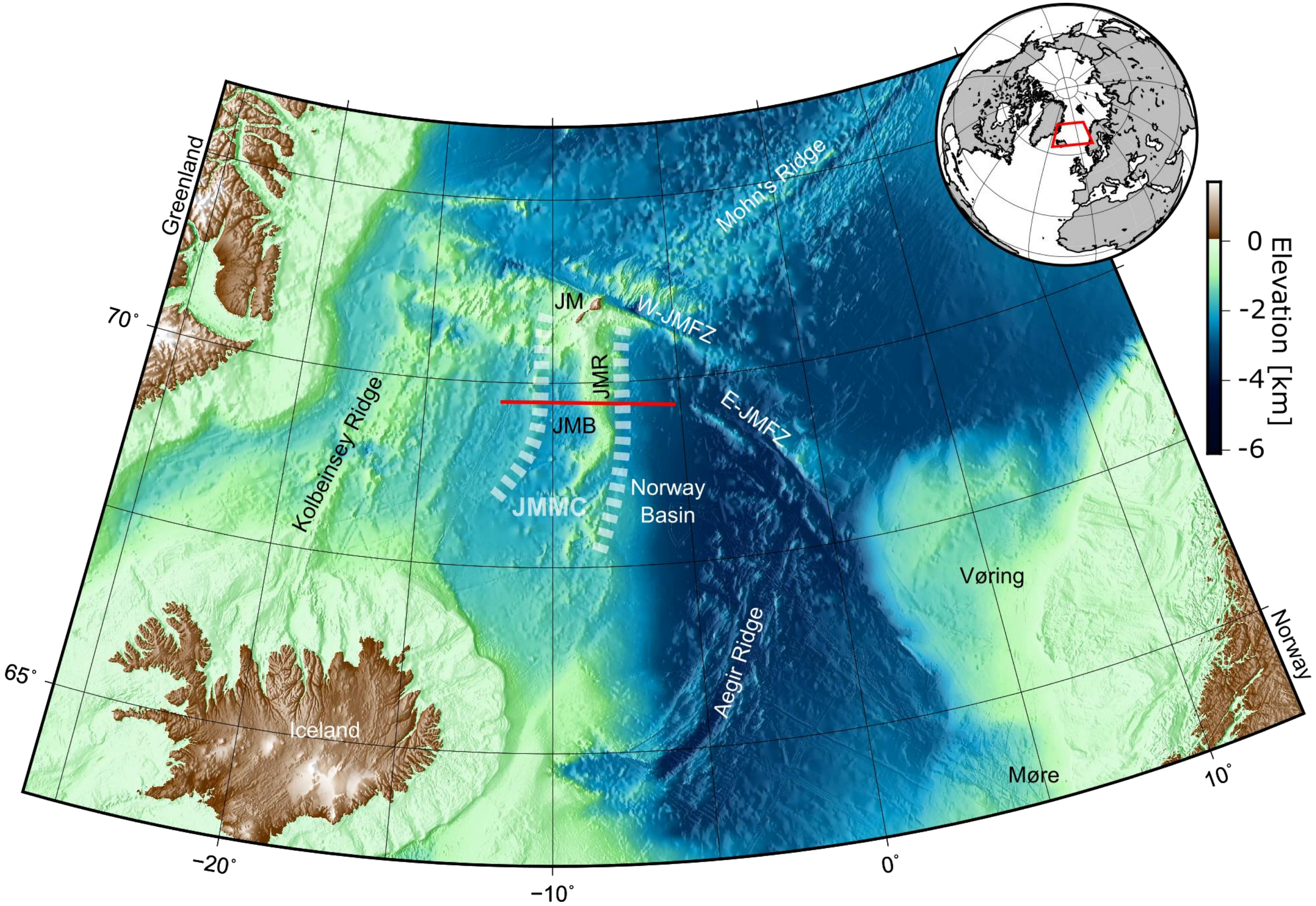

Fig. 1: Map of the northern Atlantic showing the seismic refraction profile (red line) crossing the Jan Mayen Ridge (JMR) and the Jan Mayen Basin (JMB). The extent of Jan Mayen Micro-Continent (JMMC) is indicated by the two transparent dashed lines, south of the Jan Mayen islands (JM). GMRT data (Ryan et al., 2009).

Data and Methods

The seismic refraction, the magnetic and the gravity data were acquired along a 266 km long transect during cruise MSM67 (RV Maria S. Merian) in 2017.

Seismic data:

- In total 29 ocean bottom seismometers (OBS) in a spacing of 9.5 km recorded successfully 2280 air gun shots (source with 4840 inch³).
- The seismic data were analysed by means of PASTEUP (picking), RAYINVR (forward and inverse modelling) and TOMO2D (tomography).

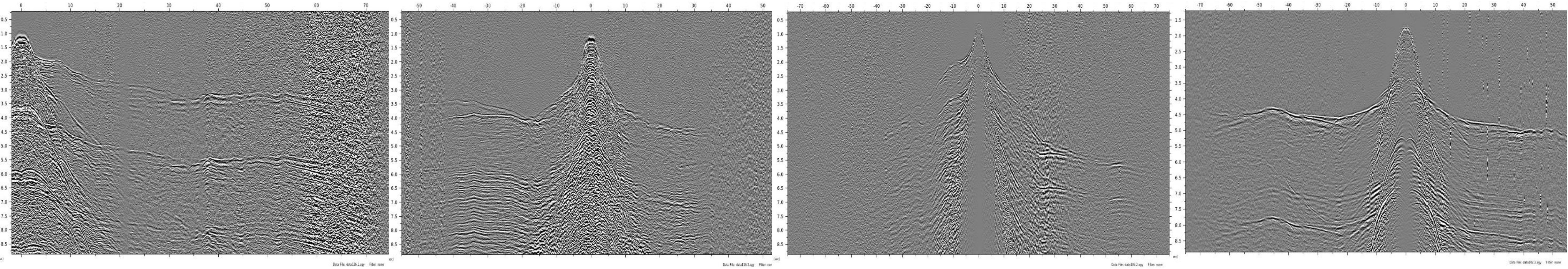

Fig. 2: Seismic record sections of OBS126 (west of the JMMC), OBS116 (JMB), OBS109 (JMR), and OBS102 (Norway Basin). Crustal and mantle phases can be observed at all stations. The stations located in the Jan Mayen Basin (JMB) are characterised by poor signal penetration for offsets larger than 30 km.

Potential field data:

- Magnetic data were recorded with a marine Magnetics SeaSpy Gradiometer consisting of two proton precision magnetometers towed ~550 m astern of the ship.
- Free-Air gravity anomaly (FAA) data were recorded with the gravimeter system KSS32-M on board. The measurements were tied to the IGSN71 net as reference on land.

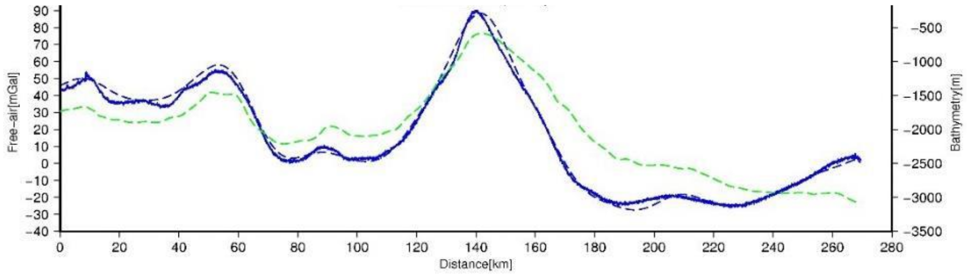

Fig. 3: Free-Air gravity acquired parallel to the seismic measurements (solid blue line), Free-Air gravity (DTU13) (dashed blue line) and bathymetry (dashed green line).

Results and Interpretation

The line extends from oceanic crust in the Norway Basin, across the microcontinent and into oceanic crust that formed at the presently active mid-oceanic Kolbeinsey Ridge.

Key results from the seismic investigations:

- The seismic velocity field can be divided into four distinct zones:

Zone #1 - *KM 0-65*: Sedimentary coverage (< 1 km), crustal thickness of 4-5 km, high velocity gradient (~1 s^{-1}) in the upper crust, low velocity gradient in the lower crust and seismic velocities up to 7.5 km/s.

→ *oceanic crust (lower magmatic budget than zone #4)*

Zone #2 - *KM 65-120*: Sedimentary coverage (~1-2 km), crustal thickness of 3-4 km, low velocity gradient (~0.25 s^{-1}) and absolute seismic velocities up to 6.2 km/s. → *extremely thinned upper continental crust*

Zone #3 - *KM 120-170*: Sedimentary coverage (~0.2-2.5 km), crustal thickness of ~4-10 km, a velocity gradient of ~0.3 s^{-1} in the entire crust and seismic velocities up to 6.8 km/s. → *thinned continental crust*

Zone #4 - *KM 170-266*: Sedimentary coverage (~2.5-4 km), crustal thickness of 5-6 km, vertical velocity gradients and absolute seismic velocities similar to *zone #1*. → *oceanic crust (older than zone #1)*

- Mantle seismic velocities increase with depth starting from ~7.8 km/s.

→ *un-serpentinised mantle*

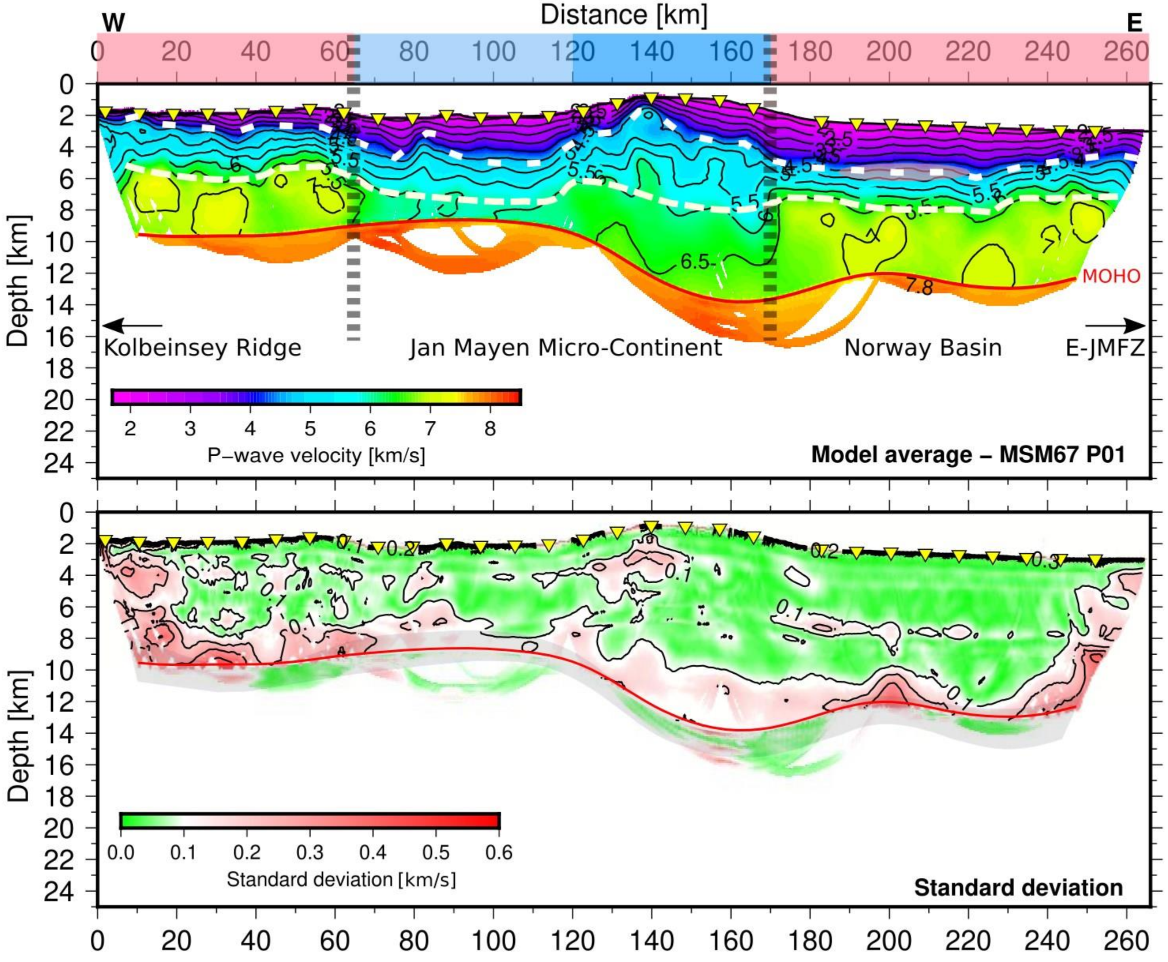

Fig. 4: Preliminary average seismic velocity field (upper panel) resulting from travel time tomography with 22 inversion runs using different starting models and added noise to the travel time picks. White dashed lines indicate the basement and the transition from upper crust to lower crust. The vertical black dashed lines indicate the transition from continental crust in the centre to oceanic crust on both profile ends. The lower panel shows the standard deviation of the resulting model set.

Results and Conclusion

The magnetic profile shows old seafloor spreading anomalies in the east (likely anomaly 24, ~52 Ma), low amplitude magnetic anomalies in the central, which are typical for many plutonic continental rocks. High amplitude anomalies of younger oceanic crust (likely anomalies C5C trough C6, ~19–16 Ma) are recognised near the western termination of the Jan Mayen Basin. The seismic velocity distribution and crustal thickness vary strongly along the profile, with velocities typical for oceanic crust at either end of the profile. Seismic velocities in the centre of the profile are typical for continental crust. Gravity modelling supports these findings.

→ The JMMC consists of thinned continental crust with a width of 100 km.

We observe features typical for volcanic rifted margins:

→ The continent-ocean transition is abrupt on both margins of the JMMC.

→ No indications for mantle serpentinisation.

Our data confirm the evolution proposed in previous studies:

1) Continental crust thins while the Norway Basin opens from ~20 km (Norway) to ~13 km (JMMC)
2) Seafloor spreading from ~52 Ma (Aegir Ridge)
3) Continental crust thins (from ~13 km to ~4 km) while Jan Mayen separates from Greenland
4) Seafloor spreading from ~19 Ma (Kolbeinsey Ridge)

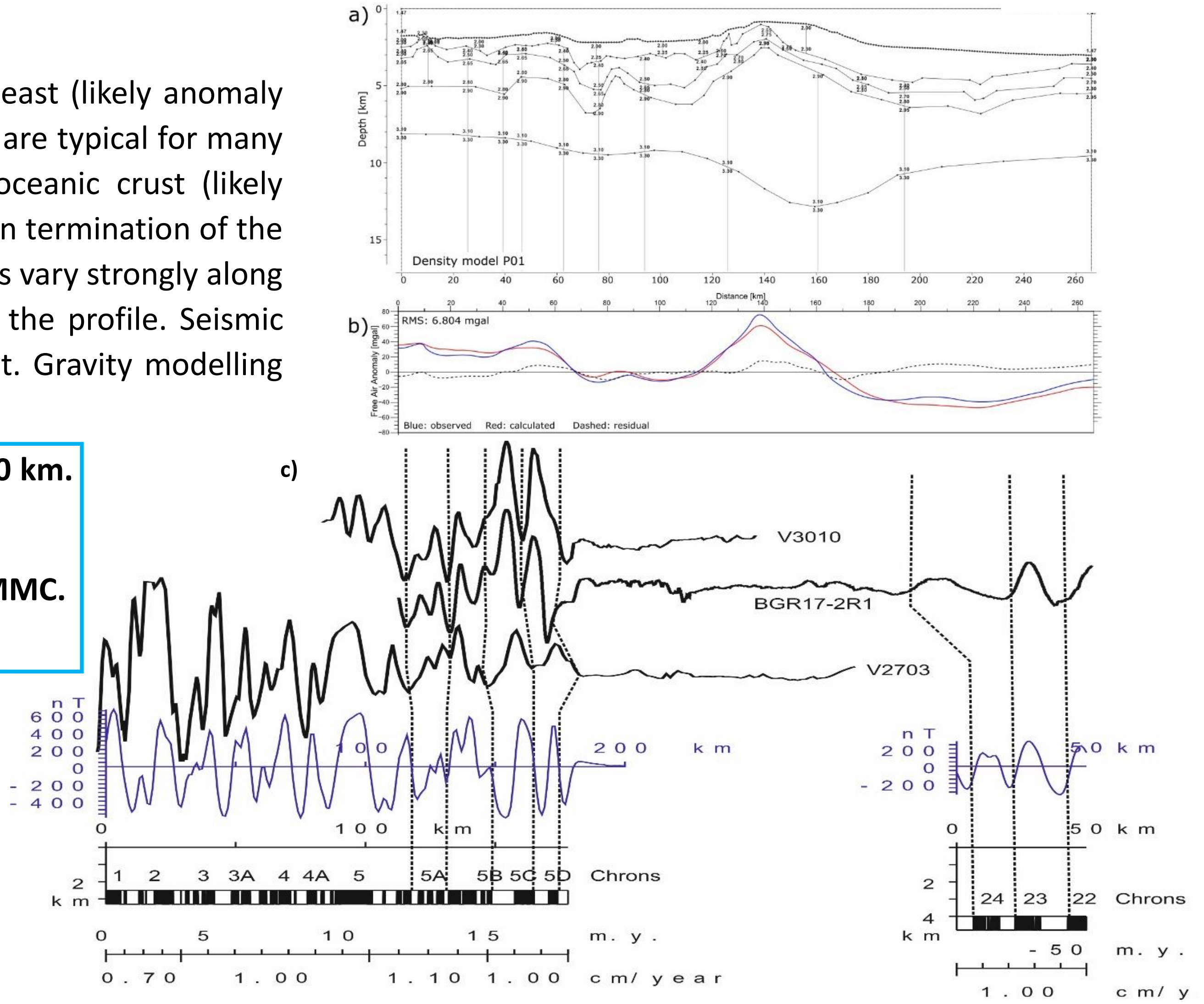

Fig. 5: (a) Density model based on seismic velocities from forward modelling. (b) Fit of the calculated and observed Free-Air gravity. (c) Magnetic data of our profile (BGR17-2R1) and two additional parallel profiles (V3010 and V2703) with the spreading history model (bottom) that fits the magnetic anomalies.