Origin of the Vøring Plateau, offshore Norway – interplay between timing of rifting and emplacement of plume material

Asbjørn Breivik

CEED, University of Oslo, 2017

Vøring Plateau setting:

Tectonophysics 468 (2009) 206–223

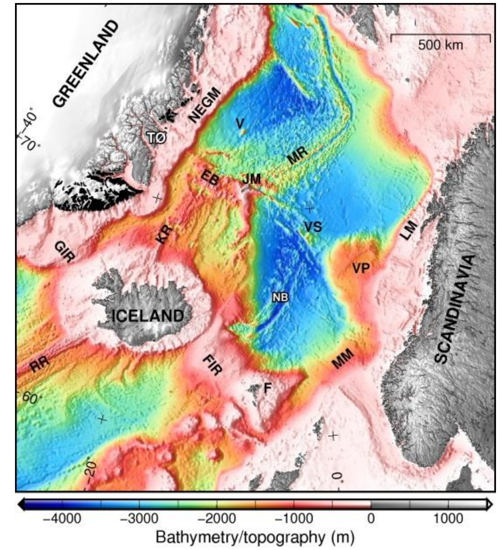
Contents lists available at ScienceDirect

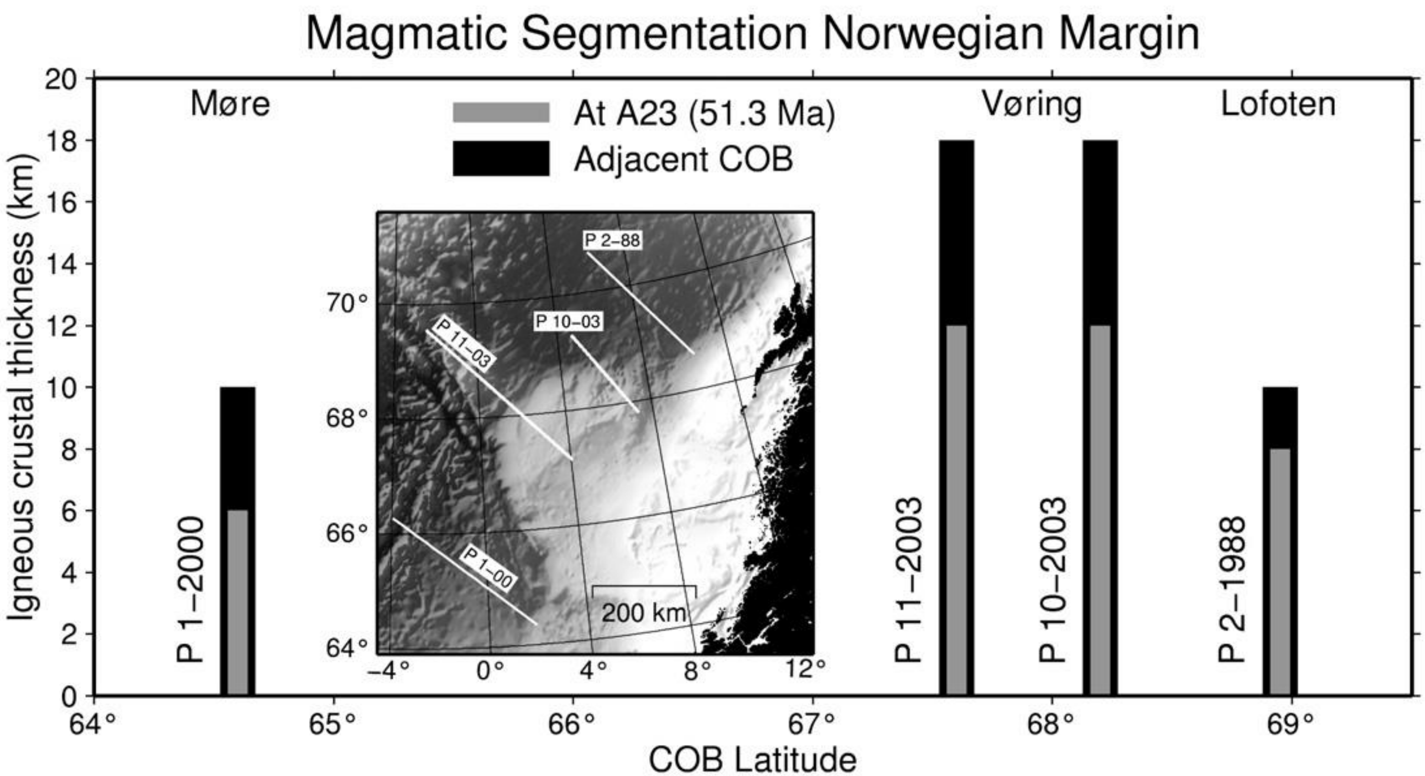
Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Magma productivity and early seafloor spreading rate correlation on the northern Vøring Margin, Norway — Constraints on mantle melting

Asbjørn Johan Breivik [a,*], Jan Inge Faleide [a], Rolf Mjelde [b], Ernst R. Flueh [c]



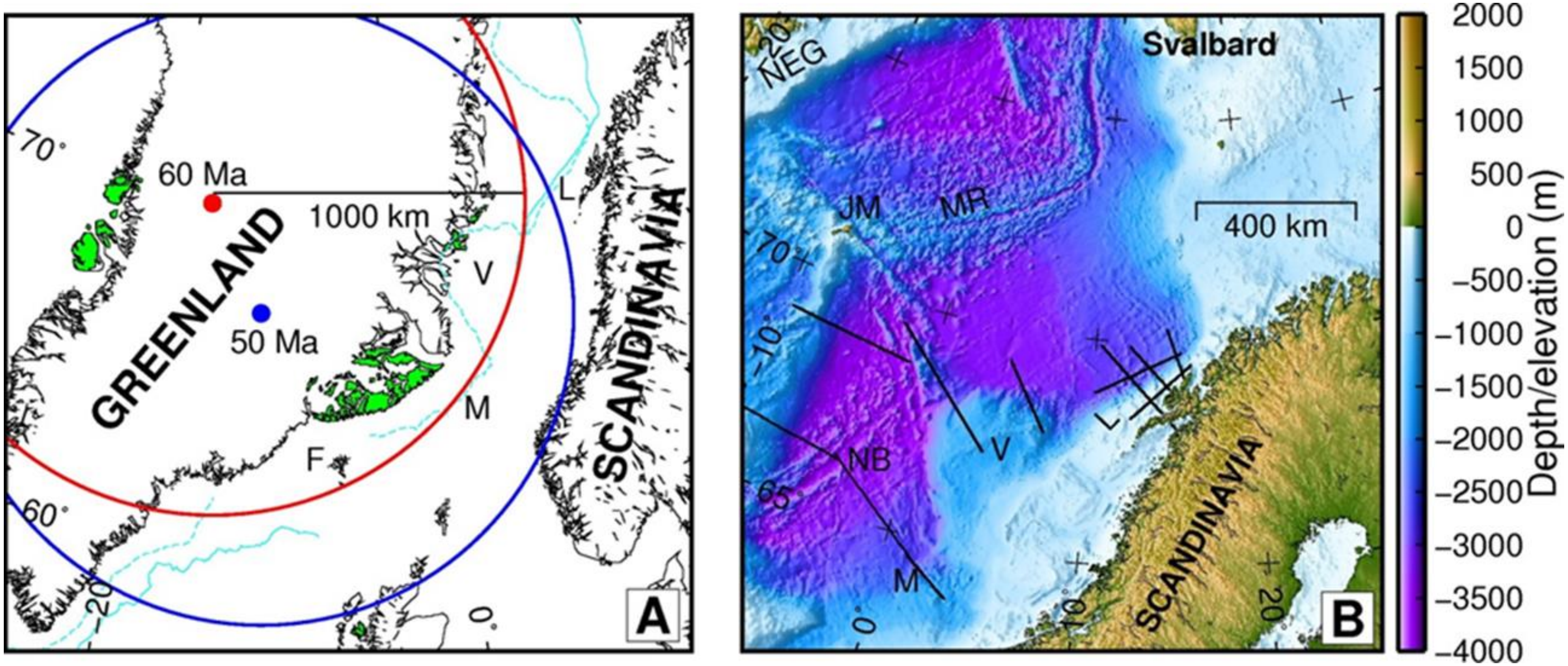


Breakup times in the NE Atlantic:

Position – The continent-ocean transition

Time – some way to determine breakup times

A complicating factor – Strong breakup volcanism

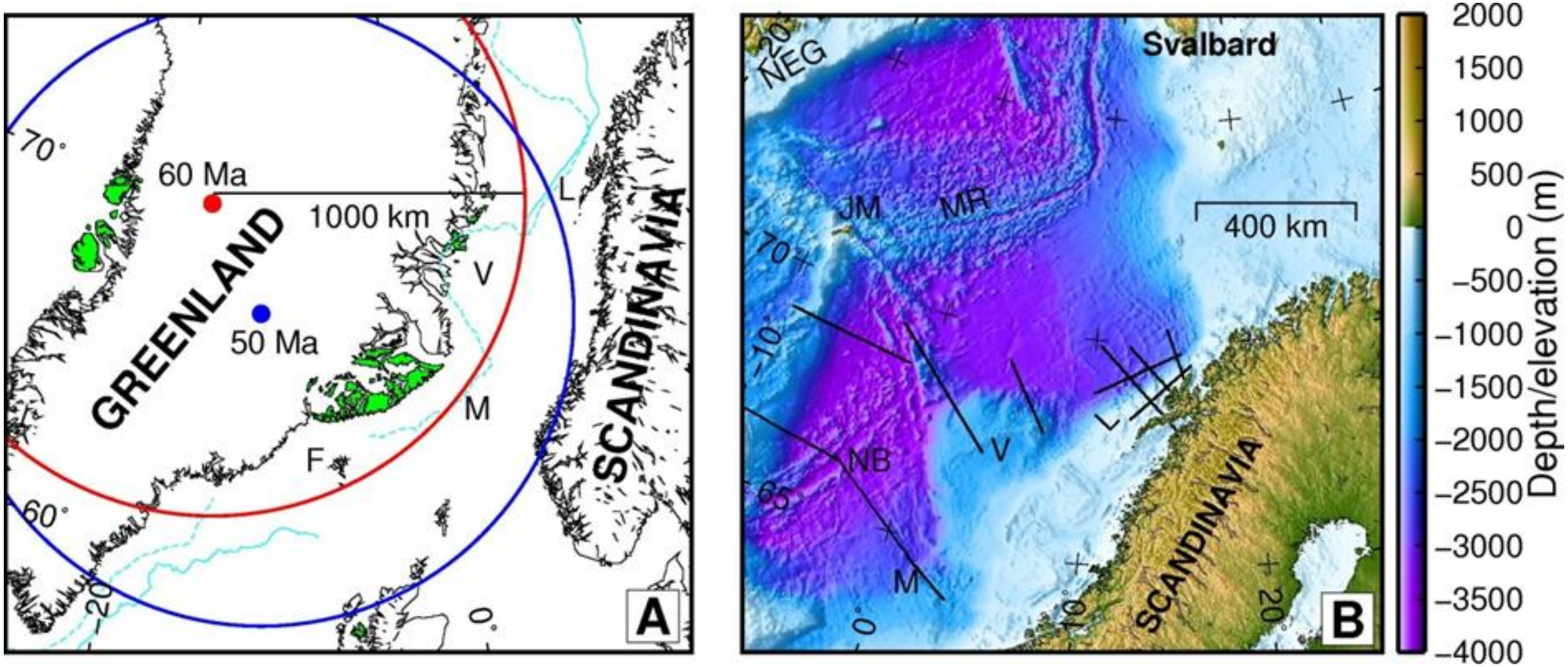


Crustal structure

Multiple generations of OBS wide angle seismic transects

Timing

Magnetic data from same surveys

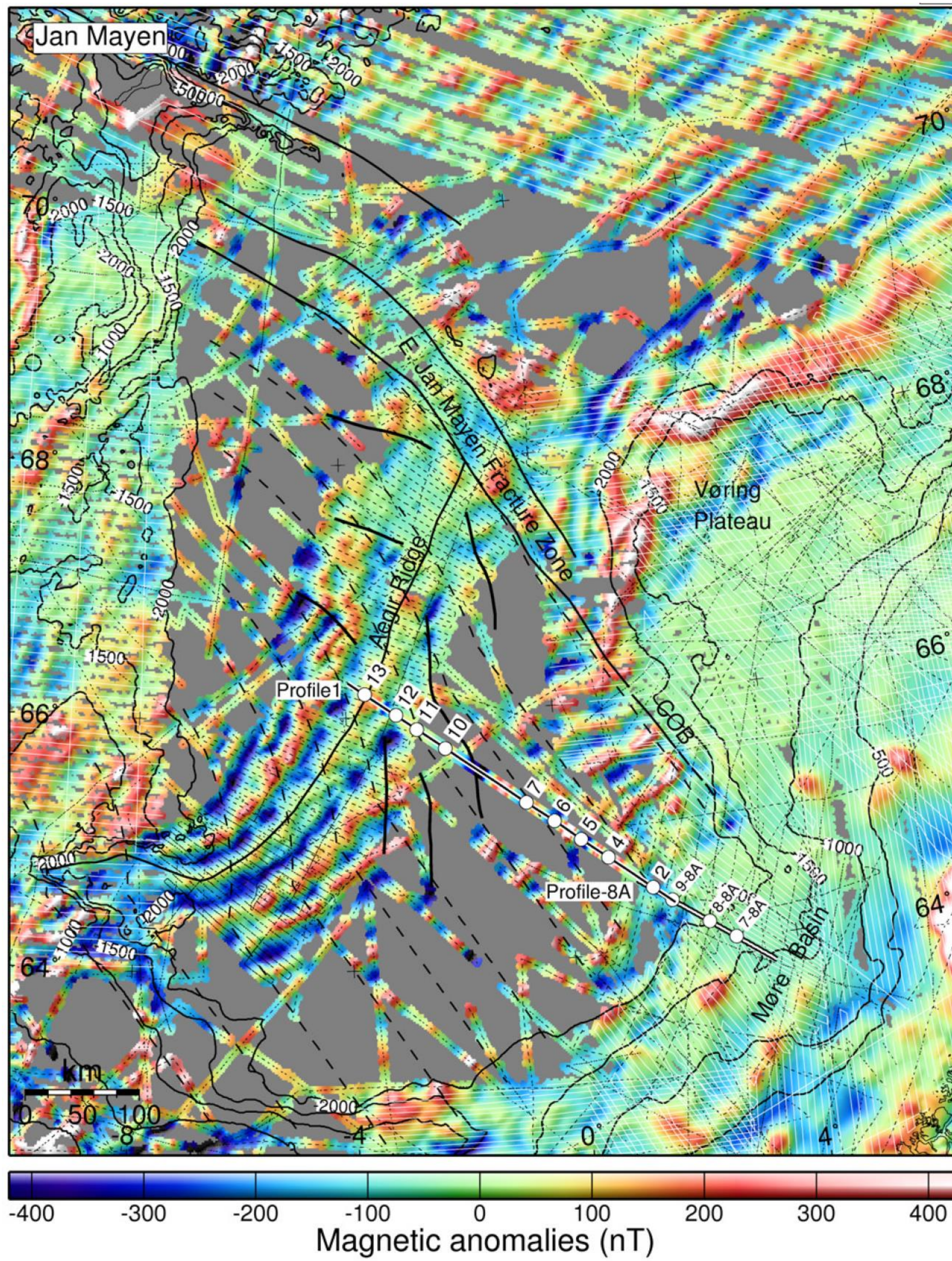


Data issues:

GSC mag compilation (1996):

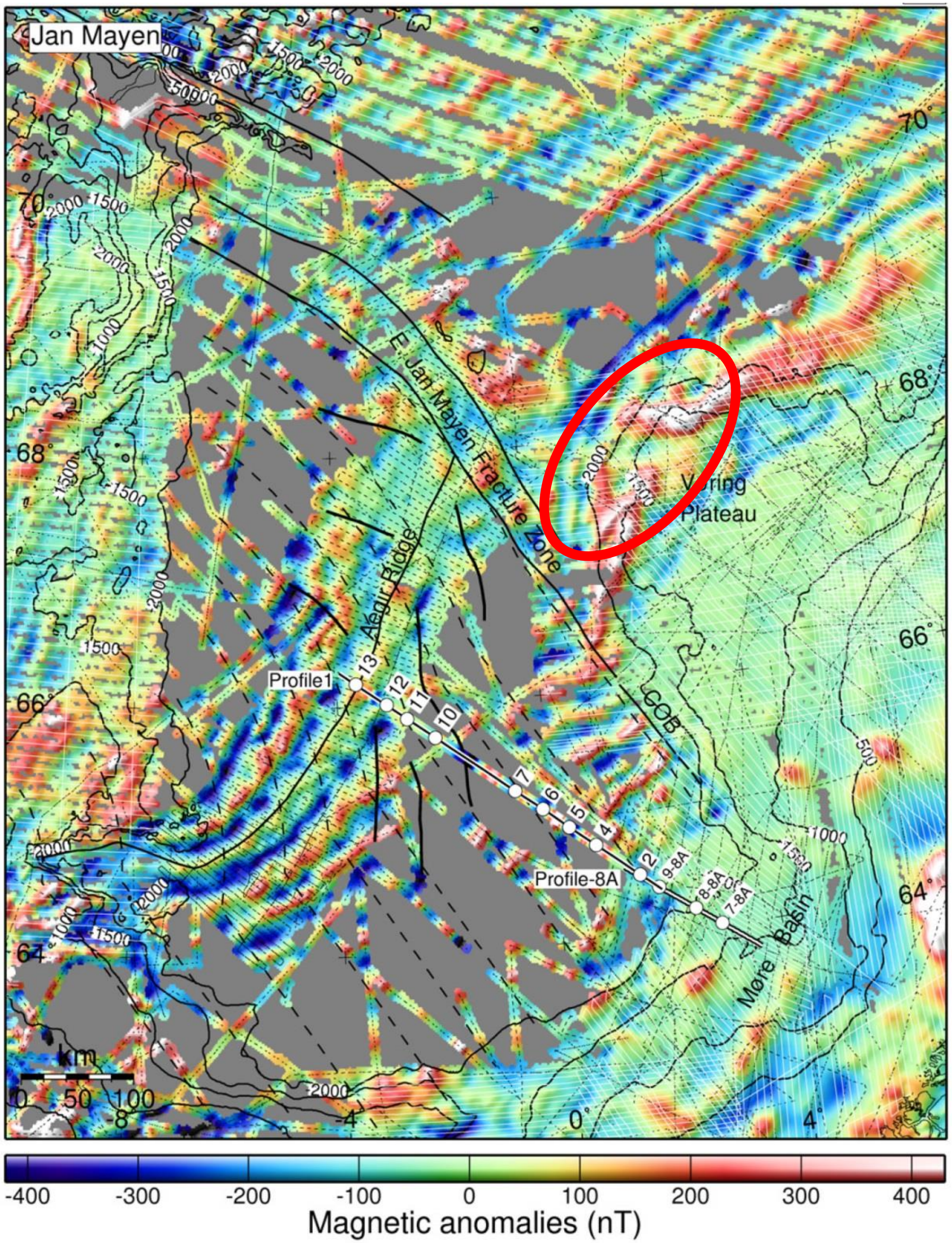
Poor coverage > 10 years ago

Also poor navigation (pre-GPS)



Interpretation issues:

Seafloor spreading anomalies not reliable timelines on the most magma-rich margin segments – subaerial volcanism



Interpretation issues:

Much reduced magmatism on Møre Margin – our reference

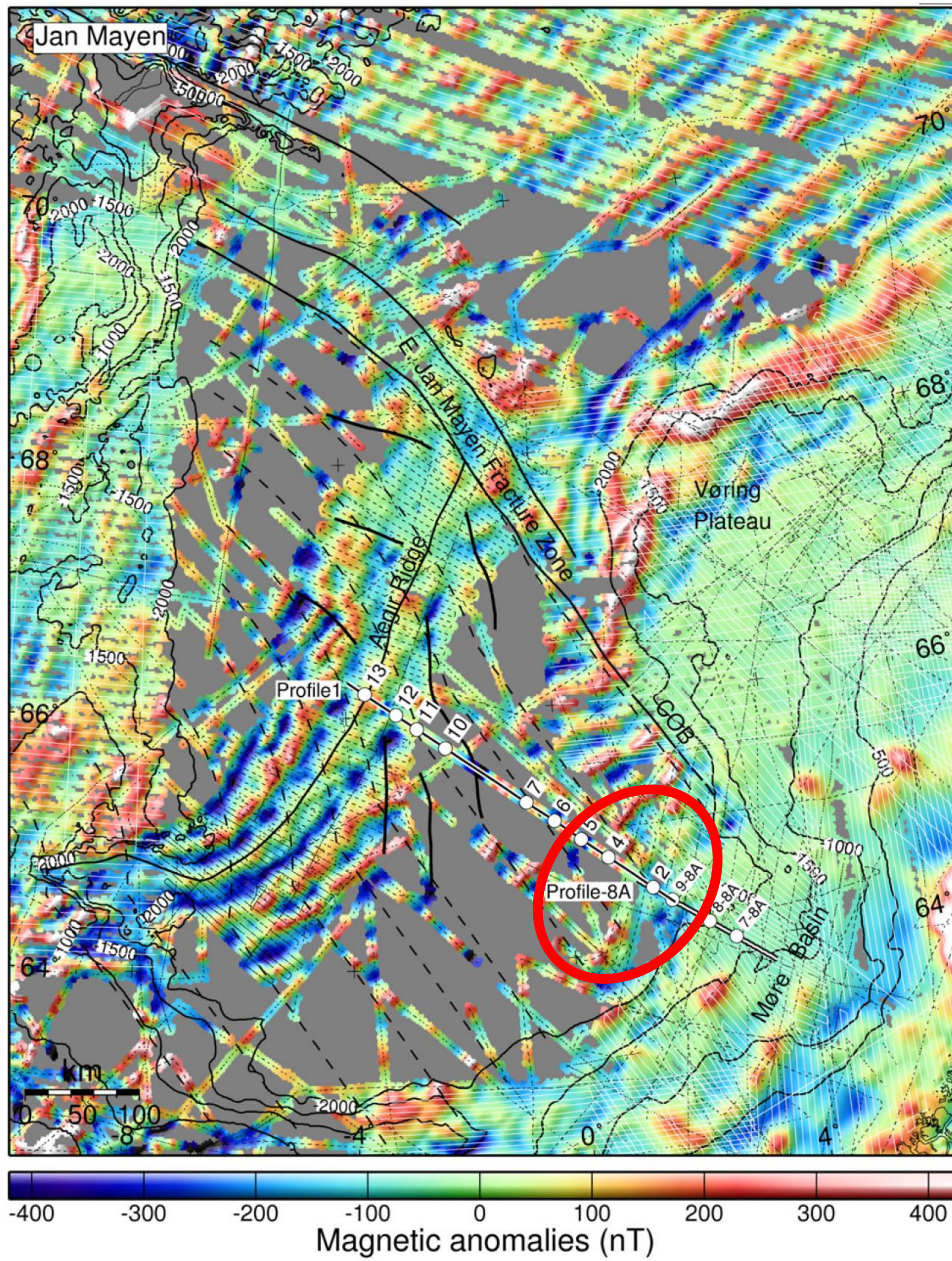
- OBS crustal transect
- New magnetic transect

Click Here for Full Article

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, B07102, doi:10.1029/2005JB004004, 2006

Rates of continental breakup magmatism and seafloor spreading in the Norway Basin–Iceland plume interaction

Asbjørn Johan Breivik,[1] Rolf Mjelde,[2] Jan Inge Faleide,[1] and Yoshio Murai[3]



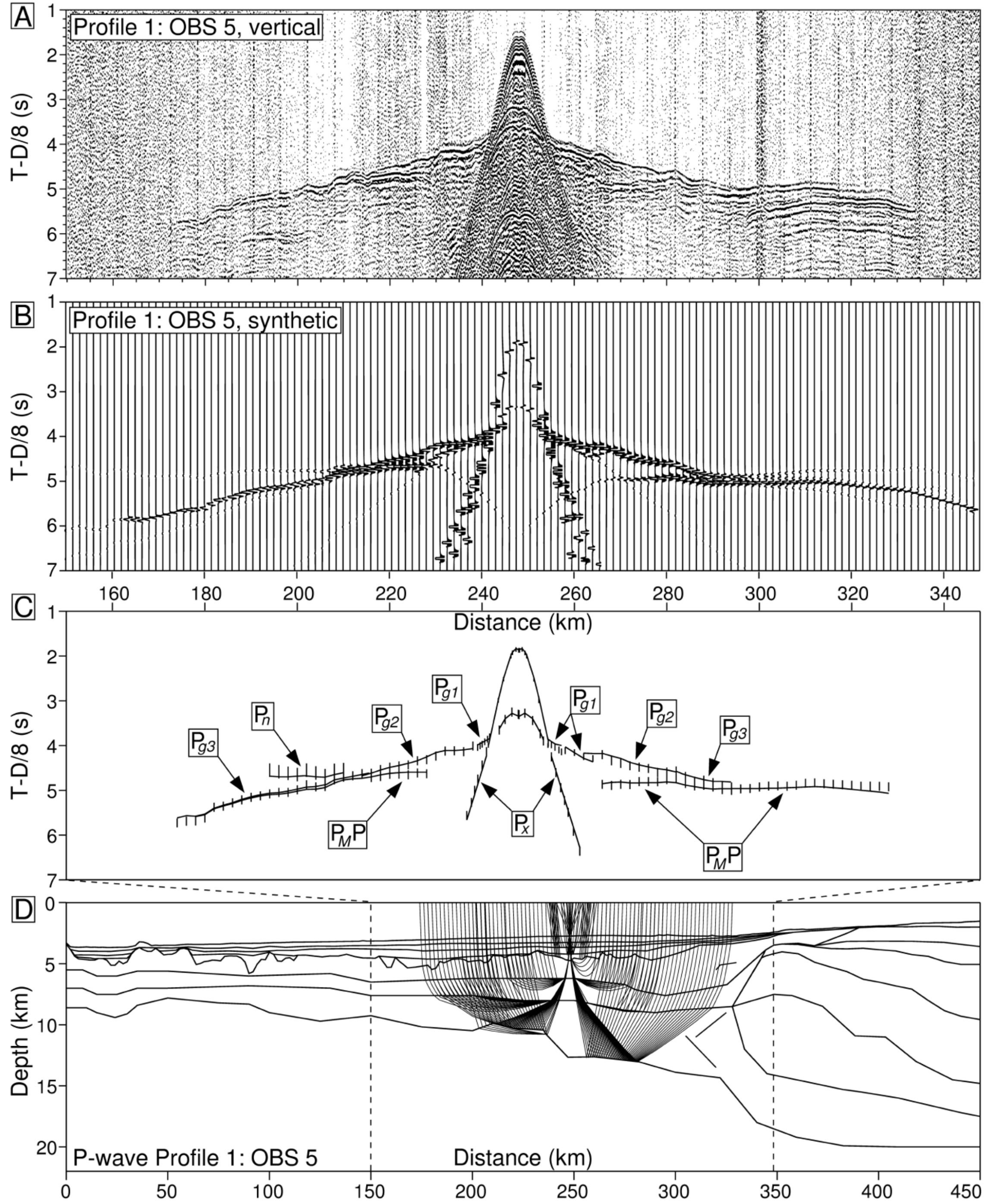
Møre Profile reference

A: OBS data

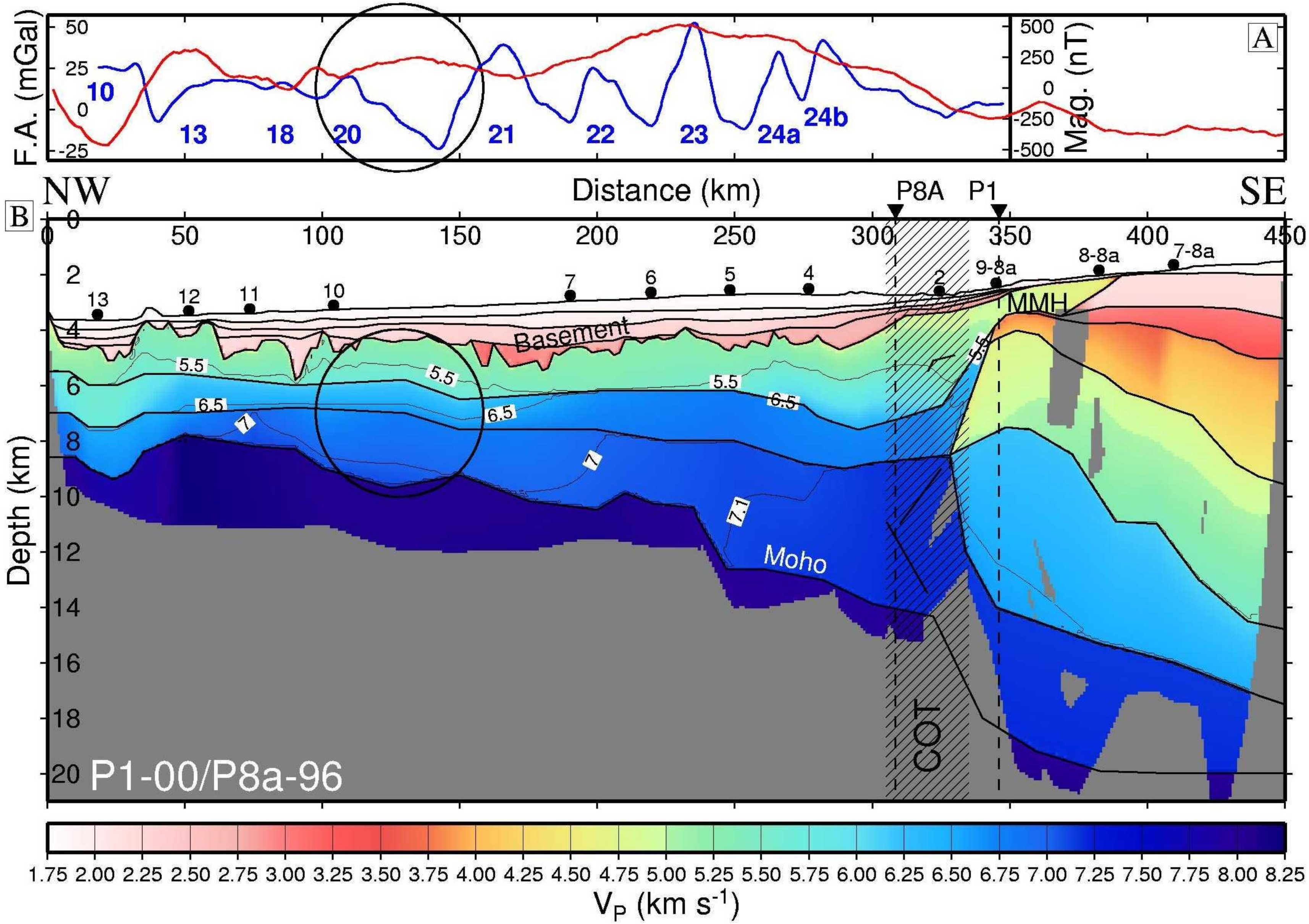
C: Interpreted and modeled travel times

D: Velocity layer model

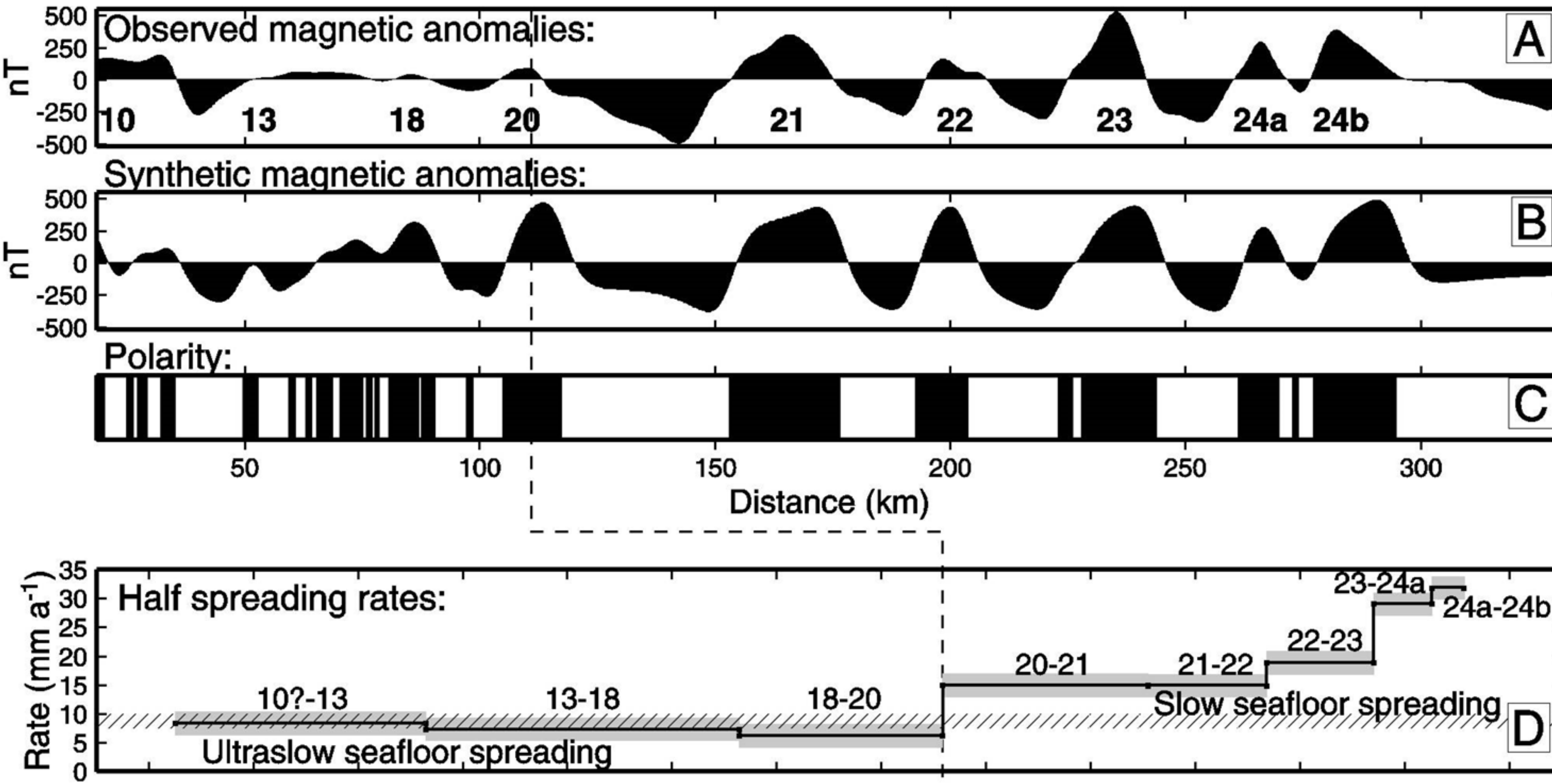
B: Synthetic amplitudes from velocity model



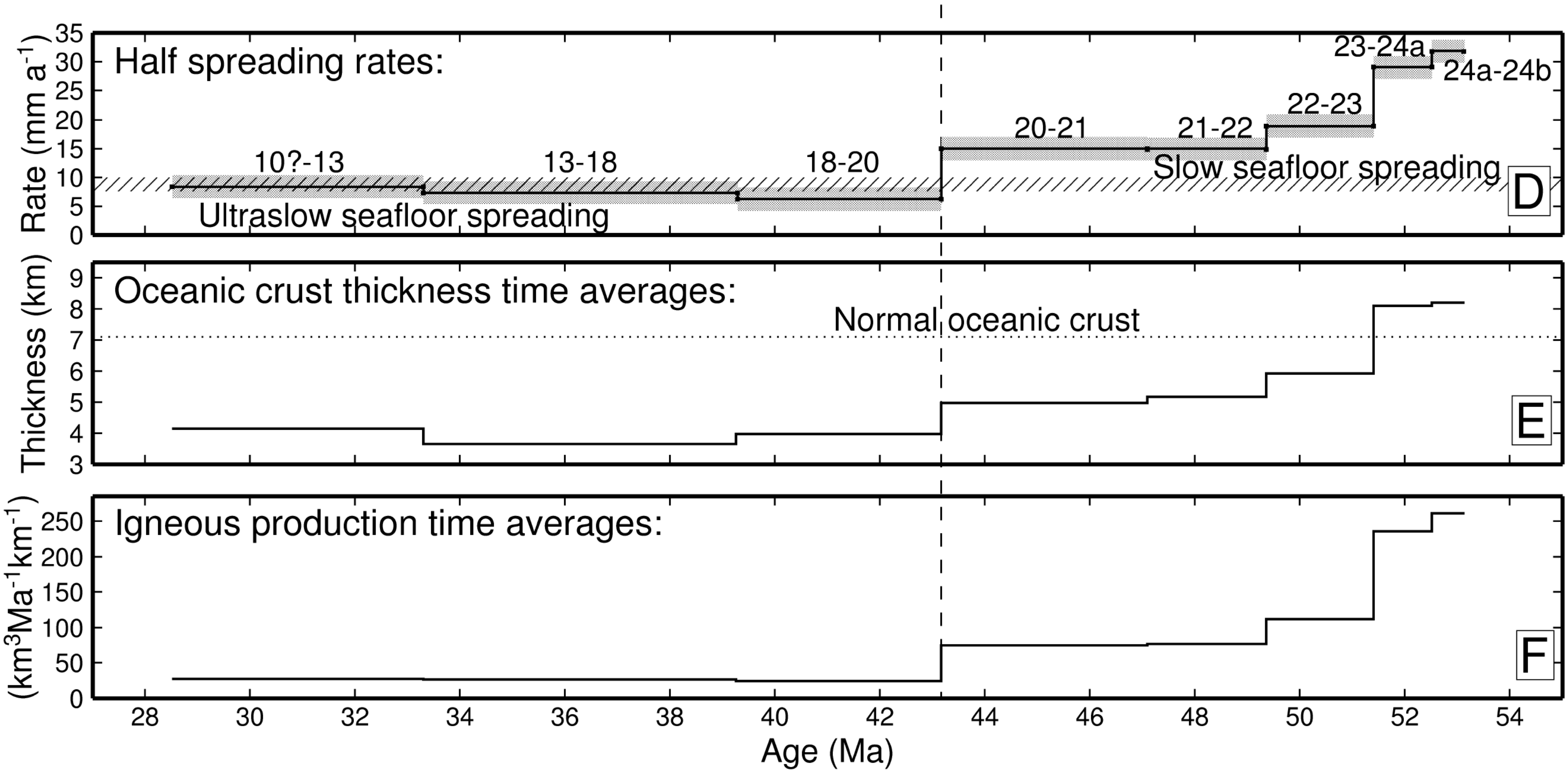
Møre Profile reference



Norway Basin Seafloor Spreading Half Rates



Norway Basin Seafloor Spreading Half Rates



Conjugate Norway Basin Seafloor Spreading Half Rates

Geophysical Journal International

Geophys. J. Int. (2012) **188,** 798–818 doi: 10.1111/j.1365-246X.2011.05307.x

The eastern Jan Mayen microcontinent volcanic margin

Asbjørn Johan Breivik,[1] Rolf Mjelde,[2] Jan Inge Faleide[1] and Yoshio Murai[3]

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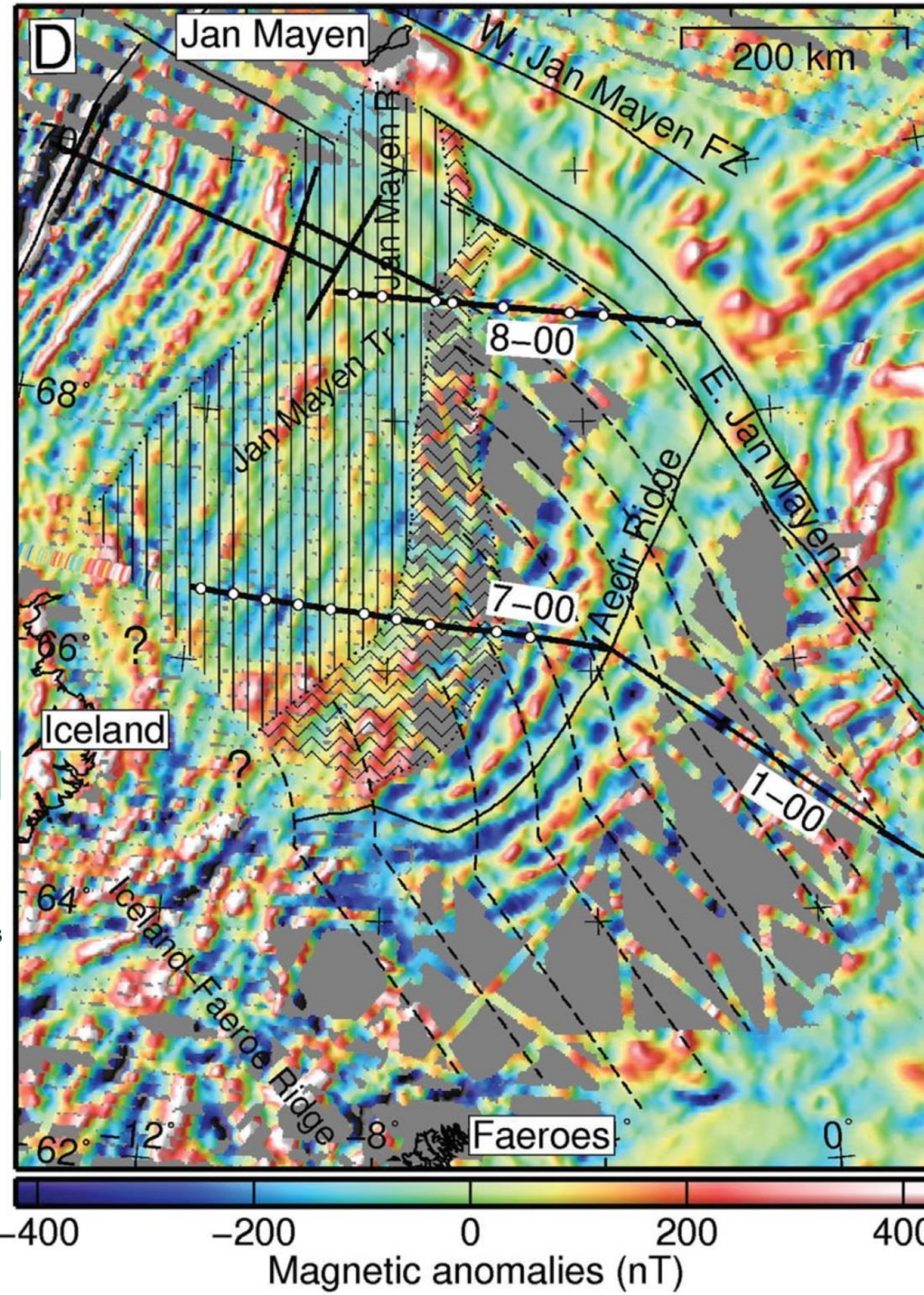
[2] *Department of Earth Science, Allégt* 41, *University of Bergen,* N-5007 *Bergen, Norway*
[3] *Institute of Seismology and Volcanology, Hokkaido University,* N10 W8 *Kita-ku, Sapporo* 060-0810, *Japan*



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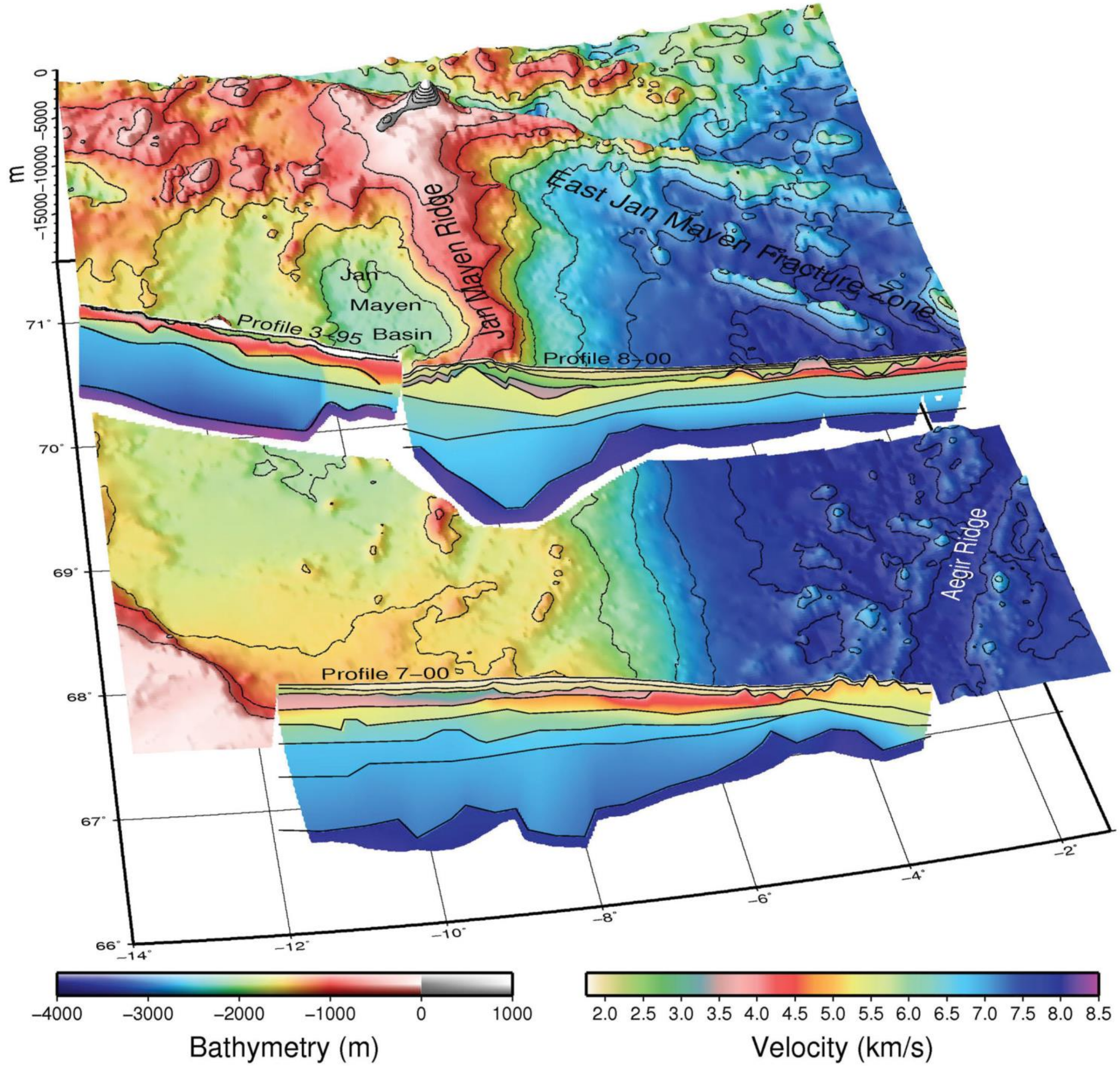

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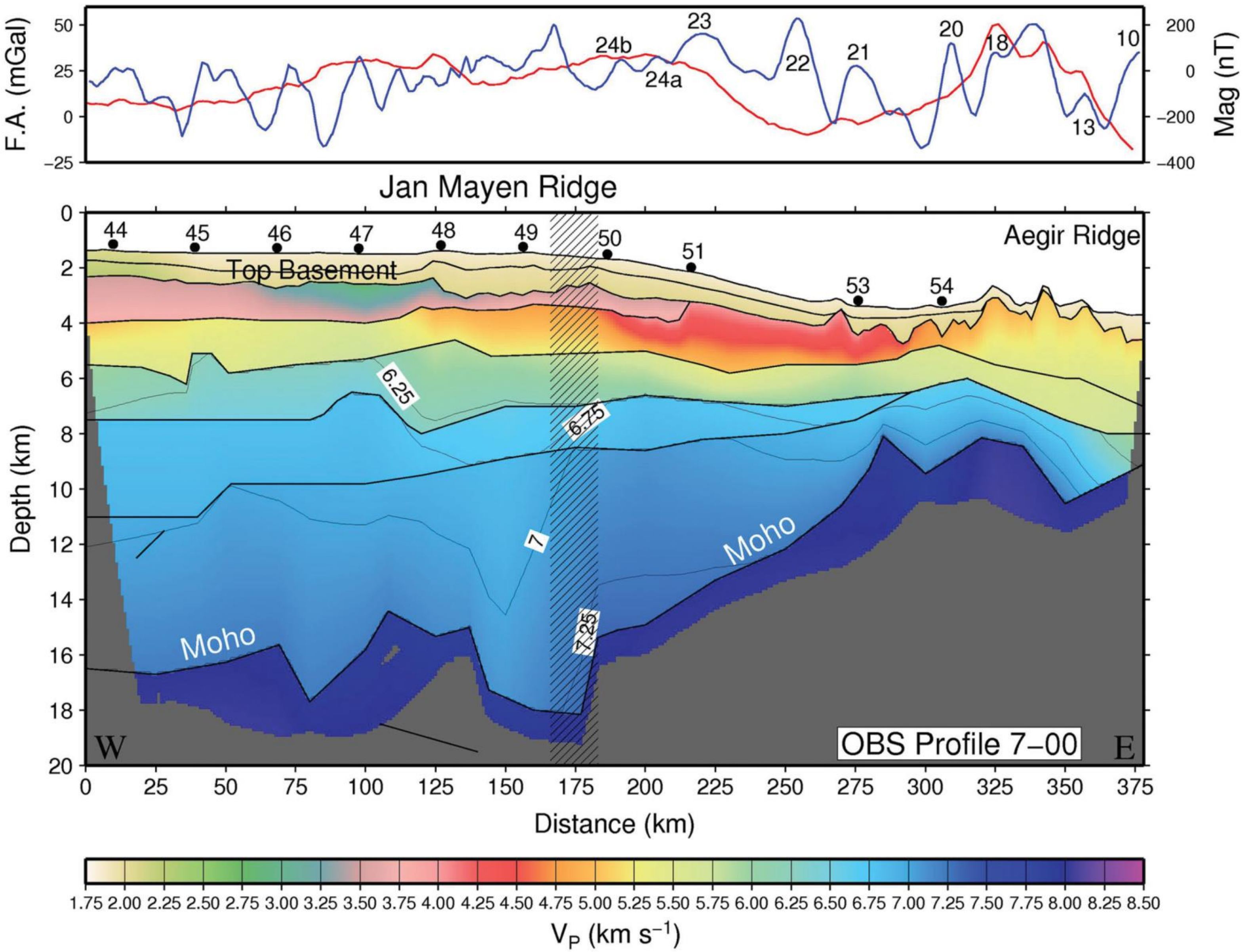

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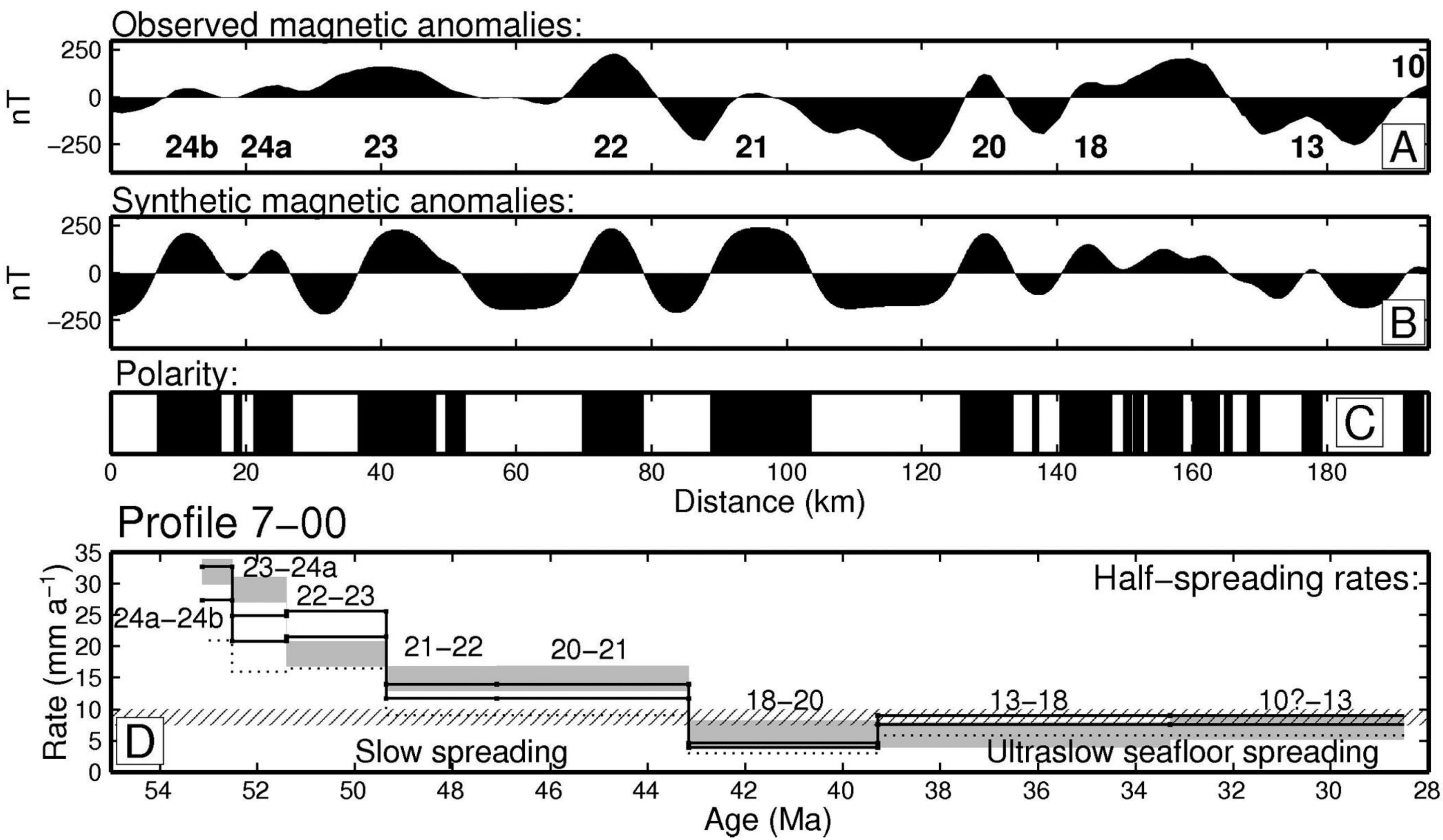
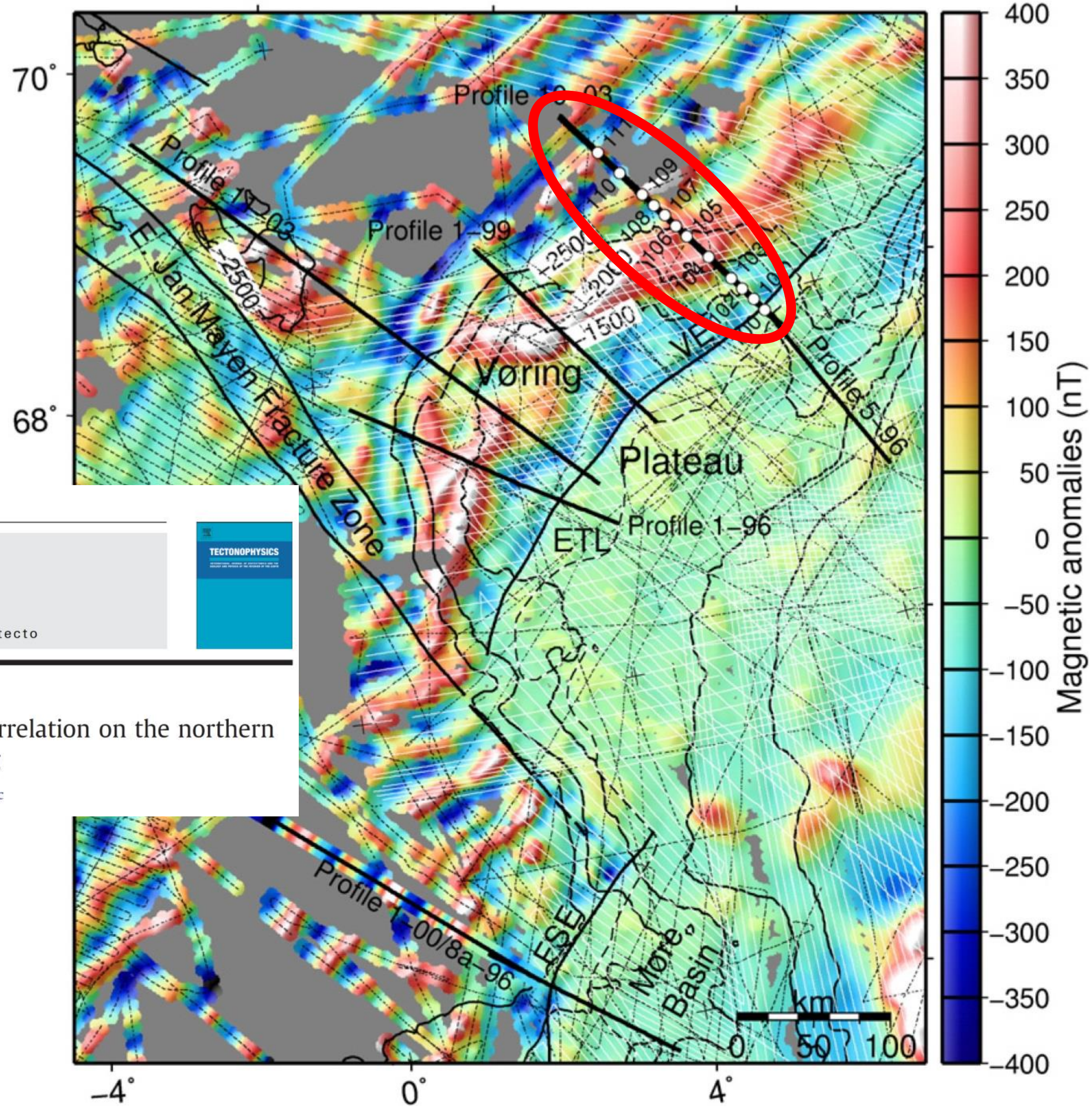


Northern Vøring Plateau Seafloor Spreading Half Rates



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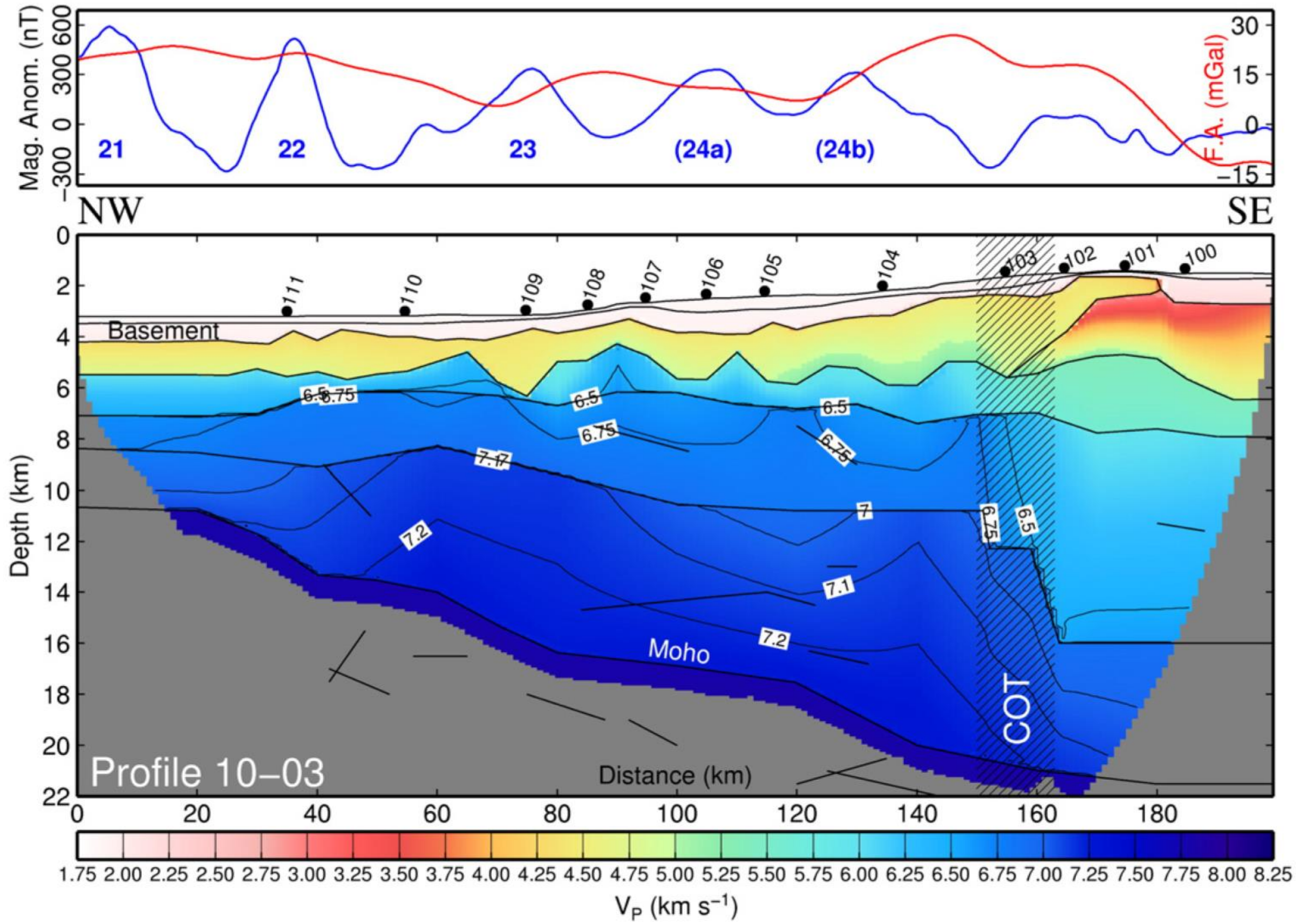
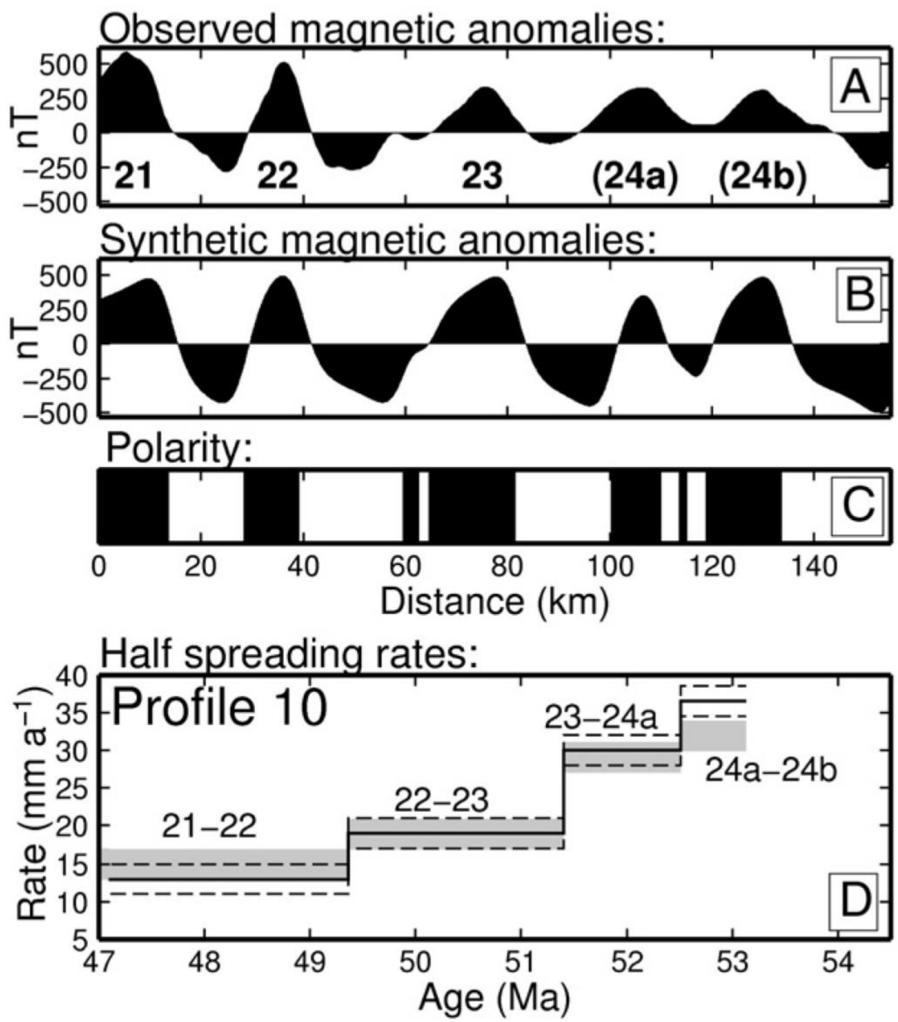


Northern Vøring Plateau Seafloor Spreading Half Rates



Lofoten Seafloor Spreading Half Rates

A new tectono-magmatic model for the Lofoten/Vesterålen Margin at the outer limit of the Iceland Plume influence

Asbjørn Johan Breivik[a,*], Jan Inge Faleide[a], Rolf Mjelde[b], Ernst R. Flueh[c], Yoshio Murai[d]

Tectonophysics 718 (2017) 25–44

Contents lists available at ScienceDirect

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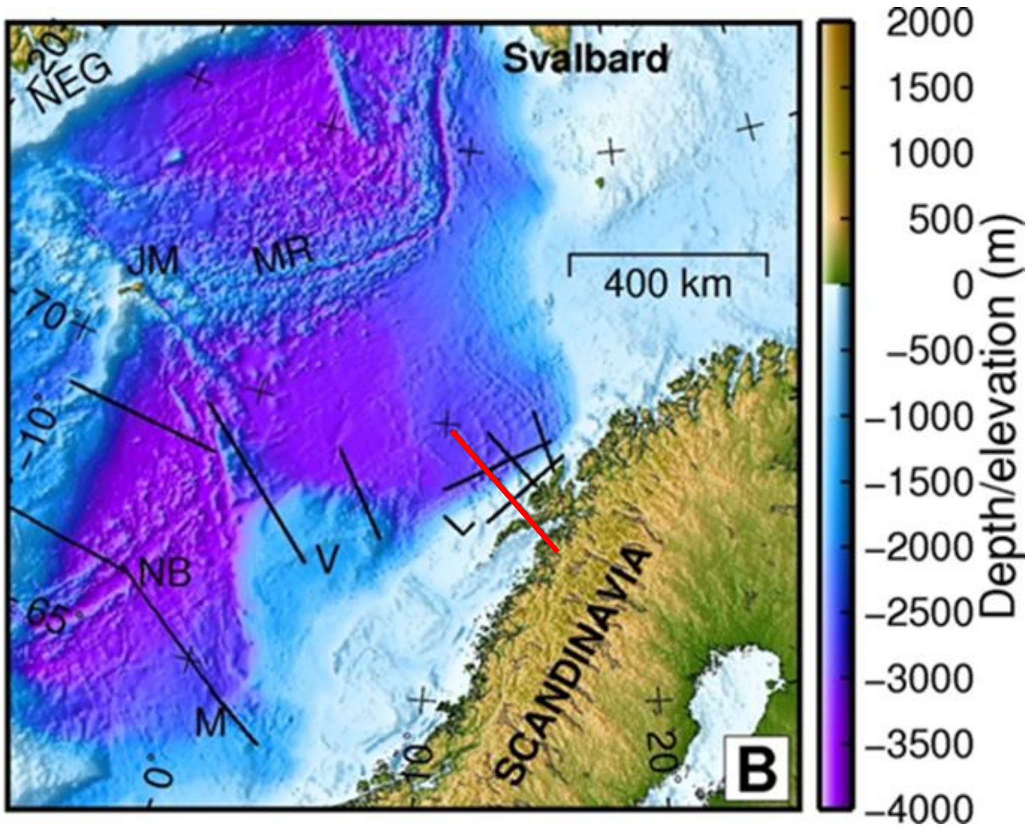
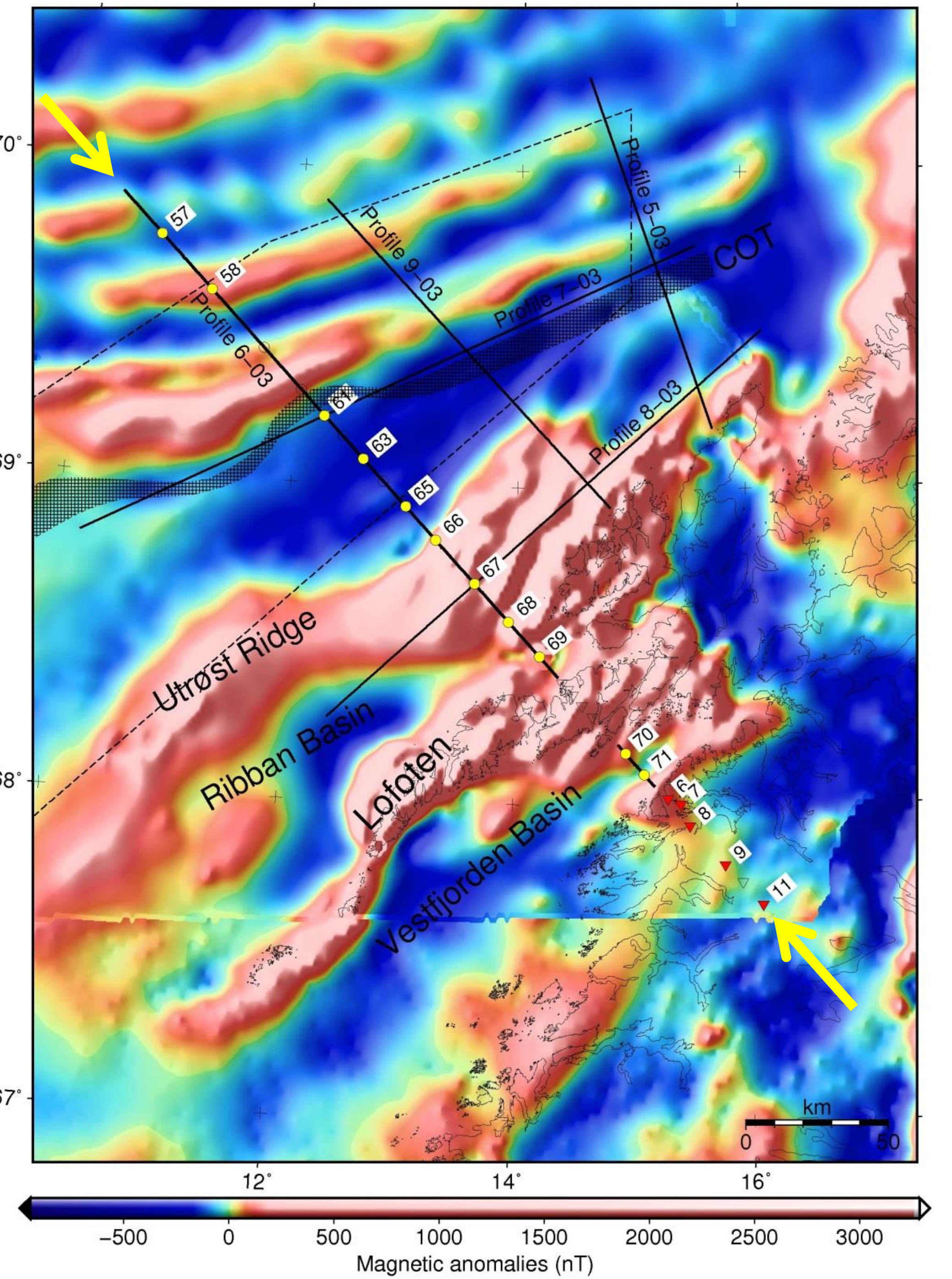
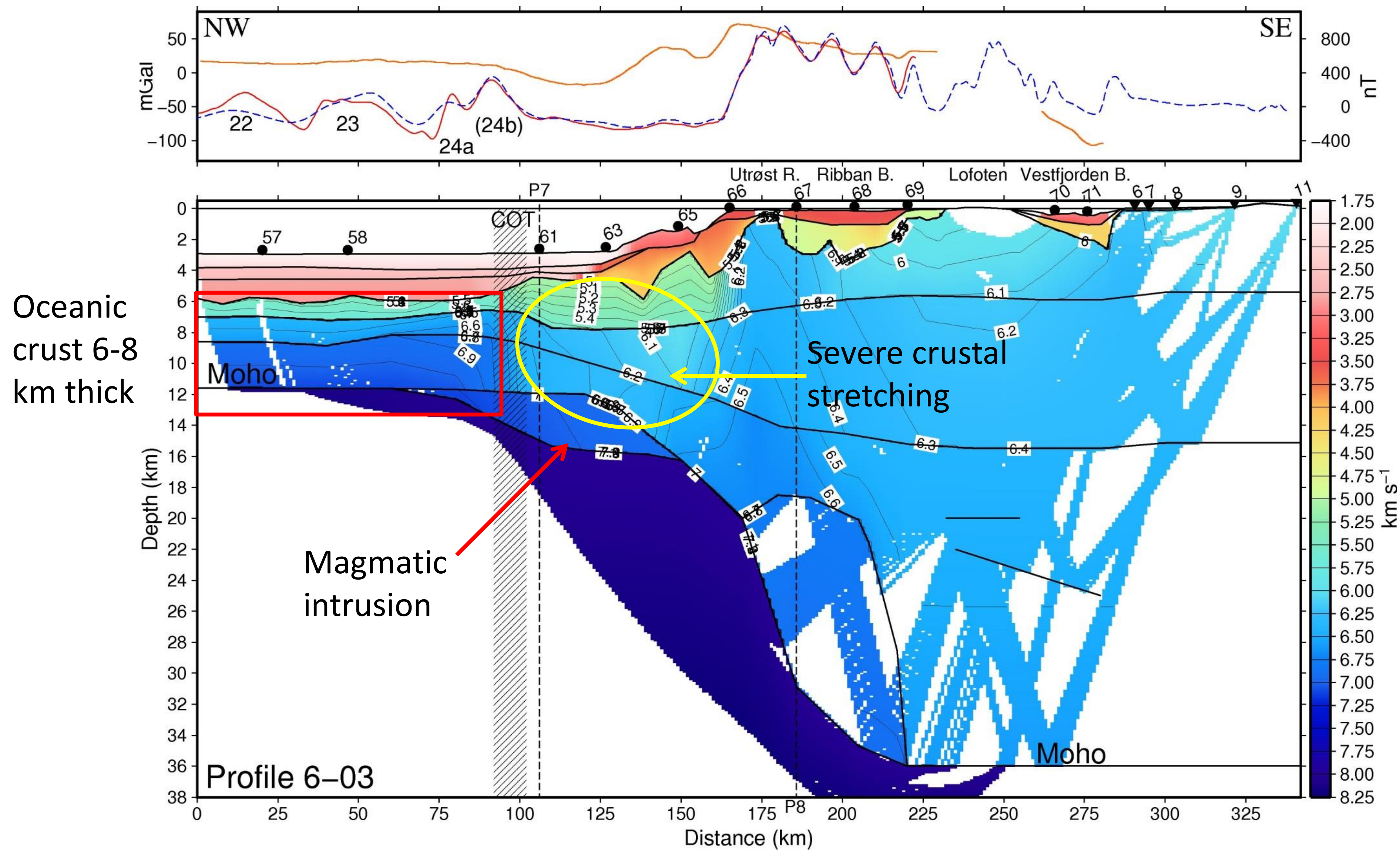


Lofoten Seafloor Spreading Half Rates

The newest magnetic survey is RAS-03 (dashed outline), only partly covering our profile

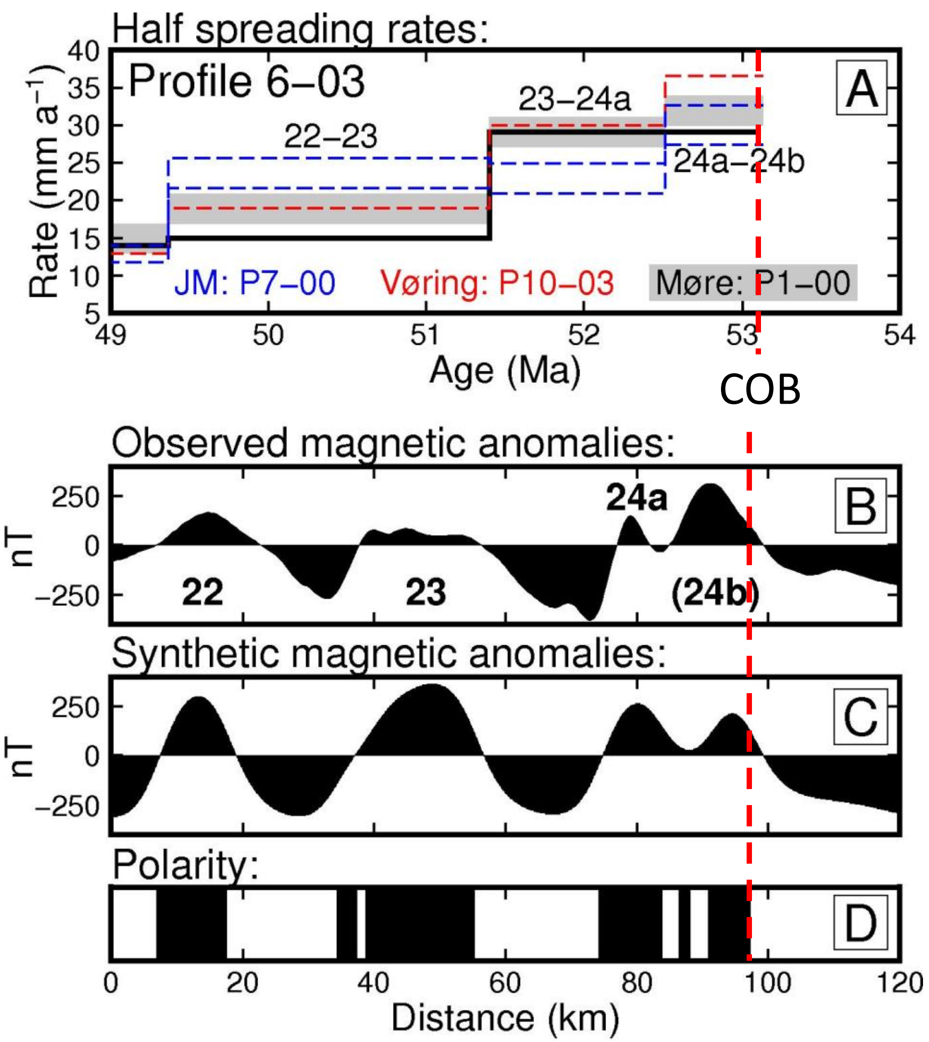


Lofoten Seafloor Spreading Half Rates

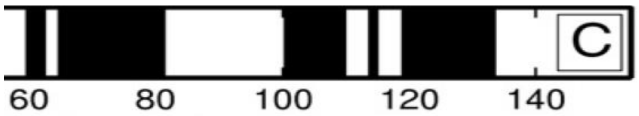


Lofoten Seafloor Spreading Half Rates

Fit only with breakup within C24R3 (53.1 Ma)

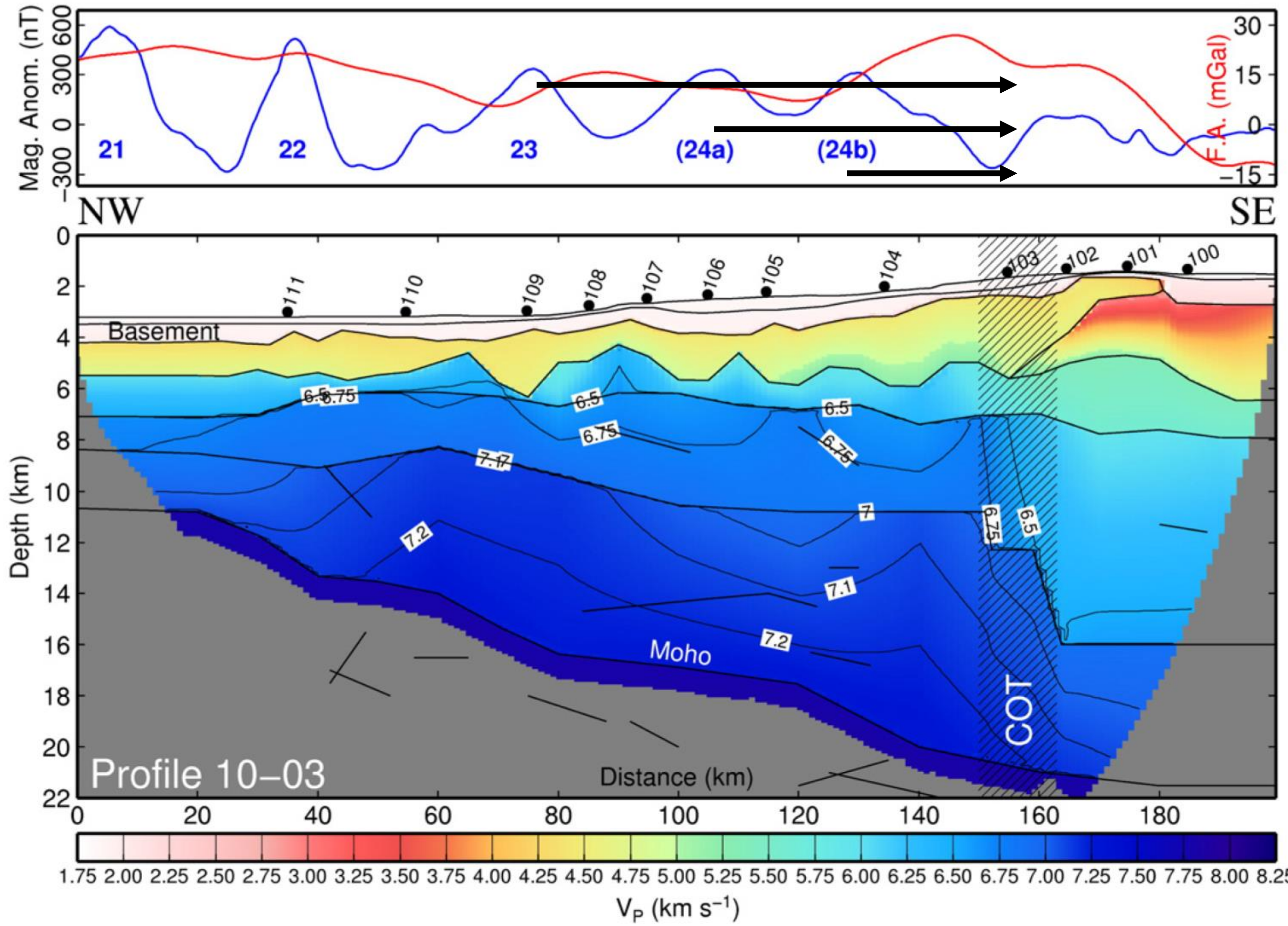


Compare N. Vøring:



Comparing breakup times

<u>Vøring Plateau:</u>
Back-calculating breakup times using derived half-spreading rates gives ~54.1 Ma



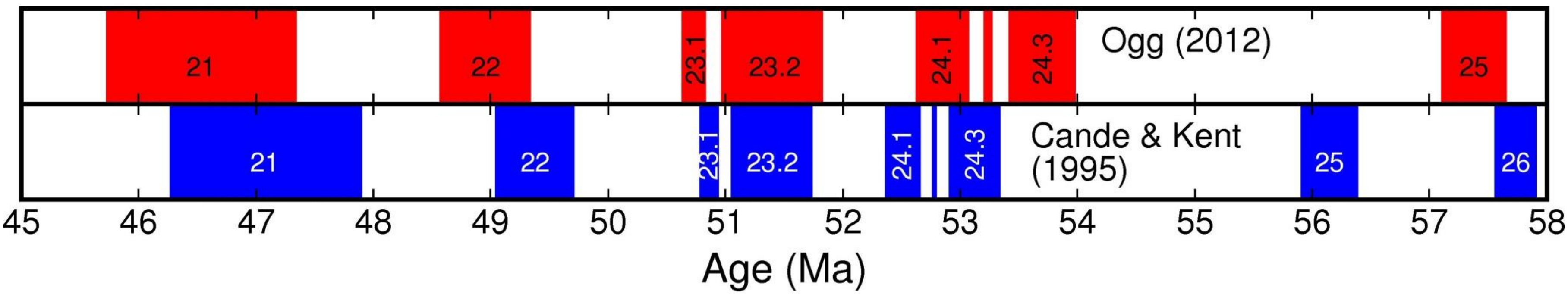
Comparing breakup times

Lofoten – Vesterålen Margin	Profile 5	53.1 ± 0.4 Ma
	Profile 9	53.2 ± 0.3 Ma
	Profile 6	53.1 <± 0.1 Ma
Vøring Margin	Profile 10	54.1 ± 0.3 Ma
	Profile AB-99	54.3 ± 0.6 Ma
Møre Margin	Profile 1-00	54.3 ± 0.6 Ma

Approximately 1 Ma delay of breakup to the Lofoten-Vesterålen margin

A word of caution

" The Times They Are A-Changin' "



All rates and times calculated using the Cande & Kent (1995) timescale

Implementing e.g., the new Ogg (2012) time scale would affect:

– absolute breakup times

– spreading rates

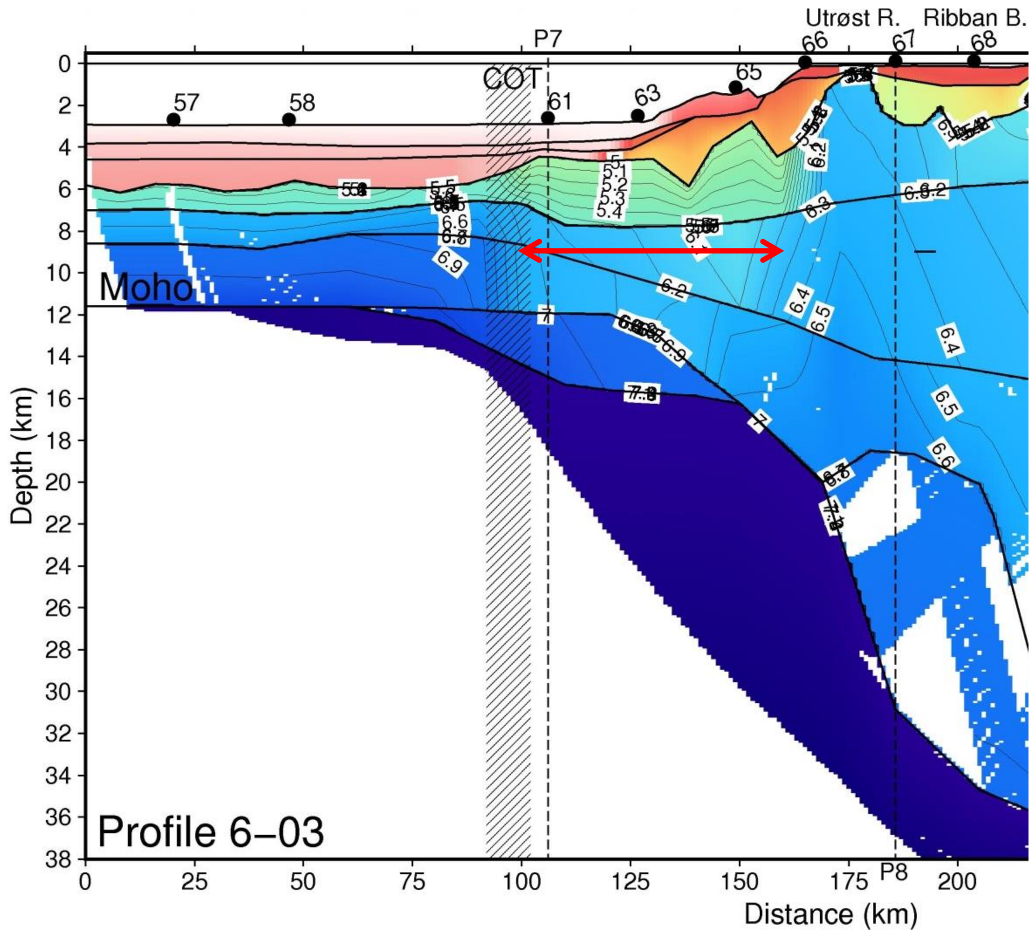
J.G. Ogg

Chapter 5

Geomagnetic Polarity Time Scale

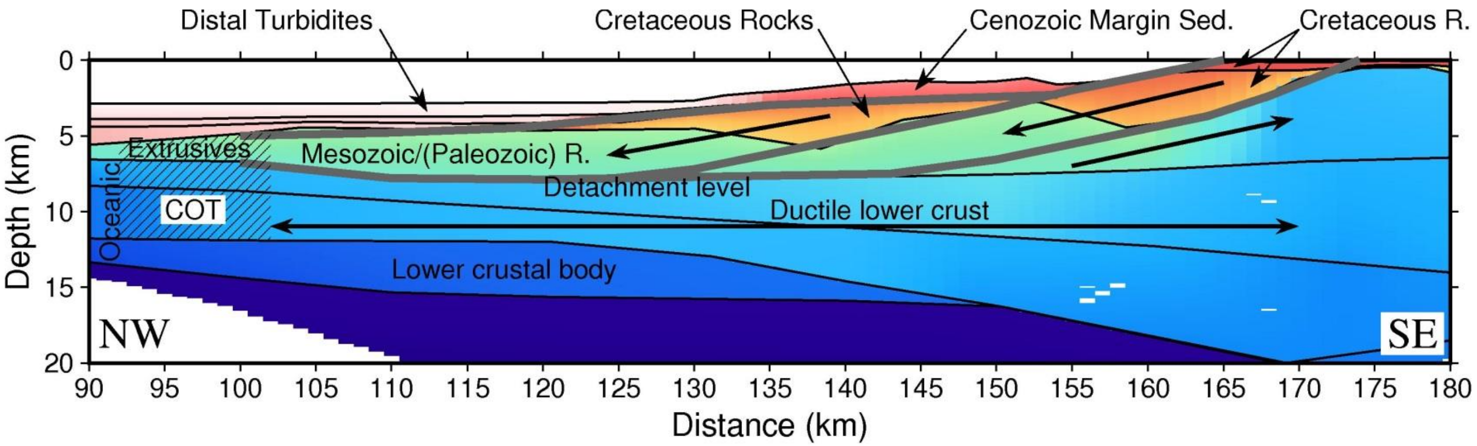
Implications of a ~1 Ma breakup delay at Lofoten

- Outer margin may have been a deep Cretaceous basin before breakup
- 1 Ma of extension at 30 km/Ma = 30 km
- Currently ~60 km wide, possibly 20-30 km wide before breakup
- Assuming 30 km of extension over 1 Ma with a start width of 30 km, gives a strain rate of $3.2 \cdot 10^{-14}\ s^{-1}$



Implications of a ~1 Ma breakup delay at Lofoten

- Development of low-angle detachments can explain observed geometry
- The heave of the two detachment faults sum to 26-30 km of extension
- Extension consistent with the delayed breakup



Comparison to other margins/rifts

	Low strain rates:		High strain rates:	
Location	Ethiopian Rift	Iberian Margin	Lofoten Margin	Woodlark basin
Crustal extension	Low	High	High	High
Strain rate	$4.2\text{-}7.4 \cdot 10^{-15}\ s^{-1}$	$4.4 \cdot 10^{-15}\ s^{-1}$	$3.2 \cdot 10^{-14}\ s^{-1}$	$1.5\text{-}2.6 \cdot 10^{-14}\ s^{-1}$
Magmatism	Extensive	Starved	Slightly elevated	Normal
Serpentinization	Not observed	Extensive	Not observed	Not observed
Mantle temperature	Unusually hot	Normal to cool	Slightly elevated?	Normal

Based on: Bastow et al. 2011, Whitmarsh et al. 2001.

From: Taylor et al. 1999

Factors determining breakup style

<u>Volcanic margins</u>

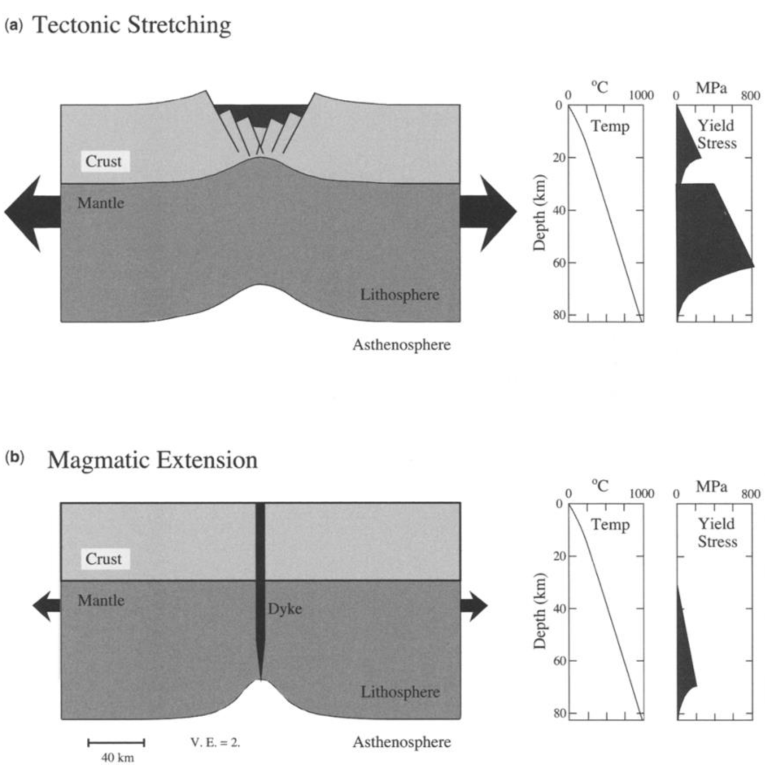
Mantle temperature –
massive pre- and post-breakup volcanism, intrusion dominate over extension

<u>Iberia-type margins</u>

Low strain rates – mantle cooling inhibits melt generation

Cool upper mantle – little magmatism, even after crustal separation

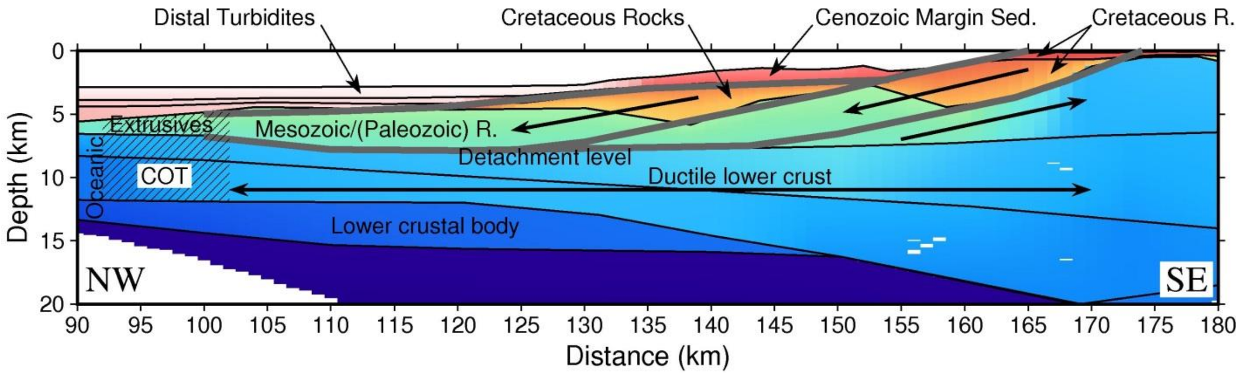
Strong lower crust – crust-penetrating low-angle faults giving deep seawater circulation and mantle serpentinization



Buck (2006)

Factors determining breakup style

Lofoten margin



High strain rates – why not more magmatism, cool mantle?

Weak lower crust – no crust-penetrating low-angle faults or serpentinization

Mantle temperature – some excess breakup magmatism, hot mantle?

Factors determining breakup style

<u>Lofoten margin</u>

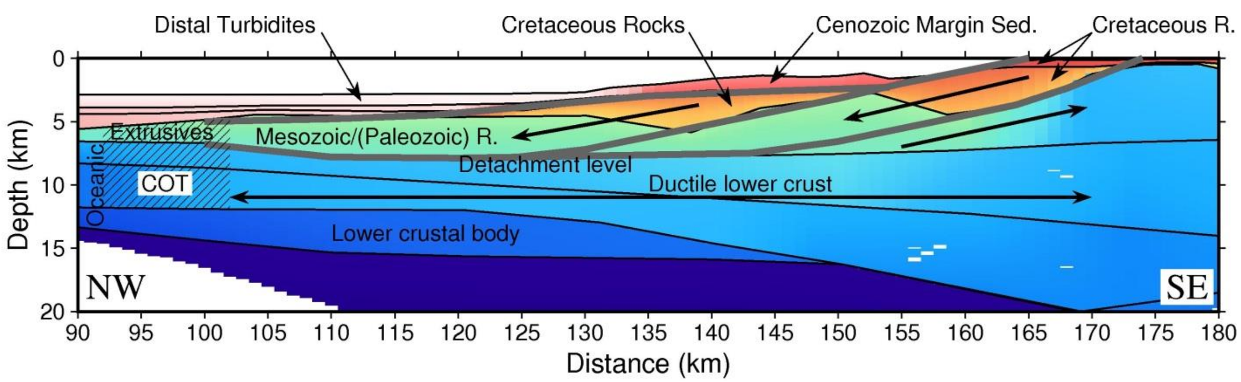
Cool/normal mantle during early rifting – favoring extension over magmatism

Late arrival of a small amount of plume material caused some elevated magmatism around breakup time

<u>Vøring margin</u>

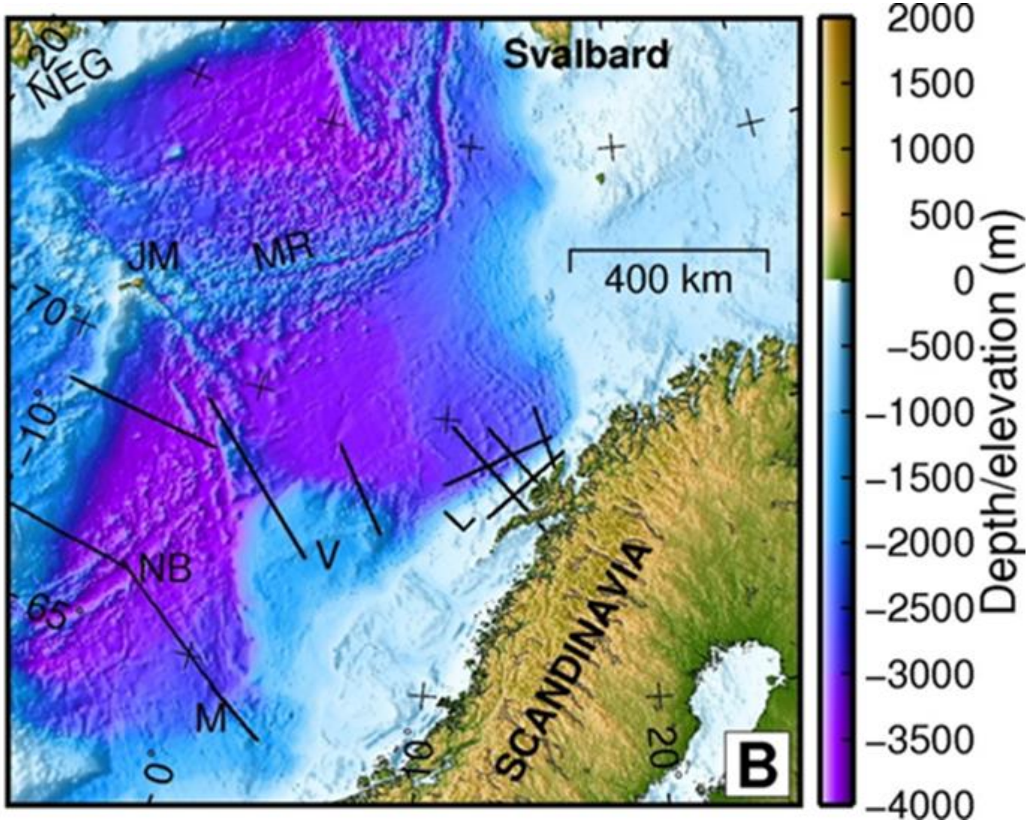
Hot plume mantle during early rifting – favoring magmatic intrusion over extension

Large quantities of hot plume material, producing much excess magmatism also after breakup



Some Conclusions – Vøring Plateau formation

- Low crustal extension due to magmatic diking becoming dominant.
- Igneous growth of crust by lower-crustal intrusions
- Creation of thick post-breakup oceanic crust



Some Conclusions – Vøring Plateau northern termination

- Abrupt transition to a deep-water plain, but no apparent tectonic offset
- Crustal extension increase to the Lofoten Margin
- Probably corresponds to the outer limit of plume material distribution during early rift stages