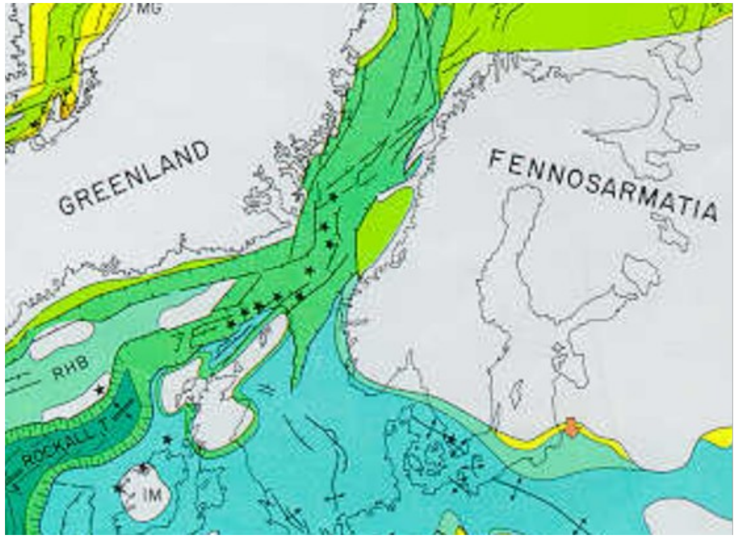
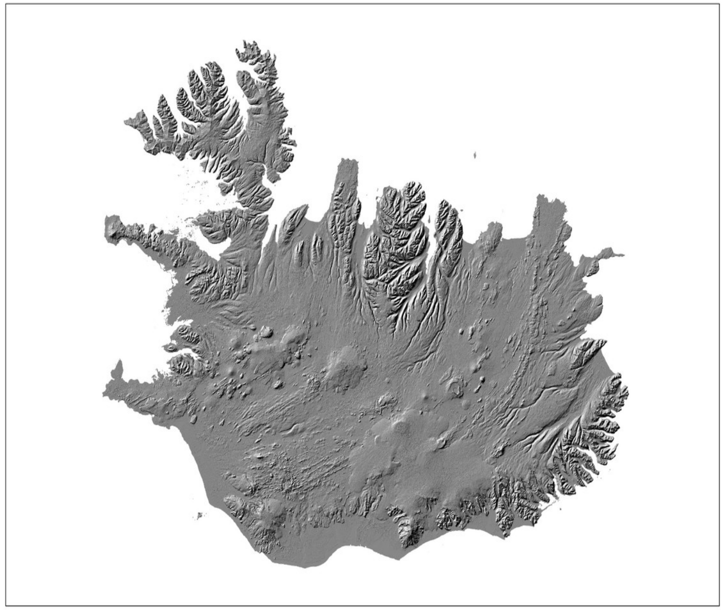
ICELAND AND THE SURROUNDING SEA FLOOR: INSIGHTS INTO A COMPLEX GEOLOGICAL SYSTEM FROM ITS ORIGINS TO THE PRESENT DAY



Rouwen Lehné

Hessian Agency for Nature Conservation, Environment and Geology



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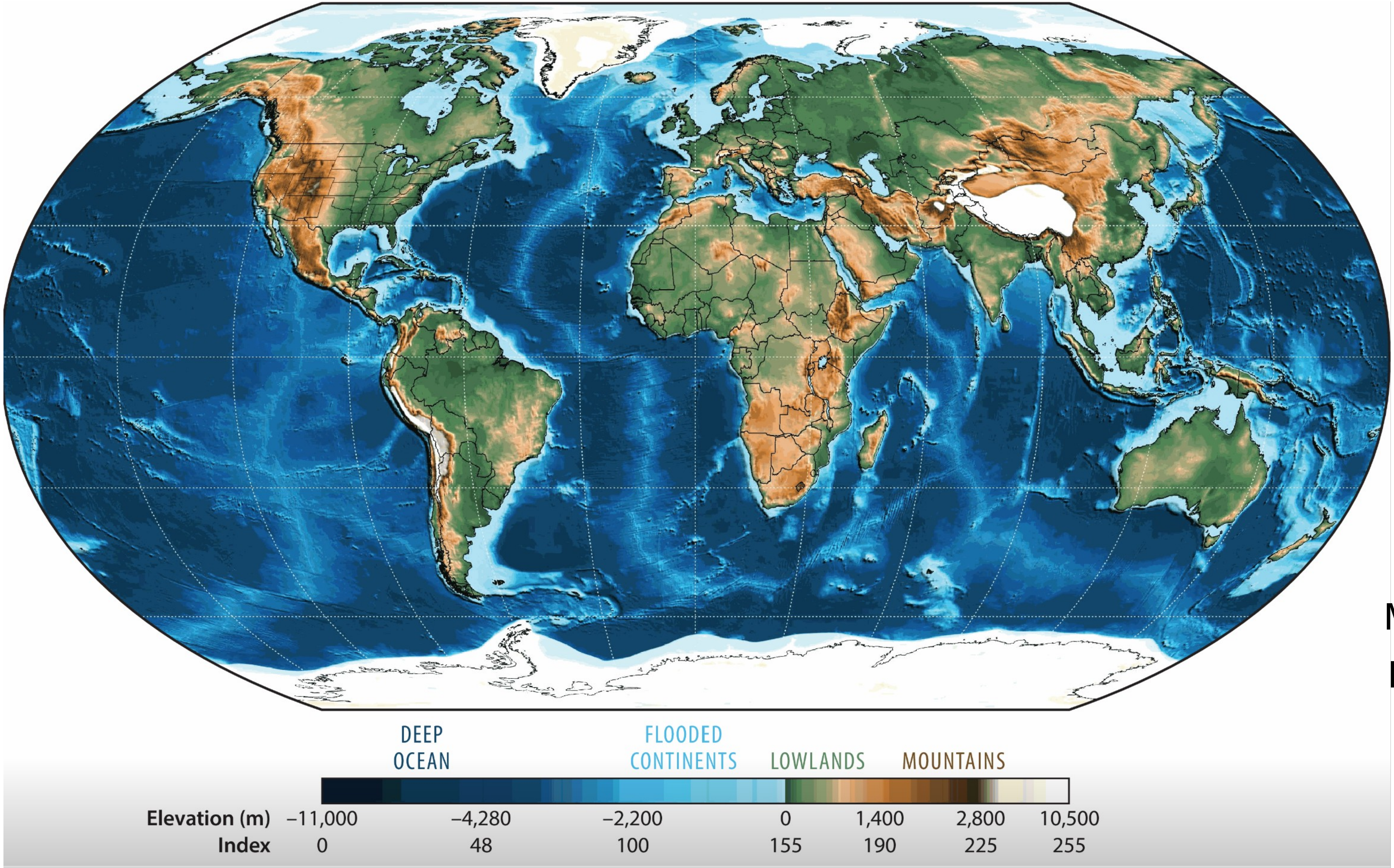
Present day status – the world we know



MOR: 60.000 km

MAR: 20.000 km

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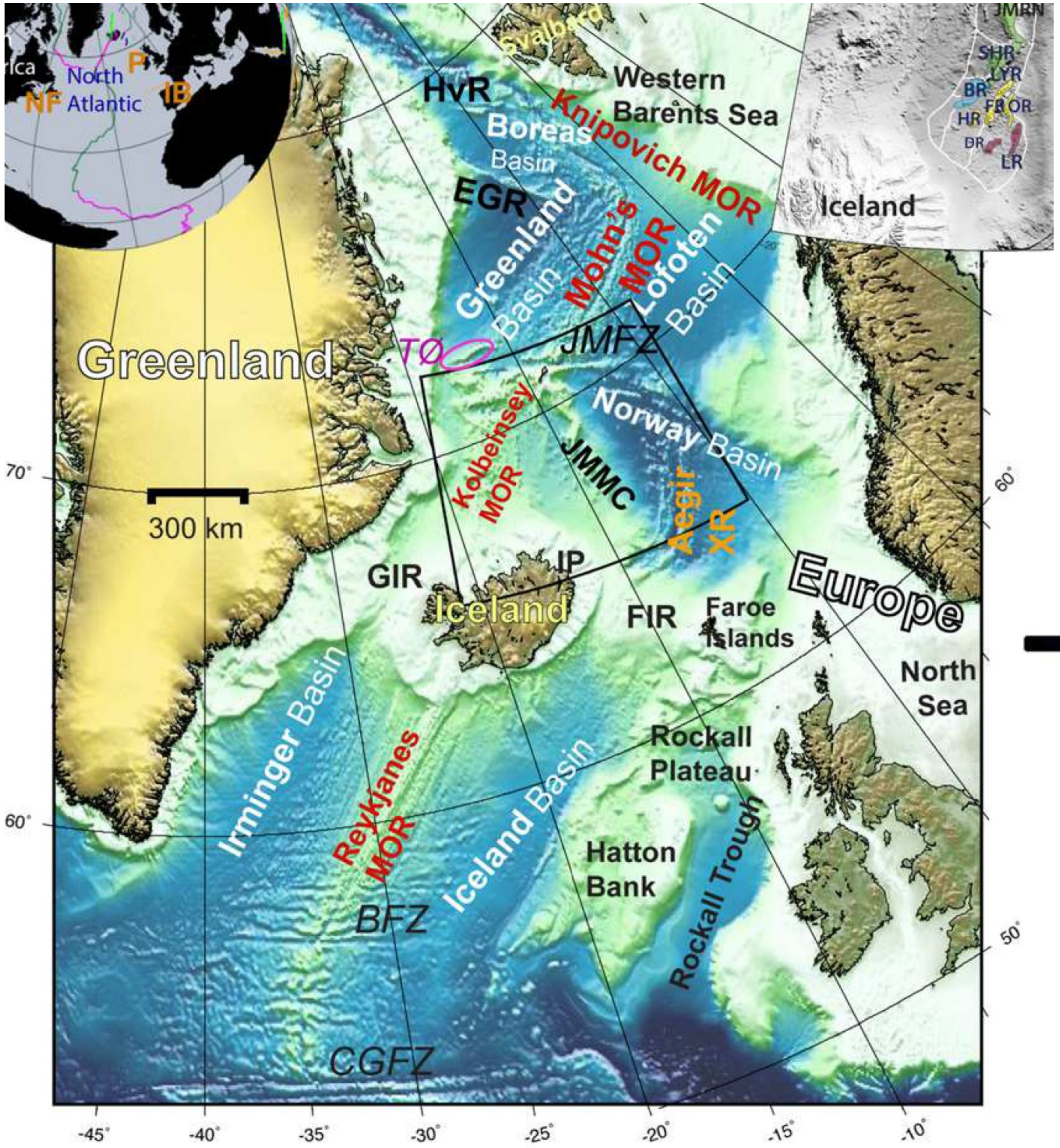
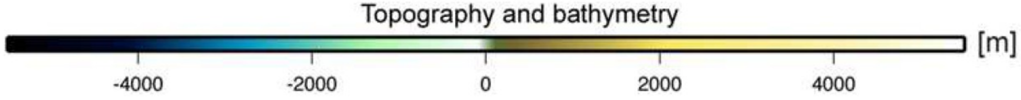
Present day status – the world we know



Iceland: 103.000 km²
Shelf: about 350.000 km²
Depth shelf: up to 400 m



Reykjanes Ridge: 950 km

(Gaina et al., 2018)

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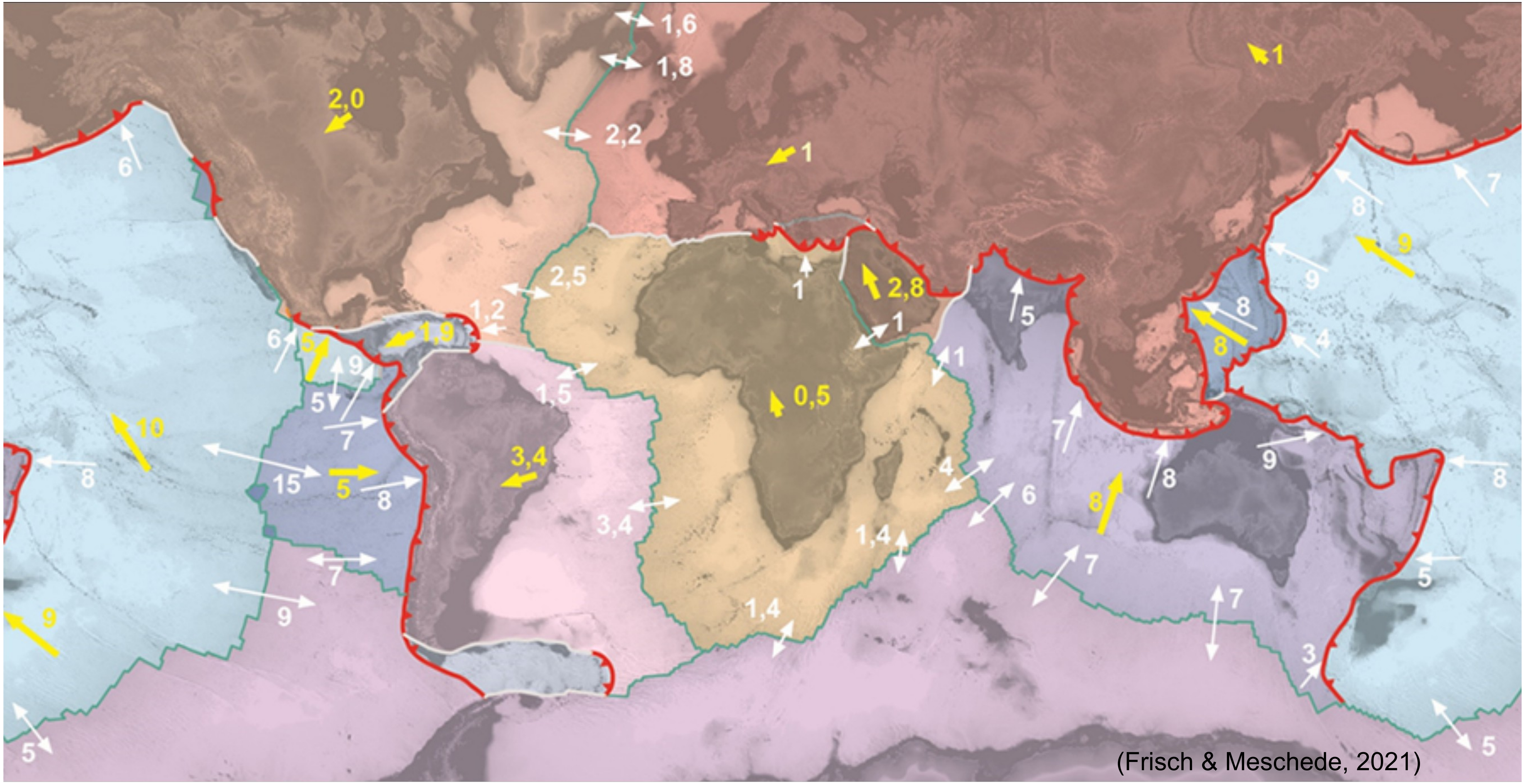
Present day status – the world we know – plate movements



Relative (white arrows) and absolute plate movement velocities (yellow arrows)

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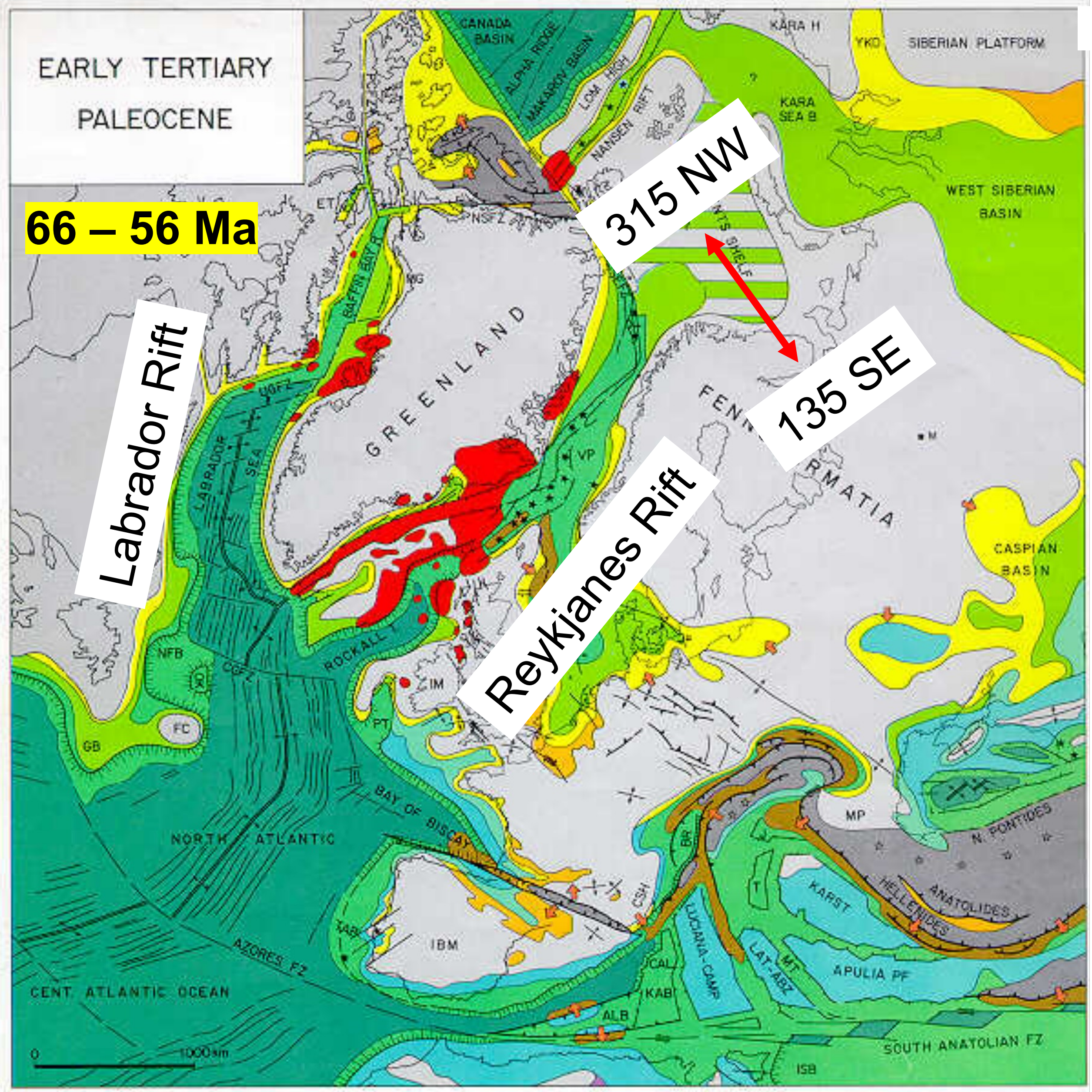
The becoming of Iceland started some 54 Ma ago



DEPOSITIONAL ENVIRONMENT AND PRINCIPAL LITHOLOGY

- MAINLY CONTINENTAL CLASTICS
- DELTAIC-SHALLOW MARINE, MAINLY SANDS
- SHALLOW MARINE, MAINLY SHALES
- SHALLOW MARINE, CARBONATES AND CLASTICS
- SHALLOW MARINE, MAINLY CARBONATES
- EVAPORITES AND CLASTICS
- MAINLY EVAPORITES
- EVAPORITES, CLASTICS AND CARBONATES
- EVAPORITES AND CARBONATES
- DEEPER MARINE CLASTICS AND/0R CARBONATES
- DEEPER MARINE, MAINLY SANDS (FLYSCH)
- BASINS FLOORED BY OCEANIC CRUST
- BASINS FLOORED BY OCEANIC CRUST CONTAINING THICK SEDIMENTS

(Ziegler et al., 2014)

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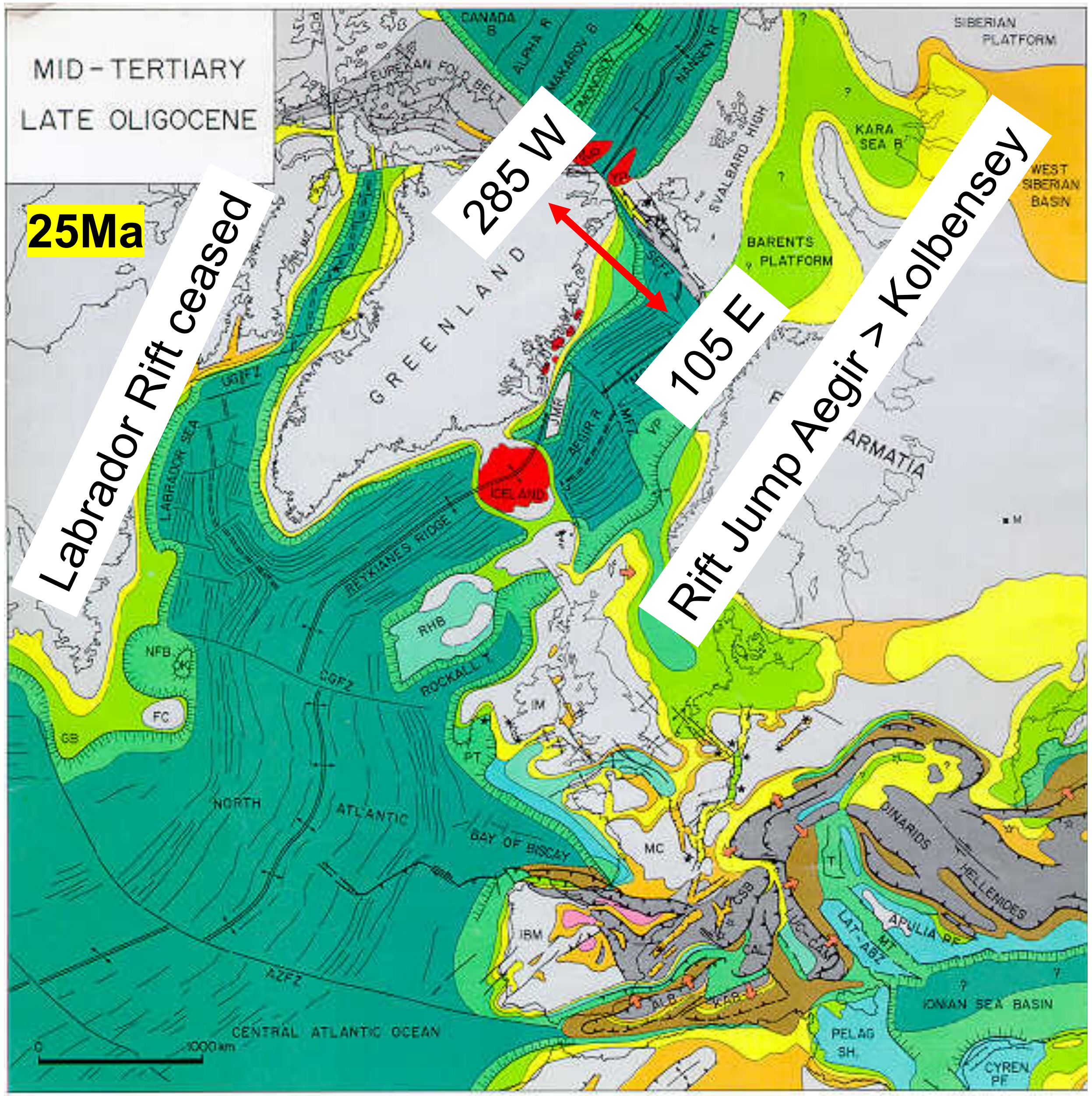
The becoming of Iceland started some 54 Ma ago



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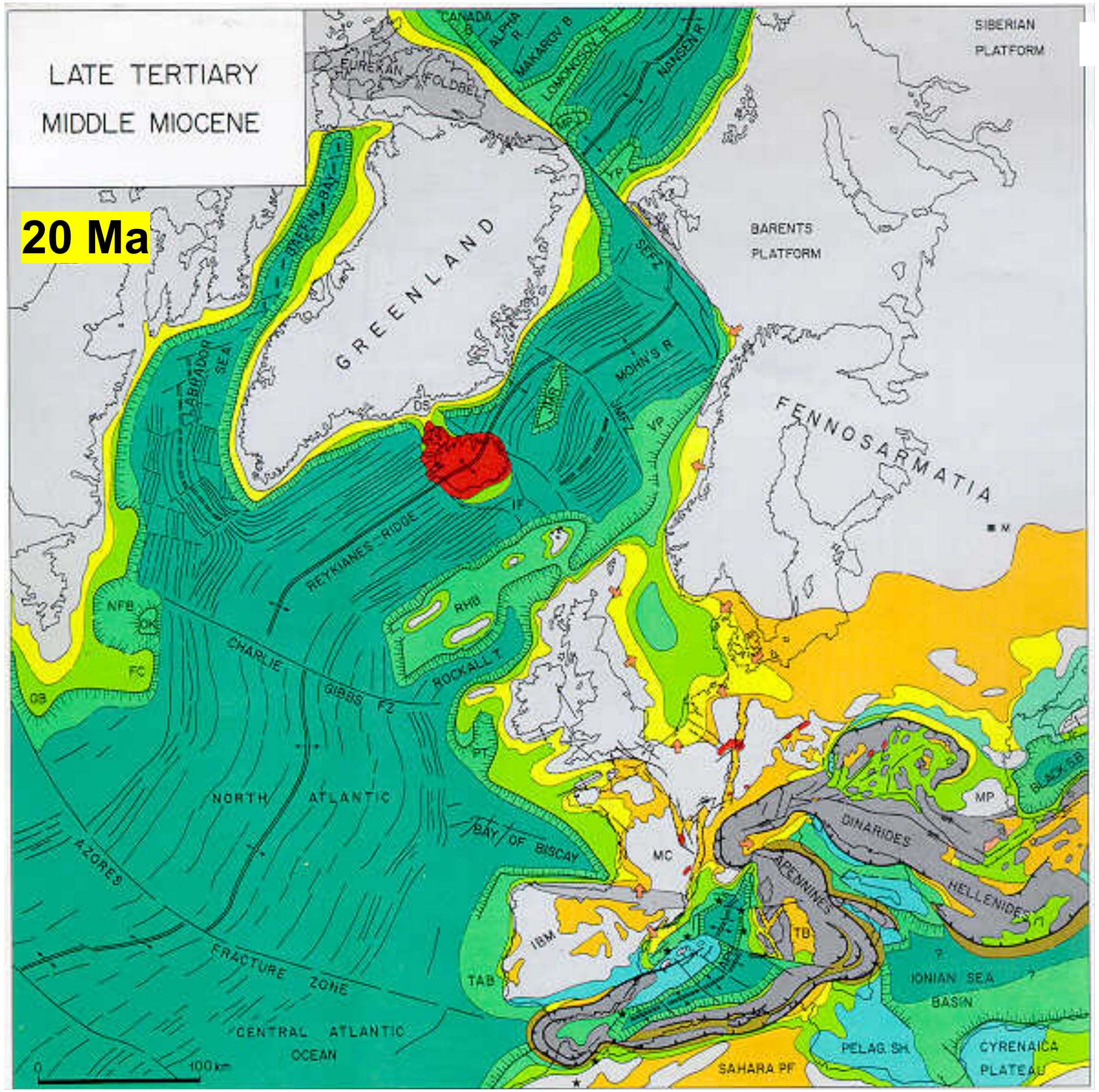

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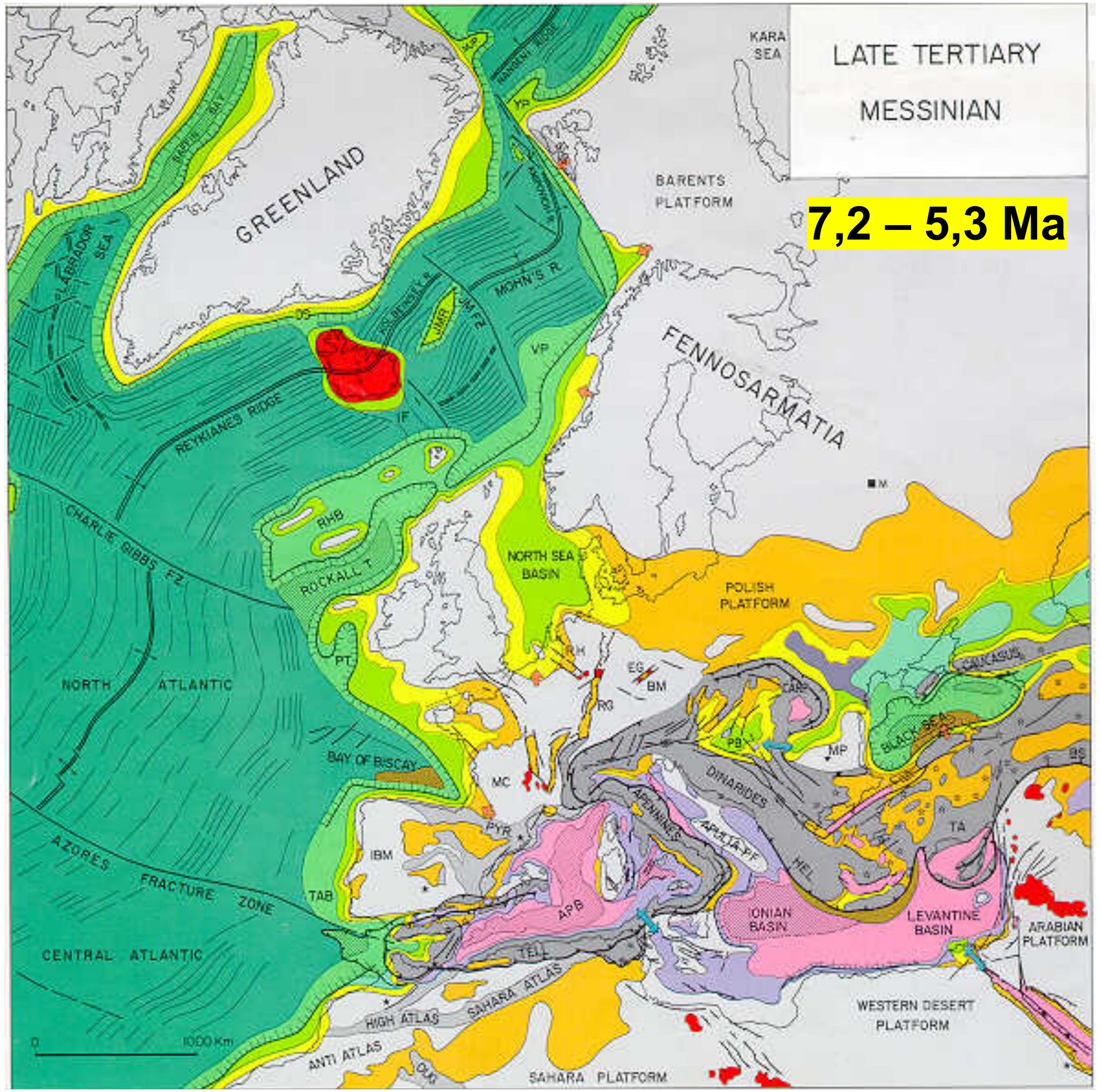

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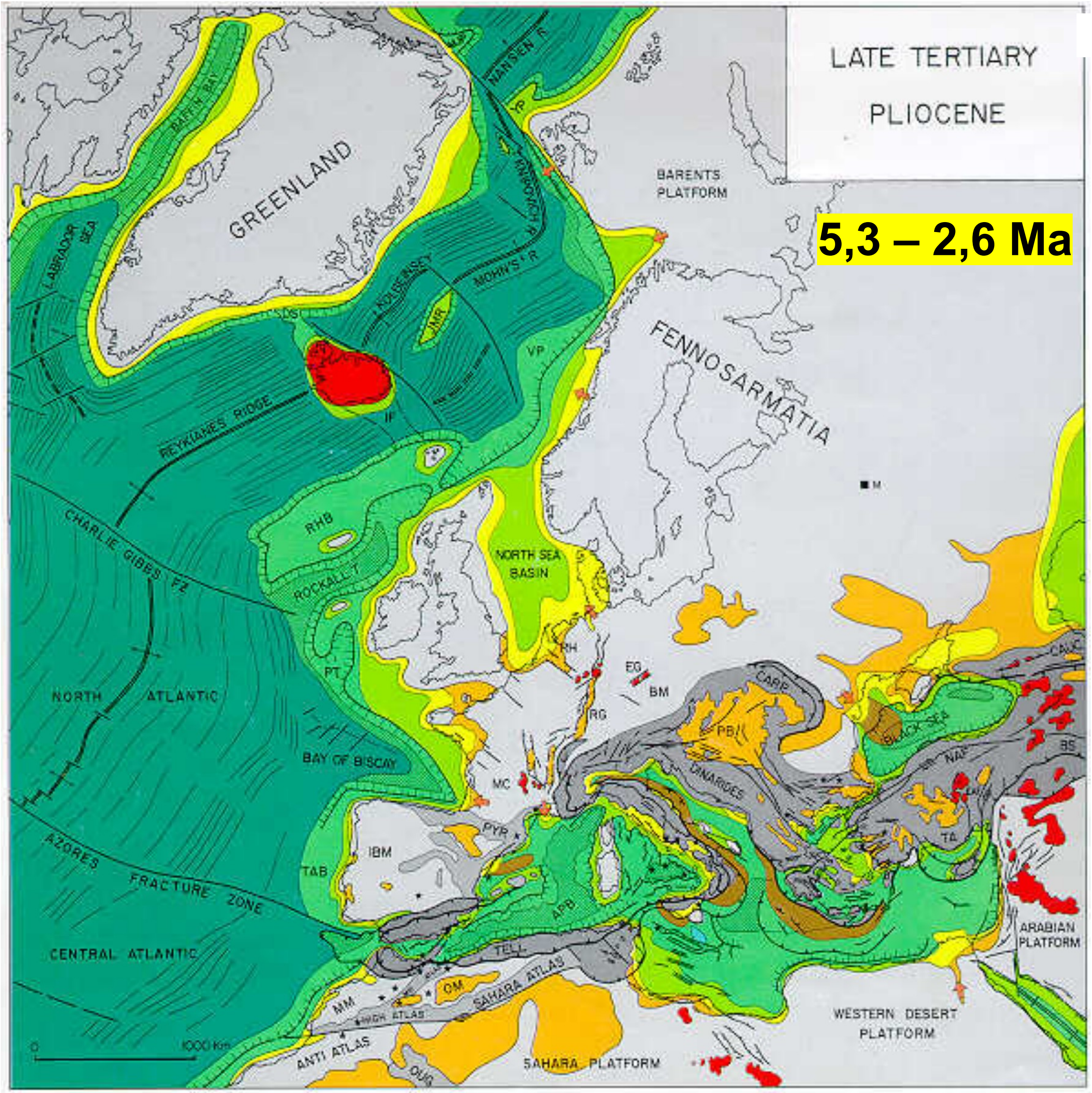

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(Ziegler et al., 2014)

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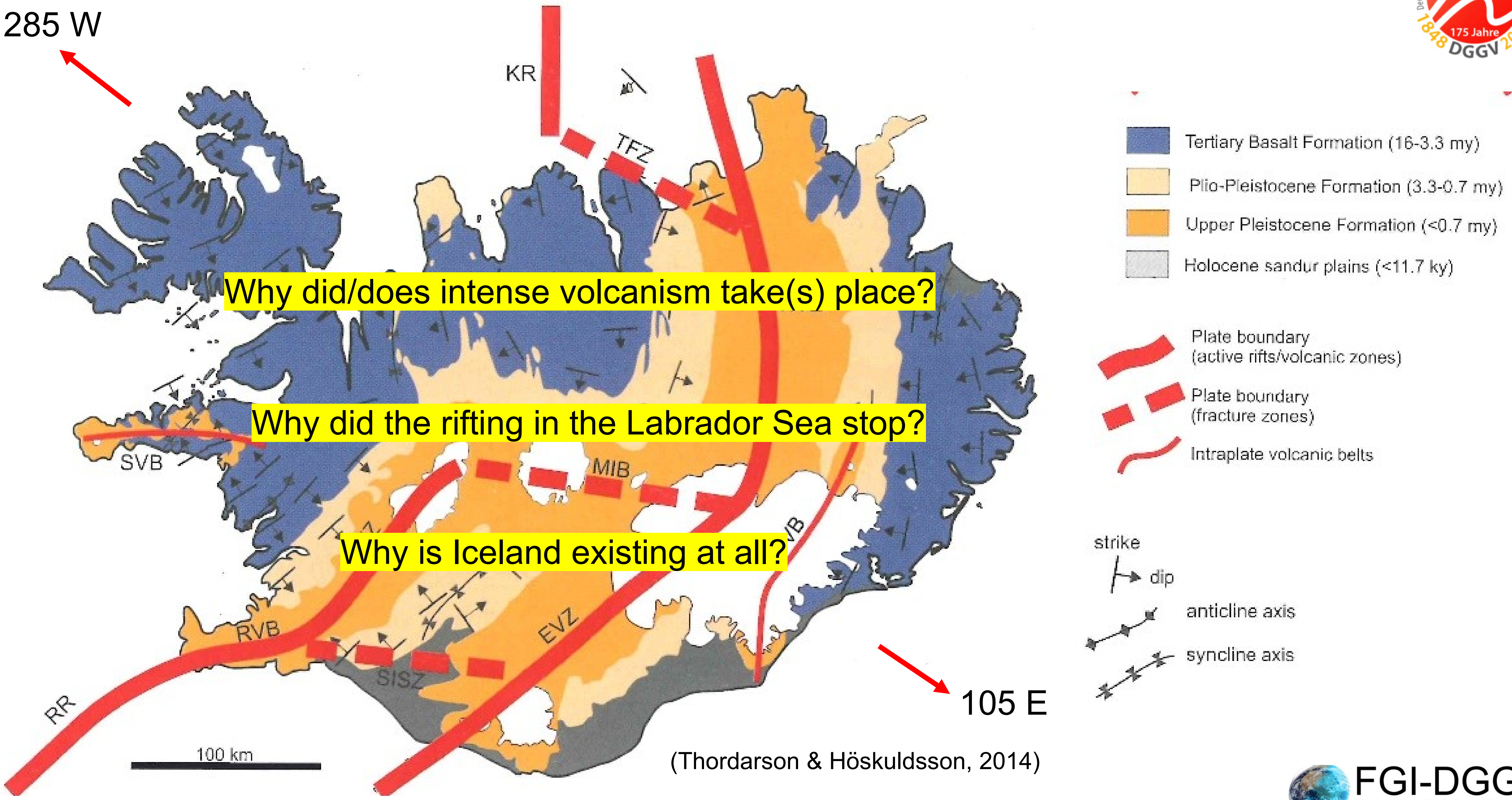
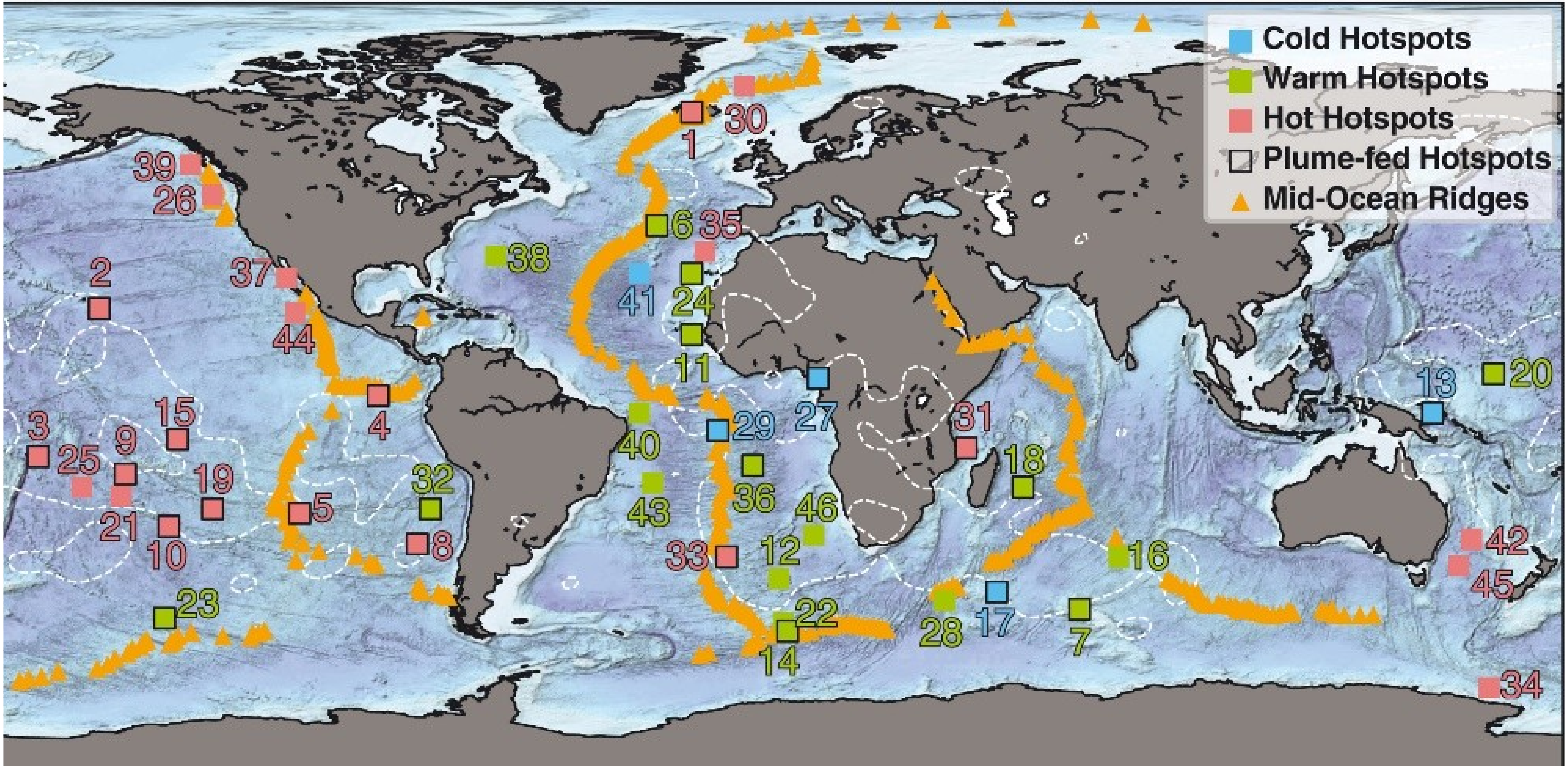
Onshore rifting Iceland



(Thordarson & Höskuldsson, 2014)

The Iceland Plume (or Hot Spot)



On the relative temperatures of Earth's volcanic hotspots and mid-ocean ridges

XIYUAN BAO, CAROLINA R. LITHGOW-BERTELLONI, MATTHEW G. JACKSON, AND BARBARA ROMANOWICZ

SCIENCE • 6 Jan 2022 • Vol 375, Issue 6576 • pp. 57-61 • DOI: 10.1126/science.abj8944

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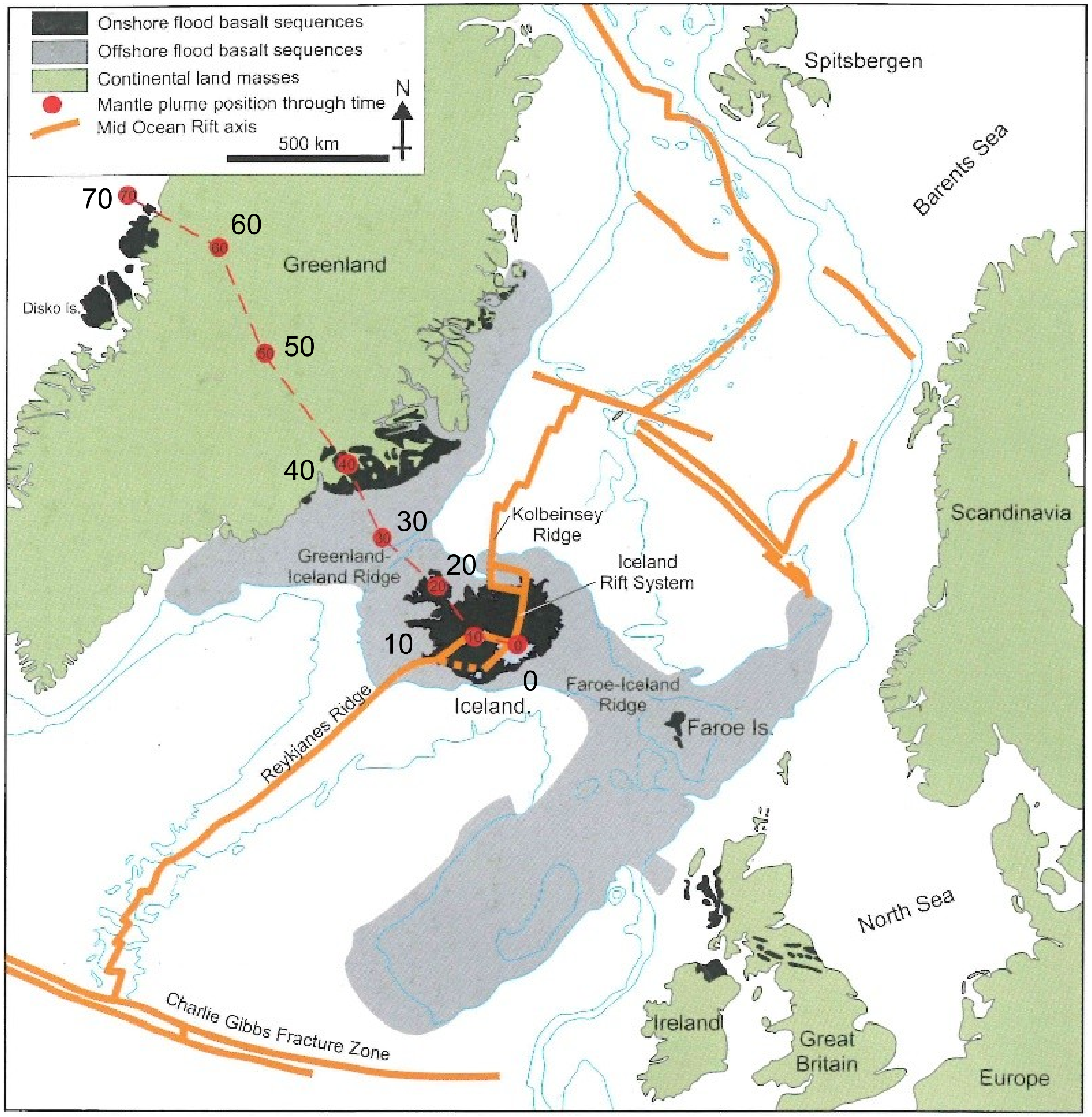
The Iceland Plume (or Hot Spot)



Absolute movement plates > 2 mm/a NW

Large Igneous Province (about 2.000 km long, about 10 Mio km³ volcanics)

Figure 1.1 Iceland is an elevated plateau in the middle of the North Atlantic, situated at the junction between the Reykjanes and Kolbeinsey Ridge segments. The red dashed line shows the position of the Iceland mantle plume from 65 million years to the present day.

(Thordarson & Höskuldsson, 2014)

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The Iceland Plume (or Hot Spot)

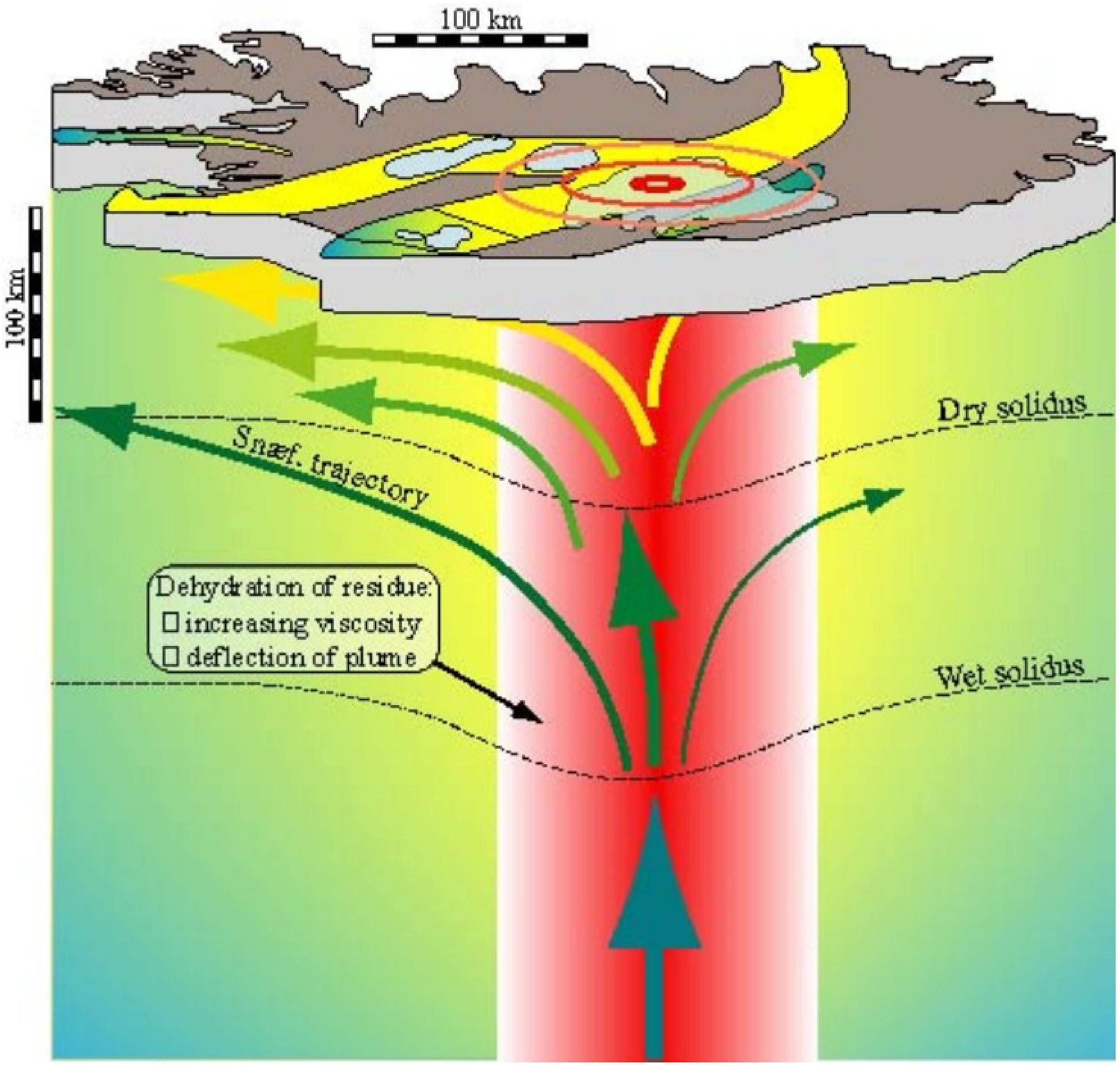

Fig. 6. Schematic illustration of flow trajectories and melting regime of the Iceland plume in relation to the volcanic rift zones (yellow) and off-rift zones (gradients from yellow via green towards blue). The degree of melt depletion of the mantle surrounding the axial plume stem is indicated schematically by colour shades from blue (least melt-depleted) to yellow (most melt-depleted). The same colour coding is used for the flow trajectories. The illustration is a combination of a three dimensional perspective and an east-west vertical cross section, with approximate plume location and dimensions based on Wolfe et al (1997), Shen et al. (2002) and Ito (2002). The crustal thicness is in accordance with Kaban et al. (2002). The initial lateral deflection of the plume flow near the wet solidus is caused by viscosity increase related to the initial dehydration melting (e.g. Ito et al. 1999).

(Trønnes 2002)

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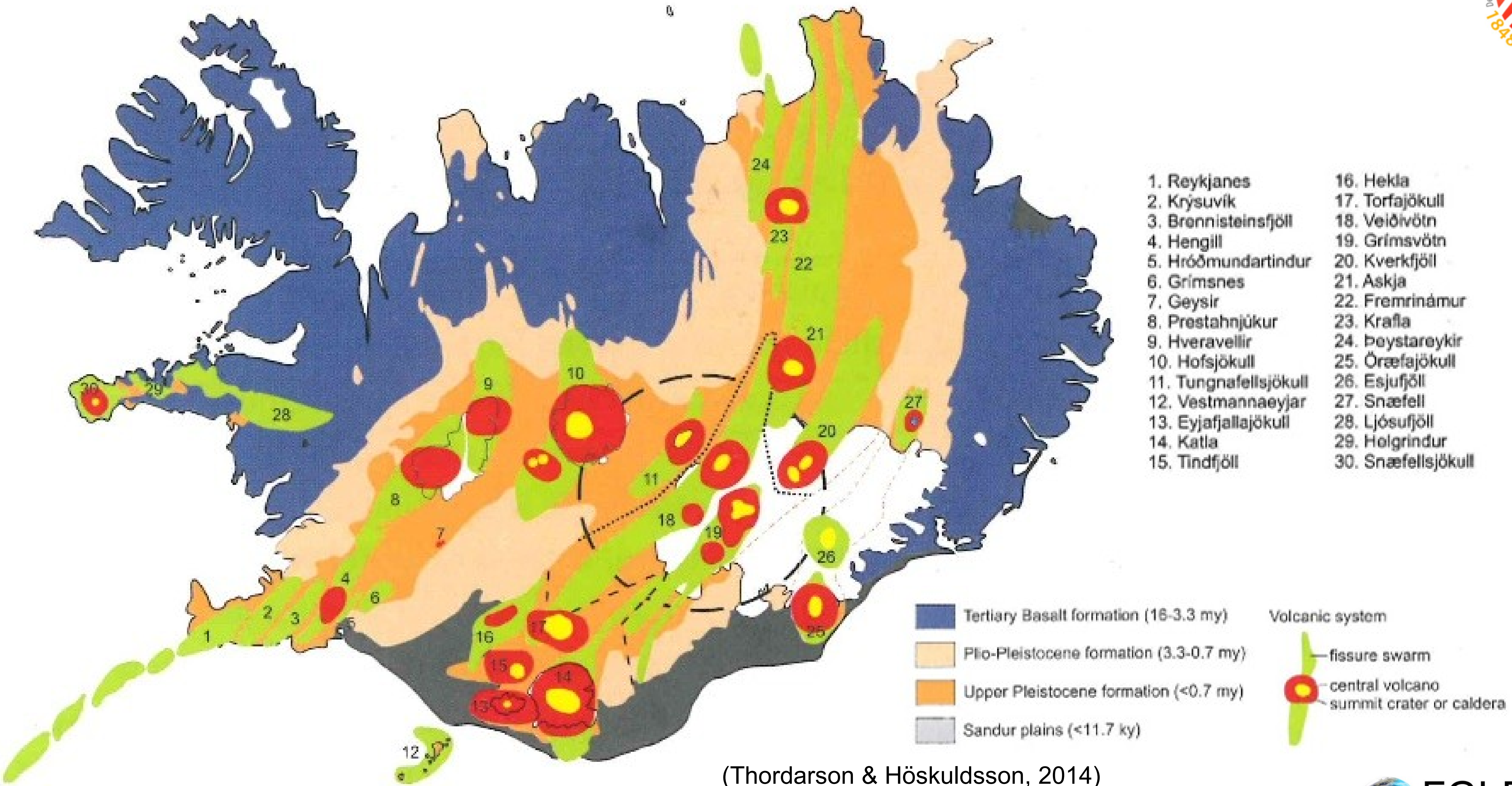
Volcanic systems in Iceland



(Thordarson & Höskuldsson, 2014)

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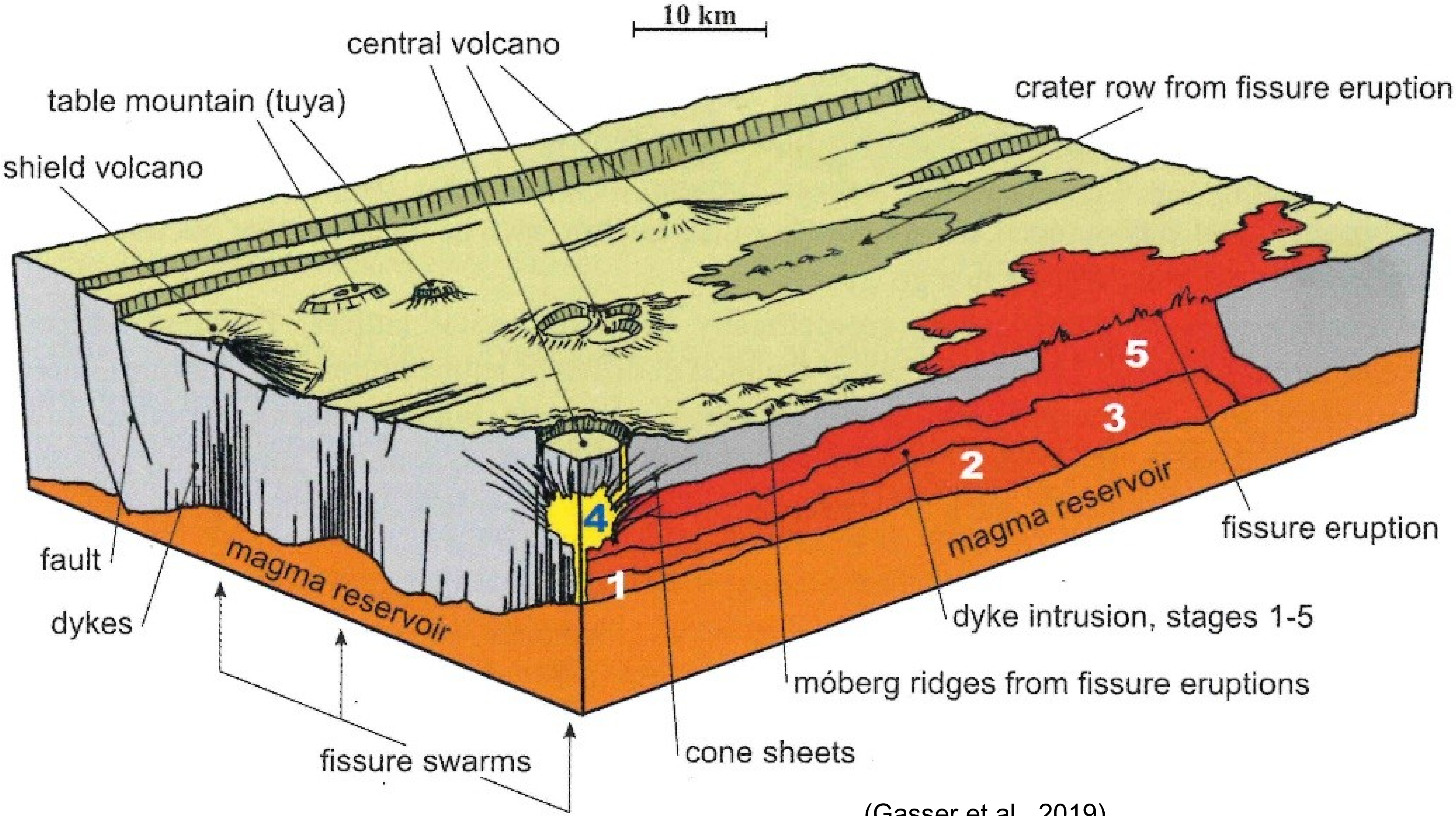
Features of a volcanic system



(Gasser et al., 2019)

Fig.9. Block diagram of the icelandic rift showing some features of Icelandic volcanic systems. Faults and dykes are indicated schematically, it's much more complicated in reality. Nr. 1-5 show different stages of magma intrusion into a fissure: (1-2) opening of the fissure starting from the central volcano; (3) magma reaches the magma chamber; (4) this can trigger an eruption from the central volcano; (5) the fissure reaches the surface in a topographically low area and erupts lava. Coloured hand drawing by Martin Gasser, based on Thordarson & Höskuldsson 2002.

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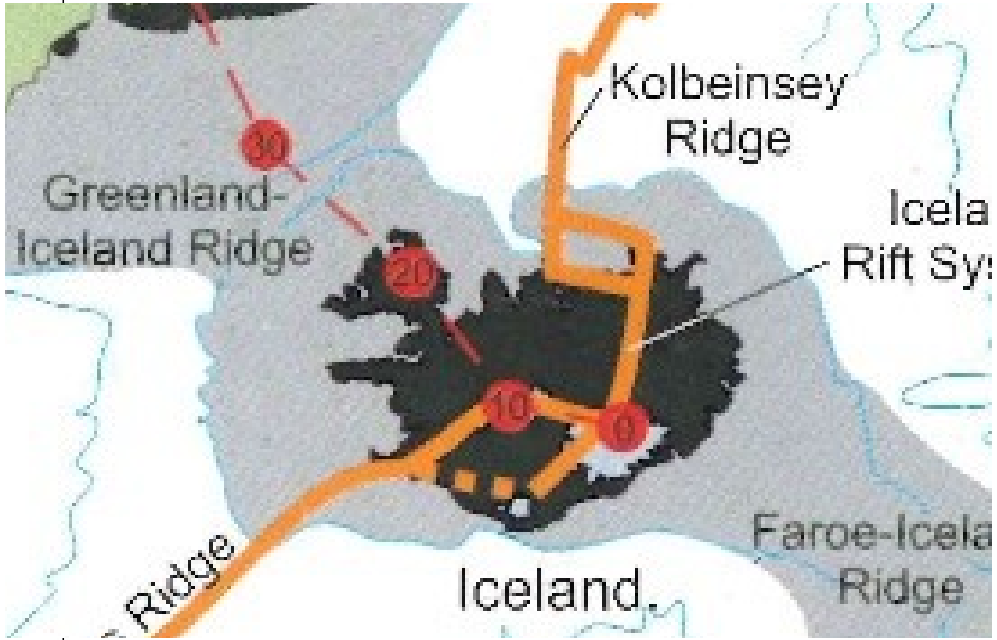
Crust thickening above the sea level

https://atlas.lmi.is/



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The Iceland Plume (or Hot Spot) causes crust thickening

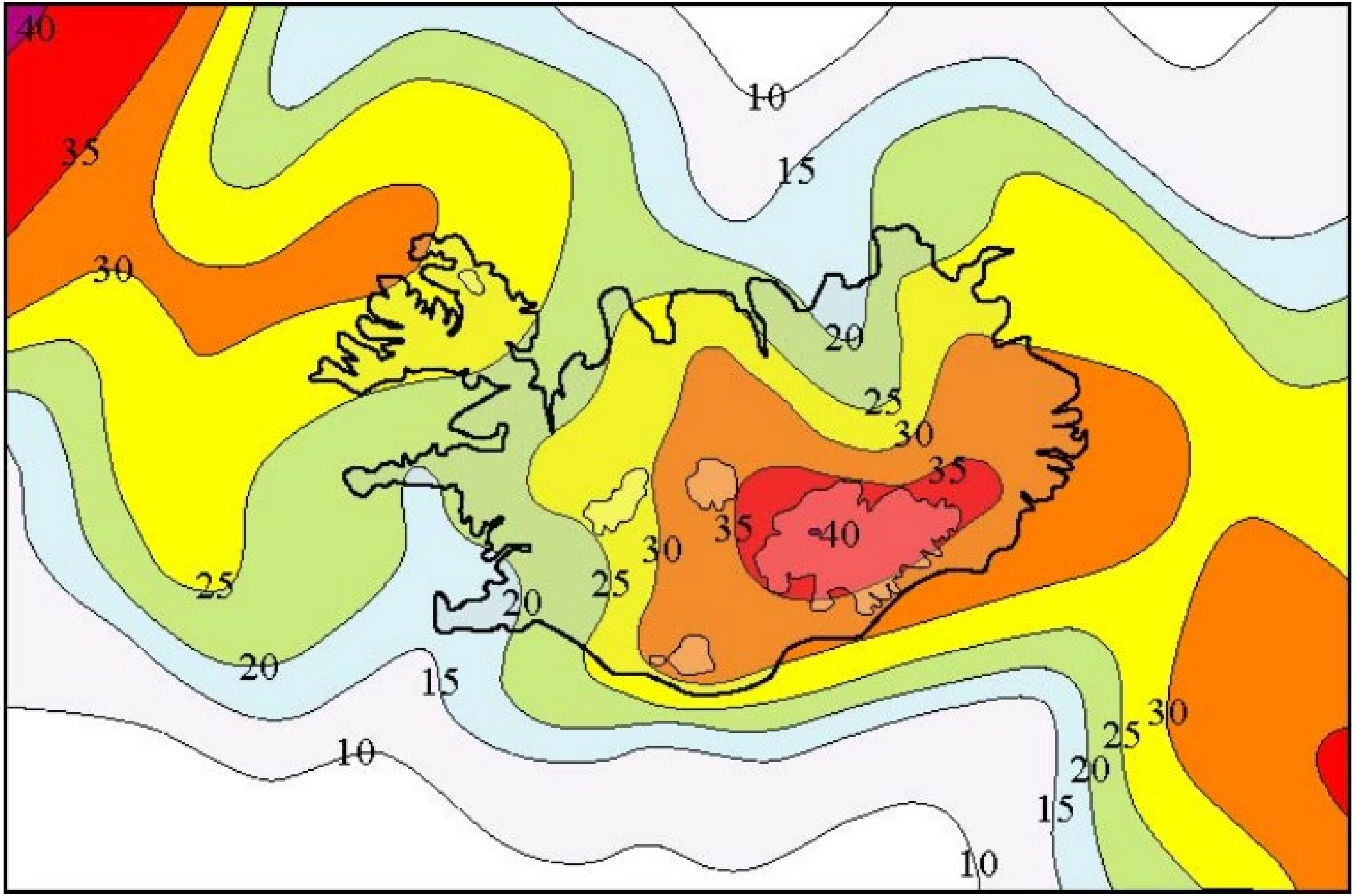

Fig. 5. Crustal thickness (km) variations across Iceland and the adjacent parts of the Greenland-Færöe Ridge (simplified after Kaban et al. 2002).

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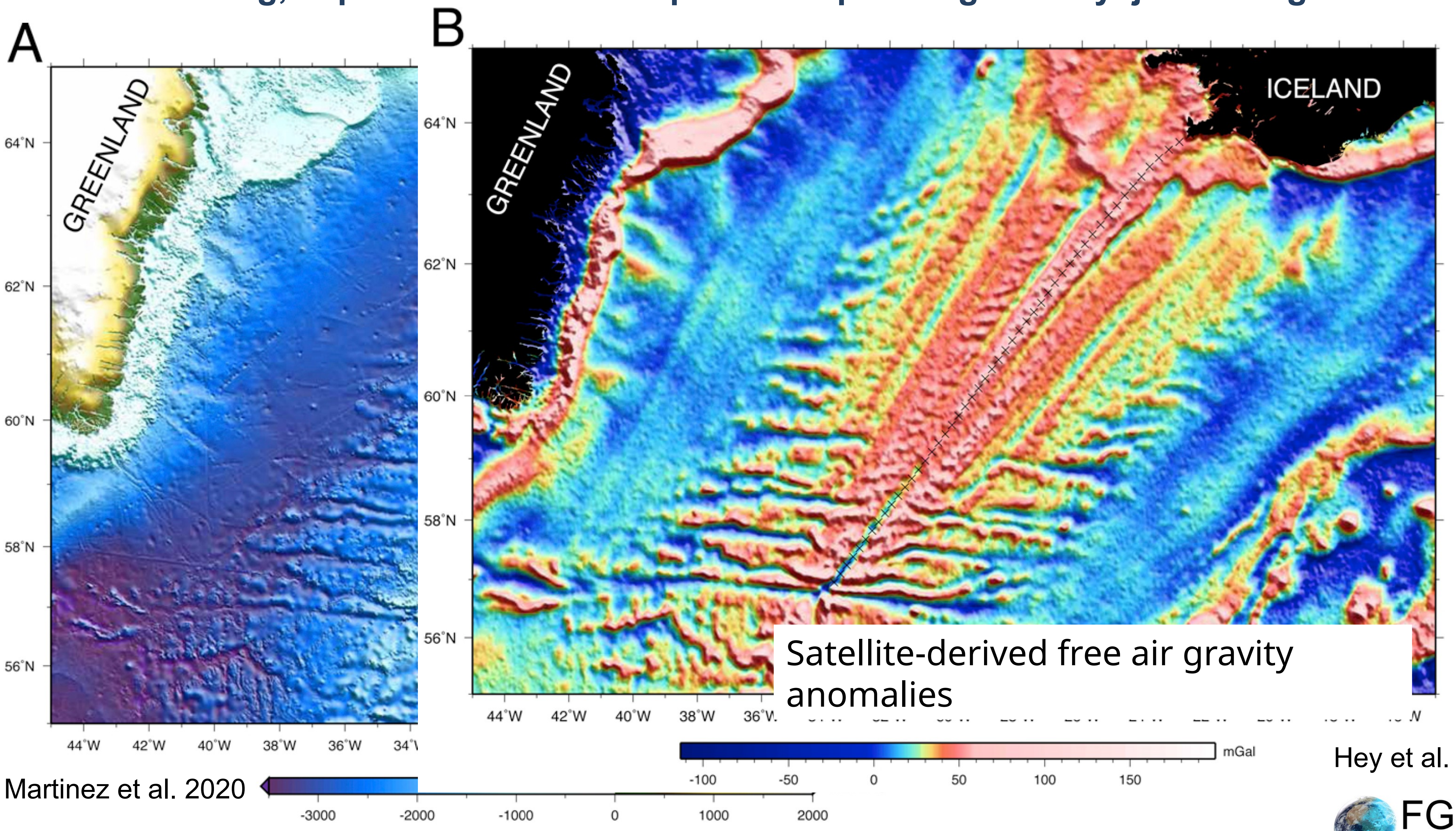
Crust thickening, depth anomalies and special shape along the Reykjanes Ridge



Martinez et al. 2020

Hey et al. 2016

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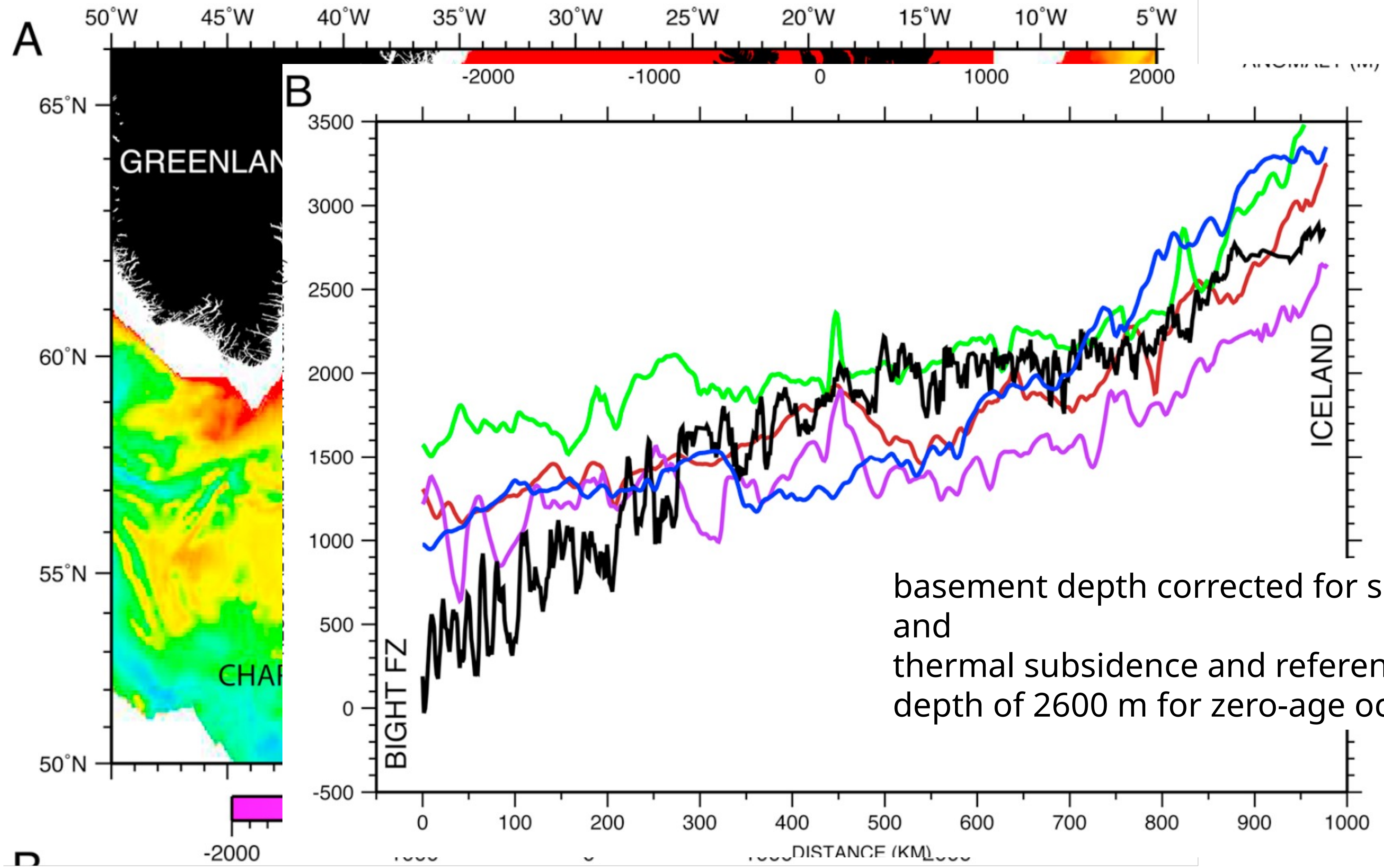
Crust thickening, depth anomalies and special shape along the Reykjanes Ridge



basement depth corrected for sediment loading and
thermal subsidence and referenced to a nominal depth of 2600 m for zero-age oceanic crust.

Martinez et al. 2020

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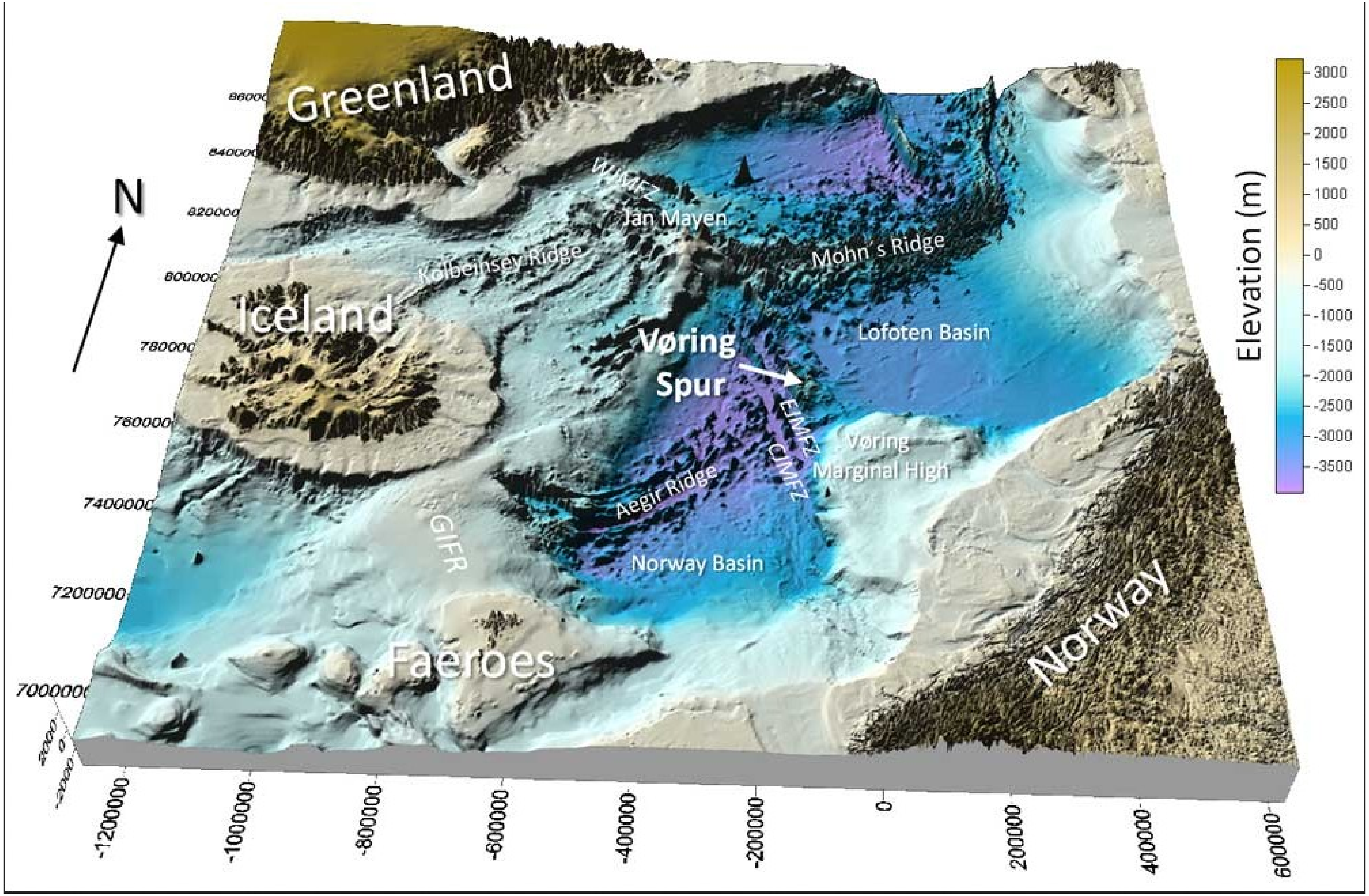
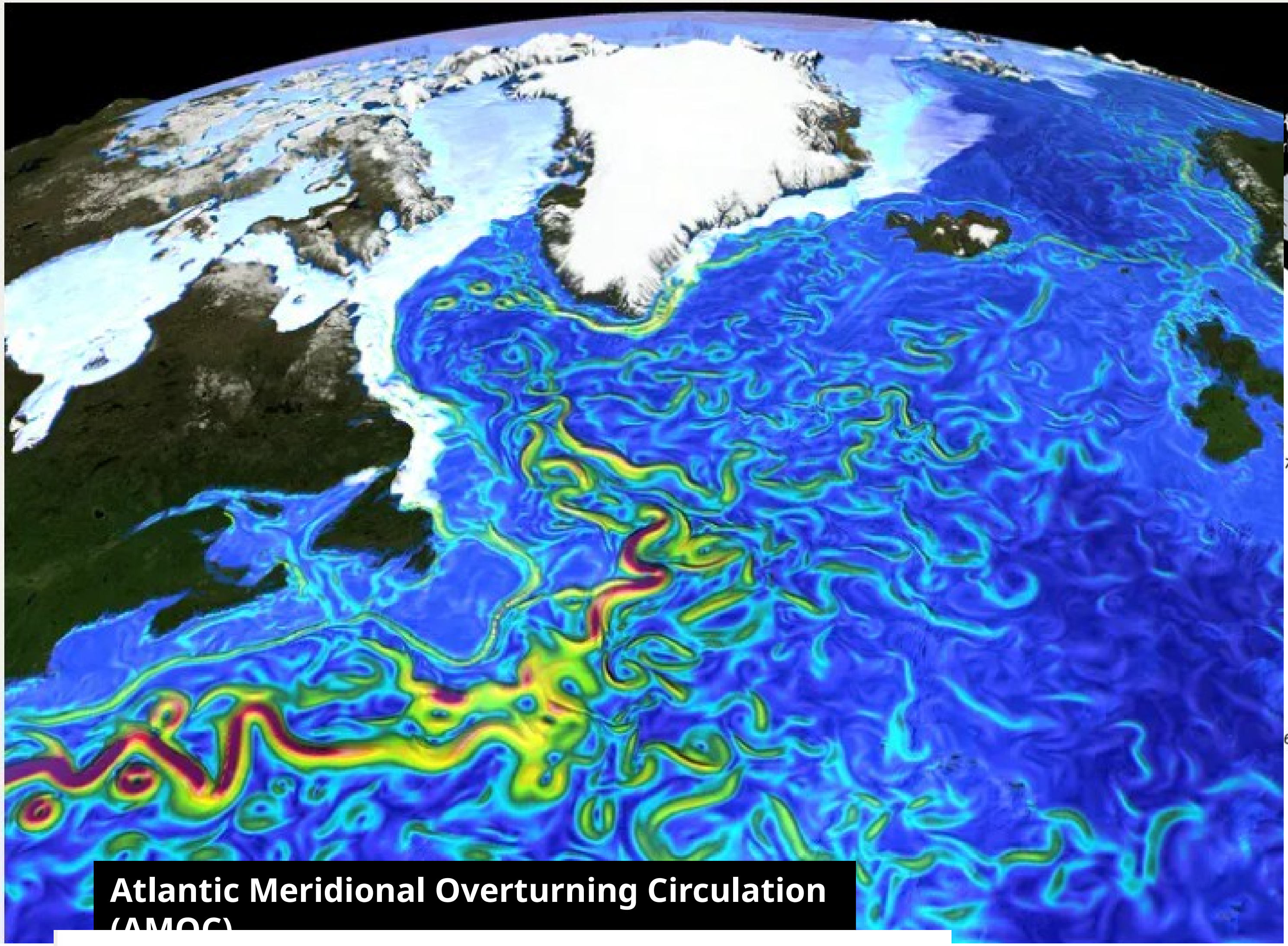
„Depth anomalies“ and thick crust act as barriers



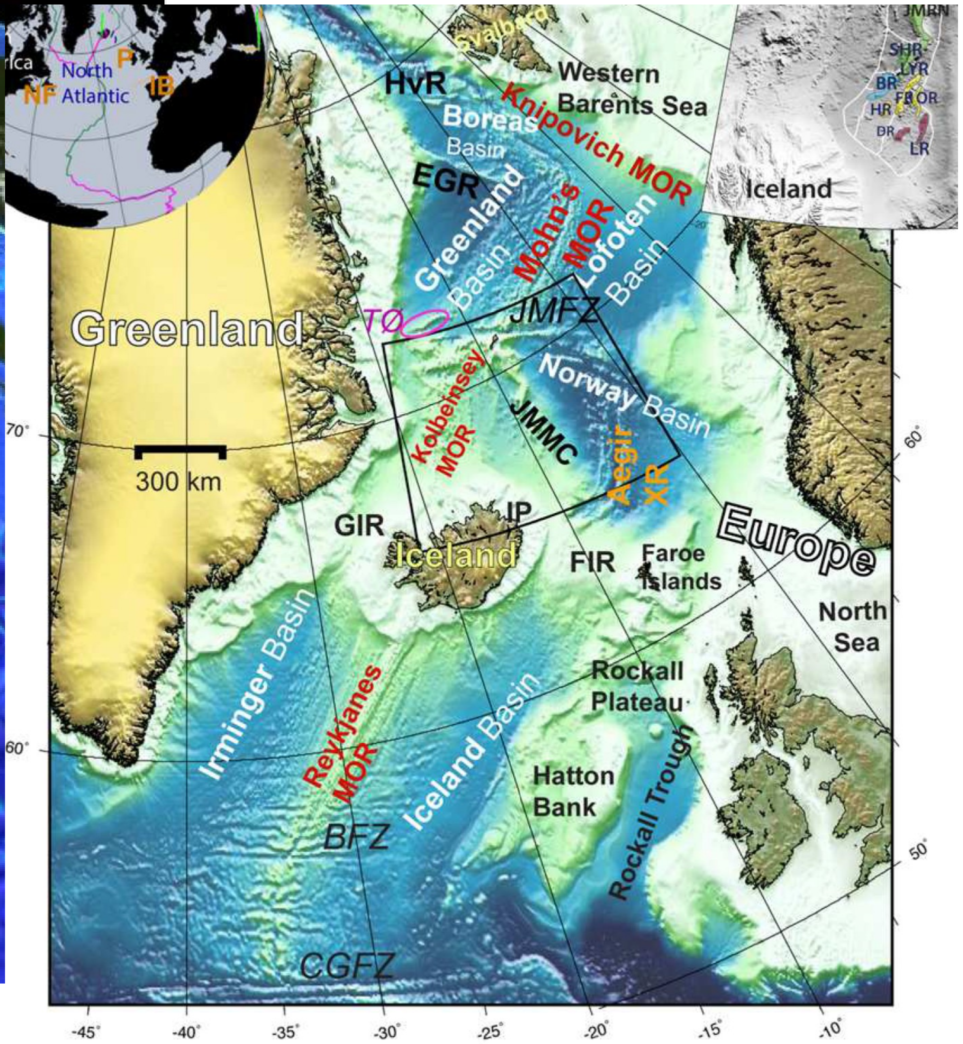
„Depth anomalies“ and thick crust act as barriers



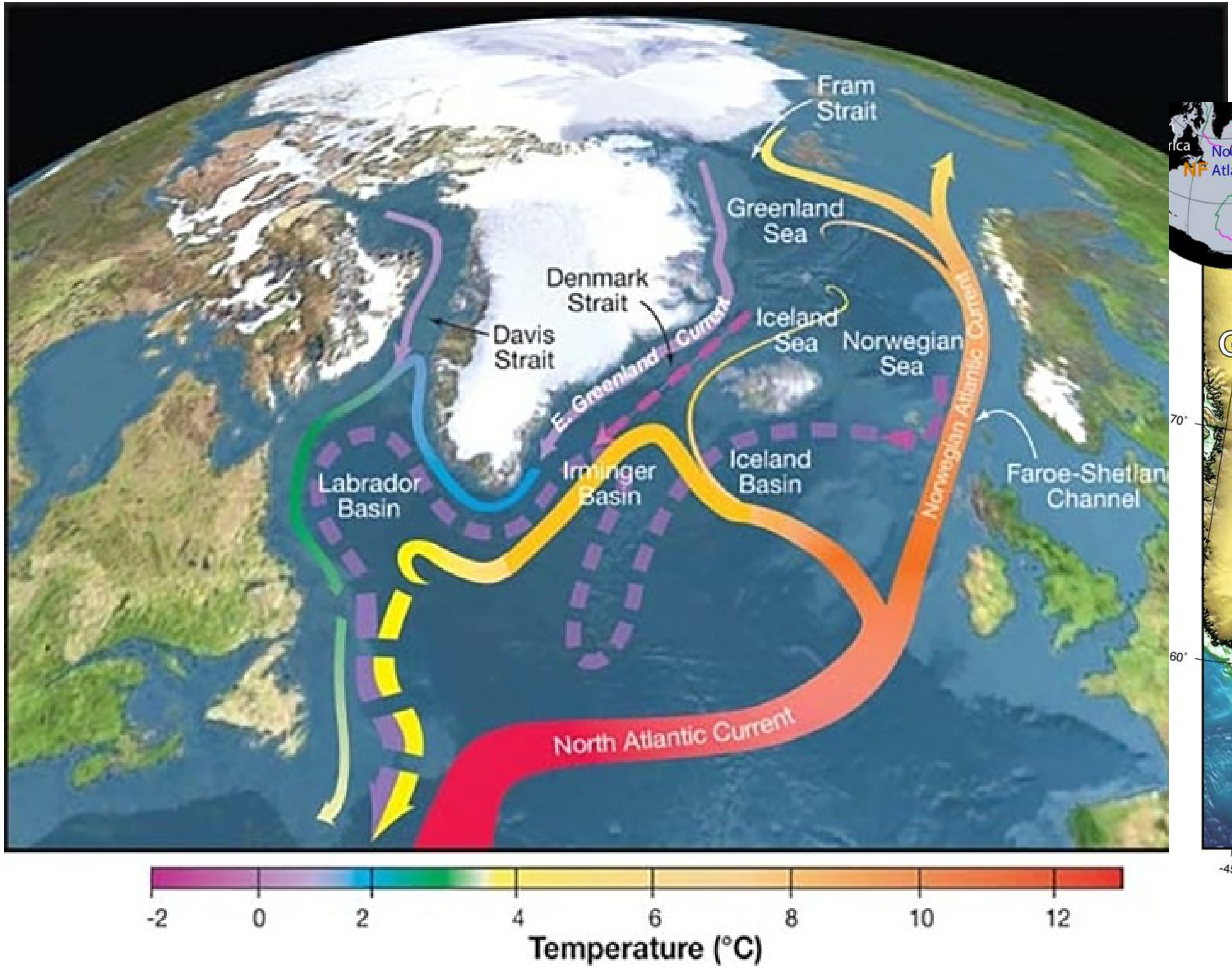
Surface currents in the North Atlantic

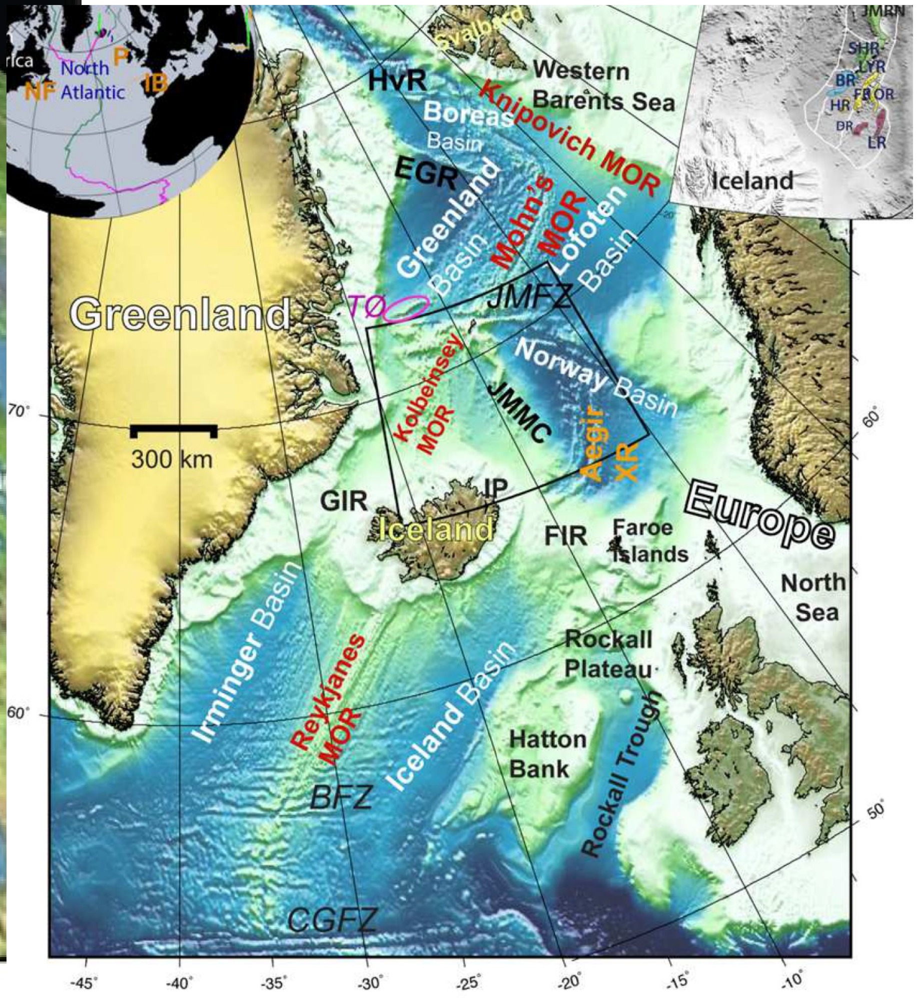
by **Erik Behrens**, GEOMAR, Kiel, Germany

Snapshot of surface speed in a eddying (0.05Â°, VIKING20) ocean sea-ice model resolving important meso-cale eddies and filaments explicitly.



„Depth anomalies“ and thick crust act as barriers





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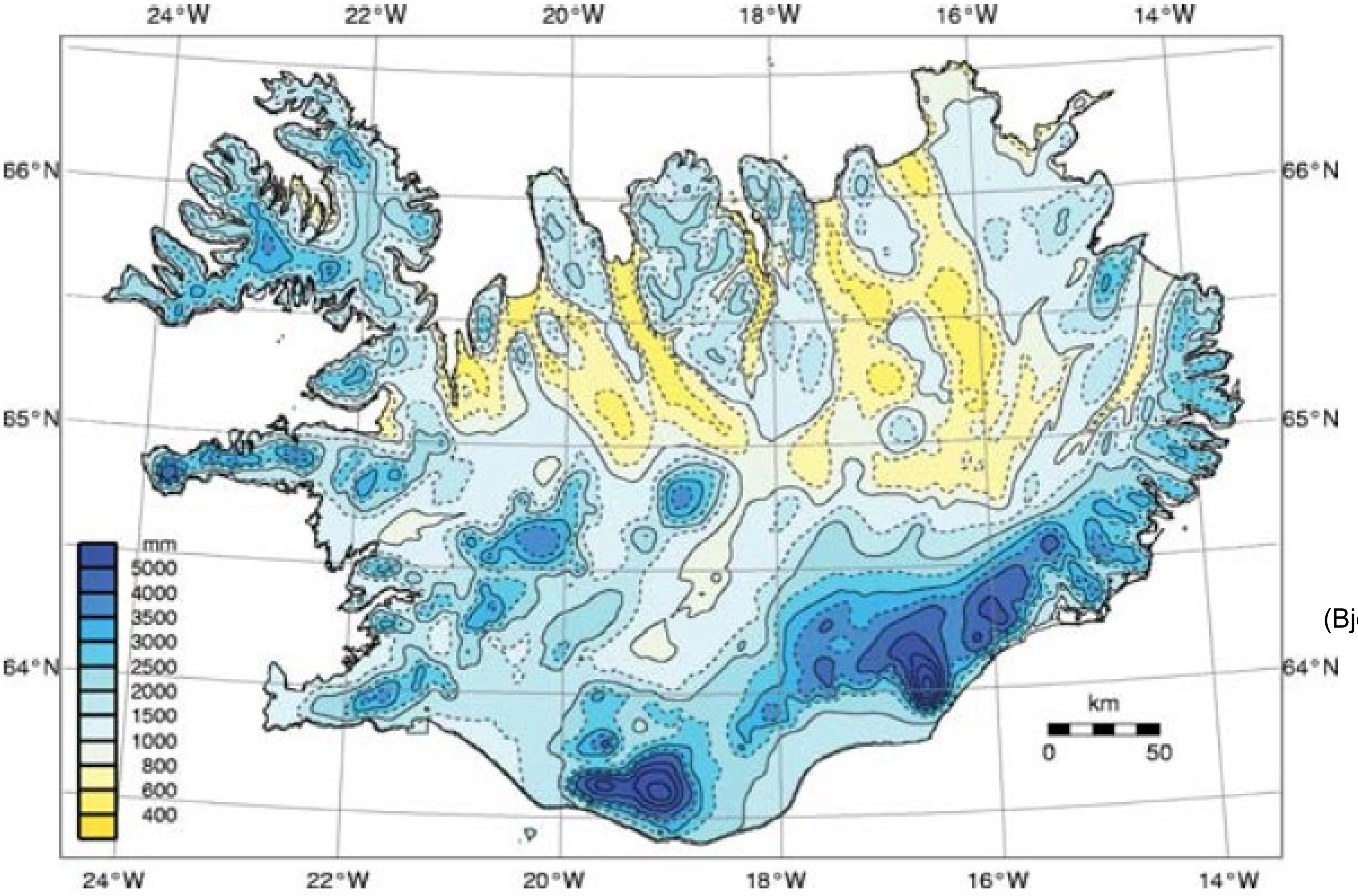
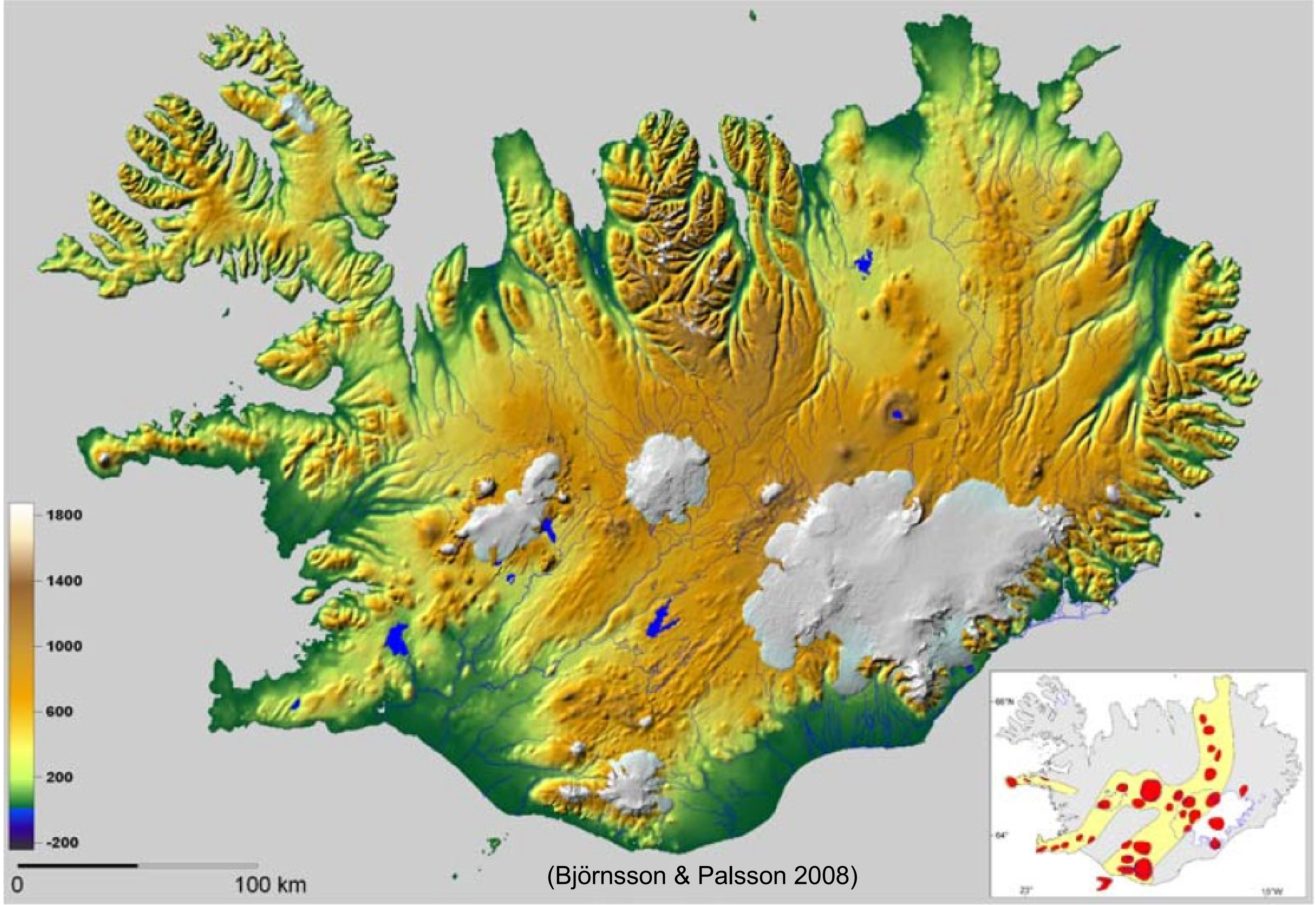
Mean annual precipitation



(Björnsson & Palsson 2008)

Figure 2. Mean annual precipitation of Iceland in 1961–1990 (Crochet *et al.*, 2007). – *Meðalársúrkoma á Íslandi 1961–1990.*

Ice cover on top of the mountain ranges



(Björnsson & Palsson 2008)

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Glaciation/deglaciation in Iceland

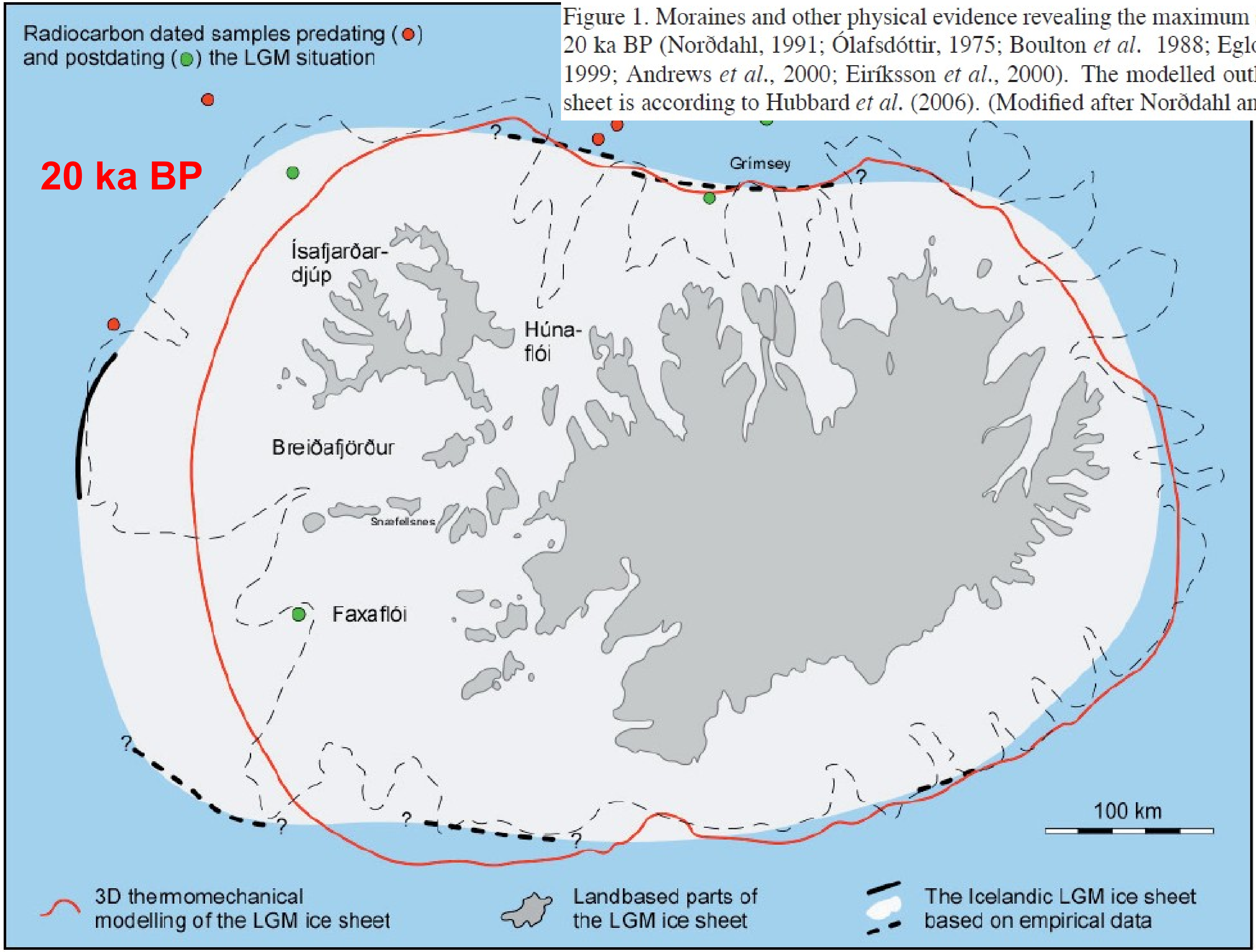

Figure 1. Moraines and other physical evidence revealing the maximum size of the Icelandic ice sheet at about 20 ka BP (Norðdahl, 1991; Ólafsdóttir, 1975; Boulton *et al.* 1988; Egloff and Johnson, 1979; Syvitski *et al.*, 1999; Andrews *et al.*, 2000; Eiríksson *et al.*, 2000). The modelled outline and land based portion of the ice sheet is according to Hubbard *et al.* (2006). (Modified after Norðdahl and Pétursson, 2005). – *Jökulgarðar og*

Hreggviður Norðdahl[1], Ólafur Ingólfsson[1], Halldór G. Pétursson[2] and Margrét Hallsdóttir[3]
Late Weichselian and Holocene environmental history of Iceland

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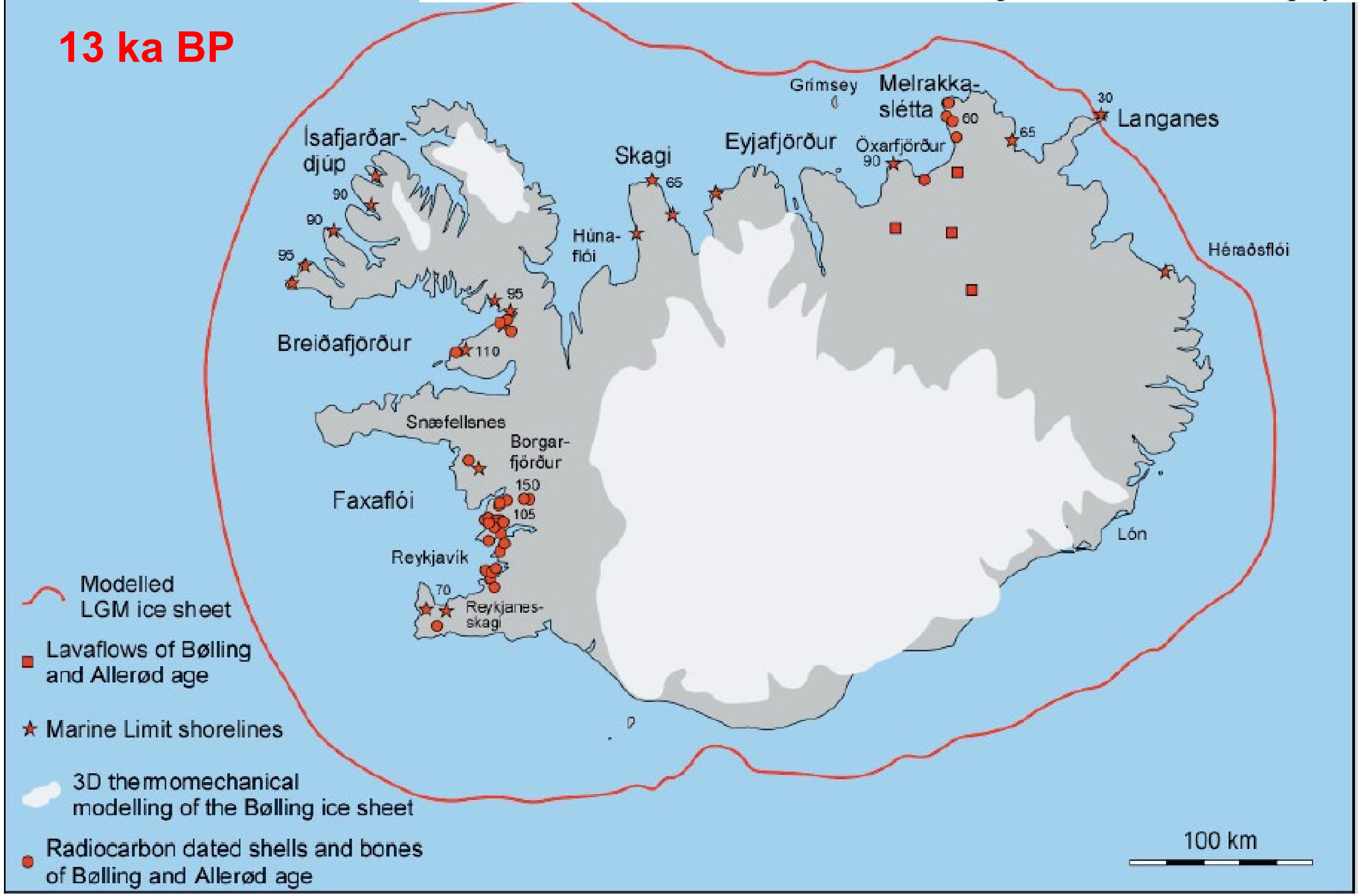
Glaciation/deglaciation in Iceland

Figure 3. Late Bølling glacier extent, marine Limit shorelines and Interstadial lava flows. Modelled outline of the Icelandic ice sheet during LGM and late Bølling times is based on Hubbard *et al.* (2006). Altitude of marine limit shorelines, radiocarbon dated shells and bones and Interstadial lava flows are from Norðdahl and Pétursson (2005). – *Niðurstöður líkanreikninga á stærð íslenska meginjökulsins í lok Böllingskeiðs fyrir um*



Hreggviður Norðdahl[1], Ólafur Ingólfsson[1], Halldór G. Pétursson[2] and Margrét Hallsdóttir[3]
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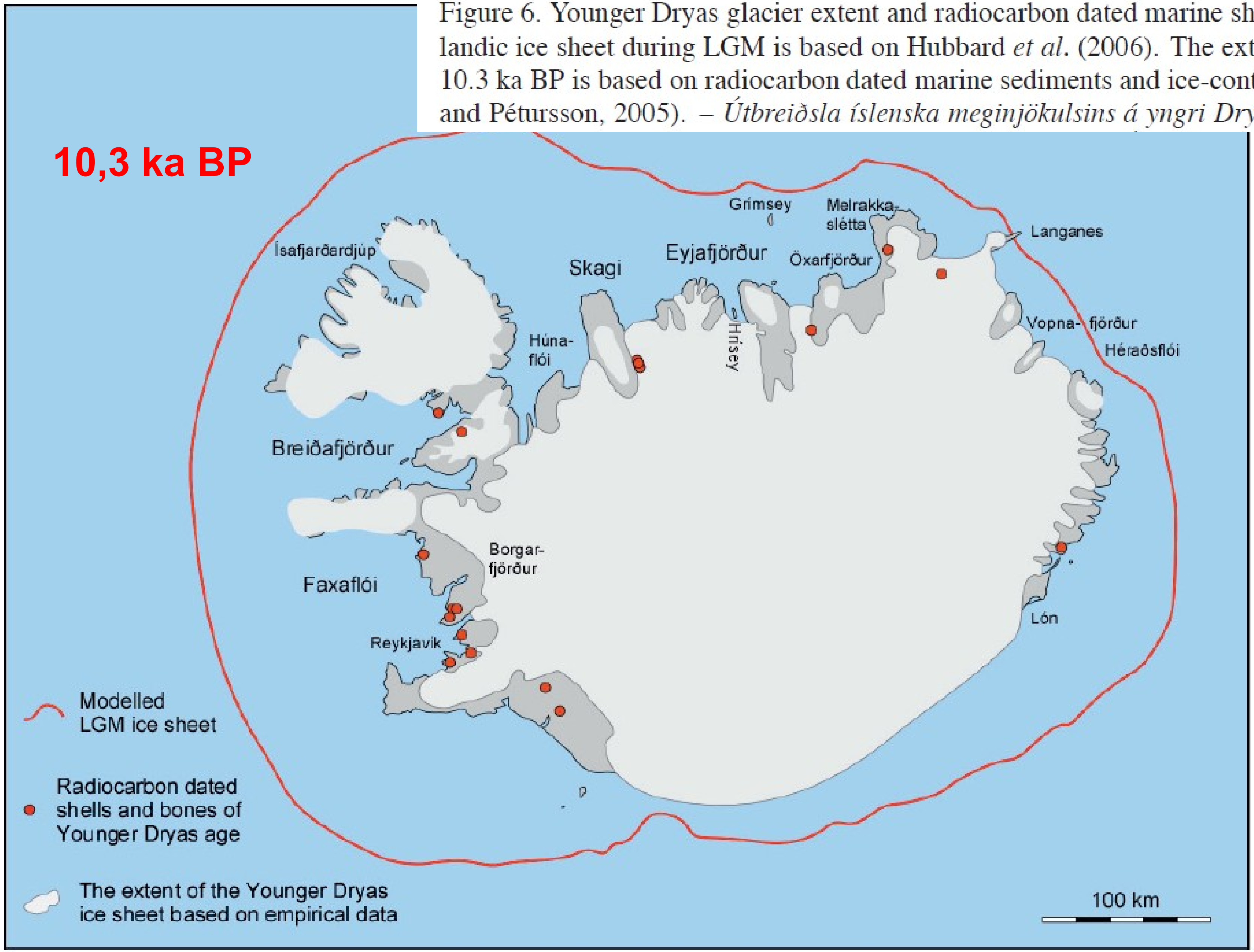
Glaciation/deglaciation in Iceland

Figure 6. Younger Dryas glacier extent and radiocarbon dated marine shells. The modelled outline of the Icelandic ice sheet during LGM is based on Hubbard *et al.* (2006). The extent of the Icelandic ice sheet at about 10.3 ka BP is based on radiocarbon dated marine sediments and ice-contact features (Modified after Norðdahl and Pétursson, 2005). – *Útbreiðsla íslenska meginjökulsins á yngri Dryas tíma (10.300 ár) skv. niðurstöðum*



Hreggviður Norðdahl[1], Ólafur Ingólfsson[1], Halldór G. Pétursson[2] and Margrét Hallsdóttir[3]
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Glaciation/deglaciation in Iceland

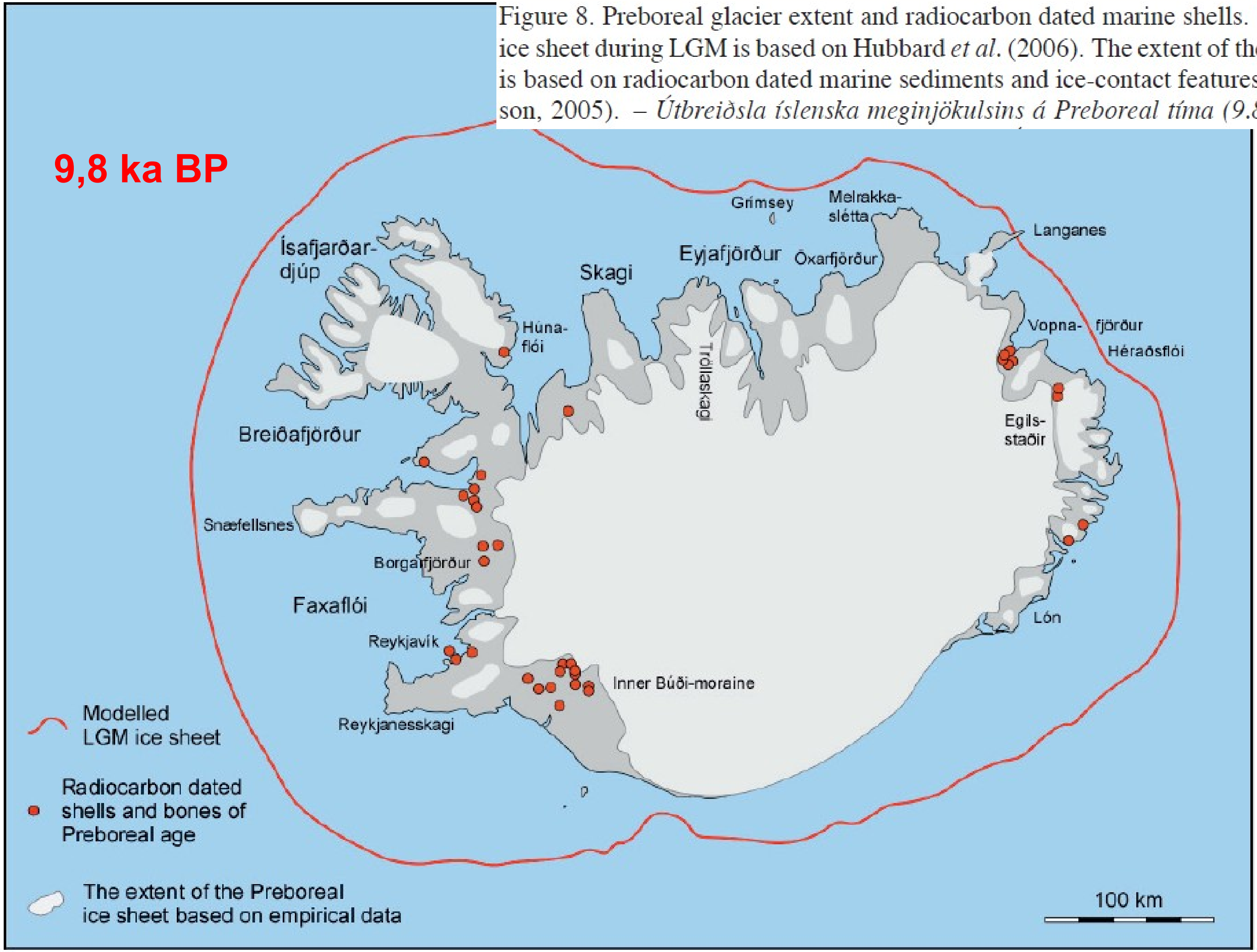

Figure 8. Preboreal glacier extent and radiocarbon dated marine shells. The modelled outline of the Icelandic ice sheet during LGM is based on Hubbard *et al.* (2006). The extent of the Icelandic ice sheet at about 9.8 ka BP is based on radiocarbon dated marine sediments and ice-contact features (Modified after Norðdahl and Pétursson, 2005). – *Útbreiðsla íslenska meginjökulsins á Preboreal tíma (9.800 ár) skv. niðurstöðum rannsókna á*

Hreggviður Norðdahl[1], Ólafur Ingólfsson[1], Halldór G. Pétursson[2] and Margrét Hallsdóttir[3]
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Glaciation/deglaciation in Iceland

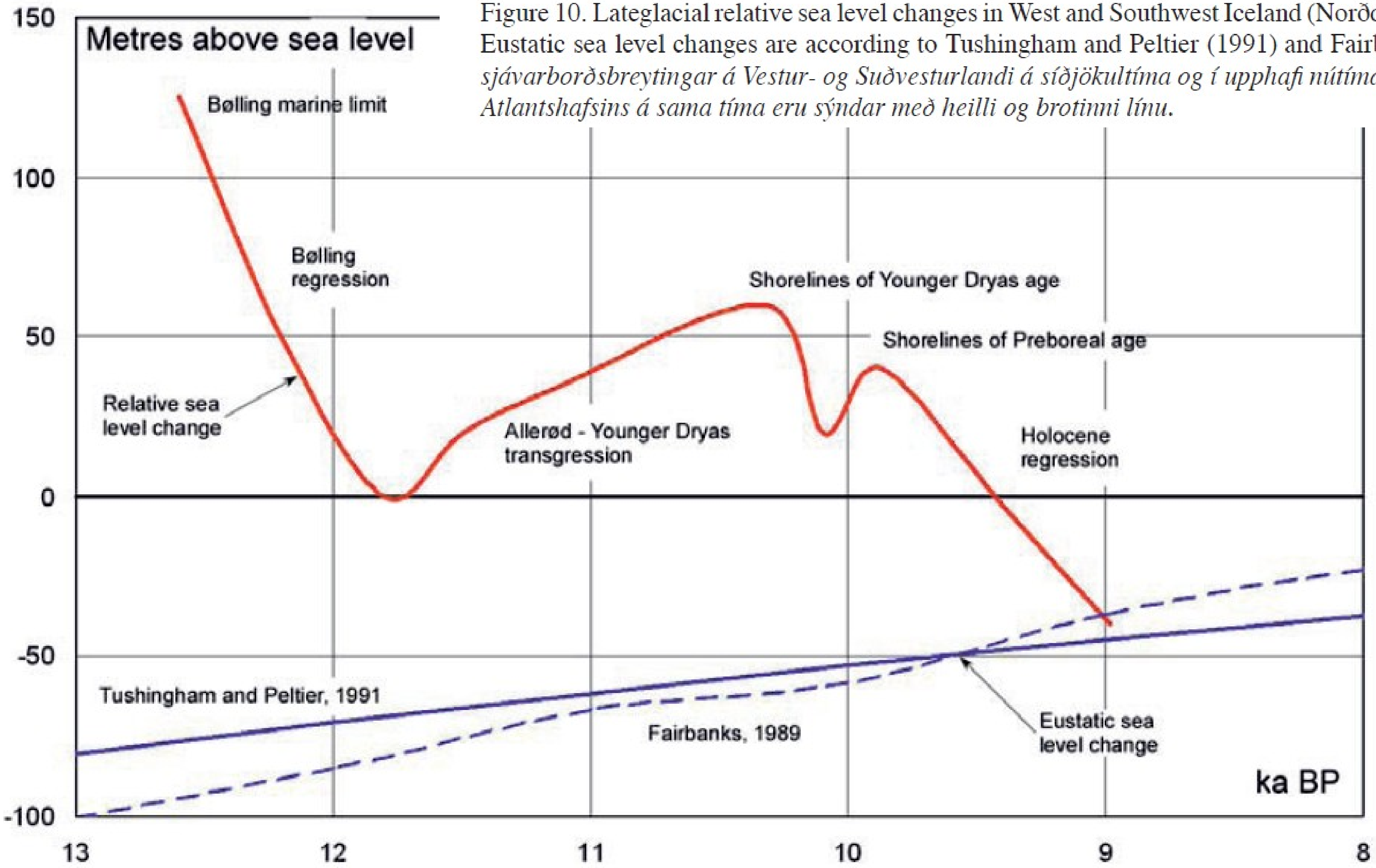

Figure 10. Lateglacial relative sea level changes in West and Southwest Iceland (Norðdahl and Pétursson, 2005). Eustatic sea level changes are according to Tushingham and Peltier (1991) and Fairbanks (1989). – *Afstæðar sjávarborðsbreytingar á Vestur- og Suðvesturlandi á síðjökultíma og í upphafi nútíma. Breytingar á sjávarhæð Atlantshafsins á sama tíma eru sýndar með heilli og brotinni línu.*

Hreggviður Norðdahl[1], Ólafur Ingólfsson[1], Halldór G. Pétursson[2] and Margrét Hallsdóttir[3]
Late Weichselian and Holocene environmental history of Iceland

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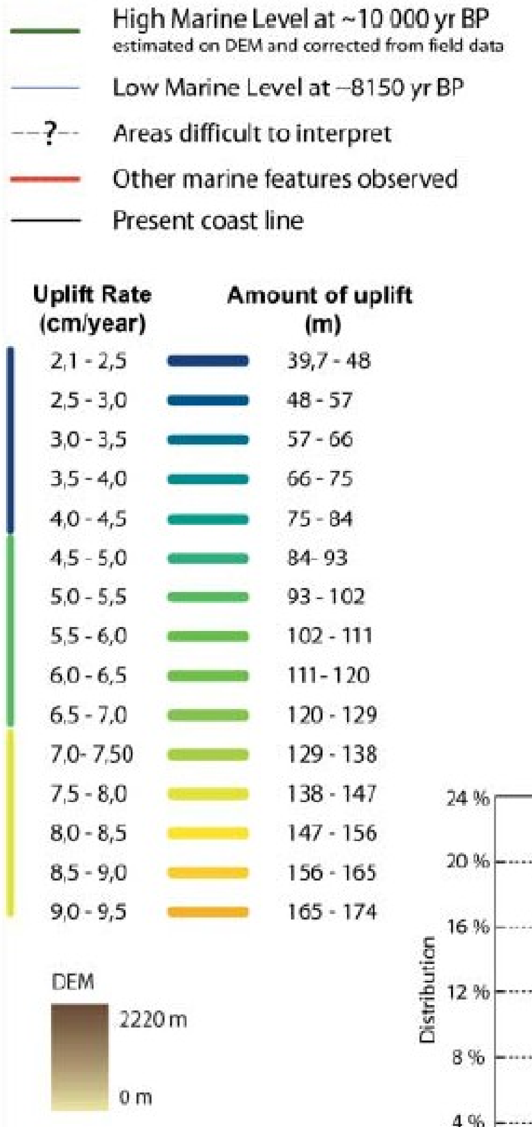
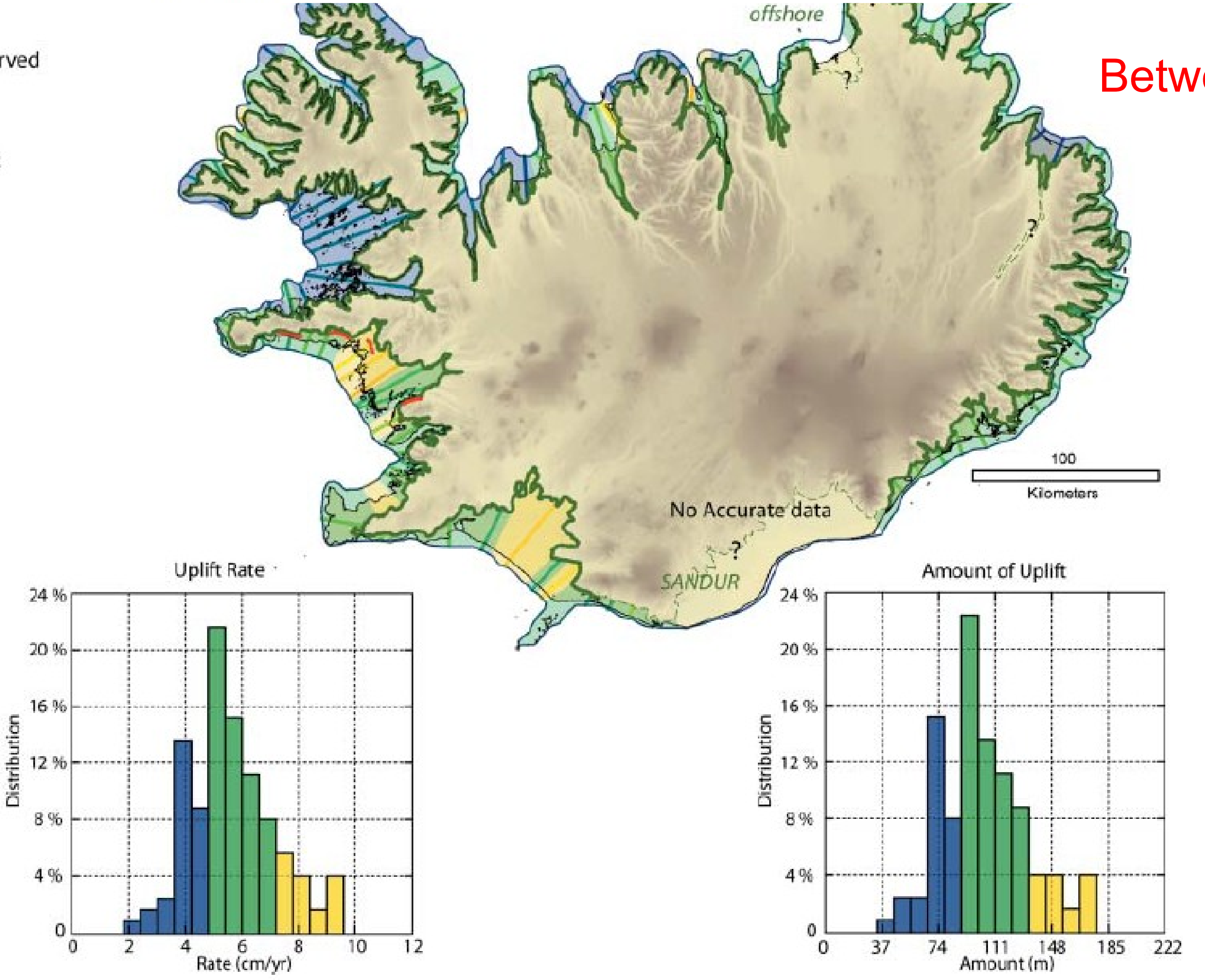
Postglacial rebound Iceland

Fig. 8. Amount and rate of uplift calculated between 10 ka ± 300 years BP and 8150 ± 350 years BP. Eustatic variations between 10 ka and 8150 years BP were taken into account for the calculation and equal 18 m (SPECMAP curve). The high marine limit determined numerically was corrected from field observations (green bold line).





Between 10.000 – 8.150 years!!

Post-glacial rebound of Iceland during the Holocene

E. LE BRETON[1]*, O. DAUTEUIL[1] & G. BIESSY[1]

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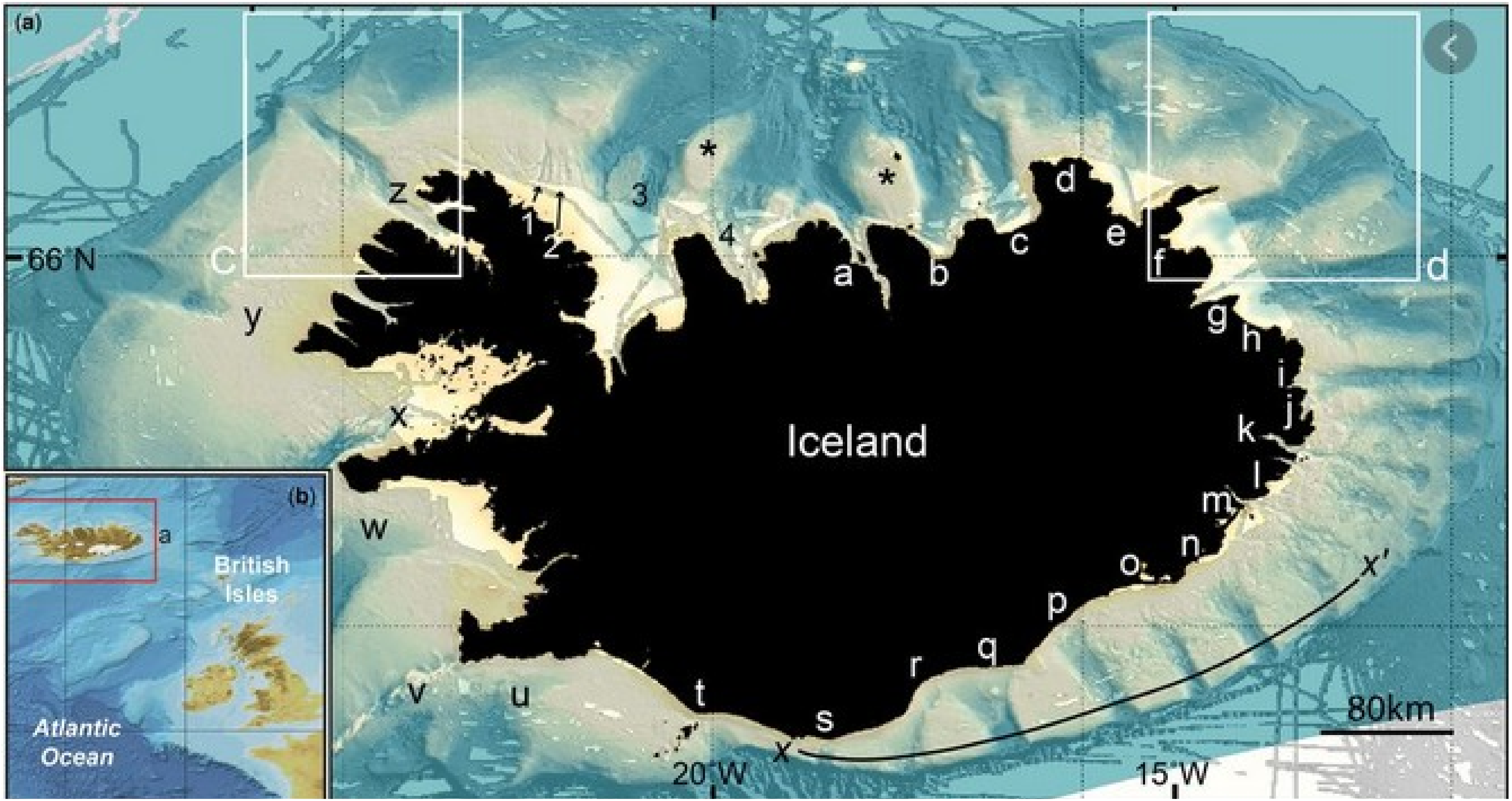
Witnesses of vertical motion – „drowned“ fjords



Volcanism after deglaciation

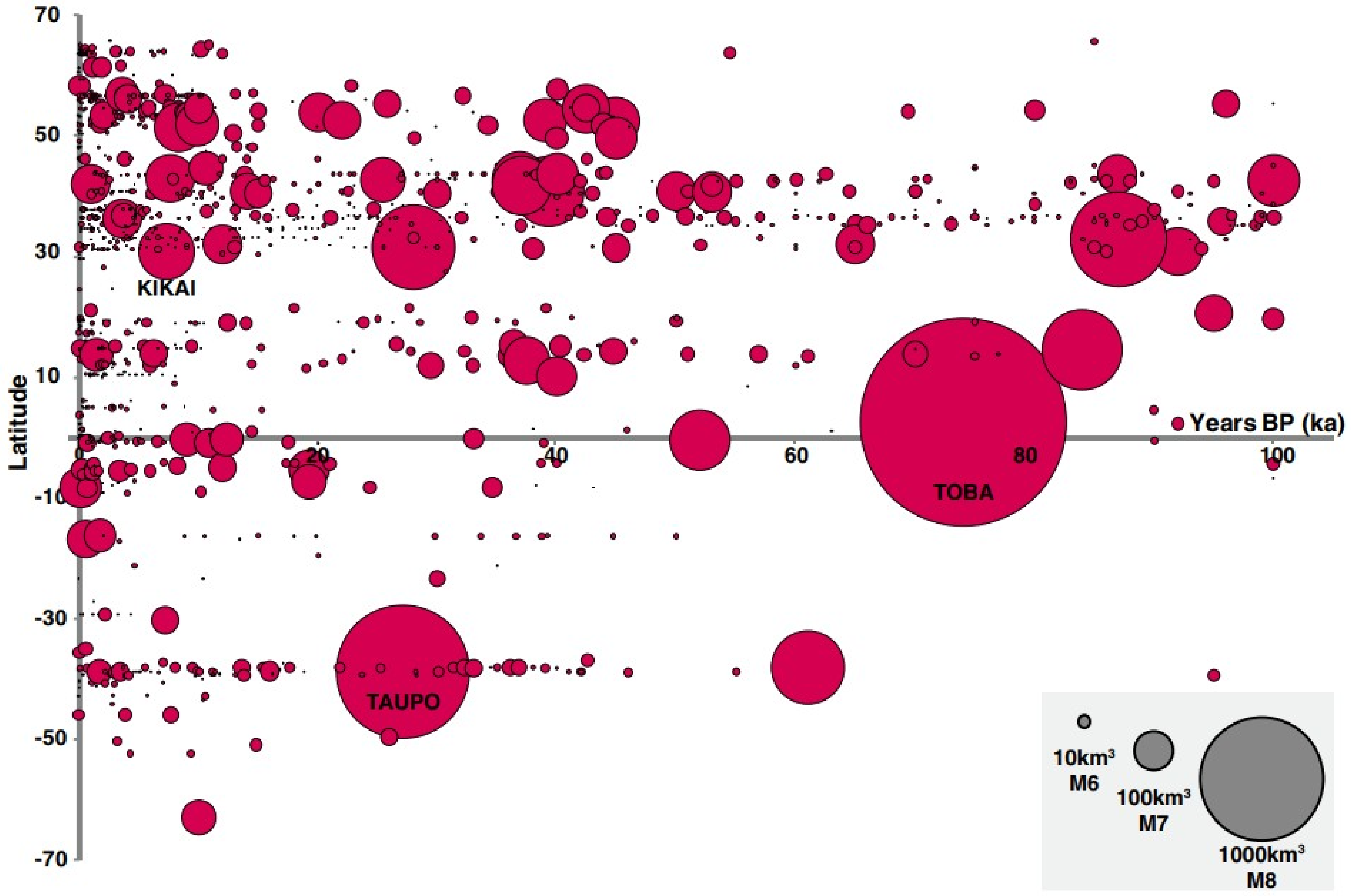


Figure 11 Global eruptions from 2013 AD to 100 ka between 70˚N and 70˚S. Circle area represents the bulk volume. Note that the volume recorded for the Kikai eruption suggests a M7.2 eruption (as shown), whilst it is published in the literature as M8.1.

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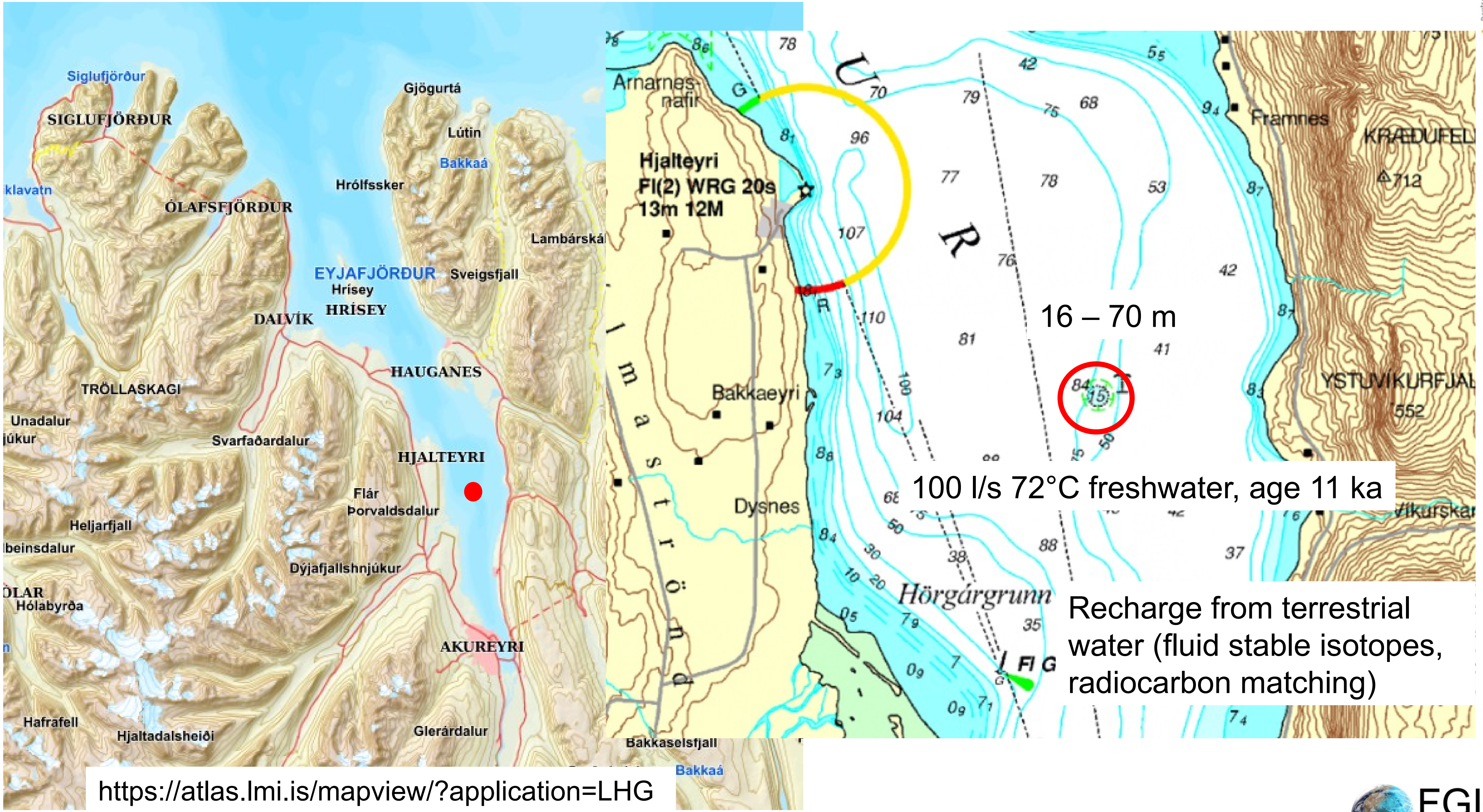
Strýtan Vent Field - Eyjafjördur



16 – 70 m

100 l/s 72°C freshwater, age 11 ka

Recharge from terrestrial water (fluid stable isotopes, radiocarbon matching)

https://atlas.lmi.is/mapview/?application=LHG

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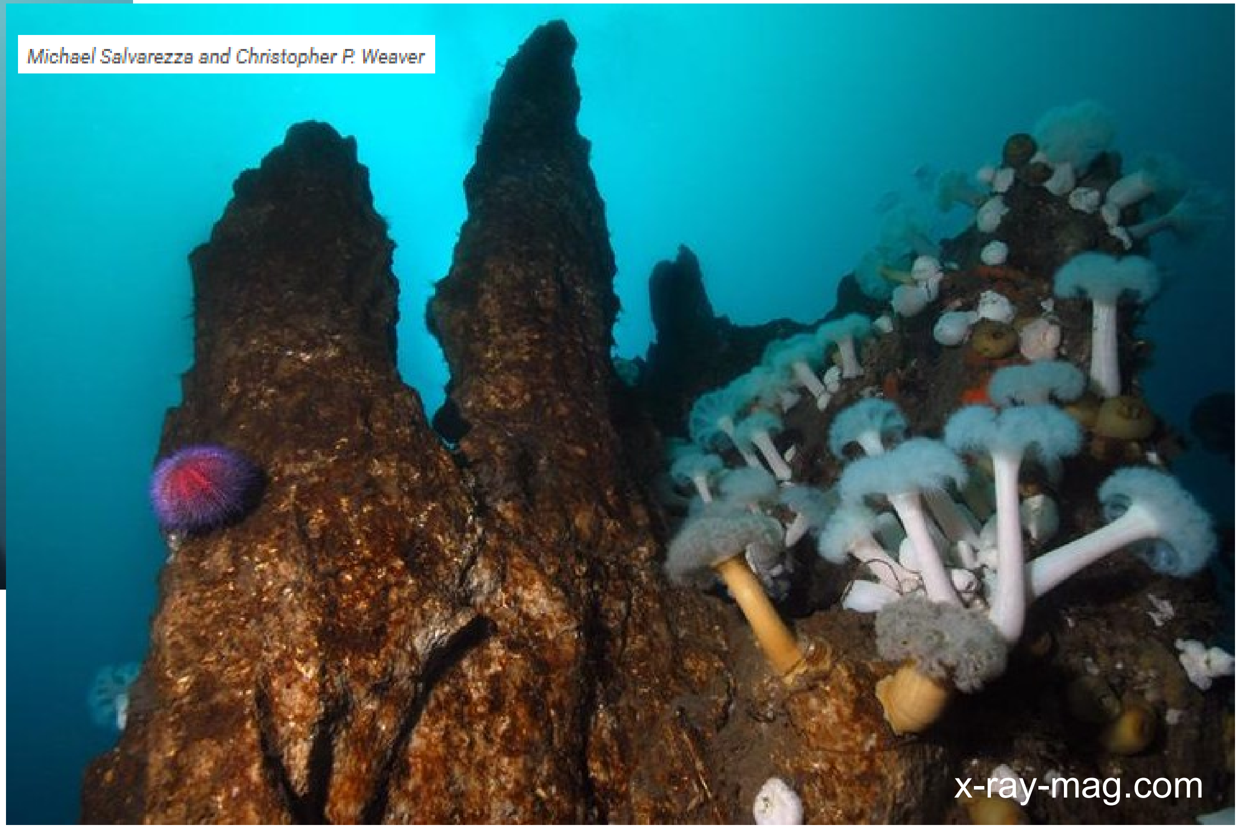
Strýtan Vent Field - Eyjafjördur

In the vicinity of the Dalvik Lineament, which is connected to the Kolbensey Ridge

Three venting sites: Big Strýtan, Arnanesstrýtur, Hrisey. Big Strýtan = anhydrite and saponite, chimneys up to 55 m

Only alkaline hydrothermal vent hosted on Basalt rock (6-12 Ma)



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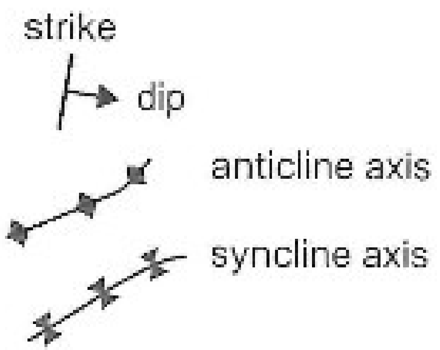
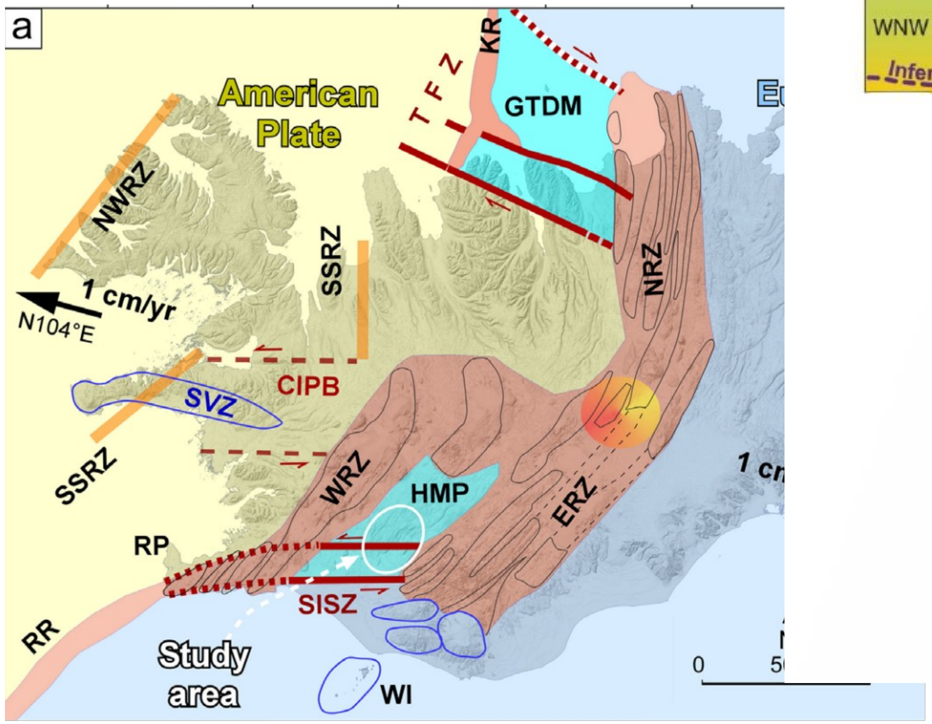
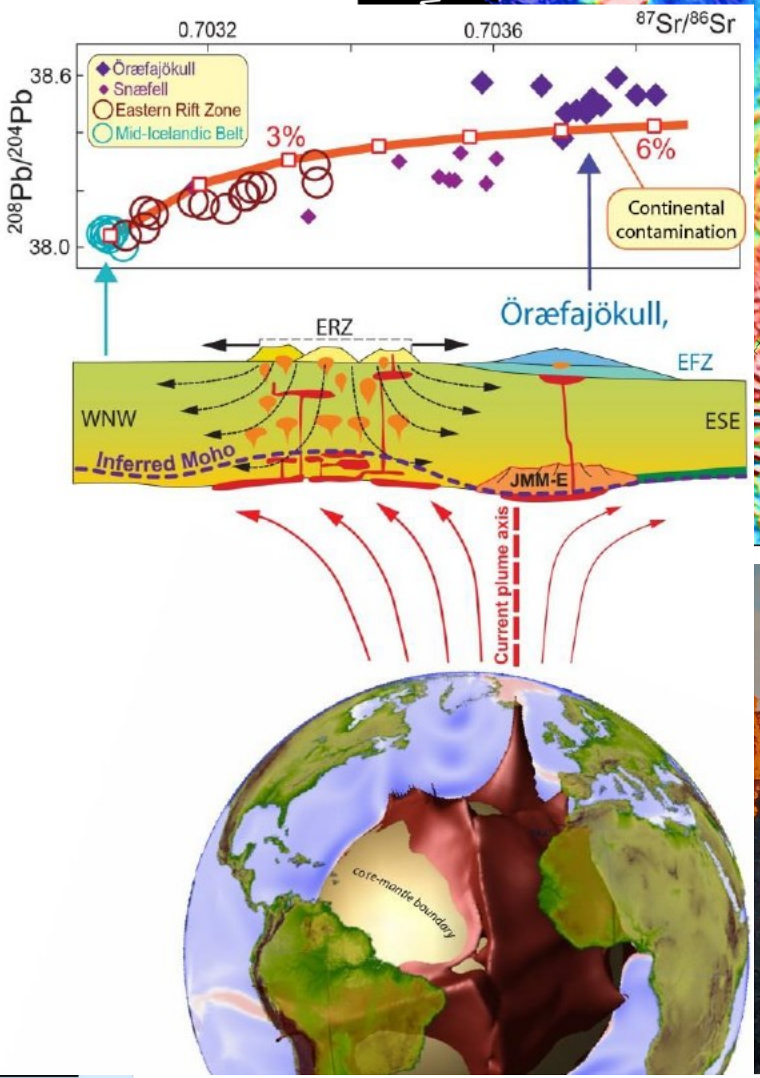
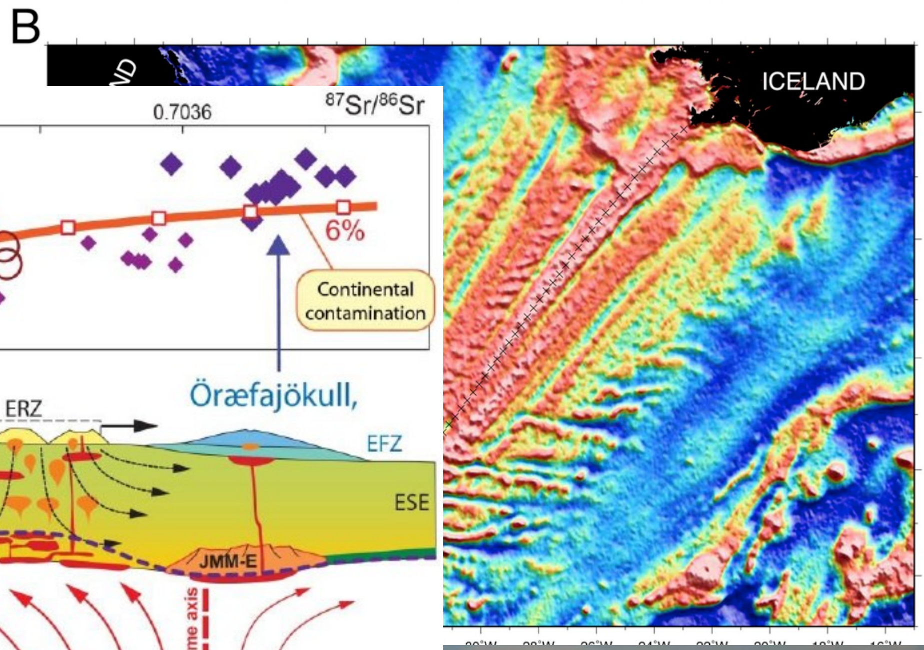
What we did not hear about

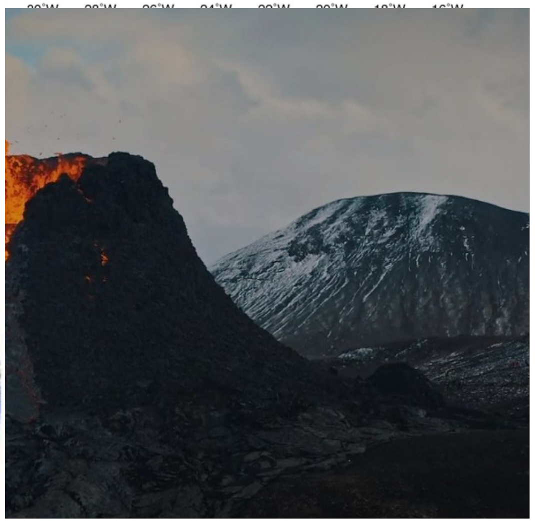






Torsvik, et al. 2015





mbl.is

How to communicate all this complexity

- Stein1 (verus.digital)
- Stein2 (verus.digital)
- Stein3 (verus.digital)
- Stein4 (verus.digital)

Attracting with modern techniques

HLNUG_2023

https://viewer.verus.digital/vd/handle?id=52dd0c85-2baa-4252-8ba1-fbdc743ba152&t=Wirbelknochen+Steppenbison

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How to communicate all this complexity

Thank you!!

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Excursions

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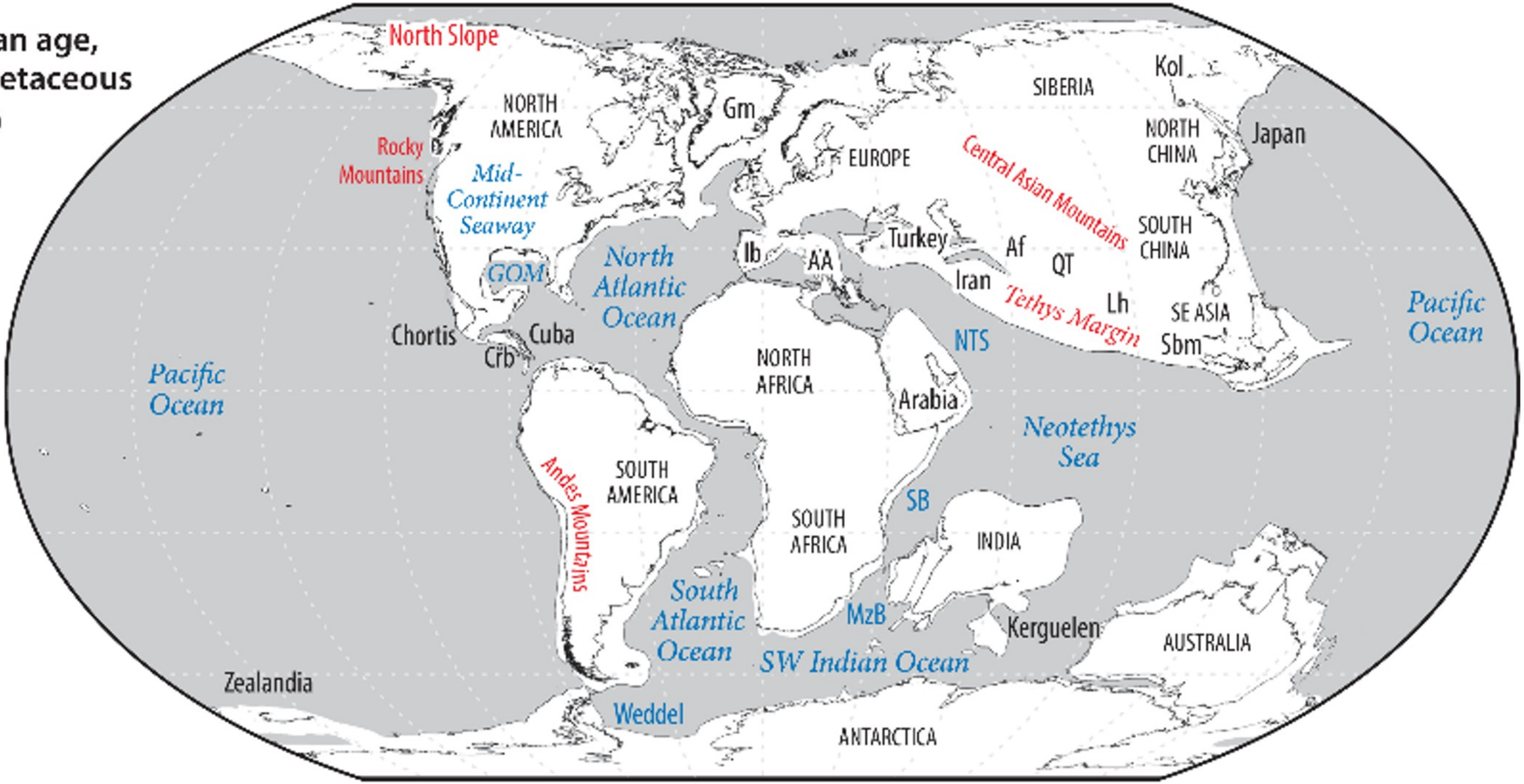
End of presentation

But it looked very different in the past

Turonian age, Late Cretaceous (90 Ma)



Scotese CR. 2021
Annu. Rev. Earth Planet. Sci. 49:679–728

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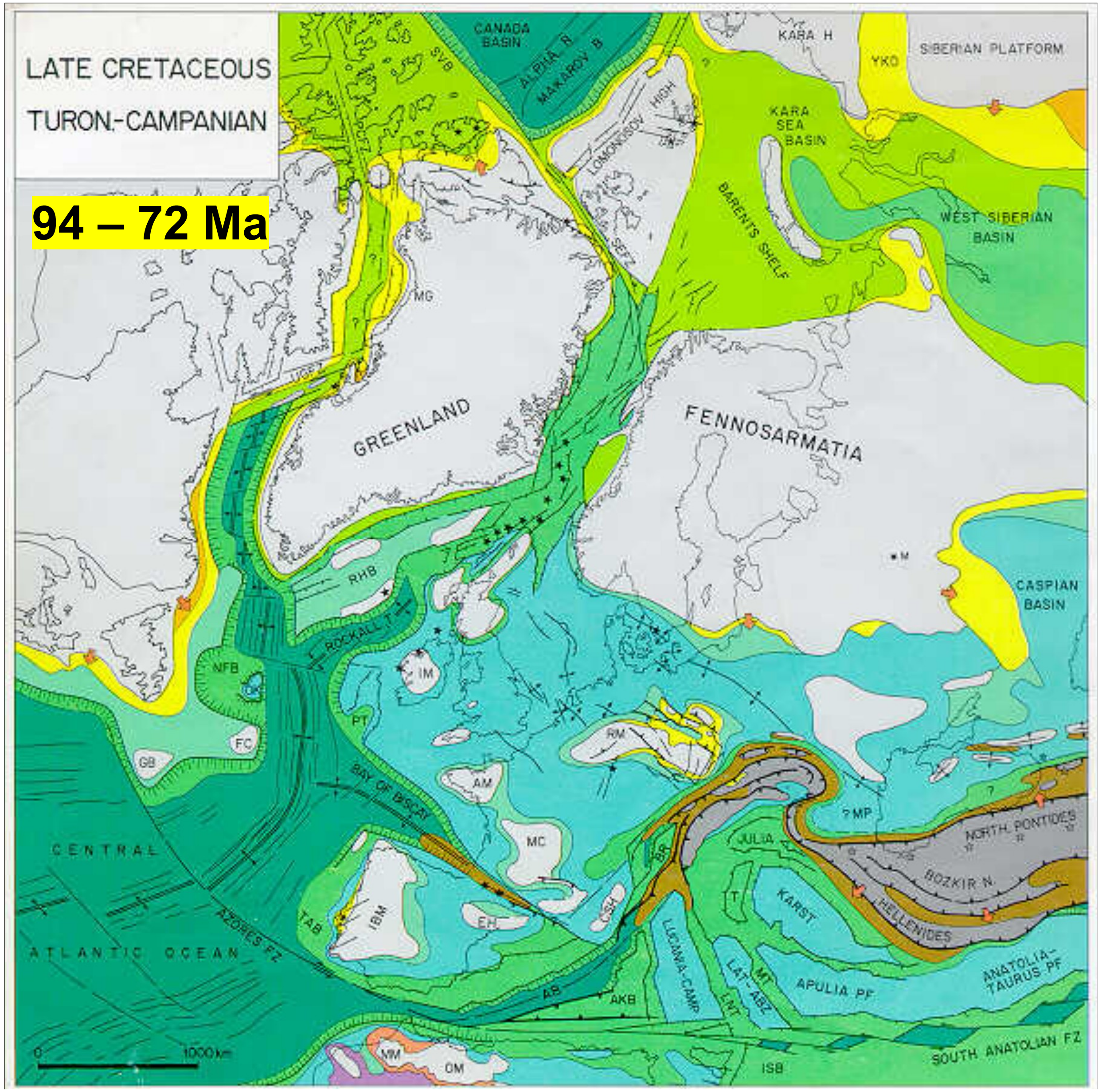
The becoming of Iceland started some 60 Ma ago



DEPOSITIONAL ENVIRONMENT AND PRINCIPAL LITHOLOGY

- MAINLY CONTINENTAL CLASTICS
- DELTAIC-SHALLOW MARINE, MAINLY SANDS
- SHALLOW MARINE, MAINLY SHALES
- SHALLOW MARINE, CARBONATES AND CLASTICS
- SHALLOW MARINE, MAINLY CARBONATES
- EVAPORITES AND CLASTICS
- MAINLY EVAPORITES
- EVAPORITES, CLASTICS AND CARBONATES
- EVAPORITES AND CARBONATES
- DEEPER MARINE CLASTICS AND/0R CARBONATES
- DEEPER MARINE, MAINLY SANDS (FLYSCH)
- BASINS FLOORED BY OCEANIC CRUST
- BASINS FLOORED BY OCEANIC CRUST CONTAINING THICK SEDIMENTS

https://www.searchanddiscovery.com/documents/97020/memoir43.htm
https://www.searchanddiscovery.com/documents/97020/

(Ziegler et al., 2014)

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Rifting History Iceland in the last 8 Ma

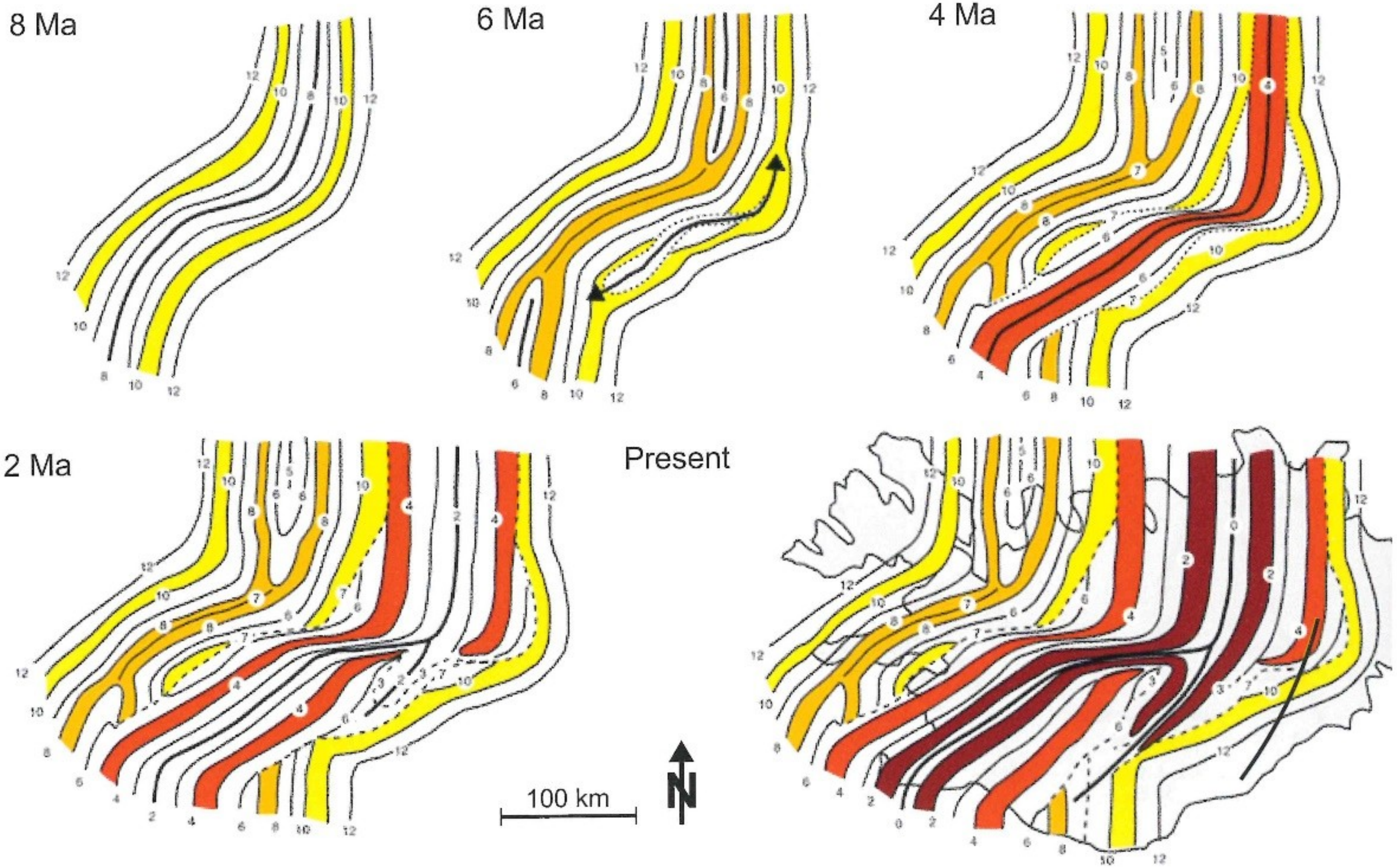

Fig.6. Depiction of Iceland's rifting history, derived from age and relative position of rocks. Each new color represents a shift in the location of the rift zone. More than one rift can be active at the same time. In the middle of Iceland, where there is a characteristic bend in the spreading axis (= rift axis), the rift zone is splitting and forming a very productive new fork to the South, with historic eruptions like Eldgjá 934, Laki 1783 and Eyjafjallajökull 2010. Another incipient rift is the Öræfajökull - Snæfell belt in the SE. Modified graphic from Dr. Ármann Höskuldsson.

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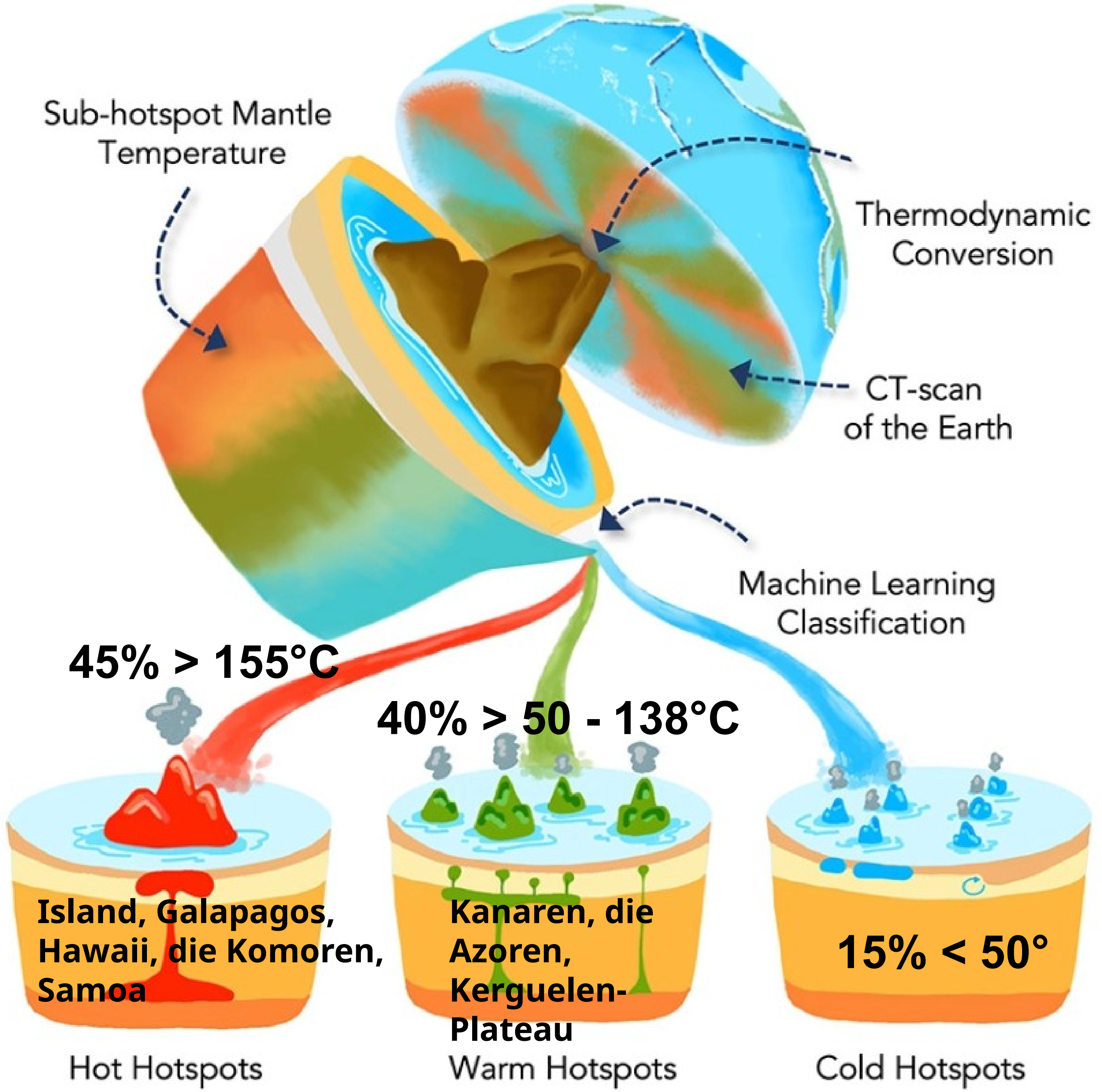
The Iceland Plume (or Hot Spot)



On the relative temperatures of Earth's volcanic hotspots and mid-ocean ridges

XIYUAN BAO, CAROLINA R. LITHGOW-BERTELLONI, MATTHEW G. JACKSON, AND BARBARA ROMANOWICZ

SCIENCE • 6 Jan 2022 • Vol 375, Issue 6576 • pp. 57-61 • DOI: 10.1126/science.abj8944

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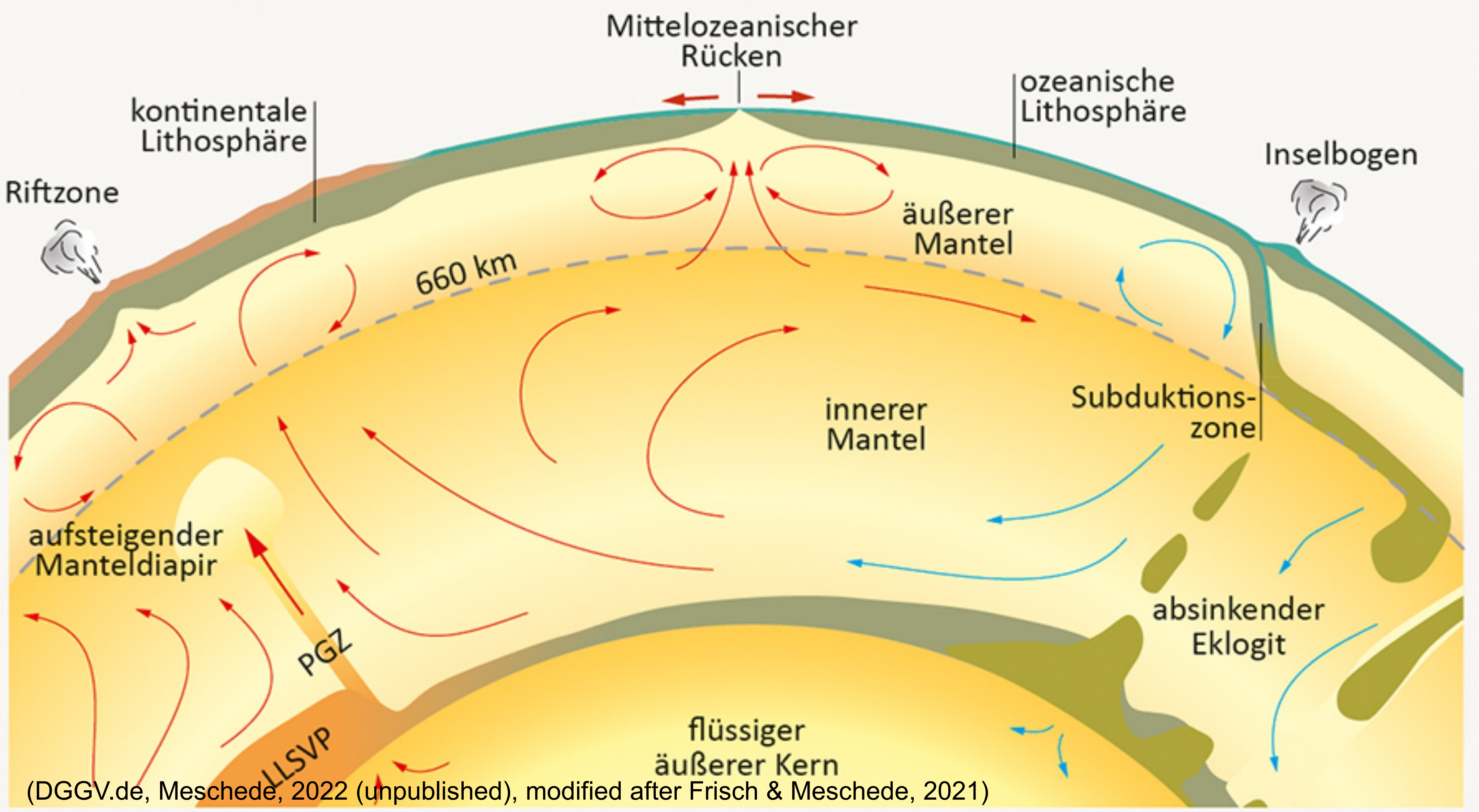
Mechanism Plate Movements



(DGGV.de, Meschede, 2022 (unpublished), modified after Frisch & Meschede, 2021)

Model for convection flows in the mantle

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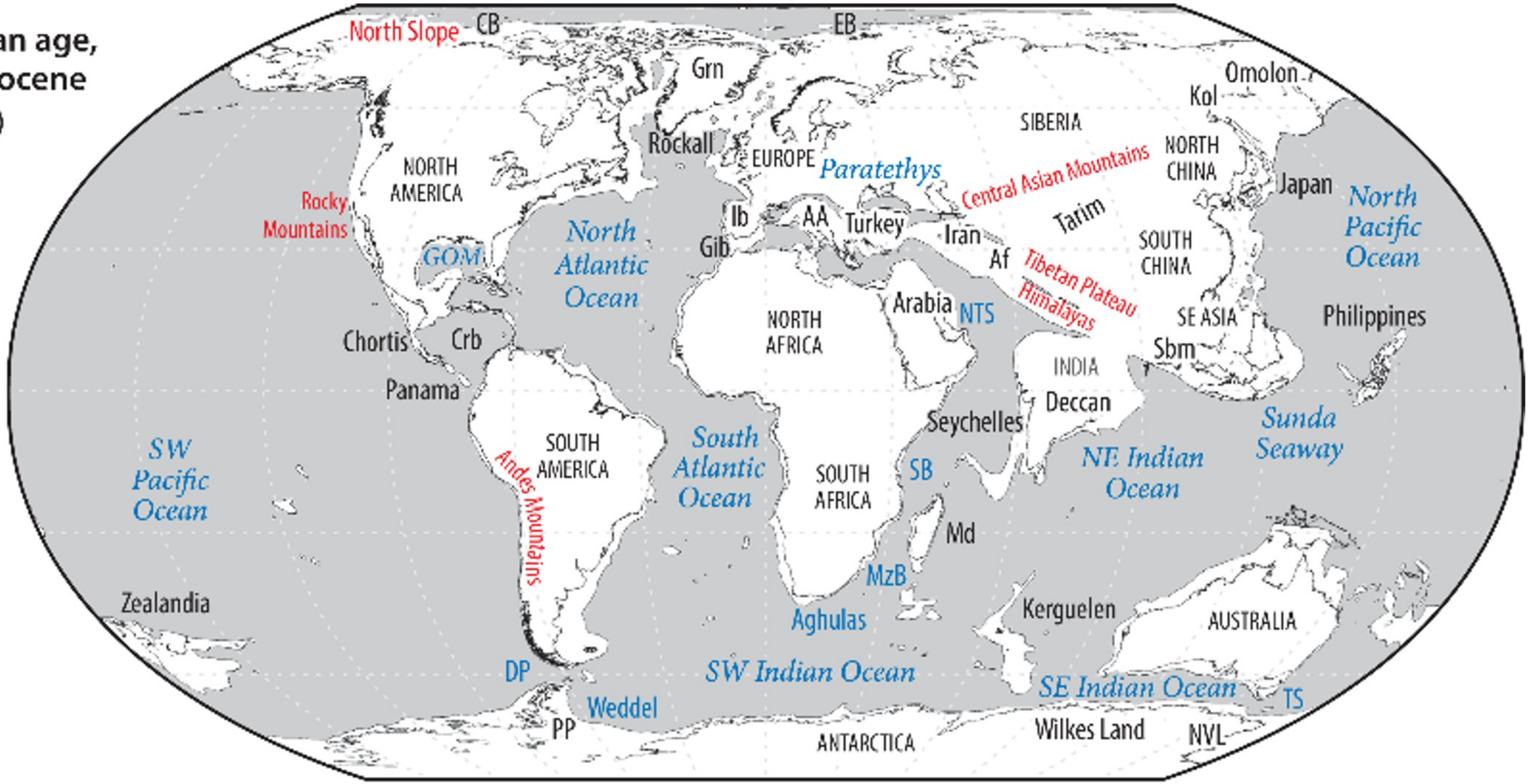
But it looked very different in the past

Ypresian age, early Eocene (50 Ma)



Scotese CR. 2021
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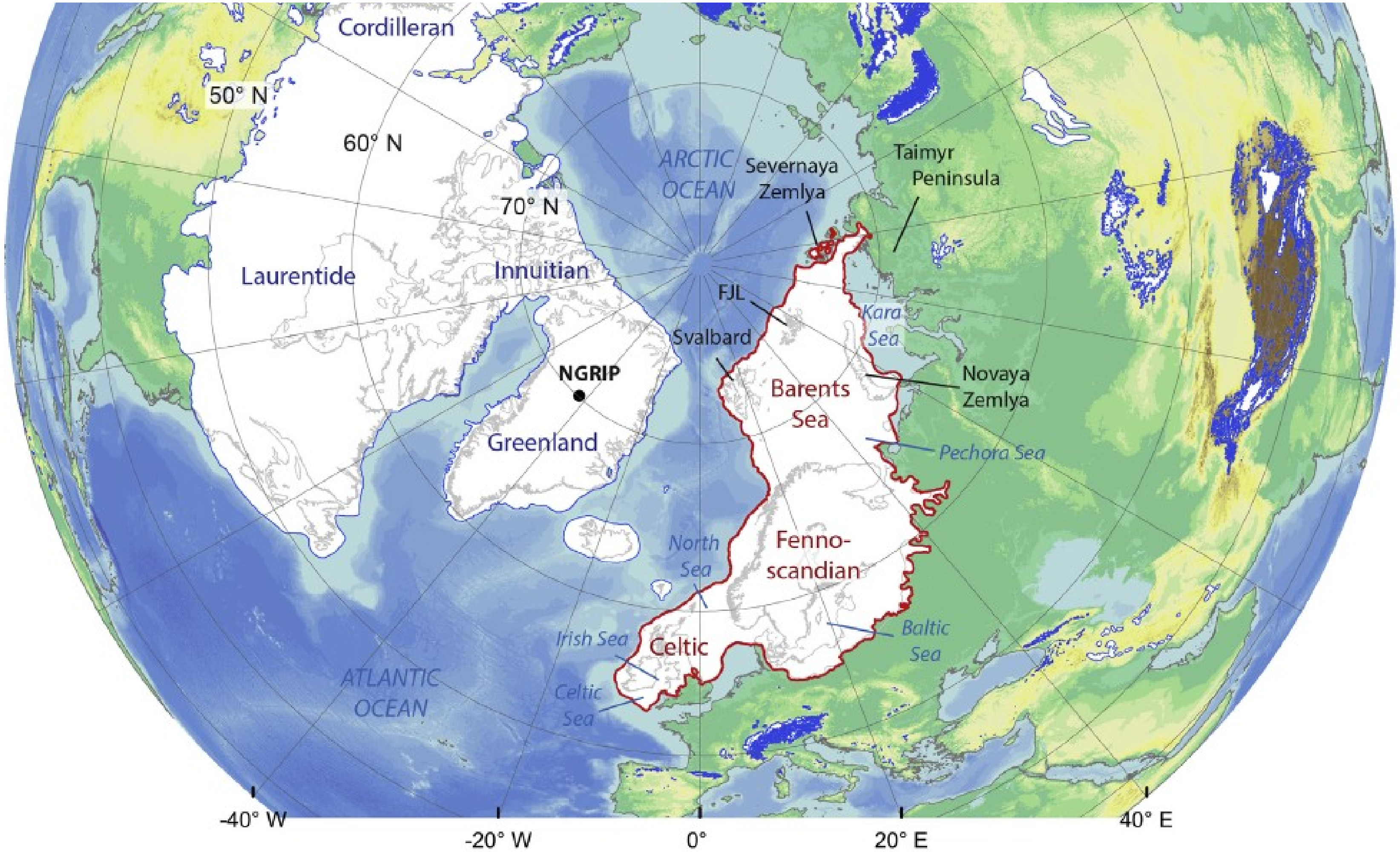
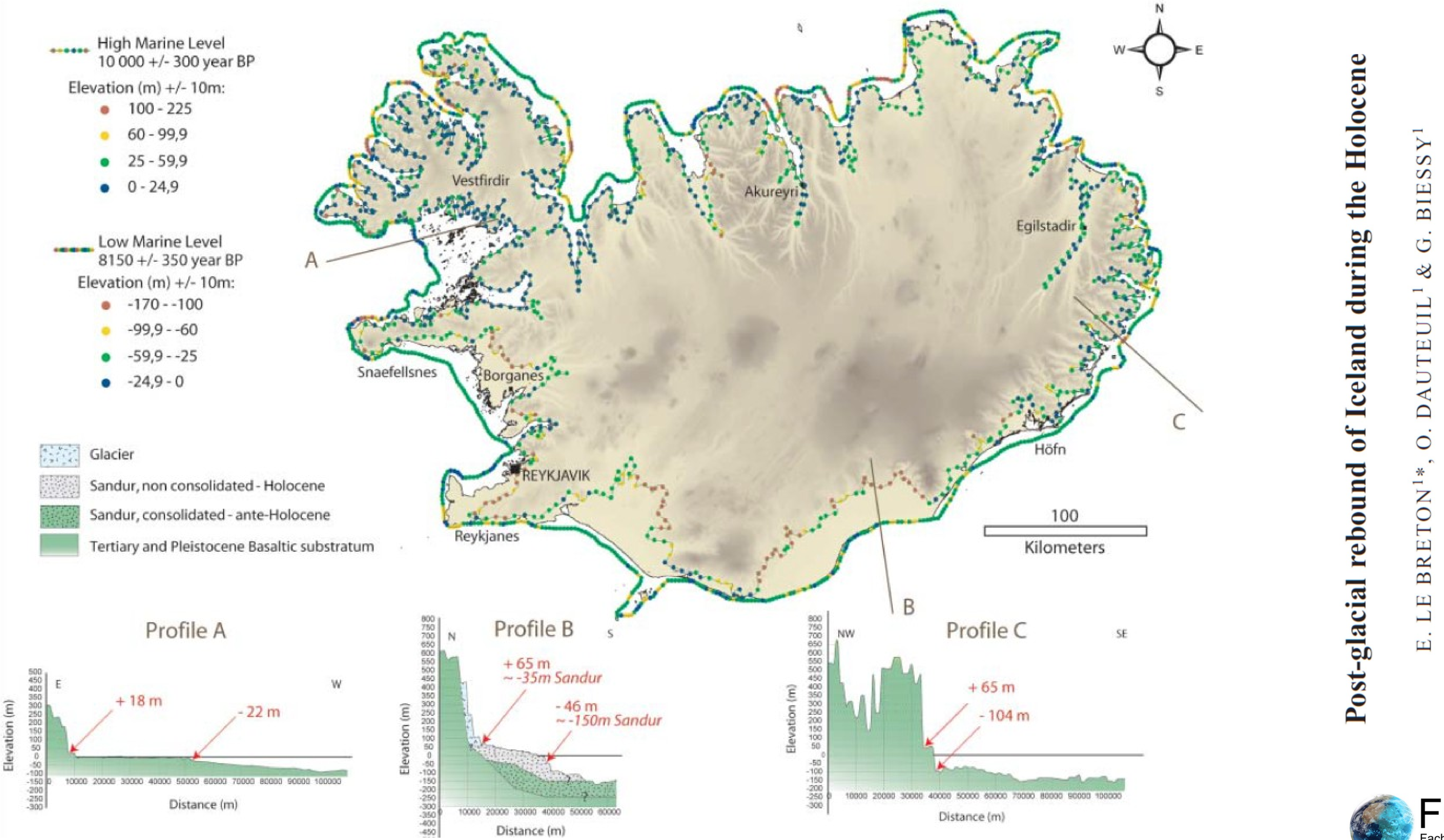
Glaciation/Deglaciation in Iceland

Fig. 1. The Late Weichselian Eurasian Ice Sheet Complex (EISC; red outline) in the context of Northern Hemispheric glaciation. The EISC comprised three semi-independent ice-sheets, though maximum extension in all sectors was not contemporaneous. Acronyms used: FJL (Franz Josef Land), NGRIP (North Greenland Ice Core Project). Glacial limits compiled from Ehlers and Gibbard (2007), Patton et al. (2015) and Stroeven et al. (2016). Topography: The GEBCO_2014 Grid, www.gebco.net. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



Postglacial rebound Iceland



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Processes impacting vertical motion

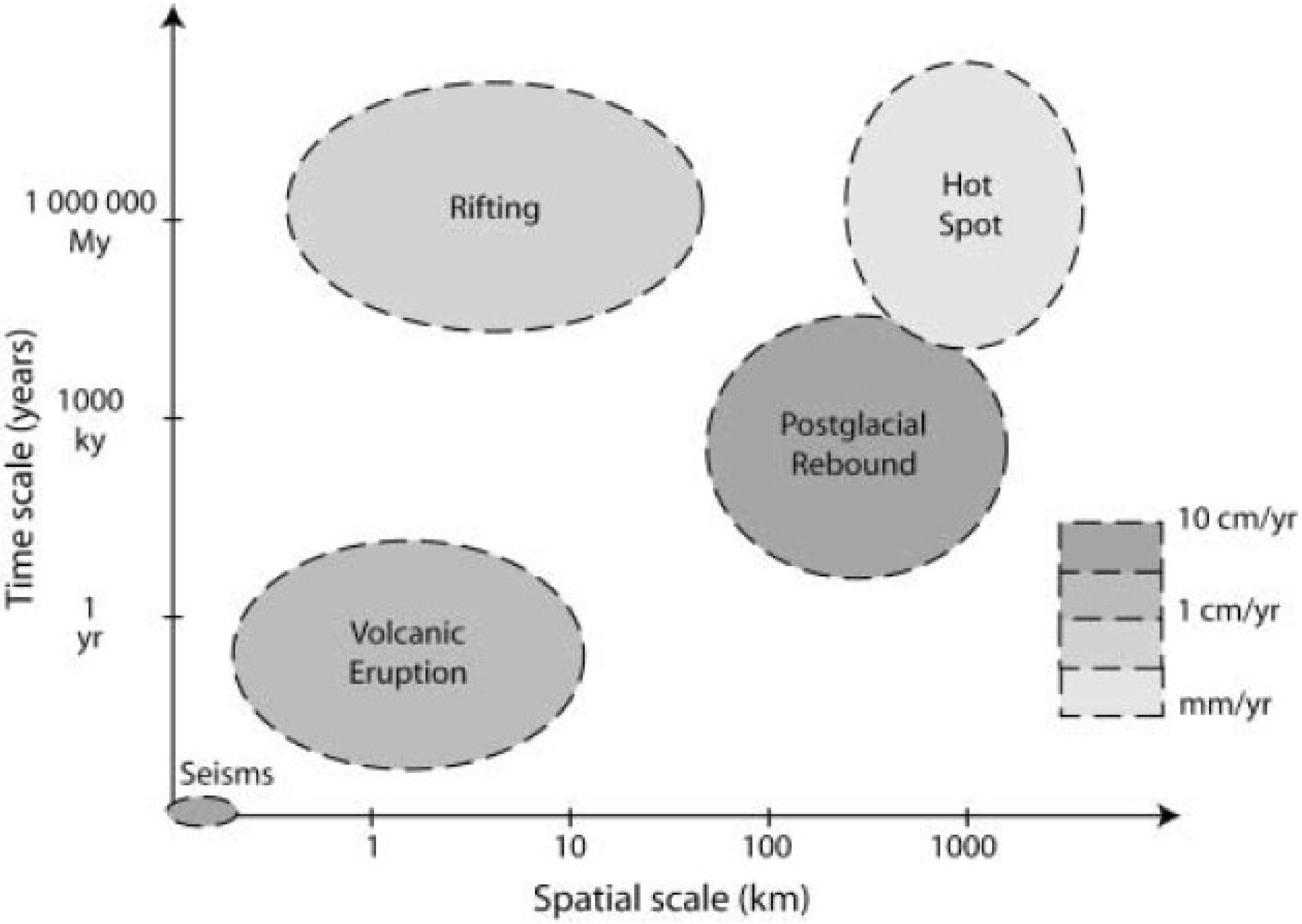

Fig. 2. Time v. space diagram of the processes generating vertical motion of Iceland (magmatic, tectonic and glacial processes). Change in the magmatic content of a magmatic chamber induces quick vertical displacement of the surface over short distances. Oceanic rifting of the mid-oceanic ridge generates vertical displacements, such as tilted blocks, at kilometre scale. The mantle upwelling underneath Iceland causes large-scale bulge of the surface (several thousands of kilometres) at a very slow rate (*c.* mm a^{-1}). Glacio-isostasy leads to fast rebound of the surface in response to ice unloading, which affects all of Iceland.

Post-glacial rebound of Iceland during the Holocene

E. LE BRETON[1]*, O. DAUTEUIL[1] & G. BIESSY[1]

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