SEGMENTED MANTLE MELTING, LITHOSPHERIC STRENGTH, AND THE ORIGIN OF TRANSFORM FAULTS: INSIGHTS FROM THE NORTH ATLANTIC

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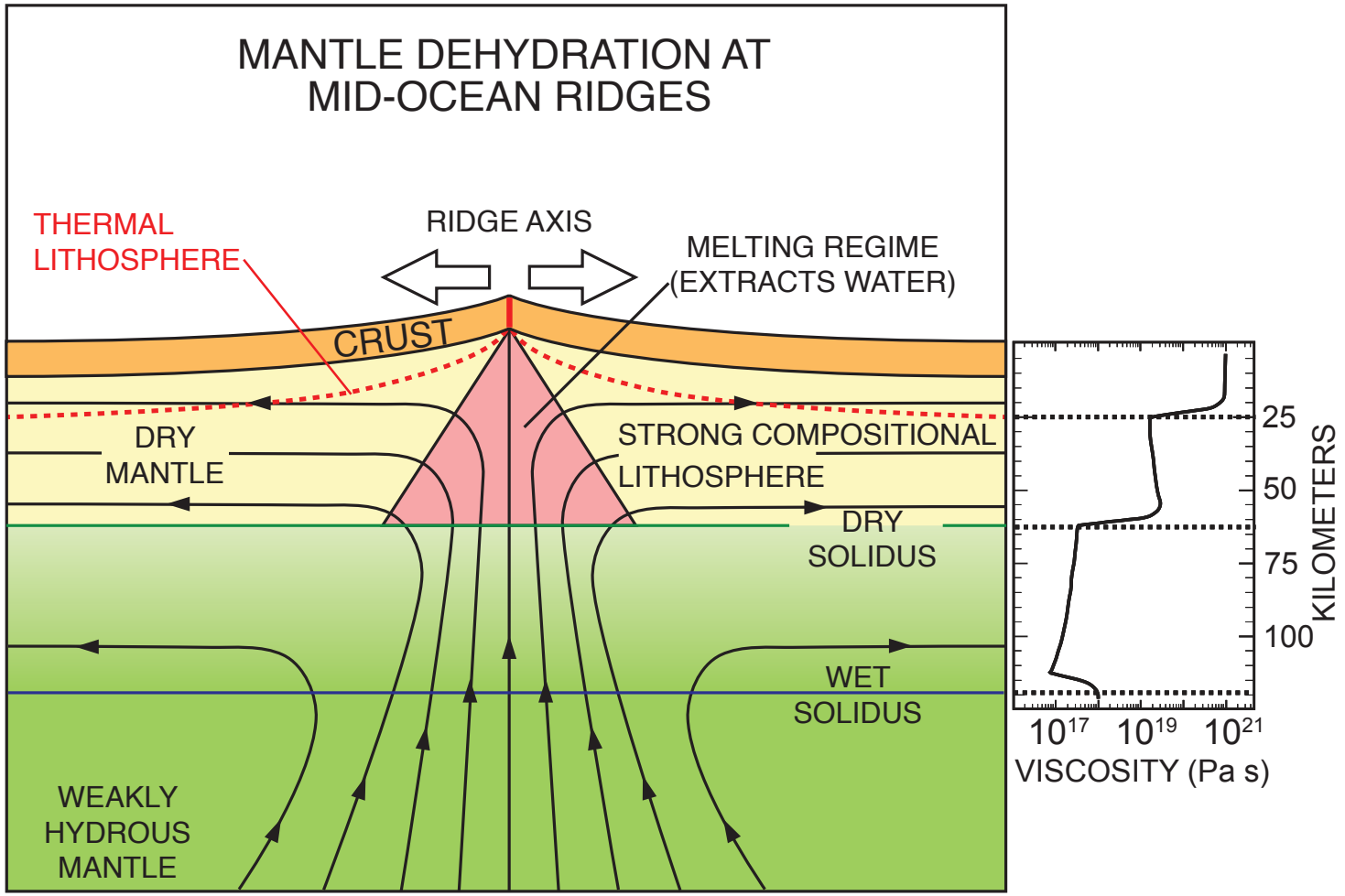
MANTLE MELTING AND LITHOSPHERIC RHEOLOGY

Hirth and Kohlstedt, 1996, EPSL



Viscosity profile from Bonatti et al., 2003, Nature

MANTLE MELTING CREATES SIGNIFICANT VARIATIONS IN LITHOSPHERIC RHEOLOGY. WATER HAS A STRONG WEAKENING EFFECT ON OLIVINE AND MANTLE MELTING AT RIDGES EXTRACTS WATER INTO THE MELT AND REMOVES IT TO THE CRUST LEADING TO A DRY AND STRONG RESIDUAL MANTLE. THE DIFFERENCE IN MANTLE VISCOSITY AFTER MELTING AND MELT EXTRACTION MAY EXCEED TWO ORDERS OF MAGNITUDE. THE CHANGE IN RHEOLOGY OCCURS RAPIDLY, CLOSE TO THE RIDGE AXIS, AND EXTENDS FROM THE MOHO TO THE DRY SOLIDUS DEPTH, THUS PRODUCING A LARGE AND RAPID CHANGE IN MANTLE SHEAR STRENGHT.

THESE EFFECTS HAVE MOTIVATED MODELS OF A DRY AND STRONG “COMPOSITIONAL” LITHOSPHERE FORMED AT MID-OCEAN RIDGES ASSUMING THAT MELT (AND WATER) ARE GENERALLY EXTRACTED EFFICIENTLY FROM THE MANTLE.

HOWEVER, MANTLE MELTING AND MELT EXTRACTION VARY STRONGLY AT MID-OCEAN RIDGES BETWEEN SEGMENT INTERIORS AND ENDS.

MULTIPLE STUDIES PROVIDE EVIDENCE FOR ELEVATED WATER CONTENT IN MANTLE AND VOLCANIC ROCKS FROM TRANSFORM DOMAINS AND NEAR RIDGE SEGMENT ENDS

Water-rich basalts at mid-ocean-ridge cold spots

Marco Ligi[1], Enrico Bonatti[1,2,3], Anna Cipriani[1,2] & Luisa Ottolini[4]

NATURE | VOL 434 | 3 MARCH 2005 | www.nature.com/nature

SCIENCE ADVANCES | RESEARCH ARTICLE

GEOCHEMISTRY

Postmelting hydrogen enrichment in the oceanic lithosphere

Veronique Le Roux[1]*, Benjamin M. Urann[1,2], Daniele Brunelli[3,4], Enrico Bonatti[4,5], Anna Cipriani[3,5], Sylvie Demouchy[6], Brian D. Monteleone[1]

Le Roux *et al.*, *Sci. Adv.* 2021; **7** : eabf6071 9 June 2021

SCIENTIFIC REPORTS
nature research

High H_2O Content in Pyroxenes of Residual Mantle Peridotites at a Mid Atlantic Ridge Segment

Pei Li[1*], Qun-Ke Xia[1], Luigi Dallai[2], Enrico Bonatti[3,4], Daniele Brunelli[4,5], Anna Cipriani[3,5] & Marco Ligi[4]

SCIENTIFIC REPORTS | (2020) 10:579 | https://doi.org/10.1038/s41598-019-57344-4

Water in Abyssal Peridotite: Why Are Melt-Depleted Rocks so Water Rich?

E. Schmädicke[1], J. Gose[1], and R. Stalder[2]

Schmädicke, E., Gose, J., & Stalder, R. (2018). Water in abyssal peridotite: Why are melt-depleted rocks so water rich?. *Geochemistry, Geophysics, Geosystems, 19*. https://doi.org/10.1029/2017GC007390

Water in enstatite from Mid-Atlantic Ridge peridotite: Evidence for the water content of suboceanic mantle?

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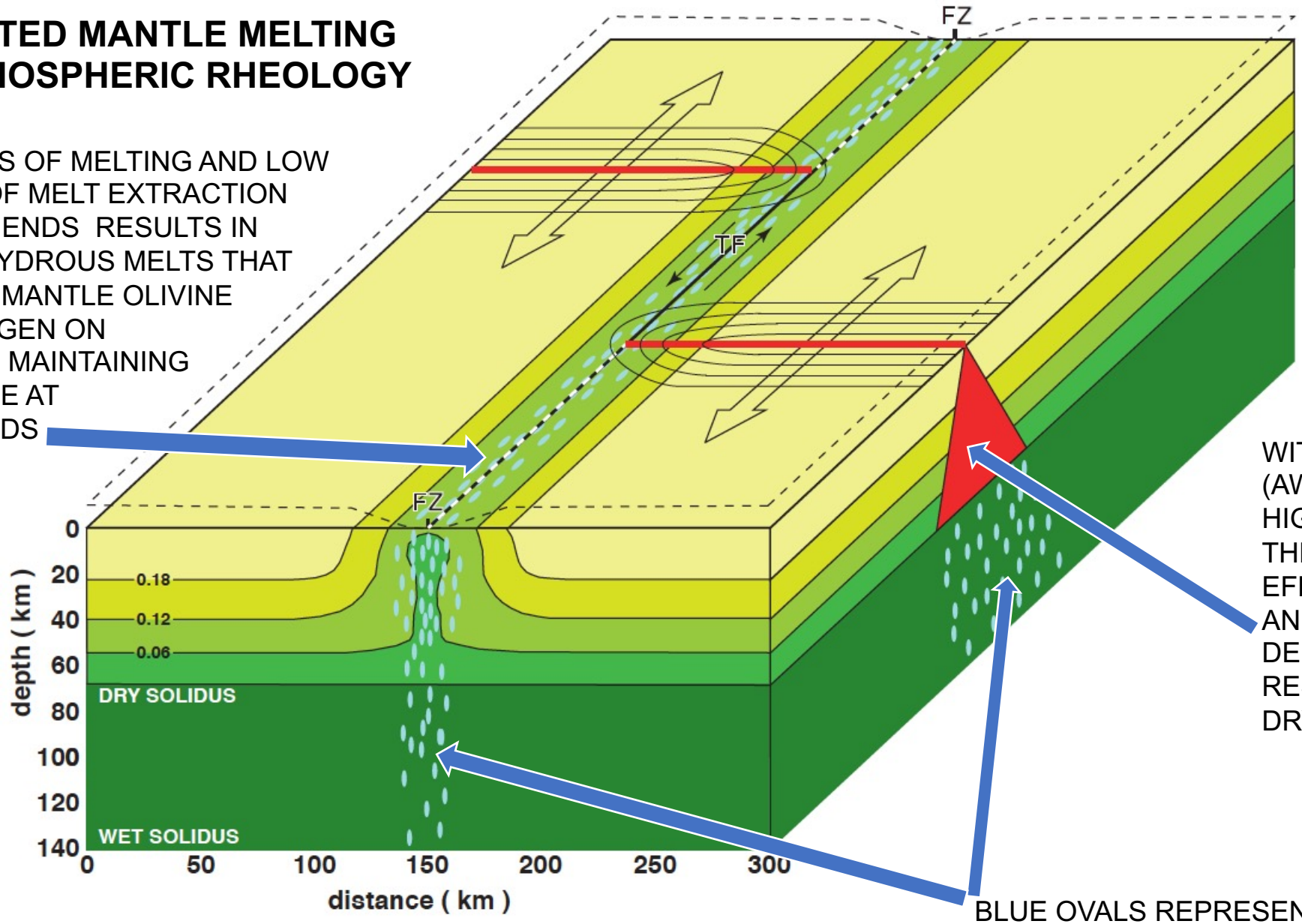
Geology, June 2009; v. 37; no. 6; p. 543–546; doi: 10.1130/G25558A.1

SEGMENTED MANTLE MELTING AND LITHOSPHERIC RHEOLOGY

LOW EXTENTS OF MELTING AND LOW EFFICENCY OF MELT EXTRACTION AT SEGMENT ENDS RESULTS IN FROZEN-IN HYDROUS MELTS THAT REFERTILIZE MANTLE OLIVINE WITH HYDROGEN ON SOLIDIFYING, MAINTAINING WEAK MANTLE AT SEGMENT ENDS



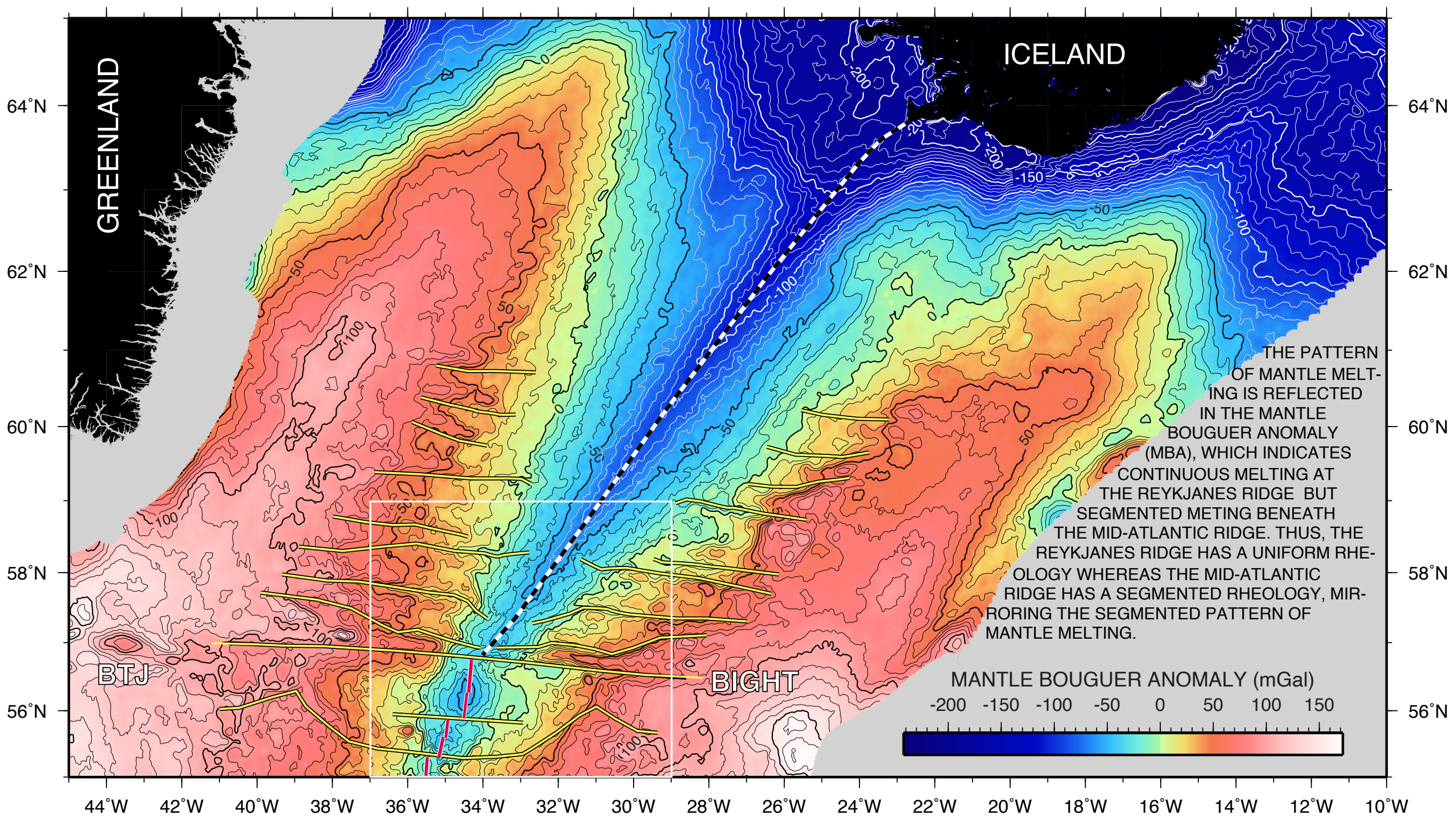
CRUSTAL LAYER (DASHED)

INCREASING MANTLE DEPLETION

WITHIN SEGMENT INTERIORS (AWAY FROM SEGMENT ENDS) HIGH EXTENTS OF MELTING IN THE RIDGE MELTING REGIME EFFICENTLY EXTRACTS MELT AND WATER LEADING TO A DEPLETED, DRY AND STRONG RESIDUAL MANTLE ABOVE THE DRY SOLIDUS

BLUE OVALS REPRESENT LOW-DEGREE HYDROUS MELTS FORMED AT SEGMENT ENDS AND IN THE “DAMP” MELTING INTERVAL BENEATH THE DRY SOLIDUS MELTING REGIME

Depletion contours after *Shen and Forsyth*, 1992, JGR

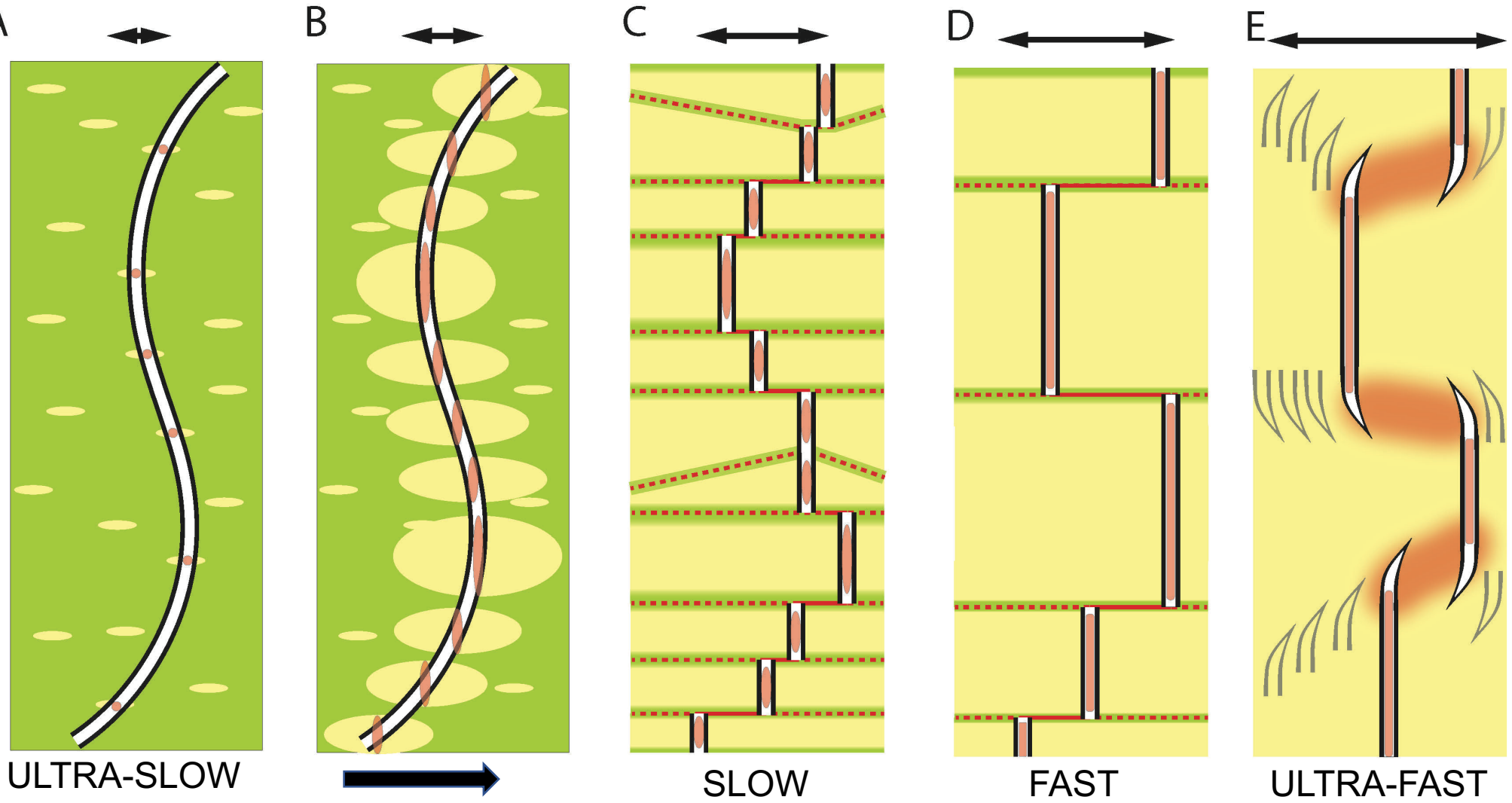

GREENLAND
ICELAND
BTJ
BIGHT
64°N
62°N
60°N
58°N
56°N
44°W
42°W
40°W
38°W
36°W
34°W
32°W
30°W
28°W
26°W
24°W
22°W
20°W
18°W
16°W
14°W
12°W
10°W
THE PATTERN OF MANTLE MELTING IS REFLECTED IN THE MANTLE BOUGUER ANOMALY (MBA), WHICH INDICATES CONTINUOUS MELTING AT THE REYKJANES RIDGE BUT SEGMENTED METING BENEATH THE MID-ATLANTIC RIDGE. THUS, THE REYKJANES RIDGE HAS A UNIFORM RHEOLOGY WHEREAS THE MID-ATLANTIC RIDGE HAS A SEGMENTED RHEOLOGY, MIRRORING THE SEGMENTED PATTERN OF MANTLE MELTING.
MANTLE BOUGUER ANOMALY (mGal)
-200 -150 -100 -50 0 50 100 150

EVOLUTION OF TRANSFORM FAULTS WITH SPREADING RATE AND THE PATTERN OF MELTING

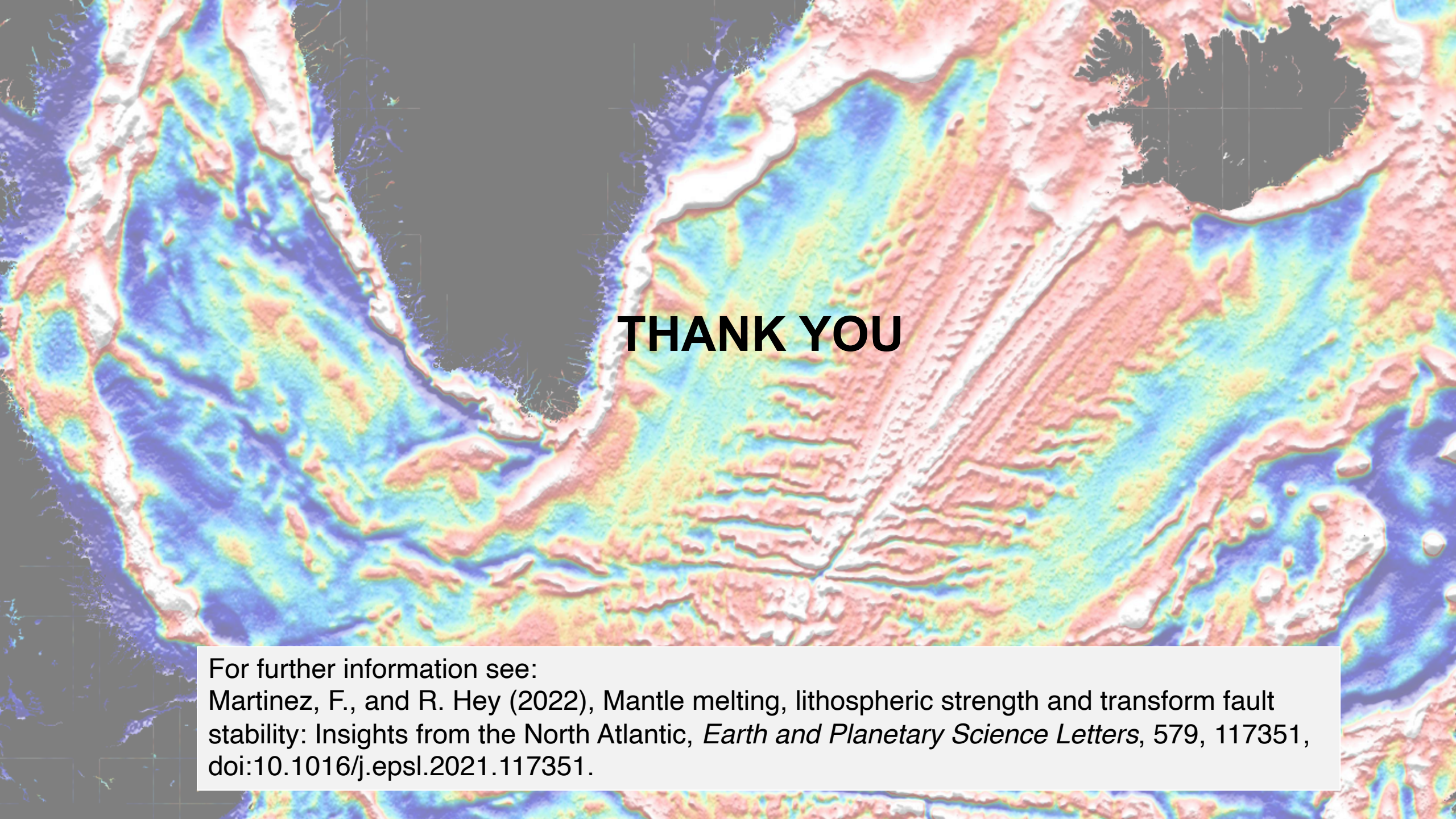
GREEN: POORLY DEPLETED WEAK MANTLE RETAINING WATER

YELLOW: DEPLETED, DRY AND STRONG MANTLE

RED: MELTING CENTERS



AT ULTRA-SLOW RATES MELTING IS LIMITED AND IRREGULAR AND MELT EXTRACTION IS INEFFICENT SO THAT NO SYSTEMATIC BANDS OF WEAK AND STRONG MANTLE ARE FORMED. AS SPREADING RATES INCREASE STABLE MELTING CENTERS BEGIN TO FORM. BY SLOW RATES STABLE SEGMENTED MELTING PREDOMINATES FORMING BANDS OF STRONG AND WEAK MANTLE, FAVORING TRANSFORM FAULTS. AT FAST RATES 3-D MELTING PATTERNS GIVE WAY TO 2-D MELTING PATTERNS WHERE LOW EXTENTS OF MELTING AND MELT EXTRACTION ONLY OCCUR AT SIGNIFICANT OFFSETS. BY ULTRA FAST RATES MELTING AND MELT EXTRACTION ARE EVERYWHERE EXTENSIVE AND WEAK AND STRONG BANDS NO LONGER FORM SO TRANSFORM FAUTLS ARE NO LONGER FAVORED.



THANK YOU

For further information see:
Martinez, F., and R. Hey (2022), Mantle melting, lithospheric strength and transform fault stability: Insights from the North Atlantic, *Earth and Planetary Science Letters*, 579, 117351, doi:10.1016/j.epsl.2021.117351.