The rift-to-drift transition in the southern North Atlantic: A stuttering start of the MORB engine?

Oliver Jagoutz[1], Othmar Müntener[1], Gianreto Manatschal[2], Daniela Rubatto[3], and Igor M. Villa[1,4]

1. Institut für Geologie, Universität Bern, CH-3012 Bern, Switzerland
2. CGS_EOST, Université Louis Pasteur, F-67084 Strasbourg, France
3. Research School of Earth Sciences, ANU, Canberra 0200 ACT, Australia
4. Universita di Milano Bicocca, 20126 Milano, Italy

It is generally accepted that rupturing of continents is followed by localized seafloor spreading at mid ocean ridges (MOR), which are considered, on geological time scales, to be symmetric and steady state. The continuity of this process is documented by the correspondence of crustal accretion ages and magmatic ages. While these processes are well studied at present-day MOR, little is known about how stable these systems are during their embryonic stage. Even though our understanding of the mechanisms associated with extension and rifting of continents improved significantly in the last decade (Whitmarsh et al., 2001) the processes that ultimately start the MOR basalt (MORB) engine and the switch from rifting to drifting are still poorly constrained. One of the most striking results of ODP drilling along the Iberia-Newfoundland conjugate margins was the scarcity of effusive magmatism and only minor volumes of intrusive rocks (Russell and Whitmarsh, 2003) even in areas with undisputed oceanic magnetic anomalies (Srivastava et al., 2000). This observation is in conflict with numerical melting models that generally predict large volumes of MORB type melt. The genetic and temporal relationships of alkaline and MORB type magmatism associated with the onset of seafloor spreading may clarify the rift-to-drift transition. Here we present new mineral U-Pb and ^{40}Ar-^{39}Ar age data together with Pb, Nd, Sr isotopic data from ODP samples (Leg 1277 and 1070) across the conjugate Iberia-Newfoundland magma-poor margins. We aim to document the igneous history related to the onset of seafloor spreading in the southern North Atlantic.

The onset of the rift-to-drift transition is accompanied (or triggered?) by alkaline magmatism documented by an alkaline dike from Site 1277. A biotite ^{39}Ar-^{40}Ar age yields a minimum age for this alkaline episode of 126.5±4.0 Ma, closely corresponding to the crustal accretion age of Site 1277. A contemporaneous magmatic event is documented on the Iberia margin at Site 1070 by the U-Pb age of a single zircon (127 ± 4 Ma) separated from a biotite-bearing albitite clast (Beard et al., 2002).

The pegmatitic gabbro at Site 1070 yields a 118±2.2 Ma hornblende age indicating that early alkaline magmatism was subsequently replaced by E-type MORB melts. Indirect dating of the (E-) MORB type lava flows at Site 1277, suggests that the MORB type magmatism occurred prior to the Aptian/Albian boundary. The earliest magmatic history of the embryonic oceanic crust is thus characterized by alkali magmatism followed by (E-) MORB type magmas. A 113.2±2.1 Ma U-Pb zircon age of a hornblende-plagioclase dike at Site 1277 indicates a revival of alkaline magmatism at the Aptian/Albian boundary. The alkaline event is contemporaneous with a morpho-tectonic event, recorded in the sedimentary architecture in the Iberia-Newfoundland margins. The event was characterized by distributed deformation affecting previously accreted oceanic crust and is probably responsible for the

formation of basement highs (Peron-Pinvidic et al., submitted). The multiple emplacement of alkaline sills at Site 1276 (105 ± 2 Ma and 97 ± 2 Ma, Hart, 2005) indicates repeated alkaline magmatic activity at the Newfoundland margin. Alkaline magmatism on the conjugate Iberian margin is documented along the Tore-Madeira rise (103 to 88 Ma, Merle et al. 2005), implying alkaline magmatism on either side of the nascent mid-Atlantic ridge.
Leached plagioclase mineral separates from MORB type gabbroic clasts and alkaline dykes have similar Pb, Sr and Nd isotopic composition to present day MORB.
There are two alternatives to explain the prolonged and heterogeneous igneous history recorded at Sites 1277 and 1070: One hypothesis is the ‘passage’ of mantle plumes, which are widespread in the Atlantic (Duncan, 1984), an alternative hypothesis was advanced by Pe-Piper et al. (1994), that Cretaceous volcanism in Newfoundland is related to decompression melting along reactivated faults. Our isotopic data however is not in accordance with hotspot hypothesis. Similar geochemical results from the alkaline sills at Site 1276 and the Grand Banks imply an isotopic signature different from the Atlantic hotspot system (Hart, 2005; Pe_Piper et al., 1994). Merle et al (2005) suggest that the emplacement of alkaline magmas on the northern Tore-Madeira Rise is neither related to oceanic crust formation nor to plume activity. The similar magmatic history at Sites 1070 and 1277 for at least 25 million years after onset of magmatic activity suggest a common process on either side of the proto mid-Atlantic ridge. Considering the basin wide change from localized to delocalized deformation at the Aptian-Albian boundary we propose an alternative model to explain the episodic revival of intra-plate alkaline magmatism.

REFERENCES

Beard, J.S., Fullagar, P.D., and Sinha, A.K., 2002, Gabbroic pegmatite intrusions, Iberia Abyssal Plain, ODP Leg 173, Site 1070; magmatism during a transition from non-volcanic rifting to sea-floor spreading: Journal of Petrology, v. 43, p. 885-905.
Duncan, R.A., 1984, Age progressive volcanism in the New England Seamounts and the opening of the central Atlantic Ocean: Journal of Geophysical Research. Pages, v. B. 89, p. 9980-9990.
Hart, S., R., 2005, Site 1276, age and geochemistry of the mafic sills, Abstract ODP Leg 210 post-cruise meeting: Briançon, France.
Pe_Piper, G., Jansa, L.F., and Palacz, Z., 1994, Geochemistry and regional significance of the Early Cretaceous bimodal basalt-felsic associations on Grand Banks, Eastern Canada: Geological Society of America Bulletin, v. 106, p. 1319-1331.
Peron-Pinvidic, G., Manatschal, G., Minshull, T.A., and Sawyer, D., submitted, The tectono-sedimentary and morpho-tectonic evolution recorded in the deep Iberia-Newfoundland margins: evidence for a complex break-up history: Tectonics.
Russell, S.M., and Whitmarsh, R.B., 2003, Magmatism at the west Iberia non-volcanic rifted continental margin: evidence from analyses of magnetic anomalies: Geophysical Journal International, v. 154, p. 706-730.
Srivastava, S.P., Sibuet, J.C., Cande, S., Roest, W.R., and Reid, I.D., 2000, Magnetic evidence for slow seafloor spreading during the formation of the Newfoundland and Iberian margins: Earth and Planetary Science Letters, v. 182, p. 61-76.
Whitmarsh, R.B., Manatschal, G., and Minshull, T.A., 2001, Evolution of magma-poor continental margins from rifting to seafloor spreading: Nature (London), v. 413, p. 150-154.