Scientific Research Publishing

Open Journal of Geology, 2024, 14, 1038-1045
https://www.scirp.org/journal/ojg
ISSN Online: 2161-7589
ISSN Print: 2161-7570

# Sunken Micro-Continents of the North Atlantic: Do the Sub-Basaltic Crust of the Faroe Islands and the Rockall Plateau Basement Represent One Single Micro-Continent?

**Jógvan Hansen**

HansenReSearch, Tórshavn, Faroe Islands
Email: jh_faroes@outlook.com

**How to cite this paper:** Hansen, J. (2024) Sunken Micro-Continents of the North Atlantic: Do the Sub-Basaltic Crust of the Faroe Islands and the Rockall Plateau Basement Represent One Single Micro-Continent? *Open Journal of Geology*, **14**, 1038-1045.
https://doi.org/10.4236/ojg.2024.1412046

**Received:** November 8, 2024
**Accepted:** December 14, 2024
**Published:** December 17, 2024



## Abstract

Seafloor extension and associated rifting in the North Atlantic Area, which started in Early Paleogene (from −62 Ma), resulted in a few micro-continents being isolated and submerged below sea levels. Published isotopic data for sunken offshore continental materials (basement) in the North Atlantic area are quite sparse, but a few do exist for the Rockall Plateau, or more precisely the Rockall Bank. Isotopic data for Early Paleogene basaltic materials, covering basement rocks of the Rockall Plateau, have hitherto only been publicised for the NW margin of the Hatton bank. The Early Paleogene basaltic archipelago of the Faroe Islands, on which some isotopic data do exist, rests on an ancient sunken continental crust of unknown geochemical and isotopic compositions. The objective of this contribution is to assess potential lead isotopic relationships between the Rockall Plateau and the Faroese sub-basaltic basement, based on the sparse available isotopic data existing for the former and using available isotopic data for slightly contaminated Faroese basaltic rocks. The results reached in this contribution point to a likely association between the Faroese sub-basaltic basement and the basement of the Rockall Bank and hence the Rockall Plateau and potentially also between Faroese basaltic rocks and contemporaneous counterparts from the Hatton Bank.

## Keywords

Lead Isotopes, Sunken Microcontinents, Faroe Islands, Rockall Plateau, Rockall Bank, Hatton Bank, Basaltic Rocks, Basement Rocks

## 1. Introduction

Excessive magmatism in the North Atlantic area in Early Paleogene times

(especially from ~62 Ma to ~50 Ma) generated vast expanses of mainly "flood basalts" in wide geographical areas [1]. Current manifestations of this magmatism are evident in areas including West Greenland (Disco and neighbouring areas), East Greenland (Scoresby Sund - Kangerlussuaq - Blosseville Coast areas), NW parts of the British Isles (NW Ireland and in the Inner Hebrides), submerged areas off West Norway (Vøring and Møre highs areas), submerged areas of the Rockall Plateau (mostly western parts) and the Faroe Islands. Collectively, these regions are most often referred to as the North Atlantic Igneous Province (NAIP) [2] [3].

The pre-rift North Atlantic area consisted of an ancient crust, which to a large degree represented terranes residual from the closure of the Iapetus Ocean, some of which originated from different settings from either side of the closing ocean being more or less juxtaposed. In the course of complex and discontinuous extension/rifting, segments of this crust became isolated on all sides and now occur as sunken sub-oceanic micro-continents or terranes, which in places are overlain by Early Paleogene basaltic crust. Current offshore areas in the North Atlantic known to harbour such ancient "sunken" continental crust in the North Atlantic include the "Faroe Islands - Rockall Plateau micro-continent" [4]-[6], the "Jan Mayen micro-continent" [7], terranes beneath the Vøring- and Møre highs offshore West Norway [8] and possibly also a micro-continent below present-day Icelandic basalts [9].

Accordingly, initial melts, which gave rise to Early Paleogene basaltic magmas of the NAIP travelled from their sources in the upper mantle and ascended through materials comprised of either basaltic oceanic crust or through more silica-rich continental crust of various thicknesses according to geographical location, while en-route to the Earth's surface. In the latter case, contamination of basaltic magmas with continental crustal materials can sometimes be detected geochemically, thus enabling researchers to ascertain geochemical compositions of crustal contaminants to some degree. However, relatively small amounts of crustal contaminants in basaltic melts are often hard or impossible to detect geochemically. In such cases, measurements using isotopes such as Strontium (Sr), Neodymium (Nd) or Lead (Pb) can sometimes reveal even small crustal contaminants in basaltic magmas, as these occur in much larger concentrations in parts of the continental crust, when compared to sources to basaltic magmas in the upper mantle [10].

In this study, Pb isotopic compositions ($^{206}$Pb, $^{207}$Pb and $^{208}$Pb normalised against $^{204}$Pb) in Early Paleogene basaltic rocks from a few sills of the Faroe Islands are contrasted against basaltic materials from the NW fringes of the Hatton Bank of similar ages and against continental materials from more silica-rich and much older basement materials of the Rockall Bank, in order to assess if isotopic relationships exist between any of these.

## 2. Geology of the Studied Area

The Faroe Islands Basalt Group (FIBG), which forms a relatively central part of the NAIP, rests on an up to ~30 km thick stretched continental basement (a sunken micro-continent) [4]. The Early Paleogene Faroese lava pile, which had an

original thickness of ~6.6 km or more can be grouped into 7 formations of various thicknesses and makeup [12]. The 3 uppermost formations of these are intruded by a few basaltic saucer-shaped sills of various sizes (**Figure 1**). Some of the latter can be grouped according to similarities in geochemical compositions, isotopic make-up and similarities in ages [11] [13]. Examples include the two segments of the Streymoy Sill and the Kvívík Sill, the two segments of the Eysturoy Sill and the Sundini Sill, while other intrusions such as the Morskranes Sill display distinct ages, geochemical and isotopic compositions.

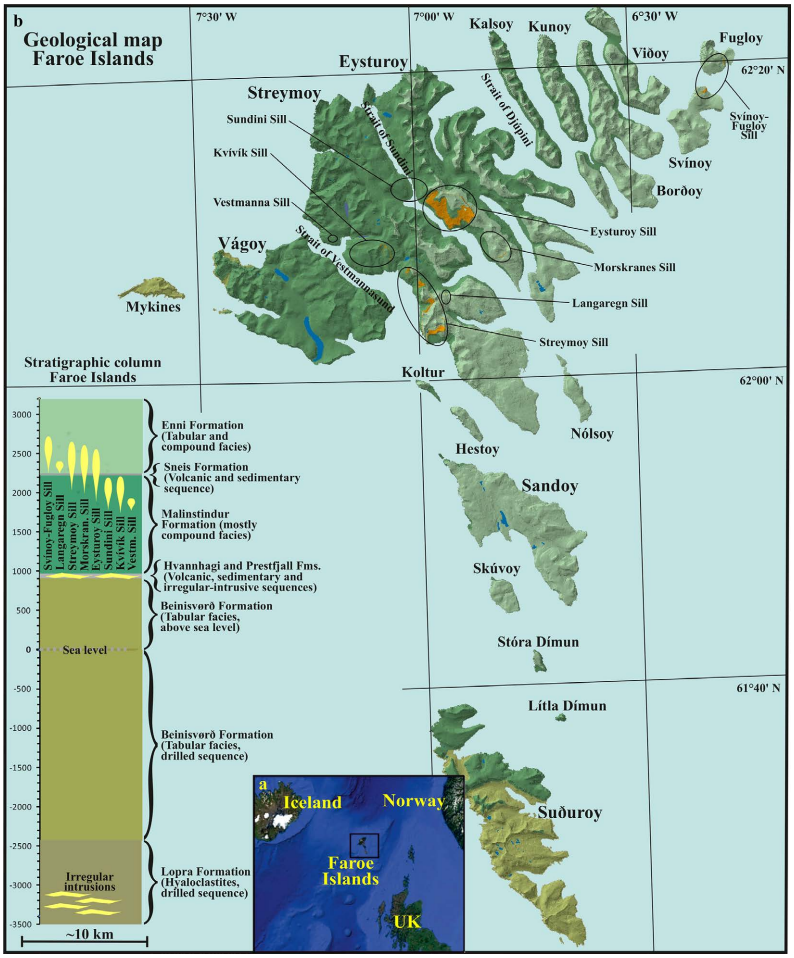


**Figure 1.** Maps of North Atlantic areas (modified from [11]). a, This image illustrates the geographical location of the Faroe Islands in the North Atlantic realm. b, Geological map of the Faroe Islands including stratigraphical column.

Parts of the Rockall Plateau are covered by widespread Early Paleogene basaltic lavas, which have been emplaced from large central igneous complexes and widespread fissures. Continental basement rocks crop out in relatively restricted parts of the Rockall Bank and the Hatton Bank [6]. The latter is thought to be made up of metamorphic terranes (gneisses and slates) overlain by sandstones and shale in places [6], while more detailed investigations of the geochemistry and petrography of selected basement materials from the Rockall Bank have revealed that these

were of granulitic and granitic compositions [14].

## 3. Reasoning and Materials

As no continental basement is exposed onshore the Faroe Islands, the one way to detect geochemical or isotopic compositions of such materials is by means of basaltic rocks, the initial melts of which may have been contaminated by the sub-basaltic continental crust they traversed, while ascending to the local lava successions from the upper mantle. A few silica-rich "presumably contaminated" basaltic horizons within the Faroese lava successions with silica ($SiO_2$) contents of 53 - 54 weight percent (Faroese basaltic rocks display silica contents of ~49 weight percent on average), which also appear to be much enriched in Sr, Nd and Pb isotopes, have been reported previously [15] [16]. As such, these could potentially be utilised to assess the geochemical and/or isotopic make-up of the Faroese sub-basaltic basement, as has indeed been attempted earlier [13]. However, preliminary results from recent own investigations (unpublished) seem to suggest that these samples could in reality be sedimentary specimen originating from within the local basaltic rocks, thus rendering them unsuitable for the actual purpose. Other possibilities include Faroese sills (**Figure 1**), which are not noticeably enriched geochemically, but which do display moderate isotopic diversities [13]. Here, the geochemically and temporally identical high-$TiO_2$ Eysturoy and Sundini sills, the geochemically and temporally identical low-$TiO_2$ Streymoy and Kvívík sills and the LREE depleted Morskranes Sill in particular are of noticeable significance.

In this contribution, selected isotopes representing these 3 Faroese sill groups are compared/contrasted against continental basement samples reported for the Rockall Bank [14] and Early Paleogene basalts reported for the NW fringes of the Hatton Bank [17] [18] (**Figure 2**). To be more detailed, Pb isotopes representing

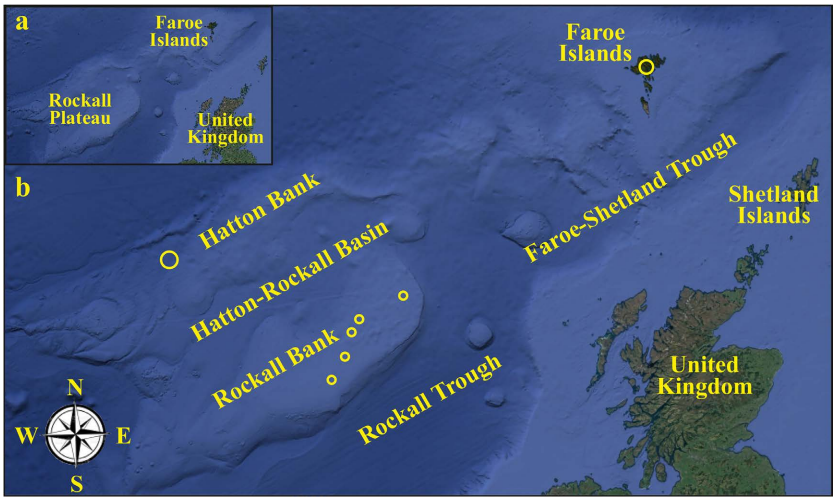


**Figure 2.** North Atlantic maps (Based on Google Earth). a, Relative geographic locations of the Faroe Islands, UK and the Rockall Plateau. b, The map depicts sites where samples used in this contribution were collected. Small circles on the Rockall Bank represent sites of basement samples, while larger circles on the Faroe Islands and NW fringes of Hatton Bank represent sites of Early Paleogene basaltic samples.

5 basement samples from the Rockall Bank, 12 basaltic samples from the NW fringes of the Hatton Bank and 11 samples from 5 Faroese sills combined, are utilised in order to assess potential mutual relationships between any of these (Figure 3). As there are no noticeable differences between configurations of ages corrected back to Early Paleogene times versus actual measured lead isotope data, measured data are used in this work.

## 4. Results and Discussion

When it comes to Pb isotopes for basaltic samples of the NE fringes of the Hatton Bank, the noticeable spread within these may suggest moderate heterogeneities within their mantle source(s) in general, while the substantial overall elongated configurations of the plotted samples combined towards larger $^{207}Pb$ values strongly point to contamination with a crustal continental source enriched in $^{207}Pb$ isotopes, potentially with Pb isotopic characteristics comparable to some of those measured for the Rockall Bank, or with a specific Hatton Bank basement even more enriched in $^{207}Pb$ (Figure 3). Researchers from an earlier isotopic study on the Hatton Bank basalts came to roughly similar conclusions [18].

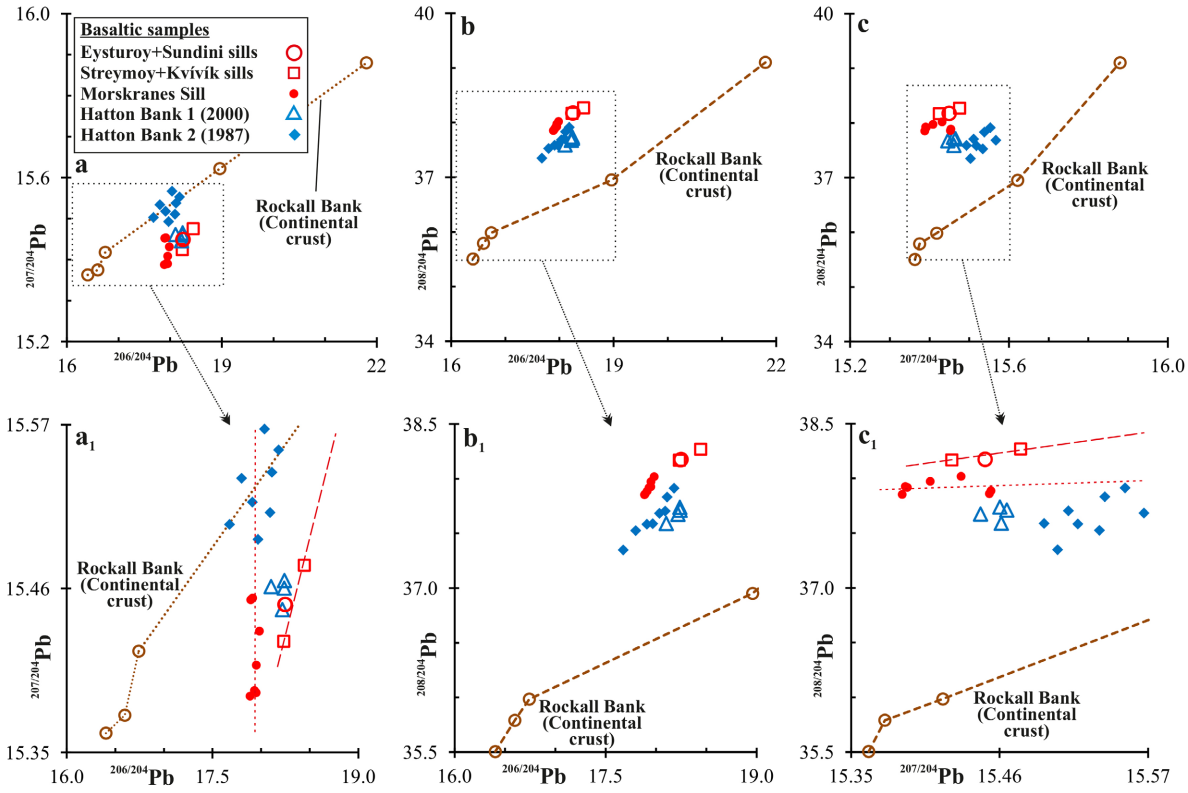


Figure 3. Bivariate lead isotope plots. a and $a_1$, $^{206/204}Pb$ versus $^{207/204}Pb$ diagram (s) representing Faroese and Rockall Plateau data. b and $b_1$, $^{206/204}Pb$ versus $^{208/204}Pb$ diagram(s) representing Faroese and Rockall Plateau data. c and $c_1$, $^{207/204}Pb$ versus $^{208/204}Pb$ diagram(s) representing Faroese and Rockall Plateau data. Dashed red lines point to probable contaminants enriched in $^{207}Pb$. Faroese data from [13], Hatton Bank data from [17] [18] and Rockall Bank data from [14].

With respect to the actual Faroese basaltic materials, the 2 samples from the

geochemically identical Eysturoy and Sundini sills display identical Pb isotope compositions despite being sampled ~10 km apart, indicating a homogeneous common mantle source for both of these, but also suggesting insignificant or no crustal contamination. The geochemically identical Streymoy and Kvívík sills, which were collected a few kilometres apart, differ chiefly in their $^{207}$Pb isotope contents, indicative of either slight heterogeneities in their mantle source(s) or (more likely) of crustal contamination. In the latter case, a sub-basaltic basement contaminant, displaying Pb isotope compositions broadly similar to some of those measured for the Rockall Bank, would be an obvious candidate (**Figure 3**). The 7 samples representing the Morskranes Sill, which were mostly collected a few tens to a few hundred metres apart, display clear evidences of crustal contamination with respect to their $^{207}$Pb isotopes. Sub-basaltic basement contaminants, displaying Pb isotope compositions broadly similar to some of those measured for the Rockall Bank would be obvious candidates. Alternatively, sub-basaltic crustal contaminants even more enriched in $^{207}$Pb isotopes than the crust of the Rockall Bank, perhaps a potential specific Hatton Bank type basement, could be invoked as a candidate for the $^{207}$Pb enrichments of Faroese basaltic rocks. After all, many of the Hatton Bank basaltic samples display a more or less direct continuation from samples of the Faroese Morskranes Sill when it comes to their $^{207}$Pb isotope compositions (**Figure 3**).

## 5. Concluding Remarks

In this short contribution (Review Paper), emphasis has been put on the detection of potential relationships between various rock suites of the North Atlantic area, including Early Paleogene basaltic rocks of the Faroe Islands versus contemporaneous basaltic rocks of the Hatton Bank area (*i.e.* on the Rockall Plateau) and Faroese sub-basaltic continental crust versus continental crust exposed on the Rockall Bank (*i.e.* on the Rockall Plateau). In order to achieve both of these objectives, lead isotopes, measured previously for these regions, have been employed. The results are twofold: i. The results point to a potential relationship between Faroese basaltic rocks in general and those measured for the Hatton Bank, ii. the lead isotopic composition of one of the selected contaminated Faroese sills in particular suggests a likely link/connection between the Faroese sub-basaltic continental crust and continental crust of the Rockall Bank and hence the Rockall Plateau.

## Acknowledgements

The Faroese isotope data stem partly from a PhD project carried out at Durham University, United Kingdom (Defended primo January 2012), financed by BP, Chevron og Geysir Petroleum, while the rest of Faroese lead isotope data were financed privately.

## Disclaimer

The author declares that there are no conflicts of interests involved in the

production of this "review" paper.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

## References


[1] Wilkinson, C.M., Ganerød, M., Hendriks, B.W.H. and Eide, E.A. (2016) Compilation and Appraisal of Geochronological Data from the North Atlantic Igneous Province (NAIP). *Geological Society, London, Special Publications*, **447**, 69-103. https://doi.org/10.1144/sp447.10

[2] Saunders, A.D., Fitton, J.G., Kerr, A.C., Norry, M.J. and Kent, R.W. (2013) The North Atlantic Igneous Province. In: Mahoney, J.J. and Coffin, M.F., Eds., *Large Igneous Provinces: Continental, Oceanic, and Planetary Flood Volcanism*, American Geophysical Union, 45-93. https://doi.org/10.1029/gm100p0045

[3] Meyer, R., van Wijk, J. and Gernigon, L. (2007) The North Atlantic Igneous Province: A Review of Models for Its Formation. In: Foulger, G.R. and Jurdy, D.M., Eds., *Plates, Plumes and Planetary Processes*, Geological Society of America, 525-552. https://doi.org/10.1130/2007.2430(26)

[4] Richardson, K.R., Smallwood, J.R., White, R.S., Snyder, D.B. and Maguire, P.K.H. (1998) Crustal Structure beneath the Faroe Islands and the Faroe-Iceland Ridge. *Tectonophysics*, **300**, 159-180. https://doi.org/10.1016/s0040-1951(98)00239-x

[5] Sammarco, C., Cornwell, D.G. and Rawlinson, N. (2017) Ambient Noise Tomography Reveals Basalt and Sub-Basalt Velocity Structure beneath the Faroe Islands, North Atlantic. *Tectonophysics*, **721**, 1-11. https://doi.org/10.1016/j.tecto.2017.09.012

[6] Hitchen, K. (2004) The Geology of the UK Hatton-Rockall Margin. *Marine and Petroleum Geology*, **21**, 993-1012. https://doi.org/10.1016/j.marpetgeo.2004.05.004

[7] Blischke, A., Gaina, C., Hopper, J.R., Péron-Pinvidic, G., Brandsdóttir, B., Guarnieri, P., *et al.* (2016) The Jan Mayen Microcontinent: An Update of Its Architecture, Structural Development and Role during the Transition from the Ægir Ridge to the Mid-Oceanic Kolbeinsey Ridge. *Geological Society, London, Special Publications*, **447**, 299-337. https://doi.org/10.1144/sp447.5

[8] Torne, M., Fernandez, M., Wheeler, W. and Karpuz, R. (2003) Three-Dimensional Crustal Structure of the Vøring Margin (NE Atlantic): A Combined Seismic and Gravity Image. *Journal of Geophysical Research: Solid Earth*, **108**, Article 2115. https://doi.org/10.1029/2002jb001838

[9] Foulger, G.R., Doré, T., Emeleus, C.H., Franke, D., Geoffroy, L., Gernigon, L., *et al.* (2020) The Iceland Microcontinent and a Continental Greenland-Iceland-Faroe Ridge. *Earth-Science Reviews*, **206**, Article 102926. https://doi.org/10.1016/j.earscirev.2019.102926

[10] Faure, G. (2001) Origin of Igneous Rocks: The Isotopic Evidence. Springer Verlag. https://doi.org/10.1007/978-3-662-04474-2

[11] Hansen, J. and Ganerød, M. (2023) On the Timing and Nature of Magmatism in the North Atlantic Igneous Province: New Implications from Basaltic Rocks of the Faroe Islands. *Earth Sciences*, **12**, 121-139. https://doi.org/10.11648/j.earth.20231205.12

[12] Passey, S.R. and Jolley, D.W. (2008) A Revised Lithostratigraphic Nomenclature for the Palaeogene Faroe Islands Basalt Group, NE Atlantic Ocean. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*, **99**, 127-158.

https://doi.org/10.1017/s1755691009008044

[13] Hansen, J., Davidson, J., Jerram, D., Ottley, C. and Widdowson, M. (2019) Contrasting $TiO_2$ Compositions in Early Cenozoic Mafic Sills of the Faroe Islands: An Example of Basalt Formation from Distinct Melting Regimes. *Earth Sciences*, **8**, 235-267. https://doi.org/10.11648/j.earth.20190805.11

[14] Morton, A.C. and Taylor, P.N. (1991) Geochemical and Isotopic Constraints on the Nature and Age of Basement Rocks from Rockall Bank, NE Atlantic. *Journal of the Geological Society*, **148**, 631-634. https://doi.org/10.1144/gsjgs.148.4.0631

[15] Gariépy, C., Ludden, J. and Brooks, C. (1983) Isotopic and Trace Element Constraints on the Genesis of the Faeroe Lava Pile. *Earth and Planetary Science Letters*, **63**, 257-272. https://doi.org/10.1016/0012-821x(83)90041-9

[16] Holm, P.M., Hald, N. and Waagstein, R. (2001) Geochemical and Pb-Sr-Nd Isotopic Evidence for Separate Hot Depleted and Iceland Plume Mantle Sources for the Paleogene Basalts of the Faroe Islands. *Chemical Geology*, **178**, 95-125. https://doi.org/10.1016/s0009-2541(01)00260-1

[17] Kempton, P.D., Fitton, J.G., Saunders, A.D., Nowell, G.M., Taylor, R.N., Hardarson, B.S., *et al.* (2000) The Iceland Plume in Space and Time: A Sr-Nd-Pb-Hf Study of the North Atlantic Rifted Margin. *Earth and Planetary Science Letters*, **177**, 255-271. https://doi.org/10.1016/s0012-821x(00)00047-9

[18] Morton, A.C. and Taylor, P.N. (1987) Lead Isotope Evidence for the Structure of the Rockall Dipping-Reflector Passive Margin. *Nature*, **326**, 381-383. https://doi.org/10.1038/326381a0