Sunken micro continents of the North Atlantic: Is the sub-basaltic Faroe Islands basement similar to the basement of the Rockall Plateau?

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Seafloor extension/stretching and associated rifting in the North Atlantic Area, which started in Early Paleogene times (From ~62 Ma), were rather complex affairs in their entireties. The pre-rift North Atlantic area was a patchwork of continental geological terrains being 'wreckages' from the closure of the ancient Iapetus Ocean. Current offshore areas in the North Atlantic known to harbour such ancient 'sunken' continental crust include the 'Faroe Islands - Rockall Plateau micro-continent', the 'Jan Mayen micro-continent', continental terranes beneath the Vøring- and Møre highs offshore West Norway and possibly also continental terranes below parts of Icelandic basalts. Published isotopic evidences for offshore continental materials (basement) of the North Atlantic are sparse, but some isotopic data exist for the Rockall Plateau, or more precisely the Rockall Bank. In this work contaminated basaltic rocks of the Faroe Islands, together with comparable materials from the NW margin of the Hatton bank are compared and contrasted with isotopic data for basement rocks of the Rockall Bank. The results for basaltic materials from at least one of the Faroese sills strongly suggest contamination with continental materials with isotopic lead compositions comparable to those reported for the Rockall Bank.

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 a wide geographical area [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. Combined these regions are most often referred to as the North Atlantic Igneous Province (NAIP) [2, 3]. Initial melts that gave rise to these basaltic magmas travelled from their sources in the upper mantle and according to location, while en-route to the Earth's surface ascended through materials comprised either of basaltic oceanic crust, or through more silica-rich continental

crust of various thicknesses. 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, very small amounts of crustal contaminants in basaltic melts are often hard or impossible to detect geochemically. In such cases, measurements using isotopes such as Sr, Nd or Pb can sometimes reveal even small crustal contaminants in basaltic magmas, as these are found in much larger concentrations in the continental crust when compared to the upper mantle [4].

In this study, Pb isotopic compositions in Early Paleogene basaltic rocks from a few sills of the Faroe Islands are compared and contrasted against those, measured for continental crust/basement of the Rockall Bank and Early Paleogene basaltic materials of the NW fringes of the Hatton Bank, in order to assess if there may be isotopic relationships between any of these.

Geology of the Faroe Islands and the Rockall Plateau

The Faroe Islands Basalt Group (FIBG), which forms a relatively central part of the NAIP, rests on an up to ~30 km thick continental basement (sunken micro-continent) [5]. The 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 [6], of which the 3 uppermost formations are intruded by a few basaltic saucer-shaped sills of various sizes (Fig. 1). Some of these can be grouped according to similarities in ages, geochemical and isotopic compositions [5, 7]. Examples include the two segments of the Streymoy Sill and the Kvivik Sill, the two segments of the Eysturoy Sill and the Sundini Sill, while other sills such as the Morskranes Sill display distinct ages, geochemistry and isotope compositions.

Parts of the Rockall Plateau are covered by widespread Paleogene lavas, which have been emplaced from large central igneous complexes and possibly also from widespread fissures, while basement rocks crop out in relatively restricted parts of the Rockall Bank and the Hatton Bank [8]. These latter are thought to be made up ofmetamorphic terranes overlain by sandstones and shale in places [8]. More detailed investigations of the eochemistry/petrography of basement materials sampled over wide geographic areas of the Rockall Bank have revealed that these were of granulitic and granitic compositions [9].

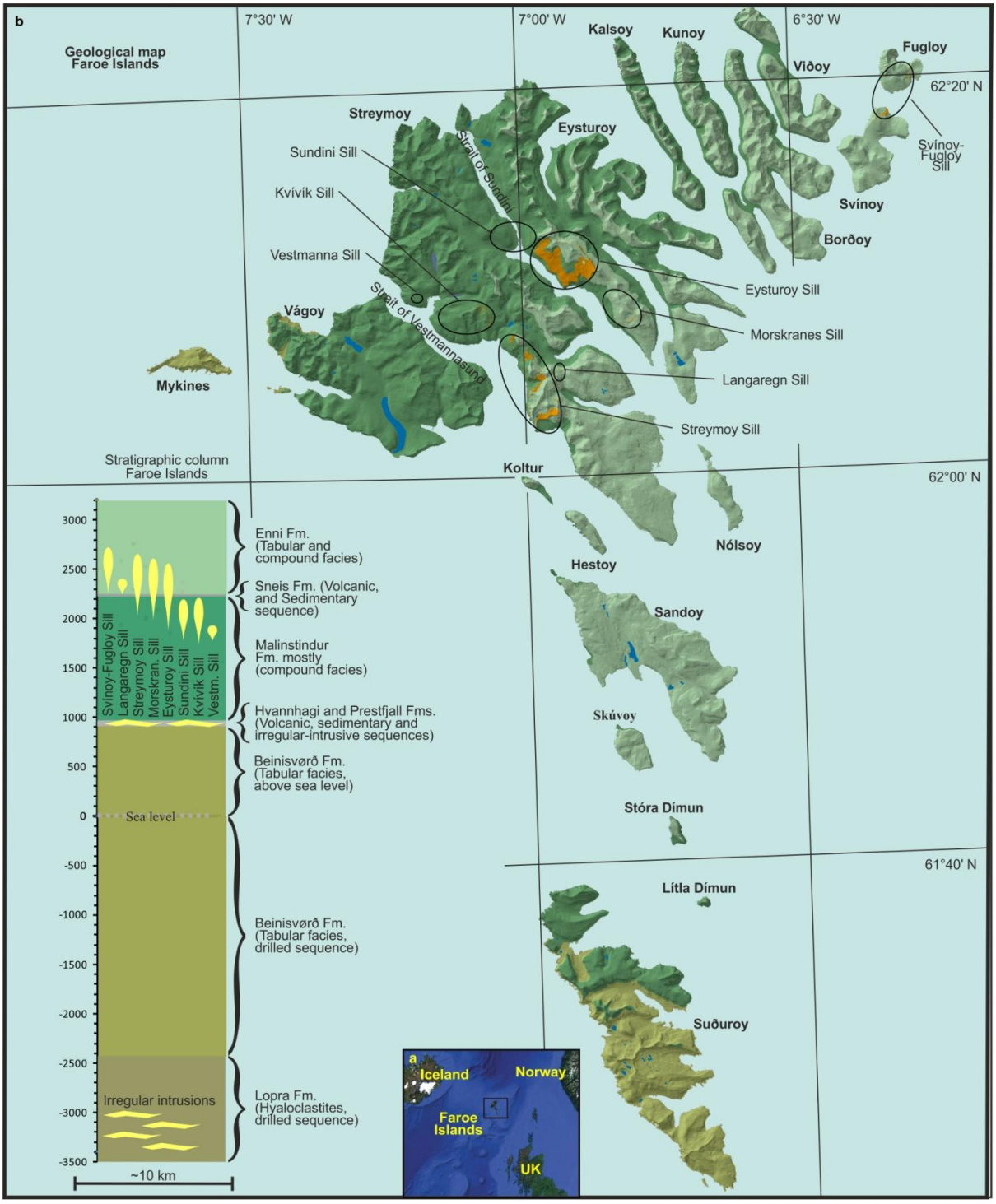

Fig.1 | Maps of North Atlantic areas (Modified from: Hansen and Ganerød, 2023)**. a**, Location of the Faroe Islands in the North Atlantic. **b**, Geological map of the Faroe Islands including stratigraphical column.

Objective and materials

In this work the aim is, if at all possible, to assess the nature of the sunken micro-continent on which the Faroese lava successions rest on, based chiefly on isotopic indications and interpretations. As no continental basement is exposed onshore the Faroe Islands, the one way to detect 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 lava successions from the upper mantle.

A few silica-rich 'presumably contaminated' basaltic horizons within the Faroese lava successions with silica contents ≥ ~53 weight percent, which also appear to be much enriched in Sr, Nd and Pb isotopes, have been reported previously [10, 11]. As such, these could potentially be utilised to assess the geochemical and/or isotopical make-up of the Faroese sub-basaltic basement, as has indeed been attempted earlier[5]. However, preliminary results from recent own investigations [unpublished] seem to suggest that these samples could be sedimentary specimen that originate from within the local basaltic rocks, thus rendering them unsuitable for the actual purpose. Other possibilities include Faroese sills, which are not noticeably enriched geochemically, but which do display moderate isotopic diversities. Here, the geochemically identical high-TiO_2 Eysturoy and Sundini sills, the geochemically identical low-TiO_2 Streymoy and Kvívík sills and the LREE depleted Morskranes Sill are of particular interest (Fig. 1).

Selected isotopes representing these 3 sill groups are compared/contrasted reported for the NW fringes of the Hatton Bank [12, 13] (Fig. 2).

Methods and results

In this contribution lead isotopes representing 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, are utilised in order to assess potential mutual relationships between any of these (Fig. 3). As there are no noticeable differences between configurations of age corrected versus

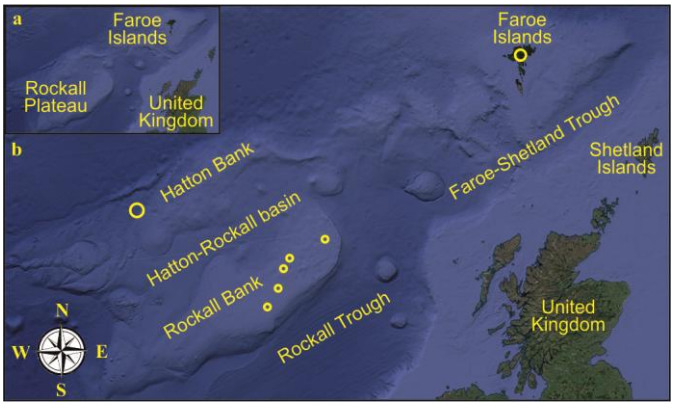

Fig.2 | North Atlantic maps (Based on Google Earth)**. a**, General/relative geographic locations of the Faroe Islands, UK and the Rockall Plateau. **b**, The map depicts sites where samples used in this contribution were collected. Small circles on the Rockall Bank represent sites of basement samples,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

actual measured lead isotope data, measured data are used in this work. against basement samples reported for the Rockall Bank [9] and Early Paleogene basalts

When it comes to lead isotopes for basalts sampled at the NE fringes of the Hatton Bank, the spread within all of these may suggest slight heterogeneities within their mantle source(s), when it comes to lead isotopes. However, the noticeable overall elongated configurations of the plotted samples combined towards larger ^{207}Pb values strongly suggests contamination with a crustal continental source enriched in ^{207}Pb isotopes, potentially with lead isotopic characteristics similar to that measured for the Rockall Bank, or with a specific Hatton Bank basement even more enriched in ^{207}Pb. Researchers from an earlier study on the Hatton Bank basalts came to roughly similar conclusions [12].

With respect to the Faroese basaltic materials, the 2 samples from the geochemically identical Eysturoy and Sundini sills display identical lead isotope compositions despite being sampled ~10 km apart, which indicate a homogeneous common mantle source for both and no crustal contamination. The geochemically identical Streymoy and Kvívík sills differ largely in their ^{207}Pb isotope contents, indicative of either slight heterogeneities in their mantl source(s) or of crustal contamination. In the latter case, a sub-basaltic basement contaminant, displaying lead

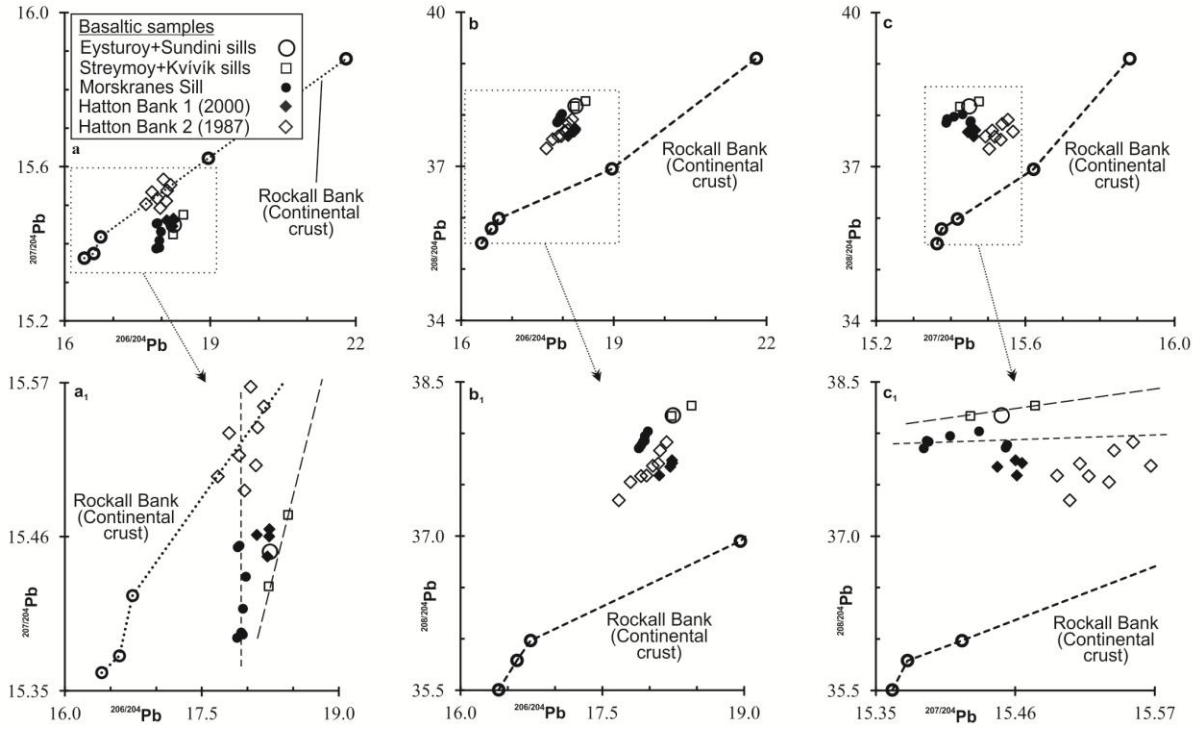

Fig.3 | Bivariate lead isotope plots. a and **a$_1$**, $^{206/204}$Pb versus $^{207/204}$Pb diagram(s) representing Faroese and Rockall Plateau data. **b** and **b$_1$**, $^{206/204}$Pb versus $^{208/204}$Pb diagram(s) representing Faroese and Rockall Plateau data. **c** and **c$_1$**, $^{207/204}$Pb versus $^{208/204}$Pb diagram(s) representing Faroese and Rockall Plateau data. Faroese data from Hansen et al. (2019), Hatton Bank data from Morton & Taylor (1987) and Kempton et al. (2000). Rockall Bank data from Morton & Taylor (1991).

isotope compositions broadly similar to that measured for the Rockall Bank, would be a natural candidate. The 7 samples representing the Morskranes Sill display clear evidences of crustal contamination with respect to their ^{207}Pb isotopes in particular. Also in this case, a sub-basaltic basement contaminant, displaying lead isotope compositions broadly similar to that measured for the Rockall Bank would be an obvious candidate. Alternatively, a sub-basaltic crustal contaminant even more enriched in ^{207}Pb isotopes, such as a potential specific Hatton Bank type basement, could be invoked as a candidate. 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 (Fig. 3).

In conclusion, sub-basaltic basement materials particularly enriched in their ^{207}Pb isotopes, similar to basement materials of the Rockall Bank, are likely candidates as contaminants responsible for the lead isotopic characteristics displayed by some basaltic sill samples of the Faroe Islands and by some basaltic lava samples of the Hatton Bank.

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