Anton Dohrn Seamount and the evolution of the Rockall Trough

E. John W. JONES a, Ruth SIDDALL a, Matthew F. THIRLWALL b, P. Neil CHROSTON c and Adrian J. LLOYD a

a Department of Geological Sciences, University College London, Gower Street, London WC1E 6BT, UK.
b Department of Geology, Royal Holloway, University of London, Egham Hill, Egham, Surrey TW20 0EX, UK.
c School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK.

Received 18/05/93, in revised form 6/12/93, accepted 13/12/93.

ABSTRACT

Seismic data from the flat-topped Anton Dohrn Seamount in the central Rockall Trough reveal that the feature is capped by a thin (~100 m) sedimentary layer which covers an extensive erosion surface lying approximately 800 m below sea level. The surface of erosion truncates a volcanic sequence that outcrops on the eastern side of the seamount to form a well-defined terrace from which alkali basalts and chalks of late Cretaceous age have been recovered. A refraction profile shot over the summit plateau and ultrasonic measurements on the basalts suggest that sedimentary and volcanoclastic units are abundant constituents of a low-velocity (3.69 km s⁻¹) volcanic core which persists to depths of over 1500 m. The seamount differs from the shallow Cenozoic volcanic piles in the region where high seismic velocities (> 5 km s⁻¹) occur close to the sea bed. Minor element abundances and REE inversion indicate that the Anton Dohrn basalts have been generated as a result of within-plate igneous activity, with most melting taking place in the spinel-garnet peridotite transition zone. Pb-isotope ratios are consistent with eruption of the basalts in an oceanic rift. There is no evidence for contamination by continental crust. The presence of late Cretaceous sediments, the REE patterns and Nd- and Pb-isotope ratios suggest that the seamount is related to a distinct phase of igneous activity pre-dating the development of the main Iceland plume. The cresta! erosion surface is probably of Paleocene age and directly associated with a broad regional uplift around Iceland. Its present depth is about one half of that predicted from subsidence models. The depth anomaly probably reflects continued dynamic support from the Iceland plume.


RÉSUMÉ

Le mont sous-marin Anton Dohrn et l’évolution du bassin Rockall

Des données sismiques du plateau du mont sous-marin Anton Dohrn, dans la partie centrale du bassin Rockall, révèlent que cette structure est surmontée d’un mince horizon sédimentaire (~100 m) couvrant une vaste surface d’érosion développée à une profondeur d’environ 800 m. La surface d’érosion tronque un
E.J.W. JONES et al.

substratum volcanique qui affleure sur le côté oriental du haut-fond pour créer une terrasse nettement dessinée d'où les basaltes alcalins et les craies datant du Crétacé terminal ont été récupérés. Un profil de sismique-réfraction pris sur le plateau sommital et des analyses par ultrasons suggèrent que les unités sédimentologiques et volcanoclastiques sont les composants abondants d'une armature volcanique de petite vitesse (3,69 km s⁻¹), qui persiste jusqu'à une profondeur supérieure à 1 500 m. Le haut-fond se distingue des autres structures volcaniques tertiaires de la région, où de grandes vitesses sismiques (> 5 km s⁻¹) sont rencontrées à proximité du fond marin. Les teneurs en éléments-traces et l'inversion des lanthanides indiquent que les basaltes Anton Dohrn ont été créés à la suite d'une activité ignée intra-plaque, l'essentiel de la fusion ayant lieu dans la zone de transition périodité à spinel-périodité à grenat. Les rapports des isotopes Pb concordent avec l'hypothèse d'une éruption des basaltes dans un rift océanique. Il n'y a aucune évidence de contamination par la croûte continentale. La présence de sédiments crétacés, la distribution des lanthanides et un faible rapport ¹⁴³Nd/¹⁴⁴Nd suggèrent que le haut-fond est en relation avec une phase distincte d'activité ignée précédant le développement du plume principal de l'Islande. La surface d'érosion sommitale date probablement du Paléocène et serait associée à un large soulèvement régional autour de l'Islande. Sa profondeur actuelle est d'environ la moitié de celle prévue par les modèles de subsidence. Cette anomalie de profondeur a probablement rapport avec un support dynamique par le plume de l'Islande.


INTRODUCTION

Anton Dohrn Seamount lies in the central part of the Rockall Trough, an elongated depression more than 2 000 m deep separating the continental shelf off Britain from the Rockall Plateau (Fig. 1). Early bathymetric surveys showed that it is a guyot with a summit level near 700 m (Dietrich and Ulrich, 1961). The origin of the feature and surrounding parts of the Rockall Trough has been the subject of much debate (Talwani and Eldholm, 1972; Roberts, 1975; Russell and Smythe, 1978; Roberts et al., 1981; Scrutton, 1986; Megson, 1987; Smythe, 1989). Some authors have suggested that the seamount is situated in a continental rift; others have argued that it lies in an oceanic trough that developed as a result of a northward propagation of the Mid-Atlantic Ridge during the Mesozoic.

It is well established that the crust in the vicinity of Anton Dohrn Seamount is much thinner than beneath the Rockall Plateau and the continental shelf west of the British Isles. The Moho depth under seismic refraction line E10 in Figure 1 is about 14 km (Jones et al., 1970), a figure which is consistent with free-air gravity anomalies recorded over the central Rockall Trough (Scrutton, 1972). By contrast, the continental crust beneath the Hebridean shelf to the east and the Rockall Plateau to the west is over 26 km thick (Scrutton, 1972; Bott et al., 1979; Jones et al., 1984). In both regions Precambrian Lewisian basement is exposed at the sea floor. Seismic refraction and wide-angle reflection measurements made with arrays of ocean bottom receivers and closely-spaced surface shots along lines G-H and I-J in Figure 1 also reveal a shallow Moho near Anton Dohrn Seamount and have been used to support the hypothesis that the region developed by asymmetrical stretching and thinning of continental crust (Roberts et al., 1988). Further south, Makris et al. (1991) have derived the velocity structure along track L-M in Figure 1 using ocean

Figure 1
Location of Anton Dohrn Seamount in the Rockall Trough. Bathymetric contours in metres are taken from Roberts et al. (1977). Positions of deep seismic profiles shot close to the seamount are labelled as follows: G-H and I-J (Roberts et al., 1988); L-M (Makris et al., 1991); E10 (Ewing and Ewing, 1959; Jones et al., 1970). K is the centre point of a two-ship oblique reflection/refraction profile shot parallel to the axis of the Rockall Trough (Joppen and White, 1990). Drill-site 1630-1A in the northern Rockall Trough is plotted from Morton et al. (1988).
Anton Dohrn Seamount and Rockall Trough Evolution

Figure 2
Bathymetry of Anton Dohrn Seamount (after Dietrich and Ulrich, 1961; Roberts et al., 1977). A-B is the location of an airgun reflection profile which is reproduced in Figure 3. C-D is an unreversed seismic refraction profile shot with a sonobuoy positioned at C; results are given in Figure 4. Basaltic rocks were recovered by dredging along the track labelled 42 on the eastern side of the seamount.

Seismic data

Airgun reflection profile A-B in Figure 3 shows a capping of sediments up to 0.1 s thick on the summit of the seamount. The sedimentary layer consists of a succession of reflectors resting on a strongly reflecting interface labelled X, which dips gently outwards from the central region. Other interpretations are possible, including ones invoking spreading during an earlier interval (Smythe, 1989) or the occurrence of swarms of linear basic intrusions separating strips of highly stretched continental crust.

Although Cenozoic sediments have been sampled from the deeper parts of the Rockall Trough by shallow coring and drilling (Latouche and Parra, 1976; Faugères et al., 1981; Masson and Kidd, 1986), basement rocks have been drilled at only one deep-water site, which lies north of Rosemary Bank (163/6-1A; Fig. 1). At this location over 1000 m of basalts and dacites were recovered below Upper Paleocene-Recent sediments. Morton et al. (1988) suggest on isotopic evidence that the basaltic rocks may have been contaminated with continental material, thus adding some support for the presence of stretched continental crust north of Anton Dohrn Seamount.

To investigate the origin of Rockall Trough further we have examined seismic data and rock samples collected from the crestal region of Anton Dohrn Seamount by the vessels R.R.S. John Murray and R.R.S. Shackleton. The seismic observations consist of a single-channel reflection recording along line A-B in Figure 2 and a refraction profile which was shot over the summit plateau on line C-D. The rocks were obtained by dredging the eastern side of the seamount along the short track labelled 42 in Figure 2. They show close similarities in composition and were found in association with chalks of Maastrichtian age which have been described earlier (Jones et al., 1974). The suite of rocks is small but has proved important to study because it comes from one of the few accessible basement windows in the axial region of the Rockall Trough.
reflects the long-term influence of the seamount topography on bottom water flow and deposition rates (Roberts et al., 1974).

The seismic velocity structure of the upper part of the seamount has been determined from an unversed refraction profile which was shot along line C-D (Fig. 2) using a free-floating sonobuoy and small explosive charges spaced at intervals of about 1 km. During the recording period the buoy drifted approximately 300 m northwards over an area of almost flat sea floor; the end of the line at C indicates its position at the mid-stage of shooting. Shot-

receiver ranges were calculated from direct water-wave arrivals using a horizontal sounding velocity of 1.489 km s$^{-1}$ derived from water temperatures and salinities. The vertical sounding velocity is 1.501 km s$^{-1}$.

Figure 4 shows a plot of arrival times for shots out to a range of 10.8 km from the sonobuoy. Two clear sets of refractions were observed, with apparent velocities of 1.98 km s$^{-1}$ and 3.76 km s$^{-1}$. The intercept time of the lower velocity line (G2) is consistent with propagation along the sea bottom; the velocity corrected for a low westward dip (0.4°) is 1.97 km s$^{-1}$. The same dip can be assumed for the second refractor (G1) since, with only a small difference (0.29 s) in intercept time, it must lie in the depth range of the shallow reflectors lying almost parallel to the sea floor on profile A-B; the dip-corrected velocity is 3.69 km s$^{-1}$.

The thickness of the sediment cover on the nearest portion of profile A-B, assuming a velocity of 1.97 km s$^{-1}$, closely corresponds with that of the 1.97 km s$^{-1}$ layer on the refraction line. The 3.69 km s$^{-1}$ refractor is thus coincident with reflector X and marks a large increase in seismic velocity at the prominent crestal erosion surface.

**DREDGED ROCKS**

Four large (5-20 kg) blocks of basalt with thin ferromanganese oxide coatings were recovered by dredging the eastern side of the seamount where reflector X outcrops. The rocks are associated with basaltic breccias containing Maastrichtian chalks, which have been described elsewhere (Jones et al., 1974), and with the reef-building coral Lophelia prolifera, fragments of which ranged from a few centimetres to more than half a metre. Calices of the terminal corallites still contained live tissue. The dredging track is shown in Figure 2.

**Petrography**

Samples were taken from the central part of each dredge block; these are designated 42A-D. In thin section, specimen 42A is a fine-grained, slightly vesicular rock showing a typical basaltic texture. It contains pseudomorphs after olivine phenocrysts, microphenocrysts and rare glomerocrysts of feldspar. The plagioclase is
dominantly labradorite with occasional bytownite in the groundmass. The latter contains magnetite, Ti-augite and devitrified glass, together with low-temperature alteration products which include clay, Fe$^{2+}$ and carbonate minerals. Carbonates also form the infillings of vesicles and veins. Sample 42B is an altered basalt having a more trachytic texture, with an alignment of fresh plagioclase laths and microphenocrysts of labradorite. There are rare glomerocrysts present, also composed of labradorite, and clay and carbonate pseudomorphs after olivine phenocrysts. The groundmass is made up of plagioclase laths, Ti-augite, magnetite and secondary clays, carbonates and Fe$^{2+}$ minerals. Vesicles and veins are filled with fibrous clay minerals and calcite.

Specimen 42C is a medium to fine-grained basalt with a sub-trachytic texture outlined by plagioclase laths, which are mainly labradorite. It contains numerous phenocrysts and microphenocrysts of clay minerals and carbonate pseudomorphs after olivine. The groundmass consists of plagioclase sub-ophitically enclosed by Ti-augite oikocrysts, as well as euhedral magnetite and rare devitrified glass. Secondary minerals are abundant. Fibrous clays form rosettes within interstices; Fe$^{2+}$-minerals, carbonates and chlorite occur in the groundmass. The few vesicles present are generally filled with zeolites, while fibrous carbonate minerals are seen in veins. Sample 42D is a fine-grained basalt with a sub-trachytic texture. It contains many phenocrysts of olivine entirely replaced by serpentine. Labradorite occurs as small laths and microphenocrysts. The groundmass is made up of plagioclase, magnetite in euhedral and skeletal forms and Ti-augite oikocrysts, as well as euhedral magnetite and rare devitrified glass. Secondary minerals are abundant. Fibrous clays form rosettes within interstices; Fe$^{2+}$-minerals, carbonates and chlorite occur in the groundmass. The few vesicles present are generally filled with zeolites, while fibrous carbonate minerals are seen in veins. Sample 42D is a fine-grained basalt with a sub-trachytic texture. It contains many phenocrysts of olivine entirely replaced by serpentine. Labradorite occurs as small laths and microphenocrysts. The groundmass is made up of plagioclase, magnetite in euhedral and skeletal forms and Ti-augite oikocrysts, as well as euhedral magnetite and rare devitrified glass. Secondary minerals are abundant. Fibrous clays form rosettes within interstices; Fe$^{2+}$-minerals, carbonates and chlorite occur in the groundmass. The few vesicles present are generally filled with zeolites, while fibrous carbonate minerals are seen in veins.

Ultrasonic measurements

P-wave velocities were measured on 2.5-cm diameter cores taken from samples 42B, 42C and 42D, using a pulse-transmission method with PZT-5A transducers operating at 1.0 MHz. Measurements were made at confining pressures up to 2.4 kbar (0.24 GPa), with a vent allowing pore fluids to escape so that pore pressures were effectively atmospheric. Velocities were determined on both the increasing and decreasing parts of the pressure cycle but the difference was small; each point on the plot in Figure 5 is the mean of two values.

Velocities in the samples, 5.2-5.8 km s$^{-1}$ at 2 kbar (0.2 GPa), are close to those predicted from their densities (2.68-2.74 Mg m$^{-3}$) using the relationships given by Christensen and Salisbury (1975). The small velocity-pressure gradients seen in Figure 5 (0.08-0.16 km s$^{-1}$/kbar; 0.8-1.6 km s$^{-1}$/GPa) have been observed in other studies of ocean floor basalts and indicate 'tight' rock specimens, with low porosities contained within low-aspect ratio cracks (see, for example, Toksöz et al., 1976). Porosities of the Anton Dohn core samples measured at atmospheric pressure are less than 2%. The velocities throughout the pressure range are appreciably higher than the 3.69 km s$^{-1}$ value obtained for the material below the sedimentary cover on refraction profile C-D (Fig. 4). Although refraction velocities are likely to be less because of the effects of large-scale fractures and joints which cannot be accounted for in our laboratory measurements, the large velocity difference is likely to reflect the inclusion of low-velocity pelagic deposits, such as the Maastrichtian chalks already sampled from the area, and thick volcanogenic sediments within the main basaltic sequence.

Geochemistry

Major element analyses of the basalts were carried out on a Philips PW 1480 X-ray fluorescence spectrometer using fused discs made from unwashed and unleached crushed samples from the interiors of the dredged blocks. In selecting the samples, care was taken to avoid any part affected by infiltration of ferromanganese oxides. Except for Co, Li and the rare earths, which were determined on a Philips PV8210 ICP atomic emission spectrometer, other elements were measured by XRF using pressed pellets with a matrix correction calculated from major element analyses. Major, minor and rare earth element...
and Nd-isotope ratios in basalts from Anton Dohm Seamount.

Table 1

**Composition of basalts from Anton Dohrn Seamount.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>42A</th>
<th>42B</th>
<th>42C</th>
<th>42D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>42.94</td>
<td>42.26</td>
<td>43.47</td>
<td>44.27</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>16.93</td>
<td>17.44</td>
<td>16.21</td>
<td>16.88</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>13.16</td>
<td>14.49</td>
<td>12.81</td>
<td>13.14</td>
</tr>
<tr>
<td>CaO</td>
<td>5.87</td>
<td>13.88</td>
<td>14.95</td>
<td>13.88</td>
</tr>
<tr>
<td>MgO</td>
<td>4.70</td>
<td>4.96</td>
<td>6.52</td>
<td>5.49</td>
</tr>
<tr>
<td>Na₂O</td>
<td>2.66</td>
<td>2.65</td>
<td>2.65</td>
<td>2.88</td>
</tr>
<tr>
<td>K₂O</td>
<td>1.453</td>
<td>1.442</td>
<td>1.006</td>
<td>1.239</td>
</tr>
<tr>
<td>TiO₂</td>
<td>1.787</td>
<td>1.833</td>
<td>1.747</td>
<td>1.856</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.318</td>
<td>0.382</td>
<td>0.287</td>
<td>0.309</td>
</tr>
<tr>
<td>MnO</td>
<td>0.171</td>
<td>0.234</td>
<td>0.194</td>
<td>0.178</td>
</tr>
<tr>
<td>Total</td>
<td>99.99</td>
<td>99.57</td>
<td>99.84</td>
<td>100.12</td>
</tr>
<tr>
<td>LOI</td>
<td>9.04</td>
<td>8.84</td>
<td>7.47</td>
<td>6.77</td>
</tr>
</tbody>
</table>

Table 2

**Pb- and Nd-isotope ratios in basalts from Anton Dohrn Seamount.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Isotopes</th>
<th>Measured ratio</th>
<th>Initial ratio (70 Ma)³</th>
</tr>
</thead>
<tbody>
<tr>
<td>42B</td>
<td>⁴⁰Pb/²⁰⁴Pb</td>
<td>18.027</td>
<td>17.922</td>
</tr>
<tr>
<td>42B</td>
<td>⁴⁰Pb/²⁰⁴Pb</td>
<td>15.448</td>
<td>15.443</td>
</tr>
<tr>
<td>42B</td>
<td>³⁹Pb/²⁰⁴Pb</td>
<td>37.989</td>
<td>37.920</td>
</tr>
<tr>
<td>42C</td>
<td>³⁹Pb/²⁰⁴Pb</td>
<td>18.197</td>
<td>18.111</td>
</tr>
<tr>
<td>42C</td>
<td>³⁹Pb/²⁰⁴Pb</td>
<td>15.495</td>
<td>15.491</td>
</tr>
<tr>
<td>42C</td>
<td>⁴⁰Pb/²⁰⁴Pb</td>
<td>38.162</td>
<td>38.040</td>
</tr>
<tr>
<td>42C</td>
<td>⁴⁰Pb/²⁰⁴Pb</td>
<td>0.51287¹</td>
<td>(±0.00001)</td>
</tr>
</tbody>
</table>

³ Initial Pb isotope ratios calculated using Th and Pb from Table 1 and assuming U = 0.3 ppm.

Initial Nd isotope ratios are normalized for mass fractionation using results obtained on NBS SRM 981. Sr isotope data were not obtained because of the limited preservation of primary igneous phases; insufficient augite is present to permit concentration by leaching.

On the Ti-Zr-Y diagram in Figure 6 the four dredge blocks fall in the within-plate basalt field and are quite distinct from the basalts of Rosemary Bank and drill-site 163/6-1A in the northern Rockall Trough (Fig. 1). The Anton Dohrn samples exhibit similar patterns on the chondrite-normalized multi-element plot in Figure 7, each showing a moderate enrichment in more incompatible elements. For comparison, Figure 7 also includes plots for MORB, ocean island basalts and Hebridean Skye lavas. Ce/Pb ratios (9-16) are higher than in continental crust (~4) but lower than in most oceanic volcanics (~25; Hofmann et al., 1986).

These lower values may imply crustal contamination or simply Pb addition during alteration. A Nb anomaly is lacking but there is a strong positive K anomaly, which again might be due to alteration or contamination by continental crust. The Pb-isotope ratios in blocks 42B and 42C (Tab. 2) are, however, more consistent with an oceanic origin for the seamount; both samples lie within the North Atlantic MORB field on a ²⁰⁷Pb/²⁰⁴Pb-²⁰⁷Pb/²⁰⁴Pb plot (Fig. 8). There is no evidence for contamination by continental crust as seen, for example, in the early Cenozoic lavas on the Isle of Skye in the Hebrides, where Pb-isotope ratios form a linear array that indicates mixing of Archaean (Lewisian) continental basement and 60 Ma mantle-derived Pb (Moorbath and Welke, 1969; Dickin, 1981). Average Pb-isotope ratios given by Dickin (1981) for Lewisian granulites and amphibolite gneiss are plotted in Figure 8 a, together with his estimated composition of the sub-Hebridean mantle.

REE patterns in Figure 9 reveal the distinctive character of the Anton Dohrn lavas compared with N-type MORB and basalts associated with the Iceland plume at drill-site 163/6-1A and DSDP site 336. The seamount samples also differ from the Jurassic lavas of the North Sea Forties Field which are related to an enriched upper mantle at the
confluence of three continental rift zones (Latin, 1990; McKenzie and O'Nions, 1991); higher REE concentrations in the range La-Dy are found in the Forties volcanics. Differences between the Anton Dohrn basalts and products of the Iceland plume are also evident from the Pb-isotope data (Fig. 8 a) and the \(^{143}\text{Nd}/^{144}\text{Nd}\) ratio of 0.512871 in sample 42C (Tab. 2), which is appreciably lower than in Icelandic basalts (O’Nions et al., 1977; Zindler et al., 1980).

**Figure 8 a**
Age-corrected Pb-isopic composition of dredge samples from Anton Dohrn Seamount compared with Atlantic MORB and Icelandic basalts (Dupré and Allegre, 1980; Cohen and O’Nions, 1982; Dusse et al., 1991), and basalts from drill-site 163/6-1A in the northern Rockall Trough (Morton et al., 1988). Points showing the mean compositions of Lewisian granulite-facies gneiss and amphibolite-facies gneiss, and an estimated composition for the sub-Hebridean mantle are taken from Dickin (1981).

**Figure 8 b**
Anton Dohrn basalts shown on a \( \varepsilon_{\text{Nd}} - 206\text{Pb}/204\text{Pb} \) plot. Compositional fields of MORB and Icelandic basalts are taken from Staudigel et al. (1984) and references cited therein.
1982). Anton Dohrn Seamount may therefore represent a small but distinct precursory plume to Iceland. The combined Pb-Nd isotope composition of its lavas (Fig. 8 b) is unusual for North Atlantic basalts (Cohen and O’Nions, 1982; Condomines et al., 1983; Elliot et al., 1991; Sun and Jahn, 1975). Some older Icelandic basalts (e.g. I-13 of Cohen and O’Nions, 1982) approach the combination of low εNd and low 206Pb/204Pb; a few Hawaiian lavas also have similar characteristics (Staudigel et al., 1984). Overall, the Pb-Nd isotopes suggest enriched mantle as a minor component of the Anton Dohrn mantle source.

**DISCUSSION**

Seismic profiles A-B and C-D show that the crest of Anton Dohrn Seamount is covered by up to 100 m of sediments which bury an almost flat erosional surface marking the top of the volcanic basement. The basement velocity of 3.69 km s⁻¹ (Fig. 4) differs little from that in the Upper Basalt Series of the Faeroes (~3.9 km s⁻¹; Palmason, 1965), but is appreciably lower than in the basaltic sequence exposed on Faeroe Bank (4.2 km s⁻¹; Jones and Ramsay, 1982). Beneath the Faeroes seismic velocities increase from ~3.9 km s⁻¹ near the surface to 4.9-5.3 km s⁻¹ at a depth of 300 m. Such an increase is not observed on Anton Dohrn Seamount; the line of 3.76 km s⁻¹ first arrivals on profile C-D extends out to the furthest shot without evidence of a break to higher velocities (Fig. 4). If material with velocities exceeding 5 km s⁻¹ is present then it must lie at least 1.8 km below the crest to account for the head-wave arrival time at the longest range. Much of the seamount is therefore made up of low-velocity volcanics, in marked contrast to the early Cenozoic basaltic accumulations associated with the Iceland plume further north.

The composition of the Anton Dohrn basalts is distinctly different from the Cenozoic lavas of the Faeroe-Iceland Ridge and at drill-site 163/6-1A in the northern Rockall Trough (Fig. 8, 9). The recovery of Maastrichtian chalcedonite from the seamount (Jones et al., 1974) indicates that it belongs to a phase of volcanic activity that preceded the eruption of the thick lava sequences to the north and the start of sea-floor spreading between Rockall and Greenland. Pb-isotope ratios in samples 42B and 42C are consistent with the conclusion of Roberts et al. (1981) that a narrow oceanic rift extended into the Rockall Trough during the Cretaceous. There is no evidence for continental contamination in the small suite of samples available to us. Pb-isotope ratios in basalts from site 163/6-1A fall above the MORB field (Fig. 8 a) which, according to Morton et al. (1988), may reflect addition of continental material. If this interpretation is correct, then a strip of oceanic basement extending along the axial region of the Rockall Trough from the south terminates against stretched continental crust between the Anton Dohrn Seamount and the lower flank of the Wyville-Thomson Ridge (Fig. 1).

Variations in the melt fraction with depth below Anton Dohrn Seamount have been derived from REE concentrations (Tab. 1) using the inversion method of McKenzie and O’Nions (1991); a 65 km-thick lithospheric cap to melting is assumed. The two curves in Figure 10 a suggest a large proportion of melt was generated in the depth and temperature range of the transition from a spinel to a garnet peridotite mantle. The calculated thickness of melt is approximately 2.5 km (D.P. McKenzie, personal communication, 1993). In Figure 10 b the dotted line shows melting caused by adiabatic decompression with a mantle potential temperature, Tp, of 1450°C (McKenzie and Bickle, 1988). The close fit of the curves for fractions exceeding 0.04 implies that the underlying mantle was some 150°C hotter than beneath a normal oceanic ridge (Tp ~ 1300°C). Melting beneath Anton Dohrn Seamount extended much deeper into the mantle (> 110 km) than...
under normal ridge crests, where it is largely confined to levels above 75 km (White et al., 1992). High mantle temperatures in this part of the Rockall Trough during the late Cretaceous may have influenced the maturation and migration rates of hydrocarbons in the Mesozoic basins beneath the adjacent continental margins.

Comparison of the morphology of Anton Dohrn Seamount with other volcanic features indicates that during the late Cretaceous it stood at least 2000 m higher than at present (Jones et al., 1974). The intense erosion that led to the formation of its striking summit plateau is likely to have taken place in the Paleocene when large areas of western Britain were uplifted and deeply denuded (Hall, 1991). At this time, some 2000 m of roof and cover formations, comparable in thickness to those eroded from Anton Dohrn Seamount, were stripped from the major igneous centres of Northwest Scotland, including Skye, Mull and Arran (George, 1966). The erosion was rapid. In the Hebrides, for example, roughly 2000 m of lavas were removed from Mull during the interval 58-56 Ma BP (Curry et al., 1978). The uplift and denudation were probably related closely to the development of the Iceland plume.

Since the extensive planation of its summit Anton Dohrn Seamount has sunk approximately 800 m. This is about 800 m less than predicted from the subsidence curves of McKenzie (1978) for a feature formed on Cretaceous (~70 Ma) ocean floor. Further south, basement depths are also smaller than those calculated from subsidence models. Near point K in Figure 1 Joppen and White (1990) have found basement to be about 700 m shallower than expected from an observed minimum stretching factor of 6. Dynamic support of the lithosphere by the Iceland plume is the most plausible explanation for the shallowness of Anton Dohrn Seamount and adjacent parts of the Rockall Trough. Buoyancy forces associated with the plume appear to have caused uplift in regions as far as 1000 km from Iceland (White and McKenzie, 1989).

Strong evidence for similar dynamic support of anomalously shallow regional topography has also been found around the Cape Verde hotspot in the Equatorial Atlantic (Courtney and White, 1986).

Acknowledgements

We are most grateful to the staff of the Natural Environment Research Council's ship operations base in Barry for their help in collecting the seismic data and dredge samples described in this paper. Rock analyses in Tables 1 and 2 were carried out at London University's Intercollegiate Radiogenic Isotope and XRF Facility at Royal Holloway. We are indebted to Professor Dan McKenzie for his advice at an early stage of the work and for allowing us to include his inversion of the rare earth element data which is shown in Figure 10. We have also benefited from discussions with Dr. Pascale Besson, Professor Dennis Curry, Professor Desmond Donovan and Dr. Hilary Downes, and from the assistance of Sheila Barrett. Thorough reviews by Dr. C. Devey and an anonymous referee helped us to improve the original manuscript. Financial support was provided by the Natural Environment Research Council (grant GR/2568).
REFERENCES


