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ORIGIN OF THE PHOENIX RIDGE BASALTS, DRAKE PASSAGE, ANTARCTICA AND IMPLICATIONS FOR EXTINCTION OF SEAFLOOR SPREADING

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1. INTRODUCTION

Understanding the sequence of events leading to the cessation of spreading at ridge segments approaching subduction zones is of great interest. In the Drake Passage, between South America and Antarctica, the last remnant of the once-extensive Phoenix-Antarctic spreading center, the Phoenix Ridge, appears to have become extinct at some time during the Pliocene (Larter and Barker, 1991). As a result, a small remnant of the former Phoenix plate, confined between the Shackleton and Hero Fracture Zones, has become welded to the Antarctic plate. Larter and Barker (1991) indicated that three inactive segments of the Phoenix Ridge survive, which called (northeast to southwest) as P1, P2, and P3 (Fig. 1). On the basis of new bathymetric and

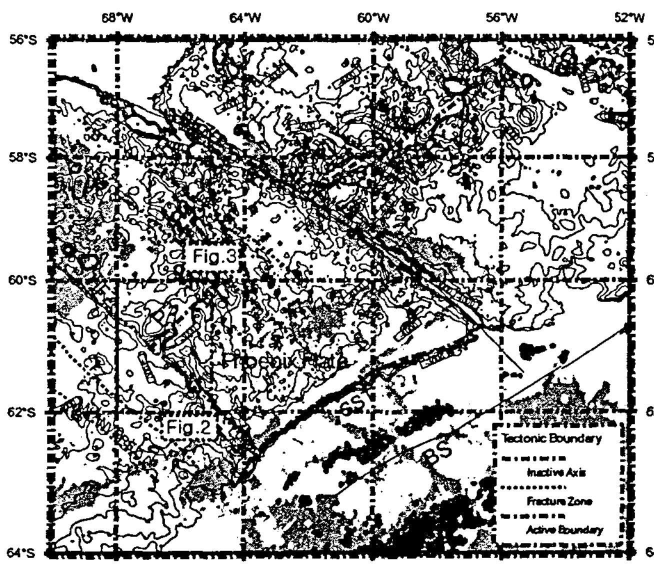

Fig. 1. Tectonic boundary map over the bathymetry predicted using satellite altimetry in Drake Passage (Smith and Sandwell, 1994). Dark gray area shows below 4000 m depth and light gray above 3000 m. Solid lines are active oundaries, dotted lines represent the fracture zones and the thick dotted lines represent inactive spreading axis. BS, Bransfield Strait; HFZ, Hero Fracture Zone; P1, P2, P3, Phoenix Ridges; SFZ, Shackleton Fracture Zone; SST, South Shetland Trench; WSR, West Scotia Ridge.

magnetic anomaly data, Livermore et al. (2000) suggested that extinction of all three remaining segments occurred at the time of magnetic chron C2A (3.3±0.2 Ma), synchronous with a ridge-trench collision south of the Hero Fracture Zone. The Phoenix Ridge has the characteristics of both intermediate-spreading ridges far away the ridge axis and slow-spreading ridges near the axis. At the last of spreading, the spreading rates have the different values between the southern and the northern flank. It means that the spreading of the Phoenix Ridge is asymmetric during the terminal activity (Fig. 2 and 3).

During the 1999-2000 austral summer season, a half of P3 segment was mapped using a multibeam echo sounder fitted to the Korean research vessel R/V *Onuri* (Fig. 2), and an anomalously big seamount at the spreading axis was found. During the 2000-2001 and 2002-2003 summer cruises with R/V *Yuzhmorgeologiya,* submarine fresh lavas from the P2 and P3 segments have been intensively dredged, and geochemically investigated.

We present new results of K-Ar ages, whole-rock geochemistry and Sr-Nd-Pb isotopes for the submarine basalts from the P2 and P3 segments, and will discuss about the time-dependent geochemical variation and the exact extinction time of the Phoenix Ridge.

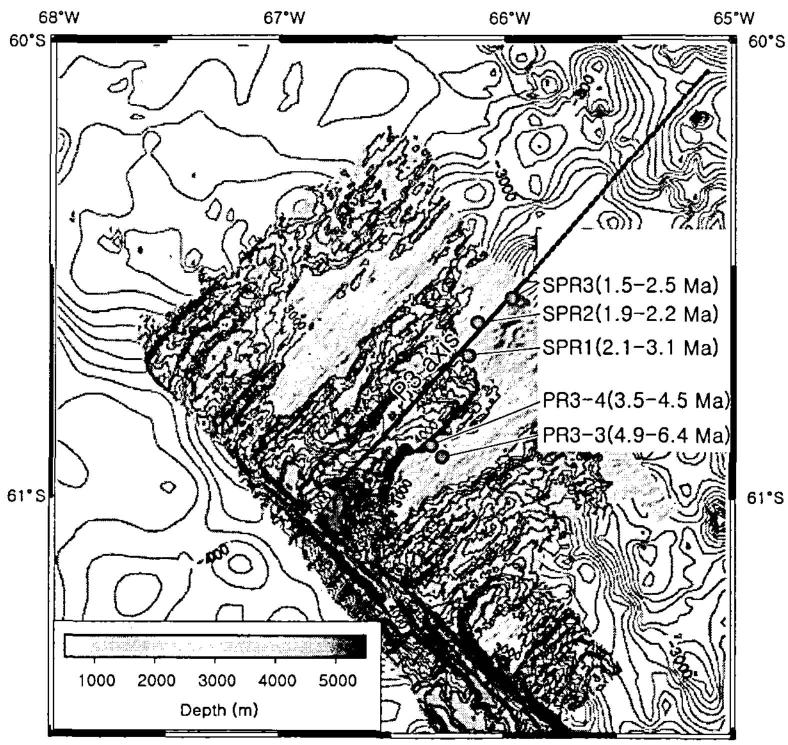

Fig. 2. Bathymetry of P3 segment of the Phoenix Ridge, obtained using SEABEAM 2000 mutibeam sonar. Shaded relief representation illuminate from northeast. Solid circles represent sampling locations together with K-Ar age ranges.

2. SUMMARY AND CONCLUSIONS

Though some of the volcanic glasses occurred at the surface of pillow lavas show abnormally old ages (older than 70 Ma) due to excess radiogenic Ar, most of lavas have K-Ar ages ranging from 1.4 to 6.4 Ma. At the P3 segment, the K-Ar ages of the southeastern rifted ridge basalts (PR3) are 3.5-6.4 Ma, and those for axial seamount basalts (SPR) are 1.5-3.1 Ma.

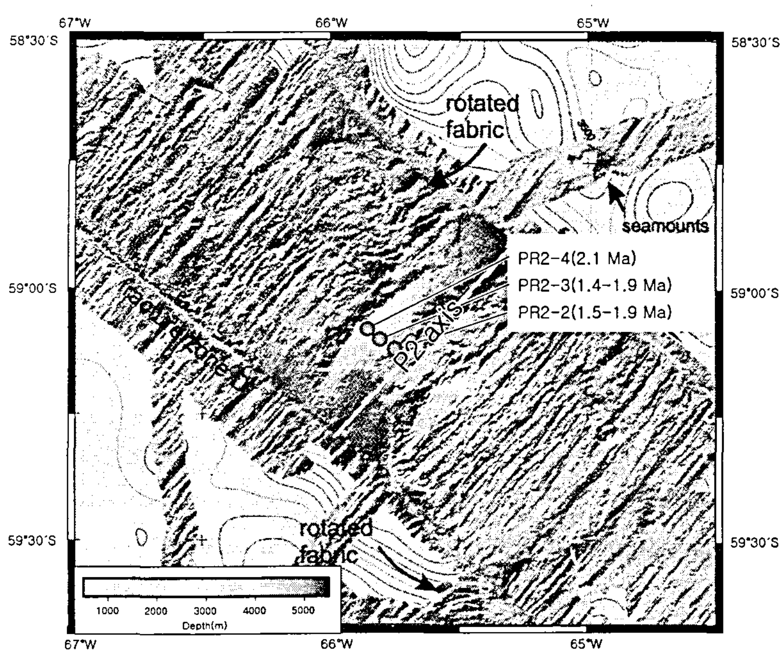

Fig. 3. Bathymetry of P2 segment of the Phoenix Ridge, obtained using Simrad EM12 multibeam sonar (Livermore et al., 2000). Shaded relief represents illumination from south. Contours indicate depths predicted from satellite altimetry (modified from Smith and Sandwell, 1994). Solid circles represent sampling locations together with K-Ar age ranges.

The K-Ar ages for the basalts at the northwestern rifted ridge in the P2 segment (PR2) are 1.4-1.9 Ma. Considering that the rifted ridge basalts were formed at a former axial topographic high, it is likely that the extinction of seafloor spreading at the P3 and P2 segments occurred at 3.3 and 1.5 Ma, respectively. This result favors a stepwise extinction model rather than a simultaneous one on the extinction of the Phoenix Ridge.

Volcanic rocks are mostly basaltic lavas with glassy surfaces, and have SiO_2 contents ranging from 49 to 52, MgO from 4 to 9 and Al_2O_3 from 15 to 18 wt.%. The volcanic lavas from the P3 segment (PR3, older than 3.3 Ma) are low-K tholeiitic basalts, and geochemically similar to N-type

MORB, except some higher concentrations of alkali elements (Cs, Rb and K). The lavas from the P2 segment (PR2) and P3 axial seamount (SPR) with younger ages than 3.3 Ma are medium-K, mildly alkaline basalts. They show similar enriched trace element patterns (E-type MORB geochemistry) except Pb concentration (Fig. 4), This temporal variation suggests that the melting degree decreased and the melting depth deepened after 3.3 Ma, following that the melting zone became cool down to a depth of garnet peridotite field.

The younger basalts (PR2 and SPR with E-type MORB geochemistry) generating from deeper mantle are isotopically less depleted than the older basalts (PR3), indicating the isotopic heterogeneity of the uppermost mantle sources responsible for the formation of primary magmas beneath the Phoenix Ridge (Fig. 5). The shallower upper mantle related to the generation of PR3 magma would have been more depleted due to time-integrated, voluminous output of magmas since late Mesozoic.

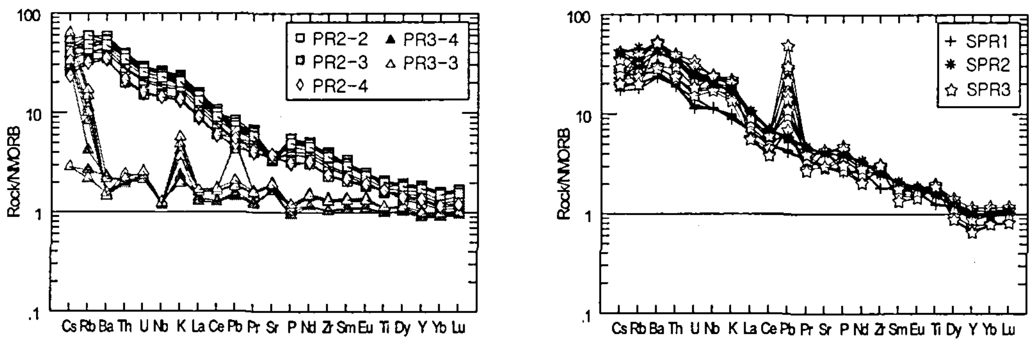

Fig. 4. N-MORB normalized diagrams of the Phoenix Ridge (Sun and McDonough, 1989).

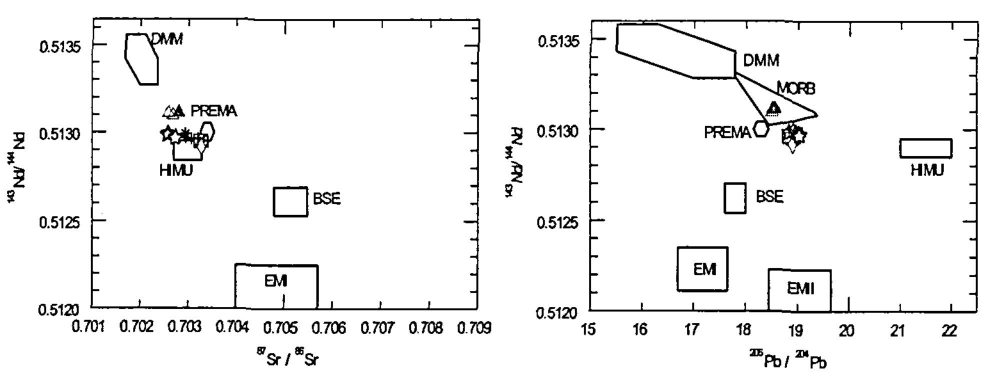

Fig. 5. Plots of $^{87}Sr/^{86}Sr$ versus $^{143}Nd/^{144}Nd$ and $^{143}Nd/^{144}Nd$ versus $^{206}Pb/^{204}Pb$ for samples from the Phoenix Ridge.

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