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Formation of the Japan Sea basin: Reassessment from Ar–Ar ages and Nd–Sr isotopic data of basement basalts of the Japan Sea and adjacent regions

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ABSTRACT

Many studies have examined the Japan Sea basalts recovered during Ocean Drilling Program (ODP) Leg127/128. Of these, the ^{40}Ar–^{39}Ar dating undertaken is important in constraining the timing of the formation of the Japan Sea; however, the implications of their results do not appear to be fully appreciated by the geological community. In this paper, I reassess the ^{40}Ar–^{39}Ar age data of the basalts with reference to Nd–Sr isotopic data. The ^{40}Ar–^{39}Ar dating was performed on basalts somewhat enriched in large-ion lithophile elements and recovered from ODP Sites 794, 795 and the lower part of 797, yielding the plateau ages of 21.2–17.7 Ma. These basalts show the Nd–Sr isotopic signature of a moderately depleted mantle source (ε_{Nd}: 0.6–6.9). In contrast, the basalts from the upper part of Site 797 have yet to be dated due to their low K content, although their Nd isotopic compositions are similar to that of MORB (ε_{Nd}: 8.4–10.4). By analogy to the secular Nd–Sr isotopic trends reported for Sikhote-Alin and northeast Japan, the age of the upper basalts at Site 797 may be inferred to be younger than the lower basalts, probably around 16 Ma. The Nd–Sr isotopic compositions of the Japan Sea basalts have been interpreted in terms of eastward asthenospheric flow, as have the lavas of the Sikhote-Alin and northeastern Japan. The timing of volcanic activity in the Japan Sea region (i.e., from 21.2 to 14.86 Ma) is consistent with the timing of rotational crustal movements inferred from paleomagnetic studies of the Japanese Islands (i.e., 14.8–4.2 Ma for southwest Japan and 16.5–14.4 Ma for northeast Japan).

Contents

1. Introduction

The debate concerning the origin of the Japan Sea moved from speculation to quantitative reasoning with Kawai et al.'s (1961, 1971) proposal regarding the bending of the Japanese Islands based on paleomagnetic data. The idea that the Japanese Islands and the Japan Sea formed as a result of back-arc spreading is consistent with Kawai et al.'s model (Uyeda and Miyashiro, 1974). During the early 1980s, researchers were especially interested in the process of the formation of the Japan Sea, particularly the

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timing of its opening. At that time, the only relevant paleomagnetic data available to researchers (in addition to that of Kawai et al.) were the studies by Otofuji and Matsuda (1983, 1984) who reported that southwest Japan underwent a clockwise rotation of 56° at around 15 Ma. Based on this finding, the resultant model of the opening of the Japan Sea is simple and clear (Otofuji et al., 1985a,b); however, the theory encountered intense objections because the rotational movement was considered much faster than that possible within the realm of plate tectonics (Lallemand and Jolivet, 1985).

Seismic surveys undertaken in the 1970s first revealed basaltic basement beneath the Japan Sea (Hilde and Wageman, 1973). In a study of the Sr and Nd isotopic compositions of Quaternary volcanics in northeast Japan, Nohda and Wasserburg (1981) found that basalts of the Japan Sea have similar isotopic and chemical compositions to those of MORB, which is known to be related to back-arc spreading at continental margins.

The significance of the results of these studies, particularly the paleomagnetic data, led the Ocean Drilling Program (ODP) to investigate the Japan Sea region (Fig. 1). ODP Leg127/128 succeeded in coring through sediments of the Japan Sea and recovering basaltic basement rocks (Tamaki et al., 1990)—a task worthy of praise given the difficulties involved in penetrating more than 1000 m of sediment and avoiding gas fields. The large amount of important data presented in ODP Science Results (1992) should have increased our understanding of the Japan Sea as a back-arc basin; however, the level of enthusiasm for research into the Japan Sea showed a rapid decline following publication of the report, as indicated by a reduction in the numbers of papers published with a focus on the Japan Sea.

It is important to ask whether this report provided satisfactory conclusions regarding the origin of the Japan Sea. The results provided in the report should have advanced our understanding in this regard, yet more than 15 years have now passed without a genuine in-depth discussion of the origin of the Japan Sea. In this study, however, it would not be constructive to dwell on or seek to explain this dearth of analysis.

Instead, it would be of great value, in terms of understanding the geologic development of the Japan Sea basin and the chance of attracting future basalt-coring projects to the area, to review those papers that deal with the geochronology of the cored basement basalts obtained during ODP Leg127/128. For this purpose, the present study reevaluates the results of Ar–Ar dating of the basement basalts and considers the data in terms of Nd–Sr isotopic compositions and trace element geochemistry. This approach is important because the ODP basalts appear to preserve their original chemical and isotopic characteristics despite their altered appearance. The aims of the present paper are to correct a misleading interpretation of the chronology of the formation of the Japan Sea and revive interest in the evolutionary processes of marginal basins within the East Asia.

2. Results of isotopic age dating

ODP Leg 127/128 targeted four coring sites (Fig. 1): Sites 794 and 797 in the Yamato Basin, and Sites 795 and 796 in the Japan Basin (Tamaki et al., 1990). Basement basalts were recovered at Sites 794, 797, and 795. Site 797 attained the greatest depth (903 m) and recovered the greatest thickness of basalt (341 m), covering the longest time span (Fig. 2).

2.1. Basalts from Sites 794, 797, and 795

Coring at Site 794 recovered 191 m of the basalt (Fig. 2) interpreted to be tholeiitic basalt based on chemistry and the quench-

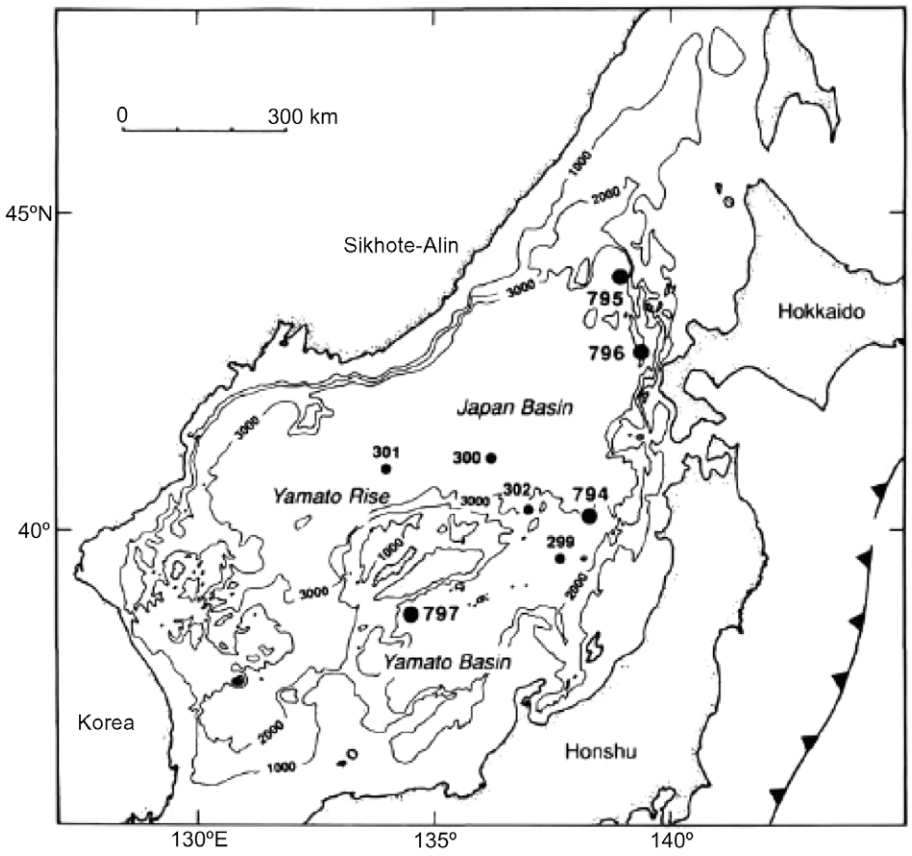

Fig. 1. Map of the Japan Sea showing the drilling sites of ODP Leg127/128. DSDP sites are also shown. Adopted from Tamaki et al. (1990).