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Discrete plumbing systems and heterogeneous magma sources of a 24 km^3 off-axis lava field on the western flank of East Pacific Rise, 14 °S.

Nobuo Geshi [a,*], Susumu Umino [b], Hidenori Kumagai [c], John M. Sinton [d], Scott M. White [e], Kiyoyuki Kisimoto [a], Thomas W. Hilde [f]

[a] *Geological Survey of Japan, AIST, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan*
[b] *Department of Biology and Geosciences, Graduate School of Science, Shizuoka University, 836, Ohya, Suruga-ku, Shizuoka, 442-8529, Japan*
[c] *Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15, Natsushima, Yokosuka, Kanagawa 237-0061, Japan*
[d] *Department of Geology and Geophysics, University of Hawaii, 1680 East-West Road, Honolulu, HI 96822, USA*
[e] *Department of Geological Science, University of South Carolina, Columbia, SC 29208, USA*
[f] *Department of Geology and Geophysics, Texas A and M University, College Station, TX 77843-3115, USA*

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Abstract

The largest known mid-ocean-ridge off-axis lava flow field occurs slightly off-axis near 14 °S along the East Pacific Rise (EPR). It comprises at least four volcanologically discrete units. We collected lava samples from 24 sites within the off-axis lava field and 7 sites on the adjacent ridge crest using the Shinkai-6500 submersible. The lava field comprises at least three distinct MORB compositions, all of which are different from the lavas collected from the nearby ridge axis. The east and west cones and the northern lobe of the lava field consist of normal MORB (N-MORB) lavas with a low concentration of incompatible elements and low LILE/HFSE and LREE/HREE ratios. By contrast, the samples from the west plain of the field have a higher concentration of incompatible elements and higher LILE/HFSE and LREE/HREE ratios indicating T-MORB character. The lava samples collected from the summit of the east cone show the highest concentration of LILE elements and LREEs among the lava field (E-MORB lava). The N-MORB of the off-axis lava field are more depleted in incompatible elements than the adjacent EPR axis lavas, possibly reflecting the re-melting of the residual mantle in the off-axis region. The E-MORB lava was probably derived from fertile mantle that did not undergo melting beneath the spreading center. T-MORB, which occupies the main part of the 14 °S lava field, is the product of magma mixing between N-MORB and E-MORB magmas.

Keywords: East Pacific Rise; off-axis volcano; mid-ocean ridge; lava flow; MORB; Shinkai 6500

* Corresponding author. Tel.: +81 298 61 3599; fax: +81 298 56 8725.
E-mail address: geshi-nob@aist.go.jp (N. Geshi).

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1. Introduction

Recent surveys along the mid-ocean ridge system have revealed the existence of many "off-axis" lava fields close to the East Pacific Rise (EPR), the fastest spreading center on the earth [1–4]. The presence of these off-axis fields indicates that the magmatic activity of the mid-ocean ridge system is not limited to the ridge axis but is spread over several kilometers extending away from the spreading center and includes off-axis volcanism. Off-axis volcanic activity adds to the pile of lava layers at the off-axis area. More than half of the extrusive layer of the EPR was possibly emplaced in the off-axis region [5,6], suggesting the importance of off-axis magmatism in the development of fast-spread ocean crust. Understanding emplacement mechanisms and the petrology and geochemistry of off-axis lava flows is therefore essential to comprehensively understand the evolution of the oceanic crust and the magmatic plumbing systems in fast-spreading ridges.

To investigate the off-axis magma plumbing process in the EPR region, we surveyed the distribution of an off-axis lava flow field on the western flank of the EPR 14 °S region and collected lava samples from it during the NIRAI-KANAI Cruise (YK04-07) in July–August 2004 using the *R/V Yokosuka* and *Shinkai 6500* submersible of JAMSTEC [7]. We conducted four dives on the 14 °S lava flow field and two dives on a nearby ridge crest ca. 30 km south of the 60 center of the 14 °S lava field (Fig. 1). In addition, we conducted one submersible dive on an off-axis seamount at 16 °S. These dives provided the first bottom observations of large off-axis lava field and the volcano-tectonic features of the ridge axis in this region. In this paper, we present the results of the petrological examinations of the 14 °S lava flow field.

2. Geographical and geological features

The 14 °S off-axis lava flow field occurs along the western flank of the EPR, 2–19 km from the nearby ridge axis. The lava field spreads from 13°40′S to 14°07′S and covers an area of approximately 49 km × 16 km (Fig. 1A, B). The total area of the lava field is 420 km^2 and its volume exceeds 24 km^3. Side-scan sonar images reveal the 14 °S lava field is recognized as a region of higher sonar backscatter as compared to the surrounding seafloor (Fig. 1C) [7]. This indicates that a thinner cover of soft sediment exists on this field.

The lava flow field can be divided into four volcanic domains based on topographic character: the east cone, west plain, west cone, and northern lobe (Fig. 1A, B). The east cone is a volcano with flat top and surrounded by arcuate terraces. The summit of the east cone is 2.5 km from the present spreading axis. The volcano is approximately 6 km across at the base and 350 m in height. Small knolls, several tens of meters high, exist on the flat top of the volcano. The surface of the cone is covered with pillow lava running down from the summit. Lavas erupted from the east cone cover an area of approximately 72 km^2 and the estimated volume of the east cone is 7.2 km^3.

The west plain comprises the central portion of the 14 °S off-axis lava field, covering an area of approximately 251 km^2, which is larger than that of the previously largest-known off-axis lava on the EPR [8]. Assuming the average thickness of the lava of the west plain to be 50 m, the total volume is estimated to be 12.6 km^3. An alignment of the low ridges running along the NNE–SSW direction occurs along the highest region of the west plain. From the topographic character and flow structure of the lava, this ridge is likely to be an eruptive fissure of the central lava flow. The main part of the west plain is characterized by smooth-surface sheet flows with many collapse pits and fissures.

The west cone is a circular flat-top seamount with a diameter of 4 km and height of nearly 350 m with smaller satellite cones aligned parallel to the present ridge axis. The lava flows from the west cone are best exposed at the western foot of the west cone and the eastern half is probably covered by the lavas of the west plain. The lavas of the west cone and the minor satellite cones are exposed over an area of about 74 km^2. The total volume of the west cone is estimated to be approximately 4 km^3. The sides of the west cone were covered by elongated pillow lava running down the slope. The sonar backscatter is the weakest on the west cone of the 14 °S off-axis lava field (Fig. 1C). This suggests that the west cone has the thickest sediment, and is likely the oldest part of the 14 °S off-axis lava field.

The northern lobe, which is characterized by a shield-like rise, is 7.5 km long and 4 km wide with a narrow branch extending along a graben to the north. The northern lobe covers an area of 22.3 km^2. Its volume is estimated to be 2.1 km^3. In the 14 °S lava field, the sonar backscatter is the highest for the northern lobe (Fig. 1C), which suggests that this region might be the youngest part of the lava field. The surface of the northern lobe is covered by pillow lava.