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15. GEOCHRONOLOGY AND PETROLOGY OF THE IGNEOUS BASEMENT AT THE LOWER NICARAGUAN RISE, SITE 1001[1]

Christopher W. Sinton,[2] Haraldur Sigurdsson,[2] and Robert A. Duncan[3]

ABSTRACT

^{40}Ar-^{39}Ar incremental heating experiments and electron microprobe analyses were performed on basaltic rocks recovered from Site 1001 during Ocean Drilling Program Leg 165. The lower Nicaraguan Rise, on which Site 1001 lies, appears to be part of a larger Caribbean oceanic plateau that makes up the core of the Caribbean plate. Our results indicate an eruption age of 81 ± 1 Ma. A single flow-rim glass is tholeiitic and almost identical to the shipboard X-ray fluorescence analyses of the whole rock. The slightly porphyritic basalts have at least two populations of plagioclase, groundmass, and glomerocrystic plagioclase laths that appear to be in equilibrium with the surrounding melt and corroded tabular phenocrysts that have a higher An content ($An_{84–86}$).

INTRODUCTION

The core of the Caribbean plate is comprised of oceanic crust that appears to be the remnants of an oceanic plateau (e.g., Duncan and Hargraves, 1984; Sinton et al., 1998). The study of this oceanic plateau has been predominantly centered on its obducted margins that are subaerially exposed along the perimeter of the plate (e.g., Klaver, 1987; Sen et al., 1988; Alvarado et al., 1997; Kerr et al., 1997; Sinton et al., 1997) because these areas are relatively accessible. However, the relationship between the obducted margins and the intact plateau has an element of uncertainty, so it is preferable to sample the plateau directly by drilling. Presently, the Caribbean crust has been penetrated by drilling during Leg 15 of the Deep Sea Drilling Project (DSDP) and most recently during Leg 165 of the Ocean Drilling Program.

DSDP Leg 15 drilled into the uppermost few meters of the oceanic crust at five sites: three in the Venezuelan Basin (Sites 146, 150, and 153), one from the Beata Ridge (Site 151), and one from the Nicaraguan Rise/Hess Escarpment (Site 152) (Fig. 1). The Colombian Basin basement was not sampled. The drilled units are thick, coarse-grained basaltic sills or flows overlain by, or intruding, foraminiferal limestone (Donnelly et al., 1973). Fossils within the overlying or intruded sediments are as old as Coniacian (89.0–85.8 Ma; Gradstein et al., 1994) in the Venezuelan Basin. The extraordinary thickness of the crust (as thick as 15–20 km in some areas) and the similar ages of sediments over the smooth basement in the Venezuelan Basin led Donnelly (1973) to conclude that the region had experienced a flood basalt event. Site 152 differs from the other DSDP sites in that it is located on thinned crust between the Hess Escarpment and the Beata Ridge and the recovered flows are surrounded by early Campanian-age sediments.

Although the main objectives of Leg 165 were to recover the sedimentary record within the Caribbean region, a secondary objective was to penetrate the igneous basement beneath the sediments. This objective was reached at Site 1001 in the southern-most edge of the lower Nicaraguan Rise along the Hess Escarpment (Fig. 1), approximately 40 km southwest of DSDP Site 152. Basaltic basement rocks were drilled in Hole 1001A for a total penetration of 37.65 m with 20.5 m recovered.

Detailed descriptions of the lithology and petrography of the basalts recovered at Site 1001 can be found in Sigurdsson, Leckie, Acton, et al. (1997). The basalts are overlain by Campanian limestones containing fossils that indicate that the basalts had erupted by at least 77 Ma. The basaltic sequence can be divided into 12 distinct units that likely represent individual lava flows and associated hyaloclastite beds. Flow margins are often highly vesiculated and glassy. The succession is dominated by aphyric basalt, but sparsely plagioclase-phyric and plagioclase and pyroxene-phyric basalts are also present.

Here we report the results of ^{40}Ar-^{39}Ar radiometric dating and electron microprobe analysis of flow-rim glass and plagioclase crystals from some of the recovered basalts. An average of three ^{40}Ar-^{39}Ar analyses indicate an eruption age of 81 ± 1 Ma. A single glass sample analyzed by microprobe analysis is tholeiitic and almost identical to the shipboard X-ray fluorescence (XRF) analyses of the whole rock. The slightly porphyritic basalts have at least two populations of plagioclase, groundmass, and glomerocrystic plagioclase laths that appear to be in equilibrium with the surrounding melt and corroded tabular phenocrysts that have a higher An content ($An_{84–86}$).

RESULTS

Electron Microprobe

A single basalt glass sample and plagioclases from three samples were analyzed for major elements using the Cameca CAMEBAX electron microprobe at Brown University. The electron beam was set at 15 nA beam current and 15 kV accelerating voltage. Analyses were performed on polished thin sections and the results are shown in Table 1.

The pillow-rim glass is from the aphyric Formation L. Its composition is tholeiitic and is very similar to the shipboard whole-rock analysis of the same flow (Table 1). Plagioclase analyses were performed on basalts from sparsely plagioclase-phyric (Formation B), plagioclase and pyroxene-phyric (Formations G and H), and aphyric (Formation L) basalts. Plagioclase phenocrysts are euhedral to subhedral and may display evidence of disequilibrium with the surrounding melt (rim corrosion and embayments). The relatively high anorthite content of phenocryst cores from Formations B (An_{84}) and H (An_{86}) and the lower anorthite contents of the rims and groundmass laths ($An_{73–60}$) also indicate that some of the phenocrysts are not in

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[2]Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882, U.S.A. (Present address: New York State College of Ceramics, Alfred University, Alfred, NY 14802, U.S.A.) sintoncw@alfred.edu

[3]College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331, U.S.A.

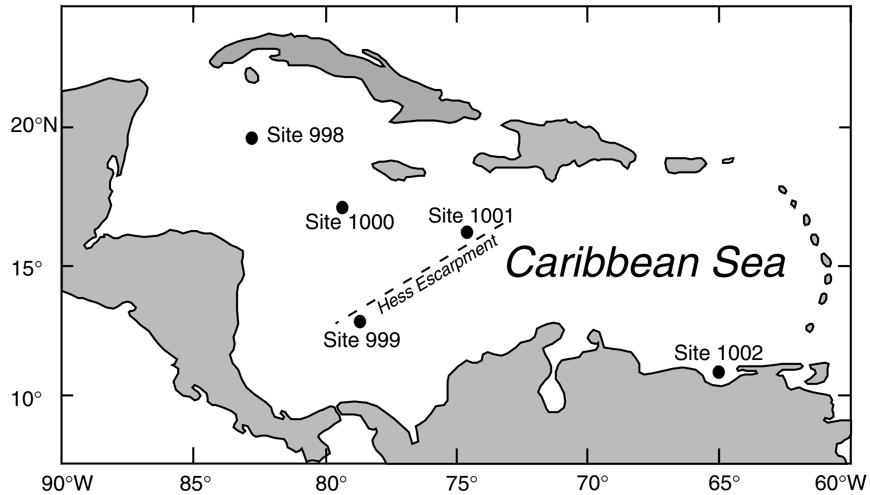

Figure 1. Schematic map of the Caribbean region showing the drilling sites for Leg 165.

Table 1. Electron microprobe analyses of Hole 1001A basalt glass and representative feldspars.

Core, section, interval (cm):	56R-2, 33	56R-2,77-80	53R-4, 105			54R-6, 134		55R-1, 9		56R-2, 33	
Formation:			Formation B			Formation G		Formation H		Formation L	
Sample:	Glass	Whole rock*	P. core	P. rim	Gmass	P. core	Gmass	P. core	Gmass	Glom.	Lath
SiO_2	49.99	49.80	46.88	53.13	53.67	50.49	55.24	46.19	49.77	49.98	50.31
TiO_2	1.48	1.45									
Al_2O_3	13.90	14.50	33.25	28.75	28.55	30.56	27.13	33.77	30.8	31.12	30.28
FeO	12.51		0.54	0.95	1.19	0.70	1.14	0.46	0.68	0.72	0.91
Fe_2O_3		11.50									
MnO	0.24	0.20									
MgO	7.32	7.01									
CaO	12.36	13.02	17.08	12.35	12.25	14.82	10.66	17.66	14.68	14.56	14.27
Na_2O	2.36	2.26	1.78	4.29	4.51	3.03	5.39	1.54	3.01	2.86	3.12
K_2O	0.05	0.19	0.00	0.00	0.02	0.01	0.04	0.02	0.01	0.01	0.01
P_2O_5	0.09	0.10									
LOI	1.45										
Total	100.30	100.05	99.54	99.47	100.19	99.62	99.61	99.64	98.95	99.25	98.91
An%			84.10	61.40	60.00	72.90	52.10	86.30	72.90	73.70	71.60

Notes: Beam conditions were 15 nA beam current and 15 kV accelerating voltage. * = from Sigurdsson, Leckie, Acton, et al. (1997). P = phenocryst, Gmass = groundmass plagioclase lath, Glom = plagioclase and pyroxene glomerocryst, LOI = loss on ignition, blank cells = element not analyzed.

equilibrium with the melt and they could therefore be defined as xenocrysts.

Geochronology

Age determinations on three whole-rock samples were performed at Oregon State University using standard ^{40}Ar-^{39}Ar incremental heating techniques (Duncan and Hargraves, 1990). Samples were irradiated at the Oregon State University TRIGA reactor for 6 hr, and neutron flux was monitored by FCT-3 biotite (28.04 ± 0.12 Ma; Renne et al., 1994). Ar isotopic composition of whole-rock basalts were determined using either an Associated Electrical Industries MS-10S mass spectrometer or a Mass Analyzer Products (MAP) 215-50 mass spectrometer attached to a low-blank, all-metal extraction line.

Individual ages for each ^{40}Ar-^{39}Ar step were calculated after corrections for background, mass fractionation, isotopic interferences, and atmospheric argon content. Step ages and Ar isotopic measurements for each sample are reported in Table 2. Plateau ages were calculated using the procedure described in Dalrymple et al. (1987), in which step ages were weighted by the inverse of their variance. Weighted linear regressions of the step compositions in each of the isotope correlation diagrams yielded a slope that is proportional to the age (isochron), with the inverse of the y-intercept giving the initial ^{40}Ar-^{36}Ar composition at the time of crystallization.

Table 2. ^{40}Ar-^{39}Ar plateau and isochron age calculations, Site 1001.

Core, section	Material	Plateau age by $1/\sigma^2$ (Ma)	^{39}Ar (% of total)	Isochron age (Ma)	*N*	^{40}Ar-^{36}Ar intercept ± 1 σ
165-1001A-						
54R-7	Basalt	81.3 ± 5.4	85	81.7 ± 6.2	6	293.7 ± 5.7
53R-3	Basalt	80.8 ± 1.3	50	80.2 ± 2.5	5	300.1 ± 5.6
56R-3	Basalt	81.0 ± 1.2	55	85.3 ± 5.6	4	290.8 ± 32.7

Notes: Section 165-1001A-54R-7 was analyzed using the AEI MS-10S and Sections 165-1001A-53R-3 and 165-1001A-56R-3 were analyzed using the MAP 215-50. Errors for both step age plateaus and isochrons are reported to 2 σ. Ages are corrected for ^{37}Ar decay, half-life = 35.1 days. $\lambda_\varepsilon = 0.581 \times 10^{-10} yr^{-1}$; $\lambda_\beta = 4.962 \times 10^{-10} yr^{-1}$. *N* = the number of steps used in the isochron calculation.

Three whole-rock analyses yielded consistent "plateau" and isochron ages of approximately 81 Ma with calculated initial ^{40}Ar-^{36}Ar values close to atmospheric (295.5). The lowest uncertainties (± 1.3 and ± 1.2 Ma) are from the plateau ages from the two samples analyzed with the low-blank MAP 215-50, although the isochron ages display much higher uncertainties. Because the ages for all three samples are close to 81 Ma, a 1- to 2-m.y. uncertainty can be assigned on the assumption that the MS10 analysis overestimates the uncertainty, primarily because of the higher system blank.

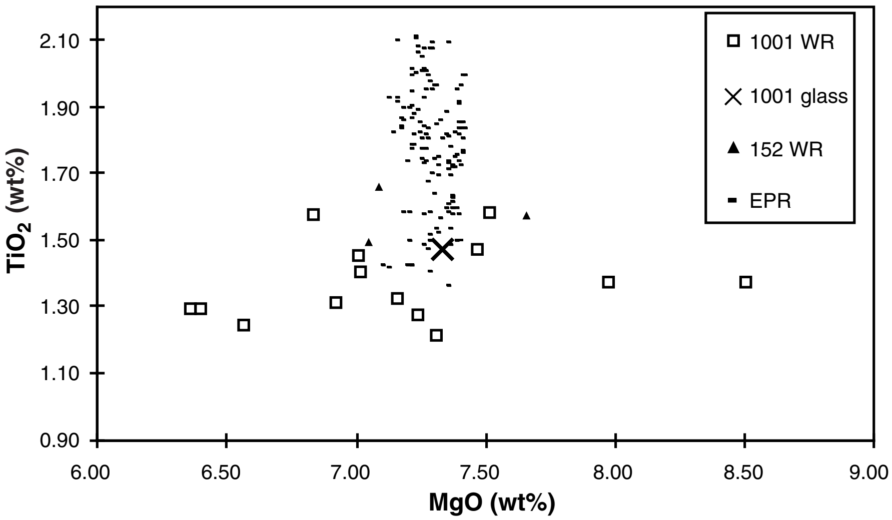

Figure 2. TiO_2 vs. MgO diagram comparing the Site 1001 basalt glass reported in this paper and the whol rock (WR) basalts from Site 1001 (Sigurdsson, Leck Acton, et al., 1997) to the basalts recovered in nearby Site 152 (Bence et al., 1975) and modern basalt glass from the East Pacific Rise (EPR; Joint Oceanographi Institutions, Inc. compilation).

DISCUSSION

The lack of significant sediment intercalations in the Site 1001 basalt stratigraphy and the similarity of the radiometric ages indicate that the penetrated lavas erupted over a relatively short time period (at least less than the uncertainty of the dating). Furthermore, the chemical variations of the basalts are very slight and indicate that all of the recovered basalts are from a single volcanic source (Sigurdsson, Leckie, Acton, et al., 1997). The shipboard XRF major and trace element analyses show that the basalts are similar to mid-ocean ridge basalts (MORB) and unpublished isotopic data from the Site 1001 basalts are also consistent with derivation from a MORB source (D.G. Pearson, pers. comm., 1998). The compositional similarity of the Site 1001 basalts and the Site 152 basalts, as well as the similarity in the age of the overlying sediments, suggests that they are related to the same magmatic event. Taken together, the uppermost igneous basement in this region of the lower Nicaraguan Rise/Hess Escarpment consists of MORB-like basalts that erupted at roughly 81 Ma.

Comparison between Site 1001 basalts and MORB erupted at the East Pacific Rise (EPR) shows that there are some subtle but significant compositional differences. Using the Joint Oceanographic Institutions, Inc., database for EPR glass analyses from 14°S to 16°N within the range of 7.2%–7.4% MgO, the Site 1001 glass (7.32% MgO) is at the lower end of the spectrum in terms of incompatible elements such as TiO2 (Fig. 2), Na_2O, K_2O, and P_2O_5. In terms of mantle source and/or melting conditions, this may signify that the Site 1001 lavas were derived from either a more depleted mantle source or higher degrees of partial melting relative to MORB.

In addition to the 90-Ma Gorgona Island basalts and komatiites (Kerr et al., 1996) and possibly some Cretaceous basalts in Haiti (Sen et al., 1988), the Site 1001/152 basalts can be included in the few MORB-like lavas from the Caribbean plateau. All of the other lavas have some “enriched” component (Sinton et al., 1998). Taken together, the mantle sources for the Caribbean plateau are diverse and laterally heterogeneous.

Based on radiometric ages from the obducted margins of the plateau, a large proportion of the plateau erupted by at least ~90 Ma, and the synchroneity of ages across the region is consistent with a flood basalt origin for the bulk of the Caribbean plateau. A volumetrically secondary, but widespread magmatic event occurred at roughly 76 Ma (Sinton et al., 1998). The ~76-Ma magmatism on the Caribbean plateau could have resulted from lithospheric extension that caused mantle upwelling and partial melting. At this time the plateau was being emplaced between North and South America (Pindell and Barrett, 1990). It is possible that associated extension produced lithospheric thinning and allowed upwelling and decompression melting of residual hot mantle. Given the uncertainty of the radiometric and fossil ages, the Sites 1001 and 152 area may fall into the ~76-Ma “event,” but it is apparent that submarine magmatism after 90 Ma occurred in various Caribbean locations (Sinton et al., 1998) and that the coincidence of ~76-Ma magmatism at several locations may not necessarily indicate a discrete event.

CONCLUSIONS

The youngest period of volcanism at the lower Nicaraguan Rise/Hess Escarpment in the vicinity of Sites 1001 and 152 occurred at about 81 Ma. The basalts are tholeiitic and generally similar to MORB in composition, although the comparatively low incompatible element concentrations (at the same MgO concentrations) in the Site 1001 glass may signify derivation from either a more depleted mantle source or higher degrees of partial melting. The volcanism at this site is part of the continuing widespread submarine volcanism in the region that postdates the initial 90-Ma eruptions of the Caribbean oceanic plateau.

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