21. LEAD ISOTOPIC COMPOSITION AND URANIUM, THORIUM, AND LEAD CONCENTRATIONS IN SEDIMENTS AND BASALTS FROM THE NAZCA PLATE

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ABSTRACT

Lead isotopic compositions and U, Th, and Pb concentrations have been determined in 11 basalt and 3 sediment samples from Leg 34 of the Deep Sea Drilling Project. The 232Th/238U ratios and the Pb isotopic compositions of the basalts suggest that they are typical oceanic tholeiites originating from the extinct Galapagos Rise. The similarity in the Pb isotopic composition, when corrected for in situ U decay, for all basalt samples analyzed suggests that they were extruded from a portion of the mantle in which the Pb isotopic composition is homogeneous, or that mantle convection and/or mixing proportions of partial melts between the mantle plume and the low velocity zone were constant for the interval 15-40 m.y. ago. The Pb concentration in the Pliocene sediment analyzed is about average for deep-sea sediments, but is about 10 to 20 times higher than those of the middle and lower Miocene sediments analyzed. The low Pb concentration in the Miocene sediments may be attributed to carbonate accumulation. The Pb isotopic composition of the lower Miocene sediment is similar to those of the basalt samples analyzed in this study, but the Pb isotopic compositions of the two overlying sediments are different.

INTRODUCTION

By drilling into the Nazca plate we may be able to determine the origin of the metalliferous sediments of the Bauer Deep (Boström and Peterson, 1966; Dasch et al., 1971) and whether Andean magmas and related ore bodies can be related chemically to subducted metalliferous sediments.

We have analyzed the Pb isotopic compositions and Pb, U, and Th concentrations of three sediment and six basalt samples from Site 319 (Holes 319 and 319A) and five basalt samples from Site 321 of Leg 34 of the Deep Sea Drilling Project.

This is a preliminary report of whole rock data. A complete report will be published upon completion of analyses of mineral separates.

EXPERIMENTAL

Samples

Samples were collected by the participants of Leg 34 of the Deep Sea Drilling Project aboard *Glomar Challenger* (Hart and Yeats, pers. comm.; Scientific Staff of Leg 34, 1974). Three sediments, representing the upper, middle, and bottom sediment units, and one basalt from just below the sediment-basalt boundary from Hole 319, five basalt samples from Hole 319A, and five basalt samples from Site 321 were analyzed for U, Th, and Pb concentrations and Pb isotopic compositions. Site 319 is in the Bauer Deep, on the west side of the extinct Galapagos Rise (13°01.04'S, 101°13.46'W). Site 321 is on the eastern edge of the Nazca plate west of the Peru-Chile Trench (12°01.29'S, 81°54.24'W). Sample depths below the sea floor and analytical results are shown in Table 1.

Analytical Procedures

Rock samples were cut into 3/4-in. cubes with a diamond saw, then washed with doubly distilled 2.5 N HC1 for about 30 sec and rinsed four times with quadruply distilled water with the aid of an ultrasonic vibrator. The cubes used for whole rock analysis were crushed in a stainless steel mortar and powdered in a carbide-lined stainless steel container by a vibrating mill.

Chemical procedures were similar to those reported by Nunes et al. (in press) with modifications to accommodate larger sample sizes. Lead, uranium, and thorium concentrations were determined by isotope dilution on an aliquot of a dissolved sample. Samples were decomposed using HClO₄ as well as HF and HNO₃ in a Teflon bomb to insure total dissolution of the sample, and thus, complete equilibrium between thorium in the spike and sample. The resulting solution was evaporated to dryness and then fumed with HClO4 to convert all fluorides to more soluble perchlorates. The residue was then taken up with dilute HNO₃ and divided into two parts, one of which was spiked (designated by an A next to the concentration data in Table 1). The concentrations of some samples were checked by total spiking a powder split before decomposition (designated by a TS in Table 1).

Lead was separated by a double anion exchange resin method, first in HBr medium and then in HC1 medium. Lead blanks ranged from 0.7 to 2.0 ng for 0.1- to 0.3-g-sized samples (TS) and from 2.0 to 4.1 ng for 0.5- to 1.0-

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|----------|---------------------|---------------|--|----------------------------|-------------------------------|----------------------|-----------------|---|----------------------------|-------------------|-------------------------------|------------------|-------------------|------------------|------------------|------------------|-------------------|----------------|
| | 9. march | | | Raw Data | | | | Corrected for Blank and Fractionation 1 | | | | | | | _ | | | |
| Sample | Sample (Interval | Depth Below | | 206 Pb | 207 Pb | 208 Pb | Type of | 206 Pb | 207 Pb | 208 Pb | 207 _{Pb} | 208 Pb | Total Spike or | U | Th | Ph | 232 _{Th} | 238 U |
| No. | in cm) | Sea Floor (m) | Sample Type | 204 Pb | 206 _{Pb} | 206 Pb | Analysis | 204 Pb | 204 Pb | 204 _{Pb} | 206 _{Pb} | 206 Pb | Aliquot | (ppm) | (ppm) | (ppm) | 238 U | 204 Pb |
| Hole 319 | | | | | | | | | | | | | | | | | | |
| 1 | 1-6, 5-6 | 7.55-7.56 | Pliocene iron- bearing cal- careous clay | 18.446 18.444 | 0.83978 0.83965 | 2.0621 | C P | 18.483 18.481 | 15.537 15.533 | 38.186 | 0.84067 0.84049 | 2.0663 | A | 2.611 | 2.405 | 70.41 | 0.952 | 2.346 |
| 2 | 7-1, 7-9 | 57.0709 | Middle Miocene nanno ooze | 18.364 18.351 18.369 | 0.84216 0.84215 0.84232 | 2.0650 | C P C2 | 18.401 18.388 18.406 | 15.511 15.501 15.520 | | 0.84294 0.84298 0.84320 | 2.0691 | A TS | 0.263 0.268 | 0.0889 0.0926 | 4.269 4.560 | 0.349 0.356 | 3.889 3.714 |
| 3 | 12-3, 135-136 | 108.8586 | Lower Miocene iron-bearing nanno ooze | 18.503 18.507 18.500 | 0.83625 0.83605 0.83603 | 2.0504 | C P C2 | 18.540 18.544 18.536 | 15.518 15.519 15.511 | 38.099 | 0.83701 0.83688 1.83681 | 2.0545 | A TS | 0.616 0.678 | 0.150 0.159 | 6.010 4.971 | 0.252 0.242 | 6.481 8.673 |
| 4 | 13-1, 68-74 | 112.1824 | Basalt | 18.498 18.501 18.506 | 0.83750 0.83699 0.83749 | 2.0491 | C P C2 | 18.541 18.540 18.538 | 15.518 15.525 15.518 | 38.064 _ | 0.83698 0.83737 0.83709 | 2.0530 | A TS | 0.0843 0.0829 | 0.0599 0.0521 | 0.3240 0.3247 | 0.734 0.649 | 16.48 16.09 |
| Hole 319 | A | | | | | | | | | | | | | | | | | |
| 5 | 1-1, 48-51 | 98.4851 | Basalt | 18.476 18.478 18.471 | 0.83941 0.83855 0.83849 | 2.0541 | C P C2 | 18.517 18.517 18.510 | 15.536 15.541 15.522 | 38.110 _ | 0.83898 0.83929 0.83858 | 2.0581 | ATS | 0.0189 0.0194 | 0.0395 | 0.4078 0.4037 | 2.157 | 2.934 3.027 |
| 6 | 2-1, 27-30 | 107.7780 | Basalt | 18.462 18.499 18.470 | 0.83910 0.83813 0.83892 | 2.0518 | C P C2 | 18.504 18.540 18.514 | 15.513 15.550 15.513 | 38.114 | 0.83837 0.83874 0.83787 | 2.0557 | ATS | 0.0237 0.0233 | 0.0510 0.0485 | 0.2861 0.2765 | 2.229 2.143 | 5.231 5.339 |
| 7 | 3-5, 75-78 | 117.7578 | Basalt | 18.550 18.543 18.551 | 0.83472 0.83348 0.83399 | 2.0430 | C P C2 | 18.592 18.584 18.594 | 15.513 15.500 15.506 | 38.038 | 0.83441 0.83404 0.83393 | 2.0468 | A TS | 0.0513 0.0520 | 0.0922 0.114 | 0.4511 0.4484 | 1.860 2.257 | 7.181 7.334 |
| 8 | 5-1, 26-30 | 128.7680 | Basalt | 18.577 18.552 | 0.83404 0.83286 | 2.0419 | C P | 18.620 18.593 | 15.529 15.496 | 38.035 | 0.83406 0.83346 | 2.0457 | A | 0.595 | 0.148 | 0.5355 | 2.576 | 7.027 |
| 9 | 6-1, 106-109 | 139.0609 | Basalt | 18.543 18.547 | 0.83462 0.83383 | 2.0440 | C P | 18.585 18.587 | $15.510 \\ 15.510$ | 38.065 | 0.83455 0.83446 | 2.0479 | A | 0.0433 | 0.0845 | 0.4622 | 2.016 | 5.927 |
| Site 321 | | | | | | | | | | | | | | | | | | |
| 10 | 14-1, 45-47 | 125.4547 | Basalt | 18.496 18.520 18.519 | 0.83554 0.83454 0.83480 | 2.0477 | C P C2 | 18.593 18.558 18.559 | 15.527 15.502 15.495 | 38.077 | 0.83509 0.83529 0.83487 | 2.0517 | A TS | 0.132 0.134 | 0.323 0.367 | 0.7094 0.7190 | 2.524 2.832 | 11.79 11.77 |
| 11 | 14-2, 115-117 | 129.6567 | Basalt | 18.591 18.575 | 0.83464 0.83358 | 2.0458 | C P | 18.636 18.616 | 15.536 15.530 | 38.157 | 0.83367 0.83422 | 2.0497 | A | 0.120 | 0.300 | 0.5044 | 2.571 | 15.12 |
| 12 | 14-3, 37-44 | 128.3744 | Basalt | 18.590 18.602 18.584 | 0.83328 0.83269 0.83309 | 2.0451 | C P C2 | 18.631 18.642 18.624 | 15.538 15.536 15.514 | 38.201 | 0.83397 0.83338 0.83298 | 2.0492 | A TS | 0.161 0.163 | 0.356 0.355 | 0.5330 0.5275 | 2.282 2.252 | 19.40 19.58 |
| 13 | 14-4, 55-57 | 130.0506 | Basalt | 18.723 18.725 18.722 | 0.82725 0.82686 0.82742 | 2.0320 2.0324 | C P P, C2 | 18.773 18.771 18.774 | 15.521 15.528 15.536 | | 0.82677 0.82724 0.83751 | 2.0355 2.0355 | A TS | 0.218 0.219 | 0.310 0.359 | 0.3186 0.3108 | 1.472 1.695 | 43.39 44.80 |
| 14 | 14-4, 58-60 | 130.0708 | Basalt | 18.692 18.675 | 0.83032 0.82942 | 2.0378 | C P | 18.740 18.720 | 15.540 15.534 | 38.216 | 0.82929 0.82981 | 2.0414 | A | 0.123 | 0.286 | 0.2891 | 2.400 | 27.13 |

 TABLE 1

 Pb Isotopic Composition; U, Th, and Pb Concentration and Sample Descriptions of Some Leg 34 Sediments and Basalts

^aConcentration data are also corrected for ²⁰⁸Pb spike contamination. Fractionation was 0.1% ±0.02% per mass unit.

^bA "C" indicates data from a concentration analysis; a "P" from a composition analysis.

^cPb, U, and Th concentrations were determined from an aliquot of dissolved sample (A) or by total spiking a powder split before decomposition (TS). dAnalysis by P. D. Nunes.

g-sized samples (A). Uranium and Th were separated by an anion exchange resin in HNO₃ medium (Tatsumoto, 1966b).

RESULTS AND DISCUSSION

Lead isotopic compositions and Pb, U, and Th concentrations are listed in Table 1. The C or P in the "type of analysis" column designates whether the data are from a composition (P) or a concentration (C) analysis. Since samples were spiked with ²⁰⁸Pb for concentration analyses, no ²⁰⁸Pb composition data were obtained from the concentration analyses.

Concentration

The sediment from Hole 319 nearest the surface (Sample 1-6, 5-6 cm) contains about 70 ppm Pb, which is about average for deep-sea sediments (Tatsumoto and Knight, 1969) but only about one-third the amount of Pb found in a metalliferous sediment sample collected 750 km east (9°S, 102°W) of the crest of the East Pacific Rise (Dasch et al., 1971). Both samples were collected from similar positions relative to the crest of the rise, but sample depths below the ocean floor were different (7.55-7.56 m for the Leg 34 sample and 4.67-4.78 m for the other). As discussed later in this paper, the Pb isotopic composition study indicates that the Pb in the sediments was probably derived from the East Pacific Rise or the extinct Galapagos Rise. The lower Pb concentration in the Leg 34 sediments may be due to a low exhalation rate of volatiles from the rise or to a large amount of carbonate in the sediments. Dasch et al. (1971) reported that their sample had only about 2.4% carbonate, whereas the Leg 34 sediments analyzed contain from about 20% to 90% carbonate (Hart and Yeats, pers. comm.).

The U, Th, and Pb concentrations in the middle Miocene nanno ooze and iron-bearing lower Miocene nanno ooze are only one-tenth to one-twentieth of those in the near-surface sediment studied in this paper. The higher Pb concentration nearer the surface at this site may be attributed to major carbonate dissolution below the calcite compensation depth (Hart and Yeats, pers. comm.).

The Kappa (232 Th/ 238 U) values of the sediments range from 0.95 in the upper section to 0.25 near the sedimentbasalt boundary. The κ 's are unexpectedly low compared to average κ values for average sediments previously estimated (Tatsumoto and Knight, 1969). The low values are probably due in part to a low Th/U ration in exhalations from the oceanic rise but mainly to calcareous ooze accumulation, since oozes are high in U relative to Th.

The basalt from Hole 319 just below the sedimentbasalt boundary (core depth 112.18-112.24 m) contains Pb and Th concentrations similar to those of basalts from Hole 319A; however, it has a relatively high U concentration and low κ value of about 0.7 as compared to κ values of about 1-2.5 in the other basalts in this study and in typical oceanic tholeiites (Tatsumoto, 1966a). The low κ value may be attributed to a partial melting process in the upper mantle producing a low- κ magma.

The U and Th concentrations in basalts from Holes 319 and 319A are significantly lower than those in basalts from Site 321, but the Pb concentrations are roughly the same. Pb concentrations in samples from Holes 319 and 319A range from 0.3 to 0.5 ppm, with no correlation to depth, while the samples from Site 321 show Pb concentrations which grade from 0.7 ppm at the top of the cored interval to about 0.3 ppm near the bottom. We do not as yet understand this depth correlation. If trace element fractionation in the magma occurred, we would expect the volatile-rich component to be extruded first, and thus, the bottom of the core would be enriched in Pb. More likely the decreasing Pb concentration with depth can be associated with decreasing sulfide concentration with depth. Analyses of mineral separates now in progress may help to prove or disprove this idea.

Lead Isotopic Composition

Figure 1 shows the Pb isotopic composition results of this study in the conventional 207Pb/204Pb versus ²⁰⁶Pb/²⁰⁴Pb and ²⁰⁸Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb diagrams. Primary lead growth curves, of chemically closed systems since the earth formed, are shown as a reference. The growth curves are based on $\mu o(^{238}U/^{204}Pb$ ratio adjusted to present day) = 7.8 and 8.0 and κo $(^{232}\text{Th}/^{238}\text{U} \text{ ratio adjusted to present day}) = 3.7$. The constants used in this paper are as follows: Primordial $Pb_{206}Pb/204Pb = 9.037$, 207Pb/204Pb = 10.294, and 208 Pb/ 204 Pb = 29.476; age of the earth = 4.57 × 10⁹ yr (Tatsumoto et al., 1973); decay constants— $^{238}U =$ $0.155125 \times 10^{-9} \text{yr}^{-1}$. ²³⁵U = $0.98485 \times 10^{-9} \text{yr}^{-1}$ (Jaffev et al., 1971) and 232 Th = 0.049475 ×10⁻⁹yr⁻¹ (LeRoux and Glendenin, 1963); $^{238}U/^{235}U$ atomic ratio = 137.88 (Shields, 1973).

The data yield negative (future) model Pb ages. This indicates that the mantle has been a chemically open system in which U and Th have been accumulated relative to Pb in the geologic past (Patterson and Tatsumoto, 1964). Shown for comparison are the Pb isotopic composition data from the Juan de Fuca-Gorda and nearby seamount basalts (Church and Tatsumoto, in press); the Reykjanes Ridge basalts (Sun et al., in press); the metalliferous sediment from the East Pacific Rise obtained by Dasch et al. (1971) and the alkali basalts from Easter Island (Tatsumoto, 1966a); and average data from the East Pacific manganese nodules in which Pb was accumulated from seawater (Chow and Patterson, 1959; Reynolds and Dasch, 1971).

The Pb isotopic composition data from the sediments and basalts from the Nazca plate all follow the tholeiite trend on the ²⁰⁷Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb diagram. They also fall within the range of oceanic tholeiites on the ²⁰⁸Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb plot. The oceanic tholeiite trend falls below the primary growth curves indicating Th depletion in the source region compared to U in the past. Specifically, the Nazca plate data do not follow the Juan de Fuca-Gorda Ridge trend on the ²⁰⁸Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb plot, but they do follow the Reykjanes Ridge trend. If the data are corrected for in situ U and Th decay to Pb for about 15 m.y. at Site 319 and 40 m.y. at Site 321 (basal sediment ages; Hart



Figure 1. ²⁰⁸Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb and ²⁰⁷Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb of some Leg 34 basalts and sediments. Also included are basalt data from Reykjanes Ridge (Sun et al., in preparation), Juan de Fuca-Gorda Ridge and E. Pacific seamounts (Church and Tatsumoto, in press), Easter Island (Tatsumoto, 1966a; ²⁰⁸Pb/²⁰⁴Pb = 15.59, ²⁰⁶Pb/²⁰⁴Pb = 19.18), East Pacific seawater inferred from manganese nodules (Chow and Patterson, 1962, average, corrected to our scale; ²⁰⁸Pb/²⁰⁴Pb = 38.92, ²⁰⁷Pb/²⁰⁴Pb = 15.69 and ²⁰⁶Pb/²⁰⁴Pb = 18.81), and data from Dasch et al.'s (1971) metalliferous sediment (²⁰⁸Pb/²⁰⁴Pb = 34.018, ²⁰⁷Pb/²⁰⁴Pb = 15.518, and ²⁰⁶Pb/²⁰⁴Pb = 18.306). Primary growth curves of closed systems with μ_0 = 7.8 and 8.0 and K_0 = 3.7 are shown for reference. The broken line in the ²⁰⁸Pb/²⁰⁴Pb versus ²⁰⁴Pb/²⁰⁴Pb diagram shows the Juan de Fuca-Gorda Ridge and seamount trend which is slightly different from that of the Leg 34 data. Sediments are labeled p = Pliocene, mm = middle Miocene, Im = lower Miocene.

and Yeats, pers. comm.), the data are pushed even further away from the Juan de Fuca-Gorda Ridge trend on the Pb/ Pb versus Pb/ Pb diagram. This may mean that the mantle source region in this area differentiated later than the Juan de Fuca-Gorda Ridge source.

Figure 2 represents an enlarged portion of the ²⁰⁷Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb diagram in Figure 1. Shown are data from the sediments and basalts from this study; Dasch et al. (1971) sediment; East Pacific seawater determined from manganese nodules (Chow and Patterson, 1962, average of East Pacific nodules corrected to our scale); and least radiogenic Juan de Fuca-Gorda Ridge basalts (Church and Tatsumoto, in press). The Pb isotopic compositions of the Leg 34 sediments are quite different from that of seawater; thus, Fe-Mn precipitates from seawater are unlikely to be the major source of the metalliferous sediments, as Dasch and others also concluded (Dasch et al., 1971; Corliss, 1971).

The Pb isotopic composition of the Pliocene sediment (Core 1, Section 6) at Site 319 is distinctly different from that reported by Dasch et al. (1971) for the sediment 750 km east of the East Pacific Rise. The Pb composition of the mid-Miocene nanno ooze from Site 319 is less radiogenic than that of the Pliocene sediment, but is similarly more radiogenic than Dasch et al. (1971) value (see Figure 2). The lower Miocene sediment has a Pb composition similar to that of the upper basalts in this study and more radiogenic than that of either of the overlying sediments analyzed. The Pb in the lower Miocene sediment may have been derived from the same source as the basalts, but the Pb in the mid-Miocene and Pliocene sediments may have been derived from a different source. Among possible explanations are: (1) the Pb exhalated from the Galapagos Rise changed in isotopic composition to that of the middle Miocene and Pliocene sediments after about 15 m.y. ago, (2) the Pb in these two sediments may have been derived from a



Figure 2. Enlargement of a portion of the ²⁰⁷Pb/²⁰⁴Pb versus ²⁰⁶Pb/²⁰⁴Pb diagram in Figure 1. The solid line is a mixing line between seawater Pb (Chow and Patterson, 1962) and least radiogenic Juan de Fuca-Gorda Pb (Church and Tatsumoto, in press). The broken line is a mixing line between the Leg 34 basalt Pb and Pb similar in isotopic composition to least radiogenic seamounts (Church and Tatsumoto, in press) and Dasch et al. (1971) sediment. The Leg 34 sediments are labeled p = Pliocene, mm = middle Miocene and Im = lower Miocene. The closed symbols represent the Leg 34 data corrected for in situ U decay.

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source similar in Pb composition to that of the Gorda Ridge basalts and was altered slightly by seawater Pb (solid line, Figure 2), or (3) the Pb isotopic compositions of these sediments may reflect mixing of Leg 34 basalttype Pb and East Pacific seamount-type Pb (broken line Figure 2). In any case, the amount of Pb in these two sediments contributed by seawater must be relatively small, since the Pb isotopic compositions of these two sediments are grossly different from that calculated for seawater (Figures 1 and 2).

The unusual freshness and groundmass olivine of the diabases and coarse-grained basalts recovered from Sites 319 and 321 caused the shipboard scientists to initially believe that they might be relatively young "off-ridge" intrusions with alkaline tendencies (Hart and Yeats, pers. comm.; Scientific Staff of Leg 34, 1974).

It has been observed (Church and Tatsumoto, in press) that the Pb isotopic compositions in basalts from seamounts near the Juan de Fuca-Gorda Ridge are more radiogenic in character and their Th/U ratios are larger the farther from the ridge the seamounts are. Because the ²³²Th/²³⁸U ratios of the Leg 34 basalts are the same as those of ridge tholeiites, and Pb isotopic compositions are different from those of Easter Island basalts, which have alkaline affinities (Bandy, 1937; Engel and Engel, 1964), we believe that the basalts are "on-ridge" volcanic products. Geochemical data on the Leg 34 basalts obtained by Thompson et al. (pers. comm., see also this volume) are typical for oceanic tholeiites, and they also believe the Leg 34 basalts to be "on-ridge" volcanic products.



Figure 3. $^{206}Pb/^{204}Pb$ versus $^{238}U/^{204}Pb$ plot for samples from Holes 319, 319A, and 321. The closed symbols represent correction for in situ ^{238}U decay to ^{206}Pb for 15 m.y. at Site 319 and 40 m.y. at Site 321. The 39 \pm 7 m.y. isochron was obtained by a least-squares fit (York, 1969). The initial $^{206}Pb/^{204}Pb$ ratio 40 m.y. ago. The $^{206}Pb/^{204}Pb$ ratio at $^{238}U/^{204}Pb = 0$ is 18.52 \pm 0.03 (10). Sediments are labeled p = Pliocene, mm = middle Miocene and Im = lower Miocene.

If we assume that the Leg 34 basalts are about 15 m.y. old at Site 319 and about 40 m.y. old at Site 321 and correct for Pb produced by in situ U decay, the Pb isotopic compositions of the basalts from both sites become the same within uncertainty, except Samples 7, 8, and 9 from Hole 319A, as shown in Figure 3. The Site 321 data yield a relatively good isochron of 39 ± 7 m.y. (1 σ , York, 1969), which agrees very well with the basal sediment age at Site 321, and an initial ²⁰⁶Pb/²⁰⁴Pb ratio 40 m.y. ago of 18.52 ± 0.03 . The samples from Holes 319 and 319A do not have a large enough spread in the ²³⁸U/²⁰⁴Pb ratio to yield a good isochron.

Even though Samples 7, 8, and 9 from Hole 319A appear to have slightly higher corrected ²⁰⁶Pb/²⁰⁴Pb ratios than the rest of the Leg 34 basalt samples, it is very unlikely that the Pb isotopic composition of these samples has been greatly altered by seawater Pb. If such were the case, we would expect these samples to also have higher 207Pb/204Pb and 208Pb/204Pb ratios, and to plot away from the dashed line in Figure 2 toward seawater. Nevertheless, the corrected Pb isotopic compositions of the Leg 34 basalts have a much smaller range than those from other limited areas, such as the Juan de Fuca-Gorda and Reykjanes ridges (Figures 1 and 2). The similarity in the corrected Pb isotopic compositions of the Leg 34 samples indicates that either they were extruded from a portion of the mantle in which the Pb isotopic composition is homogeneous, or that mantle convection and/or mixing proportions of partial melts between the mantle plume and the low velocity zone were constant from about 15 to 40 m.y. ago.

SUMMARY

The characteristics of the Leg 34 basalts are those of typical oceanic tholeiites. The Th/U ratios are about 1.5 to 2.5, and the Pb isotopic compositions are similar to those of oceanic tholeiites. We have seen no evidence that the basalts were produced by "off-ridge" volcanism. Their tholeiite characteristics and the fact that the Site 321 data yield an isochron that agrees with the basalts originated from the extinct Galapagos Rise. Our U, Th, and Pb study of mineral separates is now in progress, and our conclusions must be tested against these results, or confirmed by basalt age determinations.

The Pb isotopic compositions of the middle Miocene and Pliocene sediments from Hole 319 are different from those of the lower Miocene sediment and the Leg 34 basalt samples analyzed. This indicates that either (1) the Pb isotopic composition of the source changed to that of the upper two sediments; (2) the Pb in the upper two sediments is from a different source (for example, the present East Pacific Rise); or (3) the Pb in these two sediments may represent a mixture of Leg 34-type Pb and seamount-type Pb. Because the Pb isotopic compositions of the three sediments analyzed are grossly different from that of seawater, it is unlikely that Fe-Mn precipitates from seawater are the major source of the metalliferous sediments.

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