MAJOR ELEMENT CHEMISTRY OF BASALT GLASSES DREDGED FROM YOUNG ISOLATED VOLCANOES AND THE EAST PACIFIC RISE, 10°-14° N

by
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ABSTRACT

Major element electron microprobe analyses of over 100 dredged samples of basalt glass from the East Pacific Rise and nine young isolated seamounts near the Rise are presented along with petrographic data for the samples. These data indicate that most suites of samples from seamounts are fractionated suites of low-K_2O mid-ocean ridge basalt similar to many described previously. In addition, however, some seamount lavas differentiate toward higher K_2O, TiO_2 and other incompatible element enrichment without correlation with Mg/ /Fe ratios. These two types of chemical abundance variation trends do not correlate well with size, age or tectonic settings of the seamounts, however, the absolute amount of chemical diversity observed in the lavas of each seamount does correlate with these other variables. The data indicate that location on fracture zones is neither a necessary or sufficient condition for great chemical diversity of seamount lavas, however, seamounts on fracture zones tend to be large in size. On the other hand, relatively great age (> 3.0 m.y.) and great size ($> 200\ km^3$) are sufficient but not necessary conditions for such seamount lava diversity. These patterns may be interpreted in terms of the evolution of young oceanic central volcanoes.

INTRODUCTION

Geologic and petrologic studies of oceanic islands have added greatly to our understanding of oceanic volcanism (Daly, 1933; Baker, 1973, Sun and Sanson, 1975). However, volcanic islands may not be truly representative of oceanic central volcanism since they are only the very largest of the oceanic central volcanoes. Geologic and petrologic studies of the much more numerous wholly-submerged oceanic central volcanoes are necessary to determine: 1) The proportion of oceanic central volcano seamounts which are presently active. 2) The proportions of intra-plate volcanoes which originate near ridge crests. 3) The mean-active lives of these various types of volcanoes.

Such questions may be partly answered by a combination of field/petrologic studies of wholly-submerged volcanoes complemented by statistical studies of seamount size and abundance distributions on oceanic crust of various ages (Batiza, 1981). Batiza (1977, 1979, and 1980) presented results of studies of small ($< 500\ km^3$) young and isolated (not-grouped) oceanic central volcanoes which indicate that many such volcanoes are composed of basalt chemically similar to mid-ocean ridge tholeiitic basalt. In addition, however, some of these volcanoes are capped by alkalic and transitional basalt suggesting that these volcanoes may evolve petrologically. This evolution could be linked to temporal changes in their mantle source area as young active seamounts are carried away from ridge crests (Batiza, 1980). McNut and Batiza (1981) presented paleomagnetic data for most of these young oceanic volcanoes and showed that such data are helpful for distinguishing between volcanoes and structural features on the sea floor, providing information on their mean active growth periods and for determining eruption chronologies of individual volcanoes.

The purpose of this paper is to present petrographic and major-element composition data for samples from nine small seamounts near the East Pacific Rise (7 volcanoes and 2 structural features) and for samples dredged from the Rise. In addition, we discuss systematic relationships which exist between the petrology of these seamounts and their tectonic settings, size, and paleomagnetic characteristics. The location of these seamounts, bathymetric maps and data on the locations of dredge hauls has been presented previously (Batiza, 1980).

METHODS

The field methods employed as part of this study have been described previously (Batiza, 1979 and 1980). In Table 1 we present a sumary of the results of petrographic examination of about 250 thin sections of samples recovered in 27 dredge hauls. Table 2 gives major element compositions and the petrographic type of 135 samples from the nine seamounts and the East Pacific Rise. These analyses are electron microprobe analyses of fresh glass and therefore represent liquid compositions unaffected by crystal accumulation and alteration (Melson et al., 1976).

RESULTS

The samples studied include pieces of submarine hyaloclastites (Fig. 1), pillow lava and sheet flow (submarine pahoehoe: Figs. 2 and 3). The lava flows are mostly aphyric or very sparsely phyric, but some porphyritic types were recovered. Textures within the samples vary from glassy to holocrystalline and the only unusual texture observed consists of segregation vesicles and tubes which are sometimes abundant in the sheet flow samples (Fig. 4). In all other respects, the mineralogy and textures of these samples are similar to those of previously- described submarine basalt lavas (e.g., Bryan, 1971) and pyroclastic rocks (e.g. Schmincke et al., 1979). On the basis of the types of phenocrysts and megacrysts found in the lavas, eleven distinct petrographic types may be distinguished (Table 1).

Most of the samples have megacrysts of plagioclase (An_{60-75}) and/or olivine, but these are abundant ($> 1\%$) in only a few samples. Most of the lavas have rare phenocrysts of plagioclase or plagioclase plus olivine and it is clear from observed textural relationships that for most samples, plagioclase was the first liquidus phase. The only exceptions are from volcano ≠3 where olivine is the first liquidus phase, followed by plagioclase. Many samples also have phenocrysts and microphenocrysts of clinopyroxene. In all cases, this is the latest phase to crystallize and observed assemblages are : Pl + Ol + Cpx and less commonly Pl + Cpx.

The chemical compositions of the lavas vary widely as shown in Figs. 5 and 6. Most volcanoes exhibit some chemical variation, however, the magnitude and trends of this chemical variation are widely different between volcanoes. With some significant exceptions, most of the samples analyzed are low-K_2O mid-ocean ridge tholeiite which are chemically similar to

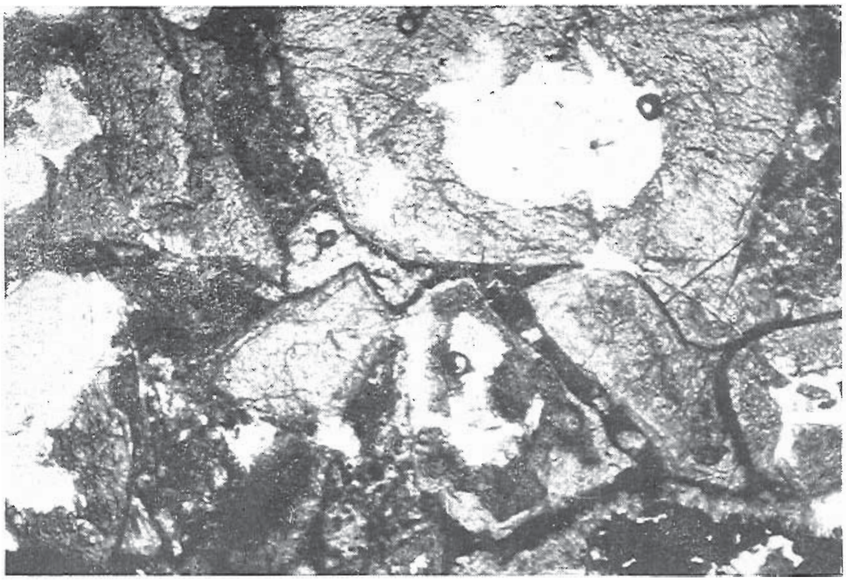

Fig. 1 — Photomicrograph of hyaloclastite 28-7D, width of frame is 2 mm. Note angular fragments of altered glass with fresh cores which are losely cemented by Fe-Mn oxides.

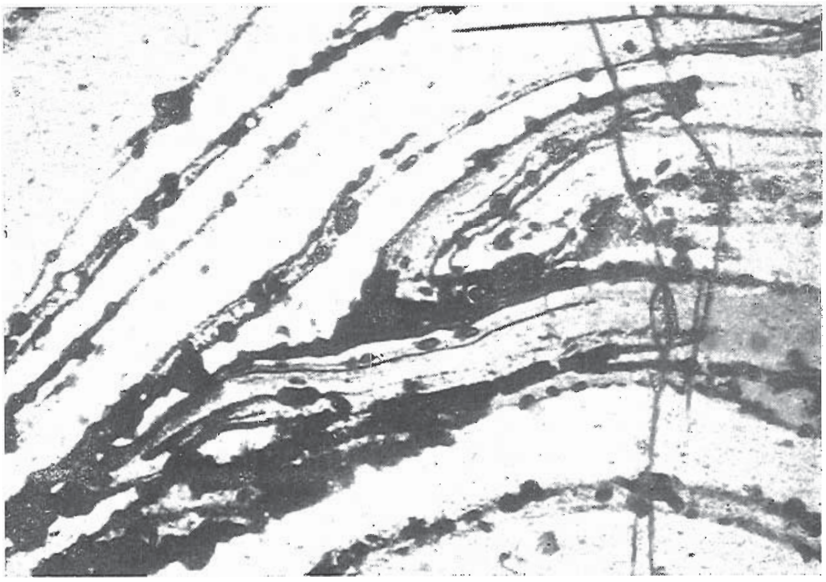

Fig. 2 — Photomicrograph of samples 19-5, width of frame is 0.11 mm. This sample of sheet flow has a thick glassy rim, pictured here, with a very pronounced flexion texture defined by tiny crystallites of silicates and opaque minerals.

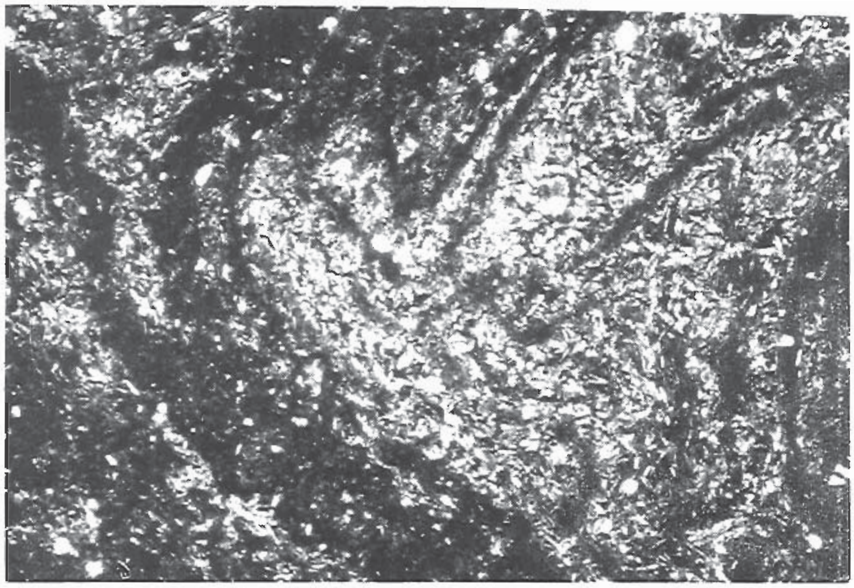

Fig. 3 — This rock is similar to the one in Fig. 2 but this photomicrograph is taken of the interior portion of the flow which is almost holocrystalline. Note the very pronounced fluxian texture. Sample is 3-2 and width of frame is 2 mm.

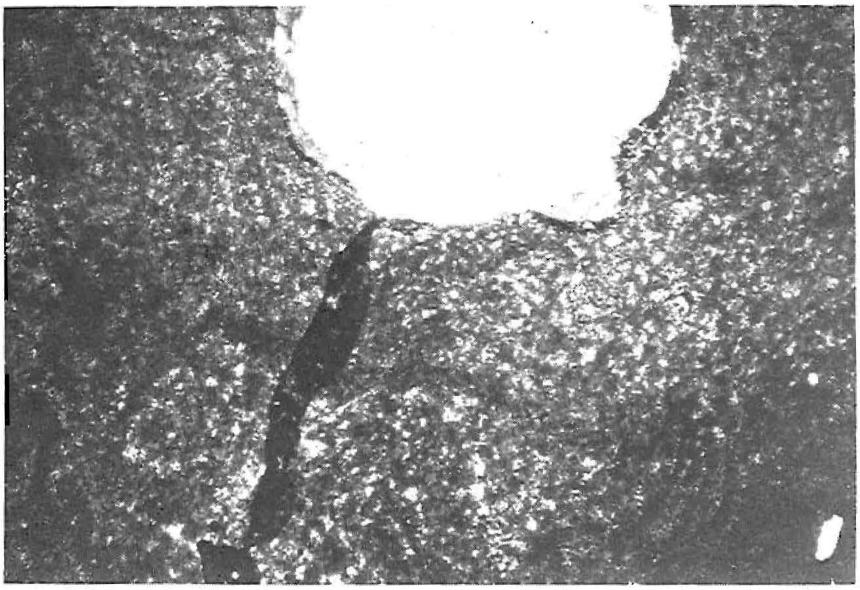

Fig. 4 — Photomicrographs of sample 23-8 which contains abundant segregation vesicles and tubes like the ones shown here. These segregations are thought to form as a result of changing lithostatic pressure during crystallization such as might be caused by extrusion and rapid flow down the steep slopes of a submarine volcano (Smith, 1967). Width of frames is 2 mm.

samples obtained from the active mid-ocean ridge system and from drilling of the oceanic crust. Suites of samples from individual volcanoes generally show a range of 100 Mg/Mg + + Fe^{2+} (Mg no.) and other element variations characteristic of suites of mid-ocean ridge basalt (Batiza et al., 1977 ; Melson et al., 1976 ; Morel and Hekinian, 1980 ; Byerly, 1980 ; Clague and Bunch, 1976 ; Frey et al., 1974 ; Natland and Melson, 1980).

In addition to these tholeiites and fractionated tholeiites the seamount dredges contain alkalic basalt and transitional basalt. These samples are not depleted in light rare earth element (LREE) and other incompatible trace elements but rather have either flat chondrite-normalized REE patterns or LREE enriched ones (Batiza, 1980). Fig. 6 shows that these transitional and alkalic lavas have distinctive variation trends of major elements as well.

Before a discussion ad interpretation of the petrology of the seamounts, the characteristics of each are given :

Seamount 1 : This volcano was discussed by Lonsdale and Spiess (1979) and Lonsdale and Batiza (1980). It is a small (47 km^3) tholeiitic volcano located within the central magnetic anomaly of the East Pacific Rise on crust 0.6 m.y. in age. Dredges of its slopes and summit have recovered tholeiitic basalt with Mg no. 60-63. Dredge 3 (Table 2) probably sampled 2 individual flows which have phenocrysts of Pl and Pl + Ol.

Seamount 2 : This volcano is also small ($\sim$ 80 km^3) and is located symmetrically across the East Pacific Rise from seamount 1. Like seamount 1, it is located on normal oceanic crust (i.e., not on a fracture zone). Lavas from its slopes and summit contain only plagioclase phenocrysts but some contain megacrysts of plagioclase and olivine. They have uniformly flat REE abundance patterns (Batiza, 1980) and slightly higher K_2O abundances than depleted mid-ocean ridge basalt (MORB) of comparable Mg no. (61-63).

Seamount 3 : This small (62 km^3) bathymetric high is located on normal crust of 1.1. m.y. in age and there is good evidence (Batiza, 1979, 1980) that it is not a volcano, but rather a structural feature. Lavas from 4 dredge hauls show variation in Mg no. of 61 to 68 and belong to two groups: a low-K_2O group and a high K_2O group (Fig. 6). Lavas of the former group have phenocrysts of either Pl or Pl + Ol and sometimes megacrysts of plagioclase. Those of the latter group (high K_2O) have phenocrysts of either olivine or Ol + Pl and lack megacrysts. These two groups differ in La/Sm ratio and other trace element abundances (Batiza 1980).

Seamount 4 : This small (74 km^3) bathymetric high is located on normal crust 1.5 m.y. in age. Like volcano 3, there is good morphologic and paleomagnetic evidence to indicate that it is a structural feature rather than a volcanic constructional feature. Three dredges of this feature yielded lavas with Mg no. of 60-64 and a variety of phenocryst assemblages but all are LREE-depleted tholeiitic basalt.

Seamount 5 : This seamount is one of the largest of this group ($\sim$ 300 km^3) and is located on a small fracture zone near crust which is 0.9 m.y. old. Paleomagnetic evidence indicates that this feature is probably a volcano but it has asymmetric slopes and other morphologic features which indicate an unusual growth history or later morphologic modification. Lavas from five dredges have phenocrysts of either Pl + Ol or Pl + Ol + + Cpx with occasional megacrysts of both plagioclase and olivine. They show great chemical diversity with Mg no. of 55 to 65 and all have slightly higher K_2O (Fig. 6) and La/Sm ratio (Batiza, 1980) than typical low-K_2O MORB.

Seamount 6 : This small ($\sim$ 70 km^3) volcano is located on crust of 3.0 m.y. age and is located very close (10 km), though not directly on, a small fracture zone. Two dredge hauls of the summit region recovered both transitional basalts with flat REE abundance patterns and LREE enriched alkali olivine basalt (Batiza, 1980). The former have either Pl or Pl + Ol phenocrysts while the latter have either Pl + Ol or Pl + Cpx phenocrysts and are highly vesicular (10-15 % vesicles). This volcano gives very unusual magnetic paleoinclinations and paleodeclinations which could be due to: 1) its small size, 2) inadequate magnetic data, or 3) unusual chemical composition of the lavas. The transitional lavas have a narrow range of Mg no. (65-67) but a wide range of K_2O and TiO_2 abundances (Fig. 6) and the alkalic lavas have a wider range of Mg no. (as low as 53). While the variation trends exhibited by all the samples are discontinuous, the samples appear to define a

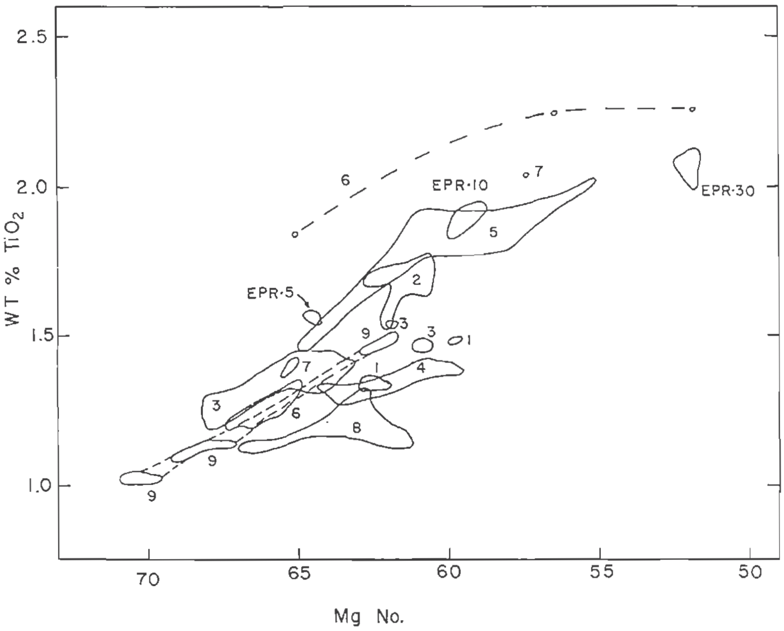

Fig. 5 — Plot of MG no. (100 Mg/Mg + Fe^{+2}) versus wt. % TiO_2 content for the glasses analyzed. Fields for samples from each seamount are shown with solid lines. Dashed lines connect groups of samples from the same volcano. Numbers of the fields correspond with the volcano numbers used in the text.

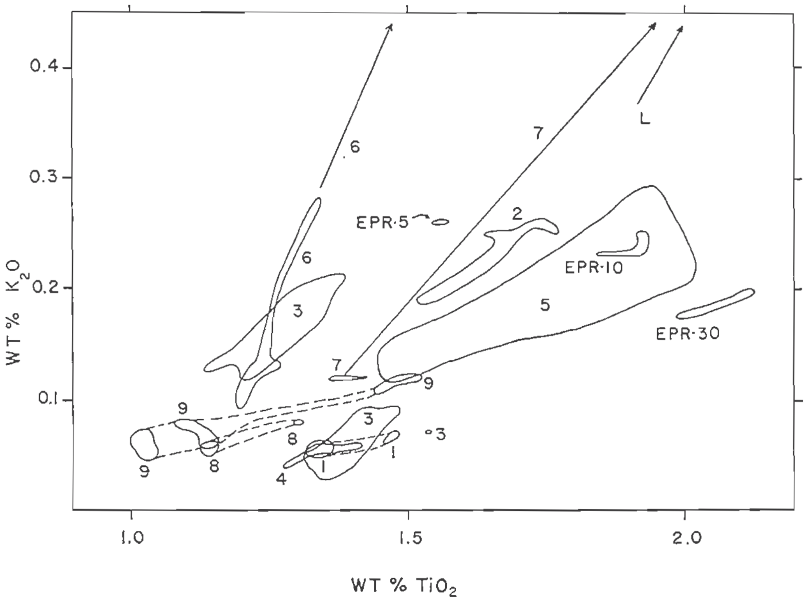

Fig. 6 — Plot of wt. % K_2O versus wt. % TiO_2 for the glasses analyzed. Same conventions as Fig. 5. Also shown is the trend labelled « L » which is from Natland and Melson (1980). Note the variable K/Ti ratios of samples from this study.

single trend toward incompatible element enrichment which is not related to changes in Mg no. (Figs. 5 and 6 and Batiza, 1980).

Seamount 7 : This is the largest seamount of the group (540 km^3) and is located on the same fracture zone as seamount 5 adjacent to crust 3.5 m.y. in age. Paleomagnetic results indicate clearly that this seamount is a volcano that is tilted northward about 15° which explains its asymmetric slopes. Rocks from two dredges include both a suite of LREE depleted tholeiites (Mg no. ~ 65 with Pl or Pl + Ol phenocrysts) and LREE enriched transitional basalts with Mg no. ~ 57, La/Sm = 1.27 (Batiza, 1980) and Pl + Cpx phenocrysts and plagioclase megacrysts.

Seamount 8 : This small (61 km^3) volcano is located on the oldest crust of any of the seamounts in this group (6.8 m.y.) and is about 10 km north of a small fracture zone. Paleomagnetic evidence indicates that in contrast to most of the others, it is younger than the crust upon which it is built. Two dredge hauls recovered LREE depleted tholeiitic basalt with Mg no. 61-63 and 67 (two groups) which all have only plagioclase phenocrysts and occasional megacrysts of plagioclase and olivine.

Seamount 9 : This volcano ($\sim$ 200 km^3 in volume) is located along the same fracture zone as seamounts 5 and 7 near crust 5.5 m.y. in age. It is apparently about the same age as the crust that it is near and grew quickly near the East Pacific Rise. Dredges recovered a suite of LREE depleted tholeiitic basalt (Batiza, 1980) with Mg no. 62-71. The lavas define three distinct groups and a discontinuous trend of chemical variation like many other tholeiitic differentiation trends (Figs. 5 and 6). Phenocrysts and megacryst assemblages are variable (Table 2) and many samples are highly porphyritic with plagioclase or plagioclase plus olivine megacrysts.

East Pacific Rise : Three dredges at the East Pacific Rise yielded lava suites which exhiibt a range of La/Sm ratios (Batiza, 1980). Samples from dredges 10 (12° N) and 30 (14° N) are LREE depleted while those of dredge 5 (11.5° N) have nearly flat patterns. The K/Ti ratios of the samples systematically increases and the Mg no. of the samples decrease from south to north along the East Pacific Rise for these three dredge haul. The samples exhibit a great variety of phenocryst and megacryst abundances (Table 2) and were all dredged from portions of the East Pacific which are morphologic horsts (Lewis, 1979).

SUMMARY OF RESULTS

Examination of the data above indicate that several generalizations may be made. However, we caution that the number of seamounts studied is small, and therefore these generalizations may only hold at this locality. Nevertheless, it is clear from this set of data that:

1) The larger volcanoes tend to occur along fracture zones. The three largest volcanoes (5, 7 and 9) occur on the O'Gorman fracture zone. It is also noteworthy that of the seven volcanoes studied, only two (1 and 2) are not either on fracture zones or very near to them such as 6 and 8 (McNutt and Batiza, 1980). The two structural features (3 and 4) are not located on or near fracture zones.

2) All of the relatively large volcanoes show great diversity of lava compositions. However, Figures 5 and 6 show that the volcanoes with the greatest chemical diversity also include volcano 6 ($\sim$ 70 km^3), showing that great chemical diversity is not a function of size alone. This relationship is not a funcion of the total number of dredges on each volcano, as volcanoes 9, 7 and 6 had only 2 each whereas volcano 8 had 3 dredges and shows much less chemical diversity.

3) The lavas from all volcanoes located on relatively old crust (3.0 m.y.) exhibit great chemical diversity. The single exception to this generalization is volcano 8, but McNutt and Batiza (1981) have shown that this one is probably much younger than the crust upon which it is built in contrast with the others: volcanoes 9 (5.5 m.y. old crust), 7 (3.5. m.y.) and 6 (3.0 m.y.).

In sumary, volcanoes which are either relatively large (100-150 km^3), or are located on fracture zones or are greater than about 3 m.y. in age tend to exhibit greater chemical diversity of lavas than volcanoes which are small (100 km^3), young (3.0 m.y. in age) and located at relatively great distance from fracture zones.

DISCUSSION AND INTERPRETATION

Because a great deal more data are yet required in order to critically evaluate the petrogenesis of the lavas from these nine seamounts and the EPR this will not be attempted in this paper. It is clear, however, that while simple low-pressure fractional crystallization may be sufficient to qualitatively explain the chemical variations of the lavas from volcanoes 8, 9, and 1, structural features 3 and 4 and possibly dredge 30 from the East Pacific Rise (Figs. 5 and 6), this mechanism alone is not sufficient to account for the variety of La/Sm ratios and levels of LREE and other incompatible element enrichments of volcanoes 2, 5, 6 and 7, seamount 3 and some of the East Pacific Rise dredged rocks. Electron microprobe, trace element mineral analyses, whole rock major element analysis and isotopic analyses (all in progress) should help to constrain the petrogenesis of these diverse lavas and allow quantitative testing of several possible hypotheses for their origins.

In this discussion we will consider the significance and possible explanations for the observed relationships between the diversity of lava chemistry and the ages, sizes and tectonic settings of the volcanoes summarized before. The observed chemical diversity is of two types: 1) fractionation trends which are very similar to those exhibited by suites of MORB (Type 1) (Figs. 5 and 6). In this case, though, the trends are usually not continuous but are defined by connecting distinct groups of samples ; 2) fractionation trends leading to correlated enrichments of K, Ti, LREE and other incompatible elements without good correlation with Mg≠ (Type 2).

It should be kept in mind that these types of variations could have quite different causes and it is therefore interesting that no correlation between age, size or tectonic setting and the specific type of chemical diversity of lavas is apaprent for these volcanoes. For example, type 2 variation is observed for lavas of seamouts 2, 3, 6, 7 and possibly 5 which vary greatly in relative age, size and tectonic setting. Thus it is the absolute magnitude of the chemical diversity rather than its type which correlates well with age, size and tectonic setting.

Because of the small number of volcanoes studied and because of the nature of the observed correlation, it is not possible to tell whether relatively great age, size or location on fracture zones is the most important single factor leading to chemical diversity (of either type). In addition these variables are probably not independent. For example, if growth rates are constant and growth periods exceed 3 m.y., the older the volcano is, the larger it will be.

It is clear from the data that location on a fracture zone is neither a necessary nor sufficient condition for great chemical diversity of lavas. Both relatively great age ($>$ 3.0 m.y.) and relatively great size ($> 200\ km^3$) are sufficient but not necessary conditions for great diversity. This assumes, of course, that the dredging obtained representative samples of the volcanoes' surfaces.

Relative age could be an important factor either because of increased opportunity for fractional crystallization to occur in sub-volcanic chambers or alternatively because of the increased chances that a volcano drifting away from the accretionary zone of the ridge crest would be fed by diverse magmatic sources different from those which melt beneath the ridge. On the other hand, great lava diversity may only be a function of small average size for individual lava flows. This in turn might be most likely in the waning stages of evolution, but very little evidence bearing on the average volumes of individual eruptions as a function of time exist for these types of volcanoes. In any case, both fractional crystallization and tapping of multiple and changing source regions are not necessarily age-dependent processes and this may explain why great age is not a necessary condition for great petrologic diversity.

Relatively large size may be an important factor because, as before, the surfaces of relatively large volcanoes may be covered by lavas erupted in the waning stages of evolution. Such activity may be a consequence of the volcano having achieved its maximum attainalbe height for a given lithosphere thickness (Vogt, 1974) or else its losing contact with a magmatic source from which it is continually being separated by plate motion (Menard, 1969). This assumes, of course, that the small volcanoes studied are still active and in fact volcano 6, though relatively small ,shows great chemical diversity. This suggests that location on fracture zones may result in larger average volcano growth rates (volcanoes 5, 7 and 9) but that fracture zones do not otherwise exert important influences on the source region characteristics or chemical diversity of small oceanic central volcanoes.

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TABLE 1

PETROGRAPHIC TYPES

Type	*Phenocrysts*	*Vol. % Vesicles*	*Megacrysts*
1.	Aphyric		
2.	Pl	<5	
3.	Pl + Ol	(a) 10-15 (b) <5	
4.	Pl + Ol + Cpx	(a) 10-15 (b) <5	
5.	Pl + Cpx	(a) 15-20 (b) 5	
6.	Pl	(a) 10 (b) <5	Pl
7.	Pl + Ol	(a) 10 (b) <5	Pl
8.	Ol	<5	
9.	None	>10	Pl (No samples with glass)
10.	Pl + Cpx	>10	Pl
11.	None	(a) 10 (b) <3	Pl + Ol
12.	Hyaloclastite		

TABLE 2

BASALT GLASS ANALYSES

SEAMOUNT 1

	3-1	*3-2*	*3-3*	*3-4*	*3-6*	*3-7*	*3-9*	*D-3 Average*
SiO_2	50.42	50.42	50.50	50.53	50.42	50.13	50.54	50.40
TiO_2	1.32	1.48	1.35	1.49	1.33	1.36	1.33	1.38
Al_2O_3	14.90	15.40	14.75	15.50	15.00	14.84	15.02	15.05
FeO*	9.82	10.05	9.82	10.14	9.91	9.80	9.72	9.89
MgO	7.56	7.05	7.74	7.02	7.60	7.73	7.73	7.49
CaO	12.50	11.85	12.42	11.97	1240	12.40	12.43	12.28
Na_2O	2.61	2.90	2.64	2.87	2.62	2.63	2.63	2.70
K_2O	0.05	0.06	0.05	0.07	0.05	0.06	0.06	0.06
P_2O_5	0.11	0.12	0.11	0.11	0.11	0.11	0.10	0.11
TOTAL	99.29	99.33	99.38	99.70	99.34	99.06	99.56	99.36
Mg no.	62.2	60.0	62.8	59.7	62.1	62.8	63.0	61.8
Petrographic Type (P.T.)	3B	3B	3B		3B	1	6B	

BASALT GLASS ANALYSES (*continued*)

SEAMOUNT 2

	4-4	*4-8*	*4-11*	*4-12*	*4-13*	*4-14*	*4-16*	*4-17*	*4-18*	*4-19*	*4-20*	*D-4 Average*
SiO_2	49.13	49.63	49.88	49.62	50.30	49.81	49.87	49.84	50.24	49.61	49.96	49.71
TiO_2	1.55	1.52	1.64	1.74	1.73	1.77	1.68	1.68	1.64	1.65	1.65	1.65
Al_2O_3	16.22	16.97	16.58	15.96	16.08	16.03	16.16	15.89	16.19	16.17	16.17	16.22
FeO*	9.20	8.89	9.34	9.25	9.22	9.41	9.18	9.23	9.22	9.35	9.25	9.23
MgO	7.11	6.82	6.77	6.91	7.11	6.80	7.25	7.03	6.94	6.98	7.06	6.98
CaO	11.79	11.89	11.89	11.75	11.68	11.95	11.70	11.76	11.78	11.69	11.72	11.78
Na_2O	3.08	3.14	3.05	3.08	3.12	3.14	3.08	3.06	3.10	3.11	3.14	3.10
K_2O	0.19	0.19	0.22	0.26	0.26	0.25	0.25	0.24	0.25	0.25	0.25	0.23
P_2O_5	0.18	0.19	0.18	0.20	0.17	0.20	0.19	0.18	0.20	0.20	0.21	0.19
TOTAL	98.45	99.24	99.55	98.77	99.67	99.36	99.36	98.91	99.56	99.01	99.41	99.09
Mg no.	62.3	62.1	60.8	61.5	62.3	60.7	62.9	61.9	61.7	61.4	62.0	61.8
P. T.	6A	11B	11B	2	2	11B	2	2	2	2	2	

BASALT GLASS ANALYSES (*continued*)

SEAMOUNT 3

	6-1	*6-2*	*6-3*	*6-4*	*6-5*	*6-6*	*6-8*	*6-9*	*6-10*	*6-11*	*6-13*	*6-14*	*6-15*	*D-6 Aver*
SiO_2	50.83	50.44	49.95	50.28	50.02	49.77	50.01	50.10	50.16	50.09	50.91	50.93	51.18	50.30
TiO_2	1.54	1.42	1.44	1.43	1.40	1.42	1.40	1.39	1.43	1.38	1.48	1.46	1.46	1.42
Al_2O_3	14.86	15.67	15.61	15.84	15.80	15.72	15.77	15.63	15.82	15.66	1503	15.08	15.07	15.53
FeO*	10.10	9.11	9.14	9.02	9.08	9.12	9.08	9.14	9.21	9.04	10.03	10.04	10.08	9.33
MgO	7.42	7.93	7.77	7.96	7.93	8.00	7.93	7.87	7.96	7.97	7.40	7.45	7.33	7.78
CaO	12.01	12.11	12.21	12.07	12.09	11.95	12.02	12.01	11.98	11.99	11.96	12.06	12.16	12.04
Na_2O	2.74	3.00	2.94	2.95	2.93	2.97	2.98	2.97	2.97	2.94	2.87	2.55	2.86	2.92
K_2O	0.07	0.09	0.07	0.08	0.08	0.07	0.06	0.07	0.06	0.07	0.09	0.08	0.09	0.07
P_2O_5	0.11	0.15	0.14	0.13	0.14	0.15	0.15	0.16	0.12	0.15	0.14	0.13	0.14	0.14
TOTAL	99.68	99.92	99.27	99.76	99.47	99.17	99.40	99.34	99.71	99.29	99.91	99.78	100.37	99.53
Mg no.	62.0	65.0	64.5	65.4	65.1	65.2	65.1	64.6	64.8	65.3	61.0	61.1	60.7	64.0
P. T.		3B	2	2	2	2		2	2	2	7B	2	2	

BASALT GLASS ANALYSES *(continued)*

SEAMOUNT 3

	7-2	*7-3*	*7-4*	*7-6*	*7-8*	*7-9*	*7-10*	*D-7 Average*
SiO_2	50.32	50.00	50.57	50.21	50.10	50.13	49.79	50.16
TiO_2	1.32	1.38	1.40	1.39	1.35	1.33	1.35	1.36
Al_2O_3	15.61	15.58	15.55	15.66	15.82	15.77	15.69	15.67
FeO*	9.37	9.40	9.53	9.46	9.17	9.17	9.28	9.34
MgO	7.91	7.84	7.74	7.74	7.97	7.99	7.98	7.88
CaO	12.16	12.30	12.18	12.27	12.31	12.14	12.10	12.21
Na_2O	3.03	3.01	3.00	3.09	2.87	2.99	3.03	3.00
K_2O	0.05	0.05	0.04	0.05	0.03	0.04	0.04	0.04
P_2O_5	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11
TOTAL	99.89	99.68	100.12	99.98	99.73	99.67	99.37	99.77
Mg no.	64.3	64.0	63.4	63.6	64.9	65.0	64.7	64.3
P. T.	3B	7B	7B	7B	3B	3B	3B	

BASALT GLASS ANALYSES (*continued*)

SEAMOUNT 3

	8-1	*8-2*	*8-3*	*8-5*	*8-6*	*8-7*	*8-8*	*8-9*	*8-10*	*8-11*	*D-8 Average*
SiO_2	49.79	49.58	49.72	49.87	49.90	50.19	49.81	50.18	49.79	49.27	49.81
TiO_2	1.33	1.34	1.24	1.21	1.29	1.26	1.20	1.28	1.21	1.30	1.27
Al_2O_3	16.53	16.66	16.29	16.03	16.74	16.39	16.14	16.68	16.23	16.73	16.44
FeO*	8.77	8.69	7.78	8.80	8.62	8.72	8.89	8.68	8.83	8.55	8.73
MgO	8.10	8.14	8.54	8.66	8.11	8.35	8.79	8.18	8.75	8.50	8.41
CaO	11.85	11.94	11.98	11.98	11.82	12.11	12.04	11.83	1.88	11.78	11.92
Na_2O	2.80	2.82	2.59	2.64	2.81	2.62	2.61	2.82	2.62	2.77	2.71
K_2O	0.20	0.17	0.13	0.12	0.18	0.14	0.13	0.18	0.14	0.20	0.16
P_2O_5	0.17	0.17	0.17	0.14	0.18	0.16	0.13	0.19	0.16	0.15	0.16
TOTAL	99.54	99.51	99.44	99.45	99.65	99.94	99.74	100.02	99.61	99.25	99.61
Mg no.	66.4	66.7	67.5	67.8	66.8	67.2	67.9	66.8	67.9	68.0	67.3
P. T.	3B	3.B	3B	8	3B	8	8	12	12	12	

BASALT GLASS ANALYSES (*continued*)

	SEAMOUNT 3						SEAMOUNT 4				
	9-1	*9-2*	*9-3*	*9-4*	*9-5*	*D-9 Average*	*11-1*	*11-2*	*12-2*	*12-3*	*13-1*
SiO_2	49.68	49.41	49.96	49.32	48.90	49.45	49.82	50.24	50.8	50.41	50.49
TiO_2	1.38	1.36	1.26	1.31	1.30	1.32	1.33	1.41	1.32	1.38	1.28
Al_2O_3	16.92	17.03	16.74	16.66	16.53	16.78	15.71	14.53	14.90	14.66	15.04
FeO*	8.79	8.83	8.71	8.65	8.72	8.74	9.22	10.20	9.78	10.17	9.49
MgO	7.41	7.52	8.24	8.07	8.16	7.88	7.79	7.51	7.58	7.10	7.83
CaO	12.23	12.12	11.92	11.76	11.98	12.00	12.47	12.43	12.66	12.77	12.45
Na_2O	2.87	2.93	2.74	2.81	2.80	2.83	2.75	2.53	2.56	2.62	2.74
K_2O	0.21	0.21	0.18	0.18	0.20	0.20	0.06	0.06	0.05	0.05	0.04
P_2O_5	0.18	0.18	0.16	0.18	0.18	0.18	0.11	0.09	0.11	0.10	0.09
TOTAL	99.66	99.59	99.91	98.94	98.77	99.38	99.26	99.00	99.14	99.26	99.45
Mg no.	64.5	64.5	66.8	66.6	66.5	65.9	64.3	60.9	62.2	59.7	63.7
P. T.	3B	8			12		4B	6B	3B	2	2

BASALT GLASS ANALYSES (*continued*)

SEAMOUNT 5

	14-1	*14-2*	*15-1*	*15-3*	*15-4*	*15-5*	*15-6*	*15-7*	*15-8*	*15-9*	*15-10*	*15-11*	*D-15 Average*
SiO_2	51.56	50.22	50.32	50.36	50.42	50.38	50.15	50.35	50.45	50.54	50.70	50.40	50.41
TiO_2	2.01	1.92	1.73	1.65	1.67	1.71	1.76	1.71	1.75	1.74	1.70	1.75	1.72
Al_2O_3	14.61	15.53	15.63	15.49	15.53	15.41	15.23	15.46	15.52	15.57	15.59	15.46	15.49
FeO*	10.77	9.28	9.18	9.14	9.21	9.33	9.28	9.16	9.34	9.26	9.19	9.24	9.23
MgO	6.31	6.79	7.15	7.13	7.11	7.07	7.07	7.16	7.01	7.10	7.25	7.09	7.11
CaO	11.15	11.71	11.93	11.88	11.87	11.80	11.76	11.92	11.88	11.85	11.86	11.92	11.87
Na_2O	3.34	3.26	3.24	3.26	3.22	3.28	3.25	3.24	3.29	3.33	3.23	3.20	3.25
K_2O	0.21	0.29	0.17	0.17	0.16	0.19	0.18	0.20	0.18	0.17	0.17	0.17	0.18
P_2O_5	0.19	0.22	0.19	0.19	0.10	0.20	0.19	0.19	0.20	0.19	0.21	0.20	0.20
TOTAL	100.15	99.22	99.54	99.30	99.38	99.37	98.87	99.39	99.62	99.75	99.90	99.43	99.46
Mg no.	55.3	60.9	62.4	62.5	62.3	61.8	61.9	62.5	61.5	62.1	62.8	62.1	62.2
P. T.	4A	3A	3A	3A	3A	3A	3A	3A	3A	3A	3A	3A	

BASALT GLASS ANALYSES (*continued*)

SEAMOUNT 5

	16-1	*17-1*	*17-2*	*17-3*	*17-4*	*17-5*	*17-6*	*17-8*	*17-9*	*D-17 Average*
SiO_2	50.84	50.48	50.37	50.22	50.30	50.45	50.69	50.37	50.23	50.39
TiO_2	1.79	1.71	1.74	1.77	1.64	1.74	1.73	1.68	1.71	1.72
Al_2O_3	14.81	15.52	15.65	15.19	15.74	15.56	15.41	15.47	15.51	15.51
FeO*	10.10	9.03	9.20	9.49	8.96	9.19	9.25	9.13	9.15	9.18
MgO	6.61	7.08	6.97	6.88	7.21	7.03	7.08	7.03	6.97	7.03
CaO	11.57	12.06	11.90	11.93	11.98	12.11	12.10	12.02	12.04	12.02
Na_2O	3.18	3.24	3.34	3.30	3.10	3.16	3.23	3.20	3.16	3.22
K_2O	0.20	0.17	0.19	0.19	0.17	0.16	0.17	0.16	0.16	0.17
P_2O_5	0.18	0.18	0.19	0.20	0.21	0.19	0.17	0.19	0.20	0.19
TOTAL	99.28	99.47	99.54	99.17	99.31	99.58	99.83	99.25	99.13	99.43
Mg no.	58.1	62.6	61.8	60.7	63.3	62.0	62.0	62.2	61.9	62.0
P. T.			3A	7A	7A	7A	1	4A	4A	

BASALT GLASS ANALYSES *(continued)*

	SEAMOUNT 5							*SEAMOUNT 6*							
	18-1	*18-3*	*19-5*	*19-8*	*19-11*	*19-12*	*19-13*	*19-15*	*19-16*	*19-17*	*19-19*	*19-21*	*19-22*	*19-23*	*D-19*
SiO_2	49.77	49.84	50.00	50.94	50.53	50.54	50.26	50.42	50.48	50.14	50.04	48.66	49.52	50.62	
TiO_2	1.46	1.46	1.24	1.23	1.23	1.23	1.20	1.20	1.22	1.27	1.25	1.84	1.25	2.24	
Al_2O_3	16.44	16.52	16.55	16.49	16.36	16.25	16.60	16.35	16.38	16.51	16.38	18.89	16.66	17.72	
FeO*	8.95	8.95	8.84	8.76	8.77	8.82	8.71	8.79	8.81	8.80	8.77	7.97	8.67	8.14	
MgO	7.68	7.76	8.24	8.18	8.08	8.31	8.12	8.46	8.22	8.10	8.10	6.88	7.84	4.94	
CaO	11.91	11.75	11.97	11.98	12.07	12.01	11.92	11.98	12.00	12.00	12.07	10.20	11.93	9.20	
Na_2O	3.07	3.08	2.77	2.75	2.76	2.74	2.78	2.63	2.81	2.74	2.71	3.48	2.79	4.09	
K_2O	0.15	0.12	0.13	0.12	0.12	0.12	0.11	0.09	0.13	0.13	0.14	0.99	0.14	1.58	
P_2O_5	0.17	0.16	0.14	0.14	0.13	0.13	0.13	0.12	0.13	0.13	0.12	0.37	0.15	0.53	
TOTAL	99.60	99.54	99.89	100.59	100.05	100.15	99.83	100.04	100.18	99.82	99.58	99.18	98.95	99.06	
Mg no.	64.7	64.9	66.5	66.6	66.3	66.9	66.6	67.3	66.6	66.3	66.3	65.1	65.6	56.5	
P. T.	3,11B	3,11B	3B	3B	3B	3B	3B		3B	3B	3B	3A	2	3A	

* Of low-K_2O samples only.

BASALT GLASS ANALYSES (*continued*)

		SEAMOUNT 6					*SEAMOUNT 7*				*SEAMOUNT 8*		
	20-1	*20-2*	*20-4*	*21-3*	*21-4*	*23-6*	*25-1*	*25-2*	*25-3*	*25-4*	*25-5*	*D-25 Average*	*26-2*
SiO_2	49.30	51.01	49.84	49.92	49.80	51.20	51.33	51.49	50.81	51.74	51.38	51.35	50.69
TiO_2	1.34	2.25	1.27	1.42	1.36	2.04	1.31	1.15	1.14	1.14	1.30	1.21	1.13
Al_2O_3	16.65	15.54	16.66	16.31	16.21	15.20	14.86	15.59	14.44	14.63	15.00	14.70	16.19
FeO*	8.87	9.95	8.83	8.95	8.84	9.61	9.67	10.42	10.19	10.22	9.71	10.04	8.93
MgO	7.74	5.23	7.84	7.91	7.85	6.04	7.66	7.74	7.85	7.76	7.67	7.73	8.46
CaO	11.75	9.84	11.94	12.11	12.04	11.08	12.58	12.83	12.81	12.72	12.53	12.69	12.59
Na_2O	2.94	4.07	2.76	2.85	2.88	3.55	2.65	2.23	2.20	2.23	2.70	2.40	2.54
K_2O	0.28	1.00	0.21	0.12	0.12	0.49	0.84	0.06	0.06	0.05	0.08	0.07	0.06
P_2O_5	0.17	0.42	0.16	0.15	0.13	0.27	0.11	0.10	0.10	0.11	0.11	0.11	0.11
TOTAL	99.64	99.31	99.51	99.74	99.23	99.48	100.25	100.61	99.60	100.60	100.48	100.30	100.70
Mg no.	65.1	52.9	65.6	65.1	65.5	57.4	62.9	61.4	62.4	61.9	62.8	62.2	66.9
P. T.	3B	5B	3B	2	3B	10	2	2	11B	11B	2		11 B

BASALT GLASS ANALYSES (*continued*)

SEAMOUNT 9

	27-1	*27-2*	*28-4*	*28-6*	*28-7*	*28-8*	*28-10*	*28-11*	*28-12*	*28-13*	*28-14*	*28-15*	*28*
SiO_2	50.26	50.06	49.71	49.03	49.16	50.33	49.06	50.37	49.10	49.39	49.23	49.55	49
TiO_2	1.09	1.14	1.13	1.02	1.03	1.51	1.04	1.48	1.03	1.01	1.03	1.01	1
Al_2O_3	17.32	17.16	16.41	17.30	17.32	15.13	17.28	15.16	17.39	17.37	17.42	17.62	17
FeO*	8.34	8.20	8.42	8.03	8.09	9.46	8.04	9.41	8.05	7.99	8.13	8.02	8
MgO	8.76	7.84	8.49	9.0	9.00	7.16	9.10	7.21	8.81	9.09	9.07	9.05	8
CaO	12.30	12.46	12.17	12.20	12.25	12.10	12.42	12.01	12.34	12.34	12.36	12.35	12
Na_2O	2.70	2.75	2.80	2.62	2.61	3.08	2.62	3.07	2.56	2.54	2.54	2.59	2
K_2O	0.08	0.07	0.06	0.05	0.06	0.12	0.05	0.12	0.07	0.06	0.06	0.07	0
P_2O_5	0.08	0.10	0.12	0.10	0.12	0.15	0.10	0.15	0.10	0.11	0.10	0.08	0
TOTAL	100.93	99.78	99.31	99.36	99.64	99.04	99.71	98.98	99.45	99.90	99.94	100.34	100
Mg no.	69.2	67.2	68.3	70.6	70.4	61.8	70.8	62.1	69.7	70.9	70.5	70.7	70
P. T.	3B	3B	2	3B	2	12	12	12	12	1	12	2	2,1

BASALT GLASS ANALYSES (*continued*)

SEAMOUNT 9

								Averages	
	28-17	*28-18*	*28-19A*	*29-19B*	*28-21*	*28-28*	*1(N-2)*	*2(N-13)*	*3(N-3)*
SiO_2	49.55	49.64	49.85	50.21	50.75	49.74	49.46	49.40	50.48
TiO_2	1.04	1.02	1.02	1.15	1.45	1.01	1.14	1.02	1.48
Al_2O_3	17.66	17.63	17.57	16.99	15.37	17.80	16.70	17.52	15.22
FeO*	8.04	8.24	8.13	8.53	9.42	8.08	8.48	8.09	9.43
MgO	9.13	8.97	8.80	8.51	7.47	9.01	8.50	8.98	7.28
CaO	12.30	12.37	12.31	12.44	12.23	12.44	12.30	12.32	12.11
Na_2O	2.54	2.60	2.60	2.75	3.04	2.59	2.78	2.59	3.06
K_2O	0.06	0.06	0.06	0.60	0.11	0.06	0.06	0.06	0.12
P_2O_5	0.08	0.07	0.09	0.08	0.14	0.10	0.10	0.09	0.15
TOTAL	100.40	100.61	100.43	100.72	99.98	100.83	100.02	100.07	99.33
Mg no.	70.8	69.9	69.8	68.1	62.9	70.5	68.2	70.4	62.3
P. T.	11	7B	3B	3B	2	4B			

EAST PACIFIC RISE GLASS ANALYSES

													Averages
	5-1	*5-2*	*10-2*	*10-3*	*10-4*	*10-5*	*10-6*	*10-7*	*10-8*	*10-9*	*D-10 Average*	*30-1*	*30-2*
SiO_2	50.02	50.31	50.32	50.44	49.96	50.05	50.46	50.79	50.11	50.30	50.30	51.15	52.33
TiO_2	1.55	1.57	1.93	1.87	1.84	1.91	1.92	1.92	1.92	2.06	1.92	1.99	2.07
Al_2O_3	15.84	15.87	15.25	15.24	15.36	15.28	14.99	15.07	15.08	14.88	15.14	14.26	13.78
FeO*	9.10	8.97	10.34	10.24	10.14	10.23	10.23	10.29	10.12	10.09	10.21	11.97	11.78
MgO	7.69	7.68	6.96	6.93	7.10	6.93	6.92	7.00	6.96	7.03	6.99	6.27	6.33
CaO	11.92	12.05	11.25	11.31	11.28	11.36	11.28	11.50	11.35	11.34	11.33	10.76	10.82
Na_2O	2.92	2.94	2.96	2.89	2.90	2.91	2.89	2.80	2.84	2.72	2.86	2.79	2.93
K_2O	0.26	0.26	0.24	0.23	0.23	0.23	0.23	0.24	0.25	0.24	0.24	0.20	0.21
P_2O_5	0.17	0.19	0.21	0.21	0.21	0.23	0.23	0.20	0.20	0.19	0.21	0.18	0.18
TOTAL	99.47	99.84	99.46	99.42	99.02	99.13	99.15	99.81	99.83	98.85	99.20	99.57	100.43
Mg no.	64.4	64.7	59.0	59.4	59.9	59.2	59.2	59.3	59.5	59.8	59.4	52.8	53.5
P. T.	7B	4B	3B	3B	3B	3B							