DEPARTMENT OF THE INTERIOR
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# Geochemistry and petrography of basalt dredged on cruise L5-83-HW from Necker Ridge, Horizon and S.P. Lee Guyot, Central Pacific Ocean

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## INTRODUCTION

Volcanic rock was dredged from three volcanic edifices in the central Pacific Ocean on U.S. Geological Cruise L5-83-HW in 1983. The R/V S.P. Lee surveyed Necker Ridge, Horizon Guyot and a guyot informally named S.P. Lee Guyot (Hein and others, 1985a), using 3.5, 12kHz and 80 $in^3$ airgun seismic-reflection profiles, dredges, free-fall hard substrate and gravity cores, CTD-oxygen probes, and deep sea video and camera tows. The primary objective of this cruise was to sample ferromanganese oxides that encrust hard substrates on the ocean floor. Mineralogy and geochemistry of ferromanganese crusts, seismic profiles of the survey-sites and detailed description of study methods are presented in Hein and others (1985a, 1985b).

This report presents petrography, whole-rock, glass and mineral chemistry for selected volcanic rock samples recovered on that cruise.

## GEOLOGIC SETTING

### Necker Ridge

Necker Ridge is a 600 km-long, NE-SW trending ridge at the NE margin of the mid-Pacific mountains (Figure 1). The ridge rises about 3 km above the adjacent abyssal sea floor to a minimum depth of less than 1600 m. The ridge crest topography is rugged to the northeast, becoming more rounded to the southwest with increasing sediment cover. Slope angles vary from about 12° to 20° (Hein and others, 1985a, 1985b).

### Horizon Guyot

Horizon Guyot is an isolated, flat-topped edifice that is about 300 km long and 75 km wide (Figure 1). It is the easternmost edifice of the mid-Pacific mountains and rises 3.5 km above the abyssal seafloor to within 1400 m of sealevel. Flanks slope from 14° to 19°, and the flat-topped summit is capped by up to 500 m of pelagic sediment (Lonsdale and others, 1972). DSDP site 171 is located in the saddle between the western and eastern parts of the guyot.

### S.P. Lee Guyot

S.P. Lee Guyot is a large flat-topped edifice in the north-central Line Islands, and measures about 80 by 125 km at its base (Figure 1). It rises about 4 km above the abyssal seafloor to a minimum depth of 900 m. The upper flanks are rugged with many volcanic pinnacles supporting little sediment cover. Volcanic knobs also dot the summit, protruding through the sediment cap which is up to 200 m thick (Hein and others, 1985a). DSDP site 165 is located on the lower western flank of the guyot.

## ANALYTICAL METHODS

Samples were studied in thin sections and bulk chemical analyses were performed in the analytical laboratories of the U.S. Geological Survey. Major element chemistry was determined by wave-length dispersive X-ray fluorescence (XRF) using methods described by Taggart and others (1982). Abundances of Rb, Sr, Zr, Ba, Y, and Nb were determined by energy-dispersive XRF. Precision and accuracy of XRF is 1 to 2% for major elements and 5 to 10% for trace elements. FeO, $CO_2$, and $H_2O$ were determined by standard wet chemical techniques (Peck, 1964). Abundances of Hf, Ta, Th, Sc, Co, Cr and the rare earth elements (REE) were determined by instrumental neutron activation analysis (INAA) using the method described by Baedecker (1979). Olivine, plagioclase, clinopyroxene, spinel and glass compositions were determined with a 9-channel electron microprobe, using 15 kv accelerating voltage and 20 nAmp sample current with a narrowly focused beam (~2 μ) for olivine, spinel and clinopyroxene, and 10 nAmp and a larger beam size (~20-50 μ) for plagioclase and glass. Natural and synthetic glasses and minerals were used as standards. Data reduction was performed using a modified version of Bence and Albee's (1968) program.

## PETROGRAPHY AND MINERAL CHEMISTRY

Dredge locations and water depths from which samples were recovered are given in Table 1, and petrographic data are summarized in Table 2. Chemical analyses of olivine, plagioclase, clinopyroxene and spinel are presented in Tables 3, 4, and 5, respectively. The samples are generally highly altered.

### Necker Ridge

The volcanic rocks recovered from Necker Ridge comprise tholeiitic and alkalic basalt. The basalt samples are pebble- and cobble-sized clasts in volcaniclastic breccia, or loose talus. Hyaloclastite composed of angular to sub-rounded palagonite fragments in calcareous matrix is also abundant. Small areas within the palagonite are fresh sideromelane with microphenocrysts of plagioclase and olivine that is only partially replaced by iddingsite. Except for two microlites in the groundmass with $Fo_{78}$, these euhedral olivine crystals are relatively magnesian with a narrow compositional range of $Fo_{84-86}$ (Figure 2a). NiO content as high as 0.28 (Figure 2b) also indicates a relatively primitive composition. The single spinel crystal included in one of the olivines (D6-A5) is low in $TiO_2$ (0.77%) and high in $Al_2O_3$ (39.5%). Plagioclase in the fresh glass is bytownite with An contents clustered around 84 to 86 (Table 4, Figure 3). Plagioclase in the altered tholeiitic sample D1-3 is much less calcic. No clinopyroxene is present in the sideromelane, indicating that olivine and plagioclase crystallized at low pressure and were quenched before clinopyroxene could crystallize. The alkalic samples have abundant clinopyroxene granules that are either too small or too altered to analyze.

### Horizon Guyot

The three samples analyzed from Horizon Guyot comprise transitional and alkalic basalt. Like samples from Necker Ridge, the hyaloclastite contains some fresh glass (D11-A7). Olivine in the sideromelane with $Fo_{80-84}$ is less magnesian than that of Necker Ridge (Figure 2a), and NiO is also correspondingly lower (Figure 2b). Plagioclase in the sideromelane is similar to that from Necker Ridge, but the alkalic sample (D14-A1) is more enriched in potassium at a similar An content (Figure 3). Similar to Necker Ridge samples, clinopyroxene is absent in the glass and too small or altered in the whole-rock samples to be analyzed.

### S.P. Lee Guyot

Samples from S.P. Lee Guyot consist of moderately to strongly alkalic basalt that are severely altered. Olivine in all samples is completely replaced by either clays or iron hydroxides. One sample (D25-1), an ankaramite, has unaltered, cm-sized clinopyroxene crystals with a narrow compositional range of $Wo_{46.3-46.7}En_{44.1-44.8}Fs_{8.7-10.1}$ (Table 5, Figure 4). These crystals have cuspate and embayed margins indicative of resorption. The rare plagioclase phenocryst in the ankaramite is bytownite ($An_{83-86}$), but a single microlite in the groundmass is high in potassium with Or content of 4.0 at an An content of 68 (Figure 3), suggesting a strongly alkalic composition. Some of the clinopyroxene in D31-1 show optical zoning with green cores and lavender rims.

## MAJOR ELEMENT CHEMISTRY

Major and minor element compositions of thirteen samples are presented in Table 6. Ten of these analyses are of whole-rock samples; whereas three analyses represent fresh sideromelane in hyaloclastite. All of the whole-rock samples are moderately to severely altered.

### Necker Ridge

The seven samples analyzed from Necker Ridge comprise tholeiitic and mildly alkalic basalt. All except samples of D1, plot in the alkalic field on the $SiO_2$ vs. alkalies plot (Figure 5, Macdonald and Katsura, 1964). However, the glass compositions (D6-A5, D7-1) are only mildly alkalic, and the remaining two samples (D5-2, D6-2) are more alkalic and more differentiated. Samples of D1 are low in $TiO_2$ for oceanic island tholeiite (Figure 6). The glass compositions appear intermediate between tholeiitic and alkalic ocean-island basalt with respect to $TiO_2$ and $P_2O_5$ (Figure 6). The two alkalic samples D5-2 and D6-2 are higher in $P_2O_5$ at a similar TiO content; especially D5-2 with $P_2O_5$ of 1.2% may reflect post-magmatic phosphatization.

### Horizon Guyot

The three samples analyzed from Horizon Guyot range from transitional between tholeiitic and alkalic to moderately alkalic basalt. The alkalic basalt (D14) is differentiated and appears transitional between basalt and hawaiite. The glass composition (D11-A7) plots on the boundary between tholeiitic and alkalic on the $SiO_2$ vs. alkalies plot (Figure 5), but well within the alkalic field on the $TiO_2$ vs. $P_2O_5$ plot (Figure 6). The most alkalic composition of D14-1 has $P_2O_5$ contents of about 1% which may be in part due to phospatization.

### S.P. Lee Guyot

The three samples analyzed from S.P. Lee Guyot are more strongly alkalic than those from the other two sites. One sample (D31-1) is a nephelinite (Figure 5). $TiO_2$ content is much higher than in samples from the other sites ranging from 3.7 to 5.4 % at a uniform $P_2O_5$ content of about 0.9 % (Figure 6).

## TRACE ELEMENT CHEMISTRY

Abundances of twenty trace elements in the whole-rock samples are presented in Table 7. Fresh glass was not abundant enough for trace element analyses.

### Necker Ridge

Rb, Sr, and Ba abundances are highly variable and range from <10 to 42, 150 to 480, and 46 to 380, respectively. However, these elements are easily mobilized by secondary alteration processes. Rare earth elements (REE) and high field strenght elements are less susceptible to alteration (e.g. Winchester and Floyd, 1976; Pearce and Cann, 1973). Chondrite-normalized REE abundances (Figure 7a) show nearly flat profiles for the tholeiitic samples similar to E-type MORB or depleted Hawaiian tholeiite. The alkalic samples (D5-2, D6-2) have steeper slopes with light REE enriched over heavy REE typical for alkalic basalt. The small negative Ce anomaly of D5-2 suggests some REE enrichment due to post-magmatic phosphatization, which is also supported by the high $P_2O_5$ content (Figure 6). A similar pattern is also observed on Zr vs. Nb (Figure 8), Zr vs. Sr (Figure 9), and Hf-Th-Ta (Figure 10) plots. Samples from Necker Ridge except for D5-2, plot in the tholeiitic field with those of D1 overlapping with oceanic ridge compositions.

### Horizon Guyot

The two samples from Horizon Guyot show REE patterns with steeper slopes than those from Necker Ridge (Figure 7b), with D14-1 more enriched than D12-7. On Zr vs. Nb (Figure 8) and Zr vs. Sr (Figure 9) plots, D12-7 lies in the tholeiitic field, whereas D14-B1 is distinctly alkalic. On the Hf-Th-Ta plot (Figure 10) both plot in the alkalic field.

### S.P. Lee Guyot

The three samples from S.P. Lee Guyot have parallel REE profiles with steeper slopes showing greater relative enrichment of light over heavy REE (Figure 7c) than the samples from the other two sites. On Zr vs. Nb (Figure 8), Zr vs. Sr (Figure 9), and Hf-Th-Ta (Figure 10) plots, all three fall consistently within the field of alkalic intra-plate basalt.

## COMPARISON WITH OTHER OCEANIC ISLAND BASALT

Volcanic rock recovered from Necker Ridge and Horizon Guyot are similar to Hawaiian tholeiitic and mildly alkalic basalt. Samples from S.P. Lee Guyot are more strongly alkalic and similar to basalt from the same site described by Natland (1976), although his study includes samples that are much more alkalic and as differentiated as phonolite (Figure 5). Natland (1976) considered these "potassic nephelinites" to be similar to potassic, mafic lava of the western African rifts. Samples recovered at DSDP site 165, near the western base of S.P. Lee Guyot also appear more strongly alkalic than the three samples of this study (Figures 5,6,8, Bass et al., 1973).

Alteration-resistant elements such as Ti, Zr, Nb, and REE are more reliable in establishing petrotectonic affinities of altered submarine rocks than major element chemistry. However, a pattern similar to that shown by major elements is observed. Necker Ridge samples are predominantly tholeiitic, similar to depleted Hawaiian tholeiites or enriched oceanic ridge basalt. Horizon Guyot samples include one transitional or mildly alkalic and one strongly alkalic composition. Previous studies (Bass and others, 1973) of samples drilled in the saddle of Horizon Guyot at DSDP site 171 include more depleted trace element compositions that appear distinctly tholeiitic and more similar to compositions from Necker Ridge. No previous analyses have been published for Necker Ridge. Trace element compositions of samples from S.P. Lee Guyot are clearly alkalic, but not as alkalic as those recovered at DSDP 165. The one trace element analysis reported by Natland (1976) for this site resembles those from DSDP 165.

The limited mineral chemistry data shows a similar pattern. Fo and An contents of samples from Necker Ridge are similar to those in depleted Hawaiian tholeiite or oceanic ridge basalt. One sample from Horizon Guyot is similar to those from Necker Ridge, whereas the second sample shows higher potassium content at similar An composition. The Or content of the single groundmass plagioclase crystal from S.P. Lee Guyot suggests a strongly alkalic composition. Unfortunately, phenocrysts in tholeiitic and alkalic lava overlap in composition and the fields established for plagioclase (Figure 3, Keil and others, 1972) and clinopyroxene (Figure 4, Fodor and others, 1975) of Hawaiian lava are not as distinct for other lava suites. For example, phenocrysts and groundmass plagioclase in alkalic basalt from the Marshall Islands span all three fields in a single thin section (Davis and others, 1986; 1987). Likewise, clinopyroxene phenocrysts in alkalic basalt from the Marshall Islands (Davis and others, 1986; 1987) span the field of tholeiitic and alkalic compositions shown in Figure 4. The single spinel crystal included in olivine in glass from Necker Ridge is distinctly higher in $Al_2O_3$ and lower in $TiO_2$ than any reported for Kilauea or Mauna Loa tholeiite (Basaltic Volcanism Project, 1982). It appears intermediate in composition between alkalic Hawaiian lava and mid-ocean ridge basalt. Similar spinel composition, although somewhat higher in $TiO_2$, has been reported from alkalic glass dredged from a small seamount near the Galapagos Spreading Center (Batiza and others, 1982).

## CONCLUSIONS

The limited number and altered state of most of these samples preclude establishing petrogenetic trends for each site. The presence of tholeiitic, transitional and alkalic basalt suggest a general pattern of evolution similar to that observed for Hawaiian volcanoes. Namely, voluminous eruptions of tholeiitic lava during the shield-building stage is capped by smaller volumes of alkalic lava during the postshield stage, and finally, after a period of quiescence, followed by very small volumes of strongly alkalic lava during the rejuvenated stage (Clague and Dalrymple, 1987). Studies of other volcanic islands such as Samoa (Natland, 1980), Caroline (Mattey, 1982), and Marshall Islands (Davis et al., 1986; 1987) suggest that during the shield stage these volcanoes erupted only transitional and mildly alkalic basalt, but follow the same progression to more alkalic postshield and strongly alkalic rejuvenated compositions. Decreasing alkalinity of compositions is undoubtedly related to increasing percentage of partial melting. Large percentage of partial melting probably results in large volumes and hence larger edifices. Horizon Guyot and especially Necker Ridge are much larger than edifices comprising most island chains in the Pacific basin. S.P. Lee Guyot is much smaller and should have a mildly to moderately alkalic shield composition. The strongly alkalic samples recovered are probably of the rejuvenated stage. Since dredging was limited to shallow depths (<2000 m), no shield stage lava was recovered. Tholeiitic and transitional lava from Necker Ridge and Horizon Guyot were dredged from water depths > 3500 m.

S.P. Lee Guyot is considered to be part of the Line island chain, which Morgan (1972) suggested formed, similar to the Hawaiian-Emperor chain, as the Pacific plate moved over a stationary hot spot. Late Cretaceous to Eocene ages determined for some of the edifices in the chain suggest a generalized age progression from NW to SE, but recurrent, synchronous Tertiary volcanism along central portions of the chain indicates a more complex origin (Haggerty and others, 1982; Schlanger and others, 1984). Horizon Guyot is on the northern end of that chain, and with a late Cretaceous age may also be part of that chain or part of the mid-Pacific mountains.

Necker Ridge is not part of the Line Island chain, but extends at nearly right angles to that chain from SW to NE. With its rugged topography, and long, narrow, continuous shape (> 600 km), it does not resemble the other edifices in the Line Island chain. No age data is available for Necker Ridge. Petrologically it appears distinct from the island chain edifices, and it may have originated at a leaky fracture zone.

## REFERENCES CITED

Baedecker, P.A., 1979, The INAA program of the U.S. Geological Survey (Reston, Virginia), in Carpenter and others, eds., Computers in activation analysis and ray spectroscopy: Conf.-78042, U.S. Department of Energy, p. 373-385.

Basaltic Volcanism Project, 1981, Basaltic volcanism on the terrestrial planets. Pergamon Press Inc.,New York.

Bass, M.N., Moberly, R., Rhodes, J.M., Shih, C.-Y., and Church, S.E., 1973, Volcanic rocks cored in the central Pacific, leg 17, DSDP. Initial Rep. Deep Sea Drill. Proj., v. 17, p.429-466.

Batiza, R., Oestrike, R., Futa, K., 1982, Chemical and isotopic diversity in basalts dredged from the East Pacific Rise at 10°S, the fossil Galapagos Rise and the Nazca Plate. Marine Geology, v.49, p. 115-132.

Bence, A. E. and Albee, A. E.,1968, Empirical correction factors for the electron microanalysis of silicates and oxides. J. Geol., 76, p.382-403.

Clague, D.A. and Dalrymple, G.B., 1987, The Hawaiian-Emperor volcanic chain, in Decker and others (eds.), Volcanism in Hawaii, vol.1, U.S.G.S. Prof. Paper 1350, p.5-54.

Davis, A.S., Schwab, W.C. and Haggerty, J.A., 1986, Geochemistry and petrology of basaltic rocks from the Marshall Islands. U.S.G.S. Open-File Report 86-273, 24pp.

Davis, A.S., Pickthorn, L.B.G., Pringle, M.S., Clague, D.A., and Schwab, W.C., 1987, Geochemistry, petrology, and age of alkalic lava from the Marshall Islands. J. Geophys. Res. (in press).

Fodor, R. V., Keil, K., and Bunch, T. E., 1975, Contributions to the mineral chemistry of Hawaiian rocks. Contrib. Min. Petrol., 50, p.173-195.

Haggerty, J.A., Schlanger, S.O. and Premoli-Silva, I., 1982, Late Cretaceous and Eocene volcanism in the southern Line Islands and implications for hot spot theory. Geology, 10, p. 427-433.

Hein, J.R., Manheim, F.T., Schwab, W.C., and Davis, A.S., 1985, Ferromanganese crusts from Necker Ridge, Horizon Guyot and S.P. Lee Guyot: Geological Considerations. Marine Geology, v.69, p.25-54.

Hein, J.R., Manheim, F.T., Schwab, W.C., Davis, A.S., Daniel, C.L., Bouse, R.M., Morgenson, L.A., Sliney, R.E., Clague, D.A., Tate, G.B., and Cachione, D.A., 1985, Geological and geochemical data for seamounts and associated ferromanganese crusts in and near the Hawaiian, Johnston Island, and Palmyra Island Exclusive Economic Zones. U.S. Geological Survey Open-File Report 85-292, 129 pp.

Keil, K., Fodor, R.V., and Bunch, T.E., 1972, Contributions to the mineral chemistry of Hawaiian rocks II. Feldspars and interstitial material in rocks from Haleakala and west Maui volcanoes, Maui, Hawaii. Contrib. Min. Pertol., 37, p.253-276.

Lonsdale, P., Normark, W.R., and Newman, W.A., 1972, Sedimentation and erosion on Horizon Guyot. Geol. Soc. Am. Bull., 83, p.289-316.

Macdonald, G. A., 1968, Composition and origin of Hawaiian lavas. in Coats, R. E., Hay, R. L., and Anderson, C. A. (eds.). Studies in volcanology. Geol. Soc. Am. Memoir, 116, p.477-522.

Macdonald, G. A. and Katsura, T., 1964, Chemical composition of Hawaiian lavas. J. Petrol., 5, p.82-133.

Mattey, D. P., 1982, The minor and trace element geochemistry of volcanic rocks from Truk, Ponape and Kusaie, Eastern Caroline Islands; the evolution of a young hot spot trace across old Pacific crust. Contrib. Min. Petrol., 80, p.1-13.

Morgan, W.J., 1972, Deep mantle convection plumes and plate motions. Am. Assoc. Pet. Geol., 56, p.203-213.

Natland, J. H., 1976, Petrology of volcanic rocks dredged from seamounts in the Line Island chain. in Schlanger, and E. D. Jackson and others (eds.) Initial Reports of the Deep Sea Drilling Project, v. 33, p.749-777. U.S. Government Printing Office, Washington.

Natland, J.H., 1980, The progression of volcanism in the Samoan linear volcanic chain. Am. J. Sci., v. 280, p.709-735.

Pearce, J. A. and Cann, J. R., 1973, Petrogenetic implications of Ti, Zr, Y, and Nb variations in volcanic rocks. Contrib. Min. Petrol., 69, p.23-47.

Peck,L.C., 1964, Systematic analysis of silicates. U.S. Geol. Survey Bull., 1170, 84 pp.

Schlanger, S.O., Garcia, M.O., Keating, B.H., Naughton, J.J., Sager, W.W., Haggerty, J.A. and Philpotts, J.A., 1984, Geology and geochronology of the Line Islands. J. Geophys. Res., 89, p. 11,261-11,272.

Taggart, J.E., Lichte, F.E., and Wahlberg, J.S., 1982, Methods of analysis of samples using X-ray fluorescence and induction-coupled plasma spectroscopy, <u>in</u> The 1980 eruptions of Mount St. Helens, Washington. U.S. Geol. Survey Prof. Pap. 1250, p. 683-687.

Winchester, J.A. and Floyd, P.A., 1976, Geochemical magma type discrimination: Application to altered and metamorphosed basic igneous rocks. Earth Planet. Sci. Lett., v. 28, p.459-469.

Wood, D.A., 1980, The application of a Th-Hf-Ta diagram to problems of tectonomagmatic classification and to establishing the nature of crystal contamination of basaltic lava of the British Tertiary volcanic province. Earth Planet. Sci. Lett., v. 50, p. 11-30.

Table 1: Dredge Locations

| Dredge No. | Location (Lat. ° N) | (Long. ° W) | Water depth (m) |
|---|---|---|---|
| Necker Ridge | | | |
| D1 | 22 ° 11.6 | 166 ° 47.7 | 4200-3950 |
| D5 | 22 ° 18.7 | 166 ° 54.0 | 2350-2100 |
| D6 | 21 ° 43.2 | 167 ° 35.0 | 2400-2100 |
| D7 | 21 ° 48.0 | 167 ° 37.2 | 2100 |
| Horizon Guyot | | | |
| D11 | 19 ° 20.8 | 168 ° 41.4 | 3790-3700 |
| D12 | 19 ° 22.1 | 168 ° 41.7 | 2000 |
| D14 | 19 ° 30.2 | 168 ° 46.7 | 1800-1750 |
| S.P. Lee Guyot | | | |
| D23 | 8 ° 24.9 | 164 ° 17.7 | 1900-1850 |
| D25 | 8 ° 23.5 | 164 ° 17.6 | 1600 |
| D31 | 8 ° 11.6 | 164 ° 12.0 | 1600-1450 |

Table 2: Petrographic Data for Volcanic Rock Dredged on Cruise L5-83-HW
from Necker Ridge, Horizon and S.P. Lee Guyot

| Sample | Vesicles | Phenocrysts | | Groundmass | Remarks |
|---|---|---|---|---|---|
| | vis.est.% | vis.est.% | minerals | minerals | |
| Necker Ridge | | | | | |
| D1-1 | <1% | ~1% | oliv > plag | plag > cpx> clay + Fe ox | clay replacing glass |
| D1-2 | <1% | ~1% | oliv > plag | plag > cpx > clay + Fe ox | clay replacing glass |
| D1-3 | <1% | <20% | plag>oliv | plag > clay + Fe ox> cpx | Fe oxide pseudomorph olivine |
| D1-6 | <3% | ~3% | plag | plag > clay + Fe ox >cpx | Fe oxide pseudomorph olivine |
| D5-2 | <50% | ~5% | oliv | plag > cpx > clay + Fe ox | Fe oxide pseudomorph olivine |
| D6-2 | <1% | ~30% | plag>oliv | plag > cpx > clay + Fe ox | Fe oxide pseudomorph olivine |
| D6-A5 | <1% | ~25% | oliv > plag | plag > glass > oliv | palagonite with minor sideromelane, fresh olivine |
| D7-1 | <1% | ~10% | oliv > plag | plag > glass > oliv | |
| Horizon Guyot | | | | | |
| D11-A7 | <1% | ~10% | oliv > plag | plag > glass > oliv | palagonite with minor sideromelane, fresh olivine |
| D12-7 | <8% | <10% | oliv > plag | plag > Fe ox + clay | olivine pseudomorphed by saponite and iddingsite |
| D14-A1 | <1% | <5% | oliv > plag | plag > Fe ox + clay | olivine with fresh cores |
| D14-1 | <1% | <8% | oliv > plag | plag > Fe ox + clay | olivine replaced |
| S.P. Lee Guyot | | | | | |
| D23-5 | <1% | 0% | none | plag > Fe oxides > cpx | clay-lined fractures |
| D23-9 | <1% | <1% | oliv | plag > Fe oxides > cpx | olivine replaced |
| D25-1 | <15 | ~45% | cpx > oliv > plag | cpx > plag > Fe ox | cpx embayed,<br>oliv. replaced by clay + $CaCO_3$ |
| D31-1 | <10% | <30% | cpx > oliv | plag = cpx > Fe ox | cpx have pale green cores |

oliv= olivine, plag= plagioclase, cpx= clinopyroxene, Fe ox= iron oxides

Table 3: Olivine Analyses

| Sample No. | D6-A5 1C | D6-A5 1R | D6-A5 2C | D6-A5 2R | D6-A5 3C | D6-A5 3R | D6-A5 4mc | D6-A5 5mc | D6-A5 6R | D6-A5 6C | D6-A5 7mc | D6-A5 8R | D6-A5 8C | D6-A5 9mc | D7-1 1R | D7-1 1C | D7-1 2R | D7-1 2C | D7-1 3mc | D7-1 4mc | D7-1 5mc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wt.% | | | | | | | | | | | | | | | | | | | | | |
| MgO | 45.4 | 44.9 | 45.4 | 44.9 | 45.3 | 45.2 | 40.4 | 40.6 | 44.9 | 45.6 | 45.3 | 45.5 | 46.1 | 45.0 | 43.8 | 44.6 | 45.0 | 44.5 | 44.4 | 44.5 | 45.1 |
| $SiO_2$ | 39.6 | 39.2 | 39.8 | 39.3 | 39.7 | 39.4 | 37.7 | 38.1 | 39.5 | 39.6 | 39.8 | 39.6 | 39.7 | 39.5 | 39.5 | 39.5 | 39.1 | 39.3 | 38.9 | 39.1 | 39.4 |
| CaO | 0.25 | 0.27 | 0.25 | 0.26 | 0.26 | 0.25 | 0.39 | 0.40 | 0.24 | 0.26 | 0.27 | 0.26 | 0.25 | 0.26 | 0.29 | 0.27 | 0.26 | 0.25 | 0.25 | 0.25 | 0.25 |
| MnO | 0.21 | 0.21 | 0.21 | 0.23 | 0.21 | 0.22 | 0.32 | 0.34 | 0.23 | 0.25 | 0.22 | 0.22 | 0.22 | 0.26 | 0.19 | 0.23 | 0.24 | 0.24 | 0.25 | 0.20 | 0.20 |
| FeO | 13.2 | 13.9 | 13.4 | 14.0 | 13.2 | 13.6 | 20.6 | 20.8 | 14.8 | 14.6 | 15.0 | 15.0 | 14.8 | 15.3 | 14.0 | 13.9 | 15.0 | 15.0 | 15.0 | 13.8 | 13.5 |
| NiO | 0.25 | 0.21 | 0.24 | 0.24 | 0.25 | 0.23 | 0.13 | 0.10 | 0.25 | 0.22 | 0.22 | 0.21 | 0.28 | 0.20 | 0.21 | 0.20 | 0.22 | 0.21 | 0.20 | 0.21 | 0.21 |
| Total | 98.9 | 98.6 | 99.3 | 98.9 | 98.9 | 98.9 | 99.5 | 100.3 | 99.9 | 100.5 | 100.7 | 100.7 | 101.3 | 100.5 | 98.0 | 98.7 | 99.7 | 99.5 | 99.0 | 98.1 | 98.7 |
| mol.% | | | | | | | | | | | | | | | | | | | | | |
| Fo | 86.0 | 85.2 | 85.8 | 85.1 | 85.9 | 85.5 | 77.7 | 77.7 | 84.3 | 84.8 | 84.4 | 84.4 | 84.7 | 84.0 | 84.8 | 85.2 | 84.2 | 84.1 | 84.1 | 85.2 | 85.7 |

| Sample No. | D11-A7 1R | D11-A7 1C | D11-A7 2mc | D11-A7 3C | D11-A7 3R | D11-A7 4mc | D14-A1 1mc | D14-A1 2mc | D14-A1 3R | D14-A1 3C | D14-A1 4R | D14-A1 4C | D14-A1 5R | D14-A1 5C | D14-A1 6C | D14-A1 6R | D14-A1 7C | D14-A1 7R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wt.% | | | | | | | | | | | | | | | | | | |
| MgO | 42.1 | 42.6 | 42.5 | 42.9 | 42.5 | 42.8 | 43.1 | 42.6 | 40.6 | 42.7 | 43.1 | 43.9 | 44.1 | 42.8 | 43.1 | 43.5 | 43.9 | 43.5 |
| $SiO_2$ | 38.3 | 38.3 | 38.7 | 39.1 | 39.0 | 38.9 | 38.3 | 38.5 | 37.6 | 38.6 | 39.6 | 40.1 | 40.1 | 39.8 | 39.5 | 39.7 | 39.8 | 39.8 |
| CaO | 0.23 | 0.24 | 0.26 | 0.24 | 0.25 | 0.25 | 0.22 | 0.21 | 0.28 | 0.22 | 0.23 | 0.19 | 0.18 | 0.23 | 0.24 | 0.20 | 0.18 | 0.19 |
| MnO | 0.28 | 0.27 | 0.27 | 0.26 | 0.26 | 0.25 | 0.29 | 0.27 | 0.33 | 0.28 | 0.29 | 0.31 | 0.25 | 0.30 | 0.29 | 0.27 | 0.27 | 0.26 |
| FeO | 18.5 | 18.0 | 18.6 | 17.9 | 18.0 | 17.8 | 17.3 | 17.7 | 20.2 | 17.8 | 17.7 | 16.7 | 16.5 | 17.6 | 17.5 | 16.9 | 16.3 | 17.1 |
| NiO | 0.16 | 0.20 | 0.15 | 0.16 | 0.16 | 0.16 | 0.15 | 0.15 | 0.12 | 0.15 | 0.13 | 0.14 | 0.18 | 0.15 | 0.12 | 0.19 | 0.17 | 0.17 |
| Total | 99.5 | 99.6 | 100.5 | 100.6 | 100.2 | 100.1 | 99.4 | 99.4 | 99.2 | 99.8 | 100.9 | 101.3 | 101.3 | 100.8 | 100.7 | 100.7 | 100.6 | 100.9 |
| mol.% | | | | | | | | | | | | | | | | | | |
| Fo | 80.2 | 80.8 | 80.3 | 81.0 | 80.8 | 81.0 | 81.7 | 81.1 | 78.2 | 81.0 | 81.3 | 82.4 | 82.6 | 81.3 | 81.4 | 82.1 | 82.7 | 82.0 |

mc= core of small crystal
R= rim of larger crystal
C= core of larger crystal

Table 4: Plagioclase Analyses

| Sample No. | D1-3 1R | D1-3 1C | D1-3 2mc | D1-3 3mc | D1-3 4R | D1-3 4C | D6-A5-9 1R | D6-A5 1C | D6-A5 2mc | D6-A5 3mc | D7-1 1mc | D7-1 2R | D7-1 2C | D7-1 3mc | D7-1 4mc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wt.% | | | | | | | | | | | | | | | |
| $SiO_2$ | 50.0 | 49.4 | 52.3 | 52.5 | 51.0 | 50.1 | 51.7 | 51.6 | 51.9 | 51.0 | 50.9 | 49.8 | 50.9 | 49.1 | 49.8 |
| $Al_2O_3$ | 30.8 | 31.1 | 28.7 | 28.5 | 29.9 | 30.9 | 29.9 | 29.9 | 29.8 | 30.2 | 30.8 | 31.3 | 31.1 | 31.9 | 31.2 |
| FeO | 0.40 | 0.39 | 0.78 | 0.75 | 0.57 | 0.45 | 0.42 | 0.42 | 0.59 | 0.41 | 0.50 | 0.41 | 0.40 | 0.40 | 0.37 |
| MgO | 0.19 | 0.20 | 0.23 | 0.19 | 0.24 | 0.20 | 0.20 | 0.20 | 0.27 | 0.16 | 0.21 | 0.19 | 0.16 | 0.22 | 0.19 |
| CaO | 15.0 | 15.1 | 12.8 | 13.2 | 14.5 | 14.7 | 13.8 | 13.8 | 13.7 | 14.2 | 14.0 | 15.4 | 14.4 | 15.9 | 15.1 |
| $K_2O$ | 0.03 | 0.02 | 0.21 | 0.06 | 0.04 | 0.04 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.05 | 0.06 | 0.04 | 0.06 |
| $Na_2O$ | 2.96 | 2.85 | 4.03 | 4.07 | 3.35 | 3.11 | 3.61 | 3.61 | 3.59 | 3.39 | 3.44 | 2.77 | 3.13 | 2.57 | 2.85 |
| Total | 99.4 | 99.1 | 99.1 | 99.3 | 99.6 | 99.5 | 99.8 | 99.7 | 100.0 | 99.5 | 100.0 | 99.9 | 100.2 | 100.2 | 99.7 |
| mol.% | | | | | | | | | | | | | | | |
| An | 73.5 | 74.5 | 62.8 | 64.0 | 70.4 | 72.2 | 67.5 | 67.5 | 67.5 | 69.4 | 68.9 | 75.2 | 71.5 | 77.2 | 74.3 |
| Ab | 26.3 | 25.4 | 36.0 | 35.7 | 29.4 | 27.6 | 31.9 | 31.9 | 31.9 | 30.1 | 30.6 | 24.5 | 28.1 | 22.6 | 25.3 |
| Or | 0.2 | 0.1 | 1.2 | 0.3 | 0.2 | 0.2 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.3 | 0.4 | 0.2 | 0.4 |

| Sample No. | D11-A7 1R | D11-A7 1C | D11-A7 2R | D11-A7 2C | D11-A7 3mc | D11-A7 4mc | D14-A1 1mc | D14-A1 2mc | D14-A1 3R | D14-A1 3C | D25-1 1mc | D25-1 2R | D25-1 2C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| wt.% | | | | | | | | | | | | | |
| $SiO_2$ | 50.3 | 51.2 | 51.7 | 50.9 | 52.8 | 53.2 | 51.0 | 50.7 | 50.4 | 51.3 | 51.0 | 45.8 | 46.9 |
| $Al_2O_3$ | 30.5 | 30.1 | 28.9 | 29.9 | 29.1 | 29.1 | 30.2 | 30.9 | 30.2 | 30.2 | 29.0 | 32.6 | 32.4 |
| FeO | 0.53 | 0.47 | 0.92 | 0.49 | 0.60 | 0.56 | 0.50 | 0.51 | 0.46 | 0.47 | 0.76 | 0.63 | 0.39 |
| MgO | 0.18 | 0.19 | 0.34 | 0.19 | 0.17 | 0.20 | 0.13 | 0.13 | 0.12 | 0.14 | 0.21 | 0.15 | 0.12 |
| CaO | 14.3 | 13.8 | 13.4 | 14.1 | 12.6 | 12.6 | 14.0 | 14.2 | 14.3 | 13.6 | 13.6 | 17.4 | 16.9 |
| $K_2O$ | 0.14 | 0.16 | 0.23 | 0.14 | 0.23 | 0.23 | 0.24 | 0.24 | 0.24 | 0.41 | 0.68 | 0.07 | 0.09 |
| $Na_2O$ | 3.32 | 3.55 | 3.62 | 3.36 | 4.09 | 4.13 | 3.36 | 3.21 | 3.37 | 3.53 | 3.29 | 1.62 | 1.88 |
| Total | 99.3 | 99.6 | 99.2 | 99.0 | 99.6 | 100.0 | 99.5 | 99.9 | 99.1 | 99.6 | 98.5 | 98.3 | 98.7 |
| mol.% | | | | | | | | | | | | | |
| An | 69.8 | 67.6 | 66.3 | 69.3 | 62.2 | 62.0 | 68.8 | 70.0 | 69.1 | 66.3 | 68.0 | 86.8 | 83.4 |
| Ab | 29.4 | 31.5 | 32.4 | 29.9 | 36.5 | 36.7 | 29.8 | 28.6 | 29.5 | 31.3 | 28.0 | 12.8 | 16.1 |
| Or | 0.8 | 0.9 | 1.3 | 0.8 | 1.3 | 1.3 | 1.4 | 1.4 | 1.4 | 2.4 | 4.0 | 0.4 | 0.5 |

mc= core of small crystal
R= rim of larger crystal
C= core of larger crystal

## Table 5: Clinopyroxene and Spinel Analyses

| Sample No. | D25-1 | D25-1 | D25-1 | D25-1 | D25-1 | D25-1 | D6-A5 |
|---|---|---|---|---|---|---|---|
| Phase | Cpx | Cpx | Cpx | Cpx | Cpx | Cpx | Spnl |
| | 1C | 1R | 2C | 2I | 2R | 3mc | 1mc |
| wt.% | | | | | | | |
| $SiO_2$ | 49.8 | 49.3 | 50.2 | 48.9 | 49.3 | 49.9 | na |
| $TiO_2$ | 1.13 | 1.29 | 1.06 | 1.38 | 1.23 | 1.28 | 0.77 |
| $Al_2O_3$ | 4.34 | 4.94 | 4.46 | 5.94 | 5.03 | 5.02 | 39.5 |
| FeO | 5.31 | 5.69 | 5.33 | 6.08 | 5.55 | 5.59 | 20.1 |
| $Cr_2O_3$ | 1.00 | 0.75 | 0.91 | 0.69 | 0.75 | 0.54 | 22.4 |
| MnO | 0.10 | 0.11 | 0.13 | 0.12 | 0.12 | 0.12 | 0.10 |
| MgO | 15.3 | 15.1 | 15.4 | 14.6 | 15.0 | 15.0 | 16.0 |
| CaO | 22.2 | 21.9 | 22.2 | 21.7 | 22.0 | 22.1 | na |
| $Na_2O$ | 0.28 | 0.32 | 0.30 | 0.35 | 0.31 | 0.31 | na |
| Total | 99.4 | 99.4 | 100.0 | 99.3 | 99.3 | 99.8 | 98.9 |
| mol.% | | | | | | | |
| Ca | 46.7 | 46.3 | 46.5 | 46.3 | 46.6 | 46.7 | na |
| Mg | 44.6 | 44.4 | 44.8 | 43.5 | 44.2 | 44.1 | na |
| Fe | 8.7 | 9.4 | 8.7 | 10.1 | 9.2 | 9.2 | na |

na= not analyzed
Cpx= clinopyroxene
Spnl= spinel
mc= core of small crystal
R= rim of larger crystal
C= core of larger crystal
I= intermediate position between rim and core

Table 6: Major Element Analyses of Volcanic Rocks dredged on L5-83-HW from Necker Ridge, Horizon and S.P. Lee Guyot

| | Necker Ridge | | | | | | | Horizon Guyot | | | S.P. Lee Guyot | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | D1-1 WR | D1-2 WR | D1-6 WR | D5-2 WR | D6-2 WR | D6-A5 GLS | D7-1 GLS | D11-A7 GLS | D12-7 WR | D14-1 WR | D23-9 WR | D23-5 WR | D31-1 WR |
| (wt %) | | | | | | | | | | | | | |
| $SiO_2$ | 46.2 | 45.8 | 46.1 | 47.2 | 47.4 | 47.9 | 47.6 | 50.1 | 46.7 | 45.3 | 44.6 | 45.0 | 39.4 |
| $Al_2O_3$ | 16.5 | 15.8 | 16.1 | 19.4 | 19.1 | 14.2 | 14.4 | 14.6 | 16.7 | 19.1 | 16.0 | 16.0 | 15.4 |
| $Fe_2O_3$ | 8.13 | 6.32 | 6.39 | 6.88 | 11.3 | na | na | na | 7.61 | 8.03 | 9.06 | 9.59 | 10.5 |
| FeO | 2.23 | 2.95 | 3.07 | 0.50 | 0.62 | 12.3* | 12.2* | 11.9* | 3.41 | 1.78 | 3.64 | 2.89 | 4.92 |
| MgO | 7.47 | 10.2 | 9.13 | 1.30 | 1.62 | 6.11 | 6.10 | 5.13 | 6.28 | 4.11 | 3.26 | 3.51 | 5.42 |
| CaO | 8.56 | 7.83 | 9.23 | 9.90 | 7.83 | 10.7 | 10.6 | 9.23 | 8.55 | 8.72 | 11.6 | 11.3 | 12.0 |
| $Na_2O$ | 2.63 | 2.55 | 2.51 | 2.94 | 3.38 | 3.67 | 3.87 | 2.85 | 2.98 | 2.70 | 2.62 | 2.68 | 1.72 |
| $K_2O$ | 0.81 | 0.60 | 0.49 | 2.58 | 1.53 | 0.58 | 0.56 | 1.36 | 1.18 | 1.28 | 1.59 | 1.53 | 0.71 |
| $TiO_2$ | 1.62 | 1.58 | 1.45 | 2.11 | 2.51 | 2.96 | 2.92 | 3.57 | 2.35 | 2.60 | 3.71 | 3.80 | 5.13 |
| $P_2O_5$ | 0.25 | 0.21 | 0.18 | 1.31 | 0.67 | 0.38 | 0.40 | 0.53 | 0.41 | 1.02 | 0.93 | 0.92 | 0.86 |
| MnO | 0.15 | 0.13 | 0.14 | 0.05 | 0.08 | 0.23 | 0.22 | 0.21 | 0.13 | 0.13 | 0.23 | 0.24 | 0.15 |
| $H_2O^+$ | 2.86 | 3.78 | 2.94 | 1.78 | 1.97 | na | na | na | 2.44 | 2.73 | 1.34 | 1.25 | 2.16 |
| $H_2O^-$ | 2.56 | 2.69 | 2.48 | 2.30 | 1.79 | na | na | na | 1.37 | 2.41 | 0.78 | 0.77 | 1.78 |
| $CO_2$ | <0.02 | <0.02 | <0.02 | 1.75 | 0.21 | na | na | na | 0.19 | 0.11 | 0.68 | 0.21 | 0.14 |
| Total | 100.1 | 100.5 | 100.2 | 100.0 | 100.0 | 99.0 | 98.9 | 99.5 | 100.3 | 100.0 | 100.0 | 99.7 | 100.3 |
| (ppm) | | | | | | | | | | | | | |
| S | na | na | na | na | na | 260 | 110 | 120 | na | na | na | na | na |

WR= whole rock
GLS= glass
na= not analyzed
FeO, $CO_2$, $H_2O$ by wet chemical analysis, analyst P. Klock
other oxides by XRF analysis, analysts A.J. Bartel, K. Stewart, J. Taggart
glass analysis by electron microprobe, analyst A. Davis
*FeO of glass analysis is total iron as FeO

**Table 7: Trace Element Analyses of Volcanic Rocks Dredged on Cruise L5-83-HW from Necker Ridge, Horizon and S.P. Lee Guyot**

| | Necker Ridge | | | | | Horizon G. | | S.P. Lee G. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample No. | D1-1 | D1-2 | D1-6 | D5-2 | D6-2 | D12-7 | D14-1 | D23-5 | D23-9 | D31-1 |
| * | | | | | | | | | | |
| Rb | 19 | <10 | <10 | 37 | 42 | 25 | 31 | 32 | 44 | 18 |
| Sr | 185 | 150 | 167 | 480 | 380 | 410 | 870 | 565 | 560 | 660 |
| Y | 25 | 20 | 20 | 37 | 34 | 22 | 42 | 28 | 28 | 36 |
| Zr | 110 | 90 | 90 | 225 | 210 | 165 | 310 | 250 | 235 | 300 |
| Nb | <10 | <10 | <10 | 43 | 24 | 32 | 104 | 41 | 40 | 57 |
| Ba | 66 | 58 | 46 | 380 | 174 | 245 | 830 | 340 | 345 | 280 |
| ** | | | | | | | | | | |
| Sc | 34.6 | 34.5 | 35.7 | 24.0 | 37.0 | 24.6 | 19.4 | 30.9 | 28.2 | 42.0 |
| Co | 40.3 | 48.2 | 48.1 | 19.1 | 23.7 | 44.7 | 30.8 | 73.9 | 43.3 | 58.8 |
| Cr | 268 | 338 | 411 | 246 | 132 | 159 | 105 | 150 | 134 | 516 |
| Hf | 2.95 | 2.85 | 2.73 | 4.76 | 4.48 | 3.99 | 5.58 | 6.04 | 5.37 | 7.11 |
| Ta | 0.46 | 0.47 | 0.39 | 2.97 | 1.39 | 2.43 | 6.59 | 3.01 | 2.74 | 3.83 |
| Th | 0.41 | 0.47 | 0.42 | 3.99 | 1.69 | 2.88 | 9.26 | 3.39 | 3.14 | 4.11 |
| La | 8.02 | 6.05 | 4.94 | 38.0 | 16.9 | 21.7 | 67.9 | 31.4 | 29.6 | 35.1 |
| Ce | 15.8 | 15.7 | 13.8 | 57.8 | 34.6 | 43.0 | 103 | 65.9 | 60.0 | 72.6 |
| Nd | 11.9 | 12.5 | 9.75 | 30.9 | 20.1 | 24.3 | 41.5 | 33.4 | 31.2 | 39.0 |
| Sm | 4.20 | 3.82 | 3.53 | 7.06 | 5.72 | 6.03 | 7.87 | 8.34 | 7.37 | 9.47 |
| Eu | 1.45 | 1.40 | 1.29 | 2.25 | 2.03 | 1.99 | 2.51 | 2.79 | 2.52 | 3.16 |
| Tb | 0.88 | 0.81 | 0.78 | 1.07 | 1.08 | 0.99 | 1.04 | 1.18 | 1.00 | 1.32 |
| Yb | 3.06 | 2.82 | 2.72 | 3.62 | 3.52 | 2.62 | 3.04 | 2.51 | 2.27 | 2.48 |
| Lu | 0.45 | 0.41 | 0.40 | 0.53 | 0.49 | 0.39 | 0.44 | 0.34 | 0.30 | 0.35 |

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*XRF analysis, analyst T. Frost

**INA analysis, analysts R.V. Mendes, J. Budahn, R. Knight,

# FIGURE CAPTIONS

Figure 1. Map showing locations of Necker Ridge, Horizon Guyot, and S.P. Lee Guyot. Ship trackline and sample and DSDP sites are indicated.

Figure 2. Olivine compositions of samples from Necker Ridge and Horizon Guyot. (A) Histogram of Fo distribution, (B) NiO vs. Fo and (C) CaO vs. Fo content show that olivine from Necker Ridge are more magnesian than those from Horizon Guyot.

Figure 3. Plagioclase compositions of samples from Necker Ridge, Horizon Guyot and S.P. Lee Guyot. Necker Ridge plagioclase is similar to that in Hawaiian tholeiite and oceanic ridge basalt. Horizon Guyot sample D11-A7 has plagioclase that is similar to Hawaiian tholeiite, but D14-A1 appears alkalic. Or content as high as 4.0% in D25-1 suggests a stongly alkalic composition for S.P. Lee Guyot. Fields of Hawaiian lava are from Keil et al. (1973).

Figure 4. (A) Ca-Mg-Fe ternary plot for clinopyroxene in the ankaramite from S.P. Lee Guyot shows compositions in the low Ca region established for alkalic Hawaiian clinopyroxene phenocrysts (Fodor et al., 1975). (B) $TiO_2$ vs. Wo contents suggests a moderately to strongly alkalic composition. P (shaded)= phenocrysts, G= groundmass.

Figure 5. Alkalies vs. silica plot for samples dredged on L5-83-HW shows Necker Ridge samples to be tholeiitic and mildly alkalic. Horizon Guyot is transitional and alkalic, and S.P. Lee Guyot samples are moderately to strongly alkalic. Fields of tholeiitic vs. alkalic lava from Macdonald and Katsura (1964). Compositions of lava dredged from the Line Islands (Natland, 1976) and compositional range of samples recovered at DSDP drill sites (shaded) in the central Pacific are shown for comparison. Mildly, moderately and strongly alkalic differentiation trends for Samoan lava are also shown (Natland, 1976). Compositions are normalized and volatile-free.

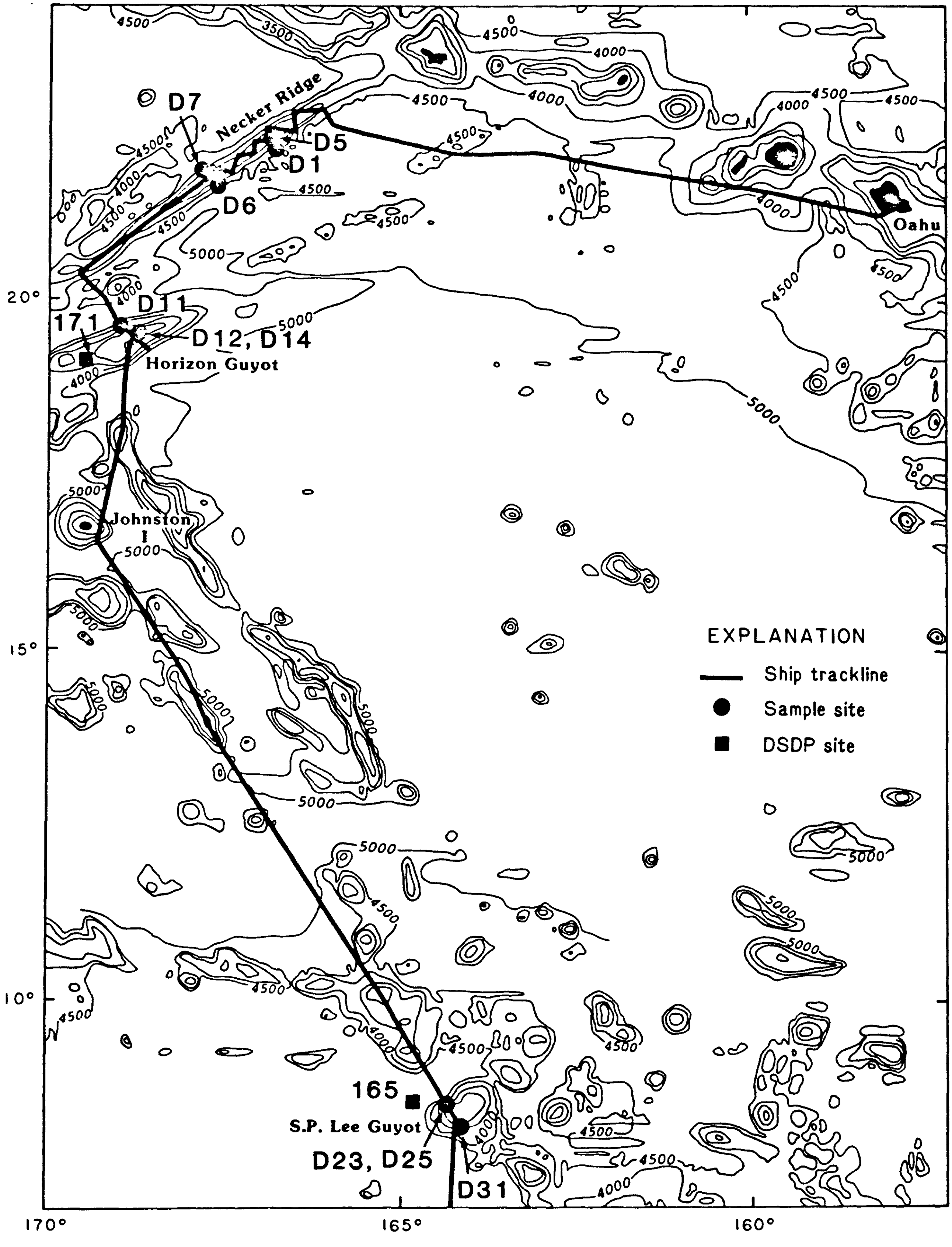
Figure 6. $P_2O_5$ vs. $TiO_2$ plot for basalt recovered on L5-83-HW shows samples of D1 from Necker Ridge in the oceanic ridge field. Two other samples from Necker Ridge and one from Horizon Guyot appear transitional between oceanic island tholeiite and alkalic basalt, whereas the remaining sample from Horizon and all of the samples from S.P. Le Guoyt are definitely alkalic. Fields from Bass et al. (1973)

Figure 7. Chondrite-normalized rare-earth elements (REE) for dredged samples show Necker Ridge (A) and one of Horizon Guyot (B) samples similar to Hawaiian tholeiite. The higher abundance of light REE and negative Ce anomaly of D5-2 from Necker Ridge indicates secondary phosphatization. The samples from S.P. Lee Guyot (C) fall well within the range of compositions observed for alkalic Hawaiian basalt. Fields for tholeiitic and alkalic Hawaiian lava from Basaltic Volcanism Project (1982).

Figure 8. Zr vs. Nb plot for dredged samples shows Necker Ridge samples as mostly tholeiitic and mildly alkalic, with compositions of D1 similar to oceanic ridge or very depleted oceanic island tholeiite. Samples from Horizon and S.P. Lee Guyot range from transitional to mildly alkalic, and from moderately to strongly alkalic, respectively. Data for DSDP 165 and fileds for oceanic ridge and alkalic basalt from Bass et al. (1973). Data for Hawaiian tholeiite from Basaltic Volcanism Project (1982).

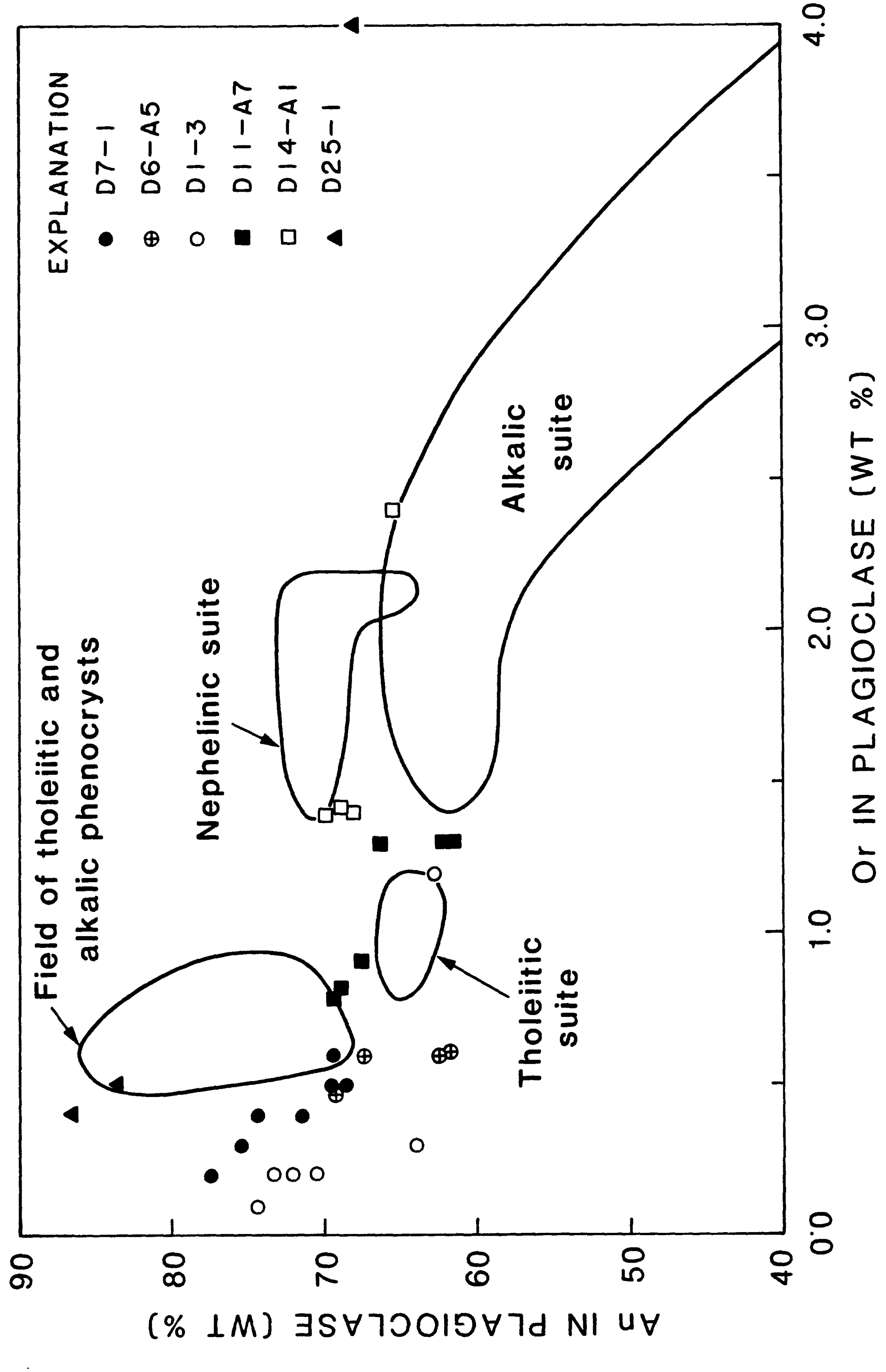
Figure 9. Zr vs. Sr plot shows a similar distribution as that shown on the Zr vs. Nb plot (Figure 8). DSDP 165 and petrotectonic fields from Bass et al. (1973).

Figure 10. Hf-Th-Ta plot for dredged samples shows samples of D1 from Necker Ridge on the boundary between the fields for normal oceanic ridge basalt (A) and oceanic island tholeiite (B). D6-2 plots in the field of E-type MORB and oceanic island basalt (B), and D5-2 in the field of alkalic within-plate basalt (C). Both samples from Horizon Guyot and all samples from S.P. Lee Guyot plot in the alkalic field (C). Petrotectonic fields from Wood (1980); A= N-type MORB, B= E-type MORB and tholeiitic within-plate basalt, C= alkaline within-plate basalt, and D= destructive plate-margin basalt.



4500
3500
4000
4500
D7
Necker Ridge
D5
D1
D6
4500
5000
Oahu
20°
D11
171
D12, D14
Horizon Guyot
5000
Johnston I
15°
EXPLANATION
Ship trackline
Sample site
DSDP site
10°
165
S.P. Lee Guyot
D23, D25
D31
170°
165°
160°

Figure 1.


EXPLANATION
● D7-1
⊕ D6-A5
○ D1-3
■ D11-A7
□ D14-A1
▲ D25-1
Field of tholeiitic and alkalic phenocrysts
Nephelinic suite
Tholeiitic suite
Alkalic suite
An IN PLAGIOCLASE (WT %)
90
80
70
60
50
40
Or IN PLAGIOCLASE (WT %)
0.0
1.0
2.0
3.0
4.0

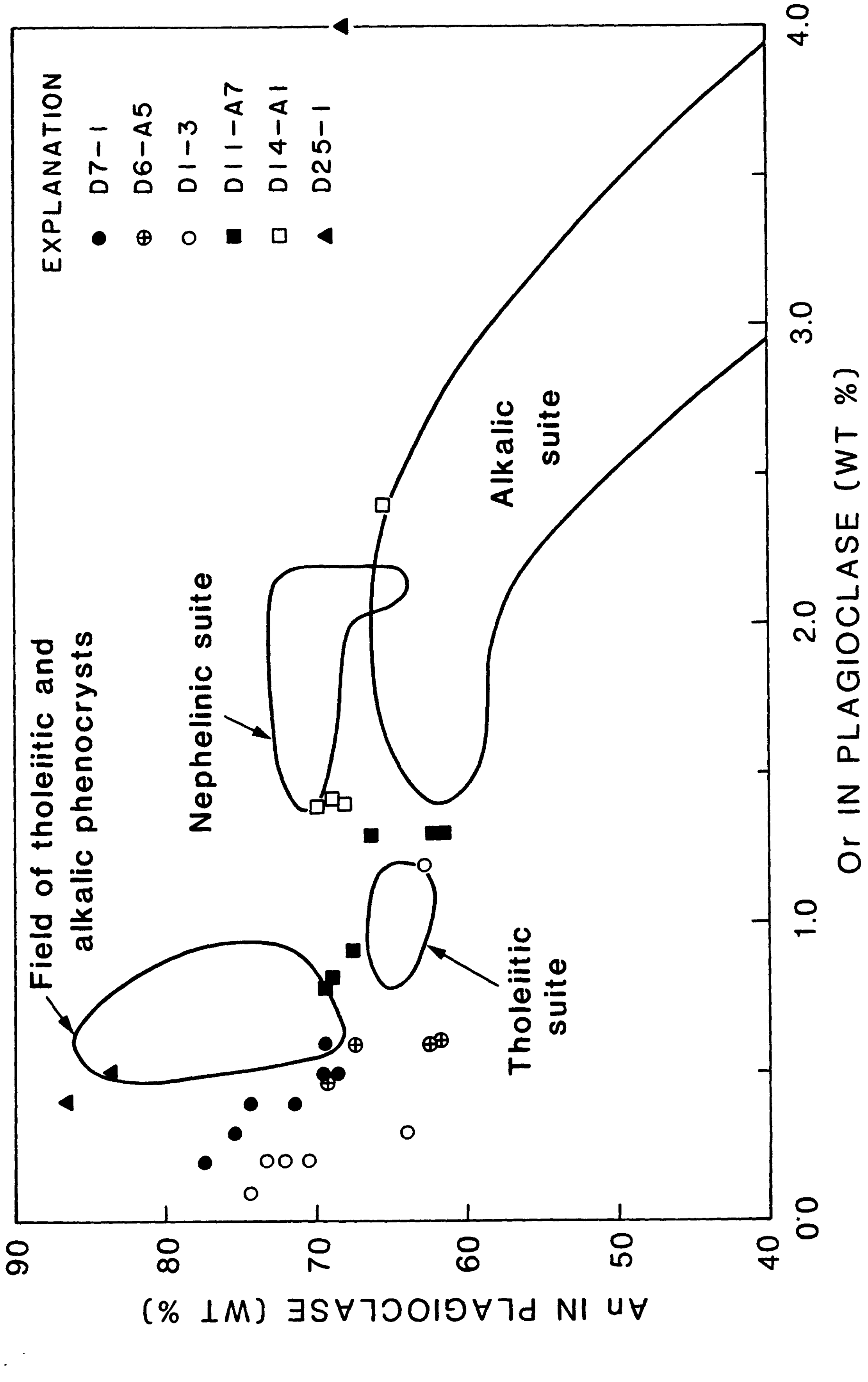

EXPLANATION
● D7-1
⊕ D6-A5
○ D1-3
■ D11-A7
□ D14-A1
▲ D25-1
Field of tholeiitic and alkalic phenocrysts
Nephelinic suite
Alkalic suite
Tholeiitic suite
An IN PLAGIOCLASE (WT %)
Or IN PLAGIOCLASE (WT %)
90
80
70
60
50
40
0.0
1.0
2.0
3.0
4.0

Figure 3.

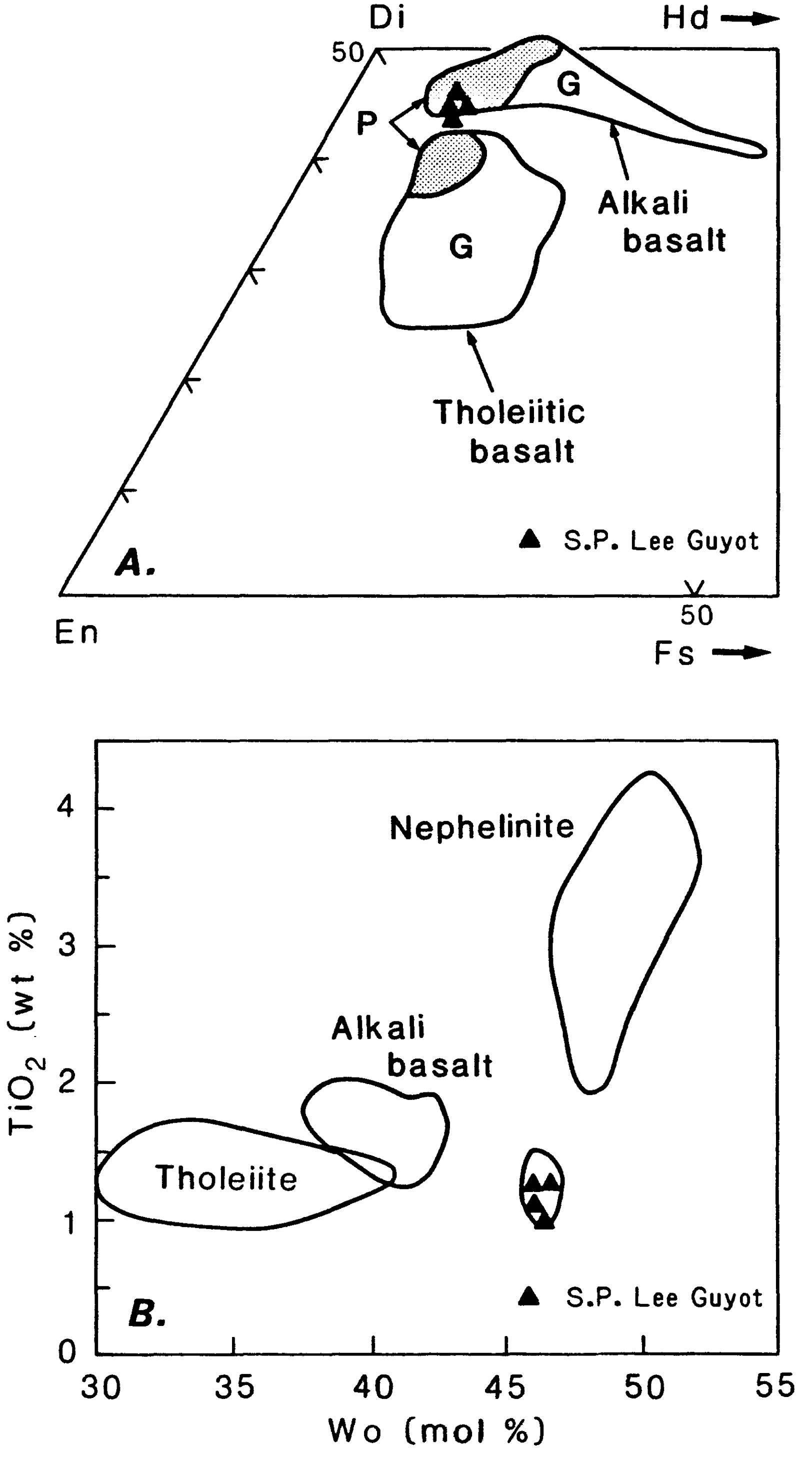

Di
Hd
50
G
P
G
Alkali basalt
Tholeiitic basalt
▲ S.P. Lee Guyot
A.
En
50
Fs
Nephelinite
Alkali basalt
Tholeiite
▲ S.P. Lee Guyot
B.
TiO$_2$ (wt %)
0
1
2
3
4
30
35
40
45
50
55
Wo (mol %)

Figure 4.

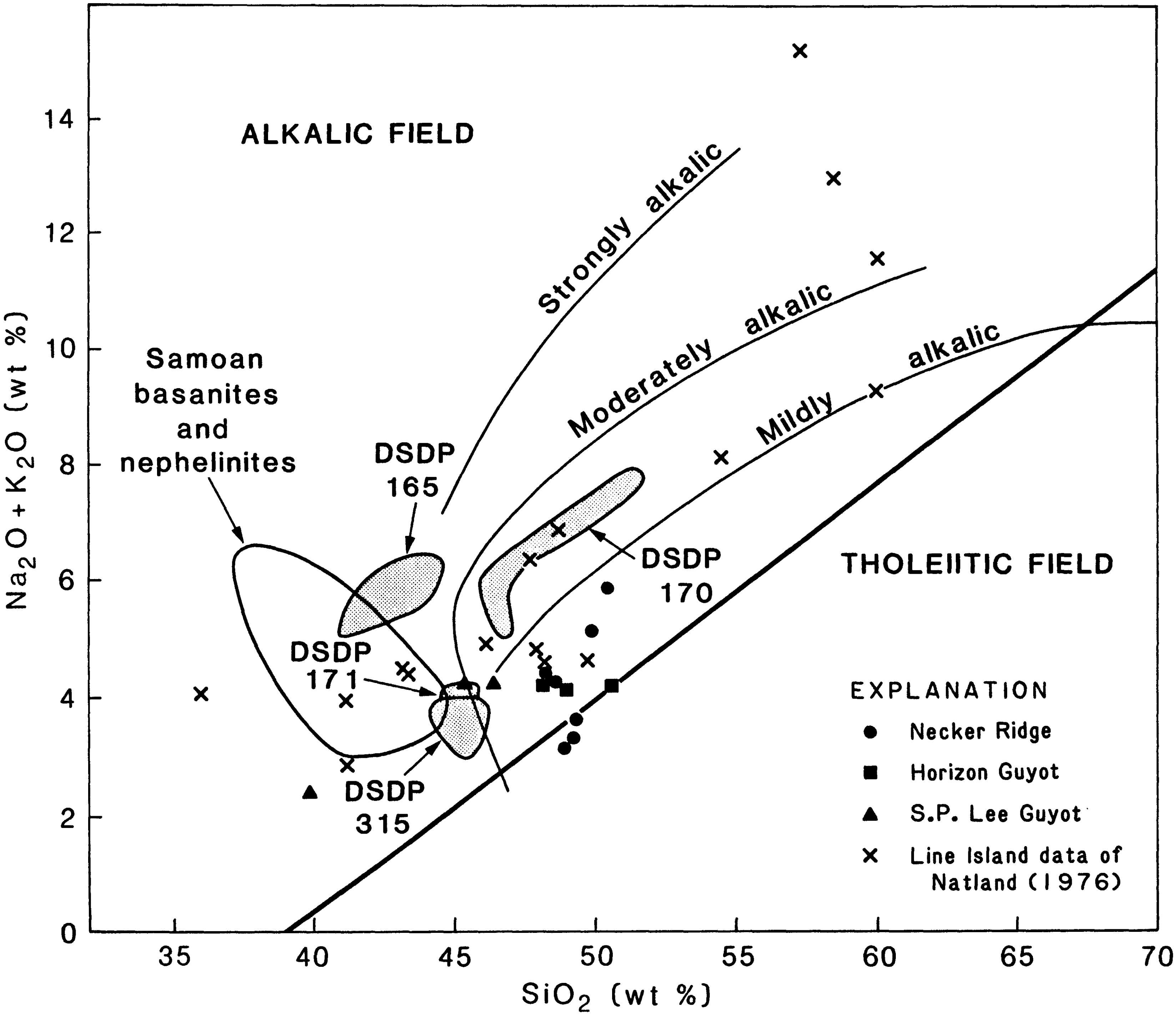

ALKALIC FIELD
THOLEIITIC FIELD
Strongly alkalic
Moderately alkalic
Mildly alkalic
Samoan basanites and nephelinites
DSDP 165
DSDP 170
DSDP 171
DSDP 315
EXPLANATION
● Necker Ridge
■ Horizon Guyot
▲ S.P. Lee Guyot
× Line Island data of Natland (1976)
$Na_2O + K_2O$ (wt %)
0
2
4
6
8
10
12
14
35
40
45
50
55
60
65
70
$SiO_2$ (wt %)

Figure 5.

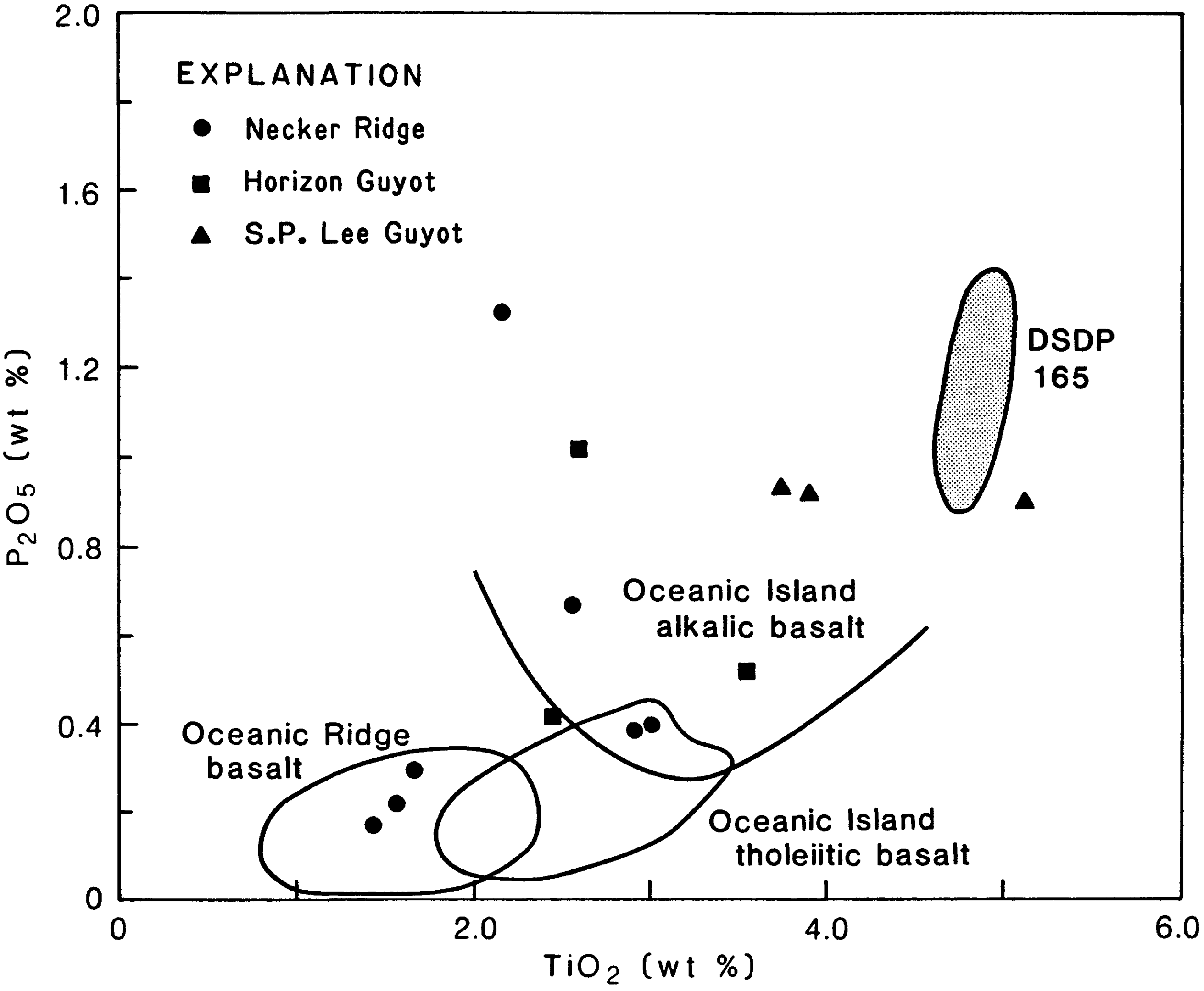

EXPLANATION
● Necker Ridge
■ Horizon Guyot
▲ S.P. Lee Guyot
DSDP 165
Oceanic Island alkalic basalt
Oceanic Ridge basalt
Oceanic Island tholeiitic basalt
2.0
1.6
1.2
0.8
0.4
0
0
2.0
4.0
6.0
$P_2O_5$ (wt %)
$TiO_2$ (wt %)

Figure 6.

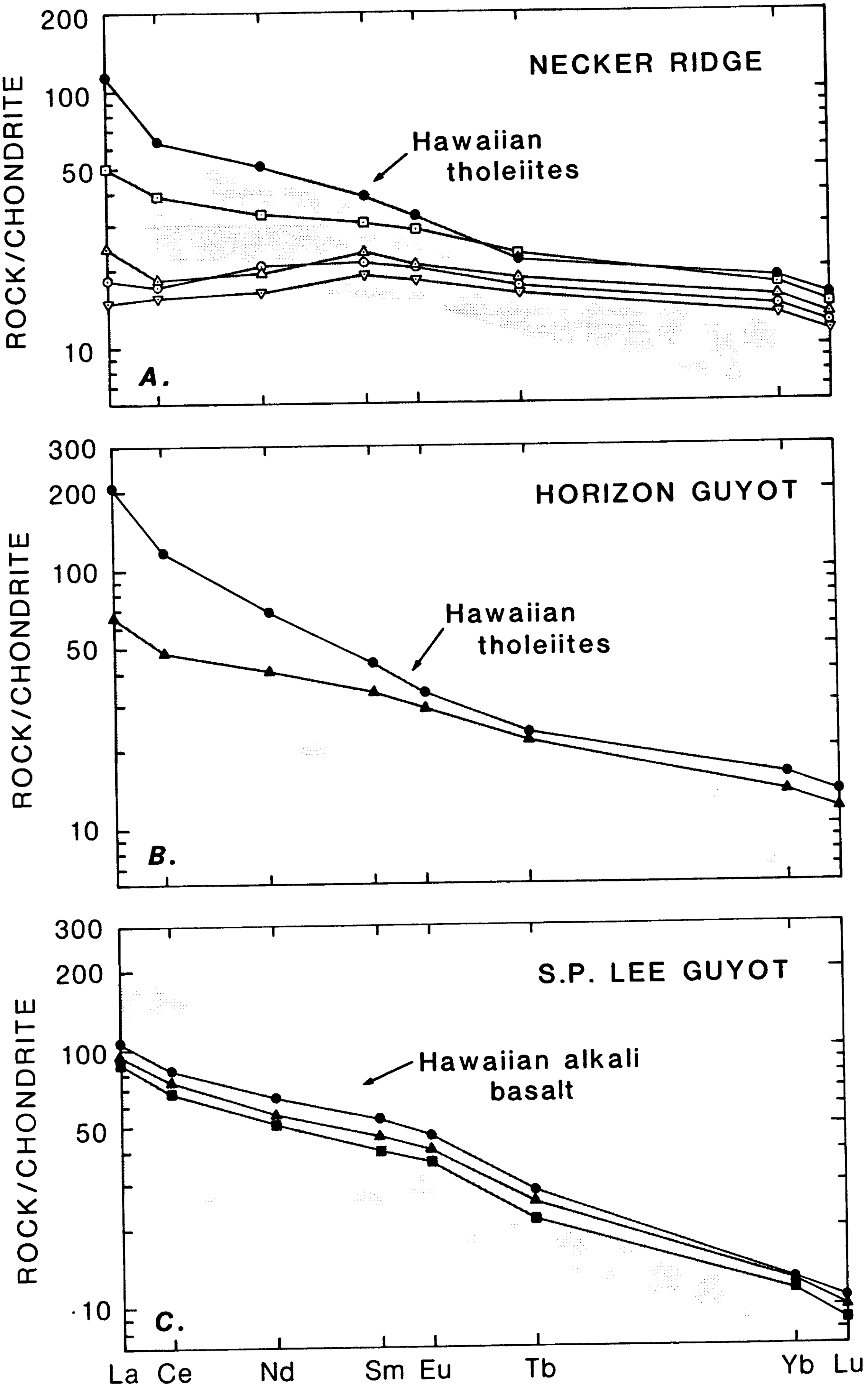
NECKER RIDGE
Hawaiian tholeiites
A.
200
100
50
10
ROCK/CHONDRITE
HORIZON GUYOT
Hawaiian tholeiites
B.
300
200
100
50
10
ROCK/CHONDRITE
S.P. LEE GUYOT
Hawaiian alkali basalt
C.
300
200
100
50
10
ROCK/CHONDRITE
La
Ce
Nd
Sm
Eu
Tb
Yb
Lu

Figure 7.

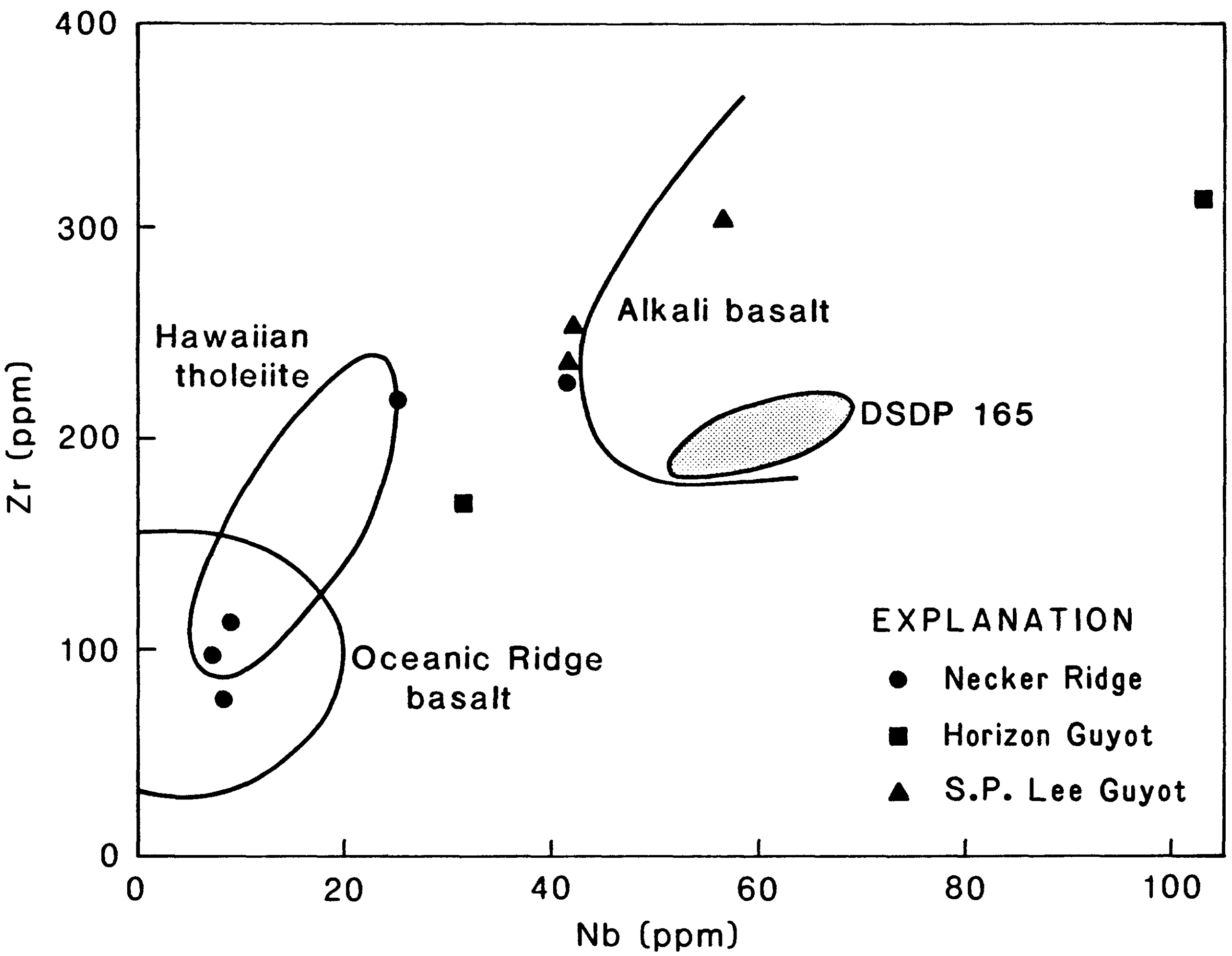
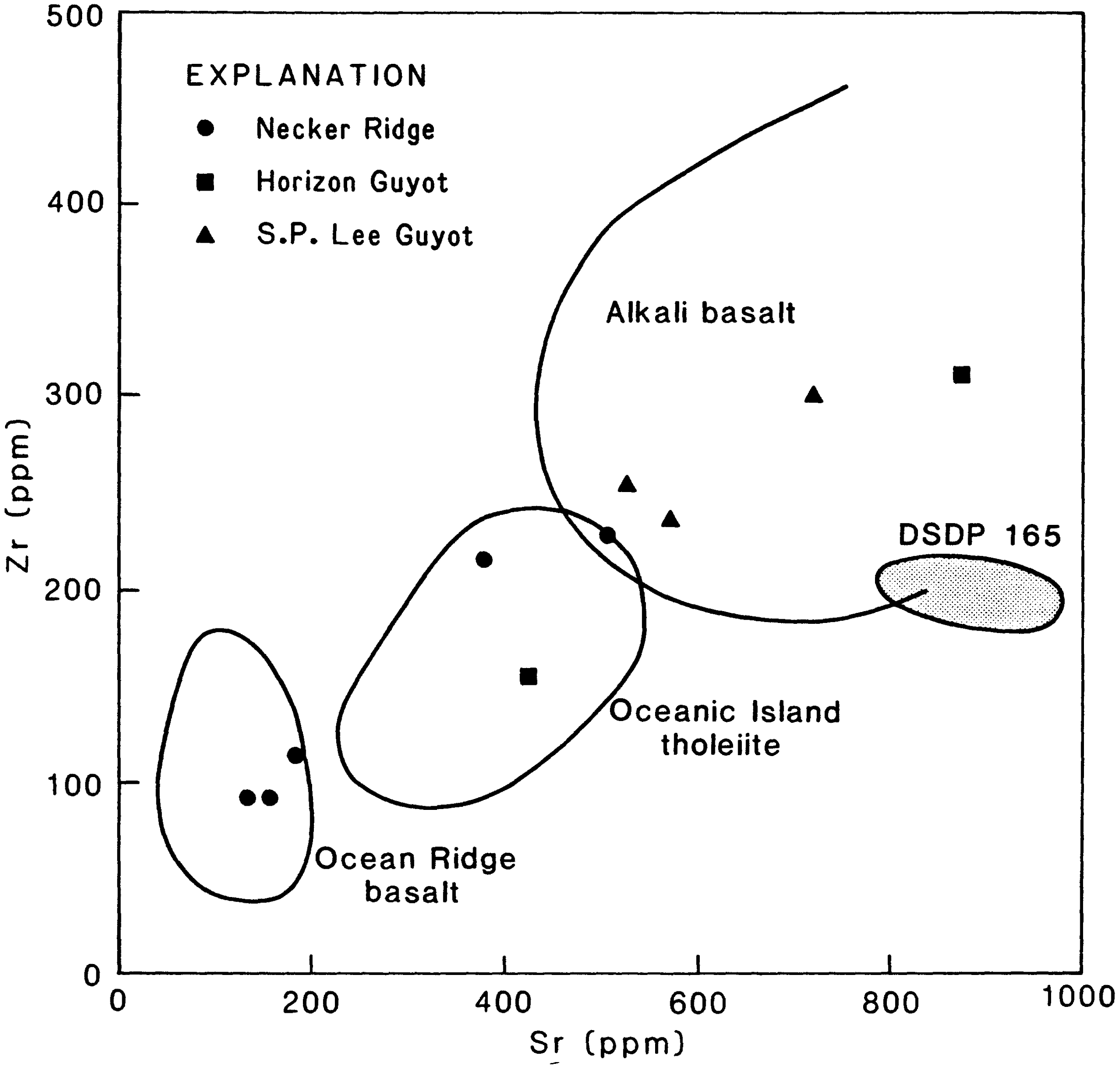

400
300
200
100
0
Zr (ppm)
0
20
40
60
80
100
Nb (ppm)
Hawaiian tholeiite
Oceanic Ridge basalt
Alkali basalt
DSDP 165
EXPLANATION
● Necker Ridge
■ Horizon Guyot
▲ S.P. Lee Guyot

Figure 8.



500
400
300
200
100
0
Zr (ppm)
0
200
400
600
800
1000
Sr (ppm)
EXPLANATION
● Necker Ridge
■ Horizon Guyot
▲ S.P. Lee Guyot
Alkali basalt
DSDP 165
Oceanic Island tholeiite
Ocean Ridge basalt

Figure 9.

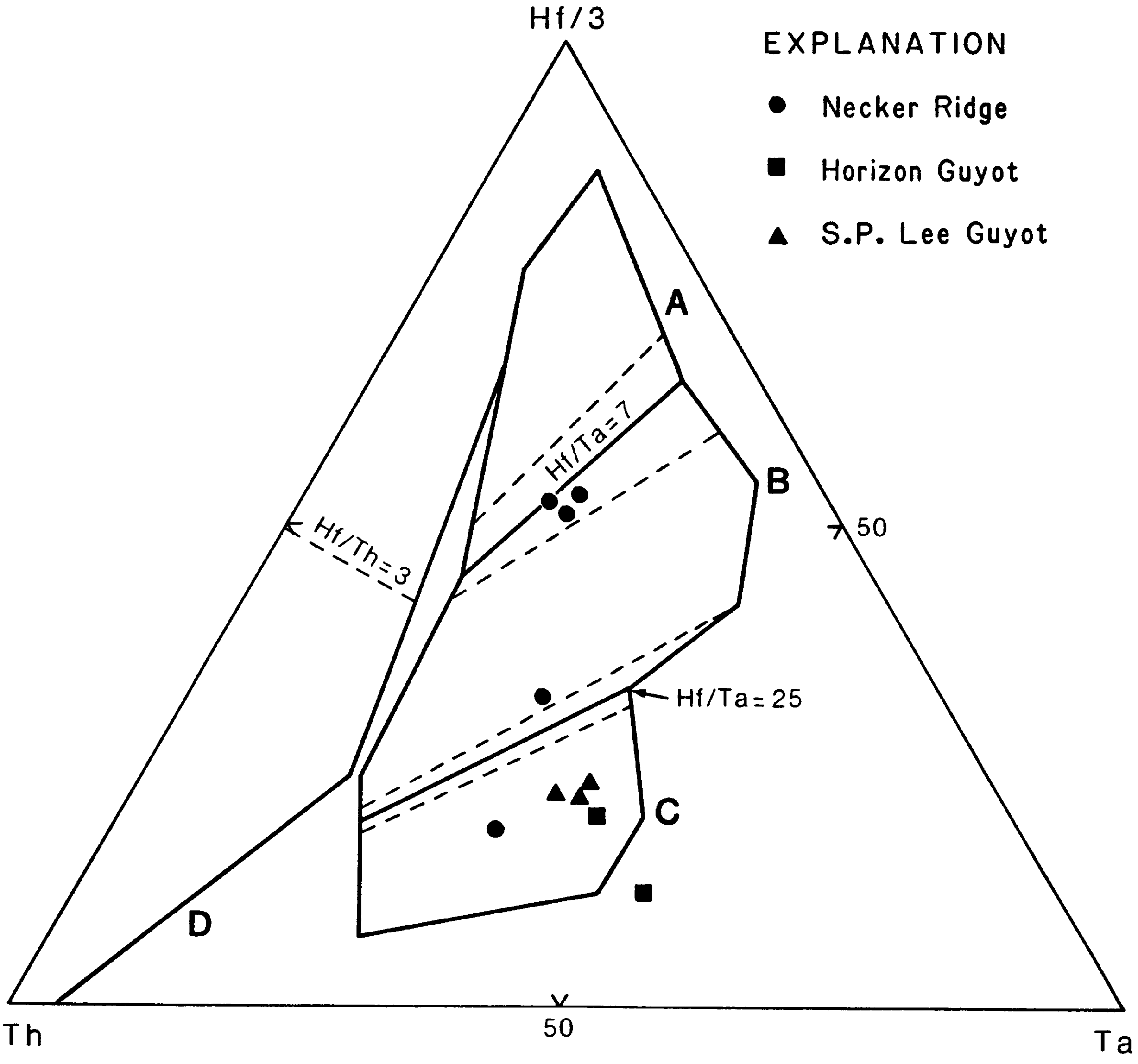

Hf/3
EXPLANATION
● Necker Ridge
■ Horizon Guyot
▲ S.P. Lee Guyot
A
Hf/Ta=7
B
50
Hf/Th=3
Hf/Ta=25
C
D
Th
50
Ta

Figure 10.