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Geological Survey

PRELIMINARY DESCRIPTION OF BASALT FROM THE SOUTHERN JUAN DE FUCA RIDGE

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OPEN-FILE REPORT
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INTRODUCTION

Scientists aboard the U.S.G.S. research vessel S. P. LEE conducted acoustic-transponder navigated dredging, deep-tow photography, and water sampling in the southern portion of the Juan de Fuca Ridge during September 4-15, 1981. The study area consists of a 6-km segment of the axial valley approximately 15 km north of the Juan de Fuca Ridge - Blanco Fracture Zone intersection (Fig. 1). Twelve of thirteen dredge attempts were successful; latitude, longitude, and depth of each dredge are listed in Table 1. Locations of transponders, dredges, hydrocasts, and vent sites are shown in Figure 2. This report describes the volcanic rocks recovered in these dredges.

Previous petrologic studies on basalt samples from the Juan de Fuca Ridge show that the southern two-thirds of the ridge is characterized by strongly fractionated mid-ocean ridge basalt with high FeO, TiO_2, MnO, P_2O_5, Na_2O, K_2O, and SiO_2 and by low MgO, CaO, Al_2O_3 (Kay et al., 1970; Scheidegger, 1973; Detrick et al., 1975; Clague and Bunch, 1976; Vogt and Byerly, 1976; and Wakeham, 1977).

Several early studies attempted to relate the chemical variation in mid-ocean ridge basalt to spreading rate and/or depth of magma generation (Bass, 1971 and Scheidegger, 1973). Kay et al. (1970) attributed the formation of Fe-Ti basalt to shallow fractionation of 35% plagioclase and 8% olivine from normal MORB compositions. More recent studies (Clague and Bunch, 1976) made use of linear least squares mixing models to show that ferrobasalt can be produced by shallow level fractionation of plagioclase, clinopyroxene, and minor olivine in the average proportion of 9.3:7.7:1 with 74% of the parental magma fractionally crystallizing.

Ferro-basalt is particularly concentrated near the Juan de Fuca Ridge-Blanco Fracture Zone intersection and 20-30 km south of the Cobb offset (Delaney et al., 1981). High amplitude magnetic anomalies (600-1200γ) are spatially associated with the ferrobasalts at the Juan de Fuca Ridge-Blanco Fracture Zone intersection (Vogt and Byerly, 1976). Propagating rifts have been identified at the Juan de Fuca Ridge (Delaney et al., 1981; Hey and Wilson, in press) similar to those found at the Galapagos Spreading Center (Hey et al., 1980) and the petrologic diversity of the rocks along the ridge may be related to these propagating rifts in a manner similar to that proposed by Christie and Sinton (1981) for the Galapagos Spreading Center.

Bottom photographs taken by the University of Washington deep-tow camera system show that the floor of the axial valley is dominantly flat sheet flows with a swirly pahoehoe-textured surface. The dominance of sheet flows in the valley is also indicated by the extremely flat topography demonstrated seismic reflection profiles. Rare pillow lavas, collapse pits, fissures, concentrations of benthic fauna, and sulfides are also present (Normark et al, 1982; Koski et al., 1982).

The morphology of dredged basalt from the area is 80% sheet flow fragments, 10% pillow fragments, and 10% sheet and pillow blisters.

The lavas are generally massive basalt with glassy to microcrystalline groundmass. Sparse phenocrysts of plagioclase (plag), clinopyroxene (cpx), and olivine (ol) occur scattered throughout the rock. There is no apparent difference in phenocryst mineralogy or abundance between different morphologies. Plagioclase phenocrysts ranging in size from 1 to 5 mm are ubiquitous in abundances of <1%. Grassy-green clinopyroxene phenocrysts 1-2 mm in size are present but comprise <<1% of the rock. Golden-brown olivine phenocrysts are more rare than clinopyroxene. Both clinopyroxene and olivine are commonly found as glomerocrysts with plagioclase. Dredge 8 is the only exception to this general description and contains small glassy samples with 10% phenocrysts of plag >> cpx > ol.

Rare gabbroic xenoliths (plag + cpx ± ol) were recovered in 6 of 12 dredge hauls (dredges 4, 5, 16, 17, 22, 26) from the entire length of ridge studied. Xenoliths range in size from <1 cm glomerocrysts to 7 x 6 x 4 cm. Larger xenoliths (>1 cm) usually consist of three phases (plag + cpx + ol), while smaller xenoliths (< 1 cm) usually consist of only two phases. Two-phase xenoliths are dominantly plag + cpx, although rare plag + ol xenoliths occur. Large xenoliths have thumbnail size clinopyroxene and olivine crystals poikilitically enclosing euhedral plagioclase. Interstitial glass or finely crystalline matrix is present up to 30%. Xenoliths are normally found near or on the upper surfaces of sheet flow fragments and are almost always found on fractures suggesting that their presence controls fracturing of the rock upon cooling.

Sampled sheet flows are generally flat with a uniform thickness of 6-8 cm and have a glass rind on the top and bottom surfaces. Altered samples tend to have more irregular shapes. Fresh glass is present on samples in eleven dredges. Glass on the upper surface has a maximum thickness of 13 mm and is usually thicker than on the basalt surface. Alteration of the glass ranges from incipient to intense palagonization with the more intense alteration often being accompanied by manganese coatings up to 2 mm thick.

The volume percent vesicles in sheet flows is <1% and is present as thin zones of pinhole size vesicles near the base of the flow and/or spherical to slightly flattened vesicles up to 1 cm across throughout the sample. Approximately 5% of the flow fragments studied contain large disc- or lens-shaped vesicles with flat bottoms. These vesicles are usually found close to the top glassy rind and reach dimensions of 70 x 30 x 8 mm (Fig. 3).

Orange staining (Fe-oxide) is ubiquitous on fracture surfaces. Other alteration varies between dredges and will be discussed in the individual dredge descriptions and is summarized in Table 2.

Pillow fragments have radial joint patterns, a curved upper surface with typically only the inner 1-3 mm of glass remaining, and range in size from 9 x 6 x 8 cm to 19 x 13 x 14 cm. Vesicles are concentrated in the cores with many pillow fragments having hollow cores. The presence of a white-to-yellowish white powdery coating on all fracture surfaces is more common than on sheet flow fragments.

Pillow and sheet blisters are defined by a flat (sheet) or gently curving (pillow) glassy upper surface and a smooth or slightly vesiculated microcrystalline basal surface. Ridges and "drip" marks often occur on the basal surface. Many samples have up to 13 mm of glass with the original surface preserved. The bottoms of the blisters are commonly lightly coated with manganese.

Samples with original glass, xenoliths, unusual vesiculation or surface structures, extreme alteration, or large size, have been labeled and described. The unlabeled samples have been re-bagged for storage at the U.S.G.S. Marine Facility in Redwood City, California. Each bag contains 15 to 25 kg. Each sample number (i.e., L11-81-WF-XX-YY) has been assigned according to the following scheme:

L11-81-WF = cruise locator, XX = dredge number, and YY = sample number.

DESCRIPTION OF DREDGES

Dredge 3

Dredge 3 is the only dredge station outside the axial valley and recovered 1 bag (∿20 kg) of small fragments with 50% pillow blisters and 50% pillow fragments. The pillow blisters are curved pieces that are convex on top and concave on the bottom. Six samples have been labeled and described. No xenoliths, large vesicles, or extreme alteration are present.

Samples 1-3 are pillow blisters with a uniform thickness of 2.5 cm. Portions of original glass are present on each sample. Bottom structures range from smooth to vesiculated with ridges common. Mn-oxide deposition ranges from light coatings on the bottom surface to thick coatings on all surfaces. Sample 2 has abundant granular Mn-oxides on all surfaces with up to 2 mm on the glassy pahoehoe upper surface (Fig. 3a).

Samples 4-6 are pillow wedges with no original glass preserved. In addition to the ubiquitous orange staining on fractures, sample 6 has abundant Mn-oxides on one side and a milky film on the top glass.

Dredge 4

Dredge 4 recovered 6 bags of samples (∿120 kg) with 45% sheet flow, 45% pillow blisters, and 10% pillow wedge fragments. Fifty-two samples have been labeled and described. Original glass is preserved on seventeen samples (1,4,5,6,20,21,23,24,25,28,29,30,31,32,38,44,52). Small (<1 cm) two-phase xenoliths are present in two samples (7,17).

Pillow blisters can be divided into two categories according to their bottom structure with 45% having pocked or vesiculated bottoms and 55% having smooth bottoms. Blisters often have highly curved surfaces (Fig. 3b). Light-to-medium coatings of manganese are present on all the basal surfaces.

Pillow fragments are commonly coated with a yellowish-white powder on all surfaces and a milky film is present on approximately 25% of the glassy rinds. Sample 37 (a & b) is an excellent example of a shelf structure in a partly hollow pillow thought to represent the surface formed as lava drained back out of the quenched outer pillow surface (Fig. 3c).

Most samples appear to be approximately the same age, although several fragments have manganese coatings and are probably older.

Dredge 5

Dredge 5 is the largest and most varied of the dredge hauls and consists of 98% sheet flow and 2% pillow fragments. Twenty-nine bags (∿580 kg) have been sent to storage. Seventy-two samples have been labeled and described.

Small amounts of original glass can be found on many samples. Samples 67-71 have been saved specifically for the large original glass surfaces. The original glass surface textures include sharkskin, fine-scale ropy, or very smooth. The fine-scale ropy texture is probably a pull-apart feature and has been used to define the up-direction on some samples. Alteration of the original glass ranges from incipient to heavy palagonitization, and some samples have a thin veneer of manganese. Two bags of glass chips have been set aside for palagonite thickness studies.

Dredge 5 contains twenty-four xenoliths (samples 1,7-26,30,33,38,72) (Fig. 4a&b). In addition to the labeled xenoliths several small bags with xenoliths to glomerocrysts (<5 mm) have been boxed and saved with the labeled samples.

A wide range of structures and alteration are exhibited in dredge 5 samples. The bottoms of samples 50-52 consist of a matrix-supported breccia with angular clasts of holocrystalline basalt ranging from 1-35 mm across and completely coated with a white-gray powder. Matrix basalt is both glassy and crystalline. The upper surfaces are flat and relatively unaltered while the basal surfaces are more irregular. These samples are probably a sheet flow that flowed over and incorporated altered brecciated material (Fig. 5a).

Approximately 10% of the samples contain the large disc-shaped to flat-bottomed tubular vesicles described in the general description of sheet flows (Fig. 5c). The more altered samples sometimes have a finely vesiculated upper surface with only the lower 2-3 mm of glass preserved and usually coated by a bright orange Fe-oxide.

Extreme alteration or presence of hydrothermal deposits occurs in approximately 50% of the samples. The most abundant alteration appears on the basal surfaces of sheet flow fragments. These basal surfaces have slightly hydrated glass that is highly fractured and completely coated with bright orange, gray, white, and green alteration. The upper surfaces are usually flat, while the basal surface is more irregular in shape.

Other types of alteration present in volumetrically minor amounts are:

1. samples completely coated with white-gray powder

2. samples completely coated with white-gray powder and with fresh glass showing through chipped-off areas of altered surface, and

3. samples with heavy Mn-oxide coating on glass or fracture surface.

X-ray diffraction and energy-dispersive X-ray fluorescenc scans done on an ARL electron microprobe were used to characterize the alteration and hydrothermal(?) deposits. The results are listed in Table 2.

Dredge 8

Dredge 8 is the only dredge to recover porphyritic samples. The dredge consists of six fragments of sheet flow and 12 small glass chips.

The six fragments of essentially aphyric sheet flow have a uniform thickness of 5 cm. The upper glassy rind has up to 5 mm of glass with none of the original glass surface preserved, and the bottom surface has up to 3 mm of glass.

The twelve small glass chips range from 2 to 5 cm across. The glass is porphyritic with up to 10% phenocrysts of plag >> cpx > ol. Alteration consists of a thick brown granular manganese coating on the top surface and some fine tan material on the basal surface.

One of the sheet flow fragments has been labeled and described. The small glass chips have been collectively called L11-81-WF-8-2.

Dredge 11

Dredge 11 recovered one bag (∿20 kg) of 100% pillow fragments. Nine samples have been labeled and described with one plastic container of glass chips with the original glass surface and a vial of old glass chips. All pillow fragments match the general description, except that several samples have a bluish-green alteration in addition to the ubiquitous Fe-oxide staining along fractures.

Dredge 12

Dredge 12 recovered only 2 pillow wedges and loose glass fragments. Only the two pillows have been labeled and they are similar to the general description. The glass chips range up to 4 cm across and can be divided into glass with the original surface, glass with heavy manganese deposits on the original surface, and old glass.

Dredge 13

Dredge 13 recovered only 4 sheet flow fragments and two glass chips.

The four small sheet flow fragments have no original glass, xenoliths, or unusual structures. Small amounts of manganese are present on the top and side of one piece. The two glass fragments (L11-81-WF-13-1 a&b) have the original glass surface preserved. The glass surface has perlitic cracks and abundant palagonite.

Dredge 16

Dredge 16 recovered one large pillow (50 x 70 x 50 cm) and 11 bags with 90% sheet flow fragments. Many of the pillow fragments are greater than 25 cm across. Seven samples have been labeled and described. All samples are similar to the general description.

Original glass is preserved on only one sample (L11-81-WF-16-1). Samples

4 through 7 contain small xenoliths or large glomerocrysts of plagioclase or plag + cpx. All samples are heavily coated with manganese oxide up to 2 mm and a white powdery alteration. Several samples have pale to light olive clay in cracks or on fracture surfaces.

Dredge 17

Dredge 17 recovered 16 bags (∿320 kg) with 70% sheet flow and 30% pillow fragments and blisters. Sixty-four samples have been labeled and described. One small bag with fragments containing <5 mm glomerocrysts, one box containing small fragments with original glass, and one box containing labeled samples 25,26,28,30,31, and 33 are stored with the bags at the Marine Facility.

Samples 17-61 have large original glass surfaces preserved. The glass surface ranges from incipiently to pervasively palagonitized. A small amount of white film, manganese, and Fe-oxides are also found on the upper glass.

Samples 1-16 contain xenoliths of plag + cpx ± ol. Sample 1 contains a large xenolith (6 x 7 x 6 cm) which consists of plag + cpx + ol with intersertal glassy matrix. The matrix makes up 50% of the xenolith. Four other xenoliths have high matrix/crystal ratios but the other 11 have very little glassy matrix.

Approximately 45% of the fragments are altered with orange, yellow, and white alteration on fractures and heavy manganese coatings on the bottom, side, and sometimes top surfaces.

Samples 62-64 have multiple drain back (shelf) structures similar to those shown in Figure 3.

Dredge 22

Dredge 22 is the only dredge haul to recover massive sulfides and hydrothermally altered basalt. The dredge recovered 20 bags of basaltic rock (400 kg) with 90% sheet flow and 10% pillow fragments and blisters. Forty-five samples have been labeled and described. Samples 1-14 are the massive sulfide samples described by Koski et al. (1982). The material stored at the Marine Facility consists of:

No. of bags	Description
6	3" thick sheet flow, relatively unaltered
1	Extremely altered flow with some original glass
1	Extremely altered flow with magnetite ± hematite
4	Extremely altered flow with abundant Fe-oxides
1	Altered flow with abundant Mn-oxide
1	Altered flow with smooth or ropy bottom structures
2	Flow with large vesicles
1	Flow with finely vesiculated bottoms
1	More massive flow
2	Pillow fragments and blisters

Samples 35-45 have the original glass surface preserved. Xenoliths are found in samples 25-32 and are all plag + cpx with both high and low matrix/crystal ratios. The plagioclase crystals in sample 26 appear to be aligned. Samples 45-50 have intersecting bottom structures, including one sample with a non-glassy pahoehoe surface and one with a crystalline pahoehoe surface overlying glass. Approximately 10% of the samples have large flattened vesicles.

One third of the samples show extreme alteration. The bottom surface of the altered flow fragments is often smooth and completely coated with a yellowish-gold oxide. Hydrothermal deposits consist of black sooty magnetite + tridymite, red hematite + crystobalite, and other Fe and Mn oxides. These deposits apparently occur on the upper surface.

Dredge 23

Dredge 23 recovered 1 bag of basalt (∿25 kg) with 50% sheet flow fragments and 50% pillow blisters. The typical sheet flow sample is 5 cm thick. No original glass surfaces, xenoliths, unusual structures, or hydrothermal deposits are present. One sample has been labeled and described.

Dredge 26

Dredge 26 recovered 9 bags of basalt (∿200 kg) with 90% sheet flow fragments and 10% pillow fragments and blisters. Within this dredge haul, 50% of the samples have original glass, 30% of the samples are moderately altered, and 20% are extensively altered. Twenty-four samples have been labeled and described.

Twenty-one samples (4-24) have large areas of the original glass surface preserved. Several specimens (4-11) show virtually no palagonitization. The other samples have undergone varying degrees of alteration with Fe-oxides, Mn-oxides, and/or a milky film coating the top surface. Four of the nine bags contain small fragments with original glass.

Samples 1-3 contain xenoliths. Sample #1 consists of a rock fractured through a 5 cm diameter plag + cpx + ol xenolith with a very low martrix/crystal ratio. The other two xenoliths are smaller (<1 cm) and only contain plag + cpx.

Abundant white-gray-orange alteration coats both the upper and lower surfaces. Glass on the altered samples is jagged and crumbly. Several samples have thick manganese coatings.

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TABLE 1.

Dredge No.	Start of Dredge Latitude	Start of Dredge Longitude	End of Dredge Latitude	End of Dredge Longitude	Average Depth (m)
3	44°38.39'	130°23.19'	44°38.65'	130°23.18'	2212
4	44°39.18'	130°22.25'	44°39.52'	130°22.20'	2230
5	44°38.37'	130°22.60'	44°38.41'	130°22.35'	2208
8	44°38.62'	130°22.03'	44°38.68'	130°22.33'	2231
11	44°39.04'	130°21.63'	44°38.96'	130°22.10'	2230
12	44°39.28'	130°21.84'	44°39.19'	130°21.90'	2235
13	44°37.72'	130°22.10'	44°37.81'	130°22.34'	2208
16	44°39.24'	130°22.41'	44°39.59'	130°21.98'	2230
17	44°39.33'	130°21.98'	44°39.40'	130°22.30'	2231
22	44°40.05'	130°21.60'	44°40.18'	130°21.59'	2208
23	44°40.25'	130°21.64'	44°40.37'	130°21.64'	2227
26	44°42.07'	130°20.72'	44°42.13'	130°20.66'	2228

TABLE 2.

Hydrothermal Minerals on Basalt Samples

Sample*	Description	XRD Mineralogy	EDS Composition**	Basalt Contamination†
5-2	brown crust	amorphous	Mn, Fe, Ca, Si	
5-3a	orange crust	amorphous	Fe, Si, Al, Ca	plag
5-3b	white-gray crust	amorphous	Fe, Si, Ca	plag, pyrox
5-4	white crust	amorphous	Si, Mg, Fe, Ca	pyrox
5-5	dark brown crust	amorphous	Fe, Mn, Ca, Si, Al, Mg	
5-6a	white material	talc & forsterite		
5-6b	yellow-green material	amorphous	Mg, Si, Fe, Al, Ca	plag, pyrox
5-6c	greenish-white material	talc & forsterite		plag, pyrox
5-44	red-orange powder	amorphous	Fe, Si, Cl, Ca	
22-7a	red material	hematite, todorokite?, α-cristobalite,magnetite		
22-7b	sooty black coating	tridymite, magnetite		
22-17	orange crust	cristobalite, magnetite		plag, pyrox
22-19	brownish-gray coating	magnetite?		plag, pyrox
22-21	white material	α-cristobalite, magnetite?		plag, pyrox
22-22	sooty black layer	tridymite, magnetite		

* Dredge # - Sample #

** Elements in order of abundance determined by scanning the carbon-coated XRD slides with a 20μ beam on an electron microprobe equipped with an energy-dispersive X-ray system

† plag is plagioclase, pyrox is pyroxene

FIGURE CAPTIONS

Figure 1. Location of USGS study area on the southern Juan de Fuca Ridge.

Figure 2. Map showing location of dredges, hydrocasts, and vents.

Figure 3. a): Sample L11-81-WF-3-2. Abundant granular Mn-oxides on all surfaces with up to 2mm on the glassy pahoehoe-structured upper surface.

b): Sample L11-81-WF-4-20. Curved blister showing bottom ridges.

c): Sample L11-81-WF-4-37. Drain-back (shelf) feature in a pillow basalt.

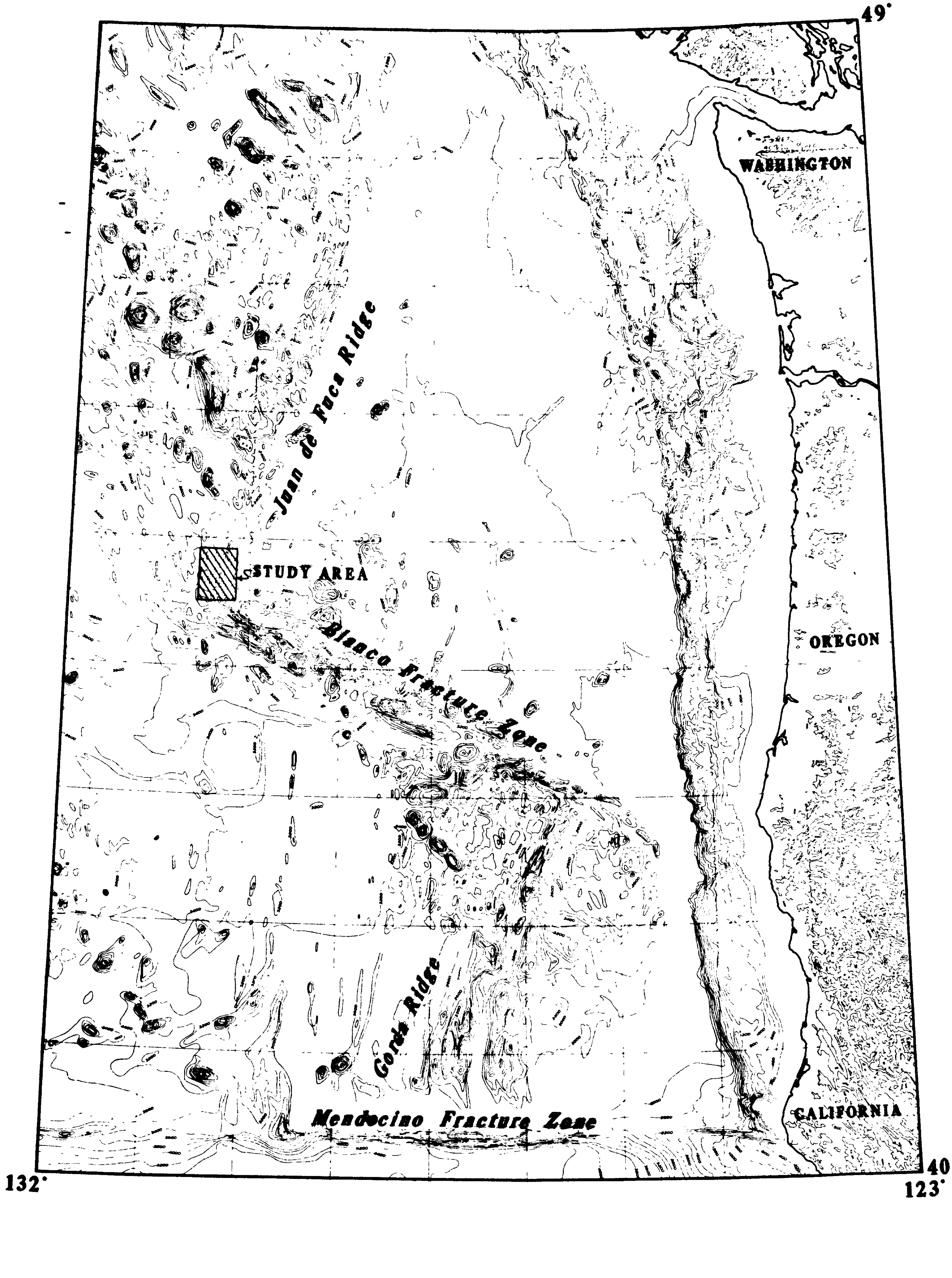
Figure 4. a): Sample L11-81-WF-5-7. Sheet flow fragment with plag + cpx + ol xenolith.

b): Sample L11-81-WF-5-1. Large plag + cpx + ol xenolith.

Figure 5. a): Sample L11-81-WF-5-50 + 52. Sheet flow fragments with fragments of basal breccia enclosed in bottom.

b): Sample L11-81-WF-5-55. Side view of elongate vesicles in sheet flow fragment.

c): Sample L11-81-WF-5-56. Top view of elongate vesicle in sheet flow fragment.


49°
WASHINGTON
Juan de Fuca Ridge
STUDY AREA
Blanco Fracture Zone
OREGON
Gorda Ridge
Mendocino Fracture Zone
CALIFORNIA
40°
132°
123°

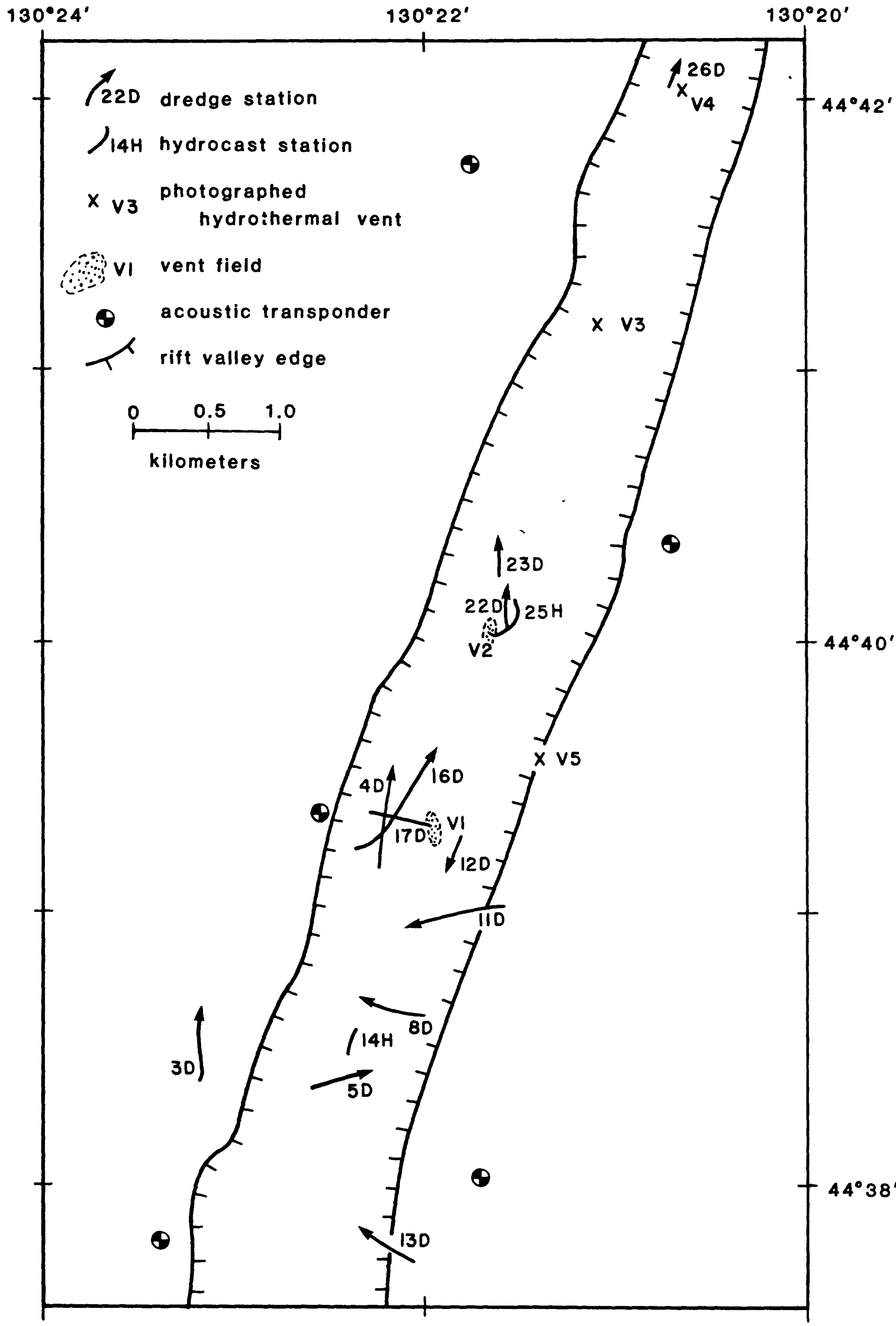

130°24'
130°22'
130°20'
44°42'
44°40'
44°38'
22D dredge station
14H hydrocast station
X V3 photographed hydrothermal vent
V1 vent field
acoustic transponder
rift valley edge
0 0.5 1.0
kilometers
26D
X V4
X V3
23D
22D
25H
V2
X V5
4D
16D
V1
17D
12D
11D
8D
14H
3D
5D
13D

FIG. 2.

Fig.3a.

Fig.3b.

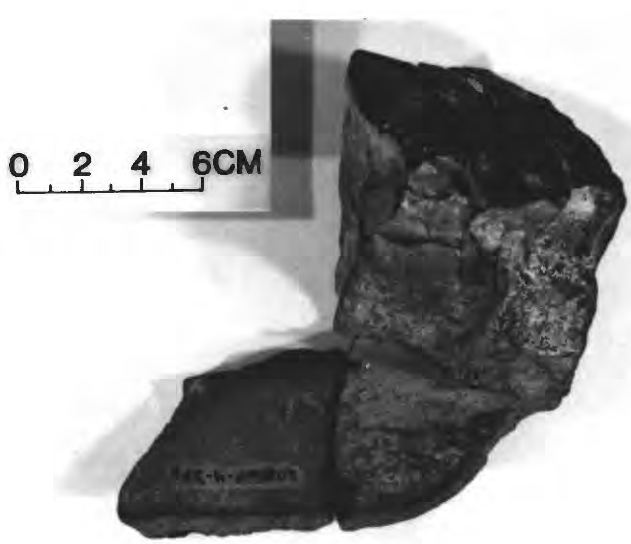


Fig.3c.

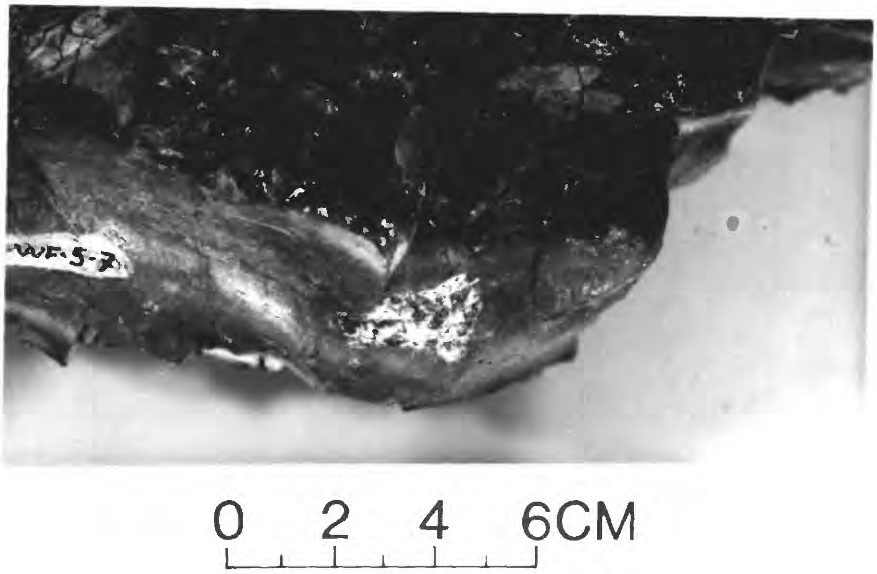


Fig. 4a.

Fig. 4b.

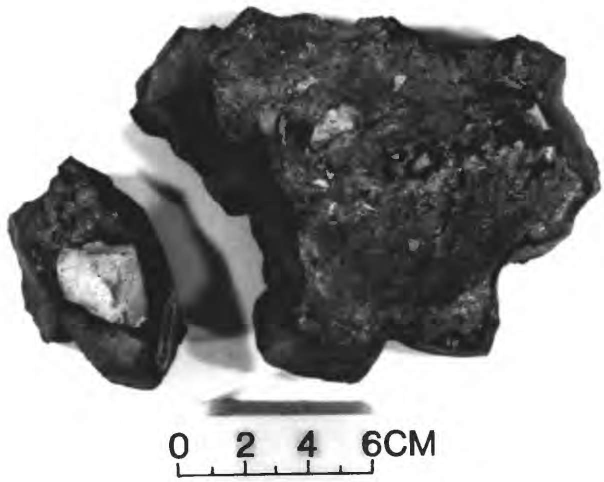


Fig. 5a.

Fig. 5b.

Fig. 5c.

ADDENDUM TO OPEN-FILE 82-200C
Preliminary Description of Basalt from
the Southern Juan de Fuca Ridge

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The following changes to open-file 82-200C have been made in order to be consistent with a detailed photographic interpretation of the study area (Grant Lichtman, pers. comm., 1982) and with nomenclature for ocean-floor basalt morphology given in Ballard and Moore (1977) and Ballard, et. al. (1979):

(1) Samples previously described as pillow or sheet blisters should now be called hollow lobate flow fragments, and

(2) Samples previously described as sheet flow fragments with curved or irregular surfaces should be called lobate flow fragments.

The above changes result in the following modification in basalt morphology distribution within dredge hauls:

Morphology Distribution of Dredge Samples from L1181WF

Dredge #	% Sheet Flow Fragments	% Hollow Lobate and Lobate Flow Fragments	% Pillow Fragments
3	0	50	50
4	45	45	10
5	90	10	0
8	glass frags	0	0
11	0	0	100
12	0	0	100
13	100	0	0
16	45	45	10
17	60	40	0
22	90	10	0
23	50	50	0
26	50	50	0

ADDITIONAL REFERENCES

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