DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Mineralogy of Sand in Turbidites from Escanaba Trough, Northeast Pacific Ocean

by

Florence L. Wong[1]

Open-File Report 89-661

[1] U.S. Geological Survey, Menlo Park, California 94025

1989

MINERALOGY OF SAND IN TURBIDITES FROM ESCANABA TROUGH, NORTHEAST PACIFIC OCEAN

Florence L. Wong
U.S. Geological Survey, Menlo Park, California

INTRODUCTION

The Escanaba Trough, southern Gorda Ridge, is a seafloor spreading center insulated from the sea by a sediment blanket as much 500 m thick (Figure 1). Hydrothermal deposits occur in the sediment in areas where volcanic basement approaches the seafloor (Morton and others, 1987). Magnetic susceptibility data on sediment cores from Escanaba Trough have placed the Holocene/Pleistocene boundary between 100 and 150 cm depth in several cores (Karlin and Lyle, 1986; Karlin, 1989). The Holocene hemipelagic depositional section is interrupted at several intervals by turbidites above this depth. Because the competent currents and stream gradients needed to transport such sediment from fairly well-defined continental sources have not been available since the last glaciation, these turbidites are thought to be reworked from older sand layers rather than primary deposits transported from the continental shelf. During geophysical surveys, sedimentary sequences have been detected on terraces uplifted on either side of Escanaba Trough as well as locally elevated sediment hills developed over volcanic complexes. These sequences constitute a likely candidate for the coarse sand (Fowler and Kulm, 1970; Karlin and Lyle, 1986). Seismic disturbances associated with the active rift zone occupied by Escanaba Trough can trigger submarine slides or slumps, returning previously uplifted material to the central trough (Karlin and Lyle, 1986).

Several cruises conducted by and in conjunction with the U.S. Geological Survey have made available many piston and gravity cores from the northern (NESCA) and southern Escanaba Trough (SESCA) study areas (Figure 2; Morton and others, 1987). This reports presents the mineralogic data determined for sandy layers from these cores. The results from this study are combined with others based on X-ray diffraction, magnetic susceptibility, and porewater chemistry by in Normark and others (in press) in a more general treatment of the sedimentology of Escanaba Trough.

Among the previous sediment studies of Escanaba Trough, Fowler and Kulm (1970) determined the mineralogy of two dredge samples of sediment uplifted on the east and west flanks of Escanaba Trough since Pleistocene time. Vallier (1970) and Vallier and others (1973) completed mineralogic studies of turbidites in 14 samples down to a depth of 390 m at DSDP site 35. Karlin and Lyle (1986) and Karlin (1989) used the magnetic susceptibility of the cores to identify turbidite layers. Karlin and Zierenberg (in press) determined by X-ray diffraction that, except for one sample with reworked hydrothermal pyrrhotite, detrital magnetite (and some ilmenite) accounted for the increased magnetic susceptibility in the turbidites.

METHODS

Most of the subsamples for this study were taken from the upper 100 cm of cores; a few samples were taken at depths greater than the postulated Pleistocene/Holocene boundary (100-150 cm; Karlin and Lyle, 1986; Karlin, 1989). A sample from DSDP site 35 (354 m below seafloor) was also examined.

Samples mentioned in the text will be identified by this scheme: YY-CC-DD, where YY is L1 for cruise L1-86-NC, L2 for L2-86-NC, and TD for TUL-89D; CC is the core number; and DD is the core depth (cm). For example, L2-2G-72 is from 72 cm depth in core 2G from cruise L2-86-NC. The DSDP sample will be referred to as DSDP-35.

Light and Heavy Mineral Separation

Subsamples of 1-2 cm^3 were taken from sediment layers initially described as either "sandy" or "silty". Each sample was treated with hydrogen peroxide to digest organic material and disaggregate clay. By decantation and sieving, three grain-size fractions were retained, 30-63 μ, 63-250 μ, and >250 μ (Table 1).

Heavy and light minerals were separated from the 63-250-μ fraction in tetrabromoethane (sp.gr. = 2.96) (Table 1). Heavy and light grains were permanently mounted in piccolyte (r.i. = 1.52) to determine mineralogy by point counting. Counts of more than 350 points were made for the heavy minerals and approximately 300 points for the light minerals (Tables 2, 3).

Other Sample Sources

Not all samples yielded enough material in the 63-250-μ fraction for heavy mineral separation. Other samples were not counted after separation because of the dearth of nonopaque grains. Compositions of the uncounted samples and of the >250-μ fraction were estimated under low-power (~30x) binocular microscopy. The 63-250-μ and >250-μ fractions were also examined for foraminifers (Quinterno, in press). The 30-63-μ fraction was not examined further.

Other samples that were byproducts of preparation for foraminifers (from P.J. Quinterno) or separated for magnetic susceptibility (from R.A. Zierenberg) were examined under binocular microscopy for general mineral occurrences and are also included in Tables 2 and 3.

DATA

A qualitative grain size relation was determined for the 30-63-μ and >63-μ fraction without considering the clay fraction. The resultant dominant "grain size" ranged from silt to medium sand (Table 1). Thus the focus on the 63-250-μ fraction in this study is fairly representative of the subsamples taken.

The heavy mineral yield of the 63-250-μ fraction ranges from 1.9-3.8% by weight for those samples that do not have an abundance of oxide or sulfide particles. In the few samples that are enriched in opaque minerals, the heavy mineral content is slightly higher; in the extreme, the sulfide sand sample (L1-27G-64) is 50% heavies (Table 1).

Light and Heavy Grain Types

Mica minerals, opaque grains, and volcanic rock fragments occur in both light and heavy mineral fractions. Chlorite is the primary mica in both fractions with lesser muscovite and biotite; phlogopite is a trace component. Except for the finer-grained samples (e.g., TD-9T-12, L1-7G-211) and the >250-μ fraction, mica minerals make up no more than 10% of the heavy fraction and 20% of the light fraction.

Opaque grains made up as much as 7% of the light fraction and about 10-26% of the heavy fraction. Opaque grains in the light fraction include thick books of mica, extremely fine-grained clays or oxides, or sulfides buoyed by attachment to lighter grains. In the heavy fraction the opaque grains include mica, oxide (mostly magnetite; Karlin and Zierenberg, in press), and sulfide particles.

Volcanic rock fragments consisting of plagioclase, clinopyroxene, and (or) opaque groundmass (oxide particles or opaque alteration product) occur in either light or heavy fraction depending on the distribution of the components; more plagioclase reduces the density of the fragment so that it is included in the light fraction, more oxide causes the fragment to appear in the heavy fraction.

Light Fraction

In addition to the grain types mentioned above, the light fraction includes feldspar minerals, quartz, other lithic fragments, and some nonmineralic material. Quartz occurs as angular to subangular monocrystalline and polycrystalline grains. Inclusion-bearing, undulose, and unstrained grains are present but not separately noted.

Plagioclase is the primary feldspar though rare microcline is present in several samples. Some feldspar grains are pristine while others are altered or contain opaque inclusions or have been chloritized.

Sedimentary Fragments. "Fine-grained rock fragments" (Table 2) are homogeneous clay aggregates that appear as subrounded pellets or ragged crusts under binocular observation (e.g., L1-27G-29 or TD-6G-25). "Sedimentary rock fragments" noted in samples L1-26G-40 and L2-2G-72 consist of quartz and feldspar grains cemented with clayey matrix. "Felsic" grains are fine-grained mosaic quartzofeldspathic fragments that differ from chert in their inhomogeneity and presence of mica and/or other mafic minerals. Binocular examination of the >250-μ samples revealed occasional Mn(?)-coated clay nodules (e.g., L1-25G-48).

Igneous Fragments. "Plutonic rock fragments" noted in sample L2-2G-72 consist of intergrown quartz and plagioclase grains. "Volcanic rock fragments" are as described above. Volcanic glass varies from colorless or brown isotropic grains to ones that are partially devitrified or altered to clay minerals. In none of the (63-250-μ) samples examined is the glass as abundant as in the samples examined by Karlin and Lyle (1986, p. 38), who found as much as 35% glass in one sample. Glass globules and fragments of glass crust were noted in several >250-μ samples, some with bluish opaline coating (e.g., TD-7P-8).

"Altered rock fragments" are otherwise unidentifiable, primarily cryptocrystalline grains. Nonmineralogic items in the light fraction include hydrocarbon traces, plant and wood fragments; tests of foraminifers, radiolarians, and diatoms; and sponge parts. The occasional carbonate fragments include tests and replaced feldspar(?) grains.

Heavy Fraction

Nonopaque grains make up the bulk of the heavy fraction of the Escanaba Trough samples; except for L1-7G-211, opaque grains constitute less than 26% of the sample; rock fragments, less than 20% (Figure 3). Clinopyroxene (20%), ordinary green/brown hornblende, and metamorphic amphibole (13%; mainly blue-green) constitute the main nonopaque heavy minerals (Table 3). Epidote and hypersthene each average 5% of the samples. Actinolite/tremolite, zircon, apatite, garnet and sphene make up less than 5% of most samples. Trace amounts of basaltic hornblende, serpentinite, glaucophane, tourmaline, and barite are present.

Altered and volcanic rock fragments are similar to those in the light fraction. The rare metamorphic grains include amphibolite and albite-epidote greenschist.

There is rare evidence of dissolution in the heavy minerals. A few of the pyroxene and amphibole grains bear the coxcomb form but none of the garnets is etched to cubic outlines as observed by Vallier and others (1973).

Sulfide minerals dominate the heavy fraction in sample L1-27G-64, a sulfide sand layer in a generally hydrothermally altered core (Morton and others, 1987). X-ray diffraction and SEM analyses identify them as pyrrhotite, sphalerite, and pyrite (Normark and others, in press). Barite is common in this sample and was noted in several others (Table 3). L1-27G-72 consists of yellowish to reddish-yellow oxidized grains in both light and heavy fractions. Opaque-filled tests were noted in L2-2G-72.

DSDP 35-14-1 (40-43 cm)

Sample DSDP-35 is from approximately 354 m below seafloor. This sandy layer consists mostly of quartz, feldspar, and pyrite. The proportion of light grains is similar to that of other samples higher in the core (Vallier, 1970). The pyrite occurs as free crystals or partially coating the quartz, feldspar or occasional carbonate grains. Besides the pyrite, the heavy fraction consists of minor or trace amounts of biotite, epidote, garnet, sphene, augite, and tourmaline; garnet in this samples has been partly dissolved as was observed in the rest of DSDP core 35 by Vallier and others (1973). There are too few nonopaque grains to determine this sample's standing relative to the other heavy mineral samples.

Other Data

Petroleum. The bottom (87-95 cm) of core L1-27G yielded evidence of mature hydrocarbon (Kvenvolden and others, in press). The presence of oil higher in the core in sample L1-27G-64 was supported by the following evidence: a non-UV-sensitive, broken film appeared during washing; immersion oil and heavy liquid were stained by the sample; and plastic spherical black blobs that were picked from the >250-μ fraction.

Biogenic Components. The processing for mineralogy may destroy microscopic tests, but the presence of any remaining forms gives a small indication of the type of environment of deposition. Calcareous planktonic and benthic foraminifers were detected in several samples (Quinterno, in press). No agglutinated foraminifers, such as are currently populating surface samples, were found but these may have been destroyed by the sample processing. Also noted but not analyzed were sponge parts, radiolarians, and diatoms. Plant fragments generally occur as blackened wood chips; unidentified flattened pale-brown shavings occur in TD-9T-12 (Table 2).

Sediment Sources

The most likely primary (continental) source of these turbidites of Escanaba Trough is the major drainages of the northwestern United States. A preliminary comparison of the Escanaba sand mineralogy with that of the sediments in the Columbia and Klamath Rivers indicates that both these areas supplied some of the sediment but the dispersal paths that resulted in the unique blend in Escanaba Trough mineralogy is unclear (Normark and others, in press).

ACKNOWLEDGMENTS

Tracy Vallier and Robert Zierenberg reviewed this report. Brad Carkins helped in sample preparation.

REFERENCES CITED

Fowler, G.A. and Kulm, L.D., 1970, Foraminiferal and sedimentological evidence for uplift of the deep-sea floor, Gorda Rise, northeastern Pacific: Journal of Marine Research, v. 28, no. 3, p. 321-329.

Karlin, R., 1989, Seacliff diving and sediment studies on the Gorda Ridge: Oregon Department of Geology and Mineral Industries Open-file Report O-89-04, 17 p.

Karlin, R. and Lyle, M., 1986, Sediment studies on the Gorda Ridge: Oregon Department of Geology and Mineral Industries Open- file Report O-86-19, 76 p.

Karlin, R., and Zierenberg, R.A., in press, Sedimentation and neotectonism in the SESCA area, Escanaba Trough, southern Gorda Ridge, *in* Morton, J.L., Zierenberg, R.A., and Reiss, C.A., Geologic, hydrothermal, and biologic studies at Escanaba Trough, Gorda Ridge: U.S. Geological Survey Bulletin.

Kvenvolden, K.A., Rapp, J.B., and Hostettler, F.D., in press, Hydrocarbons in sediment from Escanaba Trough, *in* Morton, J.L., Zierenberg, R.A., and Reiss, C.A., Geologic, hydrothermal, and biologic studies at Escanaba Trough, Gorda Ridge: U.S. Geological Survey Bulletin.

McManus, D.A., et al., 1970, Site 35, *in* McManus, D.A., et al., Initial Reports of the Deep Sea Drilling Project: v. 5, Washington, D.C., U.S. Government Printing Office, p. 165-202.

Morton, J.L., Normark, W.R., Ross, S.L., Koski, R.A., Holmes, M.L., Shanks, W.C., III, Zierenberg, R.A., Lyle, M., and Benninger, L.M., 1987, Preliminary report, cruises L1-86-NC and L2-86-NC, Escanaba Trough, Gorda Ridge: U.S. Geological Survey Open-file Report 87-375-A, 8 p.

Normark, W.R., Gutmacher, C.E., Zierenberg, R.A., Wong, F.L., and Rosenbauer, R.J., in press, Sediment fill of Escanaba Trough, *in* Morton, J.L., Zierenberg, R.A., and Reiss, C.A., Geologic, hydrothermal, and biologic studies at Escanaba Trough, Gorda Ridge: U.S. Geological Survey Bulletin.

Quintemo, P.J., in press, Quaternary foraminifers from Escanaba Trough, northeast Pacific Ocean, *in* Morton, J.L., Zierenberg, R.A., and Reiss, C.A., Geologic, hydrothermal, and biologic studies at Escanaba Trough, Gorda Ridge: U.S. Geological Survey Bulletin.

Vallier, T.L., 1970, The mineralogy of some turbidite sands from Sites 32 and 35, *in* McManus, D.A., et al., Initial Reports of the Deep Sea Drilling Project: v. 5, Washington, D.C., U.S. Government Printing Office, p. 535-539.

Vallier, T.L., Harold, P.J., and Girdley, W.A., 1973, Provenances and dispersal patterns of turbidite sand in Escanaba Trough, northeastern Pacific Ocean: Marine Geology, v. 5, p. 67-87.

Wilde, P., Chase, T.E., Holmes, M.L., Normark, W.R., Thomas, J.A., McCulloch, D.S., and Kulm, L.D., 1978, Oceanographic data off northern California-southern Oregon, 40-43° North including the Gorda deep-sea fan: Lawrence-Berkeley Laboratory Publication 251, 1 mapsheet, scale 1:815,482 at 42°N.

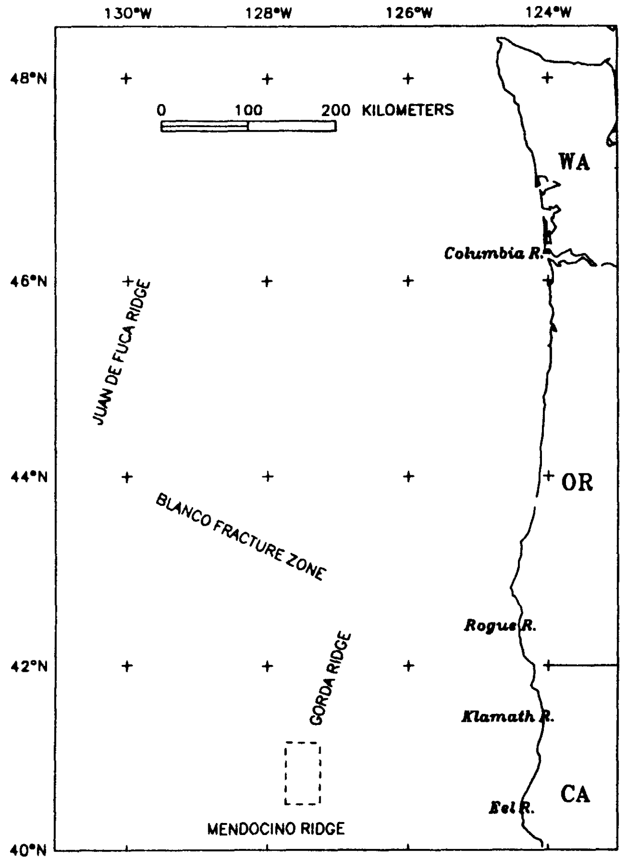

Figure 1. Regional map of the northeast Pacific with major bathymetric features. Area of Figure 2 is dashed box.

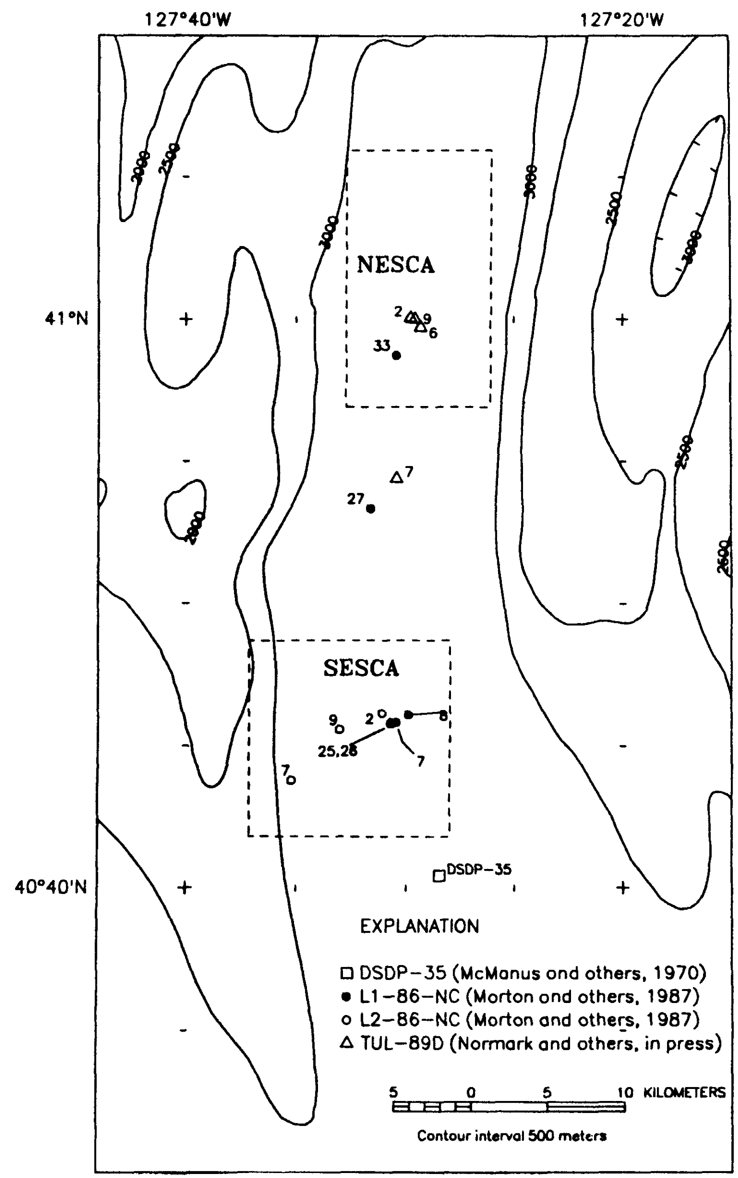

Figure 2. Location of Escanaba Trough cores that were subsampled for this study. Study areas: NESCA, northern Escanaba Trough; SESCA, southern Escanaba Trough. Bathymetry after Wilde and others (1978).

Table 1. Sample grain-size and heavy mineral data.

Sample**	30-63μ "silt" (gm)	63-250μ sand (gm)	>250μ sand (gm)	100 sand/ sd+slt		63-250μ Separates light (gm)	heavy (gm)	wt % heavies
DSDP 35-14-1 40-43 c	1.62	1.88	0.16	56	pyrite-rich	1.78	0.09	4.8
L1-86 7G 124-126 cm	0.11	0.24	0.00	69	clayey	--	--	--
L1-86 7G 211-212 cm	1.65	0.30	0.01	16		0.29	<.01	--
L1-86 8G 52-53 cm	0.97	1.60	0.02	63		1.56	0.03	1.9
L1-86 8G 150-151 cm	0.30	2.30	0.62	91		2.27	0.04	1.7
L1-86 8G 175-176 cm	0.26	2.66	1.08	94		2.60	0.03	1.1
L1-86 25G 48-49 cm	1.30	3.57	0.08	74		3.44	0.13	3.6
L1-86 25G 119-120 cm	0.69	0.54	0.05	46		0.53	0.01	1.9
L1-86 26G 33.5-35 cm	1.42	2.10	0.01	60		2.06	0.03	1.4
L1-86 26G 40-41 cm	1.41	1.35	<.01	49		1.32	0.03	2.2
L1-86 27G 29-30 cm	0.60	0.68	0.23	60		0.66	<.01	--
L1-86 27G 64-65 cm	0.30	0.22	0.20	58	metallic	0.09	0.09	50.0
L1-86 27G 72 cm	0.07	1.04	0.41	95	metallic	0.33	0.03	8.3
L1-86 33G 47-49 cm	0.13	0.09	0.00	41	clayey	--	--	--
L2-86 2G 72-74 cm	0.37	0.64	0.07	66		0.62	0.02	3.1
L2-86 7G 235-237 cm	1.12	0.01	0.00	1		--	--	--
L2-86 9G 108-107 cm	0.09	1.17	0.00	93	clayey	--	--	--
TUL-89D 2G 94-95 cm	0.49	0.33	<.01	40		0.33	0.01	2.9
TUL-89D 6G 25-26 cm	0.24	1.35	0.15	86		1.32	0.02	1.5
TUL-89D 7P 8-9 cm	0.71	3.19	0.12	82		3.08	0.10	3.1
TUL-89D 7P 24-25 cm	0.16	1.63	0.21	92		1.58	0.05	3.1
TUL-89D 7P 42-43 cm	0.23	1.84	0.31	90		1.77	0.07	3.8
TUL-89D 7P 240-242 c	0.29	0.70	0.01	71		0.68	0.01	1.4
TUL-89D 9T 12-14 cm	1.94	0.70	0.04	28	micaceous	0.68	<.01	--

**Except for standard DSDP designation, sample identification includes cruise number (L1-86, L2-86, TUL-89D), core number and type (G gravity, P piston, T trigger for piston), and sampling interval.

Notes: In the "sand/(sand+silt)" value, the silt includes only the 30-63-μ grains. Samples rich in clays were not processed further. After the heavy mineral separation, samples rich in opaque grains were not counted.

Table 2. Light mineral data.

LIGHT GRAINS (S.G. < 2.96)	NESCA			Other--							SESCA--			
	TUL89D 2G-94	TUL89D 6G-25	TUL89D 9T-12	L1-86 27G-29	L1-86 27G-64	L1-86 27G-72	TUL89D 7P-8	TUL89D 7P-24	TUL89D 7P-42	TUL89D 7P-240	L1-86 7G-211	L1-86 8G-52	L1-86 8G-150	L1-86 8G-175
Grains counted		297		393				300		298	295	403		322
Quartzose fragments														
quartz, monocrystalline		12		6				22		33	11	10		7
quartz, polycrystalline		<								3	<			
quartzite														
chert		<		<						<		<		
Feldspar														
feldspar, undiff.		7		4				13		9	3	15		15
plagioclase		20		7				12		24	6	21		21
K-feldspar, undiff.								3		<	<			
microcline		<		1				2		1		<		<
Rock fragments (RF)														
RF, altered		19		2				15		13	2	2		2
RF, volcanic		2		2				1		1	3	7		4
RF, metamorphic, undiff.														
RF, fine-grained		21		61				5		2	13	24		35
greenschist														
felsite		<		<				4		1	1			
RF, sedimentary														
RF, plutonic														
Mica minerals														
muscovite		5		5				4		1	10	4		1
chlorite		4		4				8		3	27	6		<
biotite		6		5				2		2	7	5		6
Other light grains														
opaque fragments		2		3				5		3	7	6		7
glass		x		<		x		<		1	3	<		
glassy crust		x	x				xx		x		x			
glassy globs								x			x			
sponge parts					x						x	<		
carbonate								1		2	1			
foram, calc	x		x					x	x	x	<			
diatom								<			1			
radiolarian	x			x							4			
wood fragments		x	xx				x	x	x				x	
hydrocarbon					x									
clay pellets	x	xx	x	x			x	x			x	xx	xx	x
clay "slabs"								x			x		x	xx
Mn? nodules				x			x		xx	x				
unknown				1						<	1	<		<

Table 2. (continued)

LIGHT GRAINS (S.G. < 2.96)

	L1-86 25G-48	L1-86 25G-118	L1-86 26G-40	L2-86 2G-72	L2-86 7G-235	L2-86 9G-20	L2-86 9G-48	L2-86 9G-75	DSDP 35 14-1-40
Grains counted	356		396	349					399
Quartzose fragments									
quartz, monocrystalline	22		24	27					31
quartz, polycrystalline			<	1					2
quartzite									
chert			<	1					
Feldspar									
feldspar, undiff.	13		2	10					20
plagioclase	17		22	16					29
K-feldspar, undiff.									
microcline	<		<	2					3
Rock fragments (RF)									
RF, altered	9		7	11					1
RF, volcanic	8		4	4					2
RF, metamorphic, undiff.				<					
RF, fine-grained	12		8	9					2
greenschist			<						
felsite			4	1					1
RF, sedimentary			1	1					
RF, plutonic				1					
Mica minerals									
muscovite	4		7	2					3
chlorite	5		11	4					1
biotite	2		4	2					3
Other light grains									
opaque fragments	6		6	5					<
glass	<	x	1	1			x		
glassy crust									
glassy globs									
sponge parts		x	<		x				
carbonate	x	x	1	1					3
foram, calc	x	x	x	1	x				
diatom				<	x				
radiolarian	x	x			x		x		
wood fragments	x			x					
hydrocarbon									
clay pellets	x								
clay "slabs"	x	x							
Mn? nodules	x								
unknown	1		<	1					1

Notes: All samples counted are indicated by a "grains counted" entry and percent of counts (of the 63-250-μ fraction) in the column. < = < 0.5%.

Other samples were not counted but examined for presence (x) or relatively abundant occurrence (xx) of "Other light grains".

Table 3. Heavy mineral data.

HEAVY GRAINS (S.G. > 2.96)

	NESCA			Other--							SESCA--			
	TUL89D 2G-94	TUL89D 6G-25	TUL89D 9T-12	L1-86 27G-29	L1-86 27G-64	L1-86 27G-72	TUL89D 7P-8	TUL89D 7P-24	TUL89D 7P-42	TUL89D 7P-240	L1-86 7G-211	L1-86 8G-52	L1-86 8G-150	L1-86 8G-175
Wt% HV (63-250 μ)	2.9	1.5	nd	nd	50.0	8.3	3.1	3.1	3.8	1.4	nd	1.9	1.7	1.1
Grains counted	401	388	329	416			391	355	362	344	377	356		424
Amphibole, non-metamorphic														
green hornblende	14	13	3	10			13	11	11	12	3	8		13
brown hornblende	3	3	2	3			3	5	4	3	2	6		5
basaltic hornblende	1	1		1			<	1	1	1	<	1		1
Amphibole, metamorphic														
blue-green amphibole	13	14	3	11			17	11	11	13	5	18		11
actinolite	2	2	1	1			<	<	1	2	1			<
tremolite	1	1		1			1	1	1	1	1	<		1
glaucophane											x			x
Orthopyroxene														
hypersthene	3	5	<	7			6	6	4	7	3	5		6
enstatite	1	<	<						<	1				<
Clinopyroxene														
augite	16	20	3	18			20	21	19	17	19	20		11
undifferentiated	2	3	<	2			5	4	3	2	3	6		3
Epidote														
epidote	4	3	2	5			2	4	4	5	2	3		4
zois/clinozoisite	4	3	1	2			1	1	1	1	<	2		3
Other heavy grains														
sphene	1			1			1	<	<	1		<		<
zircon	<	<							1		1	<		<
garnet	1	2	<	1			1	1	1	<	<	2		2
apatite		<		1			<	<		1	<	1		1
tourmaline	1								<	<				
Mica				7								3		3
muscovite	3	1	20				1	1						
chlorite	5	2	34				3	1	1	2	1			
biotite	5	9	17				4	2	2	2	2			
Opaque fragments	12	10	10	16			15	18	24	17	38	12		26
Cr spinel												<		
Rock fragments (RF)														
RF, altered	5	4	2	9			4	6	6	6	7	9		1
RF, volcanic	2	3	2	3			4	5	4	6	11	4		6
RF, metamorphic							<					<		1
RF, fine-grained	<		<											
greenschist														
carbonate	2		<											
barite	x				x	x								x
Sulfide														
pyrrhotite					x									
sphalerite					x									
pyrite					x									
Fe ox						x								
Unknown	3	1	1	2			2	2	2	1	2	4		

Table 3. (continued)

HEAVY GRAINS (S.G. > 2.96)

	L1-86 25G-48	L1-86 25G-118	L1-86 26G-40	L2-86 2G-72	L2-86 7G-235	L2-86 9G-20	L2-86 9G-48	L2-86 9G-75	DSDP 35 14-1-40
Wt% HV (63-250 μ)	3.6	1.8	2.2	4.7					4.8
Grains counted	411		414	416					
Amphibole, non-metamorphic									x
green hornblende	8		10	9					
brown hornblende	5		2	2					
basaltic hornblende			<	<					
Amphibole, metamorphic									x
blue-green amphibole	14		12	8					
actinolite				1					
tremolite	1		1	<					
glaucophane									
Orthopyroxene									
hypersthene	6		4	4					
enstatite									
Clinopyroxene									x
augite	20		19	20					
undifferentiated	6		3	1					
Epidote									
epidote	3		5	2					x
zois/clinozoisite	<		2	1					
Other heavy grains									
sphene	1		1						x
zircon	<		<						
garnet	1		1	1					x
apatite	1		<	1					
tourmaline			x						x
Mica	3			4					
muscovite			1						
chlorite			3						x
biotite			4						x
Opaque fragments	23		19	26					x
Cr spinel	x								
Rock fragments (RF)									
RF, altered	5		4	3					
RF, volcanic	5		7	14					
RF, metamorphic									
RF, fine-grained				2					
greenschist			<						
carbonate	x								
barite					x		x	x	
Sulfide						xx			
pyrrhotite									
sphalerite									
pyrite									xx
Fe ox									x
Unknown	4		3	2					

Notes: Wt% HV = weight percent of heavy grains in the 63-250-μ fraction; nd means <0.01g of heavy minerals was recovered so a weight percent could not be determined.

All samples counted are indicated by a "grains counted" entry and percent of counts (of the 63-250-μ fraction) in the column. < = <0.5%.

Other samples were not counted but examined for presence (x) or relatively abundant occurrence (xx) of heavy mineral grains.