25. THE MINERALOGY OF SOME TURBIDITE SANDS FROM SITES 32 AND 35

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INTRODUCTION

Samples of turbidite sands were selected from cores of Hole 35 to compare mineralogies of sands at different depths and to determine possible source areas and dispersal histories. A sample was taken from the top core of Site 32 to study the differences in mineralogy between the sands of Sites 32 and 35, which occur on opposite sides of the Mendocino and Pioneer Fracture Zones, and also to determine possible source areas. The sands at both sites are of Pleistocene age.

Four samples were taken from the sands of Site 35. Two samples (5-35-1-1 and 5-35-1-4) were selected from the top core. One sample was chosen from sand at a depth of 102 meters (5-35-5-4), and the fourth was collected from a silty sand near the bottom of the hole at 381 meters (5-35-16-2). The sample from Site 32 (5-32-1-1) was selected from a sand about 4 meters below the sea floor.

The sands are classified as lithic and arkosic sands (classification scheme of Williams, Turner and Gilbert, 1955). Notable characteristics are poor to moderate sorting and grains which are angular to subangular. If lithified, these sands would be excellent examples of lithic and arkosic wackes.

The sands were sieved, and the fractions retained for mineralogic studies were in the 88- to 177-micron size range. Heavy and light minerals were separated by means of the heavy liquid bromoform (specific gravity 2.85). Two slides of light minerals and two slides of heavy minerals were made from each sample by mounting the mineral grains in caedex (refractive index 1.55). Between 300 and 500 grains were identified and counted on each slide using a polarizing microscope with a mechanical stage.

PHYSIOGRAPHIC SETTING

Site 32, located at latitude 37°07.63′N., longitude 127°33.38′W., is in an area where sediments from the Delgada deep-sea fan are believed to be depositing, and is near the distal fan edge where terrigenous sediments are overlapping and burying abyssal hill topography.

Site 35, located at latitude 40°40.42′N., longitude 127°28.48′W., is in the medial valley of the Gorda Ridge which has been named the Escanaba Trough (terminology in McManus, 1965). Sedimentation rates are high, exceeding 560 m/m.y. Most sediments are of turbidite origin with sands and silty sands separated by mud and silty mud intervals.

MINERALOGY OF SAND-SIZE SEDIMENTS

Results from this study of sand mineralogies suggest that important compositional changes occur in the turbidite sands with depth in a single hole. Mineralogies of the sands are presented in Table 1 (light minerals) and Table 2 (heavy minerals).

Light Minerals

Feldspars, quartz, rock fragments and volcanic glasses are the major constituents in the light mineral fractions of the five samples. Altered fragments, mostly rocks and feldspars, comprise as much as 33.6 per cent of one sample (5-35-5-4). Apparently, these altered fragments were deeply weathered before transportation to the deep-sea floor.

Feldspars comprise from 35.2 to 82.5 per cent of the light fractions. The lowest feldspar percentages (35 and 36 per cent) occur at Site 32 (5-32-1-1) and at Site 35 (5-35-1-1 and 5-35-16-2). Highest feldspar percentages (72.0 and 82.5 per cent) are at Site 35 (5-35-1-4 and 5-35-5-4). Plagioclase feldspars and potash feldspars were not differentiated. Very few potash feldspars were noted during optical examination, however, and it would be surprising if they comprised more than 30 per cent of the total feldspars in any sample.

Quartz grains are remarkably fresh and angular. Some grains are subangular to subrounded, but none was observed that could be classified as well-rounded. Only rare grains contain inclusions other than small gas bubbles. One quartz fragment in Sample 5-35-5-4 contains rutile needles. Some deformed grains, showing undulatory extinction, occur in Samples 5-32-1-1 and 5-35-5-4.

Rock fragments are predominantly fine-grained sediments, foliated metamorphics, plutonic, and altered, unidentifiable rocks. Greenstone fragments in Sample 5-32-1-1 are diagnostic provenance indicators. Glassy basalt fragments in Sample 5-35-1-4 are relatively fresh. Plutonic rock fragments in Sample 5-35-16-2 are mostly quartz diorite.

Volcanic glass occurs as palagonite, basaltic glass (sideromelane) and colorless glass. The palagonite is reddish-brown in color and is difficult to distinguish from other oxidized, iron-rich fragments. Basaltic glass is dark brown and has undergone very little alteration. Clear volcanic glass, most abundant in Sample 5-35-1-1, probably represents more acidic volcanism; notable characteristics are the sharp angular edges and gas bubbles.

Chlorite content in Sample 5-35-1-1 was very high in both the light and heavy fractions. These chlorites may be both detrital and authigenic.

Heavy Minerals

The heavy mineral assemblages from samples at Sites 32 and 35 have a wide range in composition. The mineralogy of Site 32 shows the greatest diversity, and indicates source rocks in petrologically complex terranes. Major components of the heavy mineral assemblages are rock fragments, opaque minerals, pyroxenes, hornblende and chlorite. Some minerals which occur in minor amounts are worthwhile to mention because of their reliability as provenance indicators. These are glaucophane, epidote, brown tourmaline and garnet.

Rock fragments range from 12.9 to 50.0 per cent of the heavy mineral fractions. Altered, unidentifiable fragments comprise the greatest amounts in Samples 5-32-1-1, 5-35-1-4 and 5-35-5-4. Quartz diorite grains are the only rock fragments noted in Sample 5-35-16-2.

Opaque minerals are magnetite, ilmenite, hematite, pyrite and leucoxene-altered fragments. Pyroxenes present are mostly clinopyroxene (augite) and hypersthene. Single grains of enstatite were noted in Samples 5-32-1-1 and 5-35-5-4. The hornblende content ranges from 1.8 to 15.8 per cent. All hornblendes are green except for a few brown grains (oxy-hornblende) in the sample from Site 32. Chlorite is the dominant component in Sample 5-35-1-1. Reasons for this chlorite "flood" are unknown at present.

Glaucophane in Sample 5-32-1-1 points to probable source rocks in the Franciscan Formation of western California. Epidote grains in Samples 5-32-1-1 and 5-35-1-1 suggest low-grade metamorphic terranes, probably the Franciscan Formation and the low-grade metamorphic rocks in the Klamath Mountains. Brown tourmaline in 5-35-1-4 and 5-35-5-4 also indicates a low-grade metamorphic terrane, probably in the Klamath Mountains. Pink garnets in Samples 5-32-1-1, 5-35-1-4 and 5-35-5-4 are indicative of terranes in high-grade metamorphic provinces, which occur in parts of the Franciscan Formation and around plutons in the Klamaths.

SOURCE AREAS AND DISPERSAL

From this study some preliminary conclusions can be made with regards to source areas and dispersal routes of sediments. The mineralogies are compositionally diverse and immature. The diversity and immaturity are indicated by the high feldspar/quartz ratios, the abundance of unstable minerals, such as clinopyroxene and hypersthene, and the abundance of rock fragments. Combined with the angularity of the fragments, these data suggest that most of the sediments were derived from areas characterized by high relief and rapid erosion. These conditions occur all along the Oregon and California coasts.

The turbidite sand at Site 32 probably was transported down the Delgada submarine canyon. However, other canyons may have served as sediment funnels. It is not believed that the sediments were transported along the coastline from northern California (Wilde, 1958). Apparently, the Mendocino and Mattoje submarine canyons trap the southward-flowing shelf sediments and disperse them on the deep-sea floor north of the Mendocino Fracture Zone. Therefore, the sands at Site 32 were derived from local drainage basins or possibly they were transported from the south by longshore currents during the winter months when the currents flow northward. The mineralogy of the sample at Site 32 suggests source rocks in geologically complex terranes of low-grade metamorphics, fine-grained sediments, basalts and quartz-rich plutonics.

Source rocks and dispersal routes may be different for each of the sands which were sampled at Site 35. By comparing the mineralogies of these sands with the mineralogies of sands from rivers along the Oregon Coast (Kulm *et al.*, 1968), it appears that most of the sands originated in the Columbia River Plateau-Cascade Range Province of Oregon and Washington and the Klamath Mountain Province of southern Oregon and northern California. A minor part may have been eroded from the Coast Range of Oregon.

Sediments from these provinces are brought to the shoreline by rivers (such as, the Columbia, Siletz, Umpqua, Yaquina, Alsea, Salmon, Klamath, Rogue, Sixes, Coos, Mad and Eel). Submarine canyons (Astoria, Trinidad, Bear Valley, Eel and Mendocino) funnel the sands to abyssal depths from the coastline and the shelf. Apparently, sediments brought down the canyons could continue their transport along the base of the continental slope, and then flow south to the Mendocino Fracture Zone and west along the fracture zone to the Escanaba Trough. Both the topography (McManus, 1965) and the air gun records suggest this type of sediment dispersal. The Blanco Saddle (McManus, 1965) should block the south-flowing currents along the continental slope. However, the existence of this

TABLE 1
Light Minerals From Sites 32 and 35

Note: Size of grains in 88- to 177-micron range (500 grains were counted on each slide). Those minerals or rock fragments which comprise less than 1 per cent are designated by the letter "x".

Composition	5-32-1-1 4m	5-35-1-1 1m	5-35-1-4 6m	5-35-5-4 102m	5-35-16-2 381m
Rock fragments (total)	32.0	9.4	8.5	8.8	48.6
Fine-grained sediments	13.6	3.2	3.3	3.6	–
Foliated metamorphic	4.2	x	x	x	–
Plutonic	1.0	x	–	x	48.6[f]
Metamorphosed volcanics	1.0[a]	x	–	x	–
Quartzite	–	–	x	–	–
Basalt	–	–	2.0[e]	1.6	–
Altered rocks	12.2	5.2	2.8	1.6	–
Feldspars (fresh)	27.2	24.2	57.5	40.0	31.8
Feldspars (altered)	8.0	11.4	25.0	32.0	4.2
Unknowns	4.2	2.6	1.0	3.2	x
Quartz	24.0	12.4	7.5	13.0	13.8
Volcanic glass	3.4[b]	10.6	–	1.8	–
Radiolarian fragments	x	1.2	–	x	–
Chlorite	x	27.4[c]	x	x	x
Calcite	–	x[d]	–	x	–
Muscovite	–	–	–	–	x

[a] Mostly greenstone, one spilite fragment.
[b] Includes both fresh glass and palagonite.
[c] Flood of chlorite also occurs in the heavy fraction.
[d] Foraminifera fragments.
[e] Glassy.
[f] Mineralogy includes feldspar, quartz, hornblende, biotite, and muscovite. Epidote and deformed quartz grains indicate metamorphism of some source rocks.

TABLE 2
Heavy Minerals From Sites 32 and 35

Note: Minerals and rock fragments are in the 88- to 177-micron size range (300 to 500 grains were counted on each slide). Those minerals which comprise less than 1 per cent are designated by the letter "x".

Composition	5-32-1-1 4m	5-35-1-1 1m	5-35-1-4 6m	5-35-5-4 102m	5-35-16-2 381m
Rock fragments (total)	12.9	19.1	50.0[d]	20.0	39.3
Altered rocks	10.6[a]	3.8	50.0	20.0	–
Basalt and diabase	2.3	15.3[b]	–	–	–
Diorite and quartz diorite	–	–	–	–	39.3[f]
Gneiss	–	–	x	–	–
Unknowns	4.3	1.2	19.0[e]	2.8	–
Opaques	9.6	3.3	8.8	12.0	1.5
Clinopyroxene	20.3	x	4.0	16.0	–
Hypersthene	x	–	6.0	16.0	–
Green hornblende	14.8	6.5	1.8	10.8	15.7
Brown hornblende	1.0	–	–	–	–
Chlorite	25.0	68.3[c]	3.0	5.6	–
Zircon	x	–	–	x	–
Glaucophane	x	–	–	–	–
Epidote	5.2	x	2.9	x	–
Biotite	x	x	1.0	2.4	x
Garnet	1.0	–	1.0	6.8	–
Actinolite	x	–	–	–	–
Sphene	1.3	x	1.0	3.2	–
Clinozoisite-zoisite	1.0	–	–	–	–
Pyritized radiolarians	x	–	–	–	–
Enstatite	x	–	–	x	–
Kyanite	–	–	x	x	–
Tourmaline (brown)	–	–	x	2.0	–
Rutile	–	–	x	–	–

[a] Some probably are altered pyroxene.
[b] Some diorite fragments included.
[c] Some chlorites have many euhedral inclusions.
[d] Rare metamorphosed basalts are included. Most fragments are altered basalts and pyroxenes.
[e] Unknowns are extremely altered and probably represent deeply weathered rock fragments.
[f] Quartz diorite with green hornblende and metamorphosed quartz diorite with epidote.

saddle has been questioned (D. McManus, personal communication, 1969), and there probably is a valley which connects the southern part of the Cascadia Basin with the basin along the continental margin south of the Blanco Fracture Zone. If this valley exists, then the transportation of sands from more northerly sources–even from the Astoria Canyon–to the Escanaba Trough can be more easily explained.

The high percentages of augite, hypersthene and altered basaltic rock fragments in Samples 5-35-1-4 and 5-35-5-4 indicate source rocks in the Cascade Mountains and the Columbia River Plateau. These sands were apparently brought down the Columbia River and onto the deep-sea floor through the Astoria Submarine Canyon as turbidity flows. From the mouth of the Astoria fan channel the turbidity currents continued across the Cascadia Basin past the Blanco Fracture Zone to the Mendocino Escarpment. There they were diverted westward to the Gorda Ridge, where deposition occurred in the Escanaba Trough.

Mineralogies of sands from 5-35-1-1 and 5-35-16-2 contrast greatly with the other two samples and indicate different source areas. Of particular interest is the high percentage of quartz diorite rock fragments in Sample 5-35-16-2. It is not known at this time where these sands originated but the absence of minerals from other terranes suggests that this sand bed represents a turbidite flow derived from a localized source area.

CONCLUSIONS

The diversity of mineralogies in the sand beds at Site 35 reflect the different source rocks which contributed to the sediments. The turbidity currents which transported sands to the Escanaba Trough were generated in different places from along the coastlines of Oregon and northern California. Conclusions regarding source areas for sediments in an area of sedimentation like the Escanaba Trough, based only on studies of surface cores, should be tentative until the sediments at depth can be studied. This is an obvious advantage of deep-sea drilling.

Most of the turbidity currents which transported the coarse sands probably were generated during times of glacially lowered sea level. These were periods characterized by an increase in stream gradients, the narrowing of continental shelves and the location of river mouths near outer shelf edges. The thick, finer-grained intervals which separate the sands may have been deposited during the interglacial stages.

It is reasonable to believe that the sea floor configuration has changed in these areas dispersing sediments to Site 35, even during the last 500,000 years. Barriers to sediment transport probably have been created, destroyed and covered. These changes would, in part, control the amount and diversity of sediments which reached the Escanaba Trough.

The generation of turbidity currents at different places along the coastline combined with changes in sea floor topography should help account for the diversity of mineralogies, even in sands of the same hole, such as Site 35.

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