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Heavy Minerals from the Oki Spur, Japan Sea

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Abstract: The heavy minerals (63–125 and 125–250 μm in size) in the Oki Spur sediments are characterized by an assemblage of green hornblende-clinopyroxene-hypersthene and by the presence of other unstable minerals such as basaltic hornblende and olivine. Some of these minerals contain glassy rim and bubble wall structure which are indicative of a volcanic origin. Stable minerals such as zircon, tourmaline, and rutile occur rarely. These data suggest local derivation of minerals mainly from alkali volcanic rocks of the Oki Islands and nearby Sanin district of Honshu.

1. Introduction

In the deep basins of Japan Sea such as the Japan Basin, Yamato Basin and Tsushima (Ulleung[1)]) Basin, accumulation of turbidites has been predominant over pelagic sedimentation probably since Neogene time. According to SIBLEY and PENTONY (1978), the turbidites in the Japan Basin originated mainly from the Asian continent, whereas the Yamato Basin received its turbidites from central Japan largely through the Toyama Deep-Sea Channel and other sources. In the Tsushima (Ulleung) Basin the entire turbidite sequence is more than 800 m thick (TAMAKI *et al.*, 1978), and was derived probably from the surrounding continental margins of the eastern Korea and southwestern Japan. Slump and probable debris flow deposits have been found on the surrounding continental slopes of the basin (HONZA *et al.*, 1979; CHOUGH *et al.*, in prep.).

In order to identify the provenance of turbidites in the Tsushima (Ulleung) Basin, we undertook a study of heavy mineral assemblages that are characteristic of the surrounding continental shelves which border the basin. In this report we present preliminary results of the study on the Oki Spur.

The Oki Spur is the northern extension of the Shimane Peninsula and is connected northeasterly to the Oki Bank and easterly to the Oki Ridge. It separates the Tsushima (Ulleung) Basin in the west from the Yamato Basin in the east. The Oki Islands on the spur consist mainly of Pliocene and Pleistocene alkali volcanic and trachitic rocks covering or intruding the Miocene sedimentary, pyroclastic, and andesitic rocks. The Oki gneiss of Pre-Silurian is locally exposed in the eastern part of Dogo island. On the other hand, the Shimane Peninsula is mostly composed of Miocene sedimentary rocks intercalated with rhyolitic and andesitic rocks. In the region south of the peninsula Cretaceous granitic rocks are widely distributed.

Heavy minerals such as hornblende, ortho- and clino-pyroxene and rock fragments of quartz-porphyry, andesite, granite, chert, graywacke, and rhyolite have previously been reported from the spur and the Oki Bank (NIINO, 1948; MARUYAMA, 1970; FUJII and YASUDA, 1970).

The Oki Spur was recently surveyed by the

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1) This geographic name was given by KIM (1976) after the Ulleung Island which forms the northern border of the basin and is appropriately used among Korean geologists.

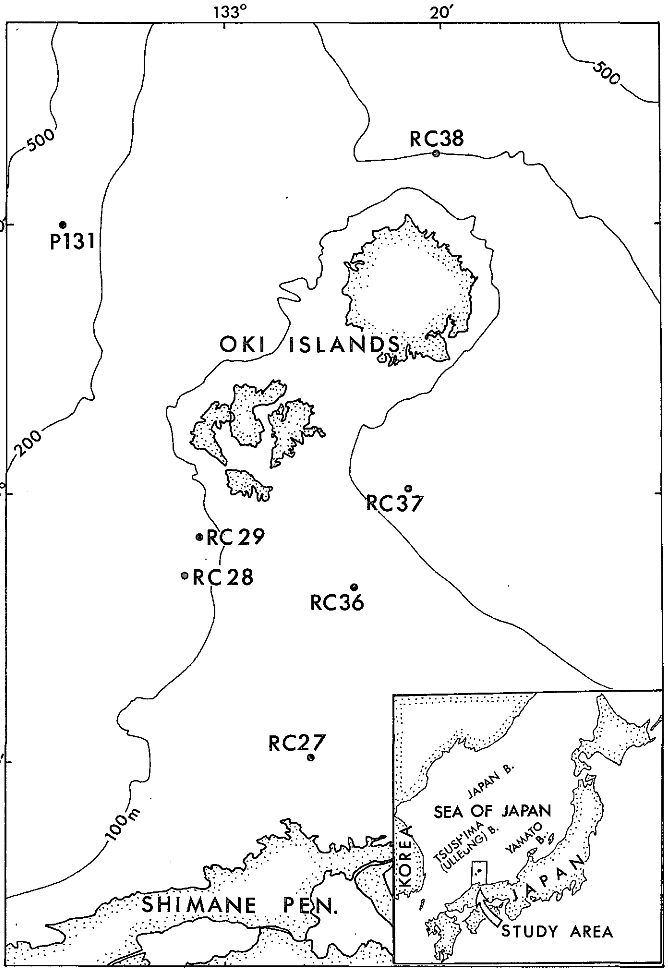


Fig. 1 Location map and sample stations.
P = piston corer; RC = rock corer.

Geological Survey of Japan aboard the R. V. Hakurei-maru (HONZA ed., 1978; INOUE ed., in prep.), during which a number of dredge and rock corer samples were obtained.

2. Materials and Methods

Sediment samples were obtained by the staff of the G. S. J. using rock and piston corers during the GH78–3 cruise, June 1978, aboard the R. V. Hakurei-maru to the Oki Spur (Fig. 1 and Table 1). Heavy mineral analysis was carried out by the staff of Seoul National University. Fourteen subsamples, each weighing about 40 grams, of 7 cores were processed for this study (Fig. 2).

The samples were heated at 40°C for about 12 hours in 10% H_2O_2 solution to remove organic matter and were boiled gently in 10% oxalic acid for 3 minutes to eliminate any iron stain. The sand grains larger than 63 μm were separated by wet sieving and they were dried and sieved for 15 minutes in a Ro–Tap mechanical shaker. To make results between samples comparable narrow size fractions (63–125 μm and 125–250 μm, respectively) were chosen.

Standard methods (CARVER, 1971) were used for heavy mineral separation (using

Table 1 Verbal description of cores

Core No.	Locations (Latitude and Longitude)	Depth of water in m.	Core length in cm.	Core description
RC 27	St.1133, 35–40.4N, 133–08.0E	72	56	Olive grey, very coarse to coarse sand with granule grains and many shell remains.
RC 28	St.1134, 35–53.8N, 132–56.5E	115	80	Olive grey, very coarse to coarse sand with many shell remains.
RC 29	St.1136, 35–56.8N, 132–57.6E	106	73	Dark olive grey, very coarse to coarse sand with many small shell fragments.
RC 36	St.1145, 35–53.5N, 133–11.8E	80	104	Olive grey, very coarse to coarse sand sort well from top of core to 59 cm. Very dark grey, medium to coarse sand intercalated with wavy sandy silt lamina from 59 cm to base of core.
RC 37	St.1146, 36–00.4N, 133–16.7E	121	80	Olive grey medium to coarse sand with shell fragments, unconformably overlying dark green or black tuff breccia.
RC 38	St.1147, 36–25.5N, 133–19.5E	230	95	Olive grey silt with sand lamina including pebbles at the lower most part. Black patches exist.
P 131	St.1130, 36–20.0N, 132–45.3E	252	501	Grey to dark grey homogeneous sandy silt with calcareous nodules and shell fragments. Sulphide patches and strong H_2S odour.

bromoform with a specific gravity of 2.88) and sample preparation. In each mount, a total of 200 grains, excluding micas, carbonates, opaque minerals, and altered minerals that could not be positively identified, were counted. X-ray diffraction method was used also for the heavy minerals that could not be identified with certainty under the petrographic microscope.

3. Petrographic Characteristics

More than 24 heavy mineral species were identified, of which only 16 occur appreciable amount (Table 2). They include hornblendes (green hornblende, brown hornblende, basaltic hornblende, and hornblende "unidentified"), pyroxenes (clinopyroxene and hypersthene), epidote, clinozoisite, zoisite, olivine, garnet, andalusite, zircon, actinolite, tourmaline, and rutile. Other minerals that are present, but not common include apatite, kyanite, glauconite, sphene, riebeckite, sillimanite, and staurolite. The heavy mineral assemblage of the Oki Spur is dominated by green hornblende, hypersthene, and clinopyroxene.

In the following sections petrographic characteristics of the common heavy minerals are described in their decreasing order of abundance.

Hornblendes

Four types of hornblendes were identified by their color, pleochroism, and birefringence. Green hornblende is dark green, brownish green, or light green. The mineral is slightly pleochronic (yellowish green to grayish green) and exhibits relatively low birefringence. Most grains are angular to subangular and a few show saw-teeth marks and glassy rim (Plate 1–i).

Brown hornblende varies from dark borwn, greenish brown to smoky brown. Like green hornblende, the brown hornblende usually is slightly pleochronic and has low birefringence.

Basaltic hornblende exhibits diagnostic pleochronism (brownish yellow to deep red) with high birefringence and a small extinction angle (0°–5°). In most cases, the grains are angular to subangular with elongate or bladed prisms

Table 2 Relative abundance

	RC 27				RC 28				RC 29			
Core depth (cm)	0–5		40–45		0–5		40–45		0–5		40–45	
Size fraction*	VF	F	VF	F	VF	F	VF	F	VF	F	VF	F
Epidote	14	8	1	12	18	10	16	10	17	5	15	10
Clinozoisite+Zoisite	1	0	2	1	3	2	3	2	4	2	5	1
Brown Hornblende	7	22	10	13	8	10	14	11	8	4	7	8
Green Hornblende	48	53	62	80	110	98	86	110	86	120	86	131
Hornblende unknown	17	6	26	2	9	15	11	6	20	16	24	5
Basaltic Hornblende	30	38	35	31	4	6	5	4	4	7	2	12
Actinolite, Tremolite	4	1	5	2	3	6	4	4	5	6	3	6
Hypersthene	56	57	45	42	17	23	19	29	13	11	20	8
Clinopyroxene	13	9	7	8	8	20	23	18	27	26	17	15
Olivine	2	1	1	0	3	3	3	1	4	3	1	0
Garnet	1	2	0	4	4	2	6	3	2	0	5	0
Andalusite	1	3	1	2	0	1	2	1	2	0	2	1
Zircon	6	0	5	3	11	3	5	1	8	0	13	2
Tourmaline	0	0	0	0	1	1	2	0	0	0	0	1
Rutile	0	0	0	0	1	0	1	0	0	0	0	0
Total count	200	200	200	200	200	200	200	200	200	200	200	200
%Heavy Mineral	8.3	3.5	7.6	5.6	5.5	1.1	5.6	0.8	7.1	0.5	7.0	0.7
%<63 μm	8.2		6.7		19.9		24.2		21.1		18.5	
%63–125 μm	4.0		1.5		10.9		11.7		11.2		10.9	
%125–250 μm	18.5		6.2		32.4		27.7		50.4		54.6	
%>250 μm	70.3		85.6		36.8		36.4		17.3		16.0	

*VF = very fine sand (63–125 μm) F = fine sand (125–250 μm)

(Plate 1–j). The crystal margin is often dusty and altered to fine grains of probable iron oxides.

Hornblende "unidentified" is distinguished from green or brown hornblende by strong absorption, distinctive pleochroism (light yellowish green to dark green) and higher birefringence. The grains are columnar or sometimes fibrous with ragged termination. Minute spots of probable iron oxides were found on many crystal surfaces. X-ray diffraction results show that the hornblende "unidentified" is close to ferrohastingsite in composition.

Clinopyroxene

Augite can not be distinguished positively from diopside under the petrographic microscope. Both are marked by pale, brownish green color and by high birefringence, as well as high extinction angle of more than 45°. Most clinopyroxenes present are severely corroded and show abundant saw-teeth marks (plate 1–e and f).

Hypersthene

Most grains of orthopyroxene present are hypersthene. Enstatite, bronzite, and eulite were scarcely found. Some hypersthenes exhibit typical pinkish to greenish pleochronism while others are yellowish to greenish. A few hypersthene grains show weak birefringence, probably due to less iron content. Hypersthenes of heavy minerals

RC 36				RC 37				RC 38				P131			
0–5		40–45		0–5		40–45		0–10		40–45		0–5		40–43	
VF	F	VF	F	VF	F	VF	F	VF	F	VF	F	VF	F	VF	F
9	4	7	8	5	3	4	3	15	3	10	12	7	2	13	3
4	0	0	2	3	0	1	2	3	0	5	2	3	0	13	1
14	16	15	17	10	4	4	6	12	15	15	8	9	22	11	6
65	57	68	68	23	46	42	46	91	30	99	87	113	87	100	118
14	10	22	4	5	11	5	6	12	6	12	8	6	11	13	10
14	5	14	12	7	7	3	5	5	2	22	16	19	4	8	2
4	2	8	6	2	1	3	3	1	1	2	7	2	3	9	7
21	81	29	60	23	18	33	25	20	51	11	14	22	22	12	22
38	13	26	18	112	93	94	99	30	87	19	44	12	46	10	21
6	2	4	2	6	13	1	3	0	1	0	0	0	2	2	7
3	4	3	2	2	1	2	0	2	2	3	2	4	0	4	0
0	2	1	0	0	0	4	1	0	0	1	0	0	1	2	1
8	4	3	1	2	2	4	0	9	2	1	0	2	0	2	2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0
200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
3.5	3.8	2.9	2.0	3.4	0.9	3.8	1.0	3.7	3.3	1.7	1.7	1.8	1.6	1.6	1.3
4.0		1.9		22.2		31.1		52.1		91.2		65.2		47.2	
0.8		0.6		46.4		49.6		5.4		7.7		24.7		48.7	
2.4		1.9		29.5		17.3		5.0		1.0		8.2		2.9	
92.8		95.6		1.9		2.0		37.5		0.1		1.9		1.2	

are predominantly euhedral in shape with glassy rim and bubble wall structure (Plate 1–c, u, v, and w). Saw-teeth marks were rarely found.

Epidote

Epidote shows a distinct pleochroism (pale greenish yellow to yellowish green) and very high birefringence. The grains mostly are angular to subrounded with equidimensional anhedral form (Plate 1–r). Solution pits also were found.

Actinolite-Tremolite

Although many grains are believed to be actinolite showing very pale green to dark green in color, actinolite can not be positively distinguished from tremolite under the petrographic microscope and counted as one group. The actinolite is slightly pleochroic, usually with non-altered slender prisms and splintered terminations (Plate 1–*l*). Colorless or dark green ferroactinolite grains were rarely found.

Zircon

Zircons found on the Oki Spur are colorless with rare pink varieties. They are euhedral in grain shape with some well-rounded corners and edges possibly caused by chemical etching (Plate 3–m, o, and p).

Olivine

Olivine, the rare detrital mineral on other continental shelves, occurs in appreciable

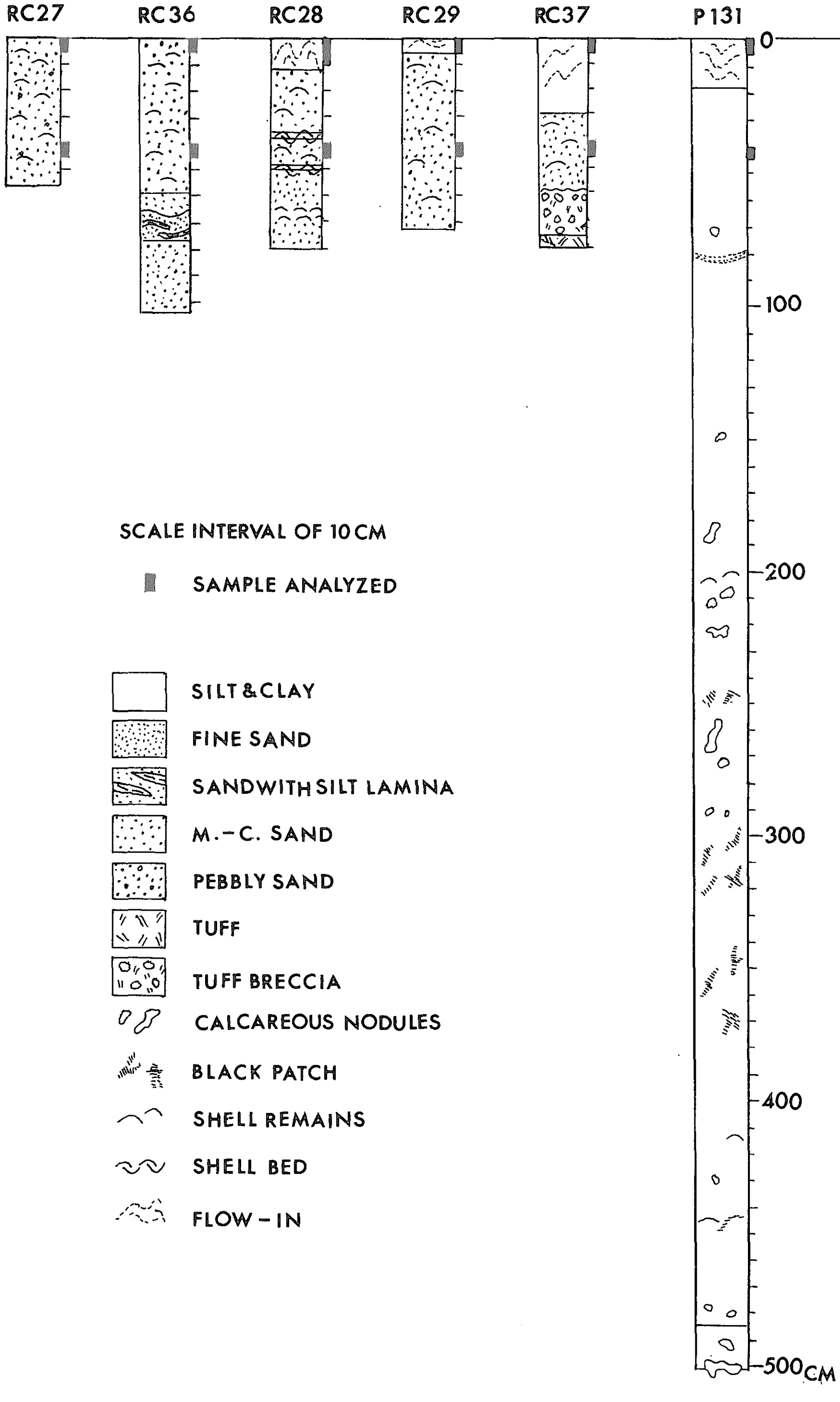


Fig. 2 Description of cores taken from the Oki Spur.

amount in the Oki Spur ranging up to 3%. Olivine grains are very pale yellow in color with high order of interference color. They are often corroded and partially altered (Plate 1–x and y). X-ray diffraction study indicates that they are mostly forsterite.

Zoisite and Clinozoisite

Zoisites are mostly colorless or grayish green in color and pleochroism is weak. An anomalous blue interference color has been observed in some grains. Clinozoisite is distinguished from zoisite by its inclined (not always) extinction and lower birefringence.

Garnet

Most garnets are salmon pink with rare occurrence of the colorless variety. In some cases anisotropic inclusions and numerous small solution pits were found. The colorless varieties include the dodecahedral form (Plate 1–t). Some of the dodecahedral garnets are abraded and contain tiny dark inclusions of unknown origin. According to the X-ray diffraction study the dodecahedral garnet is grossular.

Andalusite

Andalusite is characterized by low birefringence, length-fast and slight pleochroism. Some show striations parallel to the long axis on grain faces. Skeletal features resulting probably from chemical solution were rarely found.

Tourmaline

Both brown and blue tourmalines were identified. Grain surface is often dusty with minute dark impurities.

Rutile

Rutile present is deep red in color and its surface feature resembles that of frosted quartz grains.

4. Occurrence

The frequency of each heavy mineral, out of 200 grains counted, is shown in Table 2. The total amount of heavy minerals in each sample (63–250 μm) ranges from 0.5 to 8% by weight, of which the finer fractions (63–125 μm) are more abundant (av. 5%) than the coarser fractions (125–250 μm) (av. 2%). On the average, four types of hornblendes comprise 56% of total heavy minerals, followed by clinopyroxene (17%), hypersthene (14%),

Table 3 Percent range, mean, and standard deviation of heavy mineral component

Component	Total	Range (%)		Mean (%)		Standard Deviation	
		VF	F	VF	F	VF %	F %
Green Hornblende	2210	12–52	15–65	38.5	40.4	12.9(34)	15.3(38)
Brown Hornblende	306	2– 7	2–11	5.1	5.8	1.6(31)	2.9(50)
Basaltic Hornblende	323	1–17	1–19	6.1	5.4	5.1(83)	5.2(96)
Hornblende unknown	312	3–13	1– 8	7.0	4.2	3.3(47)	2.0(48)
Clinopyroxene	953	4–56	4–49	15.6	18.5	15.4(99)	15.6(84)
Hypersthene	804	6–28	4–40	12.2	16.5	6.2(51)	10.5(64)
Epidote	244	1– 9	1– 6	5.4	3.3	2.6(48)	1.8(54)
Actinolite Tremolite	110	1– 4	1– 3	2.0	2.0	1.2(60)	1.1(55)
Zircon	99	1– 6	0– 2	2.8	0.7	1.8(64)	0.6(86)
Olivine	71	0– 3	0– 6	1.2	1.4	1.0(83)	1.7(121)
Clinozoisite + Zoisite	65	0– 6	0– 1	1.8	0.5	1.5(83)	0.5(100)
Garnet	63	0– 3	0– 2	1.5	0.9	0.8(53)	0.7(78)
Andalusite	29	0– 2	0– 1	0.6	0.5	0.6(100)	0.4(80)
Tourmaline	6	0– 1	–	0.1	0.1	0.3(300)	0.2(200)
Rutile	5	–	–	0.1	0.1	0.2(200)	0.2(200)
Total	5600			100.0	100.2		

VF = very fine sand (63–125 μm) F = fine sand (125–250 μm)

Figs. 3–9 Histograms of individual mineral frequency expressed in percent by number. Ep = epidote; Cz = clinozoisite; bH = brown hornblende; gH = green hornblende; *H = hornblende "unidentified" (probably ferrohastingsite); Hb = basaltic hornblende; Ak = actinolite; Hy = hypersthene; Cp = clinopyroxene; Ov = olivine; Gt = garnet; Ad = andalusite; Zr = zircon; Tl = tourmaline.

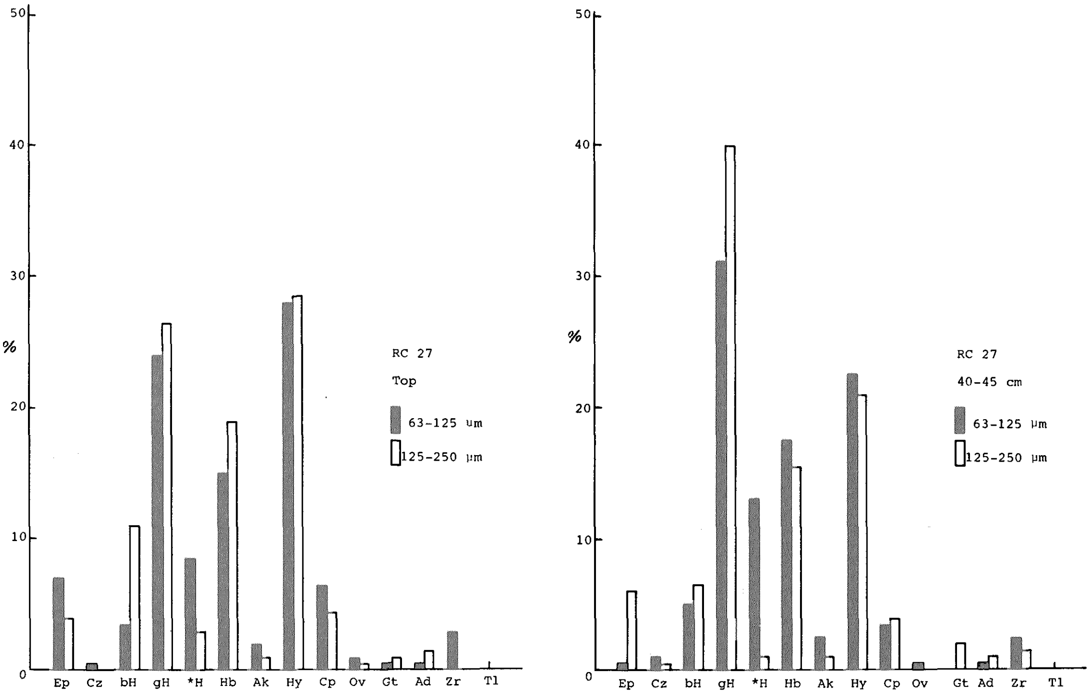


Fig. 3

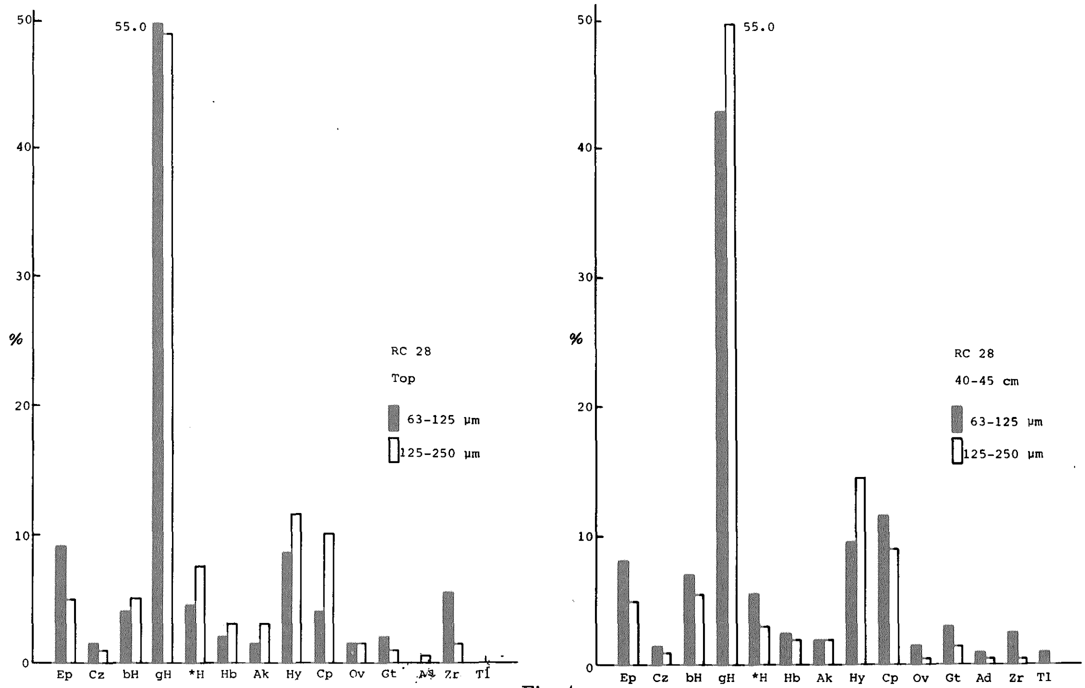
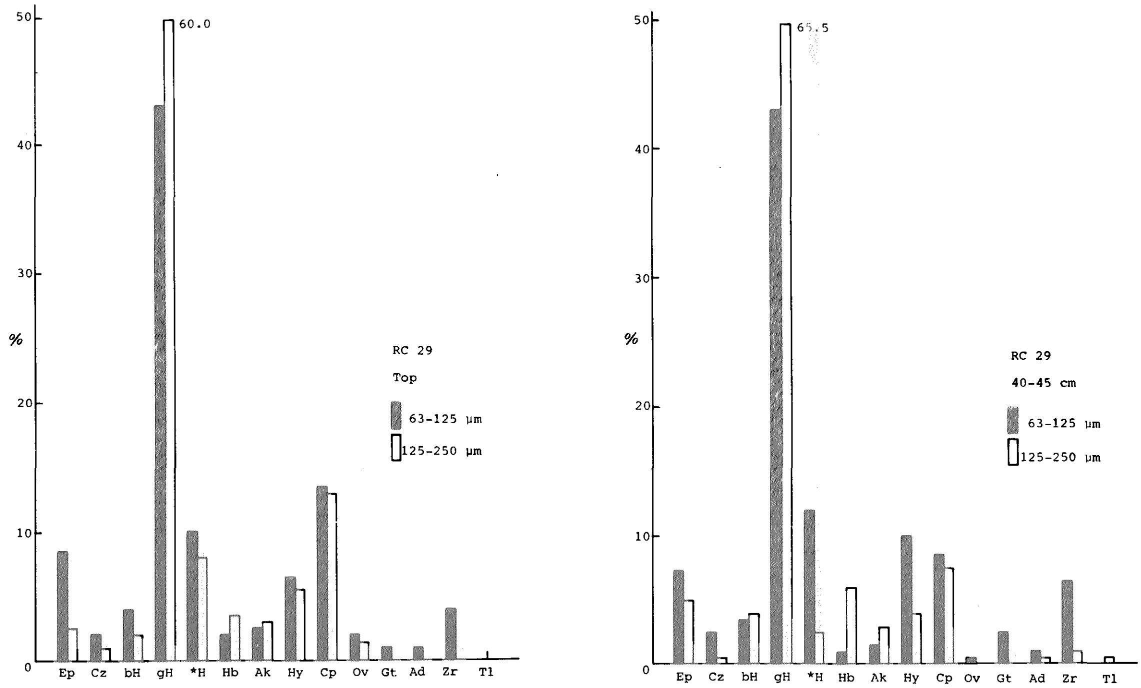
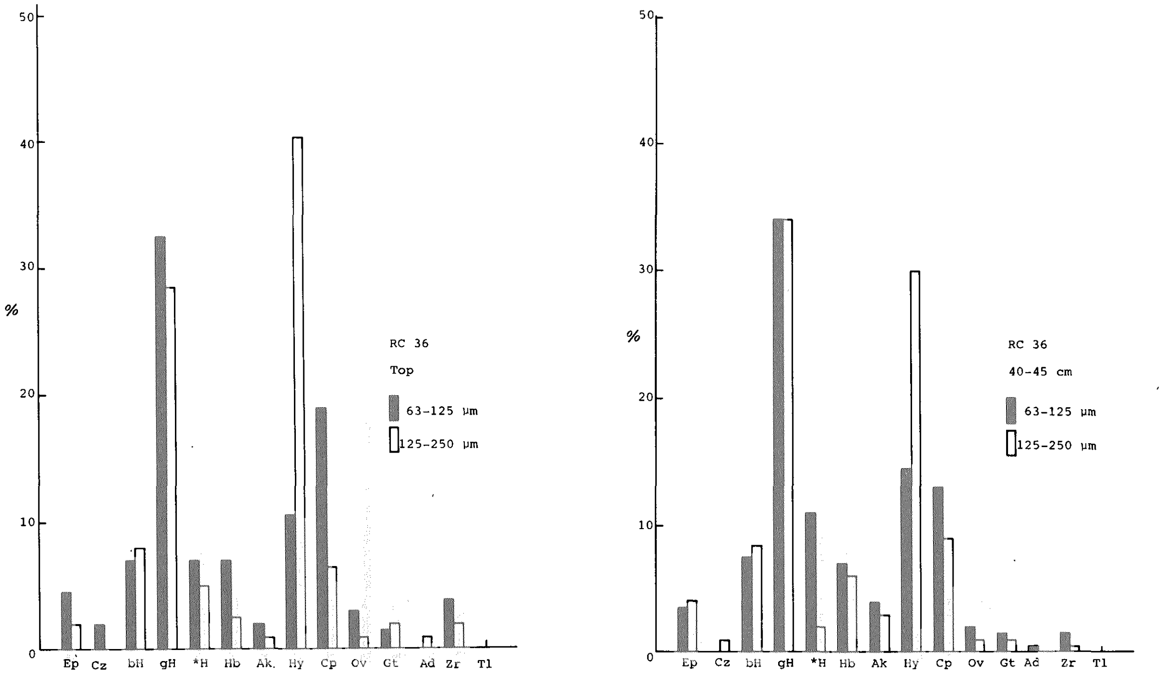


Fig. 4



50
40
30
%
20
10
0
60.0
RC 29
Top
63-125 µm
125-250 µm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl
50
40
30
%
20
10
0
65.5
RC 29
40-45 cm
63-125 µm
125-250 µm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl

Fig. 5



50
40
30
%
20
10
0
RC 36
Top
63-125 µm
125-250 µm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl
50
40
30
%
20
10
0
RC 36
40-45 cm
63-125 µm
125-250 µm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl

Fig. 6

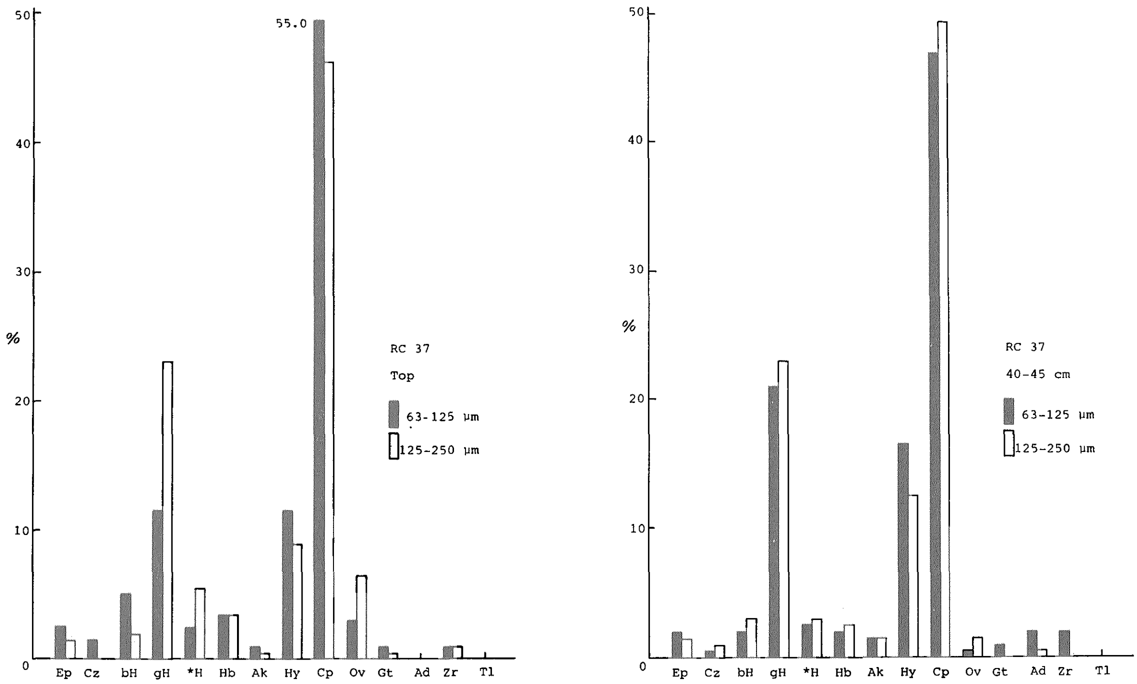

50
40
30
%
20
10
0
55.0
RC 37
Top
63-125 μm
125-250 μm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl
50
40
30
%
20
10
0
RC 37
40-45 cm
63-125 μm
125-250 μm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl

Fig. 7

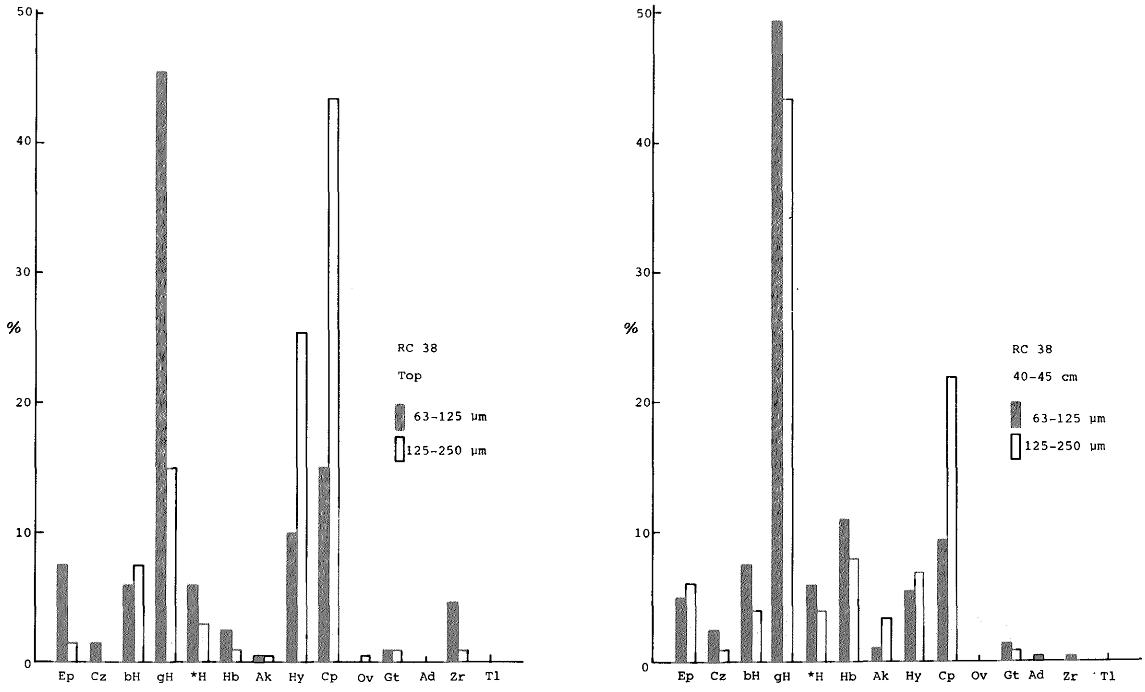

50
40
30
%
20
10
0
RC 38
Top
63-125 μm
125-250 μm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl
50
40
30
%
20
10
0
RC 38
40-45 cm
63-125 μm
125-250 μm
Ep Cz bH gH *H Hb Ak Hy Cp Ov Gt Ad Zr Tl

Fig. 8

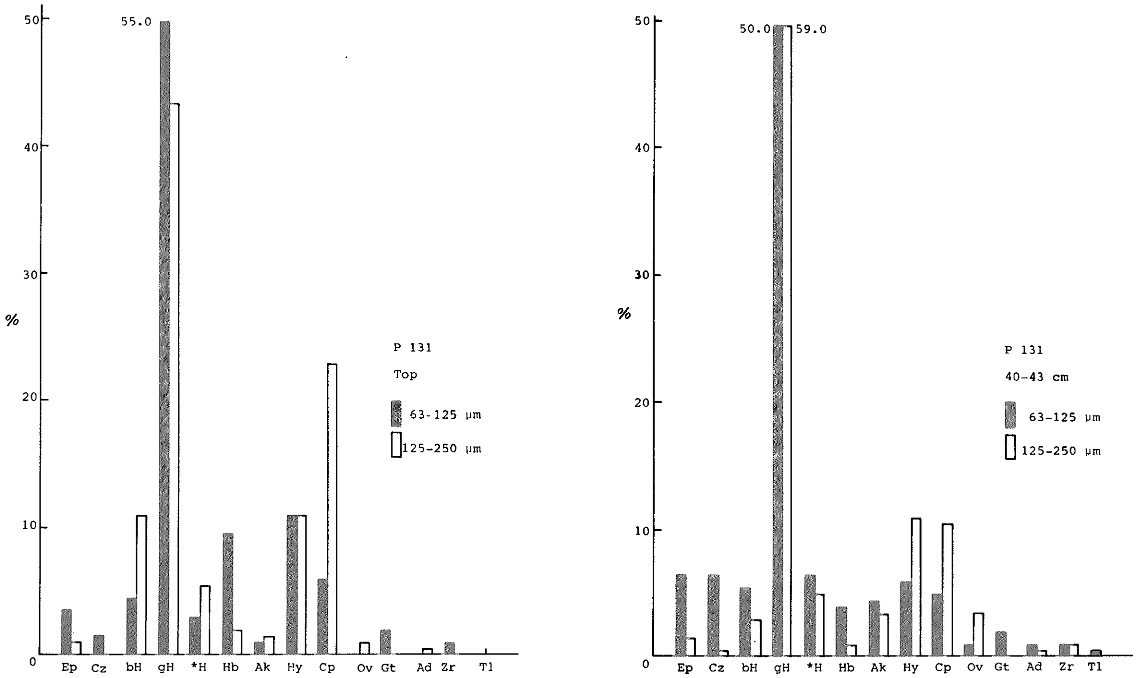


Fig. 9

epidote group (6%), olivine (2%), zircon (2%). Less common minerals include garnet (0–3%), andalusite (0–2%), tourmaline (0–1%), and rutile (0–1%). High-frequency minerals such as hornblendes, clinopyroxene, and hypersthene display a high standard deviation i.e. a wide range of occurrence (Table 3).

In Figures 3 to 9 are illustrated the mineral frequency (%) in each sample. In cores RC28, RC29, and P131 green hornblende is predominant, whereas hypersthene and clinopyroxene are increasingly important in other samples such as RC27, RC36, RC37, and RC38. In cores RC37 and RC38 clinopyroxene is more abundant than orthopyroxene. This trend is reversed in cores RC27 and RC36. In a few mineral species the variation in mineral abundance between the two size fractions seems significant, but no definite trend was found. The variance due to core depth also is minor.

Heavy minerals of the Oki Spur are represented by unstable minerals (mafic minerals) such as hornblende-clinopyroxene-hypersthene assemblage, olivine, basaltic hornblende, and by the comparatively small amounts of stable minerals, i.e., zircon, tourmaline, and rutile. The unstable minerals often contain bubbles and are characterized by glassy rim and bubble walls which are indicative of volcanic origin. Saw-teeth marks of clinopyroxene and hornblende suggest existence of chemical weathering and support the instability of the Oki mineral assemblage.

5. Provenance

The mineral assemblage of the sediments is fairly consistent with the rocks on the Oki Islands such as Neogene alkali basalt, trachyte, and alkali rhyolite with small amounts of gneiss. The drainage area of Hino River, probably one of direct sources to the Oki Spur from Honshu also consists of Neogene hornblende andesite, basalt, granite, and older (Permian to early Triassic) crystalline schist and phyllite.

The above mineral association is quite different from that of the continental shelf of eastern Korea where stable minerals are predominant (Bahk and Chough, in prep.).

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日本海隠岐海脚における堆積物の重鉱物組成

趙　成権・玉木賢策・朴　慶壽・井上英二・湯浅真人

要　旨

昭和53年６月，隠岐諸島周辺海域において GH 78-3 研究航海を実施し，ロックコアラ及びピストンコアラによって堆積物の柱状採泥を行った．そのうち RC 27・28・29・36・37・38及び P 131 の各堆積物コアについて，コア頂部及び頂部より 40-45 cm 深部の２点の重鉱物分析を行い，堆積物供給源を推定した．

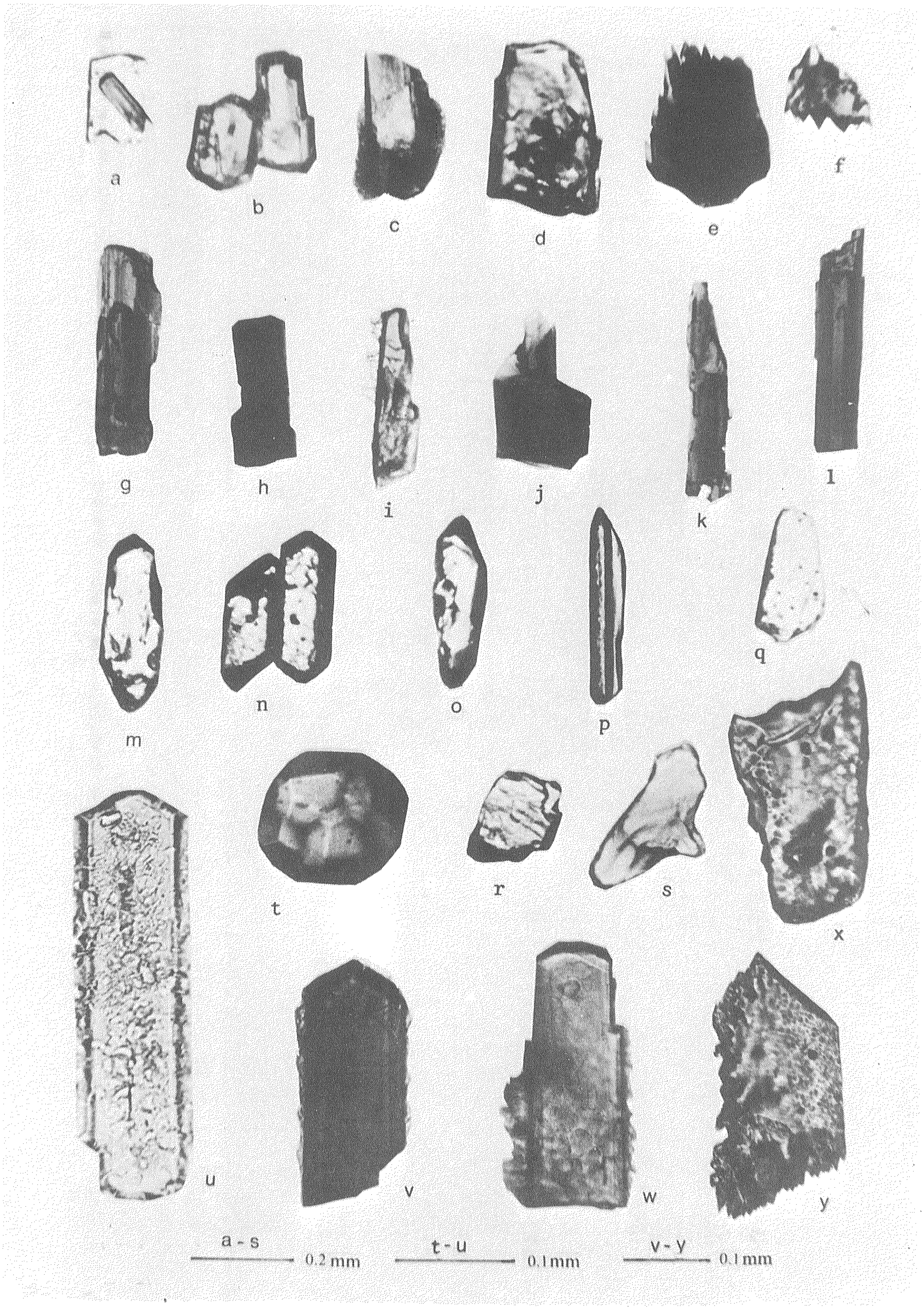
全サンプルを通じて，緑色角閃石-単斜輝石-紫蘇輝石，玄武角閃石，カンラン石のような有色鉱物の存在が特徴的である．これらの鉱物粒子にはガラス質リムやバブル・ウォール構造（bubble wall struc-

ture) を有するものがある． これらの鉱物は火山岩起源と考えられる．一方，ジルコン・電気石・ルチル等の安定鉱物はきわめて少ない．また，各コアにおける上下の鉱物組成変化は少ない．以上の結果から，海脚の表層堆積物は，隠岐諸島や島根半島付近の新生代アルカリ火山岩から主として供給されたと推定され，安定鉱物に富む韓国東側大陸棚堆積物の重鉱物組成とは対照的である．

（受付：1981年５月７日；受理：1981年６月17日）

Plate 1

a —Hypersthene, euhedral.
b —Hypersthenes.
c —Hypersthene, euhedral, enclosed by altered glass.
d —Clinopyroxene with dark stain.
e —Clinopyroxene showing saw-teeth marks.
f —Clinopyroxene showing saw-teeth marks.
g —Green hornblende showing cleavages.
h —Brown hornblende, euhedral.
i —Green hornblende with glassy rim.
j —Basaltic hornblende, subhedral.
k —Actinolite.
l —Actinolite.
m —Zircon, etched.
n —Zircon, "double" crystal.
o —Zircon, etched.
p —Zircon, elongate, severely corroded.
q —Olivine with etched pits.
r —Epidote.
s —Garnet showing conchoidal fracture.
t —Glossular; dodecahedron form.
u —Hypersthene, euhedral with glassy bubbles.
v —Hypersthene, euhedral with glassy rim.
w —Hypersthene with glassy rim and bubbles.
x —Olivine, corroded, showing bubbles.
y —Olivine, corroded and partially altered.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