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Heavy Mineral Sands on the Southeastern Continental Shelf of Korea

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한국 동남해역 대륙붕의 사립 중광물 분포

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A study of heavy mineral sands in terms of heavy mineral group and concentration has been carried out by analyzing 88 grab samples from the continental shelf off the southeast coast of Korea. Heavy mineral groups seem to be outlined and classified into four regions in the study area: 1) the western region; high concentrations of stable minerals, such as opaque mineral, magnetite, garnet and ZTR, 2) Korean Trough region; moderate concentrations of stable minerals, 3) the eastern region; abundant altered mineral and amphibole with minor of pyroxene concentration, and 4) the northeastern shelf-break region; low concentration of stable minerals with abundant altered minerals.

The sedimentologic natures of four major heavy mineral regions (groupings) seem to be influenced by physical, dynamic and hydraulic milieu and also aerial and/or subaqueous weathering processes. It seems to be, further, plausible that shallow marine waves and currents associated with neritic dynamic condition of transgressive sea might be very effective on the concentration and groupings (sorting) of heavy minerals in the surficial sediments of the continental shelf. The pyroxene-abundant heavy mineral suite (group), in fact, seems to suggest a sediment source from Japanese Islands.

한국 동남해역의 대륙붕 표층 쇄설퇴적물에 함유된 중광물 사립자의 연구를 위하여 88 정점의 표층시료가 분석되고 해석되었다. 중광물 함량의 분포지역은 크게 4지역으로 다음과 같이 나누어진다.

1) 서부지역-자철석, 석류석 및 ZTR 등의 안정한 중광물이 크게 농축되어 분포함, 2) 한국해곡지역-안정한 중과물의 비교적 우세한 분포, 3) 동부지역-각섬석류와 풍화된 광물, 그리고 휘석류의 분포가 우세함, 4) 북동부 붕단지역-안정한 광물이 적으며, 풍화 변질된 중광물이 우세함.

이와같은 중광물의 함량 및 분포양상은 대륙붕 해저에 영향을 미치는 현세 해수면 상승 (해침) 의 과정에 따른 동력학적 에너지 (파랑작동과 연안류 운동) 와 관련된 것으로 해석된다. 휘석류 중광물이 우세한 퇴적물은 일본의 화산암으로부터 기원된 것으로 제안된다.

INTRODUCTION

Sand-sized heavy minerals have traditionally been used as one of useful sedimentologic criteria to determine source of bottom sediments and their environmental conditions. Furthermore, sedimentolcgic researches on heavy minerals and placer deposits in the coastal and shelf environments have been emphasized because of their economic values and mineral exploration.

The heavy mineral sands on the continental shelf off the southeast coast of Korea (Fig. 1) have scarcely been understood, except the sedimentologic studies on shelf clastics carried by Park and Choi (1986) and Choi and Park (1993). The southeastern coast of Korea is characterized by nearly strait and semi-ria shoreline. Most of the terrigenous clastic materials from the Nakdong River are deposited within the estuarine-deltaic environment (Kim and Lee, 1980; Park and Chu, 1991). The geology of the drainage basin of Nakdong River, and along the southeastern coast of Korea is dominated by the Mesozoic sedimentary rocks of non-marine origin and scattered volcanic rocks.

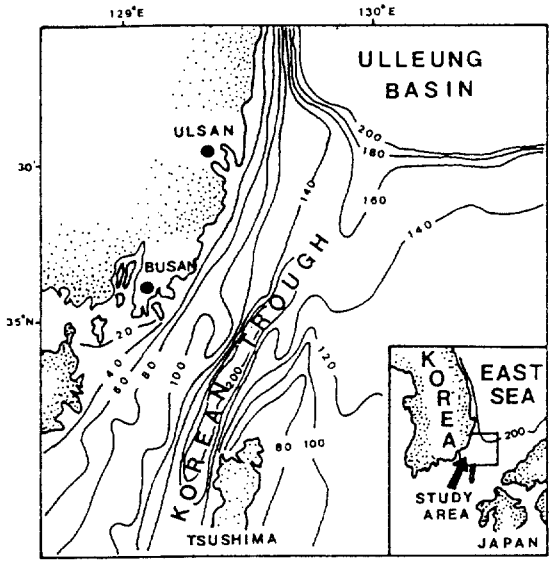

Fig. 1. Index map showing general bathymetry and the Korean Trough off the southeastern continental shelf of Korea. Depth in meter.

The southeastern continental shelf is divided into the eastern and western shelf region based on a NE-SW trending topographic depression, as shown in Fig. 1. The NE-SW trending topographic-low submarine morphology, so-called Korean Trough, is located between Korea and Tsushima Island, Japan (Fig. 1).

The clastic sediments on the southeastern continental shelf are composed primarily of relict sand sediments containing about 30% or up to 50% of shell fragments, that is, biogenic carbonates (Park, 1985; Park and Choi, 1986). Most of shells are fragmented, deeply weathered, and have the C^{14} age of about 20,910 yrs B.P. (Choi, 1990). However, some of these relict sediments are interpreted as the palimpsest sediments that might be modified and mixed with modern fine sediments under the modern

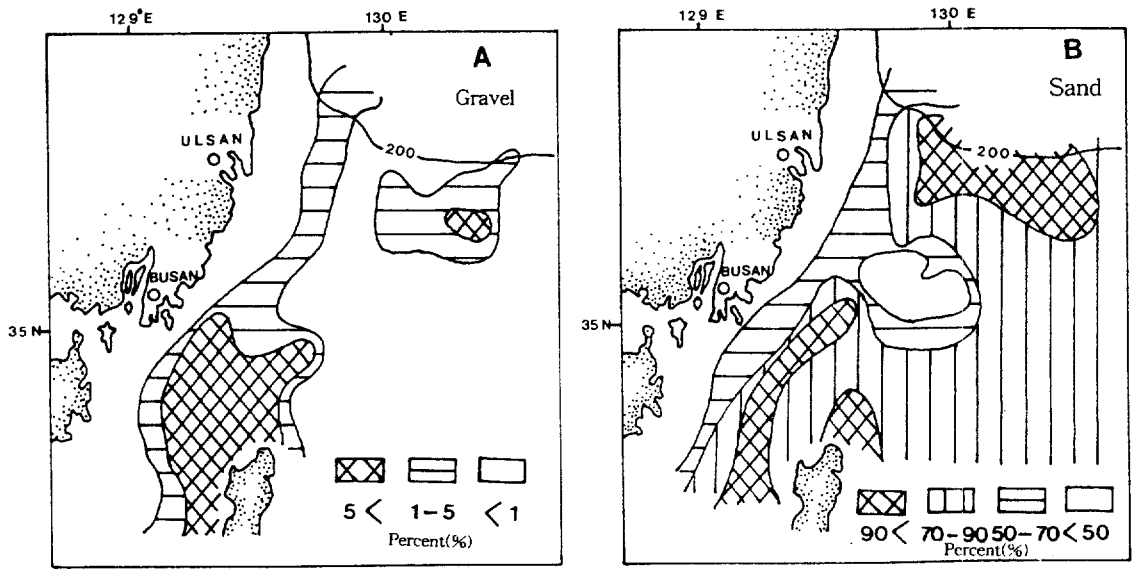

Fig. 2. Distributions of A) gravel and B) sand in the southeastern continental shelf.

shelf environmental conditions (Ohsima et al., 1975; Choi and Park, 1993).

The primary purposes of the present study are to determine heavy mineral concentration in shelf sandy sediments and their distribution pattern (grouping) and to interpret hydraulic conditions of shelf depositional environments.

MATERIALS AND METHODS

Total of 88 bottom samples from the southeastern continental shelf of Korea were taken by using Van Veen grab. Grain size analysis of sediments was made following the standard sieving and pipetting methods with 1ϕ interval. The analysis of heavy sand mineral compositions was limited to the fine sand fractions (125~250 μm) in order to reduce size-effect of mineral compositions.

Heavy sand minerals separated by Bromoform (specific gravity=2.89) were weighed to determine their respective concentrations. They were mounted on glass slides with Canada Balsam (refractive index=1.54), and about 200 grains per slide were counted under the polarizing microscope. A total of 27 heavy mineral species were identified and each mineral contents were expressed in number percentages. Magnetite minerals were, however, separated with electric magnet, and their weight percentages were calculated.

RESULTS

Coarse-grained (gravel and sand) sediment distribution and concentration of heavy sands

Fig. 2 shows the distribution of gravel and sand sediment in the study area. Gravels are mainly distributed along the floor of the Korean Trough and also on the northeastern shelf-break region. Gravels are, however, less than 1% on both the eastern and western part region of the shelf. Sands however, are dominant on the most of eastern region of shelf. In particular, more than 80% to 90% of sand are significant on the floor of the Korean Trough and on the northeastern shelf-break region. The boundary between inner shelf muddy sediments and outer shelf sandy sediments is relatively sharp.

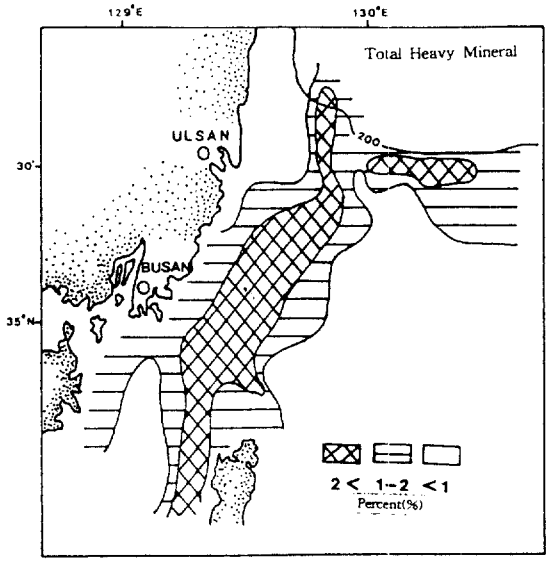

Fig. 3. Distribution of total heavy mineral concentration in the shelf.

As shown in Fig. 3, total concentration of heavy sand minerals in the study area ranges from 0.4% to 5.7%. Especially along the floor of the Korean Trough and shelf-break region heavy minerals are more than 2.0% (Fig. 3).

Opaque and altered heavy sand

The opaque heavy sand minerals in the study area range from 10% up to 50%. The reported opaque minerals in the surficial sediments on the Korean continental shelf are leucoxene, magnetite, ilmenite, hematite, and limonite (KORDI, 1989). This paper also identified the same suite of opaque minerals. More than 20% of opaque mineral content is counted on the western shelf region, and especially more than 40% of opaque minerals are concentrated near Nakdong River (Fig. 4A). Most of the sediments on eastern shelf region, on the other hand, contain less than 20% of opaque minerals.

Some of heavy sands could not be positively identified because of their significant alterations, and these sands are grouped as "altered mineral". The altered minerals range 15%~60%. Most of the alt-

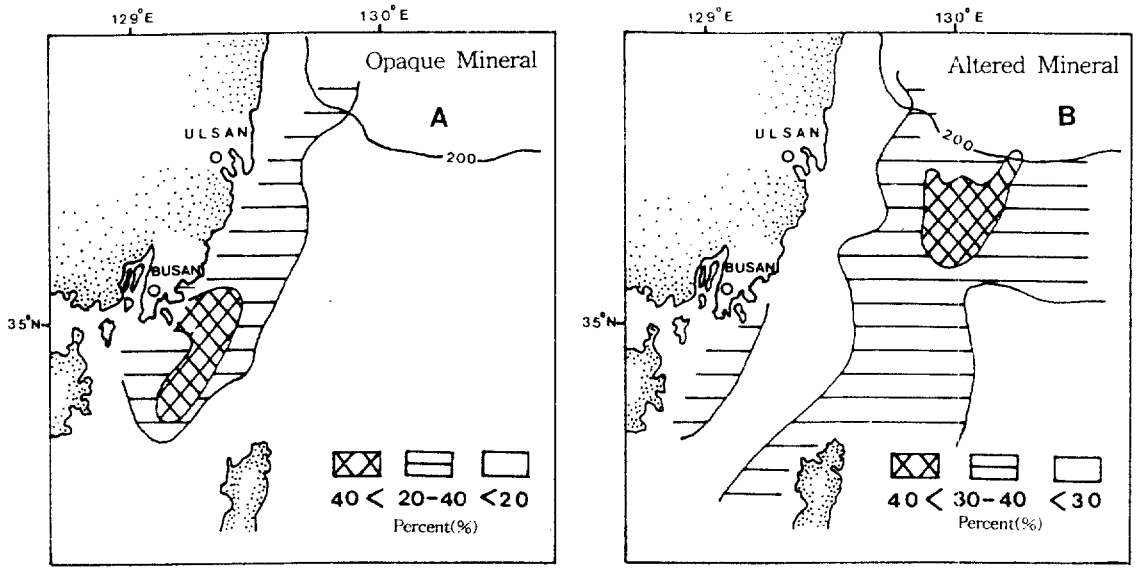

Fig. 4. Distributions of A) opaque and B) altered minerals.

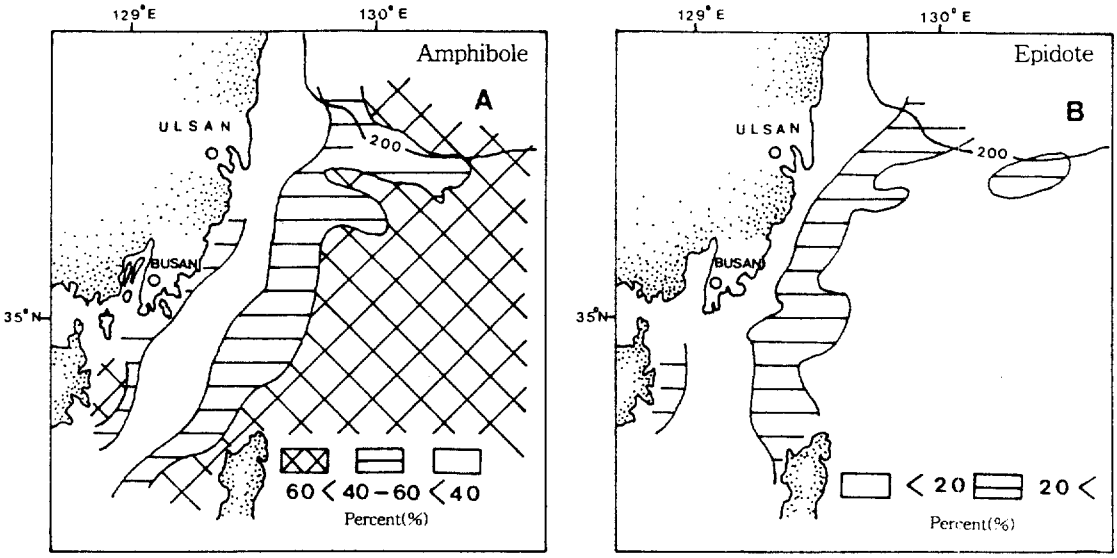

Fig. 5. Distributions of A) amphibole and B) epidote.

ered heavy sand minerals seem to be iron-coated amphiboles, epidotes, or pyroxenes. Such minerals commonly show some degree of rounding, and are generally lack in extinction. The altered minerals are abundant up tp 40% on the eastern shelf region (Fig. 4B). On the western shelf region, however, the concentrations of altered minerals decrease less than 30%, except near the mouth of Nakdong River. The distribution pattern of altered mineral shows somewhat a reverse relation to that of opaque minerals.

Non-opaque heavy sands

Non-opaque heavy sand minerals in the study

area are classified into several groups, such as amphibole, epidote, pyroxene, garnet, ZTR (Zircon, Tourmaline, Rutile), kyanite, sillimanite, staurolite, andalusite, and olivines (Choi,1990).

Amphibole group minerals (common hornblende, blue-green hornblende, tremolite-actinolite, and brown hornblende) are the most abundant minerals, and these concentrations are more than 60% on the eastern shelf region in the study area (Fig. 5A). However, amphibole concentration is less than 20% of concentration on the western shelf region, except near the mouth of Nakdong River, where amphibole contents exceed 60%.

Epidote group minerals (epidote, zoisite, and clinozoisite) are more than 20% on the floor of the Korean Trough and less than 20% in the eastern and western region of the Korean Trough (Fig. 5B).

Pyroxene group minerals (hypersthene, augite and diopside) are euhedral to sub-hedral, and some of them are attached to volcanic glasses with numerous inclusions. Pyroxene sands are abundant on the southeastern part of eastern shelf region, and are especially concentrated more than 20% near the Japanese Islands (Fig. 6A).

Garnet sands are concentrated more than 30% on the western shelf region (Fig. 6B). However, eastern shelf sediments contain less than 5% of garnets.

ZTR group minerals (Zircon+Tourmaline+Rutile) show a similar distribution pattern to that of garnet (Fig. 7A). They are more than 10% on the western shelf region. However, ZTR mineral content is less than 3% on the eastern shelf region.

Magnetite minerals are more than 20% in concentration on the western shelf region, with the maximum concentration of higher than 40% (Fig. 7B). However, magnetite contents are 10~20% on the floor of the Korean Trough, and in the eastern region of the shelf magretite content is less than 10%.

DISCUSSION

As explained above, major heavy minerals of clastic sand sediments on the southeastern continental shelf of Korea consist chiefly of opaques, amphiboles, epidotes, and garnets. Pyroxene and ZTR minerals are common. The overall content of major heavy minerals are summarized in Table 1, and the four characteristic heavy mineral regions can be distinguished;

1) the western region: Total heavy mineral content is 1.0~2.0%. The concentrations of opaque min-

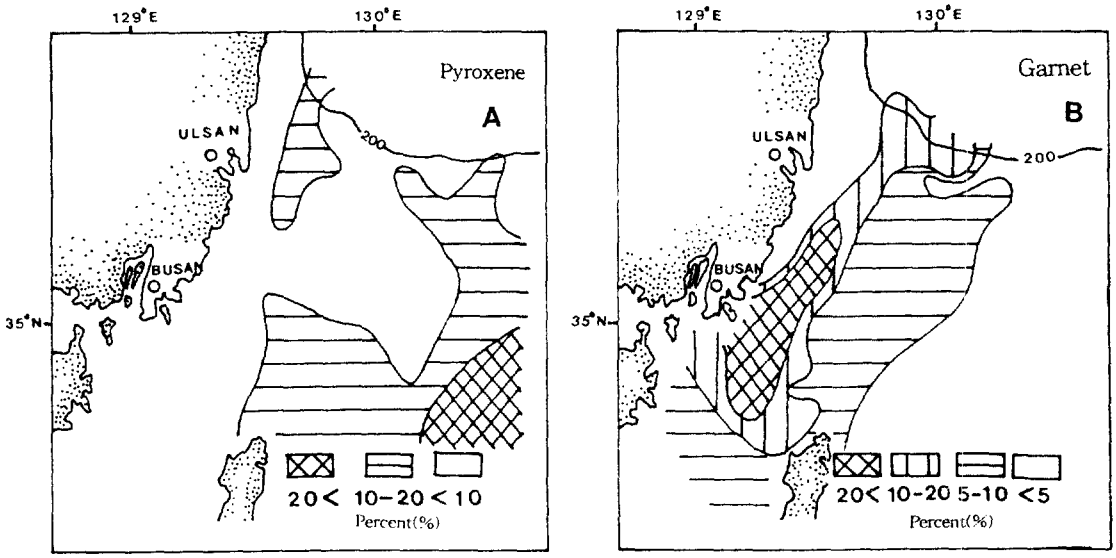

Fig. 6. Distributions of A) pyroxene and B) garnet.

Table 1. Heavy mineral compositions in each four mineral regions (grouping).

area / mineral	West Region	Korean Trough	East Region	Shelf Break
Heavy Content	1.0~2.0%	>2.0%	<1.0%	>2.0%
Opaque Min.	>20% (Max>40%)	≒20%	10~20%	<10%
Altered Min.	<30%	<30%	>30%	>40%
Omphibole	<20%	20~50%	>50%	50~60%
Epidote	≒20%	>20%	<20%	>20%
Pyroxene	<10%	<10%	>10%	<10%
Garnet	>20% (Max>30%)	>10%	<5%	<5%
ZTR	>5% (Max>20%)	>3%	<3%	<3%
Magnetite	>20% (Max>30%)	10~20%	<10%	<10%

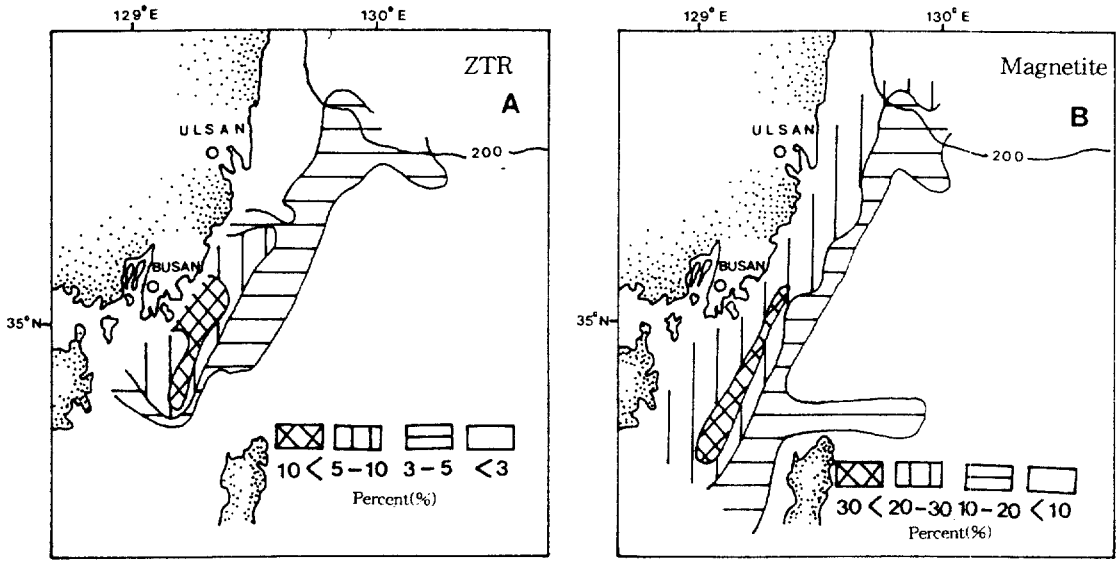

Fig. 7. Distributions of A) ZTR and B) magnetite.

eral, garnet and magnetite are more than 20%, whereas amphiboles are less than 20%. ZTR minerals are concentrated more than 5%.

2) Korean Trough region: Heavy mineral content is more than 2.0%. Opaque minerals are about 20%, and epidote and garnet are more than 20% and 10%, respectively. Magnetite grains range 10~20%, and amphiboles are 20~50%. Altered minerals are less than 30%, but ZTR minerals are more than 3%.

3) the eastern shelf region: Total heavy content is generally lower than 1.0%. Altered heavy minerals and amphiboles are more than 30% and 60%, respectively. Opaque minerals range from 10% to 20%, but garnet and ZTR minerals are less than 5% and 3%. Pyroxenes are concentrated more than 10% on the eastern shelf region especially near the Japanese Islands.

4) the northeastern shelf-break region : Total heavy mineral content is more than 2.0%. Altered heavy mineral is more than 40%, whereas opaque mineral is less than 10%. Garnets and ZTR minerals are less than 5% and less than 3%, respectively.

Based on the regional heavy mineral distribution patterns on the southeastern continental shelf studied, direct influence of clastic sediment input from Nakdong River basin seems to be not significant. In terms of heavy mineral suites, bottom sands on the eastern region are considered to be derived primarily from the volcanic source of Kyushu and Honshu Islands (Fig. 6A), because of the concentrations of characteristic pyroxene minerals. Suzuki (1975) also found the concentrations of py-

roxenes on the East China Sea shelf derived from the Kyushu Island. Most of sand sediments on the eastern region of the shelf, however, are characterized by the altered and deeply weathered heavy minerals (Fig. 4B), and by the presence of unstable heavy mineral suites such as amphiboles (Fig. 5A). These sand-sized heavy minerals are considered to be the relict sediments that might have long been experienced aerial and/or subaqueous weathering during the late Quaternary Period. Park and Choi (1986) and Choi and Park (1993) described such relict characters of the eastern shelf clastic sediments, such as weathered carbonate fragments, iron-stained quartz grains, and well-rounded gravels.

Heavy minerals in the western shelf region and the Korean Trough region are characterized by both high content of heavy minerals (Fig. 3) and more stable mineral suites, such as opaques (Fig. 4A), epidotes (Fig. 5B), garnets (Fig. 6B), ZTR minerals (Fig. 7A), and magnetites (Fig. 7B). Furthermore, these bottom sediments are dominantly coarse-grained, where gravel and sand fractions are abundant (Fig. 2). Such textural and compositional natures of the sediments are thought to represent genetic physical processes of the continental shelf during the early Holocene Period. Dynamic processes of strong waves and currents probably dominated the western shelf region of Korea Strait. Under such conditions, lighter and unstable minerals have been destroyed and winnowed out from sea bottom resulting the concentration of heavier and more stable mineral suites. Lee et al. (1988) reported the distribution of heavy minerals on the southeastern Yellow Sea, and interpreted also the concentrations of stable minerals as the basal relict sands that were deposited during the Holocene transgression period.

CONCLUSIONS

The following conclusions may be drawn from the present heavy mineral investigation on the clastic sand sediments of the continental shelf off the southeastern coast of Korea.

Four major characteristic regions could be defined based on the concentration and distribution of heavy minerals. The four regions are (1) the western region, (2) Korean Trough region, (3) the eastern region, and (4) the northeastern shelf-break region. The heavy minerals on the western region and Korean Trough region are concentrated by stable heavy mineral suites, such as opaque, garnet, ZTR, and magnetite. On the eastern region, on the other hand, heavy minerals are represented mostly by altered minerals and relatively unstable mineral suites such as amphiboles. It is suggested that the origin and nature of such heavy mineral regions are a plausible reflection of hydraulic fractionation and sub-aerial and/or sub-aqueous weathering processes during transgression and regression episodes during the late Quaternary Period. The high concentrations of pyroxene minerals on the eastern region, however, are interpreted as suggesting a sediment-source from the volcanic Japanese Islands.

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