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Distribution and Characteristics of Surface Sediments on the Continental Shelf off the Eastern Coast of Korea

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한국 동해 대륙붕 표층퇴적물의 분포와 특성

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ABSTRACT

Narrow (10-20 km wide) and steep (0.3-2.4°) continental shelf off the eastern coast of Korea is covered with terrigenous clastic sediments reflecting the Holocene fluctuation of sea level.

Surface sediments on the inner shelf consist of muddy sand and sandy mud with some gravels near the coast. However, sand or muddy sand, shell fragments and well rounded gravels occur near the edge of continental shelf at the depth of about 130-150m.

The coarse sediments near the shelf edge seem to be the relict or palimpsest sediments deposited under the nearshore environment during the low-stand or sea level due to so-called the Wisconsinan glaciation. Distribution of recent sediments near the coast and the inner shelf may reflect the affect of waves and currents precluding the deposition of fine sediment near the coast and on the shallow portion of shelf. Eastern Korean Warm Current also may have played an important role to the transport and distribution of fine sediments from the south.

The present study was supported by the Basic Science Research Institute Program, Ministry of Education, 1989 Project No. ED 89-52.

요 약

한국 동해 대륙붕 표층 퇴적물은 대부분 육성기원 쇄설성 퇴적물로 이루어져 있으며, 이 퇴적물은 홀로세 해수면 변동의 영향을 잘 나타내고 있다.

퇴적물들은 연안이나 내대륙붕에서는 이질사 혹은 사닐니로 이루어져 있고 혹은 자갈들이 나타나는 경우도 있으며, 외해로 갈수록 세립화하는 경향을 보여 외대륙붕에는 대부분이 세립의 이질 퇴적물로 이루어져 있다. 그러나 수심 약 130-150m의 붕단 부근에서는 사질, 니질사, 역니질사 등의 조립 퇴적물이 나타나며 이들은 소위 위스콘신 빙하기의 해수면이 낮았을 때 수심이 얕은 연안환경에서 퇴적된 잔류퇴적물로 생각된다.

연구해역 대륙붕에서의 현생 퇴적물 분포는 파도나 해류 등에 의하여 연안이나 수심이 얕은 곳에는 세립퇴적물이 쌓이지 못한 것으로 생각되며, 특히 대마해류에서 분리된 동한난류는 남해로부터 동해 대륙붕으로 세립퇴적물을 운반하고 분포시키는 데 큰 영향을 미칠 것으로 추정된다.

INTRODUCTION

Western margin of the East Sea bordered by the eastern coast of Korea is characterized by a narrow and steep continental shelf. Along the eastern coast of Korea the shelf is approximately 10-20 km wide and 0.3-2.4° in steepness (average 0.44°) (Lee et al., 1989). The coast line is straight and rather monotonous compared to the southern and western coast of Korea. Seafloor of the shelf is smooth and flat except for the local mounds and banks near the shelf edge. Depth contours are approximately parallel to the shoreline progressively deepening towards the steep continental slope (Fig. 1). Detailed map compiled by Choi (1989) shows the existence of the shelf break at the depth of about 130-150m.

Seismic survey reveals that the sedimentary sequence in the shelf area is relatively thin compared to the basin sediment. Shelf sediment consists of thin Quaternary sediments over the Neogene sequence trapped by block faults and folds of late Miocene. Acoustic basement consist of the Precambrian gneiss, Cretaoeous granite and sedimentary rocks (Kim, 1981; Park et al., 1981; Chough, 1983).

Riverine input of sediments is extremely limited along the eastern coast of Korea. Weathering and erosion of the steep land relief along the coast may contribute to the input of sediments into the coast and shelf. Lack of coastal embayment, hence the coast is open to the high energy environment of waves and currents, may also cause the cliff erosion and abrasion. Winnowing of fine sediments on the southeast shelf by the Tsushima currents may influence the input and dispersal of fine sediments on the shelf (Han, 1979).

66 grab (Van Veen) samples and 7 piston core samples summarize the distribution and characteristics of surface sediments on the shelf along the eastern coast of Korea. Also those samples made it possible to investigate the affect of waves and currents to the distribution pattern of modern sediments together with the effect of lower sea level during the late Wisconsin glacial period.

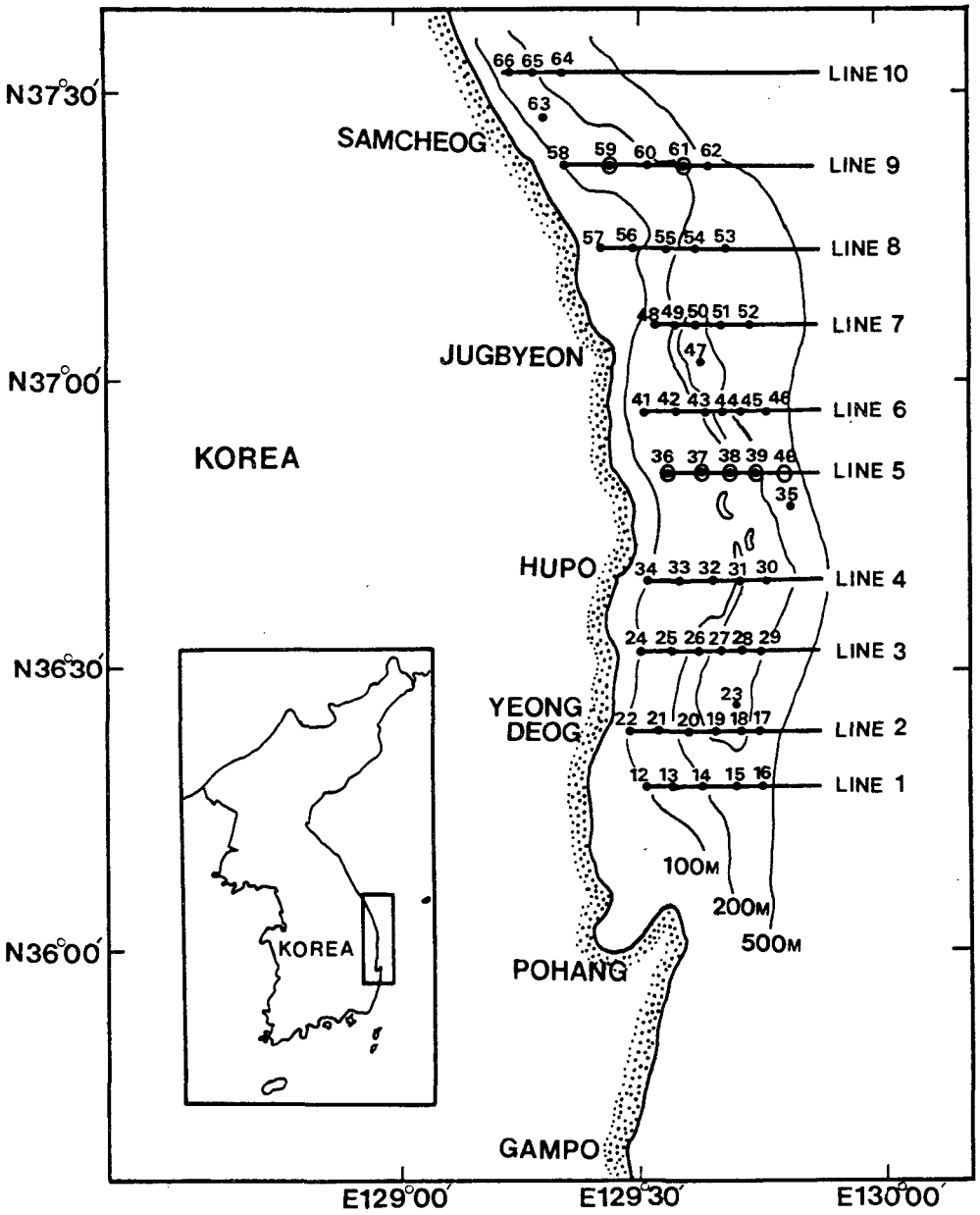


Fig. 1. Map showing the bathymetry and sampling stations of the study area. Dots and open circles denote the grab and piston core stations respectively.

PHYSIOGRAPHY

In general the seafloor of the study area is smooth and flat. Depth contours run approximately parallel to the shoreline and deepens progressively towards offshore (Fig. 1). However, detailed map of the study area shows local variation of physiography of shelf region (Lee, 1987; Choi, 1989).

North of Jugbyeon area the shelf is approximately 10-20 km wide with the steepness of

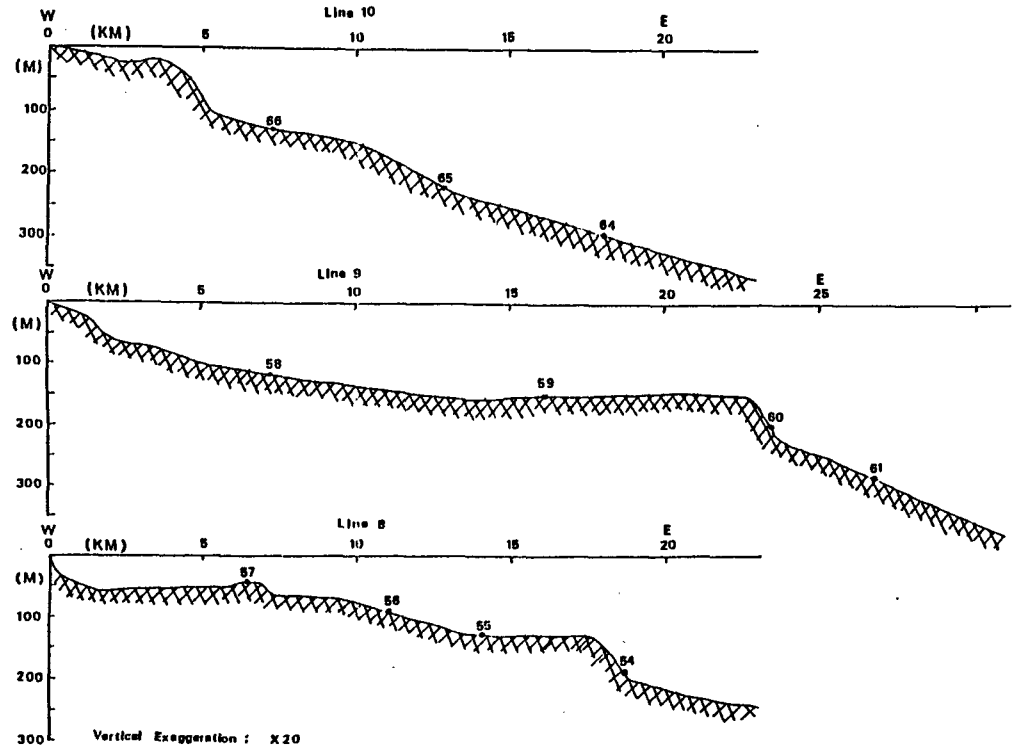


Fig. 2. Cross section of the shelf area north of Jugbyeon.

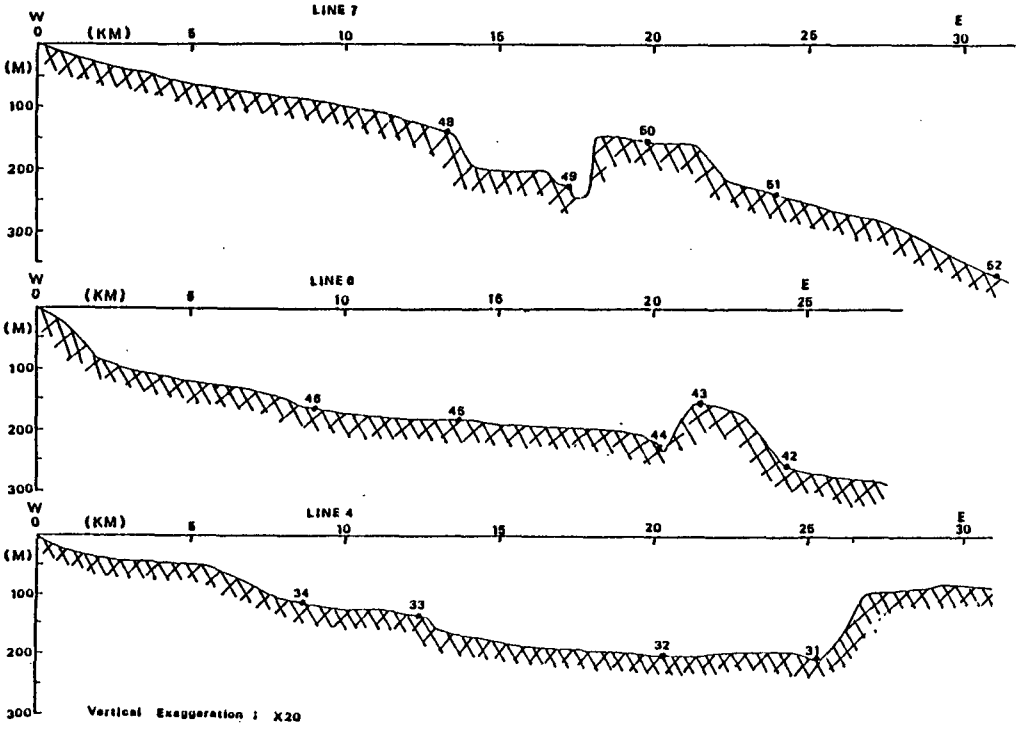
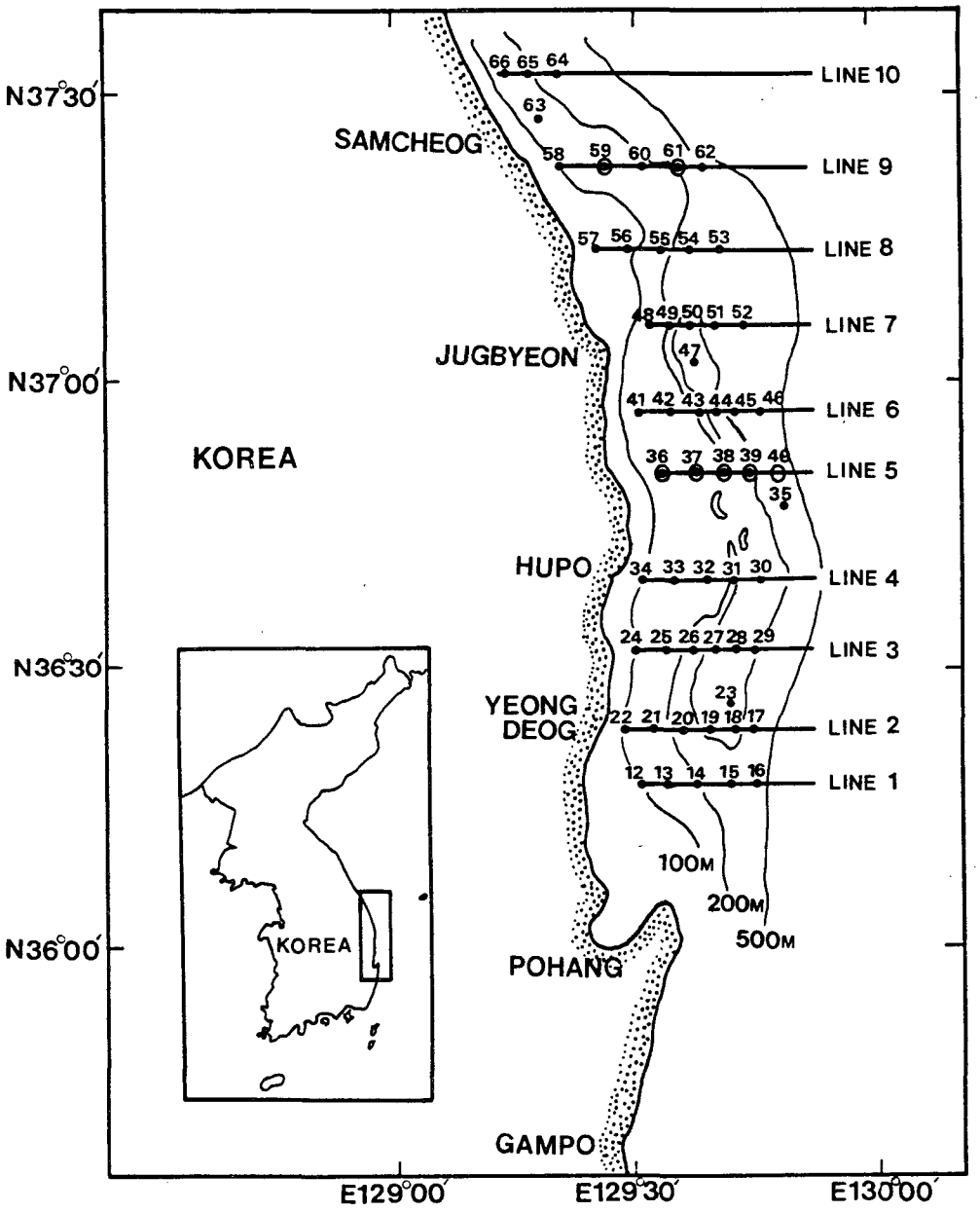


Fig. 3. Cross section of the shelf area between Jugbyeon and Yeongdeog.



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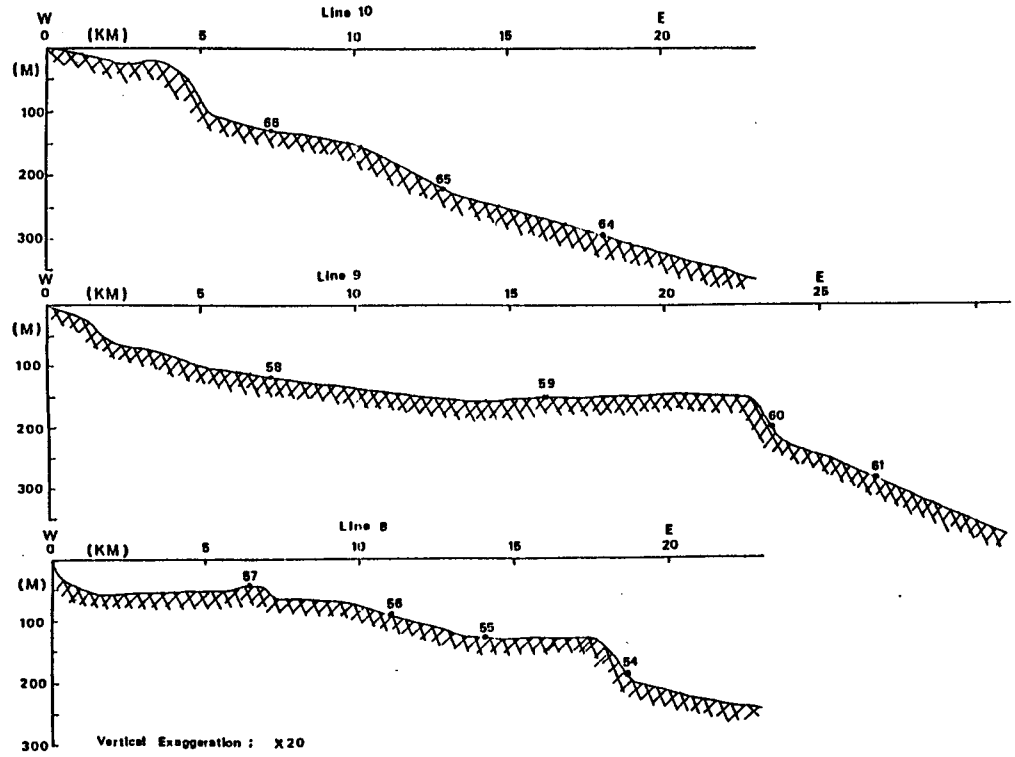

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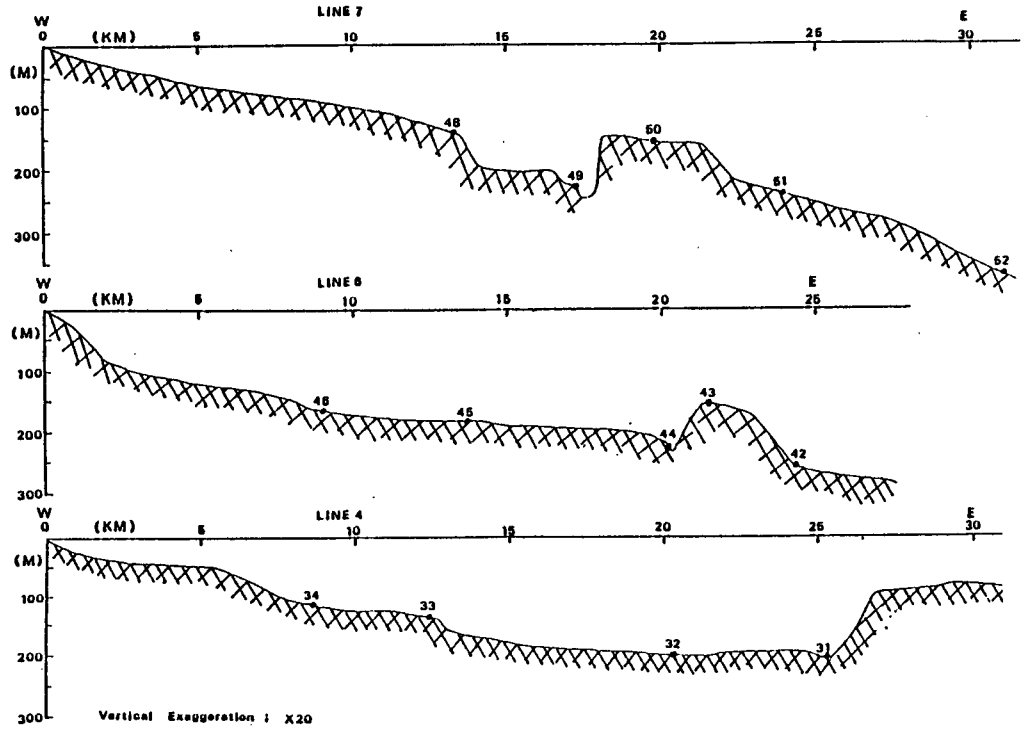


Fig. 3. Cross section of the shelf area between Jugbyeon and Yeongdeog.

0.3-2 degrees. Distinctive shelf break occurs at the depth of about 130-150m, which is characterized by the abrupt change in steepness up to 4 degrees (Fig. 2).

Further south to Yeongdeog area the shelf is characterized by a basin and bank (Hupo Basin and Hupo Bank). Shelf edge in this region is not clearly depicted (Fig. 3). The basin is approximately 200-250m deep and the bank is about 85 km long in north-south direction and 1.5-11 km wide. Depth to the top of the bank is 140-150m in the north and 110-120m in the south. Slope of the flanks is 2-12 degrees. Two hills on the top of the bank are also found at the central part and near the southern end. Minimum depth to the hills are 5m and 3m respectively. Line 4 of the Figure 3 also shows the existence of a terrace at the depth of about 140m.

South of Yeongdeong area the physiography of shelf is similar to that of the northern part of Jugbyeon area. The shelf is about 10-25 km wide and the shelf edge appears at the depth of 130-140m.

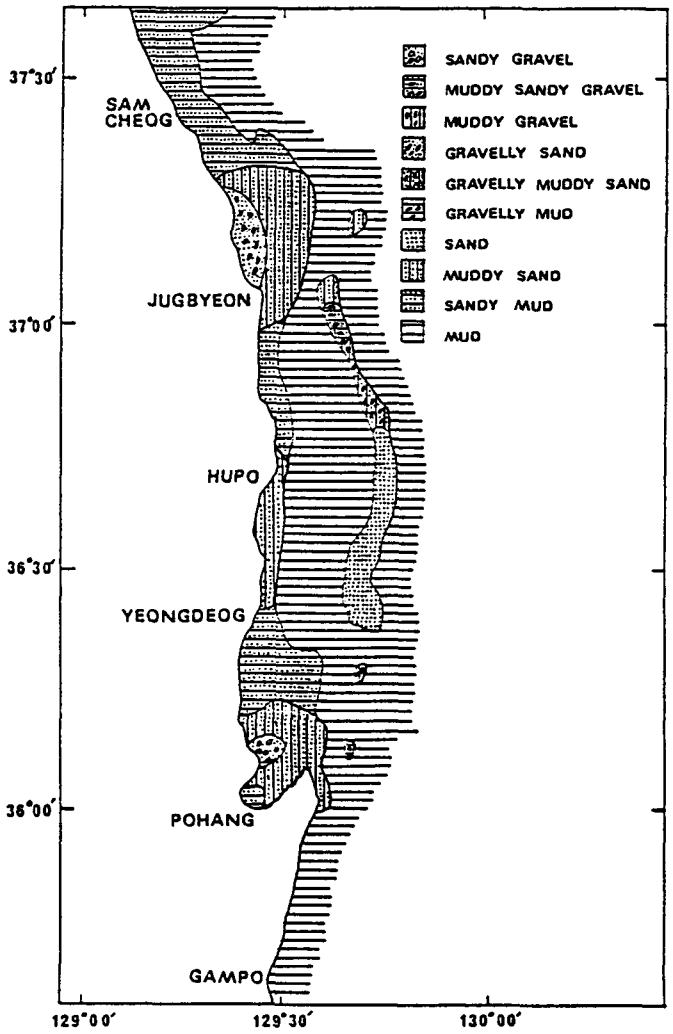


Fig. 4. Distribution of surface sediment on the shelf and upper continental slope.

DISTRIBUTION OF SURFACE SEDIMENTS

Figure 4 shows the pattern of the distribution of surface sediments on the shelf and upper continental slope. Sediments are generally poorly sorted and comprised of sand, muddy sand, and mud. The sediments contain gravels and shells locally. Sediments along the coast and on the inner shelf is coarser than those on the outer shelf and slope where the muddy sediments prevail. However, coarse sediments containing gravels and shells occur on the top of Hupo Bank, submarine terrace, and near the shelf edge.

North of Jugbyeon area most of the shelf is covered with muddy sand or sandy mud except for the local occurrence of gravelly sand near the coast. Sediments in general become finer offshore. However, on the steep slope of the shelf edge (St. 60) gravelly muddy sand containing nearly 20% gravels are found. At the depth of 130m (St. 59) the surface sediments are mud but subsurface sediments at about 10cm below the surface contained shale fragments and calcite cemented sandstones.

Bottom of the Hupo Basin and the adjacent outer shelf if mostly covered with muddy sediments, whereas the inner shelf and the coast are covered with sandy mud or muddy sand. At the seaward edge of submarine terrace (St. 33), which is 135m deep, muddy sand containing gravels occurs. On the top of Hupo Bank also coarse sediments occur. Northern part of the bank is mostly covered with muddy sandy gravel or gravelly muddy sand containing well rounded gravels up to 47% by weight (Fig. 5). On the other hand, sediments on the southern part of the bank are mostly comprised of subangular sands containing little gravel. At the depth of 76m near the soutern end of the bank (St. 23) more than 80% of the surface sediment are shells or shell fragments (Fig. 6).

Distribution of sediments on the shelf at the south of Yeongdeog area shows a similar pattern to that at the north of Jugbyeon area (Fig.

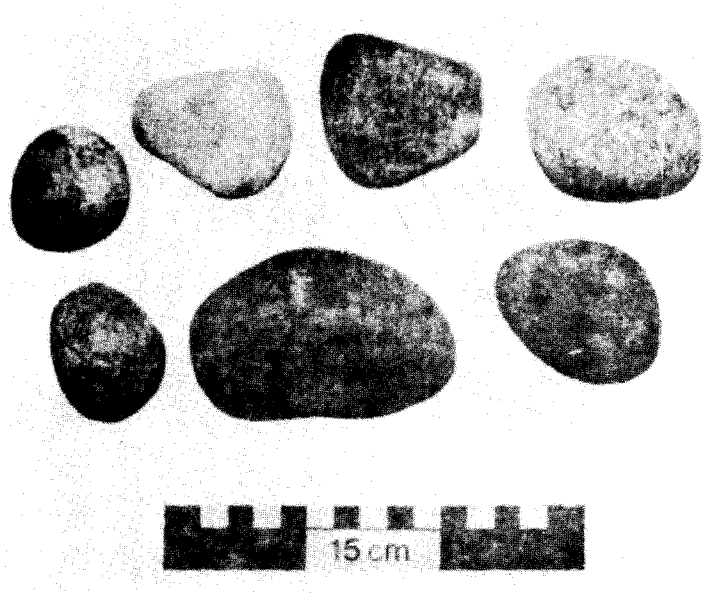
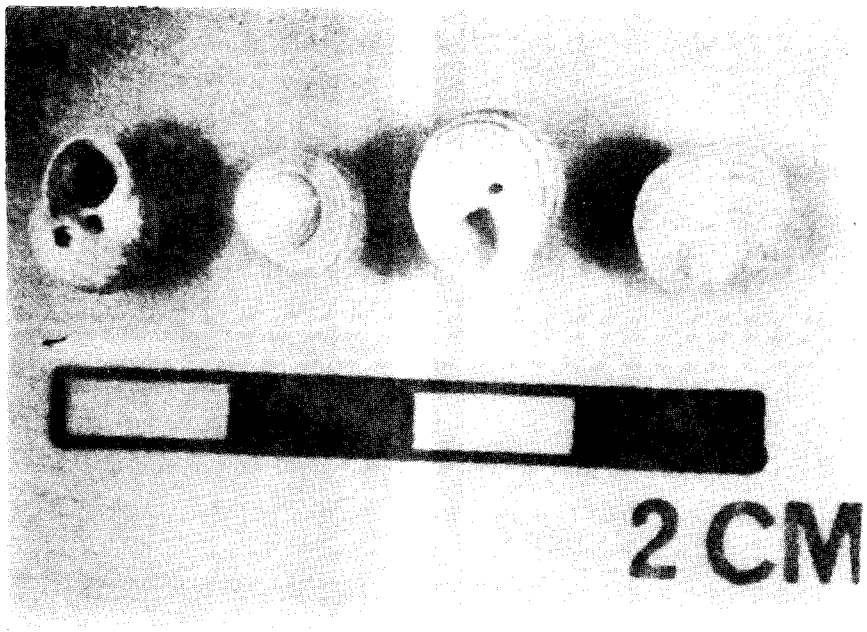


Fig. 5. Gravels in the sediment on the top of Hupo Bank in the northern part.

a) Arca boucardi



b) Homalopoma rubrum laevicostatum

Fig. 6. Shells in the sediment on the top of Hupo Bank in the southern part.

4). *Coarse gravelly mud occurs on the steep* sloping shelf edge at the depth of 190m. Gravelly mud was also found near the shelf edge at the depth of 125m.

DEPOSITION OF MODERN SEDIMENTS

Lack of sediment input through rivers and streams along the eastern coast of Korea may be responsible for the thin cover of Quaternary sediments on the shelf (Chough, 1983). Weathering and erosion of rocks from the high mountains along the eastern coast may contribute to the sediment input into the shelf. Cliff erosion and abrasion by the wave may have produced the bulk of coarse sediments near the coast (Kim et al., 1971).

According to the compiled data of wave height measurement for 5-7 years significant wave height along the eastern coast is mostly less than 0.5m with the periods of less than 4 seconds (Office of Fishery, 1988). However the frequency distribution of wave heights shows the occurrence of wave higher than 5m at the Donghae coast, whereas waves higher than 4m is almost none at the Hupo coast. This might be the result fo the bottom effect due to the existence of Hupo Bank. Deep water wave coming from the open ocean may lose some of its energy by bottom friction due to the shallow water depth on the bank, and the wave height may be lowered. Further south wave hiehgts at the Jujeon coast also rarely exceed 4m which seem to be the result of limited fetch between Korea and Japan Island compared to the northern part which is open to the wide East Sea. The lower wave height at the Hupo coast may explain the narrow band of coarse seiments and lack of gravels in the sediments on the inner shelf (Fig. 4). Waves may agitate fine sediments on the bottom to be carried away by currents. Relatively wide area of muddy sediments on the outer shelf of Hupo area may also be the result of lower wave heights since only the high waves with long period can affect the deep bottom.

A branch of Tsushima Current, the East Korea Warm Current, flows close to the eastern coast of Korea from south to noth until it turns eastward near Jugbyeon. Speed of the current is about 0.5-1.0 knots at the surface. From the north the North Korea Cold Current also flows close to the coast with the speed of about 0.2-0.5 knots. The cold current sinks under the warm current and flows further south to the shelf off Pohang (Hydrographic Office of Korea, 1982). Even though location of the front between these warm and cold currents, speeds, and directions of the currents are variable, these currents may have carried the fine sediments resuspended by waves on the shelf to the deep basin.

Table 1 shows the relative proportion of clay minerals in the surface sediment. Average proportion of kaolinite, chlorite, and illite is 9%, 16%, and 75%, respectively. Abundant illite content suggests that the part of fine sediments were transported from the Korea Strait (Aoki et al., 1974; Han, 1979; Park and Han, 1985). Occurrence of calcite in the sediment limited to the south of 36° 30′ (track line 3) also suggests the transport of sediment from the Korea Strait since the sediments on the Korea Strait contain abundant $CaCO_3$ (Chough, 1983, Choi, 1989).

Strong Tsushima Current reaching up to 1.5 knots through the Korea Strait may winnow and carry the fine sediments from the self sediments of the South Sea (Wells and Huh, 1984; Lee et al., 1989). The current may also carry some of the fine sediments derived from the Nakdong River (Lee and Chough, 1989). The current becomes weaker entering the East Sea (Hydrographic Office of Korea, 1988). However, the East Korea Warm Current still flows strong enough to carry and distribute the fine sediments ont he shelf off the eastern coast of Korea. The abundance of fine sediments at the south of Pohang may be due to the input from the south, limit of the affect of buttom flowing

Table 1. Relative percentage of clay minerals

ST. NO.	KAOLINITE (%)	CHLORITE (%)	ILLITE (%)	SMECTITE (%)	CALCITE
3	6	18	75		+ +
14	11	22	67		+ +
16	10	25	66		+
20	6	13	80	1	+
(SUB) 20	8	13	79	1	
24	7	12	80	1	
25	12	25	63		+
26	11	16	73		+
(SUB) 26	11	15	74		
29	11	30	59	1	+
31	9	13	76	1	
(SUB) 31	10	11	79	1	
33	10	14	75	1	
34	11	11	77	1	
35	7	18	75	1	
36	7	13	79	2	
38	7	11	61	1	
(SUB) 38	9	14	77	1	
41	8	10	81	2	
44	11	20	68	2	
(SUB) 44	9	13	77	1	
46	8	13	78	1	
49	8	16	75	1	
(SUB) 49	10	10	79	1	
52	9	17	74		

cold current, and lower wave heights.

RELICT SEDIMENTS AND LATE QUATERNARYY SEA LEVEL

The coarse sediments found near the shelf edge and on the top of Hupo Bank show sedimentologic characteristics which implie that the sediments were deposited under a shallow marine high energy environment.

Shale fragments in the subsurface sediment near the shelf edge at the north of Hupo Bank are up to 7cm in long axis and less than 1cm thick. Surface of the fragments show traces of oxidation and some annelida. Barnacles are also found. The calcite cemented sandstone contained approximately 1% of calcareous algae as bioclasts. Gravels on the top of Hupo bank are mostly composed of granitic gneiss, which suggest that the gravels are the product of erosion of basement rock. The gravels are well rounded (Fig. 5). They also showed the traces of iron-oxide coating, annelida and barnacles on the surface. Shells on the top of southern part of the bank are considered to be the species of intertidal or subtidal environment (Fig. 6).

The consistent occurrence of coarse sediments at the water depth of about 130-150m and the indications of shalow marine high energy environment at the time of deposition suggest that these coarse sediments near the shelf edge were deposited when the sea level was lower during the last glacial period. During the Wisconsin glacial period the worldwide sea level was approximately 130m lower than the sea level of the present time (Curray, 1965; Milliman and Emery, 1968). The submarine terrace may also be the wave-cut terrace under a coastal environment (Emery, 1965; Swift et al., 1971). The flat top, the coarse gravels and sands of Hupo Bank also suggest that the wave energy was high enough to cut the basement rocks under a shallow nearshore environment. Lee (1987) attributed the shells found at the depth of 76m on the top of the bank in the south to either post-depositional transport by currents or the deposition during the Holocene transgression.

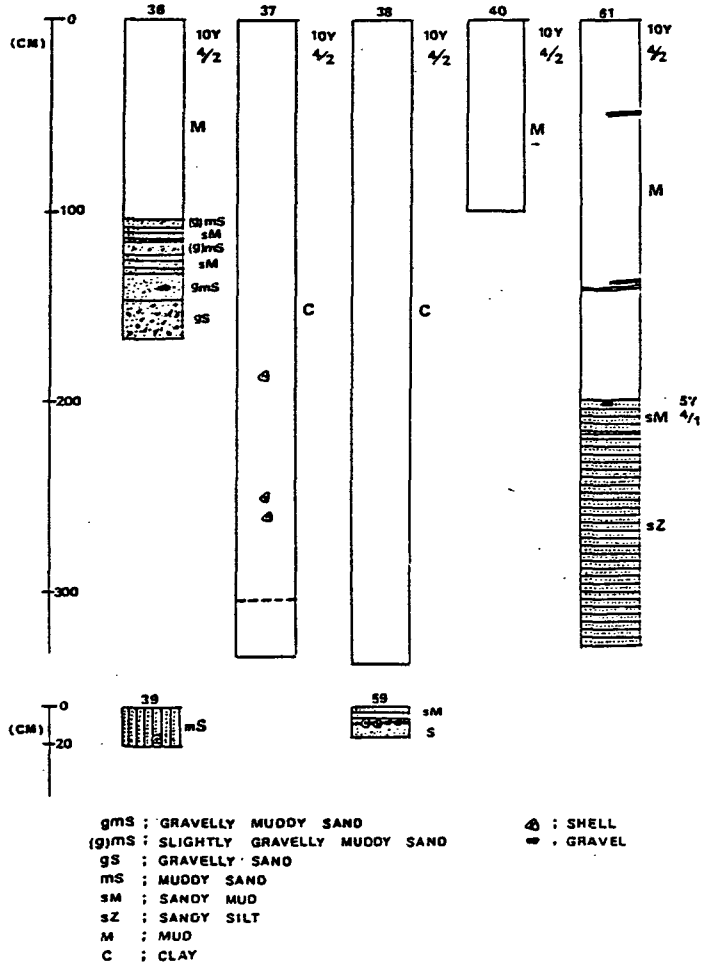


Fig. 7. Description of core samples. Water depths are 140m (St. 36), 185m (St. 37), 210m (St. 38), 135m (St. 39), 400m (St. 40), 130m (St. 59), and 284m (St. 61). St. 36 is on the inner shelf, stations 37 and 38 are in the Hupo Basin, 39 and 59 are on the top of Hupo Bank, 40 is on the seaward slope of the bank, and 61 is on the continental slope. Note the coarse fraction of subbottom sediment at St. 36 which was collected at the depth of 140m.

When the sea level was lower the Hupo Basin might have been protected from the high wave energy by the Hupo Bank. Such effect of the calm environment is reflected in the core samples which show thick accumultion of fine sediments (Fig. 7).

The existence of relict sediment on the shelf of South Sea was already reported, and suggested the sea level lower than the present sea level, that is, up to approximately 150m during the late Pleistocene glacial period (Wisconsin) (Park and Song, 1971; Choi, 1989; Park et al., 1989). Most Japanese workers also agree that sea level was about 110-140m lower around the Japanese Island during the glacial time (Iseki, 1975; Gohara, 1975; Sato and Mogi, 1982).

CONCLUSIONS

Continental shelf off the eastern coast of Korea is covered with late Quaternary sediments. The sediments are mostly sandy mud or muddy sand showing the fining offshore trend. Fine muddy sediments cover the outer shelf and slope but coarse gravelly muddy sand, muddy gravel, sand and shells occur near the shelf edge and on the top of Hupo Bank at the water depth of about 130-150m.

The modern sediments were mostly derived from cliff erosion and abrasion by waves and currents near the coast. Some portion of the fine sediments may be transported from the South Sea by the East Korea Warm Current. The waves and currents along the coast may have distributed the fine sediments towards the deeper shelf or slope.

The coarse sediments near the shelf edge and on the top of Hupo Bank indicate that these sediments are relict sediments. These sediments were deposited under a shallow coastal or nearshore environment when the sea level was approximately 130-150m lower than the present sea level during the Wisconsin glacial time.

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