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Intertidal Flat Sediments and Charateristic Sedimentary Structures in the Changgu Bay, West Coast of Korea

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Abstract: The Changgu Bay, a macrotidal coastal embayment of the west coast of Korea, is an area of extensive intertidal sedimentation. Three types of major sediment facies are identified based on grain size analysis: silt, sandy-silt, and silty-sand facies. It is found that intertidal sediment facies comprise a continuum of progressively finer sediments from lower flat to upper one.

The X-radiographs of the cores in the intertidal zone show a wide variety of physical and biogenic sedimentary structures.

The major structures include bioturbation, current ripple- and parallel-laminae. Bioturbations are observed in all core samples, especially in the silt flat zone. The degree of bioturbation increases laterally from sandy facies (low tide level) to silt facies (high tide level) due to favorable properties of fine mud for organisms. The ripple laminae, composed of current ripple foresets, characterize the silty-sand and sandy-silt flats. The parallel laminae are extensively bioturbated, and two types of laminae are distinguishable; thick-laminae with a thickness of 1 to 5mm and thin-laminae with a thickness of less than 1mm.

요약 : 서해안 장구만에 발달하는 조간대에서 24개의 표층시료 및 18개의 코아를 채취하여 퇴적물의 조직 및 퇴적구조를 조사하였다. 이 조간대 지역은 대체로 silt flat, sandy-silt flat, silty-sand flat으로 구분되며 해안선에서 바다쪽으로 갈수록 입도가 조립화되는 경향을 보여준다.

코아의 X-ray 촬영에 의해 나타나는 퇴적구조는 bioturbation, current ripple laminae, parallel laminae 등이며 지역에따라 현저한 차이를 보이고 있다. Bioturbation 구조는 1차적으로 형성된 물리적 퇴적구조를 파괴하고 있으며, 만조선 쪽으로 길수록 그 정도가 증가하고 있다. current ripple laminae는 bioturbation정도가 비교적 적은 silty-sand, sandy-silt 지역에 잘 나타나며, 몇번의 창조류와 낙조류에 의해 형성된 미세한 사층리를 잘 보여주고 있다. 내만쪽에 나타나는 parallel laminae는 silt/clay 호층의 두께 1mm이하의 층리로이루어져 있는 반면, 외만쪽에 나타나는 parallel laminae는 sand/silt 호층의 두께 1~5mm의 층리로 구성되어 있는 것이 특징이다.

INTRODUCTION

Most part of the coastal zone(area) along the west coast of Korea may be described as intertidal flats. These areas are generally considered to be depositional environments with sedimentation rate of about 2 to 6mm/year (Park, persn. comm.). The intertidal flat zone has shown to be one of the more dynamic areas in terms of sediment erosion and deposition (Anderson et al. 1981, Carling 1982, McCave 1971). However, the processes and mechanisms involved in deposition of sediment are inadequately known.

Recent investigations of some intertidal flats of the west coast of Korea(Park et al. 1984.

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Koh et al. 1984, Chang et al. 1982, Chung 1978, Chung and Park 1977) have dealt mainly with sediment types and their distributions, and geochemical properties of sediments. Little has been published about the sedimentary structures and sedimentological patterns in the intertidal flats. Because the Changgu Bay has been disturbed relatively little by man, and a wide variety of sedimentological conditions is present, it is an ideal area for such studies.

This study deals mainly with sedimentary structures observed in X-radiographs of the cores from the intertidal flat of the Changgu Bay. Emphasis is placed on recognition of structures and textures within the intertidal flats for interpreting environments of intertidal flat deposition. This paper comprises a part of M. S. thesis of Kim(1985), and more data and results are described by him. Discussions with Y. A. Park, Seoul National University, and wtih Y. S. Kim, Gongju Teachers College, were very useful.

INTRODUCTION

The Changgu Bay is a coastal embayment located at 36°5′N and 126° 37′E, about 10km north of the Keum River (Fig. 1). Average semidiurnal tidal range is 5m at Kunsan (Hydrographic Office Charts 1984). The extreme tidal range and gentle bathymetric gradient produce an extensive intertidal zone that averages 3.5km in width. The intertidal zone is dissected by two main channels with dendritic patterns of gullies. These channels extend across the intertidal zone. Major flood and ebb currents trend NE-SW with current velocities of 1.5 to 2 knots in offshore. However, detailed current direction and velocity data are not available in the study area. On field observations, the dominant water movement as the tides rise and fall is essentially perpendicular to the shoreline.

Nearshore and estuarine waters are very turbid

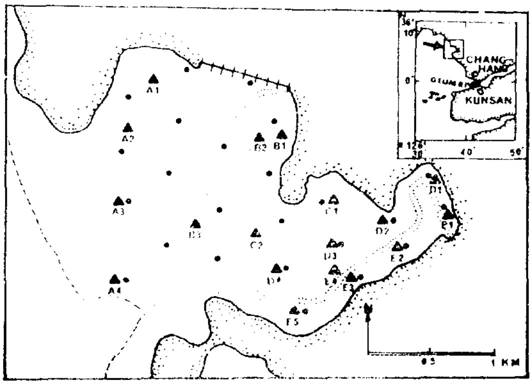


Fig. 1. Map showing study area and sampling sites (dot: surface samples, filled triangle: core samples).

mostly because of suspended matter derived from the Keum River (Park et al. 1984), indicating that sediments in this area are originated principaly from the Keum River. The concentration of total suspended matter shows a high value in the surface water (greater than 6 mg/liter) as well as in the near-bottom water (greater than 20 mg/liter).

MATERIALS AND METHODS

The sediment cores were taken at 18 locations (Fig. 1) during low tide by means of PVC plastic pipes(diameter 10 cm). The penetration was 30 to 60cm. The cores were splitted into two sections in the laboratory, and sediment slices of 1cm thickness were prepared and radiographed with an X-ray unit (model ISV-100A) under conditions of 4 KVp/3 mA. At 10cm intervals sub-samples were picked for the grain size analysis. The grain size anlysis of sediments

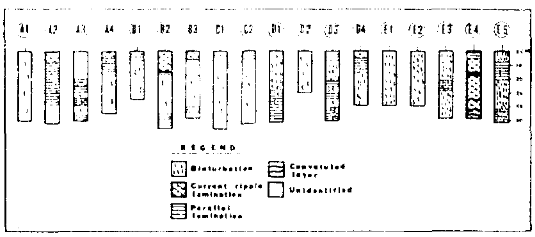


Fig. 2. Description of cores from the intertidal deposits. For location of cores, see Figure 1.

was conducted according to the procedure by Galehouse (1971) and Ingram (1971). Detailed granulometry of fine laminae found on X-radiographs was made by a microscopic examination of the dispersed samples on microslides.

In general, the x-ray radiographs provided the detailed structures in the cores and are used in this paper for illustration and explanation of sediment characteristics. Figure 2 is the description of each cores. The radiographs in Figure 4 have been selected as the characteristic and representative examples of the features discussed.

SURFACE SEDIMENT TYPES

Figure 3 shows the surface sediment types in the intertidal flat of the Changgu Bay. The intertidal flat zone can be divided into three major sub-zones according to sediment types: silt flat, sandy-silt flat, and silty-sand flat zones in seaward direction. Generally, the sediment facies of the intertidal flat comprise a continuum of progressively finer sediments across the intertidal flat zone shorewards. This result is comparable with those of many studies of the west coast of Korea (Kim 1983, 1984, Chung and Park 1977, Koh et al. 1984) as well as other areas (Reineck 1967, Evans 1965, Yeo and Risk 1981).

The silt flat occupies a narrow zone in the upper intertidal flat and ranges in width from

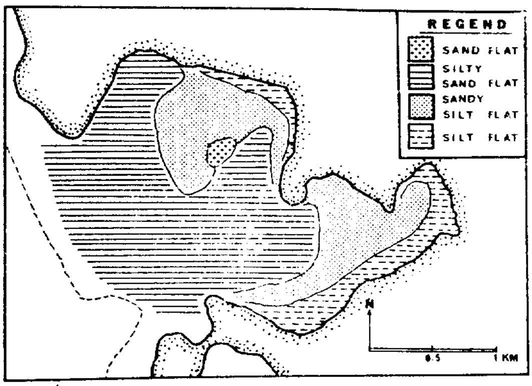


Fig. 3. Distribution of sediment types based on the nomenclature of Shepard (1954).

100 to 200m. Sediment is poorly sorted clayey silt with mean grain size between 5 and 6 phi. The sand content is lower than 20 percents by weight.

Extending seawards from the outer edge of the silt flat to the beginning of the silty-sand flat is the sandy-silt flat. The sandy-silt flat ranges from 100 to 800m in width and makes up about a third of the total extent of the intertidal flat. The sand content is in the range from 20 to 40 percents. A patch of sand flat occurs in the sandy-silt flat.

The silty-sand flat zone usually makes up more than a half of the intertidal flat zone ranging between 400 to 2000m in width. It is projected shorewards along the tidal channel to give a tongue form to its inner boundary. Sands, mainly from fine to very fine size, comprise 50 to 70 percents of the sediment by weight. Sediments in this area are poorly to very poorly sorted.

SUBSURFACE SEDIMENTARY STRUCTURES

Bioturbation Structures

The bioturbation, the disturbance of sediments as a result of the activity of benthonic animals, is frequently-observed structures in all core samples (Fig. 2). After Schaefer (1972) and Frey (1973), the following classification of bioturbation structures is applied here; deformative and figurative bioturbation structures.

The deformative bioturbation structures do not show any definite form (Plate 1-a,b). They are in general disruptive features in which the primary structures are partly or fully destroyed. The total bioturbated layer indicates the superimposition of several different burrow structures (Plate 1-f). They occur also as mottled structures in which nests of broken shells, and sandy nests are irregulary distributed.

The figurative bioturbation structures show the definite recognizable forms. Those formed by polychates are generally burrows with 0.5 to 1cm in diameter(Fig. 4-c). These burrow structures are mainly observed in cores from the fine grained silt flat. The most frequent, living polychate in the upper 15cm of sediments in this area is *Neanthes japonica*, and this species seems to be responsible for these burrowing structures. The large burrows(2 to 3cm in diam eter) formed by Crustacea are frequent in surface sediments, but these are not observed on X-radiographs.

The cores of the silty-sand and sandy-silt flats reveal less evidence of bioturbation than the cores from the silt flat zone(Fig. 2). The degree of bioturbation increases toward the inshore. This may be in part due to the unfavorable properties of the coarser sedments for the preservation of biogenic sedimentary structures.The rate of sedimentation possibly also influence the degree of bioturbation (Wetzel 1979, Reineck and Singh 1980). If the burrowing activity of the organism can not keep up with deposition of sediments, they are few even in an area that was thickly populated before the onset of rapid sedimentation.

The study of surface sedimentary structures (Kim 1985) also revealed that fine grained sediments of the upper intertidal flat zones provide the best substrates for the preservation of organism lebensspuren. Surface structures include crawling tracks and trails, and resting structures. Traces of burrows in the silty-sand flat are usually less frequent and more poorly preserved.

Ripple Cross Lamination

Most of the ripple structures are observed in the cores from the silty-sand and sandy-silt flats (Fig. 2). They occur in the uppermost part of the cores, overlying the thick parallel laminated layer(Plate 1-d). The internal structures show a form developed from current ripples of short wave length by deposition on the forset flank of the ripple. They are made of "spoon-shaped" individual sets of cross laminated layer. The thickness of individual set is not greater than 2cm. Unit lamina is not usually thicker than 1 mm. The coarse particles are observed at the bottom of individual sets. The core near the tidal channel (core E4) shows tabular cross stratification, indicating the erosional surface between individual sets. They are also partly convoluted.

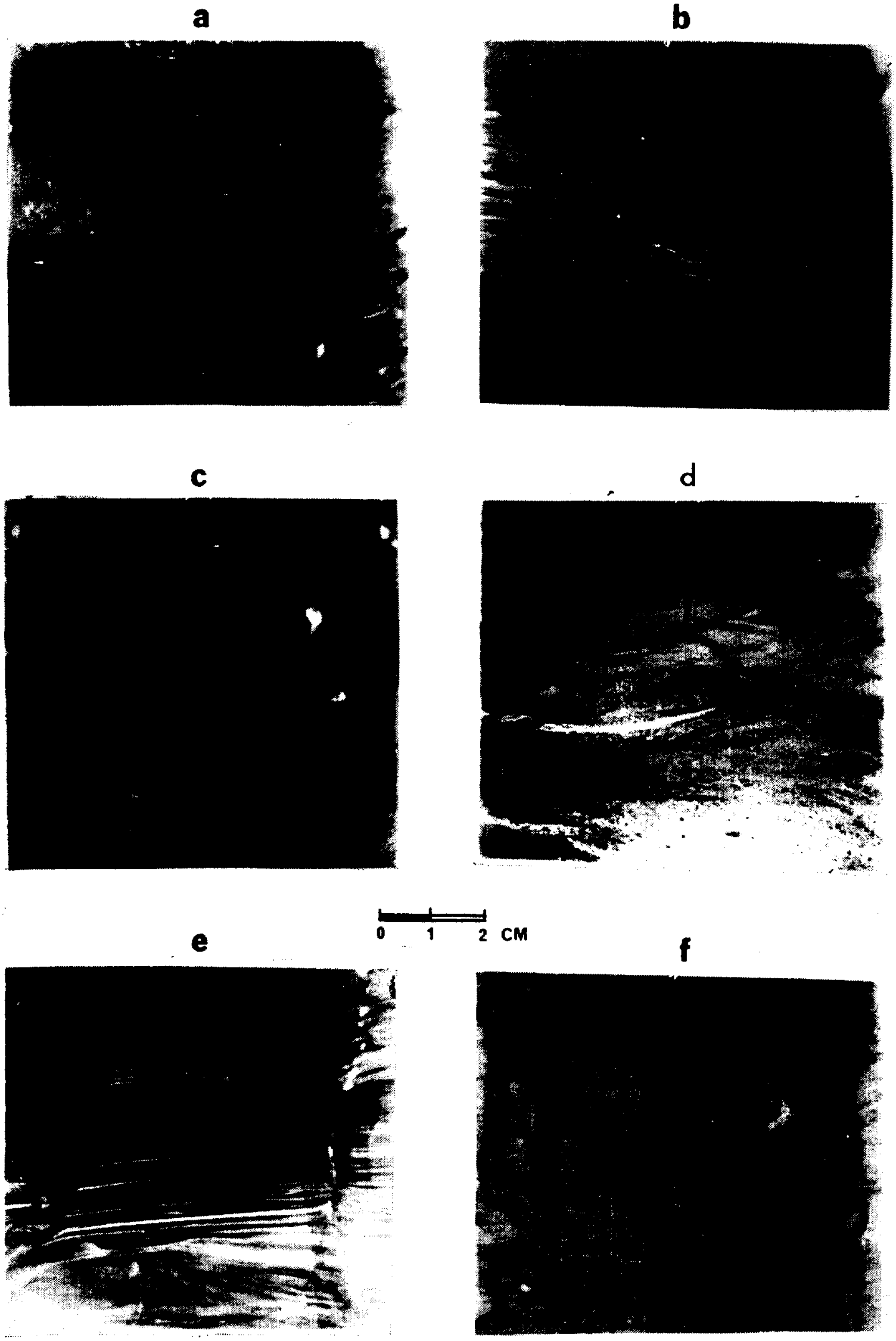
Parallel Lamination

The X-radiographs of the cores often show the parallel laminated structures (Fig. 2). Two types of lamination are classified: thick-laminated layer and thin-laminated layer. Thick-laminated layer occurs in the cores from the sandy-silt and silty-sand intertidal flats, whereas thin-laminated layer is observed in the cores from the silt flat zone. Thickness of individual laminae of thick-laminated layer is in the range from 1 to 5 mm (Plate 1-f). The analysis of grain size reveals that individual laminae consist mainly of sand/silt layer. These two different kinds are alternately repeated, and separation between them is rather sharp. The individual laminae of thin-laminated layer are not thicker than 1 mm(Plate 1-e), and are composed of silt and clay. Some parts of laminae are indistinctly bioturbated (Plate 1-b).

SEDIMENTATION ON THE TIDAL FLAT

The grain size analysis and radiographic

Plate 1. X-radiographs (positive) from selected core slices showing sedimentary structures in the intertidal deposits of the Changgu Bay. a, b and c: bioturbation structures. d: current ripple laminae. e and f: parallel laminae. a) core E5, core depth, 0~7cm; b) core E3, core depth, 22~29cm; c) core E5, core depth, 22~29cm; d) core B2, core depth, 3~9cm; e) core E5, core depth, 7~14cm; f) core A2, core depth, 8~15cm.


a
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examination of sediments make it possible to utilize their textural and structural characteristics for interpreting depositional processes in the intertidal flat. Generally, in view of fluid mechanics, clay-size grains are transported and deposited only from the suspension load, whereas sand-size and silt-size grains of mud are transported and deposited from both the suspension and the traction loads (McCave 1970, Middleton and Southard 1977).

A distinct variation in the grain size distribution of the sediment is observed across the intertidal flat of the Changgu Bay. The mean grain size of the sediments shows a shoreward decrease. The sedimentary processes acting on this sediment distribution are connected with two factors, the "settling lag" of suspended particles and the "scour lag" of depositional particles, as described by van Straaten and Kuenen (1957, 1958). The result of the "lag effect" is that the flood currents transport the fine material further shorewards. A part of material will be deposited at the end of the flood tide.

The parallel lamination is produced from tidal changes (Reineck 1980). During a single tidal phase, there is a period of current and turbu lences, when sand is transported both as traction and suspension. load During a waning current, sand and coarse silt is deposited from a turbulent flow, while finer silt and clay is retained still in the suspension. The thick-laminated sand/silt layer in the cores of the silty-sand and sandy-silt flats is interpreted to be formed at this stage. The main reason of the separation of the sand mud layer is due to differences of falling times of silt and sand grains in turbu lent water. Very thin-laminated layer of cores from the silt flat are apparently deposited during the slack water stage of the flood tide or during stand-still phases of high waters, when currents have low sediment competence and are of sufficient duration.

Small-scale ebb-and flood-foresets of current ripples, generally overlying the thick-laminated layer, represents different hydraulic conditions. Patterns of small-scale ripples are generated travelling over the rigid layer by bottom traction (Middleton and Southard 1977). If more sand is present, trains of ripples are formed which give rise to connected ripple forset structures. The superimpostion of many ebb and flood forsets indicate bi-directional sand transport during some tidal cycles.

The above sedimentary processes are discussed in terms of mean tidal action alone. However, the storm-induced variation in sediment transport is probably significant for apparently anomalous temporal and spatial sedimentation pattern. This would control the whole sedmentation rate on the intertidal flat.

CONCLUSIONS

The analysis of the sediment cores and surface samples in the intertidal flat of the Changgu Bay permits us to draw the following conclusions:

1) Intertidal flat sediments can be divided into three major facies according to the grain size data; silt, sandy-silt, and silty sandy facies, showing a shoreward decrease of grain size.

2) Bioturbations are the most frequent sedimentary structures. The degree of bioturbation increases shorewards, possibly due to the favorable properties of the fine grained sediments for the preservation of biogenic sedimentary structures.

3) Dominant physical sedimentary structures include small-scale sets of current ripple-and parallel-laminae. Current ripple-laminae predominate in the silty-sand and sandy-silt flats. Several flood-and ebb-foresets indicate bi-directional sediment transport during some tidal cycles.

4) Parallel laminae are classified into two types; thick-laminae(sand/silt layer with a thickness from 1 to 5 mm) and thin-laminae(silt/clay layer with a thickness of less than 1mm). The thick-laminated layer characterizes the silty-sand and sandy-silt flats, whereas the thin-laminated layer is significant in the silt flat.

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