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Acoustic Facies in the Western South Sea, Korea

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한국남서해역의 음향학적 퇴적상

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The Western South Sea of Korea can be divided into 4 acoustic facies (AF I-AF IV) according to the variations of acoustic characters. Typical acoustic characters revealed in high-resolution seismic profiles (3.5 kHz) are prolonged, internal reflected, non-penetrated, and transparent types. These acoustic types probably controlled by bottom condition and sediment properties such as composition and compaction of sediments.

Acoustic facies I is characterized by prolonged type which is produced by absorbing of acoustic signals on the coarse sediments including gravels and shell fragments and irregular bedforms. Acoustic facies II is characterized by internal refleted type which is probably produced by differential sediments compaction. Acoustic facies III is characterized by non-penetrated type caused by scattering of acoustic signals on the well sorted fine and very fine sand sediments. Acoustic facies IV is characterized by transparent type with non-internal reflector in limited thickness.

Acoustic types in high-resolution profiles provide important information not only about the stratigraphy of subbottom but also about the sedimentary processes in shallow sea.

한국남서해역은 음향학적 특징에 따라 4개의 음향학적 퇴적상 (acoustic facies)으로 구분된다. 고해상도 (3.5 kHz) 물리탐사기록에 나타난 대표적인 음향학적 특징은 확산된 형(prolonged type), 내부반사 형(internal reflected type), 비투과 형(non-penetrated type)과 투명한 형(transparent type)이다. 이러한 형(type)들은 해저면 상황(bottom condition)과 퇴적물의 입도, 굳기(compaction)에 따라 변화한다.

음향학적 퇴적상 I은 확산된 형이 대표적으로 나타난다. 이 형은 불규칙 또는 규칙적인 해저면 상황과 자갈, 패각편을 함유한 조립질퇴적물에 의해 음파신호가 하부로 흡수되어 나타난다. 음향학적 퇴적상 II는 내부반사형이 나타난다. 내부반사구조는 퇴적물의 굳기변화에 의해 발생하는 것으로 추측된다. 음향학적 퇴적상 III은 비투과 형이 나타난다. 이는 분급이 양호한 세립사와 극세립사가 퇴적된 곳에서 음파신호가 투과 하지 못하고 해저면에서 산란되어 나타난다. 음향학적 퇴적상 IV는 일정한 층후에 내부반사 구조가 없는 투명한 형이 나타난다.

고해상도 물리탐사 기록상에 나타난 음향학적 형들은 퇴적층서 뿐만아니라 천해저의 퇴적기작에 대한 중요한 정보를 나타낸다.

INTRODUCTION

Since acoustic characters revealed on high-resolution (3.5 kHz) seismic profiles was outlined by Damuth (1975), these have been studied by many workers (Damuth, 1975; Jacobi et al., 1975; Jacobi,

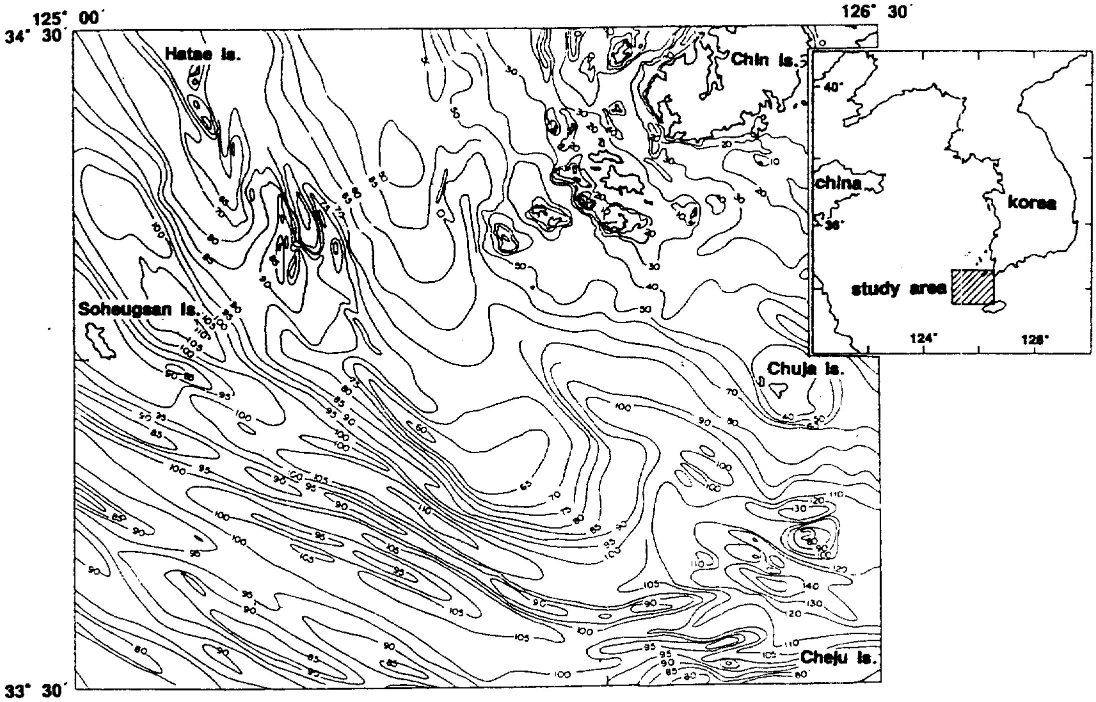

Fig. 1. Detailed bathymetric map of the Western South Sea of Korea. Contours in meters.

1976; Kolla et al., 1976; Damuth and Hayes, 1977; Damuth, 1978; Damuth, 1979; Partson and Laine, 1989). These investigations reveal that acoustic characters are related to sedimentary processes and are controlled by the relative abundance of coarse sediments (Damuth, 1978), lithification, grain size of sediments and degree of disorganization of sediments (Partson and Laine, 1989) or a combination of these. In this paper, we have used the results of these study to evaluate the various sedimentary processes in shallow continental shelf that give rise to the contrasting high-resolution seismic profiles. High-resolution seismic profiles (3.5 kHz) obtained from the Western South Sea of Korea reveal that the uppermost sedimentary sequence is characterized by a zonal distribution of acoustic characters.

The purpose of this study is to examine the correlation between acoustic characters and sedimentary processes in the shallow continental shelf like the Western South Sea of Korea.

Previous study

The Western South Sea of Korea (Fig. 1) is distinguished three distinct geomorphological features. These are (1) submarine terraces, water depth ranging from 50 to 70 m in the central part, (2) flat sea floor (water depth 90 to 100 m) with sand ridges and swales of micro-relief. Generally these features are extended from northwest to southeast, and (3) erosional moats, which generally occur at a water depth about more than 110 m.

The Quaternary sediments overlying Cretaceous volcanic basement are divided into 3 sedimentary sequences (sequence A, B and C) by two local unconformities on the continental shelf southwestern Korea (Kim et al., 1982; Werner et al., 1984; Kim et al., 1985; Kim et al., 1989). They are attributed to the last two interglacial periods, separated by erosion events during intermitting phases of regression (Werner, et al., 1984).

The surface sediments was deposited inner bay

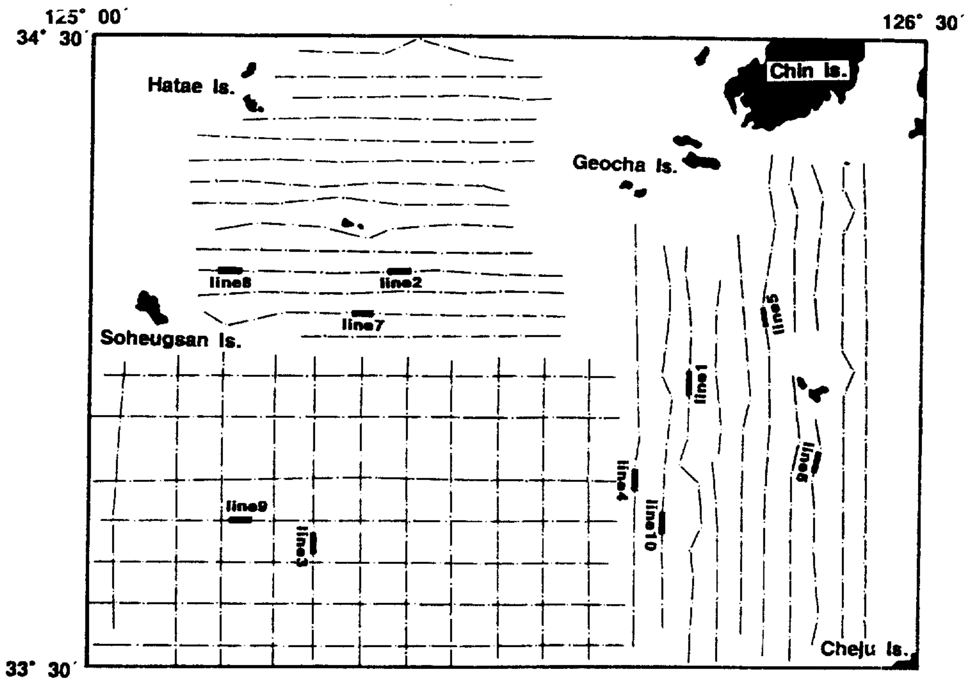

Fig. 2. Map showing tracklines of high-resolution seismic profiling (3.5 kHz). Heavy line segments with letters show location of lines illustrated in the following figures.

or estuary when the sea level was located at the depth lower than the present by 90 m (Min et al., 1990). Coarse sediments including gravels are distributed in the northern sea of Cheju Island. These are probably associated with the distribution of rocky bottom and originated there. The zonal distribution and the composition of sediments imply that these are residual sediments derived from subaerial or subaqueous weathering of underlying bedrock at the lower sea-level than that of present.

The Western Sea of Cheju Island is characterized by the ridge and swale topography composed of fine or very fine sand. These geomorphological features was manufactured by the strong tidal current, when the sea level was located at the depth lower than the present sea level by between 90 m and 80 m (Min et al., 1990).

During calm conditions of summer, muds are replenished by high river discharges and reform the band of soft material, which characteristically occurs as a series of mudflats near the coast. These mudflats thus serve as a temporary storage facility during summer accumulation and a source during winter erosion (Wells et al., 1984).

MATERIALS

High-resolution seismic profiles obtained by ORE subbottom profiler (3.5 kHz) were collected along the 3000 line-km of trackline in the Western South Sea of Korea (Fig. 2). Sonographs of the bottom were collected by EG & G side scan sonar system (105 kHz) that scanned 250 m to each side of the trackline. The survey speed was about 5~6 knots and the navigation was provided by Global Positioning System (GPS).

A total of 209 surface sediments were collected by grab sampler, and 10 core sediments by the piston corer with 9 cm diameter. Cores were split longitudinally and sampled at varying intervals. Sediment analyses include textural analysis, measurement of water content and observation of sedimentary structures. Textural analysis was performed through the dry sieve and pipette method

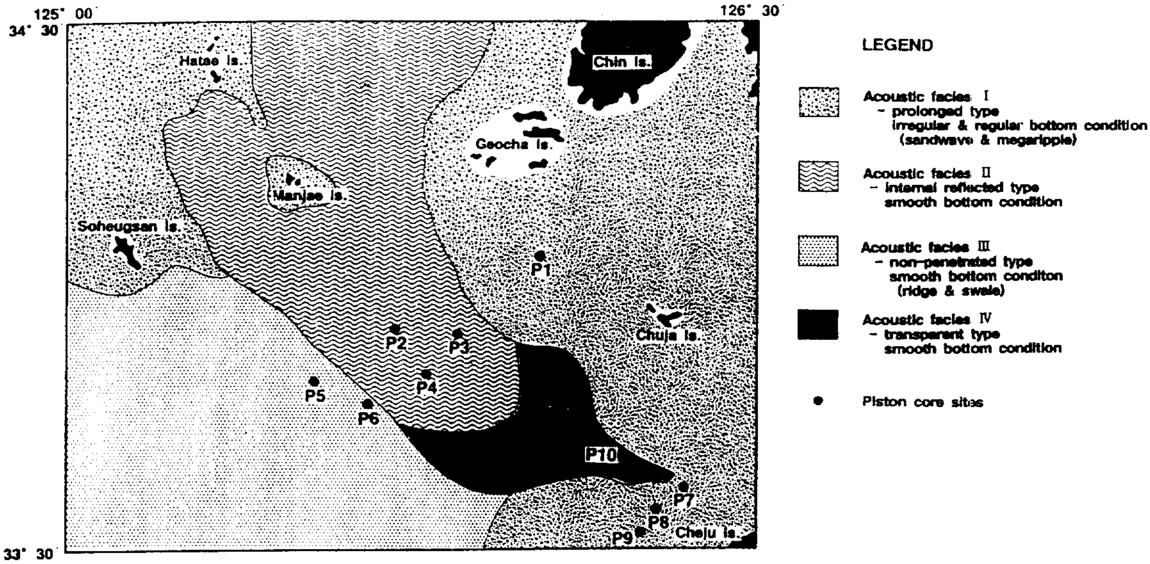

Fig. 3. Distribution map of acoustic facies and characteristics of acoustic types. Core sediments sampling sites (dots).

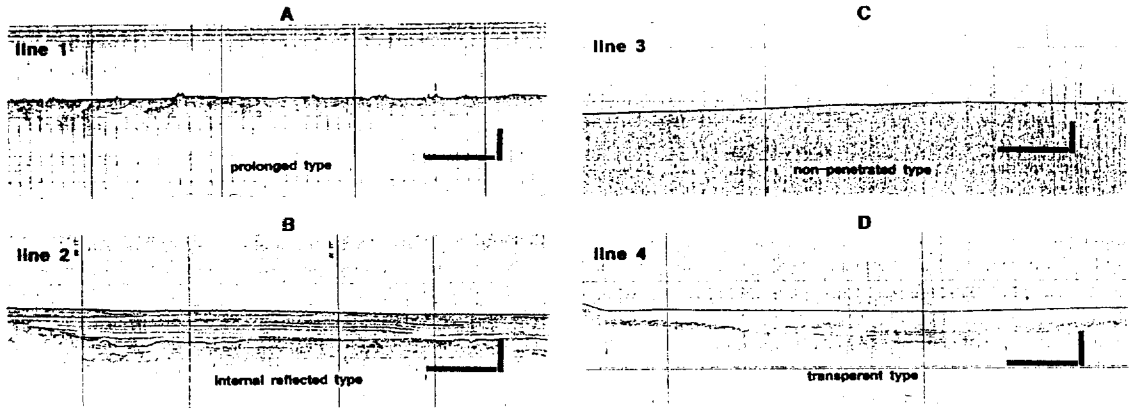

Fig. 4. Acoustic types revealed in high-resolution seismic profiles (3.5 kHz). Typical acoustic types are: A, prolonged type; B, internal reflected type; C, non-penetrated type; D, transparent type. Horizontal scale bar is 200 m and vertical scale bar is 10 m. For location, see Fig. 2.

(Folk, 1968). Core samples were subdivided by 30 ×1×1 cm plastic tray, and the subsamples were radiographed for studying the detailed sedimentary structure.

CLASSIFICATION AND INTERPRETATION OF ACOUSTIC FACIES

The Western South Sea of Korea can be classified into 4 acoustic facies (AF I~AF IV) according to the variations of acoustic types, sonographs, sediments and distribution of geomorphological patterns (Fig. 3). In the study area, typical acoustic characters revealed in high-resolution seismic profiles (3.5 kHz) are prolonged, internal reflected, non-penetrated, and transparent types (Fig. 4). These acoustic types are mainly correlated with sedimentary properties and bottom condition.

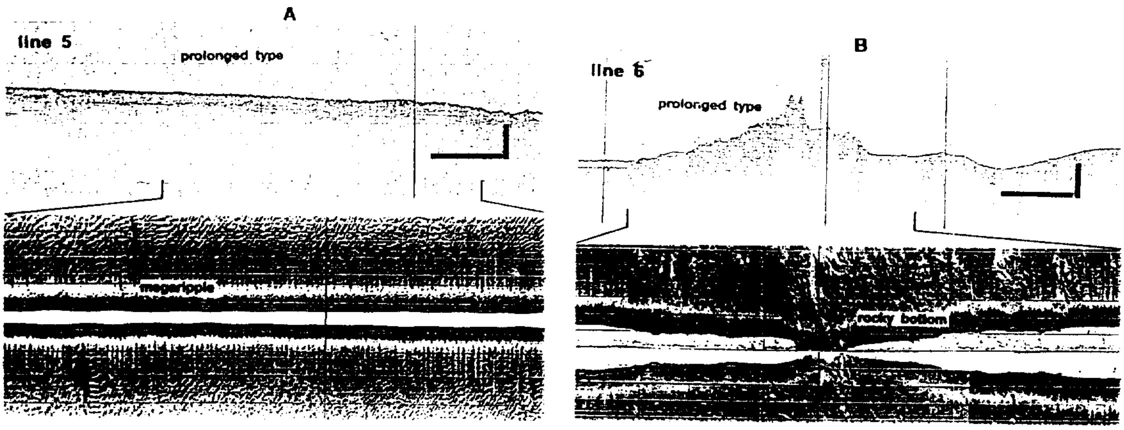

Fig. 5. Prolonged type in high-resolution seismic profiles and bottom conditions in sonographs. A: regular bedform, megaripple in sonograph and prolonged type in profile. B: rocky bottom show very prolonged type in profile. Horizontal scale bar is 200 m and vertical scale bar is 10 m. For location, see Fig. 2.

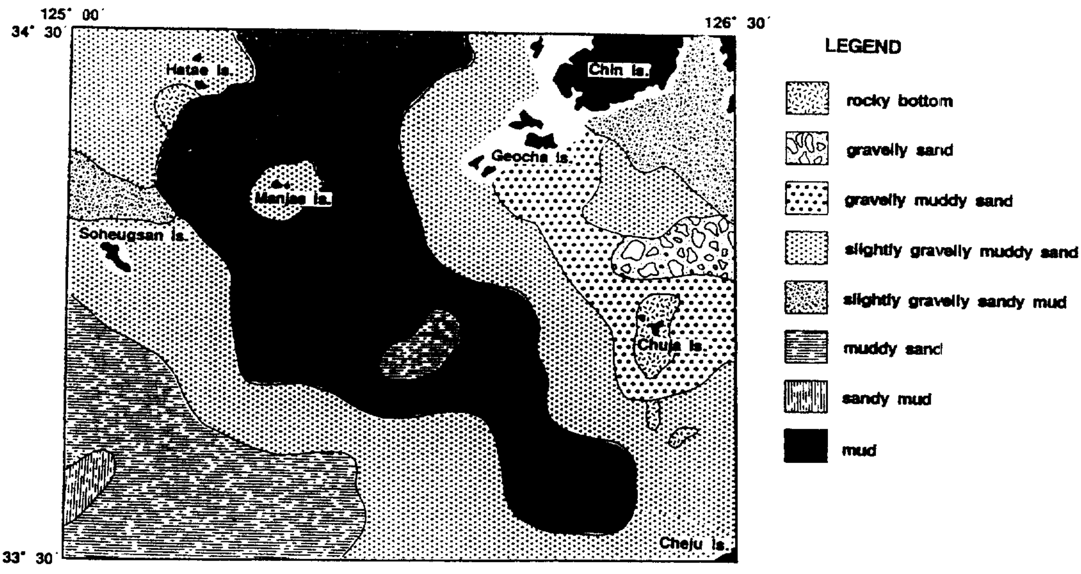

Fig. 6. Distribution of sedimentary types of the study area.

Acoustic facies I

This facies represented by prolonged type is distributed in the north of Soheugsan Island and around Chuja Island (Fig. 3), and in the wide ranges of water depth from 10 m to 150 m deep. The prolonged type is characterized by disappearence of acoustic signals to down direction in high-resolution seismic profiles (Fig. 4A). The sonographs of this type show correlation with irregular surface or some kinds of bedforms such as megaripples and sandwaves (Fig. 5A). Depositional bedforms, sandwaves and megaripples are generally revealed in the boundary of this facies. Erosional features such as moats and channels occured by strong hydrodynamic condition are distributed between Chuja and Cheju Island (Fig. 1, Min, 1987). Rocky bottoms without deposition characterized by strong prlonged types are sporadically exposed around Chuja Island and the west of Hatae

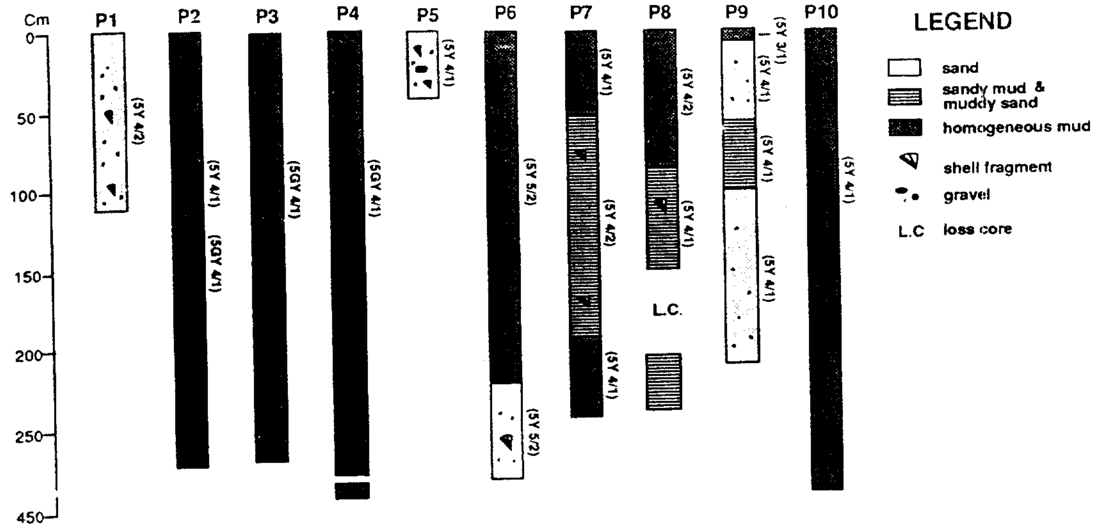

Fig. 7. Descriptions of core sediments obtained from the Western South Sea of Korea. For location, see Fig. 3.

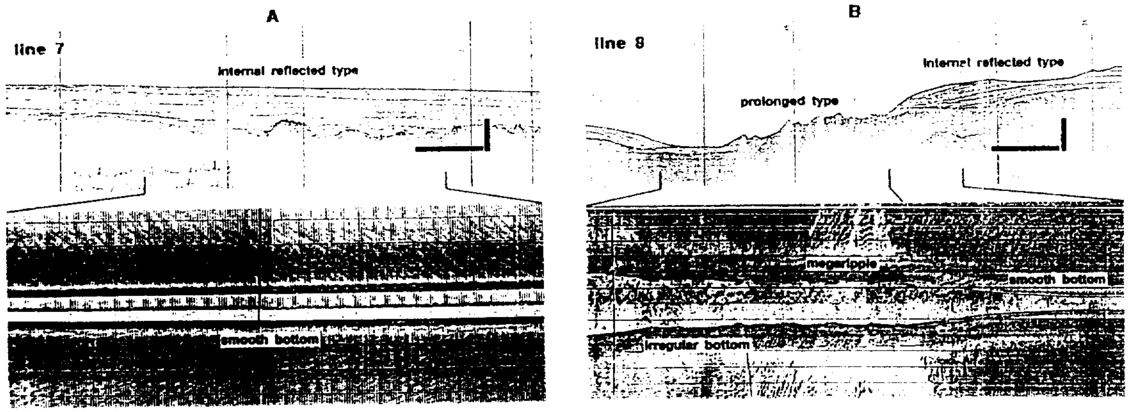

Fig. 8. Acoustic types in high-resolution seismic profiles (3.5 kHz) and bottom condition in sonogrphs. A: the surface of internal reflected type is smooth in sonograph. B: the surface of prolonged type is irregular or regular in sonograph. However, that of internal reflected type is smooth. Horizontal scale bar is 200 m and vertical scale bar is 10 m. For location, see Fig. 2.

Island (Fig. 5B).

Surface sediments of this facies generally consist of gravelly sand, gravelly muddy sand and slightly gravelly sand at most location (Fig. 6). The average mean grain size is 3ϕ. Relatively coarse sediments (0~2ϕ) are distributed in the north of Chuja Island. Core sediment obtained from the northwest of Chuja Island is penetrated a maximum of 113 cm. It is clearly composed of shell-rich sandy gravel. The grain size and shell content increase to down direction from fine-medium to coarse shelly sand (Fig. 7, P1). These sedimentary properties suggest that prolonged type of acoustic facies I result from the absorbing of acoustic energy by coarse sediments including much gravel and shell fragments, small depositional bedforms and rocky bottom.

Acoustic facies II

Acoustic characters of this facies is shown inter-

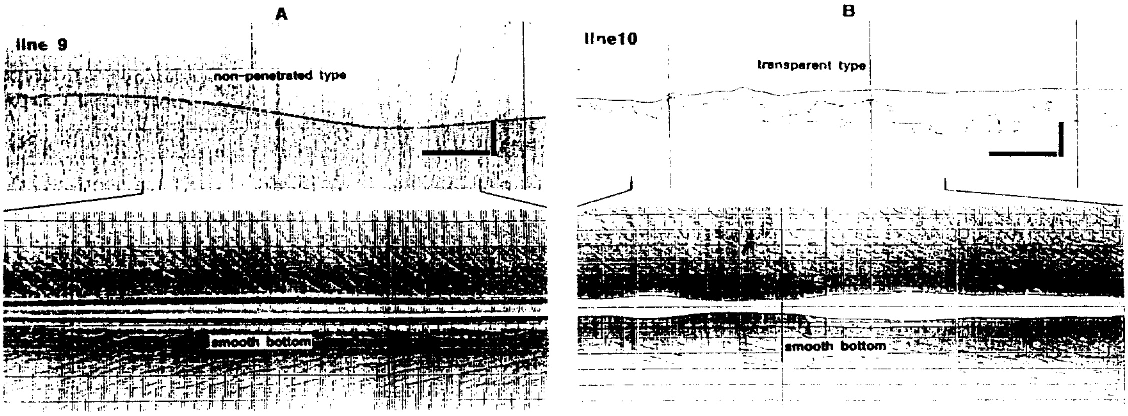

Fig. 9. Acoustic types in high-resolution seismic profiles (3.5 kHz) and bottom condition in sonogrphs. A: the surface of non-penetrated type is smooth in sonograph. B: that of transparent type is also smooth in sonograph. Horizontal scale bar is 200 m and vertical scale bar is 10 m. For location, see Fig. 2.

nal reflected type. In high-resolution seismic profiles, parallel internal reflectors are exhibted continuously in horizontal and repeatedly in vertical (Fig. 4B). But gently oblique reflectors are found in the southern boundary area. This facies is distributed from the northwestern part of the study area to the northwestern sea of Cheju Island (Fig. 3).

In sonography, sea floor exhibits generally smooth bottom condition. However, irregular surface is revealed in the western boundary which large changes water depth ranging from 50 m to 110 m (Fig. 8).

Core and surface sediments are clearly composed of hard homogeneous dark greenish-gray mud (5GY 4/1) (Fig. 7, P2, P3, P4). These homogeneous mud which have lower water content (38.5%) are relatively compacted. In radiographs, silt lamina structures are well developed repeatedly. It suggests that fine sediments are deposited relatively quickly.

Because of limited core depth, the relation between internal reflected type and lithology can not identified correctly. But this acoustic type may be controalled by the compaction of sediments.

Acoustic facies III

This facies represented by non-penetrated type is distributed in the south of Soheugsan Island (Fig. 3). Non-penetrated type shows only distinct surface reflectors without subbottom reflectors (Fig. 4C). This type is created by scattering of acoustic energy at the bottom (Damuth and Hayes, 1977). In the limited area, non-penetrated type is covered by thin transparent layer. Complex acoustic characters due to the mixing of partially transparent, non-penetrated and partially interal reflected type are revealed in the boundary area composed of muddy sand including a little gravel. Surface sediments are generally composed of well sorted fine sand or muddy sand (Fig. 6). Core sediments consist of only olive-gray (5Y 4/1) fine or very fine sand (Fig. 7, P5). The bottom condition is very smooth in sonographs (Fig. 9A). Above mentioned characteristics suggest that non-penetrated type is revealed in the area composed of well sorted fine sand with smooth bottom condition.

Acoustic facies IV

This facies characterized by transparent type is distributed in the south tip of acoustic facies II (Fig. 3). Transparent type is non-internal reflectors in limited thickness. The lower boundary of the transparent layer identified by reflectors of unconformity (Fig. 4D). The thickness of transparent layer is ranging from 3 to 20 m. The bottom condition is very smooth and does not reveal the ero-

Table 1. The acoustic characters and sedimentary properties of acoustic facies.

Acoustic Facies	Acoustic type & characters	Sediments	Bottom condition & Geomorphology	Sedimentary environments	Interpretation
AF I	Prolonged type disappearence of acoustic signals to down direction	Olive gray (5Y 4/2) shell-rich sandy gravel.	Irregular surface sandwave and megaripple Rocky bottom Erosional moats	Coastal	Absorbing of acoustic signals by irregular bottom condition and by coarse sediments including gravels and shell fragments
AF II	Internal reflected type continuous & parallel or gently oblique reflector	Hard homogeneous dark-greenish gray (5GY 4/1) mud Water content, 38.5%	Smooth bottom In some cases, irregular surface by erosion	Estuary or delta complex	Internal reflection by differential sediment compaction caused by periodic supplying of fine sediments and by periodic exposing at the subaerial environments
AF III	Non-penetrated type distinct surface without subbottom reflector	Light olive gray (5Y 5/2), well sorted fine or very fine sand & muddy sand	Smooth bottom Ridge & swale	Subtidal	Scattering of acoustic signals by well sorted fine & very fine sand
AF IV	Transparent type non-internal reflector in limited thickness	Soft homogeneous dark gray (5Y 4/1) mud Water content, 50.3%	Smooth bottom	Allochthonous deposits	Penetrating of acoustic signals to soft homogeneous mud

sional and depositional features in sonographs (Fig. 9B).

Surface and core sediments are similar to that of acoustic facies II in sedimentary texture. However, core sediments is composed entirely of soft dark-gray homogeneous mud (Fig. 7, P10) which have relatively higher water content (50.3%).

Transparent type may be produced by that acoustic signal penetrates soft homogeneous mud and reflected at the different sedimentary surface.

DISCUSSIONS

In deep sea, a qualitative correlation has been observed between the relative abundance of coarse (silt, sand, gravel), bedded sediment and acoustic characters by many workers (Damuth, 1975; Jacobi, 1976; Damuth, 1978, 1979, 1980; Embley, 1976). They sought that acoustic characters are revealed in high-resolution seismic profiles acccording to the variations of the lithology of sediments. In shallow sea, acoustic characters have correlation with sediments properties such as grain size, compaction of sediments and bottom condition. Classification, sediments and bedforms of each acoustic facies observed in the study area are summarized on Table 1.

The origin of prolonged acoustic type without subbottom reflectors of acoustic facies I is uncertain. However, it is probably formed by two evidences: (1) the coarse sediments including gravels and shell fragments; (2) irregular or regular bedforms such as sandwave and megaripple on the surface. If this interpretation is correct in this study area, prolonged acoustic type is probably revealed in the upper flow regime needed to transport such coarse sediments also produces irregular or regular depositional bedforms.

In seismic profiles, the Quaternary sediments of the Western South Sea of Korea can be divided into 3 sedimentary sequences (sequence A, B and C) by two local unconformities (Kim et al., 1982; Werner et al., 1984; Kim et al., 1985; Kim et al., 1989). Internal reflectors of sequences A and B are generally characterized by discontinuous parallel subbottom relfectors in high-resolution seismic profiles (Werner et al., 1984). The areal distribution of sequences A and B corresponds to that of acoustic facies II. Internal reflected type in acoustic facies II is not well defined there because of the limited core depth. But in comparing cored homogeneous muds of internal reflected type with those of transparent type, the water content from the former is relatively lower than that of the latter. It suggests that internal reflectors are recorded from differential sediment compaction which is caused by periodic supplying of fine sediments and by periodic exposing at the subaerial environments.

Bathymetric contours and high-resolution seismic profiles show that acoustic facies II is shaped tongue-like feature which is considered to be a large delta complex prograding from northwest to southeast. The acoustic characters, regional setting, composition of sediments and geomorphology suggest that acoustic facies II (sequences A and B) is probably formed by periodic flooding in estuary environments.

Non-penetrated type is mainly observed in the south sea of Soheugsan Island (Acoustic facies III). The surface may be the excellent reflectors of acoustic energy. Little or no sound penetrates generally to the buried sediments interfaces, because the sediment is composed of well sorted fine and very fine sand or muddy sand.

Transparent type is interpreted as the result of a slump associated with internal deformation leading to the disappearance of the origianl bedding in deep sea (Bellaiche et al., 1986). However, the evidence of slump deposits can not found in the study area. Transparent type in shallow marine may be correlated with relatively soft mud sediments deposited in the tranquil bottom condition. These sediments could be represented allochthonous deposits.

CONCLUSIONS

Acoustic characters in high-resolution profiles (3.5 kHz) provide important information not only about the stratigraphy of subbottom but also about the sedimentary processes in shallow sea.

The Western South Sea of Korea can be divided into 4 acoustic facies according to the variations of acoustic types. These acoustic types are correlated with sedimentary properties and bottom condition.

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