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Subaerially Exposed Pre-Holocene (late Pleistocene) Marine Coastal(intertidal) Deposits in the Haenam Bay, West Coast of Korea

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한국 서해안 해남만의 선현세(홍적세 후기) 연안조간대층의 대기권 노출

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ABSTRACT

The stratigraphy of intertidal deposits in the Haenam Bay, western coast of Korea shows two depositional sequence units (Unit I of Holocene and Unit II of late Pleistocene) bounded by an erosional surface of disconformity. The disconformity is related to the latest Pleistocene sea-level lowstands (probably during the LGM).

The Unit II is interpreted as intertidal deposit showing tidal sedimentary structures and crab burrow ichnology and has two parts (the upper part and the lower part) showing different lithology and character. The upper part of Unit II shows characteristic subaerial exposure features and its related lithology. Such subaerially exposed upper part (more or less 4m to 5m in thickness) is characterized by yellow-brownish sediment color, cryoturbat-ed structure, crab burrow ichnofacies and high value of shear strength. Geochemical and clay mineral analyses of the upper part sediments also indicate subaerial exposure and weathering. In particular, very high value of magnetic susceptibility of the upper part in comparison to that of the lower part is interpreted as pedogenetic weathering during the subaerial exposure period.

要　約

한국 서남해안에 위치한 해남만의 조수 퇴적층(체)에 관한 층서 설정이 제4기 후기(late Quaternary)의 시간 범위로 가능하였다. 즉 현재의 해남만에 분포하고 있는 조간대층은 지난 중기와 후기 현세(middle to late Holocene) 동안에 형성된 퇴적 지층 단위(depositional sequence unit)이며 이 지층단위는 선현세(late Pleistocene) 조간대 퇴적 지층 단위를 disconformity의 부정합 관계로 피복하고 있다. 본 연구에서는 전자를 Unit Ⅰ (8-10m 내외의 두께)이라 칭하고 후자를 Unit Ⅱ (10m 내외의 두께)라고 구분 명명하였다.

그런데 Unit Ⅱ는 암상(lithofacies)의 특징에 근거하여 상부(upper part)와 하부(lower part)로 나누어 진다. 상부는 약 3-4m의 두께를 가지고 있으며 황갈색을 분명히 나타내며, 게 구멍 화석과 동토구조(cryogenic structure) 그리고 매우 높은 값의 전단응력을 나타낸다. 그러나 하부는 회색을 띠며 낮은 전단응력 값을 나타내 상부와 뚜렷이 구분된다. 이러한 Unit Ⅱ의 상부가 나타내는 암상적 특징은 지난 간빙하기(Eemian interglacial time)에 형성된 오늘과 같은 조간대층이 18,000년 전후의 최대 빙하기(last glacial maximum : LGM) 동안 노출되었다는 증거로 해석된다. 실제적으로, Unit Ⅱ의 상부는 매우 추운 기후의 지배하에 노출되었고 오랜 동안 토양 형성 과정의 풍화작용을 받은 증거를 나타내고 있다. 따라서 이 지층의 층서학적 단위 설정과 부정합(disconformity)적인 경계 의미는 우리나라 제4기 층서(late Quaternary stratigraphy)를 규정하는데 매우 중요하다고 제안하는 바이다.

INTRODUCTION

The Yellow Sea is semi-enclosed epicontinental shelf which has a broad and low relief sea floor showing less than about 100m in water depth. The Yellow Sea basin was completely exposed to the subaerial condition several times during Quaternary sea-level lowstands. Especially during the Last Glacial Maximum (18 to 15 ka BP), the Yellow Sea shelf was emerged and completely drained (Park and Yoo, 1988; Zhao, 1990; Qin and Zhao, 1991). The environment of the Yellow Sea basin during LGM period was dominated by a dry and cold climate and locally desertized landscape(Park, 1992; Park, et al., 1993). In addition, for example, pre-Holocene marine deposits i. e. Unit II in this study might be certainly exposed.

In this paper, the aim is to describe and report various subaerially exposed features of pre-Holocene (late Pleistocene) marine coastal(intertidal) deposits, that is, Unit II in this study obtained from deep cores in the Haenam Bay intertidal flat, west coast of Korea.

LOCATION AND METHODS

The Haenam Bay located in southwestern coast of Korea is a semi-enclosed and gourd-shaped coastal bay elongated in NW-SE direction with the narrow baymouth (Fig. 1). The tidal flats in this bay are developed along both sides of the bay with average width of about 2 to 2.5 km. Vibracores were obtained at 7 sites in the bay, and in particular, deep drilling cores at 2 sites were obtained (Fig. 1).

All obtained cores were split, photographed, X-radiographed and described in detail in the laboratory. Descriptions of each core samples were concerned about the major physical and biological sedimentary structures, color, and textural characters. With a vane shear apparatus (Gilson Model No. HM-504 Torvane Rhemoeter), shear strength (hardness) was measured about 10 to 20cm intervals. Water contents of sediments were also measured at this intervals. Sediment samples were collected at 20 to 40 cm intervals for grain size analyses. These samples were analyzed following the standard grain size analysis (Ingram, 1971), and textural parameters were calculated following the graphic method.

Clay mineral analysis was made for less than 2μm sediment fractions by the smear-slide method (Biscaye, 1965). Semi-quantitative calculation of clay mineral compositions was made following the peak area method for the diffratogram after the identification clay minerals(Biscaye, 1965). In the present study, the term smectite comprises montmorillonites plus randomly interstratified montmorillonites-illite mixed layer clay minerals. Geochemical elements of bulk sediments wera analyzed in the University of London using ICP-emission spectrometer. Accuracy of analyses

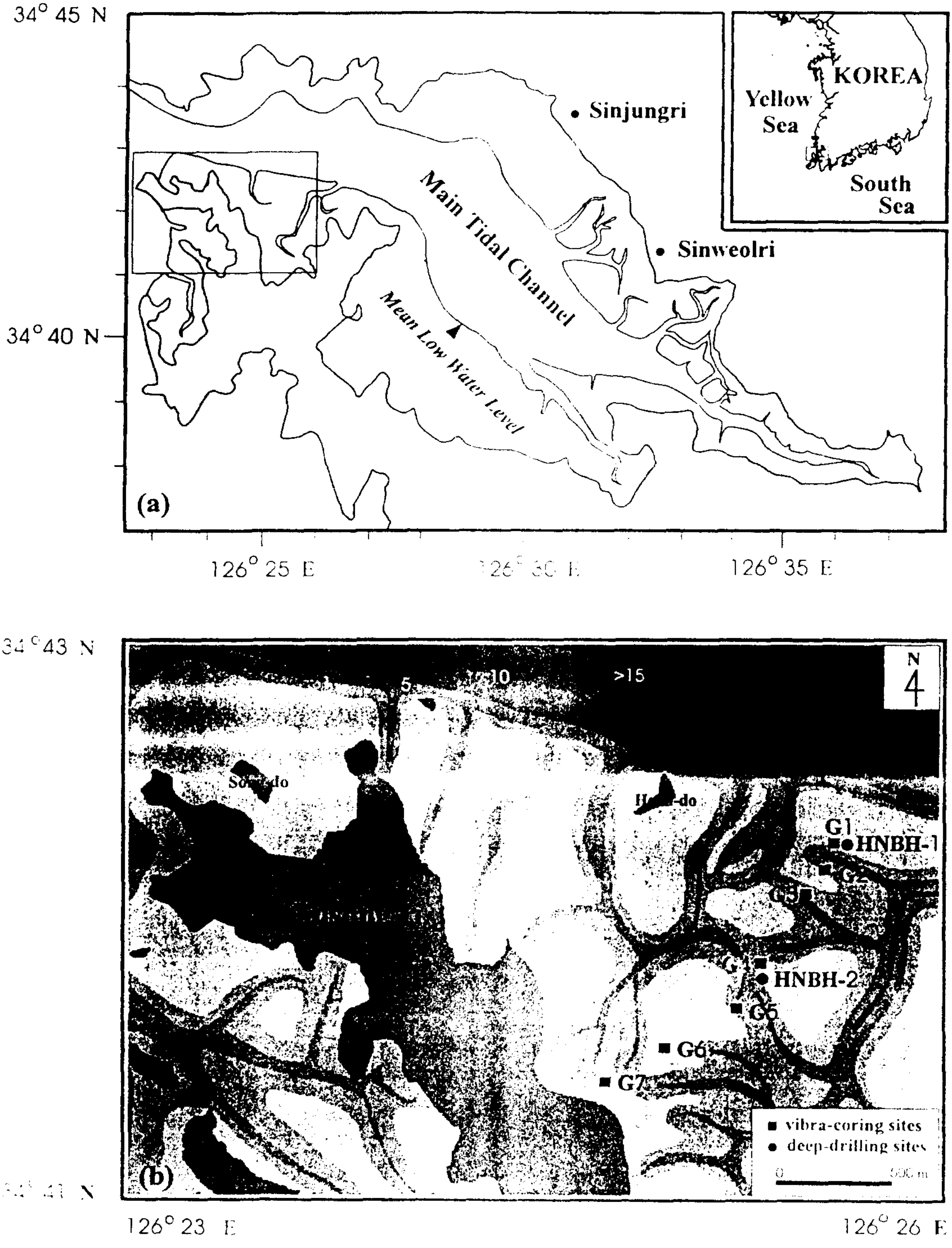

Figure 1. Index map showing the study area and coring sites.

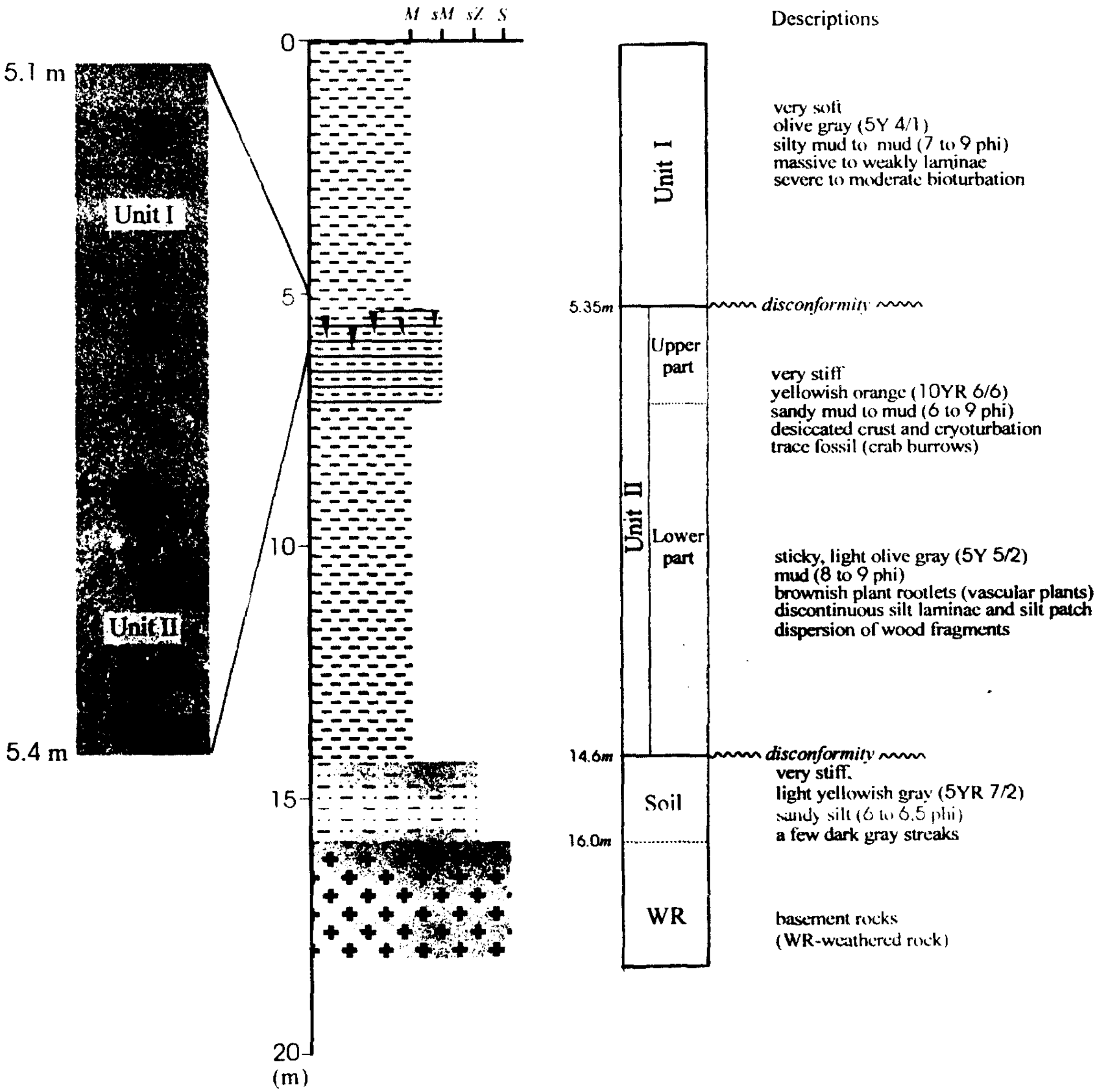

Figure 2. Lithologic columnar diagram and photography showing unconformable boundary between Unit I and Unit II.

was monitored by checking the standard references (BCSS−1 of NRC) and samples in evry batch of analysis, which maintains satisfactory results of analytical precisions within ±5%.

Sediment samples for magnetic susceptibility were taken with plastic cubes (6cc) at 10cm intervals. Low−field magnetic susceptibility was measured on a Bartington magnetic susceptibilitimeter (MS2) with an alternating field of 0.1 mT and a sensitivity of about 10−8 m^3/kg. A specimen of paramagnetic Mn_2O_3 was used as a standard for calibration of instrument.

STRATIGRAPHY

In this study, the stratigraphy based on obtained vibracores and deep drilling cores shows two main sedimentary sequences (Fig. 2). It consists of the intertidal muddy deposit (Unit Ⅰ) of Holocene transgressive sequence during the middle to late Holocene and the intertidal muddy deposit (Unit Ⅱ) of late Pleistocene in age. The boundary between Unit Ⅰ and Unit Ⅱ which can be traced for the entire bay is abrupt and irregular, indicating an interval of erosion (Fig. 2). The Unit Ⅰ is composed of olive gray (5Y 4/1) silty mud and mud with 7 to 9 phi in mean grain size.

Table 1. Average value and range of geotechnical measurements and clay mineral relative abundances of the Unit Ⅰ and Unit Ⅱ sediments in the Haenam Bay.

Unit \ Factor		Water Content(%)	Shear Strength	Illite (%)	Kaolinite (%)	Smectite (%)	Chlorite (%)
Unit Ⅰ		51 (44−70)	0.3 (0.1−0.4)	63 (60−74)	15 (11−16)	6 (4−9)	16 (12−18)
Uint Ⅱ	upper	24 (17−32)	2.3 (1.2−2.5)	75 (62−80)	23 (17−29)	1 (0−2)	1 (0−3)
	lower	40 (32−44)	0.7 (0.5−0.9)	64 (60−66)	17 (15−18)	5 (3−7)	14 (14−17)
Soil		20 (19−22)	1.5 (1.2−1.7)	64 (60−68)	33 (31−41)	3 (0−2)	0
Weathered rock		−	−	70 (67−75)	28 (21−33)	2 (1−4)	0

(Shear strength : 1kg/cm^2 in unit.)

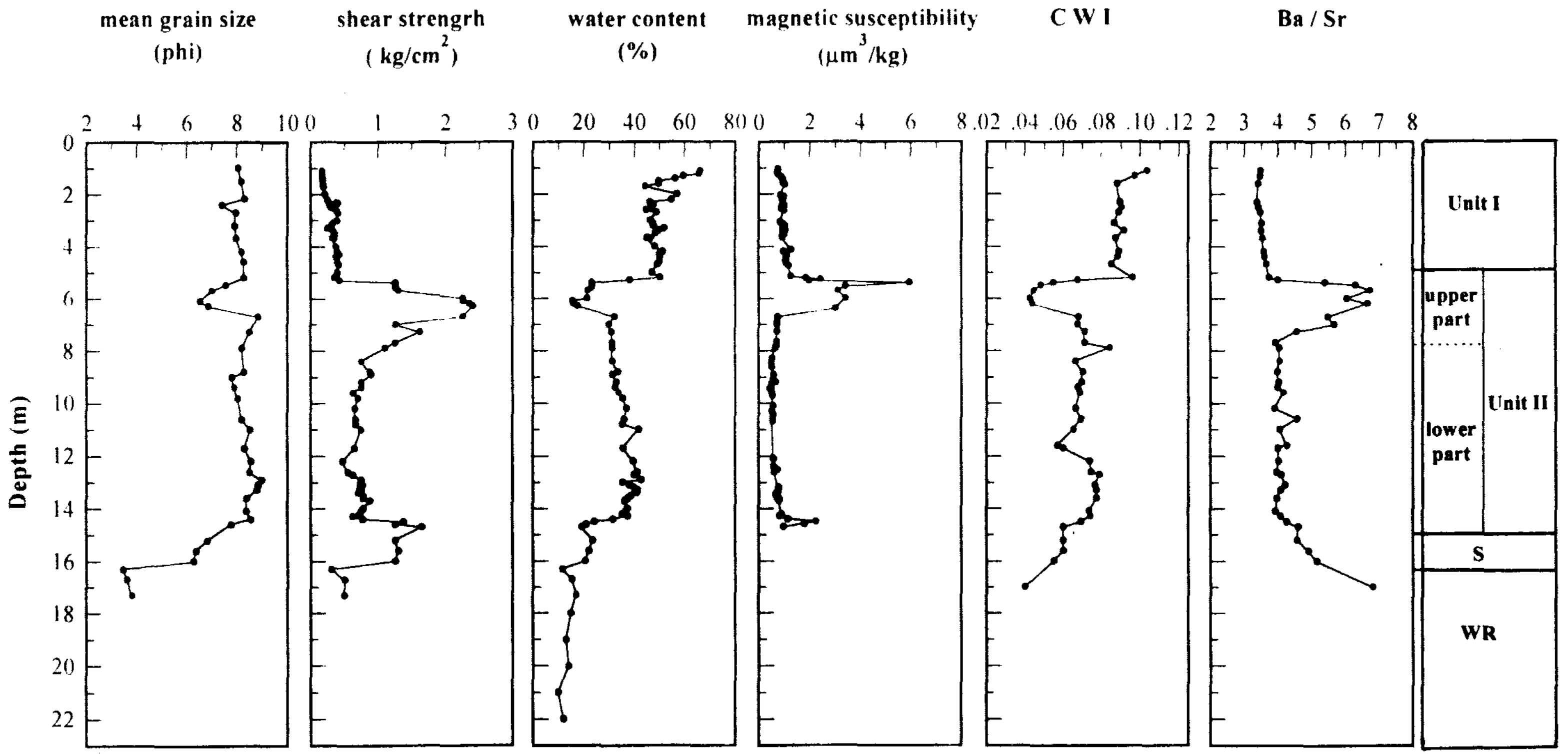

Figure 3. Diagram showing mean grain size, geotechnical properties (water content and shear strength), magnetic susceptibility and geochemical weathering indices (CWI and Ba/Sr) of the Unit I, Unit II and soil (weathered) sediments. S—soil and WR—weathered rock.

Primary sedimentary structures such as parallel and cross lamina are almost destroyed by activities of benthic organisms. Radiocarbon age datings of oyster shell (1.5m below mean sea level) and wood fragments (17.0m below mean sea level) obtaiued from Unit I are 1,362±48 and 8,524±69 yr. B P, respectively.

The Unit II can be divided into two parts (the upper part and lower part) based on various facies characters. The upper part of Unit II has yellowish orange (10YR 6/6) muddy sediments (6 to 7 phi in mean grain size), cryoturbation, crab burrow ichnofacies, and is correlated with the upper part of the so-called Kanweoldo Deposit reported from Cheonsu Bay tidal flats (Kim, 1988), Namyang Bay tidal flats (Park et al., 1995), Yongjong Island tidal flats (Choi and Park, 1996) and Hampyung Bay tidal flats (Park et al., 1997). The upper part of Unit II has less than 25% of water content and higher than 2.0kg/cm^2 of shear strength (Fig. 3 and Table 1). In contrast, the lower part of Unit II shows light olive gray to olive gray color (5Y 5/2) and consists mainly of mud with 7 to 9 phi in mean grain size (Fig. 3). Average contents of water content and shear strength of the lower part is 40% and 0.7kg/cm^2, respectively, which are almost equivalent to those of modern tidal flat sediments of Unit I (Fig. 3 and Table 1). Discontinuous silt laminae disturbed by bioturbation and silt patch are dominately observed. As a whole, the textural properties and sedimentary structurea i. e. lenticular bedding and rhythmic tidal bedding, and crab burrow ichnology observed from Unit II seem to reflect the intertidal depositional condition (Kim and Park, 1988; Park et al., 1995; Choi and Park, 1996; Park et al., 1997).

SUBAERIALLY EXPOSED FEATURES

The upper part of Unit II shows the following subaerial exposure features; yellowish brown color, much more consolidated texture, cryogenic structure, semi-consolidated crab burrow fossil and desiccation crack as shown in Figure 4. Such lithologic and geotechnical characters seem to suggest something related to lithification due to subaerial exposure under a dry and very cold climatee. Furthermore, the upper part of Unit II contains the evidences of clay mineral diagenesis and chemical weathering. The evidence is the absence of smectite and chlorite, while the presence of smectite and chlorite are 16% and 13% in the sediments of Unit I and the lower part of

Unit Ⅱ, respectively (Fig. 5 and Table 1). Segal et al. (1987) and Chamley (1989) explained that smectite and chlorite clay minerals are unstable minerals under the subaerial exposure condition.

In fact, the degree of weathering can be obtained by calculation of the chemical index (Chemical Weathering Index : CWI) using molecular proportions (Birkeland, 1984).

$$CWI = (K_2O + Na_2O + CaO + MgO)/(Al_2O_3 + TiO_2 + Fe_2O_3) \times 100$$

The labile oxides are known to be less resistant to chemical weathering, and therefore the ratio should decrease in a leaching weathering environment. Figure 3 shows the computed values of the CWI for the samples of Unit Ⅰ and Ⅱ. The value of CWI in the upper part sediments is much lower than that of the lower part sediments. Another chemical weathering index can be expressed by a Ba/Sr ratio(Feakes and Retallack, 1988). This index is also the ratio of more stable element(Ba) to the unstable element (Sr). The high value of Ba/Sr ratio of the upper part sediments of Unit Ⅱ is also shown in Figure 3.

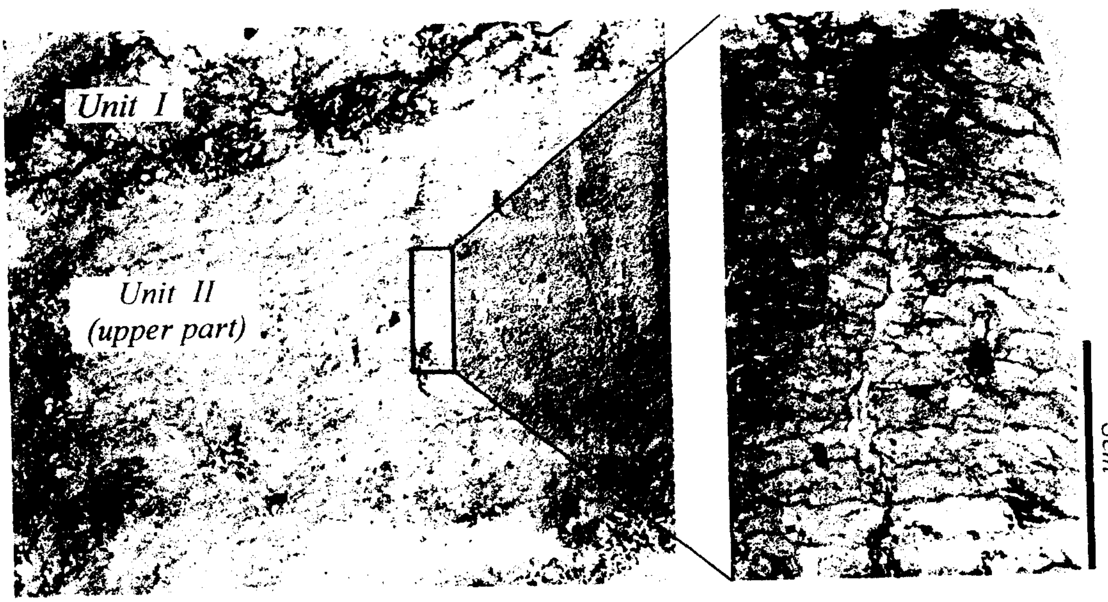

Figure 4. Characteristic cryoturbated structure observed only in the uppermost portion of the upper part of Unit Ⅱ. It is worthy to note the cryoturbated structure that is indicative of a very cold and dry climate(very possibly LGM time).

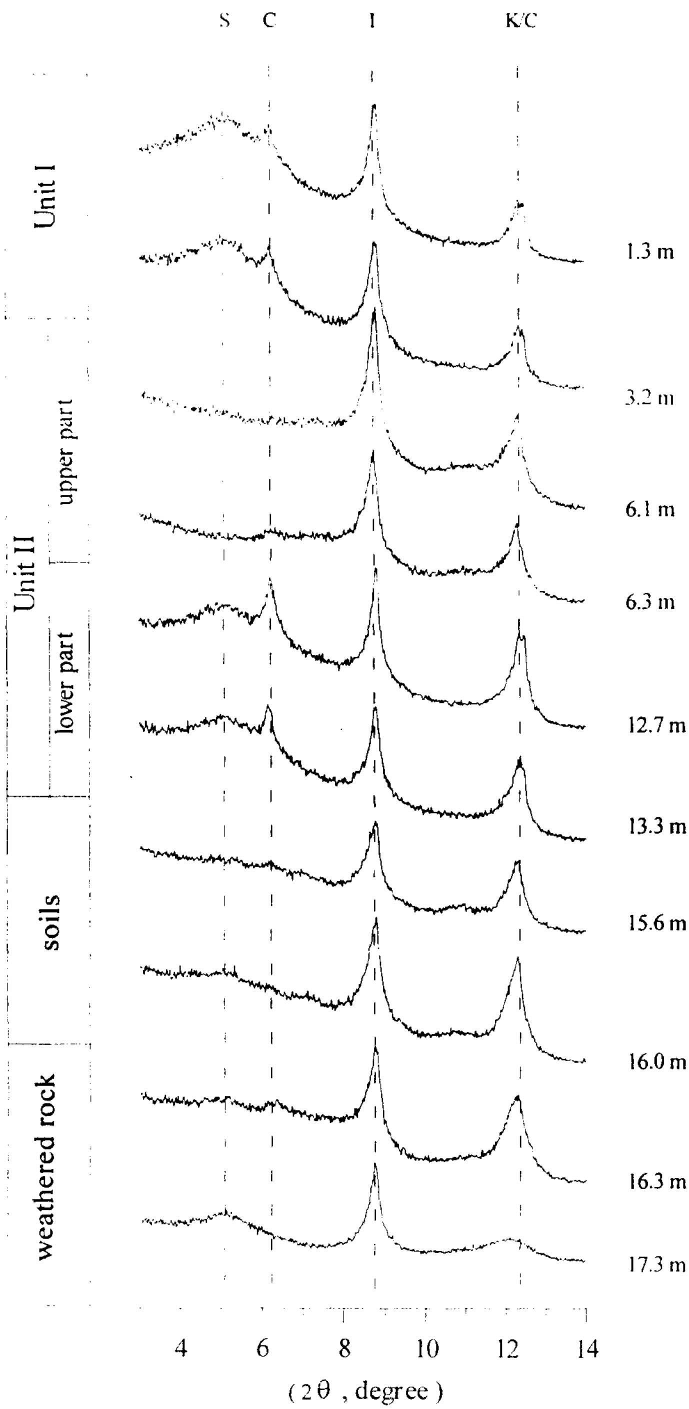

Figure 5. Diagram showing the differences of relative amounts of four major clay minerals from the fine-grained sediments of Unit I and Unit II with depth (1.3m to 17.3m).

The analysis of magnetic susceptibility measurements of Unit I and Unit II sediments shows characteristic nature as shown in Figure 3. The strong magnetic susceptibility is functional with meaningful amount of magnetic minerals in the upper part sediments of Unit II, that can be ascribed to in situ pedogenic weathering process of the upper part sediments under the subaerial exposure condition. According to Yim (1996), the pedogenic weathering of non-magnetic pyrite commonly contained in intertidal muddy sediments was resulted in the diagenetic transformation of magnetic maghemite under the subaerial exposure condition, and then, in turn, the magnetic susceptibility of the subaerially exposed sediments (tidal) was much increased and intensified. Accordingly, the data of magnetic susceptibility measurements of the upper part of Unit II support certainly the result described above by Yim (1996).

CONCLUSIONS

The stratigraphy of the intertidal deposits in the Haenam Bay shows two depositional sequence units (Unit I of Holocene and Unit II of late Pleistocene). The Unit I overlies the Unit II disconformably. The disconformity is interpreted as the period of suba-erial exposure of the Unit II probably during the LGM. Due to the subaerial exposure of the Unit II, the Unit II can be subdivided into two parts, i. e. the upper and lower part. The former has various characteristic features indicating subae-rial exposure evidences, such as cryoturbation structure, high value of shear strength, oxidized yellowish brown color of the sediments, pedogenetic and diagenetic destruction of smectite clay mineral, high value of Ba/Sr ratio and high value of magnetic susceptibility. However, the latter has not any natures suggesting the subaerial exposure.

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