Holocene Retrograding Tidal Flat Deposits in Gomso Bay, West Coast of Korea: Sequence Stratigraphic Implications

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INTRODUCTION

Tidal flats are important for understanding changes of depositional processes during relative sea-level fluctuations, particularly with respect to the Holocene transgressive systems tract (e.g., Allen and Posamentier, 1993; Dalrymple and Zaitlin, 1994). The transgressive systems tract is described principally as a backstepping or retrogradational succession of parasequences, reflecting a gradual increase in water depth as a whole (Posamentier *et al.*, 1988; Van Wagoner *et al.*, 1990). The individual parasequences bounded by marine flooding surfaces are considered to be progradational and hence shoaling-upward. In tidal flat settings, it shows a fining-upward textural trend (Van Wagoner *et al.*, 1990), inconsistent with the retrograding, coarsening-upward deposits.

The majority of facies models for modern and ancient tidal flat sequences also show a fining-upward lithology due chiefly to coastal progradation (Reineck and Singh, 1980). Such a coastal progradation is well demonstrated in most of the Holocene tidal flats worldwide, such as those of North Sea, Bay of Fundy, and the Gulf of California. The retrograding, coarsening-upward tidal flat sequences associated with landward environmental shift by gradually increasing water depth have been rarely documented. Gomso Bay on the west coast of Korea is a typical macrotidal embayment in the southeastern Yellow Sea that retains extensive tidal flats (Fig. 1). It shows poor development of salt marshes and dendritic tidal drainage systems, and lacks seaward depositional barriers compared to the counterparts of the North Sea. Together with these features, the coarsening-upward lithology of Gomso Bay represents principal characteristics of the embayment tidal flat deposits in the southeastern Yellow Sea. Therefore, the Gomso Bay deposits warrant sequence stratigraphic studies of retrogradational tidal flat settings. The purpose of the study is to establish a model for the Holocene transgressive deposits in terms of sequence stratigraphy.

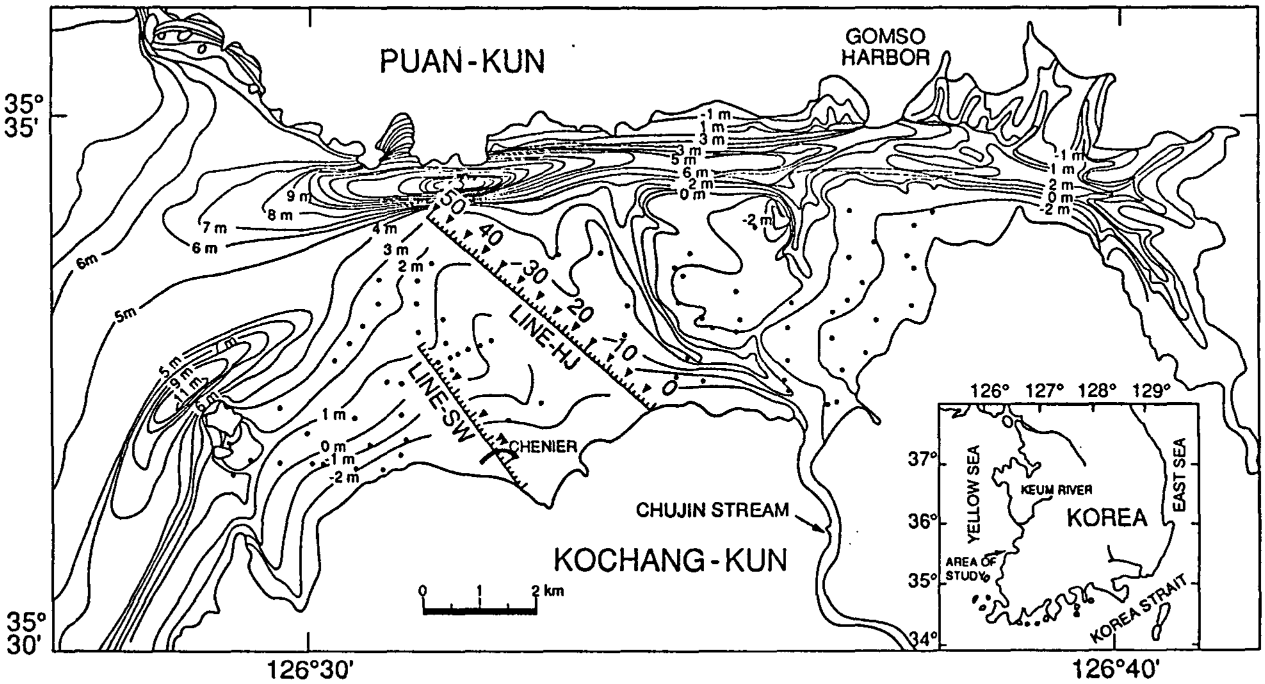


Fig. 1. Location map of Gomso Bay (inset) showing bathymetry and sampling stations. There are two transections (Line-HJ and -SW) across tidal flat. Dots and filled triangles represent sampling locations of surface sediments and vibracores, respectively.

DEPOSITIONAL UNITS AND ENVIRONMENTS

The Gomso Bay deposits can be divided into four units based on facies analysis: pre-Holocene Unit O and Holocene Units I, II, and III (Figs. 2 & 3). Unit O occurs only in the lower part (generally more than 2~3 m below surface) in landward cores. Basal parts of other cores consist of Unit I, which grades upward into Units II and III. Units II and III thin out landward (Figs. 2 & 3).

Unit O is characterized by semi-consolidated, homogeneous yellowish brown clayey silt (mean size, 6~8f), and largely composed of bioturbated mud (Facies Mb) and parallel laminated mud (Facies Mp). Unit O is almost completely devoid of any remains of marine organisms. The light color (yellowish brown) and semi-consolidation of Unit O suggest that sediments have experienced considerable oxidation processes, most likely by subaerial exposure. Radiocarbon dating on vertical *in-situ* plant roots (12,000~14,000 yrs BP) suggest that Unit O was accumulated in terrestrial environments, presumably on floodplain or coastal plain, prior to the Holocene transgression.

Unit I is characterized by intensely bioturbated dark gray silt (mean, 5~7f), and composed of bioturbated mud (Facies Mb) and parallel laminated mud (Facies Mp). Many burrows are filled with coarse sands and granules. Textural characteristics of Unit I (more than 75% mud contents) and intense bioturbation suggest that the unit was accumulated on the mud flat near high water line.

Unit II is characterized by moderately bioturbated or laminated, dark gray sandy silt and/or silty sand (mean, 4~5f). It is largely composed of bioturbated sand/mud (Facies SMb) and parallel to cross-laminated sand/mud (Facies SMp and SMx) with subordinate massive sand (Facies Sm) with shells, parallel to cross-laminated sand (Facies Sp and Sx), and deformed sand/mud (Facies SMb). The deposit of Unit II is considered to represent mixed-flat sedimentation, based largely on texture, quite similar to that of the present mixed-flat sand/mud.

Unit III is characterized by greenish yellow to olive gray very fine sand (mean size, 3~4f), and largely includes massive shelly sand (Facies Sm), bioturbated sand (Facies Sb), and parallel to cross-laminated sand (Facies Sp and Sx) with subordinate bioturbated sand/mud (Facies SMb) and parallel laminated sand/mud (Facies SMp). The unit shows wedge-shape (Fig. 2). The sediment texture (more than 75% sand) and slight to moderate bioturbation of Unit III

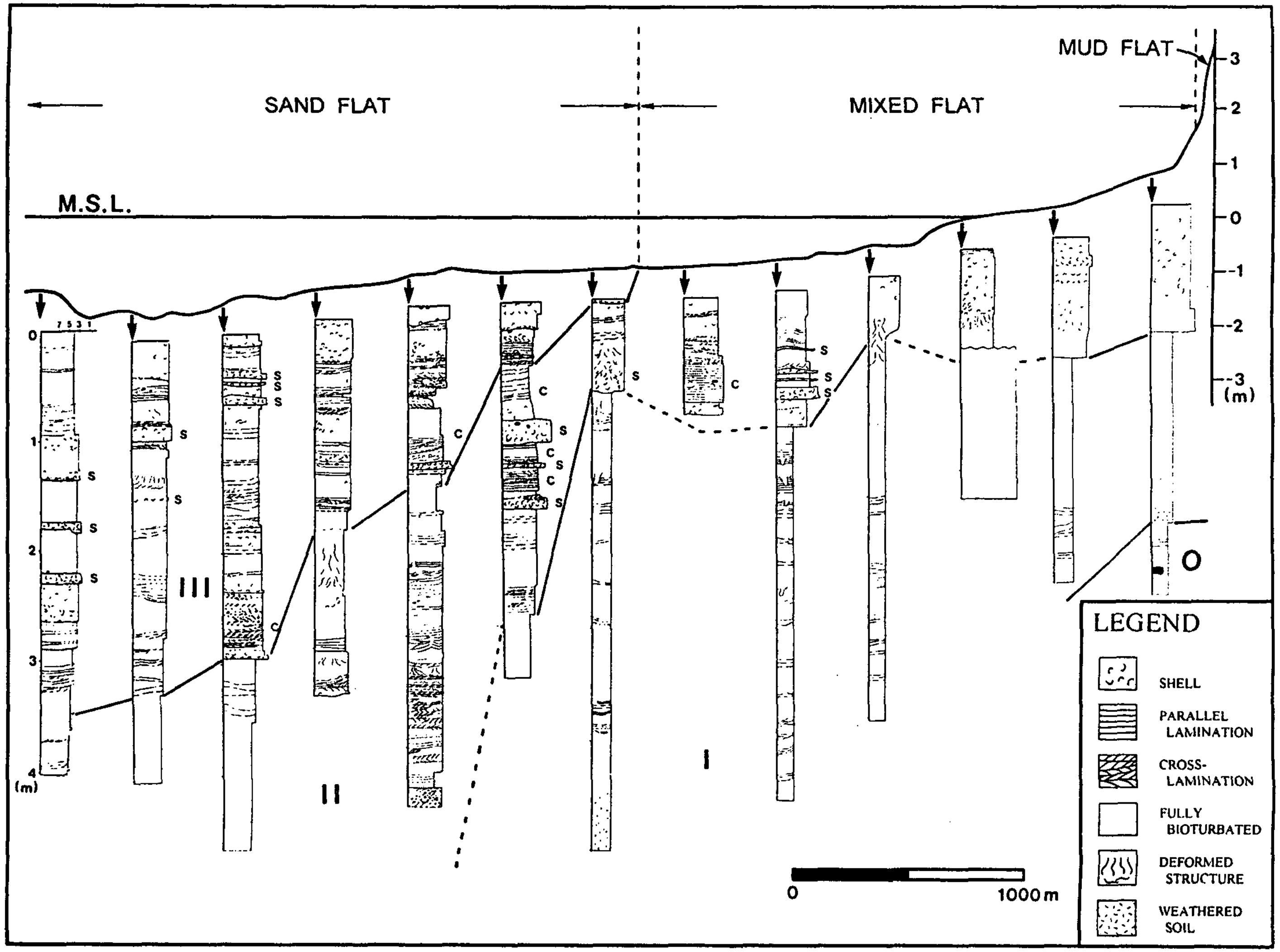


Fig. 2. Stratigraphic cross section of the Gomso tidal flat along the line-HJ (see Figure 1 for location) based on detailed description of vibracores, showing retrogradational distribution of Units O, I, II, and III. S and C represent storm and channel deposits, respectively.

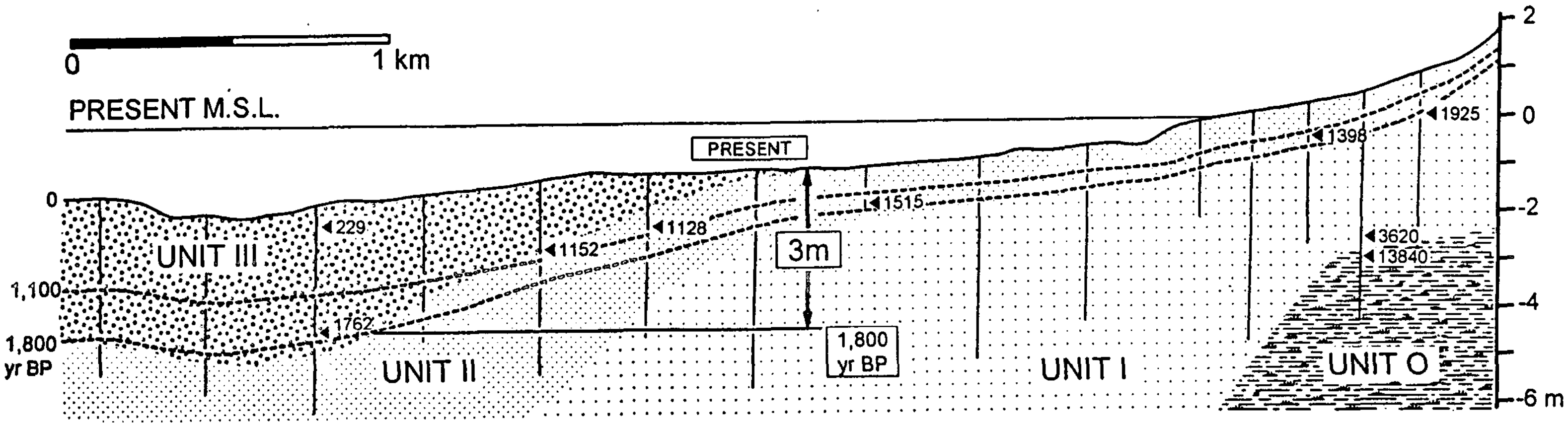


Fig. 3. Simplified stratigraphic cross section of the Gomso tidal flat, showing retrograding, coarsening-upward Holocene marine sequence (Units I, II and III) underlain unconformably by non-marine deposits (Unit O). Solid vertical lines represent vibracores. Numbers beside arrow head depict radiocarbon dates on shells and plant remains.

suggest that sediments were deposited on the sand flat near low water line. A fresh shell (*Crassostrea gigas*) at the lower boundary of Unit III in the seaward core HJ-43 (3 m subbottom) is dated at 176280 yr BP, which is regarded as the time of initiation of sand deposition on Gomso Bay.

MODEL FOR RETROGRADING GOMSO TIDAL FLAT DEPOSITS

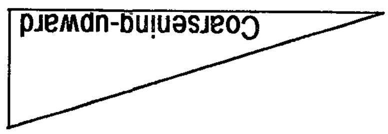
Based on the analysis of the vibracores from the Gomso tidal flat, an ideal sequence can be synthesized. It shows a coarsening-upward succession of three Holocene units overlying the pre-Holocene deposits (Table 1): (1) intensely bioturbated clayey silt (mean, 5~7; less than 25% sand) occasionally with remnant subparallel undulatory laminae, accumulated on the mud flat (Unit I; major facies, Facies Mb and Mp); (2) highly bioturbated, partly laminated sandy silt or silty sand (mean, 4~5; sand 25~75%), deposited on the mixed flat (Unit II; major facies, Facies SMb, SMp and SMx); and (3) slightly to moderately bioturbated very fine to fine sand (mean, 3~4; more than 75% sand) with abundant parallel- and cross-laminae, representing sedimentation on the sand flat (Unit III; major facies, Facies Sm, Sp and Sx). Channel and storm deposits formed under extraordinary high energy regime are observed predominantly in Units II and III. The Gomso tidal deposits show vertically retrogradational sequence from mud to sand, representing a reverse lithological trend to the most general facies models for the tidal flats.

The sequence development is largely influenced by several controlling factors, such as sea level change, tectonics, and sediment supply. The general facies models of fining-upward sequence from the tidal flats of the North Sea and Bay of Fundy represent prograding conditions with sediment supply rate exceeding that of increasing accommodation space (due to sea-level change and tectonism) (Fig. 4). By contrast, the reverse coarsening-upward sequence in the Gomso tidal deposits may result from the opposite condition. The rate of relative sea level during the mid-to-late Holocene is more or less similar among all the three areas (North Sea, Bay of Fundy , and Gomso), whereas the rate of sedimentation rate is quite different. The sedimentation rate is much lower in Gomso Bay (0.3~1.7 mm/yr based on radiocarbon datings) than in the North Sea (3~10 mm/yr) and Bay of Fundy (5~50 mm/yr). Such a low sediment accumulation is most likely responsible for the retrogradational nature in the

Gomso tidal deposits during the mid-to-late Holocene transgression (Fig. 4).

Table 1. Transgressive stratigraphy of Gomso tidal flat deposits

Units	Major facies (minor facies)	Characteristic features	Depositional environments
III	Ss, Sp, Sx, Sb (SMp, SMb)	Moderately bioturbated occasional storm and channel deposits	Sand flat
II	SMb, SMp, SMx (Ss, Sp, Sx, SMd)	Severely bioturbated rare storm and channel deposits	Mixed flat
I	Mb, Mp	Intensively bioturbated no storm and channel deposits abundant burrows	Mud flat
O		Oxidized semi-consolidated pre-Holocene plant roots absence of marine organisms	Floodplain or coastal plain (?)



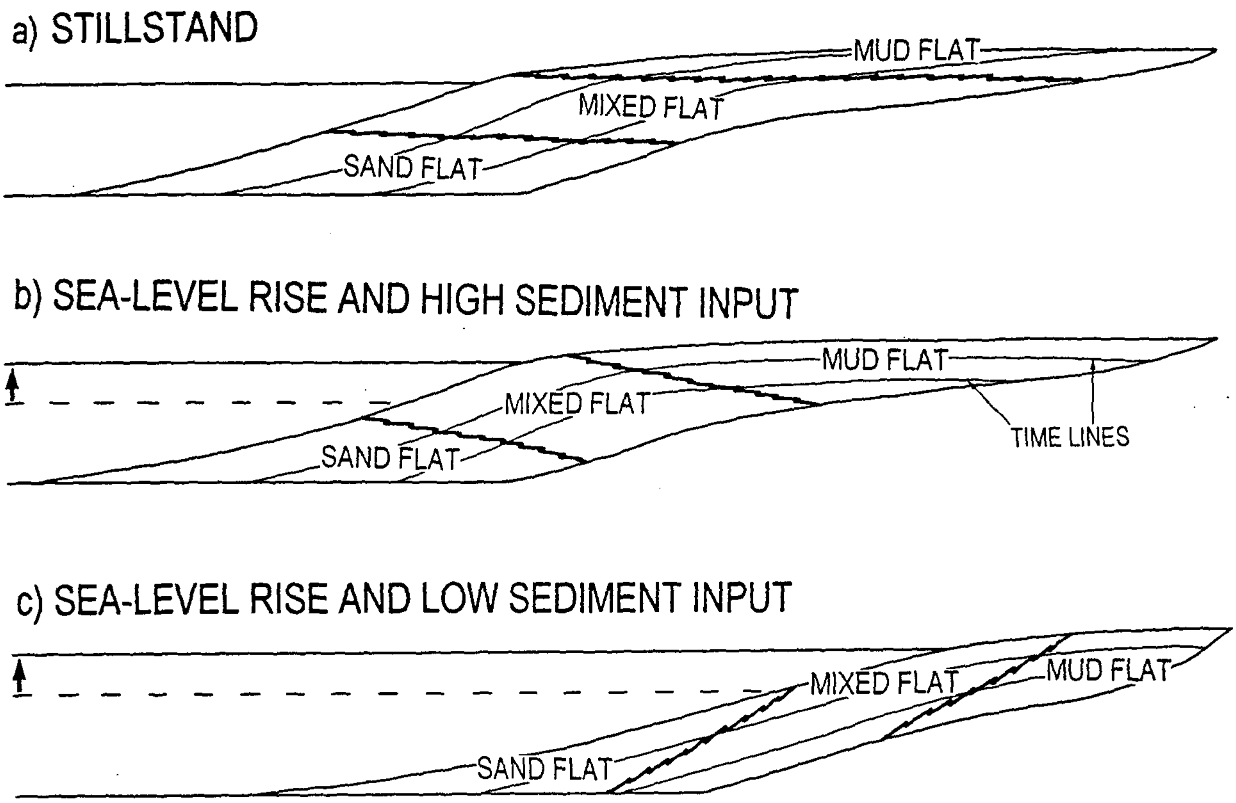


Fig. 4. Schematic cross sections showing evolution of tidal flat sequence of progradation during stillstand (a) or sea-level rise and high sediment input (b) and retrogradation during sea-level rise and low sediment input (c).

SEQUENCE STRATIGRAPHIC IMPLICATIONS

Parasequences are generally characterized by progradational and upward-shoaling associations of sedimentary facies, bounded by marine flooding surfaces representing abrupt increase in water depth (Van Wagoner *et al.*, 1990). Minor submarine erosion or nondeposition is accompanied by deepening, and a new stratum starts to prograde basinward. The retrogradational deposits (Units I, II and III in ascending order) in Gomso Bay, however, represent transgressive phase within a parasequence. Actual deposition has occurred during the increase in water depth. The retrogradational facies change may have resulted from a gradual sea-level rise without abrupt change and comprises retrogradational set of thin and undetectable higher order parasequences. A significant hiatus is present between Unit O (oxidized mud) and Unit I (marine mud). 14C ages of the topmost part of Unit O and the bottommost part of Unit I are 13,840110 yr BP and 3,620110 yr BP, respectively. This unconformable boundary can be regarded as the transgressive surface of erosion (TSE), which is a synchronous boundary of the first significant marine flooding, distinguishing the lowstand systems tract from the transgressive systems tract (Van Wagoner *et al.*, 1990). In coastal settings, it may be recognized as updip-migrating bayline position where little or no aggradation of lowstand facies has formed during transgression (e.g., Allen & Posamentier, 1993).

CONCLUSIONS

Vibracores from the tidal flats in Gomso Bay show that the Holocene intertidal deposits unconformably overlie the pre-Holocene semi-consolidated, oxidized mud (Unit O) in a retrograding, coarsening-upward sequence. The sequence consists of three units; (1) basal Unit I (intensely bioturbated silt occasionally with remnant subparallel laminae); (2) intermediate Unit II (highly bioturbated, partly laminated sandy silt or silty sand); and (3) topmost Unit III (slightly to moderately bioturbated fine sands with abundant parallel- to cross-laminae). Units I, II, and III can be interpreted as a result of tidal sedimentation on mud, mixed, and sand flats, respectively.

The retrograding, coarsening-upward sequence of the Gomso intertidal deposits resulted largely from low sedimentation rate, in contrast to other prograding, fining-upward tidal flats, such as those on the North Sea and Bay of Fundy. Based on radiocarbon dates and characteristics of each unit (texture, sedimentary structures, color, consolidation, bioturbation type and fossil etc.), the unconformable boundary between Units O and I can be regarded as the transgressive surface of erosion (TSE) formed during Holocene transgression. The Holocene Gomso deposits on the transgressive surface represent retrograding transgressive phase within a parasequence.

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