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Controls of Storms and Typhoons on Chenier Formation in Komso Bay, Western Korea

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ABSTRACT

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The high tidal flat of Komso Bay shows a typical chenier or shelly sand ridge, about 860 m long, 30–60 m wide, and up to 1.8 m high. Vertical sections of trenches across the chenier show gently landward-dipping interbeds of coarse to medium-grained shelly sands. Based on aerial photographs taken for the period of 1967–1989, sand shoals on the tidal mudflat migrated landward to form the chenier. Typhoon Ted in 1992, entering the southeastern Yellow Sea, forced the chenier to migrate further inland, resulting in a displacement of up to 11 m in a few days. Field measurements on the morphology of the chenier over a two-year period from 1990–1992 indicated that winter storms are chiefly responsible for the migration at a rate of 4–5 m per year. These facts suggest that strong waves and currents under the conditions of typhoons and/or storms have dominantly forced the chenier to migrate landward onto the muddy high tidal flat.

ADDITIONAL INDEX WORDS: *Tidal flat, southeastern Yellow Sea, sedimentology, macrotidal coast, typhoon Ted.*

INTRODUCTION

The Yellow Sea is a broad, tectonically stable basin which was submerged by the Holocene sea-level rise. Water depths in the Yellow Sea are throughout less than 110 m. In fact, the Yellow Sea is a semi-enclosed, depressed area of continental margin, and is, by definition, a true epicontinental sea. During the last low stand of sea level, the entire Yellow Sea floor was subaerially exposed (PARK, 1987). Sea level reached its present position about 3000 yr B.P. and has apparently been stable since that time.

Wind patterns in the Yellow Sea are monsoonal, with wind stress and swell direction essentially toward the north in summer. During the winter, however, storms are relatively common; winds and waves intensify and are directed toward the south. Furthermore, the Korea Coastal Current (KCC) seems to flow southward along the southeastern margin of the Yellow Sea basin and becomes stronger in winter. Semidiurnal tides in the Yellow Sea range from 1.7 m to 9.3 m.

The west coast of Korea, a riasic coast bordering the eastern Yellow Sea, shows very high tidal ranges (up to 10.5 m at spring tide) and has extensive development of tidal flats. Such tidal flats receive siliciclastic sandy and muddy sediments, locally as much as 18 to 23 m thick, generally showing a seaward-coarsening trend from high-tidal fine mud to subtidal coarse sand. Most Korean western tidal flats flank open coasts, compared with the sandier, barred North Sea tidal flats (WELLS *et al.*, 1990; ALEXANDER *et al.*, 1991).

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In the Komso Bay, far south from the Keum River (the largest river in the adjacent coastal areas), a prominent and characteristic shelly sand ridge is present on the muddy uppermost intertidal flat, that is, on the upper muddy high tidal flat (Figure 1). The shelly sand ridge consists dominantly of clastic shells and sands in an arcuate and branching shape and rests discordantly on the muddy tidal flat. This ridge in the Komso-Bay tidal flat resembles the "chenier", sedimentologically and geomorphologically, that have long time been investigated in many other coastal flats worldwide (COOK and POLACH, 1973; OTVOS and PRICE, 1979; AUGUSTINUS, 1980; WOODROFFE *et al.*, 1983). In fact, the Komso Bay shelly ridge is small in size and isolated compared with the well-known, worldwide cheniers.

Such cheniers, first studied in coastal regions of southwestern Louisiana, were interpreted to be formed by rhythmic changes in sediment supply and deposition from the nearby point source by river, i.e., the Mississippi River (GOULD and MORGAN, 1962). Subsequently, many other causal factors for chenier origin have been suggested including various dynamic coastal processes (COOK and POLACH, 1973), availability of coarse shells (GREENSMITH and TUCKER, 1969), and sea-level changes (TODD, 1968).

The primary purposes of this study is to understand the characteristic sedimentology of the chenier on the high tidal flat environment of Komso Bay, and to interpret the possible dynamic controls responsible for chenier formation and movement under the regime of macrotidal and monsoonal-climate of the southeastern Yellow Sea, i.e., the southwestern coast of Korea.

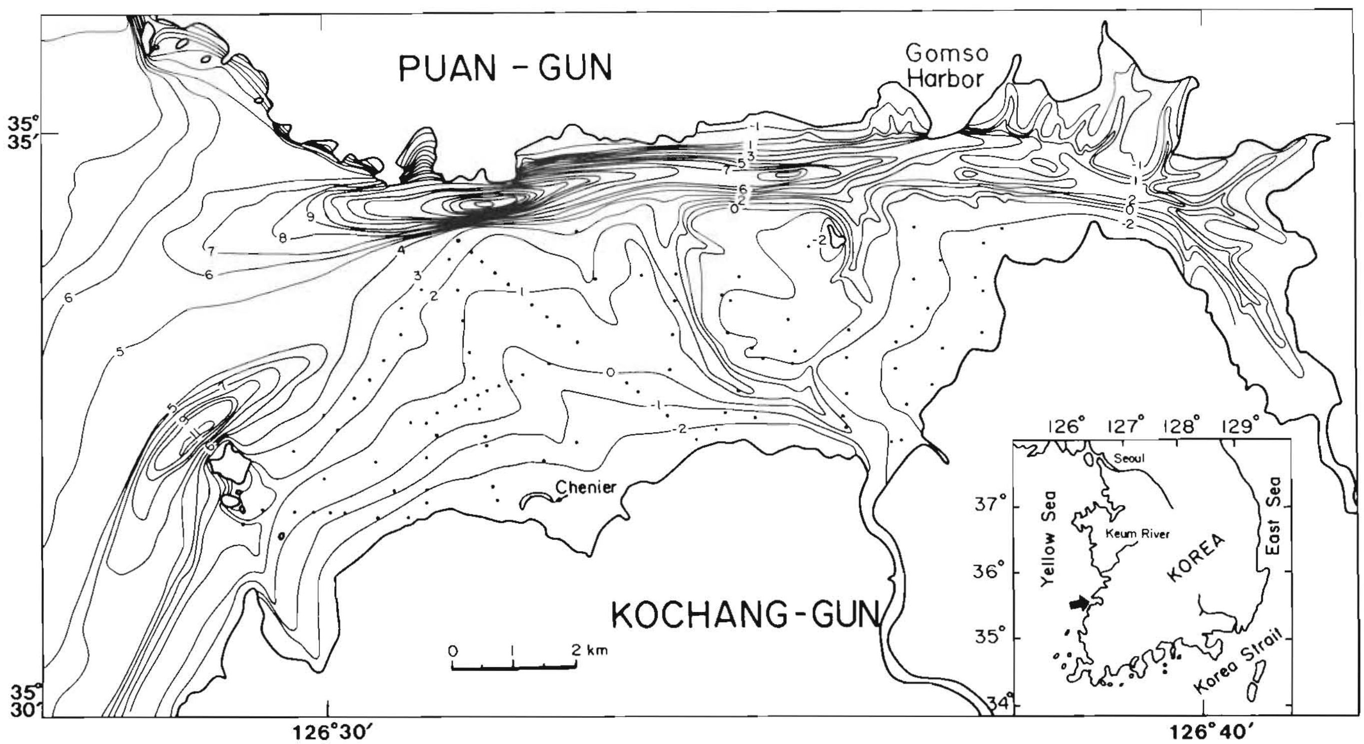

Fig. 1. Location map of Komso Bay showing surface-sediment sampling stations (dots) and bathymetry.

GENERAL HYDROGRAPHIC AND METEOROLOGICAL SETTING

The Komso Bay is a relatively funnel-shaped embayment, 6–9 km wide at its mouth and 19 km in length. A major deep tidal channel (up to 1.5 m deep and 920 m wide at low tides) dominates the bay, runs parallel to the rocky northern coast and connects to the extensive southern intertidal flat with tributary network of meandering tidal gullies (Figure 1). In fact, the tidal flat area is about 75 km^2 and the maximum width is about 4 km near the bay head mouth (Figure 1). Most of the supratidal region of the tidal flat was reclaimed and salt marsh is rare.

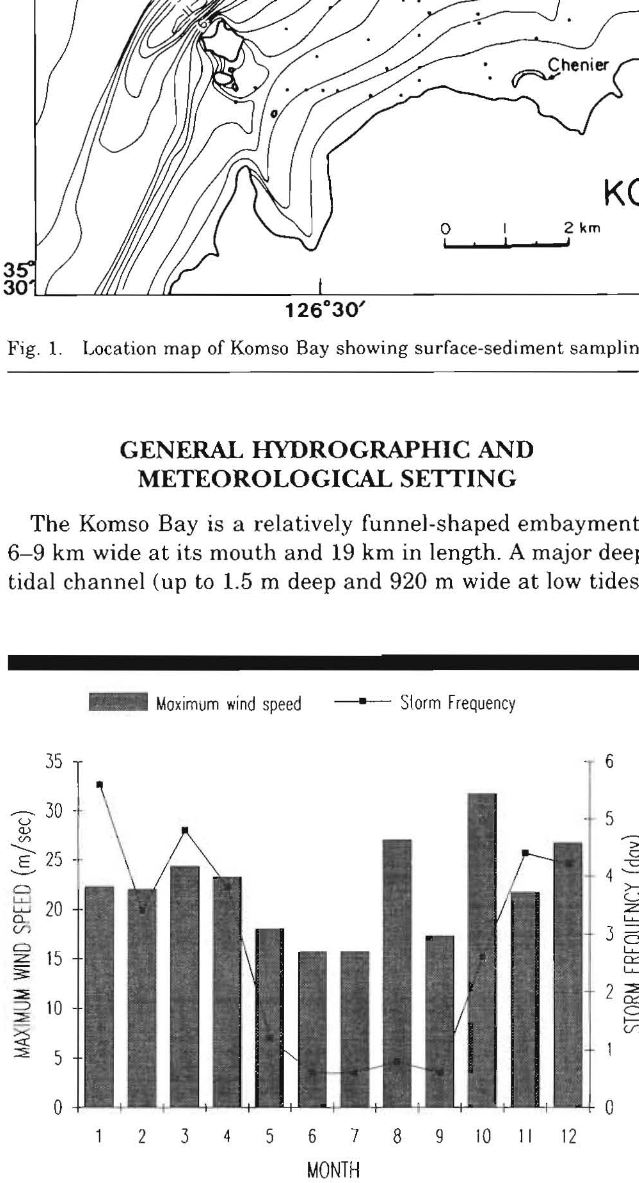

Fig. 2. Average frequency of storm days and maximum wind speed *versus* month during the period of 1976–1980.

Tides are semidiurnal, with a mean tidal range of 4.34 m (neap tide, 2.78 m; spring tide, 5.90 m; National Geographic Institute, 1981). Maximum tidal current in the main tidal channel reaches up to 1.50 m/sec in ebb and 1.15 m/sec in flood. Monsoonal dry winds are dominantly from the northwest (annual mean-velocity, 4.5 m/sec; KOREA METEOROLOGICAL ADMINISTRATION, 1991) and stronger than 20 m/sec winds prevail during the winter (from November to March). Winter waves more than 2 m high are frequent, whereas summer waves are less than 1.2 m high in general (MINISTRY OF AGRICULTURE AND FISHERY, 1989). Almost every year several typhoons influence southern Korea (South Sea of Korea); whereas, once every year or two, a typhoon hits the Yellow Sea coast of Korea during the summer season (July–October). The maximum wind speed and frequency of storm days per each month over the year during the period of 1976–1980 were analyzed from the meteorological data of the Kunsan station (Figure 2).

Figure 2 shows that the maximum wind speed over 22.5 m/sec are dominantly recorded in November–March and the maximum wind speeds about 16 m/sec are observed in June–

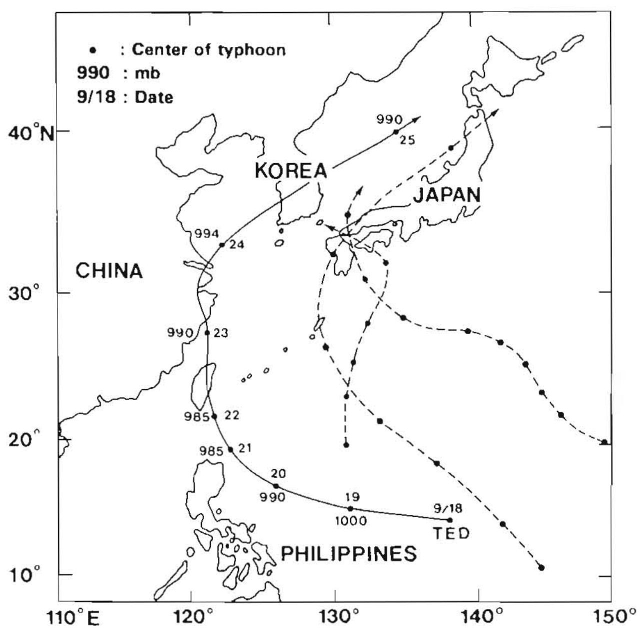

Fig. 3. Tracks of typhoon center in 1992.

Table 1. *Monthly typhoon frequency in Korea during 1967, 1976 and 1989.*

Year	Frequency of Typhoon			Total
	Jul	Aug	Sep	
1967	1 (1)			1 (1)*
1968	1	1	1	3 (0)
1969			1	1 (0)
1970	2 (1)	2		4 (1)
1971		2 (1)	1 (1)	3 (2)
1972	2 (1)	1 (1)	1	4 (2)
1973	2 (2)	1 (1)		3 (3)
1974	2 (1)	1 (1)	1	4 (2)
1975	1 (1)	1		2 (0)
1976	3	2 (2)	1	5 (2)
1977		1	1	2 (1)
1978		2	1 (1)	3 (1)
1979		2 (1)		2 (1)
1980	1 (1)	1 (1)	1	2 (2)
1981	1 (1)		2 (1)	3 (2)
1982		3	1 (1)	4 (1)
1983			1	1 (0)
Annual av.	0.7 (0.5)	1.2 (0.5)	0.8 (0.2)	2.7 (1.2)

*Frequency of typhoon affecting western Korea

August; whereas, very high maximum wind speeds over 25 m/sec are recorded in October and December. The frequency curve of storm days, defined as having a maximum wind speed over 13.9 m/sec, shows that more than 3 days per month in winter (November–March) are recorded, as compared to less than 1 day per month in summer (June–September).

Figure 3 shows typhoon origins and their center with time and routes in the summer of 1992. The route of a typhoon (TED) entering the Yellow Sea during September 18–25 is shown in Figure 3. Waves associated with such-typhoons were very rough, 3–4 m and 4–5.5 m in height near the Komso Bay in the typhoon of Cecil in 1982 and Vera in 1985, respectively (MINISTRY OF AGRICULTURE AND FISHERY, 1989).

Table 1, describing the analyzed data of typhoon routes and occurrences (1967–1983), indicates that on average one typhoon per year will affect western Korea, whereas routes to the south are more frequent.

CHENIER MORPHOLOGY AND INTERNAL STRUCTURES

Surficial distribution of 5 sediment types (sand, silty sand, sandy silt, silt and gravelly sand) on the Komso tidal flat shows that coarser sediments are dominant on the low tidal flat; finer sediments are on the high tidal flat in general. In fact, sandy silt and silt are mainly distributed on the mid to upper high flat including silty salt marsh behind the shelly ridge; muddy sediments prevail also on the bottom of tidal creeks (Figure 4).

The chenier lies relatively parallel to shore, which is uppermost high flat dominated by silty clay and salt marsh plants (*Suaeda* and *Salicornia*). The particle size analysis of the chenier shows gravel and sand particle modes in unimodal and/or bimodal patterns (Figure 5). Major mineral compositions of sand-sized materials from chenier crest part are K-feldspar (44%), plagioclase (5%), quartz (23%) and rock fragments (26%) as shown in Table 2. Gravel-sized shells of the chenier are dominantly intertidal species such as *Crassostrea gigas* (89%), *Umbonium thomasi* (2%), *Omphalium rusticus, Himia festiva, Tapes phillippinarum* and *Meretrex petechiails* (less 6–8%). In fact, oysters (*Crassotrea gigas*) are major components of the gravel-sized materials accounting for 90% of the total shells. The chenier is about 860 m long and 30–60 m wide, and its elevation is up to 1.8 m (Figure 6). The outline of western part chenier is relatively wider and about 1.2 m lower in height than the eastern part (Fig. 6). A branch part about 150 m long stretches out toward the shore at the boundary between the western and eastern part (Figure 6).

The chenier location is on the uppermost high tidal flat at approximately mean high water level (MHWL), and the upper crest of the eastern part is slightly above mean spring tide level. Accordingly, some chenier crest remains subaerially exposed during a normal mean high tide period and is mostly colonized by salt marsh plants. As shown in Figure 6, the chenier shows a sharp and horizontal contact with the upper part of the underlying high tidal flat. The characteristic internal structures of the chenier show regularly interbedded shell and coarse sand layers that dip landward gently (Figure 6).

CHENIER MIGRATION

The dominant migration features of the chenier in the one year period of 1991–1992 due to various weather conditions are characteristic as shown in Table 3.

It is seen that throughout the year (1991–1992), the west-

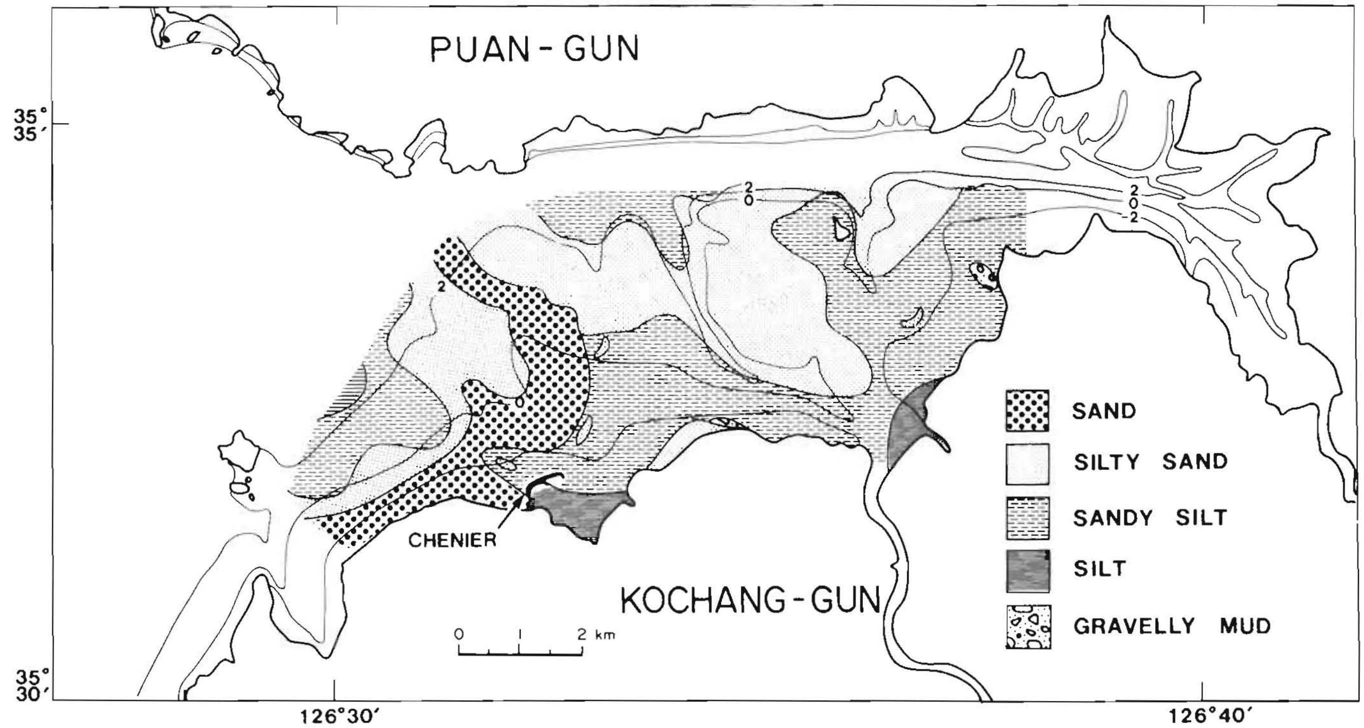

Fig. 4. Surface-sediment distributions of the Komso-Bay tidal flat.

ern part of the chenier migrated landward 4.0 m in 214 days, i.e. at a rate of about 1.8 cm per day; the eastern part did not migrate. The reason for such a difference is considered due to the position relative to the mean high water level, the eastern part of the chenier is generally above the mean high water level during the stormy winter days (119 days) and it does not move; the western part did migrate at a rate of 3.2 cm per day (3.8 m migration in 119 days). Plausible mechanisms for the chenier movement in the Komso tidal flat are washover, swash and alongshore processes. In particular, a large migration of both eastern and western parts of the chenier occurred in a few days (about 3–4 days), when typhoon Ted hit the western coastal zone of Korea in September 1992. Typhoon Ted washed over the entire chenier (western and eastern parts) and forced the chenier to move 6–11 m landward. Such relatively sudden movements in 3–4 days exceed the gradual annual movements measured over 119 or 251 days (Table 3).

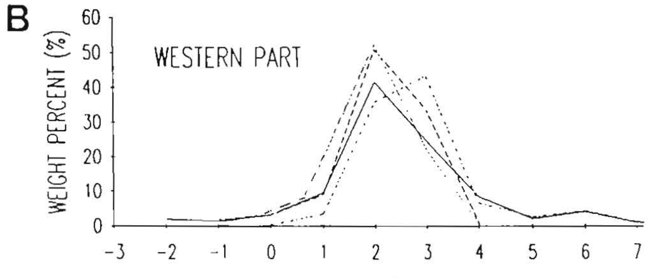

Fig. 5. Size-frequency distributions of chenier sediments.

Long-term movements of the chenier over about 23 years (1967–1989) can be examined from aerial photography (Figure 7). In 1967, the chenier existed as two different bodies, and by 1976 the two parts had both migrated landward and also become closer to one another. By 1983, the two parts

Table 2. *Mineral compositions of the sand-size sediments from chenier crest parts.*

	St. 1	St. 2	St. 3	St. 4	Mean (%)
Quartz	18.6	22.8	26.3	23.6	22.8
K-feldspar	47.1	45.0	41.9	42.5	12.0
Plagioclase	5.1	5.5	5.5	4.1	5.1
Mica	0.3	1.0	0.3	0.0	0.4
Rock fragments	28.9	24.1	23.4	27.0	25.9

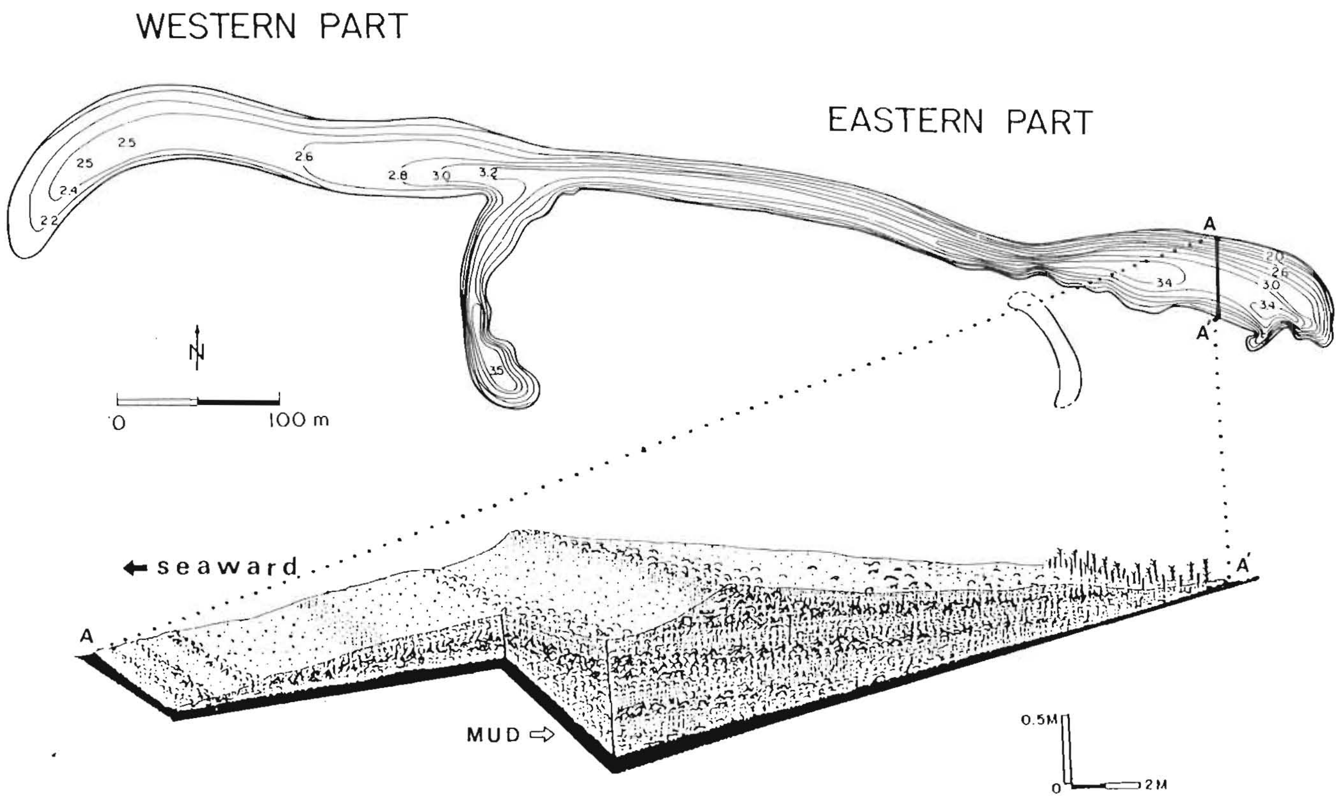

Fig. 6. Detailed morphology of chenier showing contour line in meters above mean sea level and its internal bedding structure of chenier illustrating gently landward dipping interbeds of shell and sand. Note a trench section (A-A') in the eastern part of chenier.

joined finally to form the present outline of the chenier at the present location. Accordingly, the total migrated distance is about 400 m and 150 m for the western and eastern parts of the chenier, respectively.

As shown in Table 3, the yearly total movement due to fair weather, storm and typhoon are 15 m for the western part and 11 m for the eastern section. If these data are considered to be an average value, the total migration distance over 23 years (1967–1989) would be about 300 m and 200 m, respectively. These data seem to be in good agreement with the estimated values from aerial photography.

ROLE OF STORMS AND TYPHOONS

It is not difficult to understand that waves under summer fair-weather, winter storm-weather and typhoon conditions have a different role for chenier formation and migration in the Komso Bay. In particular, the significant role of storm and typhoon for chenier migration is well recognized based on the two-year careful field measurement data (Table 3). The western part of the chenier, which is below the mean high water level throughout the year, did migrate landward 3.8 m for 119 days under stormy winter season and also the western chenier moved 6.3 m for only 3 days during typhoon Ted. Furthermore, typhoon Ted moved the eastern part of the chenier almost 11 m landward. YAN *et al.* (1989) also reported that the cheniers in the Yangtze River deltaic coastal plains might be controlled by typhoons. Strong waves due to typhoon Ted washed over both the eastern and western parts of the chenier and caused the entire chenier to move 6.3 m (eastern part) and 10.9 m (western part), respectively. Accordingly, when the role of summer fair-weather waves for 214 days in 1992 (Table 3) is considered, the role of storms and typhoons affecting chenier formation and movement seem to be more significant than the longer fair-weather season.

Table 3. *Migration distance of the eastern and western part of chenier in different climate regimes.*

Weather Condition	Measurement Period	Number Days	Migration Eastern	Migration Western
Fair Weather	20 Feb. 1992–20 Sept. 1992	214	0 m	4.0 m
Storm	25 Oct. 1992–20 Feb. 1992	119	0 m	3.8 m
Typhoon	20 Sept. 1992–25 Sept. 1992	3	10.9 m	6.3 m

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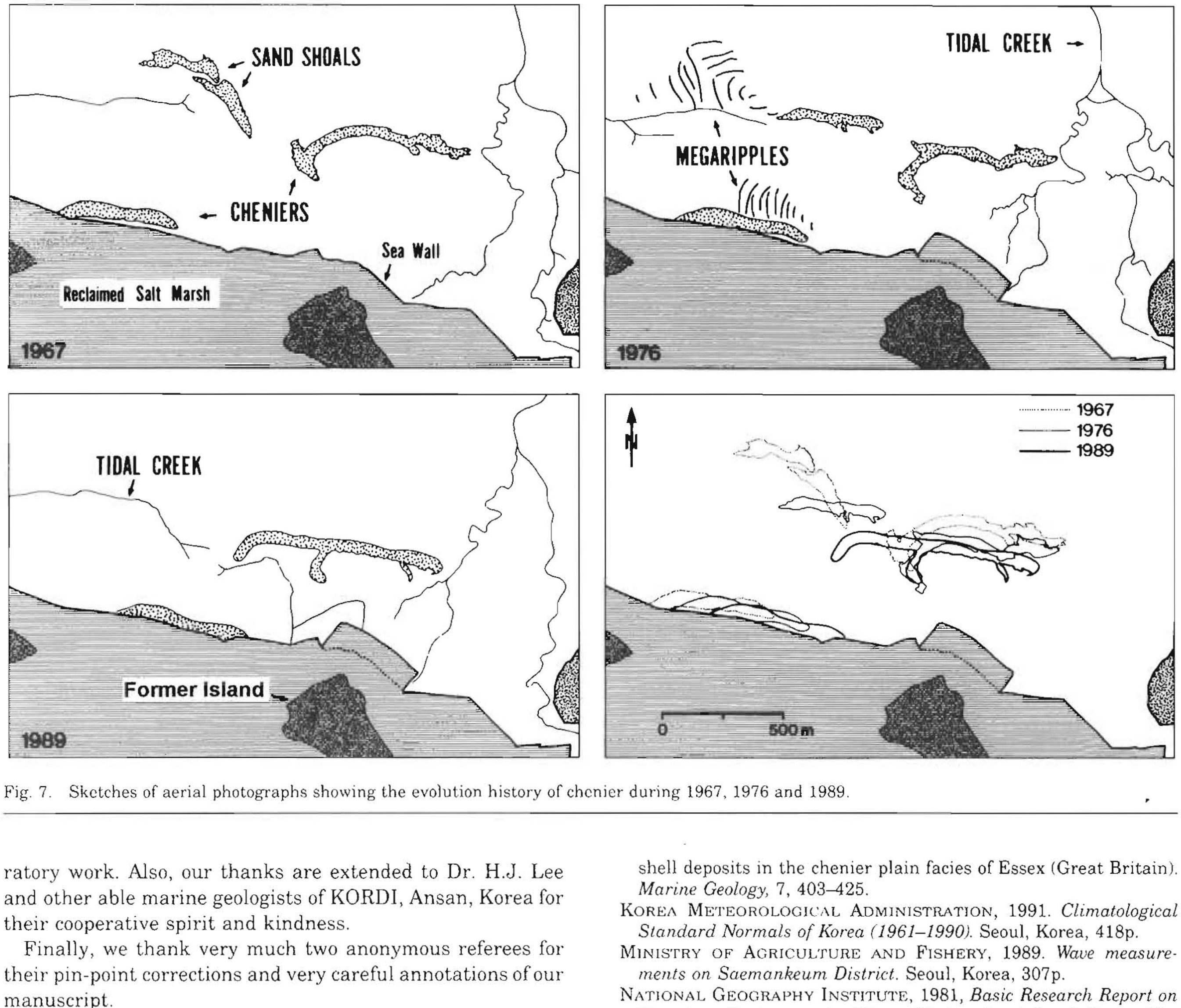

Fig. 7. Sketches of aerial photographs showing the evolution history of chenier during 1967, 1976 and 1989.

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