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Sea Level Fluctuation in the Yellow Sea Basin

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황해 분지의 해수면 변동

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A series of radiocarbon dating from intertidal, subtidal, and inner continental shelf deposits investigated along the west coast of Korea as well as from its offshore sea floor (namely, the eastern Yellow Sea Basin) show (1) the Holocene sea level rise, i.e., the eustatic sea-level history during the oxygen isotope stage 1, and (2) pre-Holocene sea-level fluctuations during the oxygen isotope stages 2 and 3.

Marine geophysical investigations in the Yellow Sea reported a possible development of desert and loess deposits due to desertization under the cold and dry climate during the Last Glacial Maximum. The Kanweoldo deposit overlain unconformably by the Holocene intertidal deposits, which is mainly exposed along the tidal channels and intertidal flats in the Cheonsu Bay, the west coast of Korea, shows the characteristic cryogenic structure (cryoturbation). Such cryoturbation structure of the Kanweoldo deposit appears to indicate the cold and dry climate under the eustatic sea-level lowering during the Last Glacial Maximum. Up to now, for the first time in Korea, the possible paleoshoreline standing before and after of the pre-Holocene interstadial period (about 30000 y BP) is shggested and its shoreline curve is constructed.

한국 서해의 조수 퇴적층 (조간대와 조하대)과 내대륙붕 퇴적층의 퇴적상 연구에 따른 방사성 탄소(^{14}C)의 연령측정에 기초하여, 현세 (Holocene)의 해수면 상승과 선현세(Pre-Holocene)해수면 변동의 사실을 규명하였다. 또한 황해 해저 퇴적층의 지구물리적 탐사(탄성파 탐사)에 의하여, 지난 최대 빙하 발달 시기 (Glacial Maximum)동안의 건조 한냉한 기후하에서 형성된 사막 사구층과 풍성 황토층의 존재를 제안하였다. 황해 천수만 조수 퇴적층 (조간대)에 의하여 부정합적으로 피복되고 있는 간월도층은 한냉한 빙하기후에 의한 결빙구조 즉, 특수한 cryogenic structure를 가지며, 절대 연령이 (약 16900 yr BP)이다. 고군산도와 신시도의 연근해저 시추자료 (약 20~23 m의 시추길이)의 암상과 탄성파 자료를 분석하므로서 도출된 퇴적환경을 기초로 하여 협재된 토탄의 ^{14}C의 연령을 측정하였고 결과적으로 국내에서 처음으로 선현세의 interstadial (약 30000 yr BP)전후의 고해수면 상대위치(고해안선)를 제시하였다.

INTRODUCTION

The late Pleistocene Epoch refers to the period between the beginning of Last Interglacial Period and the end of the Wurm Glacial Period, covering about 120,000 years (130,000 to 10,000 yr BP). During this long period, the world climate has followed a periodic pattern with glacial and interglacial

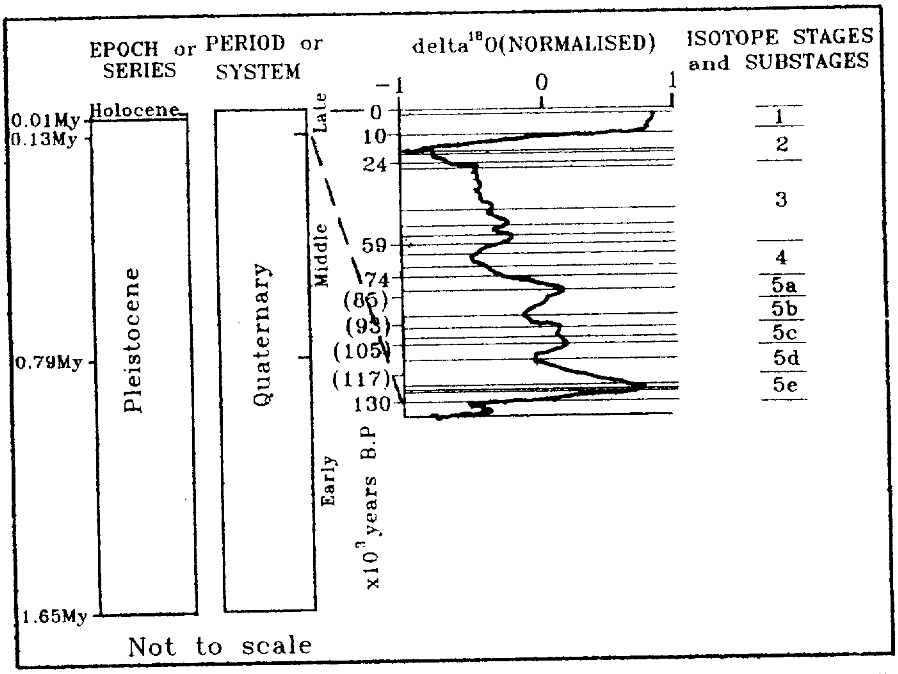

Fig. 1. The generalized time subdivisions of the Quaternary period. The Late Quaternary is additionally subdivided into oxygen isotope stages (after Martinson et al., 1987).

cycles. Measurements of $\delta^{18}O$ in pelagic foraminifera from deep-ocean cores (where the rate of sediment deposition is slow and reasonably uniform) exhibit cyclic variations with depth that Emiliani (1955) attributed to alternations between the glacial and the interglacial. These glacial-interglacial cycles correspond to the eustatic sea-level fluctuations, keeping up with the world temperature cycles. Fig. 1 (Martison et al., 1987) shows, in detail, the generalized time-divisions of the Quaternary period, in which the stable oxygen isotope stage in the late Quaternary exhibits the well-defined sea-level fluctuations. For example, odd numbers are interglacial period and even for glacial time, such as stage 1 for Holocene transgression and stage 2 for Last Glacial period.

It is generally understandable that the relative sea level is continuously changing elsewhere. Such relative sea-level variations are influenced by the combined function of the sea-level changes and land-level changes, that is, each of which is controlled by several different factors: the level of the sea affected by tectono-eustasy, glacial eustasy, geoidal eustasy, and dynamic sea surface changes, and the level of the land affected by tectonics, isotasy, geoidal deformations and compaction (Mörner, 1987; Scott et al., 1989). Therefore, the initial *a priori* assumption of the present study is that the regional eustatic curve proposed by Mörner (1987) can be used as a benchmark for comparison of sea-level records from different locations in the world. In other words, we need to understand the regional eustatic curves and should stay away from inter-regional and global correlation of eustatic curve.

This paper is an attempt to consolidate and interpret some of the earlier evidences, and to illustrate some of the most recently collected ^{14}C data, and to elucidate the evidence of climatic changes at the Last Glacial Maximum in the Yellow Sea Basin.

PREVIOUS WORKS

The Yellow Sea is a typical example of the epicontinental shelf lying adjacent to the Asian conti-

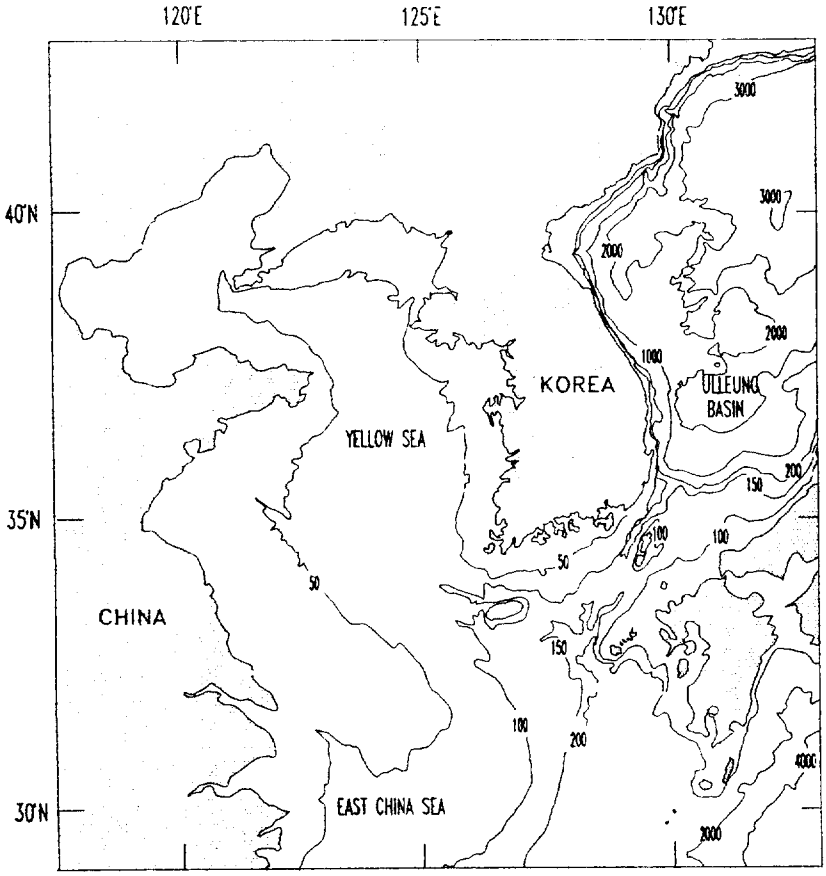

Fig. 2. Bathymetry of the Yellow Sea, East China Sea, and Cheju, Korea, and Tsushima Straits. The lowest stand of Holocene sea-level seems to be developed along the shelf edge and its outer continental shelf beyond 135 m water depth.

nent. It has a wide continental shelf and to the south of the continental shelf continues the Okinawa Trough that separates the Yellow Sea Basin from the Pacific (Fig. 2). Unlike the Japanese island-arc system, the Yellow Sea Basin has been tectonically stable on the basis of the old basin geology, even though the neotectonical activity has influenced the morphology of basin and depositional system in the Chinese part. For nearly two decades, numerous oceanographic investigations have been carried out to clarify (1) the sedimentologic characteristic of the continental shelf, and (2) the history of sea-level changes during the postglacial period in the Yellow Sea. The understanding of the Late Pleistocene-Holocene sea-level history has important implications for the distribution and the processes of sediments on the continental shelf, and the paleoceanographic and paleoclimatic records of the Yellow Sea Basin. In the geomorphological, sedimentological, and biological evidences indicative of the position of sea level, there are sometimes samples suitable for radiorcarbon datings, which provide a sound basis for the establishment of the sea-level curve. Like other studies in this investigation, radiocarbon analysis played an important role in the reconstruction of the late Quaternary sea-level history.

Since the pioneering study of sea-level history of Park (1969), it has been pointed that the Yellow Sea Basin is a good region for better understanding of sea-level changes during the late Quaternary and that the topic of sea-level history has

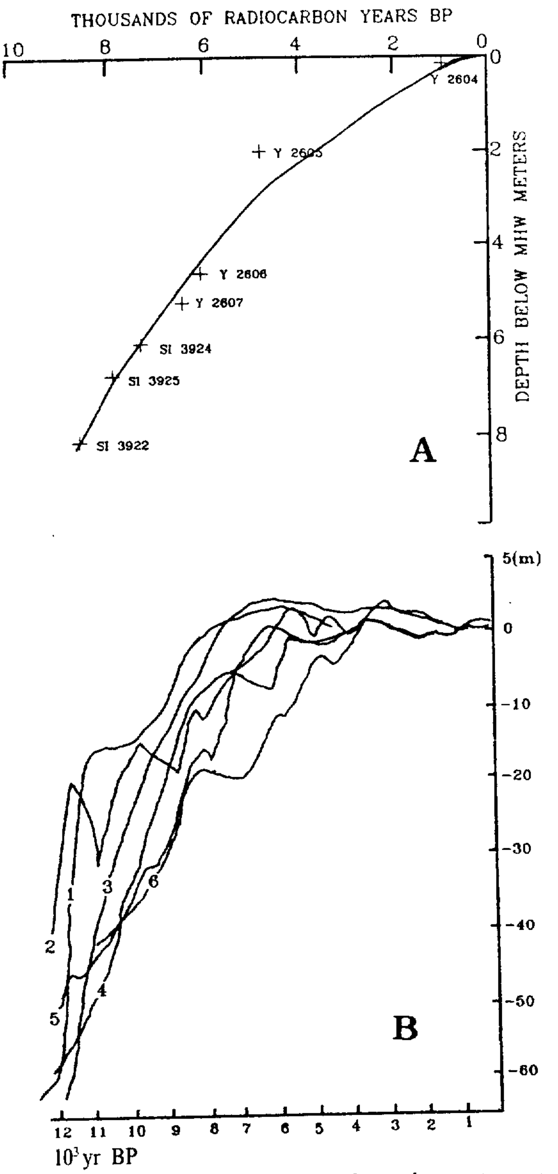

Fig. 3. Holocene sea-level curves along the west coast of Korea (a) and along the eastern coast of China (b) (after Bloom and Park, 1985 and Han and Meng, 1987). It is noted that the two different regions exhibit the history of sea-level rising during the Holocene transgression.

been one of the important research in the Yellow Sea. At that time, Park (1969) used the lithostratigraphic criteria of the tidal deposits and the radiocarbon (^{14}C) dating of peat materials along the west coast of Korea. During the two decades, the relative changes in sea level and the nature of environmental changes in the Yellow Sea margins over the last 20,000 radiocarbon years have been studied in some detail (Youn et al., 1977; Jo, 1980; Geng, 1982; Wang and Wang, 1982; Zhao et al., 1982; Park, 1983; Chen et al., 1985; Li et al., 1985; Li et al., 1987; Suk, 1989; Park, 1992). At the same time, the variations of the sea-level have been interpreted with the comparison to the lithostratigraphic, biostratigraphic, chronostratigraphic and archaeological data.

It is difficult to clearly define the Holocene sea-level history in the Yellow Sea Basin because of the difference between the published data (Fig. 3). Relative sea-level curve for the west coast of Korea, based on peat chronology, showed −8 m at 8600 yr BP, −2 m at 4800 yr BP, and 0 m at present (Fig. 3A); the sea level rose rapidly, at an average rate of about 1.6 mm/yr from 8600 yr BP to about 4800 yr BP and subsequently the rate decreased to about 0.4 mm/yr (Bloom and Park, 1985). On the other hands, Han and Meng (1987) reported about 12000 years ago the sea level was in the extent between −60 m and −40 m and about 8000 years ago the sea level was 5 m to 10 m lower than the present (Fig. 3B). Wang and Wang (1982) established the sea-level change in the East China Sea and suggested that the sea level stood at −100 m at 23000 yr BP, and −60 m at 11000 to 10000 yr BP. However, many scientists have suggested that the sea level of −145 m is the evidence of a maximum sea level lowering in the late Pleistocene time (Geng, 1982; Wang and Wang, 1982; Zhao et al., 1982; Park, 1983; Chen et al., 1985; Li et al., 1985; Suk, 1989; Park, 1992). It is also speculated that the lowest stand of Holocene sea level seems to be developed along the shelf edge and its outer continental shelf beyond 135 m water depth. Such the lowest stand of sea level might suggest the timing of the Last Glacial Maximum.

LATE QUATERNARY SEA-LEVEL HISTORY IN THE YELLOW SEA BASIN

The Last Interglacial Period started between

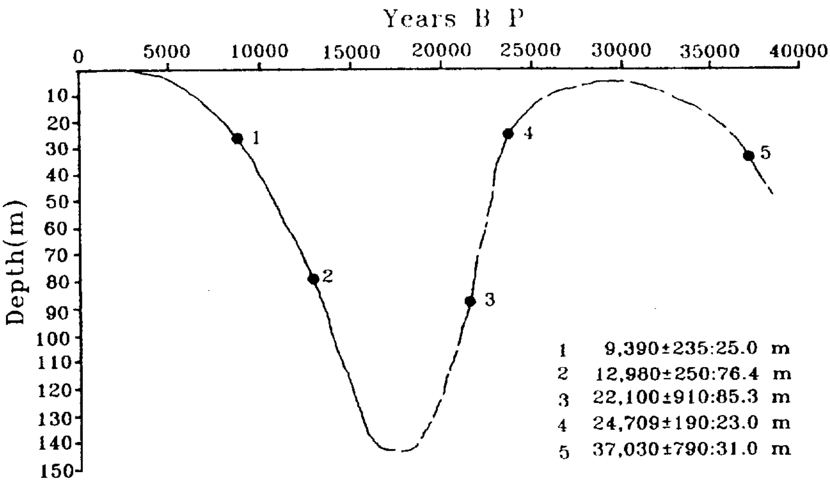

Fig. 4. Sea-level fluctuations in the southeastern Yellow Sea Basin of Korea during the late Quaternary. Note the reference level (mean high water level).

130000 and 120000 yr BP. This period reflected the existence of higher sea level on the basis of the dating of marine terraces in the Barbados island and Huon Peninsula, Papua New Guinea (Bloom et al., 1974). Emery et al. (1971) reported that the sea level was around −140 m with the age of 40000 yr BP in the southeastern coast of the Korean Peninsula. At the time of the Early Wurm Culmination Period (40000 yr BP), the sea level in the Yellow Sea Basin might have once lowered −100 m or more, the paleocoastline retreated to the Cheju Strait, and entered the outer shelf of the East China Sea, basically corresponding to 100 m isobaths (Geng, 1982).

It was generally known that at 38000 yr BP the sea level began to rise again. The ^{14}C datings of peat samples (taken from the offshore of the Keum River mouth) in the Yellow Sea revealed that the sea level had risen up to −31 m by about 37000 yr BP (Fig. 4), which corresponds to the depth-corrected Chinese data. The rising trend of the sea level indicated the termination of the Early Wurm Period. In the middle of isotope stage 3 (about 30000 yr BP), the sea level might have come up to the highest point in the Yellow Sea, since which the sea level went down again.

From about 25000 yr BP the sea level began to lower down abruptly until 20000 yr BP. The paleocoastline retreated farther to the outer shelf from −23.0 m of 23800 yr BP to −85.3 m of 22100 yr BP (Fig. 4). According to Chinese data, the lowering trend of sea level is similar to this study even though they have a little deeper depth on the same time. However, the maximum of Late Wurm Period, i.e., Last Glacial Maximum, may result in the similar lowest position of the sea level in the Yellow Sea Basin.

The lowest stand of sea level at the Last Glacial Maximum has been studied on the basis of submerged geological and geomorphological features or of the buried peat in the continental shelf. According to the present bathymetric pattern in the Yellow Sea, we can say that the minimum sea level was about −145 m that is the possible maximum limit value of the Late Wurm Glacial Period, i.e., Last Glacial Maximum. This is fully identical with the result obtained by Park et al. (1987) that the lowest stand of sea level was described by the geomorphological, sedimentological, and biological indicative features along the continental margin of the eastern and southeastern coasts of Korea. Around the Japanese islands, the age of the lowest sea level also falls between 20000 and 17000 yr BP, with the estimated depth of about −140 m (Kaizuka et al., 1977).

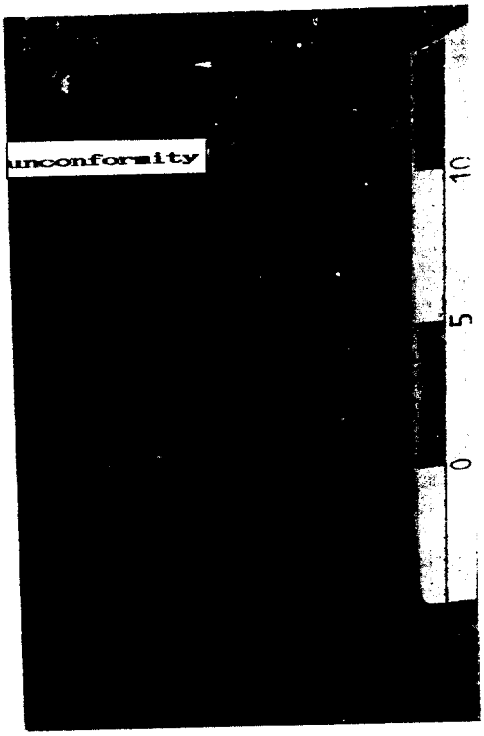

Fig. 5. The pre-Holocene Kanweoldo deposit overlain by the Holocene intertidal deposit. The underlying Kanweoldo deposit preserved a lot of cryogenic structure (cryoturbation) that indicated the cold and dry climate during the Last Glacial Maximum.

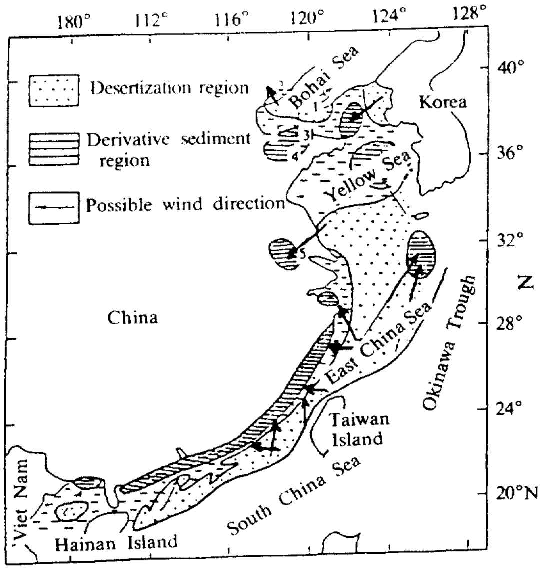

Fig. 6. Schematic appearance of the Yellow Sea and East China Sea during the Last Glacial Maximum (oxygen isotope stage 2) (after Zhao, 1990). Most of the exposed Yellow Sea shelf was desertized by the intensified wind processes under the cold and dry condition.

LATE QUATERNARY CLIMATE IN THE YELLOW SEA BASIN

The study of sea-level fluctuations has been considered as core to the understanding of climatic changes. Due to the Yellow Sea continental shelf exposed mostly between 60000 and 35000 yr BP, the sea floor was dried, weathered and oxidated. The Early Wurm glacial stage (55000 yr BP) with lowering sea level was correlated with the coldest period around Japan, as shown the subsequent development of glacial cirques on the Japanese Alps (Fujii and Naruse, 1982). Oxygen isotope analyses of benthic foraminifera in the deep Pacific Ocean (V19-3) show that the global climate cooled rapidly to about 0℃, and then cooled more slowly to the coldest value of about −1℃ at 40000 yr BP.

During the Last Glacial Maximum (18000 yr BP), the paleocoastline receded to the outer shelf of the Yellow Sea, connecting to the Chinese mainland with the Korean Peninsula as the Yellow Sea shelf was emerged and completely drained. During such period, the climate condition of the Korea became undoubtedly drier, colder, and more continental than the present. Winters were probably much more severe than the present time. Some of the pre-Holocene intertidal deposits before the Last Glacial Maximum have been reported in the west coast of Korea. It is the Kanweoldo deposit exposed along the tidal channel and intertidal flat that is overlain unconformably by the Holocene intertidal deposits (Fig. 5). Characteristically, this pre-Holocene Kanweoldo deposit well preserved the cryogenic structure (cryoturbation), a kind of periglacial structures that are produced under the cold and dry climate with almost freezing temperature (Butrym et al., 1964). It is one of good evidence that the Kanweoldo deposit experienced and indicated the cold and dry climate of the Last Glacial Maximum.

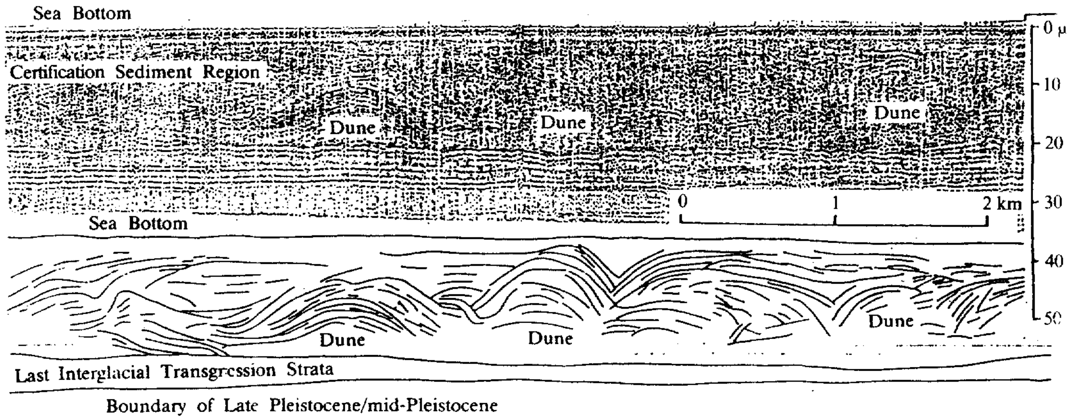

Fig. 7. Seismic stratigraphy and interpretation of the buried dune groups near "ancient wind gap" of the Yellow Sea Trough (34°45'N 123°45'E) (after Zhao, 1990).

In the cold climate condition of the Last Glacial Maximum, the average annual temperature of the whole globe was 6℃ lower than at present (Emiliani, 1966). Faunal fossil derived from the Yellow Sea shelf also reflected the cold climate such as typical microbiological fossil 'Buccella frigida (Geng, 192). With sharp temperature drop in that period, the Mongolian High Pressure became much stronger, leading to the particular monsoon climate in Eastern Asia. Under the Monglolian High Pressure, the cold and dry air flowed dominantly. Furthermore, the exposed Yellow Sea shelf at that time was the marginal place of the desert belt in the middle Asia (Fig. 6). Due to the degenerated drainage systems under cold climatic condition and the dominant wind process, the exposed shelf areas of loose sediments with sparse plants were subject to strong deflation, thus turned to be desertized. Marine geophysical investigations reported that a possible desert and loess deposits as buried dunes were developed due to desertization under cold and dry climate during the Last Glacial Maximum (Fig. 7). Zhao (1990) called these desert deposits and their derivative sediments as "residual sediments" in the Yellow Sea continental shelf during the last stage of late Pleistocene.

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REFERENCES

Bloom, A. L., W. S. Broecker, J. M. A. Chappell, R. K. Matthews, and K. J. Mesolella, 1974. Quaternary sea level fluctuations on a tectonic crust-new $^{230}Th/^{234}U$ dates from the Huon Peninsula, New Guinea. Quat. Res., **4**: 185-205.

Bloom, A. L. and Y. A. Park, 1985. Holocene sea-level history and tectonic movements, Republic of Korea. Quat. Res. (Japan), **24**: 77-84.

Butrym, J., J. Cegla, S. Dzulynski, and S. Nakonieczny, 1964. New interpretation of "Periglacial Structures". Folia Quat., **17**: 1-34.

Chen, Y., G. Peng, and W. Jiao, 1985. Radiocarbon dates from the East China Sea and their geologic informations. Quat. Res., **24**: 197-203.

Emery, K. O., H. Niino, and B. Sullivan, 1971. Post-Pleistocene sea level of East China Sea. in The Late Cenozoic Glacial Age edited by K. K. Turekian, Yale University Press, New Haven, pp. 380-390.

Emiliani, C., 1955. Pleistocene temperature. J. Geology,

63: 538-578.

Emiliani, C., 1966. Paleotemperature analysis of Caribbean core P6304-8 and P6304-9 and a generalized temperature curve for the past 425000 years. J. Geology, **74**, 109-126.

Fujii, S. and N. Naruse, 1982. Postglacial sea-level changes in the Hokuniku region, Central Japan. Quat. Res. (Japan), **21**, 183-193. (in Japanese with English abstract)Geng, X., 1982. Transgressions and regressions in the eastern China since the Late Pleistocene Epoch. Acta Ocean Sinica, **1**, 234-247.

Han, Y. and G. Meng, 1987. On the sea-level changes along the eastern coast of China during the past 12000 years. in Late Quaternary Sea-level Changes edited by Y. Qin and S. Zhao, China Ocean Press, pp. 119-136.

Jo, W.R., 1980. Holocene sea level changes on the east coast of Korean Peninsula. Geogr. Rev. Japan, **53**, 317-328. (in Japanese with English abstract).

Kaizuka, S., Y. Naruse, and I. Matsuda, 1977. Peat formations and their basal topography in and around Tokyo Bay, Central Japan. Quat. Res. (Japan), **8**: 32-50.

Li, C., G. Chen, and G. Xu, 1987. Sea-level changes in coastal zones of China since late Quaternary, in Late Quaternary Sea-level Changes edited by Y. Qin and S. Zhao, China Ocean Press, pp. 97-108.

Li, C., P. Li, and L. Wang, 1985. Postglacial transgressive-regressive sequences in coastal and deltaic areas in East China Sea. in A Collection of Oceanographic Papers from China edited by L. Yuru, China Ocean Press, pp. 105-114.

Martinson, D.G., N.G. Pisias, J.D. Hayes, J. Imbrie, T. C. Moore, Jr., and N.J. Shackleton, 1987. Age dating and the orbital theory of the ice ages-Development of a high-resolution 0 to 300000 years chronostratigraphy. Quat. Res., **27**, 1-29.

Mörner, N.A., 1987. Models of global sea-level changes. in Sea-level Changes edited by M.J. Tooley and I. Shennan, Oxford, Basil Blackwell Ltd., pp. 322-355.

Park, Y.A., 1969. Submergence of the Yellow Sea coast of Korea and stratigraphy of the Sinpyeongcheon Marsh, Kimje, Korea. J. Geol. Soc. Korea, **5**: 57-66.

Park, Y.A., 1992. The changes of sea level and climate during the Late Pleistocene and Holocene in the Yellow Sea region. The Korean J. Quat. Res., **6**: 13-20.

Park, Y.A., 1983. The nature of Holocene sedimentation and sedimentary facies on the continental shelves of Korea. in Proc. '83 Summer Conference for Domestic and Foreign Scholar of Science and Technology, Seoul, Korea. pp. 72-80.

Park, Y.A., C.S. Lee, and Y.I. Song, 1987. The lowest stand of the Holocene sea-level along the continental margin off the eastern and southeastern coasts of Korea. in Late Quaternary Sea-level Changes edited by Y. Qin and S. Zhao, China Ocean Press, pp. 239-251.

Scott, D.B., P.A. Pirazzoli, and C.A. Honig, 1989. Late Quaternary Sea-level Correlation and Applications. NATO ASI Series, v. 256, 229 pp.

Suk, B.C., 1989. Sedimentology and history of sea level changes in the East China and adjacent seas. in Sedimentary Facies in the Active Plate Margin edited by A. Taira and F. Masuda TERRAPUB, Tokyo, 215-231.

Wang, J. and P. Wang, 1982. Relationship between sea-level changes and climatic fluctuation in East China Sea since late Pleistocene. Quat. Res. (Japan), **21**: 101-114.

Youn, O.K., B.K. Park, and S.J. Han, 1977. Geomorphological evidences of post-glacial sea-level changes in Korea. J. Geol. Soc. Korea, **13**: 15-22. (in Korean with English abstract)

Zhao, S., 1990. The desertization and its derived deposits of Yellow Sea shelf during the Last stage of the Late Pleistocene. The Korean J. Quat. Res., **4**: 69-71.

Zhao, X., X., Geng, and J. Zhang, 1982. Sea level changes in eastern China during the past 20000 years. Acta Ocean Sinica, **1**: 248-258.

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