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Human Modification of Coasts in the Western Pacific Ocean

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《**Contents**》

1. Introduction

One of the most dynamic environments on earth is that bordering the half-million kilometer long interface between land and sea. Although it is a relatively narrow zone, it has proven to be one of the most attractive of environments to humans who have proceeded to exploit, colonize, and modify it at what appears to be an ever-increasing rate.

Some of the most intensively used coastal sectors on earth are those that form the western side of the Pacific Ocean. The dozen or so countries that stretch from the Equator north to the Arctic Ocean include Singapore, Hong Kong, the People's Republic of China, Japan, and South Korea, the 5 countries to be discussed in this paper.[1)]

The great variety of environments encountered by humans along the shorelines of the Orient have provided many different opportunities and challenges for exploitation and development. Thus, it is not surprising that many of its coastal sectors were occupied early in human history and that today some of the most relevant/important advances made toward our understanding of the complex relationship that exists between coastal materials, forms, and processes and human activity are coming from the region's scientists and engineers.

2. The Coastal Setting

Plate tectonics has played a major role in determining the present-day configuration and gross morphology of the coastal zone of the Orient as it has elsewhere on earth. The two dominant types of coast in the western Pacific, following the scheme by Inman and Nordstrom[2)], are 1)the tectonically active, collision type coast that forms part of the island arc that extends from the Aleutian Islands through Japan to the Philippines and beyond and 2)

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1) Because the human modification of these coasts is so complex and variable in both space and time, emphasis here is placed on contrasting technologies rather than definitive distributions.

2) Inman, D.L. and Nordstrom, C.E., 1971, "On the tectonic and morphologic classification of coasts," *Geology*, 79, pp. 1~21.

the marginal sea type coast that extends along the mainland from Kamchatka south to Singapore. The former is a relatively unstable band. It has structural trends that generally parallel the coastline and possesses a narrow continental shelf. The latter, in contrast, is more stable and has structural trends that generally do not parallel the coast.[3]

The actual appearance of these coasts depends not only on their tectonic and mineralogic history but also on other factors including the degree to which they have been modified by a variety of subaerial and subaqueous processes.[4] They range from coasts in the south where coral and mangrove growth dominate to those occasionally affected by sea ice in the north. They include shorelines that are impacted by typhoon surges, monsoon generated waves, tsunami, and earthquakes as well as those rarely affected by extreme events. Some are virtually tideless whereas others experience some of the highest tidal ranges on earth. It is little wonder with so many variables that nearly all coastal types—cliffs, sandy beaches, deltas, estuaries, lagoons, marshes, dunes—are represented.

The Republic of Singapore, which enjoys a humid tropical climate, has a shoreline 300km long. It consists of one main island (92% of its area) and over 60 others.[5] Wave energy is generally low, although the tidal range reaches 2.5m. Most of the shoreline, prior to human modification, consisted of mangrove trees although some low bluffs, sandy beaches, and coral reefs were also present. Today the length, configuration, and character of the main island and many of the smaller islands have been greatly altered by man.

Hong Kong is similar to Singapore in that it also has a short coastline (870km) and possesses numerous islands (nearly 250). However, it is very different in most other respects. It has a serrated coastline dominated by numerous bays and headlands. Sandy shorelines alternate with bluff and cliff shorelines, although on the northwest along its border with China and at the heads of some of the bays, mudflats, frequently with mangroves, are also present.[6] Much of the Hong Kong shoreline is impacted by high wave energy seasonally produced by strong easterlies, northwest monsoon winds, and typhoons.

China's indented mainland coastline is about 18,000km long which represents 56% of its 32,000km total that also includes the lengths of the shorelines of the more than 5000 islands. Chen et al.[7] write that

> ...the whole coastline may be divided into two portions, north and south of Hangzhou Bay: to the north the coast consists mainly of alternating depositional plains and some hilly regions, and to the south rocky jagged coasts predominate, interspersed with small estuarine plains and local beaches of sand or gravel.

The rivers of China, with their heavy sediment load have built large deltas and created extensive muddy coastal zones. The coral reefs and mangroves of south China give way to temperated marshes in north China. The south China coast is affected by typhoons although generally the China coast, being on an inland sea, does not have the extremely high wave

3) Eisma, D., 1982, "Asia, eastern, coastal morphology," in Schwartz, M.L., ed., *The Encyclopedia of Beaches and Coastal Environments*, Hutchinson Ross Publ. Co., pp.76~82.
4) Walker, H.J., 1975, "Coastal morphology," *Soil Science*, 119, pp.3~19.
5) Wong, P.P., 1985, "Singapore," in Bird, E.C.F. and Schwartz, M., eds., *The World's Coastlines*, Van Nostrand Reinhold Co., pp.797~801.
6) So, C.L., 1985, "Hong Kong," in Bird, E.C,F, and Schwartz, M., eds., *op. cit.*, pp.823~826.
7) Chen, J., Liu, C., and Yu, S., 1985, "China," in Bird, E.C.F. and Schwartz, M., eds., *op. cit.*, pp.813~822.

energy experienced by east Japan. Tidal ranges vary greatly although generally the south China coast is microtidal, the central part macrotidal, and the north mesotidal with the exception that the Bo Hai area is microtidal.

Japan has a coastline that, like China, is some 32,000km long. Of this total, Japan's 4 major islands, with a combined length of about 18,500km, are nearly equal in length to that of mainland China.[8] Thus, Japan's lesser islands (equalling only 3% of the total area of the country) have a shoreline length (13,500 km) about the same as that of China's 5000 islands. Japan's position on a subduction-type mobile belt accounts for a turbulent tectonic history, a history that is reflected in the country's coastline. The distinctive folding and faulting patterns of Japan have produced a relatively smooth coast along the Sea of Japan whereas deep bays and crenulated shorelines characterize the east coast The bulk of the coastline of Japan is dominated by cliffs with or without beaches at their base. Deltaic and sandy coasts are found along less than 20% of the shoreline and the beaches vary greatly in texture with boulder and shingle beaches being extensive. Generally, tidal ranges around Japan are low although in south Kyushu they approach a range of 5m. Much of the shoreline is impacted periodically by heavy waves because of tsunami (especially along the northeast coast), typhoons (especially on the east coast of southern Japan), and strong monsoon winds (mainly along the Sea of Japan). In Japan the

> ...most typical coastal situation is probably best described as one in which a hilly source region is bordered by a narrow coastal plain across which streams carry coarse textured materials into coastal waters that have a low tidal range but may be occasionally subjected to extreme events.

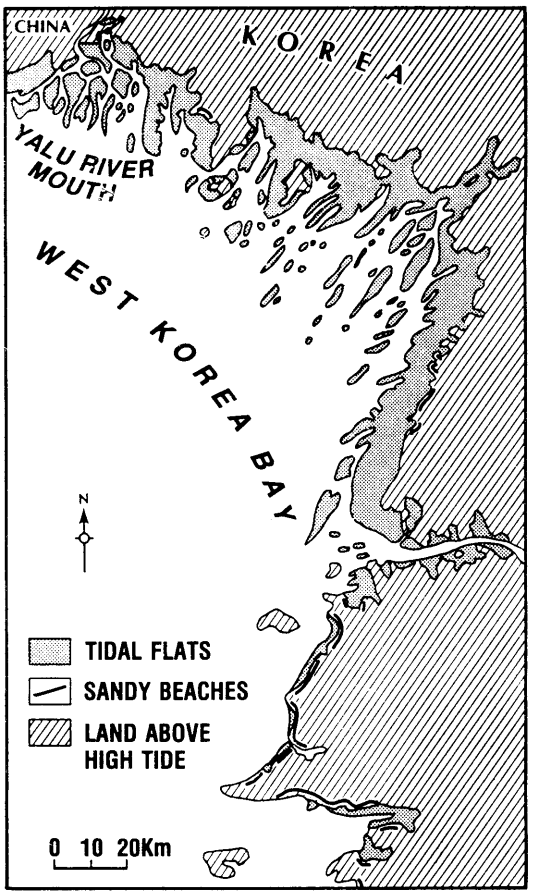

Fig. 1. West Korea tidal flats (after Eisma and Park 1985).

North and South Korea form what Eisma and Park[9] describe as a boxlike peninsula; a peninsula that has a coastline about 15,000km long. Geomorphologically the coast consists of 3 major sectors: eastern, southern, and western. The east coast, dominated by emergence, is relatively straight with some headlands and pocket beaches. Steep, short rivers have brought coarse sediments to the shore and in places created

8) Koike, K., 1985, "Japan," in Bird, E.C.F. and Schwartz, M., eds., *op. cit.*, pp.843~849.
9) Eisma, D. and Park, D.W., 1985, "North Korea and South Korea," in Bird, E.C.F. and Schwartz, M., eds., *op. cit.*, 833-841.

lengthy spits which are backed by lagoons and sand dunes. Western Korea, on the other hand, is dominated by submergence and possesses a deeply indented shoreline with thousands of offshore islands (nearly 3000 off the south and west coasts). Tidal ranges vary greatly; along the east coast they are low (less than 25cm) whereas along the south coast they range up to 3m and along parts of the west coast to more than 9m. Such a great tidal range is responsible for alternately covering and exposing vast tidal flats that have an area of over 6,000km^2 (Fig. 1). Behind the tidal flats are dunes only a few of which have been destroyed and converted for agricultural pursuits.[10)]

3. Early Utilization of the Coast

The earliest uses of the coast (i.e. those engaged in by hunting and gathering groups) produced little modification of the shoreline except for the creation of shell middens. With few exceptions, the evidence for such early use of the coast has been lost because most middens, which were usually created near sea level, were destroyed as the sea rose in level during deglaciation. Many of the middens produced since stillstand was reached about 4000 to 5000 years ago have also been destroyed —some by natural beach erosion, others by man who found them a convenient source of shell which he used in a variety of ways.

By the time sea level reached its present position, humans had already begun to utilize the coast relatively intensively. The production of solar salt, the trapping of fish, the alteration of shoreline for protection of boats, and the aiding of nature in its depositional sequence in order to plant crops in tidal flats all were early endeavors in the Orient.

Basically it is the same functions—i.e., reclamation, building ports and harbours, and protection from the sea—that are paramount in the development of artificial structures along the shoreline. These activities usually involve the human movement of the shoreline (either seaward or landward) or the attempt at trying to stabilize the shoreline in nearly the position it occurred in nature. They also usually involve alteration of the forms, processes, and materials that occur at the interface between sea and land.

4. Reclamation

Reclamation (for want of a better term) is used in this paper to mean the human modification of the natural environment so that it can be utilized in ways that otherwise would be impossible or at least impractical. Dyking a tidal flat for salt production, draining a swamp for agriculture, filling a lagoon for use as an industrial site, and dredging ponds for aquaculture or canals for marinas are examples that fit this broad definition.

(1) Agriculture

Reclamation for agricultural purposes has taken many forms in the Orient. Although all 5 countries discussed here have reclaimed coastal areas in the name of agriculture, such reclamation has been especially extensive and proportionally much more importaint in China, Japan, and Korea than in either Hong Kong or Singapore.

China. Just when reclamation for agriculture began in China is unknown. It is known that its vast alluvial and deltaic plains were used early. Actual modification—i.e. the construction of dykes, levees, and canals—of deltaic environ-

10) Park, D.W., in press, "Sonth Korea," in Walker, H.J., ed., *Artificial Structures and Shorelines*.

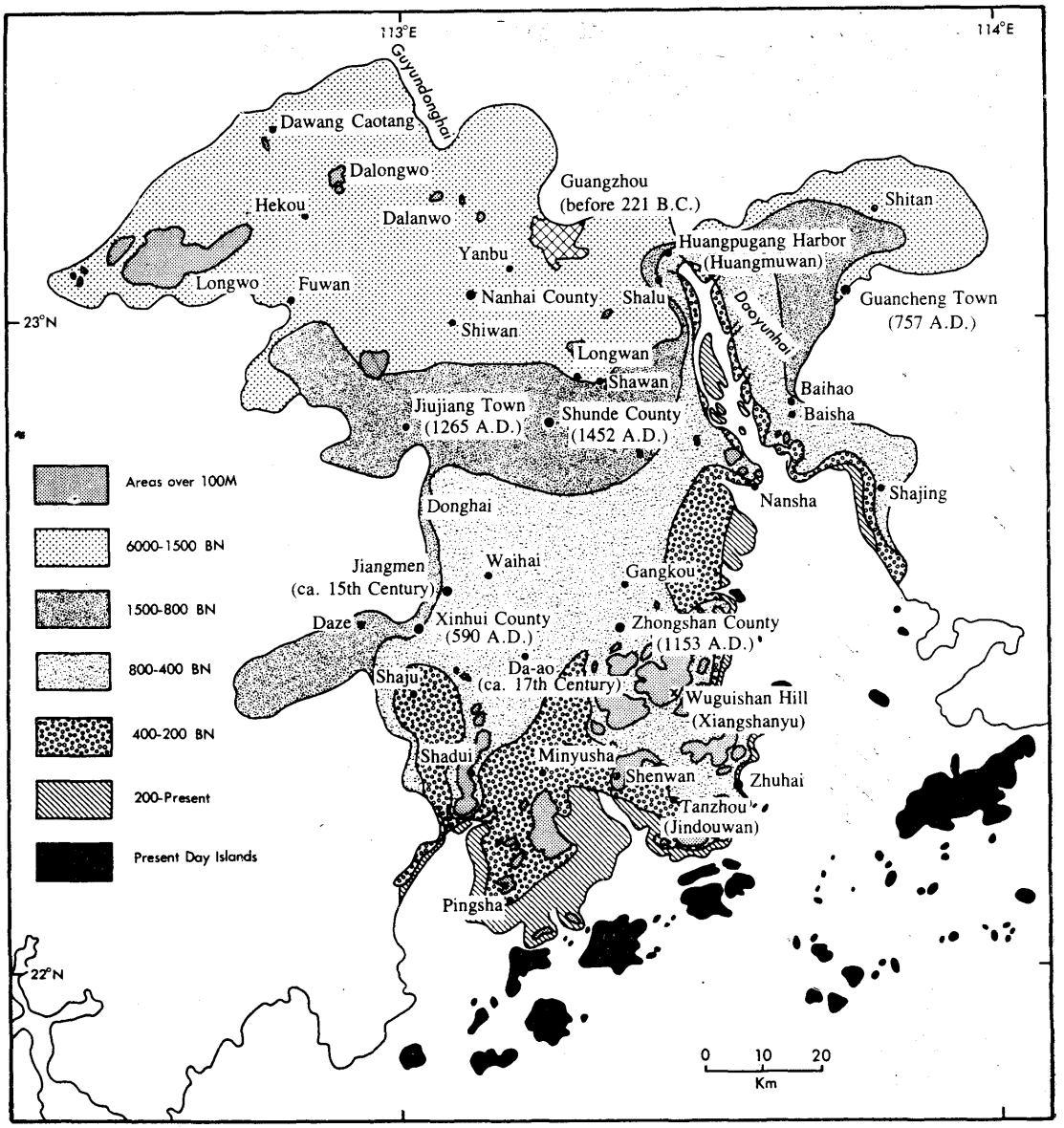

Fig. 2. The growth of the Pearl River delta in China with dates specific locations were founded (from many sources).

ments was probably at first aimed more at protection from flooding than for expansion of area and stem from well before the Christian Era began. Expansion itself occurred mainly at a pace in tune with the natural advancement of deltas.

Although in China reclamation has been practiced along all coasts where feasible, the following discussion is confined to south China and especially the Pearl River delta. The growth of the delta and the expansion of agriculture in the delta are well documented (Fig. 2) in the form of place names of settlements. Examples include Nanhai (meaning "south sea"), Waihai (meaning "offshore"), and Jiangmen (meaning "watergate"). The

latter city is more than 50km from the sea today. At some stage in the natural advancement of the delta the local farmers began to build dykes on mudflats in order to assist nature in its depositional sequence. The rapidity that such a depositional sequence, from open water to cultivation, can take place is suggested by the local saying "Yii you, lu po, huo li, cao pu" which in English means "fish swim, rudders touch bottom, cranes stand, grass spreads."[11]

The aiding of this sequence is being practised today as shown by reclamation of a 51 km^2 area at Ai Nan in the 300km^2 Huang-mao Bay just south of the mouth of the westernmost distributary. Chinese reclamation engineers constructed a dyke seaward from the shore so that it is submerged at high tide. The objective was to trap water at high tide because the amount of sediment in the water is greater during flood than during ebb tide. The plans were to allow this process of natural filling to proceed for 10 years (i.e., until 1990) and then complete the dyke converting it into a seawall surrounding the reclaimed area. This project extends seaward of a formerly reclaimed area of 8km^2 which in 1979 was beginning to be cultivated.

In addition to the construction of intertidal or submerged rubble dykes and jetties, the areas being reclaimed are usually planted with 'Cyperus malaccensis' which facilitates deposition and increases the organic matter in the reclaimed land.

By 1950, the Pearl River delta had over 1, 300km of levees and dykes, some of which are more than 7m high. Since 1950, as suggested by the Ai Nan development, many more have been added. Between 1883 and 1980, nearly 600km^2 of new land was added within the delta. Zhao states that there is another 750km^2 of potential reclaimable land in the zone down to a depth of 2m. Within the area of south China, from the Hanjiang River to Vietnam, a total of nearly 2,000km^2 of shallow mudflats have been reclaimed since 1950.

Japan. In Japan reclamation of coastal lagoons, marshes, and tidal flats as well as appropriate inland areas for conversion into rice paddy fields has been practiced for centuries. The best conditions for extensive reclamation of tidal flats is on the west coast of Kyushu and along the Seto Inland Sea where tidal ranges of up to 6m during spring tide occur.[12] Two such locations are the Ariake and Yatsushiro Bays (Fig. 3). Within these bays deltas have formed although they are on a much smaller scale than that of the Pearl River delta in China. Reclamation in these deltas began in the Yayoi Era when marshlands were drained. During the Ancient and Medieval Eras, small dykes were built on the tidal flats and canals dug to drain them. Many of these canal networks are still present although in altered form[13]. The canals served 2 functions: during high tide the fresh water ("awo") that

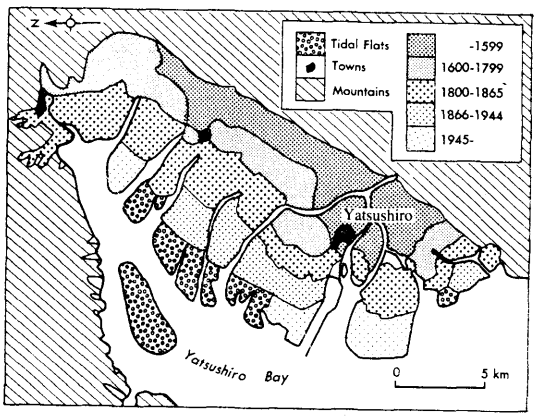

Fig. 3. Yatsushiro Bay and reclamation
(after Koike in press)

11) Walker, H.J., 1980a, "The Pearl River delta," *Scientific Bulletin*, 5, 2, pp. 1~6.
12) Koike, K., in press, "Japan," in Walker, H.J., ed., *op. cit.*
13) *Ibid.*

flowed on top of the saltwater wedge was diverted through gates into the fields and at low tide excess water was drained from the fields to the sea. In South China the practise of transferring fresh water to the fields during high tide (known as *toudad*, i.e. "stealing") was also a common practise[14] as it was in the southeastern USA during the early 19th Century.[15] In Japan, during winter, the sediment that had been trapped in the canals was dug out and placed on the fields.

In Ariake Bay, some 63km^2 of tidal flats were reclaimed in the Edo Era. Most of the reclamation projects were done by individual villages and were small. The general mothod was to place tree branches in rows and build bamboo fences behind which fine sediment would be trapped. Eventually earthen dykes were constructed. However, they were not high enough to keep outsurges generated by typhoons and flooding with sea water occasionally occurred.[16]

In general the reclamation of these 2 bays has proceeded normal to the shoreline; in Ariake Bay in a semicircular fashion and in Yatsushiro Bay in a linear fashion with growth toward the northwest (Fig. 3). Present-day reclamation involves modern technology, including the construction of concrete seawalls and the utilization of complicated pumping systems. Subsequent to World War II, the Japanese increased their pace of reclamation. The largest project was that of polderizing Hachirogata in northwest Honshu. The project, begun in 1957, transferred a 220km^2 lagoon (the second largest inland water body in Japan) into agricultural land with an area of 170km^2 by constructing a 52km long dyke within the lagoon.[17]

Although planned for rice, rice production had increased to much an extent during the 1960's and 1970's that the Hachirogata area is now used for diversified agriculture. The area is so large that a new town (Ogata) has been built in its middle.

Korea. The oldest historical record of reclamation in Korea dates back to the 14th Century.[18] The earliest projects, like elsewhere, were engineered by local peasant groups and resulted in a mosaic of rice paddys along numerous sections of the coast. The rate of reclamation increased during the late 19th and early 20th Centuries, much of it under the supervision of the Japanese. Little reclamation

Table 1. Land Reclamation in Korea (1946~76)*

	1946~60		1961~75		Totals	
	#	Area(km^2)	#	Area(km^2)	#	Area(km^2)
Governmental	28	46.9	78	85.4	106	132.3
Private	188	22.8	1,275	176.2	1,463	199.0
Totals	216	69.7	1,353	261.6	1,569	331.3

* From Walker 1982.

14) Walker, H.J., 1980a, *op. cit.*
15) Hilliard, S., 1975, "The tidewater rice plantation: An ingeneous adaptation to nature," in Walker, H.J., ed., *Costal Resources, Geoscience and Man*, XII, pp. 57~66.
16) Koike, K., *op. cit.*
17) Walker, H.J., 1986, "Human modification of the shoreline of Japan," *Physical Geography*, 7, pp. 116~139.
18) Walker, H.J., 1982, "Korea Research Institute for Human Settlements (KRIHS) and Korea's tidal flats," *Scientific Bulletin*, 7, 4, pp. 22~29.

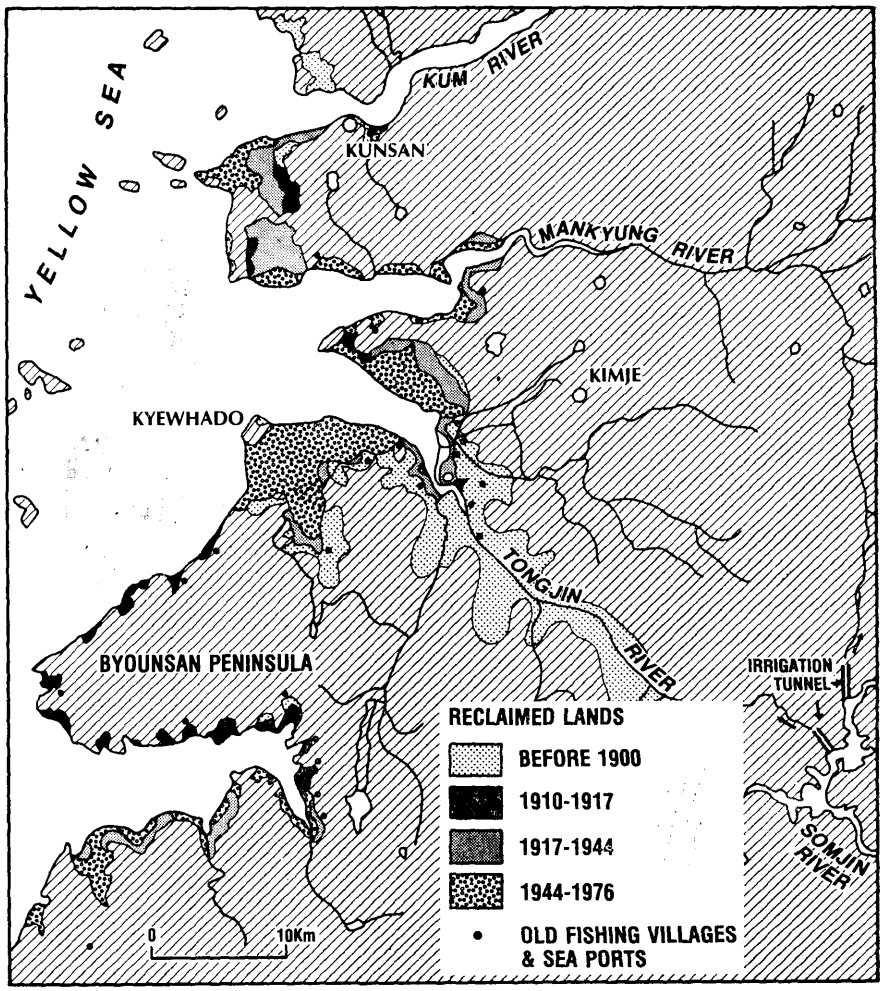

Fig. 4. Reclamation in Part of Korea to 1976.

occurred during the 1930's and early 1940's. However, since the mid-1940's, the number of projects and the areas reclaimed have increased drastically (Table 1 and Fig. 4). Although governmental participation increased during the 30-year period, private developments increased at even more rapid rates.[19]

In 1978, the Korea Research Institute for Human Settlements (KRIHS) was founded for the purpose of making recommendations to the government so that the most "efficient utilization and conservation of the national land resources" would be insured.[20] One of the first major research projects undertaken deals with intertidal area land reclamation. In 1979, a publication entitled "Investigation into the Designation of the Uses of Tidal Flat Resources" was issued in a limited edition. The plans are ambitious: whereas only 331.3km^2 of land was reclaimed between 1946 and 1976, this plan calls for a total reclamation of 7,270km^2 by 2,001 (Fig. 5). Of this total, only about 1/3 is present-day tidal flat, the rest is shallow-water land that is below present-day low tide

19) Choi, Y., Mossa, J., and Walker, H.J., in preparation, *Land Reclamation in West Korea.*
20) Korea Research Institute, 1980, *Informational Brochure.*

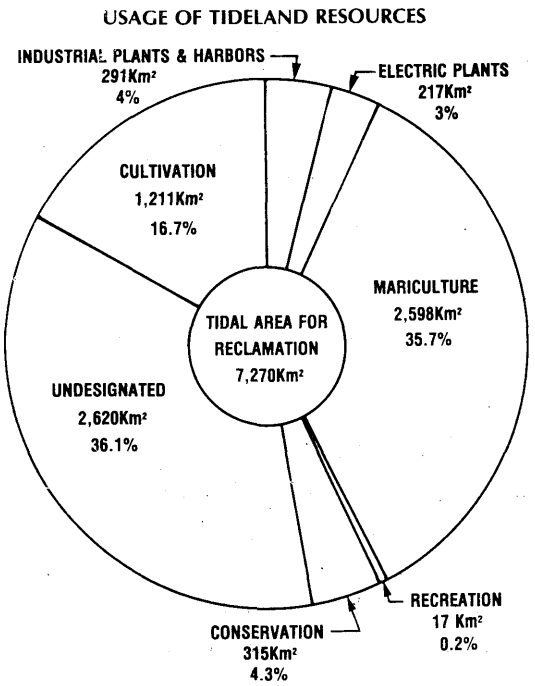

Fig. 5. Reclamation plans for South Korea (after Korea Research Institute 1980).

level. The 2,689km² of tidal flat area that it is proposed to reclaim represents about 90% of the total tidal flat area in Korea.

These massive reclamation projects are multipurposed (Fig. 5). Although about 36% of the 7,270km² area to be reclaimed is undesignated, that destined specifically for agriculture (the long-term major reason for reclamation) represents only about 17% of the total. Of great interest is the over 1/3 that is planned for maricultural pursuits.

In addition to the areal change that occurs with reclamation is the shortening of the coastline. In the case of Korea, shortening results from the construction of dykes between islands and across estuaries. For example, between 1917 and 1975 the length of the shoreline of Asan Bay was decreased by over half from 557km to 269km (Table 2).

(2) Aquaculture and Mariculture

Often contemporaneous with reclamation for agriculture has been reclamation for aquaculture. In Le Liu Commune, a 40km² reclaimed area of longstanding in the Pearl River delta of China, agricultural and aquacultural pursuits occupy about equal amounts of area. Agriculture is very diversified; crops include rice, sugar cane, and mulberries(for a silk worm industry). However, within the commune some7000 ponds occupy about 20km². These ponds are capable of producing about 3500 metric tons of fish per year much of which is shipped live to Hong Kong. The ponds, averaging less than 2m in depth, were made by transferring the deltaic sediments to adjacent fields, thus increasing their height and fertility. A number of types of fish are grown in the ponds using very systematic procedures[21)]

In some areas (as for example, northwest Hong Kong) their is less diversification and ponds occupy all of the area except for that used in the pond levees and for house sites.

Although aquaculture has been practised for centuries, there has been a recent increase in

Table 2. Shoreline Length Changes Because of Reclamation*

Region	1917(km)	1944(km)	1975(km)	% decrease
Han River Estuary	801.2		654.4	18.3
Asan Bay	557.4		268.8	51.8
Kyewhado	382.1	327.7	305.4	20.1

* From Walker 1982.

21) Walker, H.J., 1980a, *op. cit.*

its area of coverage and diversification in its practice. As noted above, reclamation plans in Korea call for about twice as much area to be devoted to it as to Agriculture (Fig. 5).

In addition to the construction of separate ponds, the utilization of nearshore marine waters for maricultural purposes is extensive and intensive, especially in Japan. There the cultivation of various types of shell fish (especially oysters) and sea weeds utilizing rafts and other structures is a major industry. The experimentation involved in the development of the "cultured pearl" was of major importance in the advancement of maricuture.

(3) Solar Salt

The production of salt has, at one time or another, been a major occupation in most countries of the world. In some areas, it was the main reason for reclamation and in other was probably 2nd only to agriculture at least until the Modern Era. The creation of evaporation pans along the shoreline and the development of trade in salt were achieved early in China, Japan, and Korea.

In China, solar salt pans were especially numerous along the coastline and the construction of canals—some of them far inland—to take the salt to market were major endeavours. The general arrangement of these pans is frequently depicted on early maps. Presently, salt production along the coast is being concentrated in a few large production areas.

As in China, salt was produced at many coastal sites in Japan, especially before the country was politically and economically unified during the Edo Shogunate (Koike in press). Subsequently, solar salt production became concentrated in a relatively few locations, especially in the tidal flat areas of the Seto Inland Sea where the tidal range is up to 3m and dry weather is common. One of the major salt producing areas was at Ako in Hyogo Prefecture. During the middle of the 17th Century its salt field covered 1.25km^2 an area that increased to 2.3km^2 by the end of the Century. The method of salt preparation in this area depends upon an initial concentration of salt in the ponds followed by boiling. This preocedure aided in the destruction of many of the forests of Japan especially in coastal areas. In 1905, the Japanese government took control of salt production. The area of salt production in 1905 was some 80km^2, and area that decreased to 50km^2 by 1925[22]. The production of solar salt in Japan was essentially discontinued by the 1970's and the solar salt pans were abandoned. Although some of these abandoned areas have been converted into aquacultural ponds, many remain unused.

Unlike in Japan, solar salt production is still extensive in Korea. The largest producing areas take advantage of the high tidal range that occurs along the west coast. Although most maps of the west coast of Korea show the location of solar salt pans it is interesting to note that in the projection for future reclamation solar salt production is not included as a separate category (Fig. 5).

(4) Industry, Commerce, Housing

Although in the past virtually all reclamation was for the promotion of agriculture, aquaculture, and solar salt production, in recent years the demand for space for housing, commercial and industrial activities, and transportation net works has led to vast reclamation efforts. These projects are usually adjacent to areas that are already being intensively used so that in many cases the only feasible expansion of

22) Koike, K., *op. cit.*

space is seaward[23]

In Japan, reclamation of nearshore areas for industry actually began before the turn of the century, however, it was not until the 1950's that it became especially large scale. From this period to the mid-1970's, mega-industrial zones were developed rapidly along the Tokyo, Nagoya, and Osaka shorelines[24]. Shapiro[25] writes:

> One of the keys to Japan's remarkable economic growth has been the use of its coastal waters as the location of vast amounts of landfill primarily for the development of its industries which are dependent on imported fuel and resources.

Tokyo's population grew so rapidly that even during the Tokugawa Shogunate part of the bay was being filled for housing. Before World War II, much of the western part of the bay was reclaimed for industry while the northern and northeastern parts were not reclaimed until after 1950. Koike in press reports that some 220km^2 of area have been reclaimed in Tokyo Bay.[26] That is an area equal to about 20% of the original size of the bay.

The importance of such reclamation in the minds of the Japanese is reflected in numerous reports. For example, the founder of the Matsushita Electric Company, in 1976, "... proposed flattening 20 percent of the nation's mountainlands and using the material to fill large areas of seacoast as a way to double the area of habitable land surface..."[27] The construction of the Kobe port area and the New Osaka Airport are examples of this thought in action.

Possibly the best example of a country trimming (or flattening) its hills and using the material as fill in nearshore waters is Singapore (Walker 1984). Singapore's ranking in the world in terms of trade and oil refining capacity is very high and it is agressively maintaining its position. Reclamation in Singapore is relatively easy given the low energy nature of coastal processes, lack of severe storms, the subdued morphology of its coast, and the good source of fill from the easily mined hills near the coast[28]. The first reclamation in Singapore occurred along the Singapore River in the 1820's shortly after the colony was established. From then to the 1960's, reclamation was mostly associated with commercial activities and was somewhat sporadic. However, from the 1960's to the present, it has been a continuous activity and has been sponsored mainly by governmental organizations. One of the major projects is the so called East Coast Reclamation Scheme which was conceived some 25 years ago. The main objective of the scheme is to provide land for the development of residential areas in the implementation of the Housing and Development Board's decentralization plan. Upon completion (planned for 1991), Singapore will have added 54km^2 of new territory during a 30-year period. When added to that previously reclaimed, Singapore

23) Walker, H.J., 1984, "Man's impact on shorelines and nearshore environments: a geomorphological perspective," *Geoforum*, 15, 3, pp.395~417.
24) Koike, K., *op. cit.*
25) Shapiro, H.A., 1984, "Coastal area management in Japan: an overview *"Coastal Zone Management Journal*, 12, 1, pp.19~56.
26) Koike, K., in Press, *op. cit.*
27) Shapiro, H.A., 1984, *op. cit.*
28) Walker, H.J., 1984, *op. cit.*
Krause, G.H., 1982, "The urban coast in Singapore: uses and management," mimeographed.

will be 10% larger than when founded[29]. The technology involved in reclamation varies greatly. In the case of Singapore, conventional methods (steam shovels, dump trucks, bulldozers) were used in the early stages of this modern project. However, present-day equipment includes bucket wheel excavators, conveyor belts, barges, and mammoth spreader machines.

Hong Kong, like Singapore, is very densely populated and, if anything, has usable land that is at an even higher premium than in Singapore because of its mountainous character. However, its indented coast with a few sizable bays does permit for some reclamation. Some of these bays, such as Sha Tin, Tue Mun, and Tsuen Wan, have been, and are being, filled and provide space for industry, commerce, recreational facilities (including race tracks) and residential towns. For such purposes, Hong Kong has reclaimed some 21km^2 of its coastal waters[30]

In Korea, the extensive reclamation plan, as mentioned above, includes 230km^2 for industrial development and 217km^2 for power plants(Fig. 5). Together these will occupy over 6% of the proposed reclaimed area and represent a significant expansion in Korea's power and industrial base.

(5) Water Supply and Airports

Two other types of reclamation that are being developed in the Orient are the creation of sea-level, fresh water reservoirs from the sea and offshore islands for airports.

Hong Kong's geologic structure mitigates against sizable and usable aquifers to such an extent that it has had to develop a variety of sources and procedures including the construction of a desalinization plant, the development of high-level surface reservoirs, the purchase of fresh water from mainland China, and the utilization of sea water for a variety of functions such as washing streets and flushing toilets. The construction of reservoirs from the sea was conceived some 25 years ago by members of the Hong Kong Public Work's Department.[31]

The objective was to dam an inlet, pump out the sea water, and allow it to fill with fresh water. The first such endeavour in the world as Hong Kong was the damming of Plover Cove, a project that was completed in 1967. One of the two largest borrow pits from which the rock was quarried for the dam became the site for the Chinese University of Hong Kong. This endeavor was so successful that it was decided to construct another, larger reservoir. This time, however, it was made by damming both ends of a strait that separtated High Island from the mainland. It involved the building of 4 coffer dams in order to keep the main dam sites free of water during construction. In addition, the riverine and marine sediments that had been deposited in the strait (up to 45m thick) had to be removed. The east coffer dam was maintained and strengthe ned after completion of the reservoir in order to protect the main reservoir dam (which reaches a height of 66m above sea level) from being eroded by the high waves that are generated by the typhoons that frequently strike this coast. This protective structure is armored by 7,000 dolos that weigh 25 tons each. The length of this reservoir is 5.6km. The 2 reservoirs have converted about 25km of seashore into freshwater shorelines and

29) Wong, P.P., in press, "Singapore," in Walker, H.J., ed., *op. cit.*
30) Walker, H.J., 1980b, "Reservoirs from the sea: Hong Kong's answer to its water supply demands, *Scientific Bulletin*, 5, 1, pp.19~25.
31) *Ibid.*

occupy an area of about 19km^2 or nearly as much as the 21km^2 area of other reclamation in Hong Kong referred to above.

One of the most recent developments in reclamation has been the placement of airports on fill. Such a use of reclaimed land is, of course, quite logical because of the large area of flat space needed for airports. One of Singapore's recent advances into the sea was for the construction of the Changi airport that opened in 1981. In some instances, runways are made by creating narrow rectangular peninsulas into the sea as, for example, in Hawaii and Hong Kong. The most ambitious example of this type airport creation is that in Osaka Bay, Japan where an offshore island large enough to support an international airport with all of the necessary facilities is being constructed.

5. Ports and Harbours

It is possible that the first major structures along the shore were associated with fishing activities and involved the development of ports the principle reason for which would have been protection from the sea. Ports and harbours in the Orient range from those that take advantage of the natural protection offered by bays, coves, and river mouths to those that have been built on open coasts. They range in size from those only large enough to shelter a boat or two to those capable of handling super tankers and they range in complexity from those protected by only a simple rock breakwater to those with lengthy jetties, mammoth concrete seawalls, dredged channels, locks, docks and warehouses, and even to those that have been carved through dunal ridges.

Singapore, with its strategic location, appears to have been destined to become a major locus of oceanic transport from its beginning in 1819 when it was envisioned as a great commercial emporium. Today, ranking behind only Rotterdam and Yokohama in tonnage shipped, it handles about 200 ships every day. By the mid-19th Century, wharves and docks, which earlier in the Century had been confined to the mouths of Singapore's rivers, had been extended along the coast itself. By 1900, Singapore had 2km of wooden wharves; during the 1960's, in keeping with port modernization around the world, it began to develop its containerization capabilities. Future developments, under the direction of the Port of Singapore Authority, include modification of islands offshore some of which have been reserved for major petroleum and petro-chemical manufacturing and the addition of some 6km^2 of land off the southeast coast in anticipation of the increased demand for more waterfront space. So[32] writes for Hong Kong that

> The numerous jetties, piers, and wharfs scattered over the harbour shore stand side by side with the multi-purpose complexes including the Ocean Terminal, the Macau Ferry Terminal, cross-harbour ferry terminals, cargo-handling basins and docks. For commercial and industrial purposes, the need for obtaining sites with deep water frontages through reclamation has been recognized since the earliest days ...The container port development at Kwai Chung in the more recent years answers a similar demand. Other structures, catering for the needs of the floating population, are embankments known as typhoon shelters, built offshore at breakwaters ...to provide safe harbourage for boats during periods of storms...

The ports and harbours of Japan have grown to such an extent from their very early beginning that today they "officially" occupy over

32) So, C.L., 1985, *op. cit.*

11,000km of Japan's 32,000km long coastline.[33] Of the nearly 4,000 total ports and harbours in Japan, some 28% are designated as commercial; the other 72% as fishing ports. The great expansion of Japan's industrial and commercial activities as discussed above not only placed demands for new land but also for expanded harbour facilities. Because the bulk of the raw materials used in Japan's industry has to come from overseas and because a high proportion of its finished products are marketed overseas, harbour facilities are at a premium. In addition to the expansion and modernization of those harbours that have long been in existence, Japan began, in the 1960's, the construction of harbours and industrial centers at some distance from major population centers as a part of its decentralization plan. One such development was at Kashima which is about 80km northeast of Tokyo.[34] It is located on a long stable Pacific coast beach backed by a series of dune ridges. The harbour, created by making a large deep Y-shaped cut through the dunes, is capable of handling vessels of 200,000tons. Some 200km^2 of the surrounding area is being developed for industry. Although the harbour is basically protected by dunal ridges and natural as well as artificial beach, it was necessary to protect the entrance channel to the harbour from the open Pacific Ocean. This protection is provided by a 4.5km-long breakwater. In the process of dredging the harbour, 50 million m^3 of sand was transferred to the beach creating reclaimed areas on both sides of the harbour entrance.

South Korea, with its strong and rapidly growing international base and its role in international commerce, has expanded its port facilities within the last few decades. Fishing harbours are numerous and like commercial harbours are affected by high tidal ranges. Although fishing boats are often high and dry during low tide, in the case of commercial harbours other provisions have to be made in adjusting to such high tidal ranges. The locks at the harbour serving Seoul are of a size to accomodate large transport vessels.

6. Shoreline Protection and Stabilization

Protection and stabilization of the shoreline by man is one of the best examples of his penchance for trying to prevent changes in an environment which he has adapted to his own purpose. Because the shoreline is an especially dynamic environment, it is not surprising that man often finds himself at odds with nature along it. Of course, in the discussion above, protection (although not the main objective) was usually implicit. In this section the objective is to look in more detail at what man is doing in the 5 countries under consideration in the name of protection, stabilization, and even re-establishment of shorelines.

The reasons for shoreline protection, in addition to those associated with reclamation and harbour construction, are both naturally and humanly induced or aggravated. Natural shoreline erosion is common along many coasts of the Orient because of sea-level change, removal of more sediment that is being received from adjacent cliffs, streams or rivers, and from offshore, and from extreme events such as earthquakes, tsunami, and typhoons. Man aids such processes by damming and mining riverine sources, protecting cliffs, placing barriers along shorelines and thus trapping sediment that would feed down-drift positions, and by inducing or aggravating subsidence,

33) Shapiro, H.A., 1984, *op. cit.*
34) Walker, H.J., 1986, *op. cit.*

among others. The relative importance of these factors varies greatly among the 5 countries concerned and even between sectors within each country.

(1) Protective Procedures and Structures

When such a great number of reasons for protection as listed above are multiplied by all of the political, economic, social, religious, and technological factors that are brought into play, it is not surprising to find an equally great variety in approaches to and structures devised for such protection.[35] Approaches to protection, stabilization, and re-construction are usually of 2 types—static and dynamic[36] The static approach is to build structures that are fixed in position and that will be (hopefully permanent. The effectiveness of such an approach depends to a large extent on the type and character of structures used—height, width, shape, material used, permeability, durability, etc. The other approach is the use of what Nordstrom and Allen call "geomorphically compatible dynamic methods." These methods include such things as beach fill (renourishment), dunes, offshore mounds, and vegetation. Such forms are "allowed to be freely worked by waves, currents, winds, or biological processes"[37]

(2) Dynamic Methods

In the Orient, as elsewhere in the world, some of these methods have been used for centuries, others are new and only relatively rare. The planting of tree belts along the coast, often mainly to serve as windbreaks for more inland positions, is an old practice. In Japan a sizeable percentage of the coast has such planted forests. Areas of sand dunes are often sparsely utilized and are usually left to nature. However, once they begin to erode—whether by natural processes or by human activities—attempts are made at protection usually by some sort of re-vegetation and/or with fences of various types. Beach nourishment has been relatively little used in the Orient, at least directly. At river mouths, dredging, with the main objective of maintaining navigable channels, results in the transfer of sand either to the beach or offshore where it is reworked and distributed by waves and currents.

(3) Seawalls and other Sea/Land Interface Structures

Sea/land interface structures are designed for the most part to separate land from sea and include dykes, levees, embankments, revetments, and bulkheads. Although used in reclamation projects and harbour construction they are also used for cliff, dune, beach, and property protection. The main reason for these structures is to control beach erosion which is considered "one of the largest world problems from the perspective of land preservation"[38] For the most part these structures are inflexible, nearly vertical, man-made cliffs which replace a natural cliff or convert sloping to irregular surfaces. They range from low walls to some over 12m in height as in typhoon and

35) Walker, H.J., 1984, *op. cit.*
36) Nordstrom, K.F. and Allen, J.R., 1980, "Geomorphically compatible solutions to beach erosion," *Zeitschrift für Geomorphology*, Supplement Volume, 34, pp. 142~154.
Walker, H.J., 1981, "Man and shoreline modification," in Bird, E.C.F. and Koike, K. eds. *Coastal Dynamics and Scientific Sites*, Komazawa University Press, Tokyo, pp. 55~90.
37) *Ibid.*
38) Horikawa, K., 1978, *Coastal Engineering*, Wiley and Sons., New York, p. 402.

Table 3. Some Characteristics of Coastal Protection in Japan*
(M.C. stands for the Ministry of Construction)

Year	1 9 7 4		1 9 8 2	
	M.C.	Total	M.C.	Total
Needing protection (km)	5,641	14,943	6,028	16,090
Coasts assigned (km)	4,594	12,180	4,908	13,168
Coasts with protections (km)	2,335	7,885	2,802	8,884
Dykes, seawalls, etc. (km)	966	2,829	990	3,202
Other shore protections (km)	1,244	4,834	1,610	5,729
Groins and jetties (number)	4,683	9,276	4,850	10,012
(km)	141	367	180	424
Detached breakwaters (number)	505	885	1,593	2,843
(km)	46	98	128	263

* From Koike in press.

tsunami threatened areas in Japan. Japan has been especially active in developing shoreline defense structures and today has about 8,000 km of dykes and seawalls along its coast(Table 3).

(4) Groins, Jetties, and Other Non-Parallel Structures

The two most common of the non-parallel structures are the groin and jetty. Groins are designed to trap drift and retard shore erosion; jetties are mainly to prevent drift from entering navigable channels and to serve as training walls for rivers. As in the case of interface structures, these forms are made from a variety of materials and vary greatly in size and number. Jetties are usually quite long and occur singly or in pairs. In contrast, groins may be so numerous that they are referred to as groin fields. Japan, with over 9,000 groins is probably the leader in the world of the use of these structures and the amount of data from Japan dealing with them is large. In many instances the groins do not do the job they were designed for and indeed often agravate down-drift erosion. At Niigata, Japan, for example attempts were made at controlling the excessive beach and udne erosion that resulted from mining in and changing the course of the Shinano River. Groins were first established but erosion continued. Subsequently these groins were connected at their seaward ends. In China, shoreline erosion occurs at a number of locations. However, at only a few of them are groins being used to tackle the problem. One such location is in the estuary of the Yangtze River where groins have been placed along the shore of Chung Ming island. In Singapore, even with its low energy conditions, erosion of the seaward margins of reclaimed areas began to occur soon after completion. Attempted protection by the use of groins proved relatively unsuccessful[39)]

(5) Detached Breakwaters

The construction of breakwaters offshore from the area to be protected (or renourished) has been quite popular in Japan but used sparingly elsewhere. They are often used in connection with groins and are usually added later. Toyoshima reports that construction of detached breakwaters at Kaike, Japan was

39) Wong, P.P., 1973, "Beach erosion between breakwaters, southeast coast Singapore," *Tropical Geography*, 37, pp. 68~73.

begun in 1971. By 1977, six had been completed and sand tombolos were beginning to form. By 1983, 5 more detached breakwaters had been constructed and nearly 300,000 m^3 of sand had been deposited between them and the shore and over 250,000 m^3 more just outside the breakwaters.[40] In Singapore detached breakwaters are used mainly off the many islands that have been proposed for recreation purposes.

(6) Construction Materials

Materials used in the construction of these static forms vary from plain earth in the case of most dykes and levees to massive concrete forms in highly vulnerable locations. Although poured concrete is one of the most common materials for seawalls, blocks of country rock (rip rap) or of fabricated forms are especially common in groins and detached breakwaters as well as for protective armor at the base of seawalls.

7. Conclusions

Man only recently has become a significant geomorphologic agent. Although his abilities at modifying the landscape are in evidence in many different environmental settings, it is especially well demonstrated in the coastal zone of the Orient.

40) Toyoshima, O., 1983, "Variation in foreshore due to detached breakwaters," *Coastal Engineering*, 18, pp. 1873~1892.

人間에 의한 海岸變化：西太平洋 諸國의 事例

H.J. Walker*

국 문 요 약;

本研究는 人間에 의한 海岸의 變化가 太平洋의 西海岸諸國에 있어 어떤 要素로 인해 나타났으며 어떠한 樣態를 야기했는지 比較·檢討하는 것을 目的으로 한다. 地球上에서 가장 活潑히 利用·變化된 海岸을 가진 西太平洋 諸國, 즉 赤度 이북으로부터 北極海에 이르는 여러 국가 중 本研究는 싱가포르, 홍콩, 中國. 日本, 韓國 등 5개국을 대상으로 한다. 이 국가들은 상당히 다양한 海岸環境으로 인해 그 이용과 개발에, 여러가지 다양한 기회를 가질 수 있었던 곳이다.

初期의 海岸利用은 海岸線을 거의 變化시키지 못하였다. 해안이용상태를 알 수 있는 증거로는 貝塚이 있으나 거의 유실된 상태이기 때문에 충분한 증거가 되지 못한다. 人間이 海岸을 集約的으로 利用하기 시작한 것은 海水面이 현재 위치에 도달하기 이전이며 이때 이미 天日製鹽, 漁勞作業, 漁船보호를 위한 海岸線變形, 潮間帶에 곡물을 심기 위한 퇴적 등이 이루어지고 있었다.

人間에 의한 自然環境의 변화 중 代表的인 것이라 할 수 있는 干拓地造成은 그 목적에 따라 農耕, 漁勞, 天日製鹽, 產業·住居, 물 공급 등 여러 측면에서 살펴볼 수 있다.

農業을 目的으로 한 干拓은 여러 형태로 이루어졌으며 특히 米作國인 中國·日本·韓國에 있어 중요한 일이었다. 中國에서 洑·堤防·運河의 건설 등 三角洲環境의 변형은 초기에는 耕地의 擴張보다는 洪水의 防止에 목적을 두었으며 耕地擴張은 주로 三角洲의 자연적 진행과 보조를 맞추어 발생하였던 것으로 보인다. 이때 삼각주의 형성을 돕기 위하여 뻘에 堤防을 쌓기도 하였고 이렇게 개간된 땅에는 퇴적을 용이하게 해주며 개간된 땅에 有機物을 증가시키는 植物을 심었다. 日本의 경우 海岸潟湖, 海岸低濕地, 潮間帶를 개간하여 米作地로 이용하는 일은 오래 전부터 있었으며 이중 潮間帶를 개간하는 것은 潮水의 차이가 큰 해안에서 주로 이루어졌다. 韓國에서의 干拓事業은 19세기 후반과 20세기초에 증가하기 시작하였고 1930년대와 40년대 초반 거의 이루어지지 않다가 40년대 중반 이래로 干拓의 수와 면적이 엄청나게 증가하였다. 여기에는 政府主導의 開發뿐만 아니라 私的인 개발도 상당히 포함되어 있는데 國土開發研究院의 調査에 의하면 2001년까지 총 7,270 km^2가 干拓될 예정이다.

水產養殖業을 위한 干拓은 주로 이를 위한 못을 건설하는 형태로 형성되었다. 평균 깊이 2m 이내인 이들 연못은 三角洲 퇴적물을 인접 평지로 이동시켜 그 높이와 肥沃度를 증가시킴으로써 조성되었다. 최근 수산양식을 위한 干拓地面積은 증가 추세에 있으며 그 실험방법에서도 多樣性을 보이고 있다.

天日製鹽과 관련된 海岸變化는 다양한 형태의 鹽田과 생산된 소금을 운송하기 위한 運河建設에서 찾아볼 수 있다. 中國에서 소금생산은 潮水의 차이가 큰 몇개 지역에 集中해 있고 日本에서는 생산이 중단된 반면 韓國에서는 서해안에서 여전히 활발히 진행되고 있다.

최근에는 住宅, 商業·工業活動, 道路網을 위한 공간에 干拓地가 사용되고 있다. 이것은 이

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미 集約的으로 토지가 이용되고 있는 곳과 인접한 지역에서 이루어지는데 日本의 도쿄—나고야—오사까 해안의 重工業團地, 싱가포르에서 이루어진 東海岸干拓計劃에 의한 住居地開發, 韓國에서 工場敷地, 發電所敷地로의 干拓地利用 등이 그 예이다. 이 밖에도 부족한 淡水를 얻기 위한 淡水貯水池 건설, 空港·滑走路 건설 등이 간척의 목적이 되어 海岸環境을 변화시키고 있다.

人間에 의한 海岸變化의 또 다른 면모는 漁業活動·商業活動을 위한 港口·港灣 건설에서 찾아 볼 수 있다. 港口·港灣은 灣·狹灣·河口등 自然構造物을 이용하여 건설된 것에서부터 開放空間에 건설된 것까지 다양하며 그 크기는 한두 漁船이 정박할 수 있는 것에서부터 거대한 油槽船을 다룰 수 있는 것에까지 다양하다. 항구는 分散政策의 一部로 主要 人口中心地 외곽에 건설되기도 하였다.

人間에 의한 海岸線保護는 人間이 자신의 목적에 맞게 적응시켜온 環境이 변화되는 것을 방지하려는 노력의 좋은 예가 된다. 海岸線保護는 海水位變化·堆積物除去에 의한 海岸線浸蝕과 같은 自然的 파괴, 人間에 의해 건설된 構造物에 의한 해안선 파괴와 같은 人工的 파괴로부터 해안의 형태를 보존하고자 하는 것이다. 여기에 사용된 방법은 대개 靜的인 方法과 動的인 方法의 두가지로 나뉜다. 靜的인 方法은 防波堤, 船舶과 같은 永久적인 構造物을 짓는 것이며 動的인 方法은 beach fill, 砂丘, 防風帶, 防風林에 의하여 파도, 바람, 생물적 변화로부터 海岸線을 보호하는 것이다.