Geomorphic Development of the Kashima Lowland, Ibaragi Prefecture

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INTRODUCTION

The Kashima lowland is situated in the southern end of Ibaragi Prefecture and is a coastal barrier between the Pacific Ocean and the River Tone. This region was designated to one of the regions for special promotion of the industrial consolidation by the Economic Counsel Board in 1957. Since then, the Ministry of Construction made ground investigations for the purpose of constructing a new harbour and an industrial city in cooperation with the Ibaragi Prefectural Government, and published THE GROUND OF THE KASHIMA REGION, IBARAGI PREFECTURE (1964).

Geologists, engineering geologists and geomorphologists have obtained many fruitful results in recent geological studies on many alluvial plains in Japan. The subsurface structure and the process of construction of the younger ground are being clarified. It is especially, interesting that existence of an unconformity which indicates the oscillation of sea level through the latest Alluvial epoch was noted in the alluvium in the Ariake Bay area in Kyushu (ARIAKE BAY RESEARCH GROUP, 1965).

The writer made several field investigations and examined the data of many bore holes for the purpose of compiling the chronology of geomorphic development of the Kashima lowland. As the result, he recognized an unconformity, due to a change of sea level, similar in appearance to that of the Ariake Bay area.

GEOMORPHOLOGY

The Kashima lowland extends to the mouth of River Tone. It is chiefly constructed from some shingle bars about 5 m above the sea. Many sand dunes formed in different ages throughout this region. By field work and using aerial photographs, the landforms of this area were divided into seven geomorphologic parts, that is Pleistocene upland, sand bar, sand dune, swampy lowland, dry lowland, beach and reclaimed land (Fig. 1).

(1) The Pleistocene upland is called the Kashima Upland. The top is remarkably flat and is about 35 m in height, nevertheless it is dissected by many valleys. At the southern end of the upland that faces the beach, dune sands creep up and thinly cover the top. The upland mainly consists of marine sandy and gravelly sediments intercalated with some thin muddy layers, and is covered by volcanic ash called the Kanto Loam. These marine formations belong to the Narita Group that developed over the northern area of the Boso Peninsula.

The Narita Group is divided into the Narita (NF in abbreviation), the Yabu (YF) and the Jizodo formations (JF).

(2) The shingle bars occupy most of the Kashima lowland. It is subdivided into the following parts : i) A bar extends from the southern end of Kashima upland to the west side of Lake Gonoike which is situated in the middle of Kashima upland. The height

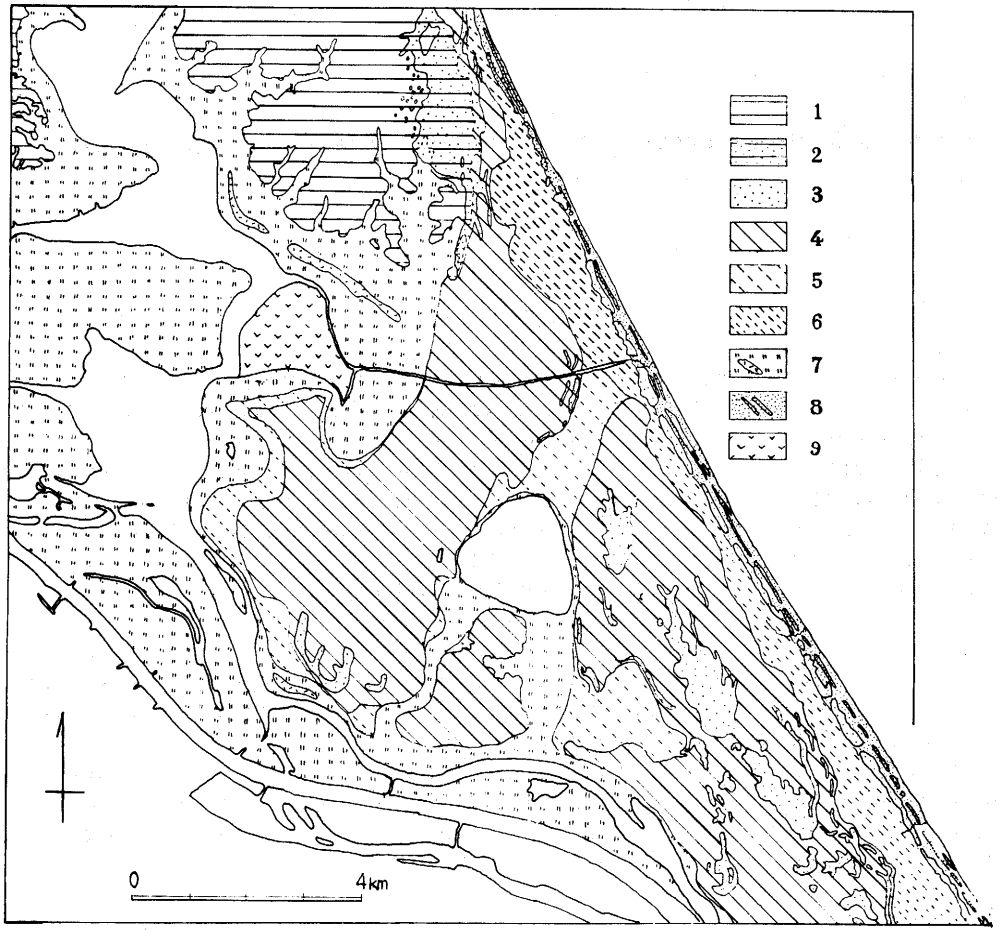

Fig. 1 Geomorphological map of the Kashima region.

1 : Pleistocene upland
2 : Sand dunes on the upland
3 : Sand dunes
4 : Shingle bars
5 : Dry lowlands
6 : Dry lowlands (coastal)
7 : Swampy lowlands
8 : Beach
9 : Reclaimed land

of the bar is 5 to 6 m. ii) A bar is sited southward of the Lake Gonoike. The height is about 3 m. iii) Another bar extends from the east side of Lake Gonoike to the mouth of the Tone. Most of the northern part of the bar is covered by sand dunes. The bar is 7 to 10 m high.

Subsurface structures of these bars are mentioned later.

(3) The sand dunes of the Kashima region have been studied by several geomorphologists. On the formation of sand dunes, ADACHI (1937) considered that sand of the shore and the banks of the river was blown to the center of the bar by north-eastern winds in summer and north-western winds in winter. TADA (1948) pointed out that a dune called Hakkodai, one of the largest dunes, is now eroding. This is based on observations of the topography of the dune and lamination of sand. Similar investigations have been made by NAKANO (1956). In his manuscript, OTANI (1966) classified the dunes by using several criteria, e.g. arrangement, shape, some characteristics of sand grains and color of the sand.

The sand dunes can be roughly classified into three groups : Older dune I, Older dune II, and Younger dune.

The dunes that belong to Older dune I are situated in the middle of the bar. They are generally larger than the others, and are the oldest in this area. Though the vegetation is considerably dense, there are many hollows that were probably eroded by wind. The Older dunes II lie along both sides of the Older dunes I. The dune sand on the seaside is finer and better sorted than the others. It seems that the difference is related to the sources of supply. The Younger dunes are parallel with the present shoreline.

(4) The swampy lowland site along the Tone. The surface is extensively flat and does not exceed 3 m above sea level. The main area of lowlands is utilized as paddy fields, so that this region is called the Suigo plain which means swampy country or a country of paddy field. The subsurface of the lowland is composed mainly of soft muddy deposits with peaty layers in places.

(5) The dry lowland running parallel behind the Younger sand dunes has probably formed as a back swamp. At present, the lowland is covered by aeolial sandy deposits.

Note on the beach and the reclaimed land are omitted in the paper.

PROCEDURE OF STRATIGRAPHICAL SUBDIVISION

It is probable that the Alluvial deposits that are found below the surface were influenced from changes of sea level during the latest Quaternary Period, and they are subdivided stratigraphicaly into some members corresponding to each rising of sea level (in the present paper, the term "Alluvial deposits" is used for the entire deposit filling the valleys which are dissected at the age of maximum Würm).

For the purpose of clarifying the geomorphic change of the Kashima region, the writer examined the data of bore holes collected in THE GROUND OF THE KASHIMA REGION, IBARAGI PREFECTURE (1964) of previous reports and additional data that were gathered. Some engineering properties, such as the facies, the value of N of the standard penetration test and the consistency, were used as criteria of correlation of unit layers and subdivision of sediments. It is said, however, that the examination of data of bore holes are generally difficult and the results are doubtful in many cases. Therefore, the following were used as considerations :

(1) It is estimated that the Pleistocene deposits that are found below the surface belong to the Jizodo (sand) and the Kasamori (mud) formations, because the deposits exposed at foot of Kashima upland belong to the Jizodo. Therefore, the gravelly deposits lying under the ground may belong to valley-filling deposits which were dissected at the maximum Würm.

(2) In this region, the deposits filling the valleys are characterized by sand and gravel. The muddy layers having relatively low N-values (not exceeding 15) lie under them or are intercalated in places. Such muddy layers differ from other muddy layers which lie at the base of gravelly deposits and have relatively high N-values (ca 30-40). The latter group may belong to the Kasamori while the former to the alluvium.

(3) These soft muddy layers are discontinuous horizontally. Moreover, they contain peaty materials and molluscan shells from an embayment condition at many localities. From the evidence, it is presumable that the muddy layers must have been deposited under a drowned valley, not a wavy open sea.

(4) From the presumption of a sedimentary environment, the Alluvium can be divided into two formations respectively having three characteristics : They are the undulating basal boundary plane, a soft muddy layer filling the hollow, and a cover of sandy,

gravelly layer. Though the sandy and gravelly layer is in contact with a similar underlying stratum, at the point of contact there is a lack of a soft muddy layer, and the N-value curves shows little ascent at the depth of the boundary between them.

Tab. 1 Stratigraphic succession.

Alluvial epoch	"Alluvial Deposits"	Uppermost	Younger dune sand layer	(YD)
			Uppermost muddy layer	(SM)
		Upper	Older dune sand layer	(OD)
			Upper gravel layer	(UG)
			Upper muddy layer	(UM)
		Lower	Lower gravel layer	(LG)
			Lower muddy layer	(LM)
Diluvial epoch	Kanto Loam (volcanic ash)			(KL)
	Narita formation			(NF)
	Yabu formation			(YF)
	Jizodo formation			(JF)
	Kasamori formation			(KF)

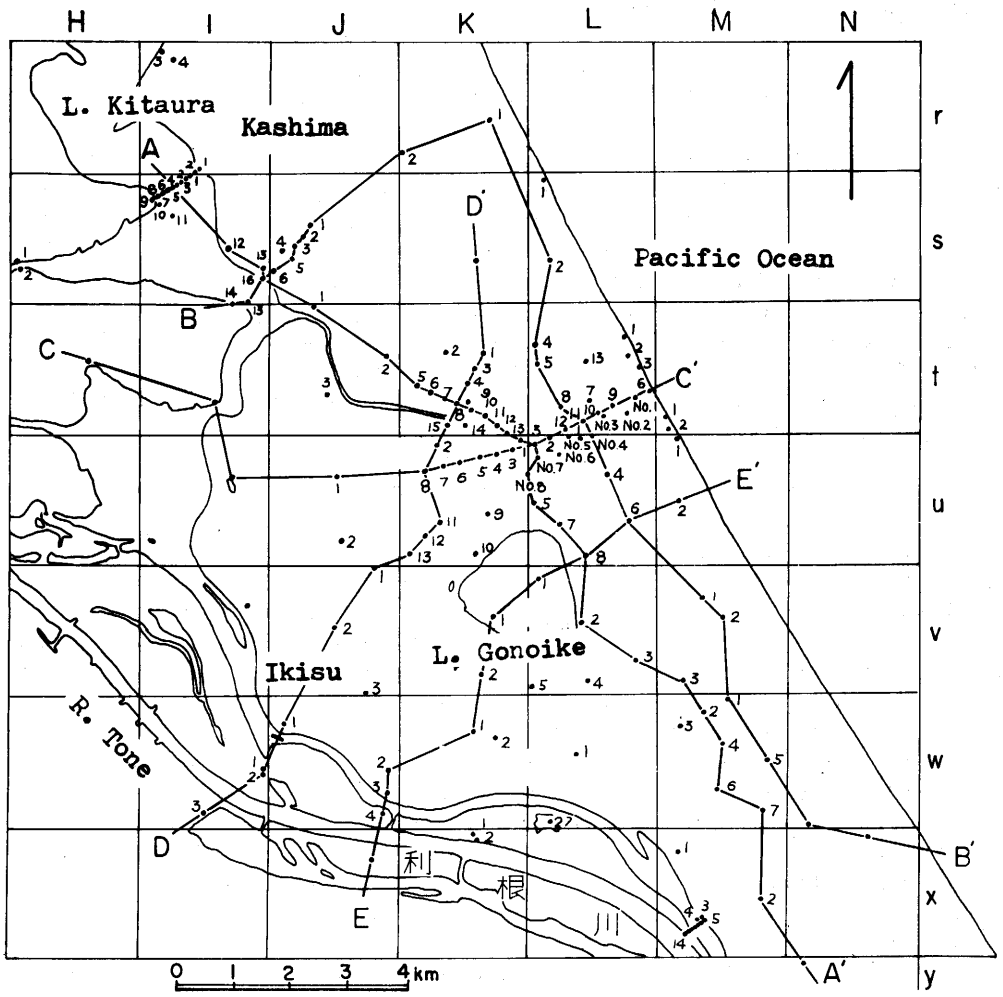

Fig. 2 Locality map of bore hole data.

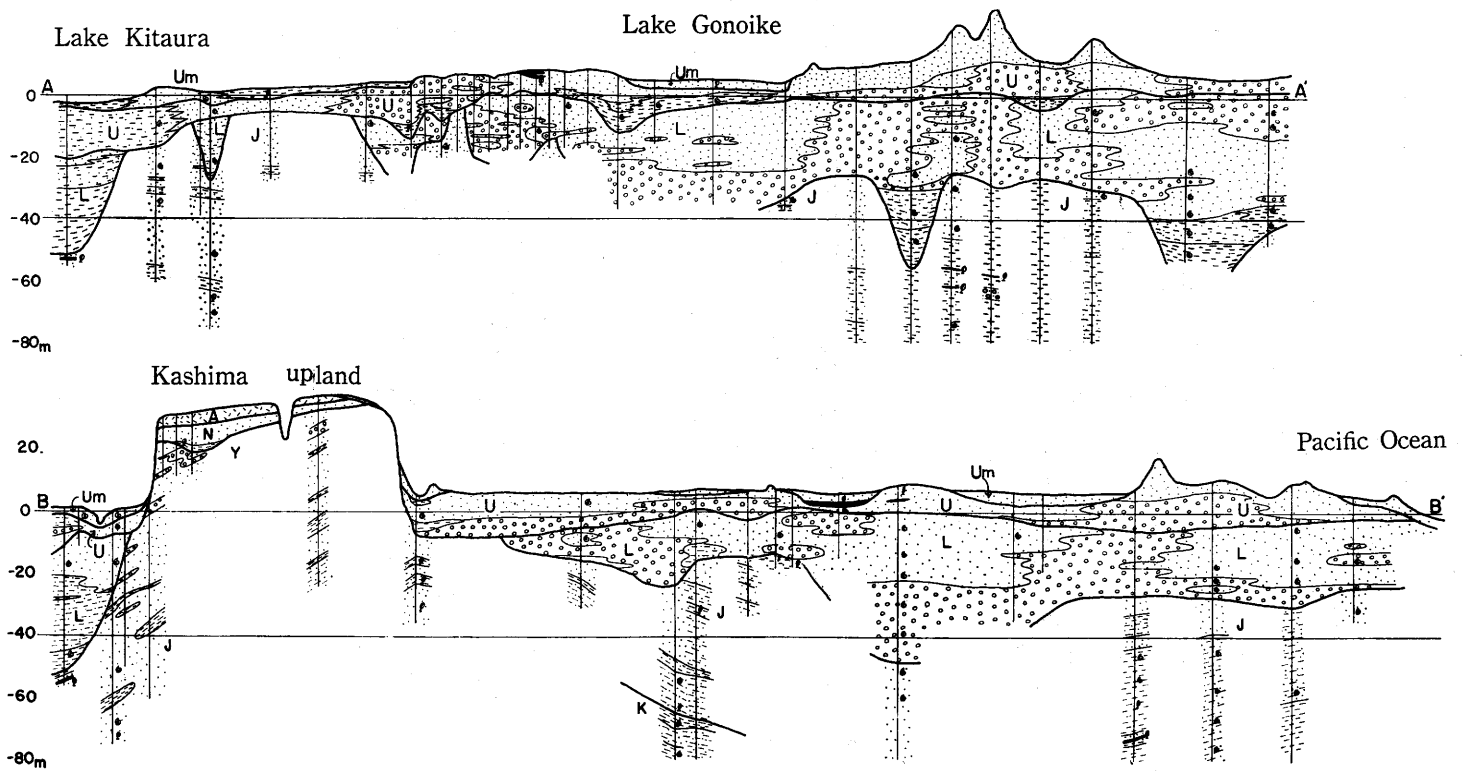

Fig. 3-1 Geological sections.

GEOLOGY OF THE SUB-SURFACE

Fig. 3 shows some geological sections of this region. The underground deposits are divided into several formations as shown in table 1. The geological characters of these strata are mentioned.

(1) The base of Alluvial deposits consists of the YF, the JF and the KF. The KF is composed of massive mudstone having generally high N-values (more than 30) as determined by bore hole data. The JF mainly consists of well sorted fine sand rarely intercalated with thin muddy layers. Two peaty layers are recognized at the basal part of the formation. The YF consists of relatively coarse sand having some gravelly layers. The KL and the NF lie at the Kashima upland but not below the lowland. The NF is composed mainly of sandy sediments and overlies the YF unconformably.

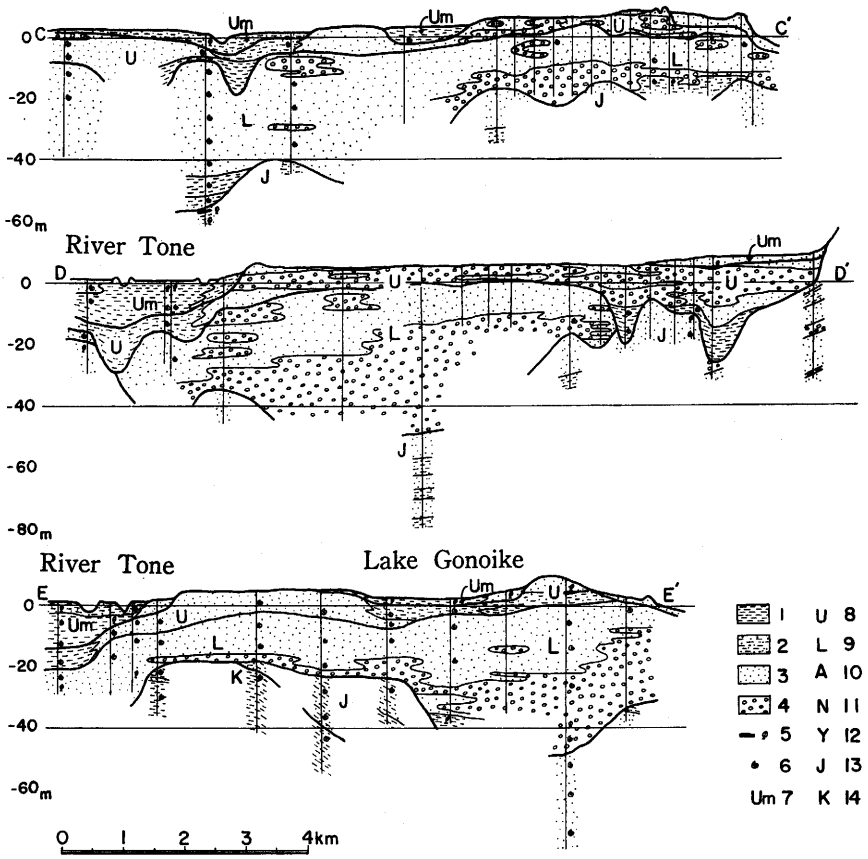

Fig. 3-2 Geological sections.

1 : clay, sandy clay, silt
2 : clayey sand, silty sand, sandy silt
3 : sand
4 : sand and gravel, gravel
5 : peat
6 : shell
7 : Uppermost formation of "Alluvial deposits"
8 : Upper formation of "Alluvial deposits"
9 : Lower formation of "Alluvial deposits"
10 : Kanto Loam
11 : Narita formation
12 : Yabu formation
13 : Jizodo formation
14 : Kasamori formation

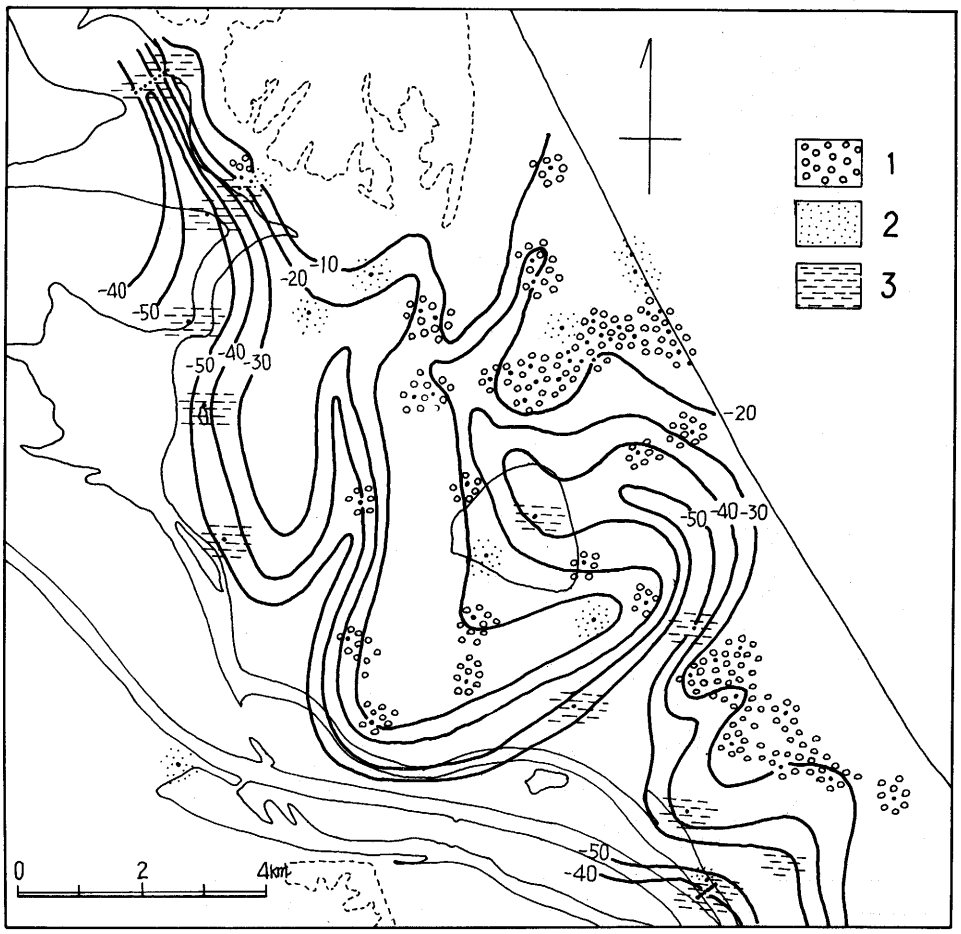

Fig. 4-1 Contour map of base of the Lower formation of "Alluvial deposits" and sedimentary facies on the base.

1 : gravels
2 : sands
3 : muds

(2) The Lower formation of Alluvial deposite is subdivided into two members, the LM and the LG. The basal plane of formation is fairly undulating. The deepest point <Mv 3> is 56.3 m below sea level so far as it is known. (The bracketed number and alphabets show respectively a point of the bore hole and a quadrangle in Fig. 2). A buried valley running around Lake Gonoike is presumed from the shape of the basal plane (Fig. 4-1).

The existence of buried valleys under the Alluvium is generally known in connection with many Alluvial plains in Japan. It is said too that the age of the formation of such valleys is at the lowest stage of the sea during the maximum Würm. In other areas, the plane shows relative flat areas at a depth of from 20 to 25 m below sea level.

The LM is composed of muddy sediments having relatively low N-values (between 10 and 15) and is distributed at only the bottoms of buried valleys. The LG consists of sand and gravel with fragments of shell that overlie the LM. At places where there is no LM, the LG directly overlie the base. The upper limit of the Lower formation is less than 4 m in height.

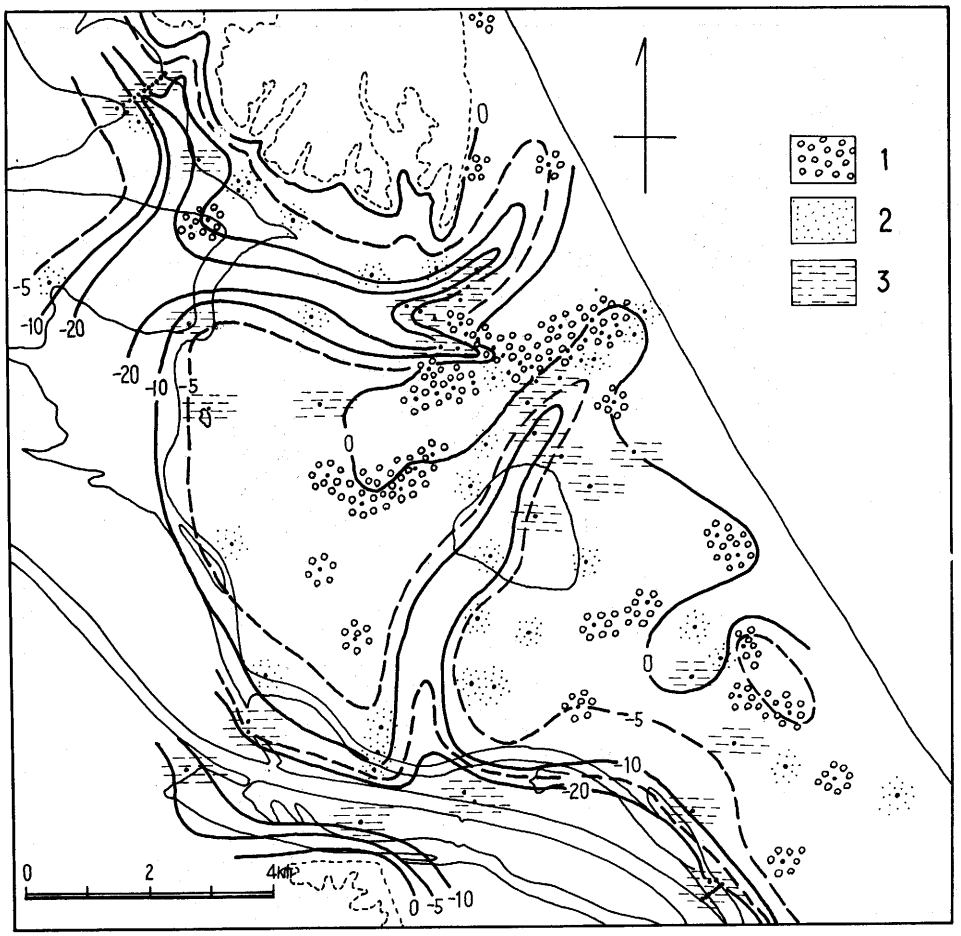

Fig. 4-2 Contour map of base of the Upper formation of "Alluvial deposits" and sedimentary facies on the base.

(3) The Upper formation of Alluvial deposits, subdivided as UM, UG and OD in ascending order, lie unconformably over the underlying formations. The plane of the boundary is undulating as in the case of the Lower formation. The deepest boundary situated at 26.7 m below the sea level. The UM which is composed of muddy layers have a fairly low N-value (from 2 to 11) and is distributed in a limited area, e.g. circumference of Lake Gonoike and to the north of Fukashiba (Fig. 4-2).

The height of the upper limit of the UG, which surely constructs the bar of Kashima, is on the average about 5 m above the sea. It suggests the approximate level of the past sea when the bar was formed. The UG is covered by the Older dune sand (OD), on which a shell mound including some potteries of the latter part of the Jomon and earlier part of the middle Jomon period were found (WAJIMA, S. et al., 1968).

(4) The Uppermost formation of the Alluvial deposits consists of the SM and the YD. The former is composed of soft muddy soils distributed in the swampy lowlands and the Younger dunes are composed of the latter. There seems to be overlie conformably

the Upper formation.

GEOMORPHIC DEVELOPMENT

From above mentioned, the geomorphic development of this region and the change of sea level during the latest Quaternary period are assumed as follows :

During the regression stage of the maximum Würm, two valleys were formed. One was along the Tone and the other ran around the Lake Gonoike.

The successive transgressions drowned these valleys, and left the Lower muddy layer (the LM). Before the maximum stage of these transgressions, sea level was stagnant and formed a wave cut terrace. The flat terrace measures -20 m at the base of the Alluvium. At the stage of maximum transgression, the sea must have rose near the present level, considering that sand and gravel (the LG) are deposited by strong stormy waves. This transgression may correspond with the Alleröd substage, because the age of the Upper formation is correlated with the Atlantic substage from archaeological data. Formerly, such a high sea level at this age was unknown. There exists this probability, for the following reasons : i) The rate of sedimentation in this region was relatively greater than the case of the other regions having an embayment environment. ii) The gravelly deposits fortunately were preserved differently from muddy deposits as in other cases.

The later regression was represented by an unconformity between the Lower and the Upper formations. From the depth of a buried valley, it is assumed that the level of sea at the time was more than 30 m below the present level. A part of a bar was dissected with the falling of the sea. At the maximum transgression in the Atlantic substage, sea level reached more than 5 m above the present level, and left coastal barriers, on which the Older sand dunes developed.

After then, the sea gradually subsided. The Uppermost formation having regressional facies deposits along Lake Gonoike. At this regression stage, the Younger sand dunes were simultaneously formed along the shore line of the Pacific Ocean.

ACKNOWLEDGEMENTS

The writer is grateful to Dr. T. Matsui of the Research Institute for Natural Resources for his kind advice. Thanks are also to Dr. S. Kaizuka and Dr. H. Kadomura, Department of Geography, Tokyo Metropolitan University, for useful discussions.

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