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Stratigraphy of the Kakegawa Pliocene in Tôtômi

By

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With Plates I—III and 4 Text-figures

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INTRODUCTION

In a former paper entitled "Molluscan Fauna of the Lower Part of the Kakegawa Series in the Province of Tôtômi, Japan"[1], I gave an outline of the stratigraphy of the Kakegawa Series and stated that I considered the age of its lower part (Dainitian) to be the Lower Pliocene. In this paper, I give a general account of the series in the same district, which lies halfway between Kyôto and Tôkyô along the Tôkaidô Railway. The fossils from the upper half of the Kakegawa, while not very numerous, may possibly amount to a considerably more number than are given in this paper, in which only the predominating members of the fauna worth enumerating in the stratigraphy and palæo-ecology are enumerated. I am now engaged in completing the list of fauna, the details of the local geology and the stratigraphy of the basement complex and of the overlying group.

Before proceeding with the description, I shall give the nomenclature of the subdivisions and the related strata:

Ogasa Conglomerate (Lower Pleistocene).

erosion

Soga Series (Upper Pliocene):

Upper Soga Beds

Middle Soga Beds (pyroclastic)

Lower Soga Beds

epeirogenic movement

Kakegawa Series:

1. This Memoirs, ser. *B*, vol. 3, no. 1.

Ketienzian stage (Middle Pliocene):
- Ketienzi Beds
- Nangô Beds } designated *Middle Kakegawa*
- Hosoya Beds } in the former paper.

Dainitian stage (Lower Pliocene):
- Tennô Sand
- Dainiti Sands

Infra-Dainitian stage (Upper Miocene):
- Siraiwa Tuff
- Infra-Dainitian Dainiti Sands

orogenic movement

Tamari Beds, Sagara Beds (Miocene).

Ooigawa Series (Lower Miocene).

It is practically impossible at present to correlate the Kakegawa Series exactly with any late Tertiary formation in remote localities. The recent southern Japonic fauna is the most closely related of all; 46.8 % of the 171 Dainitian molluscs are still living in this province. Naturally, the Kakegawa Series must be very young, as it is of the Pliocene age.

The first thing we have to do, is to establish our own standard. The age represented by the Lower Kakegawa has been named "Dainitian" and hereafter, that of the following half will be called "Ketienzian." The demarcation between the two stages will be put at the base of the Hosoya Beds. The age represented by the strata lower than the Siraiwa Tuff inclusive may be called "Infra-Dainitian" for the time being.

I personally suppose that the Dainitian and Ketienzian correspond respectively with Plaisancian and Astian. If that is so, then the Soga Series is Calabrian and the Ogasa Conglomerate belongs to the lowest stage of the Pleistocene.

Few works have been published on the geology and palaeontology of this district; some of the more important ones were cited in my former paper. I must repeat, however, that I lie under obligations to Prof. S. NAKAMURA and Mr. T. KURODA of our Institute, Mr. Y. CHITANI of the Imperial Geological Survey, and to Miss C. SCHERESCHWSKY.

THE TERTIARY ROCKS OLDER THAN THE KAKEGAWA SERIES

The Tertiary formations older than the Kakegawa Series, commencing from the bottom, are Setogawa, Ooigawa, Sagara and Tamari.

Setogawa and Ooigawa.—The formation known through long usage as the Ooigawa was a complex comprising at least two cycles of sedimentation, of which the lower group, the Setogawa, may be distinguished from the remainder, the typical Ooigawa, according to information supplied by Mr. CHITANI. The rocks belonging to the Setogawa and Ooigawa are easily distinguished from those of the overlying strata by their high consolidation. The tuff sandstone quarried at Nissaka seems to be the lower division of the Ooigawa. This is followed by alternating sandstones and mudstones and then comes a thick blue mudstone at the top. The rocks are well consolidated and the terms sandstone and mudstone may be applied in the strict sense. The Ooigawa contains few fossils, except Foraminifera. Some patches of limestone near Sagara are evidently of shallow water origin, being reefs composed of *Lithothamnium* and corals. Mr. NISHIWADA[1] has referred the most abundant alga to *Lithothamnium ramoissimum* REUSS and deemed the age of the limestone to be Miocene. Prof. YABE[2] has noticed *Gypsina inhorens* SCHULTZE and *G. vesicularis* PARKER & JONES. With these fossils as criteria we may expect the limestone to be approximately Langhian and that the Ooigawa as a whole belongs to the Lower Miocene in age, and naturally the Setogawa will be older.

Sagara Beds—This group is next in age. Its area is restricted to the southeastern part of Tôtômi only. It has been observed by geologists that the contacts of the Sagara with the Ooigawa are faults, and Mr. CHITANI[3] has assumed that the relation is uncomformable, judging from the discordancy of their dips. The Ooigawa in fact appears at the core of an anticline. The consolidation of the Sagara rocks is just intermediate between that of the Ooigawa and the Kakegawa.

The Sagara Beds are composed of alternating sands and muds, bluish muds predominating in the upper portion, with a total thickness of about 1,400 m. Near to the base, there are some seams of conglomerate intercalated in the muddy rocks.

The age of the Sagara Beds has been thought to be Miocene by Prof. YOKOYAMA[4], this opinion being based upon the fossils collected

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1) Jour. Coll. Sc. Univ. Tokyo, vol. 8, p. 236.
2) Jour. Geol. Soc. Tokyo, vol. 27, p. 391.
3) Explanatory Text of the Geological Map of Japan, Sagara (Sheet 131.) p. 5 (Japanese).
4) Jour. Fac. Sc. Univ. Tokyo, II, vol. 1, p. 324.

by Mr. CHITANI at Hirugaya and Takaoyama. The sixteen species of Mollusca named by Prof. YOKOYAMA are exclusively of the forms of the Lower Kakegawa, including such very characteristic species as *Amussiopecten praesignis* (YOKOYAMA) and *Venericardia panda* (YOKOYAMA). The occurrence of those fossils in these two localities is decidedly in the main portion of the Hagima Conglomerate, the base of the Kakegawa, but not in the Sagara. This fact is also affirmed by Mr. CHITANI himself. I still hold, however, that the fossils themselves, belong to the upper Miocene age and accordingly the view of Mr. CHITANI about the age of the Sagara stands. Fossils in the Sagara rocks are very scarce with the exceptions of Foraminifera and a Monoaxonid sponge. The latter is a characteristic fossil of the Tertiary rocks of this country and has been brought to the attention of geologists, because it is frequently found in the oil-bearing rocks of North Japan and this province. I shall speak of this sponge henceforth as *Sagarites*.

Planktonic micro-organisms such as Globigerinids may be found elsewhere in the muds. Mud from Niino near Minamiyama contains the following micro-fauna: (common species marked with*)

**Bolivinita quadrilatera* (SCHWAGER)
Bulimina inflata SEGUENZA
Cassidulina subglobosa BRADY
Clavulina communis D'ORBIGNY
Eponides tenera (BRADY)
Eponides sp.
**Globigerina inflata* D'ORBIGNY
**Globigerina bulloides* D'ORBIGNY
Globigerina (Globigerinoides) rubra D'ORBIGNY
**Globigerina (Sphaeroidinella) dehiscens* PARKER & JONES
Globorotalia tumida (BRADY)
Nonion umbilicatulus (MONTAGUE)
Sigmoilina caelata (COSTA)
Siphonodosaria sp. aff. *abyssorum* (BRADY)
Siphonodosaria sp.
Pyrgo serrata (BALLEY)
Uvigerina canariensis D'ORBIGNY

There is found a magnetic cosmic spherule in the same material.

A formal description of *Sagarites*, with appropriate comments, may be given here.

Sagarites chitanii n. gen, n. sp. (Figs. 1, 2)

The sponge is tubular, usually simple, rarely branching, with an opening at the summit, attached to the plant. The tubes are up to 50 mm. in length and 5 mm. in diameter. The outside is echinated with spicules but not corticate. It is found in muddy rocks showing cross-sections, which appear as white rings, but hardly separated from the matrix. The white substance is amorphous siliceous matter, easily turning to powder. The spicules are irregularly scattered in the white substance. In the dermal layer, the spicules have probably been

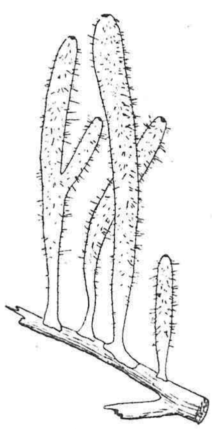

Fig. 1
Sagarites chitanii n. sp. Natural size.
Restoration

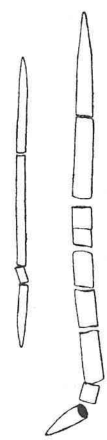

Fig. 2
Sagarites chitanii n. sp.
Oxea ×200.

roughly reticulated, judging by their horizontal and vertical orientations. They are chiefly long and slightly curved, often crooked fusiform oxea, gradually and finely pointed. Sizes are variable, measuring up to 0.32 by 0.01 mm. Besides, there are a lot of curved strongyla of various sizes, much thicker but shorter than the oxea; less often we may find broken pieces of larger spicules about 0.3 mm. in diameter; and also monoactinal tylostyli. No essential microscrela occur, but sometimes, though rarely, there are found some foreign spicules such as sigmoids and spined oxea. Probably all the spicules except the curved oxea are foreign. Indeed one of the larger spicules is hexactinal. The relative quantities of the foreign spicules are variable in individuals.

The systematic position of this sponge is not known exactly, but it belongs to the primitive Monoaxonida and is probably related to *Halichondria*. Considering that this form occurs very frequently in the oil-bearing Tertiary rocks of this country, I have ventured to name it, simply for stratigraphical purposes.

The type of this species has been obtained from the Sagara mudstone at Omaezaki. *Sagarites chitanii* is very rare in the Ooigawa, but reaches its acme in the Sagara and then declines in the following group. The upper limit is the Ketienzian.

The habitat of this sponge was presumably in the littoral belt, and it must have been drifted into the bathyal belt, floated away from the original habitat by the plants to which it attached.

Tamari Beds.—This formation is chiefly composed of muds with occasional intercalations of fine sands. It passes insensibly to silts, but never to a regular alternation.

The Tamari Beds yield *Limopsis tajimae* SOWERBY and *Turcicula argenteonitens* (LISCHKE) as frequently as the Upper Kakegawa, but these forms are nothing but facies fossils, being benthonic mud belt dwellers, and occupy the place of the *Thyasira-Lucinoma* community of the North. On a former occasion, I awkwardly mapped the Tamari as coming at the top of the Horinouti group which represents (as is discussed in this paper) a Flysch type facies of the Kakegawa Series. Subsequently, Mr. CHITANI attributed the existence of them to a lateral change from the Horinouti. This view has been supported by Prof. YOKOYAMA. More thorough observation shows, however, that the Tamari Beds lie underneath the overlapping Horinouti Group with a marked unconformity. This unconformity is a sort of angular type or nonconformity.

The Tamari are narrowly limited in the area between the two stations of Horinouchi and Kakegawa on the Tôkaidô line, and to the north. The rock is well exposed throughout the area, but nevertheless the dips are little known, owing to the homogeneity of the materials, and the high development of irregular joints. So far is known from the measurements that have been made, generally the beds have southeastward dips of from 15° to 40°; and they are evidently discordant from the general southwestward dip of the Kakegawa Series.

There are many good exposures to show the unconformable relation between the Tamari and the Kakegawa. As a rule, the latter comes to the top and the former to the bottom, divided by a marked submarine erosion surface.

The base of the Tamari Beds is exposed nowhere in the area, but it seems that the relation to the underlying Ooigawa is quite similar to the relation of the Sagara to the Ooigawa. There is an-outcrop of the Ooigawa mudstone, amidst the rocks of the Tamari, on the summit of a hill about 2 km. northeast of Horinouti. Similar exposures of the Ooigawa tuff sandstone have been found in the East and West Yamaguti districts. Perhaps the relief of the Tamari Sea floor was considerably irregular.

Fossils are not numerous. Besides the two living forms cited already, there occur a few species of *Lora*, which is a boreal genus of Turrid gastropods. The dominant members among the molluscan remains found at locality 901, about a kilometer northeast of the town of Kakegawa are *Limopsis tajimae* SOWERBY, *Limopsis crenata* A. ADAMS, *Lora rugulata* (TROSHEL), *Lora totomiensis* n. sp., *Lora* cf. *exarata* (MÖLLER), *Euspira pallida* (BRODERIP & SOWERBY) and a starved variety of a certain species of *Ancilla*. Also fractured specimens of *Turricula subdeclivis* (YOKOYAMA) and a young *Inquisitor* referable to *pseudoprincipalis* (YOKOYAMA) occur. The following species of Foraminifera are found in the material obtained from the same spot: (common species marked with*)

Cibicides sp. aff. *lobatus* (D'ORBIGNY)
Eponides sp.
Globigerina bulloides D'ORBIGNY
Globigerina inflata D'ORBIGNY
**Globigerina pachyderma* (EHRENBERG)
Globigerina (*Globigerinoides*) *cyclostoma* GALLOWAY & WISSLER
Globigerina (*Sphaeroidinella*) *dehiscens* PARKER & JONES
Loxostomum karrerianum BRADY
Nonion boueana (D'ORBIGNY)
Nonion umbilicatula (MONTAGUE)
Operculina ammonoides (GRONOVIUS)
Orbulina universa D'ORBIGNY
Sigmoilina caelata (COSTA)
Siphonogenerina raphanus (PARKER & JONES)
**Sphaeroidina bulloides* D'ORBIGNY

Those contained in the mud at the type locality of the Tamari Beds are as follows:

Bolivinita quadrilatera (SCHWAGER)
Globigerina bulloides D'ORBIGNY
Globigerina inflata D'ORBIGNY
**Globigerina pachyderma* (EHRENBERG)
Globigerina (*Globigerinoides*) *cyclostoma* GALLOWAY & WISSLER
Nodosaria scalaris (BATSH)

Orbulina universa D'ORBIGNY

Siphonodosaria sp. aff. *abyssorum* (BRADY)

Although there is some admixture of southern forms, yet the predominant species are those which live in the northern colder waters. *Lora rugulata* is known to come southwards to Rikuzen, North Japan. *Lora exarata* is distributed widely in the Arctic Ocean, but not recorded from the Japanese Islands. The other species of *Lora* seems to be extinct, but its related forms live in the boreal waters. The habitat of *Euspira pallida* is also in the North. All these shells are benthos and associated with a typical mud belt form *Limopsis tajimae* suggesting that the Tamari Beds were laid down on a relatively deep bottom. At the same time, the most abundant plankton *Globigerina pachyderma* is a northern species; hence it appears that a cold current flowed in this area. On the other hand, the fauna of the Kakegawa Series indicates a warm temperate condition equal to that of the present southwestern coast of Japan.

Sagarites chitanii occurs oftener in this group than in the Horinouti but not so frequently as in the Sagara. If this fact is allowed to be taken as a criterion, the Tamari Beds come next to the Sagara assuming that the sponge declines.

The similarity of the lithological characters of the muds of the Tamari to those of the Horinouti has caused confusion; the former is a deposit of ordinary mud belt and the latter is that of the Flysch type. The change is too sudden to be lateral and the contemporaneity of their origins can by no means be assumed, so far as the upper half of the Horinouti is concerned.

Description of *Lora totomiensis* n. sp.

Genus LORA GISTEL, 1848.

Type :—*Tritonium viridulum* FABRICIUS; (monotype, =*Bela exalata* MÖLLER)

Lora totomiensis n. sp. (*Pl. II, Figs. 17, 19*)

The shell is thin, ovate-fusiform; the whorls are 6, slightly convex and angulate; the last is about three-fourths the total height. The surface is clathrated by inconspicuous but regular spiral lines and many plicate axial costae which die out on the body-whorl. The spire is short, conical and subscalar. The dimensions are 5.7 by 2.8 mm. in the holotype and 6 by 3.1 mm. in a paratype.

Locality :—Miyawaki near Kakegawa, Loc. 901.

This new species is closely related to *Lora borealis*[1] (REEVE, 1845), but it is more ovate in outline and more conspicuously angled; the latter species has numerous close-set costae and oval apertures. *Lora totomiensis* differs from *L. rugulata* (TROSCHEL, 1866) in that the shell is ovate rather than fusiform; the spire is shorter and not so scalar, with a narrower shoulder, and that the spirals are less conspicuous lirae instead of being threads.

LATERAL CHANGE OF THE KAKEGAWA SERIES

As has already been stated, the Kakegawa Series in Tôtômi is divisible into two groups laterally, namely the normal facies and the Flysch type. The former being the typical Kakegawa may be called the Kakegawa Group and the latter will be named the Horinouti Group. The Kakegawa Group represents a complete cycle of sedimentation starting from coarser sediments deposited under the littoral sea, followed by bathyal conditions, and is concluded with the shallow water deposits named the Soga Series. These strata dip gently southwestward.

The lower half of the group changes insensibly into thick alternating beds to the southeast. Massive sands and silts thin out and are totally replaced by the Flysch type alternations of mud and sand. Roughly speaking, the line of division runs southwestward from

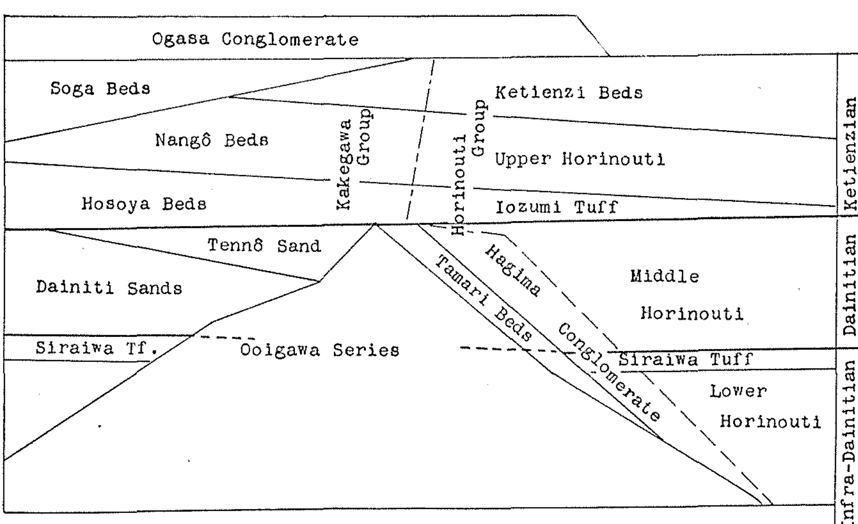

Diagram to show correlation of the Kakegawa and Horinouti Groups.

1) HARMER, Pliocene Mollusca of Great Britain, pt. II, p. 298, pl. 32, f. 12, 13.

Nisikata about a kilometer west of Horinouti. The uppermost subdivision covers the two facies—the Kakegawa and Horinouti Groups, so the latter corresponds to lower portions of the Kakegawa Series, notwithstanding it includes still lower horizons than those represented by the normal facies.

Prof. MARR[1] shows that when the belt of variables extends beyond the continental shelf, sometimes rapid vertical alternations of silt and mud occur, and the Flysch type is produced. The area occupied by the Horinouti group was in all probability a deep tract near a mountainous land very much like those deeps of the present Suruga and Sagami Bays. The slope of the deep was steep, and abundant debris were discharged upon it. It was rapidly silted up by the sediments and so the floor was raised to the level of the shelf just at the time that the deposition of the Ketienzi muds of the uppermost subdivision began.

Although it is necessary to subdivide the Horinouti for mapping purposes, yet there is hardly any scientific ground for doing this. All the tests which have been proposed by Mr. CHITANI[2] and by myself are arbitrary.

KAKEGAWA GROUP

The Kakegawa Group represents the normal facies of the Kakegawa Series, deposited under a shallow sea which existed to the west of Kakegawa. The hills are exceedingly dissected and so the valleys, filled up with Recent alluvium, are highly developed. The valley of the Saka-gawa cuts diagonally through the Kakegawa rocks which are in NW-SE. strips about 10 km. long. Thus there are two masses of hills separated by the flood plain of the Saka-gawa. Since erosion has removed a large amount of rock from the middle part of the group, it is not possible to know exactly the sequence of the strata along a cross-section.

The succession of the strata along the cross-section through Kakegawa where the series attains a thickness of about 635 m. can be made up by connecting certain prominent strata exposed on spurs projecting into the alluvial plain. The descending sequence is as follows:

Ketienzi Beds: 8. Bluish grey mud, massive, with occasional

1) Deposition of the Sedimentary Rocks, p. 127.

2) Geol. Map of Japan, scale 1 : 75,000, Sagara (sheet 131).

		intercalations of alternating fine sands and muds	224 m.
Nangô Beds	7.	Alternations of sand and mud	146 m.
	6.	Brown fine-grained thin-bedded sand	133 m.
Hosoya Beds:	5.	Silts and muds with small ferruginous nodules; white fine tuff and pumices near the bottom and the top	32 m.
Transition:	4.	Alternations of sand and mud	30 m.
Tennô Sand:	3.	Blue fine-grained sand, passes to silt toward the top	40 m.
Dainiti Sands	2.	Brown medium-grained massive sand	27 m.
	1.	Basal conglomerate	variable.

Dainiti Sands.—These are the lowest part of the lower division, and comprise the basal conglomerate, the brown massive sand in the above table and thinly bedded bluish sands with occasional interstratified shales which come out at the top in the west. The subdivision is thicker to the west, being estimated at 30 m. in the environs of Kakegawa, at 45 m. at the type locality (Dainiti) and at 70 m. near Mori. As one goes eastwards from the latter place, the Dainiti Sands decrease rapidly in thickness.

The basal conglomerate does not make a continuous bed, but it occurs sporadically in the massive sand close to the base and is variable in thickness. It often expands to a considerable thickness, over 5 m., but soon dies out within a short distance. The gravels of which it is composed are largely those of the Palaeozoic rocks. As a whole, the beds seldom contain fossils, with the exception of some localities in the Ugari district and the environs of Kakegawa where the massive sand yields rich molluscan remains. The shells are especially abundant near the very base and look as if they had been worn by undercurrents or waves and drifted up to form patches.

These heaps of organic remains and the lack of laminations in the lower portion as well, prove that an active winnowing process due to undercurrents prevailed at the bottom of the Kakegawa Sea. Prof. MARR[1] suggests that owing to the winnowing process, the amount of sediment permanently deposited in the belt of variables will be much less than it would otherwise be, and a very long period of time may be represented by deposits of no great thickness, and yet having no important physical breaks occurring in them. In fact, the difference

1) op. cit., p. 62.

between the fauna of Dainiti and that of Hônohasi is so significant as to indicate a deposition of considerably longer duration, although the distance between these localities must be considered. Of course, the faunal change thus taking place under the same conditions in a part of a cycle of sedimentation may not be expected to be very important; it is possible, however, to establish finer zones in the massive sand than in the well-bedded upper portion. The upper part of the Dainiti Sands suffered a minor winnowing process so that the laminations were retained to a certain degree. Where the sands are laminated, thin seams of shale (5 to 20cm.) are intercalated containing mica flakes and coaly matter.

I have identified 98 species of Mollusca altogether, obtained from the aggregated masses found in the basal conglomerate and the succeeding sand at Dainiti. Among the common forms noted were *Turritella perterebra* YOKOYAMA, *Suchium suchiense* YOKOYAMA, *Suchium mysticum* YOKOYAMA, *Latrunculus elatus* (YOKOYAMA), *Nassarius kurodai* MAKIYAMA, *Asthenotoma yokoyamai* MAKIYAMA, *Terebra abdita* MAKIYAMA, *Cancellaria pristina* (YOKOYAMA) and *Macoma totomiensis* MAKIYAMA. There are 40.4 % of Recent species out of the 98 species. Of these, *Cancellaria nodulifera* SOWERBY, *Ancilla albocallosa* LISCHKE and *Terebra bifrons* HINDS are the commonest. *Siphonalia cassidariaeformis declivis* (YOKOYAMA) and *Scapharca satowi castellata* YOKOYAMA are very closely related to the living species. It is a remarkable fact that, *Amussiopecten praesignis* YOKOYAYA, and *Venericardia panda* (YOKOYAMA) (the most characteristic shallow sea forms of the Kakegawa Series) are absent from this locality. A fragment of the latter species was found, but not a bit of the former. The occurrence of *Thiara totomoiensis* MAKIYAMA, an exotic freshwater form, is noteworthy.

At Asuka, about 2 km. northwest of Kakegawa, there is a lenticular accumulation of shells which represents a higher horizon than the piled up masses in the basal bed at the tunnel of Hônohasi. The following is a list of determinable forms:

Amussiopecten praesignis (YOKOYAMA)
Cancellaria pristina (YOKOYAMA)
Dentalium buccinulum GOULD
Glycymeris nakamurai MAKIYAMA
Glycymeris rotunda (DUNKER)
Limopsis chitaniana YOKOYAMA

Natica janthostoma DESHAYES
Neritaeformis sagamiensis (PILSBRY)
Oliva mustelina LAMARCK
Olivella fulgurata (ADAMS & REEVE)
Siphonalia cassidariaeformis declivis YOKOYAMA
Suchium obsoletum conglomeratum MAKIYAMA
Suchium obsoletum MAKIYAMA
Terebra subtextilis SMITH
Terebra asukensis YOKOYAMA
Turritera perterebra YOKOYAMA

A similar assemblage of fossils is seen in a small patch at Iwasibara. Calcified hard sandstones scattered in this vicinity also contain fossils very much like those listed above.

I have noted 72 species of Mollusca from the locality at Hônohasi where several accumulated masses are exposed and they have some degree of permanence. Here the most characteristic species are *Glycymeris totomiensis* MAKIYAMA, *Mercenaria yokoyamai* MAKIYAMA, *Venericardia panda* (YOKOYAMA), *Siphonodentalium nipponicum* MAKIYAMA, *Bittium kurodai* MAKIYAMA and *Terebra eoa* MAKIYAMA. *Venericardia panda* is the most abundant of all, while it is extremely rare in the sand at Dainiti. *Amussiopecten praesignis* is still absent. The living species were slightly more numerous, amounting to 41.6 %. Among the species common to Dainiti and this locality are *Acila minuta* MAKIYAMA, *Scapharca satowi castellata* MAKIYAMA, *Latrunculus elatus* (YOKOYAMA), *Siphonalia cassidariaeformis declives* YOKOYAMA, *Nassarius demissus* (YOKOYAMA), *Terebra bifrons ugaliensis* MAKIYAMA and *Clavatula dainichiensis* (YOKOYAMA). *Turritella perterebra* is by no means rare. Some forms such as *Terebra asukensis* YOKOYAMA (from *T. abdita*), *Cytharella totomiensis tachymorpha* MAKIYAMA and *Kurtziella ugali hobasiensis* MAKIYAMA differ slightly from those species found at Dainiti, and have been represented as subspecies, probably being mutations. Besides Mollusca, there is a number of *Rotalia shroeteriana* CARPENTER[1] var. tinged with ferruginous matter.

There is a good exposure of the Dainiti Sands along the west side of the hill of Tennôyama near Kakegawa, but no fossils have been obtained from there. The basal conglomerate exposed underneath a bridge close to the hill is richly fossiliferous, though the preservation is not good, having been affected by weathering. It is

1) not PARKER and JONES, because they are not responsible for the description.

not quite impossible, however, to determine the species of some of the shells. The commonest forms are *Glycymeris rotunda* (DUNKER), *Limopsis chitaniana* YOKOYAMA, *Amussiopecten praesignis* (YOKOYAMA) and *Suchium obsoletum conglomeratum* MAKIYAMA. At a glance, the assemblage of these and others, reminds one of that at Asuka. I have already stated that the transgression of the Kakegawa Sea took place from the west to the east. Overlapping of the faunal zones is obvious, and as one goes west there appear bases of earlier origin. This is also shown by the fact that a pyroclastic bed which corresponds to the Siraiwa Tuff of the Horinouti Group, reappears to the west of Dainiti at about 2 km. southwest of Mori.

The time line indicated by the Siraiwa Tuff comes earliest, followed by the fauna of Dainiti and then by that of Hônohasi which occurs on the east of the area. That of Asuka exhibits a slightly later horizon than the last mentioned. The basal bed at Tennôyama evidently corresponds to the uppermost zone. The sequence in a descending order may be named as follows, from the zonal fossils:

3. Zone of *Suchium obsoletum conglomeratum* or Asuka zone.
2. Zone of *Glycymeris totomiensis* or Hônohasi zone.
1. Zone of *Suchium mysticum* or Dainiti zone.

Of the Dainiti zone, besides the selected zonal fossil, *Suchium suchiense* and *Nassarius kurodai* are the characteristic species. *Amussiopecten praesignis* was missing in the two lower fossil zones, but later it immigrated to the area. *Limopsis chitaniana* seems to be confined to the Asuka zone. *Scapharca satowi castellate*, *Turritella perterebra* and *Latrunculus elatus* are persistent throughout the three zones. Some of the Turrid and Terebrid shells are variable in details of sculpture and show interesting mutations. All of the fossils exemplified are littoral benthos.

Tennô Sand.—Passing up from the buff massive sand, we come to the bluish grey fine massive sand of which the typical outcrop is seen at Tennôyama near Kakegawa. This bed has been numbered 3 in the table and was named Tennô Sand in the former paper. It is a wedge-shaped mass, thin away towards the west, thickest at Tennôyama, where it measures about 45 m., and vanishes altogether at Ugari about 10 km. northwest of Kakegawa. The fine sands are sometimes laminated and micaceous, and the top tends to pass into silt. The winnowing process in this case was less active than in the lower sands. Organic remains are numerous in the environs of Kakegawa; all the exposures at Nitô, Tennôyama, and Ooike yield fossils, but seldom those in Taruki about 3 km. west of Kakegawa. The fossils are not piled up, but mostly scattered in autocthonic positions. The preservation is not good except in calcareous concretions.

The lowest horizon contains a characteristic mutation of *Suchium suchiense* (YOKOYAMA). Above come the extremely fossiliferous horizons with *Turricula subdeclivis* (YOKOYAMA) and *Suchium obsoletum arenarium* MAKIYAMA, still higher, a greater number of *Amussiopecten praesignis* (YOKOYAMA) and *Crassatellites oblongatus uchidanus* (YOKOYAMA). Altogether 56 species of Mollusca have been counted, of which 53.6 % are Recent species living in the waters between Sagami Bay, and Kii Peninsula. Of the characteristic species of the Lower Kakegawa, *Turritella perterebra* YOKOYAMA, *Latrunculus elatus* (YOKOYAMA) and *Scapharca satowi castellata* (YOKOYAMA) are prolific everywhere. Foraminifera from the Tennô Sand at Tennôyama that have been examined are as follows:

Baggina totomiensis n. sp.
Bolivina aenariensis (COSTA)
**Clavulina parisiensis* D'ORBIGNY
**Clavulina communis* D'ORBIGNY
**Eponides praecincta* (KARRER)
Globigerina (*Sphaeroidinella*) *dehiscens* PARKER & JONES
Lenticulina orbicularis (D'ORBIGNY)
Lenticulina (*Robulus*) *calcar* (LINNÉ)
Lenticulina (*Robulus*) *cultrata* (MONTFORT)
Lenticulina sp.
Marginulina costata (BATSCH)
Nodosaria scalaris (BATSCH)
Nonion pompilioides (FICHTEL & MOLL)
Orbulina universa D'ORBIGNY
Quinqueloculina auberiana D'ORBIGNY
Quinqueloculina bicostata D'ORBIGNY
Rotalia beccarii? (LINNÉ)
Siphonogenerina raphanus (LINNÉ)

Besides these, there were found some monaxone spicules of sponges, an Ostracod species belonging to *Cythere* and a few Otoliths.

This subdivision of the Lower Kakegawa is based chiefly upon the lithological characters. It was laid down under a slightly deeper sea than were the underlying Dainiti Sands and may change laterally into coarse sediments near the shore.

The Tennô Sand is followed by the alternations of sand and mud labelled no. 4 in the section across Kakegawa. These latter are the link between the lower and the upper division, and die out towards the west of Dainiti. Fossils are scarce in this transitional bed. At Yasiro about 5 km. northwest of Kakegawa, it yields *Acila mirabilis* (Adams & Reeve), *Limopsis crenata* A. Adams and *Terebratulina japonica* Sowerby. These are too scanty to merit any consideration.

Hosoya Beds.—These are the lower part of the Ketienzian stage. The subdivision is composed of muds and silts, and contains two pyroclastic zones of which the lower is the thicker. In the cross-section through Kakegawa, subdivision no. 5 represents the Hosoya Beds. The beds thin away southeastwards and are replaced by the thick alternating sands and muds of the Horinouti Group. The tuffs, however, are continuous into the Horinouti Group. The lower more conspicuous pyroclastic zone is known as Iozumi Tuffite named by Mr. Chitani. It is variable in thickness, owing most probably to partial concentrations of ash and pumice or to the dispersive and accumulative winnowing processes. At Sonoda, south of Mori, the most tuffaceous portion of the Hosoya Beds is about 6 m. thick. The following is a descriptive table of the section observed in an excavation along the road between Sonoda and Hutamata:

9. Bluish silt with pumices	3 m.
8. Medium-grained sand	0.6 m.
7. Mud	0.7 m.
6. Tuffaceous sands, pumiceous, contorted	0.8 m.
5. White fine tuff	2 m.
4. Sandy white tuff	1 m.
3. Buff sand, with two thin seams of mud	38 m.
2. White sand	4.5 m.
1. Buff sand, containing gravels	?

Here in this section, the Tennô Sand does not exist but the buff sands exposed at the bottom belong to the Dainiti Sands. The beds higher than 7 are typical Hosoya Beds in their lithological characters.

The lower pyroclastic zone of the Hosoya Beds in the Ugari district is represented by a massive pumiceous silt. Going southeastwards along the strike, we meet a good exposure of the tuff about 6 m. thick in the district of Hosoya where it marks the lower boundary of the Hosoya Beds. Farther to the east, it is not well developed between Taruki and Kakegawa, but appears again on the hills about 2 km. southeast of Kakegawa. At the south end of the village of Tamari, the Hosoya Beds were directly laid down upon the basement which consists of the Tamari silts. It is difficult to distinguish the

Hosoya rocks from those of the underlying Tamari, because their appearance is very similar. Field experience has taught us that those of the upper group are characterized by small ferruginous concretions, and that they quickly turn to light clays when weathered, whereas the Tamari muds are darker and full of minor joints. Passing over the basal portion which holds pebbles, we come to the lower tuff with casts of some marine shells, the lower half of which exhibits beautiful contorted laminations, a seam of 2 cm. pumiceous sand being inserted in them; the upper half is a white compact tuff and is followed by the ordinary terrigenous muds of the Hosoya Beds. Here the thickness of the pyroclastic zone is approximately 20 m.

The Hosoya Beds are not richly fossiliferous. Those exposed along the sides of Castle Hill in Kakegawa contain fragmental shell remains. *Glycymeris rotunda* (DUNKER) with closed valves are found throughout the whole range. Besides this species, some determinable shells such as *Microfusus magnificus* (LISCHKE) *Dentalium octogonum* LAMARCK and *Natica janthostoma* DESHAYES have been collected at Hosoya. There is also an indeterminable form of *Siphonalia* which is not known living. Prof. YOKOYAMA has described a new species *Leiostraca hosoyana* from the same locality and he erroneously correlated the fossiliferous bed with the Hizikata Beds which are a mere local extension of the Upper Kakegawa or the Ketienzi Beds. The Hosoya Beds seem to be more fossiliferous westward than eastward, so shells are rather great in number in the Ugari district though not very diverse in species.

List of Mollusca from Loc. 522.

Acila mirabilis (ADAMS & REEVE)
Anomia lischkei DAUTZENBERG & FISCHER
Antigona (*Ventricola*) *casinaeformis*[1] (YOKOYAMA)
Bittium misellissimum YOKOYAMA
Chlamys (*Aequipecten*) *vesiculosus* (DUNKER)
Clavatula dainichiensis (YOKOYAMA)
Compsodrillia nakamurai n. sp.
Crassatellites nanus (ADAMS & REEVE)
Dentalium (*Antalis*) *totomiensis* n. sp.
Glycymeris rotunda (DUNKER)
Inquisitor totomiensis n. sp.

1) *Chione casinaeformis* YOKOYAMA, kown as *Venus foveolata* SOWERBY, but its locality is mentioned as Martinique.

Marginella (Stazzania) totomiensis n. sp.
Microfusus lischkei KURODA MS.
Nassarius caelatus (A. ADAMS)
Neritaeformis[1] *reiniana* (DUNKER)
Paphia schnelliana (DUNKER)
Pecten tokyoensis TOKUNAGA
Siphonalia modifica REEVE
Turris (Gemmula) totomiensis n. sp.
Uromitra nakamurai ugariensis n. subsp.
Xymene? birileffi (LISCHKE)

Other fossils at hand are a vagile simple Madreporarian coral and a single tooth of *Myliobatis*.

Shells obtained from Loc. 523, are much the same as those listed above excepting the following addenda:

Cancellaria kobayashii[2] (YOKOYAMA)
Natica adamsiana DUNKER
Inquisitor jeffreysii (SMITH)
Inquisitor totomiensis ugariensis n. subsp.
Turricula subdeclivis (YOKOYAMA)

There are some more minute gastropods and indeterminable fragments of pelecypods, but these do not seem to be very important. Of the specimens in the above lists, *Glycymeris rotunda*, *Antigona casinaeformis, Chlamys vesiculosus* and *Crassatellites nanus* are very common living species. They are bivalves, while the commonest univalves such as *Turris totomiensis* and *Inquisitor totomiensis* are not known to exist in the present seas. I have shown in my former paper how the evolution of the Dainitian gastropods is more rapid than that of the pelecypods.[3] The fact here noticed is also in harmony with that statement.

Besides the two localities mentioned above, there are many good exposures yielding fossils in this region of Ugari. The fauna, however, is too poor to furnish any valuable contribution to this research. The dominant members are always those forms cited in the above examples.

Below is a list of micro-organisms found in the silt from Loc. 523 (rare examples being omitted):

1) *Neritaeformis* MEUSCHEN, 1787=*Polinices* Montfort, 1810; type: *mammilla* L., subsequent designation by WINCKWORTH (Proc. Mal. Soc., vol. 17, p. 103, 1926).

2) *Mitra kobayashii* YOKOYAMA, Jour. Fac. Sci. Univ. Tokyo, sec. 2, vol. 2, p. 173, pl. 47, fig. 5, 1927.

3) op. cit., p. 16.

Baggina totomiensis n. sp.
Bolivina subangularis BRADY
Bulimina inflata SEGUENZA
Clavulina sp.
Elphidium subnodosum (MÜNSTER)
Eponides ungeriana (D'ORBIGNY)
Globigerina bulloides D'ORBIGNY
Globigerina inflata D'ORBIGNY
Globigerina (*Sphaeroidinella*) *dehiscens* PARKER & JONES
Globigerina (*Globigerinoides*) *cyclostoma* GALLOWAY & WISSLER
Guttulina communis D'ORBIGNY
Loxostomum karrerianum (BRADY)
Nodosaria scalaris (BATSCH)
Nonion sp. aff. *boueana* D'ORBIGNY
Orbulina universa D'ORBIGNY
Planulina wüllerstorfi (SCHWAGER)
Pulleniatina obliquiloculata (PARKER & JONES)
Rotalia beccarii (LINNÉ) var.
Siphonodasaria sp. aff. *abyssorum* (BRADY)
Siphogenerina raphanus (PARKER & JONES)
Cythere sp.

The upper portion of the Hosoya Beds where the rocks are more muddy, contains *Limopsis tajimae* SOWERBY This species is rather frequently found in the Hosoya district (Loc. 545) indicating a rather deeper sea than that where *Glycimeris rotunda* and *Microfusus lischkei* prevail.

Nangô Beds.—The Hosoya Beds are followed by the thin-bedded sands labelled 6 in the section of Kakegawa, and then come the alternating sands and muds of No. 7. Generally speaking, these beds resemble the alternating beds of the Horinouti Group in their appearances; and indeed they are mere extensions of the corresponding parts of the latter group which intervenes between the Hosoya Beds and the Ketienzi Beds of the Kakegawa group. The medium-grained sands of this section are predominant over the finer materials in the south of Kakegawa only, but they soon change to the southeastward into the usual Flysch type deposits. More field work is necessary to make clear the details of the lateral change. As one goes northwest along the strike, the beds are never the same, but they are represented by alternations of sand and mud of subequal thickness instead of thin-bedded medium-grained sands. All these strata form the middle part of the Ketienzian stage.

The upper part is less variable, consisting of uniformly alternating sands and muds, though three more sandy portions are intercalated in the Nangô district. Generally, the muds predominate over the sands in the uppermost part, so that they look very much like the muds of the Hosoya Beds and partly like those of the Ketienzi Beds. Each seam of sand or mud exposed in the eastern part of the area between Hosoya and Ugari, is thicker, having an average thickness of 40 cm. On the other hand, they are thin near the area of the Horinouti Group. Compared with the Horinouti Group, the alternations are not so rhythmic, and almost always the seams are clearly demarcated instead of showing minute Horinouti type epicycles, in which the upper boundary of each sand is indistinct, and actually turns into mud by degrees. The Nangô Beds yield a few fossils. Closed valves of *Glycymeris rotunda* (DUNKER) are the most frequent benthonic form, and fragments of *Coronura* which represent the pseudoplankton seldom occur. The following forms are recognized at Tonbe near Hosoya (Loc. 430):

"*Antiplanes*" sp.
Bathytoma lühdorfi (LISCHKE)
Glycymeris rotunda (DUNKER)
Microfusus lischkei KURODA MS.
Nassarius (*Hinia*) *caelatus dainitiensis* MAKIYAMA
Propeamussium clancularium (YOKOYAMA)
Scapharca philippiana suzukii (YOKOYAMA)
Siphonalia cassidariaeformis declivis YOKOYAMA
Siphonalia mikado MELVILL
Siphonalia sp.
Terebra straminea GRAY
Flavellum sp.

Of the above list, *Scapharca philippiana suzukii* occurs in the Kakegawa Series of Tosa and Hyûga; *Siphonalia cassidariaeformis declivis* and *Nassarius caelatus dainitiensis* are typical Dainitian, distributed in the equivalent stage of other Pliocene rocks in this country.

The following is a list of micro-fauna in the material from Ugari (Loc. 425):

Baggina totomiensis n. sp.
Cibicides lobatulus (WALKER & JACOB)
Clavulina parisiensis D'ORBIGNY
Elphidium subnodosum (MÜNSTER)
Eponides praecincta (KARRER)

Globigerina bulloides D'ORBIGNY
Globigerina crassiformis GALLOWAY & WISSLER
Globigerina dubia EGGER
Globigerina inflata D'ORBIGNY
Globigerina (Globigerinoides) cyclostoma GALLOWAY & WISSLER
Globigerina (Sphaeroidinella) dehiscens PARKER & JONES
Globorotalia tumida (BRADY)
Lagena squamosa (MONTAGUE)
Lenticulina (Robulus) calcar (LINNÉ)
Lenticulina echinata (D'ORBIGNY) var.
Lenticulina expansa CUSHMAN
Lenticulina orbicularis (D'ORBIGNY)
Lenticulina variabilis (REUSS)
Loxostomum karrerianum BRADY
Nodosaria communis D'ORBIGNY
Nodosaria lepidula SCHWAGER
Nodosaria mucronata (NEUGEBORN)
Nodosaria scalaris (BATSCH)
Nodosaria scalaris (BATSCH) var.
Operculina ammonoides (GRONOVIUS)
Orbulina universa D'ORBIGNY
**Planulina wüllerstorfi* (SCHWAGER)
Pulleniatina obliquiloculata PARKER & JONES
Rotalia beccarii (LINNÉ) var.
Saracenaria italica DEFRENCE
Saracenaria latifrons (BRADY)
**Siphonogenerina raphanus* PARKER & JONES
**Uvigerina schwageri* BRADY

Otolith sp.
Cythere sp.

Ketienzi Beds.—These were deposited in the typical mud belt and show the final subsidence of the cycle. The subdivision attains an enormous thickness, over 220 m., at the south of Nangô, but it suffered more erosion, which happened after the final emergence in the eastern part of the area. The removal of the materials was so extensive that the beds are entirely missing in the district of Ugari.

The mud of the Ketienzi Beds differs very little from that of the Tamari in lithological characters. It is more massive in fresh exposures, lighter in colour, and contains a less amount of pyrites but is more calcareous than the latter. Groups of sandy seams intervene between the massive mud. There are three distinct zones of these kinds along the cross-section through Ketienzi, the lowest zone coming 40 m. above the bottom with a thickness of 15 m. It is continuous towards the southeast, but soon splits into two groups, the upper branch of which is exposed in front of a temple named Gansyôzi, where the sandy seams are united in two thick strata separated by a bed of mud 8 m. thick, the upper one being 6 m. and the lower 12.5 m. The second zone, of which good exposures may be seen at Simomata, is situated in the middle of the division and is about 10m. in thickness at Ketienzi. The uppermost zone is less significant eastwards. In the east, there are a few other groups of sandy seams between the above three.

Fossils are not numerous. *Limopsis tajimae* SOWERBY, *Bathytoma lühdorfi* (LISCHKE) *Turcicula argenteonitens* (LISCHKE) and *Dentalium yokoyamai* n. sp. are embedded in the beds throughout the length and breadth, though not abundant. There occur more shells in the mud of Simomata (Loc. 307). They are mostly benthonic Gastropoda of the mud belt, such as *Cymatosyrinx braunsi* (YOKOYAMA), *Cymatosyrinx solicitata* (SOWERBY), *Inquisitor jeffreysii* (SMITH), *Turricula shimomatana* (YOKOYAMA), *Turris (Gemmula) totomiensis* n. sp. and *Microfusus lischkei* KURODA. Also, *Natica janthostoma* DESHAYES, *Nassarius caelatus* (ADAMS) and a few indeterminable forms belonging to *Inquisitor* and *Ancilla* occur. *Trochocerithium excelsum*[1] (YOKOYAMA) is rare but important, as this peculiar form is distributed in the Pliocene of Hyûga; nevertheless its real value in correlation has not yet been proved.

The Ketienzi mud also contains some planktonic creatures, Pteropoda, Ostracoda and Foraminifera, mostly aggregated in nodules which are often hardened by excessive amounts of calcareous substances. Some are certainly referable to the living forms, but there is some doubt on this point because the state of preservation is not good.

Various types of sponge spicules, broken pieces of echinoids, and several kinds of Otoliths may be recognized under the microscope. Micro-organisms are abundant in all parts of the mud. A few examples of the localities are shown in the table.

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1) *Cerithium excelsum* YOKOYAMA, 1928; the type of *Trochocerithium* SACCO, 1897 is *Trochus turritus* BONELLI.

HORINOUTI GROUP

As has already been stated, the Horinouti Group represents the Flysch type facies of the Kakegawa Series. There must have been a deep tract in the southeastern part of Tôtômi, under which a large amount of terrigenous materials washed out from the narrow continental shelf was deposited and silted up the deep rapidly. The group occupies an area of approximately 250 square kilometers and in general dips west-southwestward.

There are foldings of the Tertiary rocks evident along the southeast coast of Tôtômi. The most vigorous movement took place before the Kakegawa times, though the movement continued down to the final emergence. The dips of the basal part of the Horinouti Group abruptly turn, and become parallel to the dip of the Sagara Beds close by the anticline.

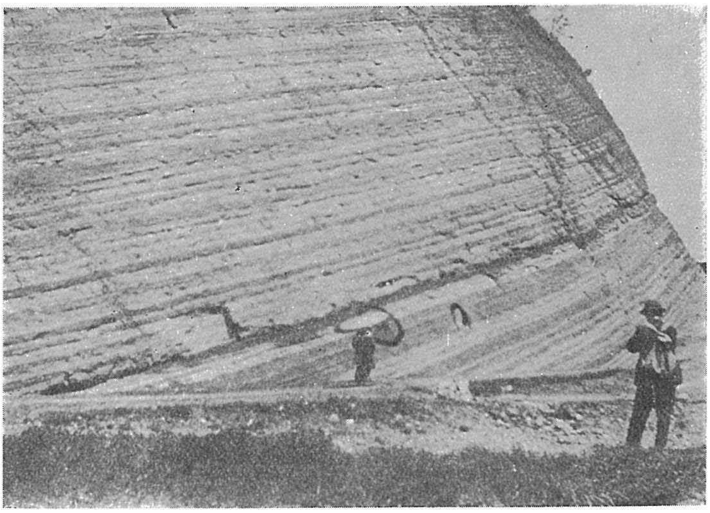

Fig. 3

Alternating sands and muds of the Horinouti Group; near the Horinouti Station. Photo. by Mr. Sakawa.

The thickness of the Horinouti is enormous, compared with its rather small area. Practically it is hard to measure owing to the fact that possible repetitions by faults are not accessible as they are concealed underneath the terrace gravels of the Pleistocene age, so that 2112 m. can be only an extremely rough estimation.

The rocks are less variable throughout this enormous thickness being invariable rhythmical alternations of sand and mud. Each seam of sand and mud is 20 cm. thick on an average but sometimes exceeds 40 cm.

The bottom of each sand layer is always clearly demarcated from the lower stratum of mud, but it passes upwards by gradations into mud, in many cases. These Flysch type alternations are due either to shifting of the direction and change in the velocity of currents, or rhythms of climatic changes, for instance the seasonal change in the case of the varve clay shown by Baron DE GEER. Prof. MARR[1] suggests that minor emergences and submergences may be other important causes. Disturbances by submarine earthquakes are no doubt operative at times upon variations in the nature of sediments.

WINKLER[2] has shown that there are four types of alternations of which "Die Bändermergelfazies" and "Die Flyschfazies" occur in the Kakegawa Series as I have mentioned above; and he further states that rhythmical sedimentation may occur as the result of periodical changes of climate. Periods of one year, and BRUCKNER'S 35 year periods, however, are too short to be taken into consideration, for strata 20 cm. thick can not accumulate under a relatively deep sea within such short periods of time. The tract upon which the Horinouti Group was laid down, was deep enough to undergo the winnowing pocesses, so no destroying action took place upon the stratification.

As in the Flysch, *Globigerina* is abundant, and predominant over other fossils. The following Foraminifera are recognized in the muds at Minamiyama:

Bolivinita quadrilatera (SCHWAGER)
Cibicides lobatulus (WALKER & JACOB)
Eponides sp.
Frondiculina sp.
**Globigerina bulloides* D'ORBIGNY
Globigerina crassiformis GALLOWAY & WISSLER
Globigerina sp. aff. *dutertrei* D'ORBIGNY
**Globigerina inflata* D'ORBIGNY
**Globigerina* (*Globigerinoides*) *cyclostoma* GALLOWAY & WISSLER
Globorotalia tumida (BRADY)
Gyroidina orbicularis D'ORBIGNY
Lagena sp.
Nonion sp.
Orbulina universa D'ORBIGNY

1) op. cit., p. 88.
2) Zum Schichtungsproblem; Neues Jahrbuch, 53 B. Bd., B, pp. 271-320, 1926.

Pulleniatina obliquiloculata PARKER & JONES

The chambers of the Foraminiferas are filled with small granular crystals of pyrites.

It is clear that the pyroclastic beds are independent of terrigenous sedimentation; though they may indicate local time lines, they can not be used in regional correlation. The tuffs of the Hosoya Beds also spread over the area of the Horinouti Group. The upper tuff is ill-defined, but the lower or the Iozumi Tuff appears as a conspicuous bed composed of alternations of white fine tuff and pumiceous sand accumulating up to 20 m. at Iozumi. It thins gradually southeastward.

About 300 m. lower than this pyroclastic horizon, there lies another tuff named Siraiwa or Hotta Tuff with a thickness of about 24 m. at the type locality. The strip runs southeastward to Minamiyama and then turns south along the northeast southwest folding of the Sagara Beds. This tuff is thinner at Minamiyama, where it is 10 m., than in the northwest. At Siraiwa near Horinouti, the bed consists of a single massive light-coloured fine tuff, but it differentiates into alternations like the Iozumi Tuff. Sometimes the pyroclastic materials were scattered in the terrigenous muds to make tuffaceous shales, a good example of which is seen at Kokuzô near Minamiyama. Remarkable contortions often found both in the Siraiwa and the Iozumi Tuffs have been attributed to subaquatic glidings by Prof. OGAWA. Under the microscope, the white substances appear as volcanic glass and little crystals but organic remains, such as *Globigerina* occur.

The alternations change to thick conglomerate near the overlapping base. The seams of sand more quickly change into beds of coarser sediments, which were derived from a narrow shelf where the action of currents was prevalent. The continental slope upon which the overlapping conglomerates were deposited was steep; hence huge angular boulders of the Ooigawa sandstones more than 5 m. in diameter were mixed with smaller boulders. The conglomerates consist of subangular fragments of the Ooigawa shale, and the Sagara muds in the east, or the Tamari muds in the north, together with subordinate rounded pebbles of older rocks.

Along the eastern border of the Horinouti Group, alternations of conglomerate and finer sediments come first, close to the floor, followed by a thick polygenetic conglomerate known as "Hagima Conglomerate" about 30 m. thick at Hagima; and then the alternating conglomerates, sands and muds come again. In the northern border, and near the normal Kakegawa area, massive sands are often intercalated between the conglomerates, and some of them extend farther into the middle area of the Flysch type alternations.

These basal and peripheral conglomerates, occasionally contain aggregate masses of shell fragments washed down from the shelf. Septaria nodules found in the conglomerate at Simoyubi seem to represent the earliest organic record of the Infra-Dainitian, containing a bivalve species, referable to the group of *Lucinoma annulata* REEVE a form associated as a rule with the group of *Thyasira bisecta* CONRAD in the Neogene rocks of this country. There is some doubt of the septaria being "remanié" derived from the Sagara Beds. Blocks of shelly limestone found in the conglomerate at Takao-yama and a slightly higher horizon than that of Simoyubi enclose Operculines, and the typical Kakegawa forms such as *Amussiopecten praesignis* and *Venericardia panda*. The climate of the early Horinouti age was warm enough to permit *Operculina* (*Operculinella*) *venosa* FICHTEL & MOLL to live on the shelf associated with the above-mentioned shells.

The fossil shells named by Prof. YOKOYAMA from the Hagima Conglomerate at Hirugaya (Loc. 809) have erroneously been thought to be from the underlying Sagara Beds. Besides *Amussiopecten praesignis* (YOKOYAMA), *Venericardia panda* (YOKOYAMA) and *Turricula subdeclivis* (YOKOYAMA) Prof. YOKOYAMA has described a few interesting new species, namely *Timoclea ozawai* (as *Venus*), "*Cardium*" *egregium* and *Crassatellites pauxillus*. There is a laminated sandstone with *Rotalia schroeteriana* CARPENTER var. in the uppermost part of the conglomerate at Hirugaya (Loc. 810).

Along the northern border, the shell remains are by no means scarce in the conglomerates; they are, however, mostly too fragmental to permit of any accurate identification, and especially those of the Tomita district have not been well surveyed as yet.

The shell sandstone with a variable thickness is exposed along the bank of a reservoir at Kumomyô about 3 km. north of Horinouti and yields ill-defined *Operculina* and fragments of *Suchium*. Passing over the valley of Sakagawa and going westward, we come to the younger horizons of the conglomerate overlapping the lower ones. The lists of the common determinable species of Mollusca from these horizons at several localities are given below, mostly in ascending order (abundant species are marked with*, and rare forms are omitted):

1. A. Teragaya, Higasi-Yamaguti (Loc. 710).
   Amussiopecten praesignis (YOKOYAMA)
   **Chione* (*Timoclea*) *ozawai* (YOKOYAMA)

Chione (*Clausinella*) *isabellina* (PHILIPPI)
Clementia vathelcti MABILLE
Paphia schnelliana (DUNKER)
Psammosolen divaricatus (LISCHKE)
Venericardia panda (YOKOYAMA)

B. In front of the temple of Koyasu-kwannon, Higasi-Yamaguti.
Neritaeformis sagamiensis (PILSBRY)
Oculina sp. (Coral)
Siphonalia cassidariaeformis declivis YOKOYAMA
Suchium suchiense (YOKOYAMA)

Perhaps this horizon (1) comes very close to that one represented by the shells at Hirugaya. I propose to call this the *Timoclea ozawai* zone as this species seemed to be chiefly confined to this horizon.

2. In a bed of massive silt resting upon the top of a small hill consisting of the Tamari muds at Honzyo (Loc. 680)
Ancilla albocallosa (LISCHKE)
Bittium misellissimum YOKOYAMA
Crassatellites oblongatus uchidanus (YOKOYAMA)
Fulgoraria (*Psephaea*) *totomoiensis* MAKIYAMA
Inquisitor jeffreysii (SMITH)
Inquisitor eoa MAKIYAMA
Limopsis crenata ADAMS
Microfusus magnificus (LISCHKE)
Paphia schnelliana (DUNKER)

This bed does not belong to the Horinouti Group in a strict sense, but possibly is a remnant of the shallow water deposits upon a narrow shelf, and a fault running from Yasaka to Sonogaya has placed the block in the present position, neighbouring the typical alternating beds.

3. A. Senba, Higasi-Yamaguti (Loc. 674).
Chicoreus totomiensis MAKIYAMA
Clementia vathelcti MABILLE
Dosinia bilunulata (GRAY)
Glycymeris nakamurai MAKIYAMA
Leda confusa HANLEY
Limopsis multistriata (FORSKÅL)
Macoma totomiensis MAKIYAMA
Oliva mustelina LAMARCK
Suchium mysticum (YOKOYAMA)
Suchium suchiense (YOKOYAMA)
Suchium obsoletum MAKIYAMA

Soletellina boedinghausi LISCHKE
Turritella perterebra YOKOYAMA
Venericardia panda (YOKOYAMA)

B. Between Senba and Awamoto (Loc. 673).
Amussiopecten praesignis (YOKOYAMA)
Cancellaria pristina (YOKOYAMA)
Chicoreus totomiensis MAKIYAMA
Chione (*Clausinella*) *isabellina* (PHILIPPI)
Glycymeris totomiensis MAKIYAMA
Limopsis multistriata (FORSKÅL)
Limopsis tajimae SOWERBY
Mercenaria yokoyamai (MAKIYAMA)
Neritaeformis sagamiensis (PILSBRY)
Paphia schnelliana (DUNKER)
Scapharca satowi castellata (YOKOYAMA)
Siphonalia cassidariaeformis declivis YOKOYAMA
Suchium mysticum (YOKOYAMA)
Suchium suchiense (YOKOYAMA)
Suchium obsoletum MAKIYAMA
Terebra bifrons HINDS
Turritella perterebra YOKOYAMA
Venericardia panda (YOKOYAMA)

Here in these localities, fragments of shells are found abundantly in concretions and in accumulations in the brown sands between the conglomerates a little above the Siraiwa Tuff. The fauna resembles very much that of Dainiti in its assemblage of Molluscan forms. *Suchium mysticum* and *S. suchiense* are the characteristic fossils of this zone. The Siraiwa Tuff which lies underneath these sands corresponds to the lower tuff observed in Sonoda near Mori.

4. Calcareous siltstones embedded in the alternations at Sonogaya (Loc. 679)
Acila mirabilis (ADAMS & REEVE)
Amussiopecten praesignis (YOKOYAMA)
Anomia lischkei DAUTZENBERG & FISCHER
Calyptraea sp.
Cantharus totomiensis MAKIYAMA
Crassatellites oblongatus uchidanus YOKOYAMA
Dosinia japonica REEVE
Glycymeris totomiensis MAKIYAMA
Leda confusa HANLEY

Macrocallista pacifica (DILLWYN)
Minolia sp.
Nassarius (*Caesia*) *demissus* (YOKOYAMA)
Mercenaria yokoyamai (MAKIYAMA)
Neritaeformis sagamiensis (PILSBRY)
Papyridea mutica (REEVE)
Psammosolen divaricatus (LISCHKE)
Siphonalia cassidariaeformis declivis YOKOYAMA
Siphonalia mikado MELVILL
Solen gordonis YOKOYAMA
Suchium obsoletum MAKIYAMA (A mutation near to *conglomeratum*)
Tellina kurodai MAKIYAMA
Terebra triseriata GRAY
Tonna sp. aff. *lischkeana* KÜSTER
Venericardia panda (YOKOYAMA)

5. Kurozumi, about 3 km. north-northeast of Kakegawa, in the conglomerate (Loc. 671).

Amussiopecten praesignis (YOKOYAMA)
Dosinia bilunulata (GRAY)
Macrocallista pacifica (DILLWYN)
Nassarius (*Caesia*) *demissus* (YOKOYAMA)
Paphia schnelliana (DUNKER)
Scapharca satowi castellata (YOKOYAMA)
Siphonalia dainitiensis MAKIYAMA
Suchium suchiense YOKOYAMA (A mutation)
Suchium obsoletum MAKIYAMA
Suchium mysticum (YOKOYAMA) (A mutation, base smooth)
Turritella perterebra YOKOYAMA
Venericardia panda (YOKOYAMA)

6. Mitare near Kakegawa, muddy conglomerate with glauconite-like substances (Loc. 670).

Dosinia japonica REEVE
Glycymeris rotunda (DUNKER)
Microfusus magnificus (LISCHKE)
Natica janthostoma DESHAYES
Scapharca satowi castellata (YOKOYAMA)
Suchium suchiense YOKOYAMA

Two corals which belong to *Oculina* and *Flabellum* respectively are also to be found in this rock.

Of these localities, the shells from (4) and (5) show evident relation with those of the Dainiti sands; they come high above the *Suchium mysticum* zone, though we have no positive data to justify correlating them with the Hônohasi zone. Those of (6) exhibit a calm water condition like the Tennô Sands.

In conclusion, I would emphatically repeat that the Horinouti Group is merely a Flysch type facies of the Kakegawa Series and that its lower parts, lower than the Siraiwa Tuff, are the deposits preceding the lowest fossiliferous horizon of the normal Kakegawa Group.

SOGA SERIES AND OGAWA CONGLOMERATE

The Soga Series is a shallow sea—and partly fluviatile deposit laid down during the period of emergence which followed the maximum subsidence of the Ketienzi Beds. It is difficult to distinguish the Soga Series from the underlying rocks by its lithological characters only; but the rocks are evidently coarser and more micaceous than the mud of the Upper Kakegawa. The rocks of the lower part, with an aggregate thickness of 50 m. are mostly sands with mica flakes, and laminated with thin layers of mud. The sands almost always enclose *Glycymeris rotunda* (DUNKER), *Suchium subsuchiense* MAKIYAMA and *Suchium giganteum* (LESSON). A bed of pumiceous and micaceous silt forms the middle subdivision immediately following the lower beds. The fossils found in this bed at various localities in the Soga district, are those of typical shallow water forms such as *Clementia vatheleti* MABILLE, *Glycymeris rotunda* (DUNKER) and *Paphia greefei* (DUNKER).

The upper subdivision of the formation—probably of fluviatile origin—is made up of current-bedded sands with pebbles to the west of the Ogasa Hills at least, but as the Soga Series ranges eastward they become laminated, micaceous sands, and silts with marine shells. In the northside valleys of the Ogasa Hills, the silts contain *Glycymeris rotunda* (DUNKER), *Macrocallista pacifica* (DILLWYN), *Xenophora exuta* (REEVE), *Dentalium weinkauffi* DUNKER, *Suchium giganteum* (LESSON) and many other insignificant forms of Mollusca.

Even the lower two subdivisions change laterally westward into typical fluviatile deposits, and in the Ugari district the real bulk of the Soga Series is made up of pebbles and sands, with an irregularly formed pyroclastic bed intervening between the upper and lower subdivisions. In fact, the latter tuff plays the rôle of an index bed corresponding to the middle pumiceous bed in the east.

Micro-organisms found in the sand taken from the basal bed at Ryôke are as follows:

Baggina totomiensis n. sp.
Cibicides lobatulus (WALKER & JACOB)
Elphidium subnodosum (MÜNSTER)
Eponides praecincta (KARRER)
Globigerina cyclostoma GALLOWAY & WISSLER
Globigerina inflata D'ORBIGNY
Globigerina bulloides D'ORBIGNY
Lenticulina (*Robulus*) *calcar* (LINNÉ)
Nonion umbilicatula (MONTAGUE)
Orbulina universa D'ORBIGNY
Operculina ammonoides (GRONOVIUS)
Planulina wüllerstorfi (SCHWAGER)
Quinqueloculina auberiana D'ORBIGNY
Rotalia papillosa compressiuscula BRADY
Siphonogenerina raphanus (PARKER & JONES)

Loxoconcha sp.
Calcareous sponge spicules.
Fragments of Echinoid tests.

Besides quartz grains, and mica particles, there is some amount of volcanic glasses.

The Soga beds are unconformably overlain by the monogenetic Ogasa Conglomerate about 150 m. thick. The gravels of the conglomerate are chiefly rocks of the Mikura Series with a few exceptions of porphyrite, granite and Palaeozoic rocks. The conglomerate overlaps a mud formation of marine origin, good exposures of the latter being seen in the environs of Hukuroi and at Gôdo in the Ikesinden district. The mud yields rich micro-fossils; for example, Foraminifera and Radiolaria are abundant in the mud of Gôdo.

STRUCTURE

Generally speaking, the area in which the Kakegawa rocks is disposed is synclinal. The syncline plunges southwestward and is very asymmetrical, the northern limb being so wide and gentle to the axis that it may be referred to as a monocline, while the other limb is limited to a narrow belt along the basement composed of the Sagara and Ooigawa Beds which are more strongly folded. Therefore, the strata may be said to be arranged in southwesterly dipping sheets, which are affected by an obliquely transverse NE-SW up-fold. Up and down folds of the Sagara Beds, however, had taken place previously to the beginning of the Kakegawa epoch.

The Horinouti Group which is the Flysch type facies of the Kakegawa Series, was deposited in the deep basin produced by the same movement as the above, and the strata overlap along the steeply sloped floor in the north of the area. This fact is clearly shown in the accompanying geological map as the strikes are diagonal or almost at right angles to the basal boundary. This steep floor seems to be the continental slope in front of the very narrow shelf which was backed by the Akaisi mountains. Huge blocks of the Setogawa and Ooigawa rocks, probably those bordering the outer or coastal zone of the mountainous land, were brought down to the slope and mingled with the finer sediments.

There is also an unconformity between the Hagima Conglomerate and the Sagara Beds. There are many reasons to account for the fact that the pre-Kakegawa folding happened under the sea so that no important time gap intervenes between the two series; they certainly represent a continuous sedimentation interrupted only by the orogenic movement. Angular and less sorted boulders of the pre-Kakegawa rocks contained in the Hagima Conglomerate were mostly supplied from the tops of the anticlines through the agency of marine erosion and partly by subaquatic slides. The Molluscan shells which lived upon the banks were driven broken to pieces, into the deeper basin of the Horinouti Sea. Submarine unconformities of this kind may not be taken as valuable data for correlation, because, though they may appear, sufficiently remarkable to be termed nonconformities, the elevational orogenic movements are more local than the epeirogenic earth-movement. If subsequent subsidence occurs, the newer rocks are unconformable at the summits of the anticlines, but they overlap their lower members on the limbs, and rest conformably upon the flat basins. There will be marked overstepping at the top of each anticline; and naturally the time gap between the basement series and the new one is at its maximum there. With the diastrophisms as criteria, we may fail, therefore, to correlate the Sagara and Kakegawa Series to the unbroken sequence of the marine bathyal Miocene and Pliocene strata in Northern Japan, which have been grouped under the head of "Mizuho Series" by Prof. YABE and Mr. AOKI.

There have been observed innumerable minor faults in the area of the Kakegawa Series, especially rich near and in the pyroclastic zones, but their effect on the entire structure is negligible, with a few exceptions along the north border. The mapping shows certain discontinuities of the strata interposed in the Recent alluvium between the hills. The most remarkable concealed dislocation of this kind, is that of the Saka-gawa valley. The displacement is not very large near Kakegawa, while it grows larger towards the west, where the southern side is evidently thrown down. It may be taken as a hinge fault, if it is permitted to assume that its concealed part is continuous with a fault between Sonogaya and the south of Nissaka.

There is also a NE-SW flexure of the Kakegawa Group in the Ugari district, as is shown in the geological map. It is clear that the flexure as well as all the above-mentioned dislocations accompanied the epeirogenic movement before the commencement of the cycle of the Soga Series.

PALÆO-ECOLOGY

It has been demonstrated in the former paper "Molluscan Fauna of the Lower Part of the Kakegawa Series etc." that the temperature of the Lower Kakegawa waters was about the same as that of the present sea of the Kii Peninsula. The seas of Japanese Islands are capable of apportionment into two provinces, namely northern and southern, according to the distributions of the living Mollusca. The southern province, which is obviously related to the Indo-Pacific Province, is generally known to European malacologists as the Japonic Province and is considered to consist of the Japanese Islands together with Corea and a stretch of the adjacent mainland coast of unknown extent. The fauna is governed by the warm "Kurosio" current which permits subtropical species to extend far north to Kinkazan where the cold "Oyasio" current keeps them back.

The fauna of the Kakegawa Series is really of the Kurosio type with a few exceptions. This is shown by the fact that the majority of the living members of the fauna are distributed in the southern Japonic Province. Thus *Glycymeris rotunda* (DUNKER), *Pinna attenuata* REEVE, *Myadora reeveana* SMITH, *Clementia vatheleti* MABILLE, *Macrocallista pacifica* (DILLWYN), *Paphia schnelliana* (DUNKER), *Antigona (Ventricola) casinaeformis* (YOKOYAMA), *Raëta pulchella* (ADAMS & REEVE), *Corbula erythrodon* (LAMARCK), *Corbula scaphoides* HINDS, *Theodoxus (Clithon) retropictus* (MARTENS), *Acmaea pygmaea* (DUNKER), *Bursa ranelloides* (REEVE), *Bezoardica japonica* (REEVE), *Neritaeformis sagamiensis* (PILSBRY), *Eunaticina papilla* (GMELIN), *Oliva* *mustelina* LAMARCK, *Ancilla albocallosa* (LISCHKE), *Cancellaria spengleriana* DESHAYES, *Terebra straminea* GRAY, *Terebra bifrons* HINDS, *Asthenotoma difficilis* (SMITH), *Inquisitor jeffreysii* (SMITH), *Siphonalia mikado* (MELVILL), *Siphonalia stearnsii* PILSBRY and *Microfusus magnificus* (LISCHKE) have been recorded from the seas between Tateyama and Nagasaki. Some of them are distributed as far south as the China Sea and the Philippines. Many of the extinct species and subspecies are evidently allied to living representatives of the southern province. The following molluscan genera belong to the Indo-Pacific element: *Heliacus*, *Cypraea*, *Bezoardica*, *Bursa*, *Biplex*, *Cantharus*, *Latrunculus*, *Chicoreus*, *Acupurpura*, *Cyphonochilus*, *Thais*, *Strigatella*, *Lyria*, *Oliva*, *Ancilla*, *Trigonostoma*, *Terebra*, *Turris*, *Asthenotoma*, *Cytharella* and *Conus*.

Foraminifera are not of great use in drawing inferences as to temperature, for many of the species are eurythermic; but the shallow water benthos *Operculinella venosa* (CUSHMAN) and *Rotalia schroeteriana* CARPENTER live only in the subtropical and tropical regions of the present Indo-Pacific Province. Judging from the fact stated above we may conclude that the Kakegawa fauna as a whole lived in the warm waters of the Kurosio.

Aside from a few forms, the fossils are such as live in the open sea in water having only a slight range of salinity. *Thiara totomiensis* MAKIYAMA is the only one which lived in freshwater, according to the evidence afforded by recent species of the same genus found in the Tropics. The absence of *Batillaria*, *Tympanotonos*, *Cerithidea*, *Clava*, *Corbicula* and *Ruditapes* which are liable to be present in brackish water deposits of the Pliocene of this country, and of the solitary example of the freshwater form as well, indicates that very little brackish water material had access to the area under discussion.

Acmaea pygmaea (DUNKER) which is rarely found in the Dainiti Sands is evidently a littoral shell which lived on hard rocks. Probably *Theodoxus retropictus* (MARTENS), *Thais nakamurai* MAKIYAMA and *Lacuna intermedia* MAKIYAMA had a similar habitat. The listed species of the Dainitian stage do not represent the communities of that age, because they were mostly piled up by winnowing actions into lenticular masses, and moreover some dead gastropod shells might have been transported by hermit crabs. Therefore such fossil heaps in the Dainiti Sands indicate the mixed up communities of the adjacent sea bottoms. There is little fear of any considerable amount of benthonic individuals under deeper waters being mixed with them except in the case of very thin shells.

According to the data of the living species, the heaps are amalgamated formations of littoral shells on a sandy beach from the intertidal belt to shorewater. The common bivalves in the localities at Dainiti such as *Scapharca satowi castellata* YOKOYAMA, *Dosinia japonica* REEVE, *Tellina kurodai* MAKIYAMA, *Macoma totomiensis* MAKIYAMA, *Mactra sulcataria* DESHAYES and *Corbula erythrodon* LAMARCK, as well as the absence of *Amussiopecten praesignis* (YOKOYAMA) indicate the littoral condition. They feed on micro-organisms and are preyed upon by carnivorous gastropods.

There is a probable relationship between the occurrence of *Scapharca satowi castellata* and the fossil form of *Neritaeformis sagamiensis*. The relationship would be what is termed, "carnivore niche."[1] Scavengers such as *Suchium suchiense* (YOKOYAMA). *Suchium mysticum* (YOKOYAMA), *Nassarius caelatus dainichiensis* (YOKOYAMA), *Caesia demissa* (YOKOYAMA) and the species of *Olivella* occur abundantly.

The amalgamated formations at various localities near Hônohasi are of a slightly later origin than those at Dainiti; and at the same time they are composed of certain communities under slightly different ecological factors from the latter. Here *Glycymeris totomiensis* MAKIYAMA, *Mercenaria yokoyamai* (MAKIYAMA) and *Venericardia panda* (YOKOYAMA) are abundant while *Scapharca satowi castellata* is by no means rare. In a locality at Taruki, *Amussiopecten praesignis* and *Limopsis chitaniana* YOKOYAMA are the commonest constituents. These micro-phagous bivalves together with the scavengers *Olivella*, *Nassarius* and *Suchium obsoletum* MAKIYAMA indicate a littoral sandy bottom. The presence of *Amussiopecten* and the total absence of the freshwater form, we may attribute to a slightly deeper belt. Associated with the appearance of *Glycymeris totomiensis*, the number of *Natica janthostoma* apparently increased in the Hônohasi zone. The latter carnivore is always found with *Glycymeris* in the Neogene rocks of this country, and perhaps is responsible for most of the holes in the beaks of victims.

The winnowing process was less active in the deeper sea under which the Tennô Sand was laid down. Hence it is evident that the animal communities have been preserved with less disturbance than in the Dainiti Sands. *Mercenaria yokoyamai*, *Chione isabellina*, *Macoma totomiensis*, *Mactra sulcataria*, *Panope japonica*, *Cantharus totomiensis*, *Thais nakamurai* and the species of *Terebra* are un-

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1) Elton, C., Animal Ecology, p. 63, 1927.

represented, though they were common as facies fossils in the underlying bed. On the other hand, *Crassatellites yagurai* MAKIYAMA, *Crassatellites oblongatus uchidanus* (YOKOYAMA), *Fissidentalium yokoyamai* MAKIYAMA, *Lischkeia alwinae* (LISCHKE), *Xenophora exuta* (REEVE), *Bursa ranelloides* (REEVE), *Bezoardica japonica* (REEVE), *Lyria mizuhonica* MAKIYAMA, *Psephaea totomiensis* MAKIYAMA, *Uromitra nakamurai* MAKIYAMA, *Turricula subdeclivis* (YOKOYAMA), *Inquisitor jeffreysii* SMITH), *Siphonalia mikado* MELVILL and *Microfusus magnificus* (LISCHKE) appeared for the first time in this horizon. These data may be used to draw the conclusion that the communities were on fine sand bottoms of the sublittoral zone. There were also niches filled by monaxonidan sponges and Foraminifera. As mentioned in the former paper, slight changes of assemblage occurred during the period of the deposition either in stratigraphical sequence or in ecological succession. Perhaps both the series of events were operative.

The bottom materials were very fine and in part they are muddy enough to be designated as silt, so that the shells adapted to coarser sands, such as *Cancellaria nodulifera* SOWERBY and *Nassarius kurodai* MAKIYAMA, with their coarse noduliferous sculptures, did not favour the Tennô Sand. *Scapharca satowi castellata*, *Venericardia panda*, *Latrunculus elatus* (YOKOYAMA), *Ancilla albocallosa* (LISCHKE) and *Turritella perterebra* YOKOYAMA had a wider range both in space and time, and extend from the littoral Dainiti Sands up to the sublittoral Tennô Sand. *Amussiopecten praesignis* had also a wide range but it might not hawk about the littoral zone. It is clear on looking over the faunal list that most of the burrowing bivalves are recorded from sandy beds. Thus *Panope*, *Mercenaria*, *Mactra*, *Solen* and *Lutraria* are confined to the Dainiti Sands.

The Hosoya Beds are more fossiliferous in the Ugari district where the fossil communities, as well as the characters of the rocks, show a sublittoral environment. The change in the assemblage of fossils from that in the underlying Tennô Sand is remarkable. Many of the Tennô species disappeared from the area and were replaced by newcomers such as *Antigona casinaeformis* (YOKOYAMA), *Chlamys vesiculosa* (DUNKER), *Compsodrillia nakamurai* MAKIYAMA, *Crassatellites nanus* (ADAMS & REEVE), *Dentalium totomiensis* MAKIYAMA, *Inquisitor totomiensis* MAKIYAMA, *Neritaeformis reiniana* (DUNKER), *Pecten tokyoensis* TOKUNAGA, *Turris totomiensis* MAKIYAMA, *Cancellaria kobayashii* (YOKOYAMA) and *Natica adamsiana* DUNKER. *Clavatula dainichiensis* (YOKOYAMA), *Nassarius caelatus* (ADAMS) and *Uromitra* *nakamurai ugariensis* MAKIYAMA differ slightly from the Dainitian forms. Although no relevant data based on the ecology of the recent forms can be found, the communities may be judged as sublittoral, otherwise, either a few well-recognised littoral or certain bathyal benthos would be present. Now let us see what is the cause of the renewal of the sublittoral fauna. One of the probable working hypothesis is that the volcanic activity in the beginning of the Hosoya age killed many of the organisms which lived in the Dainitian Sea. According to J. WALTHER,[1] LO BIANCO observed the effects of the eruption of Vesuvius in 1906 on the marine animals of the adjacent seas. The investigation shows that a remarkable disturbance of the animal community took place. Now, the tuff of the Hosoya Beds attains the considerable thickness of 20 m., evidence of a more violent eruption than that of Vesuvius in 1906. The upper portion of the Hosoya Beds consists of muds and contains a community similar to that of Ketienzi Beds.

The dominant molluscan remains of the Ketienzi Beds are *Limopsis tajimae* SOWERBY, *Dentalium yokoyamai* MAKIYAMA, *Turcicula argenteonitens* (LISCHKE) and *Psephaea totomiensis* MAKIYAMA. The community was persistent throughout the whole range of the division, indicating an uneventful habitat in the mud belt, which coincides with the twilight zone. According to Messers KURODA and FUJITA.[2] *Turcicula argenteonitens* has been dredged at depths between 200-2100m. KURODA has informed me that *Limopsis tajimae* comes up to the littoral zone of Toyama Bay during the height of winter, but its favourite habitat seems to be the mud belt.

Echinoids are extremely rare, for the turbid bottom water did not suit them. A specimen of *Schizaster japonica* A. AGASSIZ collected by Mr. OOTUKA is the only determinable example. The plankton is represented by *Globigerina* and *Pteropoda*, of which the former is abundant everywhere in the rocks, but the latter occurs in nodules. The nodules contain *Cavolina*, *Clio* and *Creseis* as well as some bivalves such as *Cuspidaria*, *Leda* and *Thyasira*. *Turcicula argenteonitens* is found in many cases. The origin of these nodules is unknown. It is known, however, that the altered viscosity of the water delays the sinking of the bodies of the surface fauna and produces what has been called "artificial bottoms" upon which a special twilight fauna appears to feed. Eventually patches of such

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1) Allgemeine Palaeontologie, p. 332.

2) Ann. Ocean. Res., Tôkyô, vol. 3, no. 1, 1929.

artificial bottoms of the Ketienzi Sea were embedded in the mud and thus the nodules would be produced.

The fossils of the Tamari Beds show an environment similar to the Ketienzi, represented by the community of *Limopsis tajimae* and *Turcicula argenteonitens*. At the same time, they comprise a boreal genus *Lora* which was almost absent in the Ketienzi. The bottom temperature of 8.2°C was observed by FUJITA at the depth of 216 m. off Inubô-ga-saki, where a few living specimens of *Turcicula argenteonitens* were obtained. This temperature may not be unfavourable to *Lora*. The most likely hypothesis to explain why *Lora* did not live in the Ketienzi Sea is that a barrier existed on the east of the area at that time and prevented the immigration of the boreal animals.

The habitat of the Soga fauna was evidently clear sublittoral water. Echinoids were abundant but became scarce in the middle pyroclastic subdivision.

In the paper[1] entitled "The Evolution of Umbonium" I have discussed the phylogeny of the Japanese *Umbonium* which is distinguished from the typical *Umbonium* as the subgenus *Suchium*. The species of *Suchium* have been classified into two species groups or gens, namely those of *Suchium suchiense* and *Suchium mysticum*. The lineage of the latter gen has been assumed to start from *S. mysticum* (YOKOYAMA) of the Dainiti zone, but recent research has shown that *S. obsoletum* MAKIYAMA is older and more persistent than *S. mysticum*. Consequently *S. mysticum* must be looked upon as a mutation.

The habits and radula of recent *S. moniliferum costatum* (KIENER) were observed by Mr. Is. TAKI.[2] *Suchium* is a scavenger living in the littoral and sublittoral zones of the Japanese Islands and it prefers sandy bottoms to muds. It lived in the littoral and sublittoral zones of the Kakegawa and Soga Seas. Several species, subspecies, and submutations have been recognized. Each variety has a wide ecological, but a relatively small stratigraphical range. We can see that the chief genotypic characters are confined to their sculptures. For instance, *S. mysticum* has coarser spiral costae, than *S. obsoletum*. If natural selection exercises any important influence upon the divergence of species, we should expect to find that the characters separating species would in many cases be of obvious survival value. In the case of *Suchium*, however, the characters separating the gens and

1) Jap. Jour. Geol. Geogr., vol. 3, pp. 119-130, 1924.
2) The Venus, vol. 1, p. 175, 1929.

mutations cannot be called adaptive, having apparently no direct utility.

In the former paper, I introduced the idea of saltatory mutation to explain the evolution of *Suchium*. This idea be repeated here: saltations of genotypic characters arose in one or a few individuals in the population of any species and a rapid increase in the number of such types took place; accidentally the expanded new forms would replace the population. They might spread rapidly, emigrating to sparsely populated places. Their predecessors would be entirely destroyed because with their declined powers of recolonisation they could not cope with the expanding newcomers. This is not a case of the survival of the fittest. The genotypic characters which can only be regarded as the outward and visible expressions of the germ-plasm seem to have their own natural terms of existence. In this connexion, Prof. J. P. SMITH[1] says: "Throughout the Miocene, into the Pliocene, and up to the present, little evolution of forms is seen. Species appear with all their characteristics distinctly marked, run their course, and disappear from our ken, without any appreciable change. The geologist, looking over collections from the lowest Miocene to the Recent fauna, rarely sees the evolution of marine invertebrates. He sees only the sudden appearance of forms, and equally sudden disappearance of the same, without knowing whence they came, or how they disappeared." But the argument cannot apply to the evolution of the adaptive ornamentations. There may be some important objections to this argument, because it deals merely with the visible characters of shells.

Abstract

A general account of the Kakegawa Series in Tôtômi is given. The series comprises two lateral divisions, of which one, the Flysch type facies, is named the Horinouti Group, and the other group (Kekegawa Group) represents a normal cycle of sedimentation, commencing from the littoral deposits of the Dainiti Sands, gradually changing upwards into the muddy deposition of a twilight zone. The passage between the two extremes is exhibited by the sublittoral silts of the Hosoya Beds and by the alternating sands and muds of the Nangô Beds. The nomenclature of these subdivisions is given in the introduction. The Kakegawa Series is also divisible into three stages

1) Geologic Range of Miocene Invertebrate Fossils of California; Proc. Calif. Acad. Sci. 4th ser. vol. 3, p. 168, 1912.

based upon the fossils; they are *Infra-Dainitian*, *Dainitian* and *Ketienzian*. Infra-Dainitian and Dainitian may be demarcated by the Siraiwa Tuff. The base of the Ketienzian is considered to be the bottom of the Hosoya Beds. The littoral sands of the Dainitian stage comprises three distinct fossil zones, namely the *Suchium mysticum*, *Suchium obsoletum conglomeratum* and *Glycymeris totomiensis* zones. The Tennô Sand is considered to be deposited under a sublittoral water containing rich molluscan remains which indicate the condition. The typical Infra-Dainitian and Dainitian species are *Turritella perterebra*, *Latrunculus elatus*, *Suchium obsoletum*, *Venericardia panda*, *Scapharca satowi castellata* and *Pecten praesignis*. The sublittoral fauna in the Hosoya Beds largely differs from the preceding one. The characteristic forms are *Cancellaria kobayashii*, *Turris totomiensis*, *Dentalium totomiensis*, *Pecten tokyoensis* etc. The Ketienzi Beds which are the topmost part of the Ketienzian stage yield deep sea fossils e. g. *Limopsis tajimae* and *Turcicula argenteonitens*. The Kakegawa fauna as a whole is of the warm Kurosio type. The Horinouti Group was laid down in a deep tract which lies in front of a very narrow continental shelf and attains an enormous thickness. The Infra-Dainitian portion of the group is especially thick and its very base yields the oldest fossils of the Kakegawa Series. Along the border of this deep tract, there was deposited polygenetic conglomerate which contains fragments of shells rolled down from the shelf. The orogenic movement before the Kakegawa epoch had practically continued to the late Infra-Dainitian times. There was a marked epeirogenic movement in the final age of the epoch and the sublittoral deposition of the Soga Series which overlies the Ketienzian represents the emergence at the beginning of the next cycle. We have no positive data to correlate these Pliocene rocks with those of other countries, but I conjecture that the Dainitian corresponds to the Plaisancian of Europe. I am now confirming the existence of the Dainitian and Ketienzian faunas in other parts of this country. In the last chapter I summarised the palaeo-ecological observations. Some new descriptive terms for Gastropoda are proposed in the following pages.

List of Foraminifera from the Ketienzi Beds.

R=rare, P=present, C=common.

	I	II	III	IV	V	VI
REOPHACIDAE						
Haplostiche dubia d'Orbigny	R					
TEXTULARIIDAE						
Textularia abbreviata d'Orbigny	R	R	R			
agglutinans d'Orbigny	R					
VERNEUILINIDAE						
Clavulina communis d'Orbigny	P	R	R			P
MILLIOLIDAE						
Quinqueloculina curta Cushman	R					
disparilis d'Orbigny	R					
lamarckiana d'Orbigny	R					
bicostata d'Orbigny	R					
seminulum (Linné)				R		
auberiana d'Orbigny				R		
Triloculina oblonga d'Orbigny var.	R					
Pyrgo sp.	R					
OPTHALMIDIIDAE						
Cornuspira foliacea (Philippi)	R					
LAGENIDAE						
Lenticulina (Robulus) calcar (Linné)	P	R	P	P		P
cultrata (Montfort)	P	P	P	P		
Lenticulina orbicularis (d'Orbigny)	R	C	P		P	P
rotulata Lamarck	P					
rotulata umbonata Cushman		P				
calcarata Cushman var.		R	R			
totomiensis Makiyama	P	P				
expansa (Cushman)	R					
gibba (d'Orbigny)	R					
sp. aff. reniformis (d'Orbigny)		R				
tricarinella (Reuss)			R			
acutiauricularis (Fichtel & Moll)		R				
sp. A.						R
sp. B.	R					
sp. C.	R					
sp. D.			R			
Marginulina tenuis Bornemann	R					
glabra d'Orbigny					R	
Dentalina communis d'Orbigny	R					R
Nodosaria scalaris (Batsch)	P	P	P		P	P
catenulata Brady	R	R	R		R	
pyrula d'Orbigny	R					R
annulata (Terquem & Berthelin)	R		R			
pauciloculata Cushman	R				R	
vertebralis Batsch	R		R		R	
sp. aff. perversa Schwager	R					

	I	II	III	IV	V	VI
obliqua Linné	R					
mucronata Neugeborn					R	
longirostrata Cushman						R
Nodosaria? lepidula Schwager	P		P		P	P
Glandulina laevigata d'Orbigny			R			
Saracenaria italica Defrance	P				R	
Vaginulina sp.					R	
legumen elegans d'Orbigny						R
Frondicularia inaequalis Costa					R	
Lagena striata strumosa Reuss	R					
hexagona (Williamson)					R	
POLYMORPHINIDAE						
Gattulina communis d'Orbigny	R	R				
NONIONIDAE						
Nonion boueana d'Orbigny var.			R	R		
umbilicatula (Montague)					R	
Elphidium subnodosus (Münster)	R		R	R		
CAMFRINIDAE						
Operculina ammonoides (Gronovius)	P		P	P		R
HETEROHELICIDAE						
Bolivinita quadrilatera (Schwager)	P	C	P			C
Plectofrondicularia totomiensis Makiyama						R
BULIMINIDAE						
Bulimina subornata Brady					P	P
aculeata d'Orbigny						P
Virgulina schreibersiana Czjzek	R					
Rectobolivina bifrons (Brady)	C	C	C		P	R
Bolivina beyrichi alata (Seguenza)					R	
UVIGERINIDAE						
Uvigerina striata d'Orbigny	P	R	R	R	C	P
Siphonogenerina raphanus (Parker & Jones)	C			C	P	P
Siphonodosaria sp.	P	P	P		P	P
ROTALIIDAE						
Discorbis sp. (=saulcii Brady, non d'Orbigny)	P					
isabelleana (d'Orbigny)						R
Gyroidina soldanii d'Orbigny	P	P	P			R
orbicularis d'Orbigny					R	R
Eponides praecincta (Karrer)	R		R		R	
culter (Parker & Jones) var.	R	R	R			
sp.		P		P		
umbonata (Reuss)					R	
Rotalia sp.	P	P	R	R	R	
Baggina totomiensis Makiyama				R	R	
CASSIDULINIDAE						
Cassidulina subglobosa Brady		R				
crassa d'Orbigny					R	
CHILOSTOMELLIDAE						
Chilostomella cf. ovoidea Reuss			R			R
Chiostomellina cf. fimbriata Cushman			R			
Pullenia sphaeroides (d'Orbigny)	R	R	R		R	

	I	II	III	IV	V	VI
GLOBIGERINIDAE						
Globigerina bulloides d'Orbigny	C	C	C	C	C	C
inflata d'Orbigny	C	C	C		C	C
dubia Egger	R	R	R	R		P
crassiformis Galloway & Wissler	R	R	R	R		
apertula Cushman			P			
sacculifera Brady					R	
subcretacea Chapman			R			
(Globigerinoides) cyclostoma Galloway & Wissler	P			P		P
rubra d'Orbigny		R				
conglobata Brady			R			
(Sphaeroidinella) dehiscens Parkers & Jones	P	P	P		P	P
Orbulina universa d'Orbigny	C	P	P	P	P	P
Pulleniatina obliquiloculata (Parker & Jones)	P	P		P	P	P
GLOBOROTALIDAE						
Globorotalia tumida (Brady)	P	R	R		R	R
ANOMALINIDAE						
Anomalia grosserugosa (Gümbel)	R	R	?			
Planulina ariminensis d'Orbigny	R					
wüllerstorfi (Schwager)				R	R	
Cibicides lobatulus (Walker & Jacobs)	R	R	R	R		R

Description of the Localities.

I. Loc. 308, about 100m. south of the Loc. 307.
II. Loc. 307, a road-side cutting at Simomata.
III. Loc. 307′, the same cutting as 307, but the material obtained from the top of the cutting.
IV. Loc. 308′, about 20m. south of 308.
V. Loc. 321, an exposure at Ketienzi.
VI. Loc. 397, a road-side cutting at Hatagaya near Takatenzin.

DESCRIPTION OF THE NEW SPECIES AND SUBSPECIES

Scaphopoda

Genus DENTALIUM LINNÉ, 1758.

Type: *Dentalium elephantinum* LINNÉ; subsequent designation by CHILDREN, 1822.

The subgeneric position of the following new species is uncertain:

Dentalium yokoyamai n. sp. (*Pl. I, Fig. 1.*)

1920. *Dentalium complexum* DALL: YOKOYAMA, Foss. Miura Penin., p. 101, pl. 6, fig. 27.

1927. *Dentalium* (*Fissidentalium*) sp., MAKIYAMA, this Memoirs, ser. B. vol. 3, p. 58.

I have doubtfully referred this species from the Tennô Sand to *Dentalium complexum* of Prof. YOKOYAMA and have compared it with *D. subrectum* MARTIN and *D. junghuhni* MARTIN. Now, knowing that the species occurs very frequently in the muddy rocks of the Kakegawa Series, I venture to name it, because DALL's species from Hawaii is quite a different species. The materials of the Kakegawa confirm the former reference to the Lower Musasino form.

It is a straightish shell increasing more rapidly in diameter than *D. complexum* DALL, 1895. In this respect, the shell resembles *D. formosum* ADAMS & REEVE, 1848; the sculpture, however is finer. The type measures 55 mm. in length, 12 mm. in larger diameter and 5 mm. in lesser diameter; it was found in a mudstone at Nozima near Yokosuka, Miura Peninsula and is preserved in the Imperial University of Kyôto.

Subgenus ANTALIS H. & A. ADAMS, 1854.

Type: *Dentalium entalis* LINNÉ, (tautonymy).

Dentalium (Antalis) totomiensis n. sp. (*Pl. I, Figs. 2—4.*)

The shell is regularly and moderately curved, with a gradual increase in diameter; it is not shining or polished. The tip is hexagonal or heptagonal with flat intercostal spaces, which later become convex as the primary costae are catagenetic. The intercostal spaces remain smooth until the tube attains the diameter of about 1.3mm., when a secondary costa appears in each of them; the tertiary costae likewise begin later on. Since the spaces are not equal in width, the appearance of the later costae is variable; as a matter of fact, it is retarded in the narrower interspaces; sometimes none of the tertiary costae develop at all. In full grown specimens fine quaternary costae are often present. The aperture, over 3 mm. in diameter, is round. The round tube of the adult portion has many unequally spaced costae of unequal sizes. The incremental lines are not oblique; they are well-marked on the anterior surfaces. The anal orifice bears a wide, fairly deep apical notch on the convex side; some individuals have a thin fragile secondary tube which protrudes slightly at the apex. The length of the holotype (Loc. 522), whose oral apertures is fractured, is 28.8mm., and its diameter is 2.4mm. at the apex and 4.3mm. at the aperture. In all probability, the shell may attain a length of about 40 mm. and a diameter of 5 mm. The above description partly depends upon the paratypes.

The Japanese living affinities are *D. octangulatum* DONOVAN, 1803 and *D. sexcostatum* SOWERBY, 1860 (=*hexagonum* GOULD, 1859), but the present species is easily distinguishable from them, in that the primary costae are catagenetic and not so strong; the section is round in the anterior portion; and in that it has more predominant secondary, tertiary and quaternary costae. *D. heptagonum* BOETTGER, 1883, a Tertiary form of Sumatra, Java, and Timor bears some resemblance to the present new species, but that species differs in having anagenetic primary costae which create the angular section of the tube in the later development. The present new species is very common in the Hosoya Beds of the Ugari district.

Gastropoda

Terminology

The spiral ribs or threads which start from the first post-embryonic or post-nepionic volution are designated primary spirals. The secondary spirals are those interstitial threads which appear later on next to the primary ones; the tertiary and quaternary spirals follow in succession and the spirals of later development may likewise be defined in this way.

In *Turris* (=*Pleurotoma*), the spiral sculptures differentiate into four groups, namely the sutural, carinal, peripheral and basal. A carinal spiral is the strongest and is usually on the angle of the whorl. The several spirals in front of the carinal are the peripherals. In some species of *Turris*, the peripheral and basal spirals are not well differentiated.

Incrementals are the axial ornaments parallel to the growth-line; longitudinals are those that are oblique to the growth-line. The axial element in *Gemmula* is incremental, while that in *Inquisitor* (=*Drillia*) is longitudinal.

Genus TURRICULA SCHUMACHER, 1817

Type: *Turricula flammea* SCHUMACHER, 1817 (monotype).

Turricula shimomatana (YOKOYAMA)

1926. *Pleurotoma shimomatana* YOKOYAMA, Jour. Fac. Sci. Univ. Tokyô, ser. 2, vol. 1, p. 330, pl. 38, figs. 6, 7.

1928. *Pleurotoma subdeclivis* var. *tuberculata* YOKOYAMA, Ibid., vol. 2, p. 339.

T. shimomatana is related to *T. subdeclivis* YOKOYAMA, 1926 as has been stated by Prof. YOKOYAMA. The shell of the former species, however, is broader, and is furnished with a relatively shorter canal in front. The angle of the whorl is round and axially plicately tubercled. The anal sinus is a little shallower and lies nearer the angle. In *T. subdeclivis*, the shell is slender with a longish canal and the anal sinus is farther from the angle. Some individuals of the latter species show very obscure tubercles on the angle especially in the early stage of development. The name *shimomatana* is valid and must be retained for the forma *tuberculata* of Prof. YOKOYAMA. His *Pleurotoma subdeclivis* var. *striato-tuberculata* is decidedly not *Turricula* but *Bathytoma*, because the sinus lies just upon the angle.

T. shimomatana is widely distributed in the Ketienzian. It is known also from the Pliocene rocks of Hyûga and Kazusa.

Subgenus GEMMULA WEINKAUFF, 1876.

Type: *Pleurotoma gemmata* REEVE; subsequent designation by COSSMANN, 1896.

Turris (Gemmula) totomiensis n. sp. (*Pl. I, Figs. 10, 11.*)

This species has a similar pattern of sculpture to *Turris* (*Gemmula*) *granosa* (HELBLING, 1779). Briefly speaking, it is a miniature of the latter species. The holotype measures 20.1 mm. in height and 5.9 mm. in diameter. The shell is turreted with an acute and slender spire and a longish canal. The protoconch is a smooth naticoid shell consisting of about two volutions with a more oblique suture than in the adult. There are 9 post-embryonic whorls, of which the last one is approximately 11 mm. in height.

The primary spiral sculptures consist of a sutural, a carinal, three peripherals and numerous basals. The carinal spiral is a flat-topped costa projecting from the surface of the whorl with sloped bases; it is situated at about the middle of the penultimate whorl. The top of the costa is obscurely striated in the adult whorls. The sutural costa is about half as wide as the carinal. The peripherals are a little broader than the sutural. The concave interspaces of the primary costae are sculptured with secondary threads, of which those on the shoulder between the sutural and the carinal are regular, and equally spaced; those on the peripheral zones are less conspicuous. The secondary threads appear in the sixth whorl. The basals are subequal or sometimes alternating. There are no longitudinals. Incrementals are present; they are catagenetic and represented by more or less distinct gemmules upon the carinal. The whorls later than the seventh have no such gemmules. The growth-lines are highly developed on the anterior portion of the whorl and they override the peripherals and basals making a granulated appearance on them. The suture is distinctly impressed, descending a little from the posterior slope of the posterior peripheral spiral to the top of the middle one.

The anal sinus is rather deep, situated at the carinal, and extending a little below it. The periphery is round, with a contracted base below which is then drawn out into a longish narrow cone. The canal is straight and subvertical. The columella is also subvertical and drawn out into a fine point.

This species is fairly common in the silts of the Hosoya Beds at Ugari, but very rare in their eastward extension. Loc. 522, type locality; 523, 524, 525, 530, 532, 533, 539.

The present species resembles "*Pleurotoma*" *coronata* MÜNSTER, 1843 a European Miocene form in sculptures and general outline. The spire of the latter species, however, is more scalar, with the angle at the middle of the whorl, and its incremental ornaments are not catagenetic. This new species is distinguished from *Gemmula granosa* (HELBLING) by its smaller size and narrower spire. Another related fossil species is "*Pleurotoma*" *coronifera* MARTIN, 1880 of Java and Sumatra, which has less differentiated primary spirals and non-catagenetic incrementals. All these resembling species have distinct nepionic volutions with incremental plicae which are not represented in the present new species.

Genus INQUISITOR HEDLEY, 1918.

Type: *Pleurotoma (Drillia) sterrha* WATSON (original designation).

I have used HEDLEY'S *Inquisitor* instead of *Drillia* auct. non GRAY. GRAY'S type of *Drillia* is *umbilicata* REEVE, 1838 which was put under the head of *Clavatula* by MALTZAN.[1] *Drillia* seems to be valid, as has been stated by WOODRING[2], for the West-African group, but is not to be used for the Indo-Pacific groups hitherto called "*Drillia*," which name has been improperly ressurected by GRAY.[3]

The type of *Inquisitor*, however, resembles *Crassispira*, having a distinct sutural costa which is ill-defined or totally absent in the Japanese group of "*Drillia*" *jeffreysii* SMITH, 1875 (non HARMER, 1918).

Inquisitor totomiensis n. sp. (*Pl. I, Fig. 6.*)

The shell presents a likeness to *Inquisitor jeffreysii* SMITH, but is much smaller, and has obscure spiral ornaments. It measures 20.5 mm. in height and 6.2mm. in diameter. Whorls are 10 in number. The early two volutions form the protoconch. The spiral ornamentation is represented by obsolete striations. No incremental sculpture is recognized, except distinct growth-lines on the body-whorl. The longitudinal sculpture consists of high subvertical ribs; the ribs are 13 in number on the penultimate whorl, 9 on the second post-embryonic whorl; they suddenly rise from the smooth subsutural space and give a shouldered appearance in profile; then they gently slope toward the anterior suture and die out on the base. The tops are convex and the interspaces are concave, and nearly twice as wide as the ribs. The anal fasciole lies in the shoulder zone in front of the suture. The sinus is shallow, close to the suture, with a slightly reflexed lip. The aperture is about 8mm. in height, including a fairly long canal.

I. jeffreysii has distinct spirals and less predominating and more oblique longitudinals. *Melatoma lygdina* HEADLEY, 1922 bears some resemblance to the present species, but it is impossible to deal with opercula in palaeontology.

The only material is the holotype obtained from the Hosoya Beds (Loc. 522).

Inquisitor totomiensis ugariensis n. subsp. (*Pl. I, Fig. 5.*)

This form differs from the preceding species in that the shell is less turreted and wider; and that it has a greater number of more

1) Jahrb. Deut. Malak. Gesell. vol. 10, p. 121, 1883.
2) Miocene Mollusks from Bowden, pt. 2. p. 148, 1928.
3) Hedley, Rec. Aust. Mus,, vol. 13, p. 236. 1922.

oblique ribs. The holotype measures 17.4 by 6.4mm. The ribs in the body-whorl number 15. The whorls are 8 in number exclusive of a missing protoconch. Occurrence: in the Hosoya Beds at Ugari (Loc. 523).

Genus COMPSODRILLIA WOODRING, 1928.

Type: *Compsodrillia urceola* WOODRING, (original designation).

Compsodrillia nakamurai n. sp. (*Pl. II, Fig. 18.*)

A single specimen with its outer lip fractured is the only one at hand. It is very much like the type species of *Compsodrillia* in outline and in sculpture. The height is 13mm. and the diameter is 3.7 mm. The whorls are 8 in number, of which the early two are the protoconch and the last is about 7mm. in height. The protoconch is round and smooth, as is usual in *Inquisitor*. The axial sculpture consists of suboblique round longitudinal ribs overriden by spirals. They are narrower than the swollen ribs of the genotype. The first few ribs on the whorl next to the nepionic are entirely incremental plicae; there are 10 ribs in the last whorl, 12 in the first post-nepionic whorl, and they vanish posteriorly close to the suture and also towards the constriction in front. There is a sutural cord. Four primary cords and a secondary one are present in the penultimate whorl. In the three early volutions, the primary cords are three in number, the lowest one being concealed underneath the suture; the middle one of these three is slightly stronger than the others. The secondary appears first in the fourth whorl between the middle and the lower primary cord. The base is ornamented with basal threads. The anal fasciole is close to the suture.

This species occurs in the Hosoya Beds at Ugari, (Loc. 522).

A recent Japanese species named "*Drillia*" *fortilirata* SMITH, 1879 differs from the present species in having a higher spire. The generic position of this species is doubtful, for unfortunately the link between the Miocene of Jamaica and the Pliocene of this country is unknown.

Genus UROMITRA BELLARDI, 1887.

Type: *Voluta (Mitra) cupressina* BROCCHI; subsequent designation by COSSMANN, 1899.

Uromitra nakamurai ugariensis n. subsp. (*Pl. I, Figs. 7–9.*)

The species was described in my former paper in 1927. The subspecies, herewith named, differs from the species, in that the early whorls are ornamented with axial plicae of incremental nature. The holotype measures 12.3mm. in height with 8 volutions, and 3.9mm. in diameter. There are about 20 plicae, vertical and slightly arcuate. They are markedly catagenetic and die out before the last volution. Other characters are much the same as in the species.

This unique group comprising the species, this subspecies, and a species referred to as *oebenus* LAMARCK by Prof. YOKOYAMA, is apparently related to the European group of *U. plicatula* (BROCCHI, 1814) from which, however, it is distinguished by the more numerous plicae.

U. nakamurai ugariensis n. subsp. occurs in the silt of the Hosoya Beds in Loc. 522, a horizon evidently younger than that of the species.

Subgenus STAZZANIA SACCO, 1889.

Type : *Marginella emarginata* BONARELLI, (monotype).

Marginella (Stazzania) totomiensis n. sp. (*Pl. II, Fig. 13.*)

The shell resembles the type of the subgenus in outline, but it is thicker and smaller with a more slender spire. The dimensions are as follows : height, 6.3mm. ; diameter, 2.6mm. ; height of the aperture, 3.7mm. The whorls are 4 in number, smooth and polished, very slightly convex, broadly rounded at the periphery. There is no sign of concavity at the base.

The aperture is narrow and has a thickened outer lip which is smooth inside and flattened along the anterior two-thirds of its length, the flattened region ending above in a slight prominence. The columella is furnished with four plaits, the posterior two of which are nearly horizontal, shorter and smaller ; the other two are oblique and much stronger ; the lowest one forming the margin of the basal sinus of the aperture, which is not very well developed. A film of callosity expands widely over the parietal wall and runs in an axial direction.

The type locality of this species is at Ugari, (Loc. 522).

A living form *M. binotata* SYKE, 1905 occurs in the water of Kii and apparently resembles the present fossil species in general features except for the dentation of its outer lip.

Foraminifera

Genus LENTICULINA LAMARCK, 1804.

Type : *Lenticulites rotulata* LAMARCK ; Subsequent designation by CHILDREN, 1823.

LAMARCK's genus *Cristellaria*, 1812 cannot be used here, because its type as designated by CHILDREN (Quart. Jour. Sci., Lit. & Arts, vol. 15, p. 73.) is *Cristellaria squammula* LAMARCK, which is synonymous with *Nautilus planatus* FICHTEL & MOLL, the type of *Peneroplis* MONTFORT, 1809. *Lenticulina* was changed by LAMARCK himself into *Lenticulites* for binominal use in fossil species, but the latter should be rejected.

Lenticulina totomiensis n. sp. (*Pl. II, Figs. 12, 14, 15.*)

A species with combined characters of *L. echinata* (D'ORBIGNY, 1846) and *L. papillosa* (FICHTEL & MOLL, 1803). The test is compressed, umbonate, composed of many long tapering chambers, usually more than 12. The chambers are visible from the outside. It differs from *L. echinata* in that the latter is more biconvex and comparatively few chambered. The suture is remarkably limbate, and irregularly tubercled near the umbo. A few large knobs are scattered in the umbonal region. The tubercled suture resembles the later development found in *L. echinata* but not so distinctly beaded as in *L. papillosa* or in the early development of *L. echinata*. The periphery is acute, very narrowly rounded but not carinate, furnished with short spines. The spines are subequidistant, single, doubled or bifid. The later chambers in the senile stage tend to uncoil. The aperture is similar to that of *L. echinata*. Larger diameter without spines up to 2.5mm.

The holotype and the paratypes were obtained from the Ketienzi Beds at Simomata near Kakegawa, (Loc. 307). This peculiar form seems to be distributed throughout the Ketienzi Beds with a relatively narrow vertical range.

A many-chambered variety of *L. echinata* which occurs in the Nangô Beds bears some resemblance to the present form, but that species has a distinct carinate periphery with simple long spines and more or less pappilate surface in the early stage of development.

Genus PLECTOFRONDICULARIA LIEBUS, 1903.

Type: *Plectofrondicularia concava* LIEBUS, (original).

Plectofrondicularia totomiensis n. sp. (*Pl. II, Fig. 16.*)

The test is compressed, elongate, approximately symmetrical and slightly tapering towards the round initial end, the greatest breadth being made by the last chamber. The peripheral portion of the test is furnished with three sharp plate-like carinae, one in the middle line, the other two lateral. The broad face is almost flat, ornamented with a few high and thin axial costae, which are continuous from the initial end to the apertural end, being independent of the chamber; occasionally secondary costae appear in the later stages of development. The chambers in the earliest portion are biserial; the later ones are uniserial and broader than high. The sutures are slightly limbate, sloping to the sides, becoming more or less depressed in the later development. The aperture is a narrow slit situated at the middle of the end.

The holotype was obtained from the Ketienzi Beds at Takatenzin. It measures 1.16mm. in height and 0.28mm. in breadth.

This species is related to *P. californica* CUSHMAN & STEWART, 1926, but it has the prominent and continuous costae on the flat broader face. *P. paucicostata* CUSHMAN & JARVIS, 1929 is ornamented with similar costae, but they are catagenetic in that species, while those of this new species are decidedly anagenetic. We have not previously reported the occurrence of this peculiar genus in the Japonic region, living or fossil.

Genus BAGGINA CUSHMAN, 1926.

Type: *Baggina californica* CUSHMAN, (original designation).

Baggina totomiensis n. sp. (*Fig. 4.*)

This form has close affinity to the type species in having a similar subglobular test with the clear lunate space on the last chamber above the aperture, and in the manner of coiling. The visible outer chambers count up to 6; they are inflated and rapidly increasing, so

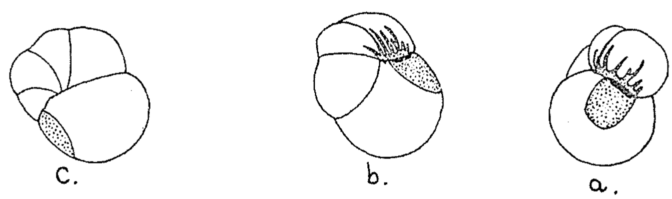


Fig. 4.
Baggina totomiensis n. sp. ×20.
a. Apertural view.
b. Ventral view.
c. Dorsal view.

that the last chamber in the adult makes up nearly half the volume of the test. The surface is finely and closely perforate except in the lunate area where the substance is thinner and less closely perforate.

The sutures are superficial in the early development but later become more or less depressed, slightly more so on the ventral side, for the chambers are more inflated on this side. The aperture is elongate and narrow, situated on the ventral side of the last chamber. The margins of the early chambers along the aperture are radiately grooved, giving a denticulate appearance. The umbilicus is narrower but slightly deeper in this species than in the type of the genus.

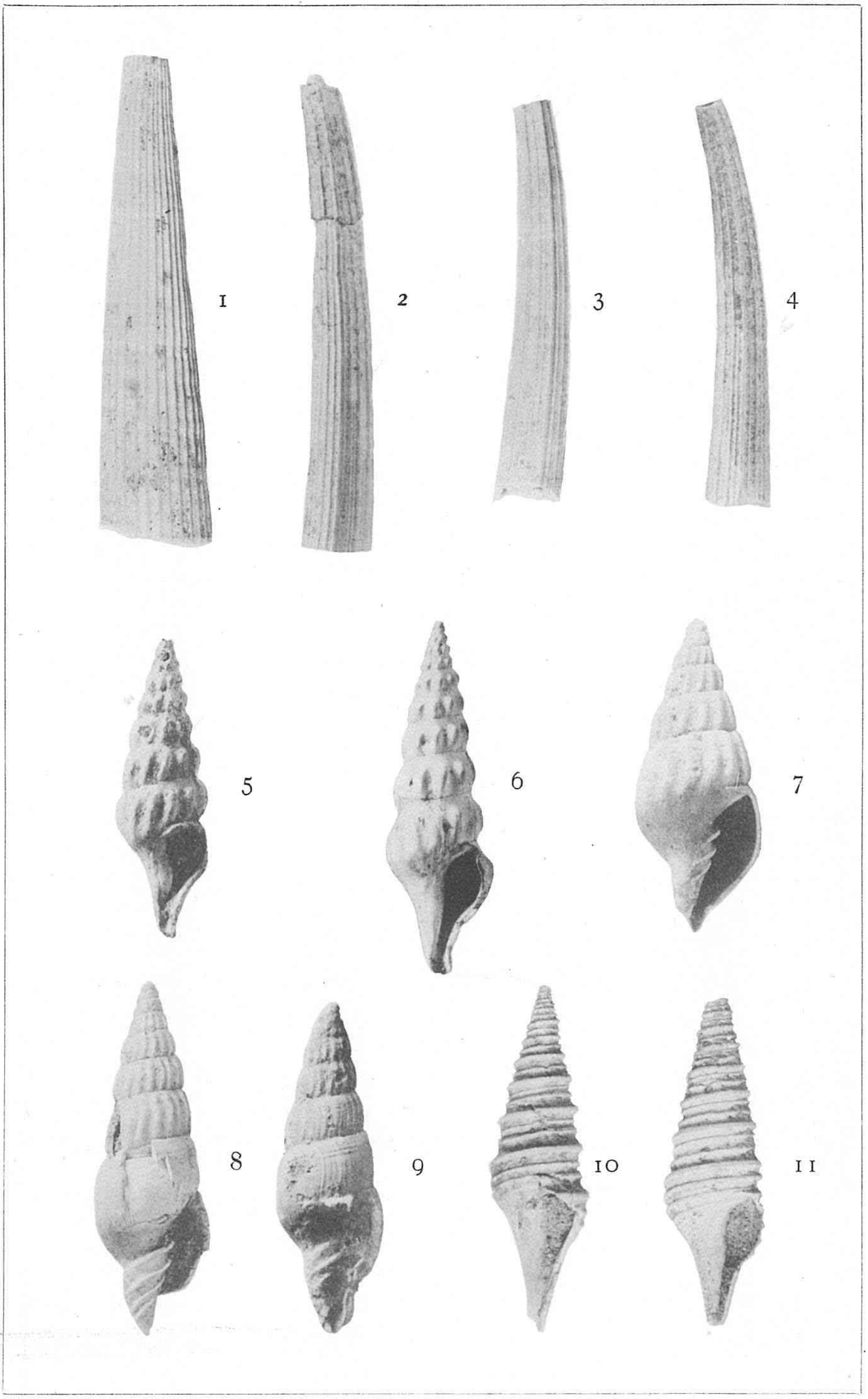
The holotype from the Tennô Sand measures 0.82 mm. in larger diameter and 0.58 mm. in height (=thickness of the last chamber). This species is widely distributed in the Kakegawa Series.

Pulvinulina philippinensis CUSHMAN, 1921 (=*P. haueri* BRADY, non D'ORBIGNY, 1846) may perhaps be *Baggina*. It differs from the present species in having less globular chambers and a simple aperture.

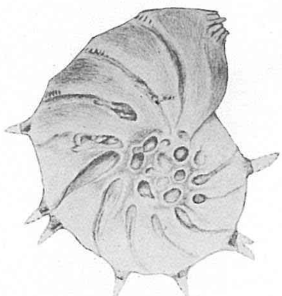
EXPLANATION OF PLATES

Plate I.

Plate II.



N. TAKAHASI. Photo. J. MAKIYAMA.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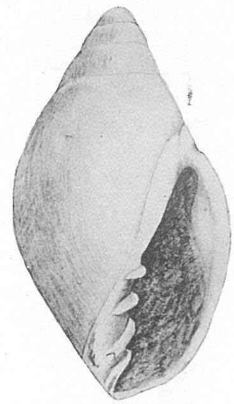
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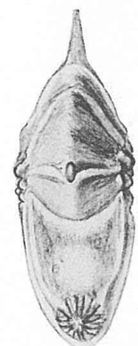
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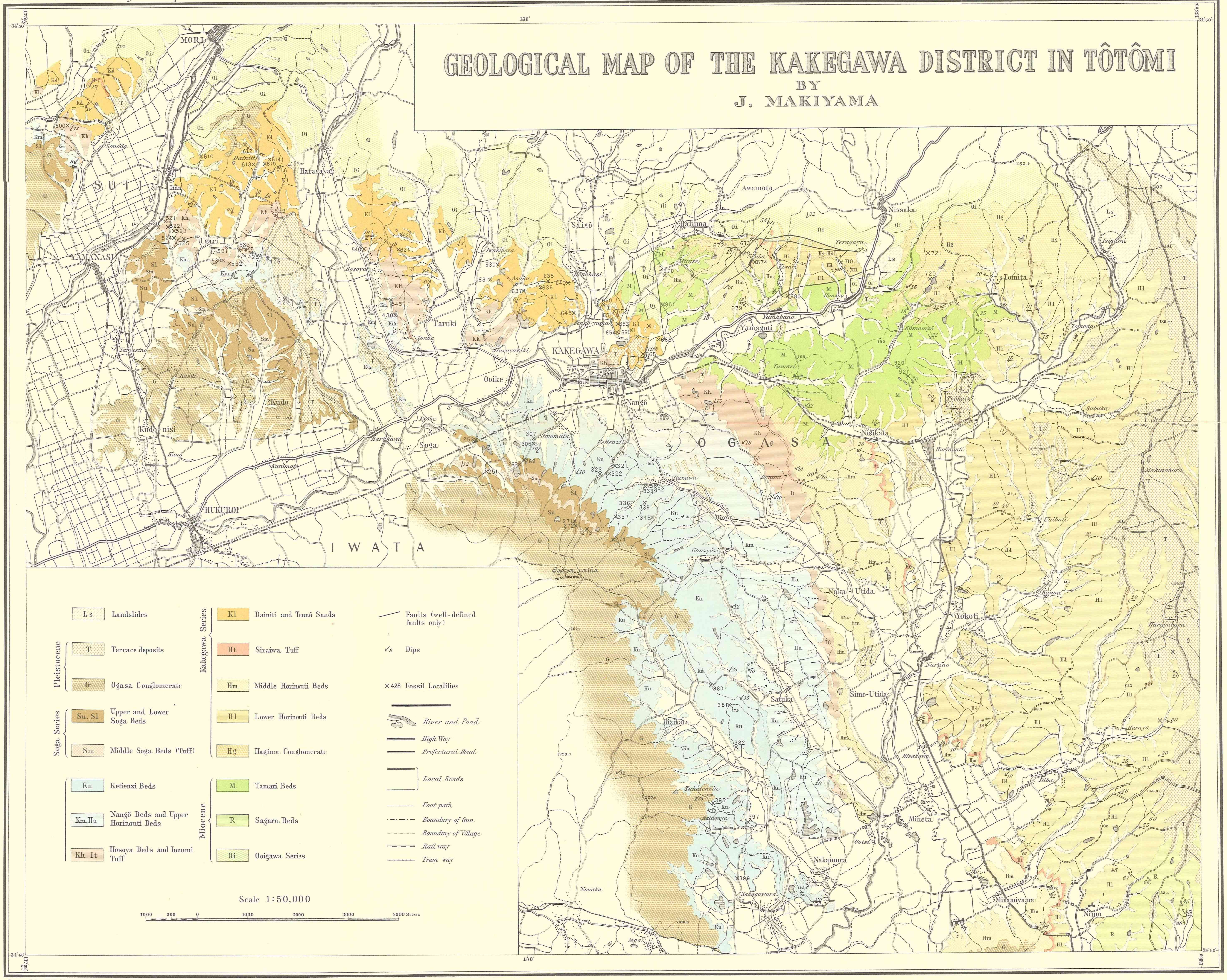
N. Takahasi. Photo. J. Makiyama.



Engraved by M. Saitô