

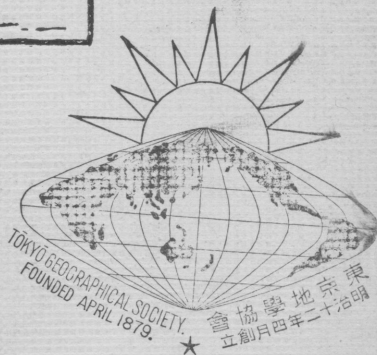
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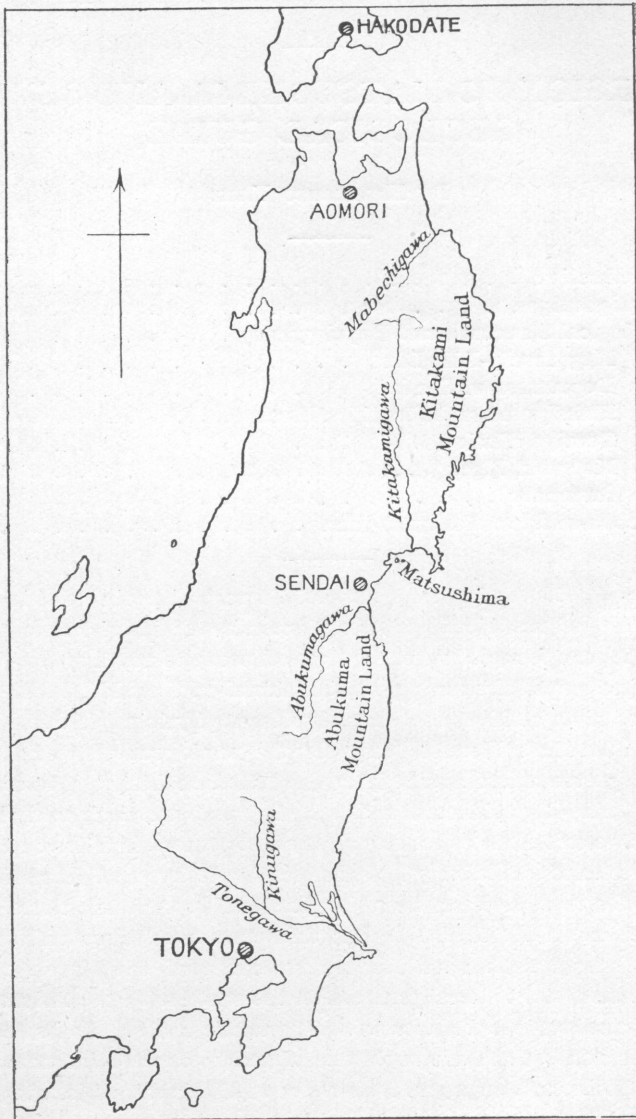
EXCURSION TO MATSUSHIMA AND SENDAI; GEOLOGICAL GUIDE

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Introduction North from the Kwantô Structural Basin (Guide-Book, Excursion C-6), there extends a series of linear depressions which are occupied successively from south to north by the valleys of the Kinu-gawa, Abukuma-gawa, Kitakami-gawa and Mabechi-gawa. This zone of depressions is a very significant physiographical dividing line in Northeast Honshû, superficially analogous to but of very different geotectonical nature from the "Median Line" of Southwest Japan (Guide-Book, Excursion C-3). It has been since early times one of the main lines of intercourse and at present is followed by the Main Northeastern Railway Line connecting Tokyo and Aomori.

To the west of this zone of longitudinal depressions, there arises the backbone of Northeast Japan; this consists of elevated Neogene sedimentaries together with numerous cones of the Great Bandai Volcanic Arc and is amalgamated at the south with the Shimotsuke Mountainland of the Palaeozoic and granitic rocks. To its east, on the other hand, there are two mountainlands, one of Abukuma (plus Yamizo-Torinoko Range) and the other of Kitakami, which, together with the Hidaka Range of Hokkaidô, are sometimes regarded as representing parts each elevated, some horst-like, of three parallel meridional zones, of old geological formations and fundamental to



Text-Fig. 1.

Outline map of Northeast Japan showing the sites of Sendai and Matsushima and the two mountainlands of Abukuma and Kitakami.

the construction of Northeast Honshū. According to this interpretation, the Abukuma Mountainland, Kitakami Mountainland and Hidaka Range do not represent three sections of one and the same zone, later separated by an eastward shifting of the northern section relative to the southern, as they were once thought to be.

The hilly district in which Matsushima and Sendai are situated occupies just the interspace between the southernmost part of the Kitakami Mountainland (Ojika Peninsula) and the northern end of the Abukuma Mountainland; the almost straight shore line, in the meridional trend, of the Tertiary foreland of the Abukuma Mountainland adjoins there in a broad smooth curve to the shore line of the Kitakami Mountainland, which is very rich in indentations. The sandy coastal plain, with a smooth shore line, extending from a little south of the mouth of the Abukuma-gawa to that of the Kitakami, is, however, interrupted by the headlands of the Matsushima Block, which embraces the Bay of Matsushima and is distinguished by a shore line indicating very recent submergence of land.

Sendai ($140^{\circ}52'$ E long. and $38^{\circ}16'$ N lat.) is one of the important cities in Northeast Japan, with a population of 118,000, being the capital of Miyagi Prefecture and the site of its Prefectural Office, the Court of Appeal, the Second Army Division and Tōhoku Imperial University. The railway station of Sendai is 217 and 226 miles distant from Uyeno (Tokyo) and Aomori respectively.

Matsushima Station lies 15 miles NE from Sendai; it stands two miles west of the small village of Matsushima, which overlooks the tranquil waters of the Bay of Matsushima, containing numerous small pine-clad isles. The very lovely scenery here is counted among the "Three Famous Sights" of Japan, and has been famed since very early times. "The Japanese find beauty in it under all circumstances; when wrapped in mist, or drenched in rain; or when the moonlight idealizes it and imparts an almost superhuman beauty to it."

Stratigraphy Marine Deposits of the Mizuho Period (the Japanese Neogene) are extensively developed in Northeast Honshū; these do not exist, however, on most parts of the surface of the Kitakami and Abukuma Mountainlands, which are two positive elements of Northeast Honshū, repeatedly elevated since the Mesozoic. Nor are these exposed in volcanic fields, being deeply hidden

beneath a thick cover of younger volcanic materials. The younger Cenozoic formations, partly marine and partly terrestrial, form dissected and often beautifully terraced plateaux of variable height, some almost horizontal and others tilted, with a more or less inclined surface. The materials of the Cenozoic sediments are dominantly volcanic; the Mizuho Period was a time of intense volcanic activity in the Japanese Archipelago.

In the hilly district enclosing Matsushima and Sendai, the foundation rocks underlying the Cenozoic deposits are exposed nowhere except in the marginal part; a single exception to this general rule is the *Monotis* Bed of the Ladinic stage exposed along the railway cutting between the two stations of Rifu and Matsushima near Yahata, 2.5 km. south of Shiwogama. The *Monotis* Bed is composed of dark gray sandy shale, lithologically quite similar to that of the *Ceratites* Bed of Inai near Ishinomaki; while the *Ceratites* Bed contains several species of *Hollandites*, *Monophyllites*, *Ptychites*, *Gymnites* and *Sturia*, and is almost free from other molluscan remains, the *Monotis* Bed contains in fairly great number shells of *Monotis*, some of which are identical with those found in the *Daonella* Bed of Zōhōin near Sakawa, in the province of Tosa (Shikoku), and rather rarely, ammonites belonging to *Monophyllites*, *Ptychites* and some other genera not yet definitely discriminated.

The Cenozoic deposits of the present district have been better studied in the environs of Sendai than elsewhere; the composite standard section of the strata, given below, is a compilation of the records of observations on a number of good exposures not far distant from the city.

1. Terrace deposits, younger than the Aobayama Group.
2. The Aobayama Group. Clay, sand and gravel; often cross-bedded; about 3-7 m. thick. Unconformable to the underlying formations.
3. The Upper Umoregi Group. A loose sandstone with interbedded thin shale at the uppermost part; a fossiliferous layer in this contains marine Mollusca such as *Panopaea*, *Macoma*, *Cardium*, etc. (the Dainenji Shell Bed). Shale predominating in the main part, with occasional layers of sandstone, pumice and also of lignite seams. A cross-bedded loose quartz sandstone at the base unconformably overlies at places the next older group; the

physical break is distinct, but probably of little stratigraphical significance.

Total thickness 10-15 m.

4. The Middle Umoregi Group. This comprises in descending order:

Tuffaceous shale intercalating two thin lignite seams; 6 m.

A thin lignite seam.

Pumice beds in alternation with shale and thin lignite seams; about 2.5 m.

The Hirosegawa tuff; a massive pumiceous tuff, with no sign of stratification; 7-10 m.

Clay with lignite seams; erect tree trunks are not seldom found in this horizon; 1 m.

Sandstone, sometimes conglomeratic; 2-3 m.

Unconformable to the underlying group.

5. The Tatsunokuchi Group. Mostly composed of tuffaceous shale, but sandy in its middle part; about 30 m. thick. A marine formation with intercalations of four prominent shell beds, typically exposed opposite the city of Sendai in the deep gorge of Tatsunokuchi, in which flows a right tributary of the Hirosegawa. The following list shows the Mollusca obtained in this group.

List of the Fossil Mollusca found in the Tatsunokuchi Group,
after a Preliminary Determination by Mr. S. Nomura.

(Species with an asterisk are common)

Glycimeris yessoensis Sow.

G. sp.

**Scapharca trilineata* Conrad var. *japonica* Yabe and Saga (MS nom)
= *S. auricula* Yokoyama

Ostrea gigas Thunbg.

Chlamys sp.

C. sp.

**Pecten wadai* Yabe and Nagoya (MS nom)

P. cfr. *turpiculus* Yok.

Monia macrochisma Desh.

Anomia lischkei Dautzenberg & Fisher

Lucinomia annulata Rve.

Phacoides sp.

Papyridea cfr. *pauperculus* Yok.

**Dosinia* cfr. *japonica* Rve.

D. sp.

Paphia sp.

Meretrix meretrix L.

**Amianthus yabei* Nomura

A. *yabei* Nomura var. *elongata* Nomura

Macoma sp.

M. *dissimilis* v. Martens

M. sp.

Spisula cfr. *voyi* Gabb

Mya arenaria var. *japonica* Jay

**Panope generosa* Gld. var. ?

**Corbula hayasakai* Nomura (MS nom)

Cerithium humile Lke. ?

Serpulorbis sp.

**Polinices sendaiensis* Nomura (MS nom)

Besides, the Tatsunokuchi Group contains often whale bones, sharks' teeth, and also rarely, bones and teeth of terrestrial mammals; the most important of these vertebrate remains are

Carcharodon megalodon Charlesworth

Trilophodon sendaicus Matsumoto

6. The Lower Umoregi Group. This comprises in descending order:

Gray tuff with a lignite seam (0.7 m); 3 m.

Cross-bedded sandstone; 7 m.

Gray tuff; 2 m.

Conglomerate; 1.8 m.

Gray sandy tuff with plant remains; 2 m. thick.

The fossils most common in this plant bed are

Fagus sylvatica L. var. *sieboldi* Max.

Sasa cfr. *borealis* Shibata and Makino

S. Shimizu maintains that the Lower Umoregi and the upper part of the next or Mitaki Group are contemporaneous, though in two different facies of sediments, one with intercalated lignite seams and the other entirely composed of volcanic materials.

7. The Mitaki Group. Essentially composed of pyroclastic material, such as volcanic tuff, tuff-breccia, agglomerate tuff, lava agglomerate and extruded andesite sheets; the tuff is pisolitic

in part; in total 20-25 m. or more thick. The andesite belongs to the category of two-pyroxene andesite and is sometimes drusy. The Mitaki Group apparently shows a gradual transition downward to the Saboyama Group.

8. The Saboyama Group. This is the lowest division of the Neogene rocks developed in the direct neighbourhood of the city. Marine sandy deposits, essentially composed of sandstone of pale greenish colour, with subordinate shale and sandy shale, all of which are tuffaceous; besides, there are some interbedded tuffs.

In total 50 m. thick; certain horizons are fossiliferous, the fossils being mostly marine shells belonging to *Nassa*, *Neptunea*, *Conus*, *Dentalium*, *Tellina* and *Phacoides*, etc; also tests of diatoms and spicules of sponges are very common in the sedimentaries of this group.

At Shiwogama, a thick complex of tuffs and tuffites is overlaid by another of shale and sandstone, with interbedded massive tuffs. This upper series is beautifully banded at certain horizons, and in such parts, the plant bed of Shiwogama is intercalated. Kryshtofovich¹⁾ has described the following plants from it:

Sabal sp.

Juglans nigella Hr. ?

Fagus sp.

Castanea kudingi Kov.

Ficus sp.

Liquidambar formosana Hance

Vitiophyllum sp.

Kryshtofovich has expressed his belief that this flora is somewhat older than the Mogi flora of the province of Hizen, studied in detail by Nathorst and Florin.

H. Sone succeeded in procuring from the plant bed elephants' teeth, which were referred by H. Matsumoto²⁾ to *Prostegodon latidens* Clift.

The latter author believes that the *Trilophodon sendaicus* from the Mitaki Group is of the Upper Pontian age and that

1) Kryshtofovich in Jour. Geol. Soc. Tôkyô, vol. XXVII, 1920.

2) Matsumoto; Sci. Rep. Tohoku Imp. Univ. 2nd Ser. (Geol.) Vol. X, No. 1, 1926.

the *Mastodon latidens* from the plant bed of Shiwogama is of the Lower Pontian age.

9. The Akiu Group. Comprises in descending order:
 Alternating layers of tuffaceous shale and sandstone, with plant fossils; 10 m. In a lot of plant fossils collected by D. Satō, Kryshstofovich¹⁾ discriminated:
Taxodium distichum miocenum Hr.
Betula brongniarti Ettingsh.
B. macrophylla (Goeppert) Hr.
B. sp.
Alnus nostratum Hr.
 Liparitic tuff-breccia; 90 m.
 Tuffaceous shale, tuffaceous sandstone and conglomerate, with a lignite seam 0.25 m. thick; 15 m.
10. The Moniwa Group.
 Alternating layers of tuffaceous sandstone, tuffaceous shale and tuff; 30 m.
 Conglomeratic sandstone with numerous marine fossils; 15 m.
 Very calcareous at the base, approaching almost to impure limestone; the fossils are:

List of the Fossil Mollusca found in the Moniwa Group,
 after a Preliminary Determination by Mr. S. Nomura.
 (Species with an asterisk are common)

- **Chlamys* sp.
Ostrea sp.
Chama sp.
Venericardia sp.
Antigona sp.
Cardium sp.
Panope sp.
Tegula argyrostoma var. *distinguenda* Dkr.
 **Siphonalia matsumotoi* Nomura (MS nom)
Purpura cfr. *burnetti* Ad. et Rve.
Xenophora cfr. *exuta* Rve.
 **Terebratalia smithi* Arnold
 Besides, *Echinanthus* sp. is common.

1) Kryshstofovich, l.c., p. 7.

The basal deposit covers with a distinct unconformity the surface of an andesite flow of the lower group, which shows numerous bore holes of certain boring Mollusca.

11. The Natorigawa Andesite Group. Flows of two-pyroxene andesite.
12. The Nagafukuro Group. Green tuff, with a yellowish, loose, cross-bedded sand at the base; traversed by andesite and liparite dykes; more than 90 m. thick.
Unconformable to the underlying group.
13. The Takatate Group. Thick massive gray tuff, with fossil woods; conglomeratic at the base.
Distinct clino-unconformity.
14. The Baba Group. Tuffaceous sandstone and shale in alternation, with plant fossils.

A plant bed exposed at Ejiri 6 km. south of Tsukinoki Station, which is believed to belong to the Baba Group, contains

Comptoniophyllum japonicum Nathorst
in great profusion.

Through the palaeontological and stratigraphical studies of Matsumoto, Hayasaka, Aoki, Shimizu and Yoshii, it is now almost established that the complexes from the Moniwa upward to the Tatsunokuchi correspond to the Tokiwa Series of the foreland Tertiary of the Abukuma Mountainland.

There is a thick series of tuffs and tuffites extensively developed around the Bay of Matsushima. These rocks are in all possible varieties, some well stratified and others massive; some fine grained and clayey, and others medium to coarse grained and sandy or even agglomeratic, containing scoriae of pumice and andesite and blocks of the latter in abundance. All are whitish in colour, with more or less grayish or yellowish tints; the only dark coloured ones are agglomerates which are often unconformably intercalated in tuffs and tuffites. At places the tuffites contain plant impressions and more rarely marine shells; besides, silicified woods are sometimes found in them. The plant beds of Shiwogama already referred to probably represent a horizon in the upper part of this thick complex of tuffs, tuffites and agglomerates; the beds in total certainly much exceed 100 m. and are now believed to be equivalent to the Saboyama Group. Of course, this correlation is only in a broad sense and not

exact, because there is a possibility of the uppermost part of this complex corresponding to the Mitaki Group and, not less, of the lower part corresponding to a part of the Akiu.

Geological Structure and Physiognomy. Nagamachi-Rifu Line There is an important dislocation line extending from the vicinity of Nagamachi near Sendai, beyond the village of Rifu, farther northeastward. It separates the fertile coastal plain of Miyagi (Miyagi-no-hara) lying to its southeast from a dissected plateau lying to its northwest. As the Aobayama Group of the plateau makes a flexure near Nagamachi along the tectonic line, it must be of a younger date. The coastal plain of Miyagi, 7.5 km. broad, is about 10 m. above the present sea-level along the tectonic line; the plain is covered by fans or deltas which were formed at places where the streams of Natori, Hirose and Nanakita once dejected materials transported by them just after leaving the plateau. These streams as well as other streamlets have cut out shallow trenches in running down the plain southeastward to the Pacific; the plain has been elevated a little in very recent times.

The tectonic line mentioned above should be called the Nagamachi-Rifu Line; physiographically, it is well marked by a distinct scarp bordering the plateau, except for the base of a trapezoidal hollow in the plateau, 5 km. long, on which the city of Sendai is situated.

Depression of Sendai The trapezoidal hollow of Sendai is not a depression in a geological sense, as it is bordered by a fault only along its north side, and not along its southwest side, as has often been imagined to be the case. It is on the average 30 m. high along its basal side, that is to say, the Nagamachi-Rifu Line, and thence gradually ascends northwestwards until it attains to about 50 m. On the whole, it is flat, but there is a median uplift of nearly northeast to southwest trend, by which the two valleys of the Hirose-gawa and the Hirawatasuto-gawa, a tributary of the Nanakita, are separated. The depression of Sendai must be an erosion hollow, and originally was a part of Mukai-yama, a small block or fragment of the plateau. The high, almost vertical escarpment of the northeastern border of Mukai-yama is entirely due to the stream erosion of the Hirose-gawa. Although the contrast between the low and high land separated by this steep wall is so striking a feature as to suggest the pre-existence of a fault along the

line of escarpment, yet there is no structural evidence actually observed to support this interpretation.

River terraces are well developed along the Hirose-gawa and Hirawatasuto-gawa, the highest and most singular one being 50 m. in height. This does not seem to belong to the system of terraces made by the present course of the streams, but evidently antedates them, while the lower ones evidently represent former cycles of erosion of the present streams.

The Mukai-yama and Nanakita Blocks

That part of the plateau lying to the southwest of Sendai is called Mukai-yama (*Mukai* means *opposite*); it is 100-200 m. high, with its wavy and obscurely terraced surface gently sloping down from northwest to southeast. There are several consequent valleys, all small but deep. At one time, Mukai-yama was twice as large as at present, extending over the erosion hollow of Sendai to the Dainohara fault; before the dislocation of the Dainohara fault took place, the Mukai-yama Block was continuous with that of Nanakita lying between the fault line and another parallel one, indicated by the valley of the lower course of the Nanakita-gawa. The uppermost rocks of the Mukai-yama Block are the clays, sand and gravel of the Aobayama Group; the gravel and sand beds are flexured along the Nagamachi-Rifu Line, as mentioned above.

Tomiya Block

Beyond the fault valley of Nanakita, there is a third block, the Tomiya Block, which is very similar to the Nanakita Block in every respect, but larger and correspondingly higher. Both are tilted blocks, with their surface gently descending northeastwards. While the Nanakita Block is only 3 km. broad and hardly attains 90 m. along the tilted edge, the Tomiya Block is 10 km. broad and has a crest line higher than 100 m. on the average; the latter block extends northward to the valley of the Yoshida-gawa. Further, the two blocks have in common several parallel consequent valleys in the second cycle of erosion, indicating a very recent uplift of land. The Aobayama Group also occurs on the surface of these two blocks.

Matsushima Block

From Rifu to Matsushima Station, the railway line follows a narrow passage with the general trend of northeast to southwest, which is a direct prolongation of the Nagamachi-Rifu Line in its straight southern half. Along its northern half, however, there is no structural evidence of its being

an important dislocation line. Nevertheless, the narrows, as a whole, can be taken as an important physiographical boundary separating the Tomiya Block at its northwest side from the Matsushima Block at its southeast, because the land-surface of the former descends gradually northwards as stated above, while that of the latter, on the contrary, descends southeastward from this boundary line.

The Matsushima Block embraces the Bay of Matsushima and is somewhat quadratic in outline, measuring 17 km. from northeast to southwest. Excepting Miyato-jima, which is the largest island and protrudes 4 km. into the open sea, the breadth of the Matsushima Block from northwest to southeast is on the average about 9 km. The Bay of Matsushima is rectangular in its general outline, although the shore line is extremely irregular, being rich in indentations.

The block has been recently submerged, hence there are numerous off-shore islets detached from the headlands. The promontories and islets are steeply cliffed all around; otherwise, however, they are not much modified, in spite of the friable nature of the rocks which easily submit to both subaerial and marine erosion. The entire absence of islets in the middle part of the bay and the regular arrangement of the large islands, Miyato-jima, Urato-jima, Nono-jima, Katsura-jima and others, along the ocean border which is thus almost land-locked except for narrow channels, seem to indicate that the bay is trough-like. The shore line essentially follows the valleys or gullies which in orientation depend on faults. There are two prevailing directions of the faults in this district, one of NW-SE and the other of NE-SW. Accordingly, the indentations of the shore line and also the channels are elongated in various combinations of these two directions.

The bay is very shallow and the channels leading to the open ocean also, the deepest point at the southwest of Katsura-jima sounding 8 fathoms. The bottom of the bay is muddy, and everywhere covered by dense growths of sea-grass, *Zostera*, etc.; it is much frequented by eels. There is no noteworthy river emptying water into the bay, except the Takagi-gawa, which is an artificial canal to drain water from a swamp, the Shinai-numa, 7 km. due north from the mouth of the canal.

The bay-heads of nearly all the small indentations, except those facing the open sea, are rapidly being filled up by mud; and here and there we see an extensive muddy tidal flat. These land growths.

extend seawards; this is due to the accumulation of mud rather than to the emergence of land. There are no raised beaches and terraces along the coast, or double notches on the face of the sea-cliffs; in short, there is no trace of any conspicuous emergence of land since the last submergence. What appear to be young coastal terraces are either a part of the old land-surface or artificial ones. The terrace of Godaidō is one of the best examples of the latter class. The northernmost channel of the outer border of the bay is almost completely choked up by the broad sand spit of Tōna or, more properly, by a series of four sand spits, and repeated efforts are necessary to keep it open.

The relief of the Matsushima Block is as irregular as the shoreline; minor irregularities are mostly due to the initial wavy surface of the land, subsequently a little modified by denudation, while the larger ones were caused by later dislocations. In general, the faults recognized in the present district fall into two categories in regard to the dates of their origin; to one category belong all those which antedate the even land-surface and to the other, all those of later origin which displaced it. First to be mentioned is a line of elevation connecting Tomi-yama (116.8 m.) on the mainland and Ōtakamori (105.8 m.) on Miyato-jima; the line marks approximately the northeastern border of the bay and has the trend NW-SE. Northeast from this line, the dissected land-surface is almost horizontal, hill-tops averaging 60 m., and southwest, the land-surface descends southwestwards from 60 m. to less than 30 m.; between these two low leveled fields, Tomi-yama and Ōtakamori are elevated horst-like. There are many other elevated ridges of the same trend, but of smaller scale; the 50 m. height along the northeastern border of Katsura-jima and the hill 55 m. high called Tamon-zan, near Yogasaki along the northeastern border of the peninsula of Shichigahamamura, are only two examples. The two ridges last mentioned are tilted edges.

On the west side of the bay, flat-topped Dan-zan is 170 m. high. Close to it on the east and separated from it by deep valleys, arranged on a line, runs a meridional ridge, which is lower than Dan-zan, being 122.2 m. on Shirasaka-yama, 138.2 m. on Anetori-yama and 103.6 m. on Washinoō-yama. The eastern face of the ridge is a distinct escarpment, in front of which extends a low dissected platform with hill-tops regularly 60 to 70 m. high. Thence, the land-

surface descends in steps to 20 m. near the village of Matsushima and on the adjacent islets.

There is probably a fault running along the southern foot of Dan-zan, which, beyond a valley of ENE-WSW trend, abruptly descends to a height of 100 m. This fault is often regarded as a continuation of the Nagamachi-Rifu Line.

Of the two systems of faults or trend-lines, the NE-SW element is dominant in the physiognomy of the southwestern part of the bay, while the NW-SE element prevails in its northeastern part, the boundary between these two parts nearly coinciding with the north-east coast of the peninsula of Shichigahama-mura and its north-western prolongation. In the vicinity of Shiwogama, moreover, there is one more element of east to west trend, which almost suppresses the two others; thus the plateau-surface gently descends from north to south near Shiwogama and is dissected by a deep valley of equatorial direction, in which the western half of the town of Shiwogama is embraced.

Shiwogama, with a population of 16,800, is a prosperous, busy fishermen's town, touched only by small shore liners, as the Bay of Matsushima is too shallow to afford good anchorage for larger vessels. The unfavourable geographical situation does not allow of the further growth of Shiwogama to a larger, modern city capable of carrying on important and export trade. Conditions will, of course, be much improved in the days when the construction of the harbour, now in progress at a cost of several million yen, has been brought to completion.

The Matsushima Block is in most places not covered by any younger sediments other than a very thin layer of soil. In its southernmost part only, it is overlaid by a gravel bed composed of rounded pebbles mostly of andesites; further, there are similar deposits at a few points along the valley of Akanuma, at the north-eastern prolongation of the Nagamachi-Rifu Line. There the pebbles of the gravel bed are partly andesites and partly sandy shale of the *Daonella* Bed, usually all well rounded; in one case, however, they are angular blocks of the *Daonella* shale. Excluding these gravel beds, there is no deposit on the surface of the Matsushima Block which corresponds to the Aobayama Group of the Mukai-yama, Nanakita and Tomiya Blocks.

Summary So far brief accounts have been given of the geology, geological structure and physiography of the district, including Sendai and Matsushima; these may be summarized as follows:

The oldest rocks exposed in the Matsushima Block are those of the *Daonella* Bed; this is a stratigraphical element quite unknown in the Abukuma Mountainland, but well represented by the Inai Series in the southernmost part of the Kitakami Mountainland. The latter has only one fossiliferous horizon, the *Ceratites* Bed, of the Anissic age, so far as we know at present; but the lithological similarity of the *Ceratites* Bed and *Daonella* Bed is so great that we feel warranted in taking the *Daonella* Bed of the Matsushima Block as an element proper to the Kitakami Mountainland.

The Matsushima Block is a land submerged very lately or, more properly expressed, it has been subject to a continuous process of submergence until a very recent time; it has no sign distinctly marked physiographically of recent emergence; in this point also, it agrees quite well with the Kitakami Mountainland, which is of the same altitude except in its northernmost part.

All the other blocks referred to in the preceding pages—the Tomiya, Nanakita and Mukai-yama Blocks, as well as the foreland of Miyaginohara, which is certainly a deep sunken block—have been elevated some 10 m. in a rough estimation since the late submergence. In this behaviour, they agree with the Abukuma Mountainland, but not with the Kitakami.

In the annexed table we present a tabular view of the successive geological events experienced by the present district.

Sendai and Vicinity	Matsushima and Vicinity
1. Deposition of the Mizuho Series (the Japanese Neogene), partly marine and partly terrestrial; volcanic action violent somewhere in the adjacent districts.	
2. The Post-Mizuho tectonic disturbance.	
3. Deposition of the Aobayama Group, which is assumed to be nearly contemporaneous with the Narita Series of the Kwantō Structural Basin (Guide-Book, Excursion C-6), on the disturbed and eroded surface of the Mizuho Series. Simultaneous production of an even land-surface over a very extensive area.	
4. Emergence of land, and block movement.	
5. Submergence of land.	Continued submergence.
6. Final uplift of approximately 10 m.	

Kitchen-midden of Miyato-jima

Finally it remains to say a few words only about the kitchen-midden of Miyato-jima. Kitchen-middens are not rare around the Bay of Matsu-shima; the most noteworthy one, however, is on the island of Miyato-jima near the small village of Satohama. A score of complete human skeletons have been excavated from this site, making it renowned among our anthropologists and archeologists.

Along the southwestern side of the Ōtakamori ridge, there is an inlet called Satoura, deeply incised southeastwards. One of the small, low and narrow prolongations of land at the bay-head is surrounded by fishermen's hamlets; this is Satohama. There the kitchen-midden fills a part of a small valley or gully; it consists of about eighteen shell-bearing layers, more or less distinctly stratified and is vertically more than three meters thick. It forms now part of a terrace, about 10 m. above the present sea-level, which is quite level on the surface, perhaps artificially made so. The kitchen-midden is covered by a thin soil. According to H. Matsumoto, the stone implements and potteries found at this site are of the type of the mediaeval stone age of Japan.

List of the *Mollusca* found in the kitchen-midden of Satohama.
(After I. Hayasaka)

Lamellibranchiata:

Anodonta sp.

Arca inflata Rve.

A. sp. (*obliquata* Rve. ?; cited by Hayasaka as *A. obliquata* Gray, which is a South African species)

Corbicula sp.

Cyclina chinensis Chemnitz

Mactra veneriformis Deshayes

Meretrix meretrix L.

Mya arenaria var. *japonica* Jay

Mytilus grayana Dkr.

Nodularia biwae Kobelt

Ostrea gigas Thunb.

Paphia philippinarum Ad. et Rve.

Pecten laetus Gld.

P. *yezoensis* Jay

Saxidomus purpuratus Sowb.

Gastropoda:

Chrysodomus arthriticus (Val.) Bernardi
Haliotis gigantea Gmel.
Littorina sitchana var. *brevicula* Philippi
Polinices ampla Phil.
Potamides multiformis Lischke
Rapana bezoar var. *thomasiana* Crosse
Tegula argyrostoma Gmel.
Thais bronni Dkr.
T. cfr. *luteostoma* (Chemn.) Dill.
Tonna luteostoma Kuester
Turbo coronatus Gmel.

The twenty-six species enumerated above, are all extant; most abundant of them are *Paphia philippinarum* and *Cyclina chinensis*, which are now found in the Bay of Matsushima in great profusion. Besides, fragments of skeletons and teeth of wild boar, deer, whales, and indeterminable birds and fishes are not rare.

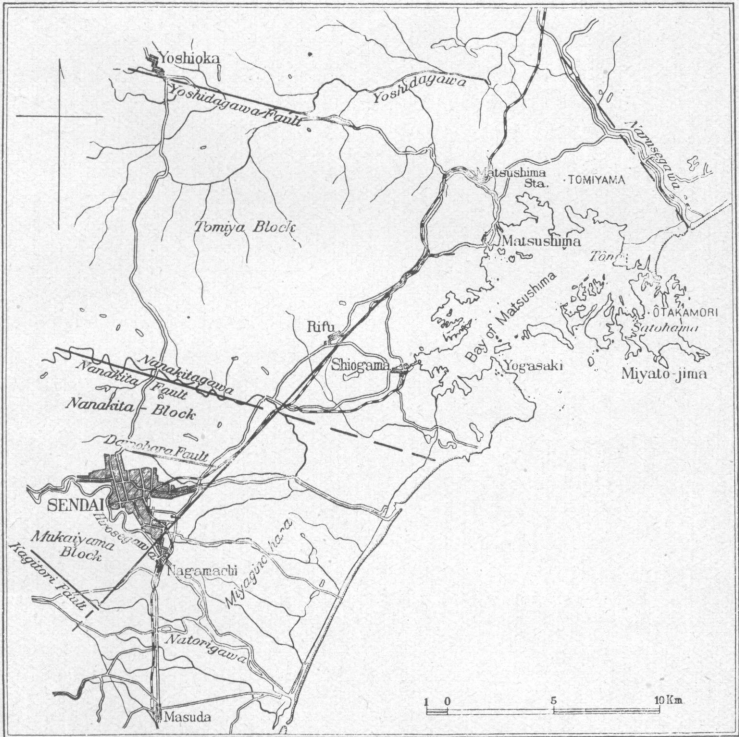
Human skeletons have been found just beneath the soil and in the uppermost part of the shell mound; the place must have been a funeral ground, as all the bodies were buried in a peculiar manner (Pl. III), along with various potteries (Pl. IV, figs. 1-2) and ornaments. A case of double burial was observed at this site; it consisted of a very aged male laid on his right side in an attitude as if embracing a child laid on its back and left side. According to Prof. R. Koganei, it is a very rare occurrence in Japan to find human skeletons buried at the top of shell layers; usually they are laid near the base. The majority of the skeletons found bore the red tint of iron oxide on the upper portions of their bodies, especially on the face and breast. Skeletons found in Japanese shell mounds belong, according to Matsumoto, to two different types, the Aoshima type and the Miyato dwarf type.

“Aoshima Type: moderately short, male adults standing about five feet two to four inches. Large-headed. Dolicho-mesocephalic. Glenoid fossae shallow; post-glenoid spine rather deep. Shallow-faced; though the face is not so shallow in absolute measurement, yet it is so broad as to be ranked among shallow-faced types in facial index; forehead retired, face convex in lateral view, more or less strongly prognathous. Floor of the nasal cavity and front surface of the upper jaw joined by a pair of grooves. *Torus palatinus* often wide-developed. Mandible very strong; chin not very strongly

projected, and rounded in upper and lower view, except in some female skulls. Palatine and dental arches of both jaws more or less long and large, like the half of an ellipse. Teeth strong; molars often of unreduced type, the upper ones being usually four-cusped.

“Miyato Dwarf Type: Very short, male adults standing about five feet to five feet two inches. Size of head moderate, mesobrachycephalic and in some cases brachycephalic. Glenoid fossae and postglenoid spine moderate. Shallow-faced, the face being very shallow both in absolute measurement and in proportion; forehead not retired; straight-faced, orthognathous.”¹⁾

1) H. Matsumoto: Notes on the Stone Age People of Japan. Amer. Anthropologist (N.S.), vol. XXIII, No. 1, 1921.



Geo-tectonic map of the district including Sendai and Matsushima.

Plate II.

Tomiya, 116.8 m.

Fukuura-jima

Kuno-shima

Ôtakamori, 105.1 m.
Miyato-jima

Katsura-jima

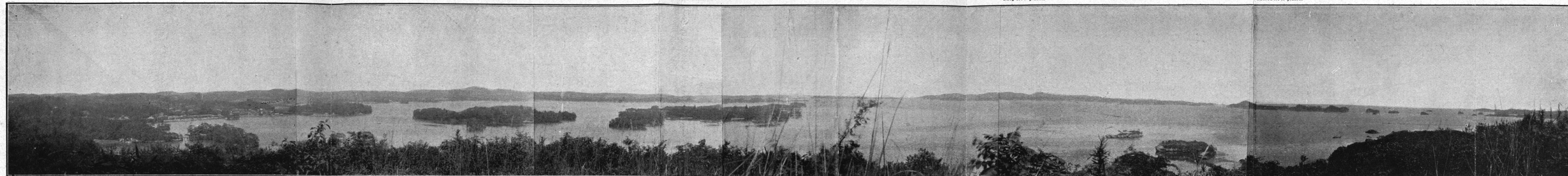


Fig. 1. A panoramic view of the Bay of Matsushima from Karigana-yama, 79 m.

SSE

S

SW

W

NW

N

NE

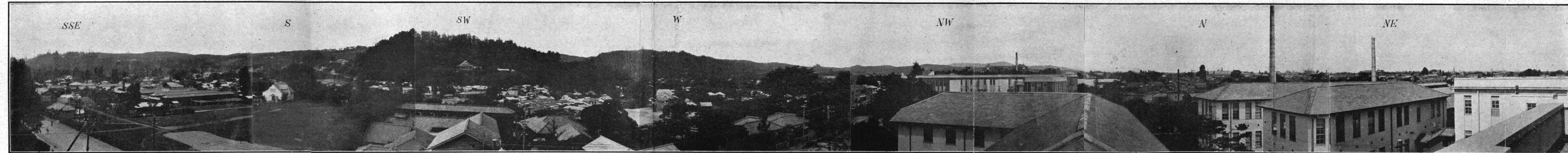


Fig. 2. A panoramic view around Sendai from the roof of the Institute of Geology and Palaeontology, Tôhoku Imperial University.



Plate IV

Fig. 1.

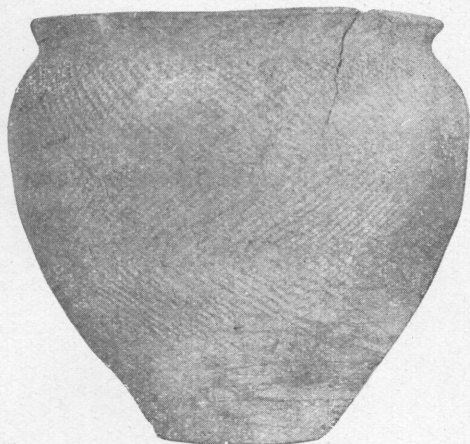


Fig. 2.



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