The Geology of Sendai and its Environs

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FOREWORD

About forty years have elapsed since Dr. Hisakatsu Yabe, Professor Emeritus of the Tôhoku University (Yabe, 1913, p. 4), first published on the geology of the Tertiary strata developed in the immediate environs of Sendai City, Miyagi Prefecture. Since then, through the continued efforts of subsequent workers, our knowledge on the geology, paleontology, petrology, and geomorphology of the Cenozoic sediments deveoloped in Sendai and its environs has progressed, and it now seems to be a suitable occasion to present in brief form, the present status concerning the geology of the said region.

The results herein presented contain the observations by the former members of our Institute and those attained in recent years by the present members of the Institute of Geology and Paleontology, Tôhoku University, Sendai.

INTRODUCTION

The geology of Sendai and its environs covers the region extending from the northernmost part of the Abukuma massif west to Shiroishi-machi (lat. 38°N., long. 140°38′–140°48′E.) at the south, north to near the southeastern part of the Kitakami massif and west to near the Ou Mountains or the central backbone ranges of northern Japan (lat. 38°31′N., long. 140°45′10.6″–140°15′10.4″E.) at the north. Thus, the original meaning of Sendai and its environs is considerably enlarged to include this extensive area. This enlargement was undertaken from geomorphological reasons as well as from the view point of geography.

This extensive region is provided with a smooth, gently concave coast line interrupted only by the irregularity produced by Matsushima Bay. Matsushima Bay is a recently submerged block, deeply indented and arrayed with many recently submerged islets detached from the mainland. The young flat coastal plain, about 4 km wide at the southeastern part of this area rapidly broadens to about 10 km near Nagamachi and Sendai along the Tôhoku main railway line.

Northeastwards the plain lessens in width to about 8 km and is there abruptly interrupted by the hilly region of the Matsushima area.

The hilly region bordering the flat coastal plain with which the topographical change is abrupt comprises rocks of the Paleozoic, Mesozoic, and Cenozoic formations, among which those of the last-mentioned predominate. The abrupt physiographical change from the young and flat coastal plain to the hilly region is due to a fault, named in this report as the Rifu-Nagamachi fault.

The region lying west of the flat coastal plain consists of geomorphologically young topographical features as presented by the deep and narrow gorge of Tatsunokuchi in the southern border of Sendai City, the hilly area which have been little dissected by subaerial denudation and the existence of small hanging valleys, fossil valleys and evidences of continued emergence relative to sea-level. The rivers, however, do not appear so young as the gorge of Tatsunokuchi as their history appears to be longer than that of the gorge.

The geomorphological features reveal differential movement which has been important in the contribution of the present day topographical features.

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FOUNDATION OF THE TERTIARY

The foundation rocks of the Tertiary sediments are exposed only in limited areas within the present sheet; they comprise the Paleozoic Wariyama formation in the northern part of the Abukuma massif, the Triassic Rifu formation which is characterized with *Daonella* in the central part of the sheet, and the granodiorites of Mesozoic age which crop out in the southern part of the area dealt with herein.

The Paleozoic Wariyama formation is exposed only in a narrow strip in the southeastern part of the area. Here the Miocene Tsukinoki formation, a terrestrial facies of the marine Moniwa formation, unconformably overlies the west flank of the folded and truncated schists and slates of the Wariyama formation, and also the granodiorite. On the eastern flank of the same region, the Paleozoic Wariyama formation and Mesozoic granodiorites are unconformably overlain with the Pliocene Kameoka and Tatsunokuchi formations. The Wariyama and granodiorites are also seen to underlie the Tsukinoki formation and the Takadate andesite on the northern side of the Akukuma River in the southeastern part of the area with unconformity.

The Triassic Rifu formation of clayslate, conglomeratic sandstone and sandstone is unconformably overlain with the Shiogama agglomerate and in fault or unconformable contact with the Miocene Aoso formation in the area between Rifu and Matsushima stations along the Tôhoku main railway line. Elsewhere the foundation rocks of the Tertiary are not exposed.

THE TERTIARY FORMATIONS

The Tertiary formations (Table 1) within the area of Sendai Proper can be subdivided into groups and formations based upon their lithology, paleontology, and stratigraphy. The lithology and thickness of the respective formations exposed in the area of Sendai Proper are summarized in Table 1.

Owing to that the stratigraphical units applied in the area of Sendai Proper cannot be used in other areas within the same sheet, it has been found desirable to establish formation names for the reason that the lithological designations of the formations at the type localities within the area of Sendai Proper are not applicable to other areas. For this reason, as will be noticed from the correlation table of columnar sections, the sheet bhas een subdivided into the following areas, namely, Sen-nan, Sendai Proper, Tomiya, Shiogama, and Matsushima-Nobiru.

For the sake of convenience, the Tertiary formations within the area of Sendai Proper including the area of Sen-nan will be described, and correlative stratigraphical units will be included therein. In the areas just mentioned the following units have been recognized.

NATORI GROUP

Type locality.-Area between Takadate-yama, Takadate-mura west to Akaishi, Oide-mura, Natori-gun, along the Natori River (lat. 38°15–38°12′N., long. 140°41′–140°50′E.). Total thickness 250 meters.

The Natori group is chiefly marine except for the terrestrial facies in the vicinity of Tsukinoki-machi where a 130 meter thick, plant-bearing formation is intercalated by interfingering with the Takadate andesite, and where brackish water facies exist as in the vicinity of Mitaki in the western border of Sendai City. The andesite at the lower and the agglomeratic tuff at the upper parts of the

Table 1
Composite Stratigraphical Sequence of Sendai Proper with Lithological and Paleontological Characteristics

Age	Name of: Group	Name of: Formation	Thickness (meter)	Lithologic Character	Paleontologic Character
Pleistocene		TERRACE DEPOSITS	1-5	Gravel, sand and clay; in several heights	
		AOBAYAMA	5-30	Gravel, sand, clay and tuff	
Pliocene	SENDAI	DAINENJI	30-130	Loose sandstone, siltstone, tuff, conglomerate, tuffaceous shale, pumiceous shale, lignite.	*Callithaca adamsi* *Abies balsamea* *Liquidambar formosana*
		YAGIYAMA	20-30	Alternation of tuff and siltstone, tuffaceous siltstone, lignite, conglomerate.	*Fagus crenata*
		HIROSEGAWA TUFF	15-100	Massive tuff, pumiceous to sandy; pisolitic at base, charcoal	
		KITAYAMA	1-10	Tuff, siltstone, sandstone, lignite, basal conglomerate	*Sequoia japonica* *Cryptomeria japonica*
		TATSUNO-KUCHI	30-60	Alternation of tuffaceous sandstone and siltstone, sandstone granule conglomerate	*Fortipecten takahashii* *Cancer minutoserratus* *Trilophodon sendaicus*
		KAMEOKA	15-50	Siltstone, tuff, sandstone, lignite, granule conglomerate	*Glyptostrobus europaeus*
		MITAKI ANDESITE	200	Basaltic andesite, tuff, agglomerate, interfingering with the KAMEOKA Formation	
	AKYU	SHIRASAWA	330	Laminated shale, white sandy tuff, alternation of shale, tuff and sandy shale	*Liriodendron honsyuensis* *Firmina platanifolia*
		YUMOTO	150	Massive tuff-breccia, liparitic green tuff, agglomeratic tuff, inferior lignite	

Miocene	NATORI	TSUNAKI	130	Agglomeratic tuff, sandstone, shale, tuff.	*Glycymeris matumoriensis*
		HATATATE	130	Alternation of sandstone and shale, shale and sandstone	*Ancistrolepis yamanei* *Siratoria siratoriensis* *Marginulina sendaiensis*
		MONIWA	60–130	Sandstone, granule conglomerate, tuff, shale, lignite, impure limestone	*Lepidocyclina japonica* *Nonaochlamys notoensis* *Lyropecten kagamianus* *Eostegodon pseudolatidens* *Echinolampas yoshiwarai* *Comptoniphyllum Naumanni* *Cinnamomum lanceolatum*
		TAKADATE	60–250	Andesite, agglomerate, agglomeratic tuff	
Paleozoic WARIYAMA, Mesozoic Granodiorites, Triassic RIFU					

Natori group indicate volcanism prior to and during the first stage of marine transgression and during the last stage of regression. Facies similar to the Tsukinoki are also found in the Shiogama and Matsushima-Nobiru areas where the Shiogama agglomerate grades upwards to a plant-bearing formation with brackish water shells in its upper part.

The Natori group in the area of Sendai Proper can be subdivided into four cartographic units based upon lithology and paleontology. These four units here classified into formations, are in upward succession, the Takadate andesite which interfingers in part with the terrestrial Tsukinoki and marine Moniwa formations, the Moniwa formation, Hatatate and Tsunaki formations. In the Tomiya area are developed the following units in upward succession, namely, Koyabara andesite, Otsutsumi, Aoso, and Nanakita formations. In the Shiogama area are recognized the Shiogama agglomerate, Sauramachi formation and Ajiri formation. In the Matsushima-Nobiru area the formations in upward succession are named, Shiogama agglomerate, Nobiru formation, Hamada formation and Hatsuhara formation in which is included the Matushima tuff member in its lower part and the Bangamori formation with the Shirasakayama tuff as its member. All of the named formations are conformable with one another and in the area of Sendai Proper, contain marine fossils throughout. The Tsukinoki formation is a terrestrial facies of the marine Moniwa and its correlative in the Shiogama area is the Sauramachi formation and the lower part of the Ajiri formation, judging from the evidence afforded by the occurrence of *Eostegodon pseudolatidens* Yabe (Yabe, 1950, pp. 61–65) and plant leaves as *Comptoniphyllum* and *Liquidambar*.

Table 2
Stratigraphical Sequence of the Tertiary Sediments in the Tomiya, Shiogama, and Matsushima-Nobiru Areas

Tomiya Area	Shiogama Area	Matsushima-Nobiru Area
Miyatoko formation (100m thick)	Missing	Missing
Ishikura formation (70m thick)	Yakushi formation (20m thick) Geba formation (50m thick)	
Missing	Matsugahama andesite and its agglomerate	
Nanakita formation (75–80m thick)	Missing	
Aoso formation (70–160m thick)		Bangamori formation (70–160m thick) with Shirasakayama tuff member (50–100m thick)
Otsutsumi formation (400–500m thick)		Hatsuhara formation (0–100m thick) with Matsushima tuff member (0–100m thick)
	Ajiri formation (250m thick)	Hamada formation (100–250m thick)
	Sauramachi formation (100m thick)	Nobiru formation (100m thick)
Koyabara andesite base unknown	Shiogama agglomerate (100m thick)	
	Rifu formation (Triassic)	

1. TAKADATE ANDESITE

Type locality.-Takadate-yama, Takadate-mura, Natori-gun, in the southeastern part of Sendai City (lat. 38°11′30″N., long. 140°50′E.). Thickness 250 meters.

The Takadate andesite which comprises two-pyroxene, hypersthene, augite, and hornblende andesite overlies the pre-Tertiary granodiorite in the region west of Iwanuma station on the Tôhoku main railway line, and includes andesitic agglomerate, agglomeratic tuff and tuffaceous sandstone besides lava flows. This volcanic complex interfingers with the lower part of the marine Moniwa formation and also with the terrestrial Tsukinoki formation, which consists of granule conglomerate, tuffaceous sandstone, brecciated or pumiceous tuff, and lignite. *Eostegodon pseudolatidens* Yabe (Yabe, 1950, pp. 61–65), a lower Miocene elephant was discovered from this formation at Funaoka near the type locality of the Tsukinoki

Table 3 Flora from the Tsukinoki Formation with Localities and other details

Formation	Tsukinoki																			
Plant beds	Higashine			Ejiri					Matsumoto		Tsukinoki-machi									Hazaka
Localities / Fossil plants	1. Sakatsuda	2. Higashi-Kosaka	3. Kosaka	4. Ejiri	5. Hosoya	6. Kajiuchi	7. Shôgakuji	8. Shinyashiki	9. Matsumoto	10. Aramachi	11. Shirahata	12. Kashiwaishi	13. Iwanoiri	14. Karimata-zaka	15. Funabasama	16. Chiyonokawa	17. Nakanouchi	18. Takoji	19. Tatenomae	20. Hazaka
⦿ 1. *Goniopteris strica* (Ung.) A. Br.		×																		
2. *Pteris* sp.		×		×		×														
◎ 3. *Sequoia* sp.					×															
4. *Cyperites* sp									×											
● 5. *Populus balsamoides* Göpp.				×																
6. *P.* sp.		×		×						×										
● 7. *Salix Lavateri* Heer				×																
8. *S.* sp.		×		×												×				
◎ 9. *Comptoniphyllum Naumanni* Nath.				×		×										×			×	×
10. *Juglans* sp.									×					×						
11. *Pterocarya* sp.														×						
12. *Carpinus carpinoides* Makino										×										
13. *C. laxiflora* Bl.												×		×		×				
● 14. *C. palaeojaponica* Endô (MS)				×																
15. *C.* sp.														×						
● 16. *Castanea* sp. (*C.* cfr. *Kubinyi* Kov.)				×																
17. *C.* sp.		×							×											
18. *Fagus* sp.																				×
● 19. *Quercus drymeja* Ung.												×								
20. *Q. glauca* Thunb.														×						
21. *Q. serrata* Thunb.												×								
22. *Q.* sp.		×							×			×	×	×					×	
⦿ 23. *Dryophyllum Dewalquei* Sap.									×			×								
⦿ 24. *D.* sp.									×									×	×	
25. *Celtis sinense* Pers.		×					×													
● 26. *Ulmus longifolia* Ung.			×																	
27. *U.* sp.		×		×						×		×					×			
● 28. *Zelkova Ungeri* Kov.		×							×		×	×								
● 29. *Ficus tiliaefolia* Heer								×	×			×								
30. *F.* sp.	×								×			×		×						
● 31. *Cinnamomum lanceolatum* Heer																			×	
● 32. *C. Scheuchzeri* Heer														×						
33. *C.* sp.													×	×						
34. *Litsea* sp. (*L.* cfr. *glauca* Sieb.)														×						
● 35. *Laurus primigenia* Ung.												×								
36. *L.* sp.			×	×								×	×							
◎ 37. *Liquidambar formosana* Hance									×			×		×						
◎ 38. *L.* sp.							×		×				×							
39. *Hamamelis* sp.		×																		
40. *Sorbus* sp.															×					
41. *Sapium japonicum* Pax. et K. Hoffm.														×						
● 42. *Ilex cornuta* Lindl. et Pax.														×						
43. *Euonymus* sp.																	×			
44. *Acer* sp.									×											
45. *Paliurus* sp.										×										
46. *Trapa* sp.															×					
47. *Styrax* sp.														×						
48. *Viburnum* sp.											×	×		×						
Total of species	1	10	2	10	1	2	2	1	12	4	2	13	4	15	2	3	2	1	4	2

◎ Exotic genus ○ Exotic species ⦿ Extinct genus ● Extinct species

Loc. No.	Localities	Altitude (above sea-level)	North Latitude	East Longitude	Situation from base of Formation	Thickness of Formation
1.	Road cut about 300 m east of Dai, Sakatsuda Higashine-mura, Igu-gun.	40m	38° 0′ 28″ 3	140° 48′ 51″ 7	20m	(90m) (excluding andesite, basalt and agglomerate)
2.	Road cut west of Higashi-Kosaka, Higashine-mura, Igu-gun.	10m	38° 2′ 43″ 3	140° 49′ 4″ 1		
3.	Cliff about 120 m west of main road west of Kumanomae, Kosaka, Higashine-mura, Igu-gun.	10m	38° 2′ 28″ 3	140° 48′ 29″ 0		
4.	a) Quarry about 250 m north of Kidokoro (site of pumping plant) b) Quarry (Gotanda) about 300 m north of Kidokoro c) Quarry about 200 m west of Shionoiri, Ejiri, Kitago-mura, Igu-gun.	40m	38° 1′ 13″ 3 38° 1′ 21″ 6 38° 1′ 31″ 6	140° 48′ 4″ 8 140° 48′ 4″ 1 140° 48′ 2″ 1	35m	
5.	West side of road at Hosoya, Kitago-mura, Igu-gun.	20m	38° 1′ 36″ 6	140° 47′ 51″ 7		
6.	Cliff of Denjô-zan about 200 m west of Kaji-uchi, Kitagô-mura, Igu-gun.	20m	38° 0′ 58″ 3	140° 47′ 18″ 6		
7.	Cutting back of house at Shôgakuji, Kitagô-mura, Igu-gun.	20m	38° 2′ 15″ 2	140° 47′ 45″ 6		
8.	Road cut 200 m east of Shinyashiki, Kitagô-mura, Igu-gun.	20m	38° 2′ 31″ 6	140° 48′ 4″ 1		
9.	Cliff back of former Matsumoto Primary School, Kitagô-mura, Igu-gun.	20m	38° 1′ 3″ 3	140° 46′ 39″ 3		
10.	Cliff about 300m west of Aramachi, Kitagô-mura, Igu-gun.	20m	38° 1′ 13″ 3	140° 46′ 45″ 5		
11.	Quarry south of triangular point (62.6 m), 700m west of Shirahata, Tsukinoki-machi, Shibata-gun.	30m	38° 4′ 10″ 3	140° 48′ 10″ 4	40m	
12.	Cliff narrow path running to north from national road near Kashiwaishi, Tsukinoki-machi, Shibata-gun.	30m	38° 4′ 11″ 6	140° 47′ 24″ 8		
13.	Outcrop around field 400 m west of Iwanoiri, Tsukinoki-machi, Shibata-gun.	20m	38° 3′ 48″ 3	140° 46′ 35″ 2		
14.	Cliff of west side of farmer's house at Karimatazaka, Tsukinoki-machi, Shibata-gun.	20m	38° 4′ 9″ 1	140° 47′ 8″ 3		
15.	Cliff back of Funabasama Primary School, Tsukinoki-machi, Shibata-gun.	15m	38° 4′ 16″ 6	140° 46′ 29″ 0		
16.	Road about 100 m north of Chiyonokawa, Tsukinoki-machi, Shibata-gun.	30m	38° 4′ 36″ 6	140° 47′ 20″ 7		
17.	Road cut about 200 m weest of Nakanouchi, Tsukinoki-machi, Shibata-gun.	30m	38° 4′ 51″ 6	140° 47 25″ 2		
18.	Road cut about 200 m east of Takôji, Tsukinoki-machi, Shibata-gun.	20m	38° 4′ 55″ 0	140° 47′ 6″ 2		
19.	Cliff about 300 m west of Tatenomae, Tsukinoki-machi, Shibata-gun.	10m	38° 5′ 1″ 6	140° 48′ 4″ 1		
20.	Road cut about 500 m south-east of Hazaka, Tsukinoki-machi, Shibata-gun. Cutting back of farmer's house about 600 m south of Hazaka, Tsukinoki-machi, Shibata-gun.	30m	38° 5′ 5″ 0 38° 5′ 51″ 6	140° 46′ 49″ 1 140° 46′ 33″ 1		

Table 4 Flora from the Upper Part of the Sauramachi and Ajiri Formations

Formation	Sauramachi formation				Ajiri formation													
Plant beds	Nishi-Shiogama		Koma-tsuzaki	Yoshi-zu	Hon-Shiogama				Higashi-Shiogama				Kita-Shio-gama	Sugâ	Hama-da	Ajiri		Suginoiri
Localities / Fossil plants	1. Nishi-Shio-gama No.1	2. Nishi-Shio-gama No.2	3. Kamotsuzaki	4. Yoshizu	5. Hon-Shio-gama No.1	6. Hon-Shio-gama No.2	7. Hon-Shio-gama No.3	8. Hon-Shio-gama No.5	9. Higashi-Shio-gama No.1	10. Higashi-Shio-gama No.2	11. Higashi-Shio-gama No.3	12. Higashi-Shio-gama No.4	12. Kita-Shio-gama	14. Suga	15. Hamada	16. Ajiri No.1	17. Ajiri No.2	18. Suginoiri
1. *Lygodium* sp.	×																	
2. *Abies* sp.												×						
3. *Pinus* sp. (*P.* cfr. *densiflora* Sieb. et Zucc.)								×										
◎ 4. *Sequoia japonica* Endô	×																	
◎ 5. *S. sempervirens* Endl.	×	×			×	×		×						×				
◎ 6. *Taxodium distichum* Rich.			×															
⊙ 7. *Sabalites* sp.																		
8. *Smilax china* L.								×										
9. *Salix* sp.1										×								
10. *S.* sp.2			×			×	×	×				×						
◎ 11. *Comptoniphyllum Naumanni* Nath.								×				×	×					
● 12. *Juglans nigella* Heer																		
13. *J.* sp. (*J.* cfr. *Sieboldiana* Maxim.)						×		×				×						
14. *Pterocarya rhoifolia* Sieb. et Zucc.			×						×						×			
15. *Alnus firma* Sieb. et Zucc.			×															
16. *A.* sp.			×	×		×		×										
17. *Carpinus carpinoides* Makino	×		×															
18. *C. laxiflora* Sieb. et Zucc.	×		×															
● 19. *Castanea Kubinyi* Kov.												×						×
20. *Fagus crenata* Bl.			×															
○ 21. *F. americana* Sweet							×					×			×			
22. *F.* sp.																		
23. *Quercus sp.* (*Q.* cfr. *glauca* Thunb.)			×															
24. *Q.* sp.			×		×													
⊙ 25. *Dryophyllum* sp.												×			×	×	×	
○ 26. *Celtis occidentalis* L.			×															
27. *C.* sp.	×																	
28. *Ulmus japonica* Sarg.				×														
● 29. *Zelkova Ungeri* Kov.									×									
○ 30. *Ficus tiliaefolia* Heer			×	×	×	×	×		×									
31. *F.* sp.										×								
32. *Magnolia* sp. (*M.* cfr. *praecocissima* Koidz.)									×									
33. *Cinnamomum* sp. (C. cfr. *comphora* Nees et Ebern.)								×								×		
34. *Lindera umbellata* Thunb.			×															
◎ 35. *Liquidambar formosana* Hance	×			×			×	×	×			×	×	×	×			
36. *Sapium japonicum* Pax. et K. Hoffm.			×															
37. *Ilex macropoda* Miq.												×						
38. *I.* sp.													×		×			
● 39. *Acer nordenskiöldi* Nath.	×																	
40. *A. Matsumurae* Koidz.							×											
41. *A. pictum* Thunb.							×											
● 42. *A. polymorphum* (*palmatum*) *pliocaenicum* Sap.							×											
○ 43. *A. sinense* Pax.	×																	
○ 44. *A. trifidum* Hook et Arn.											×							
45. *A. sp.*	×				×													
⊙ 46. *Vitiophyllum* sp.							×											
47. *Hibiscus Hamabo* Sieb. et Zucc.							×											
48. *Idesia polycarpa* Maxim.						×												
49. *Aralia* sp.		×	×	×	×		×											
50. *Vaccinium uliginosum* L. ?			×															
Total of Species	10	2	15	4	4	7	10	9	4	2	1	9	3	2	5	2	1	1

◎ Exotic genera ○ Exotic species ⊙ Extinct genera ● Extinct species

Locality No.	Localities	Altitude (above sea level)	North Latitude	East Longitude	Situation from base of Formation	Thickness of Formation
1.	Cliff about 200m west of Nishi-Shiogama Station of Senseki electric railway, Shiogama.	25m	38° 18′ 33″ 3	141° 1′ 13′ 5	50m	Sauramachi (100m)
2.	Cliff about 500m north of Nishi-Shiogama Station of Senseki electric railway, Shiogama.	20m	38° 18′ 36″ 6	141° 1′ 24″ 8		
3.	Campus of Shiogama Second Primary School, Shiogama.	45m	38° 19′ 20″ 0	141° 1′ 25″ 9	50m	
4.	South side of road of Yoshizu, Shiogama.	40m	38° 19′ 43″ 4	141° 1′ 22″ 8		
5.	Cliff back of Shiogama Municipal Office, Shiogama.	5m	38° 18′ 43″ 3	141° 1′ 34″ 1	24m	Ajiri (250m)
6.	Cliff about 130m west of Shiogama Police Station, Shiogama.	10m	38° 18′ 49″ 1	141° 1′ 33″ 1		
7.	Cliff at South corner of Chikko Street and Ojimacho, Shiogama.	10m	38° 18′ 51″ 6	141° 1′ 40″ 4	53m	
8.	Hill about 150m north of Shiogama Gas Company, Nakanoshima, Shiogama.	20m	38° 18′ 35″ 0	141° 2′ 0″ 0	100m (I) 109m (II)	
9.	East side of road 700m north of Higashi-Shiogama Station of Senseki electric railway, Shiogama.	35m	38° 19′ 37″ 5	141° 1′ 54″ 8	24m	
10.	East side of road 350m north of Higashi-Shiogama Station of Senseki electric railway, Shiogama.	35m	38° 19′ 27″ 5	141° 1′ 59″ 0	53m (I)	
11.	East side of road 500m north of Higashi-Shiogama Station of Senseki electric railway, Shiogama.	35m	38° 19′ 31″ 4	141° 2′ 5″ 2	68m (II)	
12.	North side of railroad about 150m east of Higashi-Shiogama Station of Senseki electric railway, Shiogama.	30m	38° 19′ 18″ 4	141° 2′ 1″ 0	100m (I) 109m (II)	
13.	West side of railroad cutting about 450m east of Kita-Shiogama Station of Tôhoku coast railway line, Shiogama.	20m	38° 19′ 56″ 7	141° 2′ 16″ 6	53m (I) 68m (II)	
14.	Entrance of tunnel of En-Shô Drive way 400m east of Suga, Rifu-mura, Miyagi-gun.	15m	38° 20′ 8″ 7	141° 2′ 22″ 8	24m	
15.	Cliff about 500m south of Hamada Station of Senseki electric railway, Rifu-mura, Miyagi-gun.	30m	38° 20′ 38″ 7	141° 2′ 36″ 2		
16.	Cliff about 150m west of Ajiri, Shiogama.	15m	38° 18′ 35″ 8	141° 2′ 9″ 3	100m (I) 109m (II)	
17.	Cliff about 200m and 350m east of Ajiri, Shiogama.	10m 20m	38° 18′ 40″ 8 38° 18′ 40″ 0	141° 2′ 21″ 8 141° 2′ 25″ 1		
18.	West side of railway cutting of Suginoiri village, about 500m. northeast of Higashi-Shiogama Station, Shiogama.	30m	38° 19′ 33″ 3	141° 2′ 20″ 7		

Table 5 Fossils from the Moniwa Formation including the Lower Part of the Otsutsumi Formation

Species \ Localities	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII
1. *Lepidocyclina japonica* YABE														×			
2. *Terebratulina crossei* DAVIDSON																×	×
3. *T. moniwaensis* HATAI								×				×					
4. *T. helenae* HATAI																	×
5. *Terebratalia gouldii* (DALL)								×									×
6. *T. sendaica* HATAI								×									×
7. *T. tenuis* (HAYASAKA)																	×
8. *Coptothyris adamsi* (DAVIDSON)		×				×						×	×	×	×	×	×
9. *Dallina miyatokoensis* HATAI																	×
10. *Laqueus rubellus* (SOWERBY)																	×
11. *Nipponothyris subovata* HATAI						×											×
12. *Echinolampas yoshiwarai* P. DE LORIOL																×	
13. *Acila divaricata* (HINDS)		×															
14. *Nuculana moniwaensis* NOMURA												×					
15. *Arca* cf. *ocellata* REEVE											×			×			
16. *Pseudogrammatodon dalli* (SMITH)												×	×	×	×		
17. *Glycymeris vestitoides* NOMURA		×						×									
18. *Crenella otutumiensis* NOMURA and HATAI												×					×
19. *Volsella modiola* (LINNÉ)																	×
20. *Mytilus crassitesta* Lischke																	×
21. *Placopecten akihoensis* (MATSUMOTO)					×			×		×		×		×		×	×
22. *Chlamys arakawai* (NOMURA)												×	×	×	×	×	×
23. *C. kaneharai* (YOKOYAMA)					×	×		×						×			
24. *C. miyatokoensis* (NOMURA and HATAI)											×						×
25. *C. nisataiensis* (OTUKA)						×							×		×		
26. *Nanaochlamys notoensis* (YOKOYAMA)		×			×	×				×		×	×	×		×	×
27. *Placopecten protomollita* (NOMURA)		×			×	×				×		×					
28. *C. cosibensis* (YOKOYAMA)							×										×
29. *C. otutumiensis* (NOMURA and HATAI)																	×
30. *C. swiftii* (BERNARDI)																	×
31. *Aequipecten yanagawaensis* (NOMURA and ZINBÔ)						×				×	×	×		×	×	×	
32. *Lyropecten kagamianus* (YOKOYAMA)					×					×		×		×			
33. *L. kagamianus miyagiensis* (NAKAMURA)																	×
34. *Limatula subauriculata* (MONTAGU)												×					
35. *Lima (Acesta) goliath* SOWERBY														×			
36. *Anomia cytaeum* GRAY															×		
37. *Pododesmus macroschismus* (DESHAYES)																	×
38. *Ostrea gigas* THUNBERG		×															×
39. *O. sinensis* GIMELIN												×					
40. *Crassatellites pauxillus* (YOKOYAMA)												×				×	
41. *Taras cumingi* (HANLEY)													×			×	
42. *T. ustus* (GOULD)											×			×			
43. *Lucinoma acutilineatum* (CONRAD)	×	×		×						×	×						
44. *Laevicardium ? murataensis* (NOMURA)		×															
45. *Trachycardium shiobarense* (YOKOYAMA)		×						×		×	×	×		×			
46. *Cerastoderma ? goisiense* (NOMURA)															×		
47. *Dosinia kaneharai* YOKOYAMA		×					×					×	×	×	×		
48. *D. nomurai* OTUKA										×				×	×	×	
49. *D. sibataensis* NOMURA		×															
50. *Pitar itoi* (MAKIYAMA)														×	×		
51. *Clementia vatheleti* (MABILLE)	×																
52. *Saxidomus* cf. *nuttallii* (CONRAD)												×				×	
53. *Venus toreuma* GOULD						×		×									
54. *Callista sinensis* (HOLTEN)	×																
55. *Chione osyuensis* NOMURA and ONISI		×									×						
56. *Mercenaria chitaniana* (YOKOYAMA)		×															
57. *M. yokoyamai* (MAKIYAMA)										×		×		×		×	
58. *Paphia ? takadatensis* MATSUMOTO		×										×				×	
59. *Siratoria siratoriensis* (OTUKA)		×															
60. *Spisula ploynyma voyi* (GABB)															×		
61. *Mactra ? charischema* MATSUMOTO		×														×	
62. *Schizothaerus* cf. *nuttallii* (CONRAD)															×		
63. *Macoma tokyoensis* MAKIYAMA	×	×								×		×					
64. *Panope japonica* (A. ADAMS)		×					×						×	×		×	
65. *Mya japonica* Jay								×						×			
66. *Thracia beringi* DALL			×														
67. *T.* cf. *beringi* DALL				×													
68. *Dentalium* cf. *weinkauffi* DUNKER												×					
69. *D. yokoyamai* MAKIYAMA		×		×													
70. *Haliotis japonica* REEVE													×				
71. *Turcica preimperialis* NOMURA													×	×		×	
72. *Tegula protonigerrima* NOMURA													×	×			
73. *Trochus goisiensis* NOMURA															×		
74. *T. oidensis* NOMURA												×	×	×			
75. *Turbo parvuloides* NOMURA													×				
76. *Umbonium miyagiense* NOMURA and ZINBÔ																	
77. *Turritella s-hataii* NOMURA		×															
78. *Cheilea yanagawaensis* NOMURA and ZINBÔ		×													×		
79. *Capulus natorianus* NOMURA															×		
80. *Crepidula* cf. *aculeata* (GMELIN)					×											×	
81. *Tugurium exutum* (REEVE)							×							×	×	×	
82. *Polinices kiritaniana* YOKOYAMA																	
83. *P.* cf. *melanostoma* (GELIN)		×										×					
84. *Natica janthostoma* DESHAYES																	
85. *Sinum yabei* OTUKA		×									×	×					
86. *Morum macandrewi* (SOWERBY)												×					
87. *Galeodea ogawarensis* NOMURA and ÔNISI																	
88. *Semicassis* cf. *japonica* (REEVE)												×					
89. *Shichiheia yabei* (NOMURA and HATAI)														×			
90. *Fusitriton nipponensis natorianus* (NOMURA)														×			
91. *Apollon yabei* (NOMURA and HATAI)														×			
92. *Ancistrolepis tricordatus* NÔMURA and ONISI		×															
93. *Siphonalia* cf. *gravitesta* NOMURA and ZINBÔ													×	×			
94. *S. prespadicea* NOMURA and ZINBÔ														×	×		
96. *Neptunea koromogawana* NOMURA												×					
95. *Babylonia kozaiensis* NOMURA													×				
97. *Phos (Coraeophos) nakamurai* (KURODA)		×															
98. *Olivella iwakiensis* NOMURA and HATAI		×															
99. *Cancellaria muratana* NOMURA and ONISI		×															
100. *Megasurcula arai* (NOMURA and ONISI)		×															
101. *M. siogamensis* (NOMURA)														×			
102. *Conus moniwanus* NOMURA										×		×					
103. *Isurus hastalis* AGASSIZ																	

Loc. No.	Localities	North Latitude	East Longitude	Situation from base of the Formation
I	River cliff about 150m W of bridge 500m W of Adachi, Murata-machi, Shibata-gun.	38° 08′ 0″	140° 42′ 04″	10m
II	Road-side cutting about 1km NW of primary school at Adachi, Murata-machi, Shibata-gun.	38° 08′ 41″	140° 42′ 15″	10m
III	To the west of Murata Primary School, Murata-Machi, Shibata-gun.	38° 03′ 09″	140° 42′ 09″	10m
IV	Road cut about 250m NE of primary school at Koizumi, S of Murata-machi, Shibata-gun.	38° 06′ 12″	140° 44′ 08″	10m
V	Exposure on path about 1km S of Hasekura, Tomioka-mura, Shibata-gun.	38° 06′ 04″	140° 42′ 09″	25m
VI	Road cut 50m S of the Nanamagari Pass in the north of Murata-machi, Shibata-gun.	38° 08′ 02″	140° 45 58″	?
VII	Hashimoto, Ogawara-machi, Shibata-gun.	38° 03′ 31″	140° 43′ 31″	25m
VIII	1.5km SSE of Yatsuki, Enda-mura, Katta-gun.	38° 04′ 22″	140° 40′ 50″	25m
X	To the west of Hira (or Kanagase), Kanagase-mura, Shibata-gun.	38° 02′ 04″	140° 41′ 08″	25m
XI	Creek 600m NW of shrine at Hirasawa, Enda-mura, Katta-gun.	38° 57′ 36″	140° 40 52″	10m
XII	Creek N of Moniwa electric power-house, Oide-mura, Natori-gun.	38° 13′	140° 47′ 26″	1～2m
XIII	Junction of tributary and Natori River, a short distance E of bridge at Akaishi, Oide-mura, Natori-gun.	38° 12′ 16″	140° 45′ 29″	5～10m
XIV	Road-side cutting immediately SW of Akyu station at Kita-Akaishi, Oide-mura, Natori-gun.	38° 12′ 51″	140° 45′ 26″	3m
XV	River cliff NE of Goishi, Tomioka-mura, Shibata-gun.	38° 11′ 44″	140° 43′ 38″	5～10m
XVI	N foot of Takadate Hill, about 400m Wof Kumano shrine at Kumanodô, Takadate-mura, Natori-gun.	38° 11′ 59″	140° 50′ 43″	5m
XVII	Cliff of pond at junction of two tributaries of upper course of Miyatoko River, about 1.1km NW of Dôniwayama, Miyatoko-mura, Kurokawa-gun.	38° 22′ 44″	140° 49′ 08″	5m

formation. Plant fossils occur in the Tsukinoki formation as indicated in Table 3.

Correlatives of the Takadate andesite are the Koyabara andesite and its agglomerate in the western part of the Tomiya area, the Shiogama agglomerate in the Shiogama area, the Asahiyama and Nonodake andesites in the area immediately north of the northeastern end of the present sheet, the Ko-oku basalt in the Ogawara district immediately in the southern end of the Sen-nan area. Other correlatives are, the Nagane volcanics in the Kakuda district in southern Miyagi Prefecture, and the Inase andesite in Iwate Prefecture.

In the Shiogama area the Shiogama agglomerate is overlain conformably with a plant-bearing and *Eostegodon pseudolatidens* Yabe yielding formation, and in the western part of the Tomiya area the Koyabara andesite and its agglomerate is conformably overlain with the Otsutsumi marine shell-bearing formation, while in the Matsushima-Nobiru area, the Shiogama agglomerate is succeeded upwards with the Nobiru formation which comprises tuff, tuffaceous sandstone and siltstone. The flora from the Sauramachi formation as well as from the overlying Ajiri formation in the Shiogama area are given in Table 4.

2. MONIWA FORMATION

Type locality.-River cliff along a tributary of the Natori River at Moniwa, Oide-mura, Natori-gun (lat. 38°13'N., long. 140°47'E.). Thickness 60–130 meters.

The Moniwa formation, which interfingers in its lower part with the Takadate andesite, comprises grayish-green, coarse sandstone, volcanic conglomerate, granule conglomerate, green-brown tuffaceous sandy shale, brown coarse sandstone and impure limestone carrying remains of simple corals as *Balanophyllia* and *Flabellum*. Fossils occur throughout the formation (Table 5). This formation interfingers with the Takadate andesite in part, and the latter with the Tsukinoki terrestrial formation as already mentioned in earlier lines. The Moniwa is overlain conformably with the Hatatate formation.

Fossils are abundant in the Moniwa formation, and especially noteworthy is the discovery of *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe by Wataru Hashimoto and S. Hanzawa (Hanzawa, 1935, p. 533), from a coarse sandstone about three meters above the Takadate andesite at Kita-Akaishi in Oide-mura, Natori-gun and also the same Foraminifera was found by J. Iwai, N. Kitamura, and T. Shibata in our Institute in the same horizon exposed near the electric power house at Moniwa in the same village. Molluscs are the predominant fossils and among them occur such warm water genera as *Conus*, *Tugurium* and others. Smaller foraminifera, brachiopods, echinoids, simple corals, shark's teeth, cirripeds and bryozoans are also common in the formation.

The molluscan fauna of the Moniwa is largely composed of rocky shore inhabitants, such as *Anomia*, *Ostrea*, and *Spondylus* besides others, while brackish water types are rare, although mud- and sand-loving forms as *Macoma*, *Solen* and *Panope* are intermingled; these are considered exotic as can be shown by the lithological nature of the sediments in which they occur. These mentioned genera also indicate that the Moniwa in its larger part was of very shallow water. The fauna of the Moniwa formation is given in Table 5.

The Tsukinoki formation (Table 3) is characterized by *Comptoniphyllum-Liquidambar* flora of S. Endo, and contains a warm climate assemblage. From a correlative horizon of the Tsukinoki formation, a lower and upper jaws of *Eostegodon pseudolatidens* Yabe with the tusks in situ have been discovered. Detached molars of this elephant have also been found in the lower part of the Ajiri formation in the Shiogama area in association with the *Comptoniphyllum-Liquidambar* flora.

Table 6

Molluscs found in the Hatatate Formation in the Ogawara District in the Sen-nan Area

Species \ Localities	1	2	3	4
1. *Clinocardium shiniiense* (Yokoyama)		×		
2. *Cardita siogamensis* (Nomura)	×			
3. *Lima* (*Acesta*) *goliath* Sowerby			×	
4. *Lucinoma acutilineatum* (Conrad)	×			×
5. *Macoma incongrua* (v. Martens)			×	
6. *M.* cf. *secta* Conrad.			×	
7. *M. tokyoensis* Makiyama			×	
8. *Mercenaria yokoyamai* (Makiyama)				×
9. *Volsella modiolus* (Linnaeus)			×	
10. *Panope japonica* (A.Adams)			×	
11. *Lyropecten kagamianus* (Yokoyama)		×		
12. *Pitar itoi* (Makiyama)		×		
13. *Spisula polynyma voyi* (Gabb)		×		
14. *Thracia hitosaoensis* Nomura		×		
15. *Thyasira.* (*Conchocele*) *bisectoides* Kuroda		×		
16. *Venus toreuma* Gould	×	×		
17. *V. yokoyami* Makiyama				×
18. *Galeodea ogawarensis* Nomura and Onishi				×
19. *G.*cf. *tohokuensis* Nomura and Zinbo				×
20. *Morum macandrewi* (Sowerby)		×		
21. *Natica janthostoma* Deshayes				×
22. *Olivella iwakiensis* Nomura and Hatai				
23, *Shichiheia yabei* (Nomura and Hatai)			×	
24. *Trochus oidensis* Nomura		×		
25. *Dentalium yokoyamai* Makiyama	×		×	×

No.	Localities	North Latitude	East Longitude	Situation from base of Form.
1	Road cut 1.5km NNW of Tsutsumi, Kanagase-mura, Shibata-gun	38° 03′ 34″	140° 41′ 44″	100m
2	Stream side below the bridge at Nittera, Kanagase-mura, Shibata-gun	38° 03′ 28″	140° 42′ 27″	80m
3	Road cut 200m E of the junction of two roads at Oyamada, Ogawara-machi	38° 03′ 44″	140° 42′ 55″	70m
4	Road cut to the west of Fukuda, Ogawara-machi	38° 03 05″	140° 43′ 20″	80m

Available evidence shows that the Moniwa formation is purely marine while its correlative deposits are either terrestrial or marine in aspect. The fauna and flora both indicate a warm climatological condition, and the distribution of the marine facies indicates the first extensive marine transgression of the Miocene in Japan. The climate of the lower Miocene was uniform.

Correlatives of the Moniwa are the lower part of the Otsutsumi formation in the Tomiya area, the Sauramachi formation and the lower part of Ajiri formation in the Shiogama area, Nobiru formation and a part of the Hamada formation in the Matsushima-Nobiru area, the Kanagase formation and Tsukinoki formation in the Sen-nan area, the Kanayama formation in the southern part of Miyagi Prefecture and the Oido formation in the area immediately north of the northern end of the present sheet. Stratigraphical and paleontological research has resulted in confirming the contemporaneity of the above-mentioned formations with the Moniwa.

3. HATATATE FORMATION

Type locality.-Hatatate to Sawoyama, northwest of the Hatatate station on the Akyu electric line, Nishi-Taga-mura, Natori-gun (lat. 38°14′10″–38°13′15″N., lat. 140°49′20″E.). Thickness 130 meters.

The Hatatate formation comprises tuffaceous sandstone, tuffaceous shale, tuff, an alternation of tuffaceous shale and tuffaceous sandstone and sandstone with shale. This is conformable with the Moniwa formation. Although molluscan fossils are not abundant at the type locality, the Hatatate formation of the Ogawara district in the Sen-nan area has yielded the molluscan species cited in Table 6.

Recently, Y. Takayanagi (1952, pp. 52–64) made a detailed study of the Foraminifera from this formation at Moniwa, Oide-mura, Natori-gun ; he distinguished the following species :

Textularia sp.
Nodosaria sp.
Marsinulina sendaiensis Asano
Lagena laevis (Montagu)
*L.*cf. *prelucida* (Montagu)
L.sulcata spicata Cushman and McCulloch
G. problema d'Orbigny
G. yabei ovale Cushman and Ozawa
Polymorphina yabei Asano
Sigmoidella elegantissima (Parker and Jones)
Robulus pseudorotulatus Asano
Lagenodosaria sp.
Dentalina soluta Reuss
Lag. laevis naggi Cushman and Gray
L. sulcata laevicostata Cushman & Gray
Guttulina pacifica Cushman and Ozawa
G. yabei Cushman and Ozawa
Polymorphina charlottensis Cushman
Sigmomorphina notoensis Asano
Nonion akitaense Asano

N. japonicum Asano	*N. nakosoense* Asano
N. nicobarense Cushman	*N. pompilioides* (Fichtel and Moll)
N. scaphum (Fichtel and Moll)	*Pseudononion japonicum* Asano
Astrononion sp.	*Elphidium advenum gorokuense* Takayanagi
E. etigoense Husezima and Maruhasi	*E. sendaiense* Takayanagi
E. sp.	*Cribroelphidium yabei* Asano
Buliminella elegantissima (d'Orbigny)	*Virgulina* sp.
Bolivina robusta Brady	*B.* cf. *seminula* Cushman
Uvigerina cf. *hootsi* Rankin	*U. proboscidea* Schwager
U. cf. *subperegrina* Cushman and Kleinpell	*Angulogerina kokozuraensis* Asano
Entosolenia hexagona Williamson	*E. lucida* Williamson
E. marginata (Montagu)	*E. orbignyana* (Seguenza)
E. squamosa (Montagu)	*Discorbis* sp.
Eponides frisidus callidus Cushman and Cole	*E. umbonatus* (Reuss)
Rotalia beccarii hatatatensis Takayanagi	*Cancris auriculus* (Fichtel and Moll)
Baggina sp.	*Valvulineria* sp.
Cassidulina japonica Asano and Nakamura	*C. orientale* Cushman
C. subglobosa Brady	*C.* cf. *yabei* Asano and Nakamura
Epistominella japonica Asano	*Ehrenbergina* sp.
Pullenia bulloides (d'Orbigny)	*P. salisburyi* R.E. and K.C. Stewart
Sphaeroidina bulloides d'Orbigny.	*Anomalina* sp.
Planulina cf. *wuellerstorfi* (Schwager)	*Hanzawaia tagaensis* Asano
Cibicides aknerianus (d'Orbigny.)	*C. lobatulus* (Walker and Jacob)
C. cf. *pseudoungerianus* (Cushman)	*C.* sp.
Globigerina bulloides d'Orbigny.	*Globorotalia seituia* (Brady)

From the foraminiferal faunule cited above, Y. Takayanagi concludes that the sedimentary environment of the Hatatate formation can be classified into two phases, an early one represented by a shallow sea in an unstable area, and a later one, which is represented by a deeper sea and a more stable condition.

From strata developed about 300 meters in the upper course of the valley about 2 km south of Yachi in Hirose-mura, J. Iwai collected foraminiferal samples which were determined by Y. Takayanagi. This strata lies conformably below the typical Tsunaki formation, but its precies horizon was left in doubt owing to that is lower part is unexposed. The Foraminifera identified by Y. Takayanagi are the following :

Dentalina subsoluta (Cushman)	*Robulus pseudorotulatus* Asano
Lagena acuticosta Reuss	*L. sulcata spicata* Cushman and McCulloch
L. laevis (Montagu)	*Polymorphina yabei* Asano
Sigmorphina notoensis Asano	*Nonion pompilioides* (Fichtel and Moll)
Elphidium etigoense Husezima and Maruhasi	*E. sendaiense* Takayanagi
Buliminella elegantissima (d'Orb.)	*Bolivina robusta* Brady
Uvigerina proboscidea Schwager	*Angulogerina kokozuraensis* Asano
Entosolenia lucida Williamson	*E. marginata* (Montagu)
E. squamosa (Montagu)	*Eponides umbonatus* (Reuss)
Cassidulina orientale Cushman	*Pullenia bulloides* (d'Orbigny)
Sphaeroidina cf. *compacta* Cushman and Todd	*Planulina* cf. *wuellerstorfi* (Schwager)
Cibicides aknerinanus (d'Orbigny)	*C. lobatulus* (Walker and Jacob)
C. pseudoungerianus (Cushman)	

From these foraminifera, Y. Takayanagi suggested that they belong to his horizon J as established in the Hatatate formation near Moniwa in Oide-mura, Natori-gun, thus settling the stratigraphical position of the strata, which was hitherto unknown as to precise position.

K. Asano (1937, pp. 28–35) also reported on a few smaller Foraminifera from the Hatatate formation.

Besides the above-mentioned fossils, *Echinanthus sendaicus* Nisiyama (MS), the characteristic Miocene sponge, *Sagarites* sp., a cancroid crab called *Mursia takahashii* Imaizumi (Imaizumi, 1925, pp. 88–95) occurs from the marginal facies of the formation where *Panope japonica* (A. Adams) is rather common.

Although shallow water facies of the Hatatate formation are found in its marginal portions, the formation as a whole, indicates the maximum deepening of the Natori group in the area of Sendai Proper. In the formation deep water forms as *Ancistrolepis*, *Yoldia*, *Nuculana*, and *Lima* are fairly common, while rocky shore inhabitants are lacking.

The lithological characters of the Hatatate formation are fairly uniform in the Sen-nan area as well as in that of Sendai Proper, but in the Tomiya area, the correlative is the upper part of the Otsutsumi formation, which comprises conglomeratic sandstone, shale, tuffaceous sandstone thereby indicating a shallower water condition than that of the Hatatate in the area of Sendai Proper. In the Shiogama area, the Hatatate is represented by the upper part of the Ajiri formation, which comprises tuff, tuffaceous siltstone, tuffaceous sandstone and conglomerate. In the Matsushima-Nobiru area the formation is represented by the Hamada formation which consists of conglomerate intercalating inferior lignite seams, but contains marine tuff, tuffaceous siltstone and sandstone as the predominating members. In the northern part of the Matsushima-Nobiru area, the Hamada has yielded marine diatoms and radiolaria, thus indicating that the water depth in this region was also rather deep as in that of Sendai Proper.

The type locality of the Ajiri formation is in the area between the Shiogama Municipal Office and the Shiogama harbour, while that of the Hamada is in the continuous outcrop along the driveway extending along the bay-coast from Hamada station on the Senseki electric line, northeastwards to near Matsushima-Koen station on the same line.

From the lithological characteristics and paleontological features, it seems that the upper part of the Otsutsumi formation in the Tomiya area, the upper part of the Ajiri in the Shiogama area and the Hamada in the Matsushima-Nobiru area, represent the shallow water facies of the much deeper Hatatate formation in the area of Sendai Proper, although it is evident that the Hamada in the northern part of the last-mentioned area may have been nearly as deep as that of the Hatatate in the area of Sendai Proper, as can be judged from the occurrence of marine diatoms and radiolarian remains in that particular area.

The characteristic Miocene mammal *Desmostylus japonicus* Yoshiwara and Iwasaki occurs in the uppermost part of the Ajiri formation and in a similar position in the Hamada formation. Both localities of *Desmostylus* occur in a horizon stratigraphically higher than that from which *Eostegodon pseudolatidens* Yabe was found, and *Vicarya* occurs in a position stratigraphically between the two mentioned vertebrate fossils.

The marine fossils occuring from the Hatatate formation in the Ogawara district of the Sen-nan area and from the middle and upper parts of the Ajiri formation in the Shiogama area are given in Tables 6, 7_{I} and 7_{II} respectively.

In the Shiogama area marine fossils are abundant, but the plant fossils show a decrease in number of both individuals and species. Here the *Comptoniphyllum-Liquidambar* flora in association with other warm climate plants occur, although their number is few. The marine shells are characterized by the occurrence of *Siratoria siratoriensis* (Otuka), *Turritella s-hataii* Nomura, *Vicarya* and several species of *Batillaria*. This fauna and flora show that the upper part of the Ajiri formation in the Shiogama area is a deposit formed near land, probably in an embayment within the influence of drainage from the land.

4. TSUNAKI FORMATION

Type locality.-Vicinity of Tsunaki, Oide-mura, Natori-gun (lat. 38°14′30″N., long. 140°48′20″E.). Thickness 130 meters.

The Tsunaki formation conformably covers the Hatatate and comprises brecciated and pumiceous tuff, tuffaceous sandstone, agglomeratic tuff, tuffaceous

Table 71
Molluscan Fossils from the Middle Part of the Ajiri Formation of the Shiogama Area

Species \ Localities	1	2	3
1. *Acila divaricata* (Hinds)		×	×
2. *Nuculana confusa* (Hanley)	×		×
3. *N. inermis* (Yokoyama)			×
4. *Anadara trilineata* (Conrad)		×	×
5. *Placopecten akihoense* (Matsumoto)			
6. *Chlamys kaneharai* (Yokoyama)			
7. *Nanaochlamys notoensis* (Yokoyama)			×
8. *Cardita siogamensis* (Nomura)		×	
9. *Lucinoma acutilineatum* (Conrad)	×		
10. *Miltha k-hataii* (Otuka)		×	
11. *M. nuttallii* (Conrad)		×	
12. *Trachycardium shiobarense* (Yokoyama)		×	
13. *Clinocardium ciliatum* (Fabricius)	×		
14. *C. narusawaense* (Nomura)	×	×	
15. *Siratoria siratoriensis* (Otuka)	×		×
16. *Arcopagia ? minuta* (Lischke)	×		
17. *Macoma incongrua* (v. Martens)	×		×
18. *Solen gouldi* Conrad	×		
19. *Mya joponica* Jay			×
20. *Panope japonica* (A. Adams)			×
21. *Turritella s-hataii* Nomura			×
22. *Cerithidea cingulata* (Gmelin)		×	
23. *C. ozakii* Nomura			×
24. *Vicarya yokoyamai* Takeyama		×	
25. *Batillaria tateiwai* Makiyama		×	×
26. *B. yamanarii* Makiyama		×	×
27. *Proclava atukoae* (Otuka)			×
28. *P. otukai* (Nomura)		×	
29. *Cerithiopsilla tokunagai* Otuka ?			×
30. *Epitonium nagaminense* Otuka		×	
31. *Natica janthostoma* Deshayes	×		
32. *Phos (Coraeophos) iwakianus* (Yokoyama)			×

Loc. No.	Localities	North Latitude	East Longitude	Situation from base of Formation
1.	Northern side cliff of the small hill, 170 m NE of the junction of the two roads, 500m E of Nishi-Shiogama station of the Senseki electric railway line, Shiogama City.	38° 18′ 39″	140° 01′ 33″	50m
2.	Railroad cutting at north entrance of the first tunnel from Higashi-Shiogama station of the Senseki electric railway line, Shiogama City.	38° 19′ 28″	141° 02′ 14″	70m
3.	Railroad cutting at south entrance of the second tunnel from Higashi-Shiogama station of the Senseki electric railway line, Shiogama City.	38° 19′ 44″	141° 02′ 21″	50m

shale, and rarely with inferior lignite seams. Marine fossils occur sporadically at the type locality, but in profusion in the Tomiya, Shiogama, and Matsushima-Nobiru areas. In the Tomiya area the correlatives of the Tsunaki are the Nanakita and Aoso formations, while in the Matsushima-Nobiru area the correlatives are

Table 7II Fossil Molluscs from the Upper Part of the Ajiri Formation of the Shiogama Area

Species \ Localities	1	2	3
1. *Acila divaricata* (Hinds)	×	×	
2. *Nuculana confusa* (Hanley)	×		
3. *Yoldia* sp.		×	
4. *Arca trilineata* (Conrad)		×	
5. *Patinopecten kimurai tiganouraensis* (Nakamura)		×	
6. *Cardita siogamensis* (Nomura)		×	
7. *Trachycardium shiobarense* (Yokoyama)		×	
8. *Dosinia anguloides* Nomura		×	
9. *D. nomurai* Otuka		×	
10. *Siratoria siratoriensis* (Otuka)	×	×	
11. *Lutraria sieboldtii* Deshayes		×	
12. *Macoma incongrua* (v. Martens)	×	×	
13. *M. tokyoensis* Makiyama		×	
14. *Fabulina iridella* (v. Martens)	×		
15. *Phaxus izumoensis* (Yokoyama)		×	
16. *Panope japonica* (A. Adams)		×	
17. *Panomya simotomensis* Otuka		×	
18. *Mya japonica* Jay			×
19. *M. miyagiensis* Nomura		×	
20. *Proclava atukoae* (Otuka)	×		
21. *Sinum yabei* Otuka		×	
22. *Murex tiganourana* Nomura	×	×	
23. *Phos (Coraeophos) iwakianus* (Yokoyama)			×
24. *Fulgoraria striata* (Yokoyama)		×	
25. *Cancellaria kobayashii* (Yokoyama)		×	
26. *Megasurcula siogamensis* (Nomura)		×	

Localities	North Latitude	East Longitude	Situation from base of Formation
1. Eastern side-cliff, to the west of a boat-house, 300 m N of Ajiri, Shiogama City.	38° 18′ 38″	140° 02′ 06″	140 m.
2. Western side-cliff of the Ajiri hill, 500 m N of Ajiri, and about 300 m E of the junction of the two roads in Nakanoshima, Shiogama City.	38° 18′ 47″	141° 02′ 17″	170 m.
3. Near the Myô shrine at Magaki-jima, 700 m E of Higashi-Shiogama Station of the Senseki electric railway line, Shiogama City.	38° 19′ 12″	141″ 02′ 25″	130 m.

the Bangamori, Shirasakayama tuff member and the Hatsuhara formation. In the Shiogama area equivalents of the Tsunaki formation do not occur.

From the type locality, K. Hatai identified *Glycymeris matumoriensis* Nomura and Hatai and *Dosinia nomurai* Otuka, besides several others of minor importance. The first mentioned fossil is particularly abundant in the Nanakita formation in the Tomiya area.

Compared with the Hatatate formation, the Tsunaki in having many *Glycymeris*, mud-loving or sand-loving species is a much shallower water deposit, and the shallowing of the seas is well exhibited by the presence of inferior lignite

Table. 8 Fossil Molluscs from the Tsunaki Formation and Its Correlatives

Species \ Localities	1	2	3	4	5	6
1. *Anadara ninohensis* (Otuka)						
2. *A. trilineata* (Conrad)		×				×
3. *Glycymeris cisshuensis* Makiyama				×	×	
4. *G. matumoriensis* Nomura and Hatai		×	×	×		
5. *Mytilus crassitesta* Lischke						×
6. *Placopecten akihoense* (Matsumoto)						×
7. *Chlamys cosibensis* (Yokoyama)						×
8. *C. kaneharai* (Yokoyama)		×	×	×	×	×
9. *C. crassivenia* (Yokoyama)						
10. *C. miyatokoensis matumori* Nomura and Hatai	×					×
11. *C. swiftii* (Bernardi)					×	×
12. *Patinopecten paraplebejus* (Nomura and Hatai)						×
13. *Cardita ferruginea* A. Adams		×				
14. *Lucinoma acutilineatum* (Conrad)					×	
15. *Trachycardium angustum* (Yokoyama)			×			
16. *Dosinia kaneharai* Yokoyama		×	×	×		×
17. *Pitar itoi* (Makiyama)						×
18. *Callista sinensis* (Holten)						×
19. *Chione ensifera chehalisensis* (Weaver)		×				×
20. *Paphia undulata* (Born)				×		
21. *Spisula polynyma voyi* (Gabb)		×				
22. *Macoma optiva* (Yokoyama)						
23. *Arcopagia ? minuta* (Lischke)						
24. *Neptunea hukusimensis matumori* Nomura and Hatai		×			×	×

Localities	North Latitude	East Longitude	Situation from base of Formation
1. River cliff SW of Tsunaki, Oidemura, Natori-gun.	38° 15′ 0″	140° 48′ 38″	10 m.
2. Road cut, 500 m. SW of the summit of Dôniwa-yama, Miyatoko-mura, Kurokawa-gun.	38° 22′ 30″	140° 49′ 55″	3 m.
3. Road cut, 100 m. SE of the junction of the highway and the railway of the Sendai line, about 1.7 km NE of Ishikura, Miyatoko-mura.	38° 22 16″	140° 51′ 32″	8 m.
4. Road cut, of the Riku-U highway, immediately N of the bench-mark (39.26), 750 m. N of Kumagaya, Tomiya-mura, Kurokawa-gun.	38° 32′ 55″	140° 52′ 39″	4 m.
5. 150 m W of the second bridge from Kokuda, Tomiya-mura, Kurokawa-gun.	38° 23′ 05″	140° 52′ 44″	2 m.
6. Southern cliff of a large pond immediately E of the junction of the two roads, 1.3 km. NE of a shrine at Matsumori, Nanakita-mura, Miyagi-gun.	38° 22′ 16″	140° 51′ 32″	2 m.

of local distribution, false-bedding and shallow water shells. The fossils from the Tsunaki formation and its correlatives in the Tomiya area are given in Table 8.

The fossil molluscs occuring in the Tsunaki and Nanakita formations as shown in Table 8 are characteristic of the Miocene and have rather extensive yet but short geological range. Probably none of the characteristic ones occur in Pliocene deposits, and the majority of the Tsunaki fauna (including that of its equivalent) become extinct before the close of the Middle Miocene.

It may be added that the *Glycymeris* zone at the base of the Nanakita formation occupies a position slightly above the middle of the Tsunaki formation at the type locality, while the cross-bedded sandstone and persistent tuff of the Aoso formation in the Tomiya area corresponds to the tuff complex in the lower part of the Tsunaki formation in the area of Sendai Proper. Tracing the Aoso formation eastwards to the Matsushima-Nobiru area, it is found that the persistent tuff of the Aoso laterally changes into the Shirasakayama tuff member, while the cross-bedded sandstone of the Aoso merges into the basal part of the Bangamori formation and that the upper part of the latter mentioned is nothing but the greater part of the Aoso formation, but in different lithological facies, thus awarding the establishment of new stratigraphical names.

AKYU GROUP

Type locality.-Area between the Akyu station along the Akyu electric line, Oide-mura, Natori-gun in the southwestern part of Sendai City, north to Shirasawa and Kumagane stations on the Senzan railway line, in the northwest of Sendai (lat. 38°13′–38°17′N., long. 140°14′–140°44′E.). Thickness 450 meters.

The Akyu group is a terrestrial facies and can be subdivided into the Yumoto formation below and the Shirasawa above. The former is characterized with tuff breccia and agglomeratic tuff and the latter with predominating shales and minor intercalations of tuff, with many plant fossils. This group is unconformable with the underlying Natori group and also with the overlying Sendai group of Pliocene age.

1. YUMOTO FORMATION

Type locality.-From the stone quarry east of the Akyu station on the Akyu electric line to near Yumoto, Akyu-mura, Natori-gun (lat. 38°13′20″–38°13′N., long. 140°43′20″–140°44′20″E.). Thickness 150 meters.

The Yumoto formation unconformably overlies the Tsunaki and comprises green liparitic tuff, light brown porous massive tuff breccia, tuff conglomerate, tuffaceous sandstone, inferior lignite seams and dacite. The green liparitic tuff has been known as the Hayama green tuff, and the dacite as the Kamabusa dacite. This formation is not distributed in the Tomiya, Shiogama, and Matsushima-Nobiru areas but is found farther northwards and also in the Sen-nan area southwards as far as near Koriyama City in Fukushima Prefecture.

This terrestrial formation forms the base of the Paleo-Sendai lake recently designated by S. Hanzawa (1950, pp. 74–98) and is overlain by the Shirasawa formation, which contains freshwater fish, freshwater diatoms and many plant leaves.

Table 9 Fossil Plant Leaves from the Shirasawa Formation

Formation / Plant beds / Localities / Fossil plants	Shirasawa										
Plant beds	Akyu		Naga-buku-ro	Baba	Shimo-kura	Fukuoka		Okubushi			
Localities	1. Shirasaka-tōge	2. Nishizawa	3. Nagabukuro	4. Baba	5. Shimokura	6. Fukuoka	7. Fujisawa	8. Okubushi	9. Kami-Shinden	10. Ōtsutsumi	11. Yakegawara
1. *Woodsia polystichoides* Eat		×									
2. *Taxus* sp.		×						×			
3. *Torreya* sp.						×					
4. *Abies* sp.	×										
◎ 5. *Keteleeria Davidiana* Beissn.		×									
● 6. *Pinus shirasawaensis* Endô (MS)		×									
◎ 7. *Glyptostrobus europaeus* Heer	×				×				×		
◎ 8. *Sequoia sempervirens* Endl.		×			×			×			
◎ 9. *Taxodium distichum* Rich.						×	×	×			
10. *Thuja Standishii* Garr	×	×									
● 11. *Pseudosasa purpurascens* Makino								×	×		×
12. *Populus balsamoides* Goepp.						×		×	×		×
13. *Salix Koriyanagi* Kimura						×					
14. *Salix* sp.	×	×									
15. *Juglans Sieboldiana* Maxim.		×				×		×			
● 16. *Pterocarya japonica* Endô (MS)								×			
17. *P. rhoifolia* Sieb. et Zucc.		×				×					
18. *Alnus firma* Sieb. et Zucc.	×	×									
19. *A. tinctoria* Sarg. var. *glabra* Call.	×	×			×		×				
20. *A. Matsumurae* Call.											
21. *A. Maximowiczii* Call.	×	×	×		×	×					
22. *A. multinervis* Call.						×					
● 23. *Betula Brongniartii* Ett.	×	×									
24. *B. dahurica* Pall.	×					×					
25. *B. Ermani* Cham. var. *communis* Koidz.	×	×	×			×					
26. *B. globispica* Shirai					×	×					
○ 27. *Betula luminifera* H. Winkl.		×	×	×	×		×				
28. *B. Maximowicziana* Regel.	×	×	×		×	×					
○ 29. *B. papyrifera* Marsh	×	×			×	×					
30. *B. lauschii* Koidz.						×					
31. *B. ulmifolia* Sieb. et Zucc.		×		×		×	×				
32. *B.* sp.	×	×			×	×					
○ 33. *Carpinus betulus* L.		×									
34. *C. carpinoides* Makino					×			×	×		
35. *C. erosa* Bl.					×				×		×
36. *C. laxiflora* Bl.							•	×			
● 37. *C. ôsawaensis* Endô et Okutsu (MS)							×	×			
● 38. *C. palaeojaponica* Endô (MS)		×									
○ 39. *C. rankanensis* Hayata		×				×					
● 40. *C. sendaiensis* Endô (MS)		×									
41. *C. yedoensis* Maxim.						×		×	×		
42. *Ostrya japonica* Sarg.	×			×							
43. *Castanea pubinervis* Schneid.			•			×		×			
44. *Fagus crenata* Bl.	×	×				×		×	×		×
45. *F. japonica* Maxim.		×							×		
● 46. *F. lanceolata* Okutsu							×				
● 47. *F. palaeo-crenata* Endô et Okutsu	×				×	×		×	×	×	×
48. *Quercus crispula* Bl.						×			×		×
49. *Q. serrata* Thunb.						×		×	×		
50. *Q.* sp. (*Q.* cfr. *acuta* Thunb.)	×	×				×					
51. *Q.* sp. (*Q.* cfr. *dentata* Thunb.)		×				×					×
52. *Q.* sp.						×					
○ 53. *Celtis mississippiensis* Basc.											
54. *C. sinensis* Pers.		×						×			
55. *Ulmus Davidiana* Planch var. *japonica* Nakai		×									×
56. *U.* sp. (*U* cfr. *laciniata* Mayr.)			×								
57. *Zelkova serrata* Makino	×			×		×	×	×	×		×
● 58. *Ficus ruminiana* Heer	×	×									
59. *Braussonetia papyrifera* L'.Herit, ?		×									
60. *Cercidiphyllum japonicum* Sieb. et Zucc.		×									
◎ 61. *Liriodendron honsyûenis* Endô	×				×	×			×		
62. *Magnolia* sp.	×										
63. *Cinnamomum* sp. (*C. cf. sompfora* Nees. et Ebern.)				×				×			
64. *Parabenzoin praesox* Nakai								×			
◎ 65. *Sassafras yabei* Endô et Okutsu					×						
66. *Litsea glauca* Sieb.		×		×		×		×			
● 67. *Hydrangea sendaiensis* Okutsu		×									
68. *H.* sp.											
69. *Sorbus alnifolia* K. Koch.						×					
70. *S.* sp.		×			×						
71. *Prunus Ssiori* Fr. Schm.	×	×									
72. *Sapium japonicum* Pax. et K. Hoffm.	×	×						×			
○ 73. *Ilex cornuta* Ldl. et Paxt.		×				×		×			
74. *Acer capillipes* Maxim.											
75. *A. carpinifolium* Sieb. et Zucc.			×		×						
76. *A. daibolium* Bl.						×		×			
77. *A. suseptemlobum* (Gr. v. Schw.) Koidz.						×					
○ 78. *A, Francheti* Pax.						×					
79. *A. japonicum* Thunb.	×				×	×					
80. *A. Miyabei* Maxim.	×				×	×					
● 81. *A. miyagiense* Endô (MS)		×						×			
● 82. *A. Nomurai* Okutsu	×		×			×					
● 83. *A. Okutsui* Endô (MS)				×					×		
● 84. *A. Ozakii* Endô (MS)		×						×			
85. *A. pictum* Thunb.	×	×			×	×		×			×
86. *A. pictum* Thunb. subsp. *Mayri* Koidz.											
● 87. *A. polymorphum* (*palmatum*) *pliocaenicum* Sap.		×				×					
88. *A. rufinerve* Sieb. et Zucc.	×	×									
● 89. *A. trilobatum* A. Br.	×										
● 90. *A. yabei* Endô et Okutsu	×										
91. *A.* sp. (*A.* cfr. *nikoense* Maxim.)		×			×	×	•	×	×		×
92. *A.* sp.		×				×			×		×
93. *Meliosma myriantha* Sieb. et Zucc.				×							
● 94. *Tilia distans* Nath.	×				×	×					
◎ 95. *Firmiana platanifolia* Schott. et Endl. ?		×			×						
96. *Hibiscus Hamabo* Sieb. et Zucc.	×	×									
97. *Stewartia pseudo-Camellia* Maxim.		×	×								
98. *Hedera* sp.	×										
99. *Kalopanax ricinifolius* Mig.						×					
100. *Aucuba japonica* Thunb.								×	×		×
101. *Cornus* sp.	×	×									
102. *Clethra barbinervis* Sieb. et Zucc.						×					
103. *Rhododendron* SP. (*R. cfr. obtusum* Planch. var *Koempferi* Wils.)								×			
104. *R.* sp. (*R.* cfr. *Quinquefolia* Biss. et Noore.)								×			
105. *Vaccinium* sp. (*V.* cfr. *Yatabei* Makino)										×	
106. *Styrax japonica* Sieb et Zucc.										×	
107. *S, Obassia* Sieb et Zucc.						×					
◎ 108. *Catalpa ovata* G. Don.		×									
Total number of species	34	50	8	7	22	43	7	30	18	3	13

◎ Exotic genera ○ Exotic Species ● Extinct Species

Locality No.	Localities	Altitude (above sea level)	North Latitude	East Longitude	Situation from base of Formation
1.	Shirasaka-tōge (pass), 2km north of the Akyû Station of the Akyû electric line, Akyû-mura, Natori-gun.	220m	38° 14′ 11″ 2	140° 44′ 16″ 4	5m
2.	East side of the road 1km South-east of Nishizaya, Akyû-mura, Natori-gun	160m	38° 14′ 27″	140° 42′ 44″ 4	1-2m
3.	Left bank of a valley 200m east of the Nagabukuro bridge, Nagabukuro, Akyû-mura, Natori-gun.	120m	38° 14′ 53″ 2	140° 41′ 10″ 4	1-2m
4.	Both sides of the road, near a pond 500m north of Baba, Akyû-mura, Natori-gun.	120m	38° 43′ 7″ 3	140° 39′ 55″ 5	60m
5.	Road near the Shimokura water power plant, Osawa-mura, Miyagi-gun.	100m	38° 18′ 28″ 3	140° 42′ 34″ 4	1-2m
6.	Valley of Jōnouchi (Southern cliff of the Kammuri River), Fukuoka, Nenoshiroishi-mura, Miyagi-gun.	100m	38° 21′ 20″ 2	140° 45′ 53″ 4	5m
7.	Valley 1km west of Fujisawa, Nenoshiroishi-mura, Miyagi-gun.	120m	38° 20′ 47″	140° 46′ 30″ 7	7m
8.	West side of a valley 1km south of Okubushi, Ōsawa-mura, Miyagi-gun.	160m	38° 9′ 53″ 5	140° 44′ 58″ 4	90-100m
9.	Valley about 2km west from Kami-Sinden, Ōsawa-mura, Miyagi-gun	170m	38° 18′ 54″ 4	140° 44′ 32″ 4	90-100m

Table 9 Fossil Plant Leaves from the Shirasawa Formation

		Formation / Plant beds / Localities / Fossil plants	Shirasawa										
		Plant beds	Akyu		Naga-buku-ro	Baba	Shimo-kura	Fukuoka		Okubushi			
		Localities	1. Shirasaka-tôge	2. Nishizawa	3. Nagabukuro	4. Baba	5. Shimokura	6. Fukuoka	7. Fujisawa	8. Okubushi	9. Kami-Shinden	10. Otsutsumi	11. Yakegawara
	1.	Woodsia polystichoides Eat		×									
	2.	Taxus sp.		×						×			
	3.	Torreya sp.						×					
	4.	Abies sp.	×										
◎	5.	Keteleeria Davidiana Beissn.		×									
●	6.	Pinus shirasawaensis Endô (MS)		×									
◎	7.	Gryptostrobus europaeus Heer	×				×				×		
◎	8.	Sequoia sempervirens Endl.		×			×			×			
◎	9.	Taxodium distichum Rich.						×	×	×			
	10.	Thuja Standishil Garr	×	×									
●	11.	Pseudosasa purpurascens Makino								×	×		×
	12.	Populus balsamoides Goepp.						×		×	×		×
	13.	Salix Koriyanagi Kimura						×					
	14.	Salix sp.	×	×									
	15.	Juglans Sieboldiana Maxim.		×				×		×			
●	16.	Pterocarya japonica Endô (MS)								×			
	17.	P. rhoifolia Sieb. et Zucc.		×				×					
	18.	Alnus firma Sieb. et Zucc.	×	×									
	19.	A. tinctoria Sarg. var. glabra Call.	×	×			×		×				
	20.	A. Matsumurae Call.											
	21.	A. Maximowiczii Call.	×	×	×		×	×					
	22.	A. multinervis Call.						×					
●	23.	Betula Brongniartii Ett.	×	×									
	24.	B. dahurica Pall.	×					×					
	25.	B. Ermani Cham. var. communis Koidz.	×	×	×			×					
	26.	B. globispica Shirai					×	×					
○	27.	Betula luminifera H. Winkl.		×	×	×	×		×				
	28.	B. Maximowicziana Regel.	×	×	×		×	×					
○	29.	B. papyrifera Marsh	×	×			×	×					
	30.	B. lauschii Koidz.						×					
	31.	B. ulmifolia Sieb. et Zucc.		×		×		×	×				
	32.	B. sp.	×	×			×	×					
○	33.	Carpinus betulus L.		×									
	34.	C. carpinoides Makino					×			×	×		
	35.	C. erosa Bl.					×				×		×
	36.	C. laxiflora Bl.								×			
●	37.	C. ôsawaensis Endô et Okutsu (MS)							×	×			
●	38.	C. palaeojaponica Endô (MS)		×									
○	39.	C. rankanensis Hayata		×				×					
●	40.	C. sendaiensis Endô (MS)		×									
	41.	C. yedoensis Maxim.						×		×	×		
	42.	Ostrya japonica Sarg.	×			×							
	43.	Castanea pubinervis Schneid.						×		×			
	44.	Fagus crenata Bl.	×	×				×		×	×		×
	45.	F. japonica Maxim.		×							×		
●	46.	F. lanceolata Okutsu							×				
●	47.	F. palaeo-crenata Endô et Okutsu	×				×	×		×	×	×	×
	48.	Quercus crispula Bl.						×			×		×
	49.	Q. serrata Thunb.						×		×	×		
	50.	Q. sp. (Q. cfr. acuta Thunb.)	×	×				×					
	51.	Q. sp. (Q. cfr. dentata Thunb.)		×				×					×
	52.	Q. sp.						×					
○	53.	Celtis mississippiensis Basc.											
	54.	C. sinensis Pers.		×						×			
	55.	Ulmus Davidiana Planch var. japonica Nakai		×									×
	56.	U. sp. (U cfr. laciniata Mayr.)			×								
	57.	Zelkova serrata Makino	×			×		×	×	×	×		×
●	58.	Ficus ruminiana Heer	×	×									
	59.	Braussonetia papyrifera L'.Herit, ?		×									
	60.	Cercidiphyllum japonicum Sieb. et Zucc.		×									
◎	61.	Liriodendron honsyûenis Endô	×				×	×			×		
	62.	Magnolia sp.	×										
	63.	Cinnamomum sp. (C. cf. sompfora Nees. et Ebern.)				×				×			
	64.	Parabenzoin praesox Nakai								×			
◎	65.	Sassafras yabei Endô et Okutsu					×						
	66.	Litsea glauca Sieb.		×		×		×		×			
●	67.	Hydrangea sendaiensis Okutsu		×									
	68.	H. sp.											
	69.	Sorbus alnifolia K. Koch.						×					
	70.	S. sp.		×			×						
	71.	Prunus Ssiori Fr. Schm.	×	×									
	72.	Sapium japonicum Pax. et K. Hoffm.	×	×						×			
○	73.	Ilex cornuta Ldr. et Paxt.		×				×		×			
	74.	Acer capillipes Maxim.											
	75.	A. carpinifolium Sieb. et Zucc.			×		×						
	76.	A. daibolium Bl.						×		×			
	77.	A. euseptemlobum (Gr. v. Schw.) Koidz.						×					
○	78.	A, Francheti Pax.						×					
	79.	A. japonicum Thunb.	×				×	×					
	80.	A. Miyabei Maxim.	×				×	×					
●	81.	A. miyagiense Endô (MS)		×						×			
●	82.	A. Nomurai Okutsu	×		×			×					
●	83.	A. Okutsui Endô (MS)				×					×		
●	84.	A. Ozakii Endô (MS)		×						×			
	85.	A. pictum Thunb.	×	×			×	×		×			×
	86.	A. pictum Thunb. subsp. Mayri Koidz.											
●	87.	A. polymorphum (palmatum) pliocaenicum Sap.		×				×					
	88.	A. rufinerve Sieb. et Zucc.	×	×									
●	89.	A. trilobatum A. Br.	×										
●	90.	A. yabei Endô et Okutsu	×										
	91.	A. sp. (A. cfr. nikoense Maxim.)		×			×	×		×	×		×
	92.	A. sp.		×				×			×		×
	93.	Meliosma myriantka Sieb. et Zucc.				×							
●	94.	Tilia distans Nath.	×				×	×					
◎	95.	Firmiana platanifolia Schott. et Endl. ?		×			×						
	96.	Hibiscus Hamabo Sieb. et Zucc.	×	×									
	97.	Stewartia pseudo-Camellia Maxim.		×	×								
	98.	Hedera sp.	×										
	99.	Kalopanax ricinifolius Mig.						×					
	100.	Aucuba japonica Thunb.								×	×		×
	101.	Cornus sp.	×	×									
	102.	Clethra barbinervis Sieb. et Zucc.						×					
	103.	Rhododendron SP. (R. cfr. obtusum Planch. var Koempferi Wils.)								×			
	104.	R. sp. (R. cfr. Quinquefolia Biss. et Noore.)								×			
	105.	Vaccinium sp. (V. cfr, Yatabei Makino)											
	106.	Styrax japonica Sieb et Zucc.										×	
	107.	S, Obassia Sieb et Zucc.						×				×	
◎	108.	Catalpa ovata G. Don.		×									
		Total number of species	34	50	8	7	22	43	7	30	18	3	13

◎ Exotic genera ○ Exotic Species ● Extinct Species

Locality No.	Localities	Altitude (above sea level)	North Latitude	East Longitude	Situation from base of Formation
1.	Shirasaka-tôge (pass), 2km north of the Akyû Station of the Akyû electric line, Akyû-mura, Natori-gun.	220m	38° 14′ 11″ 2	140° 44′ 16″ 4	5m
2.	East side of the road 1km South-east of Nishizaya, Akyû-mura, Natori-gun	160m	38° 14′ 27″	140° 42′ 44″ 4	1-2m
3.	Left bank of a valley 200m east of the Nagabukuro bridge, Nagabukuro, Akyû-mura, Natori-gun.	120m	38° 14′ 53″ 2	140° 41′ 10″ 4	1-2m
4.	Both sides of the road, near a pond 500m north of Baba, Akyû-mura, Natori-gun.	120m	38° 43′ 7″ 3	140° 39′ 55″ 5	60m
5.	Road near the Shimokura water power plant, Osawa-mura, Miyagi-gun.	100m	38° 18′ 28″ 3	140° 42′ 34″ 4	1-2m
6.	Valley of Jônouchi (Southern cliff of the Kammuri River), Fukuoka, Nenoshiroishi-mura, Miyagi-gun.	100m	38° 21′ 20″ 2	140° 45′ 53″ 4	5m
7.	Valley 1km west of Fujisawa, Nenoshiroishi-mura, Miyagi-gun.	120m	38° 20′ 47″	140° 46′ 30″ 7	7m
8.	West side of a valley 1km south of Okubushi, Ôsawa-mura, Miyagi-gun.	160m	38° 9′ 53″ 5	140° 44′ 58″ 4	90-100m.
9.	Valley about 2km west from Kami-Sinden, Ôsawa-mura, Miyagi-gun.	170m	38° 18′ 54″ 4	140° 44′ 32″ 4	90-100m
10.	Valley about 3km west from Ôtsutumi, Nenoshiroishi-mura, Miyagi-gun.	170m	38° 19′ 24″ 6	140° 45′ 10″ 4	90-100m
11.	Vallya about 1.3km west from Yakegawara, Nenoshiroishi-mura, Miyagi-gun.	140m	38° 19′ 52″ 9	140° 45′ 34″ 4	90-100m

The Yumoto formation is represented in the northern part of Miyagi Prefecture by the lower part of the Akakura formation, and in Fukushima Prefecture by the lower part of the Katabira formation.

2. SHIRASAWA FORMATION

Type locality.-Between Baba to the vicinity of Shirasawa, Akyu-mura, Natori-gun (lat. 38°15′30″–38°17′00″N., long. 140°39′00″–140°41′40″E.). Thickness 330 meters.

The Shirasawa formation conformably overlies the Yumoto and comprises laminated tuffaceous shale and tuff, cross-bedded white or gray tuff, fine sandy shale, shale, cross-bedded buff-coloured tuff, conglomerate, pumiceous tuff, sandy tuffaceous shale and lignite seams. Plant fossils are abundant as shown in Table 9.

The Shirasawa formation can be subdivided into several lithological facies, as the Itaoroshi bed of laminated shale, white sandy tuff and an alternation of laminated tuffaceous shale and tuff at the top, underlain with the Baba bed of cross-bedded white or gray tuff, angular andesite blocks locally contained therein, and fine sandy shale, and the Shirasakatoge bed of tuffaceous shale and cross-bedded buff-coloured tuff.

The Shirasawa formation with many plant beds, as indicated in Table 9, is characterized by lacking the *Comptoniphyllum-Liquidambar* flora of the Natori group, and is replaced by a cooler climatic assemblage consisting of the following noteworthy plants, as identified by S. Endo and H. Okutsu, namely, *Liriodendron honsyuensis* Endo and Okutsu, *Ficus ruminiana* Heer, *Fagus crenata* Blume, besides others. Recently freshwater diatoms have been found by T. Kanaya who identified the followings, namely,

Melosira italica (Ehr.) Kütz. var. *valida* Grunow........	dominant
M. undulata (Ehr.) Kütz., var. *Normanni* Arnott.	rare
Tetracyclus lacustrus Ralfs.	rare
Fragilaria construens (Ehr.) Grun.	rare
Synedra capitata Ehr.	rare
Navicula gastrum Ehr.	rare
Epithemia argus Kütz.	rare
E. Hyndmanni W. Smith	common
E. sorex Kütz.	rare
E. sorex var. *gracilis* Hustedt	common
E. turgida (Ehr.). Kütz.	rare

According to T.Kanaya, the flora is characterized with *Melosira italica* (Ehr.) var. *valida* Grunow which occupies about 90 percent of the entire flora and by the genus *Epithemia*. Among these eleven species which are all freshwater, *Melosira italca* (Ehr.) Kütz. var. *valida* Grun. flourishes in the Alpine region and also in lowland areas in northern Europe as a planktonic form in lakes, while the species of the genus *Epithemia* attach themselves to freshwater plants in the littoral region of lake shores.

The Shirasawa from its distribution, floral content, presence of freshwater diatoms and of freshwater fishes, is believed to have been deposited in a lake, which S. Hanzawa has described in detail (Hanzawa, 1950, pp. 74–98). This lake has a considerable north-south extension and also probably of fair width. The breadth of the lake is at present unknown because of its eastern and western sides having been completely destroyed by subsequent erosion.

The Shirasawa formation in the Ogawara district in the Sen-nan area has a thickness of only about 50 meters, and is lacking in shale facies and no conglomerate has yet been found at its base, thus only the lower part of the formation or the Baba facies is represented. Tracing the Shirasawa northwards, a conglomerate appears at the base, the tuff becomes stratified and intercalates tuffaceous shale, pumiceous tuff and inferior lignite seams in the Murata district, also in the Sen-nan area. Advancing still northwards, shale facies are increased and the maximum shale facies is in the area between Akyu and Shirasawa in the western hilly region of Sendai. Northwards of the Nanakita River, the Akyu group is almost lackng in the present sheet, except for a restricted area in the northwestern part of Miyazaki-mura.

The lateral change in facies of the Shirasawa formation together with the distribution in the present sheet, shows that the southern marginal facies of the paleo-Sendai lake is between Ogawara and Murata ; the northern extension of this lake is in the north of the present sheet. The western and eastern margins of this lake has been destroyed by subsequent denudation and only by restoration can we gain a general idea of its original outline.

With NE-SW trend in the upper course of Azukizawa, Hirose-mura, Miyagi-gun, and south of Takinohara in Akyu-mura, Natori-gun, as well as west of Yakeoka in Kawasaki-mura, Shibata-gun, there is a complex consisting of stratified tuffaceous sandstone, tuffaceous siltstone, tuffite, and inferior lignite seams containing plant fragments underlain with green tuff, all of non-marine origin, which lie below the tuff breccia of the Yumoto formation, but show a gradual transition upwards into to it. This complex probably is a stratified facies of the Hayama green tuff which occupies a horizon in the lower part of the Yumoto proper.

The Shirasawa formation is represented in northern Miyagi Prefecture by the middle and upper parts of the Akakura formation, and in Fukushima Prefecture by the upper part of the Katabira formation.

Table 10 Fossil Flora from the Different Formations of the Sendai Group

	Fossil plants	1. Kameoka	2. Sanjunin-machi	3. Sankichi lignite mine	4. Kagitori	5. Komatsushima	6. Bikunizaka	7. Hyôjyôgawara	8. Nishitaga	9. Atagoyama	10. Otamayabashi	11. Aobayama	12. Futatsuzawa	13. Nishi-futatsuzawa	14. Kongô-zawa	15. Kometogi-zawa	16. Miyazawa	17. Kano	18. Suzunosawa	19. Kanaarai-zawa
	Formations	Kameoka						Tatsuno-kuchi		Kitayama		Yagiyama				Dainenji				
	Plant beds	Kameoka		Kagitori		Komatsu-shima		Hyô-jo ga-wara	Nishi-taga	Atago-yama	Ota-maya-bashi	Aoba-yama	Futatsu-zawa		Kon-gô-zawa	Dainenji			Koeji	Kana arai-zawa
	1. *Lygodium* sp.	×								×										
	2. *Osmunda* sp. (*O.* cfr. *japonica* Thunb.)	×																		
	3. *Picea* sp.								×											
○	4. *Abies* sp. (*A.* cfr. *balsamea* Mill.)		×																	×
◎	5. *Glyptostrobus europaeus* Heer	×		×	×					×					×			×		
◎	6. *Sequoia japonica* Endô														×					
◎	7. *S. sempervirens* Endl.	×			×						×									
◎	8. *Taxodium distichum* Rich.			×																
	9. *Pseudosasa purpurascens* Makino	×	×	×				×	×	×				×						
	10. *Phragmites* sp.				×	×														
	11. *Cyperites* sp.												×							
◎	12. *Trachycarpus* sp.							×												
	13. *Populus* sp.							×					×							
	14. *Salix* sp.			×									×						×	
○	15. *Juglans cinerea* L.							×												
	16. *J.* sp. (*J.* cfr. *Sieboldiana* Maxim.)			×				×					×							×
	17. *Alnus japonica* Sieb. et Zucc.			×								×	×							
	18. *A.* sp.			×							×									
○	19. *Carpinus betulus* L.							×												
	20. *C. laxiflora* Bl.			×																×
	21. *C. yedoensis* Maxim.							×												
	22. *C.* sp.																			×
	23. *Castanea pubinervis* Schneid.																			×
	24. *Fagus crenata* Bl.	×	×			×	×		×				×	×		×	×	×	×	×
	25. *Quercus crispula* Bl.					×		×												
	26. *Q.* sp.																	×		
	27. *Ulmus Davidiana* Planch. var. *japonica* Nakai							×												
	28. *Zelkova serrata* Makino			×																
	29. *Brasenia schreberi* J. F. Gmel.												×							
●	30. *Cinnamomum Scheuchzeri* Heer	×																		
	31. *C.* sp.									×										
●	32. *Hydrangea sendaiensis* Okutsu							×												
○	33. *Ilex cornuta* Lindl. et Pax.																			×
	34. *I.* sp.				×															
	35. *Wistaria flaxibunda* DC.?												×							
	36. *Buxus.* sp.				×															
	37. *Acer diabolicum* Bl.							×												
	38. *A. euseptemlobum* (Gr. v. Schm.) Koidz.												×							
●	39. *A. Nordenskiöldi* Nath.													×						
	40. *A. pictum* Thunb.	×						×					×							
	41. *Tilia japonica* Simk. ?												×							
	42. *T.* sp.								×											
	43. *Myroxylon ?* sp.												×							
	44. *Trapa natans* L.					×														
◎	45. *Liquidambar* sp. (*L.* cfr. *formosana* Hance)																			×
	46. *Cornus* sp.												×							
	47. *Tripetaleia paniculata* Sieb. et Zucc. ?												×							
	48. *Rhododendron* sp.												×			×				
	49. *Vaccinium* sp.												×							
	50. *Styrax japonica* Sieb. et Zucc.			×																
	51. *Viburnum furcatum* Bl.	×				×														
	Total of Species	9	3	10	5	5	1	12	4	4	2	1	16	3	2	2	1	3	2	8

◎ Exotic genera ○ Exotic species ● Extinct species

Loc.No.	Localities	Altitude (above sea level)	North Latitude	East Longitude	Situation from base of Formation	Formation
1.	Cliff about 200 m South of Ushigoe-Bashi near Kameoka, Sendai.	75m	38° 15′ 43″ 8	140° 50′ 47″ 6	10m	Kameoka (30m)
2.	South side of cliff of the Hirose River 450 m below Ushigoe-bashi near Kameoka, Sendai.	60m	38° 15′ 37″ 9	140° 51′ 0″ 6	15m	
3.	Valley about 1.2 km. northwest of Ushiroda, Nishitaga, Sendai.	100m	38° 13′ 58″ 3	140° 50′ 10″ 4	20m	
4.	Left bank of river about 200 m southeast of Kagitori-bashi, Kagitori, Sendai.	35m	38° 13′ 8″ 7	140° 50′ 47″ 6	10m	
5.	Cliff about 200 m. west of Sendai Christian Orphant Nursery, Komatsushima, Sendai.	70m	38° 17′ 0″ 0	140° 53′ 50″ 2	25m	
6.	Road about 300 m north of Bench Mark. 11.99 m, Bikuni-zaka, Sendai.	30m	38° 16′ 57″ 0	140° 55′ 44″ 5	20m	
7.	River floor of the HiroseRiver east bank of Zoological garden, Sendai.	40m	38° 15′ 1″ 7	140° 52 7 2″	30m	Tatsuno-kuchi (40m)
8.	West side of cliff about 500 m west of Higashi-hara, Nishitaga, Sendai.	35m	38° 13′ 17″ 6	140° 50′ 53 8″	20m	
9.	Cliff about 300 m northwest of Atago water power plant near Atago-bashi, Sendai.	40m	38° 14′ 37″ 4	140° 52′ 44″ 5	5m	Kitayama (6m)
10.	East side of cliff 100 m north of Otamaya-bashi, Sendai.	45m	38° 14, 54″ 5	140° 52′ 19″ 7	2m	
11.	Tatsunokuchi and Chiyo lignite mine about 500 m southwest of Ôhashi, Sendai.	70m	38° 15′ 4″ 1	140° 51′ 35″ 2	15m	Yagiyama (25m)
12.	West side of cliff of Futatsu-zawa 400 m northwest of Kano, Sendai.	40m	38° 13′ 57″ 0	140° 52′ 22″ 8	20m	
13.	West side of cliff of Nishi-Futatsuzawa about 2 km northwest of Kano, Sendai.	80m	38° 14′ 18″ 3	140° 51′ 26″ 9	20m	
14.	Kongôzawa lignite mine about 1.5 km northwest of Ushiroda, Nishitaga, Sendai.	120m	38° 14′ 10″ 8	140° 51′ 11″ 9	15m	
15.	East side of cliff of Kometogi-zawa about 1 km southwest of Atago-bashi, Sendai.	70m	38° 14′ 14″ 1	140° 52′ 36″ 2	20m	Dainenji (110m)
16.	West side of cliff of the Hirose River 100 m north of Miyazawa-bashi, Sendai.	25m	38° 14′ 18″ 3	140° 53′ 15″ 1	50m	
17.	East side of cliff of Futatsu-zawa 600 m. north of Kano, Sendai.	70m	38° 14′ 2″ 9	140° 52′ 30″ 2	20m	
18.	East side of cliff of Suzuno-sawa 700 m south of Otamaya-bashi, Sendai.	80m	38° 14′ 41″ 2	140° 52′ 7″ 2	35m	
19.	Cliff and bottom of valley 600 m north of Kanaarai-zawa, Sendai.	40m	38° 13′ 27″ 5	140° 51′ 41″ 4	10m?	

The geological age of the Akyu group is considered Upper Miocene from its paleontological evidence and stratigraphical position within the columnar section of northern Japan.

SENDAI GROUP

Type locality.-River cliff along the Hirose River, from Mitaki in the western border of Sendai City to Dainenji in the southern part of Sendai City (lat. 38°16′–38°14′N., long. 140°50′–140°53′E.). Total thickness 495 meters.

The Sendai group of Pliocene age, as in the case of the Miocene Natori and Akyu groups, can be subdivided into several distinct formations upon lithological and paleontological data ; these formations are of extensive distribution within the present sheet as well as in the region extending from Hitachi-Omiya in Ibaragi Prefecture, to Hanamaki in central Iwate Prefecture along the east coast of the Abukuma massif and the Kitakami Valley area. The Sendai group is divisible into the following formations which partake the characteristics given separately.

1. MITAKI ANDESITE

Type locality.-Mitaki and its vicinity in the western border of Sendai City (lat. 38°16′N., long. 140°50′E.). Thickness 200 meters.

The Mitaki andesite which unconformably overlies the older formations, comprises extruded andesite sheets, lava, agglomerate, agglomeratic tuff, tuff breccia, and volcanic sand ; the andesite is basaltic, dark gray, usually compact, and medium-grained. This andesite is locally cavernous with calcite druses, porphyritic and with long crystals of anorthite. The andesite interfingers with the Kameoka formation in the western border of Sendai.

The distribution of the Mitaki andesite is restricted to a small area in the western border of Sendai City, but correlative volcanics are found in the Shiogama area and in the northern part of Iwate Prefecture.

2. KAMEOKA FORMATION

Type locality.-Along the Hirose River at Kameoka in the western part of Sendai City (lat. 38°15′40″N., long. 140°50′20″E.). Thickness 50 meters.

The Kameoka formation interfingers with the Mitaki andesite and its agglomerate in the western part of Sendai City, and comprises conglomerate or volcanic sand, agglomerate, tuff, sandstone, tuffaceous sandstone, cross-bedded gray sandstone, an alternation of siltstone and sandstone, siltstone intercalating lignite seams, and an alternation of tuff and sandstone. Plant leaves (Table 10) are found in the lignite seams and drift woods occur in several horizons. The fossil woods as identified by M. Shimakura are given in Table 11.

Table 11
Fossil Woods from the Miocene and Pliocene Formations of Sendai and Its Environs

Fossil woods \ Formations	Hatatate	Kameoka	Tatsunokuchi	Kitayama	Yagiyama
1. *Piceoxylon miyagiense* Shimakura (MS)		×	×		
2. *P.* (*Pseudotsuga*) *japonicum* Shimakura (MS)				×	
3. *P.* sp.				×	×
4. *Cedroxylon* (*Abies* sp.)		×			×
5. *C.* (*Tsuga* sp.)		×			×
6. *C.* sp.			×		×
7. *Pinuxylon* (*Diploxylon*) cfr. *Paxii* Kräusel				×	×
8. *Sciadopityoxylon verticillatoides* Shimakura (MS)			×		
9. *Glyptostroboxylon tenerum* Kräusel		×		×	×
10. *Taxodioxylon sequoianum* (Merckel) Gothan		×		×	×
11. *Cupressinoxylon thujopsoides* Takamatsu					×
12. *C.* sp.	×	×	×		×
13. *Alnoxylon* sp.				×	
14. *Betuloxylon* sp.	×				
15. *Castanea* cfr. *crenata* Sieb, et Zucc.		×			
16. *Castanoxylon* cfr. *crenatoides* Shimakura	×				
17. *Fagonium crenatoides* Shimakura (MS)		×			
18. *Fagoxylon* sp					×
19. *Quercinium* sp.		×			
20. *Zelkova* cfr. *serrata* Makino		×			
21. *Cercidiphyllum* sp.	×				
22. *Liquidambaroxylon* sp.				×	
23. *Camellia* sp.	×				
Total of species	5	10	4	8	9

Where the Mitaki is lacking, a persistent conglomerate bed takes its place, the most typical development being 500 meters north of Nakayamafudo in Nanakita-mura, Miyagi-gun, where the pebbles of the conglomerate consist wholly of andesite, which are well water worn and of cobble-size. This conglomerate is persistent and is found extensively in the area of distribution of the formation. Plant fossils are by no means common in the Kameoka formation, but S. Endo discriminated, *Abies balsamea* Miller, *Glyptostrobus europaeus* Heer, *Cinnamomum Scheuchzeri* Heer, besides others. Among fossil woods, M. Shimakura distinguished *Taxodioxylon sequoianum* Gothan and *Glyptostroboxylon tenerum* Kräusel as shown in Table 11. These plant fossils are more related to the Akyu group than to the next younger Kitayama formation in having *Glyptostrobus* and *Cinnamomum*.

Recent pollen analyses of the lignite of the Kameoka formation yielded according to M. Shimada (1951, pp. 47–50), such types as *Alnus*, *Betula*, *Fagus*, *Liquidambar*, *Liriodendron*, *Pseudotsuga*, *Quercus* and some of the *Sequoia*-type. His analyses shows that *Quercus* is most abundant, occupying 62.9 percent of the total, followed by the genus *Liriodendron* which gave 21.7 percent and *Pseudotsuga* of 6.5 percent, while the remaining genera amounted only to 3.0 percent or less.

Table 12 Fossil Molluscs from the Tatsunokuchi Formation within Sendai City

Species \ Localities	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. *Anadara tatunokutiensis* (Nomura and Hatai)	×	×		×						×	×		×	×
2. *Glycymeris gorokuensis* Nomura	×									×				
3. *Volsella modiola* (Linné)		×						×						
4. *Mytilus grayanus* Dunker	×													
5. *Fortipecten takahashii* (Yokoyama)	×	×		×			×	×	×					
6. *Chlamys* sp.	×													
7. *Anomya cytaeum* Gray	×													
8. *Pododesmus macroschismus* (Deshayes)	×													
9. *Ostrea gravitesta* Yokoyama	×	×												
10. *O. palaeodenselamellosa* Nomura	×													
11. *Taras cumingi* (Hanley)	×													
12. *T. ustus* (Gould)											×		×	
13. *Lucinoma acutilineatum* (Conrad)	×		×		×			×		×			×	
14. *Mysella japonica* Yokoyama	×													
15. *Chama* sp.	×													
16. *Clinocardium bulowi* (Rolle)	×													
17. *C. pseudofastosum* Nomura	×	×							×	×				
18. *Trachycardium gorokuense* (Nomura)	×													
19. *Erycina sendaiensis* Nomura	×													
20. *Dosinia tatunokutiensis* Nomura	×	×					×	×						
21. *Meretrix parameretrix* Nomura	×			×										
22. *Pitar sendaica* Nomura	×	×		×	×		×	×		×	×	×		
23. *P. sendaica monstrosa* Nomura	×	×												
24. *Callista brevisiphonata* (Carpenter)	×	×							×	×				
25. *Mercenaria chitaniana* (Yokoyama var.	×										×			
26. *Venerupis japonica* (Deshayes)	×													
27. *V. ? hirosegawana* Nomura	×													
28. *Tellina ? sendaica* Nomura	×													
29. *Macoma incongrua* (V. Martens)		×	×						×	×				
30. *M. praetexta* (V. Martens)	×													
31. *M. sectior* Oyama	×													
32. *M. tokyoensis* Makiyama	×	×	×											
33. *Spisula polynyma voyi* (Gabb)	×	×	×			×	×		×	×				×
34. *Lutraria* sp.	×		×											
36. *Sanguinolaria olivacea* (Jay)	×										×			
36. *Siliqua pulchella* (Dunker)	×													
37. *Solen krusensterni* Schrenck	×													
38. *Panope japonica* (A. Adams)	×	×	×		×				×					
39. *Aloidis venustus* (Gould)	×													
40. *Cryptomya busoensis* Yokoyama	×													
41. *Mya japonica* Jay	×		×					×		×	×		×	×
42. *Cyrtopleura dilatata* (Souleyst)	×		×											
43. *Chlorostoma yabei* (Nomura)	×													
44. *Skenea basilirata* Nomura	×													
45. *Lacuna i-hayasakai* Nomura	×													
46. *Littorivaga brevicula* (Philippi)	×													
47. *Alvania arayai* Nomura	×													
48. *Caecum yotume* Nomura	×													
49. *Lemintina* sp.	×													
50. *Batillaria s-hataii* Nomura	×													
51. *Polinices kiritaniana* (Yokoyama) var.	×	×			×		×	×						
52. *Tritonalia adunca* (Sowerby)	×													
53. *T.* sp.	×													
54. *Retusa gorokuensis* Nomura	×													

Loc. No.	Localities	North Latitude	East Longitude	Situation from base of Formation
1.	South cliff of the Hirose River, about 400 m SE of Gôroku, in the western part of Sendai City.	38° 15′ 20″	140° 48′ 33″	80m
2.	Cliffs along the tributary of the Hirose River, 1.2–3.2 km W of Zuihô-den, Sendai City.	38° 14′ 35″～ 38° 15′ 02″	140° 50′ 16″～ 140° 51′ 22″	70m
3.	River floor of the Hirose at Hyôjogawara, about 200 m E of Kadan, Sendai City.	38° 15′ 02″	140° 52′ 07″	20m
4.	Cliff along the Hirose River immediately SE of bridge about 400m NW of electric power house in Sendai City.	38° 14′ 41″	140° 43′ 05″	20m
5.	Cliff along the Hirose River, immediately SE of bridge Atago-bashi, Sendai City.	38° 14′ 34″	140° 43′ 02″	20m
6.	Cutting of the Tôhoku line at Renbô-kôji, about 1 km SE of Sendai Station, Sendai City.	38° 14′ 56″	140° 53′ 24″	20m
7.	Valley cliff about 400 m NW of Ohashi Bridge, Sendai City.	38° 15′ 28″	140° 51′ 28″	35m
8.	Cliff along the Hirose River, immediately SW of Yodomi-bridge, Sendai City.	38° 15′ 46″	140° 51′ 31″	35m
9.	Cutting of the Senzan line E of Yamayashiki about 800 m NW of Osaki shrine, Sendai City.	38° 16′ 26″	140° 50′ 26″	80m
10.	A valley, N of Kameoka shrine, Sendai City.	38° 15′ 26″	140° 50′ 43″	60m
11.	Cutting of Senzan line, about 300 m N of Miyagi Normal School, Sendai City.	38° 16′ 37″	140° 52′ 53″	40m
12.	Ground of the Tôhoku Pharmacological College at Komatsushima, Sendai City.	38° 16′ 55″	140° 53′ 18″	60m
13.	Road cutting of Riku-U highway, about 1.4 km N of Tsutsumi-machi, Sendai City.	38° 17′ 37″	140° 52′ 38″	45m
14.	Cutting of Senzan line at Aramaki, Sendai City.	38° 16′ 50″	140° 50′ 50″	45m

The Kameoka formation is extensively distributed in Miyagi and also in the southern part of Iwate Prefectures, and everywhere it is unconformable with the older formations and conformable with the next younger Tatsunokuchi formation.

3. TATSUNOKUCHI FORMATION

Type locality.-The Tatsunokuchi gorge in the southwestern border of Sendai City (lat. 38°14′40″N., long. 140°51′E.). Thickness 30–60 meters.

The Tatsunokuchi formation which is conformable with the Kameoka formation, comprises tuffaceous sandstone, light gray tuff, conglomerate, sandy tuff, massive gray tuff, cross-bedded tuff, an alternation of gray tuffaceous sandstone and siltstone and massive blue siltstone. Fossil marine shells occur throughout and a sandy siltstone with sand-pipes forms the upper limit of the formation.

The molluscan shells reported from the formation are given in Table 12.

Besides molluscan shells, T. Nagao (1094, pp. 69–73) described *Cancer minutoserratus* Nagao, a shallow water crab which occurs in profusion in a sandy tuffaceous siltstone near the former Zoological Garden at Hyojogawara in Sendai City. Whale bones and a well-preserved specimen of *Delphinus* have also been found in this formation. The discovery of molar teeth of *Trilophodon sendaicus* Matsumoto from this formation at Kitayama in Sendai City is noteworthy. This elephant seems to have been adopted to cold climatic conditions.

The Tatsunokuchi formation is characterized by such molluscan species as *Anadara tatunokutiensis* (Nomura and Hâtai), *Dosinia tatunokutiensis* Nomura, *Fortipecten takahashii* (Yokoyama) and many other thick-shelled shallow water forms. The first mentioned from its large size, heavy test and associated fauna can be considered as a reflection of peculiar conditions then prevailing. Typical plants from this formation are *Juglans cinerea* Linnaeus, *Pseudosassa purpurascens* Makino, *Carpinus yedoensis* Maximowicz, *Fagus crenata* Blume and *Quercus crispula* Blume, besides others as shown in Table 10.

From the Tsunokuchi formation at Goroku in the western border of Sendai City, Y. Takayanagi (1950, pp. 23–28), where S. Nomura (1938, pp. 235–275) described on a large molluscan fauna, found an interesting foraminiferal faunule. This faunule, according to Y. Takayanagi consisted of the following species.

Massilina sp.	*Lagena acuticosta* (Reuss)
Robulus limbosus (Reuss)	*Robulus* sp.
Sigmorphina sp.	*Nonion akitaense* Asano
N. pacificum (Cushman)	*Pseudononion japonicum* Asano
Astrononion aomoriense Asano	*Elphidium fax barbarense* Nicol
E. etigoense Husezima and Maruhasi	*E. advenum* (Cushman)
E. sendaiense Takayanagi	*Cribroelphidium yabei* (Asano)

Uvigerina sp.	*Entosolenia squamosa* (Montagu)
Rotalia beccari (Linnaeus)	*Eponides karsteni* (Reuss)
Discorbis globularis (d'Orbigny)	*D. nipponica* Husezima and Maruhasi
Planulina sp.	*Cibicides labatulus* (Walker and Jacob)
Cibicides refulgens (Montfort)	*Globigerina bulloides* d'Orbigny

This foraminiferal fauna, according to Takayanagi comprises an assemblage which thrived in the eulittoral-sublittoral zone and was found in horizons in which there were no molluscan shells. From the assemblage it may be seen that deposition probably took place in an embayment, not in the open sea.

The Tatsunokuchi formation is extensive in distribution, being known from the vicinity of Hitachi-Omiya-machi in Ibaragi Prefecture, to the environs of Ichinoseki City in Iwate Prefecture, along the Koromo River, where it is known by the name of Yushima formation. Everywhere the Tatsunokuchi formation is characterized with tuffaceous, blue, soft siltstones, in which abundant, shallow, cold water molluscan shells occur.

Recently, J. Iwai collected samples of diatomaceous earth in this formation exposed at Yamayashiki-Kunimitoge to the west of Sendai City, in which Kanaya discriminated the following species of diatoms:

Melosira sulcata (Ehr.) Kütz.	rare
Stephanopyxis turris (Grev.) Grunow	rare
Coscinodiscus curvatulus Grunow	common
Coscinodiscus excentricus Ehrenberg	not common
Coscinodiscus marginatus Ehrenberg	common
Actinoptychus undulatus (Bail.) Ralfs	abundant

According to Kanaya, the above-cited species are all marine forms and this assemblage is represented by *Actinoptychus undulatus* and *Coscinodiscus excentricus*. *Actinoptychus undulatus* is a neritic benthonic form, *Coscinodiscus excentricus*, oceanic-neritic planktonic form, *Melosira sulcata*, tychopelagic form, and the remainder, are planktonic forms.

4. KITAYAMA FORMATION

Type locality.–Railway cutting along the Senzan railway line at Kitayama in the northwestern border of Sendai City (lat. 38°16′40″N., long. 140°50′30″E.). Thickness 1–10 meters.

The Kitayama formation is disconformable with the underlying Tatsunokuchi formation, and comprises basal conglomerate, sandstone, conglomerate, tuff and sandstone, lignite beds, white tuff, yellow sandstone, tuffaceous siltstone and clay with erect tree stumps, and white tuffaceous siltstone.

The Kitayama formation has yielded some plant fossils (Table 10), which were determined by S. Endo as, *Alnus firma* S. and Z., *A. japonica* S. and Z., *Fagus crenata* Blume, *Cryptomeria japonica* G. Don, *Sequoia japonica* Endo, *Cinnamomum Heeri* Lesseux, and *Virburnum furcatum* Blume, while Shimakura identified such woods as *Pinuxylon* (*Diploxylon*) cf. *paxi* Kräusel, *Glyptostroboxylon sequoianum* Gothan, *Quercinium*, *Liquidambaroxylon*, *Alnoxylon*, and *Cedroxylon*, although most of the specific names were not determined.

Fossil pollen from the lignite of the Kitayama formation, according to analyses by Shimada (1951, pp. 47–50) consisted of the genera, *Abies*, *Acer*, *Alnus*, *Betula*, *Chamaecyparis*-type, *Cunninghamia* (?), *Fagus*, *Ilex*, *Liquidambar*, *Liriodendron*, *Picea*, *Pinus*, *Pseudotsuga*, *Sciadopitys*, *Sequoia*-type and *Tilia*. Among these genera, *Alnus* occupied 16.2 percent of the total, *Sequoia*-type 12.5 percent, *Sciadopitys* 10.6 percent, *Acer*, *Fagus*, *Ilex*, *Liquidambar* and *Pinus* 7–7.8 percent, *Cunninghamia* (?), *Picea* and *Tilia* amounted to 4.8–4.9 percent, while the remaining amounted to only 2.8 percent of the total distinguished genera.

The Kitayama formation is extensively distributed in the environs of Sendai City and is an important source of brown coal in the Sanbongi district north of Sendai. This formation is distributed northwards to Hanamaki in Iwate Prefecture; its development along the foreland of the northern part of the Abukuma massif in the southeastern part of the present sheet is very poor.

5. HIROSEGAWA TUFF

Type locality.–River cliff of the Hirose River opposite Hyojogawara in the southern part of Sendai City (lat. 38°51′30″N., long. 140°51′50″E.). Thickness 10–100 meters.

The Hirosegawa tuff begins with a fine-grained pisolitic tuff which conformably overlies the Kitayama formation; it comprises massive pumiceous tuff with wood stems or trunks and blocks of natural charcoal, sandy tuff, pisolitic tuff, and sandy pumiceous tuff and locally with dacite flow.

Although of volcanic origin, the Hirosegawa tuff maintains a rather uniform thickness and is distributed chiefly in the area of Sendai Proper, from where it extends to the southern part of Iwate Prefecture. The tuff is particularly thick in the Tomiya area, where it attains about 100 or a little more meters, due chiefly to that area being near the center of its eruption.

The Hirosegawa tuff in Fukushima Prefecture may be represented by the Shirakawa dacite and its agglomerate which has rather extensive distribution, and in Iwate Prefecture, by the Gobuta tuff.

6. YAGIYAMA FORMATION

Type locality.–Northeastern slope of Yagiyama behind Otamaya, in the southern border of Sendai City (lat. 38°15′N., long. 140°52′E.). Thickness 20–30 meters.

The Yagiyama formation like the Kitayama is a terrestrial deposit. It overlies the Hirosegawa tuff and comprises massive white tuff, thin-bedded tuffaceous sandstone, lignite beds, sandstone, coarse-grained tuff, loose quartz sand and white tuff in upward succession. *Fagus crenata* Blume is a characteristic fossil plant in this formation, the other plants being as shown in Table 10.

The Yagiyama formation is not so extensively distributed as the Kitayama and Kameoka formations, and its typical development is restricted to the area of Sendai Proper. The lignite from this formation is the chief source of brown coal in Sendai City and exceeds that of Kitayama and Kameoka formations in both quality and quantity.

From this formation, Shimada (1951, pp. 47–50) was successful in obtaining pollen from the lignite. He found pollen of the genera, *Abies*, *Acer*, *Alnus*, *Betula*, *Carpinus* *Chamaecyparis*-type, *Fagus*, *Liquidambar*, *Pinus*, *Pterocarya*, *Quercus*, and *Tsuga*. Of these genera, *Alnus* occupied 36.8 percent of the total, *Fagus* 32.3 percent, *Quercus* 13.7 percent, while the genera *Carpinus*, *Pterocarya* and *Pinus* amounted to 3.6 percent and the other genera totaled only 2 percent.

The terrestrial Kitayama, Hirosegawa tuff and Yagiyama formations, after submergence was subject to transgression of shallow seas which resulted in deposition of the Dainenji formation.

7. DAINENJI FORMATION

Type locality.-Dainenji hill in the southern part of Sendai City (lat. 38°14′N., long. 140°51′50″E.). Thicknes 50–130 meters.

The Dainenji formation is conformable with the Yagiyama foımation and comprises sandy siltstone, tuff, coarse-grained sandstone, cross-bedded sandstone, tuffaceous siltstone, conglomerate, and intercalates lignite seams. Fossil molluscs and plants remains occur in the formation.

The molluscan fossils from this formation as discriminated by K. Hatai are, *Anadara* cf. *amicula* (Yokoyama), *Dosinia japonica* (Reeve), *Cyclina sinensis* (Gmelin), *Macoma incongrua* (Martens), *M. tokyoensis* Makiyama, *Mya japonica* Jay, *Ostrea gigas* Thunberg, *Panope japonica* (A. Adams), *Callithaca adamsi* (Reeve), *Venerupis* (*Amygdala*) sp., *Natica janthostomoides* Kuroda and Habe, *Polinices didymus* (Bolten), and the plant leaves of importance are the last appearance of *Liquidambar formosana* Hance, which occurs in association with *Abies balsamea* Miller and *Fagus crenata* Blume. Some marine diatoms have been found by J. Iwai from Kunimitoge, western border of Sendai City in this formation.

According to Kanaya, the samples of diatoms from the locality just cited contain the following species, namely,

Melosira granulata (Ehr.) Ralfs	common
M. sulcata (Ehr.) Kützing	dominant
Stephanopyxis turris (Grev.) Grunow	rare
Coscinodiscus curvatulus Grunow	rare
C. cf. *inclusus* Rattray	common
C. oculus-iridis Ehrenberg	rare
Auliscus sculptus (W. Smith) Ralfs	fairly common
Triceratium sp.	rare
Synedra affinis Kütz. var. *fasciculata* (Kütz) Van Heurck	rare
Navicula cf. *abrupta* Gregory	rare
Stephanogonia sp.	rare

This flora is represented by *Melosira sulcata* (Ehrenberg) Kützing and *Auliscus sculptus* (W. Smith) Ralfs and all the species cited above except for *Coscinodiscus* cf. *inclusus* Rattray and *Melosira granulata* (Ehr.) Ralfs are marine inhabitants. The last-cited two species are fresh water, forms and their presence in this floral assemblage is considered to suggest the influence of river water during the depoition of the formation in the locality, whence the diatoms were collected. The presence of *Coscinodiscus* cf. *inclusus* Rattray bears another importance, since the upper limit of its vertical distribution hitherto known is Pliocene.

The Dainenji formation is limited in distribution to Sendai and its suburbs. Marine formations corresponding to the Dainenji are unknown from the Prefectures of Miyagi, Fukushima and Iwate.

AOBAYAMA FORMATION

Type locality.-Aobayama in the western part of Sendai City (lat. 38°15′N., long. 140°51′E.). Thickness 10–65 meters.

The Aobayama formation unconformably overlies the Sendai group and comprises gravel and sand in the lower, succeeded upwards with bedded pumiceous tuff, sand, clay, gravel, tuff and gravel. Fossils are unknown from this formation. It is believed that the Aobayama formation is of marine origin, because of its extensive distribution on the 80–100 meter level, not only in the area of Sendai Proper, but also along the Pacific borderland of the Abukuma massif in the southeastern part of the present sheet.

The tuff which occupies the upper part of the Aobayama formation is designated as the Azukijima tuff member and its thickness is estimated at about 20–35 meters, while the predominating conglomerate of the formation measures 10–30 meters in thickness.

In the village of Enda in Katta-gun in the Sen-nan area is developed fresh water deposits which have been called the Paleo-Enda lake by H. Okutsu (1950, pp. 49–58) and also have been known as the Enda diatom beds (Okutsu, 1950, pp. 8–11). Herein it is designated as the **Enda formation.** The freshwater deposit is estimated at about 50 meters in thickness and comprises diatomaceous earth, pumiceous tuff, sandy tuff and locally of agglomerate. It overlies with unconformity the Miocene Shirasawa and Moniwa formations and is unconformably overlain by conglomerate along its western margin. The lake deposit is roughly horseshoe-shaped and corresponds to the Aobayama formation in stratigraphical position.

The Enda formation can be subdivided into two parts, the lower comprising sandy clay and sandy silt intercalating peat and overlain with diatomite, while the upper part of the formation consists of blue to green diatomite in the lower and of yellow diatomite in the upper, these are intervened with pumiceous tuff.

The diatoms from the Enda formation have been identified by Okutsu as follows :

Melosira spp.	*Stephanodiscus astraea* (Ehr.) Grun.var. *spinulosa* Grun.
S. a. var. *intermedia* Friche	*S. a.* var. *minutula* Grun.
Synedra ulna (Nitzsch) Ehr. var. *danica* Grun	*Cocconeis placentula* (Ehr.) var. *lineata* Cleve
Navicula sp.	*C. p.* var. *euglypta* Cleve
Cymbella cistula (Hemp.) Grun.	*C.* sp.
Gomphonema angur var. *gauteri* v. H.	*G.* sp.
Epithmia turgida (Ehr.) Kütz.	*E. zebra* (Ehr.) Kütz.
E. z. var. *porcellus* Grun.	*E. sorex* Kütz.
Rhopalodia gibba (Ehr.) Müll.	

These diatoms represent according to him, a flora which indicates that the climatic conditions were much colder than that prevailing now in the present area.

The fragments of wood found in the Enda formation were identified by Shimakura as *Piceoxylon* sp., *P.* aff. *laricinum* Kräusel, *Cedroxylon* sp., *Betuloxylon* sp., and *Fraxinus* sp. Fossil leaves of the Aceraceae, Betulaceae, and Fagaceae were found in the formation.

The pollen found in the peat from the lower part of the formation were reported by Okutsu (1950, p. 9) to give the following percentages by analyses, *Pinus* 32.2 percent, *Fagus* 31.1 percent, *Betula* 20.0 percent, *Abies* 8.8 percent, *Tsuga* 4.3 percent and unidentified species 3.6 percent. This analyses is in good agreement with the percentage obtained from the fossil-leaves.

Table 13 Terraces developed along the Rivers in the Areas of Sendai Proper, Sen-nan, Tomiya, and Matsushima after R. Tayama

Name of River / Terrace	Shiroishi And Matsu River	Goishi River	Natori River			Hirose River				Nanakita River	Yoshida River		Hana River
Ôjôjihara Terrace	x	Sasaya Terrace (480 360) (260-240)	?	x	x	Ist Level ? (350-300)	Hatamae Terrace (280-215) Akasaka Terrace (260-190)	x	x	Uenohara Terrace (200-80)	Ôkubo Terrace (120-90)	x	Ôhara Terrace (160-60)
Nanakita Terrace	Hara Terrace (200-180)* Nagano Terrace (110-130)	Kawauchi Terrace (320-300) (230-220)	Hongoya Terrace (400-280) Takihara Terrace (280-270) Ishigami Terrace (250-200)	Hitokita Terrace (160-95)	Uenohara Terrace (110-60)	1st Level (350-300) 2nd Level (280-240) 3rd Level (250-220)	Ôhara Terrace (240-190) ●Nakahara Terrace {I, II} (220-120)	1st Level {I, II} (130-100)	Dainohara Terrace {I, II, III, IV} (100 50)	Asukahara Terrace (200-60) {I, II, III, IV, V, VI}	Sawanami Terrace (140-110) Yoshioka Upper Terrace (50-30)	Nakamura Upper Terrace (50-30)	Motomachi Terrace (55-50)
Natori Terrace	Nagabukuro Terrace (100 60)	Nogami Terrace (280-240) Kawasaki Terrace (210-170)	Baba Terrace (260-160) ●Yumoto Terrace (150-110)	●Higashi-Akaishi Terrace (120-80)	Kagitori Terrace (60-52,5)		Ayashi Terrace (Upper) (180-117.5)	2nd Level {I, II} (95-90)	Sendai-Uemachi Terrace {I, II, III} (75-35)	Hanawa Terrace (11-30) {I, II, III, IV, V} Nanakita-Uemachi Terrace	Yoshioka Lower Terrace (27.5-17.5)	Nakamura Lower Terrace (30-20)	
Hirose Terrace		Ono Terrace (180-140) Ozawa Terrace (150-300)	●6th Level	●Moniwa Terrace (100-70) Kita-Akaishi Terrace (80-50)	Ôsawa Terrace (60-50) Tomihama Terrace {I, II}		● {Ayashi Terrace (110 85) (Lower), Ôkatsuso Terrace (120-85)} Ôtakei Terrace (100-75)	3rd Level {I, II} (85 75) 4th Level (70-65)	Sendai-Nakamachi Terrace {I, II, III} (65-30)	Nenoshiroishi Terrace (62.5 20) {I, II, III} Nanakita-Shitamachi Terrace			
Yoshida Terrace	4th Level (Lowest Terrace)			Lowest Terrace	Jûnikami Terrace (30)		Lowest Terrace (70)	5th Level (Lowest Terrace) (60)	Sendai-Shitamachi Terrace {I, II, III} (40-20)	Iwakiri Terrace (27.5-10)	●Lowest Terrace (20-15)	●Lowest Terrace (10-5)	Lowest Terrace

* Height in meters, ● Terraces continued

Table 13 Terraces developed along the Rivers in the Areas of Sendai Proper, Sen-nan, Tomiya, and Matsushima after R. Tayama

Name of River / Terrace	Shiroishi And Matsu River	Goishi River	Natori River			Hirose River				Nanakita River
Ōjōjihara Terrace	x	Sasaya Terrace (480-360) (260-240)	?	x	x	1st Level ? (350-300)	Hatamae Terrace (280-215) Akasaka Terrace (260-190)	x	x	Uenohara Terrace (200-80)
Nanakita Terrace	Hara Terrace (200-180)* Nagano Terrace (110-130)	Kawauchi Terrace (320-300) (230-220)	Hongoya Terrace (400-280) Takihara Terrace (280-270) Ishigami Terrace (250-200)	Hitokita Terrace (160-95)	Uenohara Terrace (110-60)	1st Level (350-300) 2nd Level (280-240) 3rd Level (250-220)	Ōhara Terrace (240-190) ● Nakahara Terrace {I, II} (220-120)	1st Level {I, II} (130-100)	Dainohara Terrace {I, II, III, IV} (100-50)	Asukahara Terrace (200-60) {I, II, III, IV, V, VI}
Natori Terrace	Nagabukuro Terrace (100-60)	Nogami Terrace (280-240) Kawasaki Terrace (210-170)	Baba Terrace (260-160) ● Yumoto Terrace (150-110)	● Higashi-Akaishi Terrace (120-80)	Kagitori Terrace (60-52,5)		Ayashi Terrace (Upper) (180-117.5)	2nd Level {I, II} (95-90)	Sendai-Uemachi Terrace {I, II, III} (75-35)	Hanawa Terrace (11-30) {I, II, III, IV, V} Nanakita-Uemachi Terrace
Hirose Terrace		Ono Terrace (180-140) Ozawa Terrace (150-300)	● 6th Level	● Moniwa Terrace (100-70) Kita-Akaishi Terrace (80-50)	Ōsawa Terrace (60-50) Tomihama Terrace {I, II}		● {Ayashi Terrace (110-85) (Lower), Ōkatsuso Terrace (120-85)} Ōtakei Terrace (100-75)	3rd Level {I, II} (85-75) 4th Level (70-65)	Sendai-Nakamachi Terrace {I, II, III} (65-30)	Nenoshiroishi Terrace (62.5-20) {I, II, III} Nanakita-Shitamach Terrace
Yoshida Terrace	4th Level (Lowest Terrace)			Lowest Terrace	Jūnikami Terrace (30)		Lowest Terrace (70)	5th Level (Lowest Terrace) (60)	Sendai-Shitamachi Terrace {I, II, III} (40-20)	Iwakiri Terrace (27.5-10)

* Height in meters, ● Terraces continued

Yoshida River		Hana River
Ôkubo Terrace (120-90)	×	Ôhara Terrace (160-60)
Sawanami Terrace (140-110) Yoshioka Upper Terrace (50-30)	Nakamura Upper Terrace (50-30)	Motomachi Terrace (55-50)
Yoshioka Lower Terrace (27.5-17.5)	Nakamura Lower Terrace (30-20)	
●Lowest Terrace (20-15)	●Lowest Terrace (10-5)	Lowest Terrace

List of the Fossil Leaves found in the Enda Formation

1. *Abies firma* Sieb. et Zucc.
2. *Pinus* sp.
3. *Sasa* sp. (*S.* cfr. *albo-marginata* Makino et Shibata)
4. *Juglans Sieboldiana* Maxim.
5. *Carpinus laxiflora* Bl.
6. *C. carpinoides* Makino
7. *C. Tschonoskii* Maxim.
8. *C. yedoensis* Maxim.
9. *Ostrya japonica* Sarg.
10. *Castanea pubinervis* Schneid.
11. *Fagus crenata* Bl.
12. *Celtis* sp. (*C.* cfr. *sinensis* Per. var. *japonica* Nakai)
13. *Zelkova serrata* Makino
14. *Cercidiphyllum* sp. (*C.* cfr. *japonicum* Sieb. et Zucc.)
15. *Benzoin umbellata* Rehd. ?
16. *Acer aizuense* Nakai
17. *A. carpinifolium* Sieb. et Zucc.
18. *A. crataegifolium* Sieb. et Zucc.
19. *A. eupalmatum* Koidzumi
20. *A. japonicum* Thunb.
21. *A. pictum* Thunb.
22. *A. rufinerve* Sieb. et Zucc.
23. *A. Sieboldiana* Mig.
24. *Tilia* sp.
25. *Myriophyllum* sp. (*M.* cfr. *spicatum L.*) var. *muricatum.* Maxim.
26. *Fraxinus* sp.

TERRACE DEPOSITS

Terrace deposits along the rivers flowing eastwards into the Pacific Ocean can be subdivided into several heights. Sand, gravel, and clays are deposited on these river terraces. The terraces vary in number and height along the different rivers owing to differential movement.

According to R. Tayama (1933, pp. 61～67), the terraces developed along the rivers of Shiroishi, Goishi, Natori, Hirose, Nanakita, Yoshida and Hana can be classified into five groups as shown in Table 13. These range in age from the Pleistocene to Recent.

The Miyaginohara, is the broad coastal plain which is separated from the adjoining hilly region by a fault extending from near Nagamachi or farther south northwards to beyond Rifu on the Tôhoku main railway line. This young coastal plain is incised by shallow streams draining from the hilly region, and has small water bodies on its surface.

The submerged topography of Matsushima Bay is a typical feature interrupting the smooth coastal plain. The many islets are nothing but detached portions of the mainland and their surfaces are thought to be a peneplain of pre-Aobayama age. The deep identations of the inner shore line of the bay may represent heads of drowned valleys. Niches and holes of boring shells above the high tide level clearly indicates recent emergence although the general topography is one of submergence, which took place prior to the just mentioned emergence.

VOLCANICS

Volcanic activity within the present area can be divided into seven or eight periods, ranging in age from pre-Miocene to Recent.

From the occurrence of andesite and liparite pebbles in the conglomerate at the base of the Moniwa formation it is evident that some volcanism producing them must have existed before Takadate and Moniwa time ; these are classified as pre-Moniwa volcanics.

Most extensive and characteristic is the volcanic activity during early Natori time. The Takadate-, Shiogama-, Koyabara-, Ko-oku-, Asahiyama-, Nonodake-andesite and correlatives such as the Ishikoshi-, Ryozen- and Inase-andesites, the Nisatai-, and Goyasu liparites, all represent intense volcanisms prior to or about the same time as the first transgression of the Neogene seas in Japan. A characteristic of this period of volcanism is that their interfingering with marine fossil-bearing sediments is not a rare feature and they are also found to interfinger with terrestrial deposits such as the Tsukinoki formation in the Sen-nan area. The andesites are generally two-pyroxene, hypersthene, hornblende or augite in composition and besides flows, agglomerates and their tuffs are commonly found in association.

The third period of volcanism within the present area was only slight, as only thin flows of andesite-agglomerate have been found to occur in the Tsunaki formation. Correlatives of this period of volcanism have not yet been found. The second and third period of volcanism took place in Lower to Middle Miocene time.

The fourth period poured out the Kamabusa dacite and the Akyu andesitic agglomerate ; both of these activities are referred to Upper Miocene time, since they belong to the Akyu group which is of that age from paleontological evidence.

The fifth period of volcanic activity is well marked in the environs of Sendai. The Mitaki basaltic andesite, the Matsugahama, Yogasaki andesitic agglomerates, and the andesites of Taihakusan, Kamegamori and Atagoyama all can be referred to this period. The age of this volcanism is Lower Pliocene. Corresponding activitity is also found in northern Iwate Prefecture, while an earlier one occurs in the northern part of Miyagi Prefecture and in the southern part of Iwate Prefecture. This earlier period of dacite eruption is Upper Miocene and corresponds to that of the Akyu time in age.

The physiographical features of the Lower Pliocene volcanoes are still preserved, and restoration of their original forms is not so difficult compared with the older volcanoes whose features are destroyed by subsequent denudation.

The sixth period of volcanism is represented by the Hirosegawa tuff and its corresponding lava is the Shirakawa dacite in the southern part of Fukushima

Prefecture. The age of this activity is probably Middle Pliocene.

The andesites of Nanatsumori in the northwestern part of Sendai or in the western corner of the Tomiya area are evidently younger than that of the Hirosegawa tuff which it extrudes, and may mark the seventh period of volcanism in the present sheet. There is at present no evidence showing the contemporaneity of the Nanatsumori with those of the others mentioned above.

The youngest volcanic activity is represented by the Aoso volcanics in southern Miyagi Prefecture and its correlative in the western part of Akyu-mura in the southwestern part of the area of Sendai Proper, is known as the Natori volcanics. This period is believed to be younger than the Aobayama formation and to belong to the Upper Pleistocene to Recent.

CORRELATION

Correlation of the stratigraphic sequences established in the areas of Sen-nan, Sendai Proper, Tomiya, Shiogama, and Matsushima-Nobiru is rendered rather easily in the first two areas, but owing to the strata developed in the other three areas not being directly traceable in the field, considerable difficulty has arisen. In the following lines are presented the views on correlation of the different strata. Details of the stratigraphic sequence in the different areas are shown in the annexed table and also in the columnar sections.

Throughout the areas mentioned above either andesites or their agglomerates or both are found to represent the lowest sequence, and in the Sen-nan area the volcanics just mentioned are found to overlie unconformably the Paleozoic Wariyama formation or Mesozoic granodiorite, while in the Shiogama and Matsushima-Nobiru areas the similar volcanics are found in similar relationship with the Triassic Rifu formation. Therefore, the stratigraphical relationship of those volcanics to the underlying foundation rocks is correlative.

The Takadate andesite, Koyabara andesite and Shiogama agglomerate all represent a similar period of intense volcanic eruption which is characteristic of northern Honshu. These volcanics either interfinger or are conformable with the overlying sedimentaries. In the Sen-nan area the Takadate andesite interfingers with the terrestrial Tsukinoki formation, in the area of Sendai Proper, it interfingers with a part of the marine Moniwa and Hatatate formations, in the Tomiya area the Koyabara andesite is conformable with the overlying Otsutsumi formation, in the Shiogama area the Shiogama agglomerate grades upwards into the terrestrial Sauramachi formation, and in the Matsushima-Nobiru area the Shiogama agglomerate is in similar relationship with the next younger Nobiru formation. Thus, verifying the contemporaneity of the mentioned volcanics to the sedimentaries overlying them.

From the Tsukinoki formation has been discovered a complete upper and

Table 14

Correlation Table of the Formations Developed in the Areas of Sen-nan, Sendai Proper, Tomiya, Shiogama, and Matsushima-Nobiru

Group	Sendai Proper (including Sen-nan Area)	Tomiya Area	Shiogama Area	Matsushima-Nobiru Area
	Aobayama formation (Enda formation)	Missing	Aobayama formation	Missing
Sendai Group	Dainenji formation Yagiyama formation		Missing	
	Hirosegawa tuff	Miyatoko formation		
	Kitayama formation	Missing		
	Tatsunokuchi formation	Ishikura formation	Yakushi formation	
	Kameoka formation Mitaki andesite		Geba formation Matsugahama andesite	
Akyu Group	Shirasawa formation Yumoto formation	Missing	Missing	
Natori Group	Tsunaki formation	Nanakita formation		
		Aoso formation		Bangamori from. Shirasakayama tuff member
				Hatsuhara form. Matsushima tuff member
	Hatatate formation	Otsutsumi formation	Ajiri formation	Hamada formation
	Moniwa formation			
	Tsukinoki formation		Sauramchi form.	Nobiru formation
	Takadate andesite	Koyabara andesite Base unknown	Shiogama agglomerate	
	Palaeozoic Wariyama formation Mesozoic granodiorite		Triassic Rifu formation	

lower jaws of *Eostegodon pseudolatidens* Yabe, a characteristic lower Miocene elephant whose isolated molar teeth have been found in the lower part of the Ajiri formation in the Shiogama area. In association with the mentioned elephant is found the *Comptoniphyllum-Liquidambar* flora, which occurs in the Sauramachi formation ; this fact supports the correlation of the Tsukinoki with the Sauramachi and Nobiru formations. The Moniwa which is a marine formation correspond to the terrestrial Tsukinoki has yielded *Lepidocyclina japonica* Yabe, *Nanaochlamys notoensis* (Yokoyama) and numerous other fossils as can be noticed from Table 5, corresponds to the lower part of the Otsutsumi formation in representing the first phase of marine transgression in the Neogene in Northern Honshu, possesses a remarkably similar Pectinidae fauna and occurs in similar stratigraphical relationship with the underlying andesites, and therefore, should be considered as belonging to a similar position in the stratigraphical column.

The Ajiri formation in the Shiogama area which has yielded the teeth of the circum-Pacific *Desmostylus* in its uppermost part, is correlated with the uppermost part of the Hamada formation in the Matsushima-Nobiru area from the occurrence of the same mammal. *Vicarya* occurs in the middle part of the Ajiri formation which, together with the Hamada formation occupies a horizon higher than the Sauramachi with the *Comptoniphyllum-Liquidambar* flora and *Eostegodon*-bearing lower part of the Ajiri, and Nobiru formations as well as that of the Tsukinoki formation. Such relationship brings the Ajiri and Hamada formations in a position corresponding to that of the Hatatate. The Hatatate in its facies and fauna does not resemble the middle part of the Otsutsumi, Ajiri, or Hamada formations, but from its stratigraphical position, climatic conditions indicated by the fauna and relationship to the overlying sedimentaries, is considered to be the equivalent of those formations.

Although the Matsushima tuff member and the Hatsuhara formation, the Bangamori formation and its Shirasakayama tuff member are not represented in the Shiogama area, the latter mentioned tuff member can be traced to the basal part of the Aoso formation and the greater part of the Bangamori is nothing but the larger part of the Aoso formation, thus their correlation seems to be well established. The Hatsuhara formation and its Matsushima tuff member are correlated with the upper part of the Otsutsumi formation from the fact that the Shirasakayama tuff member of the overlying Bangamori formation can be traced to the lower part of the Aoso formation, thus bringing the Hatsuhara and its member in a position corresponding to the upper part of the Otsutsumi, being held below by the fauna and flora of the Ajiri, Hamada, and Hatatate formations and by the lowermost part of the Otsutsumi formation. Thus verifying the correlation shown in the Table 14.

The stratigraphical relationship of the upper Otsutsumi, Aoso, and Nanakita formations to the Tsunaki is also in need of some explanation. The *Glycymeris* zone at the base of the Nanakita formation is well represented in the lower part of the approximately upper one-third of the Tsunaki, and the tuff at the base of the Aoso is well developed in the lower part of the middle Tsunaki, thus suggesting that they should be thus correlated with one another. The lower part of the Tsunaki formation is correlated with the upper part of the Otsutsumi and also with the Hatsuhara formation including its Matsushima tuff member, chiefly from stratigraphical position and lithological resemblance. Upholding the view is the contemporaneity of the underlying formations with one another and that of the overlying with one another.

The Akyu group is not represented in the Tomiya, Shiogama, and Matsushima-Nobiru areas, and its correlation in the areas of Sen-nan and Sendai Proper is verified by the fact that it can be traced directly in the field.

The Matsugahama andesite and its agglomerate like the Mitaki andesite and its agglomerate is unconformable with the underlying Miocene formations and grades upwards into the Geba formation of about 30 meters in thickness. The Geba formation like the Kameoka contains lignite seams and is overlain conformably with the Yakushi formation of some 20 meters in thickness. The Yakushi formation corresponds to the Tatsunokuchi in its faunal assemblage and lithological characters. Accordingly, correlation between the Matsugahama, Geba and Yakushi formations with the Mitaki, Kameoka, and Tatsunokuchi formations is justified by their stratigraphical relationships to the older formations, sequence of their lithological characters and faunal and floral contents.

Although the Mitaki and Matsugahama andesites and agglomerates are lacking in the Tomiya area, both the Kameoka and Tatsunokuchi formations of Sendai Proper and the Geba and Yakushi formations of the Shiogama area are represented. Although the Ishikura formation in the Tomiya area is considered to be an equivalent of the aforementioned two formations, difference is found in that it cannot be subdivided so easily upon lithological characters owing to complexity of the formation by faults. The contemporaneity is, however, justified upon faunal content and similarity in lithological features, although disturbed by subsequent movement.

The Kitayama and Hirosegawa formations of Sendai Proper do not occur in the Shiogama and Matsushima-Nobiru areas, and the first mentioned in the Tomiya area is replaced by poorly developed conglomerate beds, while the Hirosegawa tuff becomes extraordinarily thick, attaining as much as 100 meters or a little more in comparison with only about 10–15 meters in the area of Sendai Proper. However, the correlation of the Hirosegawa tuff with the Miyatoko formation is justified by direct tracing in the field and also by lithological characteristics.

The Yagiyama and Dainenji formations are unknown in the areas of Tomiya, Shiogama, and Matsushima-Nobiru. However, the next younger Aobayama formation is represented in the Shiogama area, but not in the Matsushima-Nobiru, and Tomiya areas.

In the Sen-nan area there is developed a rather thick deposit of diatomaceous freshwater lake deposit, which from stratigraphical position is considered to be a correlative of the Aobayama formation. This freshwater lake deposit is now covered in part with the Aoso volcanics.

GEOMORPHOLOGY

A. PHYSIOGRAPHY

1. Rivers

The oldest river in the present area is the Abukuma River at the south; this river meanders northwards then eastwards through the alluvial plain bordered by the Miocene terrestrial facies of the Moniwa formation, which in turn was deposited against the Mesozoic granodiorite and the Paleozoic Wariyama formation, which is the northern extension of the Abukuma massif. At the northern tip of the Wariyama formation, the Abukuma River makes an abrupt eastward change in its course to drain into the Pacific Ocean at Arahama-machi. The course of the Abukuma River along the western flank of the northern extension of the Abukuma massif is governed by the backbone ranges and not by any tectonic phenomenon, while the abrupt eastward course is related to an E-W fault.

The Naruse River meanders southward through the broad alluvial plain of Kimitsuka and Nango in Toda-gun in the northern part of the present area, and through the hilly region built of the Hamada formation to empty into the Pacific Ocean at Nobiru in the Matsushima-Nobiru area. There is no stratigraphical evidence proving the relation of this river to tectonics.

The rivers, Yoshida, Nanakita, Hirose, Natori, and Shiroishi, named in succession from north, all flow eastwards through Miocene to Pliocene formations. Of the aforementioned, the Yoshida River is a tributary of the Naruse River and meanders through the broad alluvial flat of E-W trend.

None of the above-mentioned rivers, except probably the Shiroishi are governed by faults, and their courses, as known at present, have no connection with tectonics. All are consequent rivers. The courses of these rivers seem to be controlled by the lithological characters of the rocks through which they flow.

The Okura River, a tributary of the Hirose River in the marginal part of the Ayashi basin in the west of Sendai City, is influenced by differential movement. This tributary now flowing southwards, is responsible for the construction of the terraces in several heights on the northern side of the Hirose River in the basin.

The terraces distributed along the above-mentioned rivers can be classified into five groups as already shown in Table 13. The distribution, difference in height and upstream inclination of the terraces provide data for concluding Recent warping in that area.

2. Basins

Among the basins in the present area, those of Ayashi in the west of Sendai along the upper course of the Hirose River, and Kawasaki along the upper course of the Goishi River in the west and southwestern parts of Sendai, respectively, are most noteworthy. Other basins of smaller size are the Tsukinoki-Funaoka, Ogawara-Murata basins, both in the southern part of the present sheet, the Enda basin, in the southern corner, and minor ones as Goishi-, Akaishi-, Sakunami-, Moniwa-basins and several isolated basins in the hilly region of Tomioka-mura.

All of the above-mentioned basins are isolated yet arranged roughly in N-S direction parallel with the general trend of the axis of warping. These basins are a result of river erosion associated with damming by warping and faulting as in the case of the Ayashi and Moniwa basins.

The basin-like depression of Sendai City is surrounded on three sides by hilly regions and open only seawards. The present site of Sendai is a product of river erosion associated with differential uplift. The valley wall of the Hirose River between Yagiyama and Atagoyama in the southern border of Sendai is a product of river erosion.

A characteristic fossil valley exists at Okuboyachi in the southern border of Sendai. This valley extends parallel with the Hirose River with which it was once a tributary. This fossil valley, originally a tributary of the Hirose River, by piracy, was captured by the Hirose River. The headward side, then preserved as a hanging valley, was later undercut to the level of the present Hirose River. Progressive headward erosion and down-cutting resulted in the present Tatsunokuchi gorge. The downstream side from the broad meander of the present Hirose River east to Dainenji hill for a distance of 2 km marks the present site of the fossil valley. The bottom of the fossil valley from the level of the Hirose River measures about 20 meters.

Besides this characteristic fossil valley, there are several among which that of Kuromonshita is nothing but a tributary of the one described above.

3. Miyagino Coastal Plain

The Miyagino coastal plain is the broad plain physiographically separated from the adjoining hilly region on the west by two major tectonic lines, one extending from Hisanohama in Fukushima Prefecture north to beyond Iwanuma, and is known as the Hisanohama-Iwanuma dislocation line (fault and tilting), and another, extending from the south of Nagamachi northwards to beyond Rifu-mura, is known as the Nagamachi-Rifu fault. This coastal plain with a breadth of about 4 km in the southern part of the present area, rapidly broadens to about 10 km near Sendai, and again lessens to about 8 km where it is abruptly interrupted by the hilly region which marks the southern boundary of the Shiogama district.

With an average elevation of about 5 meters, the Miyagino coastal plain is incised with the meadering Abukuma River at the south, the Natori River in the middle and by the Nanakita River at the north. The Hirose River joins the Natori

River near Shinden, northeast of Rikuzen-Nakada station on the Tôhoku main line. There are no other noteworthy rivers or streams emptying into the Pacific Ocean from this plain.

The development of deltas and fans at the mouths of the above-mentioned rivers near the physiographical break have been modified by subaerial denudation and by artifical reworking of the land for agricultural purposes.

On the coastal plain are many enclosed water bodies as Torinoumi, Akaie, Hiroura, and Akawanuma, enumerated from the south, besides several smaller ones. These water bodies are arranged close to and parallel with the smooth coastal line and are characterized by having their southern margin broad and their northern one narrowed. These may have been formed by shifting sands due to wind and current actions. The lakes of Onuma, Kita-Naganuma and Minami-Naganuma, which are of quadrangular shape, are situated farther inland; these are relics due to emergence.

Also on the coastal plain are found several small shell-mounds, a few of which been excavated.

4. Matsushima Bay

The smooth coast line is interrupted by the sharply indented water body with many islets of Matsushima Bay. Matsushima Bay is surrounded on three sides by hilly regions consisting of the rocks of the Rifu formation, Miocene Shiogama agglomerate, terrestrial and equivalents of the Moniwa, Hatatate, and Tsunaki formations, and of the Pliocene Matsugahama andesite and Kameoka and Tatsunokuchi equivalents.

The shore line of the bay is arrayed with deeply indented inlets, caves, and embayments of various sizes, bordered with steep cliffs except for where the valley heads of the drowned valleys have been partially filled by sediments brought down by drainage, where reclaiming of the land has been undergoing, and also to emergence.

Most of the islets and islands, which are merely detached portions of the mainland, have rather flat surfaces and are cliffed regardless of the weak nature of the tuffaceous rocks of the Ajiri formation. The flat surfaces of the islets represent the Pleistocene peneplain.

That the bay of Matsushima is due to submergence can be readily recognized by the physiographical features, while recent emergence is indicated by the niches and holes of boring shells above the high tide level. Emergence is still in progress.

5. Landslides

Landslides of rather large scale have occured at Dainenji hill, between Goroku and Monjudo in the southern and western borders of Sendai, respectively, Shimokura in Osawa-mura, Miyagi-gun, and in the eastern front of the tunnel to the east of the Ochiai station on the Senzan railway line namely between Gorku and Monjudo.

All of these landslides are of similar origin. The landslide of Dainenji hill took place between the Dainenji and Aobayama formations, and that of between Goroku and Monjudo, between the tuff and agglomerate within the Mitaki volcanics, and that along the Senzan railway line between the agglomerate and tuff within the Mitaki volcanics. These are all due to water seepage after heavy rainfall. The Mitaki agglomerate is easily disintergrated by percolating waters.

As a result of these landslides the landscape has changed considerably. Between Goroku and Monjudo, the landslide produced a small hill known now as Hanareyama, and left between it and the original mass, a small pond. At Dainenji hill a long and high scarp was made as a result of landsliding.

B. STRUCTURAL FEATURES

The structure of the formations of the Natori group differs somewhat according to region as shown in the annexed tectonic map. In the Kakuda-Tsukinoki region, the formations show an undulating synclinal structure against the N-S axis. In the Murata-Ogawara region the general trend is NE-SW with NW dips. In the Nanakita-Tomiya and Moniwa-Goishi regions the formations gently undulate from their NE-SW axis.

The terrestrial Akyu group in the western part of Sendai shows a NE-SW trend similar to that of the Natori group in the last-mentioned two regions, but without undulating structure, the formations dip eastwards. In the Ogawara region the Akyu group with NE-SW trend, dips to the NW.

The Sendai group in the Sendai district has a general trend of ENE-WSW with gentle undulations from that axis. In the Shiogama district the general trend varies to NE-SW, with the formations gently undulating towards the SE.

The important faults recognized within the present area are the Kagitori fault, Ashinokuchi thrust, Murata thrust, Nagamachi-Rifu fault, and Hisanohama-Iwanuma fault and tilting.

1. Kagitori fault

The Kagitori fault extends from Kagitori in Nishi-Taga-mura, in NNW direction to Tsunaki in Oide-mura; this can be traced over a distance of 8 km. This fault traverses within the Sendai group along its basal part; the Kagitori fault has displaced the Aobayama formation, thus its age is post-Aobayama. The magnitude of the displacement is not known, since the fault plane is parallel with the dipping strata.

In the north of Tsunaki village there are several minor thrust faults. These have close relation with the Kagitori fault. In a cutting of the Tsunaki formation about 50 meters east of the Kagitori station along the Akyu electric line, a thrust fault of N10–20°W, NE40° can be seen traversing the terrace gravels.

2. Ashinokuchi thrust fault

The Ashinokuchi thrust can be seen in the upper course of the Kanaaraizawa behind Mikamine hill, and in Futatsuzawa behind Dainenji hill, as well as along the northern foot of the Dainenji hill ; the general trend is NE, and the thrust fault can be traced for more than 3 km. At the first mentioned locality, the Kitayama formation, and at the second locality, the Hirosegawa tuff, are thrust up on the Dainenji formation from the south. At the second locality, a minor thrust can be seen cleaving the Aobayama formation. The thrust plane dips at about 30° SE, and the displacement is estimated at 30–40 meters. The northeast extension of the thrust can be seen along the cliffs of the Hirose River, but its further extension is uncertain.

In the north of Murata-machi in Shibata-gun, there is a thrust fault with a displacement of slightly less than 100 meters ; this thrust has a ENE-WSW trend, and has been traced for about 3 km. Here the Moniwa formation of the Natori group is thrust up on the Shirasawa formation of the Akyu group. Since the general direction of the strike of the Murata thrust coincides with that of the Ashinokuchi thrust fault with which it appears to be an extension, one is lead to believing the former as the prolongation of the latter. However, the direction of movement is just the opposite, thus they must be considered as independent.

3. Nagamachi-Rifu fault

This fault with a vertical displacenent of less than 50 meters extends in NE-SW direction of Nagamachi to beyond Rifu on the Tôhoku main railway line along the eastern side of the basin-like depression of Sendai City. This fault has been traced for over 20 km, and marks the physiographic boundary between the broad Miyagino coastal plain and the hilly region of Yagiyama and Nanakita. According to data from wells bored in several places in the coastal plain, this fault brings the Lower Pliocene Tatsunokuchi formation in contact with the Pleistocene Aobayama formation while in the north of Rifu the fault comes between the Aoso formation and the Shiogama agglomerate or the Triassic Rifu formation. The southern extension of the Nagamachi-Rifu fault is the Hisanohama-Iwanuma fault and tilting line.

Parallel with the Nagamachi-Rifu fault, the young terraces show recent upwarping, this is to be known as the Miyagino axis of upwarping. In the western side of the Miyagino upwarp there is a depression, formed as downwarping relative to the upwarping. The axis of upwarping are shown in the annexed tectonic map.

4. Hisanohama-Iwanuma fault and tilting line

This line can be traced from Yusuji, north of Hisanohama, Futaba-gun in Fukushima Prefecture, northward until Iwanuma in Natori-gun, and can be traced for a distance of about 100 km. This line occurs between the Abukuma massif and its foreland of Pliocene formations now buliding up the low hills and coastal plain there. The first displacement of the Hisanohama-Iwanuma fault and tilting line was a little more than 80 meters, and occurred prior to the deposition of the Miocene Taga group of the Joban coal-field, while more recent movement, with a displacement of only about 15 meters, occurred during post-Aobayama time.

In the region south of the Abukuma River, this line occurs between the Pliocene Kameoka formation of the Sendai group and the Paleozoic Wariyama formation which was intruded by the Mesozoic granodiorite. Northwards this line separates the Tatsunokuchi formation from the Takadate andesite which interfingers with the Tsukinoki terrestrial and the marine Moniwa formations. In the west of Iwanuma-machi no fault has been found, here the Tatsunokuchi formation unconformably covers the Takadate andesite.

All of the above-mentioned faults are of post-Aobayama age.

Besides the above-mentioned important faults, there are also several others to be mentioned. The fault extending from Mitaki in the western border of Sendai to Ishikura in Miyatoko-mura, Kurokawa-gun, is an old one. At Mitaki, the Tsunaki formation unconformably overlain with the Mitaki andesite, and at Ishikura, the Hatatate formation unconformably overlain with the Tatsunokuchi formations, have their rocks crushed and much disturbed. This fault as well as the Hisanohama-Iwanuma fault is of post-Tsunaki and pre-Mitaki age. The direction of the Mitaki-Ishikura fault coincides with the prolongation of the Hisanohama-Iwanuma fault and tilting line. From the distribution of the Tatsunokuchi formation it seems that the transgression of the Tatsunokuchi sea was hindered by the fault scarp at that time. In the vicinity of Ishikura, the Tatsunokuchi formation and the overlying Hirosegawa tuff, by the action of faults, was inserted in a graben-like depression made up of the Hatatate and Tsunaki formations. The northern extension of the Mitaki-Ishikura fault is now covered with volcanic ejecta of the Nanatsumori.

In the Ayashi basin, the Kameoka and Tatsunokuchi formations are distributed along the Hirose River east of Ayashi, while on the southern part, the Shirasawa formation of the Akyu group is exposed. Between the Miocene and Pliocene formations there is a E-W fault now covered with terrace deposits. This fault may have cut the northern extension of the Kagitori fault. The terrace gravel cut by a minor fault near Goroku is believed to be of a younger date.

The Shishiochi fault south of Otamaya in the western Sendai shows a vertical displacement of about 10 meters within the Hirosegawa tuff and the overlying Yagiyama formation ; the northern side was thrown down.

In the Matsushima district there are numerous faults trending in NW-SE or NNE-SSW directions ; all of these seem to be of small displacement. These faults seem to be related to the construction of the submerged bay.

From the distribution and inclination of the terraces developed along the rivers of Shiroishi, Goishi, Natori, Hirose, Nanakita, Yoshida, and Naruse, it is evident that there has been Recent up- and downwarping. The chief axes of them are the Nanakita, Natori, Mitaki, and Yumoto Downwarping relative to upwarping occurred between the main axes of upwarping.

GEOLOGICAL HISTORY

Following deposition of the Paleozoic Wariyama and Triassic Rifu formations there occurred folding and faulting, accompanied with intrusion of granodiorite into these sedimentaries. Metamorphism by the granodiorite intrusion, and by folding and faulting may have been responsible for the formation of schists in the Paleozoic Wariyama and of the schistose granodiorite. The abovementioned disturbances together with minor movement of the Miocene, and Pleistocene faulting seem to be responsible for the varied directions in strike and dip of these formations.

After the aforementioned rocks were folded and faulted, there occurred extensive denudation, probably covering the whole or the greater part of the Eocene. This was a land stage. Over this eroded surface there occurred intensive volcanic activity, resulting in the present area, in the production of andesite and liparite. These volcanic rocks were later subjected to extensive denudation, marking the stratigraphical break existing between the Paleogene and Neogene formations of Japan. The pebbles of these Oligocene andesite and liparite flows are found in the conglomerate of the Miocene Moniwa formation.

Upon this eroded surface of pre-Miocene age, there occurred extensive volcanic activity resulting in the production of flows of andesite, basalt, liparite, and their agglomerate and tuffs. During this period of volcanism, land condition prevailed in the Sen-nan area, in part of Sendai Proper and also in the Shiogama area, while elsewhere marine transgression had already begun. Lower Miocene deposits interfinger with the flows of andesite and their agglomerates in the southern area of Sendai Proper and also in the northernmost part of the Matsushima-Nobiru area.

The present area was influenced by the northward invasion of southern seas and the land was under the influence of warm climatic conditions. The land conditions favoured the luxuriant growth of the *Comptoniphyllum-Liquidambar* flora and the migration of *Eostegodon pseudolatidens* Yabe from the Asiatic continent.

The marine conditions were also warm as can be known from the occurrence of *Lepidocyclina* (*Nephrolepidina*) *japonica* Yabe, *Echinolampas yoshiwarai* P. de Loriol, and tropical molluscan genera as *Conus*, *Morum* and others. This warm water condition and mild climate continued to the Middle Miocene when conditions gradually altered to cool. The terrestrial Tsukinoki and the marine Moniwa formations are the characteristic Lower Miocene formations in the present area.

The transgression of shallow water of the Moniwa gradually merged into deeper water sediments by gradual submergence, resulting in deposition of the Hatatate formation, in the Tomiya, Shiogama, and Matsushima-Nobiru areas, shallow water conditions still prevailed although a part of the latter mentioned area was subjected to submergence. The fauna of the Hatatate formation in having *Ancistrolepis*, *Yoldia*, *Nuculana* and other deep water mollusca, represents the maximum deepening of the Natori group. These fossils evidently indicate deep water rather than cold thermal conditions. This sea was deepest in the area of Sendai Proper, shallower in the Tomiya and Shiogama areas and moderate in the Matsushima-Nobiru area, in the latter area *Desmostylus* and *Vicarya* characteristic to the Middle Miocene have been found.

Gradually the seas became shallower during Tsunaki time. The shallowing due to the regression of the sea and relative uplift of the land, was accompanied with slight volcanicity during and near the final stage. Marine shells occur in association with agglomeratic tuff in the upper part of the Tsunaki formation thus indicating that the agglomeratic tuff was partly marine. The presence of shallow water molluscs in the Matsushima-Nobiru area, of inferior lignite in the Tsunaki district in the western part of Sendai Proper and of wide-spread false-bedding in the Tomiya area are all evidences of the shallowing of the seas by regression and relative uplift of the land.

The climatological conditions during Tsunaki time were cooler than that of Moniwa time as can be recognized by the change in faunal assemblages.

The withdrawal of the Tsunaki seas was followed with uplift of the land which was thereby subjected to denudation, faulting and tilting,. This stratigraphical break marks the first movement of the Hisanohama-Iwanuma fault and tilting line, and also of its extension, here to be called the Mitaki-Ishikura fault. This activity was succeeded by eruption of Kamabusa dacite.

As a result of the above-mentioned movement or disturbance, the present depression between the backbone ranges or Ou Mountains and massifs of Abukuma and Kitakami was brought into existence. It is in this depression that the Akyu group was deposited.

Just before the close of Shirasawa time, dacite eruption occurred in the southern part of Iwate Prefecture and in the northern part of Miyagi Prefecture. This eruption was followed by extensive denudation, folding, and submergence of the land. This period marks the stratigraphical break between the Miocene and Pliocene.

The flora of the Shirasawa time is replaced by a cool climatic assemblage characterized by *Sassafras Yabei* Endo and Okutsu, *Fagus americana* Sweet, and others, while the *Comptoniphyllum-Liquidambar* flora so characteristic of the Lower and Middle Miocene Natori time has become extinct. The flora of the Upper Miocene represents an elevation about 800 meters in present day Aomori Prefecture. This cool climatic flora is a characteristic features of the Upper Miocene of Japan. Shirasawa time is also important because of its representing the extensive Paleo-Sendai lake, already described in detail by S. Hanzawa (1950, pp. 85–90).

The opening of the Pliocene in the Sendai and other areas commenced with eruption of flows of andesite and its agglomerate accompanied with tuffs. Where these volcanic are lacking, thick beds of conglomerate with andesite blocks take their place.

Gradual submergence of the land, periodic volcanic activity and the formation of terrestrial deposits in the marginal regions of the paleobay now coming into existence, resulted in the interfingering of the lignite beds of the Kameoka formation with the Mitaki andesite in the western border of Sendai. Continued submergence of the land lead to the transgression of marine water over the terrestrial deposits, by which the long and narrow Tatsunokuchi formation was deposited.

Prior to the major transgression, fluctuation of the sea relative to the land resulted in the alternating layers of lignite and marine shell bearing beds. This short period of fluctuation was soon overcome by rather extensive marine transgression which is responsible for the buliding of the Tatsunokuchi formation.

The Tatsunokuchi formation extending from near Hitachi-Omiya in Ibaragi Prefecture, along the Pacific foreland of the Abukuma massif, northward until near Ichinoseki City in Iwate Prefecture, was deposited in a shallow sea which brought down from the north the characteristic scallop known as *Fortipecten takahashii* (Yokoyama). The fauna of this sea is typified by the paucity of species, abundant individual number, large and heavy shells and cold water aspect. Only shallow water facies are recognized during Tatsunokuchi time.

Gradual regression of the sea left false-bedded tuffaceous sands and sandstones or siltstónes with sand-pipes at the uppermost, while continued regression relative to uplift of the land again brought the Tatsunokuchi deposits to subaerial denudation.

After a short period of denudation, terrestrial conditions again prevailed during which time the Kitayama formation with lignite was deposited. The marginal facies of the Kitayama yield such brackish water shells as *Corbicula leana*

Prime, thus proving that the formation, in part, was within the influence of either land drained water or marginal lagoon facies. Following deposition of the Kitayama formation under modified climatic conditions, volcanicity commenced. By this volcanicity thick beds of ash were deposited. This ash is partly subaerial and partly subaqueous as can be inferred from the stratified and more or less water sorted portions of it, also the evidence of stream deposition is seen at places as along the Hirose River opposite the former zoological garden at Hyojogawara in Sendai City. Pisolitic tuff at the basal part of the Hirosegawa tuff, false-bedding, natural charcoal and drift woods, all serve to tell the conditions prevailing at this time.

The Hirosegawa tuff by gradual lowering of the land was subjected to lagoonal conditions under which the lignite beds of the Yagiyama formation was deposited. In the Yagiyama formation of terrestrial origin are found lignite beds which are workable and of fair quality. The flora of this time seems to have become more moderate compared with the temperatural conditions indicated by the cool Shirasawa flora.

The Yagiyama formation, formed during submergence of the land, was by continued submergence overflown with a shallow sea which was responsible for the construction of the Dainenji formation. The fauna of the Dainenji sea consists of species now living in the region of northeren Iwate Prefecture to the sea area of Miyagi Prefecture. This fact implies that the conditions were moderate and similar to the conditions now prevailing off the aforementioned areas.

Gentle folding and emergence of the land relative to regression of the sea lead to the extensive denudation or Pleistocene peneplanation which marks the stratigraphical break between the Pliocene and Pleistocene in the region under discussion. The time endured by the Sendai group was a quiet period, there being no indications of folding, faulting or other noteworthy diastrophic movement.

After deposition of the marine laid Aobayama formation, revival of the Hisanohama-Iwanuma fault and tilting line and the Nagamachi-Rifu fault, the broad coastal plain of Miyagi was submerged prior to its emergence which brought its present form into existence. By the influence of the above-mentioned faults the eastern part of the Matsushima and the northern part of the Shiogama districts were thrown down to make Matsushima Bay. The submerged region has drowned valleys now covered with thick mud. This diastrophism was accompanied with the Ashinokuchi thrust, Murata thrust, Kagitori fault, and many other faults, normal and reverse, of various magnitudes.

This down-throw of considerable magnitude was followed by gradual uplift of the land during which time the rivers, Shiroishi, Natori, Hirose, Nanakita, Yoshida, and Naruse, then already in existence, had begun terrace making. The terraces formed by the mentioned rivers, classified into five groups, according to height, were later subjected, by warping, to slight tilting along the axes of roughly N-S and E-W directions. The rate of uplift of Matsushima Bay seems to have been slower than that of the adjacent regions, although emergence of the bay is still continuing,

During construction of the above-mentioned terraces, volcanicity had commenced, whereby the Aoso and Natori volcanics poured out andesite lava and ash in large quantities.

The period following construction and volcanicity of the aforementioned was experienced with landsliding at Dainenji, between Monjudo and Goroku and also along the Senzan railway line. These landslides seem to have had direct relation with subsurface movement.

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