The Cenozoic Strata of Noto, Japan

AUTHOR(S):

Ishida, Shiro

MEMOIRS OF THE COLLEGE OF SCIENCE, UNIVERSITY OF KYOTO, SERIES B,
Vol. XXV, No. 2 Geology and Mineralogy, Article 2, 1959

The Cenozoic Strata of Noto, Japan

By

Shiro ISHIDA

Geological and Mineralogical Institute, University of Kyoto

(Received Aug. 31, 1959)

Abstract

The Mioene Noto Group represents the submarine volcanism in the ages of "the Green Tuff". It is classified into the Suzu, Yanagida and Anamizu Formations. The Suzu Formation shows a cycle of sedimentation and yields *Miogypsina*, *Vicarya* and *Vicaryella*, the well-known Middle Miocene forms, but its upper part represents the epibole of *Sagarites*, that is considered to be the Upper Miocene. The Yanagida Formation is characterized by dacites and basalts. It is the Green Tuff of the lower Middle Miocene indicated by *Bunolophodon* and the *Liquidambar-Comptonia* flora. The Anamizu Formation is characterized by the andesitic ejection. Of the 13 terraces around the peninsula, the lowest coastal terrace (60 to 15 m in height) yields mollusks, foraminifers and plants showing a warm temperate circumstance. These formations are folded and faulted, represented by two EW synclines. A general view of the historical geology is given in the section of "Structure". The stratigraphical correlation to the other regions are mentioned in the final section.

Introduction

The Noto peninsula geologically being a part of "the Miocene Green Tuff region"[1] is consisting of the neogene strata[2)3)4)5)6)7)8)9)10)11] over the basement of the Hida complex, that is granite gneiss, crystalline limestones and granites. Some terrace sediments are also seen. The west boundary of the district concerned is defined by the road connecting Wajima and Anamizu. The elevated hill range is in the northwest part, inside of which are wide flat surfaces of terraces very gently sloping towards the south inner shore. The range includes Mt. Kônosu 567 m, Mt. Hachibuse 543.6 m, Mt. Kofuji 424.8 m, Mt. Hôryû 468.5 m and Mt. Neko in the vicinity of Kakuma 412.7 m. Only the Miocene beds, "Noto Group"[12] and the terrace sediments are under the writer's examination. The basement complex cannot be seen within this limit. No Pliocene rock exists in this district. The stratigraphical succession of the Miocene is determined as follows, in descending order :—

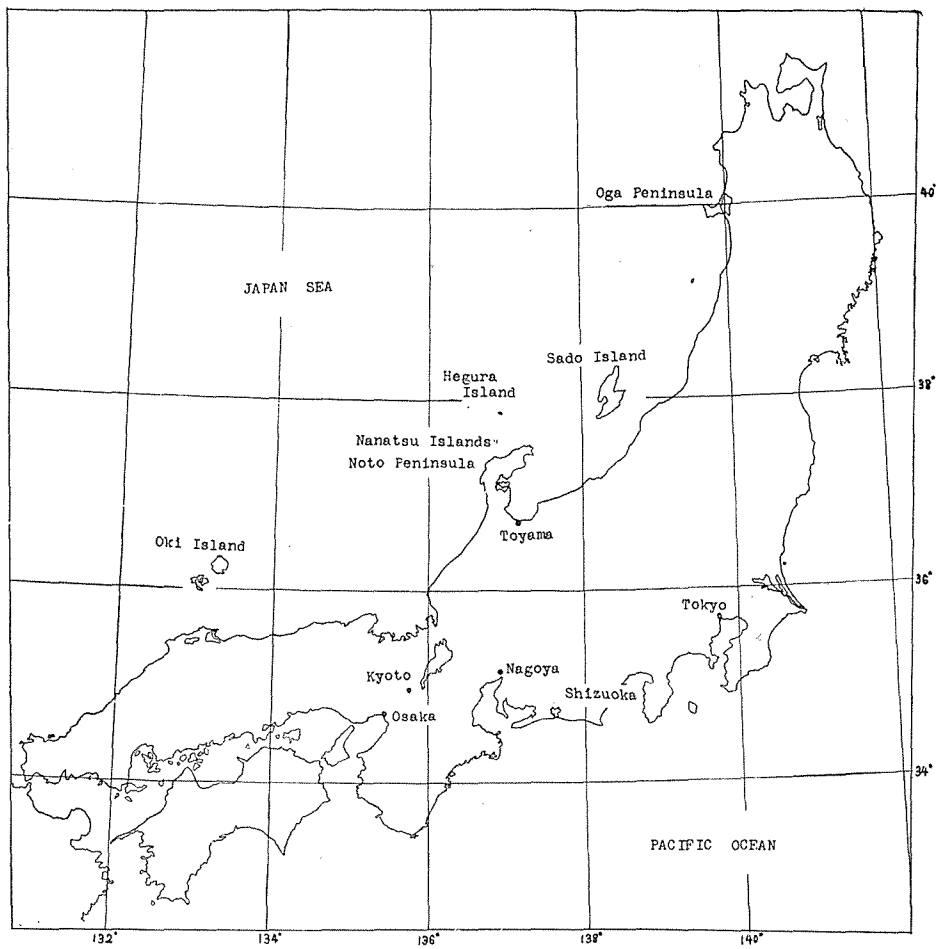


Fig. 1. Index Map.

SUZU FORMATION

Najimi black mudstone, with a glauconite bearing flinty bed and partly diatomaceous beds.
Iwakurayama liparite and Awagura tuff
Akagami hard shale, in part diatomaceous
Higashi-innai alternations, with the middle Miocene fauna

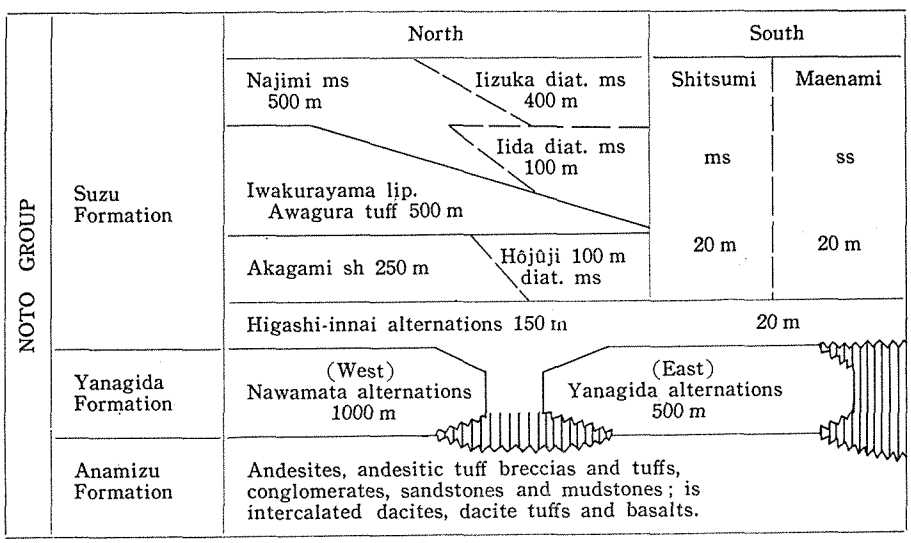
YANAGIDA FORMATION

basalts and dacitic sediments with the middle Miocene flora and *Bunolophodon annectens*

ANAMIZU FORMATION

andesites, andesite pyroclastics and clastic sediments derived from them.

Small patches of the Suzu seen on the sea-shore of the south are made of two parts. The lower subdivision is the Higashi-innai alternations. The upper is Shitsumi Aphrocallistes mudstone and Maenami calcareous sandstone, both correlated to the section between the Najimi and Akagami horizons. The Maenami yields *Chlamys crassivenia* and *Aphrocallistes* sp..



Anamizu Formation[12]

The basal Formation consits of alternating andesites, andesite tuffs and its tuff breccias and conglomerates with alternations of sandstone and mudstone. There are also intercalation of small masses of dacite, dacite tuffs and basalts. In the Shinobu area, there is a diorite sheet intruded into the andesite. This diorite is given a name "the Shinobu diorite".

The andesites are augite hyperthene and augite hyperthene hornblende andesite. There is no propyrite in this district.

The andesite tuff breccias largely contain angular cobble with subordinate pebbles and blocks of andesites. The matrices of the tuff breccias are coarse andesite tuffs, tuffaceous sandstones and mubstones.

The conglomerates contain subround to round cobbles of andesites, and also a smaller quantity of the pebbles and boulders. The matrices of conglomerates are coarse andesitic sandstone.

The alternations of sandstone and mudstone are chiefly andesitic or dacitic, and contain also arkose sandstones and shales. The shales contain the plant fossils, *Libocedrus* sp., *Glyptostrobus europaeus, Metasequoia occidentalis,* at Soyama, Ikuro and Konoki.

The dacites and basalts always coexist, and their rock characters are same as those of the Yanagida Formation.

The rock characters of the diorite vary from place to place between diorite and gabbro, showing certain alterations that suggest the epithermal effect.

The Anamizu was made under the waters, and yields small foraminifers in the sandstones at Uwano and the north of Ikuro. With this exception, there is no evidence of its marine origin. At the east of Anamizu, the alternations of sandstone and mudstone are intercalated by the lignitic relics of *Monocotyledoneae,* apparently autochthonous origin.

Ts : Terrace sediments

A : Anamizu Formation
- Adt : Dacite tuffs
- Ad : Dacites
- Ab : Basalts
- Asm : Alternations of sandstone and mudstone
- Ac : Conglomerates
- At : Audesite tuff breccias
- Aa : Andesites

Fig. 2. Geological map of the Soyama area.

The arkose sandstones and shales exposed in the E–W anticlinal core of Guntani and Soyama are the lowest horizon of the Anamizu seen in the area. They may belong to the Masuho Formation[14], the lowest member of the Noto Group. The

andesite was eroded in part and overlain by conglomerate, which is again overlain by another sequence of rocks consisting of andesite, andesite tuff breccia, arkose sandstones and shales, conglomerates and alternations of sandstone and mudstone.

The andesites make the thick masses arranged along the north-south line connecting Mt. Kofuji and Mt. Futago. All the Masses thin away westwards. The thinned andesites are replaced by the andesite tuff breccias and then the breccias are replaced by conglomerates. The alternations of sandstone and mudstone successively take the places of the conglomerates. The dips are 10° to 45° to nouthwest in the north side of Soyama, while those in the southside are 15° to southeast.

Yanagida Formation

The Yanagida Formation consisting of dacites, basalts and dacitic tuffaceous sediments lies over the Anamizu Formation. The Yanagida Formation, in the east, consists of the alternations of dacite, dacite tuff as well as basalt, with subordinate andesite limited to a small area to the northwest of Hôjûji. The lithofacies of the last is represented by the alternating dacitic materials with a name of "the Yanagida alternations". In the west, the Yanagida consisting of conglomerates and the alternations of dacite tuff, tuffaceous sandstone and mudstone is given a name of "the Nawamata alternations".[15]

The dacite is light gray, light red or blue in colour, includes the phenocrysts of andesine in the glassy or cryptocrystalline groundmass, and shows the flow structure and the platy joints. The chemical composition of the dacite at Jûhassoku is as follows.

SiO_2	72.76
Fe_2O_3	1.98
FeO	0.48
Al_2O_3	16.50
CaO	3.04
MgO	0.46
K_2O	1.02
Na_2O	2.93
$+H_2O$	0.46
$-H_2O$	0.34
	99.97

analysed by KASAMA*

A dacite flow is generally 150 m in thickness and and 3-4 km in horizontal diameter.

The dacite tuff is dark gray or green coloured and pumiceous, and contains accidental fragments of andesites belonging the Anamizu. The pumice of tuff are mostly the pebbles or cobbles in size. The tuff is intercalated by the mudstone containing Radiolaria at Oya and Ogi. At Ushitsu, the alternations of tuffaceous mudstone and sandstone of the Yanagida contain diatoms of fresh water, *Melosira.*

The basalt is black and lustrous, and bearing olivine and augite. When weathered, it is characterized by the patches of white feldspar, the brown olivines and the onion structure. Generally a flow sheet of basalt is 20 m thick with a diameter some 3-6 km.

* The Industrial Art Institute of Ishikawa Prefecture.

Amygdaloidal druses filled with aragonite or calcite; the virgin waters are found at Koiji, north of Ushitsu, Suzugamine and Omou. Chemical composition** of the basalt of Koiji is as follows.

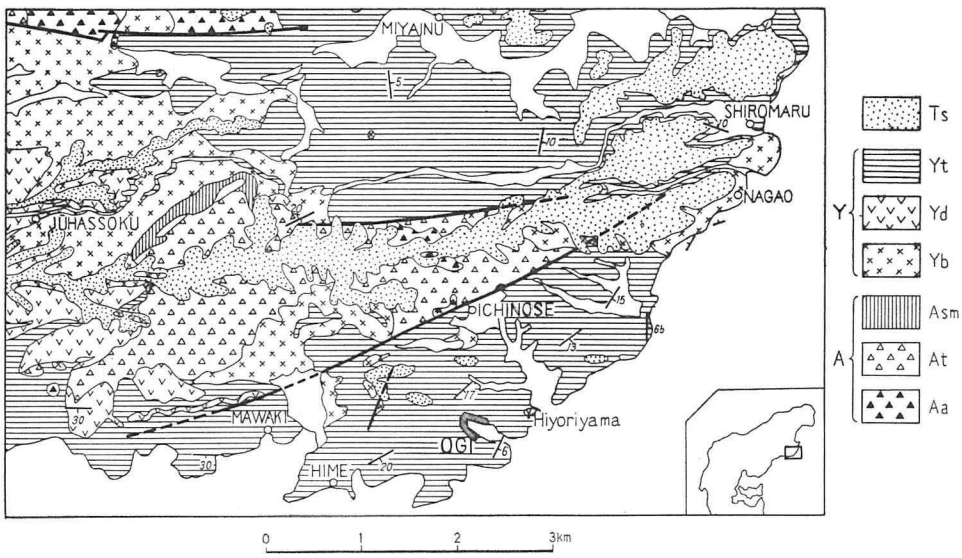
SiO_2	51.31
TiO_2	0.81
Fe_2O_3	13.36
Al_2O_3	14.99
CaO	9.85
MgO	5.22
MnO	0.08
K_2O	0.55
Na_2O	2.75
	98.92

The basalt overlies the andesite tuffs of the Anamizu conformably in the area Ogi and the north of Ushitsu. At the east of Wajima, the basalt thins away eastwards into the andesite tuff breccia under the dacite, while on the other hand, the Yanagida alternations abut the andesites and andesite tuff breccias of the Anamizu between Komata and Ushitsu and in the hills northwest of Matsunami.

In the northeast end of the peninsula, the dacite tuff intercalates the light orange-coloured tuffaceous shales with the plant fossils. The tuff conformably overlies the alternations of conglomerate, sandstone of the Anamizu. The sandstones of the alternations contain some foraminifers. The shales have in them the fossil plants[16] those do not give any evidence for the marine origin, but there is a lacustrine form *Hemitrapa*. The following fossil plants are those remind the Daijima-type species[17]: *Picea* sp., *Pinus* spp., *Metasequoia occidentalis*, *Taiwania* sp., *Libocedrus* sp., *Comptonia naumannii*, *Carya miocathayensis*, *Platycarya miocenica*, *Pterocarya* spp., *Alnus kefersteinii*, *Betula mioluminifera*, *B.* 3 sp., *Carpinus micoordata*, *C. miocenica*, *C. miofargesiana*, *C. shimizui*, *C. subedoensis*, *Ostrya japonica oblongibracteata*, *Fagus* sp., *Castanea atavia*, *C. ungeri*, *Cyclobalanopsis mandraliscae*, *Dryophyllum* sp., *Lithocarpus protokonishii*, *Quercus subvariabilis*, *Celtis* sp., *Ulmus longifolia*, *Zelkova ungeri*, *Ficus plinerva*, *Cinnamomum miocenum*, *Liquidambar "formosana"*, *Albizzia* sp., *Cercis miochinensis*, *Maachia* sp., *Podogonium knorri*, *Mallotus* sp., *Acer florni*, *A. palaeodiabolicum*, *A. subpictum*, *Rhus miosuccedanea*, *Spondias* sp., *Sapindus kaneharai*, *"Dodonea" japonica*, *Berchemia miofloribunda*, *Paliurus miosinicus*, *Zizyphus* sp., *Tilia distans*, *Hemitrape borealis*, *Fraxinus* spp.

The rock characters of the Nawamata are not essentially different from that of the alternations of sandstone and mudstone in the Anamizu. However, the Nawamata is stratigraphically situated at the same horizon as the Yanagida alternations. *Bunolophodon annectens*[18] has been discovered in the Nawamata at Hosoya.

** Graduation thesis of Faculty of Science, Kanazawa University by H. NAKADE (1959).



Ts: Terrace sediments Y: Yanagida Formation A: Anamizu Formation

- Yt: Dacite tuffs
- Yd: Dacites
- Yb: Basalts
- Asm: Alternations of sandstone and mudstone
- At: Andesite tuff breccias
- Aa: Andesites

Fig. 3. Geological map of the Ogi area.

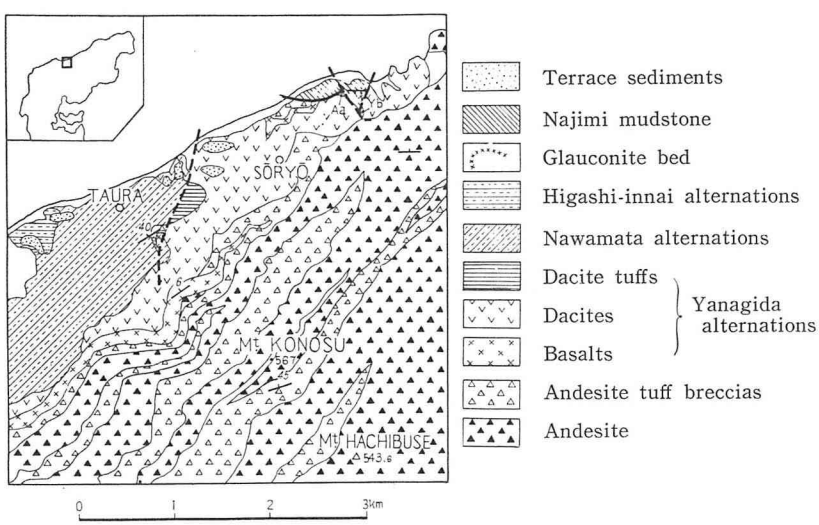
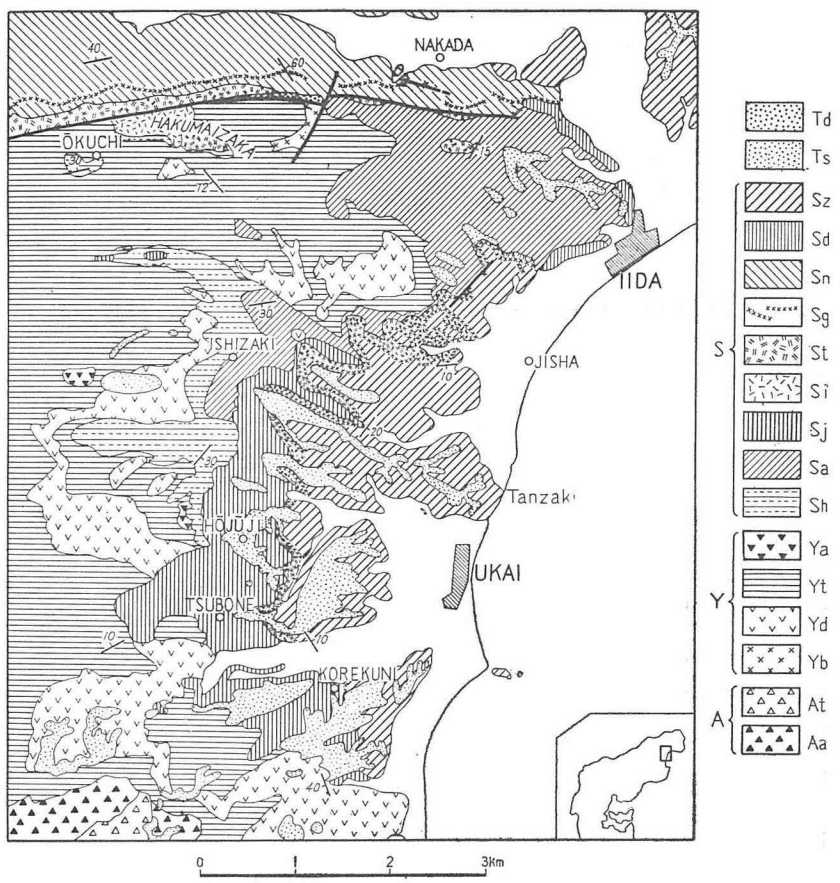


Fig. 4. Geological map of the Mt. Kônosu area.

Suzu Formation

The marine Suzu Formation was deposited over the Yanagida Formation. The Suzu Formation, in the north, is made of thick strata intercalating the liparites and liparite tuffs. They are folded with an axis of east and west direction. On the contrary, it is thin and almost horizontal in the middle and the southern parts.



Td : Talus deposits
Ts : Terrace sediments
S : Suzu Formation
- Sz : Iizuka diatomaceous ms
- Sd : Iida diatomaceous ms
- Sn : Najimi ms
- Sg : Glauconite bed
- St : Awagura tuff
- Si : Iwakurayama liparite
- Sj : Hôjûji diatomaceous ms
- Sa : Akagami sh
- Sh : Higashi-innai alternations

Y : Yanagida Formation
- Ya : Andesites of the Yanagida
- Yt : Dacite tuff
- Yd : Dacites
- Yb : Basalts

A : Anamizu Formation
- At : Andesite tuff breccias
- Aa : Andsites

Fig. 5. Geological map of the Ukai area.

The Suzu Formation conformably overlies the Yanagida, but for that it overlies obliquely the erosion surface in Ushitsu. It unconformably overlies the Anamizu Formation in areas where the Yanagida is lacking. The succession of the Suzu in the north side is as follows, in descending order:—

Najimi mudstone[19] is black to brown, massive, partly shaly, with a glauconite bearing flinty bed and contains *Sagarites chitanii*, Radiolaria, sponge spicules and diatoms. The foraminifers is rare excepting the material from north of Higashiyamanaka and Yanagida. *Conchocele disjuncta, Lucinoma acutilineatum, Chlamydoselachus* sp., *Carcharodon megalodon* and *Isurus hasitalis* are the noteworthy fossils though rare. It is diatomaceous in Wajima, the south of Najimi and Iizuka. The upper diatomaceous mundstone that is the very bed bearing glauconites is named "Iizuka diatomaceous mudstone"[20]; the lower one is named "Iida diatomaceous mudstone"[21]. These are blue black, massive, soft, and containing a great number of Radiolaria and sponge spicules in addition to diatoms[22], *Coscinodiscus, Actinocyclus, Actinoptychus, Arachnoidiscus, Biddulphia, Diploneis, Mastogloia, Rhabdonema, Stephanopyxis, Triceratium.* Where the Najimi mudstone is changing into the diatomaceous mudstone, there are several intercalations of the flinty bed.

In the west part of the area of the Najimi mudstone, its base is black, flinty, 2 m to 3 m thick, with dense glauconites grains. This glauconite bearing flinty bed is situated in a higher horizon than the base of the Najimi, in consequence of the thinning of the Awagura towards the east.

The flinty hard shales which have no glauconite lie at about the same horizon as the glauconite bearing flinty hard shale. There is diastem below the shale as shown by that the glauconite bearing bed is made of siliceous colloid or clay and is widely continuous.

Iwakurayama liparite[23] and Awagura liparite tuff[24] are of the same origin. The liparite is seen in Iwakurayama and Hakumaizaka. It is gray white or light green in colour, and in part it has conspicuous phenocrysts or in the other part it indicates the flow structure. The phenocrysts are biotite, quartz and oligoclase or andesine. The chemical composition of the liparite obtained at the north of Hakumaizaka is as follows.

SiO_2	75.91
Fe_2O_3	0.51
FeO	0.41
Al_2O_3	14.76
CaO	0.62
MgO	0.30
K_2O	3.12
Na_2O	2.08
$+H_2O$	1.26
$-H_2O$	0.54
	99.51

analysed by KASAMA

The tuff is light blue to green, pumiceous and thickest at around Iwakurayama; the thickness suddenly decreases westwards.

Akagami shale[25] is gray or light orange in colour, siliceous and hard, with *Sagarites chitanii* and some foraminifers. It yields *Paramusium* sp. and *Schizaster* sp. in the lower part. At the northeast end, thick Akagami overlies the dacite tuff of the Yanagida.

At Tsubone and Hôjûji, the southwest of Iida and Kirihata, the Akagami horizon is represented by a diatomaceous mudstone similar to Iida diatomaceous mudstones. The Hôjûji diatomaceous mudstone[26] contains Foraminifera, Radiolaria and sponge spicules.

Higashi-innai alternations[27]

The upper part consisting of alternations of sandstone and mudstone largely contains carbonized fragments of plants in the sandstones, and *Sagarites chitanii* in the mudstones. The lower part yields *Pecten kimurai*, *Lucinoma acutilineatum* and *Shichiheia etchüensis* in Kuninagade and Wanizaki. At Kakuma, there is no upper bed but for a glauconite bearing gray coloured fine sandstone 1 m in thickness.

The lower part consists of alternations of conglomerate, sandstone and mudstone. The conglomerates are characterized in connexion with the basements *in situ*. It is rich in marine organisms such as; *Miogypsina kotoi*, *Operculina complanata japonica*, *Astriclypeus manni*, Bryozoa, *Protolobophyllia* sp., *Meandra* sp., *Montastrea* sp., *Lithothamnium* sp. The fossil fauna shows a shallow and warm environment and contains some important mollusks[28] as follows. *Anadara kurosedaniensis*, *Ostrea* sp., *Ctena* sp., *Turbo parvuloides*, *Nerita* sp., *Cypraea* sp., *Proterato* sp., *Vicaryella notoensis*, *Conus tokunagai*.

In the middle area, the Suzu Formation is about 200 m thick and almost horizontal over the dacite tuff. The Suzu and Yanagida Formations in this area abut the andesite of the Anamizu. The Akagami shale is lacking in this area.

Najimi mudstone is brown, silty, with foraminifers and not intercalated by the glauconite bearing bed.

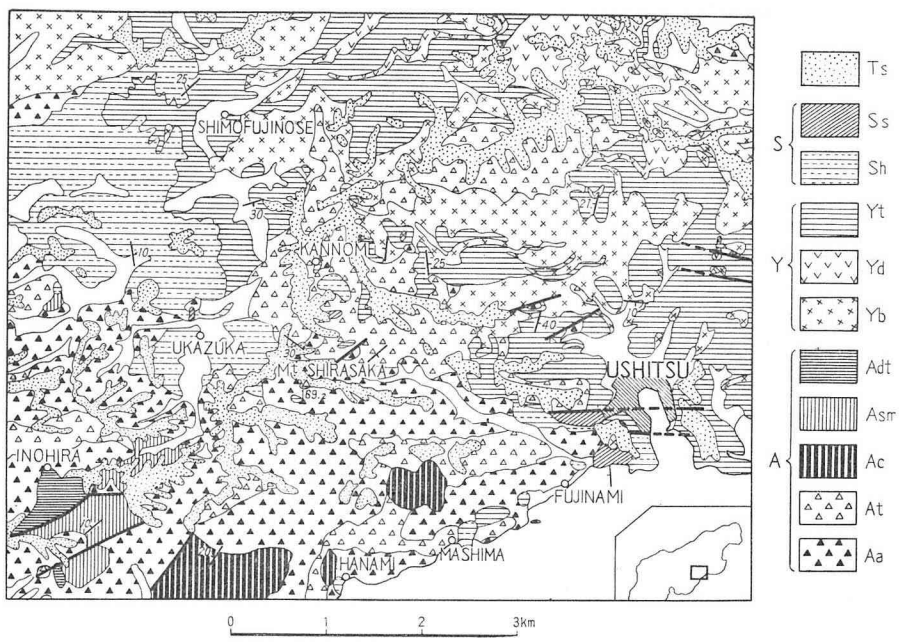
Awagura tuff is not over 40 m in thickness.

Higashi-innai alternations consising of conglomerates and sandstones yield *Miogypsina kotoi*, *Operculina complanata japonica* and mollusks.[29] At Tokunari, molluscan fossils such as *Anadara kurosedaniensis*, *Vicarya callosa*, *Vicaryella notoensis* and *Batillaria yamanarii* are discovered.

The Suzu Formation in the southern area exists only as intermittent patches along the shore, and it is naturally thin.

Shitsumi Aphrocallistes mudstone is characterized by a large amount of the spicules of *Aphrocallistes* sp. and no solidification. It is massive black, partly sandy and contains rich diatoms and Radiolaria. It contains a considerable quantity of scattered glauconites and is intervened between the glauconites bearing flinty beds at Ōkabuto, and contains the phosphate ore[30] at Ushitsu and Shitsumi. *Desmostylus japonicus* has been discovered at Shitsumi[31]; the exact occurrence is not known.

Maenami calcareous sandstone consists of silstones and fine sandstones. It overlies the Higashi-innai in Maenami and Zenzukaiwa and is lying over the liparite tuffs in Wajimazaki. It yields *Chlamys crassivenia* and *Aphrocallistes* sp.



Ts : Terrace sediments
S : Suzu Formation
- Ss : Shitsumi ms
- Sh : Higashi-innai alternations

Y : Yanagida Formation
- Yt : Dacite tuffs
- Yd : Dacites
- Yb : Basalts

A : Anamizu Formation
- Adt : Dacite tuffs
- Asm : Alternations of ss & ms
- Ac : Conglomerates
- At : Andesite tuff breccias
- Aa : Andesites

Fig. 6. Geological map of the Ukazuka area.

Higashi-innai alternations consisting of conglomerates and sandstone occur at Majima, Hanami, Yanami, Ukawa, Ōkabuto and Kanami with fossil mollusks and foraminifers as follows: *Anadara abdita, Leukoma* sp., *Venerupis siratoriensis, Littorinopsis miodelicatula, Cerithium ancisum, Nassarius simizui, Operculina complanata japonica.*

At the north of Matsunami, it is muddy with cast of such fossils as: *Anadara* sp., *Striarca* sp. *Volsella* sp., *Joannisiella* sp., *Felaniella ferruginata, Lucinoma acutilineatum, Bellucina* sp., *Clinocardium* sp., *Nemocardium* sp., *Dosinia* sp., *Clementia* sp., *Paphia* sp., "*Macoma*" sp., "*Tellina*" sp., *Fusinus* sp., *Siphonalia* sp., *Nassarius* sp., "*Cylichna*" sp., *Dentalium* sp.,

At Ukazuka, the fine sandstone is rich in fossil mollusks and small foraminifers, and there is *Operculina complanata japonica.* The mollusks are as follows:
Nucula (*Lamellinucula*) sp., *Acila submirabilis, Nuclana* (*Thestyleda*) sp., *Saccella confusa congiensis, Anadara abdita, A. ogawai, Glycymeris minoensis, Chlamys akitana, Volachlamys* sp., *Placopecten* sp., *Pecten* (*Serratovola*) sp., *Ostrea* sp., *Crassatellites toyamaensis, Venericardia* (*Megacardita*) sp., *Joanisiella meisensis, Thyasira* sp., *Notomyrtea* sp., *Bellucina* sp., *Dosinia akasiana, Tigamona* sp., *Leukoma itoigawae, Venerupis*

siratoriensis, *V.* (*Amygdala*) sp., *Solidicorbula erythrodon nisataiensis*, *Clementia iizukai*, *Tellina* sp., *Dentalium* spp., *Emarginula* sp., *Calliostoma* spp., *Turritella s-hataii*, *Cerithidea* sp., *Cerithium* sp., *Cancellaria* sp., *Nassarius kometubus*, *Conus* spp..

Terrace Sediments

The elevated hill range is in the northwest part, inside of which are wide flat surfaces of terraces very gently sloped towards the south inner shore. Terraces of various heights are encountered. There are identified 13 terraces along the section of Mt. Hachibuse and Kanami, 5 km to the southeast of Hashikari, those 360, 320, 300, 260, 220, 180, 160, 140, 120, 100, 80, 60, and 40 m. Almost uniform white gray to light ochreous clays with quartzose sand beds are found upon all of these terraces with some local exceptions met with elswhere near the east and north sides. The clays and sands attain 10 m in thickness, but more commonly they are 1.5 to 2 m. Evidently these were deposited under the waters though no fossil is found in the sediment.

The terrace sediments of the heights between 60 m and 15 m in the east and north sides are coastal. Those have been named Hiradoko terrace and Matsunami terrace.[31] They are consisting of 5 m thick sands, clays and gravels. At Hiratoko and Miyainu, the fossil shells,[32][33] foraminifers[34] and plants occur in the bluish-gray sand and clay of the basal part. The fauna is that lived in the water of the warm current. The flora includes *Fagus crenata*, the indicator of the temperate forest region.

Structure

The Note Group is folded and faulted with the trends of NE–SW, and gently folded with NS to NWN–SES trends. Thus, it is evident there are two crossed elements that controlled the sedimentation of the Noto Group and the structure of the peninsula. The submarine topography[35] in the north extension of the peninsula shows this control of the two elements.

Soyama anticline (1) of the Anamizu runs from Soyama to Hashikari with E–W trend and gentle pitch westwards.

Tategayachi-pass anticline (2) and Ogi anticline (3) are joined with two formations the Anamizu and the Yanagida. They are conformable here. Both the north and south wings of the Ogi are faulted. Therefore, it is able to say the anticline is horst-like.

Mt. Hôryû anticline (4) runing from the south of Higashi-innai through Mt. Hôryû to Iida is situated in the south side of main syncline of the Suzu. The Yanagida and the Suzu Formations being conformable are making this anticline which is asymmetrical. The beds of the north wing largely dip to the north, and there is a fault. This fault is named Hakumaizaka fault (5). The anticlinal crest is merging in the north of Yanagida and depressed downwards near Iida in the east.

Suzu syncline (7) is the main syncline of the Suzu Formation forming a synclinorium in part. The dips of beds of the south wing are steep to overturned with a partly fault.

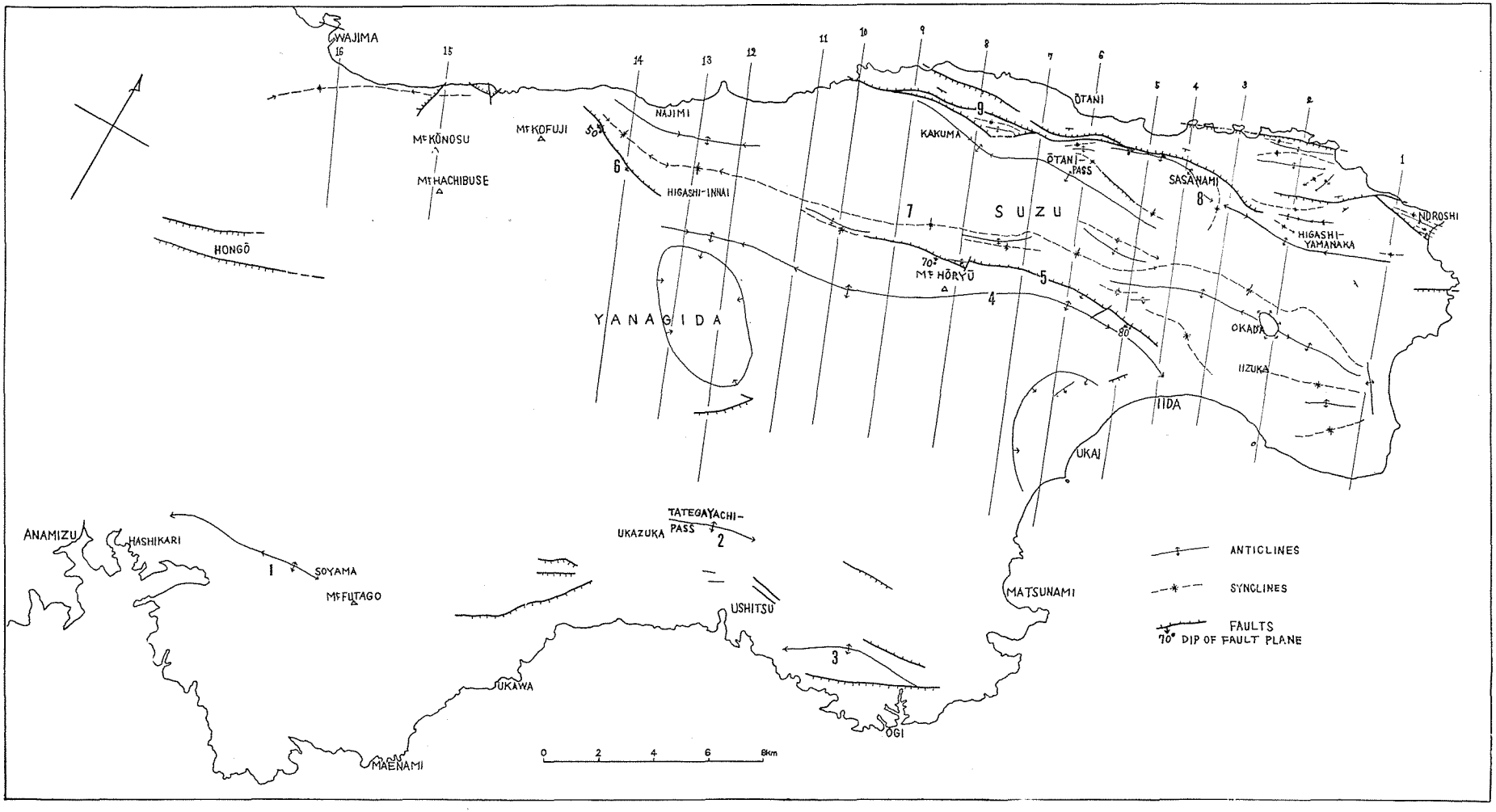


Fig. 7. Outline map of structure.
Paralell lines with numbers 1–16 show locations of profiles (Fig. 9).

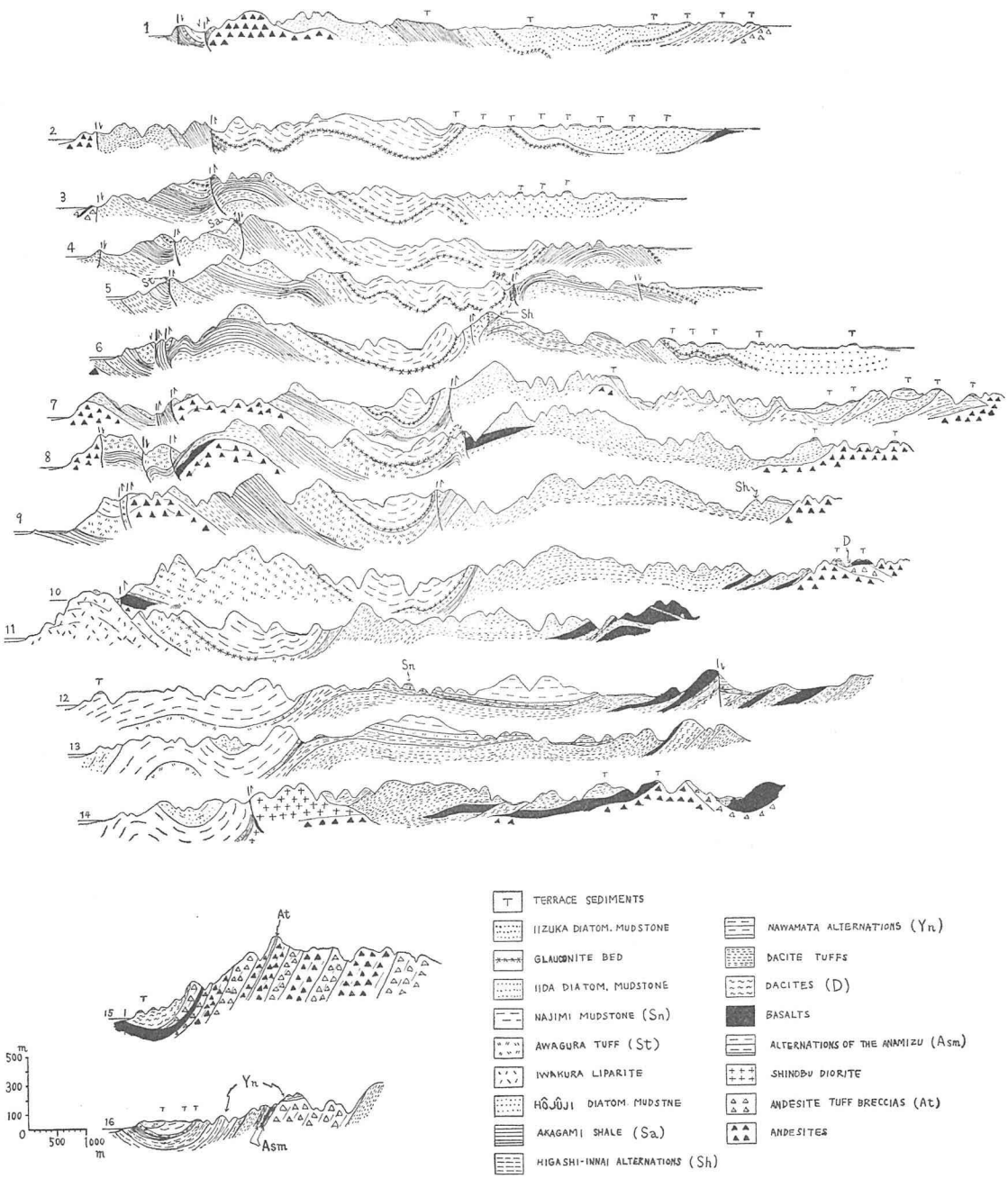


Fig. 8. Geologic profiles of the north part.

Shinobu fault (6) is situated in the west part of the south wing. It is a reverse fault dipping 50° to the south.

The Hakumaizaka fault is a high-angled reverse fault thrused toward the north. The Nakada gypsum deposits[37] are in the line of the fault. The each gypsum ore is fusiform with a diameter of 100 m and chiefly occurs in the Najimi mudstone. The ore is included in the matrix of balck clay containing zincblende, calcite, pyrite and chalcopyrite. The deposit belongs to the so-called "Black Ore" the hydrothermal deposit.

Saikai fault (9) running from Maura to Karakasa is situated on the axis of syncline.

Sasanami anticline (8) runs from the north of Norisada through Sasanami to Mt. Yamabushi. The west part of the anticline is inclined northwards and situated in the south side of the Saikai fault. The east part is saddle-like in the vicinity of Higashi-yamanaka.

Of the Anamizu Formation in the west area, the andesite is replaced by the tuff breccia, the conglomerate, the sandstone and the mudstone. The alternating beds of those are monoclinic in the north of the Soyama anticline, though the extension of the fault through Hongô breaks the monotonousness in the east end. The above facts may indicate that the Anamizu has been built outwards with a certain initial dip started from the vicinity of Soyama, and that the andesite accompanying the tuff breccia erupted during this age and the great mass exposed to the immediate wave erosion.

The west area and the part of Fujio to Ōtani and of the northwest of Matsunami in the east have been elevated in the age of the Yanagida. The Yanagida filled up the depression of the Anamizu. Although the eastward extension of the fault of N70°–80°E through Hongô has not been assuredly ascertaind, it may exist farther eastwards to the south limit of the area, because inasmuch as the dacite tuff of the Yanagida is especially thick, it is possible to assume a fault of the basement.

The Suzu is thickest in the north of the area of the thick dacite tuff. This part of the area seems to have been a miniature geosyncline. The sedimentation of the Suzu is effected by two elements. The E–W depressions are in the north side and in the east extension of the fault through Hongô. The axes of N–S depressions are (a) through Wajima and Anamizu, (b) through Najimi and Ushitsu and (c) of the trend of NS through Iida. The isopachal highs take places to the north of each crossing of the depressions of NS and EW, as Wajima, Najimi, Yanagida, Iizuka and Ukai.

Those areas excepting Yanagida are rich in diatomaceous mudstones, especially at the east, Iizuka and Ukai. The folds and faults have developed in the Suzu between Najimi and Iizuka. There are two synclines of a E–W direction. The Suzu syncline in the south side is asymmetrical. It has an axial plane inclined to the south and a reverse fault thrusted towards the north in the south wing. The north syncline is closed. There is the Saikai fault. These structures harmonize with the recent geography.

In the middle area, the Suzu is forming basins or flat. On the sea-shore of the south, the small patches of the Suzu abut the Anamizu. It appears that the

south shore line was made during the age of the Suzu. The Shitsumi Aphrocallistes mudstone is in inlets of the Anamizu and abuts on it. The Najimi of Yanagida differs from that of the north side and from the Shitsumi of the south shore. Their boundaries are found in the Mt. Hôryû anticline and the Tategayachi-pass anticline. Therefore, the anticlines may have been grown to some degree in the age of the Najimi.

The Suzu Formation is thin and the changes in its lithofacies are well-marked as compared with the Yatsuo of Toyama basin. The elevating back land—Hida district—was in the south side of the Toyama. Noto was a submarine plateau or flat-topped islands detached from the main land during the acme of the Miocene transgression. The pyroclastics of the Anamizu, the Yanagida and the Higashi-innai alternations were ejected from volcanoes in this district and deposited under the waters nearby. Being fine-grained, the Akagami and the Najimi are uniform in their lithofacies. It shows no rising back land.

Correlation and Age

The Note Group is similar to the Miocene beds of Island Sado[36] and Oga peninsula[37] representing the west facies of the Green Tuff in succession and thickness.

The Anamizu, Yanagida and Suzu Formations are respectively correlated to the Iwaine, Iôzen, and Yatsuo[38] and Otokawa Formations of Toyama basin.[39][40] The Yanagida differs from the Iôzen in accompanying the basalt. The Higashi-innai alternations are very much like the lower and middle Yatsuo in lithology and fauna.

	Yatsuo fauna	*Higashi-innai fauna*
	Acila submirabilis	*Acila submirabilis*
l.	*Anadara abdita*	*Anadara abdita*
l.	*A. kakehataensis*	*A. kakehataensis*
l.	*A. kurosedaniensis*	*A. kurosedaniensis*
m.	*A. ogawai*	*A. ogawi*
m.	*Pecteo kimurai*	*Pecten kimurai*
m.	*Chlamys nisataiensis*	*Chlamys nisataiensis*
	Ostrea gravitesta	*Ostrea gravitesta*
	Crasssatellites toyamaensis	*Crassatellites toyamaensis*
l.	*Geloina stachi*	*Felaniella ferruginata*
l.	*G. yamanei*	*Lucinisca k-hataii*
	Lucinisca k-hataii	*Dosinia nomurai*
	Dosinia nomurai	*Leukoma itoigawae*
	Leukoma itoigawae	*Venerupis siratoriensis*
	Venerupis siratoriensis	*Protothaca taeiwai*
l.	*Protorotella yuantaniensis*	*Calliostoma namuchakuensis*
l.	*Littorinopsis miodelicatula*	*Turbo parvuloides*
m.	*Turritella kadonosawaensis tsudai*	*Littorinopsis miodelicatula*
m.	*T. kadonosawaensis yoshidai*	*Turritella s-hataii*
l	*Cerithidea miofluviatilis*	*Cerithidea tokunagai*
	Vicarya yokoyamai	*C. kanpokuensis*

	Vicaryella notoensis	*Vicarya callosa japonica*
l.	*Telescopium nipponicum*	*Vicaryella notoensis*
l.	*Batillaria yamanarii*	*Batillaria yamanarii*
	B. tateiwai	*B. tateiwai*
	Euspira meisensis	*Euspira meisensis*
	Shichiheia etchuensis	*Shichiheia etchuensis*
	S. yokopamai	*S. yokoyamai*
m.	*Miogypsina kotoi*	*Miogypsina kotoi*
m.	*Operculina complanata japonica*	*Operculina complanata japonica*

m.: *abundant in middle Yatsuo*
l.: *abundant in lower Yatsuo*

The middle Yatsuo fauna differs from the lower Yatsuo as shown in the above list.

Tsuda[41] describes that *Anadara abdita* and *Anadara ogawai* is limited in the middle Yatsuo and *Anadara kakehataensis* and *Anadara kurosedaniensis* are limited in the lower Yatsuo.

The Higashi-innai in the south and middle areas but for Tokunari is correlated to the middle Yatsuo; the lower Higashi-innai of Tokunari and the area of north side is correlated to the lower Yatsuo.

Both the middle Yatsuo and the Higashi-innai of the south area have in them abundant *Miogypsina* and *Operculina*. These uppermost beds are the limit of *Miogypsina*. They are correlated to Tozawan[42] of Shizuoka. The upper Higashi-innai in the north area may be correlated to Tozawa, though no *Miogypsina* has been found there.

The lower Yatsuo is correlated to Togarian,[43][44] lower Middle Miocene. The lower Higashi-innai of the north area may be correlated to Togarian.

The Yanagida Formation and the Iwzen of Toyama are the Green Tuff of Togarian indicated by *Bunolophodon* and the *Liquidambar-Comptonia* flora.

The Yanagida is correlated to the Daijima of Oga in having the fossil flora including *Liquidambar* and *Comptonia*. The flora largely contains the species of Ennichi of Korea and Shanwang of China. Being the leading fossil for "Obere Mollase" or Helvetian Stage, *Podogonium knorri* is common to the "obere Süsswassermolasse" of Switzerland. However it occure in the Shanwang series of China which is supposed to be the Upper Miocene.

Then, the Yanagida and the Higashi-innai can be correlated to the Vindobonian Stage. The Anamizu has no fossil except for a few plants and small foraminifers, those not indicate an age. The Akagami, the Najimi, the upper Yatsuo and the Otokawa are correlated to Yuian[45] of Shizuoka representing the epibole of *Sagarites chitanii*. It is the Upper Miocene.

The Maenami sandstone is correlated to Yuian in having *Chlamys crassivenia*.

The coastal terrace sediments of 15 m to 60 m high in level are well dissected. The sediments yield the fossil shells and foraminifers of warm current living species. It is reasonable to consider that the current came through the Tsushima Straits. It is generally accepted that the Strait was opened in a certain time between the middle and the late Pleistocene ages.

Acknowledement

This research was carried out under the direction of Professor J. MAKIYAMA of this Department. The writer was helped by Mr. K. MASUDA of Sendai who has worked on the same field especially on its molluscan fossils.

References

1) MINATO, YAGI and HUNAHASHI, Bull. Earthq. Res. Inst., 34 (1956), 3.
2) OGAWA, Expl. Text. Geol. Map, Japan, "Suzumisaki" sheet, 1 : 2000,000. (1907).
3) OGAWA, Expl. Text. Geol. Map, Japan, "Wajima" sheet, 1 : 200,000. (1908).
4) MOCHIZUKI, On the Hiratoko Shell-Bed and the Tertiary Formation near Suzumisaki, Noto., Jour. Geol. Soc. Japan, 39 (1932), 460, (in Japanese).
5) NAGAHAMA, Geology of Machino and Yanagida District, Ishikawa Prefecture, Jour. Geol. Suv. Japan, 2 (1951), 11 (in Japanese).
6) AKAMINE, Geology of the Hôryû Mountain-land, Noto Peninsula, Ishikawa Prefecture, Misc. Rep. Res. Inst. Natur. Resour., 26 (1952), (in Japanese).
7) SUZUKI and KITAZAKI, Geology of the North-Eastern Part of the Noto Peninsula, Ishikawa Prefecture, Misc. Rep. Res. Inst. Natur. Resour., 28 (1952), (in Japanese).
8) SUZUKI and KUBO, Geology of the Coastal Region of the Northern East of the Noto Peninsula, Misc. Rep. Res. Inst. Natur. Resour., 31 (1953) (in Japanese).
9) KUBO, Geology of the Yanagida District, Noto Peninsula, Jour. Geol. Soc. Jap. 59 (1953), 698, (in Japanese).
10) MASUDA, On the Geology of Machino-machi, Najimi-mura and Yanagida-mura, Fugeshi-gun, Ishikawa Prefecture, Jour. Geol. Soc. Japan, 50 (1954), 703, (in Japanese).
11) ISHIDA and MASUDA, Geology of the Northeastern Region on Noto Peninsula, Japan, Jour. Geol. Soc. Japan, 62 (1956), 735, (in Japanese).
12) SUZUKI, Jour. Geol. Soc. Japan, 56 (1950), 656, pp. 305-306, (in Japanese).
13) KUBO and SUZUKI, Jour. Geol. Soc. Japan, 54 (1948), 638, p. 139, (in Japanese).
14) SUZUKI, *op. cit.* (1950).
15) KASENO, ARAKIDA and MATSUURA, Jour. Geol. Soc. Japan, 61 (1955), 718, p. 360, (in Japanese). Nawamata is situated at 8 km southwest of Wajima.
16) ISHIDA and MASUDA, *op. cit.* (1956). The Orito member is included in the Yanagida.
17) TANAI, Report No. 163, Geol. Surv. Japan (1955), (in Japauese).
18) TAKAI, Jubilee Pub. Commem. Prof. H. YABE, M.I.A. Sixtieth Birthday 1 (1939).
19) MASUDA, *op. cit.* (1954).
20) MOCHIZUKI, *op. cit.* (1953).
21) AKAMINE, *op. cit.* (1952).
22) OKUNO, Atlas of Fssil Diatoms from Japanese Diatomite Deposits (1952).
23) SUZUKI and KUBO, *op. cit.* (1953).
24) It was named by OTUKA, MASUDA, *op. cit.* (1956).
25) ISHIDA and MASUDA, *op. cit.* (1956).
26) AKAMINE, *op. cit.* (1952).
27) The Akagami is excepted from the Higashi-innai of MASUDA, *op. cit.* (1954).
28) ISHIDA and MASUDA, *op. cit.* (1956).
29) MASUDA, Trans. Proc. Palaeont. Soc. Japan, N. S. 20 (1955), 21 (1956).
30) IMAI, and YAMADERA, Jour. Geol. Soc. Japan, 58 (1952), 678.
31) TAKAI, Misc. Rep. Res. Inst. Natur, Resour., 5 (1944), (in Japanese).

32) OTUKA, Bull. Earthq. Res. Inst., 8 (1953), 1-3.
33) OTUKA, *op. cit.* (1954).
34) ISHIDA and MASUDA, *op. cit.* (1956).
35) ASANO, Jour. Geol. Soc. Japan., 44 (1937), 1231.
36) TANABE, Geograph. Rev. Japan, 16 (1940), 7-8.
37) ŌTSUKA, FUKUO, SUGIURA, ISHIDA and KIDA, Jour. Geol. Soc. Japan 62 (1956), 703, p. 379, (in Japanese).
38) TSUDA, Jour. Geol. Soc. Japan, 62 (1956).
39) ŌHASHI, Jour. Geol. Soc. Tokyo, 37 (1930), 447.
40) Kurosedani and Jôyama formation of TSUDA, Jour. Paleontology, 30 (1956) 4.
41) SAKAMOTO, IMAI, MIZUNO, SUMI and INOUE, Jour. Geol. Surv. Japan, 10 (1959), 2.
42) MATSUMOTO and IKEBE, Jour. Inst. Polytech. Osaka City Univ., Ser. G, 3 (1956), 4.
43) TSUDA, Jour. Fac. Sci Niigata Univ., Ser. 2, 1 (1953), 2.
44) MAKIYAMA, Mem. Coll. Sci., Univ. Kyoto, Ser. B, 19 (1947), 1.
45) MAKIYAMA, Ibid. (1947).
46) MAKIYAMA, Proc. Sixth Pacific Sci. Cong. (1939).
47) MAKIYAMA, *op. cit.* (1939).

GEOLOGICAL MAP OF NORTHEASTERN NOTO (By S. ISHIDA)

Mem. Coll. Sci., Univ. Kyoto, Ser. B, Vol. XXVI, No. 2, Pl. 2