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Geology of Southern Noto Peninsula, Central Japan, with Reference to the Cenozoic History

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I. INTRODUCTION

In Japan, one of the most attractive problem in geology seems to be the so-called "Green Tuff Movement" which commenced with the dawn of the Neogene time (MINATO, 1952 ; MINATO, YAGI and HUNAHASHI, 1956). The Hokuriku district including Noto Peninsula is a sub-branch of the "Green Tuff Area" in Japan, and belongs to the Hokuriku-San'in geological province in Southwest Japan (Cenozoic Research Group of Southwest Japan, 1960).

Although the Neogene formations are rather thin compared with the Neogene basins in Northeast Japan, the Neogene basin in the Hokuriku district is worthy of attention from several viewpoints. That is, the marginal character as well as the rather simple structure of the Neogene sedimentary basin in Hokuriku area has an advantage over other basins in order to elucidate the Neogene stratigraphy, especially the biostratigraphy and change of facies in detail. Furthermore, the paleogeographic and geotectonic development throughout the Neogene time has good records in the Neogene strata of the Hokuriku district which are useful to make clear the Neogene history as a whole. The writer thinks, therefore, that the study of the Neogene history in Hokuriku area should contribute to elucidate the history of "Green Tuff Area" in Japan as well as the historical development of the Circum-Japan Sea region.

In a previous paper, the writer and his coworkers gave a sketch of the Neogene history in the eastern Hokuriku area, and referred to some general problems deduced from it (KASENO, SAKAMOTO and ISHIDA, 1961). In the present article, the writer attempts to give a brief description of the geology of Southern Noto Peninsula, and to refer to the stratigraphic and paleogeographic treatment on the Neogene time in connection with geotectonic standpoint.

The geology of Southern Noto Peninsula has been studied by many geologists. A pioneer work by T. OGAWA (1908) and a preliminary note by K. MOCHIZUKI (1928) were succeeded to Y. OTUKA (1934, 1935a, 1935b). Lately, several local geologic maps and stratigraphic descriptions have been published by K. SUZUKI and U. KITAZAKI (1949), K. KUBO and T. SUZUKI (1950), and Y. KUWANO (1951). Phosphorous deposits in the Neogene strata were studied by U. KITAZAKI and Y. ICHIDA (1950), and by H. IMAI and H. YAMADERA (1952).

Since 1950, the writer has studied the geology and stratigraphy of the whole extent of Southern Noto Peninsula together with his many students and coworkers. Some of the result has been published in Japanese and several articles on local geology are preparing now. The following description and discussion is a summary of works by the writer from 1950 to 1960.

II. OUTLINE OF THE GEOLOGY OF SOUTHERN NOTO

The geological map and geologic sections of the Southern Noto Peninsula are shown in Plates I and II. The mapped area is mainly composed of the Neogene formations which unconformably cover the pre-Neogene basement. The latter is represented by gneiss and granite, wide exposures of which are restricted to two areas, i. e. Mt. Hôdatsusan area and Mt. Sekidôsan area. Surface exposures and estimated relief of the pre-Neogene basement are shown in Fig. 1.

The gneisses exposed in the northern half of Mt. Hôdatsusan and the eastern part of Mt. Sekidôsan are probably correlated with the so-called Hida Metamorphic Complex, and are intruded by granites in western Sekidôsan and southern half of Mt. Hôdatsusan.

The Neogene formations ranging from early Miocene to late Pliocene are widely exposed in the mapped area, and are divided into seven stages as follows (KASENO, SAKAMOTO and ISHIDA, 1961):

Hanyû stage	Plio-Pleistocene
Himi stage	Pliocene
Otokawa stage	Latest Miocene
Higashibessho stage	Late Miocene
Kurosedani stage	Middle Miocene
Iwaine stage	} Early Miocene
Nirehara stage	

Numerous names of stratigraphic units (members) have been given by many geologists including the writer and his coworkers who studied the mapped area or a part of it. These members or formations are correlated with each other as shown in Table I by the writer. As the stratigraphic relations of the Neogene strata are the key subject of the present article, the writer will enter into details in later chapters.

The Quaternary deposits in the mapped area are divided into three as follows: (1) Early or middle Pleistocene member such as Takashina beds which distribute in the west side of Nanao; (2) Late Pleistocene marine terrace deposits which sometimes contain shell-beds such as Wakura-eki shell beds; (3) Alluvial deposits, the widest of which occupies the Ôchi Graben. A systematic research of the Quaternary deposits and history is now in progress by the writer and his coworkers, but details will not be given in this article.

III. GEOLOGIC STRUCTURE OF SOUTHERN NOTO

In the Southern Noto Peninsula, the Ôchi Graben is a conspicuous geomorphologic feature (Y. OTUKA, 1934, 1935a, 1935b), which is defined by two straight cliffs running subparallel to each other from northeast to southwest in direction.

Geomorphologically the Southern Noto Peninsula is divisible into three units, that is, (1) northwestern hilly land (Togi-Nanao mass), (2) Ôchi Graben, a flat alluvial plain having width of 3 to 4 km., and (3) southeastern mountainous land which is subdivided into three subunits: (3a) Sakiyama area, (3b) Sekidôsan area, and (3c) Hôdatsusan area.

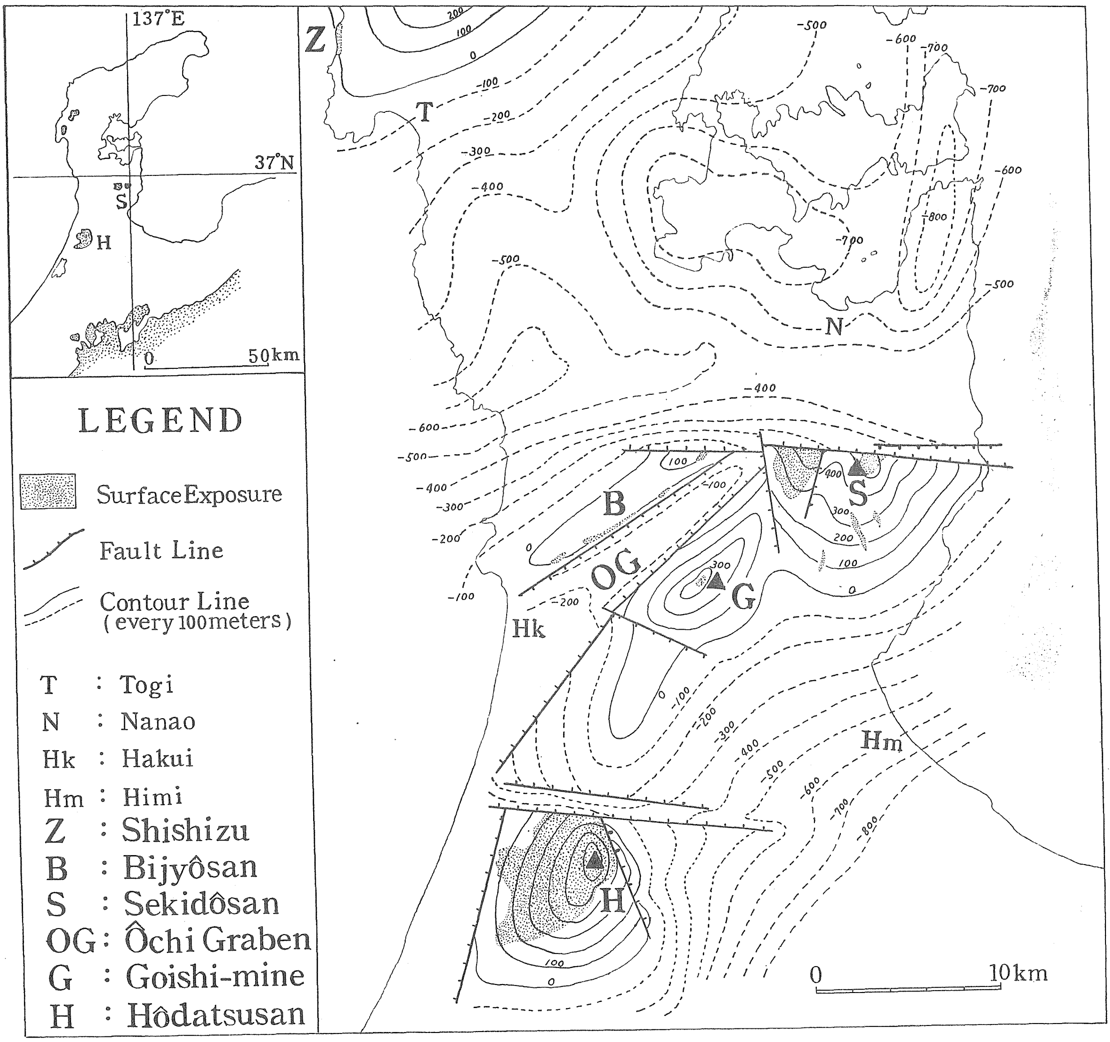

Fig. 1. Map showing the surface distribution and subsurface relief of the pre-Neogene basement in Southern Noto Peninsula. Contour values every 100 meters mean the height (depth) compared with the present sea level.

Geomorphological units and subunits mentioned above approximately coincide with the present structural divisions as shown in Plate III, the geological map (Plate I) and geologic sections (Plate II).

The Togi-Nanao mass is a low hilly land composed of relatively thin Miocene strata which are nearly horizontal or gently inclined to southeastward. It corresponds to the southern marginal portion of the Noto geologic province (KASENO, SAKAMOTO and ISHIDA, 1961), and is considerably different from the other parts of the mapped area in the structure and stratigraphy of the Neogene strata. A simple monoclinal structure as well as the thin Miocene sediments of the Togi-Nanao mass is suitable for clarifying the detailed litho-stratigraphy and bio-stratigraphy, and for restoring the paleogeographic changes throughout the Miocene epoch.

The Ôchi Graben is a remarkable tectonic unit in Southern Noto, which has been particularly activated since the end of the Neogene period. It is evident, however, that the Ôchi Graben or its antecedent structural boundary already existed along the northern slope of Mt. Sekidôsan area, and played an important role during the Neogene time. The Sekidôsan fault zone at present may be corresponded to such a tectonic boundary dividing two structural units, that is, the Noto geologic province in the north and the Toyama geologic province in the south (KASENO, SAKAMOTO and ISHIDA, 1961).

The southeastern mountainous land is divided into three tectonic subunits, the boundaries between which are designated by two remarkable fault zones, that is, Sekidôsan and Hôdatsusan fault zones.

The Sakiyama area is composed of two parts, the Sakiyama syncline in the north and the Sakiyama fault zone in the south. The northern part was the site of deposition throughout the Pliocene epoch, but the southern part turned into an emergent mass since the early Pliocene.

The Sekidôsan area is the southeastern wall of the Ôchi Graben, forming an asymmetrical anticline running from northeast to southwest as a whole. The Sekidôsan anticline is steeply inclined to northwestward and gently to southeastward. The northern half of the anticlinal structure is mainly composed of the lower Neogene strata of various facies accumulated on the pre-Neogene basement having an irregular relief. The southern half of the Sekidôsan anticline corresponds to the deposition site throughout the Neogene time, where thick strata of various facies had been accumulated from middle Miocene to Pliocene.

The Hôdatsusan fault zone which is characterized by many parallel faults running from west to east, is the most remarkable tectonic feature in the mapped area. One belt of 500 m. width shows an overturned structure, which is composed of coarse sandstone showing the graded bedding (Plate III).

The Hôdatsusan mass is a dome structure as a whole, the northern limit of which is defined by parallel faults, and the southeastern slope is composed of thick Neogene strata gently inclined outward. Along the Hôdatsusan fault zone there is an elongated anticline (Kôjiro anticline) and the Kuwanoin syncline, the boundary between both forming a flexure.

IV. NEOGENE STRATIGRAPHY IN SOUTHERN NOTO

In Southern Noto Peninsula, all stages of the Neogene established on the basis of stratigraphy in the Toyama Neogene sedimentary basin (KASENO, SAKAMOTO and ISHIDA, 1961) have their representatives, which are correlated to each other as shown in Table I. The thickness and facies of the strara vary from place to place as diagramatically shown in Plate IV. Detailed descriptions of those members established by several authors in a part of the mapped area will not be mentioned here, except a brief summary as follows.

(1) **Nirehara stage** (Early Miocene)

Although the surface distribution of the strata belonging to the Nirehara stage is restricted to small area around Hôdatsusan mass, it is reasonably supposed that the Nirehara stage has wide and continuous subsurface distribution in Southern Noto except for the Sekidôsan area (Plate IV).

The Nota sandstone member (Ôta formation) directly covering the pre-Neogene basement of Hôdatsusan mass, is composed of medium to coarse sandstone with round pebbles of cherty rocks. It contains no volcanic materials, and yields plant fossils such as *Acer* sp., *Aralia* sp., *Carpinus* sp., *Cinnamomum* sp., *Quercus* sp., *Rhododendron* sp, and *Zelkova* sp. (MURAMOTO, J., 1956 MS). The maximum thickness of the Nota sandstone member is estimated to be 200 meters around Hôdatsusan mass, and seems to have nearly the same thickness in other parts of the mapped area except for the Sekidôsan area.

(2) **Iwaine stage** (Early Miocene)

An enormous amount of volcanic products was accumulated on the northern half of the mapped area, which is mainly composed of the lavas of two pyroxene andesite and their volcanic breccias, an average thickness of which is estimated to be 500 meters or more.

Andesitic volcanic and pyroclastic rocks mentioned above belong to the Anamizu formation in the Northern Noto Peninsula (ISHIDA, S. 1959), which is correlated with the Iwaine formation in the southern part of the Toyama sedimentary basin (KASENO, SAKAMOTO and ISHIDA, 1961). The maximum thickness of the andesitic volcanics in the Southern Noto area may be more than 800 meters at the northwestern corner of Togi area.

Another pyroclastic rocks in the mapped area is the Nota volcanics (Uriu formation) around Hôdatsusan mass, the thickness of which is 600 meters or more. It is mainly composed of rhyolitic tuff breccias with insertions of welded tuff. A part of tuff breccias yields silicified woods such as *Taxodioxylon sequoianum*, *Cupressinoxylon* sp., *Tilia* sp. and *Fagus* sp. (MURAMOTO, J. 1956 MS).

(3) **Kurosedani stage** (Middle Miocene)

The strata belonging to this stage are variable in facies and thickness from place to place. In the northwestern end of the mapped area, non-marine deposits composed of three members are known (Araya conglomerate, Kusaki alternation and Yamatoda mudstone). The Kusaki alternation is 20 to 25 meters in thickness and contains thin layers of lignite, some of which has been worked out in Sanmyô area. It contains rarely molluscan fossils such as *Cristaria* aff. *plicata* apparently indicating a fresh-water environment. The Yamatoda mudstone is a homogeneous clayey mudstone containing considerable amount of non-marine diatom remains such as *Melosira granulata*, and yields well preserved plant fossils known as "Notonakajima Flora." (Suzuki and Kitataki, 1949; Hanayama, R., 1955 MS; Matsumoto, R., 1957 MS; Ichikawa and Kaseno, 1963).

The Tane alternation and the lower part of the Shiroyama conglomerate to the north of Sekidôsan mass may be of non-marine origin, containing thin layers of lignite and silicified woods. Conglomeratic facies is the characteristic products of this stage, and we find the Dômi, Shiroyama and Sekidôsan conglomerate members around Sekidôsan mass. These conglomerates are mainly composed of andesite gravels, with small amount of gravels of granite and gneiss. The lower part of the Shingû conglomerate in Himi-Shio area and the Kawai conglomerate around Hôdatsusan mass are also the products of this stage, the gravels in which are mostly of gneiss and granite.

On the southern slope of the Sekidôsan mass, the strata of the Kurosedani stage are strongly variable in facies and thickness, and divided into several lithologic members. The Kunimi mudstone to the southwest side of Sekidôsan is a marine black mudstone containing small foraminifers, echinoids and molluscs, and has insertions of pale-greenish dacitic tuff and tuff breccia (Otaki tuff). The Kunimi mudstone changes laterally to the Nagasaka muddy alternation and the Isobe sandy alternation.

The upper part of the Kurosedani stage in the mapped area yields marine fossils at several localities. They are *Miogypsina kotoi* and *Operculina complanata japonica*, and many ill-preserved molluscan shells, bryozoans etc.

The uppermost horizon of the Kurosedani stage is marked by tuff layers, the Ôdomari tuff in Sekidôsan-Nadaura area and the Miyajima tuff around Hôdatsusan mass. These tuff and pyroclastic layers are mostly dacitic in character, suggesting an intense acid volcanism at this stage in or around the mapped area.

In Nanao-Notojima area, the strata of Kurosedani stage are scarcely known or very thin. The lowest part of the Shichihara mudstone in Nanao area, and the Hannoura conglomerate and a part of the Suso mudstone in Notojima area may be correlated to this stage.

The Takabatake conglomerate and the Taki conglomerate which occupy the both sides of the Ôchi Graben, are thick conglomeratic facies of Higashibessho stage, but the lower part of them may belong to the Kurosedani stage.

(4) **Higashibessho stage** (Late Miocene)

This stage is characterized by a homogeneous mudstone in general. The Nakanami mudstone and Takado mudstone in Himi-Nadaura area are typical ones, and the Hamada mudstone in Nakajima area also belongs to this stage. The Fuchigatani tuffite around Hôdatsusan mass and the Ogawa tuffite in Himi-Nadaura area are also included.

In Southern Noto area, the upper part of the Higashibessho stage is represented by a unique facies, mainly composed of coarse grained materials which were derived from the land of granite and gneiss. The Mio sandstone in Himi-Shio area and the Kono sandstone around Hôdatsusan mass are composed of arkosic coarse sandstone showing graded bedding, and inserted with irregular lenses of conglomerate. In the northern part of the mapped area, the Akaura sandstone is the product of this stage, composed of homogeneous coarse granitic sandstone showing cross-lamination. A remarkable conglomeratic facies of this stage develops typically on both sides of the Ôchi Graben, that is, Takabatake conglomerate and Taki conglomerate members.

In the Togi-Nanao mass and southern Sakiyama area, the uppermost horizon of the Higashibessho stage is locally represented by a peculiar type of calcareous sandstone which is mostly composed of calcareous organic remains. They are, the Nanao calcareous sandstone in Nanao-Notojima area and the Izumo calcareous sandstone in Takahama area, which contain fossil scallops such as *Pecten kagamianus*, *Chlamys crassivenia* and *Chlamys notoensis*, several species of brachiopods and bryozoans, echinoid remains and a large amount of smaller foraminifers. These calcareous biogenic deposits have close relation with the peculiar type of phosphorous deposits at Hiuchidani of Takahama area and Nanao and Notojima areas. (KITAZAKI and ICHIDA, 1950 ; IMAI and YAMADERA, 1952).

(5) **Otokawa stage** (Latest Miocene)

In the northern part of the mapped area, that is, in Sakiyama, Nanao and Notojima areas, the lowest horizon of this stage is sometimes represented by a thin (1 to 2 meters) layer of glauconitic sandstone or flinty shale which suggests an interruption of sedimentation or a diastem.

These glauconitic sandstone or mudstone which were deposited in shallow sea bottom sometimes contain abundant remains of a silicisponge (*Aphrocallistes* sp.) and *Chlamys crassivenia*.

On the southern slope of Mt. Sekidôsan (Himi-Shio area) the lower part of the Otokawa stage is represented by two tuffaceous members, i. e. the Ogume greenish sandstone and the Kuzuba tuffaceous alternation which frequently contains *Chlamys crassivenia*, *Lucinoma acutilineatum* and other species of molluscs. In the Nadaura area, these two members abruptly decrease in thickness and change to a thin glauconitic and tuffaceous layer, that is, the Moridera green sandstone.

The middle part of the Otokawa stage is generally represented by a homogeneous massive black mudstone containing scanty megafossils. In the Nanao-Notojima area, there is a peculiar type of diatomaceous mudstone—the Wakura diatomaceous mudstone (ICHIKAWA and KASENO, 1963). The uppermost part of this stage is also represented by a homogeneous silty black mudstone, with thin insertions of whitish acid tuff layers and hard nodule layers. The Ao or Inazumi mudstone in Himi-Shio area and the Akasaki and Futaana siltstones in Nanao-Notojima area belong to this stage. The thickness of strata of the Otokawa stage considerably varies from place to place, the maximum attains to 800 meters along the northern margin of the Hôdatsusan mass.

(6) **Himi stage** (Pliocene)

The strata of this stage cover the Otokawa stage conformably or unconformably. They are lithologically subdivided into four types of facies as follows:

(a) Yabuta facies is a homogeneous calcareous siltstone containing abundant remains of planktonic and benthonic foraminifers as well as molluscs and echinoids. It is represented by the Yabuta siltstone in Himi-Nadaura area and the Sakiyama siltstone in Sakiyama area.

(b) Onma facies is composed of homogeneous fine to very fine sandstone which contains the molluscan shells belonging to the "Onma-Manganjian fauna" (Pliocene molluscan fauna in Japan Sea coast of Japan). Typical Onma facies is represented by the Onma formation in Kanazawa area. In the mapped area the Kojima sandstone near Nanao and the Suginoya siltstone in Shio area belong to it.

(c) "Natsukawa facies" is the coarse grained calcareous sandstone which contains abundant remains of calcareous organisms. They are, various species of molluscs, bryozoans, brachiopods, foraminifers and calcareous algae. In Himi area the Natsukawa facies occupies an upper horizon of the Himi stage. At the northwestern corner of the Hôdatsusan mass, a small mass of this type is known near Yamazaki.

(d) Brownish sandstone generally occupies the upper horizon of the Himi stage, and becomes rather coaser compared with the lower horizon. The Nakagawa sandstone in Shio area and the Onma sandstone to the west of Hôdatsusan mass belong to it.

V. NEOGENE PALEOGEOGRAPHY IN SOUTHERN NOTO

The paleogeographic changes during the Neogene time in the Southern Noto area are shown as a series of paleogeographic maps (Figs. 2-11). A brief explanation will be added in the following lines.

(1) **Nirehara age** (Early Miocene)

The first stage of the Neogene history in the Hokuriku district began with a shallow water basin of non-marine character. No volcanic activity is known in the mapped area. The Sekidôsan mass was an eastern end of the land which occupied the west side of the Noto Peninsula at present. Coarse clastic materials were transported by rivers and poured into the shallow water basin to form an accumulation of coarse sandstone and conglomerate (Ôta formation), which contains considerable amount of well-rounded small pebbles of cherty rocks. The origin of these cherty rocks is an open question, because we cannot find any source area of them on the surface of present land.

(2) **Iwaine age** (Early Miocene) (Fig. 2)

The Nirehara age which is characterized by the deficiency of volcanism was succeeded by an age of intense volcanism which supplied an enormous amount of volcanic products. Throughout the Iwaine age, a land existed to the west of the mapped area, which had a peninsula-like projection to the east side. On the peninsula which embraced the Sekidôsan and Hôdatsusan masses, the volcanic activity was rather meager compared with the other parts of the mapped area. To the north side of the "Sekidôsan Peninsula," the andesitic pyroclastic materials originated from numerous submarine centers of eruption were rapidly accumulated in the water basin to form a thick and complicated series of pyroclastic rocks, which attaind to 500 to 800 meters in thickness. On the southeastern slope of the Hôdatsusan mass, on the other hand a strange type of volcanic product was deposited. It was mainly composed of rhyolitic or dacitic tuffs containing considerable amount of welded tuff, which was presumably brought about by an explosive acid volcanism taken place at this stage on the lost land situated to the west of the mapped area.

(3) **Kurosedani age** (Middle Miocene) (Figs. 3, 4)

After an intense phase of volcanim during Iwaine age, the volcanic products were successively added to the pre-existed land composed mainly of gneiss and granite, and a complicated shore line appeared at the early stage of Kurosedani age. Newly formed land surface as well as the sea bottom had presumably a complicated relief, which was the principal cause of the diversity of environment at Kurosedani age. In accordance with the difference of environment, sediments of various facies indicating marine or non-marine conditions were deposited in the mapped area.

At the northwestern end of the mapped area, there was a closed lake of fresh water which was attached to the southern margin of "North Noto Land" composed mainly of volcanic rocks of Iwaine stage. Clastic materials derived from the northern land area were slowly accumulated in the shallow lake basin, and the basal conglomerate and lignite-bearing alternation were formed. At last, a homogeneous mudstone containing numerous species of fresh water diatoms in association with plant leaves was deposited. According to the plant fossils at this stage, climate was rather warm at Kurosedani age.

To the southeast of Nanao, there was a small embayment of brackish character, where the Tane alternation and the lower part of the Shiroyama conglomerate were accumulated. These members contain thin layers of lignite and yield plant leaves and fossil wood trunks at some places. Gravels in conglomerate were mostly derived from the land of andesitic rocks, which were rapidly poured into the small basin.

In the southeastern side of Sekidôsan mass and around Hôdatsusan mass, thick sediments of various facies were deposited during the Kurosedani age. Coarse clastic sediments such as coarse sandstone and conglomeratic sandstones were rapidly and irregularly accumulated around Sekidôsan and Hôdatsusan masses, which were mostly derived from the pre-Neogene land mass composed of granitic rocks. Various types of alternation composed of sandstone and siltstone were deposited around Sekidôsan mass, some of which were characterized by graded bedding. In a small embayment to the south of Sekidôsan mass, a black shale facies of marine origin was formed (Kunimi mudstone).

The volcanism in Kurosedani age is scarcely known in the mapped area, although several layers of acid tuffs are inserted. On the southeastern slope of Hôdatsusan mass, we find the Miyajima green tuff member which is composed of acid tuff and tuff breccias. There might be a center of eruption nearby the Hôdatsusan area, but we have no criterion to make an assertion.

The upper part of the Kurosedani stage is marked by the occurrence of marine fossils such as *Operculina complanata japonica, Miogypsina kotoi* and several species of molluscs. The faunal assemblage at this stage suggests a shallow and rather warm sea of Kurosedani age.

(4) **Higashibessho age** (Late Miocene) (Figs. 5, 6)

At the early phase of Higashibessho age, the sea level rather rapidly uprose and the pre-existed land mass disappeared beneath the sea, to bring about a simple shore line as shown in Fig. 5. Although the conglomeratic facies was produced on the shllower banks, other parts of the sea became considerably deep, where the thick mudstone of homogeneous facies was deposited. Judging from the widest extent of the sea and the dominance of homogeneous black shale facies throughout the area, it is not difficult to regard the Higashibessho age as the acme of Neogene transgression in Hokuriku district (Kaseno, Sakamoto and Ishida, 1961).

The later half of the Higashibessho stage is characterized by a wide distribution of coarse clastic sediments in the mapped area, which suggests a phase of rapid upheaval of the surrounding land then existed. Some parts of the sandy facies of this stage might be a secondary derivation from the coarse clastic sediments of Kurosedani stage. In other words, the coarser sediments around Sekidôsan and Hôdatsusan masses were raised up in association with the upheaval of older land masses, and reworked and scattered by the sea currents to form a thick strata of coarse sandstone which is characterized by the graded bedding.

(5) **Latest Higashibessho to Early Otokawa age** (Fig. 7)

In connection with the phase of rapid upheaval of the western land which supplied a large amount of coarse clastic sediments at the latest stage of Higashibessho age, the Southern Noto area tentatively entered into a pause period of sedimentation. Owing to a general tendency of retreat of the wide sea of Higashibessho age, rather complicated shore lines appeared again. Because of an interruption of the sinking movement as well as the peculiar pattern of paleogeography, various types of extraordinary sediments were formed along the shore lines and on the shallow sea bottom.

Calcareous sandstones such as Nanao and Izumo calcareous sandstones are the very product at this stage, which are mainly composed of calcareous organic remains of pectinids, brachiopods, bryozoans and echinoids. These deposits are sometimes closely connected with the peculiar phosphorous deposits which might be originated from the gregarious aggregation of various organic remains or substance. Another type of peculiar deposit is the glauconitic layers and glauconitic sandstone which frequently contain abundant remains of silicisponge named *Aphrocallistes* sp. These features seem to be enough to deduce a shallow sea shore fringing the rock cliff at that time.

(6) **Otokawa age** (Latest Miocene) (Fig. 8)

After an episodic interruption of subsidence which had a great influence on the whole extent of the mapped area, a new epoch of transgression arrived again. During the middle to late Otokawa age, the sea was considerably widened, and the thick strata of homogeneous silty mudstone covered the almost all extent. In a semi-closed small basin situated in Wakura-Notojima area, the silty mudstone was strongly diatomaceous owing to scanty supply of clastic materials from the land around the basin (ICHIKAWA and KASENO, 1963). In spite of the large extent and considerable depth of the sea, judging from the lithofacies and the poorer contents of plaktonic foraminifers, the marine territory of Otokawa age was presumably of more or less closed character compared with that of Higashibessho age.

One of the most remarkable fact in Otokawa age is the great diversity of thickness of strata from place to place, mainly because of the difference in amount of subsidence, varying from 200 meters in Nanao area to 800 meters along the northern side of Hôdatsusan mass.

(7) **Himi age** (Pliocene) (Figs. 9, 10)

After a transgression in Otokawa age, the marine invasion was narrowed temporarily due to a regression, which is shown by local unconformities in the mapped area. A new land including Hôdatsusan mass had begun to emerge, and a diastrophic movement accompanied with it had taken place. Sooner or later, the Pliocene sea invaded in the area mainly due to a rapid rise of sea level. Compared with the sea of Otokawa age, the Pliocene Himi sea was colder and of open sea character.

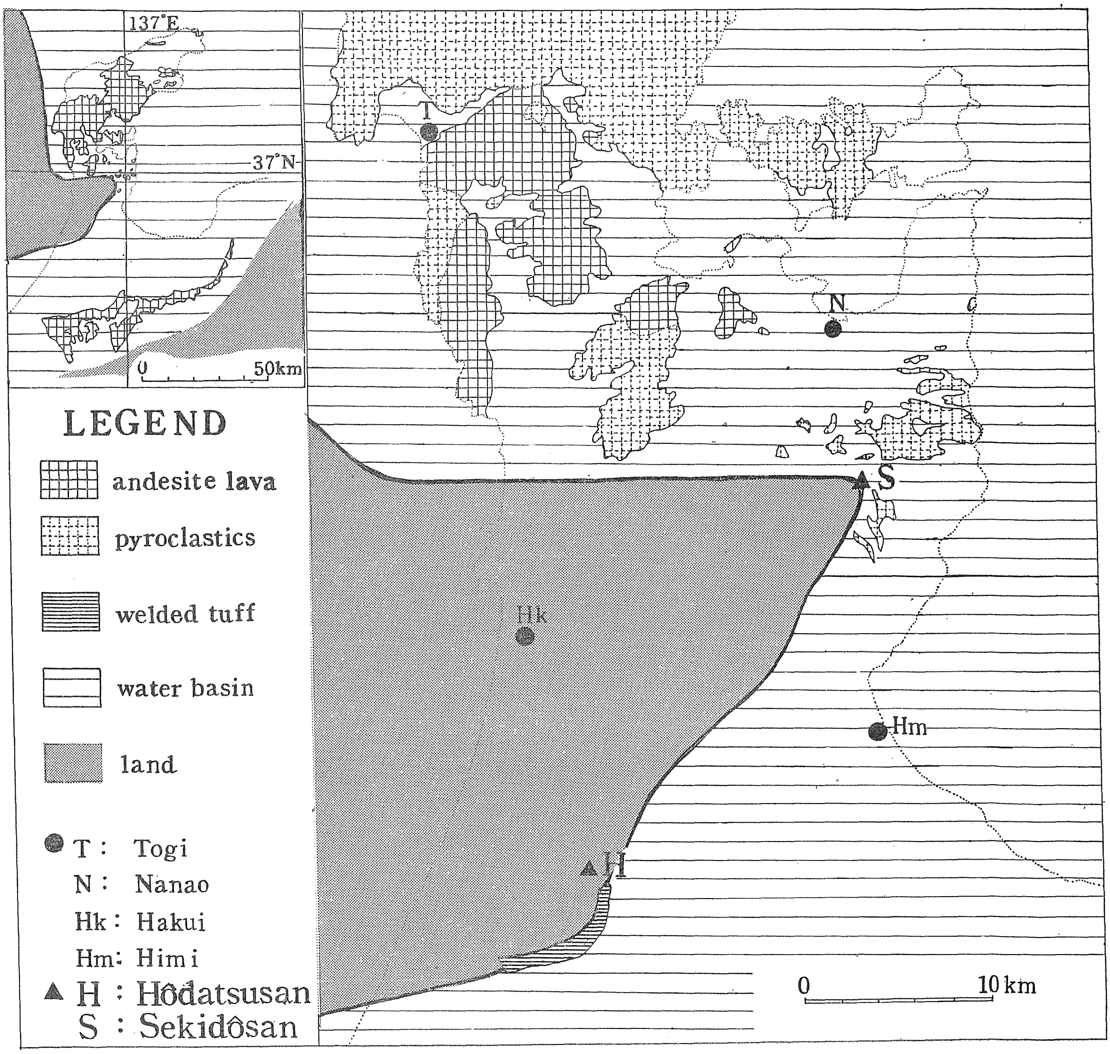

Fig. 2. Paleogeographical map of Southern Noto in Iwaine age (Early Miocene).

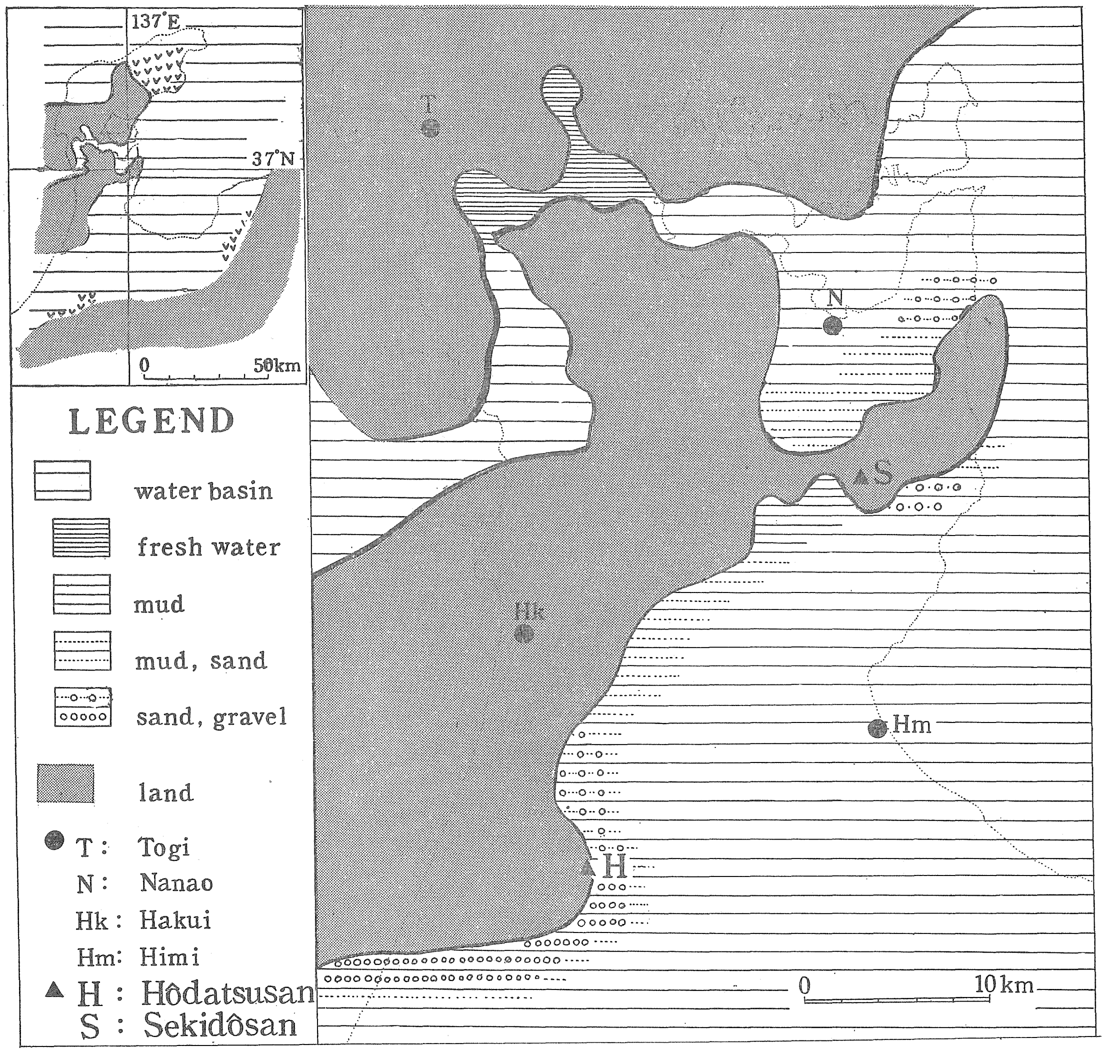

Fig. 3. Paleogeographical map of Southern Noto in early Kurosedani age (early Middle Miocene).

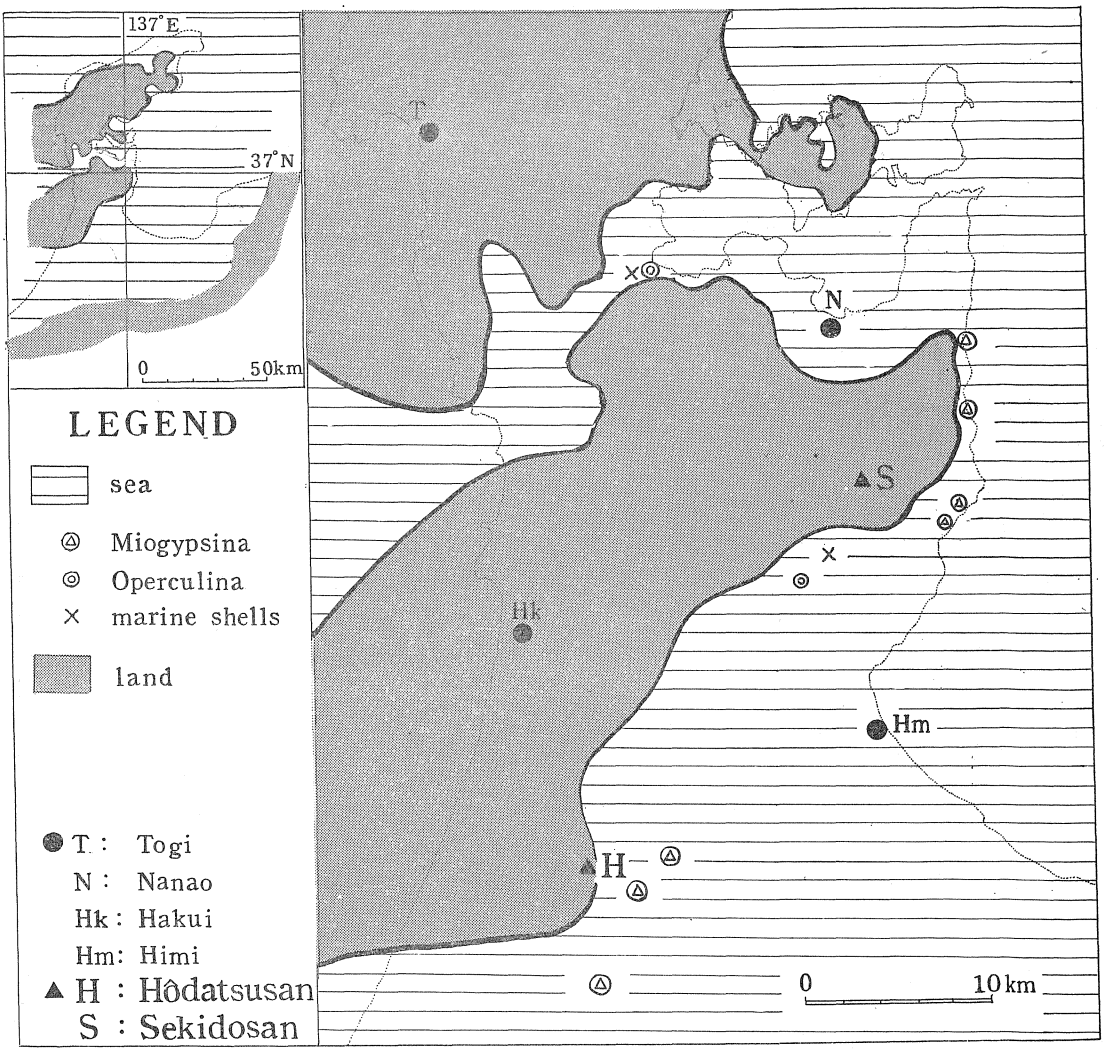

Fig. 4. Paleogeographical map of Southern Noto in late Kurosedani age (late Middle Miocene).

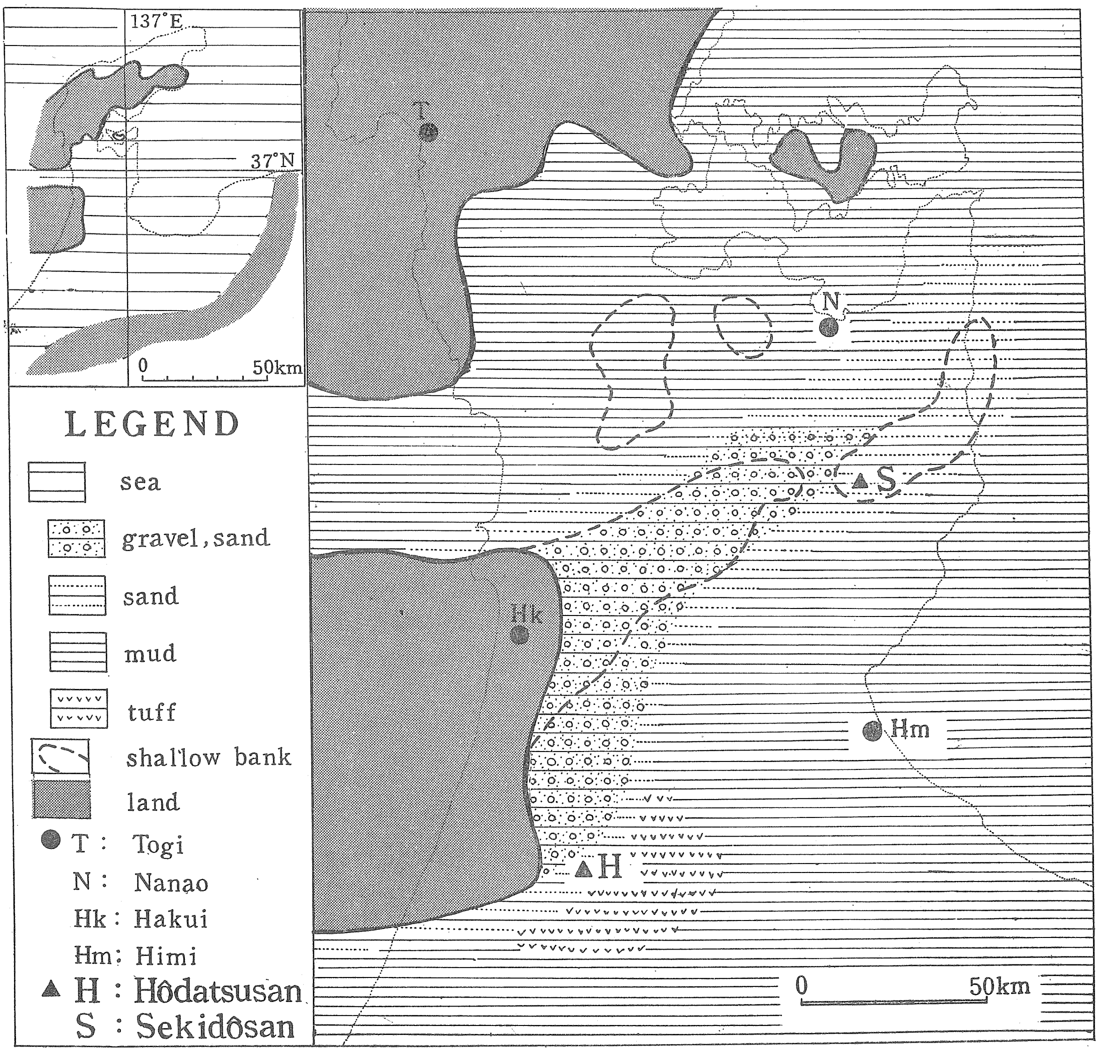

Fig. 5. Paleogeographical map of Southern Noto in early Higashibessho age (early Late Miocene).

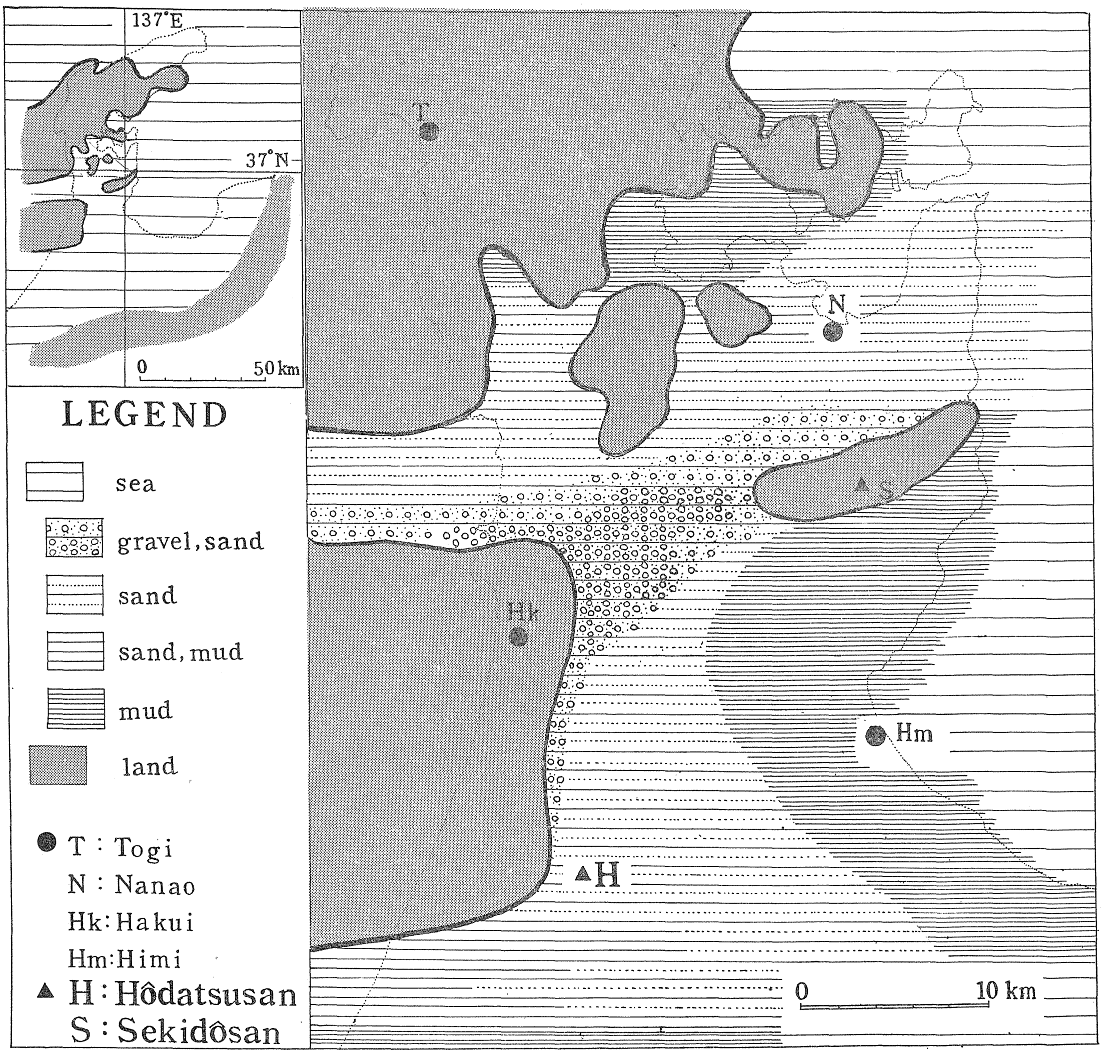

Fig. 6. Paleogeographical map of Southern Noto in late Higashibessho age (middle Late Miocene).

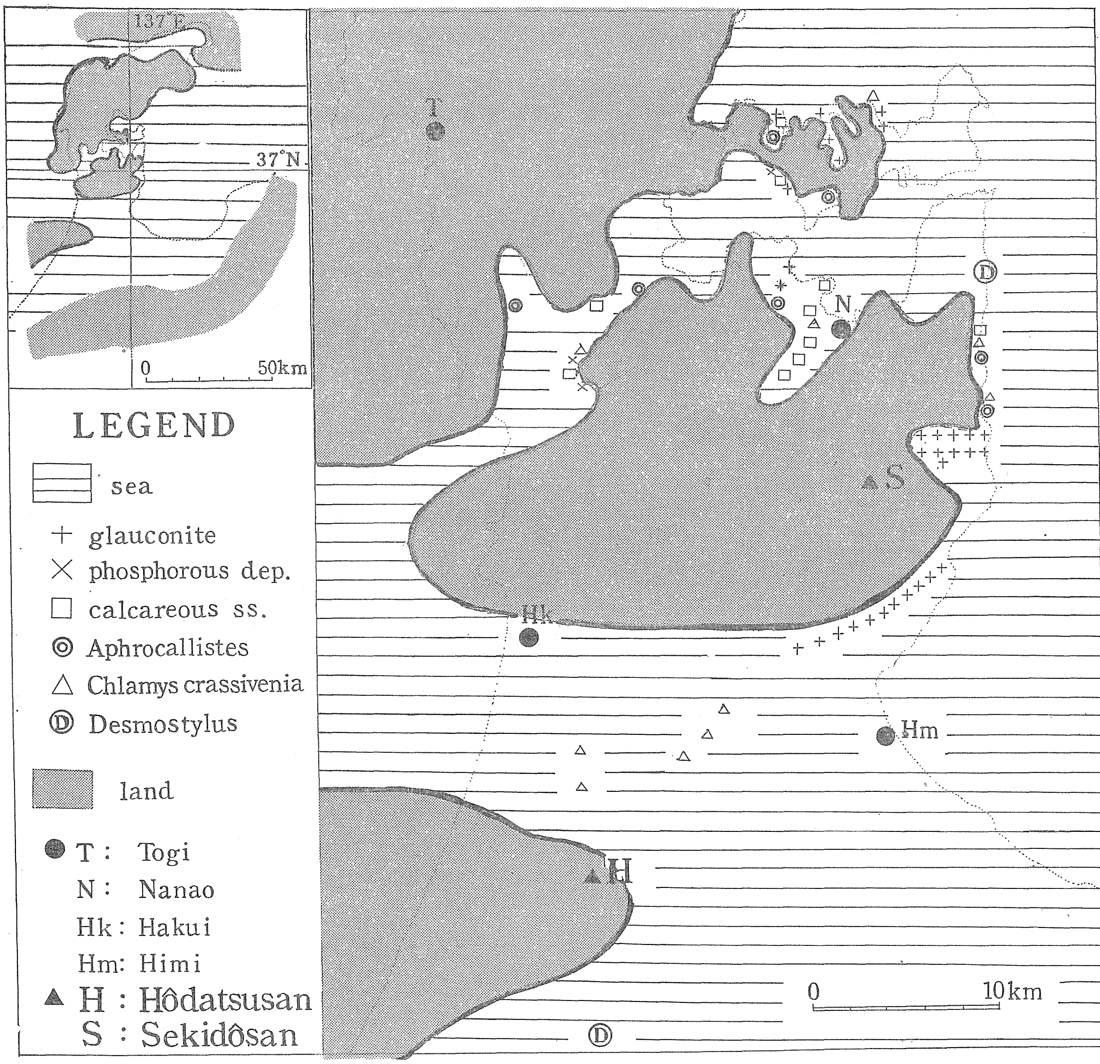

Fig. 7. Paleogeographical map of Southern Noto in the latest Higashibessho to early Otokawa age (late Late Miocene).

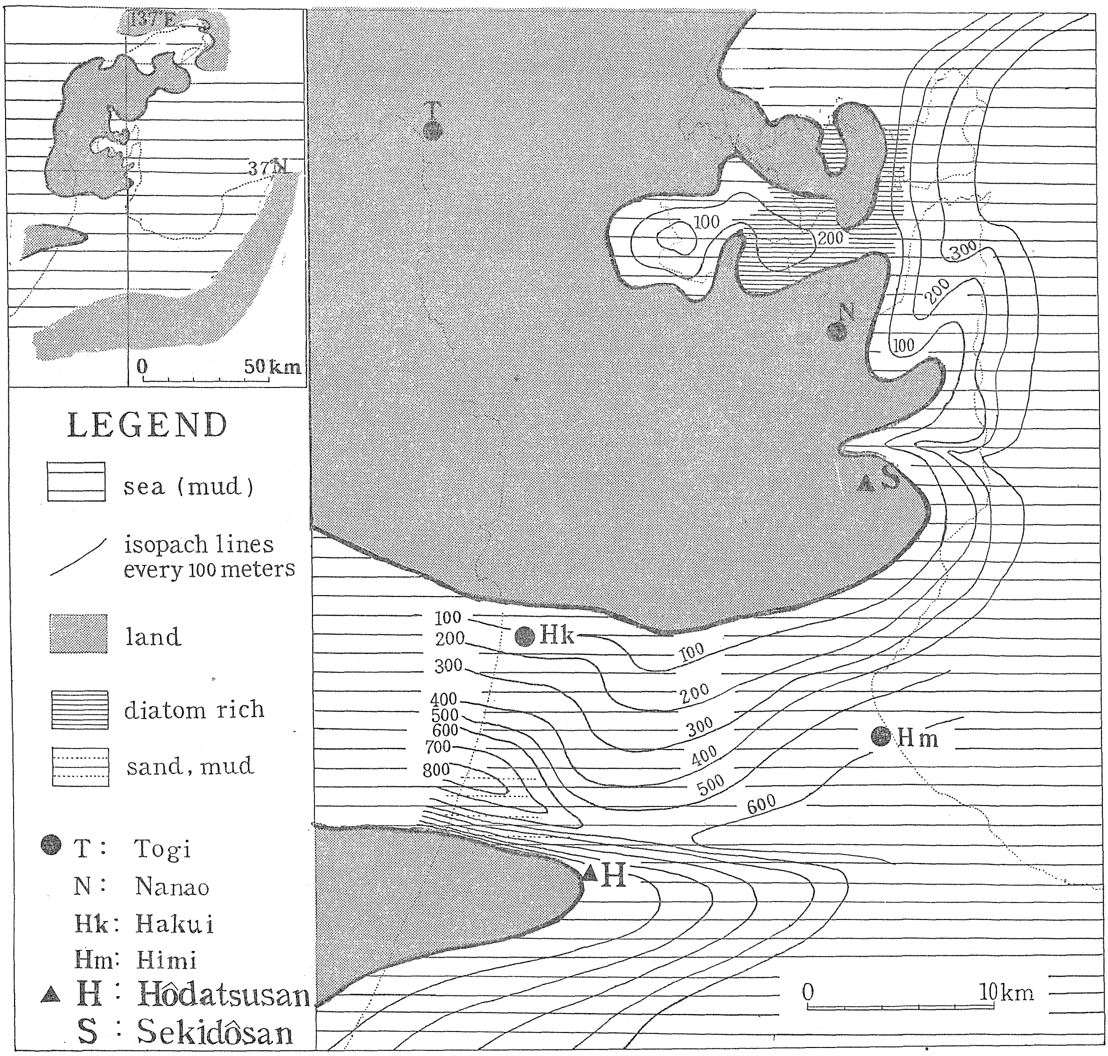

Fig. 8. Paleogeographical map of Southern Noto in the middle to late Otokawa age (Latest Miocene).

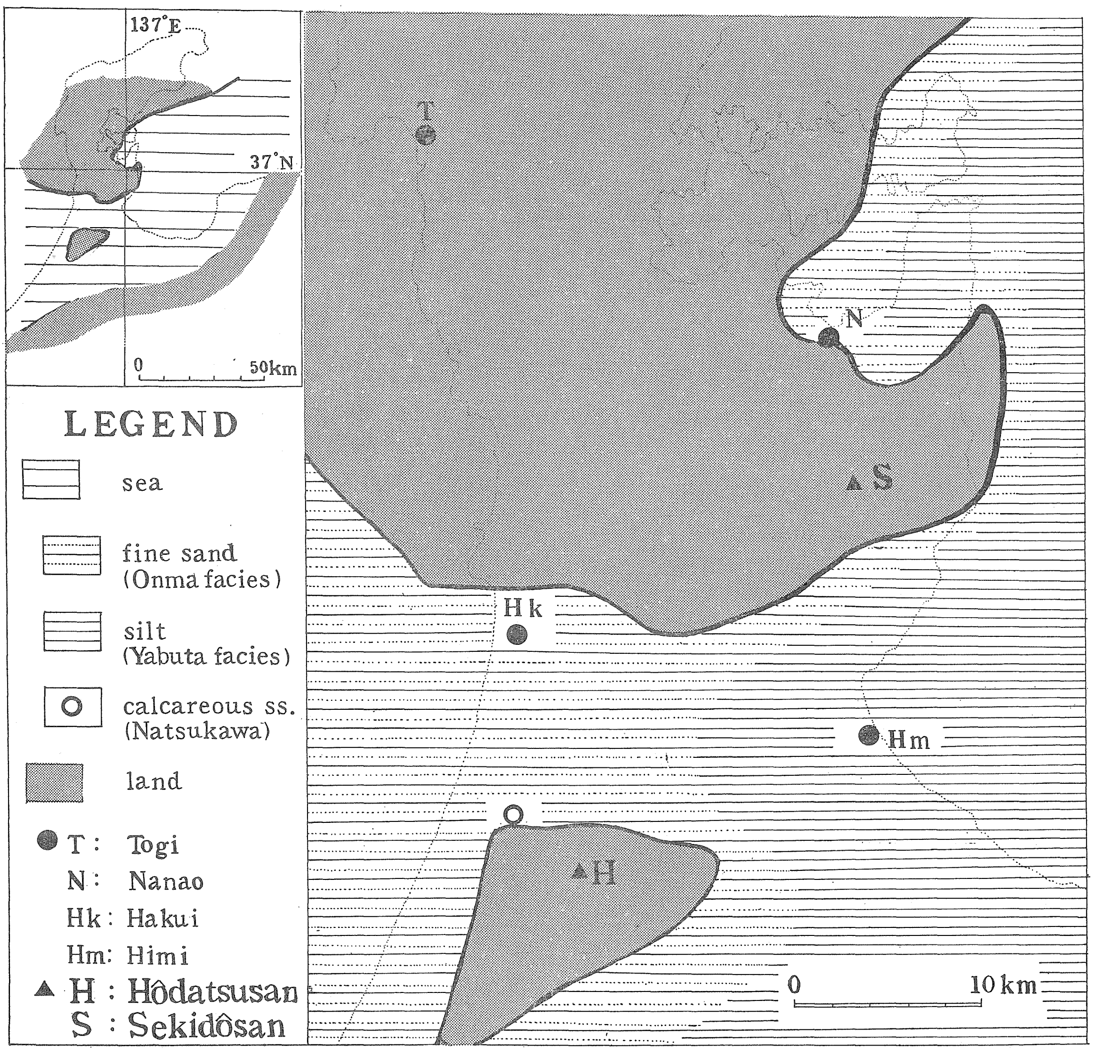

Fig. 9. Paleogeographical map of Southern Noto in early Himi age (Early Pliocene).

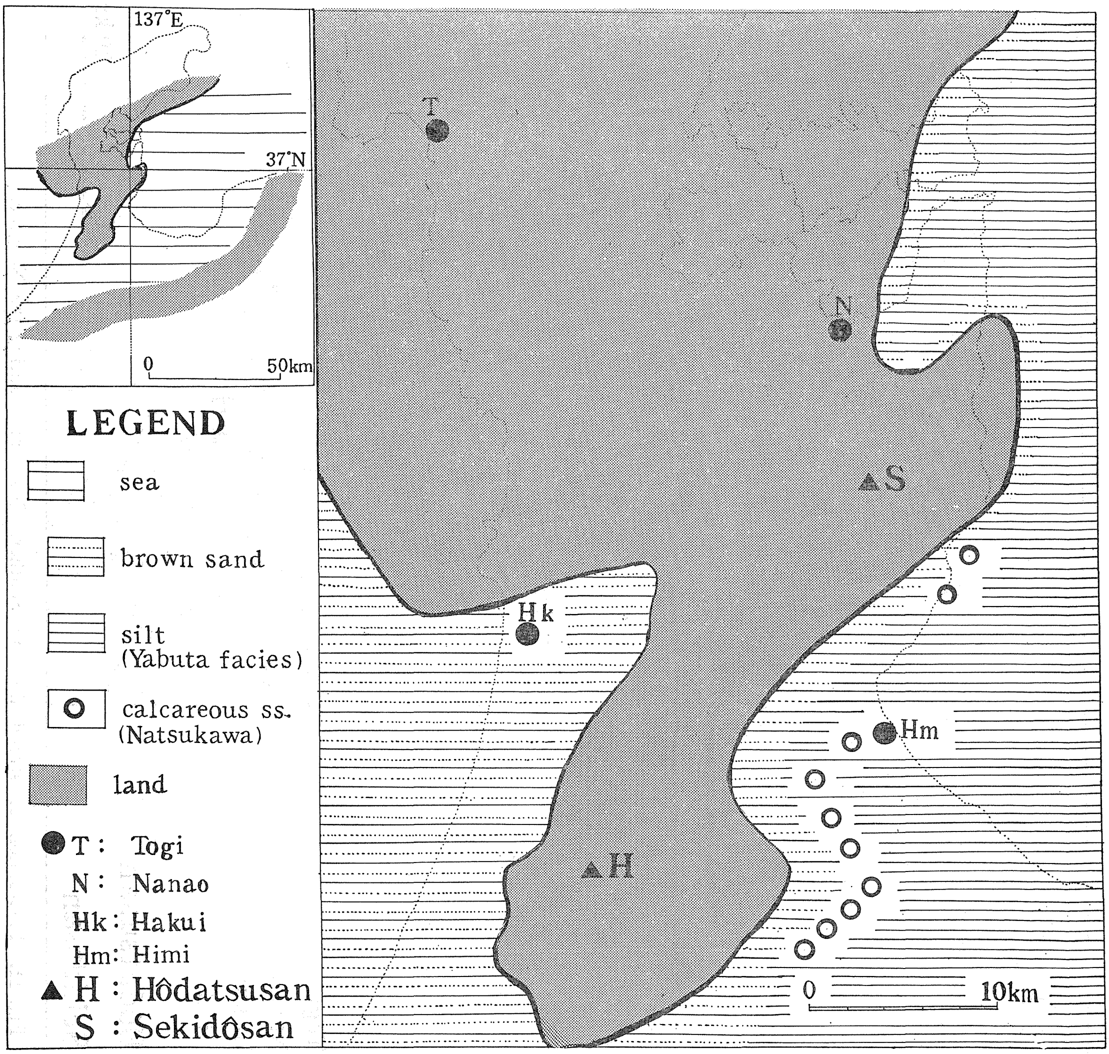

Fig. 10. Paleogeographical map of Southern Noto in late Himi age (Late Pliocoene).

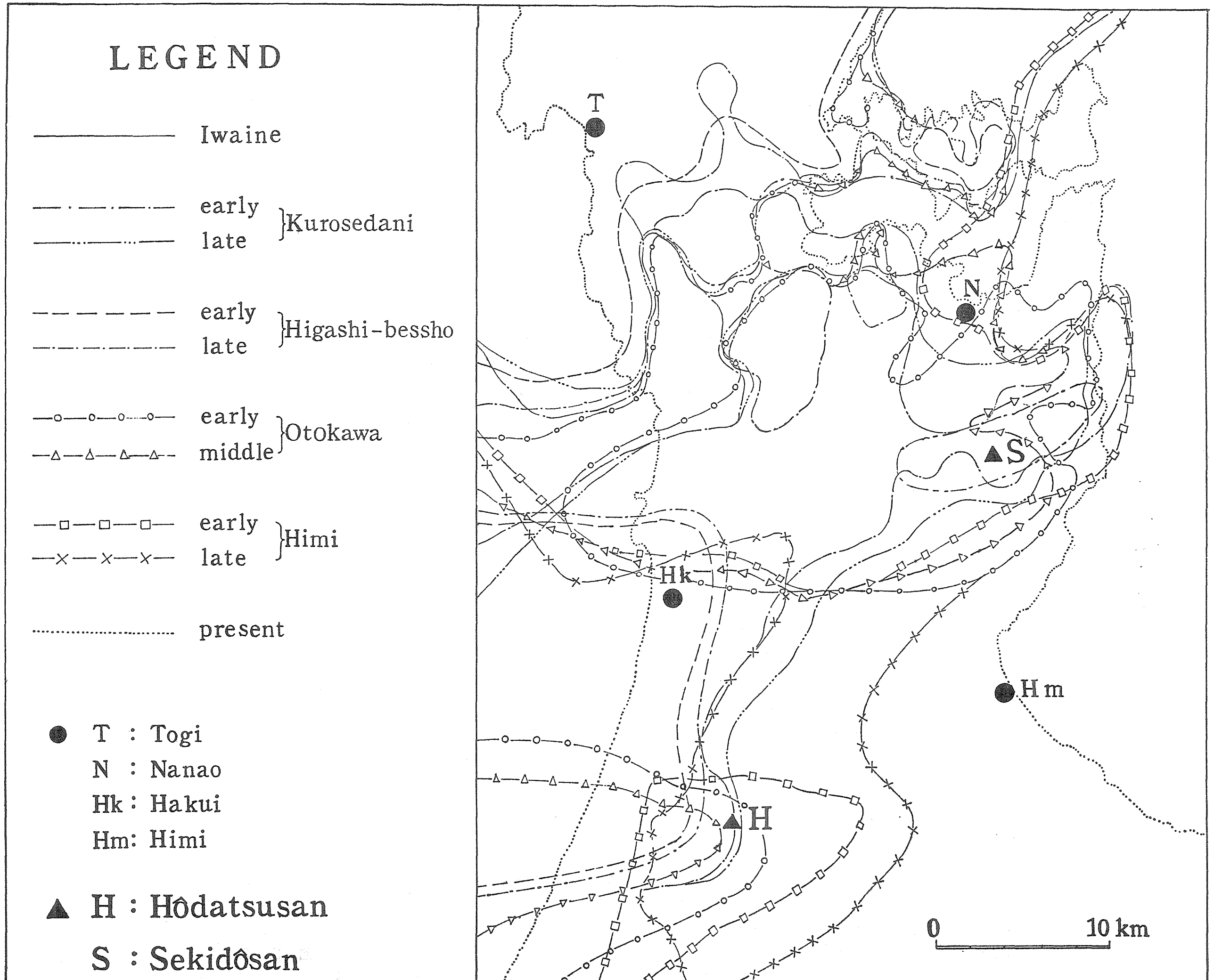

Fig. 11. Fluctuation of strand lines in Southern Noto area during the Neogene.

The shallow and cold sea of Himi age was the site of deposition of homogeneous fine sandstone, where an abundant remains of molluscan shells were buried associated with a large amount of benthonic and plaktonic foraminifers. The molluscan fauna named "Onma-Manganjian fauna" is the most representative Pliocene fauna in the Circum-Japan Sea region. On the deeper sea bottom of Himi age the siltstone containing abundant remains of planktonic foraminifers as well as molluscan shells was accumulated, which formed the Yabuta facies in Nadaura-Himi area. Throughout these processes the Sekidôsan-Hôdatsusan axial ridge had been gradually rising to form a new barrier in Southern Noto area. The Natsukawa facies composed of calcareous coarse sandstone appeared at this stage along the southeastern side of the new land mentioned above.

Owing to the emergence of the new land area, the Himi sea became shallower at late Himi age, and a medium to coarse brownish sandstone was formed. Although we have no proof in the mapped area, judging from the knowledge in adjacent areas, the Pliocene Himi sea immediately turned into a non-marine basin of Hanyû age at the end of the Pliocene epoch.

VI. REMARKS ON THE GEOTECTONIC HISTORY

In a contribution to the Neogene history in the eastern Hokuriku district, the writer and his coworkers recognized four stages of the Neogene sedimentary basin as follows (Kaseno, Sakamoto and Ishida, 1961):

1) Birth of the Neogene basin (Nirehara age, Early Miocene)
2) Progressive phase of the basin (Iwaine, Kurosedani to Higashibessho ages—Early to Late Miocene)
3) Turning point in the history (Latest Higashibessho to Earliest Otokawa ages—Late Miocene)
4) Retrogressive phase of the basin (Otokawa, Himi and Hanyû ages—Latest Miocene to Early Quaternary)

In the Southern Noto area dealt with in preceding chapters, four stages of the Neogene basin mentioned above are similarly recognized. The Neogene tectonic history in Southern Noto was strongly influenced by the structure of pre-Neogene basement, and the "pre-Otokawa disturbance" of Late Miocene is particularly emphasized above all. After the progressive phase of the Neogene basin from Early to Late Miocene, a general tendency of upheaval of the surrounding land and the basin itself had begun in the late Higashibessho age. In accordance with this movement, a large amount of coarse clastic sediments was supplied to the sea from the surrounding lands. Then the whole area ceased to sink, with the consequence of formation of various types of peculiar sediments such as calcareous biogenic sandstones, sponge-bearing sandstone and glauconitic layers.

The "pre-Otokawa disturbance" recognized in Southern Noto area should have a great significance to elucidate the Neogene history in Circum-Japan Sea region.

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SELECTED REFERENCES

(E) : in English; (J+E) : in Japanese with English Abstract ; (J) : in Japanese

AOKI, T. (1956) : Geology of the Nanao-Tatsuruhama District, Ishikawa Prefecture (MS). Graduation Thesis of the Kanazawa University. (J+E)

Cenozoic Research Group of Southwest Japan (1960) : An Outline of the Cenozoic History of Southwest Japan, *Chikyukagaku*, no. 50/51, p. 56–65. (J+E)

CHIJI, M. (1959) : Some Species of *Uvigerina* and Their Stratigraphic Occurrences in the Nadaura District of the Toyama Tertiary Basin, *Bull. Osaka Museum Natural History*, no. 11, p. 15–30. (E)

CHIJI, M. (1960) : Microbiostratigraphy of the Neogene Formation in the Nadaura District, Toyama Prefecture, Japan, *Bull. Osaka Museum Natural History*, no. 12 p. 63–95. (J+E)

CHIJI, M. (1961) : Neogene Biostratigraphy of the Toyama Sedimentary Basin, Japan Sea Coast, *Bull. Osaka Museum Natural History*, no. 14, p. 1–88. (J+E)

HANAYAMA, R. (1955) : Geology of the Nakajima District, Kashima-gun, Ishikawa Prefecture (MS). Graduation Thesis of the Kanazawa University. (J+E)

ICHKAWA, W. (1950) : The Correlation of the Diatom-bearing Mudstones in the Noto Peninsula and the Vicinity of Kanazawa City, *Jour. Geol. Soc. Japan*, vol. 56, p. 49–56. (J+E)

ICHIKAWA, W., KASENO, Y. et al. (1955): Geology of Ishikawa Prefecture, Published by the Hokuriku

Branch of Geol. Soc. Japan, p. 1–48. (J)

ICHIKAWA, W., KASENO, Y. and KOJIMA, K. (1955) : On the Miocene Non-marine Diatomite in the Vicinity of Nakajima-machi, Noto Peninsula, Japan, *Jour. Geol Soc. Japan*, vol. 61, p. 381–386. (J+E)

ICHIKAWA, W. (1960) : On the Fossil Marine Diatoms in the Wakura Beds, Noto Peninsula, Japan, *Sci. Rep. Kanazawa Univ.*, vol. 7, no. 1, p. 175–214. (E)

ICHIKAWA, W. and KASENO, Y. (1963) : Diatomaceous Deposits of Noto, Japan. Published by Ishikawa Prefectural Government, p. 1–45. (J+E)

IKEBE, N. (1949) : Tertiary Formations in Western Toyama and Eastern Ishikawa Prefecture, *Chigaku*, no. 1, p. 14–26. (J)

IKEBE, N. et al. (1951) : Geological Studies in Toyama and Ishikawa Prefectures, Part 3, Mt. Hôdatsu and Mt. Futakami Areas, *Chigaku*, no. 3, p. 7–16. (J)

IMAI, H. and YAMADERA, H. (1952) : The Peculiar Phosphate Deposits in the Noto Peninsula, Japan, *Jour. Geol. Soc. Japan*, vol. 58, p. 79–92. (J+E)

IMAI, I. (1963) : Geological Map of "Ôchigata" Sheet and Its Explanatory Text. Geological Survey of Japan (in press). (J+E)

ISHIDA, S. (1959) : The Cenozoic Strata of Noto, Japan, *Mem. Coll. Sci. Univ. Kyoto, ser. B*, vol. 26, p. 83–101. (E)

Ishikawa-ken (1951) : Geological Map of Ishikawa Prefecture in Scale 1:200,000. Ishikawa Prefectural Government. (J)

Ishikawa-ken (1953) : Geology and Mineral Resources of Ishikawa Prefecture. Ishikawa Prefectural Government, p. 1–130. (J)

KASENO, Y. et al. (1957) : Stratigraphical Studies on the Neogene Formations of the Nadaura District, Toyama Prefecture, Japan, *Jour. Geol. Soc. Japan*, vol. 63, p. 167–181. (J+E)

KASENO, Y. (1959) : Some Problems on the Tertiary Formations of Hokuriku District, *Bull. Kansai Branch, Geol. Soc. Japan*, no. 38. (J)

KASENO, Y., SAKAMOTO, T. and ISHIDA, S. (1961) : A Contribution to the Neogene History of the Eastern Hokuriku District, Central Japan, *Memorial Volume of Prof. J. MAKIYAMA*, p. 83–95. (J+E)

KITAZAKI, U. and ICHIDA, Y. (1950) : On Phosphorite Beds in Noto Peninsula, *Jour. Geol. Soc. Japan*, vol. 56, p. 127–135. (J+E)

KITAZAKI, U. and ICHIDA, Y. (1951) : Glauconite-bearing Strata of Noto Peninsula, *Misc. Rep. Research Inst. Natural Resources*, no. 19/21, p. 164–169. (E)

KUBO, K. and SUZUKI, T. (1950) : On the Coal-bearing Tertiary of the Mt. Sekido District, Noto Peninsula, *Bull. Geol. Survey Japan*, vol. 1, p. 270–277. (J+E)

KUWANO, Y. (1951) : Geology of Noto-jima, Ishikawa-ken, Japan, *Misc. Rep. Research Inst. Natural Resources*, no. 19/21, p. 158–163. (J+E)

MAKIYAMA, J. (1930) : An Outline of the Tertiary Formations in Toyama and Ishikawa, *Chikyu*, vol. 14, p. 161–174. (J)

MATSUMOTO, R. (1957) : Geology of the Sanmyô-Takahama Area, Hakui-gun, Ishikawa Prefecture (MS). Graduation Thesis of the Kanazawa University. (J+E)

MATSUMOTO, T. and IKEBE, N. (1958) : Volcanostratigraphical Studies on the Neogenic Hokuriku Province, North Central Japan with Special References to the Volcanic Rocks in the Toyama Basin, *Jour. Inst. Polytechnics Osaka City Univ., ser.* G, vol. 3, p. 79–112. (E)

MATSUSHIMA, Y. (1954) : Geology of the Ôchi-Shio District, Hakui-gun, Ishikawa Prefecture (MS).

Graduation Thesis of the Kanazawa University. (J+E)

MINATO, M. (1952) : Problems of the "Green-Tuff Regions" in Japan, *The Study of the Cenozoic* (Shinseidai-no-Kenkyu), no. 14, p. 1–10. (J)

MINATO, M., YAGI, K. and HUNAHASHI, M. (1956) : Geotectonic Synthesis of the Green Tuff Regions in Japan, *Bull. Earthq. Res. Inst. Univ. Tokyo*, vol. 34, p. 237–264. (E)

MISAWA, M. (1960) : Geological Study on the Neogene Formations in the Northeastern Slope of the Hôdatsusan, Southern Noto Peninsula, Japan (MS). Graduation Thesis of the Kanazawa University. (J+E)

MOCHIZKUI, K. (1928) : Preliminary Notes on the Paleogeography and Geomorphological Development in Southern Noto Peninsula, *Geogr. Review Japan*, vol. 4, p. 1044–1064. (J)

MURAMOTO, J. (1956) : The Geological Studies of the Northeastern Slope Side of the Hôdatsusan, Southern Noto Peninsula, Japan. (MS). Graduation Thesis of the Kanazawa University. (J+E)

NAGAHAMA, M. (1952) : Applied Micropaleontological Studies on the Tertiary Formations of the Sekidô Mountainland on the Ishikawa-Toyama Frontier, *Misc. Rep. Research Inst. Natural Resources*, no. 25, p. 46–51. (J+E)

NAKASEKO, K. (1952) : Microbiostratigraphy of the Yokawa Group in Western Toyama, *Sci. Rep. Osaka Univ.*, no. 1, p. 73–79. (J+E)

NISHIJIMA, T. (1958) : The Geological Studies of the Sakiyama District, Noto Peninsula, Central Japan (MS). Graduation Thesis of the Kanazawa University. (J+E)

OGAWA, T. (1908) : Explanatory Text of the Geological Map in Scale 1 : 200,000, "Wajima" Sheet, Geol. Survey Japan. (J)

OTUKA, Y. (1934) : The Oti Graben of Noto Peninsula, North Central Japan, *Geogr. Review Japan*, vol. 10, p. 645–670. (J+E)

OTUKA, Y. (1935a) : Stratigraphy of the Northeastern Part of the Oti Graben, Ishikawa Prefecture, *Jour. Geol. Soc. Japan*, vol. 42, p. 483–510. (J+E)

OTUKA, Y. (1935b) : The Oti Graben in Southern Noto Peninsula, Japan, Part 1–2, *Bull. Earthq. Res. Inst. Univ. Tokyo*, vol. 13, p. 218–235, 806–845. (E)

SAKAMOTO, T., IMAI, I., MIZUNO, A., SUMI, Y. and INOUE, M. (1959) : Cenozoic Strata in the Southern Part of the Toyama Sedimentary Basin, *Bull. Geol. Survey Japan*, vol. 10, p. 75–82. (J+E)

SUZUKI, K. and KITAZAKI, U. (1949) : Fundamental Consideration of the Geology of Coal, *Misc. Rep. Research Inst. Natural Resources*, no. 13, p. 39–58. (J+E)

TAKAI, F. (1944) : *Desmostylus* Occurred in the Phosphorite Deposits of Noto Peninsula, *Misc. Rep. Research Inst. Natural Resources*, no, 5, p. 59–62. (J)

Toyama-ken (1957) : Geological Map of Toyama Prefecture 1:200,000, and Its Explanatory Text. Toyama Prefectural Government. (J+E)

YOKOYAMA, M. (1928) : Semi-Fossil Shells from Noto, *Geol. Survey Japan, Report* no. 101, p. 113–128. (E)

YOKOYAMA, M. (1929) : Pliocene Shells from Nanao, Noto, *Geol. Survey Japan, Report* no. 104, p. 1–7. (E)

Abbreviations of Member Names Used in Plates I, II and IV.

Himi Stage (Pliocene)

hn : Nakagawa Sandstone (Shio area)
hk : Kojima Sandstone (Nanao area)
ho : Onma Sandstone (Hôdatsu area)
hs : Sakiyama Siltstone (Sakiyama area)
hy : Yabuta Siltstone (Nadaura area)
hg : Suginoya Siltstone (Shio area)
hw : "Natsukawa facies"---Calcareous Sandstone

Otokawa Stage (Latest Miocene)

ox : Kasashio Mudstone (Nakajima area)
ow : Wakura Diatomaceous Mudstone (Wakura and Notojima)
of : Futaana Mudstone (Notojima)
oak : Akasaki Mudstone (Sakiyama area)
om : Mushizaki Mudstone (Sakiyama area)
os : Sugata Mudstone (Nadaura area)
oh : Hijirikawa Mudstone (Shio area)
ok : Kuwanoin Mudstone (Himi–Kamisho area)
oa : Ao Mudstone (Himi–Nadaura area)
oy : Yoshida Alternation (Northern Hôdatsu area)
og : Ogume Sandstone (Himi–Shio area)
omk : Mukoze Sandstone (Shio area)
mgs : Moridera Green Sandstone (Himi–Nadaura area)
kz : Kuzuba Tuff–Alternation (Himi–Shio area)
nt : Nakada Tuff (Nadaura area)
gl : Glauconitic Layer (Nadaura, Sakiyama, Nanao and Notojima areas)

Higashibessho Stage (Lete Miocene)

nn : Nanao Calcareous Sandstone (Nanao area)
sz : Sazanami Calcareous Sandstone (Sakiyama area)
iz : Izumo Calcareous Sandstone (Takahama area)
ak : Akaura Sandstone (Nanao, Sakiyama and Takahama areas)
mi : Mio Sandstone (Himi–Shio area)
ko : Kono Sandstone (Eastern Hôdatsu area)
hm : Hamada Mudstone (Nakajima–Sanmyo area)
nk : Nakanami Mudstone (Nadaura area)
yt : Yoshitaki Mudstone (Nadaura area)
td : Takado Mudstone (Himi area)
mk : Mikohara Mudstone (Shio area)
ft : Fuchigatani Tuffite (Eastern Hôdatsu area)
ogt : Ogawa Tuffite (Himi–Nadaura area)
sc : Shichihara Mudstone (Nanao–Takahama area)
ss : Suso Mudstone (Notojima)

hcg : Hannoura Conglomerate (Western Notojima)
tka : Takabatake Conglomerate (Southeastern side of Ôchi Graben)
tki : Taki Conglomerate (Northwestern side of Ôchi Graben)

Kurosedani Stage (Middle Miocene)

od : Ôdomari Tuff (Nadaura area)
myt : Miyajima Green Tuff (Eastern Hôdatsu area)
km : Kunimi Mudstone (Sekidôsan–Himi area)
kf : Kakefuda Sandstone (Sekidôsan area)
sw : Serikawa Sandstone (near Ninomiya, Ôchi Graben)
sr : Shiroyama Conglomorate (Southern Sakiyama area)
sk : Sekidôsan Conglomerate (around Sekidôsan)
sg : Shingu Sandstone–Conglomerate (Shio area)
kw : Kawai Sandstone–Conglomerate (Southern Hodatsu area)
is : Isobe Sandy Alternation (Sekidosan–Himi area)
ng : Nagasaka Muddy Alternation (Sekidôsan area)
ta : Takio Alternation (Southeastern side of Ôchi Graben)
ts : Tsuboike Altereation (Northeastern Hôdatsu area)
tn : Tane Alternation (Southern Sakiyama area)
yd : Yamatoda Diatomeceous Mudstone (Nakajima–Sanmyô area)
ks : Kusaki Alternation (Sanmyô–Nakajima area)
ar : Araya Conglomerate (Sanmyô–Nakajima area)

Iwaine Stage (Early Miocene)

va : Andesites and Andesitic Pyroclastic Rocks
vu : Uriu Formation—Dacite, Dacitic Welded Tuff (Southeastern margin of Hôdatsusan)

Nirehara Stage (Early Miocene)

ns : Oota Formation—Conglomeratic Sandstone(Southeastern margin of Hôdatsusan)