67. The Oti Graben in Southern Noto Peninsula, Japan. (Part 2).

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4. Stratigraphy of the Environs of the Oti graben.

In this chapter, the stratigraphy of the environs of the Oti graben is described. The writer observed the following stratigraphic succession in this district:–The basal complex, which is the marble bearing gneiss and the granite near Sekidosan (石動山), is intruded by andesite and its derivatives that are overlain by the Neogene Tertiary beds.

For convenience, the writer has divided this district into three parts, namely, the southeastern part, the southeastern wall, and the northwestern part, all of the Oti graben.

The southeastern part consists of the Sekidosan mountainland and the west coast of Toyama bay. Although the stratigraphy of this province has been studied by MOCHIZUKI,[1] YAMANOUCHI,[2] and ESASHI,[3] only the former has so far published his work on the stratigraphic divisions with some brief remarks, the papers of ESASHI and YAMANOUCHI being as yet unpublished. In this paper, the writer, in order to avoid undue profusion of stratigraphic terms, will restrict himself as far as possible to those that have been adopted by previous authours, resorting to new ones only when absolutely necessary. The following stratigraphic succession is observed in this province in descending order:–Alluvial deposits, the Sazanami terrace deposits, the Himi sand beds, the Yabuta silt beds, the Yositaki mud beds, the Domi sand beds and andesites, and the Kosidi granite and gneiss.

The province of the southeast wall of the Oti graben includes the major parts of the southeast wall of the Oti graben, and the Sakiyama peninsula between the South Nanao bay and the bay of Toyama. The stratigraphic succession in this province as observed, in descending order is:–Alluvial deposits, the Akasaki and the Sakiyama terrace deposits, the Nozaki silt beds, the Entunagi mud beds, the Iori sand

1) K. MOCHIZUKI, *Geogr. Rev. Japan*, **4**, (1928), (in Japanese).
2) H. YAMANOUCHI, *Grad. Thet. Geol. Inst., Imp. Univ. Tokyo*, (1928).
3) S. ESASHI, *Grad. Thet. Geol. Inst., Kyoto. Imp. Univ.*, (1925).

beds, the Domi conglomerate beds and the andesites, and the Kosidi granite and gneiss, besides which are the talus deposits and fanglomerates derived from the southeast scarp of the graben. The Nozaki and the Entunagi beds are exposed in the eastern half of Noto(-zima) Island.

The northwestern part of the Oti graben consists of the Tumuki shell beds, the Kozima sand beds, the Wakura, Akaura, and Nanao beds, the last four of which are Neogene. The basal complex of this province are the andesite mass and its agglomeratic mass and gneiss breccias. The Hanoura (半ノ浦) beds, so-called by T. OGAWA,[4] in Noto (-zima) Island is a deposit contemporaneous with the Nanao beds.

Beside these beds, there are exposed at Hukami (深見), near Taduruhama (田鶴濱), loose sand and silt beds, which may be contemporaneous with MIMURA's[5] Takasina beds. The lastnamed, believed to be younger Neogene, are underlain by the Wakura beds with unconformity near Hukami. Basal andesite masses are exposed at Tadatu (直津) in Nisiminato-mura, Wakura, the Akakura mountainland, and Hosoguti. Gneissic breccias are exposed south of Yosikawa, at the foot of the Bizyosan fault scarp.[6]

Detailed stratigraphy.

a. The southeast part of the Oti graben.

The stratigraphy of the southern part of this province was studied by ESASHI, MOCHIZUKI, and YAMANOUCHI. ESASHI's manuscript, which is preserved in the Kyoto Imperial University, has been referred to in part by Prof. J. MAKIYAMA.[7] MOCHIZUKI's opinion has been published in his papers. YAMANOUCHI's paper, which is in manuscript, and which is now preserved by the Tokyo Imperial University, has been referred to in part by MOCHIZUKI.[8]

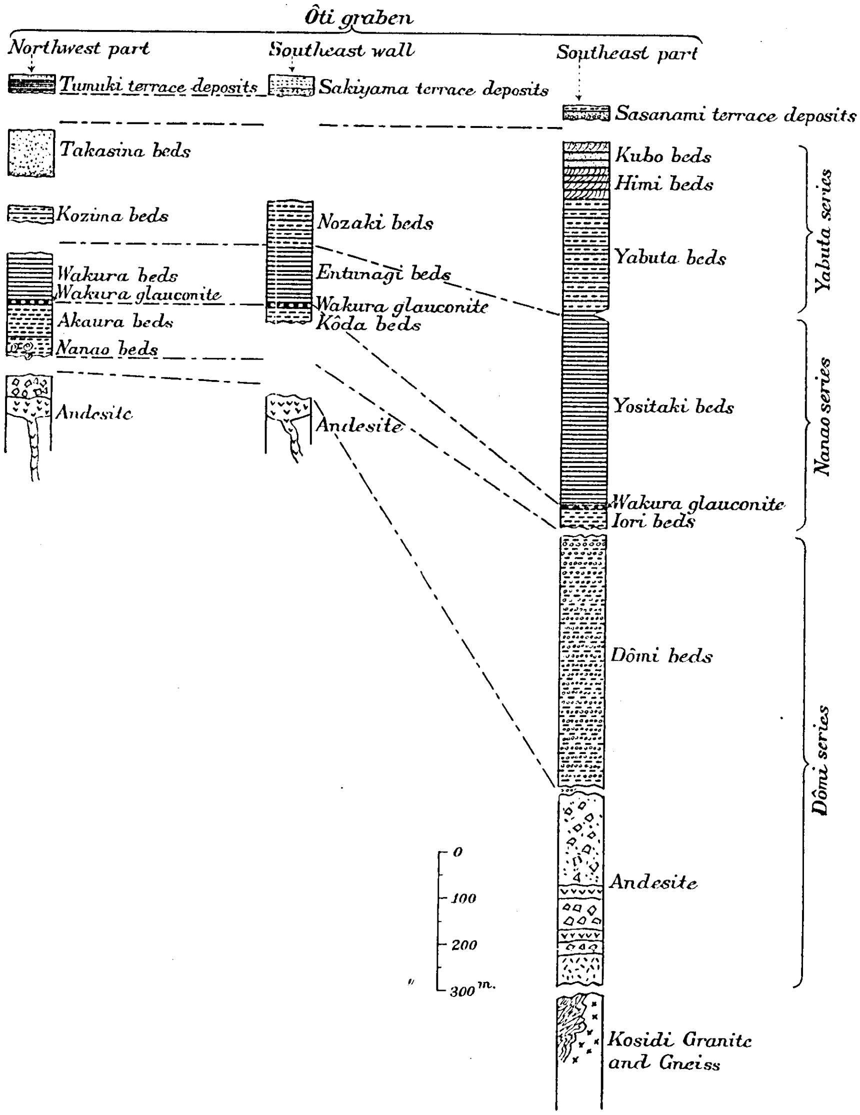
MOCHIZUKI,[9] has worked out the following stratigraphic succession of strata in descending order: the Himi, Nadaura, Yositaki, Kumabuti, and Ketagata beds. According to J. MAKIYAMA,[10] ESASHI's stratigraphic succession consists of three series, namely, upper, middle, and lower. The lower, called the Yokawa series, is a thick complex of tuffaceous mudstone and sandstone. The middle, called the Yabuta series, be contemporaneous with the Omma series near the city of Kanazawa (金澤).

4) T. OGAWA, *Expt. Text. Geol. Map. Japan* "Wajima" sheet, 1: 200,000, (1908).
5) S. MIMURA, *Grad. Thet. Geol. Inst., Kyoto Imp. Univ.*, (1928).
6) K. MOCHIZUKI, *op. cit.* (1928).
7) J. MAKIYAMA, *Chikyu*, **14** (1930), (in Japanese).
8) K. MOCHIZUKI, *op. cit.* (1928).
9) K. MOCHIZUKI, *op. cit.* (1928).
10) J. MAKIYAMA, *op. cit.* (1930).

The lower part of the Yabuta series is the Yabuta tuffaceous fine sand and silt beds, containing *Thyasira nipponica* YABE and NOMURA, while the upper is the Izumo pumiceous sand with many shallow-sea mollusca. The Yabuta series is concordant with the Yokawa series in the north of Yabuta village, but discordant with the Yokawa, west of the town of Himi (氷見). The fossils from the Yabuta series is a shallow-sea fauna found west of Himi. The upper series is called the Kubo series.

The writer observed the following stratigraphic succession in this province (Table II). Fig. 11 is a geologic map of this district.

Table II.



The Sazanami terrace deposits.

Of the many coastal terraces along the west coast of Toyama bay, the writer's Sazanami terrace, about 60~70 m above sea-level, is developed near Sazanami (佐々波) in Kitaoonomi-mura, Isikawa prefecture (Fig. 11). It extends from Musizaki (虫崎), north of Sazanami, to the environs of Hanazono. The material of the terrace deposits, which rest horizontally on Tertiary bed rock, consists mostly of weathered sand and rounded gravels of varying thicknesses, of which the white fine weathered quartzite pebbles which are often mistaken for pumice, are characteristic of these deposits.

Field observations (Sazanami terrace deposits) (Fig. 11, [Plate]).

Between Hanazono and Kurosaki.

Loc. 1. Gravel beds, unconsolidated, rest on dark greyish mudstone beds with unconformity. Gravel beds almost horizontal; varying in thickness, but generally about 4 m.

Loc. 2. Thickness of gravel beds gradually decreases from loc. 1 to loc. 2. Size of gravels small, about 0·5 cm diameter; white pumice like weathered quartzite grains visible in reddish-brown fine sands and gravels. Gravels unconsolidated, resting on bed rocks with unconformity. Surface of terrace accords with depositional surface of gravel beds.

Loc. 3. Kurosaki. No gravel beds here, but reddish-brown soils, in which white quartz grains are visible, are developed. Height of terrace near Kurosaki about 60~70 m, as in loc. 1 and 2.

Between Simosazanami and Musizaki.

Loc. 4. Fine-grained sand and gravel beds about 3 m thick, which rest on bed rock with unconformity, form surface of terrace about 60~70 m above sea-level. These gravels about 1 cm diameter. White pebbles of weathered quartzite found in these beds. Surface of terrace very flat with rice fields on them. Some small mounds, about 2 or 3 m high, scattered on terrace surface.

Loc. 5. On small road descending from surface of terrace to Musizaki (loc. 6), no rocks exposed. Similar terraces formed near Kamisazanami, Musizaki, and Iori on west coast of Toyama bay. The terraces, 60~70 m high, near Oonoki in Kitaoonomi-mura and Yamasaki in Sakiyama-mura may be contemporaneous with the terraces near Sazanami, Hanazono. Sazanami terrace deposits everywhere barren of fossils.

The Himi beds.

The Simazaki beds.

The Simazaki beds may be either ESASHI's Izumo beds or part of the Himi beds of MOCHIZUKI. In this paper, the writer treats the Simazaki beds as a part of the Himi beds. The Simazaki beds are alternations of sand and fine-sand bed, containing many fossil mollusca, bryozoa, and sponges. These beds are exposed on wall of hill scarp behind Simazaki village, in Zyunityo-mura.

Sand beds pumiceous, and sometimes crossbedded; pumice of these beds mostly andestic tuff.

Table III. Fossils from the Himi beds.
(Simazaki) (Otuka, 1935).

Puncturella nobilis (A. ADAMS)
Puncturella hirasei OTUKA n. n.
Umbonium akitanum SUZUKI
Homalopoma amussitata (GOULD)
Tachyrhynchus venustellus (YOKOYAMA)
Antiplanes kamchatica DALL
Navicula boucardi (JOUSSEAUME)
Arca amicula YOKOYAMA
Glycymeris aff. *rotunda* (DUNKER)
Limopsis tokaiensis YOKOYAMA
Pseudamussium intuscostatum (YOKOYAMA)
Chlamys swiftii etchegoini (ANDERSON)
Patinopecten tokyoensis kimurai (YOKOYAMA)
Patinopecten plebejus YOKOYAMA
Anomia sp.
Ostrea sp.
Lima subauriculata MONTAGU
Astarte hakodatensis YOKOYAMA
Astarte alaskensis DALL
Venericardia ferruginosa (A. ADAMS et REEVE)
Venericardia ferruginea (A. ADAMS)
Venericardia nakamurai YOKOYAMA
Corbicula sp.
Lucina acutilineata CONRAD
Cardium sp.
Macoma aff. *tokyoensis* MAKIYAMA
Tellina salmonea (CARPENTER)
Aloidis venustus (GOULD)
Myadora fluctuosa GOULD
Thracia transmontana YOKOYAMA
Waldeheimia sp.

The writer's Simazaki fauna, the fauna of Simazaki beds, is a shallow-sea fauna, influenced by cold current.

Table III gives the species collected from the Simazaki sand beds. From this list, the writer concludes that the Simazaki beds are not older than middle Pliocene in age, and not younger than earliest Pleistocene.

Field observations:

Near Simazaki, Zyunityo-mura. (Fig. 12)

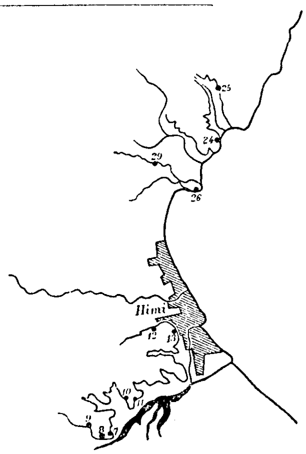


Fig. 12.

Zyunityo. Loc. 7. Alternation of sand and fine sand, strike about N60°E, dip about 3°~5° SW. Fossiliferous, calcareous, coarse grained.

Loc. 8. Fossiliferous sands exposed, on middle part of cliff wall, back of Simazaki village; stratification almost horizontal.

Loc. 9. Alternation of coarse-grained sand and fine sand; strike about N15°～20°E, dip 3° ES; barren of fossils.

Loc. 10, 11, 12. Consolidated coarse-grained sand, calcareous.

Loc. 13. Greyish-blue sand, fossiliferous, differing slightly from typical rocks of Simazaki shell beds.

The Yabuta beds.

ESASHI's Yabuta beds are typically exposed on a hill scarp at Yabuta, Ao village, in Yabuta-mura. A part of MOCHIZUKI's Nadanoura beds are in the Yabuta beds.

These beds may be seen between Ozakai (大境) (in Unami-mura) through the villages of Unami, Yabuta, and Ao. The coasts of these villages are collectively called Nadanoura (灘浦).

The Yabuta beds consist of bluish grey silt beds, the sandy shale of some Japanese authors; the stratification consisting of thick bed, in which calcareous nodules are often contained in the bedding planes. *Thyasira nipponica* YABE et NOMURA is a characteristic and commom species in these beds.

The upper limit of the Yabuta beds is not exposed in this province. According to MOCHIZUKI and ESASHI, the Yabuta beds are overlain by the Himi (Izumo) beds with conformity. The lower limit of the Yabuta beds is underlain by the upper Yositaki beds. According to J. MAKIYAMA,[10] Yabuta beds are underlain by the Yokawa (the writer's Yositaki) series with erosional unconformity southeast of the town of Himi. MOCHIZUKI has reported the following fossil mollusca from the Yabuta beds (Table IV).

Table IV. Fossils from the Yabuta beds
(After MOCHIZUKI)

Nuculana pernuloides (ADAMS) (DUNKER)
Nuculana ramsayi (SMITH)
Nuculana sp.
Yoldia japonica PILSBRY
Thyasira nipponica YABE et NOMURA
Lucina acutilineata CONRAD
Petricola aequistriata SOWERBY
Tellina (Arcopagia) siamensis ? MARTENS
Zirfaea subconstricta (YOKOYAMA)
Dentalium sp.
Natica janthostoma DESHAYES

Field observations: (Fig. 11, 12.)

Ozakai (in Unami-mura, Himi-gori, Toyama pref.)

Loc. 14. Conformable stratigraphic relation exposed on sea cliff. Yabuta beds distinguished from uuderlying Yositaki beds by color of weathered surfaces of these two formations.

Loc. 15. Boundary of Yositaki and Yabuta beds. The latter strike about N40° ~45°E; dip about 5° SE.

Loc. 16. Exposures of Yabuta beds numerous in Ozakai.

Loc. 17. Strike about N40°E, dip 10° ES. Silt beds; fossiliferous.

Loc. 18. Strike and dip more or less disturbed; northern part of this locality N80°E: 15°SE; but southern N35°W: 5°NE. Fossiliferous coarse grained sandstone.

Loc. 19. Strike N55°E, dip 10°SE; Strike and dip south of loc. 19 take general trend N35°E.

Loc. 20. Yabuta beds exposed.

Loc, 21. Upper Yositaki beds exposed.

Unami

Loc. 22. Yabuta beds exposed on sea cliff; more or less sandy, strike N35°E, dip 7°SE; Good exposures.

Loc. 23. Yabuta beds extend to summit of this mountain spur.

Yabuta

Loc. 24. Type locality of Yabuta beds.

Loc. 25. Boundary of Yabuta and Yositaki beds exposed here.

Loc. 26. Yubuta beds exposed.

The Yositaki mud beds.

The Yositaki beds, so named by MOCHIZUKI, are black mud beds exposed near Yositaki village. These beds are overlain by the Yabuta beds with conformity in the northern part of this province but with unconformity in the southwestern part. In this paper ESASHI's Yokawa series, and parts of MOCHIZUKI's Nadanoura and Yositaki beds are included in the Yositaki mud beds.

The present writer has subdivided the Yositaki beds into three parts, namely, the upper Yositaki, the Nakada pumice bed, and the lower Yositaki.

The upper Yositaki beds, which are overlain by the Yabuta, are typically exposed at Sugata in Nakada-mura. The weathered surface of these beds, which consists of dark greyish or black mud, are coloured with some brown or yellow substance. These beds are barely distinguishable from the lower Yositaki beds. Their stratification, although indistinct, is massive. The upper Yositaki beds are barren of fossils except certain very small white objects, as figured in fig. 218, Pl. LVII.

The Nakada tuffaceous beds, which are overlain by the upper Yositaki, are typically exposed on the northeast shore of Nakada (loc. 27), in Mera-mura (village). They are well exposed everywhere in Nakada, but scarcely so in the other localities, with the result that the distribution of these tuffaceous beds had to be determined with only a few field observations. The pumice of the Nakada tuffaceous beds in the type locality, which are about 2 cm in diameter, came from andesite tuff.

In the Sugata valley the writer failed to find any exposures of these beds, while in the Yabuta valley (loc. 28), he found a sand bed directly overlain by the Nakada tuffaceous beds of the type locality. Nakada tuffaceous beds are exposed at the eastern end of a reservoir, west of Ao (loc. 29) (about 600 m northwest of a bench mark at Ao). The size of the pumice here exceeds 1 cm in diameter.

From the few observations made of the Nakata tuffaceous sand, and by the relations of these exposures, it was found that the Nakada tuffaceous beds generally strike N30°E, and intercalate with the Yositaki beds, as shown in Fig. 11.

The lower Yositaki beds. As was done by MOCHIZUKI, the writer has selected for type locality the lower Yositaki beds on the dark greyish mud exposed at Yositaki, in Ao-mura.

The rocks of these beds, which closely resemble to those of the upper bed, rarely contain marly nodules. The lower Yositaki beds near Nakanami show platy joints, which IIZUKA[11] calls Nakanami black platy shale. The lower Yositaki beds near Tonohama are often cracked into fine blocks of about 3 cm diameter. IIZUKA calls this facies of the lower Yositaki, the Tonohama black shale.

The lower Yositaki beds contain thin tuffaceous beds, its lower limit being underlain by the Iori sand beds (loc. 30). The lower Yositaki beds gradually change their facies to sandy near the boundary of the Iori beds and the lower Yositaki beds.

Aphrocallistes sponge, and other fossils were collected from this boundary.

Generally, the lower Yositaki beds are barren of fossils, although they contain minute white objects about 3 mm. long, as shown in Fig. 218, Pl. LVII.

The distribution of the lower Yositaki beds is as shown in fig. 11. As will be seen from this map, the distribution of the lower Yositaki beds extends from Iori in Kitaoonomi-mura through Musizaki, Sazanami, and Hanazono, to Yositaki in Yatusiro-mura, generally with strike N15°$\sim$20°E, and dip 5°$\sim$2°E in the northern part and strike N45°E, dip 10°$\sim$20°SE in the southern.

The Iori beds.

The type locality of the Iori beds is the sandstone exposed near Iori in Kitaoonomi-mura, Isikawa prefecture. The Iori sandstone beds,

11) IIZUKA, "Nippon Tisitukosansi", Imp. Geol. Surv. Japan (1932), 148.

which are greyish blue, alternates with sandstone both calcareous and non calcareous. The weathered surfaces of these rocks are tinged brown.

The Iori beds at the type locality gradually merge into the overlying Yositaki beds with conformity, up to a thickness of a meters. This stratigraphic relationship is easily observed on the shore of southern Iori (loc. 30). The thickness of the Iori beds varies considerably. Fossils are rare in these beds.

The following fossils were collected from the sea-shore of Iori:

Aphrocallistes sp.
Chlamys crassivenia YOKOYAMA
Terebratulina quantoensis YOKOYAMA
Terebratella aff. crossei (DAVIDSON)

From the Iori beds exposed at Tobayasi (外林) (loc. 31), in Kitaoonomi-mura, *Chlamys crassivenia* YOKOYAMA was obtained, besides which the following fossils were collected from the shores of Siratori (loc. 32) in Kitaoonomi-mura, and from Kamisazanami in Kitaoonomi-mura: *Terebratulina?* sp., *Terebratulina caput-serpentis* (LINNÉ,) *Chlamys swiftii etchegoini?* (ANDERSON), *Chlamys* sp.

Terebratulina caput-serpentis (LINNÉ) was collected from the Iori sand beds under the bridge of high way at Kamisazanami (loc. 33).

These beds are not developed in the southern part of this province.

Glauconite sandstone bed, which is often developed between the Yositaki and the Iori beds, is exposed at Asao (麻生) and Sazanami in Kitaoonomi-mura, and Kurosaki (黒崎), Oiide (生出) (Fig. 15) in Minamioonomi-mura. As will be described later, similar glauconite sand is exposed between the Wakura mud beds and the upper Nanao (the Akakura sand beds).

Although as already mentioned, the upper limit of these beds is always overlain by the Yositaki beds, either with conformity or unconformity, the lower limit is underlain by the next underlying Domi beds, agglomerates, and andesites.

The Domi beds.

The Domi beds consist of black sandstone, conglomerate, agglomerate breccia, and greyish sandstone, all exposed near Domi (loc. 34) in Kitaoonomi-mura.

These beds will be subdivided according to its rocks when further studies have been made, until when they will be treated as a single formation. MOCHIZUKI's Kumabuti beds may probably be included in the Domi beds. The conglomerate of the Domi beds in the type locality consists of subrounded black pyroxene andesite pebbles of about 5 cm diameter. The sand and fine conglomerate alternations of the Domi beds contain many silicified woods.

The total thickness of the Domi beds, which in the type locality is about 250 m, thins out near Sazanami, whereas near Oguri, Simidudaira, it is about 200 m. On the road (loc. 35) from Suno in Kitaoonomi-mura to the town of Nanao, where the Domi beds contain fossil plants, the writer collected a cone of *Sequoia* aff. *sempervirens* ENDLICHER. As far as the writer knows, this plant fossil is a characteristic species of the Japanese Miocene.

It is notable that the Domi beds exposed south of the line connecting Takebe in Kosidi-mura and Onotomari in Minamioonomi-mura, contain thick yellow tuffaceous sandy beds and a few conglomerates.

Volcanic mass.

Overlain by the foregoing sedimentary rocks, andesite masses are exposed at a number of places, such as at Takebe in Kosidi-mura, Oonotomari in Minamioonomi-mura, Oiide in Minamioonomi-mura. These volcanic masses are exposed north of the line connecting Takebe (武部) and Oonotomari (大泊).

The Siratori volcanic mass.

The Siratori volcanic mass is an andesite mass exposed on the seashore between Siratori and Domi (百海). This pyroxene andesite is distributed only over a small area.

The Kooziyama andesite mass.

The Kooziyama andesite mass, which is exposed on the highway (loc. 36) between Nanao and Iori, south of Kooziyama (柑子山) in Kitaoonomi-mura. As shown in Fig. 16, this andesite mass extruded the yellow tuffaceous rocks, the original position of which cannot be traced near this locality. The andesite, and the agglomeratic conglomerate exposed near Kooziyama overlie the Kooziyama andesite mass with slight unconformity.

The eastern end of this andesite mass is cut by a fault by which the east part is thrown downward.

The Asao agglomerate and andesite mass.

The agglomerate and andesite mass, exposed for some distance near Simidudaira (清水平) and Asao (loc. 37) in upper Simosazanami valley, consist of two pyroxene andesite and augite bearing olivine andesite, their agglomerate, and other pyroclastic material. Its structure is not definitely known. This mass is overlain by the Domi beds with unconformity.

The configuration of the boundary of the unconformity between the Domi beds and the Asao mass is very irregular in its height as shown in Fig. 11. In their external features, the Oiide agglomerate and andesite mass, to be described in the next paragraph, closely resemble this mass. This unconformity is exposed near Suno (須能) in Kitaoonomi-mura.

Field observations (Boundary between Domi beds and Asao agglomerate and andesite mass).

Loc. 38. Alternation of yellowish tuffaceous coarse grained sandstone and agglomerate exposed on the upper part: andesitic agglomerate exposed below the alternation with unconformity.

Loc. 39~40. Weathered andesite.

Loc. 41. Yositaki beds underlain by agglomerate and andesite mass, intercalating brownish-yellow irregulary stratified volcanic material; exposure shown Fig. 14.

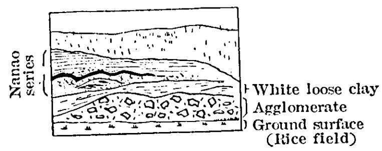


Fig. 14

Loc. 42. Glauconite sandstone bed exposed.

Loc. 43. Boundary between the Iori and Domi beds and the Yositaki beds exposed.

Loc. 44. Light yellowish tuff here intercalated.

Loc. 45. Alternation of dark brownish sandstone and conglomerate underlain agglomerate with unconformity; at Simidudaira, alternation strikes N45°W and dips NE 10°~18°; agglomerates and light yellowish tuff exposed on a small road between loc. 8 and Asao.

Loc. 47. Domi conglomerate beds exposed.

Loc. 48. Domi beds, closely allied to those at Simidudaira, exposed. These Domi beds overlie agglomerate at valley floor of Sazanami valley on road between Nanao and Suno.

Loc. 49. Similar exposure as that of loc. 78. Southeast wall of this valley consists of volcanic material.

Loc. 51. This exposure consists of more or less soft loose weathered soils supposed to be the Domi beds. No exposures of agglomerate or andesite on road connecting Suno and Nanao.

Loc. 52. Boundary of Domi beds and andesite and agglomerate mass exposed west of Suno. Boundary plane almost horizontal, dipping about 5° eastward.

Loc. 53. Boundary of Domi sandstone and andesite agglomerate seen here.

Loc. 54, 55. Exposure of Yositaki beds and weathered glauconite sandstone beds, the Domi beds, and andestic agglomerate seen here stratified in (descending) order named.

Loc. 56. Iori sandstone exposed, but not the Asao agglomerate and andesite mass.

The Oiide agglomerate and andesite.

The andesite rocks exposed on the upper course of Kumabuti is called the Oiide volcanic mass.

This volcanic mass, which is exposed for a considerable length along the Kumabuti valley, consists of pyroxene andesite and agglomerate, and yellowish tuffite beds, the distribution of which is shown in Fig. 11.

The Minakami green tuffite beds.

The whitish yellow tuffite beds, intercalated with the Oiide agglomerates, gradually changes color to green (loc. 58), resembling the so-called green tuff formation of northeast Japan. This Minakami green tuffite may antedate the upper part of the Oiide agglomerate mass, but its exact stratigraphic relation is not known. Although the present writer distinguishes these green tuffite beds from the Oiide mass here, the two formations are treated as one in the geologic map (Fig. 11).

The Kosidi gneiss.

The Kosidi gneiss, which is exposed on the northeastern slopes of Mt. Sekido(-san), consist of biotite gneiss and marble, its general strike being about N45°W. This rocks was metamorphosed by injection of the Kosidi granite, which is exposed behind Kosidi village.

b. The southeast wall of the Oti graben.

Raised beach of Akasaki.

At the mouth of the Akasaki valley (loc. 61) in Higasiminato-mura, a shell bearing silt bed rests unconformably on Tertiary bed rock in a small area about 10 m high. This silt bed is overlain by a thick brown sand bed. The fossil shells collected from this silt bed are shown in Table I, col. 1 (in Part 1). Judging from these shells and their stratigraphic relations, the bed may be similar to the Tumuki bed, as explained in Part 1.

The Sakiyama terrace deposits.

The so-called Sakiyama terrace bed is a loose coarse grained granitic sand bed, forming a 30～40 m terrace in Sakiyama-mura. This terrace bed, the thickness of which is about 5 m, but varying in places, rests unconformably on Tertiary bed rock.

The writer could find no fossils in this bed, which is well exposed on the sea-cliff at Mimuro (loc. 62) and Unoura (loc. 63) in Sakiyama-mura.

From its attitude and height of terrace, this terrace bed may be contemporaneous with the Tumuki terrace bed.

The Nozaki silt beds.

Besides these surface terrace deposits just described from this province, Neogene formation is exposed in the area from the eastern part of Notozima to Sakiyama peninsula.

The Nozaki beds so called by MOCHIZUKI, is the uppermost of these Neogene formations. The type locality of these beds is Nozaki (野崎) in Higasizima-mura. The Nozaki beds, which consist of bluish grey tuffaceous silt beds, whose dry weathered surface is light grey, end in which marly nodules are often found, are sometimes stratified as shown in Fig. 17 (loc. 64). Among the fossil shells commonly found in these beds are *Thyasira nipponica* YABE and NOMURA, *Turritella fortilirata saishuensis* YOKOYAMA, and *Nuculana onoyamai* OTUKA.

These beds, which are distributed over the southeastern half of Higasizima-mura and the greater part of Sakiyama-mura, extending to Higasiminato-mura, are narrowly exposed near Kozima in Nanao town, MIMURA calls them the Kozima beds. Judging from its rocks, fossils, and stratigraphic position, as has been done by Onoyama,[12] these Nozaki beds may be contemporaneous with the Yabuta beds already described.

Owing to absence of the overlying Neogene beds, the upper limit of the Nozaki beds is unknown. Its lower limit however is underlain by the Entunagi beds, although the boundary between these two beds is not very sharp.

Near Higasiminato and Sakiyama-mura, some white tuffaceous beds of about 1 m thick are interbedded near the boundary of these two formations, which tuffaceous zones enabled the writer to easily distinguish the Nozaki beds from the Entunagi, although in most cases the writer had distinguish the one from the other by its rocks, these tuffaceous beds being often of uncertain formation in other localities.

The fossil localities of the Nozaki beds lie north of Nozaki (loc. 66), Kamiyukawa (loc. 67) in Sakiyama-mura, Nakamura (loc. 68), Kayato (栢戸), Tono (殿), Uwaso (上澤), and Matuo (松尾) (loc. 71), Tobeiyati (藤平谷内) (loc. 86, 87) in Higasiminato-mura.

The following fossil shells were collected by the writer from these localities (Table V).

Table V. Fossils from the Nozaki beds.
(Y. OTUKA, 1935).

Nuculana onoyamai OTUKA
Acila divaricata (HINDS)
Glycymeris yessoensis (SOWERBY)
Arca amicula YOKOYAMA
Chlamys sp.
Lima sp.
Mytilus sp.
Astarte alaskensis DALL
Thyasira nipponica YABE et NOMURA
Lucina acutilineata CONRAD
Turritella fortilirata saishuensis YOKOYAMA
Turritella fortilirata motidukii OTUKA
Epitonium angulatosimile OTUKA
Neptunea uwasoensis (OTUKA)

12) T. ONOYAMA, *op. cit.* (1933).

The Entunagi beds.

The Entunagi beds are massive dark-greyish mud beds, the exposed parts of which, like the Yositaki beds already described, are tinged yellow. The weathered surface of the Entunagi beds is reddish brown. Small white objects (*Sagarites* ? sp.) and *Aphrocallistes* sponge are contained in them, the latter being very common in the basal part of the Yositaki beds. The type locality of the Entunagi beds is Entunagi (縁繋) in Nakanosima-mura. These beds, which are underlain by the Notozima andesite and the Koda beds, may be contemporaneous with the Wakura beds to be described later.

These beds are to be seen most everywhere in Nakanosima-mura, and from Sobogaura in Higasizima-mura, to Akasaki in Higasiminato-mura. Near Akasaki, they contain marly nodules. The islands Karasu (-zima), Tera (-sima), Yome (-sima), and Kosiki (-zima), all in South Nanao bay, consist of Entunagi beds.

Some tuffaceous beds near the upper limit of the Entunagi beds seem to be related to the Nakada tuffaceous zone of the Yositaki beds. These tuffaceous beds may be seen in the grounds of the Yatugasaki Primary School (loc. 72) in Higasizima-mura, in a cliff (loc. 73) near the tunnel between Nozaki and Koda, at a point (loc. 74) 500 m west of Nozaki, in the west and east (loc. 75) of Hidesima (日出島), and in Kadosima (鹿渡島) (loc. 76) in Sakiyama-mura, on the sea shore (loc. 77) of Mimuro, Konogi (此木) (loc. 78) in Higasiminato-mura, in the eastern hill (loc. 79) of Akasaki, and in Tobeiyati (loc. 80), Matuo (loc. 81), Uwaso (loc. 82), and Kayato (loc. 34), Nakamura (loc. 84, 85), all in Higasiminato-mura.

Other localities of the Entunagi beds extend from Onogi (大野木), Kitaoonomi-mura, through Himura, Tobayasi, to Matuo in Higasiminato-mura along the Ikakeyama flexure zone, which last will be described later.

The Koda beds.

The Koda beds are ovelain by the Entunagi beds with unconformity, a glauconitic sand bed being intercalated between the two beds. This glauconitic sand bed is exposed on the road (loc. 88) between Koda and Sanami, and in the grounds of a shrine (loc. 89) east of Koda village. South of these exposures, this glauconitic sand bed is indistinct.

The Koda beds, which are closely allied to the Akaura and the Nanao beds in the Northwest province of the Oti graben, in rock characters, and which consist of coarse grained white or light greyish sandstone, are believed to be contemporaneous, stratigraphically, with the Akaura beds.

The Koda beds, narrowly distributed in Higasiminato-mura and Sakiyama-mura, differ slightly in rock features from the type.

Stratigraphically the fossil bearing sandstone (the Iori beds) near Tobayasi, Iori may be contemporaneous with the Koda sandstone.

The Domi beds.

The Domi beds in this province are found on the southeast side of the Oti graben, where they consist of coarse grained conglomerate and alternation of sand and mud bed of variable thickness. Near Kosidi-mura, the components of the gravels in the conglomerate are mainly andesites, granite and gneiss, but on the north, these beds consist mainly of andesites and their agglomerates.

These andesites and their agglomerates and the gneiss and the granite underlain with unconformity by the Domi beds.

The Korosa agglomerate.

The agglomerate exposed near Korosa in Tokuda-mura, and called the Korosa agglomerate, consists of pyroxene andesite, and is overlain by the Domi beds.

The Takebe andesite.

This pyroxene andesite is exposed in the east valley of Takebe, adjoinning Kosidi granite.

The Kosidi granite.

This granite which is exposed in Ninomiya valley, Kosidi-mura, intrudes into the Kosidi biotite gneiss.

The Kosidi biotite gneiss.

The Kosidi biotite gneiss is exposed on the steep southeast slope of the Oti graben, near Ninomiya in Kosidi village, the general trend of the gneissosity being about N 60°E. The marble intercalated in this gneisose rock is worked as raw material for cement.

c. *Northwestern part of the Oti graben.*

The formations exposed here, besides the Alluvium and the Tumuki and Tokuda terrace deposits, show stratigraphic succession of Neogene as follows, in descending order:–

The Kozima, Wakura, Akaura, and Nanao beds, andesites, and gneiss breccias.

The Kozima beds.

The Kozima beds are the silty sandstone formation exposed on the hill scarp behind Kozima, west of Nanao. They are more or less tuffaceous, and contain many fossil foraminifera, mollusca, etc.

The fossils collected from these beds (loc. 91) are *Turritella fortilirata motidukii* Otuka, *Epitonium angulatosimile* Otuka, *Astarte hakodatensis* Yokoyama, *Cardium* sp., etc., many species of *Polymorphinidae*.

Near Iwaya (岩屋) at Nanao, these beds, which are underlain by the Nanao beds with unconformity are overlain by the gravel beds and coarse grained sand beds of Tumuki. The fossil mollusca, *Epitonium angulatosimile* OTUKA, *Turritella fortilirata motidukii* OTUKA, and *Astarte hakodatensis* YOKOYAMA are common species of Omma series of ONOYAMA, near the city of Kanazawa, from which the writer concludes that these Kozima beds may be contemporaneous with the Omma and Nozaki beds already described.

The Wakura beds.

The Wakura beds are a dark greyish massive mud or silt formation containning many diatoms.

The exposed surface of these beds is tinged yellow, the weathered parts being reddish brown.

T. OGAWA[13] gave it its name owing to its being typically exposed at Wakura, between the Wakura hot spring town and the Wakura railway station.

Isizaki, the northeast part of Isizaki-mura is the precise locality where the Wakura beds are exposed.

These beds are exposed also in the island of Noto (-zima) from Hanoura to Byobuzaki and Suso, and in the western part of Wakura from Tazuruhama to Sirahama and Kasasiho-mura. The Wakura beds exposed in the western half of Notozima are distributed in patches, resting on the Tertiary andesite bed rock with unconformity around this part of the island.

Hakonairie (箱名入江) and Magari (曲) in Nakanosima-mura, Suso-(須曽) (loc. 99)-Hanoura, and Minami (南) (loc. 90) in Nisizima-mura, are the other localities of Wakura beds in Noto (zima). The basal part of the Wakura beds exposed at Tadatu (直津) (loc. 93) and Minami and containing *Aphrocallistes* sp., are limited by a glauconitic sandstone bed, such as is seen in the basal part of the Entunagi (Yositaki) beds. This glauconitic sandstone bed, which is well exposed on a railway cutting south of the Wakura station, the writer calls the Wakura glauconitic sandstone bed.

Field observations on the Wakura glauconitic sandstone bed.

Loc. 90. In the southeastern part of Minami in Nisizima-mura, Is. Noto (-zima), Wakura glauconitic sandstone bed exposed on road between Minami and Magari. The almost horizontal bed contains *Aphrocallistes* sp.

Loc. 94. Takada in Akakura-mura. Glauconitic sandstone bed visible here on highway, but owing to weathered condition, exposure indistinct.

Loc. 95. On railway cutting southeast of Wakura station. Strike, N 40°E: dip 5°NW (type locality.)

13) T. OGAWA, *op. cit.*, (1908).

Loc. 96. On cutting along highway south of Wakura station.

Loc. 97. On road between Akaura and Hunao.

Loc. 98. On cliff southeast of Tadatu (Fig. 11). Wakura glauconitic sandstone bed here underlain by andesite and agglomerate with unconformity, intercalating with thin Akaura sand.

The Nanao beds.

The Akaura beds.

The Nanao beds are subdivided into two formations, the upper, the Akaura and, the lower, the Nanao. The Akaura beds, so named by K. MOCHIZUKI, are the greyish white coarse grained sand beds exposed near lake Akakura. These coarse grained sand consist of granitic sand, with rarely marine fossils. They are underlain by the Nanao beds with conformity, being rarely crossbedded, and are exposed from the southern part of Isizaki in Isizaki-mura to Siratori in Tokuda-mura, where they are underlain by the Takasina andesite and its agglomerate.

In Is. Noto (-zima), these beds are narrowly exposed around the Island at Minami, and Suso-Byobusaki-Hanoura.

The Nanao beds.

The next underlying beds, called Nanao beds by Prof. T. OGAWA[14] are contemporaneous with his Hanoura beds.

Iwaya (loc. 100), west of Nanao and Tumuki (loc. 101), north of Nanao are the type localities of these beds.

The Nanao beds at Iwaya contain many fossil mollusca and brachiopoda, the writer having collected the following species there (Table VI).

Table VI. Fossils from the Nanao beds.
(Y. OTUKA, 1935).

Patinopecten kagamianus (YOKOYAMA)
Chlamys notoensis YOKOYAMA
Chlamys hastatus ingeniosa? YOKOYAMA
Terebratulina septentrionalis COUTHOUY
Terebratulina japonica (SOWERBY)
Magelania lenticularis tenuis HAYASAKA
Coptothyris grayi aomoriensis HAYASAKA
Chlamys crassivenia YOKOYAMA
Pecten sp.
Laqueus rubellus SOWERBY
Isurus hastalis SOWERBY
Carcharodon megalodon (CHARLESWORTH)
Carcharodon sp.
Carcharias cuspidatus (AGASSIZ)

Latter 7 species were not collected by the writer.

14) T. OGAWA, *op. cit.* (1908).

Besides these fossil mollusca and brachiopoda, we find many bryozoa, spines of echinodermata, and foraminifera, but the characteristic species of the Kozima beds that overlie the Nanao beds with unconformity were not found in the Nanao beds here.

Among of the fossils, *Patinopecten kagamianus* YOKOYAMA and *Carcarodon megalodon* CHARLESWORTH are species common to the Middle Neogene of Japan.

According to ONOYAMA, these fossil mollusca resemble to those contained in his Omma series, while *Patinopecten kagamianus* (YOKOYAMA) is a characteristic species of ONOYAMA's Minamikanda series, which are overlain by the Omma series with slight unconformity.

Patinopecten kagamianus (YOKOYAMA) and *Chlamys notoensis* YOKOYAMA occur in the Saoyama series near Sendai, which is considered by H. YABE, to be Tortonian or Sarmatian in age, from which the writer is convinced that the Nanao beds may be contemporaneous deposits with the Minamikanda of ONOYAMA, and probably older than the Omma series. The Wakura beds above the Nanao beds are therefore contemporaneous with the Yositaki and the Entunagi beds, which are overlain by the Nozaki and the Yabuta beds with unconformity, while the Yabuta beds are certainly contemporaneous with the Omma series.

As far as the writer knows, no sedimentary rocks older than the Nanao beds are found in this province, although some volcanic rocks are found below the Nanao beds with unconformity.

The other exposures of the Nanao beds is in Hanoura, in Nisizima-mura, in which they are exposed below the sea-level. The mineral phosphates of this region come from these Nanao beds. Fossil localities of the Nanao series are loc. 100, 102, 103, 104, and 105.

The Takasina andesite and agglomerate.

The Takasina andesite and agglomerate are exposed on the west slope (loc. 106) of the pass between Iwaya, near Nanao, and Hannyano in Takasina-mura, and also west of Tadatu, in Nisiminato-mura.

These andesite beds are overlain by the Wakura and the Nanao beds with unconformity.

The Akakurayama andesite.

The Akakurayama andesite mass is what forms the mountain Akakura (yama). It is exposed at Otu (大津) (loc. 107) inKan agasaki-mura, clearly showing platy joints. It is overlain by the Wakura beds with unconformity at Otu.

15) H. YABE, *Rep. Geol. Palaeontol. Inst., Tohoku Imp. Univ.* **12** (1935), 23, (in Japanese).

The Notozima andesite.

The western half of Is. Noto (-zima) consists mainly of this andesite, which is overlain by the Wakura beds and the Koda beds with unconformity. Two pyroxene andesite is exposed at Hanoura.

Breccias of Gneiss.

The steep slope of the northwestern side of the Oti graben consists of gneiss breccias. The writer failed to trace the original gneiss mass whence these breccias came. On the top of this steep slope a coarse grained sandstone beds lie on the breccias, which here may be a basal conglomerate of those coarse grained sandstone beds.

MIMURA,[16] who described the Takasina beds, thought they might be Pliocene. The present writer observed these beds both in Takasinamura and Tazuruhama village, in the latter of which they rest on the Wakura mud beds with unconformity.

d. Conclusion.

Correlation of strata.

In the preceeding chapters the writer has described the stratigraphic succession in these three provinces. In this one he discusses the chronologic relationships of these stratigraphic successions.

Palaeontologically and petrologically, it is not unreasonable to correlate the Nozaki beds in the east of Is. Notozima with the Yabuta beds on the west shore of the bay of Toyama. The Wakura beds can be correlated with the Entunagi beds in Is. Notozima. These two beds consist of the same dark greyish muds. *Aphrocallistes* sp. occurs in the basal part of the Entunagi, the Wakura, and the Yositaki beds. In the basal parts of these, a glauconitic sandstone bed is sometimes exposed. These evidences may justify the correlation of these three beds with one another. The Entunagi beds which as will be described later, are exposed on the Ikakeyama flexuous zone, are underlain by the Iori sandstone near Tobeiyati with conformity. Since the Iori sandstone beds are overlain by the Yositaki with conformity at Iori, the Yositaki beds and the Entunagi beds (or the Wakura beds) are underlain by the same Iori beds with conformity. They must be stratigraphically contemporaneous with each other.

The writer has already described the occurrence of tuffaceous beds between the Entunagi and the Nozaki beds, which become indistinct toward the north. As the tuffaceous bed corresponding to this tuffaceous bed lying between the Entunagi and the Nozaki beds in the southeast, the writer is able to name the Simazaki sand of the Himi beds

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16) MIMURA, *Grad. Thetis. Geol. Inst., Kyoto Imp. Univ.*

and the Nakada tuffaceous beds in the southeast province of the Oti graben. As just described, the basal part of the Yositaki beds are exposed at Iori, while the Nakada tuffaceous beds are exposed in the upper half of the Yositaki beds, the Yabuta beds being interbedded between the Simazaki beds and the Yositaki beds. The Simazaki beds are, stratigraphically, the upper horizon of the tuffaceous bed between the Entunagi beds and the Nozaki beds. It being impossible to correlate the Simazaki beds with the upper part of the Entunagi beds from palaeontological grounds, the writer is of opinion that the Nakada tuffaceous beds may be contemporaneous with the tuffaceous beds between Entunagi beds and the Nozaki beds.

The fossil mollusca collected from the Simazaki beds listed in Table III, show that the Simazaki beds is not so old as the typical Omma beds near Kanazawa. Of these, a few species are reported only from the upper Pliocene. The Yabuta beds below the Simazaki, which may be the lower half of the Pliocene, is correlated with the Omma series as has been done by ONOYAMA.

The geologic age of the Nanao beds is the most important point for discussion. The fossil mollusca from the Nanao beds may not be the oldest Neogene. The strata containing these fauna in other localities are the Moniwa beds near Sendai, the Omma series near Kanazawa, and the Neogene beds of Simane prefecture.

The molluscan fauna of the Moniwa beds near Sendai studied by H. MATSUMOTO.[17] *Patinopecten kagamianus* (Yokoyama) and *Chlamys notoensis* Yokoyama are the common species of the Nanao and Moniwa beds. A part of the Moniwa beds may be contemporaneous with the Nanao beds.

ONOYAMA, from the palaeontological point of view, correlates the Nanao beds with his Tagawa beds,[18] but the writer is unable to agree with his views. He collected *Chlamys notoensis* (YOKOYAMA) and *Chlamys crassivenia* (YOKOYAMA) from his Tagawa beds, both of which are characteristic of the Nanao beds. His Tagawa (part of Omma) beds however contain no *Patinopecten kagamianus* (YOKOYAMA), which is a characteristic species of ONOYAMA's Minamikanda series below the Omma series. The Nanao moreover is lower than the Omma. The Nanao beds may therefore be contemporaneous with a certain part of his Minamikanda series.

The Neogene Tertiary of Simane perfecture, which is the type locality of *Patinopecten kagamianus* (YOKOYAMA.), TUBOTA[19] divided

17) H. MATSUMOTO, *Sci. Rep. Tohoku Imp. Univ.* [ii] **13** (1930), 95~105.
18) T. ONOYAMA, *Chikyu* **19** (1933), 276.
19) R. TSUBOTA, *Grad. Thetis Geol. Inst., Kyoto Imp. Univ.* (1932).

this Neogene Tertiary, the Sinzi group, into the following subdivisions in descending order: the Huzina, Kimati, Sagusa, Sakura, and the Sandy tuffaceous beds. The upper beds contain *Cultellus izumoensis* YOKOYAMA, *Macoma optiva* (YOKOYAMA) and *Patinopecten kagamianus* (Yokoyama), etc. ONOYAMA correlates these beds with his Minamikanda series, in which the writer is in agreement.

The Domi beds below the Nanao beds, being volcanic land deposits, contain *Sequoia* sp. (aff. *sempervirens* ENDLICHER) and other silicified woods. According to ENDO,[20] *Sequoia* flourished during the Japanese middle Tertiary. Since the Nanao beds which may be upper or middle Miocene, are younger than the Domi, the last named beds may be middle or lower Miocene.

The Miocene *Miogypsina-Operculina* horizon of Northwest Japan is situated in the lower half of ONOYAMA's Minamikanda series.

The Wakura, Entunagi, and the Yositaki beds resemble the Kubiki mud series (so-called black shale formation) of the oilfields of Northeast Japan, which contain *Pseudamussium peckahmi* (Gabb),[21] and *Aphrocallistes* sp. The Wakura beds also contain latter fossil. Though these formations are generally barren of fossils, the occurrence of these fossils shows that the formations may be contemporaneous with each other. These formations being believed to be upper Miocene by Japanese geologists, the Nanao beds may be older than the Kubiki mud series, Wakura, and other formations.

From these considerations the Nanao beds may be middle Miocene or upper Miocene. On this-basis the writer makes the general stratigraphic succession near the Oti graben to be as follows:

The Tumuki, Hiradoko, Sakiyama terrace deposits may be Pleistocene, and the writer calls them the Hiradoko series. The Sazanami terrace may belong to another group of Pleistocene deposits or it may be contemporaneous with the Hiradoko series.

The Takasina beds of MIMURA may be upper Pliocene. The Himi beds may be upper or middle Pliocene and occupy the upper horizon of the Yabuta series. The Yabuta, Nozaki, and Kozima beds may be middle or lower Pliocene, and contemporaneous with ONOYAMA's Omma series. The writer calls these beds the Yabuta series.

The Yositaki, Entunagi, and Wakura mud beds are collectively called the Wakura beds. The Yabuta beds are underlain by the Wakura mud beds with para-unconformity.

The Iori, Koda, Akakura, and Nanao sand beds are grouped under

20) S. ENDÔ, "Japanese Neogene Flora", *Iwanamikoza* (1933), (in Japanese).
21) T. OSE, *Jour. Geol. Soc., Japan* (1934), (in Japanese).

Nanao sand beds. The Nanao series, which consist of the Wakura mud and Nanao sand beds, may be contemporaneous with the major part of ONOYAMA's Minamikanda series, the upper Miocene or middle Miocene. The Domi series consist of the Domi beds and other andesitic pyroclastic formations resting on the Kosidi granite and gneiss. The geologic age of the Domi series may be lower or middle Miocene. Table VII is a correlation table of some Japanese Neogene.

Table VII. Correlation Table of Some Japanese Neogene (Y. OTUKA 1935).

Localities	Lower half of Pliocene	Miocene		
Akita-pref. (By CHITANI)	Yuri series	Ogasima series		
		Hunagawa	Onagawa beds	Daisima
Niigata-pref. (By OMURA)	Tyuetu series	Kubiki series		
		Teradomari		
Southern Noto (OTUKA)	Yabuta series	Nanao series		Domi ser.
		Wakura	Akaura & Nanao	
Northern Noto (By MOCHIZUKI)	absent	Iiduka beds	Wakayama beds	Orido beds
Kanazawa (By ONOYAMA)	Omma series	Minamikanda series		
Idumo (By TSUBOTA)	absent	Huzina and Kimati beds		
Sendai (By YABE)	?	?	Moniwa beds	

5. The geologic structure of the environs of the Oti graben. (see Fig. 11 and 13).

In this chapter, the writer describes the geologic structure of the environs of the Oti graben. First, we shall consider the crustal movements as inferred from the rocks, the thickness of strata, and the distribution of the geologic formations, and considered second, the structural history of the Oti graben as establisned from the deformation of the strata.

In these provinces, the andesite, the agglomerate, and the tuffite of the Domi series directly rest on the basement complex of the Kosidi granite and gneiss with unconformity. And on these andesite and pyroclastic rocks, the Domi conglomerate and sandstone beds, in which the silicified wood and other fossil plant leaves are contained, are laid. As no intercalating beds are found between the basal complex and the Domi pyroclastic rocks, the andesite of the Domi series would extrude directly on the erosional surface of the basal complex. The thickness of this volcanic formation varies, and it sometimes exceeds 400 m. Since the Domi series contain continental plant leaves and large stems of silicified woods without marine evidences, it would appear that this volcanism occurred on the land surface. Since the Domi conglomerate consists of andesites, basal granite, and gneiss, during the Domi stage, the andesitic volcanism was active in the granite and gneiss mountains, while the rivers dissected these volcanic lands. The relative heights of these volcanoes and mountains exceed 400 m.

During the succeeding stage, the Nanao transgression or Nanao regional subsidence occurred, as the result of which the marine Nanao series were deposited on the Domi series with unconformity. The lower part of the Nanao series consists of coarse grained sand, e. g. the Akaura sand beds, the Nanao sand beds, the Iori sand beds, and the Koda sand beds. These sand beds which are thick near Iori and Nanao, about 150 m thin out toward the south. The black mud beds of the upper Nanao series, e. g., the Wakura, the Entunagi, and the Yositaki beds, are distributed over a wide area, overlapping the underlying sandstone; the thickness of these beds varies. On the west coast of Toyama Bay the thickness of these mud beds increases about 100 m. They may be seen overlapping the sand beds near Is. Noto (-zima) and Sekidosan.

In Noto (-zima) island, the mud beds are directly underlain by the Notozima andesite without the Nanao sand beds. The line of unconformity between the mud and the andesite is closely related to the contour lines of recent topography. The depressed reliefs are occupied by the mud beds, while the upheaved reliefs consist of the underlying andesite (see geologic section EF in Fig. 13), which peculiarity in the geology and topography may be explained as follows: The Nanao series began to deposit on the dissected reliefs of Notozima andesite before the andesite areas were completely denuded, the valleys composed of the soft Nanao series being easily dissected again owing to the different resisting powers of the andesite and the Nanao series.

Consequently during the early Nanao stage, this area was drowned, and irregular outlines of the sea shore and small islands were formed; that is to say the land was subsided relatively to the sea during the early Nanao stage, before the land was denuded.

The mud beds, the upper part of the Nanao series, namely, the

Wakura beds, became broadly exposed on the Suzu-misaki, northern Noto. The writer found these mud beds on the Sekidosan mountainland, 400 m above sea-level (Fig. 11). This extensive distribution of thick beds of pelagic fine muddy beds suggests that the mud beds cover the whole Noto peninsula, at any rate the Sekidosan mountainland. Notwithstanding this wide distribution, the thickness of the mud beds varies considerably which may be explained by the erosion that succeeded the Nanao stage before the deposition of the Yabuta series to be described later.

According to J. MAKIYAMA, the Nanao series are unconformably overlain by the Yabuta series with an erosional surface. Near Nanao, the lower part of the Nanao series are unconformably overlain by the Yabuta series without the upper Nanao series, while the unconformity between the Nanao and the Yabuta seems to be a para-unconformity resembling the unconformity seen between the Kakegawa series and the Tamari series in Siduoka prefecture[22] and also between the Takanabe groups and the Tuma groups in Miyasaki prefecture.[23]

If the Nanao series near Nanao had really denuded away, the writer is opinin that the area near Nanao upheaved relative to the other part, which would be favourable to denudation of the Nanao series before the deposition of the Yabuta series.

It appears to the writer that the Yabuta series were deposited on a relatively flat surface. The thickness of the Yabuta series runs fairly uniform the rocks showing only a small variety, although it is impossible to tell whether or not the Yabuta series completely covered the Sekidosan area during the early Yabuta stage. It may however be true, that the east of Nanao, Sakiyama peninsula, and Noto (-zima) island, and the west coast of Toyama bay, at least, were at one time covered by the Yabuta sea. The Yabuta series consist of pelagic calcareous sands and pelagic species of fossil mollusca, e.g., *Thyasira nipponica* YABE and NOMURA, *Yoldia onoyamai* OTUKA, *Turritella fortilirata saishuensis* YOKOYAMA, *Epitonium angulatosimile* OTUKA etc., whence it may accepted that the sea in which the Yabuta series was deeply deposited covered the broad area of Noto. But during the late Yabuta stage, the sea-bottom gradually shallowed and the sea regressed. The upper Yabuta, the Himi beds, show this regression. The Himi beds consist of coarse-grained sand containing shallow sea and brackish molluscan remains. It was during this stage, that Mt. Seki-

22) J. MAKIYAMA, *Mem. Coll. Sci., Kyoto Imp. Univ.*, [B], **3**, **1**.
23) Y. OTUKA, *Geogr. Rev. Japan.*, (1930), 1048~1074, (in Japanese).

dosan must have emerged from the sea.

Summarising the foregoing, the following crustal movements in this region may be inferred:

(1) Volcanism was active on the erosional surface of granite and gneiss. River erosion predominaed during this stage.

(2) The Domi conglomerate contained silicified woods, land plants, and plant leaves.

(3) Marine transgression (or subsidence of land) of the Nanao stage occurred before river erosion had ended (Miocene). Beginning of the deposition of the lower Nanao series.

(4) Progress of marine transgression (or gradual subsidence of land). Deposition of the upper Nanao series.

(5) Local elevation of the land near the Oti graben bottom.

(6) Deposition of the Yabuta series. (Local denudation of the Nanao series. Gradual subsidence of the land). (Early Pliocene.)

(7) Beginning of the regression (or gradual upheaval of the land).

(8) Deposition of the shallow sea formation near Simazaki.

(9) Upheaval of the land. Beginning of the late Tertiary erosional stage. Formation of the Akakura mountainland and Takasina hill. (Late Pliocene—Early Pleistocene.)

(10) Gradual subsidence of land. Marine erosion of the Sazanami and Tumuki stage.

(11) Upheaval of land. Formation of the Sazanami and Tumuki terrace. (Late Pleistocene.)

(12) Rejuvenation of rivers. Dissection of these terraces begin.

(13) Subsidence of land. Formation of irregular outline of the recent shore line.

In the next paragraph, the writer will study the crustal movement inferred from deformation of the strata, and in doing so classifies the deformation of the geologic formation into faulting and folding.

Faulting.

Owing to lack of good exposures, the faults in this region could not be accurately determined, although no large fault of megatectonical importance was found. In the Domi beds and the beds below them many minor faults and folds were found, which however are the necessary accompaniment of megatectonic deformations.

The followings are the principal faults in these regions:

Ogoti fault.

The Ogoti fault extends from Ogoti, north of Mt. Sekidosan, westward to Takebe. In a small valley south of Takebe, Kosidi-mura, Kasima-gori, Isikawa-pref, Kosidi granite contacts with andesite and its agglomeratate in a vertical fault plane, which strikes about N80°W, or EW, and which, though covered with the Domi conglomerate near Korosa, reappears on the north slope of Mt. Sekidosan at Ogoti. Though the eastern extension of this fault line seems to reach Oonotomari in Minamioonomi-mura, the writer was unable to find any exposure of this fault line there. An exposure, on the shore of Oonotomari, shown some minor faults (strike about N80°E) cutting a conglomerate mixed with breccias of gneiss and andesite (N45°∼20°W: NE15°∼45°).

This conglomerate exposed near the boundary of basal gneiss and the Domi beds at Hirasawa, Mera-mura, Himi-gori, and on the southeast side of the Oti graben, the gneiss breccias at Oonotomari suggest that the boundary of the basal gneiss is somewhere near the exposure. The Yositaki beds here strikes N60°W, and dip NE30° in a small valley south of Toonohama, the strike of which deviates from the general trend of the Yositaki beds, although the original trend is recovered near Hanazono. At an exposure 2700 m west of the village of Toonohama, the Yositaki beds abruptly disappear and the slope of the mountain steepens, the breccias of basal gneiss being seen on the slope. This exposure of gneiss breccias suggests that the basal gneiss may be exposed near the slope, but this fault line is generally hidden by the overlying strata. The part of the fault line that is exposed near Korosa seems to be covered by the Domi beds. But andesite and agglomerate of the lower Domi series are cut by this fault line, the southeast part of which is upheaved relatively to the opposite side, where basal Kosidi gneiss covered by the Domi beds is exposed. On the opposite side are developped thick andesite and agglomerate. The character of the gravels in the upper part of the Domi series on both side of the fault line differ from each other. On the southwest part of this fault line, this conglomerate consists of gneiss, while on the opposite side the breccias of gneiss gradually decrease in both frequency and size while toward northeast black andesite blocks increase.

Kooziyama fault.

The Kooziyama fault, which is a small normal fault that runs N∼S or N15°E from the northeast part of Kooziyama, dips 60° westward and cuts the Iori beds. There is a down-throw on its eastern part. The strike and dip of the strata are N15°E, and 30°∼18°E. Another small fault parallel to this Kooziyama fault was observed west of Kooziyama village.

Siratori fault.

The Siratori fault is a small vertical fault running westward from the northern end of Siratori village, in Kitaoonomi-mura. Geologically, the part north of this fault line is the down throw side, while topographically this fault scarp is obsequent. The sandstone of the Iori beds on the north side of the fault is vertically flexed up along this fault plane. The south side of this fault forms a land slide topography, in which a large area of the slope slips gradually toward the sea.

Ikakeyama flexure and fault.

The Ikakeyama flexed zone and fault extend from Oonoki to Tobayasi through Himuro, west of Mt. Ikake. Along this zone, the strata on the west side are flexed up steeply westward, and sometimes vertically faulted.

Observations on the route from Himuro to Tomari.

The Nozaki beds are exposed almost horizontally at Himuro, but near the pass between Himuro and Kamiyukawa, they strike N20°W and dip 10°E.

East of the pass, these beds strike N30°E and dip 30°W, while west of the exposure just mentioned, they strike N35°E, and dip 45°W, and strike N30°E, and dip 70°W. In this way the angle of dip gradually increases as the exposure goes eastward, while on the top of the pass the angle of dip rapidly decreases, the strata being exposed horizontally.

This flexed zone changes into a vertical fault west of Mt. Ikake. The exposure of this fault is seen at a reservoir south of Kayato (Fig. 18), in which locality, the Yabuta series contacts directly with the Domi beds on account of this fault, but not with the Nanao series.

On a small road in the Domi valley from Domi village to Nakamura village, the following exposures were observed. The larger part of the Domi valley consists of Domi beds containing silicified woods. On the western end of the Domi village, black sands and black conglomerates containing silicified woods, are exposed.

Black andesitic sand and gravel beds containing much silicified wood, and which are exposed at the west end of Domi village, dip either horizontally or gently eastward. At the water fall on the valley floor of the Domi, west of Domi, these sand and gravel beds of the Domi series strike N18°W and dip 15°W. An anticline may be seen between these two above mentioned localities. The westerly dip of these strata gradually becomes steep toward the west. The black mud of the upper Nanao series is exposed near the turn in the Domi valley. In the meridional valley of the upper course of the Domi valley, the upper part of the Nanao series strikes from N15°E to N30°E and dip in 40°W. Although on the slope from Sawano to Nakamura, the upper part of the Nanao series and the Yabuta series have the same inclination of strata as the preceeding locality, their dips become somewhat steep, about 45°. On this slope, the writer observed a white tuff zone continued to Matuo.

At the Nanakura village, the westward dip of the Yabuta series becomes quite gentle, then gently dipping eastward about 10°~3° to form a syncline.

A similar structure is seen on the road from Uwaso to Tobayasi; namely, N10°E; E5° at Uwaso (loc. 70); N35°E: NW20° at Uwaso (loc. 83); N30°E: NW36°, east of Uwaso (loc. 82); N32°E: NW45°, east of Uwaso (loc. 85). Thus the dip gradually increases as one goes eastward, the underlying strata appearing in succession. But on the top of the Ikake range, where the Nanao series are exposed, the dip suddenly becomes gentle.

This flexed zone, which extends westward along the highway between Iori and Nanao to Yati and Sano in Higasiminato-mura, unites with the flexure of the east wall of the Oti graben.

Field observations near Matuo:

At the north end of Matuo village may be seen that a white tuff bed strikes N45°W and dips 10°NE.

In the valley, southeast of Matuo village, is exposed the boundary of the Nanao and the Yabuta series. The strata as measured on the underlying Nanao series strikes N60°E and dips in 45°NW.

On the road connecting Matuo village with the Iori and Nanao highway, 150 m distant from the highway, the upper part of the Nanao series strike in N75°E, and dip 30°N.

Near the summit of the highway, sand beds of the Nanao series strike EW, and dip 35°N.

At a point 300 m southeast of the pass, the gravel beds of the Domi series strike N80°E, and dip 25°N.

The Nanao series strike EW, and dip 30°N on the sharp turn of the highway on its west slope; they also strike N85°E, and dip 35°N in the valley of Sano in Higasiminato-mura. At the head of the Sano valley, the Domi conglomerate is exposed.

The overlying Yabuta series which are exposed east of Sano village, strike N 70°~75°E and dip 18°~40°N.

In the southeast valley of Sano, the valley, immediately southeast valley of the highway, the Nanao series are exposed, striking N45°E, and dipping 82°W. The inclination of these strata is very steep. At the exposure 200 m east of the exposure, just mentioned, the strata dip 45°N.

Flexure and fault zone of the southeast wall of the Oti graben.

The steep southeast slope of the Oti graben is topographically visible in Is. Noto (-zima), as described in the chapter under "Topography", but there is no geologic evidence there of this flexure and fault zone. Near Akasaki, in Higasiminato-mura, we find a flexure and a fault, which seem to be parallel to the topographic boundary line.

On the sea shore, south of Akasaki in Higasiminato-mura, the upper Nanao series, which strike in N10°W or NS and dip 18°W, are cut by a normal fault that strikes about N10°∼20°W, and steeply dips (about 70°W), while a tuff bed, which is horizontally intercalated near the upper part of the Nanao series is exposed on the west side of this fault, which is a down throw.

In the west down thrown side of this fault, the strata strikes N 30°W, and dip 32°W.

In the Akasaki valley, the upper part of the Nanao series, which contains marly nodules, are exposed on the valley floor. It dips westward near the sea shore, while 500 m east of it, the strata dips 5°∼3°E, forming a gentle anticline. The Yabuta series appear above the Nanao series 700 m east from the sea shore.

The fault just mentioned, which runs through Kaimonzi toward Tobeiyati, cuts in a vertical plane the Yabuta series north of Kaimonzi village.

Judging from the exposures along the road from the north of Tobeiyati to Nakamura, over a mountain pass, the Yabuta series strike NS and dip 45°W near a shrine at the western foot of the pass, while the angles of dip gently diminish east of the shrine. At the exposure 100 m east of the shrine, the strike is N10°W, and dip 33°W. On the exposure 550 m east of the shrine, the strike is N40°E, and the dip 5°E, forming a gentle anticline. The fault observed at Kaimonzi disappears in this locality. A gentle anticline is seen in the south valley of Kaimonzi.

The Yabuta series strike NS and dip 20°W at the Tamon shrine of Tobeiyati. In the bottom of the Tobeiyati valley, the angles of dip gradually descreases. At a point 900 m east of Tamon shrine, the strike is N 25°E, and the dip is 14°E. The axis of the asymmetrical anticline near Kaimonzi is situated 500 m east of the Tamon shrine, the west wing of which anticline is steeper than the east wing. It gradually disappears toward the south, merging into the Ikakeyama flexed zone.

These structures were inferred from the position of the Yabuta and the Nanao series in the Sakiyama peninsula. On the southern part of this area is exposed a flexure on a large scale, forming the geologic southeast wall of the Oti graben.

Two valleys south and north of Siroyama in Yatago-mura show this flexed structure. Traversing this south valley of Siroyama from the northwest, thick talus deposits are spread out in the form of a fan from the mouth of this valley toward the graben bottom. This valley dissects the steep slope of the southeast wall of the Oti graben. At the foot of the wall, the coarse grained sandstone of the Domi series is exposed, its strike being N70°E, and dip 30°N. A little southeast of this exposure, an alternation of reddish-brown coarse and fine sand beds, with strike N60°E, and dip 55°N, are exposed on the valley wall; on the next southeast exposure along this valley the strike and dip of the strata are N70°~75°E and 35°N.

In the bottom of this valley, the alternation of coarse and fine sand beds gradually change to coarse and to alternation of gravel and coarse-grained sand beds. The gravel beds consist largely of subangular blocks of gneiss and granite.

The angle of this structure, which dips 30°W continues under Siroyama, abruptly decreases on the southeastern part of Siroyama, with the result that, in this valley, the faults do not show the graben structure, the evidences of the geologic structure show pointing rather to a flexed structure.

In the north valley of Siroyama, where a similar flexed structure is observable, the strike is N50°E and the dip 60°NW.

Near Kunogi and Notozima in Tokuda village, a similiar structure is exposed namely, the strata has a westward dip at the foot of the southeast wall of the Oti graben, but horizontal at the summit. The anticlinal part between the horizontal beds near the summit and the steeply inclined beds on the graben wall has eroded away exposing the lower part of the Domi series, and sometimes basal granite and gneiss. In the valleys of Eso and Takebe, the andesite rocks of the lower part of the Domi series, are exposed on the anticlinal part.

The Kotoge fault, which is exposed on this southeast wall of the Oti graben near Takebe, does not affect the topography of the southeast wall of the Oti graben.

On the road from Ninomiya through Syakusitoge to Sekidosan, clear outcrops are exposed, showing that the Domi series overlie the basal gneiss with unconformity. The gneissosity generally strikes N 20°E, the dipping gently eastward. (Steep dips rare.) Near Syakusitoge a fault that is exposed, cuts the Domi beds. This fault strikes N10°W, and dips 80°W. Some normal faults parallel to the southeast fault scarp of the Oti graben are exposed on the northwest slope of the pass between Kotake and Himi.

The Domi beds on this slope strike about N40°~50°E, parallel to the general trend of this fault scarp, and dip northwestward 32°, 50°, 40°. But near Kitakihara, a village on the upper part of this slope, the basal gneiss and granite are exposed. On the summit of the pass, the Domi beds reappear horizontally. On the southeast slope of this pass, the Domi beds gently dip southeastward with the overlying formations namely the Domi, the Nanao, and the Yabuta series, appearing in the order named with a gentle dip.

From the foregoing geologic observations, the southeast wall, at any rate, of the Oti graben, is the geologic fault and flexed zone owing to which the graben bottom depressed relatively to the Sekidosan mountainland. The width of the flexed zone is 1·1 km, at its widest part (the thickness of the Domi beds measured on this flexed zone is about 600 m). Since in the southeast part of this flexed zone, the strata gently dips southeastward, the width of these area of gentle dip as measured at right angles to the general trend being from about 2 km at the narrowest and 12 km at the widest, the anticline between the flexed zone of the southeast wall of the Oti graben and the gently dipping part southeast of the flexed zone is not a simple anticline as seen in the simple folding structure, but an asymmetric syncline, where narrow west wing itself is considered to be a boundary zone between the block of the graben bottom and the block forming the southeast part of the Oti graben.

A similar relation is observable in the Ikakeyama flexure. The width of this flexed zone which is only 200～400 m, sometimes changes into a steep normal fault. The dips of the strata along this flexure zone are about 50°. While the northwest part of this flexure consists of the gently southeasterly dipping Yabuta series. This gently dipping area whose width measured at right angles to the general trend is about 2 km is cut by the Kaimonzi fault, from all of which the Ikakeyama flexed zone may be considered the southeastern boundary line of the block forming the gently dipped area.

These geologic facts lead the writer to believe in the existence of a block whose strata gently dip southeastward and are bounded by a zone of flexure and faulting. As will be discussed later, the geologic facts that the structure of the block gently dips southeastward, while the block is depressed relatively to the southeast side with normal fault and flexed zone, support the conclusion that the blocks which were formed by tension cracks on the backbone of an anticline on a large scale are depressed by gravity relatively to the wings of the anticline.

Fault in the northwest part of the Oti graben.

As described in the chapter on topography, the northwest side of the Oti graben is by its straight discordant boundary line, considered a clear fault topography while the geologic evidences of fault topography in the graben are very rare. Most of the evidences may be concealed by the younger talus deposits. Prof. J. Makiyama, found a fault near Tizi by which the northwest side has been thrown down. Lack of exposed faults cannot, however, nullify the fault scarp topography of the northwest side of the Oti graben. It could easily by assumed that the geologic fault is concealed under the Alluvial or younger deposits. But near Hosoguti, southeast of Kokubu on the northeast part of the Oti graben, the Nanao beds are exposed below the Tokuda terrace deposits in the graben bottom, from which geologic facts the writer is forced to conclude that the northwest margin of the graben bottom is not so greatly displaced relatively to the northwest part of the graben, seeing that topographically the straight valley of Oharaigawa may be considered a fault valley representing the northwest margin of the Oti graben, while the Nanao beds are exposed on both side of the straight valley and are not displaced relatively to each other.

At arie, southeast of Tokuda station, a deep boring was made from the results of which the Nanao beds seem to exend about 200 m below the ground surface of the graben bottom. Judging from the geologic map, the Nanao beds should be exposed on the land surface of Arie, whereas contrary to what we should expect as just stated, boring showed the Nanao sand beds at great depth. A relative depression of the graben bottom is therefore recognizable near Arie. From the lack of geologic evidences in the fault scarp topography of northwest wall of the Oti graben, some authors may deny the existence of a fault. For the lack of geologic evidence there are two possibilities; the one being that no fault exists, the other being that the fault is completely concealed by the younger deposits. In the former case, there is unquestionably no fault, whereas in the latter case, it may or may not be present. The writer therefore presumes the existence of fault from the auxiliary topographic and geologic features that do not contradict its existence, although its exact position, expect that it is on the northwest side of the Oti graben is naturally not determinable. As described in the chapter on topography, the river system on the back slope of the fault scarp like topography northwest of the graben is cut by the straight valleys and fault scarp of the northwest wall of the Oti graben. These head-cut river systems lead the writer to conclude that the northwest wall of the Oti tectonic valley originated from either a fault or a fault scarp.

The geologic structure of the northwest part of the Oti graben gently tilts northwestward, the basal part (gneiss breccias) cropping out at the foot of the fault-scarp-like slope. The Domi beds on the southeast wall are flexed downward and submerged under the bottom of the graben. It is therefore necessary to expect a fault or flexure structure on the northwest side of the graben bottom in order to explain the presence of these submerged formations in the northwest part of the graben.

Akaura flexure.

The Akaura beds, a part of the Nanao series, and distributed from Akaura to Sirouma, gently dip northwestward, and are overlain by the Wakura beds. The Akaura flexure is exposed at Hyakumatu near the Akaura lagoon and the pass (72 m south of Kurama-yama) west of Kozima near Nanao. The general dip of the Akaura beds is gentle and about $2° \sim 3°$, while on the flexed zone, the dip becomes steep toward the east, the western side of this zone having upheaved relatively to the opposite side. The northern and southern ends of this flexed zone were not traced. The width of the flexed zone is about 200 m. These displacement characteristics of the flexure differ completely from those of the Ikakeyama flexure.

Noto-zima.

Notozima (island) shows a structure quite independent of the preceeding localities. This island, which consists of two parts, the east and west is divided by the line that connects Koda and Sanami. The eastern side of the line consists of the Yabuta and Nanao series, and the west of andesite and the Nanao series.

The geologic structure of the east part is gentle and monoclinal. The Nanao series, which is underlain by the Notozima andesite, lie at the base of the Tertiary. The Yabuta series overlie the Nanao with conformity. These formations strike about N$20° \sim 30°$E, and dip 5°E. This monoclinal structure is disturbed by the Nozaki flexure, which is exposed at Nozaki, the eastern end of the island. On this flexed zone the Nozaki beds of the Yabuta series dip 50°W and strike N10°E. The northern end of this flexed zone is submerged in Toyama bay, while its southern end disappear near Koguti-seto.

This flexed zone dips steeply westward against the general dip of this area. In its sence of displacement, these characteristics of the flexed zone are similar to those of the Ikakeyama flexure.

The geologic nature of the boundary between the Notozima andesite and the Nanao series may be unconformity, but there is no fault. If any fault exists, it is probably a small scale one. The Nanao series, distributed around the andesite mass, occupies the depressed part of the andesite mass with unconformity. These Nanao series are developed almost horizontally, as may be seen at Magari in Nakanosima-mura, the bay head of Hakonairie, in Minami in Nisizima-mura, and in Hanoura and Suso. Comparing the heights of these almost horizontal Nanao series with that of Koda, the writer could find no difference between them, so that if any faults exist between the Nanao series and Notozima andesite along the line connecting Koda and Sanami, they are most likely on a small scale.

From the topographic map, the southeast wall of the Oti graben seems to extend from Hutaana along the topographic line to Sobogaura in Is. Noto (-zima), but so far as the writer knows, no geologic evidences of the flexure and fault have been found along the line neither in the Nanao nor the Yabuta series.

The northwestern wall of the Oti graben seems to extend to the topographic line of Koda and Sanami, but, as previously said the geologic evidence, if it could be called so, is merely an unconformity which may not be the result of a fault.

Folding.

The folding structure of the geologic formation developed near the Oti graben has already been described.

The eastern area of Sekidosan is a monoclinal structure dipping southeastward about $10°\sim20°$, with a younger formation exposed southeast of the older. The angles of dip gradually decrease toward the Sekidosan ridge, on which the lowest formation, the Domi series, is exposed. The Domi series exposed here are disturbed by minor folds and faults with very irregular strike and dip of strata. But in its larger structural relations, the strata forms an anticline of which on a large scale, the axis is situated along the ridge of Sekidosan. The exposure at Sekidosan, Arigahara, southeast of Kotake; Kitakihara pass; Arayama pass; Korosa; Masugata pass, and the east ridge of Siroyama, show horizontal strata. As both the flexed structure of the southeast wall of the Oti graben and the Ikakeyama flexure affect the Yabuta series, these flexed structures may postdate the formation of the Yabuta series; tnat is the geologic Oti graben was formed after the early Yabuta stage.

The writer ventures to say that, before the formation of its graben structure, the Oti graben area was a broad anticline, the southeastern wing of which is the southeast slope of Sekidosan, and the northwestern wing the northwest part of the Oti graben. The anticlinal axis is situated along the graben bottom. After the formation of the anticline, some underground geologic blocks near the anticlinal axis were depressed by gravity, and the overlying strata flexed along the margin of these depressed blocks. Figure 19 shows these structures besides the distribution of the dip angles, from which the distribution of the flexed zone may be clearly seen.

6. Tectonic history of the Oti graben.

Tectonic history of the Oti graben since the deposition of the Domi stage may easily be inferred.

There was a land surface on which the Kosidi granite and gneiss were exposed during pre- or early Miocene. There are no clues pointing to the relative heights of the reliefs of the land surface, which last was laid just before the deposition of the Domi series.

During the early Domi stage, volcanic activities were frequent on this land surface, as may be inferred from all these andesite masses namely, Akakurayama, Notozima, Kooziyama, Asao and Siratori andesites. The andesite exposed so widely in the Noto peninsula are the products of this stage. Relief forming went on extensively during this volcanic stage. Mountains of granite and gneiss and volcanoes were prominent features in this region, all of which in due course were dissected by rivers. The Domi conglomerate was formed during this erosional stage, and so was the Ogoti fault, the southern part of which was upheaved while its north side was depressed, and in which was accumulated the thick Domi conglomerate.

The Domi series, which have a continental character were dissected by river erosion. But the transgression of the Nanao series occurred before river erosion had dissected out these mountains and volcanoes of the Domi stage.

The writer previously said[24] that the volcanic activity was succeeded either by transgression of the sea or subsidence of land. In Noto, a similar relation of volcanic activity to transgression or subsidence is seen in the case of the Domi and the Nanao series. Evidence that deposition began before erosion had completed its work is seen in the Nanao series of Is. Notozima, as previously stated.

The transgression of the Nanao sea which affected a wide area, is believed to be the extension of Miocene marine transgression of *Operculina-Miogypsina* horizon which is distributed over the western half of northeast Japan, western Hokkaido, and in the prefectures of Isikawa, Toyama, Gihu, Siga, Hirosima, Okayama and Simane, and in Tyosen.

Noto, during this stage, was an archipelago. The Nanao stage was succeeded by upheaval of land, characterized by upwarping.

24) Y. OTUKA, *Bull. Earthq. Res. Inst.*, **12**, 3,

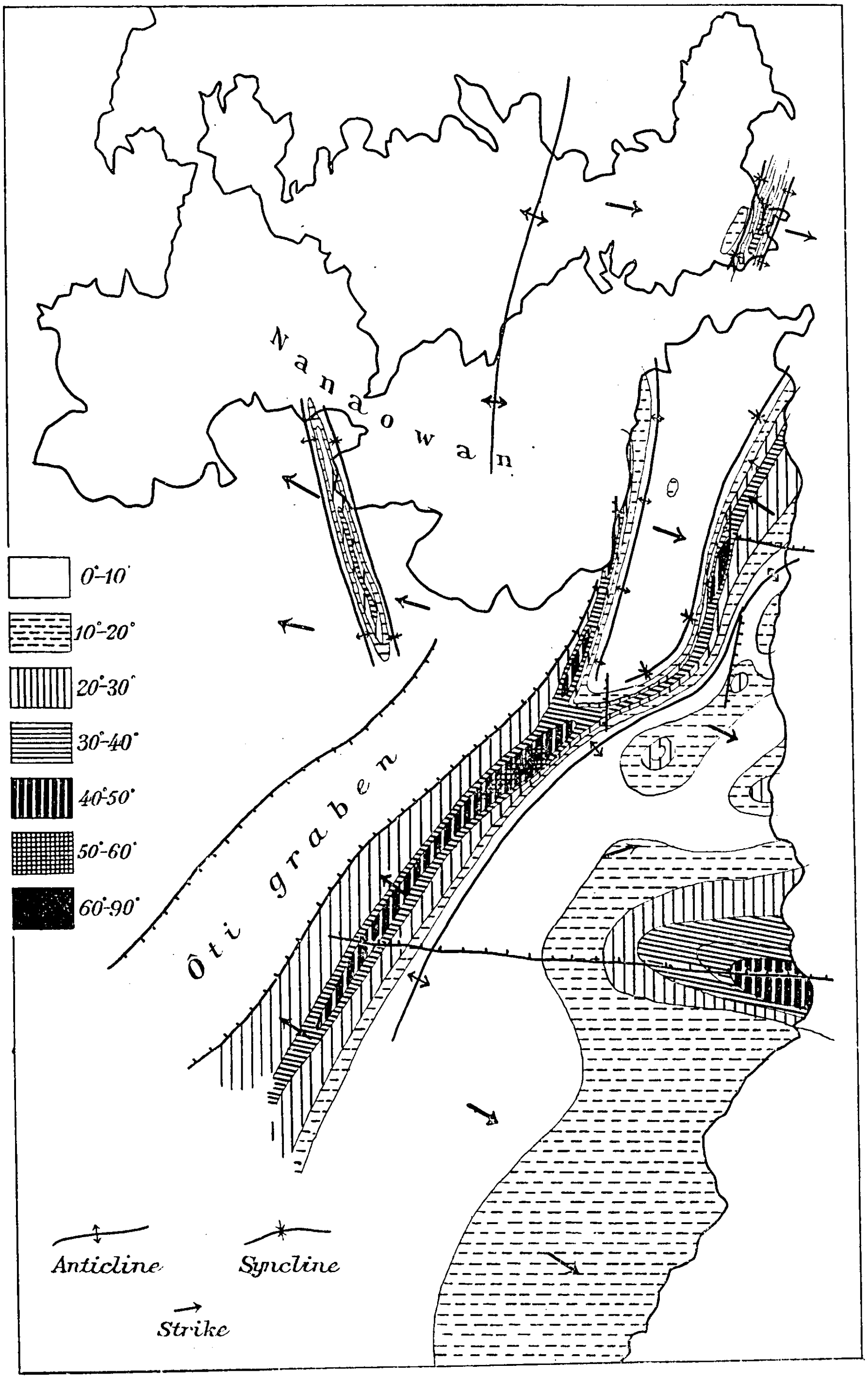

Fig. 19. Distribution map of angles of dip.

Figure 19 is a distribution map of the thickness of the upper Nanao series (the Wakura, Entunagi, and Yositaki beds). As shown in Fig. 20, the thickness of the upper Nanao series, which is thin near Nanao, is thick in the southeastern part of Sekidosan. Near Nanao, the lower part of the Nanao is directly overlain by the Yabuta series, with the result that namely the environs of Nanao were denuded more than the southeastern part of the Sekidosan; that is the upper Nanao series had not accumulated near Nanao. At any rate, it is certain that the environs of Nanao upheaved relatively to the surrounding areas; in other words, the Oti graben region was upwarped during the pre-Yabuta and late Nanao stages. The subsidence of the Yabuta stage succeeded this upwarping. The upwarping of the Oti graben region seems to have continues during the Yabuta stage. (The formations contemporaneous with the Yabuta series are restricted to the southern part of Noto). Regression of the sea was began during the late Yabuta stage. The coarse material and shallow sea fauna of the Himi series testify to the regression of the late Yabuta stage. During this stage of regression, the Sekidosan mountainland should have emerged above sea-level, followed immediately by subaerial denudation.

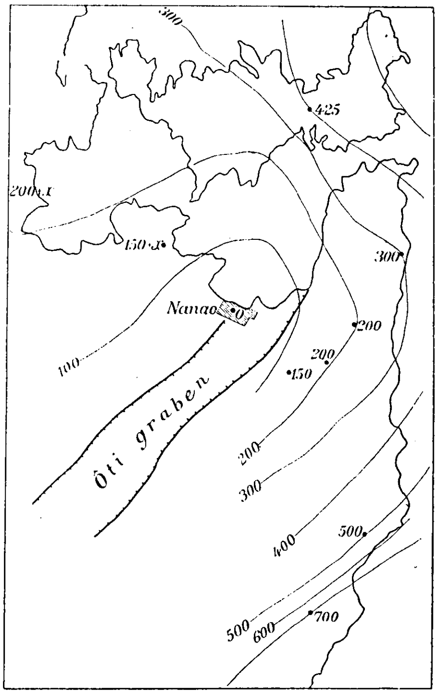

Fig. 20.

The formation of the Oti graben is believed to be concurrent with the early Yabuta (post-Nozaki) stage, as also that the graben structure of the pre-early Yabuta stage had not then existed. The area occupied by the Oti graben was rather upwarped before or during the early Yabuta stage.

The writer therefore believes that the Oti graben structure was formed in the post-early Yabuta stage, namely, post-early Pliocene, while the low reliefed surface of the Sekidosan, Akakura mountainland, were, topographically speaking formed during latest Pliocene. The amount of topographic displacement of the Oti graben is about 200 m, while the geological displacement exceeds 1000 m. The difference between these two displacements shows that the geologic graben was in existence before the formation of the topographic graben, which last was formed after the formation of the low reliefed surface of the Sekidosan and Akakura mountainland. Since the geologic graben was formed during post-early Pliocene and pre-latest Pliocene, the age of the geologic Oti graben may be late Pliocene. Topographically, the following history is inferred.

During latest Pleistocene, the region of the Oti graben was denuded into a low reliefed surface after the formation of the geologic Oti graben. Upwarpings of the Sekido and Akakura mountainland followed this denudation, while the tilting and upwarping of the Noto peninsula, inferred from the summit-level, and which was described in the previous chapter, may be contemporaneous with these upwarpings.

The topographic graben was formed during the post-Akakura and post-Takasina stages, although during the Tumuki stage, the topographic graben had already existed. The sea of the Tumuki stage invaded the Oti graben and formed the Tokuda terrace. After the formation of the Tumuki terrace surface, a 30～40 m upheaval of land (or subsidence of the sea-level) occurred in these regions, and the Oti graben bottom was tilted southwestward.

The upheaved coastal terraces were dissected. Recently, after which they subsided and many drowned valleys were formed along the eastern coast of Noto, during which stage, the graben bottom seems to have tilted down southwestward.

7. Conclusion.

The writer does not think that the Nanao earthquake of 1933 originated from the Oti graben. The origin of the earthquake deep seated below the earth's surface, mechanisms of the earthquake being inferrable only from the earthquake motions, although geologic conditions are necessary to explain the mechanisms and the earthquake disturbances. The Nanao earthquake area was surveyed by Rikutisokuryobu (the Military Land Survey) and discribed by T. SUZUKI.[25] As will be seen from these reports the earthquake disturbances are closely related to the geologic structure. According to the report of Rikutisokuryobu, the bench marks (Nos. 9300, 9301, 9302, 9303, 9304) between Wakura and Nanao all situated near the epicentre of the Nanao earthquake were upheaved, and bench marks on each side of the graben and graben bottom seem to have moved in diffferent ways. (See Fig. 3 B in Part 1.)

According to SUZUKI, the Akaura lagoon sank during the earth-

25) T. SUZUKI, *Bull. Earthq. Res. Inst.*, **12**, 1.

quake, while bench mark no. 9302, situated on Tertiary, near the Akaura lagoon rather upheaved, so that the depression of the Akaura lagoon during the earthquake may be explained by the settling of loose Alluvial mud and sand around the lagoon through earthquake motion.

The towns on the loose Alluvial deposits were severely shaken by the earthquake, much more so than those on the bed rock. This diference in the distribution of earthquake damage as related to the geology of the region may be explained by the shock resisting nature of the houses and the character of the earthquake motions, which suffer changes in their passage through loose material.

Additional notes.

It will be seen from the foregoing discussions that the volcanic activities were succeeded by marine transgression during a time so short as the Japanese early Neogene.

That a depressed structure had formed along the back bone of an anticlinel structure was made evident by a study of the Oti graben. This geologic characteristics has been studied by AMPFERER,[26] CLOOS,[27] E. SEIDL.[28] But in the case of the Oti graben, the faults that form along the backbone of an anticline as the result of the tension cracks are replaced by flexure structure. This characteristic of the Oti graben structure may not harmonise with the results of experiments made by other writers. To explain this flexuous structure, it is necessary to consider the pre-existing block structure or the underground block structure below the Neogene beds of Noto.

It is therefore the intention of the writer to try and ascertain by further studies the particular agency or agencies that were responsible for the anticline, and whether or not the flexures described in the foregoing pages are the result of pre-existent block structure.

The writer has expected that this study will make it possible to form an idea of the geotectonic development of the Sado island and Yamato submarine bank, under the assumption that these island and bank have geologic structural characteristic similar to those of the Noto peninsula. It will be expected from the foregoing studies that these island and bank have been formed into the recent isolated topography since the Diluvial age, and that their geology should have been isolated since the later Pliocene. This expectation will partly make sure by the study of geologic structure of Sado island.

26) AMPFERER, *Zeischr. Geomorphologie* **1** (1925).
27) CLOOS, *Geol. Rundschau*, **19** (1928).
28) SEIDL, "Bruch und Fliess Formen der Technischen Mechanik, und ihre Anwendung auf Geologie und Bergbau", (1934), 215.

Fig. 11.
Geological Map of the Environs of Nanao
(by Yanosuke OTUKA. 1935).

(震研彙報 第十三號 圖版 大塚)

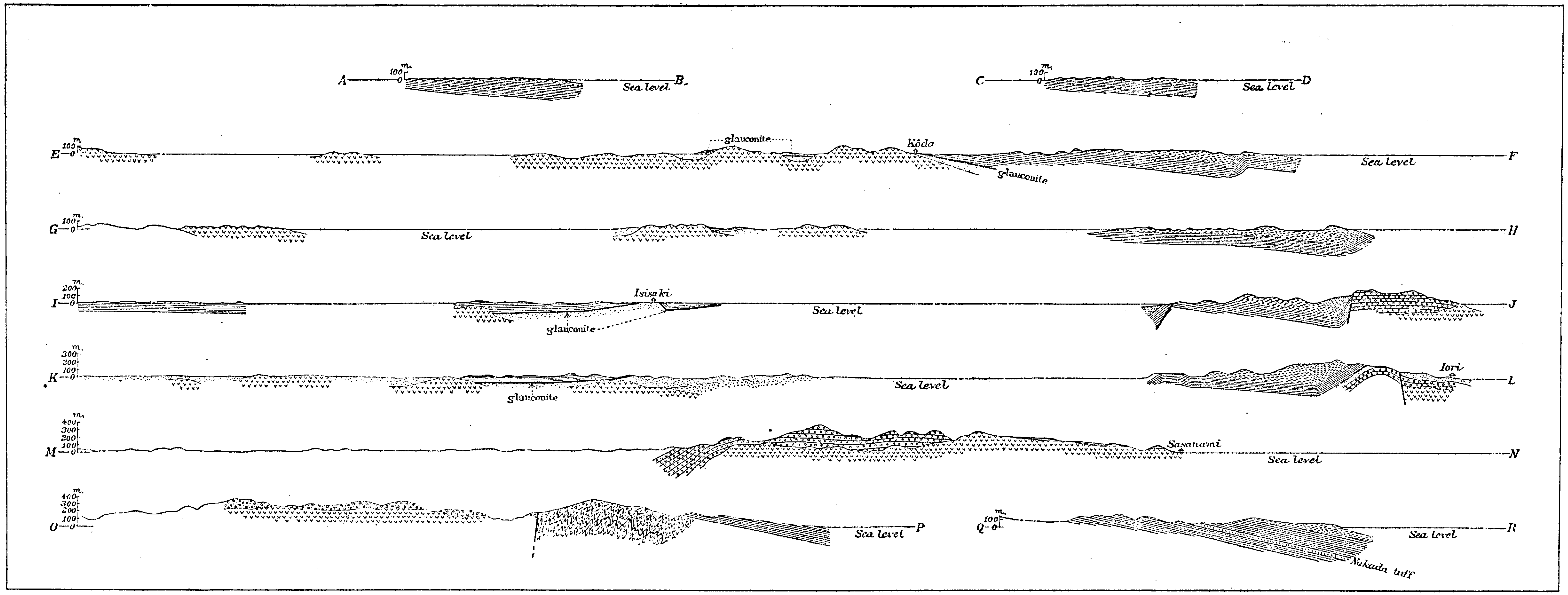

Fig. 13. Geological profile of the environs of Nanao by Yanosuke OTUKA. (1935).

[Bull. Earthq. Res. Inst., Vol. XIII, Pl. LII.]

Fig. 15. Exposure of Wakura glauconite sandstone (a) near Oiide.

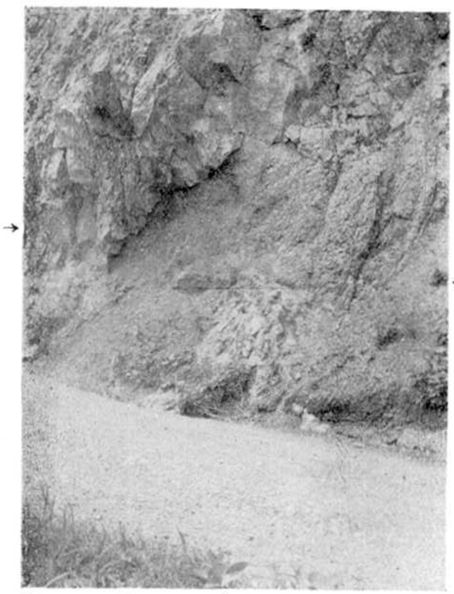

Fig. 16. Exposure of Kooziyama andesite (a) which intruded into yellow tuff (b).

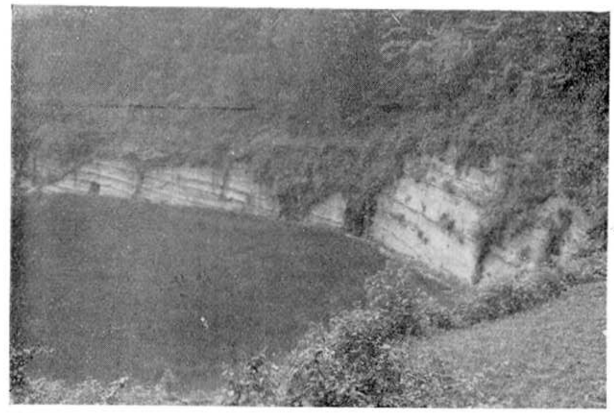

Fig. 17. Alternation of marly beds of Lower Yabuta series near Akasaki.

Fig. 18. Exposure of fault of Ikakeyama flexed zone. The Yabuta series are exposed on the left side of this figure, and the Domi series on the right.

能登半島南部邑知地溝 (2)

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この論文に於いては邑知地溝の東北部の層位及び構造に就いて論じた．

著者は先づこの地域を邑知地溝の東南部・邑知地溝の東南側・邑知地溝の西北部に分ち，之等各地域の層序を決定してゐる．（第2表參照）．七尾統の地質時代は中上部中新統としてゐる．

次に之等各地域の層序を比較對比して，地質構造論を行ふ基礎を作つてゐる．

地質構造の章では，第1に造陸運動的地殼運動を考察してゐる．著者によれば火山活動は沈降運動を伴ふことを指摘し，百海火山活動期に七尾海進時代が續いてゐることを擧げてゐる．

第2に斷層・皺曲等地層の層位から知られる地殼運動を論じ，邑知地溝に向つて落込む地溝式地質構造の存在を指摘してゐる．併し注意しておくことはこの地溝式をなす各地塊の境界は斷層でなく主として撓曲構造によつて代表されてゐる事實である．且つ一般傾斜は地溝の東南では東南方へ，地溝の西北では西北方へ向つてゐることである．この地質構造上の地溝は藪田統堆積中か又はそれより以後に構成せられたものであること．この地溝構造構成以前の邑知地溝地域が地質學上如何なる構造上の特性を持つてゐたかは，興味ある問題であるが，著者は七尾統上部の厚さの分布圖を作り，邑知地溝地域が最も薄くなつてゐるので，之を藪田統堆積以前の削剝に歸し，此の地域に軸を有する曲隆運動の存在を推定してゐる．著者は之等の地質學的事實が，曲隆構造背部に張力裂罅を生じて，その背部各地塊が重力によつて陷入る諸種の模型實驗の結果と類似性あるを説いてゐる．各地塊の境界は實驗によれば斷層で代表されるべきであるが，邑知地溝の場合には撓曲構造で境界が代表されてゐるので，この構造上の相異の説明として，地下に潜在する地塊構造を認めやうとしてゐる．