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Stratigraphy of the Toyokoro Hill, Eastern Hokkaido

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Abstract: The Toyokoro Hill is situated in the southernmost part of the Tokoro-Toyokoro Zone. Basement consisting of the Toyokoro Formation of Jurassic age is surrounded by the Neogene Tertiary and Quaternary formations. These younger sediments are composed of the Tokachichurui Group, the Okawa Formation, the Ushishubetsugawa Group and the Tokachi Group in ascending order. The Pliocene Takikawa-Hombetsu Fauna occurs at the lower horizon of the Tokachi Group. Geologic structure of the investigated area is characterized by the Toyokoro Dome and transverse faults cutting it, and also by active faults developing along the western margin of the dome.

1. Introduction

The Toyokoro Hill is situated to the southeast of the Tokachi Plain, eastern Hokkaido and has a flat feature with an altitude of about 300 m above sea level. Geologically, the area comprises the southernmost part of the Tokoro-Toyokoro Zone and is also located at the junction between the axial part of Hokkaido and the Outer Zone of the Kuril Arc (HUNAHASHI, 1957; SAKO, 1963; SAITO *et al.*, 1967) (Fig. 1).

The author has been engaged in the geological investigation of the area since 1966 and has reported already a part of these studies in a series of papers (MATSUI *et al.*, 1970, 1978; MIYASAKA *et al.*, 1978; SHIBATA *et al.*, 1975, 1979; YAMAGUCHI, 1970; YAMAGUCHI *et al.*, 1973, 1978; YAMAGUCHI and YOKOTA, 1974). Several distinctive features such as the existence of the so-called "green tuff facies" in the lower part of the Miocene, the development of the Setana Fauna at the lower horizon of the Pliocene, and also, characteristics of geologic structure of the area, have been clarified by these works. An outline of stratigraphic succession and characteristics of tectonic development of the area are summarized in this paper.

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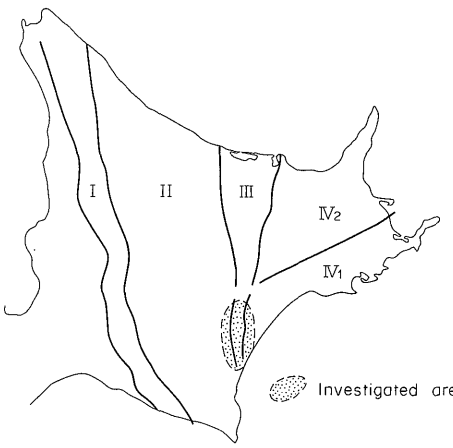

Fig. 1 Map showing the geotectonic division of Central to East Hokkaido and the location of the investigated area (dotted).

Central Hokkaido . . I: Kamuikotan Tectonic Zone
II: Hidaka Zone
III: Tokoro-Toyokoro Zone
East Hokkaido. . . . .IV_1: Outer Zone of Kuril Arc
IV_2: Inner Zone of Kuril Arc

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2. Outline of Geology

The Toyokoro Hill comprises the southernmost part of the Tokoro-Toyokoro Zone where the Neogene formations develop around the Toyokoro Formation of Jurassic age. This geologic framework was pointed out as early as in 1930's (NEMOTO and SASA, 1933; NEMOTO *et al.*, 1933). In 1962, ONITSUKA proposed a standard stratigraphic succession of the Neogene system in the Tokachi Region, summarizing the data obtained from extensive oil exploration surveys in the region carried on since 1956. This exploration work has largely contributed to the understanding of the geology of eastern Hokkaido. In the same year, the geologic sheet map of scale 1: 50,000 "Yudonuma" which covers the southeastern part of the studied area was compiled by MATSUNO. OKA (1979) reported on his geological investigations of the Neogene formations in the southern part of the Toyokoro Hill.

The basement, the Toyokoro Formation, which characterizes the Tokoro-Toyokoro Zone, shows a narrow distribution at the western central part of the Hill as separated horst blocks.

The author divided the Neogene and the lower part of the Quaternary into three groups and one formation; namely the Tokachichurui Group, the Okawa Formation, the Ushishubetsugawa Group and the Tokachi Group in ascending order, based on lithofacies, paleontological as well as stratigraphical evidences.

The Tokachichurui Group is divided into two formations, the Toyokoro Coal-bearing Formation of brackish to fresh water origin and the Toberi Formation intercalated with peralkaline rhyolite welded tuff. These two formations are of antecedent sediments in the Neogene transgression and are distributed closely around the Toyokoro Formation.

The Okawa Formation made up mainly of marine mudstone overlies unconformably the Tokachichurui Group and crops out surrounding it.

The Ushishubetsugawa Group overlies conformably the Okawa Formation and is extensively exposed in the area. It is divided into the Oikamanae and Taiki Formations. The Oikamanae Formation is composed mainly of hard mudstone and conglomerate. The Taiki Formation is characterized by diatomaceous siltstone.

The Tokachi Group is subdivided into the Nukanai, Komahata, Ikeda, Osarushinai, Shibusan and Mikawa Formations in ascending order based on lithology and contained fossils. The stratigraphic succession of the group reflects a transition of sedimentary environment from littoral shallow sea to inland lake conditions. The group is distributed at the marginal part of the area and covers the underlying formations unconformably.

Geologic structure of the area is characterized by the Toyokoro Dome elongated in the N–S direction, the core of which is occupied by the Toyokoro Formation. Historical devel-

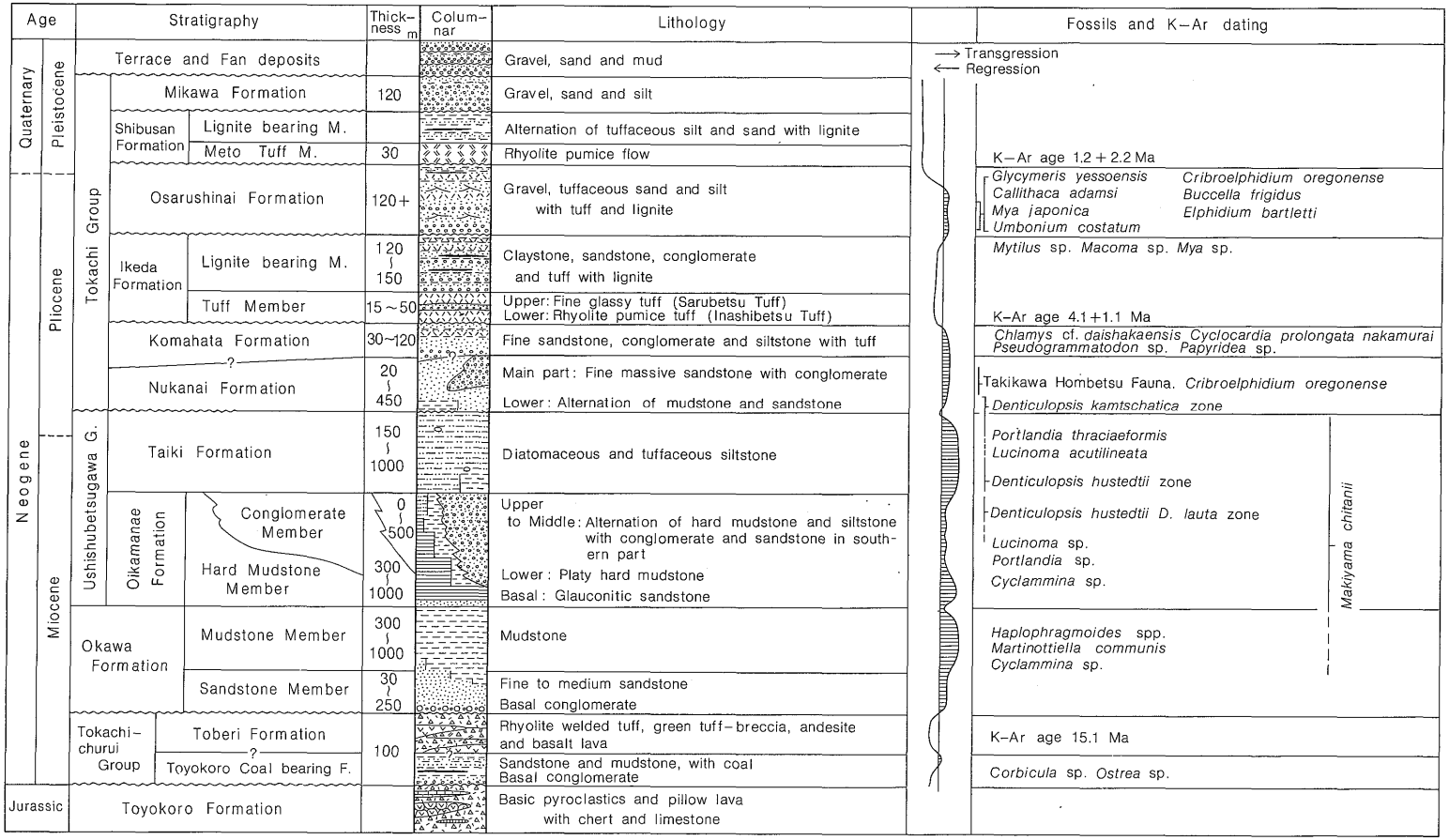

Fig. 2 Generalized stratigraphic succession of the Toyokoro Hill.

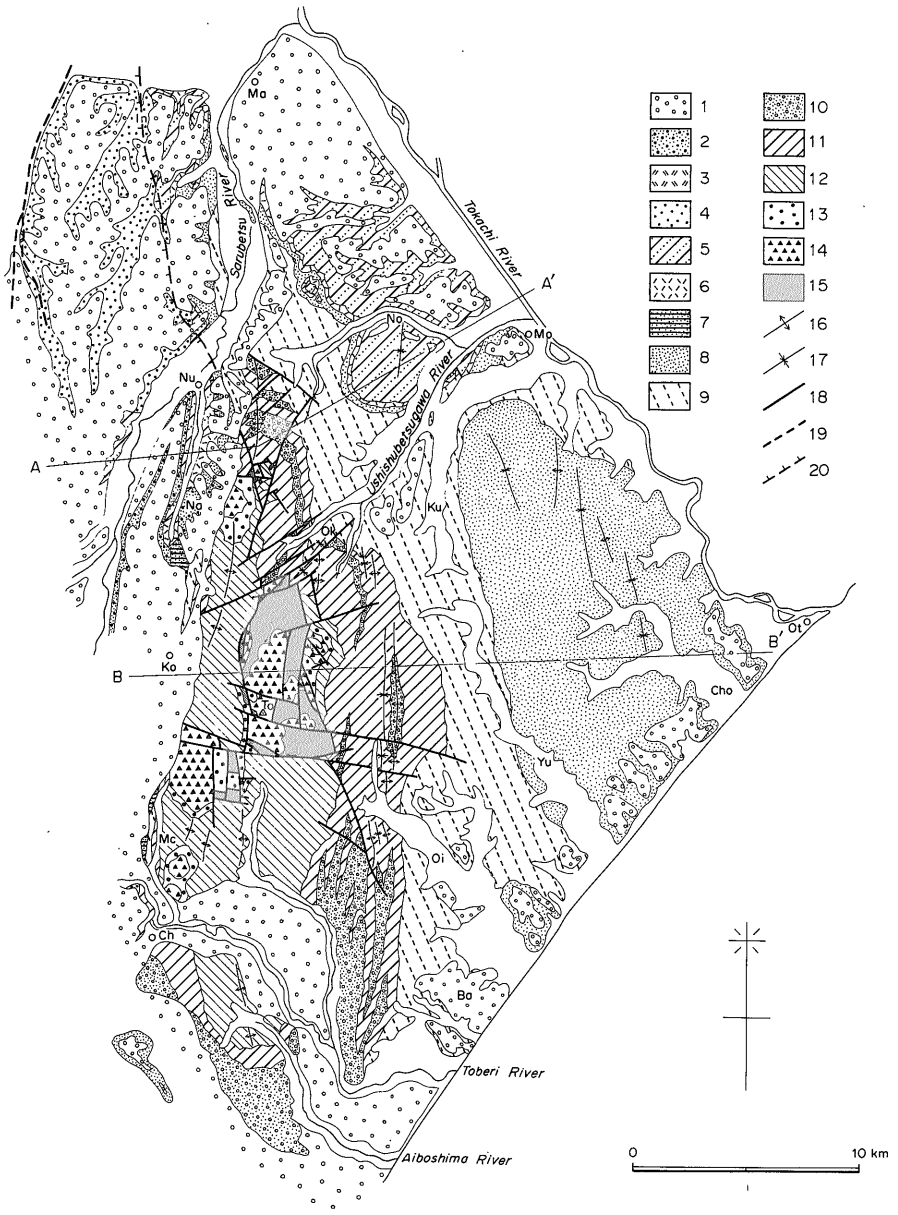

Fig. 3 Geological map of the Toyokoro Hill.

1. Terrace deposits, 2. Mikawa Formation, 3. Shibusan Formation (Meto Tuff Member), 4. Osarushinai Formation, 5 and 6. Ikeda Formation (5. Lignite-bearing Member, 6. Tuff Member), 7. Komahata Formation, 8. Nukanai Formation, 9. Taiki Formation, 10 and 11. Oikamanae Formation (10. Conglomerate Member, 11. Hard Mudstone Member), 12 and 13. Okawa Formation (12. Mudstone Member, 13. Sandstone Member), 14. Tokachichurui Group, 15. Toyokoro Formation, 16. anticlinal axis, 17. synclinal axis, 18. fault, 19. active fault, 20. warping line.

Abbr: Ba: Bansei, Ch: Churui, Cho: Chobushi, In: Inashibetsu, Ku: Kubo, Ma: Makubetsu, Mc: Motochurui, Mo: Moiwa, Na: Nakasato, No: Noyaushi, Nu: Nukanai, Oi: Oikamanae, Ok: Okawa, Ot: Otsu, Yu: Yudo, To: Toberi-yama.

opment of the Toyokoro Dome is estimated from the change in rock facies and from the thickness of respective Neogene formations. Doming up began in the Ushishubetsugawa stage and up- and downward movements continued intermittently until the Tokachi stage. Tectonic movement in the Tokachi stage became marked with transverse faulting of E–W trend and has much effect on the evolution of the Tokachi Tectonic Basin.

3. Stratigraphy

3.1 Toyokoro Formation (Nemoto *et al.*, 1933)

The Toyokoro Formation is exposed in a narrow area extended from the upper stream of the Ushishubetsugawa River to that of the Toberi River, central part of the Toyokoro Hill (Figs. 3, 4). The formation is covered unconformably by the Toyokoro Coal-bearing Formation of the Tokachichurui Group. It is composed mainly of basic tuff and contains pillow lava, chert and lenticular beds of limestone. The formation is considered to be correlative with the Nikoro Group in the northern part of the Tokoro-Toyokoro Zone and with the Sorachi Group in the axial zone of Hokkaido; the both latter two being Jurassic in age (Hashimoto, 1955).

3.2 Tokachichurui Group (new name)

The Tokachichurui Group newly defined in this paper comprises the Toberi Group of Miyasaka and Kikuchi (1978) and a part of the Tokachimakubetsu Formation of Onitsuka (1962). The group is divided lithologically into two formations, the Toyokoro Coal-bearing Formation and the Toberi Formation.

3.2.1 Toyokoro Coal-bearing Formation (Sasa *et al.*, 1952)

The formation covers unconformably the Toyokoro Formation and is exposed in a limited area. It consists mainly of grey mudstone with abundant coaly substance and is intercalated by several beds of fine- to medium-grained sandstone of 5 to 10 cm thick. In the basal part, a conglomerate bed of 1 to 5 m thick which carries angular pebbles derived from the basement rocks is recognized. Coal seams are usually thin and discontinuous, but maximum thickness of two meters is rarely observed. Total thickness of the formation is

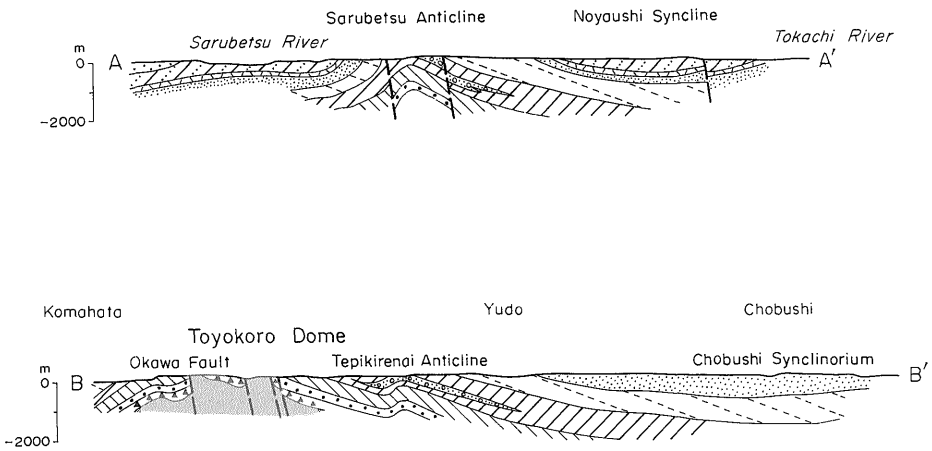

Fig. 4 Geological cross-sections of the Toyokoro Hill.

roughly estimated to be less than 100 m.

Such brackish molluscan fossils as *Ostrea* sp. are found in the formation. SASA *et al.* (1952) considered the formation to be Paleogene in age. However, the author is of the opinion that the formation is the Neogene from the reasons as follows: 1) Lithofacies of the formation is quite different from that of Paleogene formations in the Kushiro Coal Field; 2) The formation is closely accompanied by the overlying Toberi Formation described below.

3.2.2 Toberi Formation (new name)

The Toberi Formation corresponds to the lower part of the Nakasato Formation of ONITSUKA (1962). It is distributed *en échelon* along the axis of the Toyokoro Dome. It is found that a basalt lava of the formation overlies concordantly the Toyokoro Coal-bearing Formation in the Kogawa River area. On the other hand, the formation is overlain unconformably by the Okawa Formation with a basal conglomerate.

The formation is composed entirely of volcanic rocks such as lava, volcanic breccia, tuff breccia, tuff and welded tuff of various compositions. In the upper stream of the Okawa River, successive accumulation of basalt lava, green tuff breccia, andesite and rhyolite welded tuff is observed, and this fact indicates that the compositional change from basic to acidic occurred in volcanic activity during the Toberi time. NEMOTO (1933) called this rhyolite welded tuff as glassy sodic rhyolite or "okawaite". SATOH (1976) studied the same rock and concluded that it is peralkaline comendite from its mineral assemblage and chemical composition.

Judging from the distribution and change in thickness of the formation, it is suggested that the eruptive activity occurred along fissures parallel to the western margin of the Toyokoro Hill.

3.3 Okawa Formation (ONITSUKA, 1962)

The Okawa Formation redefined by YAMAGUCHI (1970) includes the upper part of the Nakasato Formation and the total Okawa Formation of ONITSUKA (1962) all together. ONITSUKA (ibid.) divided the Tokachimakubetsu Formation into the Nakasato Formation of effusive rocks and conglomerate, and the Okawa Formation represented by mudstone. However, the Nakasato Formation can be divided into two members by a distinct unconformity between the lower volcanic rocks and the upper conglomerate. In addition, the upper conglomerate grades into the Okawa Formation of ONITSUKA. Consequently, the Okawa Formation here defined comprises the above-mentioned conglomerate and the Okawa Formation of ONITSUKA.

The formation covers the Tokachichurui Group unconformably and is distributed in the western central part of the area, and is surrounding the Tokachichurui Group. The formation is lithologically subdivided into two members, the Sandstone Member below and the Mudstone Member above. The formation ranges in thickness from 400 to 1,200 m.

3.3.1 Sandstone Member

The member is distributed around the Toberi Formation. It is always accompanied by a basal conglomerate bed containing boulders of rhyolite welded tuff. The bed ranges in thickness from one to ten-odd meters. The main part of the member consists of bluish grey well-sorted massive tuffaceous sandstone. The thickness of a single layer is about several tens of centimeters and grain size generally changes from coarse to fine upward. Sandstone sometimes contains thin seams of coaly shale. From this sandstone bed, near the triangulation station 331 m, west of Okawa, *Ostrea* sp., *Mytilus* sp., *Venericardia* sp. and *Cardium* sp. were found. ONITSUKA (1962) reported the occurrence of foraminiferal species such as *Rotalia* cf. *tochigiensis* and *R.* sp. The member ranges in thickness from 30 to 250 m.

3.3.2 Mudstone Member

The Sandstone Member grades into the overlying Mudstone Member through an alternation of two facies. Mudstone is soft and dark grey to brownish dark grey in color and tends to break into angular fragments by weathering. Sandstone is bluish grey in color and well-sorted fine-grained tuffaceous one, usually with graded bedding. Sometimes, boulders of red chert, porphyrite and rhyolite welded tuff of several tens of centimeters in diameter are found in the lower part of the member. The upper part of the Mudstone Member is characterized by the common occurrence of arenaceous foraminifera represented by *Martinottiella communis*, *Haplophragmoides* spp. and *Cyclammina* sp.

The member has a total thickness of 200 to 300 m in the Ushishubetsugawa area, while the thickness increases southward to reach 800 to 1,000 m along the Toberi River.

3.4 **Ushishubetsugawa Group** (new name)

The Ushishubetsugawa Group corresponds to the Toberi Group of ONITSUKA (1962) and covers the underlying Okawa Formation conformably. It is widely distributed in the area and can be divided into two formations, the Oikamanae Formation represented by hard mudstone with conglomerate, and the Taiki Formation characterized by diatomaceous massive siltstone. This group ranges in thickness from 500 to 800 m in the western limb of the Toyokoro Dome (Fig. 5), and ranges from 2,000 to 2,200 m in the eastern limb (Fig. 6).

3.4.1 Oikamanae Formation (NEMOTO *et al.*, 1933; ONITSUKA, 1962)

ONITSUKA (1962) divided the Oikamanae Formation of NEMOTO *et al.* (1933) into the Okawa and Oikamanae Formations based on lithofacies and fossil evidences.

The Oikamanae Formation is widely distributed around the Okawa Formation from the upper reach of the Ushishubetsugawa River to that of the Oikamanae River. It is apparently concordant with the underlying Okawa Formation. However, at a few localities, a basal sandstone layer of 20 m thick containing glauconite and pumice grains, covers directly mudstone of the Okawa Formation with a sharp boundary. On the other hand, at the point 5.3 km west of Oikamanae, the uppermost mudstone of the Okawa Formation grades into the Oikamanae Formation containing glauconite grains and intercalation of hard mudstone. The Oikamanae Formation grades into the Taiki Formation.

The formation is divided into the Hard Mudstone Member and the Conglomerate Member. The Conglomerate Member is developed mainly in the middle part of the Oikamanae Formation, but in the southwestern area of the Oikamanae River, it occupies the middle and upper parts of the formation, being dominated by coarser facies. The two members show partly an interfinger relation.

a) Hard Mudstone Member (new name)

The member is represented by the so-called "hard shale" and is distributed in the area along the Kogawa and Oikamanae Rivers. It is composed of alternation of hard platy mudstone of 5 to 10 cm thick and siltstone of 1 to 2 cm thick. In the upper reaches of the Kogawa and Oikamanae Rivers, a layer of pumice tuff of 10 to 20 m thick can be traced as a good key bed in the lower horizon of the member. Alternation with sandstone is also developed in the middle horizon of the member. Alternation of hard mudstone with diatomaceous siltstone of the upper horizon grades into the Taiki Formation by increasing an amount of siltstone. Marly nodules of 0.5 to 1 m in diameter are sometimes found in the member. Megafossils are not abundant but some molluscan species such as *Lucinoma* sp., *Portlandia* sp. and *Makiyama chitanii* are recognized from the upper horizon. Arenaceous foraminifera and diatom are often found from soft siltstone. The member ranges in thickness from 300 to 700 m in the western limb of the Toyokoro Dome and from 800 to 1,000 m in the east.

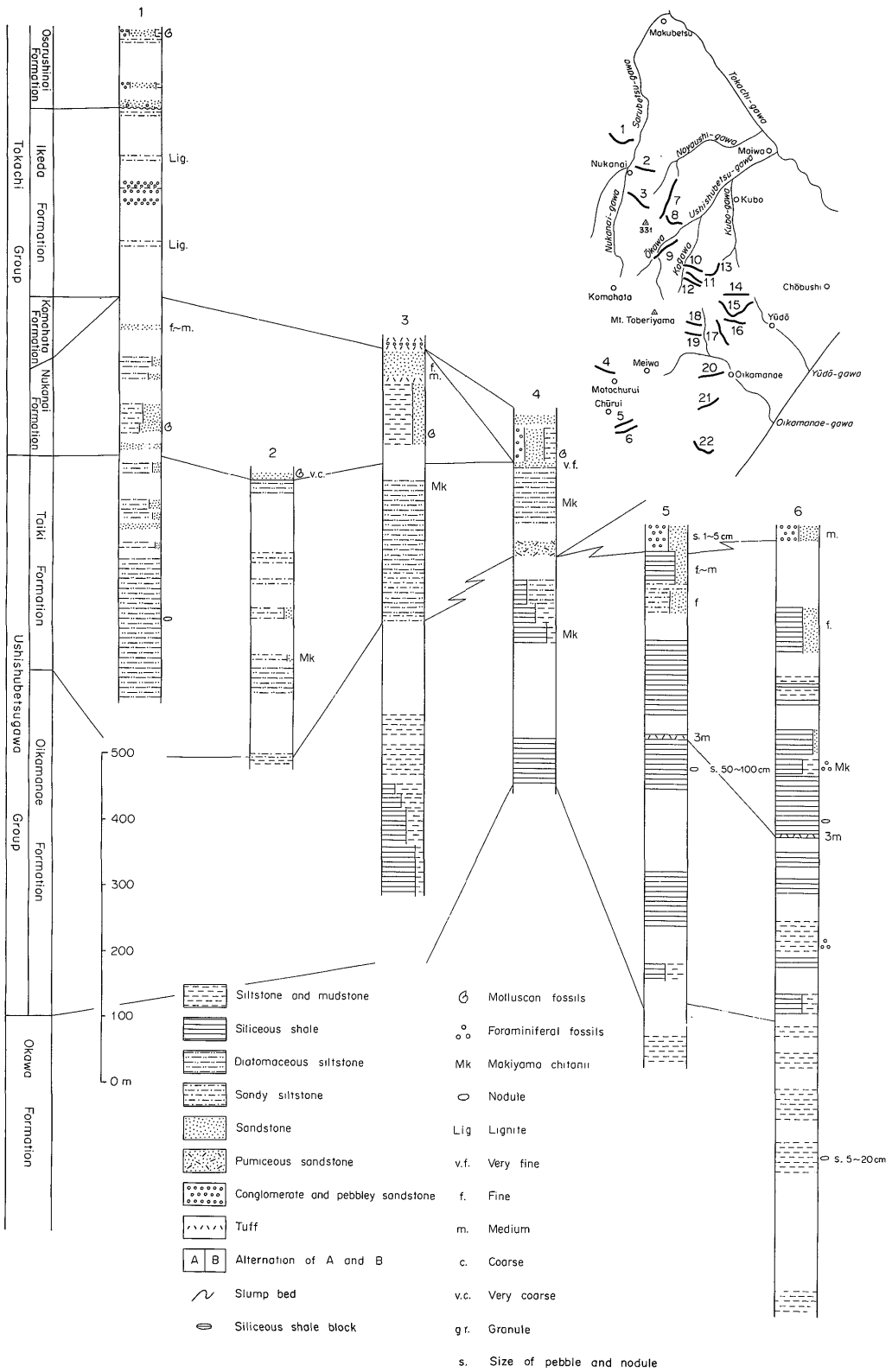

Fig. 5 Columnar sections of the Ushishubetsugawa Group in the western limb of the Toyokoro Dome.

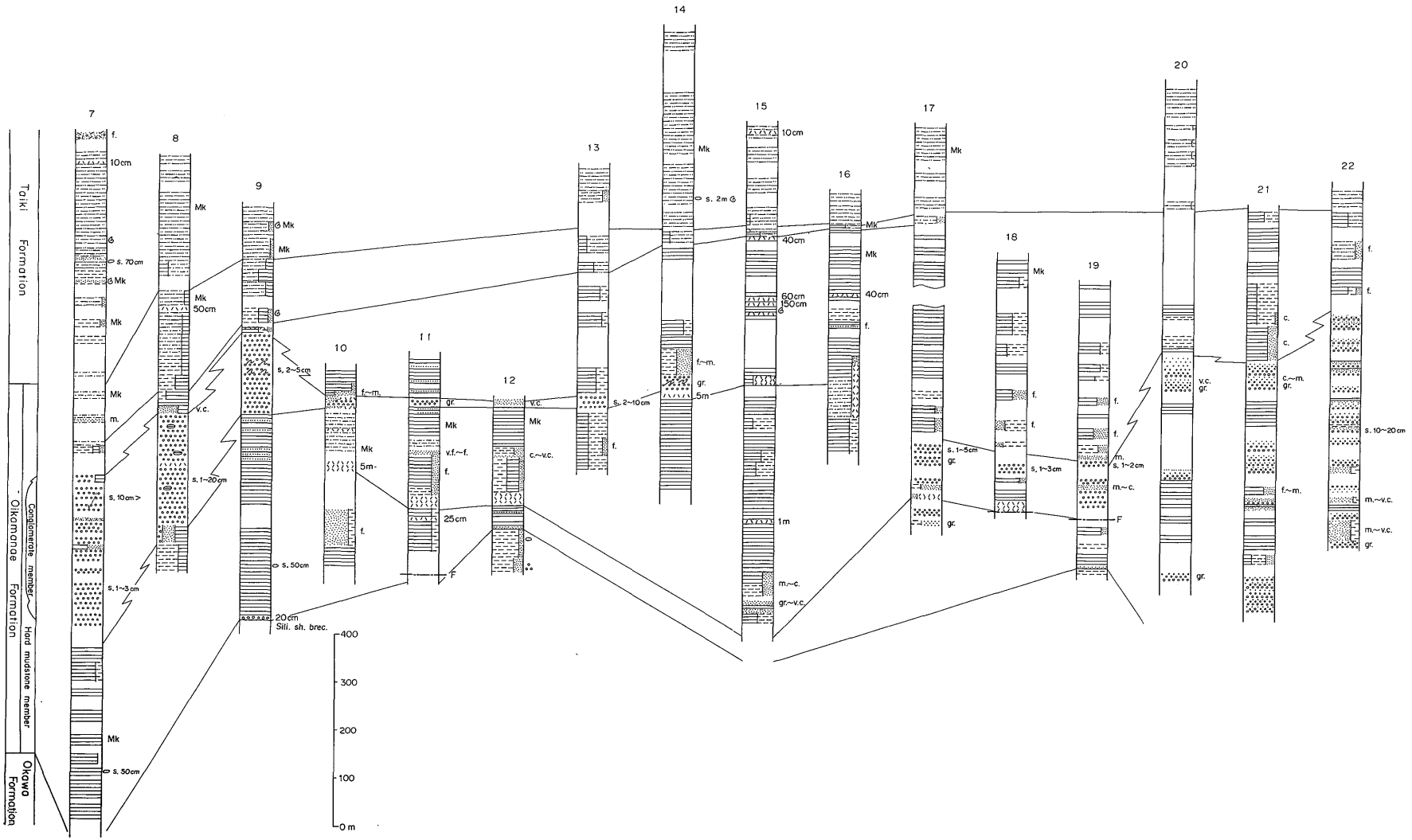

Fig. 6 Columnar sections of the Ushishubetsugawa Group in the eastern limb of the Toyokoro Dome.
Legend is the same as in Fig. 5

b) Conglomerate Member

The member occupies usually the middle horizon of the Oikamanae Formation and it dominates in the northern and southern areas. The member is characterized by repeated sedimentation of graded layers from conglomerate to sandstone whose thickness ranges from 1 to 10 m. Slump deposits are often seen, which are composed of poorly sorted medium- to coarse-grained sand with blocks of hard mudstone.

Pebbles of the conglomerate are mostly of rocks derived from the Hidaka Metamorphic Zone, and rarely of volcanic rocks of the Toberi Formation. MIYASAKA and KIKUCHI (1978) called it the "Hidaka facies" of the Oikamanae Formation and suggested that the southern Hidaka Metamorphic Zone violently upheaved since the middle stage of Oikamanae period.

The member varies in thickness from place to place, 200 to 300 m in the north, 500 m in the south and 0 to 20 m in the central. This fact suggests differential subsidence within the sedimentary basin of the Oikamanae Formation. No fossils have been reported from the member.

3.4.2 Taiki Formation (NEMOTO *et al.*, 1933)

The Taiki Formation is equivalent to the Moiwa Mudstone Formation (NAGAO and MITANI, 1960) and to the Shiranuka Formation (TANAI and YAMAGUCHI, 1965). The formation grades from the Oikamanae Formation and is overlain by the Nukanai and Komahata Formations with a partial unconformity. It shows extensive distribution from the Noyaushi River to Yudonuma.

The formation is composed of greenish grey diatomaceous to tuffaceous siltstone which breaks into pale yellowish white blocks when weathered. It shows usually no bedding, but frequently intercalated with white fine-grained glassy tuff layers of 5 to 15 cm thick. Large calcareous nodules of 2 m in diameter are also contained. Diatom fossils and *Makiyama chitanii* are abundant, but megafossils are rarely found except a few specimens of *Yoldia* sp. and others.

The formation ranges in thickness from 150 to 350 m in the western limb of the Toyokoro Dome and from 900 to 1,000 m in the east.

3.5 Tokachi Group (MITANI *et al.*, 1958; YAMAGUCHI *et al.*, 1978)

MITANI *et al.* (1958) gave the name of the Tokachi Group to the Pliocene sediments distributing along the Toshibetsu River and divided it into the Hombetsu, Ashoro and Ikeda Formations. Tokachi Research Group has investigated the Plio-Pleistocene of the Tokachi Plain and reexamined the Tokachi Group together with the Obihiro Formation of NEMOTO *et al.* (1933). The Tokachi Group is now subdivided in ascending order into eight formations, namely the Hombetsu (equivalent to the Nukanai Formation), Komahata, Ashoro, Ikeda, Osarushinai, Oribeyama, Shibusan (including Meto Tuff Member) and Nakasato Formations (YAMAGUCHI *et al.*, 1978).

In the Toyokoro Hill, there distribute the Nukanai, Komahata, Ikeda, Osarushinai, Meto and Mikawa (equivalent to the Nakasato Formation) Formations (Fig. 7). The Tokachi Group overlies the Ushishubetsugawa Group with a partial unconformity.

3.5.1 Nukanai Formation (MIYASAKA *et al.*, 1978)

The Nukanai Formation corresponds to the Nukanai Sandstone Formation (NAGAO and MITANI, 1960; YAMAGUCHI, 1970), to the Noyaushi Formation (ONITSUKA, 1962) and to the Chobushi Formation (MATSUNO, 1962; TANAI and YAMAGUCHI, 1965).

In the Noyaushi River area, a pebble-bearing sandstone bed overlies the Taiki Formation with eroded surface. Mode of occurrence of trace fossils of 10 to 20 cm in length found at the top of the Taiki Formation also supports the presence of unconformity. On the other

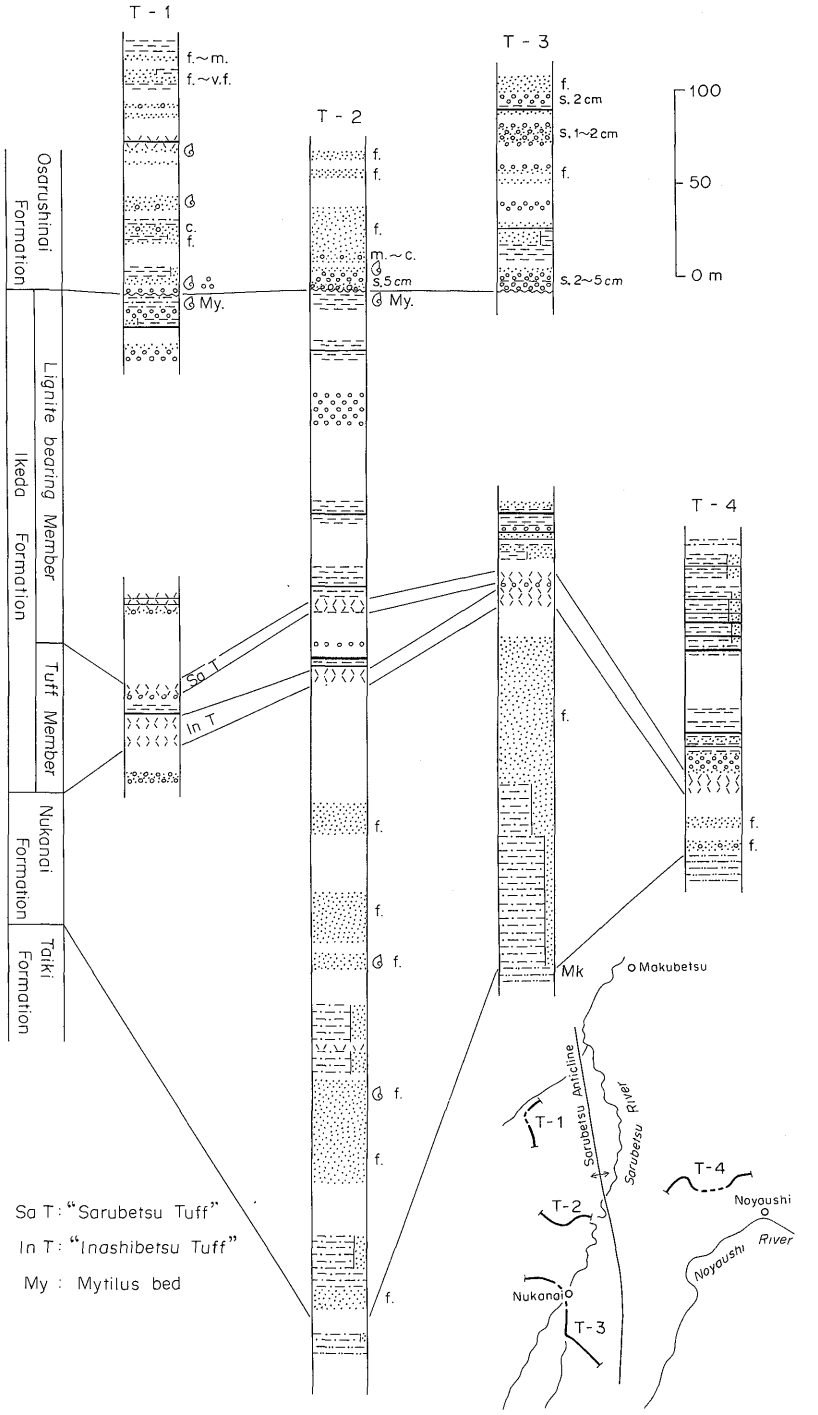

Fig. 7 Columnar sections of the Tokachi Group in the northern part of the Toyokoro Dome.
Legend is the same as in Fig. 5

hand, in the eastern side of the Toyokoro Dome, siltstone of the Taiki Formation grades into this formation intercalating sandstone beds. The formation shows separated distribution on the both sides of the Sarubetsu anticline (Fig. 8) and in the eastern side of the Kubo-Yudo area.

The basal part of the formation is composed of alternation of grey sandy siltstone and dark greyish green fine-grained sandstone. Siltstone is poorly sorted in general compared with that of the Taiki Formation. The main part of the formation is characterized by poorly sorted bluish grey to dark green massive fine-grained sandstone.

The upper part of the formation consists of well-sorted soft fine-grained sandstone. Mica flakes are found throughout the formation. In the eastern side of the Kubo-Yudo area, however, conglomerate is developed and is called the Sunagawa Conglomerate Bed by NAGAO and MITANI (1960). The bed laterally changes its facies into sandstone in the Chobushi River area.

The formation is the horizon which yields the Takikawa-Hombetsu Fauna characterized by *Fortipecten takahashii*, and contains diatom fossils in sandy siltstone. It is also characterized by the presence of foraminiferas such as *Cribroelphidium oregonense* and *Buccella frigidus*, and by the absence of *Makiyama chitanii* which is common in the Ushishubetsugawa Group.

The formation varies in thickness from place to place, 200 to 350 m in the western limb of the Sarubetsu anticline, 20 to 60 m in the eastern limb and 300 to 450 m in the Chobushi River area.

3.5.2 Komahata Formation (MATSUI *et al.*, 1970)

The Komahata Formation is of the same stratigraphic position as the Nukanai Formation, but their direct relationship is not ascertained. However, the author discriminated two formations based on the difference in lithofacies and fossils, and defined the Komahata Formation separately in this paper. It is distributed in limited areas near Nakasato and Motochurui.

The formation is composed mainly of loose sandstone and muddy sandstone with the intercalations of pebble-bearing sandstone and conglomerate. Abundant molluscan fossils and foraminifera are found in this formation. MIYASAKA *et al.* (1978) reported *Patinopecten* (*Mizuhopecten*) *yessoensis*, *Monia macrochisma*, *Cyclocardia ferruginea*, *C. prolongata nakamurai*, *Nuttallia commoda* and subordinate amounts of *Chlamys coshibensis*, *Fortipecten takahashii*, *Lucinoma annulata*, *Clinocardium* sp., *Serripes* sp. and *Mya* sp. In addition, *Pseudogrammatodon* sp., *Chlamys* cf. *daishakaensis* and *Papyridea* sp., which are characteristic species of the Setana Fauna, are also reported. Foraminiferal fauna from this formation is represented by such species as *Cibicides lobatulus*, *C. aknerianus*, *Elphidium subarcticum* and *Elphidiella arctica*, and is quite different from that of the Nukanai Formation. This is one of the reasons to separate the Komahata Formation from the Nukanai Formation as afore-mentioned.

Thickness of the formation is 120 m in southern Nakasato and 30 to 50 m in Motochurui.

3.5.3 Ikeda Formation (OISHI and WATANABE, 1932; MATSUI and YAMAGUCHI, 1970)

The Ikeda Formation proposed by MITANI (1964) is divided into two parts, lower and upper, by an unconformity in between. MATSUI and YAMAGUCHI (1970) redefined the lower part as the Ikeda Formation. It is distributed in the northern Toyokoro Hill and covers the underlying Nukanai Formation unconformably.

The formation is composed of Tuff and Lignite-bearing Members with a total thickness of 100 to 200 m.

a) Tuff Member

The Tuff Member corresponds to the Inashibetsu and the Sarubetsu Tuff Beds of OKAZAKI (1957). The member is distributed

on both sides of the Sarubetsu anticline. In the western side, the member is divided into two parts by intercalated pebble and lignite-bearing beds of 2 to 30 meters thick. The lower part is composed of poorly sorted rhyolitic pumice tuff carrying biotite- and quartz-bearing pumice abundantly. The upper part is composed mainly of fine-grained glassy andesitic tuff. Lithological aspects indicate that they are of pumice flows. In the eastern side, the member is made up of well-sorted glassy tuff which is similar in composition to andesitic tuff of the western side. The tuff bed can be traced as far as the Toshibetsu River area to the north. It ranges in thickness from 15 to 50 m.

b) Lignite-bearing Member

The member covers the Tuff Member conformably and is distributed on both sides of the Sarubetsu anticline. The member is of fresh to brackish water origin and is composed of claystone, sandstone and conglomerate with frequent intercalations of tuff and lignite. Lignite seams prevail in the northern area. The uppermost part of the member is composed of shallow marine facies in which such molluscan fossils as *Mytilus* sp., *Macoma* sp. and *Mya* sp. are found. In the lignite seams, fossil seeds of *Menyanthes trifoliata* are commonly recognized. Total thickness of the member is estimated to be 100 to 150 m.

3.5.4 Osarushinai Formation (Matsui and Yamaguchi, 1970)

The Osarushinai Formation is equivalent to the lower half of the upper Ikeda Formation of Mitani (1964), and the Humbe Sandstone Member of the Ikeda Formation of Okazaki (1957). The formation covers unconformably the Ikeda Formation and crops out in the western Sarubetsu River area.

Matsui and Yamaguchi (1970) defined the formation in the Osarushinai Hill, its type locality, north of the Tokachi River, describing that sand and gravel beds are dominant in the lower and upper parts, and that sand and silt beds are predominant in the middle, these beds being partly in interfinger relation. Within the investigated area, the lower and middle parts are distributed.

The basal part is composed of poorly sorted subangular pebbles of slate, hornfels and granitic rocks, while the main part is generally composed of the alternation of rounded gravel and sand layers with cross-bedding. The upper part consists of well-sorted fine to medium-grained sand and silt with the intercalation of lignite seams. The formation is regarded as being of littoral embayment deposition. Fossil enclosures are often recognized; in which marine molluscan fauna of boreal embayment species such as *Glycymeris yessoensis*, *Callithaca adamsi*, *Peronidia* sp., *Macoma* sp. and *Mya japonica* and of warm current species, *Umbonium costatum* and others, are contained.

Foraminiferal fauna is represented by the species such as *Elphidium bartletti*, *E. clavatum*, *Cribroelphidium oregonense*, *Buccela frigidus* and *Buliminella elegantissima* (Matsuzawa *et al.*, 1978). Total thickness of the formation exceeds 120 m.

3.5.5 Shibusan Formation (Yamaguchi *et al.*, 1973)

The Shibusan Formation is nearly equivalent to the upper half of the upper Ikeda Formation of Mitani (1964) and overlies the Osarushinai Formation unconformably. It is divided into three members, the Kuttari Welded Tuff and the Meto Tuff Member at the basal part, and the Lignite-bearing Member. The formation crops out far west from the northwestern margin of the Toyokoro Hill and only the Meto Tuff Member is found within this area.

Meto Tuff Member (Matsui and Yamaguchi, 1970)

Matsui and Yamaguchi (1970) gave the name to the pumice flow bed near Meto, Ashoro City, 40 kilometers north of the Toyokoro Hill, and its southern extention reaches the western margin of this area.

At the type locality, the member is divided into lower biotite rhyolite pumice flow deposits and upper hornblende hypersthene dacitic pumice flow deposits, intercalated by a conglomerate layer of 1.5 m thick. Only the lower part, biotite rhyolite pumice flow deposits, are recognized in this area. The member is represented by loose tuff consisting of pumice and lithic fragments, and is grey to pale grey in color. The member is also found by drilling underneath the alluvial plain around Obihiro City. Thickness of the member is estimated to be less than 30 m.

3.5.6 Mikawa Formation (YAMAGUCHI *et al.*, 1978)

The Mikawa Formation corresponds to a part of the Obihiro Formation of OISHI and WATANABE (1932) and of NEMOTO *et al.* (1933) and a part of the Higher Terrace Gravel of HASHIMOTO (1955), OKAZAKI (1957) and MITANI (1964). The distribution of this formation is limited in a narrow area in the western margin of the Hill. The formation covers unconformably the Ikeda and Osarushinai Formations, and is composed mainly of gravel with occasional intercalations of sand and silt. Pebbles of the gravel bed are of older rocks from the Hidaka zone. They are rather well-sorted compared with those of terrace deposits, and sandstone pebbles of 3 to 5 cm in diameter are dominant. They are cemented by muddy sand and are loosely consolidated.

Taking into consideration of the distribution of the formation and its constituents, it is plausible that a large amount of clastic material was supplied by violent upheaval of the southern Hidaka Mountains and deposited in graben-like depressions along the western margin of the Toyokoro Hill.

Total thickness of the formation is estimated to be about 120 m in maximum.

4. Geologic Age and Correlation

For the discussion of geologic age and correlation of the above-mentioned Neogene formations, the Nukanai Formation and the Ushishubetsugawa Group may be considered as key formations.

The Nukanai Formation is the horizon which yields the Takikawa-Hombetsu Fauna (FUJIE and UOZUMI, 1957) represented by *Fortipecten takahashii* and *Cribroelphidium oregonense*. It is also referred to *Denticulopsis kamtschatica* zone (KOIZUMI *et al.*, 1980) from a biostratigraphic zoning by diatom fossils. Furthermore, K–Ar age of the Tuff Member (Inashibetsu Tuff Bed) of the Ikeda Formation is reported to be 4.1 ± 1.1 Ma (SHIBATA *et al.*, 1975). Consequently, the Nukanai Formation is considered to be early Pliocene in age and is correlative with the formations such as the Kotan Formation of the Akan Group in the Kushiro Coal Field, the Horokaoshirarika Formation of the Fukagawa Group and the Yuchi Formation in the Tempoku Coal Field. From the upper horizon of the Tokachi Group, the following K–Ar ages are known: an obsidian pebble from the Oribeyama Formation $= 1.70 \pm 0.16$ Ma, the Meto Tuff Bed $= 1.2 \pm 2.2$ Ma, the Kuttari Welded Tuff $= 0.96 \pm 0.10$ and 0.75 ± 0.38 Ma (SHIBATA *et al.*, 1979). These results suggest that the Tokachi Group has an extent from Pliocene to Pleistocene in age.

The Ushishubetsugawa Group is lithologically characterized by "hard shale" in the lower part and diatomaceous siltstone in the upper. In addition, the biostratigraphic correlation by diatom indicates that the Taiki Formation corresponds to the range from *Denticulopsis hustedtii* zone to *D. kamtschatica* zone (KOIZUMI *et al.*, 1980). On the other hand, the upper part of the Oikamanae Formation yields diatom fossils belonging to *Denticulopsis hustedtii* – *D. lauta* zone. From these evidences, the group is considered to be middle Miocene to early Pliocene in age and can be correlated with the strata from the Atsunai to Shiranuka Formations in the Kushiro Coal Field and with those from the Wakkanai to Koitoi Formations in the Tempoku Coal

Field.

It is rather difficult to determine the definite age of lower Neogene formations because of the lack of paleontological and geochronological data, but it is possible to make some considerations as described below. The Okawa Formation is covered by the Oikamanae Formation and is characterized by *Haplophragmoides renzi*, *Martinottiella communis* and others which are found commonly in early to middle Miocene formations such as the Kawabata and Kotambetsu Formations in the western margin of Central Hokkaido. Therefore, the formation is considered to be early to middle Miocene in age.

The Tokachichurui Group is characterized by a coal-bearing bed in its lower part and volcanic rocks with peralkaline rhyolite welded tuff in the upper, but it is impossible to find equivalent formations in Central and Eastern Hokkaido. However, K–Ar age of peralkaline rhyolite welded tuff from the Toberi Formation is reported to be 15.1±0.6 Ma (SHIBATA *et al.*, 1975) and the group is unconformably covered by the Okawa Formation. Therefore, the Tokachichurui Group is tentatively referred to the lower Miocene.

5. Geologic Structure

Geologic structure of the Toyokoro Hill is characterized by the Toyokoro Dome elongated in the N–S direction with the Toyokoro Formation as a core. This structure is modified by several transverse faults and neotectonic movements parallel to the western margin of the Hill (Fig. 8).

5.1 Fold

The Toyokoro Dome is made up of an anticlinorium of N–S trend in which several anticlines are recognized such as the Sarubetsu, Churui and Tepikirenai anticlines. They are generally short in length and seem to be a group of small-scale anticlines. This structure may be a reflection of that of basement blocks which is considered to be distributed unevenly under the Tertiary. Generally speaking, the strata incline more steeply in the western limb of anticlines than in the eastern (Fig. 4) and thus it is considered that tectonic force acted westward.

The anticlinorium is accompanied by a few synclines, the Taiki syncline at its southwestern margin, and the Chobushi and Noyaushi synclines on the eastern area of the Hill (Fig. 8). This geologic structure of the Toyokoro Hill is well corresponding to the gravity anomaly of the area (MATSUDA and SUDA, 1964), namely the Taiki, Chobushi and Noyaushi synclines to the low anomaly and the central part of the Hill to the high.

5.2 Fault

Faults of this area are of two principal trends: N–S trending faults parallel to the axis of the dome and separating the Neogene from the pre-Tertiary rocks, and of E–W trending ones which traverse the axis of the dome.

The former is parallel to the direction of the Tokoro-Toyokoro zone and controls the distribution of pre-Tertiary basement blocks. For example, the Okawa fault is considered to have been formed in relation with an upheaval of the dome which began at the initial stage of deposition of the Ushishubetsugawa Group and to have bordered the western boundary of basement blocks.

The latter, transverse faults, in which two directions of E–W and ENE–WSW are recognized, may have been formed with intermittent upheavals of the basement after the deposition of the Nukanai Formation, and successively after the formation of N–S trending faults. The Moiwa fault, among others, displaced northern blocks downward relative to southern one. On the other hand, the fault system of E–W trend is developed in the southern area. For example, the Meiwa fault caused large right lateral displacement of the basement blocks.

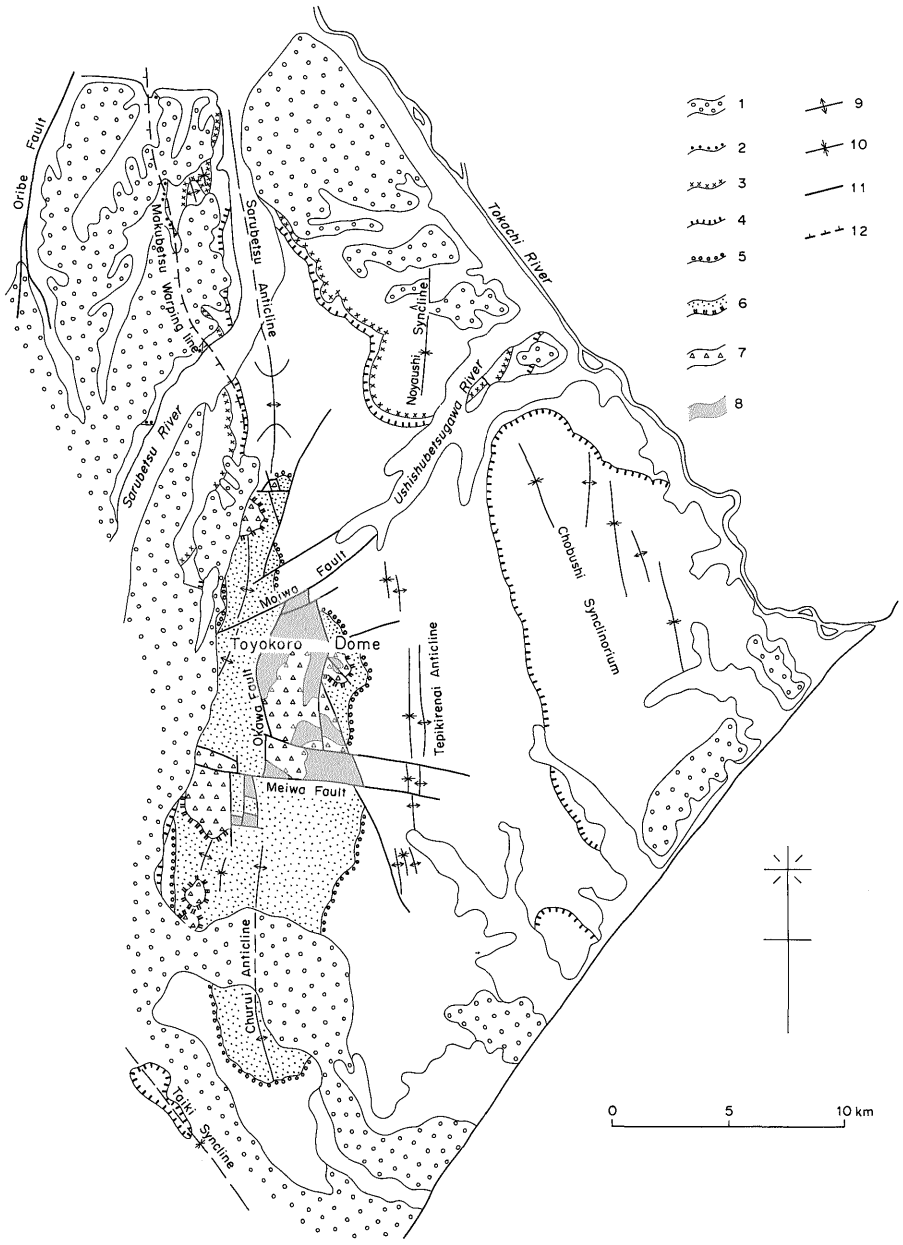

Fig. 8 Structural map of the Toyokoro Hill.

1. Terrace deposits, 2. Base of Osarushinai Formation, 3. Base of Ikeda Formation, 4. Base of Tokachi Group, 5. Base of Ushishubetsugawa Group, 6. Okawa Formation, 7. Tokachichurui Group, 8. Toyokoro Formation, 9. anticlinal axis, 10. synclinal axis, 11. fault and active fault, 12. warping line.

5.3 Quaternary tectonic features

Quaternary tectonic features recognized in the studied area are the Oribe fault and the Makubetsu warping.

The Oribe fault is a normal one of west side down. The fault can be traced from Sakurayama, 25 km north of Obihiro City, to the western margin of the Toyokoro Hill. It is evidenced that the fault displaces the Meto

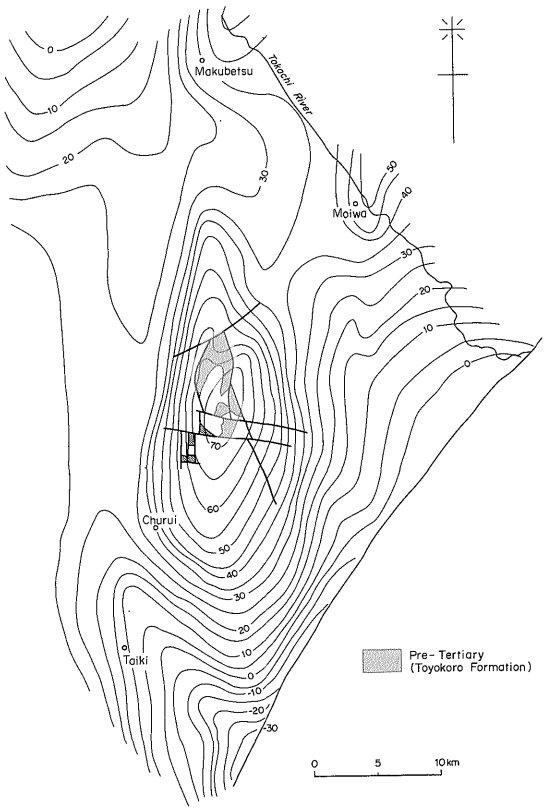

Fig. 9 Contour map of Bouguer anomalies (MATSUDA *et al.*, 1964). Contour interval is 5 mgals.

Tuff Member (MATSUZAWA *et al.*, 1981; AKIBA *et al.*, 1981).

The Makubetsu warping was once called the Makubetsu Steep Dipping Zone (YAMAGUCHI *et al.*, 1978; MATSUI *et al.*, 1978). The warping can be traced almost parallel to the axis of the Sarubetsu anticline from Inashibetsu to Nukanai. The strata in the area have a general dip of 10°, while those of the central part of the warping have dips of 20° to 60°. It was also clarified that the Oribe fault and the Makubetsu warping displaced a gravel bed of middle Pleistocene fan deposits (MATSUI *et al.*, 1980).

At the end of the Miocene, the Kitami-Urahoro horst (MIYASAKA and KIKUCHI, 1978) began to move up at the western margin of the Kushiro Coal Field. Then, tilting blocks of the horst thrusted up toward west and formed subsiding areas at its front. These movements continued until present and played an important part to make up the "Tokachi Tectonic Basin" (MATSUI *et al.*, 1978).

Above-mentioned neotectonic features in this area are considered to be resulted from the evolutional process of the Tokachi Tectonic Basin.

Summary

1) The Toyokoro Hill occupies the southernmost part of the Tokoro-Toyokoro Zone and the Neogene and Quaternary are developed around the Toyokoro Formation of Jurassic age.

2) The Neogene and Quaternary are divided into the Tokachichurui Group, the Okawa Formation, the Ushishubetsugawa Group and the Tokachi Group in ascending order.

3) From K–Ar age data, paleontological evidences, lithologic characteristics and stratigraphic succession, these strata are dated as follows: The Tokachichurui Group is early Miocene in age, the Okawa Formation early to middle Miocene, the Ushishubetsugawa Group middle Miocene to early Pliocene and the Tokachi Group early Pliocene to early Pleistocene.

4) Geologic structure of the Toyokoro Hill is characterized by the Toyokoro Dome of N–S trend and by fault system of two directions. In the northwestern limb of the dome, neotectonic features are recognized. These structural characteristics can be interpreted as those of the evolution process of the Tokachi Tectonic Basin.

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地 名 対 応 表

Chobushi	長節	Churui	忠類	Inashibetsu	稲士別
Kogawa	小川	Komahata	駒畠	Makubetsu	幕別
Meto	芽登	Mikawa	美川	Moiwa	茂岩
Nukanai	糠内	Oikamanae	生花苗	Okawa	大川
Osarushinai	長流枝内	Shibusan	渋山	Taiki	大樹
Toberi	当縁	Tokoro	常呂	Toyokoro	豊頃
Yudo	湧洞				

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北海道東部，豊頃丘陵の層序について

山口昇一

要旨

北海道東部の豊頃丘陵は，地質構造上，常呂-豊頃帯の南部に位置する．ジュラ紀とされている豊頃層を基盤に，これをとり囲むように新第三系・第四系が発達している．

基盤の豊頃層は，常呂-豊頃帯の構成員で，地域の中央で地塁状に狭い範囲に分布し，主として塩基性凝灰岩からなっている．

新第三系及び第四系は，下位から十勝忠類層群，大川層，牛首別川層群及び十勝層群に大きく4区分される．十勝忠類層群は新第三紀初期の堆積層で，汽水～淡水成の豊頃夾炭層と，アルカリ流紋岩溶結凝灰岩を伴う火山岩類からなる当縁層により構成される．大川層は泥岩を主とする海成層で，十勝忠類層群を不整合に覆っている．牛首別川層群は，硬質泥岩・礫岩を主体とする生花苗層と，珪藻質シルト岩を特徴とする大樹層からなる．いずれも海成層で，下位の大川層を整合に覆っている．十勝層群は，岩相，含有化石などそれぞれに特徴を有する糠内層・駒畠層・池田層・長流枝内層・渋山層（芽登凝灰岩部層）及び美川層によって構成される．これらは沿岸浅海成相から，順次内湾成相，湖成相へと変化し，堆積盆地の分化消滅の過程を示している．

これらの各層は，中新世前期から更新世前期にわたって堆積したものと考えられるが，とくに十勝層群下部の糠内層からは，鮮新世を指示するとされる滝川-本別動物群を産する．また，牛首別川層群の中部から上部にかけては，中新世中期末から鮮新世前期を示唆する珪藻化石群が見いだされる．さらに十勝忠類層群当縁層のアルカリ流紋岩溶結凝灰岩の K-Ar 年代は，中新世前期末を示している．

地質構造は，基盤の豊頃層を核として，南北方向に延びる豊頃ドーム構造を基本に，これを切る胴切断層と，豊頃丘陵の西縁にみられる活構造によって特徴づけられる．これらの構造は，中新世後期末以降活発化した十勝造盆地運動と密接に関係するものである．

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