5. *Some Geological Considerations of the Neogene Sediments Exposed at the Western Margin of the Yamagata Basin.*

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Introduction

Neogene sediments are largely exposed on the hilly land adjacent to the western margin of the Yamagata Basin, extending northwards or southwards to other districts and disappearing beneath the lava flows, agglomerates and mud flows of the Hayama Volcano and Shirataka Volcano.

These sediments have very complicated features in stratigraphy and geological structure. They have already been investigated by Y. Funayama[1] and others[2] in connection with the possibilities of oil resources in this area.

The sediments exposed here, however, have been almost entirely neglected as regards the determination of mineral compositions and rock-fragments contained in them, although it is very necessary from such various geological standpoints as sedimentation, source, igneous activity, etc. For this purpose, the field and laboratory works of sedimentary petrology on these sediments were recently started by the writers[3].

To examine mineral components, many speciments were collected from different horizons of the sediments distributed at the area interposed between the Yamagata Basin and the Mogami-gawa. Such specimens are mostly represented by tuffaceous and pumiceous sediments. They were mechanically analysed respectively, and their thin sections were closely examined. The results of this investigation indicate that they

1) Y. FUNAYAMA and S. TAKAHASHI, *Bull. Geol. Surv. Japan*, **3** (1952), 1–9.

2) T. ICHIMURA, S. MINAKAWA and O. YAMAGATA, *Jour. Geol. Soc. Japan*, **61** (1955), 357.

3) T. ICHIMURA, *Jour. Gcol. Soc. Japan*, **61** (1955), 354.

K. AOKI, Graduation Theisis, *Inst. Earth Sc. Fac. Educ. Yamagata Univ.*, (*M.S.*), (1956).

Fig. 1. Map showing the location where the specimens of sandy or tuffaceous rocks were collected.

are rich in the minerals and rock-fragments supplied from various sources, particularly from the intrusive and extrusive rocks, suggesting that igneous activities took place repeatedly during and prior to the deposition of Neogene sediments.

General Features of Topography and Geology

The area is situated between the Yamagata Basin and the Mogami-gawa, including the hilly land which extends from Aterazawa to Yamanobe and Miyajuku. It is easy of access from Yamagata through several bus roads and the Aterazawa Railway Line.

The hilly land here is more or less elevated at its central part, but is gradually descends towards the Yamagata Basin and the Mogami-gawa, being complicatedly dissected by the Uguisu-zawa, Yu-zawa, Okurihashi-gawa, etc. It is generally 300–400 meters high above sea-level and is frequently fringed by terraces along the Mogami-gawa. The southern end of this area is, on the other hand, bordered by the Shirataka Volcano which rises up to 922 meters above sea-level at the highest point (Fig. 1).

The hilly land under consideration is built up of Neogene sediments and overlying volcanics as well as Quaternary fluvial deposits (Figs. 2–3). Among them, Neogene sediments are mainly composed of tuff, tuffaceous sandstone, shale, mudstone, siltstone and conglomerate. Such

Table I. Succession of Neogene sediments exposed near the Yamagata Basin.

Groups	Formations	Thickness	Shinjō Basin Katō & Taguchi (1950)
Sagae Group	Omi Formation	45 m.	Yamuke Formation
	Inazawa Formation	200–300 m.	Sakekawa Formation
	Ōya Formation	200–250 m.+	Mitsumori Formation
Murayama Group	Hongō Formation	100–240 m.	
	Hashigami Formation	130–220 m.	
	Mazawa Formation	30–150 m.	Furukuchi Formation
	Tsunatori Formation	25–130 m.	
	Mizusawa Formation	250–520 m.+	Kusanagi Formation
	Tsukioka Formation	600 m.	
Yamagata Group	Hodōji Formation	50–300 m.+	Kaneyama Formation
	Ōisawa Formation	180 m.+	

(in descending order)

sediments laterally pass into one another, resulting in the different facies even in the same formation. Stratigraphically, they can be correlated with the upper half of the Neogene sediments in the adjoining district where the preceeding classification has been tried by S. Minakawa and O. Yamagata[4] in 1955 (Table I).

So far as is known at present, the sediments exposed in the field of the writers are represented by the Inazawa Formation (100 m. −), Nakanosawa Formation (50-200 m. +), Hashigami Formation (170-200 m. +), Mazawa Formation (150 m. +) and Tsunatori Formation (30-60 m. +). These formations gradually pass into one another and indicate different lithological characters changing from place to place. Moreover, the sediments here are usually tuffaceous and frequently pumiceous, although there are some formations rich in shale or mudstone.

The oldest sediments of this area are dark grey shale, tuffaceous sandstone and tuff of the Tsunatori Formation exposed mainly on the cutting near the Yoshizawa Bridge connecting Jōmyōji and Yoshizawa. The shale bed here is frequently intercalated with a coarse tuffaceous sandstone and contains many concretions at its lower horizon. It passes downwards into tuff or tuffaceous sandstone mottled with green spots. Such sediments are also to be seen along the Uguisu-zawa or elsewhere.

The Mazawa Formation is traceable from north to south at the eastern periphery and western half of this area, being extensively exposed in connection with the Tsunatori Formation and Hashigami Formation. It is characterized by the predominance of shale and siltstone of a dark grey color, but there is a gradual increase of tuff or tuffaceous sandstone as it approaches the Tsunatori Formation. In these cases, the formation of the eastern periphery extends from Hirashio to Tsubuteishi southwards, passing Oterabara, Takatori-yama, Yanagizawa, Oninome, Makibukuro, Sugishita, Shirasaka, Takinohira and Uwadaira.

One of the remarkable features indicated by the lower half of this formation is the frequent occurrence of fairly indurated shale of a dark grey color. This kind of shale is well exposed along the truck road between Jōmyōji and Yoshizawa or Takinohira, where it is found together with coarse sandstone. The similar shale is also seen at Yanagizawa and Shirasaka as well as at the lower course of the Uguisu-zawa.

The upper half is, on the other hand, composed of common black shale or siltstone and grades to the Hashigami Formation with an increase of tuff or tuffaceous sandstone.

4) T. ICHIMURA, S. MINAKAWA and O. YAMAGATA, *op.* cit., (1955), 357.

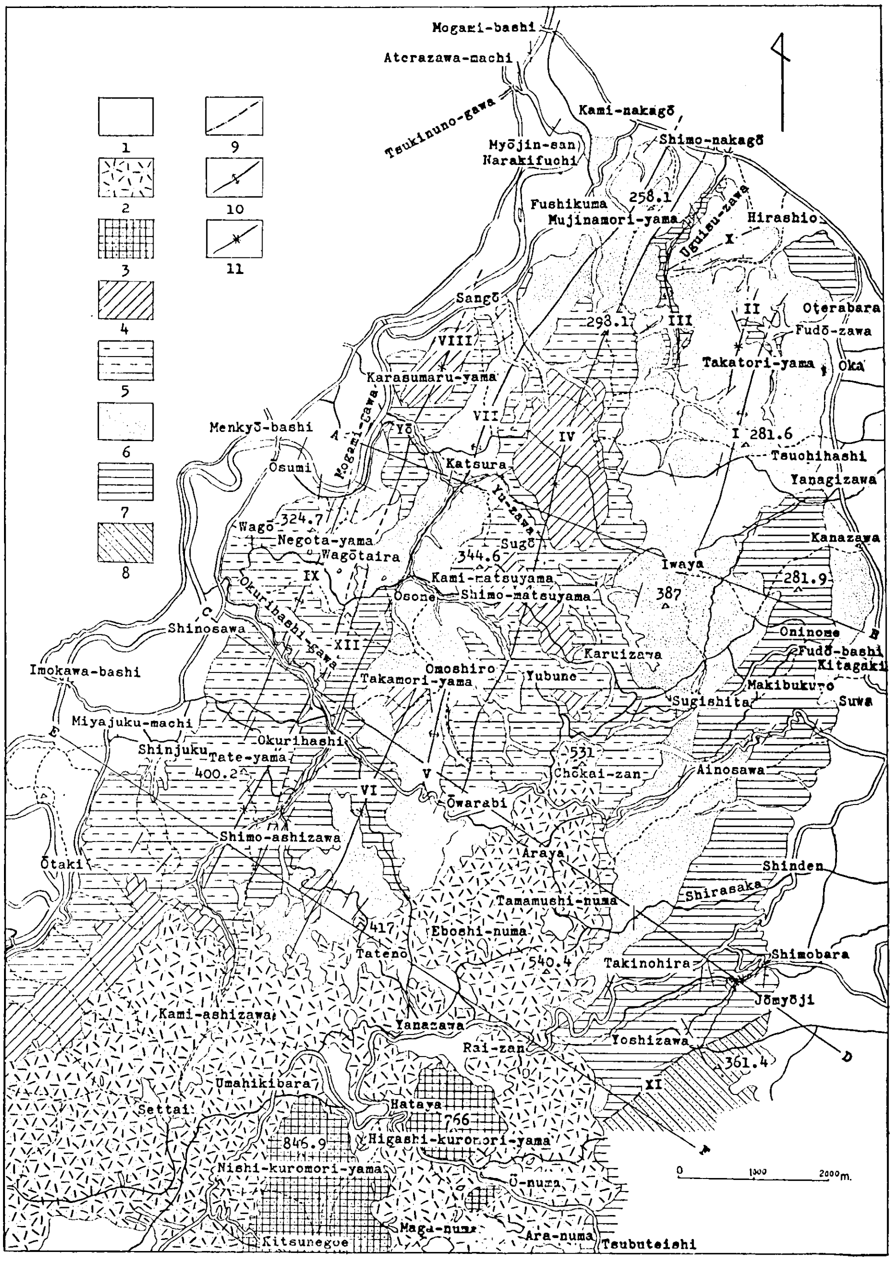

Fig. 2. Geological map of the hilly land adjacent to the western margin of the Yamagata Basin.

1=Quaternary sediments, 2=Mud flows of the Shirataka Volcano, 3=Lava flows of the Shirataka Volcano, 4=Inazawa Formation, 5=Nakanosawa Formation, 6=Hashigami Formation, 7=Mazawa Formation, 8=Tsunatori Formation, 9=Fault, 10=Anticlinal axes, 11=Synclinal axes, I=Takatori-yama anticline, II=Takatori-yama syncline, III=Uguisu-zawa anticline, IV=Kami-matsuyama syncline, V=Omoshiro anticline, VI=Takamori-yama syncline, VII=Okurihashi anticline, VIII=Karasumaru-yama syncline, IX=Negota-yama anticline, X=Hirashio fault, XI=Yoshizawa fault, XII=Shimo-ashizawa fault.

The northern end of the Mazawa Formation at the western area begins to be exposed along the anticline axis between Yō and Katsura, where it appears beneath the Hashigami Formation. Moreover, the formation is almost continuously traceable south-southwestwards across Shimo-ashizawa, and the western side of its southern half comes in contact with the Nakanosawa Formation, being bordered by a fault between them. Mainly, it consists of dark grey or black shale, and the high frequency of tuffaceous sandstone beds close to the Hashigami Formation is also noticeable as in the case of the eastern periphery.

The Hashigami Formation reveals the most extensive distribution, being characterized by the predominance of a very remarkable cross-bedding and tuffaceous or pumiceous sandstone. The occurrence of conglomerate, shale and siltstone is very rare.

The cross-bedding is very commonly seen in tuffaceous or pumiceous sandstone. It has two kinds of structure, viz., large size and small size (Figs. 5–6). These good exposures are observable at several places such as Shimo-nakagō, Hirashio—the Uguisu-zawa, the eastern side of the Mogami-gawa between Yō and Ōsumi, Ainosawa—Okurihashi and Yubune—Omoshiro or elsewhere.

The most remarkable cross-bedding is always found at the transition stage to the Nakanosawa Formation. It is coarsely and distinctly bedded with an alternation of hard and soft bands, being exposed at Mogami-bashi, Myōjin-yama, Narakifuchi, Iwaya, Ainosawa, Ōwarabi and Shimo-ashizawa—Tateno (Fig. 5).

The Hashigami Formation mentioned above indicates some anomalies at the area surrounding Hirashio, where it is occasionally tuffaceous and massive conspicuously without any noticeable cross-bedding. This formation was formerly named "Hirashio Formation"[5] in which tuff and tuffaceous sandstone is rich in angular fragments, large or small, of hard shale, black shale and siliceous liparite as well as in such minerals as hypersthene and augite. It is also noteworthy that some violent disturbance due to a submarine eruption seems to have taken place during the deposition of these sediments.

In the Hashigami Formation, conglomerate or conglomeratic sandstone is found close to the Nakanosawa Formation and contains such kinds of pebbles as liparite, felsophyre, felsite, dolerite, basalt, green tuff, shale, etc.

5) Y. FUNAYAMA and S. TAKAHASHI, *op. cit.*, 5.

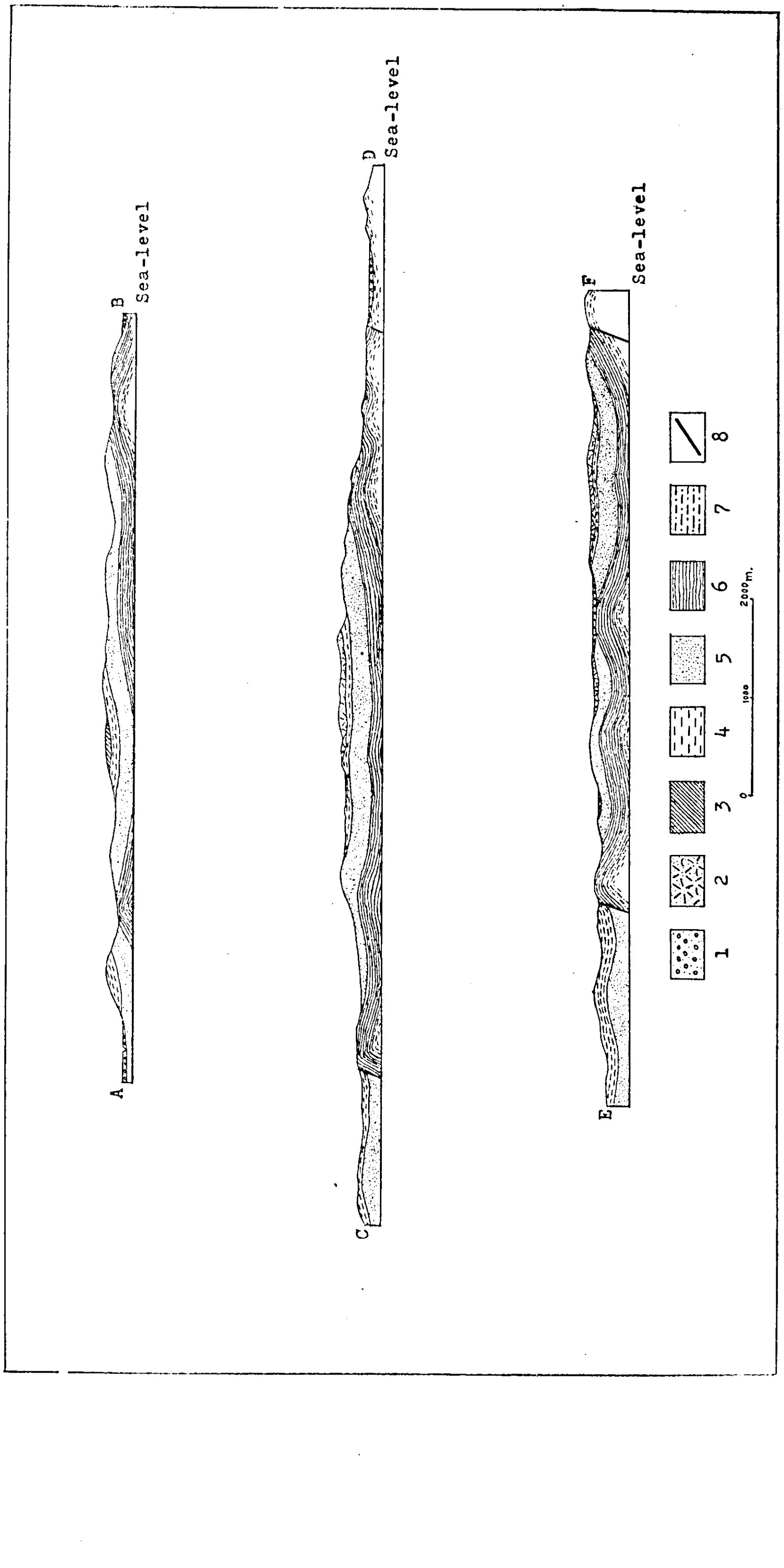

Fig. 3. Geological profile of the hilly land adjacent to the western margin of the Yamagata Basin.
1=Quaternary sediments, 2=Mud flows of the Shirataka Volcano, 3=Inazawa Formation, 4=Nakanosawa Formation, 5=Hashigami Formation, 6=Mazawa Formation, 7=Tsunatori Formation, 8=Fault.

The Nakanosawa Formation[6] is a combined name of the Hongō Formation and Ōya Formation almost inseparable in the writers' field. The formation is mostly shaly or silty, although there is an increase of tuffaceous sandstone upwards or downwards. The exposures of this formation known at the area include Nariai, Sangō, Yō, Menkyō-bashi, Negota-yama, Wagō, Shinosawa, Shimo-matsuyama, Karuizawa, Yubune, Miyajuku—Shimo-ashizawa, Miyajuku—Kami-ashizawa, Kami-ashizawa—Shimo-ashizawa and Kamigō, where sandy rocks are always characterized by the absence of cross-bedding. The relationship between the Nakanosawa Formation and Hashigami Formation can be confirmed on the cliffs near Menkyō-bashi and at the junction of the Mogami-gawa and Yu-zawa as well as on the cutting of the bus road between Ainosawa and Ōwarabi.

Some plant and animal fossils have been collected by Y. Funayama[7] from the lowest horizon of the Nakanosawa Formation exposed near Yō, Sugō, Menkyō-bashi, Shinjuku and others. They are *Fagus crenata*, *Fagus* cfr. *crenata*, *Fagus* sp., *Salix?* sp. cfr. *Salix longa?*, *Styrax* sp., *Ancistrolepis* sp., *Cerastoderma narusawaense*, *Cerastoderma* cfr. *shinjiense*, *Gastrana?* sp., *Linthia* sp., *Linthia yoshiwarai*, *Lucinoma acutiliformis*, *Natica?* sp., *Potamilla* n. sp., *Serripes yokoyamai*, *Serripes* sp., *Tyasira quadrata*, *Tyasira* sp., fish scales and fish bones. Besides these, *Calcharodon* and *Tellina* sp. are contained in the tuffaceous sandstone exposed on the cutting near Yō.

The Inazawa Formation gradually changes to the Nakanosawa Formation downwards. Mainly, it consists of tuffaceous sandstone, siltstone and mudstone. The distribution of this formation can easily be noticed from a distance, since it frequently shows a very gentle topographical feature and has a greyish white color due to weathering. The best exposure is seen at the uppermost course of the Yu-zawa, where it is largely exposed on the cliff without showing any stratification. The formation is found in a small extension as compared with the Nakanosawa Formation and is sporadically traceable from the east of Katsura to Ōtaki and Sugiyama, passing through Karuizawa, Yubune, Chōkai-zan,

6) This formation includes those exposed at the area including Wagō, Furumaki, Shinosawa, Shinjuku, Tateno, Shimo-ashizawa, Kami-ashisawa and Ōtaki, where they formerly mapped by Funayama as the Miyajuku Formation and Okurihashi Formation as well as the Shimo-matsuyama Member of the Toyoda Formation.

7) Y. FUNAYAMA and S. TAKAHASHI, *op. cit.*, 4–5.

Funayama believes that quite similar kinds of fossil are found in the Miyajuku Formation and Okurihashi Formation as well as in the Nakanosawa Member of the Toyoda Formation, but they are considered by the writers to be of the same horizon.

Sangō, Karasumaru-yama, the upper course of the Okurihashi-gawa and Kami-ashizawa.

Several formations of this area are mostly exposed with a strike of N–S to N30°E, although they are frequently disturbed intensely by faulting and folding. One of remarkable structural features is the abundance of anticline and syncline with repeated exposures of various sediments. There are five anticlines and four synclines. They are named the Takatori-yama anticline, Uguisu-zawa anticline, Omoshiro anticline, Okurihashi anticline, Negota-yama anticline, Takatori-yama syncline, Kami-matsuyama syncline, Takamori-yama syncline and Karasumaru-yama syncline. The position of such anticlines and synclines is shown in the geological map (Fig. 2).

Of these, most important is the Okurihashi anticline, which is traceable from Kanaya to Shimo-ashizawa south-southwestwards, passing through Mujinamori and the eastern side of Karasumaru-yama. It is 10 kilometers long and has a steeper inclination on its west-wing. Moreover, the area is traversed by three faults represented respectively by the Hirashio fault, Yoshizawa fault and Shimo-ashizawa fault. In the last case, the Nakanosawa Formation seems to have been displaced downwards against the Mazawa Formation.

The eroded surface of these Neogene sediments are partly covered by the mud flows and lava flows erupted from the Shirataka Volcano. The lava flows are composed of olivine two-pyroxene andesite, two-pyroxene andesite, hornblende-bearing olivine two-pyroxene andesite, hornblende-bearing two-pyroxene andesite and hornblende-bearing two-pyroxene dacite, constructing Shirataka-yama, Higashi-kuromori-yama, Nishi-kuromori-yama and other small domes around a large caldera, where the undulating surface of mud flows is adorned with small beautiful ponds and swamps. The mud flows of this volcano are extensively distributed as compared with the lava flows mentioned above. They are likely to have erupted several times in connection with lava flows, and the largest one extends northwards to Chōkai-zan. The andesite fragments of these mud flows are olivine two-pyroxene andesite, two-pyroxene andesite and hornblende-bearing two-pyroxene dacite.

The accumulation of Quaternary sediments chiefly took place along the older and present river courses. They consist of gravel, sand and clay, the older deposits forming some terraces along the Mogami-gawa and its tributaries.

Lithological Characters of Neogene Sediments

As has already been stated, Neogene sediments of this area include several formations ranging from the Tsunatori Formation up to the Inazawa Formation. Most of these formations are characterized by the high frequency of tuffaceous rocks, although such formations as the Mazawa Formation and Nakanosawa Formation are partly composed of shale, mudstone and siltstone. It, therefore, suggests that there were repeated igneous activities during and prior to the deposition of Neogene sediments. In this case, the tuffaceous rock is mostly represented by tuff and tuffaceous sandstone associated closesely with non-tuffaceous sandstone, conglomeratic sandstone and conglomerate, being sometimes intercalated with shale, mudstone and siltstone.

Of these, tuff, tuffaceous sandstone and non-tuffaceous sandstone have been selected for sedimentary petrography, because they contain mineral components and rock-fragments that can be easily examined under the microscope. Exclusive of some heavy components, nearly the same kinds of minerals are found in each formation together with angular or subangular pieces of granite, plagioliparite (rhyolite), perlite, granophyre, felsite, felsophyre, dacite, andesite, propylite, basalt, green tuff, pumice and shale. They are summarized as follows.

(1) Tsunatori Formation:—The mineral components in the tuff and tuffaceous sandstone of this formation are quartz, orthoclase, plagioclase, biotite, glauconite, allanite, cordierite, garnet, actinolite, green hornblende, hypersthene, ilmenite, limonite, magnetite, tourmaline and pink zircon. Green hornblende is, however, very scarce as compared with the tuffaceous or non-tuffaceous sandstone of the Hashigami Formation. These minerals are intermixed with minute fragments of plagioliparite, andesite, propylite, basalt, shale and green tuff, being cemented by tuffaceous matrix.

(2) Mazawa Formation:—The frequency of tuffaceous or non-tuffaceous sandstone gradually increases towards the Hashigami Formation. In such a case, they are composed of quartz, microcline, orthoclase, plagioclase, biotite, glauconite, actinolite, bluish green hornblende, brown hornblende, green hornblende, tremolite, augite, hypersthene, olivine (?), ilmenite, limonite, magnetite (hematite), pyrite, pyrrhotite, allanite, epidote, anatase, garnet, rutile, titanite, tourmaline, colorless zircon, pink zircon and angular fragments of granite, plagioliparite (rhyolite), andesite, basalt, propylite, green tuff, shale, pumice as well as of tuf-

faceous matrix. Of these, green hornblende is usually abundant in the sandstone close to the Hashigami Formation, but is absent or almost absent in other cases. Such a tendency can be seen in the specimens collected on the cutting near Ainosawa and Suwa. The same may be said of actinolite, brown hornblende and hypersthene. The occurrence of the last mineral is, however, known only in the sandstones exposed along the bus road between Takinohira and Yanazawa as well as near Suwa.

(3) Hashigami Formation:—The most important feature of the Hashigami Formation is the high frequency of tuffaceous or non-taffaceous sandstone with a grey or dark grey color in association with pumiceous sandstone. The mineral components of these rocks have some similarities to those of the Mazawa Formation and Nakanosawa Formation, consisting of quartz, microcline, orthoclase, plagioclase, biotite, muscovite, calcite, chlorite, glauconite, actinolite, bluish green hornblende, brown hornblende, green hornblende, tremolite, augite, hypersthene, olivine (?), ilmenite, limonite, magnetite (hematite), pyrite, allanite, epidote, zoisite, anatase, apatite, garnet, rutile, spinel, staurolite, titanite, topaz (?), tourmaline, colorless zircon and pink zircon. Among them, green hornblende is abundantly present as compared with other heavy minerals. This may be one of characteristic features in the Hashigami Formarion. The tuffaceous sandstone exposed near Hirashio is, however, rich in hypersthene and augite. The frequent occurrence of these minerals is also known at the area including Kami-nakagō, Karuizawa—Oninome, Iwaya—Yanagizawa, Sangō and Yō.

The light and heavy minerals mentioned above are embedded in the tuffaceous or pumiceous matrix together with such minute rock-fragments as granite, andesite, basalt, felsophyre, plagioliparite (rhyolite), propylite, pumice, green tuff and shale.

(4) Nakanosawa Formation:—It is lithologically distinguishable from the Hashigami Formation in the standpoint of the occasional occurrence of shale beds, although there are many mineralogical similarities between them.

The mechanical analyses and microscopical investigations indicate that the tuffaceous or non-tuffaceous sandstone of this formation contain quartz, microcline, orthoclase, plagioclase, biotite, muscovite, calcite, chlorite, glauconite, actinolite, bluish green hornblende, brown hornblende, green hornblende, tremolite, augite, hypersthene, ilmenite, limonite, magnetite (hematite), pyrite, allanite, epidote, zoisite, anatase, apatite, garnet, rutile, titanite, tourmaline, colorless zircon and pink zircon, andesite, basalt, felsophyre, plagioliparite (rhyolite), perlite (?), propylite, pumice, green tuff and shale. They are cemented with a tuffaceous or pumiceous matrix.

(5) Inazawa Formation:—A gradual transition can be seen between the Inazawa Formation and Nakanosawa Formation, with an upward decrease in the frequency of tuffaceous or non-tuffaceous sandstone, in which quartz, microcline, othoclase, plagioclase, biotite, chlorite, bluish green hornblende, brown hornblende, green hornblende, tremolite, hypersthene, olivine (?), ilmenite, limonite, magnetite (hematite), allanite, epidote, zoisite, garnet, rutile, staurolite (?), tourmaline, colorless zircon and pink zircon are found together with the rock-fragments derived from andesite and plagioliparite. They are embedded in the tuffaceous or pumiceous matrix. In this case, it is noteworthy that hornblende and hypersthene or augite are nearly or entirely absent. Other heavy minerals are also present in low frequency.

The mineral components and rock-fragments in many specimens obtained from each formation are summarized in the following table (Table II).

Microscopical Characters of Mineral Components and Rock-fragments

Exclusive of such fine-grained sediments as shale or mudstone, mechanical analyses and microscopical investigations of thin sections were carried out on 115 specimens to examine the mineral components and rock-fragments contained in tuffaceous or non-tuffaceous sandstone and siltstone. They are listed in the preceeding table (Table II).

Of these, quartz is the commonest component in most specimens and generally takes an angular or subangular form. The crystal is usually rich in liquid inclusions and occasionally reveals a wavy extinction. There are also many crystals subjected to magmatic corrosion, suggesting that they were supplied from plagioliparite, rhyolite or dacite.

In contrast with the abundance of quartz, microcline is scarcely present as minute fragments, 1.3 mm. across in the largest crystal. Similarly, orthoclase is an unimportant component and is lacking in some specimens. It is characterized by the frequency of perthite.

Plagioclase is, however, widely distributed, and it is richly contained in different kinds of sandstone exposed at this area. It ranges from albite to labradorite or bytownite and has a fresh appearance as in the

Table II. Mineral components and rock-fragments contained in the sandy or tuffaceous rocks.

	(1)	(2)	(3)*	(4)	(5)*	(6)	(7)	(8)	(9)	(10)	(11)	(12)*	(13)*	(14)*	(15)	(16)	(17)	(18)*	(19)	(20)	(21)*	(22)*	(23)*	(24)	(25)	(26)	(27)	(28)*	(29)
Quartz	×	×	—	×	—	×	×	×	×	×	×	—	—	—	×	×	×	—	—	×	—	—	—	×	×	×	×	—	×
Microcline	×	—	—	×	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×	×	—	—
Orthoclase	×	—	—	×	—	—	—	×	—	×	—	—	—	—	×	—	×	—	×	—	—	—	—	—	×	—	×	—	×
Plagioclase	×	×	—	×	—	×	×	×	×	×	×	—	—	—	×	×	×	—	×	—	—	—	—	×	×	×	×	—	×
Biotite	×	×	—	×	—	×	×	×	×	×	—	—	×	×	×	×	—	×	×	×	×	—	—	×	×	×	×	×	×
Muscovite (sericite)	—	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calcite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlorite	×	—	—	—	—	—	—	×	×	—	×	—	—	—	×	×	—	—	—	—	×	—	—	×	—	×	×	—	×
Glauconite	—	—	—	—	—	×	×	×	×	—	—	—	—	—	×	×	—	—	—	—	×	—	—	×	×	—	—	—	—
Actinolite	×	—	×	—	—	×	—	×	×	—	—	—	×	×	×	—	—	—	×	×	—	—	—	—	×	—	—	×	×
Bluish green hornblende	×	—	—	—	—	×	—	—	—	—	—	—	—	—	×	—	—	—	×	—	—	—	—	—	—	×	—	—	—
Brown hornblende	×	—	—	—	—	×	—	—	—	—	—	—	×	—	—	—	—	×	—	—	—	—	—	—	—	×	×	—	—
Green hornblende	×	—	—	×	×	×	×	×	×	×	×	×	×	×	×	—	×	×	×	×	×	—	—	—	×	×	×	×	×
Tremolite	×	—	×	—	—	×	—	×	—	—	—	—	×	—	—	—	—	×	×	—	—	—	—	—	×	×	—	×	?
Augite	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	×	—	×	×	×	—
Hypersthene	—	—	—	×	—	—	—	—	—	—	—	×	—	—	—	—	—	×	×	—	—	×	—	×	—	×	×	—	—
Olivine	?	—	—	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—	?	—	—	—
Limonite	—	—	—	—	—	×	×	—	×	×	—	—	—	—	—	×	×	—	—	—	—	—	—	×	×	—	—	—	—
Magnetite (ilmenite, hematite)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Pyrite	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pyrrhotite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Allanite	×	—	×	×	×	—	—	×	×	×	—	—	×	—	×	×	—	×	×	×	×	—	×	—	—	×	×	×	×
Epidote	×	—	×	×	×	×	×	×	—	×	—	×	×	×	×	×	—	×	×	×	×	—	×	×	×	×	×	×	×
Zoisite	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anatase	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	×	—	—	×	—	—	—	—	—	—	—	—
Apatite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cordierite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Garnet	×	—	×	×	×	×	×	×	×	×	—	×	×	—	×	×	×	×	×	×	×	×	×	×	×	×	×	?	×
Rutile	×	—	×	—	—	—	—	×	—	—	—	—	—	—	—	×	—	—	×	—	—	×	—	×	×	—	×	×	—
Spinel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Staurolite	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Titanite	—	—	—	—	—	—	?	—	×	×	—	—	—	—	—	—	—	—	×	—	—	×	×	—	×	×	—	?	×
Topaz	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	×	—	×	—	×	×	×	×	×	—	—	×	×	—	×	×	—	×	×	×	×	×	×	—	×	×	×	×	×
Colorless zircon	—	—	×	—	×	×	—	—	—	—	—	—	—	—	—	—	—	×	×	×	—	—	—	—	—	—	—	×	—
Pink zircon	×	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Granite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Andesite	×	—	—	—	—	—	—	—	—	×	×	—	—	—	—	—	×	—	×	—	—	—	—	—	—	×	×	—	—
Basalt	—	—	—	—	—	—	—	—	?	×	×	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Felsophyre & plagioliparite	×	—	—	—	—	—	—	×	×	×	×	—	—	—	—	×	×	—	×	—	—	—	—	—	×	×	×	—	×
Perlite	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
propylite	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Green tuff	—	—	—	—	—	—	—	×	×	—	—	—	—	—	—	—	×	—	×	—	—	—	—	—	—	—	—	—	—
Shale	—	—	—	—	—	—	—	—	—	×	—	—	—	—	×	—	—	—	×	—	—	—	—	—	—	—	—	—	—
Pumice & tuffaceous substance	×	×	—	—	—	×	×	×	×	×	×	—	—	—	×	×	×	—	×	—	—	—	—	×	×	×	×	—	×
Foraminifera fossils	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—

	(30)*	(31)	(32)*	(33)	(34)	(35)*	(36)	(37)	(38)*	(39)*	(40)	(41)	(42)*	(43)*	(44)	(45)	(46)	(47)*	(48)	(49)	(50)	(51)	(52)*	(53)	(54)	(55)	(56)*	(57)*	(58)*
Quartz	—	×	—	×	×	—	×	×	—	—	×	×	—	—	?	×	×	—	×	×	×	×	—	×	×	×	×	—	—
Microcline	—	×	—	×	—	—	—	×	—	—	—	—	—	—	×	—	×	—	—	×	×	—	—	×	×	×	—	—	—
Orthoclase	—	×	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×	—	×	×	—	—	—	×	×	×	—	—	—
Plagioclase	—	×	—	×	×	—	×	×	—	—	×	×	—	—	×	×	×	—	×	×	×	×	—	×	×	×	×	—	—
Biotite	×	×	—	×	—	×	×	×	×	×	×	×	—	×	×	×	×	—	×	×	×	—	×	×	×	×	—	—	—
Muscovite (sericite)	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—
Calcite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlorite	×	×	—	—	—	—	—	—	—	×	—	—	—	—	—	—	×	—	—	×	×	—	—	×	—	—	—	—	—
Glauconite	—	—	—	×	—	—	×	—	—	—	—	×	—	—	×	—	—	—	×	—	—	—	—	—	×	×	—	—	—
Actinolite	—	×	×	×	×	×	×	×	×	×	×	×	—	×	—	—	×	—	—	×	—	×	—	—	—	×	×	×	×
Bluish green hornblende	—	—	—	×	—	×	×	—	—	—	—	×	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Brown hornblende	—	—	×	—	—	—	—	—	×	—	—	—	—	×	—	—	—	—	—	×	×	—	—	—	—	—	—	—	×
Green hornblende	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	—	×	×	×	×	×
Tremolite	—	×	×	—	—	×	—	—	×	×	—	×	—	—	×	×	—	—	—	×	—	×	×	—	×	—	×	×	×
Augite	—	?	—	—	—	—	—	—	—	×	×	—	×	×	—	×	—	—	×	×	—	×	×	—	—	—	—	—	×
Hypersthene	×	×	×	—	—	×	—	—	—	×	×	—	×	×	—	—	—	×	×	×	×	×	×	—	—	—	—	—	—
Olivine	—	×	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—
Limonite	—	—	—	×	×	—	×	—	—	—	—	×	—	—	—	—	—	—	×	—	—	×	—	—	×	×	×	—	—
Magnetite (ilmenite, hematite)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Pyrite	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pyrrhotite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Allanite	×	?	×	×	—	×	×	×	×	×	—	—	—	×	×	—	×	—	×	×	×	—	×	×	×	×	?	—	×
Epidote	—	×	×	×	×	×	—	×	×	×	×	×	—	×	—	—	×	×	×	×	×	×	—	×	×	×	×	×	×
Zoisite	—	×	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	?	—	—	—
Anatase	—	—	—	—	—	×	—	—	×	×	—	×	—	—	—	—	—	—	×	—	×	—	—	—	—	×	—	—	—
Apatite	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cordierite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Garnet	—	×	×	×	—	×	×	—	×	×	—	×	—	×	—	—	×	×	×	×	×	—	×	—	—	—	—	×	×
Rutile	—	×	×	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	×	—	—
Spinel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Staurolite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Titanite	—	×	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	×	—	—	—	—	—	—	—	—
Topaz	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	—	×	×	×	—	×	×	×	×	×	—	—	—	×	×	—	×	×	—	×	—	×	—	×	—	×	—	×	×
Colorless zircon	—	×	×	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pink zircon	×	×	×	×	×	×	×	×	×	×	×	×	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Granite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Andesite	—	×	—	—	—	—	—	×	—	—	×	—	—	—	—	×	×	—	—	×	—	×	—	×	—	—	—	—	—
Basalt	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
Felsophyre & plagioliparite	—	×	×	×	—	—	—	×	—	—	×	—	—	—	×	×	×	—	—	×	×	—	—	×	×	—	—	—	—
Perlite	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
propylite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Green tuff	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Shale	—	×	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—
Pumice & tuffaceous substance	—	×	×	×	×	—	×	×	—	—	×	—	—	—	×	—	×	—	×	×	×	×	—	×	×	×	×	—	—
Foraminifera fossils	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

	(59)*	(60)	(61)	(62)*	(63)	(64)	(65)*	(66)	(67)	(68)	(69)*	(70)	(71)*	(72)	(73)*	(74)	(75)	(76)	(77)*	(78)	(79)	(80)	(81)*	(82)*	(83)	(84)	(85)	(86)	(87)
Quartz	—	×	×	—	×	×	—	×	×	×	—	×	—	×	—	×	×	×	—	×	×	×	—	—	×	×	×	×	×
Microcline	—	—	—	—	×	×	—	—	—	×	—	×	—	—	—	×	—	×	—	×	×	×	—	—	×	×	—	×	—
Orthoclase	—	—	—	—	?	×	—	×	—	×	—	×	—	—	—	×	—	×	—	×	—	—	—	—	—	×	—	×	—
Plagioclase	—	×	×	—	×	×	—	×	×	×	—	×	—	×	—	×	×	×	—	×	×	×	—	—	×	×	×	×	×
Biotite	—	×	—	—	×	×	×	×	×	×	—	×	×	×	×	×	×	×	×	×	×	×	—	×	×	×	×	×	—
Muscovite (sericite)	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calcite	—	—	—	—	—	×	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	×	—	×	—
Chlorite	—	×	—	—	×	—	—	×	×	×	—	—	—	—	—	—	×	—	—	×	—	×	—	—	×	—	—	×	—
Glauconite	—	×	—	—	×	×	—	—	—	×	—	—	—	×	—	×	—	×	—	×	—	—	—	—	×	—	×	×	—
Actinolite	—	—	—	—	—	—	×	—	—	×	—	×	—	—	×	—	—	—	—	×	—	×	×	—	×	—	×	—	—
Bluish green hornblende	×	×	—	—	—	—	—	—	—	—	—	—	—	—	×	—	×	—	—	—	×	—	—	×	—	—	—	—	—
Brown hornblende	—	—	×	—	×	—	×	—	—	×	—	×	—	×	×	—	—	—	×	—	—	—	—	—	×	—	—	—	—
Green hornblende	×	×	×	×	×	×	×	×	×	×	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Tremolite	—	—	×	×	—	×	×	—	×	×	—	—	×	×	—	?	—	—	—	×	×	?	—	×	—	—	×	—	—
Augite	×	—	×	—	—	×	×	—	—	×	—	×	—	×	×	—	×	×	×	×	×	—	—	—	—	—	—	—	×
Hypersthene	—	×	×	—	—	×	×	—	—	×	—	—	×	—	—	×	×	×	×	×	×	—	—	—	—	—	—	×	—
Olivine	—	—	—	—	?	—	—	—	—	—	—	—	—	?	—	—	?	?	×	—	—	—	—	—	—	—	—	—	—
Limonite	—	—	—	—	×	—	—	×	×	—	—	×	—	×	—	—	—	—	—	×	—	—	—	—	×	—	×	×	—
Magnetite (ilmenite, hematite)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Pyrite	—	×	×	—	—	×	×	—	—	×	×	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—
Pyrrhotite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Allanite	×	×	×	×	×	×	×	×	—	×	×	×	×	×	?	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Epidote	—	×	×	×	—	×	×	×	—	×	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×	—	×	—	×
Zoisite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anatase	—	—	—	—	—	—	×	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Apatite	—	—	—	—	—	×	×	—	—	×	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cordierite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Garnet	—	×	×	—	—	×	×	×	×	×	—	×	—	×	×	×	×	×	—	×	×	×	×	×	×	—	—	×	×
Rutile	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	×	—	—	—	×	—	—	—	—
Spinel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Staurolite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
Titanite	—	—	×	—	—	—	×	—	×	×	—	×	—	—	—	—	×	×	—	—	×	?	?	—	—	—	—	—	×
Topaz	—	—	—	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	—	×	×	—	×	—	—	—	—	×	—	—	×	×	×	×	×	×	—	—	×	—	×	×	×	—	×	×	—
Colorless zircon	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	×	—	—	—	—	—	—	—	—
Pink zircon	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Granite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	×	—	—	—	—	—	—	—
Andesite	—	—	×	—	×	×	—	×	×	—	—	×	—	×	—	×	×	×	—	—	×	×	—	—	×	—	×	—	×
Basalt	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—	—	×	—	—	—	—	×	—	—	—
Felsophyre & plagioliparite	—	—	×	—	×	×	—	×	×	×	—	×	—	×	—	×	×	×	—	×	—	×	—	—	×	×	×	×	×
Perlite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Propylite	—	×	—	—	×	—	—	—	×	×	—	—	—	×	—	—	—	×	—	—	—	×	—	—	×	×	×	×	—
Green tuff	—	×	—	×	—	—	—	—	×	×	—	—	—	—	—	—	×	—	—	—	×	×	—	—	—	×	×	?	—
Shale	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—
Pumice & tuffaceous substance	—	×	×	—	×	×	—	×	×	×	—	×	—	×	—	×	—	—	—	—	×	—	—	—	×	×	×	×	×
Foraminifera fossils	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—

	(88)*	(89)	(90)	(91)	(92)*	(93)*	(94)*	(95)*	(96)	(97)	(98)*	(99)	(100)	(101)	(102)	(103)	(104)*	(105)	(106)*	(107)	(108)	(109)	(110)	(111)	(112)	(113)	(114)	(115)*
Quartz	—	×	×	×	—	—	—	—	×	×	—	×	×	×	×	×	—	×	—	×	×	×	×	×	×	×	×	—
Microcline	—	×	×	×	—	—	—	—	—	×	—	×	—	×	×	×	—	×	—	—	—	×	—	×	—	—	—	—
Orthoclase	—	×	×	×	—	—	—	—	×	×	—	×	—	×	×	—	—	×	—	×	—	—	×	×	—	×	—	—
Plagioclase	—	×	×	×	—	—	—	—	×	×	—	×	×	×	×	×	—	×	—	×	×	×	×	×	×	×	×	—
Biotite	—	×	—	×	—	—	—	—	×	×	×	×	—	×	×	×	×	×	×	—	×	×	—	×	×	×	—	—
Muscovite (sericite)	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calcite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chlorite	—	×	×	—	—	—	—	—	—	×	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
Glauconite	—	×	×	×	—	—	—	—	—	—	—	×	×	—	×	×	—	×	—	×	—	—	×	×	—	×	—	—
Actinolite	—	—	×	—	—	×	—	—	×	×	×	—	—	×	×	×	—	—	—	—	—	—	—	×	—	×	—	—
Bluish green hornblende	—	—	—	—	—	×	×	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brown hornblende	—	—	×	×	—	×	—	—	—	—	×	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—
Green hornblende	×	×	×	×	×	×	×	—	×	×	×	×	×	×	×	×	×	×	—	?	×	×	×	×	—	—	×	×
Tremolite	—	—	—	—	—	×	—	—	—	×	—	—	—	—	×	×	—	—	—	—	—	—	—	—	—	—	—	—
Augite	—	×	×	×	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—
Hypersthene	×	—	—	—	—	—	×	×	×	—	—	×	—	—	—	—	×	×	—	×	—	—	—	×	×	×	×	—
Olivine	—	?	—	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Limonite	—	×	—	×	—	—	—	—	×	×	—	×	×	—	—	×	—	×	—	×	×	×	×	×	×	×	×	—
Magnetite (ilmenite, hematite)	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Pyrite	×	—	—	—	—	—	—	—	—	—	×	—	×	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
Pyrrhotite	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
Allanite	×	×	×	×	×	×	×	—	×	×	×	×	—	×	×	×	×	—	—	×	×	×	—	×	×	×	—	×
Epidote	×	×	×	×	×	×	×	—	×	×	×	×	×	×	×	×	—	—	—	×	—	—	—	—	—	—	—	—
Zoisite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anatase	—	—	—	—	—	—	—	—	—	×	—	—	—	—	×	×	—	—	—	—	—	—	—	×	—	—	—	—
Apatite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cordierite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—
Garnet	×	×	—	—	×	×	×	×	—	×	—	×	—	×	×	×	—	×	—	—	×	×	×	×	—	×	×	×
Rutile	—	—	—	—	—	—	—	—	—	×	—	—	—	×	—	×	—	—	—	—	—	—	—	—	—	—	—	—
Spinel	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Staurolite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Titanite	—	×	×	—	—	—	—	—	—	—	×	×	×	—	—	×	—	×	—	—	—	—	—	—	—	—	—	—
Topaz	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tourmaline	×	—	—	?	×	—	—	—	—	—	—	—	—	—	—	×	×	—	—	—	—	—	—	×	—	—	×	—
Colorless zircon	—	—	—	—	—	—	—	—	—	—	—	—	×	×	—	—	—	—	×	—	—	—	—	×	—	—	—	—
Pink zircon	×	×	×	×	×	×	×	—	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Granite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	?	—	—	—	—	×	—	—	—	—	—	—	—
Andesite	—	×	×	×	—	—	—	—	×	×	—	×	×	?	×	×	—	×	—	×	×	×	×	×	×	—	—	—
Basalt	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
Felsophyre & plagioliparite	—	×	×	×	—	—	—	—	×	?	—	×	×	×	×	×	—	×	—	×	×	×	×	×	×	—	×	—
Perlite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Propylite	—	—	—	—	—	—	—	—	×	—	—	—	×	—	—	×	—	—	—	—	×	×	—	—	×	—	—	—
Green tuff	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	?	×	—	×	×	—	×	—
Shale	—	×	—	×	—	—	—	—	×	—	—	—	×	—	—	×	—	×	—	×	—	—	—	—	—	—	×	—
Pumice & tuffaceous substance	—	×	?	×	—	—	—	—	×	—	—	×	×	×	×	×	—	×	—	—	×	×	×	×	×	×	×	—
Foraminifera fossils	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—

(1)–(5)=Inazawa Formation, (6)–(39)=Nakanosawa Formation, (40)–(94)=Hashigami Formation, (95)–(111)=Mazawa Formation, (112)–(115)=Tsunatori Formation.

* Light minerals are partly undetermined.

Table III. Localities of sandy rocks in the preceeding table.

		Village or town	District or city
(1)	Yō-Iwaya (Tuffaceous sandstone)	Aterazawa-machi	W. Murayama-gun.
(2)	Kami-matsuyama-Yubune (〃)	Yamanobe-machi	E. Murayama-gun.
(3)	〃 (Siltstone)	〃	〃 .
(4)	〃 (〃)	〃	〃 .
(5)	Shinjuku-Kami-ashizawa (Fine sandstone)	Asahi-machi	W. Murayama-gun.
(6)	Nariai (Fine sandstone)	Aterazawa-machi	〃 .
(7)	〃 (〃)	〃	〃 .
(8)	Yō (Tuffaceous sandstone)	〃	〃 .
(9)	〃 (Siltstone)	〃	〃 .
(10)	〃 (Coarse sandstone)	〃	〃 .
(11)	The Uguisu-zawa (Coarse sandstone)	Nakayama-machi	E. Murayama-gun.
(12)	〃 (〃)	〃	〃 .
(13)	Menkyō-bashi (Tuffaceous sandstone)	Asahi-machi,	W. Murayama-gun.
(14)	Kami-matsuyama (〃)	Yamanobe-machi	E. Murayama-gun.
(15)	〃 (〃)	〃	〃 .
(16)	Iwaya (Nodule in siltstone)	Nakayama-machi	〃 .
(17)	〃 (Tuffaceous sandstone)	〃	〃 .
(18)	Shimo-matsuyama (〃)	Yamanobe-machi	〃 .
(19)	Wagōtaira-Wagō (〃)	Asahi-machi	W. Murayama-gun.
(20)	Wagō (〃)	〃	〃 .
(21)	Nōchū (Sandstone)	〃	〃 .
(22)	Nōchū-Yatsunuma (Siltstone)	〃	〃 .
(23)	〃 (Coarse sandstone)	〃	〃 .
(24)	Yatsunuma (Siltstone)	〃	〃 .
(25)	〃 (Sandstone)	〃	〃 .
(26)	Yubune (Sandstone)	Yamanobe-machi	E. Murayama-gun.
(27)	Yubune-Chōkai-zan (Coarse sandstone)	〃	〃 .
(28)	〃 (Sandstone)	〃	〃 .
(29)	Omoshiro-Ōwarabi (Fine tuffaceous sandstone)	〃	〃 .
(30)	Furumaki (Sandstone)	Asahi-machi	W. Murayama-gun.
(31)	Miyajuku (Tuffaceous sandstone)	〃	〃 .
(32)	Shinjuku-Shimo-ashizawa (Sandstone)	〃	〃 .
(33)	Shinjuku-Tateyama (Siltstone)	〃	〃 .
(34)	Shimo-ashizawa (Fine tuffaceous sandstone)	〃	〃 .
(35)	〃 (Fine sandstone)	〃	〃 .
(36)	Shinjuku-Kami-ashizawa (Siltstone)	〃	〃 .
(37)	〃 (Tuffaceous sandstone)	〃	〃 .
(38)	Ōtaki (Fine sandstone)	〃	〃 .
(39)	Shimo-ashizawa-Kami-ashizawa (Tuffaceous sandstone)	〃	〃 .
(40)	Mogami-bashi (〃)	Aterazawa-machi	E. Murayama-gun.
(41)	Kanaya (Fine sandstone)		Sagae-shi
(42)	Kami-nakagō (〃)		〃 .
(43)	Myōjin-yama (Tuffaceous sandstone)		〃 .
(44)	Narakifuchi (〃)		〃 .
(45)	〃 (Sandstone)		〃 .
(46)	Hirashio (Fine sandstone)		〃 .
(47)	〃 (〃)		〃 .
(48)	〃 (〃)		〃 .
(49)	〃 (〃)		〃 .
(50)	〃 (〃)		〃 .
(51)	〃 (〃)		〃 .
(52)	The Uguisu-zawa-Hirashio (Tuffaceous sandstone)		〃 .
(53)	The Uguisu-zawa (Fine sandstone)		〃 .
(54)	The Fudō-zawa (〃)	Nakayama-machi	E. Murayama-gun.
(55)	Oka (〃)	〃	〃 .
(56)	〃 (〃)	〃	〃 .

(to be continued.)

(continued.)

		Village or Town	District or city
(57)	Fushikuma (Fine tuffceous sandstone)	Aterazawa-machi	W. Murayama-gun,
(58)	Sangō (Sandstone)	〃	〃 .
(59)	〃 (〃)	〃	〃 .
(60)	〃 (Coarse sandstone)	〃	〃 .
(61)	〃 (〃)	〃	〃 .
(62)	Tsuchihashi (〃)	Nakayama-machi	E. Murayama-gun.
(63)	Yō (Tuffaceous sandstone)	Aterazawa-machi	W. Murayama-gun,
(64)	〃 (Coarse sandstone)	〃	〃 .
(65)	〃 (Tuffaceous sandstone)	〃	〃 .
(66)	〃 (〃)	〃	〃 .
(67)	〃 (Coarse tuffceous sandstone)	〃	〃 .
(68)	Ōsumi (Fine tuffaceous sandstone)	Asahi-machi	〃 .
(69)	〃 (〃)	〃	〃 .
(70)	Iwaya-Yanagizawa (Tuffaceous sandstone)	Nakayama-machi	E. Murayama-gun.
(71)	〃 (〃)	〃	〃 .
(72)	〃 (〃)	〃	〃 .
(73)	〃 (Conglomeratic sandstone)	〃	〃 .
(74)	Oninome (Tuffaceous sandstone)	Yamanobe-machi	〃 .
(75)	Kitagaki-Oninome (〃)	〃	〃 .
(76)	Oninome-Karuizawa (〃)	〃	〃 .
(77)	Iwaya (Conglomeratic sandstone)	Nakayama-machi	〃 .
(78)	Karuizawa (Tuffaceous sandstone)	Yamanobe-machi	〃 .
(79)	〃 (Conglomeratic sandstone)	〃	〃 .
(80)	Karuizawa-Ōtera (Tuffaceous sandstone)	〃	〃 .
(81)	Yamanobe-Ainosawa (〃)	〃	〃 .
(82)	Osone-bashi (〃)	〃	〃 .
(83)	Takamori-yama-Omoshiro (Tuffaceous sandstone)	〃	〃 .
(84)	Omoshiro (Conglomeratic sandstone)	〃	〃 .
(85)	Okurihashi-Takamoriyama (Tuffaceous sandstone)	Asahi-machi	W. Murayama-gun.
(86)	Okurihashi-Ōwarabi (〃)	〃	〃 .
(87)	〃 (〃)	〃	〃 .
(88)	〃 (〃)	〃	〃 .
(89)	Ōwarabi (〃)	〃	〃 .
(90)	Ainosawa-Ōwarabi (〃)	Yamanobe-machi	E. Murayama-gun.
(91)	〃 (〃)	〃	〃 .
(92)	Tamamushi-numa-Shinden (〃)	〃	〃 .
(93)	〃 (Sandstone)	〃	〃 .
(94)	Shimo-ashizawa-Tateno (Tuffaceous sandstone)	〃	〃 .
(95)	The Uguisu-zawa (Sandstone)		Sagae-shi .
(96)	The Fudō-zawa (Coarse sandstone)	Nakayama-machi	E. Murayama-gun.
(97)	Yanagizawa (Tuffaceous sandstone)	〃	〃 .
(98)	Oninome (〃)	Yamanobe-machi	〃 .
(99)	Suwa (〃)	〃	〃 .
(100)	〃 (Sandstone)	〃	〃 .
(101)	Yamanobe-Ainosawa (Sandstone)	〃	〃 .
(102)	〃 (Tuffaceous sandstone)	〃	〃 .
(103)	Ainosawa (〃)	〃	〃 .
(104)	Okurihashi (〃)	Asahi-machi	W. Murayama-gun.
(105)	Shimo-ashizawa (〃)	〃	〃 .
(106)	Takinohira (〃)	Yamanobe-machi	E. Murayama-gun.
(107)	Takinohira-Yanazawa (Sandstone)	〃	〃 .
(103)	Yoshizawa (Tuffaceous sandstone)	〃	〃 .
(109)	Ideshio (Sandstone)	Murakizawa	Yamagata-shi .
(110)	〃 (〃)	〃	〃 .
(111)	〃 (Tuffaceous sandstone)	〃	〃 .
(112)	Shimobara (〃)	Yamanobe-machi	E. Murayama-gun.
(113)	Ideshio (Tuff)	Murakizawa	Yamagata-shi .
(114)	〃 (Brecciated tuff)	〃	〃 .
(115)	〃 (〃)	〃	〃 .

case of microcline.

The occurrence of biotite is not so remarkable as compared with quartz and plagioclase, although it is commonly found in several specimens. Some of its crystal is twisted and irregularly outlined. This mineral is strongly pleochroic from light yellow (X) to dark reddish brown or dark brown (Y, Z), being partly altered to chlorite.

Muscovite is, on the other hand, very rare, and is observed only in several thin sections, whereas sericite forms a scaly aggregate in feldspar crystals.

In fossiliferous specimens, calcite is extremely abundant and constructs the matrix of other components. Such examples can be seen in tuffaceous sandstone collected from the Hashigami Formation of Iwaya—Omoshiro and the Yu-zawa.

Chlorite seems to be a secondary mineral derived chiefly from biotite and partly from other ferro-magnesian minerals. The frequent occurrence of this mineral is known in the tuffaceous sandstone exposed at Hirashio (Hashigami Formation).

Besides it, the light mineral with a green color is represented by glauconite which occurs in some tuffaceous or non-tuffaceous fine sandstone and siltstone of the Mazawa Formation, Hashigami Formation and Nakanosawa Formation. The mineral is noticeably contained in the tuffaceous sandstone obtained at the opposite side of Yoshizawa village (Tsunatori Formation), at the upper course of the Yoshi-zawa (Mazawa Formation), Takinohira—Yanazawa (Mazawa Formation) and Takamori-yama—Omoshiro (Hashigami Formation) as well as in the siltstone of Hirashio (Hashigami Formation). It has a rounded from and beautiful aggregate polarization color. Moreover, a micaceous crystal resembling mica is found in the sandstone from the cutting between Karuizawa and Ōdera.

Several kinds of amphibole determined under the microscope are actinolite, bluish green hornblende, brown hornblende, green hornblende and tremolite. Among them, actinolite is to be seen in various formations, but is low in its frequency, showing a weak pleochroism between colorless (X, Y) and faint green (Z). In other amphiboles, green hornblende (Fig. 7) is most predominant, whereas bluish green hornblende and brown hornblende are almost same in frequency. All of these hornblendes are distinctly pleochroic, viz., light yellow (X), light green (Y), bluish green (Z); light brown (X), brown (Y), reddish brown (Z); light yellow (X), yellowish green (Y), green (Z). The extinction angle, $Z \wedge c$, is 17°–19°. These kinds of hornblende are particularly abundant in the tuffaceous or non-tuffaceous sandstone of the Mazawa Formation, Hashigami Formation and Nakanosawa Formation from which other formations are distinguishable with scarcity of hornblende crystals. Some of the green hornblende is remarkable for the presence of "hacksaw structure"[8]. The largest crystal is 0.44 mm. long in green hornblende. Tremolite is distributed to a small extent, and its frequency is nearly same as actinolite.

The occurrence of augite (Fig. 8) and hypersthene (Fig. 9) is also a characteristic feature of the Hashigami Formation and Nakanosawa Formation. Of these minerals, augite is very commonly seen in the tuffaceous sandstone obtained from Narakifuchi, Mogami-bashi of Aterazawa, Iwaya—Yanagizawa, Hirashio, Ōwarabi—Ainosawa, Ōwarabi—Okurihashi, Oninome—Karuizawa, Kitagaki—Oninome and Sangō (Hashigami Formation) as well as in the similar kinds of sandstone exposed at the Uguisu-zawa, Yubune and Chōkai-zan—Yubune (Nakanosawa Formation). It has a faint green color and is 0.73 mm. long and 0.34 mm. across in the largest crystal. Its extinction angle, $Z \wedge c$, is 40–41°. Moreover, there is a hacksaw structure in some crystals. Hypersthene is often assocsated with augite in almost the same frequency. In this case, the hacksaw termination of hypersthene srystals (Fig. 9) is more striking than that of augite (Fig. 8). Such examples can be seen in the tuffaceous sandstone exposed at Mogami-bashi, Hirashio, Oninome—Karuizawa, Yō—Iwaya, Kami-nakagō, Kitagaki—Oninome, Hirashio—the Uguisu-zawa and Fudō-zawa (Hashigami Formation) as well as in the similar sediments distributed along the Uguisu-zawa (Nakanosawa Formation). This mineral is very abundant in the tuffaceous sandstone obtained on the cutting between the Uguisu-zawa and Hirashio (Hashigami Formation) and along the Uguisu-zawa (Nakanosawa Formation). Sometimes, there are well-defined crystals. The largest crystal is 1.1 mm. is long and 0.37 mm. across.

The occurrence of a colorless mineral identified with olivine is known in the tuffaceous sandstone from the Yu-zawa, Kami-matsuyama—Shimomatsuyama and Yō (Nakanosawa Formation). The same mineral is also contained very scarcely in the non-tuffaceous sandstone from Oninome—Karuizawa (Hashigami Formation).

8) C. H. EDELMAN, *Fort. Min. Krist. Pet.*, **16** (1931), 67–68.
C. H. EDELMAN u. D. J. DOEGLAS, *Min. Pet. Mitt.*, **42** (1931), 482–490.
F. J. PETTIJOHN, *Sedimentary Rocks*, (1948), 490–491.

In most specimens, allanite (Fig. 10) is a characteristic mineral with a strong absorption from dark brown (X) to dark reddish brown (Y) or light brown (Z). Its frequency is, however, very low except in the tuffaceous sandstone from near Jōmyōji (Tsunatori Formation) and the non-tuffaceous sandstone found at Kitagaki—Oninome and Karuizawa—Oninome (Hashigami Formation) as well as in the tuffaceous sandstone of Chōkai-zan—Yubune (Nakanosawa Formation). The mineral has a wide distribution in all formations, and well-defined prismatic crystals are to be seen in the sandstone from Karuizawa—Oninome (Hashigami Formation) and the tuffaceous sandstone from Chōkai-zan—Yubune, Shimo-ashizawa and near Menkyō-bashi (Nakanosawa Formation). Its largest crystal is 0.44 mm. in length. Epidote is commonly found in most sandy rocks except those of the Tsunatori Formation, being abundant in the tuffaceous sandstone of Chōkai-zan—Yubune (Nakanosawa Formation). In the epidote group, zoisite is a rare mineral whose occurrence seems to be confined to only the tuffaceous or non-tuffaceous sandstone of the Inazawa Formation, Nakanosawa Formation and Hashigami Formation.

The frequency of anatase (Fig. 11) is exceedingly low, when compared with that of allanite and epidote which are seen in almost all specimens collected by the writers. The crystal takes a sharp pyramidal form with striations parallel to the intersection of (111) and (110), being 0.15 mm. long and 0.07 mm. across in the largest one. It has an indigo-blue or dark brown color, and some of it is weakly pleochroic. The occurrence of this mineral is restricted to the specimens of tuffaceous sandstone gained from Yanagizawa, Yamanobe—Ainosawa, Yoshizawa—Hayasaka (Mazawa Formation), Mogami-bashi, Hirashio, Oka, Yō, the northern foot of Negota-yama, Osone-bashi (Hashigami Formation), Kami-matsuyama—Shimo-matsuyama, the opposite side of Shinosawa, Shimo-ashizawa and near Ōtaki (Nakanosawa Formation).

The similar frequency is also shown by apatite (Fig. 12). This mineral is found scarcely in the tuffaceous sandstone exposed widely at the eastern foot of Tate-yama (Nakanosawa Formation), the Yu-zawa, Iwaya and the northern foot of Negota-yama as well as near Yō (Hashigami Formation), where it mostly reveals a remarkable cross-bedding. Such apatite has a stout prismatic habit, being 0.29 mm. long in the largest crystal. Its crystal generally occurs in a fresh appearance, but on rare occasions exhibits a dark core due to decomposition.

Garnet is a scanty but characteristic mineral contained as rounded crystals or angular pieces with varying ranges of color, viz., pink, light brown, reddish brown, red and colorless. Among them, pink garnet is in high frequency as compared with others, and the reddish brown variety is commonly present in the tuffaceous sandstone of the Yu-zawa (Hashigami Formation) and non-tuffaceous sandstone of Nōchū and Hachibe (Nakanosawa Formation). Red or light brown garnet is, however, almost absent in the specimens from this area.

Magnetite, ilmenite, hematite and limonite are very extensively distributed in all kinds of sandy rocks, although the frequency of these minerals is much variable from place to place. In many specimens, ilmenite is a noticeable mineral with a hexagonal platy form and jet-black color. Hence, it is easily distinguishable from magnetite and hematite. In general, the decomposed sandstone and siltstone are rich in limonite. Mostly, it has a very irregular form and seems to have partly been derived from pyrite.

Pyrite is a common mineral in the tuffaceous or non-tuffaceous sandstone from Jōmyōji—Yoshizawa (Tsunatori Formation), Oninome—Fudō-bashi (Mazawa Formation), Sangō, the Yu-zawa, Yō, Oninome—Karuizawa, Ōwarabi—Okurihashi, the northern foot of Negota-yama (Hashigami Formation) and Shinjuku—Shimo-ashizawa (Nakanosawa Formation). The crystal is represented by cube and pentagonal dodecahedron. There are also some granular aggregates resembling marcasite. Moreover, the specimens from Takinohira (Mazawa Formation) and Kitagaki (Tsunatori Formation) contain pyrrhotite in a negligible amount.

In some specimens, tourmaline (Fig. 13) and rutile occur as minor components. Usually, the former has a granular or fragmental form, although there are well-defined crystals with a stout prismatic habit in the tuffaceous rocks from Menkyō-bashi, near Nariai, Shinjuku—Kami-ashizawa and Shimo-ashizawa (Nakanosawa Formation). It is strongly pleochroic with following absorption colors, viz., (i) X=light blue, Z=blue, (ii) X=light brown, Z=brown, (iii) X=yellowish brown, Z=dark yellowish brown, (iv) X=grey, Z=dark grey, (v) X=greyish brown, Z=dark brown, (vi) X=greyish brown, Z=blue, (vii) X=greyish blue, Z=dark greyish blue. The latter is, on the other hand, slightly pleochroic from reddish brown to yellowish brown, and tuffaceous sandstones of Yō and Chōkai-zan—Yubune (Nakanosawa Formation) indicate a rare occurrence of minute knee-shaped twin.

The specimens collected from many places are free of cordierite, spinel and staurolite except the sandstones of Yoshizawa (Tsunatori

Table IV. Frequency of some heavy minerals.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Actinolite	①		①			①		①	①				①	①	I				①	①
Brown hornblende	①					①							①					①		
Green or bluish green hornblende	III		I	VII	①	IV	II	I	IV	II	III	I	I	VI	II		①	IV	I	①
Tremolite	I		①			①		①					①					①	①	
Augite												II								
Hypersthene				①								V						①	①	
Olivine	?							?											?	
Magnetite (ilmenite, hematite)	VI	X	IX	IV	IX	VI	VII	IX	VII	IX	VIII	IV	VIII	V	VIII	IX	X	VII	X	IX
Pyrrhotite																				
Allanite	①		①	①	①			①	①	①			①		①	①		①	①	①
Zoisite					I															
Anatase								①										①		
Apatite																				
Cordierite																				
Garnet	①		①	①	①	①	①	①	①	①		①	I		①	①	①	①	①	①
Rutile	①		①					①								①			①	
Spinel																				
Staurolite			?																	
Titanite							?		①	①									①	
Topaz																				
Tourmaline	①		①	①		①	①	①	①			①	①		①	①		①	①	①
Colorless or pink zircon	II		II	①	II	I	I	II	I	I	I	①	II	I	I	II	I	I	I	II

	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)	(40)
Actinolite					①			①	①		①	①	①	①	①	①	①	①	①	①
Brown hornblende						①	①					①						①		
Green or bluish green hornblende	①				①	V	II	II	I	①	①	V	I	①	V	III	①	V	III	I
Tremolite					①	①		①			①	①			①			①	①	
Augite				I		II	II	①			?								①	I
Hypersthene		①		I		①	①			①	①	I			III				II	VIII
Olivine						?					①	?								
Magnetite (ilmenite, hematite)	VIII	VIII	IX	IX	IX	IV	VIII	VIII	VII	IX	IX	V	IX	X	IV	VII	IX	V	VI	II
Pyrrhotite																				
Allanite	①		①			①	①	①	①	①	?	①	①		①	①	①	①	①	
Zoisite											①						I			
Anatase	①														①			①	①	
Apatite												①								
Cordierite																				
Garnet	①	I	I	①	①	①	①		①		①	①	①		①	①		①	①	
Rutile		①		①	I		①	①			①	①		①						
Spinel																				
Staurolite																				
Titanite		①	①		①	①		?	①		①	①	①							
Topaz																				
Tourmaline	①	①	①		①		①	①	①		①	①	①		①	①	①	①	①	
Colorless or pink zircon	III	III	I	I	I	I	I	I	II	II	II	I	I	I	I	I	II	I	I	①

	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)	(57)	(58)
Actinolite	①		①			①			①		①				①	①	①	①
Brown hornblende			①						①	①								①
Green or bluish green hornblende	I	I	III	VI	VI	I	①	I	IV	III	II	II		I	I	III	III	II
Tremolite	I			①	①				①		①	①		①		①	①	①
Augite		I	①		I			①	I		II	I						①
Hypersthene		IX	①				①	①	I	I	I	VIII						
Olivine									①									
Magnetite (ilmenite, hematite)	IX	I	VIII	IV	IV	IX	VIII	IX	VI	VII	VII	II	IX	IX	IX	VII	VI	VIII
Pyrrhotite																		
Allanite			①	①		①		①	①	①		①	①	①	①	①		①
Zoisite									①						?			
Anatase	①							①		①					①			
Apatite																		
Cordierite																		
Garnet	①		①			①	①	①	①	①		①					①	①
Rutile									①							①		
Spinel																		
Staurolite																		
Titanite								①	①	①								
Topaz																		
Tourmaline			①	①		①	①		①		①		①		①		①	①
Colorless or pink zircon	II		I	I	①	II	III	II	I	I	①	①	I	I	II	I	I	I

	(59)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(67)	(68)	(69)	(70)	(71)	(72)	(73)	(74)	(75)	(76)	(77)	(78)
Actinolite							①			①		①			①					①
Brown hornblende			①		①		①			①		①		①	①				①	
Green or bluish green hornblende	IV	IV	II	II	II	V	III	VIII	IV	VI		IV	IV	III	VI	III	III	II	I	IV
Tremolite			①	①		①	①		①	①			①	①						①
Augite	II		III			①	①			①		II		I	①		I	II	III	I
Hypersthene		①	I	V		①	①			①			①			①	I	I	II	①
Olivine					?									?				?	①	
Magnetite (ilmenite, hematite)	V	VI	VI	IV	IX	V	VII	III	VII	IV	X	V	VII	VII	V	VII	VII	VII	VI	IV
Pyrrhotite																				
Allanite	①	①	①	①	①	①	①	①		①	①	?	①	①	①	①	I	I	①	①
Zoisite																				
Anatase							①			①										
Apatite						①	①			①				I						
Cordierite																				
Garnet		①	①	①		I	①	①	①	①		①		①	①	①	①	①		①
Rutile															①					
Spinel																				
Staurolite																				
Titanite			①				①		①	①		①					①	①		
Topaz														?						
Tourmaline		?		①	①							?	①	①	①	①	①	①		
Colorless or pink zircon	I	II	①	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II

	(79)	(80)	(81)	(82)	(83)	(84)	(85)	(86)	(87)	(88)	(89)	(90)	(91)	(92)	(93)	(94)	(95)	(96)	(97)
Actinolite			①		①		①					①			①			①	①
Brown hornblende					①							①	①		①				
Green or bluish green hornblende	I	II	II	I	III	X	①	①	①	V	II	V	I	①	V	VI		III	I
Tremolite	①			①			①								①				①
Augite	①								①		III	①	IV					①	
Hypersthene	V							①		①						①	I	①	
Olivine											?								
Magnetite (ilmenite, hematite)	V	IX	IX	VIII	VIII	I	X	X	IX	VI	V	V	VI	X	VI	V	IX	VIII	VIII
Pyrrhotite																			
Allanite	①	①	①	①	①	①	①	①	I	①	①	①	①	①	①	①		①	①
Zoisite																			
Anatase				①															①
Apatite																			
Cordierite																			
Garnet	①	①	①	①	①			①	①	①	①			①	①	①	I		①
Rutile	①				①														①
Spinel												①							
Staurolite		①																	
Titanite	①		?						①		①	①							
Topaz																			
Tourmaline	①		①	①	①		①	①		①			?	①					
Colorless or pink zircon	I	I	I	I	I	①	I	I	I	I	I	I	I	I	I	I	I	II	II

	(98)	(99)	(100)	(101)	(102)	(103)	(104)	(105)	(106)	(107)	(108)	(109)	(110)	(111)	(112)	(113)	(114)	(115)
Actinolite				①	①	①								①		①		
Brown hornblende	①				①	①												
Green or bluish green hornblende	V	II	①	II	II	V	①	①		?	①	①	①	①			①	I
Tremolite					①	①												
Augite										①								
Hypersthene		①					①	①		I				①	①	①	①	
Olivine				?														
Magnetite (ilmenite, hematite)	VI	IX	IX	IX	IX	V	X	IX	III	VIII	IV	IX	V	IX	II	IX	VIII	VI
Pyrrhotite								①										
Allanite	①	①		①	①	①	①			①	II	I		①	IV	①		I
Zoisite																		
Anatase					①	①								①				
Apatite																		
Cordierite																	①	
Garnet		①		①		①		①			①	①	①	①		①	①	I
Rutile				①		①												
Spinel																		
Staurolite																		
Titanite		①				①		①										
Topaz																		
Tourmaline						①	①							①			①	
Colorless or pink zircon	I	I	II	I	I	I	I	II	VIII	III	VI	I	VI	II	VI	II	II	V

①<1%, I=1-10%, II=11-20%, III=21-30%, IV=31-40%, V=41-50%, VI=51-60%, VII=61-70%, VIII=71-80%, IX=81-90%, X=91-100%.

Formation), Ainosawa—Ōwarabi (Hashigami Formation) and Kami-matsuyama (Inazawa Formation) respectively, but contain zircon in almost all cases.

So far as has been examined by the writers, zircon (Fig. 14) is composed of two varieties, pink and colorless, the former being more predominant. The crystals are combinations of (100), (110); (110), (111) and (110), (111), (100), (311). They have a prismatic or granular form, and the pink variety is sometimes characterized by a long prismatic crystal with an etched surface. Such crystals are commonly rich in prismatic or granular enclosures with unknown characters.

Besides the mineral components mentioned above, it is worth noting that various kinds of rock-fragments are contained in almost all specimens. They are granite, plagioliparite (rhyolite) (Figs. 15~16), perlite, granophyre (Fig. 17), felsophyre (Fig. 18), felsite, dacite, andesite (Fig. 19), propylite (Fig. 20), basalt (Figs. 21~22), green tuff (Fig. 23), shale and pumice (Fig. 24) embedded in the tuffaceous or pumiceous or sandy matrix. Most predominant are plagioliparite, felsophyre or felsite and represent the main rock-fragments in each formation, taking a rounded or angular form and indicating a microgranitic or spherulitic groundmass with corroded quartz phenocrysts.

Other noticeable rocks are andesite and propylite with a pilotaxitic groundmass. The occurrence of fragmental perlite is, however, restricted to the tuffaceous sandstone from the Uguisu-zawa and Shimo-ashizawa (Nakanosawa Formation), and green tuff is found in nearly same frequency as propylite. Basalt and shale are, on the other hand, very rare as in the case of granite. Moreover, the specimens from Yō, the Uguisu-zawa, Mogami-bashi, Hirashio, the northern foot of Negota-yama (Hashigami Formation) are always characterized by the abundance of pumice. There are also many specimens with large amounts of tuffaceous or glassy substance.

In association with them, the remains of foraminifera are sometimes seen in the tuffaceous sandstones of Okurihashi—Owarabi, Yamanobe, the upper course of the Yoshi-zawa (Mazawa Formation), Narakifuchi, Omoshiro (Hashigami Formation), Katsura—Kami-matsuyama, Okurihashi —Takamori-yama (Nakanosawa Formation).

The frequency of some heavy minerals is shown in Table IV.

Some Geologidal Considerations on the Environment of Sedimentation

One of the characteristic features confirmed from the investigations of sediments distributed extensively in this district is the abundance of such rock rich in tuffaceous substance except for formations almost completely composed of argillaceous rocks. The mineral components of these sediments mostly have an angular form and reveal a fresh appearance, although there are sometimes sericitized orthoclase and plagioclase as well as chloritized biotite. It is also noticeable that apatite and cordierite are still preserved in some specimens, since these minerals are very easily decomposable. Such facts, therefore, suggest that the sediments exposed here were not transported from a distance. Moreover, glauconite is contained in several formations ranging from the Tsunatori Formation up to the Nakanosawa Formation, indicating the sedimentation to have possibly taken place in rather shallow water[9]. This may be similarly inferred from the high frequency of cross-bedding shown by the sandy rocks of the Hashigami Formation and others which are supposed to have been accumulated under a deltaic condition. In such cases, most of the Hashigami Formation probably correspond to the topset or foreset bed, whereas the Nakanosawa Formation may pass from the topset bed to bottomset bed by going westwards.

The deposition of these sediments seems to have taken place in the basin built up largely of granitic masses. It can be guessed from the extensive distribution of granitic rocks in the surrounding area, as is indicated by those of Yamadera, Gando-san, Ryū-zan, Fubira-san, Banjō-zan, Takato-yama, Kamanohata, Isazawa, Asahi-dake, Shōjiga-take, Ōhibara-yama, Akamidō-dake, Ishimidō-dake and others which are not included in the writers' map. At that time, the basin was probably opened northwards, and the accumulation of Neogene sediments was preceeded by that of green tuff in association with repeated igneous activities. Such kinds of green tuff are well exposed on the hilly land behind and at the eastern side of the Shirataka Volcano, being intercalated and traversed by plagioliparite (rhyolite), perlite, felsophyre, andesite, propylite and basalt. These volcanics are represented by sill,

9) W. H. TWENHOFEL, *Treatise on Sedimentation*, (1926), 339.
J. TAKAHASHI and T. YAGI, *Econ. Geol.*, **24** (1929), 838-851.
A. HADDING, *Lunds Univ. Arsskrift, N. F. Avd. 2*, **23** (1932), 153.
T. ICHIMURA, *Mem. Fac. Sc. and Agr. Taihoku Imp. Univ.*, **22** (1940), 61.

dyke and lava flow. Among them, the large exposures of rhyolite and felsophyre flows associated closely with perlite, plagioliparite and andesite are known at the neighbouring area which includes Togami-yama, Omori-yama, Hasedō, Sukarita, Kakumaba, Takatori-yama and Kyōzuka-yama. It is, however, noticed that the occurrence of these volcanics is quite unknown at the area investigated by the writers, notwithstanding that their minute fragments are commonly contained in almost all sandy rocks collected from various formations under consideration. The fragments are frequently found together with those of green tuff and shale. Besides, there are conglomeratic sandstones with many pebbles of volcanics mentioned above. From such evidences, it can be say that green tuff beds already deposited within the basin were locally upheaved and subjected to contemporaneous erosion during the sedimentation of younger formations. This erosion possibly began with the accumulation of the Tsunatori Formation, and the sediments are likely to have been supplied from the area where green tuff and associated volcanics had been exposed together with the granitic rocks and old sedimentary rocks. The green tuff beds exposed here were probably eroded down to the lower horizon characterized by the presence of propylite.

Igneous Activities during and prior to the Deposition of Neogene Sediments

There is much evidence of igneous activities at the mountainous or hilly area adjacent to the Yamagata Basin, where Neogene sediments are extensively exposed. Such activities are now believed to have taken place during and prior to the accumulation of these sediments including large granitic intrusions.

So far as is known from the geological features in surrounding districts, these activities are inferred to have started with the intrusions of granitic or dioritic rocks, and such geological events are supposed to to have been repeated several times.

The granitic or dioritic rocks here are composed of granite (granodiorite), quartz diorite, diorite, aplite, pegmatite and quartz veins. They are mostly pre-Miocene intrusives except some small bodies considered to have been injected into green tuff and associated sediments.

The next activity is represented by the eruption of andesite lavas which rest upon the eroded surface of granitic rocks and are unconformably overlain frequently by Neogene sediments. This type of andesite is not found on the hilly land near the Yamagata Basin, but is to be seen near Funabiki-yama rising up at the boundary between Miyagi and and Yamagata Prefectures. It was then followed by other kinds of andesite exposed now on Ryūga-take and at the uppermost course of the Tsukinuno-gawa.

Intense activities are also indicated by the remarkable distribution of green tuffs in the adjacent area. Moreover, these activities resulted in the repeated injections or extrusions of plagioliparite (rhyolite), perlite, felsophyre, granophyre, felsite, dacite, andesite, propylite, basalt (dolerite), etc. during the deposition of green tuff beds. At this area, however, the occurrence of Neogene holocrystalline intrusives has not yet been confirmed, although some plutonics ranging quartz diorite to gabbro were found by I. Katō[10] at the northeastern margin of the Shinjō Basin.

Besides, tuffaceous or pumiceous sediments are extremely abundant in the upper horizon of Neogene formations distributed on the hilly land between the Yamagata Basin and the Mogami-gawa, suggesting that the activity was repeated even after the sedimentation of green tuff. They are strikingly abundant in the Tsunatori Formation, Hashigami Formation and Nakanosawa Formation. Mineralogically speaking, the tuffaceous rock of the Hashigami Formation and Nakanosawa Formation occasionally reveal the high frequency of hypersthene or augite crystals at the area covering Hirashio, Mogami-bashi, Karuizawa, Oninome, Iwaya, Yanagizawa, Kami-nakagō, Sangō, Yō, Kami-ashizawa and Shimo-ashizawa. This evidence seems to suggest that the submarine eruption repeatedly happened and supplied two minerals mentioned above during the deposition of the Hashigami Formation and Nakanosawa Formation. It is furthermore proved by the abundance of fragmental hard shale, black shale and siliceous liparite embedded in the tuff or tuffaceous sandstone beds exposed near Hirashio. Tertiary lava flows or intrusive bodies are, however, entirely lacking at the area occupied by the sediments ranging from the Tsunatori Formation up to the Inazawa Formation.

Sources of Mineral Components

As has already been stated, the Neogene sediments of the hilly land under consideration contain various kinds of light and heavy minerals supplied from the sources of the surrounding area, where intrusives and extrusives as well as older sedimentaries have been subjected to the intense erosion.

10) KATŌ, *Sc. Rep. Tōhoku Univ., III*, **5** (1955), 76-84.

Of these, some quartz crystals are supposed to have been derived from plagioliparite (rhyolite) or dacite, being embedded in most of tuffaceous or non-tuffaceous sandstones exposed here. Other quartz crystals are, however, believed to have had their sources in granite (granodiorite) and quartz diorite.

Microcline and orthoclase are found in very low frequency as compared with quartz. In these cases, orthoclase occasionally reveals a microperthetic structure, suggesting that such a type of orthoclase was supplied from granite or pegmatite together with microcline. The orthoclase crystals free of this structure were, on the other hand, brought from the area, where granite, plagioliparite, felsophyre, etc. had been exposed. Generally, the phenocrystic orthoclase is rather scarce in plagioliparite (rhyolite) or felsophyre of the surrounding districts. The main source of orthoclase is, therefore, attributed to granitic rocks.

The most important mineral next to quartz is plagioclase which is always characterized by a very fresh appearance. The geological features of the neighbouring area indicate that it came from such plutonics and volcanics as granite (granodiorite), quartz diorite, diorite, gabbro, plagioliparite (rhyolite), felsophyre, dacite, andesite, propylite and basalt (dolerite).

The occurrence of biotite is, however, not so remarkable as quartz and plagioclase. So far as is known at present, biotite granite or hornblende biotite granite, pegmatite, plagioliparite (rhyolite) and other sediments metamorphosed by granitic intrusions are likely to have supplied this mineral during their erosion. It is somewhat different from muscovite whose source was probably pegmatite.

Hornblende is noticeably present in some specimens, as is shown by its bluish green or green variety. They have different sources. For instance, the bluish green hornblende is considered to have originally been a component mineral of metamorphic rocks, whereas the green variety was undoubtedly supplied by the erosion of hornblende biotite granite, hornblende granite, quartz diorite, diorite, hornblende plagioliparite, etc. In contrast with them, the occurrence of the brown hornblende is restricted to a small extent, and its distribution depends upon the exposures of gabbro, gabbro pegmatite and lamprophyre. Besides these, actinolite and tremolite are respectively the erosion products of some actinolite schist and impure limestone recrystallized by the granitic intrusion.

Augite and hypersthene are not so largely distributed as green hornblende. They are locally found in high frequency, but are occasionally absent even in the beds of the same horizon. Such a mode of occurrence seems to suggest that the submarine eruption took place intermittently during the sedimentation and led these two minerals to the local concentration. They are furthermore characterized by the frequency of well-defined crystals derived from the andesitic lavas and ejecta.

Iron ores are also important components in some specimens, and several sources are inferred for each case. The most noticeable occurrence is shown by ilmenite with a jet-like color and six-sided platy form. It is not infrequently contained in the Neogene andesite exposed here and there at the area behind the Shirataka Volcano.

As to allanite, it is already known that this mineral occasionally occurs in granite or granodiorite forming the foundation of the Zaō and Gando Volcanoes as well as in those of Asahi-dake[11]. Similar plutonics may be the sources of apatite, titanite and pink garnet, but epidote is likely to have had its origin in epidotized granite or granodiorite and propylite.

Tourmaline is usually seen in granite, pegmatite, aplite and also in metamorphosed sediments (for example, hornfels). In these rocks, the tourmaline crystals of pegmatite and aplite have some different pleochroic scheme, viz., light blue (X) or light brown (X) to blue (Z) and greyish blue (Z). Those of hornfels or other metamorphosed sediments are, however, pleochroic from light yellowish brown (X) to dark brown (Z), taking a well-deffned crystal form in most cases. Most of tourmaline crystals in the Neogene sediments are, therefore, supposed to have been brought from the contact aureole as in the case of staurolite and cordierite.

Rutile is not rare in granite and such a green rock as amphibolite or hornblende schist, and anatase is apt to occur in granite and quartz-porphyry, but their mother rocks have not yet been confirmed in the surrounding districts. Similarly, it is still obscure from where spinel was supplied. Oliving is hardly preserved in sediments, since it is easily subjected to decomposition, and its possible source may be olivine basalt associated closely with green tuff beds.

Zircon is, on the other hand, a common accessory mineral in granite, granodiorite and plagioliparite. It is worth noting that the zircon crystals from granitic rocks of adjacent area are mostly represented by pink or

11) Personal Communication by T. OGURA.

colorless varieties with a stout prismatic habit and well-defined form.

Those of plagioliparite are, however, frequently elongated and always have a pink color, being sometimes corroded to a crub-like form with an irregular outline. The crystals from such different sources are found together in the Neogene sandy rocks exposed here and on the adjacent hilly land. Moreover, there are glauconite, pyrite, chlorite, calcite and limonite which are diagenetic or secondary minerals indifferent from the sources of sediments.

Summary

(i) Neogene sediments free of green tuff are largely exposed on the hilly land between the Mogami-gawa and Yamagata Basin. They are represented by the Tsunatori Formation, Mazawa Formation, Hashigami Formation, Nakanosawa Formation and Inazawa Formation, being composed of conglomeratic sandstone, tuffaceous or non-tuffaceous sandstone, siltstone, shale, mudstone, tuff, etc.

(ii) These Neogene sediments were intensely folded and faulted, but they have a general strike of N–S to N30°E, showing anticlinal or synclinal structures.

(iii) Many specimens represented mostly by the tuffaceous or non-tuffaceous sandstones were collected from various parts of each formation to examine mineral components and rock-fragments contained in them. For this purpose, the microscopical investigations of their thin sections and isolated minerals separated by mechanical analyses were carried out on these specimens. The minerals determined in this way are quartz, microcline, orthoclase, plagioclase, biotite, muscovite (sericite), calcite, chlorite, glauconite, bluish green hornblende, brown hornblende, green hornblende, actinolite, tremolite, augite, hypersthene, olivine, hematite, ilmenite, limonite, magnetite, pyrite, pyrrhotite, allanite, epidote, zoisite, anatase, cordierite, garnet, spinel, staurolite, titanite, topaz (?), colorless zircon and pink zircon. Moreover, they are found in association with such rock-fragments as granite (granodiorite), plagioliparite (rhyolite), felsophyre, felsite, granophyre, perlite, dacite, andesite, propylite, basalt (dolerite), pumice, green tuff and shale.

(iv) Various kinds of mineral components and rock-fragments as well as the pebbles of conglomeratic sandstone suggest that their sources were granite (granodiorite), quartz diorite, diorite, gabbro, pegmatite, aplite, lamprophyre, plagioliparite (rhyolite), felsophyre, felsite, perlite,

granophyre, dacite, andesite, propylite, basalt (dolerite), amphibolite, hornblende schist, actinolite schist, biotite schist, hornfels, green tuff and associated sandy or shaly rocks.

In the surrounding districts, important intrusives and extrusives are granite or granodiorite, plagioliparite (rhyolite), felsophyre, andesite, propylite and basalt. Among them, granite or granodiorite constructs a base rock overlain by Neogene sediments, whereas plagioliparite and other kinds of volcanics are closely associated with green tuff beds intercalted by siltstone, mudstone, shale and sandstone.

(v) The Neogene sediments exposed here and at the adjacent area are likely to have been deposited in the basin surrounded partly by the exposures of granite (granodiorite) and other plutonic rocks as well as of some metamorphosed sediments. It is also inferable that green tuff beds were locally upheaved during the accumulation of still younger Neogene sediments and were subjected to the contemporaneous erosion. The mineral components and rock-fragments of Neogene sediments younger than green tuff are, therefore, supposed to have been supplied from the surrounding area, where green tuff and associated volcanics had extensively been exposed together with granitic rocks.

(vi) Volcanic substances are abundantly present in the Neogene sediments of the hilly land bordered by the Mogami-gawa, Yamagata Basin and Shirataka Volcano. They are remarkably tuffaceous and sometimes pumiceous, excluding the tuff intercalated between them. Such a lithological character may partly depend upon the erosion of green tuff beds already deposited, but it can also be said that volcanic eruptions took place repeatedly on the sea bottom and its adjacent land during the continuous accumulation of sediments. The possibilities of submarine eruption are indicated by the abnormal features which are not infrequently found in the beds of tuff and tuffaceous sandstone exposed near Hirashio or elsewhere.

Acknowledgement

The writers wish to express their cordial thanks to the staff of the Teikoku Oil Company who gave them an opportunity to start their field works. They are also indepted deeply to Dr. H. Tsuya and Mr. T. Watanabe of the Earthquake Research Institute whose kindness largely facilitated their laboratory investigations. A part of this investigation

Fig. 4. A panoramic view of the hilly land adjacent to the western margin of the Yamagata Basin. This picture was taken from the summit of Nishi-kuromori-yama.

1=Gassan, 2=The Mogami-gawa, 3=Ha-yama, 4=Aterazawa, 5=Chōkai-zan between Yubune and Araya, 6=Yanazawa, 7=Rai-zan, 8=Hataya, 9=Higashi-kuromori-yama, 10=Yamagata Basin, 11=Ō-numa, 12=Gando-san.

Fig. 5. Cross-bedding of tuffaceous sandstone exposed on the cutting of bus road between Aino-sawa and Ōwarabi.

Fig. 6. Cross-bedding of tuffaceous sandstone exposed along the trail between Hirashio and the Uguisu-zawa.

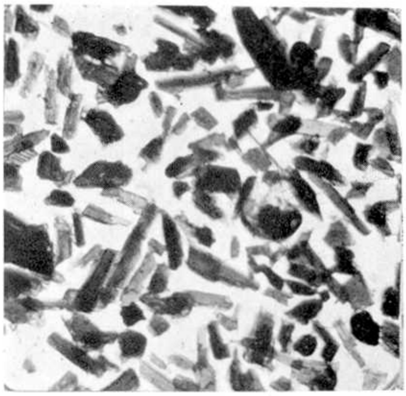

Fig. 7. Hornblend crystals (conglomeratic ss., Hashigami Formation, Omoshiro). ×40.

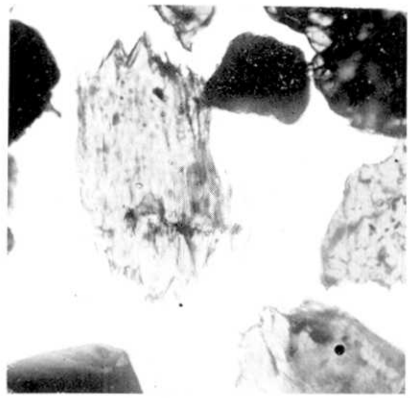

Fig. 8. Augite crystals with a hacksaw structure (tuffaceous ss., Hashigami Formation, Oninome-Karuizawa). ×100.

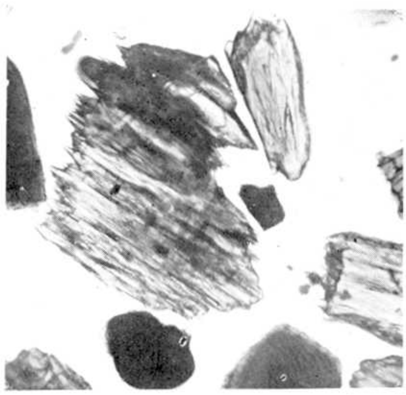

Fig. 9. Hypersthene crystals with a hacksaw structure (tuffaceous ss., Hashigami Form., Oninome-Karuizawa). ×100.

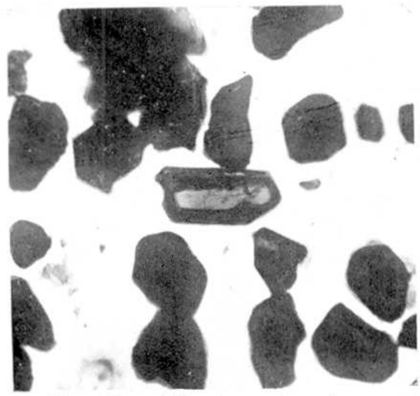

Fig. 10. Allanite, prismatic crystal (tuffaceous ss., Nakanosawa Formation, Wagōtaira-Wagō). ×100.

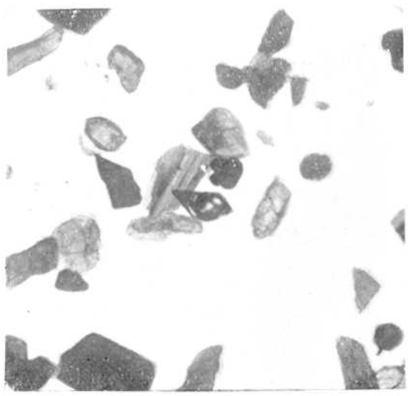

Fig. 11. Anatase, pyramidal crystal (taffaceous ss., Hashigami Formation, Oka). ×100.

Fig. 12. Apatite, prismatic crystal (tuffaceous ss., Hashigami Formation, Iwaya). ×100.

Fig. 13. Tourmaline, prismatic crystal (tuffaceous ss., Nakanosawa Formation, Wagōtaira-Wagō). ×100.

Fig. 14. Zircon crystals (siltstone, Inazawa Formation, Kami-matsuyama). ×100.

Fig. 15. Plagioliparite-fragment (tuffaceous ss., Hashigami Formation, Iwaya). ×100.

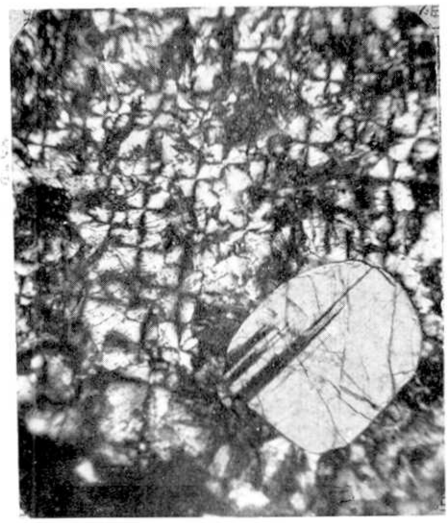

Fig. 16. Spherulitic rhyolite-fragment (ss., Mazawa Formation, Suwa). ×100.

Fig. 17. Granophyre-fragment (brecciated tuff, Tsunatori Formation, Deshio). ×100.

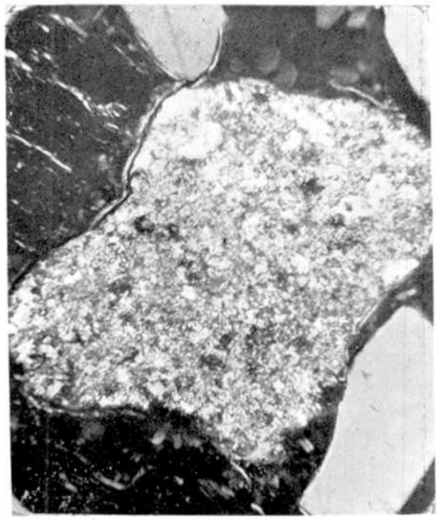

Fig. 18. Felsophyre-fragment (tuffaceous ss., Hashigami Formation, Ainosawa-Ōwarabi). ×100.

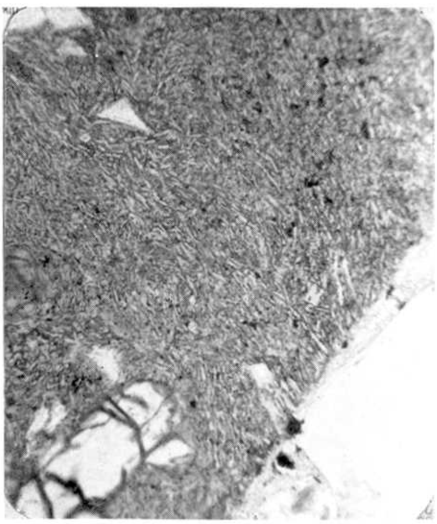

Fig. 19. Andesite-fragment (ss., Nakanosawa Formation, Yubune). ×100.

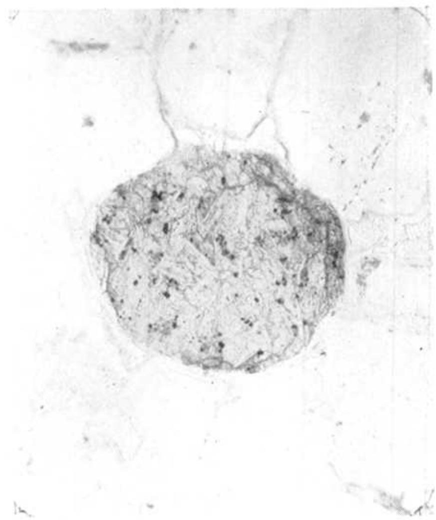

Fig. 20. Propylite-fragment (tuffaceous ss., Hashigami Formation, Ainosawa-Ōwarabi). ×100.

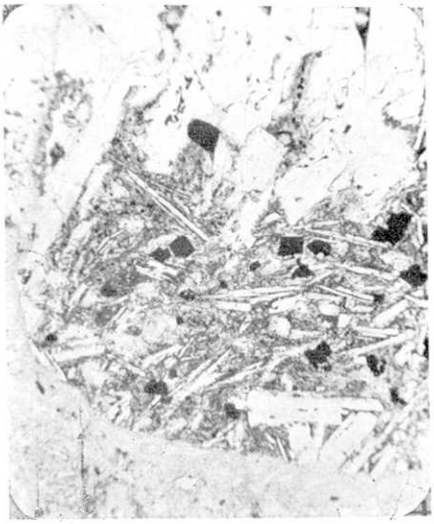

Fig. 21. Basalt-fragment (ss., Hashigami Formation, Hirashio . ×100.

Fig. 22. Dolerite-pebble (conglomeratic ss., Ma awa Formation, Oninome). ×100.

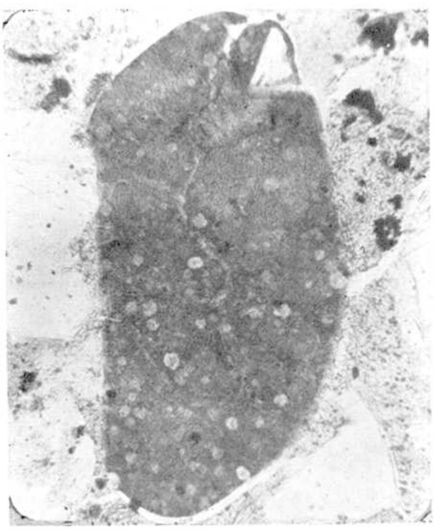

Fig. 23. Green tuff-fragment (ss., Nakanosawa Formation, Yubune-Chōkai-zan). ×100.

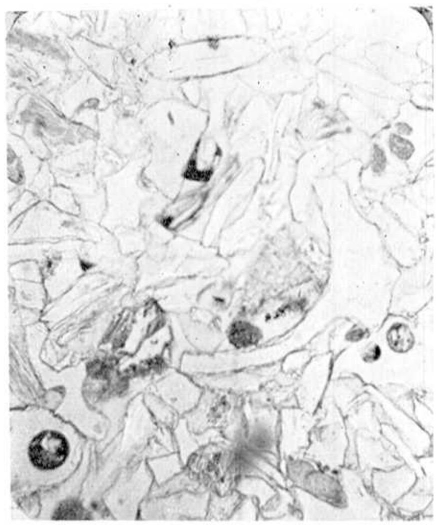

Fig. 24. Pumice-fragments (tuffaceous ss., Nakanosawa Formation, Shinjuku-Kamiashizawa). ×100.

was carried out with the aid of an Education Ministry Grant for Natural Science.

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5. 山形盆地西縁の新第三紀堆積岩に関する地質学的考察

山形大学 {市村 毅 / 青木和子}

山形盆地と最上川との間を占める丘陵地帯には，新第三系が広く露出している．この新第三系を形成する堆積岩は，凝灰岩，凝灰質砂岩，非凝灰質砂岩，頁岩，泥岩，シルト岩，礫岩などであり，それ等の中でも凝灰質の岩石が特に多い．凝灰質砂岩，非凝灰質砂岩，シルト岩には，石英（蝕融されたもの多し），正長石（屡々微ペルト構造を示す）微斜長石，斜長石，黒雲母，白雲母，方解石，海緑石，緑泥石，帯青緑色角閃石，透角閃石，陽起石，普通輝石，紫蘇輝石，橄欖石，褐簾石，緑簾石，黝簾石，鋭錐石，燐灰石，柘榴石，菫青石，スピネル，十字石，電気石，金紅石，クサビ石，磁鉄鉱，赤鉄鉱，褐鉄鉱，チタン鉄鉱，黄鉄鉱，磁硫鉄鉱，トパツ(?)，ジルコンなどと共に，花崗岩，文象岩，斜長石石英粗面岩，真珠岩，珪長斑岩，珪長岩，石英安山岩，安山岩，変朽安山岩，玄武岩，緑色凝灰岩，頁岩の微小片，浮石片および凝灰質物を含有する．これ等の内容から分る様に，この地域の堆積岩は，主として斜長石石英粗面岩，安山岩，玄武岩，変朽安山岩などと共に花崗岩花崗閃緑岩およびその関係岩類，古期の堆積岩，変成岩，緑色凝灰岩などよりなる地域からその各種材料が供給され，然も浮石とか凝灰質物が上下の地層を通じて多い点は，各地層の堆積当時，火山活動(陸上海底共)が非常に劇しかつたことを物語つている．更に各種の鉱物は，角立ち，且つ新鮮なる外観を有するものが多い．従つてこの地域の堆積岩を形成する材料は決して遠方から運ばれたものでなく，現在の周縁地域における地質が示す通り，恐らく材料の根源が，白鷹火山以南の最上川最上流地域，山形盆地以東および寒河江川の上流地域あたりにあつたものと想像される．
