Geology of the Shakotan Peninsula, Hokkaido, Japan.

Hiromitsu YAMAGISHI

Abstract: The Shakotan Peninsula, situated at the northern extension of the Northeast Japan Arc, is characterized by wide distribution of Neogene formations, which are composed of the Kayanuma Formation, the Furubiragawa Formation, the Tomari Formation, the Onenai Formation, the Yobetsu Formation, the Tohmarugawa Formation and the Nozuka Formation, in ascending order. Almost of the formations include abundant volcaniclastic rocks; excepting for the Kayanuma Formation, the rocks in the Neogene formations are the products of submarine volcanism, such as hyaloclastites, subaqueous pyroclastic flow deposits and their reworked sediments.

The basins where the Neogene deposits with the exception of the Kayanuma Formation were formed, developed on both wings and northern extension of a main anticline constituting the backbone of the Shakotan Peninsula.

The Tomari Formation and the Furubiragawa Formation, both of which are of Kunnui age, were formed through collapsing on both wings of the main anticline trending NW-SE. The former spreaded southwestward, whereas the latter northeastward. Both of them are accompanied by dome and semi-dome structures due to intruding of several kinds of rocks.

The Onenai Formation of Yakumo age developed on both wings and northern extension of the main anticline. In the western part of the basin of the Onenai Formation, a dome structure due to upheaving of the basement rocks was constructed, whereas in the eastern part, an anticline trending N-S was formed by intruding of basalt dykes and sills.

The basins of the Yobetsu Formation of Kuromatsunai age and the Nozuka Formation of Setana age were limited to the northern coast of the Shakotan Peninsula, whereas the Tohmarugawa Formation of Kuromatsunai age developed toward the inland of the Shakotan Peninsula, crossing over the main anticline.

INTRODUCTION

The Shakotan Peninsula is situated in the northern part of southwest Hokkaido, which belongs to the northern extension of the inner belt (“Green Tuff Region”) of Northeast Japan Arc (Fig. 1). The Peninsula consists of mountains and hills generally ranging from 500 to 1,000 meters in altitude. Erosion by rivers and wading has been proceeded. The coastal cliffs are 100 meters high above sea level, along which benches are developed.

Numerous metallic ore deposits of copper, lead and zinc have been found in the peninsula. The stratigraphy, geological structures of the Neogene formations and metallic ore deposits in the peninsula have been studied by Nemoto (1942), Saito et al. (1952), Kikuchi et al. (1954), Nemoto et al. (1955), Narita et al. (1965), and
Hasegawa et al. (1969). Recently, detailed geologic maps and reports on the basal part of the peninsula have been published by Saito et al. (1967, 1968, 1969), and maps and reports of the western half of the peninsula have been presented by the author and others (Yamagishi and Ishii, 1979; Yamagishi, 1980).

The present paper outlines the geology of the whole peninsula, in particular, from lithological point of view.

In the stratigraphical study of the Shakotan Peninsula, an appropriate classification of subaqueous volcanic rocks is essential, because volcaniclastic rocks are ubiquitous in the peninsula, most of which were produced by submarine volcanism in Neogene age. In the course of investigation of the volcaniclastic rocks of Neogene age, the author proposed a scheme of their classification (Yamagishi, 1979).

On the basis of the classification, the lithology of the formations will be described in this paper.

**STRATIGRAPHY**

The Shakotan Peninsula is mostly composed of Neogene system, which overlies the basement rocks of Pre-Tertiary age, being partly covered by Pleistocene andesite lavas and Quaternary deposits (Figs.2 and 3). The Neogene system is divided into 6 formations as follows; the Kayanuma Formation, the Furubiragawa Formation, the Tomari Formation, the Onenai Formation, the Yobetsu Formation and the Nozuka Formation, in ascending order.

Table 1 shows a correlation chart of formations of previous reports and geologic sheet-maps of various parts of the Shakotan Peninsula, in comparison with those in this paper on the geology of the whole peninsula.
Fig. 2 Geologic map of the Shakotan Peninsula.
1. Fault, 2. Terrace deposit (Figures show the order of height), 3. Landslide deposit.
13. Pyroxene andesite lava, 14. Sandstone, volcanic conglomerate and hyaloclastite,
15. Hornblende dacitic hyaloclastite with feeder dykes, 16. Rhyolitic pumice tuff, 17. Siltstone and shale,
21. Hornblende andesitic hyaloclastite with altered massive lava,
26. Hypersthene augite andesite hyaloclastite with feeder dykes,
27. Altered hornblende andesite hyaloclastite with feeder dyke,
28. Altered hornblende andesite feeder dykes, 29. Volcanic conglomerate, 30. Sandstone and shale,
31. Pyroxene andesite hyaloclastite, 32. Altered andesitic lava(A), 33. Rhyolitic pumice tuff, 34. Dacitic lava,
35. Conglomerate, 36. Coal-bearing shale, 37. Rhyolitic pumice tuff and tuff breccia,
38. Rhyolitic welded tuff, 39. Altered andesitic lava(B), 40. Granite,
41. Black slate, chert and metamorphic rock, 42. Dip and strike, 43. Cross section line.
Table 1 Correlation chart in the Shakotan Peninsula.

<table>
<thead>
<tr>
<th>KAMOTO et al. (1942)</th>
<th>SAITO et al. (1952)</th>
<th>Yamagishi et al. (1979a)</th>
<th>Menoto et al. (1985)</th>
<th>Yamagishi et al. (1979b)</th>
<th>This paper</th>
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<tr>
<td>Sand, gravel and lavas</td>
<td>Sand, gravel and volcanics</td>
<td>Terrace and landslide deposits</td>
<td>Terrace deposits and lavas</td>
<td>Terrace deposits, landslide deposits and lavas</td>
<td>Terrace deposits, landslide deposits and lavas</td>
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<td>Nemukuma Formation</td>
<td>Kambuzi-saki Formation</td>
<td>Takarugawa Formation</td>
<td>Bikuni-Yusu Formation</td>
<td>Moruka Formation</td>
<td>Tokarugawa Formation</td>
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<td>Yobetsu Formation</td>
<td>Kamoenai Formation</td>
<td>Shibai Formation</td>
<td>Kaimen Formation</td>
<td>Yobetsu Formation</td>
<td>Kamoenai Formation</td>
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<td>Kaimen Formation</td>
<td>Shibai Formation</td>
<td>Kaimen Formation</td>
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<td>Genie Group</td>
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Basement of the Shakotan Peninsula

The basement rocks exposed sporadically in the northwestern and southwestern area of the Shakotan Peninsula are called Sannai Formation (Nemoto, 1942), and Riyamunai Formation (Saito et al., 1952), respectively. They are composed of chert and black slate, being accompanied by metamorphic rocks such as amphibolite in places. Several granitic rocks intruded in the basement rocks, which affected thermal metamorphism resulting in formation of hornfels. The largest granitic body is exposed at the southwestern area of the Shakotan Peninsula. Its lithofacies range from granite to hornblende porphyry through quartz diorite. The main lithofacies contain quartz, K-feldspar, plagioclase and biotite as major constituent minerals.

Fig. 4 Geologic structure of the Shakotan Peninsula.
The basement rocks are cropped out at the centers of several domes and semi-dome structures which are aligned along a main anticline trending from NW to SE along the southern coast of the Shakotan Peninsula (Fig. 4).

**Neogene System**

*Kayanuma Formation*

This formation, first described by Nemoto et al. (1942), is distributed in the southwestern part of the Shakotan Peninsula, contacting with the granitic rocks of Pre-Tertiary age. It occupies a part of the main anticline trending NW to SE. The formation consists of welded tuff, green tuff breccia and coal-bearing shale. The welded tuff is K-feldspar rhyolite which is generally compact, hard and brown in color. It is intercalated with rhyolitic lavas in places. The welded tuff contains attenuated pumice, phenocrysts of K-feldspar, quartz and rhyolite lava fragments, and accidental fragments of black slate (Plate I, 1). The green tuff breccia is massive pumice tuff containing rhyolitic fragments, and shows grading upward into tuffaceous siltstone. The coal-bearing shale is mainly composed of black hard shale intercalated with mudstone, and fine siliceous sandstone interbedded with coal beds. Plant remains have been reported from the coal-bearing shale, which were assigned to the Aniai type flora by Tanai (1961). The Kayanuma Formation is, therefore, correlative with the Fukuyama Formation of Lower Miocene in southwest Hokkaido.

*Furubiragawa Formation*

This formation, named by Saito et al. (1952), is typically exposed along the upper stream of Furubiragawa River, and occupies the central part of the Shakotan Peninsula. It is composed of basal conglomerate, basaltic pillow lavas, basaltic to andesitic hyaloclastites, pumice tuff and hornblende andesitic hyaloclastites, in ascending order (Figs. 5 and 6).

The basal conglomerate is composed of angular–subangular and rounded cobbles, pebbles and a few boulders, most of which are of rhyolite and granite (Point “b” of Fig. 2; Fig. 7). The pebbles of rhyolite seem to have been derived from the welded tuff and the rhyolitic rocks in the Kayanuma Formation. A few pebbles of crystalline schist are found in some outcrops (Point “a” of Fig. 2; Fig. 8). The matrix consists of tuffaceous sandstone which contains plagioclase, quartz, hornblende as the main constituent minerals.

In lithological point of view, the conglomerates represent talus deposits which formed at the margins of the collapsed basins. The total thickness of the conglomerate is estimated to be about 800 meters. The conglomerates are intercalated with sandstone
and shale. They are blackish gray in color, and occupy the upper part of the basal conglomerate. Several plant fossils are found from them as follows:

Metasequoia occidentalis (Newberry) Chaney
Picea kaneharai Tanai et Onoe
Pterocarya ezoana Tanai et N. Suzuki
Alnus sp.
Fagus antipoda Heer
Quercus sp.
Ulmus longifolia Unger
Wisteria fallax (Nathorst) Tanai
Rhus cfr. miosuccedanea Hu et Chaney

Determined by T. Tanai
<table>
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<tr>
<th>Sedimentary Unit</th>
<th>Description</th>
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<tbody>
<tr>
<td>Hyaloclastite(B)</td>
<td>Lapilli tuff - tuff breccia; most of lapilli are angular-shaped andesitic fragments with perlitic cracks</td>
</tr>
<tr>
<td>Pumice tuff</td>
<td>Lapilli tuff; most of lapilli are attenuated tabular pumices. The interstices are filled up with scattered perlitic glass and lithic fragments.</td>
</tr>
<tr>
<td>Thin bedded tuff</td>
<td>Ash tuff; glass shards and pumices are arranged with lamination.</td>
</tr>
<tr>
<td>Pumice tuff</td>
<td>Lapilli tuff; most of lapilli are attenuated pumice and andesitic lithic fragments. The interstices are filled up with perlitic glass and lithic fragments.</td>
</tr>
<tr>
<td>Thin layered mudstone</td>
<td>Slumping with &quot;mud balls&quot;</td>
</tr>
<tr>
<td>Hyaloclastite(A)</td>
<td>Pillow breccia; most of blocks are andesitic lithic fragments. The matrix is composed of perlitic glass with scattered basaltic fragments</td>
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<tr>
<td>Hyaloclastite(A)</td>
<td>Pillow breccia; most of blocks are pillow fragments. The matrix is composed of scattered andesitic fragments in major amount of basaltic fragments</td>
</tr>
<tr>
<td>Closed-packed pillow lava</td>
<td>Most of the pillows show ellipsoidal in shape and contain abundant vesicles</td>
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Fig. 6 Columnar section of a part of the Furubragawa Formation (part of "A" in Fig. 5).
Fig. 7 Composition of the basal conglomerate of the Furubiragawa Formation at Kamitutamatagawa River, upper stream of the Furubiragawa River.

Fig. 8 Composition of the basal conglomerate of the Furubiragawa Formation at Hiyamizugawa River, upper stream of the Furubiragawa River.
According to Tanai (oral communication), the flora indicates that the basal part of the Furubiragawa Formation was formed during the Nishikurosawa age.

Shell fossils are also found from the sandstone and shale are follows:
- *Macoma* sp.
- *Clinocardium* sp.
- *Periploma* sp.
- *Yoldia* sp.
- *Phaladomya* sp.

Determined by M. Akamatsu

The sandstone and shale are estimated to be 200 meters in total thickness.

The basaltic pillow lavas are composed of abundant ellipsoidal pillows of a few tens of centimeters in diameter, and 10 meters in thickness (Plate I, 2). The pillow lavas are overlain by basaltic to andesitic hyaloclastites, pumice tuff and hornblende andesitic hyaloclastites in ascending order (Fig. 6). The hyaloclastites contain broken pillows and blocks, a few centimeters in diameter. The upper part of the hyaloclastites is richer in andesitic blocks than the lower part, whereas the lower part is richer in basaltic broken pillows than the upper part (Fig. 6). The matrix of the hyaloclastites shows vitroclastic texture and is composed of scoriaceous glassy fragments and perlitic glass. The hyaloclastites are classified into Type A as mentioned later.

The pumice tuff shows massive or weakly stratification, and are overlain by thinly bedded tuff. The basal part of the pumice tuff is intercalated with thin layered mudstone including scattered pumice fragments (Fig. 6, Plate I, 3). The occurrence shows that the pumice tuff has originated from subaqueous pyroclastic flow (Fiske, 1963) which flowed on unconsolidated muddy sediment.

The hornblende andesitic hyaloclastites are composed of angular fragments with perlitic cracks in the cogenetic tuff. The hyaloclastites are called Type B as mentioned later. These volcanic rocks of this formation were considerably chloritized due to hydrothermal alteration.

The Furubiragawa Formation exposed at the basal part of the Shakotan Peninsula are composed of black slates intercalated with rhyolitic rocks. The rhyolitic rocks show alternation of massive lavas and hyaloclastites.

Under the microscope, the lavas contain phenocrysts of plagioclase, quartz and K-feldspars in felsic groundmass.

The Furubiragawa Formation trends SW-NE and gently dips northward, showing a monoclinic structure. This formation overlies unconformably both of the Kayanuma Formation and the basement rocks.
Tomari Formation

This formation, named by Saito et al. (1952), and recognized by Yamagishi et al. (1979), occupies the southwestern coast of the Shakotan Peninsula and the western wing of the main anticline. This formation is composed of basal conglomerate (Furushiki Conglomerate; Kubo, 1954), alternation of sandstone and tuff (Kozawa Sandstone–Tuff), volcaniclastic rocks (Kabuto Volcaniclastic Rocks), in ascending order (Fig. 9). The basal conglomerate consists of angular–rounded cobbles to pebbles which were mostly derived from the Kayanuma Formation and the basement.

The cobbles decrease in size upward from angular (Plate I, 4) to rounded in shape. The alternation of sandstone and tuff is composed of grayish sandstone and green pumice tuff intercalated with crystal and vitric tuffs.

The volcaniclastic rocks consist mainly of hyaloclastites interbedded with their reworked sediments.

The hyaloclastites are composed of angular fragments of hornblende andesite and hypersthene–augite andesite, both of which are more or less affected by hydrothermal alteration (Plate II, 1). Most of the fragments are considered to have originated by brecciation and shattering of magma due to quick chilling in contact with water at the time of effusion. In this case, the hornblende andesitic magma tends to produce hyaloclastite (Type B; Yamagishi, 1979; Yamagishi et al., 1979), which is mostly composed of angular fragments in the cogenetic tuff. This type of hyaloclastite includes in places “pseudo–pillows” (Plate II, 2; Watanabe and Katsui, 1976). On the other hand, hypersthene–augite andesitic breccia occurs as both hyaloclastites of Types A and B (Plate II, 3). The Type A of hyaloclastite is composed of concentric pillows (Plate II, 4) and their broken fragments in a cogenetic tuff (Yamagishi, 1979; Yamagishi et al., 1979).

The Kabuto Volcaniclastic Rocks were subjected to hydrothermal alteration. The lower part of them is characterized by chlorite–calcite epidote zone, whereas the upper part by montmorillonite zone. Between the lower and upper part, chlorite & montmorillonite mixed layer–zeolite zone is found. The Tomari Formation is probably correlative with the Furubiragawa Formation. The Tomari Formation trends NW to SE and dips westward. The basal conglomerate (Plate I, 4) of this formation overlies the rhyolitic welded tuff of the Kayanuma Formation and black slates of the basement (Riyamunai Formation; Saito et al., 1952), with steep clino–unconformity. Both of the Furubiragawa Formation and the Tomari Formation are correlative with the Kunnu Formation of Middle Miocene in Southwest Hokkaido.

Onenai Formation

This formation, named by Yamagishi and Ishii (1979), is distributed from northwest to northeast coast of the Shakotan Peninsula. It consists of alternation of
Fig. 9 Geologic columnar sections of the Tomari Formation and the Kyanuma Formation.
6. Andesitic tuff, 7. Hornblende andesitic hyaloclastite (Type B),
8. Hypersthene augite andesitic hyaloclastite (Type A and B), 9. Epiclastic volcanic rock,
10. Rhyolitic welded tuff.
hard shale & tuff, altered andesitic rocks, in ascending order.

The alteration of hard shale & tuff is composed of hard shale, pumice and scoria tuff, which are intercalated with perlitic rhyolitic lavas. It is overlain by hyaloclastites of Type B (Fig. 10). Both of the pumice and scoria tuff show massive in the lower part and bedded in the upper part. They contain abundant nodule-like "armoured mud balls" (Bell, 1940). They are ellipsoidal or spherical and a few tens centimeters in diameter. Any of them has a piece of mudstone enclosed in a thick crust of pumice tuff (Plate III, 1 and 2).

The perlitic rhyolitic lavas vary in lithofacies from massive lavas with columnar joints to brecciated lavas (Plate III, 3) due to quenching in subaqueous environment at the time of effusion.

The andesitic rocks are affected by hydrothermal alteration, forming such vein-type ore minerals as copper, lead and zinc. The andesitic volcanioclastic rocks are composed of hyaloclastites of Type B, epiclastic volcanic breccia, and volcanic conglomerate, which are intercalated with pumice tuff breccia originated from subaqueous pyroclastic flow.

The hyaloclastites of Type B show chaotic and unsorted features, including "pseudo-pillows" in places. The epiclastic volcanic breccias are mostly derived from the hyaloclastites, showing faint bedding. The volcanic conglomerates are mainly composed of subangular cobble-boulders, which are also derived from the hyaloclastites of Type B. The outcrop of the pumice tuff breccia shows that the lithic fragments are concentrated in the lower part, whereas the pumice fragments in the upper (Plate III, 4).

This formation exposed along the Furuugawa River in the northern part of the Shakotan Peninsula, overlies unconformably the basement of black slate and

![Fig. 10 Geologic columnar section of the Onenai Formation along Onenai coast. 1. Hypersthene augite hyaloclastite, 2. Hard shale, 3. Pumice tuff including "armoured mud balls," 4. Scoria tuff, 5. Pumice tuff]
granitic rocks. The outcrops along the Furubiragawa River show that the volcanioclastic rocks lacking in normal sediments are intruded by basalt sills, and overlies conformably the Furubiragawa Formation.

At the Shakotan-misaki the hornblende andesite hyaloclastites of Type B include large "pseudo-pillows", and are intruded by many feeder-dykes with columnar joints.

The Onenai Formation trends E-W with gentle dipping to the north, being accompanied by small dome, anticline and syncline. It is correlative with the Yakumo Formation of Upper Miocene in Southwest Hokkaido.

**Yobetsu Formation**

This formation, defined by Nemoto (1942), is well developed along the northern coast of the Shakotan Peninsula. It is mainly composed of siltstone and volcanioclastic rock members in ascending order. The siltstone is generally massive and intercalated with tuffaceous sandstone, pumice tuff, and epiclastic volcanioclastic rocks. The upper part of the siltstone displays slumping structures.

Nemoto (1942) reported the following fossils from the siltstone along the Yobetsu River.

*Navicula boucardi* Jousseaune
*Glycymeris yessoensis* (Sow)
*Ostrea* sp.
*Chlamys swifty* Bernardi
*Ch. swifty* var. *eltchegcini* (Anderson)
*Pecten* sp. aff. *P. prebejus* Yok.
*タルス* *gouldi* (Yok.)
*Lima goliath* Sow
*Tellina* sp.
*Monia macrophismus* Desh
*Natica janthostoma* Desh
*Patelloida pallida* (Gould)
*P.* sp.
*Olivella fortnei* Ad
*Plicifusus* sp.
*Potamides* sp.
*Fusitriton oregonensis*
*Voluta megaspina* Law
*Echinorchinus* sp.

The volcanioclastic rocks consist of hyaloclastites (Type B), massive lavas, and the epiclastic volcanioclastic rocks. The hyaloclastites of Type B are composed of angular
fragments of quartz-bearing biotite-hornblende andesite as essential fragments. The massive lavas, 5–10 meters in thickness, have platy or columnar joints and clinkers at the surfaces. The epiclastic volcaniclastic rocks are composed of subangular to angular breccias of cobble to pebble size, which are quartz-bearing hornblende andesite, pyroxene andesite, and basalt in composition. Their interstices are filled up with siltstone.

The Yobetsu Formation trends EW and gently dips north, and conformably overlies the Onenai Formation.

**Tokmarugawa Formation**

This formation, defined by Yamagishi et al. (1979), composes the ridges on both sides of the Furubiragawa River which trends from southwest to northeast, and the basins along the Umekawa River.

This formation is made up of massive siltstone in the lower part and the volcaniclastic rocks in the upper part. The former is interbedded with rhyolitic pumice tuff at the upper part in places, and the latters are mostly composed of dacitic hyaloclastites (Type B) accompanied by feeder–dykes with regular joints.

The pumice tuff is massive and contains rhyolitic lithic fragments in the lower part, whereas it is laminated in the upper part.

This formation is almost horizontal and overlies unconformably the Furubiragawa Formation, the Onenai Formation and the Tomari Formation. Both of the Yobetsu Formation and the Tokmarugawa Formation are probably correlative with the Kuromatsunai Formation of Upper Miocene in southwest Hokkaido.

**Nozuka Formation**

This formation, first nominated by Nemoto (1942), is distributed separately in two places; Kamui-misaki area and the northern coast of the Shakotan Peninsula. In the former place, it consists of coarse sandstone with lamination, intercalated with volcanic conglomerate, being accompanied by hornblende dacitic hyaloclastites (Type B) and a minor amount of pyroxene andesite lavas. The volcanic conglomerate contains characteristically subangular fragments of greenish pumice tuff. It trends from south to north and dips 30° W at the Kamui-misaki. The Nozuka Formation exposed along the northern coast is composed of alternation of siltstone, sandstone and conglomerate, being interbedded with peat. The following fossils of shells are found:

- *Polynemamusium alaskense* (DALL)
- *Cyclina* sp.

Determined by M. Akamatsu
This formation is almost horizontal and overlies unconformably both of the Yobetsu Formation and the Onenai Formation. It is probably correlative with the Setana Formation of Upper Pliocene in Southwest Hokkaido.

**Intrusive Rocks**

**Granitic rocks**

The rocks intruding into the Neogene formations vary from granodiorite to granodiorite-porphyry in lithofacies. Several bodies of the plutonic rocks are exposed along the upper stream of the Shikaribetsu River, the Sakazukigawa River and the Bikuni coast. The granitic bodies are divided into two facies; granodiorite of the inner part and granodiorite-porphyry at the margin. Most of the bodies are affected by hydrothermal alteration, to some extent.

Under the microscope, the granodiorite in essentially composed of plagioclase, quartz, K-feldspar, hornblende and biotite, whereas granodiorite-porphyry consists of abundant phenocrysts of plagioclase, quartz and mafic minerals in a groundmass consisting of quartz, K-feldspar and mafic minerals. Hydrothermal alteration proceeded to epidote and sericite substituting feldspars and mafic minerals.

**Mafic intrusive rocks**

The mafic intrusive rocks are exposed at Nonamei coast, along the middle and upper stream of the Furubiragawa River, and at the base of the Shakoton Peninsula. The rocks from Nonamei coast are gabbros occurring as dykes with columnar joints. The rocks from the middle stream of the Furubiragawa River occur as basalt sills with columnar joints, whereas those from the upper stream are mostly basalt dykes of a few to tens of meters thick. The rocks distributed at the base of the Shakoton Peninsula are mainly composed of columnar jointed basalt dykes.

Under the microscope, the gabbro is composed of plagioclase, hypersthene and augite, whereas the basalt contains plagioclase, hypersthene and augite, showing intersertal or intergranular texture. Most of the rocks are to some extent altered to form chlorite and other clay minerals. The basalt dykes are aligned from NNW to SSE.

**Intermediate and felsic intrusive rocks**

The intermediate to felsic rocks intruding into the Neogene formations in the Shakoton Peninsula are andesite, dacite and rhyolite.

The andesitic rocks of large scale are found as intrusive bodies in the Furubiragawa Formation exposed along the upper stream of the Furubiragawa River, whereas those of
small scale are distributed within the Tomari Formation along the southwestern coast of the Shakotan Peninsula. The andesitic rocks of both large and small scale are hornblende andesite and pyroxene andesite. They occur as massive dykes with columnar joints, but their outer margins grade laterally into hyaloclastites which suggest that the dykes acted as feeders for the hyaloclastites (Yamagishi et al., 1979). Most of the andesites are subjected to hydrothermal alteration, to some extent.

Under the microscope, the rocks do not preserve the original texture due to alteration, but phenocrysts of plagioclase, hornblende and pyroxene are still partly discernible.

The dacitic rocks are sporadically distributed as small and large dykes. The small dykes intruded into the Tomari Formation in southwestern part of the Shakotan Peninsula, the Onenai Formation in the northeastern part and the Yobetsu Formation along the northern coast.

Under the microscope, the rocks contain quartz, plagioclase and hornblende as main phenocrysts.

The large dykes are developed at the base of the Shakotan Peninsula, northeast of Iwanai Town and along the Shikaribetsugawa River. They intruded into the lower and middle part of the Furubiragawa Formation, and into the volcaniclastic rocks of the Onenai Formation.

Under the microscope, the rocks contain quartz, plagioclase and pyroxene as main phenocrysts in a devitrified groundmass.

Small rhyolite dykes are found along the coast of the Shakotan-misaki. They are characteristic of banded flow-layer.

**Quaternary System**

The Quaternary system developed in the Shakotan Peninsula is recognized as Pleistocene lavas, terrace deposits and landslide deposits.

*Pleistocene Lavas*

Large portion of the northern part of the Shakotan Peninsula is occupied by andesite lava flows which constitute flat-topped mountains or mesas of early Pleistocene age, i.e. Ohomoriyama lava and Shakotandake lava (Yamagishi and Ishii, 1979). The former is glassy hypersthene-augite andesite, whereas the latter olivine-bearing hornblende andesite.

Both of them are massive lavas with columnar and platy joints.
Terrace deposits

The terrace deposits mainly develop along the northern coast of the Shakotan Peninsula. They are composed of gravel and sand, and are divided into four terrace deposits based on the difference of level. The older terrace deposits are recognized along the Yobetsu coast at height of 70 to 200 meters above sea level, while the younger terrace deposits are developed along the rivers flowing from south to north, at height of 60 to 20 meters above sea level.

Landslide deposits

Large ancient landslide deposits are found abundantly in the Shakotan Peninsula. Most of them are developed at the margins of the flat-topped Pleistocene lavas which constitute cap-rock structures, and at the boundary between the volcaniclastic rocks and the siltstone of the Tohmarugawa Formation which is almost horizontal.

GEOLOGIC STRUCTURE AND GEOTECTONIC HISTORY

The geologic structure of the Shakotan Peninsula is characterized by the presence of main anticline along the backbone of the Shakotan Peninsula, which trends from NW to SE and plunges toward north (Fig. 4). Several sedimentary basins are developed on the wings and extension of the anticline (Narita, et al., 1965; Yamagishi, et al., 1979; Fig. 4 and 11) since the Kunmii age. The southwestern part of the anticline where granitic rocks intruded, is called “Shakotan Dome” (Ohtagaki, 1960). Along the main anticline, the basement rocks are exposed, which constitute the central core of dome or semi-dome structures.

Forming of the main anticline was followed by small doming in large basins, whereas small syncline structures were also formed in the basins. The Neogene formations are cut by many faults trending NW and NS.

The basin of the Kayanuma Formation is characterized by rhyolitic pyroclastic flow erupted and emplaced on dry land, which was followed by deposition of coal-bearing lacustrine sediments.

During the Nishikurosawa age of Middle Miocene, the basins of the Furubiragawa Formation and the Tomari Formation were formed through collapsing which provided talus-like basal conglomerates on both wings of the main anticline trending NW-SE (Fig. 4). Followed by the collapsing, submarine volcanism occurred violently in both of the basins. The volcanism produced a large amount of hyaloclastites and subaqueous pyroclastic flows.

The Tomari Formation and the Furubiragawa Formation developed SW and NE from the main anticline, respectively.

Both of the formations show monoclinic structure as a whole, though they are partly
Fig. 11 Distribution and development of the basins in the Shakotan Peninsula.
folded and are accompanied by dome and semi-dome structures due to intrusive rocks.

The Tomari Formation was intruded by granitic rocks resulting in forming of a semi-dome structure plunging westward as shown along the Sakazukigawa River, whereas the Furubiragawa Formation by altered andesitic rocks, resulted in forming of a dome structure as shown along the middle stream of the Furubiragawa River (Fig. 4).

The Onenai Formation, the Yobetsu Formation and the Nozuka Formation developed toward north one after another along the main anticline (Fig. 11).

The basin of the Onenai Formation of Yakumo age spreaded furthermore from west to east, crossing over the main anticline. In this basin, submarine volcanism of andesite–dacite was characteristic.

The western part was accompanied by doming due to upheaving of the basement rocks, whereas the eastern part was by doming due to intruding of large basalt dykes and sills, resulted in forming of an anticline trending from south to north (Fig. 4).

The basins of the Yobetsu Formation of Kuromatsunai age and the Nozuka Formation of Setana age were limited to the northern coast of the Shakotan Peninsula. In the former, hornblende andesitic volcanism occurred violently in submarine environment, whereas in the latter weak volcanic activity is recognized. Forming of the Nozuka Formation during Pliocene age, separated from each other, was followed by constructing of the basin of the Yobetsu Formation.

The basin of the Toharugawa Formation of Kuromatsunai age were developed toward the inland of the Shakotan Peninsula, crossing over the main anticline, from southwest to northeast.

After uplifting of the whole Shakotan Peninsula into land, a large amount of andesite lava flows overlay the Neogene formations mentioned above, in particular, in the northern part of the peninsula during early Pleistocene age.

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積丹半島の地質

山岸宏光

要旨：東北日本弧の北端にあたる積丹半島は、先第三紀の基盤岩を不整合におおって、火砕岩を主とする新第三紀層が広く分布している。それらは、下位から上位へ、茅沼層、古平川層、若根内層、余別層、トーマル層および野塚層などからなっている。これらの新第三紀層は火砕岩類を含み、特に、茅沼層以外の地層は火砕岩類はハイアソクラスタイト、水中火砕流およびそれらの二次堆積物などの海底火山活動の産物である。

茅沼層以外の新第三紀層の堆積したペーズンは積丹半島の骨格を形成した背斜軸の両翼およびその北端に発展した。

訓練期に属するは見川層と古平川層はこの背斜軸の両翼に、陥没によって形成され、前者は半島の南西部に、後者は北東部に広がった。いずれも、貫入岩によるドーム構造、半ドーム構造をともなっている。

八雲期の尾根内層は、背斜軸の北端と両翼に広がる。尾根内層のベースの西部では、基盤の隆起にともなうドーム構造が形成され、その東部では、玄武岩の岩脈やシルの貫入によって南北方向の背斜軸が形成されている。

黒松内期の余別層と瀬戸内層の野塚層は積丹半島の北部海岸に限られるが、黒松内期のトーマル川層は、背斜軸を横切って、積丹半島の内陸部に広がった。

Aniai 阿仁合 Shakotandake 積丹岳
Bikuni 美国 ShiKaribetsugawa 留別川
Fukuyama 福山 Tohmarugawa トーマル川
Furubiragawa 古平川 Tomari 泊
Furushiki 古舩 Toyohama 豊浜
Furugoawa 古宇川 UmeKawa 梅川
Hiyamizugawa 冷水川 Yakumo 八雲
Iwanai 岩内 Yobetsu 余別
Kabuto 宮 Kamoenai 神恵内
Kamifutamatagawa 上二股川
Kamui-misaki 神威岬
Kawashira 川白
Kayanuma 茅沼
Kozawa 小沢
Kunui 訓練
Nishikurosawa 西黒沢
Nonamai 沼前
Nozuka 野塚
Ohmoriyama 大森山
Onenai 尾根内
Riyamunai リヤムナイ
 Sakazukigawa 盆川
Sannai 珊内
Setana 瀬棚
Shakotan 積丹
Plate I
1. Handspecimen of rhyolitic welded tuff of the Kayanuma Formation, Kayanuma; elongated pumice lapilli, glass patches and shelly fragments are arranged in a parallel direction.
2. Close-packed pillow lava in the Furubiragawa Formation, upper stream of the Furubiragawa River.
3. Handspecimen of subaqueous pyroclastic flow deposits interbedded from the Furubiragawa Formation, upper stream of the Furubiragawa River.
4. Talus-like basal conglomerate of the Tomari Formation, Riamunai; angular to subangular fragments of dominant black slate and volcanic fragments in a sandy matrix, contacting black slate of the basement with clino-unconformity plane.
Plate II
1. Hyaloclastite of altered hornblende andesite from the Tomari Formation, Sakazuki coast; angular fragments are arranged at random in a cogenetic tuff. Both fragments and matrix are subjected to hydrothermal alteration, resulted in green colored rocks.

2. Hyaloclastite (Type B) of hornblende dacite Onenai Formation, Bikuni; poorly sorted cogenetic breccia including a "pseudo pillow" of rectangular in shape. The "pseudo pillow" shows columnar and curved jointing perpendicular to the outer surfaces.

3. Hyaloclastite (Type B) of hypersthene augite andesite from the Onenai Formation, Furubira; poorly sorted cogenetic breccia composed of angular fragments, including a "pseudo pillow" of radially jointed ellipsoidal in shape.

4. Concentric pillow in the hyaloclastite (Type A) of hypersthene augite andesite from the Tomari Formation, Kamoenai; pillows have abundant vesicles of spherical or ellipsoidal in shape in the central part, whereas concentric joints are developed along the outer.
Plate III

1. Subaqueous pyroclastic flow deposits including abundant "armoured mud balls" similar to the nodule, from the Onenai Formation, Onenai; balls are composed of pieces of mudstone in the core and siliceous tuff of the enveloping crust.

2. An "armoured mud ball" from the subaqueous pyroclastic flow deposits in the Onenai Formation, Onenai.

3. Subaqueous perlite breccia of rhyolite in the Onenai Formation, Kawashira.

4. Subaqueous pyroclastic flow deposits from the Onenai Formation, Furubira; lithic fragments are concentrated in the lower part, whereas the pumice fragments in the upper.