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Study on the Stratigraphy of Onikōbe Area, Miyagi Prefecture, Japan

——with special reference to the development of the Onikōbe Basin——

By

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Abstract

As to the genesis of the Onikobe Basin, many geologists have been wondering whether this is a Krakatau type caldera, a volcano-tectonic depression, a resurgent cauldron or merely one of the late Miocene tectonic depressions. In this paper the author discusses the possibility of a kind of resurgent cauldron:

The author recognized, within the basal conglomerate of the Onikobe Basin deposits, cobbles and pebbles of the Kitagawa Dacitic Welded Tuff, which covers at present an extensive area mainly to the east of the basin; therefore the genesis of the Onikobe Basin is later than the eruption of the welded tuff, which is possibly Plio-Pleistocene in age. Based on the stratigraphical analysis, the basin deposits are divided into four formations, namely from older to younger; the Akazawa, the Miyazawa, the Kawakurazawa and the Onikobe Formations. As the final phase, the Takahinata Dacite, which formed a lava dome, was extruded within the basin. The Akazawa and the Kawakurazawa Formations include augite-hypersthene andesite lava, while the Miyazawa Formation and the Takahinata Dacite are characterized by dacitic volcanic activity. Within the basin a nearly rhomb-shaped block exists, which consists of the Green Tuff of Miocene age and pre-Tertiary granodiorite. Surrounding the block, the Akazawa and the Miyazawa Formations dip steeply, proving that the block was uplifted specially after the deposition of the Miyazawa Formation. The rhomb-shaped block is in most places defined by substantial fault lines of nearly NNE-SSW and NW-SE directions, which are also the trends of the main faults in this region.

The author considers that the Onikobe Basin was formed by passing through the following seven stages:

Stage I	The formation of a strato-volcano near Katayama and the regional tumescence.
Stage II	The caldera-forming eruptions of the Kitagawa Dacitic Welded Tuff.
Stage III	The formation of a caldera by collapse or subsidence.
Stage IV	The filling of the caldera by volcano-sedimentary deposits.
Stage V	The uplift of the Zanno-mori Block and the deposition of mud-flow like deposits.
Stage VI	The formation of a marginal trough and its filling up by sediments.
Stage VII	The extrusion of the Takahinata Dacite.

The sequence of events is quite similar to that of the Valles Caldera, which was reported by Smith and Bailey (1968). But the differences in detail are also recognized. The main differences are:

1) The scale is about one half of that of the Valles Caldera.
2) The volcanism is characterized by andesitic and dacitic activities but no evidence of rhyolitic activity is recognized.
3) The general doming of the caldera floor is not known, instead a large basement block of 2.5 × 2.5 km was uplifted in the northwestern part of the caldera.

4) The ring-fracture volcanism did not occur. Only the Takahinata Dacite lava dome was extruded in the southeastern part of the caldera.

These variations may due to the differences in the crustal conditions.

I. Introduction

The Onikobe Basin, situated in the northwestern corner of Miyagi Prefecture, Northern Honshu is shown on the location map (Fig. 1); it is physiographically characterized by the oval-shaped depression having such central peaks as Arao-dake (984.2 m), Tsukushi-mori (992 m), Zanno-mori (938.4 m), Yatsu-mori (938.4 m) and Mt. Takahinata (769.1 m). In the basin the Eai River flows around the peaks in a counterclockwise direction and the Tashiro River, a tributary of the Eai River, flows clockwise, with both representing an elliptical river pattern. The long axis of the ellipse is about

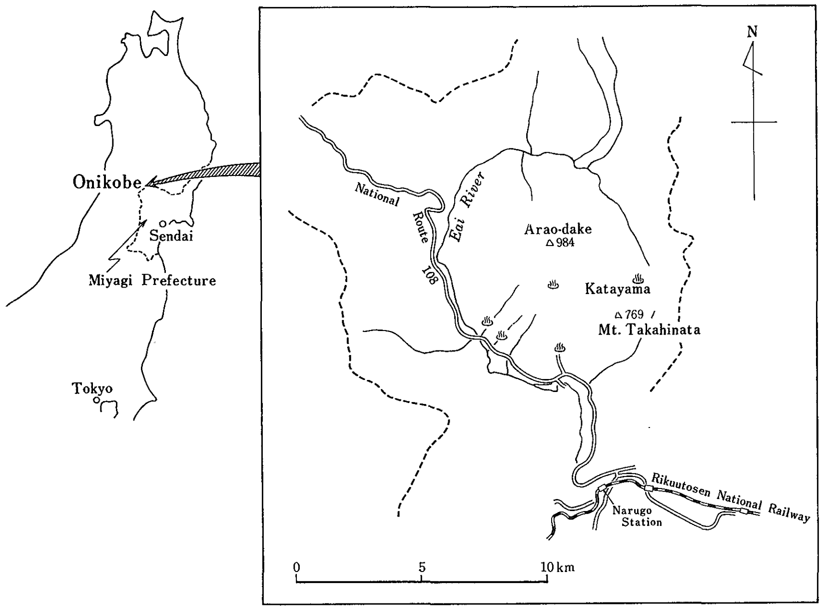


Fig. 1 Location of the Onikobe area

10 km long with its direction NNW-SSE and the short axis is 7.5 km long with its direction ENE-WSW. The western side of the basin is bounded by a mountain range of about 1,200 m above sea level, which is a part of the backbone ranges of Northern Honshu, while the eastern side is bounded by hilly land reaching about 550 m to 700 m above sea level. This field is accessible by a 20 minutes' drive from from Narugo Station of Rikuutosen National Railway through National Road 108.

This study was commenced to set a geologic framework for the understanding of the hydrothermal system of the area, which is now undergoing reconnaissance by Electric Development Co., Ltd. . In the course of the study, the author was also interested in the peculiar geologic development of the basin, about which he clarified some points. Field work was carried out from 1967 to 1971, in total about 110 days. Topographic maps used for the field work were 1/10,000 and 1/25,000 scale ones.

II. Previous Works

This area has been studied by several geologists. Here, a brief review is presented, focussing the attention on the difference of opinions concerning the geologic development of the basin.

In 1953, KATO and SHIMADA published a geologic map, covering the whole of the area mapped in the present work and including also the Sanzugawa Basin to the north. In the report they differentiated the lacustrine deposits of the Onikobe Basin into the Akazawa Formation of the uppermost Miocene, the Miyazawa Formation, and the Onikobe Formation of Quaternary age. The Miyazawa Formation conformably overlies the Akazawa Formation, while the Onikobe Formation is unconformable with the former two formations. They correlated the Akazawa Formation with the Sanzugawa Formation developed about 10 km to the north and concluded that the two formations were deposited in the basins, formed by the crustal deformation of the backbone ranges of Northern Honshu during late Miocene age. As to the Onikobe Formation the result of a further sedimentological study was reported by SHIMADA in 1955.

Also in 1953, KUNO published a paper entitled "Formation of Calderas and Magmatic Evolution", in which the Onikobe Basin was treated as a Krakatau type caldera, though no detail was reported concerning the development of the basin. In 1955, KATSUI published a brief note on the petrography of the welded tuff around the Onikobe caldera. In 1956, KITAMURA reported the stratigraphical position of the welded tuff. He called it Kitakawa Dacites and regarded it Plio-Pleistocene in age. In 1961, TANIDA described the petrography of the welded tuff and called it Kitagawa welded tuff.

In 1958, Geological sheet map and its explanatory text of "Onikobe" on the scale of 1/75,000 by KATAYAMA and UMEZAWA, were published from the Geological Survey of Japan. They discovered pre-Tertiary granodiorite and the Green Tuff in the northwestern part of the basin. Concerning the lacustrine deposits they proposed quite a different stratigraphy, differentiating them into the Arao Formation, probably late Miocene to early Pliocene in age, and the Onikobe Facies of the Himematsu Formation of late Pliocene or early Pleistocene age. They concluded that the basin topography of this area was formed by the tectonic depression occurred during late Pliocene time.

In 1959, NAKAMURA et al. published the results of geological research, which was carried out to ascertain the relation between the geological structure and the occurrences of natural steam in the area. They called the entire lacustrine deposits within the basin the Onikobe Group and regarded its age as from Pliocene to Pleistocene, which they further subdivided into five formations. They clarified also a dome structure of the lacustrine deposits around Zanno-mori.

In 1965, MATSUNO and NISHIMURA published a geologic map of the area based on the photogeologic method and subsequent geologic field survey. They named the dome structure clarified by NAKAMURA, the Kamiashizawa Dome and regarded it as a structural dome. They considered that this basin was formed by the depression along several concentric ring faults in post-Miocene time.

It is easy to know by this brief summary of ideas of the previous workers that so many diverse hypotheses exist concerning the stratigraphy, the geologic age and the structural development of the basin. The differences of opinion seem to be caused mainly by such reasons as the abrupt facies changes inherent in the lacustrine deposits and the volcanic products, the structural complexity of the lacustrine deposits and the lack of concrete data to correlate the lacustrine deposits within the basin with the other strata elsewhere.

III. Geology

Granodiorite and schists constitute the basement rocks of the area. The granodiorite has been considered a part of batholith intruded in the early stage of the upper Cretaceous (KAWANO and UEDA, 1966), while the schists are correlated with the metamorphosed facies of Paleozoic sediments (KATO and SHIMADA, 1953). The Green Tuff of Miocene age, which is composed of various volcanic products with minor intercalations of marine shale, sandstone and conglomerate, covers the basement rocks unconformably. After the deposition of the Green Tuff, the whole of the area was uplifted by an orogenic movement in which the Onikobe Basin was formed accompanied by volcanism and the deposi-

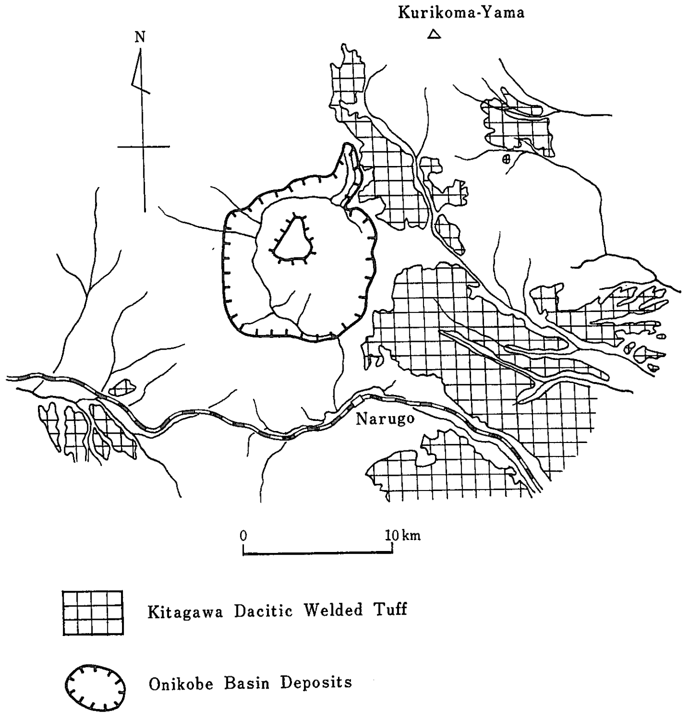


Fig. 2 Distribution of the Kitagawa Dacitic Welded Tuff and the Onikobe Basin Deposits (After TANIDA, 1961. The distribution of the Onikobe Basin Deposits was added by the present author)

tion of lacustrine sediments. Contrary to the opinions of most previous workers, however, the present author believes that the Kitagawa Dacitic Welded Tuff, which covers an extensive area mainly to the east of the mapped area (Fig. 2), was effused before the formation of the Onikobe Basin; the evidence for this is the fact that cobbles and pebbles of the welded tuff are found in the basal conglomerate of the lacustrine deposits.

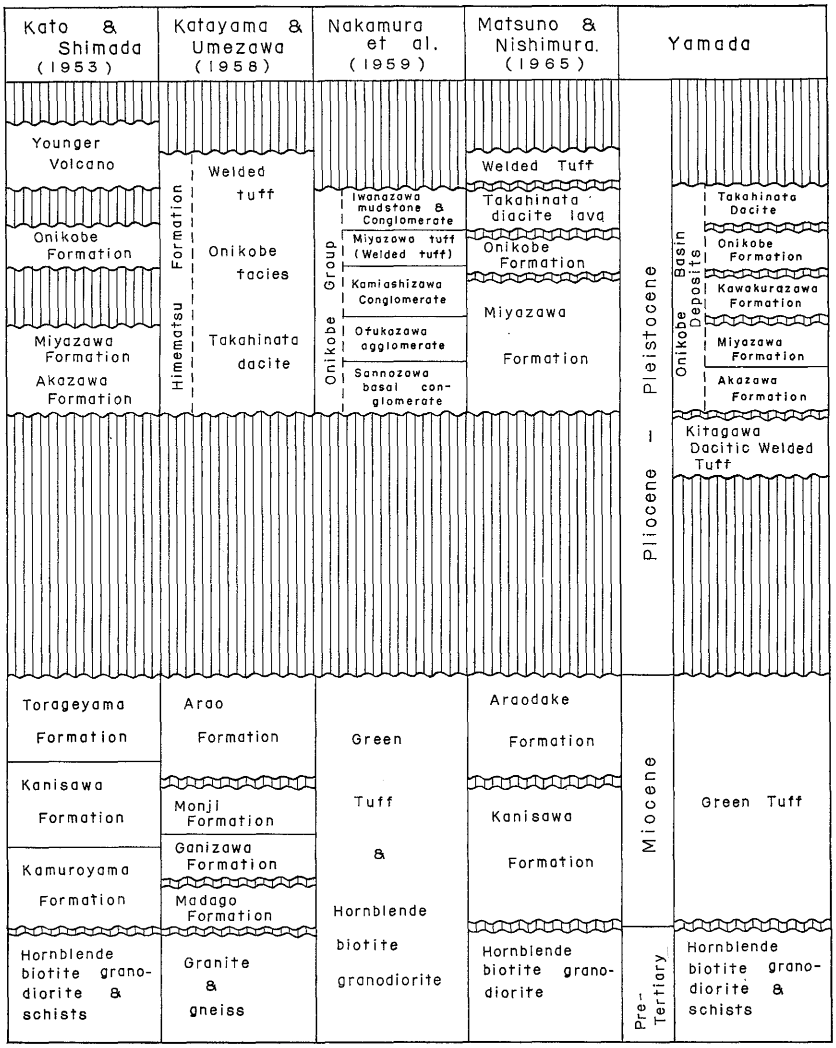
The author considers that the lacustrine sediments and the volcanic materials accumulated in the Onikobe Basin should be considered as the products of one sequence of volcanic and tectonic activity. Therefore, in the present work the author calls them the Onikobe Basin Deposits. He differentiated them into the following five stratigraphic units; namely from older to younger, the Akazawa Formation, the Miyazawa Formation, the Kawakurazawa Formation, the Onikobe Formation and the Takahinata Dacite. Some of the formation names are the same as those of the previous workers but they are redefined. An almost rhomb-shaped block consisting of the Green Tuff and granodiorite crops out in the northwestern part of the basin, which was uplifted, as mentioned later, mainly after the deposition of the Miyazawa Formation. In the paper the author calls it the Zanno-mori Block.

In order to compare the present stratigraphy with those of the previous workers, a table is presented (Table 1).

III. 1 Basement Rocks

Schists: The schists crop out only along the cuttings of National Road 108 and at the mouth of the Suginomori-zawa (valley or creek). The trend of the outcrops are of nearly NE-SW direction and this is in accordance with one of the directions of the main faults in this area. Boulder-sized schist blocks are scattered in the middle course of the Ashi-zawa, though the actual outcrop of the original rocks was not ascertained. The locality is just on the northeastern extension of the main schist exposures.

Table 1 Correlation of the stratigraphy of the present work with those of the previous workers



The schists are composed of green and black varieties. The green schist is a muscovite-albite-quartz-chlorite schist. The schists originated probably from Paleozoic sediments.

Granodiorite: The granodiorite crops out extensively along the western and southern borders of the basin and sporadically at the upper reaches of the Kusaki-zawa, the Kawakura-zawa, the Hine-zawa, the Kamiashi-zawa and the Ashi-zawa. The granodiorite is frequently intruded by dykes and breccia dykes of rhyolite, propylite, diorite, quartz diorite, etc., which are probably associated with Miocene volcanic products. The granodiorite is biotite-hornblende granodiorite and some parts show weak gneissose texture.

III. 2 Green Tuff

The Green Tuff probably covered the whole area thickly in Miocene age. The unconformable relation with the basement granodiorite is clearly visible in the lower course of the Sabu-sawa and at other places, where a basal conglomerate consisting of boulders and cobbles of the granodiorite exists. At some places, however, propylitized andesite lava seems to directly cover the granodiorite. In general, it appears that the so-called Green Tuff activity in this area commenced with andesitic volcanism, which was succeeded by dacitic or rhyolitic one, sedimentation of tuffaceous sandstone and black shale, and once again by dacitic or rhyolitic volcanism. The andesitic activity is represented by andesite lava flows accompanied by andesitic tuff breccia and lapilli tuff, which have been altered into green or dark green colour. The rhyolitic or dacitic activity, which followed, are characterized by tuff breccia but in some places represented by fine tuff or lava flows, which generally assume from white-green to whitish colour. After those intense volcanic activity a short period of comparatively calm marine environment probably prevailed in this area, during the time black shale, tuffaceous sandstone and conglomerate were deposited, though locally andesitic activity took place. This comparatively calm period was succeeded by intense dacitic or rhyolitic pyroclastic flow activity, forming thick tuff rich in xenolithic fragments, conglomeratic tuff and welded tuff.

Ore veins are frequently found specially near dioritic intrusive bodies. The ore veins and faults prevalent in this area are of NNE-SSW or NE-SW and NW-SE or WNW-ESE directions.

III. 3 Kitagawa Dacitic Welded Tuff

The dacitic tuff has been generally called "Haiishi (ash stone)" after gray, ashy matrix. The distribution of the welded tuff is known only outside of the basin. Therefore, in the present geologic map* only a narrow eastern part is occupied by this welded tuff but the same welded tuff covers extensively outside of the mapped area to the east, northeast and southeast as mentioned before. As to the stratigraphic relation of the welded tuff with the Onikobe Basin Deposits, there are several opinions (SHIMADA, 1955; NAKAMURA, 1959; etc.). According to the author's observation, this welded tuff covers directly the Green Tuff usually with very thin conglomerate and white, sandy tuff at its base, while the basin deposits abut against the Green Tuff at the basin margin, nevertheless, cobble-sized blocks and pebbles of this welded tuff are included in the conglomerate beds of the Onikobe Basin Deposits at the Kamanai-zawa, the Zanno-zawa and at other localities. The conglomerate beds at the Zanno-zawa are considered stratigraphically the basal part of the basin deposits and have been considered a part of the Akazawa Formation by KATO and SHIMADA (1953) and the basal conglomerate by NAKAMURA (1959).

This welded tuff is generally a dark-gray coloured coarse ashy tuff and columnar joints are developed at some places outside of the mapped area. Detailed stratigraphical analysis of the welded tuff itself is lacking, but this welded tuff consists of several sheets separated by thin beds of conglomerate and fine tuff. The upper part of the fine tuff usually contains accretionally lapilli. A petrographic description of the welded tuff collected near Uzen-akakura Station, about 10 km southwest of Onikobe, has been reported by KATSUI (1955). The welded tuff in the mapped area contains plagioclase, quartz, hypersthene, augite, hornblende and magnetite as the phenocrysts and shows quite similar welding structure in the groundmass glass to the one described by KATSUI. According to KITAMURA (1956), the age of the welded tuff is Plio-Pleistocene.

III. 4 Onikobe Basin Deposits

III. 4. 1 Akazawa Formation

This formation constitutes the lowermost portion of the basin deposits and is characterized by the products of andesitic activity and conglomerate facies as a whole. The main outcrops of this formation are restricted to the immediate surroundings of the Zanno-mori Block and Katayama area, but small outcrops of andesite lava at the upper reaches of the Miya-zawa and the westside of Katayama pass are also considered to belong to this formation. The northern and northwestern parts of the formation consist mainly of thick conglomerate beds and thin-bedded siltstone, which are intercalated with minor layers of augite-hypersthene andesite lava, its tuff breccia, andesitic pumice tuff and dacitic pumice tuff. On the other hand, the southern and southeastern portions consist mainly of thick augite-

* The geologic map, *i.e.*, "Geological Map of Onikobe" on the scale of 1:25,000, by the present auther, is separately published from Geological Survey of Japan.

hypersthene andesite lava flows and its tuff breccia. At the Katayama area, the core samples from bore-holes consist mainly of augite-hypersthene andesite lava, its tuff breccia and lapilli tuff up to about 900 m in depth (HITOSUGI, 1969 and 1970); therefore the whole basin deposits in the area are represented almost solely by the products of the andesitic activity, which probably constituted a strato volcano.

In the present geologic map, the author subdivided the formation into five facies according to the main lithofacies. They are the conglomerate facies, the andesite lava and tuff breccia facies, the siltstone facies, the andesitic tuff and volcanic sandstone facies, and the pumice tuff facies. All of them are mutually interfingering or changing facies laterally.

The conglomerate facies comprises thick conglomerate beds, which consist mainly of pebbles and cobbles of the Green Tuff and granodiorite with white greenish coloured loose tuffaceous sand matrix. Some parts of the conglomerate contain boulder-sized angular blocks of the Green Tuff, while in the middle stream of the Zanno-zawa it contains cobble-sized blocks and pebbles of the Kitagawa Dacitic Welded Tuff as described in the previous chapter.

The andesite lava and tuff breccia facies comprises mainly dark gray or black coloured augite-hypersthene andesite lava flows and the tuff breccia. At least three sheets of lava seem to have flowed out and some parts of them have columnar joints.

The andesitic tuff and volcanic sandstone facies comprises lapilli tuff, volcanic sandstone and andesitic pumice tuff. They are dark greenish or white bluish colour but assume buff yellowish colour whem weathered. Andesite tuff breccia was partly included in this facies while siltstone and thin beds of white coloured pumice tuff are intercalated in this facies in some places. A large bluff existing at the head of a tributary of the Zanno-zawa exposes a bed some 10 m thick of buff-yellow coloured pumice tuff inbedded within the conglomerate facies, which shows platy parting by flattened pumice. Under the microscope this pumice tuff contains plagioclase and augite as the main phenocrysts, so that it is considered to be an andesitic pumice tuff.

The siltstone facies comprises mainly thin-bedded or laminated siltstone, but buff-yellow or white coloured massive fine tuff, thin beds of pumice tuff and sandstone are sometimes intercalated.

The pumice tuff facies comprises several metres to several centimetres thick pumice tuff beds, which are intercalated in the siltstone facies of this formation especially in the northern part. As to the genesis of each bed no detailed study was done, therefore it is difficult to judge whether this is pumice fall or pumice flow or reworked pumice beds.

The Akazawa Formation dips steeply surrounding the Zanno-mori Block and specially on its northwestern side the whole formation inclines almost vertically. The dip becomes steeper near the block and in general reaches 70 degrees except on the southeastern side, where the siltstone facies dips in general 40 degrees to the southwest. However the exact stratigraphic relations of the siltstone with the underlying conglomerate and also with the overlying andesite lava were not ascertained there, therefore stratigraphic and structural problems remain. In the middle course of the Zanno-zawa, a crest of an isoclinal anticline is observed within the siltstone facies of the formation, which is interpreted as an indication of minor folding within the formation. The direct relationships of the formation with the granodiorite or the Green Tuff are visible only around the Zanno-mori Block, where generally fault relations are conceivable, except at the southeastern flank, from the crushing of the granodiorite or the Green Tuff, besides at some places from the existence of white coloured fault clay. The thickness of this formation around the block is estimated to be about 500 m.

From the upper part of this formation the following fossil plant leaves were reported by KATO and SHIMADA (1953); *Betula Maximowiciziana* REGEL, *Carpinus* sp., *Fagus* sp. and *Fagus Crenata* BLUME.

III. 4. 2 Miyazawa Formation

This formation covers a large area mainly within the elliptical river course and is characterized by hornblende dacite lava flow, its tuff breccia and pumice flow. The northern part of this formation consists mainly of thin-bedded siltstones and a sheet of pumice flow, which is more than 50 m thick, however, at the northeastern part two sheets of about 50 m thick pumice flow were recognized. In the southern part of the area, this formation comprises hornblende dacite lava and its tuff breccia, two sheets of thick pumice flow, siltstone, conglomerate, and augite-hypersthene andesite lava with its tuff breccia. The correlation of strata in the southern part with those of the northern and northeastern parts may be best accomplished by correlating the lower pumice flow which is considered to exist at the base of this formation. This formation was subdivided into eight facies in the present map according to the main lithology. They are the dacitic lava and tuff breccia facies, the tuff breccia and pumice tuff facies, the pumice flow facies, the fine tuff facies, the siltstone facies, the andesite lava facies, and the andesitic tuff, laminated siltstone and conglomerate facies, and the conglomerate facies.

The dacitic lava and tuff breccia facies comprises lavas and breccias of hornblende dacite, which crop out at the heads of southern tributaries of the Taki-zawa and in the upper reaches of the Eai River. A small outcrop exists separately in the higher reaches of the Tashiro River. As the blocks of this dacite are included dominantly in the tuff breccia and pumice tuff facies, the author considers it one of the earliest volcanic activities of the formation, though so far the dacite has been regarded as a part of the Takahinata Dacite.

The tuff breccia and pumice tuff facies comprises tuff breccia, volcanic conglomerate, pumice tuff and rarely volcanic sandstone. It crops out in the middle reaches of the Obuka-zawa and on the southwestern side of Katayama pass. This facies is overlain by a thick pumice flow at the Obuka-zawa, while at the Aka-zawa by the siltstone facies.

The pumice flow facies comprises two sheets of subaqueous pumice flow, which consist mainly of 10 to 20 cm large pumice lumps and ash matrix. The lower one is exposed in the lower reaches of the Obuka-zawa, the Kobuka-zawa and the Aka-zawa, while the lower pumice flow at the Suginome-zawa and the Komata-zawa, and the pumice flow in the northwestern part are correlated to this one. The basal part of this pumice flow is rich in andesite fragments and sometimes contains mud-ball, while the upper part consists of fine tuff. In the present work, the fine tuff part was separately mapped because it is very thick and characteristic. The upper flow crops out on the hillside to the west of the Miya-zawa and the upper reaches of the Hine-zawa, while the upper pumice flow at the Suginome-zawa and the Komata-zawa are correlated to this one. The thickness of each flow is more than 50 m.

The fine tuff facies comprises white coloured fine tuff and in some places some 15 cm large pumice lumps are included near its base. This facies crops out along the lower reaches of the Fukiage-zawa, the Miya-zawa and the Arao River, and also in the northwestern part of the basin. This facies lies immediately over the lower pumice flow facies and is considered to be the upper part of the subaqueous pumice flow; while similar fine tuff exists in some places on the upper pumice flow too, but in the present work, which could not be separately mapped.

The siltstone facies crops out in the middle reaches of the Miya-zawa, the Fukiage-zawa and the Aka-zawa, and separately in the northern part of the basin. At the former localities, it consists mainly of rather massive siltstone and overlies the fine tuff facies, while in the latter area, it consists mainly of thin-bedded or laminated siltstone.

The andesite lava facies comprises probably only a sheet of augite-hypersthene andesite lava, which crops out in the middle courses of the Hine-zawa and the Kawakura-zawa and also in the lower course of the Eai River. Stratigraphically it lies over the siltstone facies of this formation. The augite-hypersthene andesite can not be distinguished petrographically from that of the Akazawa Formation.

The andesitic tuff, laminated siltstone and conglomerate facies comprises andesitic tuff, conglomerate, sandstone and laminated siltstone, which crop out at the Kawakura-zawa, the middle reaches of the Hine-zawa, the hillside to the west of the Miya-zawa and separately in the area east of Ogama-Megama. In this facies, angular siltstone blocks, cobbles and pebbles derived from the underlying lake deposits are frequently included and also slumping structures are frequently observed. So far as can be seen, however, this facies overlies conformably the siltstone facies of this formation.

The conglomerate facies is distributed along the margins of the basin but is visible only at the northern margin of the basin, while at most other places it is not visible owing to the cover of younger deposits. The distribution is so narrow that it was not separately mapped in the geologic map, but shown only in the cross sections.

Near the Zanno-mori Block this formation dips steeply overlying the Akazawa Formation, while apart from the block it dips rather gently. At the southern part of the basin, this formation lies nearly horizontal. The strata of this formation have been disturbed by minor folding, minor faulting, slumping structures, breccia dykes and so on. The upper part of this formation, specially, seems to have been deformed before consolidation.

The stratigraphical relation of this formation with the underlying Akazawa Formation is everywhere conformable so far as can be seen. At the southeastern border of the basin, this formation directly overlies the Green Tuff with thin basal conglomerate beds at the base.

The thickness of the formation in general is estimated to be about 300 m.

III. 4. 3 Kawakurazawa Formation

This formation was proposed by the present author (TANI et al., 1968). The reasons for the proposal of this formation are the unconformable relation with the underlying Miyazawa Formation which was observed at several places and its characteristic facies as described below, though several problems remain as to its distribution. In the present work, the author transferred the pumice flow facies which was included in this formation in the previous work to the Miyazawa Formation. The Kawakurazawa Formation defined in the present work comprises augite-hypersthene andesite lava, its tuff breccia, andesitic tuff, conglomerate, mud-flow like deposits and rare intercalations of siltstone and sandstone. This formation is distributed in two separated areas, one at Yatsu-mori peak and the hilly land north and west of the Katayama area, the other at hill tops west of the Miya-zawa and in the lower reaches of the Kusaki-zawa. In the former area this formation consists of augite-hypersthene andesite lavas and its tuff breccia, while at the latter area this formation consists of mud-flow like deposits, conglomerate with angular pebbles and cobbles of all sorts of underlying rocks, andesitic tuff, and rare intercalations of siltstone and sandstone.

Andesite lava of this formation lies unconformably over the siltstone facies of the Miyazawa Formation at the eastern tributary of the upper course of the Aka-zawa. Near the Zanno-mori Block this formation lies over the lower formations with marked angular unconformity. The andesite lava of the formation and that of the Akazawa and the Miyazawa Formations could not be distinguished petrographically. The thickness of this formation is estimated to be about 100 m.

III. 4. 4 Onikobe Formation

This formation is distributed at the marginal parts of the basin and consists mainly of conglomerate and thin-bedded siltstone. No volcano-genetic strata are intercalated in this formation, though conglomerate beds consisting of augite-hypersthene andesite cobbles and pebbles with tuffaceous sand matrix are intercalated in this formation in the upper reaches of the Iwana-zawa, the Nigori-zawa and the Taki-zawa, which were interpreted in the present work as the secondary products derived from the andesitic volcanic products of the underlying formations. In the present geologic map this formation was not subdivided according to the facies, but as to the distribution of the different facies of the formation, the author wishes to refer the readers to the work of SHIMADA (1955). The boundaries of the formation, however, were changed somewhat in the present work.

The stratigraphic relation between the Onikobe Formation and the Kawakurazawa Formation is visible on the western bank of the Eai River near Ishibuchi village, where thin-bedded siltstone of this formation overlies unconformably a mud-flow like deposit of the Kawakurazawa Formation. At the heads of the Iwana-zawa, the Nigori-zawa and the Taki-zawa, however, the relation is obscure, moreover the conglomerate beds of the Onikobe Formation in the area show, as mentioned above, volcanic conglomerate affinities, which somewhat resemble those of the Kawakurazawa Formation.

Therefore the possibility of an interfingering relation between them remains there. The unconformable relation of this formation with the Miyazawa Formation is clearly visible at the Suginome-zawa and in a southern tributary of the Taki-zawa. At the former locality, nearly flat lying conglomerate beds of this formation abut against the steeply dipping lower pumice flow of the Miyazawa Formation. At the latter locality, coarse sandstone of this formation, which sometimes includes cobble- and boulder-sized blocks of the underlying dacite, abuts against the hornblende dacite lavas or breccias of the Miyazawa Formation. The outer margin of this formation abuts everywhere against the Green Tuff or the basement rocks. At the top of this formation, very gently inclined planation surfaces are recognized in some places at about 500 m to 600 m above sea level, which are probably remnants of the depositional surface of this formation. From the above-described data the author considers that this formation is unconformable with the older formations as a whole, although at most other places the unconformable relation was not ascertained.

This formation generally dips less than 20 degrees. Locally, however, steeper dips exist and specially in the lower part of this formation, slumping structures and unconformable relations are recognized, which have probably only local and minor significance concerning the geological development of the basin.

Fossil plant leaves *Carpinus* sp. and *Fagus* sp. were reported by SHIMADA (1955) from the Kamiashi-zawa. The boundary of this formation along the stream is, however, rather ambiguous so that in the present work the locality might be a part of the Miyazawa Formation. Also fossil diatoms were reported from this formation (ICHIKAWA, 1955; etc.)

The thickness of this formation is estimated to be roughly 100 m.

III. 4. 5 Takahinata Dacite

This dacite constitutes Takahinata peak which has been considered a lava dome. In the previous report (TANI et al., 1968), the author considered that the Takahinata Dacite is covered unconformably by the Onikobe Formation in the upper course of the Arao River. In the present work, however, he transferred the part of dacite to that of the Miyazawa Formation.

Two types of rocks, both containing hornblende, are recognized in the dacite. One of them is coarse grained and blackish in colour, while the other is rather reddish in colour and has a flow structure.

III. 5 Terrace Deposits, Pediments, Alluvium, etc

Younger lake deposits exist in the topographic depression at the Katayama area, which has been considered a phreatic explosion crater formed after the extrusion of the Takahinata Dacite. The lake deposits consist of clayey sediments and conglomerate beds. In several of clayey beds, high sulphur contents were reported (TAKAHASHI, 1953). The thickness of the lake deposits is estimated to be about 10 m.

The river terraces are developed mainly along the elliptical river course and divisible into lower and higher terraces. The higher one is about 70 m above the present river floor, while the lower one is about 30 m to 40 m above the present level of the river. The terrace deposits consist of gravel beds and the thickness is in general about 2 m.

Broad piedmont conglomerates develop at the southeastern border of the basin and cover mainly the Onikobe Formation unconformably. The piedmont deposits consist of rubbly conglomerate, which contains angular blocks and cobbles of Green Tuff and granodiorite. The thickness reaches probably more than 5 m at maximum.

Alluvium develops also mainly along the elliptical river pattern. The conglomerate bed developed to the south of Todoroki hotsprings is extremely hard cemented, probably because of hotspring sinter concretion.

IV. The Geologic Development of the Onikobe Basin

Based on the data presented in the previous chapters the author considers that the Onikobe Basin was formed by the following seven stages (Fig. 3).

Stage I. The formation of a strato-volcano near Katayama and the regional tumescence.

Before the effusion of the welded tuff, this area consisted geologically of the Green Tuff of Miocene age and the basement rocks. Judging from the bore-hole data, however, as mentioned in the previous chapter it is possible that an andesitic strato-volcano existed at the Katayama area. Also on the outside of the present mapped area to the immediate south, near Mt. Handawara, andesite lava and andesitic tuff are overlain by the welded tuff, though the relation of this andesite with that of the Katayama area is not known. The distribution of the welded tuff is not known within the caldera. Judging from the topography and the distribution of the welded tuff, the Green Tuff and the basement rocks seem to have been uplifted near the caldera margin. Therefore it is conjecturally possible that the tumescence of the area took place before the effusion of the welded tuff.

Stage II. The caldera-forming eruptions of the Kitagawa Dacitic Welded Tuff.

In order to determine the eruption center of the welded tuff, a systematic study of the welded tuff itself is urgently needed. Judging from the general sequence of the development of the Onikobe Basin, however, it is possible that the welded tuff was effused from within the basin. The author deduces that the welded tuff may have covered only the low-lying area which probably existed to the east of the basin. The effusion might have been taken place several times as described in the previous chapter. The age of effusion is not certain but according to KITAMURA (1956) it is Plio-Pleistocene.

Stage III. The formation of a caldera by collapse or subsidence.

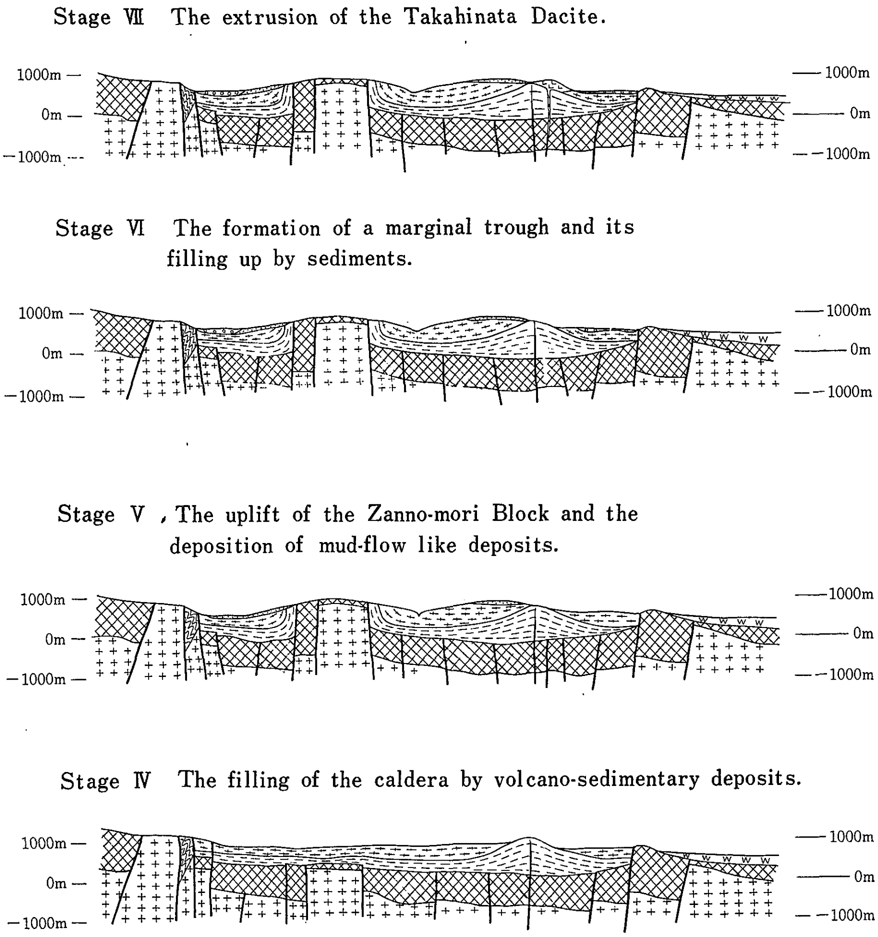
The distribution of the basin deposits is restricted within the present basin topography and the deposits seem to abut against the Green Tuff and the basement rocks at the basin margin. Therefore the original depression took place probably within the area covered at present by the Onikobe Basin Deposits. The original shape of the depressed area may have been neither circular nor elliptical due to the structural weaknesses which had existed before the eruption of the welded tuff. Judging from the gravity survey data (RIKITAKE, et al., 1965), the northwestern corner of the basin, which is covered at present mainly by the Onikobe Formation may have also depressed.

Stage IV. The filling of the caldera by volcano-sedimentary deposits.

Immediately after the depression a lake may have been formed in the northern part of the basin, within which thick conglomerate beds were deposited, while at the Katayama area augite-hypersthene andesite activity was probably continuing. The lake was enlarged probably by the erosion of the rim of the depression and gradually rather more stable conditions were established, during the time thin-bedded siltstones were deposited. Dacitic volcanic activity commenced at this time somewhere near Katayama and a hornblende dacite lava and the lower pumice flow were effused. The lower pumice flow probably extended throughout the basin and covered the lake bottom entirely except topographically higher places. The lake should have become shallower and narrower by the deposition of those volcanic products.

Stage V. The uplift of the Zanno-mori Block and the deposition of mud-flow like deposits.

The uplift of the Zanno-mori Block then commenced and the lake became further narrower. As the result the distribution of the upper pumice flow was restricted to the areas narrower than that of the lower one. The still unconsolidated upper part of the Miyazawa Formation suffered from slumping. The uplifted area was partly eroded on which and also within the remnant of the lake, mud-flow like deposits and conglomerate of the Kawakurazawa Formation were deposited. Locally augite-hypersthene andesite activity took place. As the result the lake disappeared. The Miyazawa and the Akazawa Formations were deformed and eventually resulted in the geologic structure existing at present.



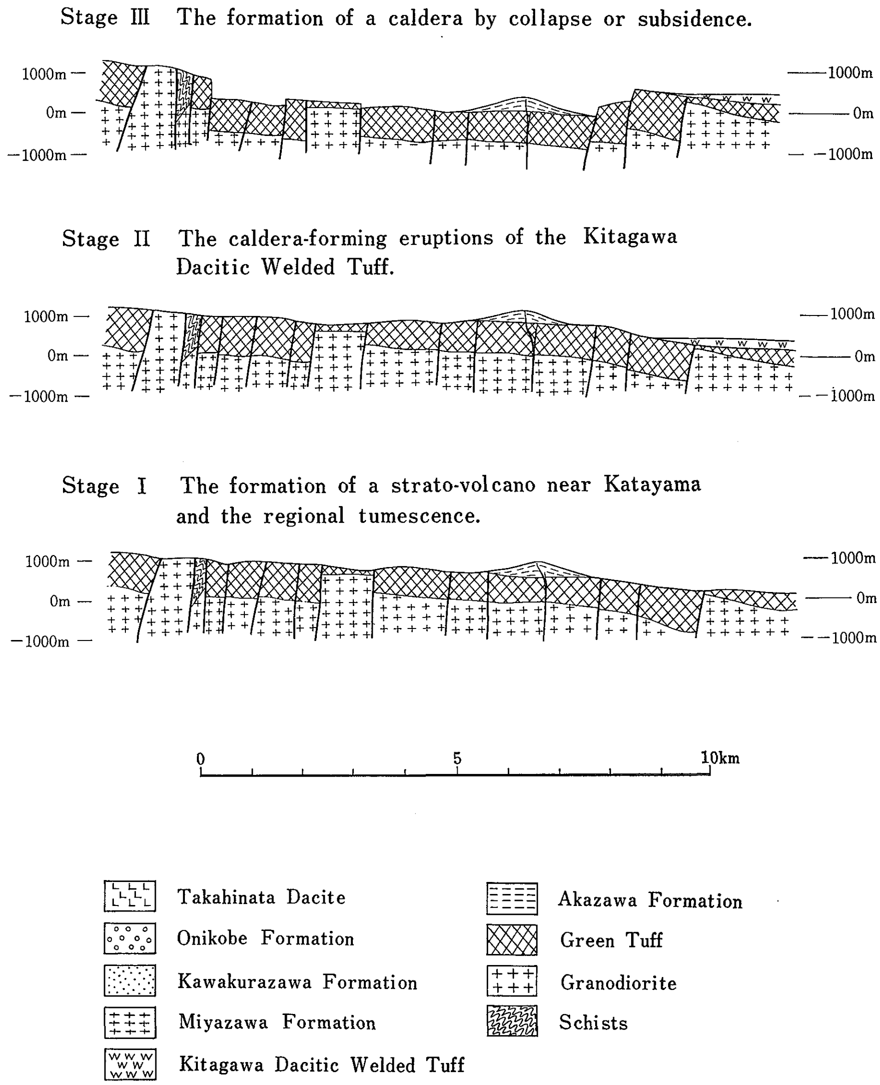
3-a

Stage VI. The formation of a marginal trough and its filling up by sediments.

The river system which is rather similar to the present one may have begun to dissect the marginal part of the basin. When the river floor reached near the level of the present river floor, presumably the southeastern corner of the basin was slightly uplifted and the river gradually turned into a narrow horseshoe-shaped lake in which the Onikobe Formation may have been deposited.

Stage VII. The extrusion of the Takahinata Dacite.

The Takahinata Dacite may have extruded at this stage and constructed a lava dome. The uplift of the northeastern corner of the basin presumably stopped and a river system gradually dissected the area leaving terraces. At present the hydrothermal manifestations are observed within the basin.



3-b

Fig. 3 Schematic reproduction of the geologic development of the Onikobe Basin

V. Conclusion

The lacustrine deposits and the volcanic products within the Onikobe Basin (the Onikobe Basin Deposits) are divided stratigraphically into the Akazawa, the Miyazawa, the Kawakurazawa and the Onikobe Formations in ascending order. As the final phase the Takahinata Dacite was extruded in the southeastern part of the basin. The Akazawa, the Miyazawa and the Kawakurazawa Formations can be further subdivided according to the main lithofacies as shown in the geological map of Onikobe. On the evidence that cobbles and pebbles of the Kitagawa Dacitic Welded Tuff are contained within the conglomerate facies of the Akazawa Formation (the basal conglomerate of lacustrine deposits), the effusion of the welded tuff is prior to the formation of the basin. According to KITAMURA (1956); the age of the welded tuff is Plio-Pleistocene. Within the basin a nearly romb-shaped block (the Zannomori Block) exists, which consists of the Green Tuff of Miocene age and pre-Tertiary granodiorite.

Surrounding the block, the Akazawa and the Miyazawa Formations dip steeply, which proves that the block was uplifted specially after the deposition of the Miyazawa Formation. The block is in most places defined by substantial fault lines.

The Onikobe Basin is considered to have been formed by passing through the following seven stages:

Stage I The formation of a strato-volcano near Katayama and the regional tumescence.
Stage II The caldera-forming eruptions of the Kitagawa Dacitic Welded Tuff.
Stage III The formation of a caldera by collapse or subsidence.
Stage IV The filling of the caldera by volcano-sedimentary deposits.
Stage V The uplift of the Zanno-mori Block and the deposition of mud-flow like deposits.
Stage VI The formation of a marginal trough and its filling up by sediments.
Stage VII The extrusion of the Takahinata Dacite.

From the evidences presented so far it is possible to regard the Onikobe Basin as a kind of Krakatau type caldera. Moreover it is worthy to note that the development of the Onikobe Basin, considered above, is quite similar to that of the Valles Caldera reported by SMITH and BAILEY (1968), though the differences in detail are also recognized. The main differences are:

1) The diameter of the Onikobe caldera is estimated to be about 10 km and the volume of the ash flow deposits, about 40 km^3. Therefore the scale of the caldera is about one half of that of the Valles Caldera.
2) Before the effusion of the ash flow, probably, a small andesite strato-volcano existed.
3) The volcanism is characterized by andesitic and dacitic activities but no evidence of rhyolitic activity is recognized.
4) The general doming of the caldera floor did not exist, therefore no domical graben and volcanism are known. Instead the uplift of about 2.5 × 2.5 km large block of the basement rocks took place in the northwestern part of the basin.
5) The major ring-fracture volcanism did not occur. Only the Takahinata lava dome was extruded in the southeastern part of the basin. While a marginal trough was formed and the Onikobe Formation was deposited.
6) The distribution of the caldera-forming ash flow has not been discovered within the caldera.

Those variations between two calderas may due to the differences in the crustal conditions.

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** In Japanese
* In Japanese with the abstract in English

宮城県鬼首地域の地質層序について

——とくに鬼首盆地の構造発達史について——

山田 営三

要　旨

鬼首盆地内に発達する湖成層および火山噴出物の層序を検討した．湖成層の基底の礫岩中に，同盆地周辺に広く分布し，北川石英安山岩質熔結凝灰岩と呼ばれている熔結凝灰岩の人頭～拳大の礫が含まれており，同盆地の形成は，同熔結凝灰岩噴出後のカルデラ陥没によるものであることが明らかにされた．そして，その形成の時期は，これまでの知見に従えば鮮新～更新世である．

湖成層および火山噴出物は，下位から赤沢層，宮沢層，河倉沢層，鬼首層および石英安山岩に区分される．宮沢層堆積後になって，基盤岩の緑色凝灰岩および花崗閃緑岩からなる山王森ブロックが盆地内北西部に隆起した．続いて河倉沢層の堆積を経て，周辺に形成されたトラフを埋めて鬼首層が堆積し，その後に高日向石英安山岩ドームが形成された．

これら湖成層および火山噴出岩の層序および層相を検討し，鬼首盆地の構造発達史を組立て，同盆地が一種のクラカトア型カルデラであることを明らかにし，さらに resurgent cauldron である可能を述べた．