Geomorphological Development of the Mukaimachi Basin, Ymagata Prefecture

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Kunio OMOTO

1. Introduction

Most of the basins in the backbone range of the northern Japan, are originated in the Neogene tectonic movements. The tectonic basins situated in the crest of the Honshū island, formed the sedimentary basins and kept isolated lake levels. In and surrounding these basins, the Pleistocene pyroclastic deposits are distributed widely, showing the close relationships of the Tertiary tectonic movements and the Pleistocene volcanic activities that controlled the formation of the present topography.

The author has reported on the geomorphology of the inland sedimentary basins, belonging to the Pacific Ocean drainage (K. Omoto, 1964, 1966, 1967). In this paper, he took the Mukaimachi basin to discuss the formation and development of the basin. Also he attempted to correlate the geomorphological surfaces between the Pacific Ocean and the Sea of Japan drainage, and to clarify the tectonic movements in the backbone range.

Acknowledgments

This study was carried out while the present author was in the graduate course of the Tohoku University. The author wishes to express his hearty thanks to Professor Kasuke Nishimura for his critical comments and helpful suggestions. And also he wishes to express his appreciation to Professor Toshio Noh for his critical reading of the manuscript. The field work was supported partly by the Scientific Research Grant of the Ministry of Education.

Location and topography

The Mukaimachi basin is located at the northeastern corner of the Yamagata prefecture (Fig. 1). The area is in the western side of a transverse valley across the Ōu backbone range. The basin is about 15 km wide from the east to the west, and about 20 km from the south to the north, showing a complicated form. The Mukaimachi basin is surrounded by basins, such as Onikōbe, Shinjō, Obanazawa, and Nakayamadaira-Narugo basin. The margin of the basin, except

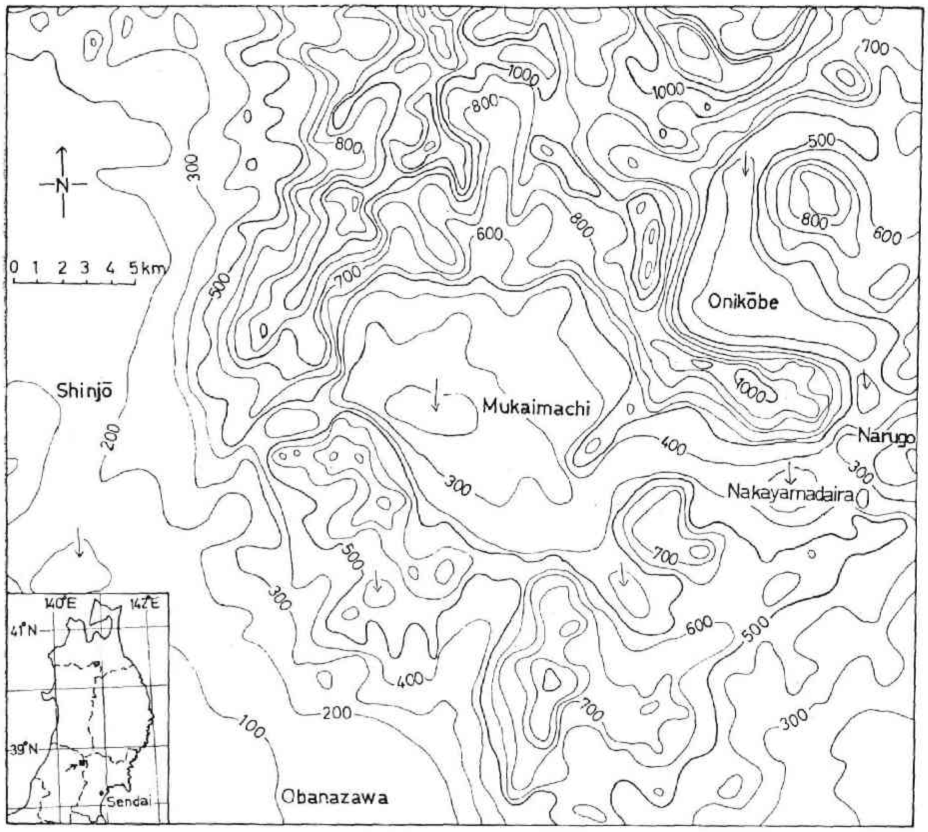

Figure 1. General index and restored map of the Mukaimachi basin (contour interval 100 m)

on its eastern side, is clearly defined by the steep mountain flanks. The river system consists of the Oguni river and its tributaries. The Oguni river flows from the southeast corner of the basin to the center, and flows from the east to the west on the basin floor. The southern half of the river system shows combined directions of SE-NW or SW-NE and S-N. While the northern half shows the NE-SW direction. These directions of the river system suggest the local geotectonic trends. The Myōjin river, one of the major tributaries of the Oguni river, rises at Sakaida, the divide with the Pacific Ocean drainage, as a "*Talwasserscheide*". At the foot of the mountain flanks, there is hill-land not so much dissected, still keeping flatness of its original surface. Along the Oguni river and its tributaries, several levels of river terraces develop.

Previous works

The geological survey of the Mukaimachi basin has been carried out by many geologists; Ryōhei Morimoto (1942), Shōji Ijiri (1942), Kunio Uetoko (1942), Toshio

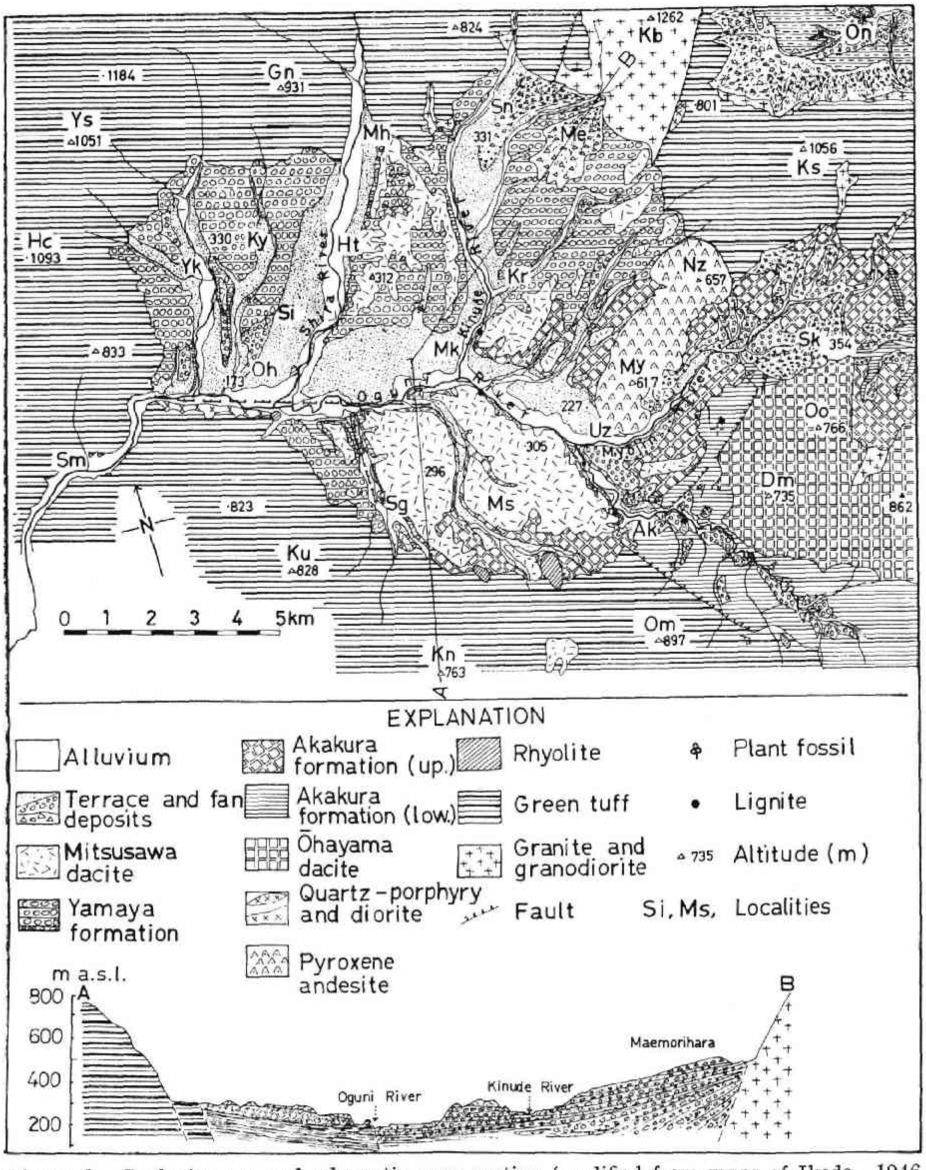

Figure 2. Geologic map and schematic cross section (modified from maps of Ikeda, 1946, Taguchi, 1961, and Ōsawa, 1964). Localities are explained below Tab. 1.

Ikeda (1946), Norihisa Hayakawa (1948), and recently by Kazuo Taguchi (1961). But their stratigraphical divisions and correlations disagreed one another. The author assumes these disagreements as following: The study area is one of the "Tertiary type section" across the northeast Japan, and the hardness of the correlation is due to the physiographic situation at the center of the backbone range. The geological work by Ikeda had very precise descriptions, and his stratigraphy has been used as a standard stratigraphical sequence in this area. After topographical division, he referred to some topography. Yoshio Katsui (1955) reported on the welded tuff sample collected from the southwest of Uzen-Akakura railroad station. Osamu Yamagata and Katsuyoshi Konno (1961) made a palynological study of pollen, collected from the vicinity of the spa of Akakura.

Table 1. Stratigraphy of the Mukaimachi basin

Age	Stratigraphy	Rocks and sediments
Holocene	Alluvium	Gravel, sand and clay
Pleistocene	Terrace and fan deposits	Gravel, sand, clay and peat
	Mitsusawa dacite	Dacite, welded tuff, pumiceous tuff and dacitic tuff
	Yamaya formation	Conglomerate, siltstone, and dacitic tuff
Pliocene ?	Akakura formation Upper	Dacitic tuff, siltstone and conglomerate
Miocene younger	Akakura formation Lower	Siltstone, Pumiceous tuff and dacitic tuff
Miocene middle	Ōhayama dacite	Dacite, dacitic tuff, and agglomerate
	Tertiary volcanics and dyke rocks	Quartz porphyry, and diorite (Tertiary granite)
		Pyroxene andesite lava and its coarse-grained pyroclastics
		Rhyorite, coarse-grained pyroclastic lava and welded tuff
Miocene older	Green tuffs	Pyroxene andesite lava and its pyroclastics (with dacite pyroclastics, mudstone and basalt lava)
Pre-Neogene	Bed rocks	Granite and granodiorite

Localities; Ak: Akakura, Dm: Daimyōjin, Gn: Gongenmori, Hc: Hachigamori, Ht: Hatsugasawa, Kb. Mt. Kobuchi, Kn: Mt. Kinzan, Kr: Kurosawa, Ks: Mt. Koshiba, Ku: Mt. Kumanogaeshi, Ky: Kami-Yokokawa, Me: Maemorihara, Mh: Madohusagi, Mk: Mukaimachi, Ms: Mitsusawa, My: Mt. Myōjin, Nz: Mt. Nukazuka, Oh: Ōhori, Ōm: Mt. Ōmori, On: Onikōbe, Oo: Mt. Ōha, Sg: Suginoiri, Si: Shimo, Sk: Sakaida, Sm: Semi Sn: Shinnosawa, Uz: Uzen-Akakura railroad station, Yk: Yakushihara, Ys: Mt. Yarinosaki

As for topography, Tarō Tsujimura (1932) had assumed that the Mukaimachi and Onikōbe basins were calderas. Tatsuo Wakō (1961) reported on the "Maemorihara plain", northeastern part of the basin. The precise description of the whole basin topography has not been made yet.

The outline of the geology, based on Ikeda (1946), Taguchi (1961), and Ōsawa (1964), shown in Fig. 2 and Tab. 1, is as following: The mountains surrounding the basin floor consist of "green tuff", granite, diorite, and the Tertiary volcanic rocks. The hill-land consists of Yamaya formation and Mitsusawa dacite, overlaid with Akakura formation. The fanglomerate and terrace deposits are younger deposits than above mentioned. There is a long time-span between the Akakura formation, believed to be Miocene time, and the Pleistocene Yamaya formation and the Mitsusawa dacite. The present author thinks that it is a very important problem that there is no Pliocene sediment in this region.

2. Division of the topography and its description

The author divided the topography of the area based on the field work and the aerophoto reading into "Mountains, Uzen hill-land, Mukaimachi terraces, and Alluvial lowland". Fig. 3 and 4 show the distribution and the schematic profiles of each topography. The division was due to the continuity of the topography, preservation of initial form, relative height above river floors, underlying materials and bed rocks, and their facies.

Mountains

The marginal mountains of the basin were formed by block movement, and uplifted since Miocene to make the present backbone range. Therefore they differ from the Dewa hill-land, west of the Mukaimachi basin, which was formed by folding. The author subdivided the mountains, northern and southern at the Oguni river, by its summit level (Fig. 1). The northwest ridges of the former, Mts. Hachimori (1093 m a.s.l.), Hiuchidake (1238 m a.s.l.), Komata (1367 m a.s.l.), and Kamuro (1365 m a.s.l.), divide the basin from Shinjō basin, and the northeast ridges, Mts. Ōshiba (1120 m a.s.l.), Kobuchi (1262 m a.s.l.), and Koshiba (1056 m a.s.l.), divide the basin from Onikōbe basin. While Mts. Kumanogaeshi (828 m a.s.l.), Kinzan (763 m a.s.l.), and Ōmori (897 m a.s.l.) of the southwest ridges divide the basin from the Obanazawa basin. The eastern ridge of Mt. Higekushi (756 m a.s.l.) and Mt. Ōha (766 m a.s.l.) forms the drainage divide of the Pacific Ocean and the Sea of Japan. The northern mountains are higher than the southern, and their elevations range from 1000 m to 1350 m above sea-level. While the southern mountains show the elevation from 700 m to 900 m above sea-

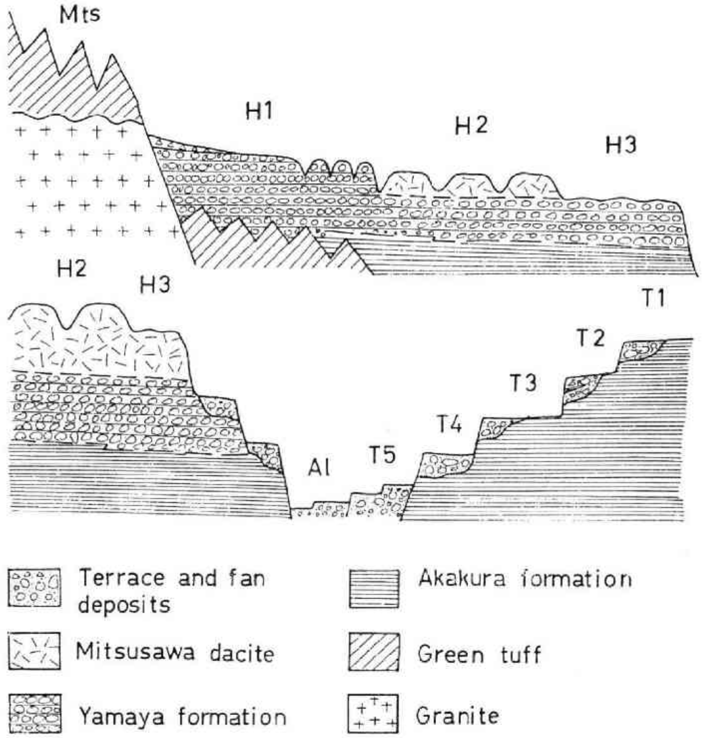

Figure 3. Schematic profiles of the topography (Mts, H1–3, T1–5, and Al, are same as in Fig. 4. The upper pofile is based on the northern, and the lower profile is based on the southern side of the Oguni river.)

level. The difference between the subdued form of southern mountains and the rugged form of the northern mountains, is originated from the difference of elevations. Some of these ridges preserve flatness and low relief. But the mountain flanks are deeply dissected. The mountains consist of green tuff, granite, quartz-diorite and dacite.

Uzen hill-land

At the foot of the dissected mountain flanks, the hill-land topography with the summit accordance in the elevation of 560 m to 280 m a.s.l., develops widely in the basin. The hill-land consists of the Pleistocene Yamaya formation and Mitsusawa dacite, or the Miocene Akakura formation in some localities. The boundary of topography is quite obvious both morphologically and geologically. The hill-land is subdivided into three geomorphological surfaces, based on the preservation of initial surface, continuity, and distribution of Mitsusawa dacite.

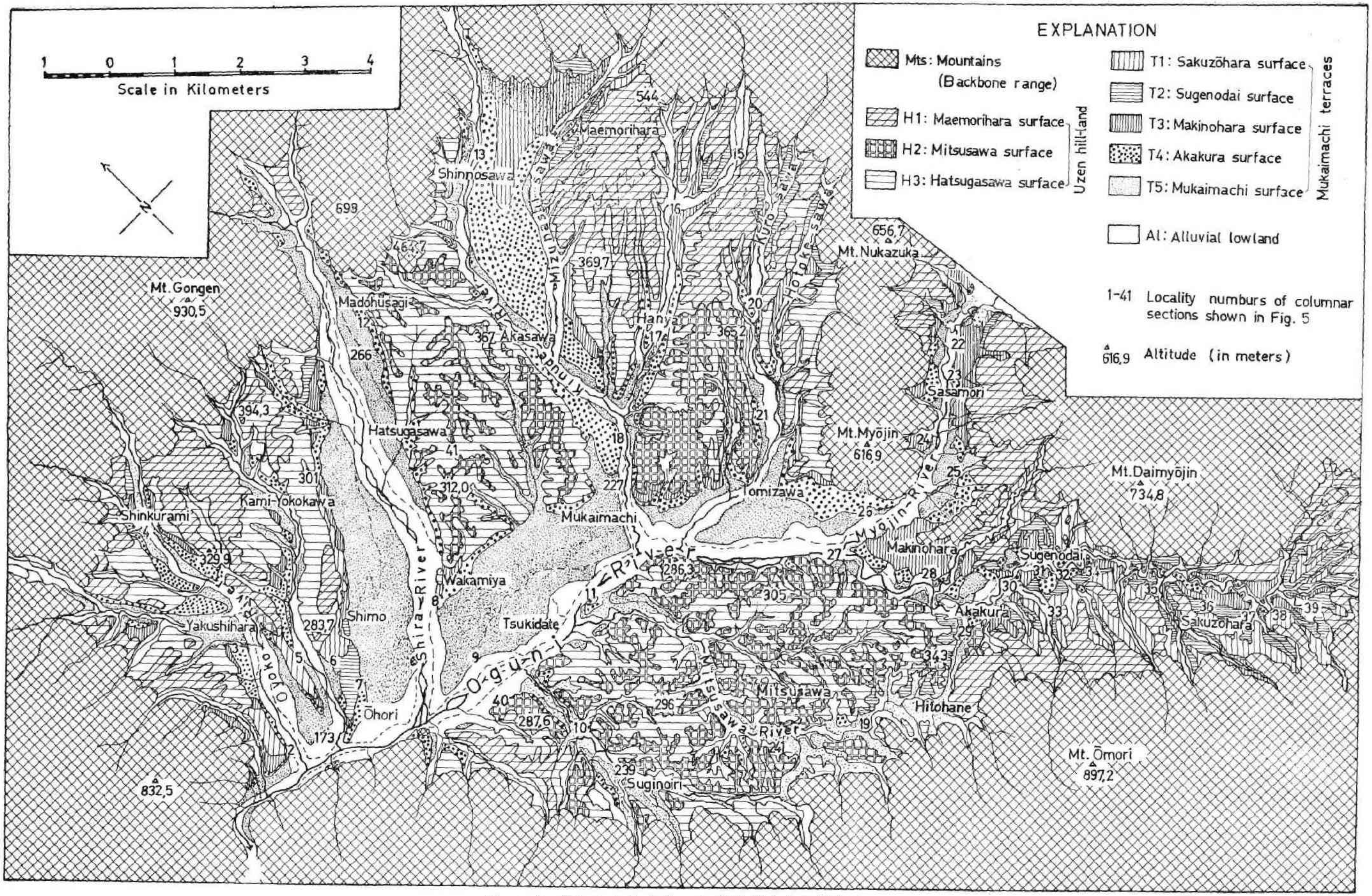

Figure 4. Geomorphological map of theMukaimachi basin

H1: Maemorihara surface

This is the oldest and highest geomorphological surface that is much dissected but still maintains initial flat surface or flat-topped crest. At Maemorihara, northeast of the basin, there remains typical flat surface in elevation of 540 m to 360 m a.s.l. (Pl. I–1, 3). Apart from there, the flat surface disappears, but the level of the hill tops remains very flat. This surface, in most cases, consists of Yamaya formation. Though the flat surface is limited at Maemorihara, the flat summit accordance and the top of the old gravelly beds may be a sedimentary surface of the Yamaya formation. But in the southeast of the basin, this surface is an erosional surface of the Akakura formation without doubt.

H2: Mitsusawa surface

Along the Oguni river at the center of the basin, there is a table land seemingly a river terrace. The height in the northern part ranges from 400 m to 280 m a.s.l., while in the southern part 330 m to 250 m a.s.l. This surface is considerably dissected, but still keeps flatness or summit accordance in low relief. The valleys which dissect this surface are in most cases shallow and transitive to the next lower surface (H3). The materials which compose this surface are Mitsusawa dacite. Along the left side of the Oguni river, the columnar joints of welded tuff are observable from the vicinity of the spa of Akakura to Mukaimachi. In other localities, the dacite changes tuffaceous, and in the north of Mukaimachi, fluvial facies are recognized (Loc. 41). The flat hill top surface seems to be an accumulation surface of the Mitsusawa dacite (Pl. I–2, 4).

H3: Hatsugasawa surface

This is the lowest hill-land. The surface is very flat and less dissected than H2. The typical topography of this surface is observed at the Hatsugasawa, where it seems like "*Leistenflur*". The elevation of this surface ranges from 380 m to 290 m a.s.l. in the northern part, and 320 m to 240 m a.s.l. in the southern part. This is an erosional surface of the Mitsusawa dacite in the southern part, and of the Yamaya formation in the northern part (Pl. I–6, II–4, 5). In the northern part, it seems as if "protected terrace" by the Mitsusawa dacite. The boundary of the Mitsusawa dacite and the Yamaya formation is almost conformable and is continuous to this surface.

Mukaimachi terraces

Five levels of well-preserved terraces at various elevations above the present stream level were recognized along the Oguni river. They are designated from the highest to the lowest (and the oldest to the youngest); Sakuzōhara, Sugenodai, Makinohara, Akakura, and Mukaimachi surface. The terraces in the upper stream

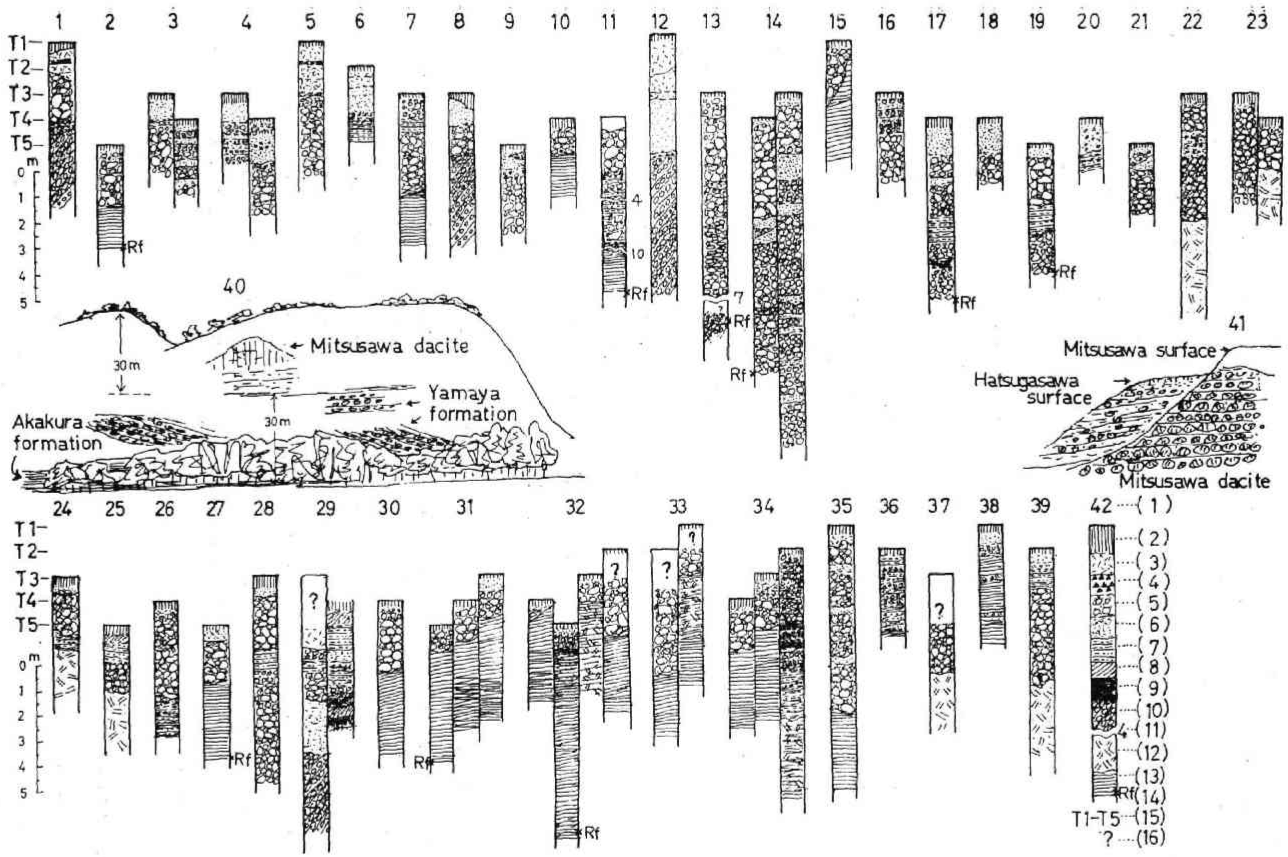

Figure 5. Columnar sections of the terrace deposits and the sketches of outcrops. Explanation: (1) Locality number shown in Fig. 4, (2) Black surface soil, (3) Volcanic ash, (4) Volcanic sand, (5) Gravel, (6) Sand, (7) Silt, (8) Clay, (9) Peat, (10) Yamaya formation, (11) Abbreviated part in meters, (12) Upper Akakura formation, (13) Lower Akakura formation, (14) Present river floor, (15) Side bars of sections show the connection of T1–5, (16) Hidden part

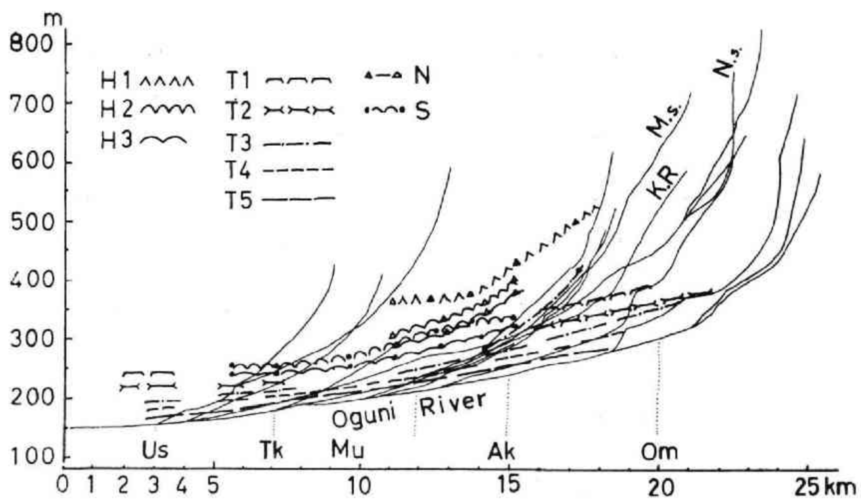

Figure 6. Long-profiles of each geomorphological surface and present river floor (H1–3 and T1–5 are same as in Fig. 4. M.s.: Mizunashi-sawa, K.R: Kinude river, N.s: Nabekura-sawa, a tributary of Myōjin river, N: Northern part of the basin, S: Southern part of the basin, Us: Usugi, Tk: Tsukidate, Mu: Mukaimachi, Ak: Akakura, Om: Ōmori. The T3 of the northern part is projected based on the relative height along the Mizunashi-sawa.).

of the Oguni river develop well, while in the center of the basin the higher terraces are poorly preserved. The terraces are covered with gravels and sandy materials derived from the green tuff and granitic rocks of the mountains. These deposits overlie the Tertiary sedimentary rocks of the Akakura formation with unconformity. The columnar sections of these terrace deposits are shown in Fig. 5. The long-profiles of the Oguni river, its major tributaries and related terrace surfaces are shown in Fig. 6.

T1: Sakuzōhara surface

This surface is the highest and oldest river terrace surface along the stream, although it is not so continuous nor so well preserved as lower one. The elevation of the surface ranges from 390 m a.s.l. upstream to 240 m a.s.l. at the western part of the basin. The gravel deposits of the terrace are generally unstratified although sand or silt lenses, which rarely exceed 0.5 m in thickness, are interbedded with coarse gravels at some localities. Gravels are about 2 m thick, and are angular and boulder to cobble size. The matrix is largely sand, with silt and clay derived from underlying Tertiary sediment. The maximum boulder size is commonly exceeding 50 cm in diameter. In some localities, the author could not recognize any gravel deposit, and so some of the surface without gravel deposit may be erosional surface.

T2: Sugenodai surface

This is the second river terrace surface which is about 20 m to 30 m lower than the higher one. The gravel deposits of the terrace rarely exceed 6 m in thickness and consist of green tuff and dacite. The size of the gravels is cobble to boulder and the form is angular to sub-round. In Loc. 34, the stratified tuffaceous siltstone bed and peaty clay bed with drift woods lying under angular gravel bed (Pl. II–2).

T3: Makinohara surface

The projected elevation of this terrace surface is approximately 350 m a.s.l. upstream and 190 m a.s.l. downstream. This surface is almost continuous along the Oguni river, and is the standard surface for correlation. The terrace deposits are 2 m to 5 m in thickness and similar to those of T1. In Makinohara, south of Uzen-Akakura station, this surface is the widest along the Oguni river.

T4: Akakura surface

The distribution of this terrace surface is limited in the meander zone at the vicinity of spa of Akakura. The top of the gravel bed stands approximately 30 m above the present stream. The terrace deposits are 5 m in thickness and include generally sand or silt bed interbedded with coarse gravel in the upper deposits. The Uzen-Akakura station is on this surface.

T5: Mukaimachi surface

This is the lowest terrace surface, continuous along the main river and its tributaries of the Oguni river. The top of the terrace deposits is about 10 m above the present stream level and the bed is about 5 m in thickness. The gravels are cobble to boulder in size, angular to round and fresh. They consist of green tuff, granite and diorite. The matrix is largely sand, and in some localities silt and clay.

Alluvial lowland

The alluvial lowland develops along the present stream. In some localities, the Oguni river is cutting into the alluvial lowland and two swing cusps with 1 m, rarely exceed 2 m, are observable. This lowland is flooded once in a few years. And so the deposits are gravels in various size, sand and clay, as those of the present river floor. The Oguni river and its major tributaries show braided courses in the center of the basin.

3. Discussions

Origin of the basin

Tarō Tsujimura (1932) had assumed that the Mukaimachi basin was a caldera. The term "caldera" is applied in general to the volcanic depression, mainly caused by the Quaternary volcanic activities. It is obvious that the marginal mountains consist of the Miocene pyroclastic rocks and lava, called "green tuff", or granite and quartzdiorite. The sedimentary area of the Akakura formation forms the present basin floor. These geological and morphological data suggest that the outline of the basin was originated from the depression after the Miocene volcanic activities. The northern margin of the basin floor faces to the E-W trend fault scarp, the eastern part to the NNW-SSE, the western part to the NNE-SSW or N-S and WNW-ESE. The southern floor is also bounded by the fault scarp of the NW-SE ternd. The Mukaimachi basin is subdivided into three sub-basins and a graben by the above mentioned fault system. The centers of the sub-basins are Shimo, Maemorihara, and Shimo-Mitsusawa. The graben is in the upstream of the Oguni river. These faults are in most cases found by the photo-geological interpretation. It is obvious that the steep moutain flanks were not formed by the fluvial process only. Judging from the fault system, the Mukaimachi basin was not formed by simple block movement but was formed by several block movements.

Correlation with the Pacific Ocean drainage area

The upstream of the Myōjin river, a major tributary of the Oguni river, is near the valley divide at Sakaida in the center of the transverse valley of the Ōu backbone range with the upstream of Daiya river, a major tributary of the Eai river belonging to the Pacific Ocean drainage. The drainage at Sakaida station is at the

Table 2. Correlation with the Pacific Ocean drainage area

Mukaimachi (1)	Nakayamadaira (2)	Narugo (3)	Nakaniida (4)	Sendai (5)
Uzen hill-land	Rikuu hill-land	Rikuu hill-land Rikuzen hill-land	Hill land	Aobayama surface
Sakuzōhara surface	Higashizawa surface	Sanjō surface	Daihara terrace	Dainohara terrace
Sugenodai surface	Nishihara surface	Daigakunōjō surface	Hara terrace	Kamimachi terrace
Makinohara surface	Shokubutsuen surface	Myōsada surface	Onoda terrace	Nakamachi terrace
Akakura surface	Nakayamadaira surface	Takahara surface		
Mukaimachi surface	Hebinoyu surface	Kamigawara surface	Nakaniida terrace	Shitamachi terrace
	Yakeishihata surface			

(1) Present study, (2)・(3) K. Omoto, (1966, 1967), (4) T. Wakō, (1964), (5) H. Nakagawa, et al., (1960, 1961)

fan end and its elevation is 338 m a.s.l. It is possible to correlate this fan surface and its upper and lower surfaces with geomorphological surfaces of both the Pacific Ocean and the Sea of Japan side. The Makinohara surface in the drainage area of the Sea of Japan is correlative with Shokubutsuen surface of the Pacific Ocean drainage from their continuity. The correlation based on the C-14 data will enable to yield an accurate conclusion. Fortunately, it is possible to determine the age of the terrace formation from the drift woods and peat layers in Sugenodai surface in the Mukaimachi basin and in Nishihara surface of the Nakayamadaira basin. Tab. 2 shows the correlation of each geomorphological surface among the study area and the Pacific Ocean drainage system. The correlation between the Mukaimachi basin and the Shinjō or Obanazawa basin is difficult to forecast because of the discontinuity of the surfaces at the Semi gorge, west of the basin.

Geotectonic movements

There are three ladle-like basins, Mukaimachi, Nakayamadaira and Narugo basin, in the transverse valley across the Ōu backbone range. In this basin zone, there are lake deposits of the Tertiary and Quaternary, and the latter is well preserved, remaining an accumulation surface. Therefore it is possible to find the lake levels from the elevation of these surfaces. The present elevation of the accumulation surface in the center of each basin and the relative height above the present stream level are 300 m a.s.l. and 100 m in the Mukaimachi basin; 320 m a. s. l. and 120 m in the Nakayamadaira; 260 m a.s.l. and 140 m in the Narugo basin. The divide at the fan end in Sakaida is approximately 340 m a.s.l. The elevation of both main river floors outside the basin zone are approximately 100 m a.s.l. Accordingly the mount of whole upheaval since the beginning of the Pleistocene is at least 120 m. At the vicinity of Sakaida, the Miocene Akakura formation is almost uplifted up to above 360m a.s.l. with characteristic horizontal laminated strata.

The river terraces well develop at the upstream but poorly develop in the center of the basin. This tendency is especially clear in higher terraces (Fig. 4). The long-profiles show the steep inclination at the upstream (Fig. 6). This is remarkable in the upper stream of the Oguni river, Myōjin river, Kinude river and Mizunashi-sawa. In the narrow fan-like topography southwestern foot of Mt. Koshiba, where the terrace scarps of the Kinude river and the Mizunashi-sawa increase gradually its height above stream levels toward the mountain front. The deposits of this fan-like topography are sands and gravels which are extremly large in size, exceeding 50 cm in diameter, and the deposits are unstratified at the upstream, whose thickness is over 30 m at the fan top. However, in the mid-stream there are stratified sand beds which seem to have been deposited under the graded condition. It would be impossible to deposit under the present condition. The author could not observe the Yamaya formation at the right side of the Mizunashi-sawa. There was fanglomerate at the fan top. But he recognized the Yamaya formation in the left side of the downstream. The flat surface of the left side of the Mizunashi-sawa is the accumulation surface of the Yamaya formation (Pl. I–1, 3). Accordingly, the fan-like topography here is a fan obviously, but there remains a doubt to assume it to be a typical "eroded fan" as Wakō (1961) said, because of its thick deposits. This fan surface, nowadays, is a fan-terrace which submerges into lower surface at the junction of the Kinude river and the Mizunashi-sawa. Owing to the gravimetric survey of Rikitake et al. (1966), the area is in the center of subsidence and the bed rocks are 1500 m below the sea-level. This subsiding movement might be a cause that tilted the fan surface.

The bed rock of Mitsusawa dacite in the north side of the Oguni river is 40 m higher than the south. The Yamaya formation underlying the Mitsusawa dacite is fluvial or fluviatile-lake deposits, and there is no angular unconformity between them. According to Yagi et al. (1960); "The welded tuffs may be taken as the feature of terrestrial formation. But it may be welded when the pumice deposits flowed into shallow lake and filled it up". Therefore the most of the welded tuff in this area with columnar joints deposited above the fluvial level. After the deposition of the dacite, about 40 meter' difference in elevation was caused between the left and the right side along the Oguni river. The author assume that the subsidence of the southern half of the basin was caused by (1) isostatic subsidence after the explosion of dacitic pyroclastics, (2) autocompaction of the Yamaya formation caused by the weight of dacite, (3) subsidence of magma chamber, (4) faults along the Oguni river and its tributaries, (5) others. But the whole volume of the Mitsusawa dacite was not enough to subside the whole basin (see next paragraph). Accordingly, the subsidence of the magma chamber will be denied. The Yamaya formation underlying the Mitsusawa dacite is too thin to cause 40 meter' subsidence. Also the Mitsusawa dacite seems not to enough to cause the isostatic subsidence. It is true that there are faults along the Oguni river and its tributaries. But it is difficult and insufficient to explain the whole subsidence of the southern half of the basin. The author assumes that this subsidence was caused by the combination of the faults and other above mentioned causes. Anyway, the difference in elevation of the underlying bed of the Mitsusawa dacite, concentration of the welded parts in the south, the poor development of the higher terrace in the center of the basin, the southern deviation of the Oguni river, and the abrupt changes of the river system, whose directions of NE-SW and SE-NW change into the south and the north, all these facts prove the subsiding tendency in the central basin, especially deeper in the south. And the increase of the relative height of the terrace surfaces above the present stream levels at the upstreams, also shows the uplift of the backbone range.

Volcanisms

Where the Tertiary tectonic basins have lake deposits of the Tertiary and the Quaternary, there are Quaternary volcanoes and its pyroclastic deposits in the basin and surrounding. This is a very important fact. The author has reported on some of these basins (K. Omoto, 1964, 1966, 1967), and the Mukaimachi basin. The pyroclastic deposits of the Mukaimachi basin are limited within the basin, and form the flat "tuff sheet". The pyroclastic deposits are approximately 30 meters in thickness, and the upper part of the dacite is welded tuff. The welded parts, 5 meters to 10 meters in thickness, show the columnar joints. They are observable along the left side of the Oguni river from the vicinity of the spa of Akakura to Mukaimachi. Apart from here, the thickness and the welded part decrease gradually, and the hard dacite changes into soft dacitic tuff and pumiceous tuff. The soft tuffaceous part is obviously deposited under the fluvial level in the vicinity of Hatsugasawa. But in most cases, pyroclastics deposited above the fluvial level. Katsui (1955) reported on the welded tuff, collected from the southwest of the Uzen-Akakura station, which was produced from "Onikōbe caldera." But many geologists agreed that the Onikōbe basin was formed under Tertiary block movements. The mechanism of explosion of this Mitsusawa dacite is the important problem to be solved. It is impossible to suppose a large volcano from this "tuff sheet." These pyroclastics seem to have been poured out from the fissures or crypt-volcano. The two major faults, NW-SE trend form a graben in the vicinity of the spa of Akakura. The heavy minerals of the Akakura formation in this graben are hyperthene, augite, hornblende and especially in the upper part, the hornblende is dominant (Taguchi, 1961). The Mitsusawa dacite also consists of hyperthene, hornblende, and augite in heavy minerals. The thick and well welded parts of the Mitsusawa dacite are along the extention of the NW-SE fault line of the graben. These facts suggest that the Tertiary tectonic line decided the location of the Pleistocene volcanic activities. Shigeo Doi (1963) reported that the magma resulting in welded tuffs originated from the tectonic movement characterized by the fracture movement. The close relation of the tectonic movement and the volcanic activity is important. But in this basin, the pyroclastics had not so much volume to result the large depression. The author estimated that the whole volume did not exceed 1 km^3. This volume is less than the lower limit of the pyroclastics causing the caldera depression estimated by Hisashi Kuno (1957) and R.L. Smith (1960).

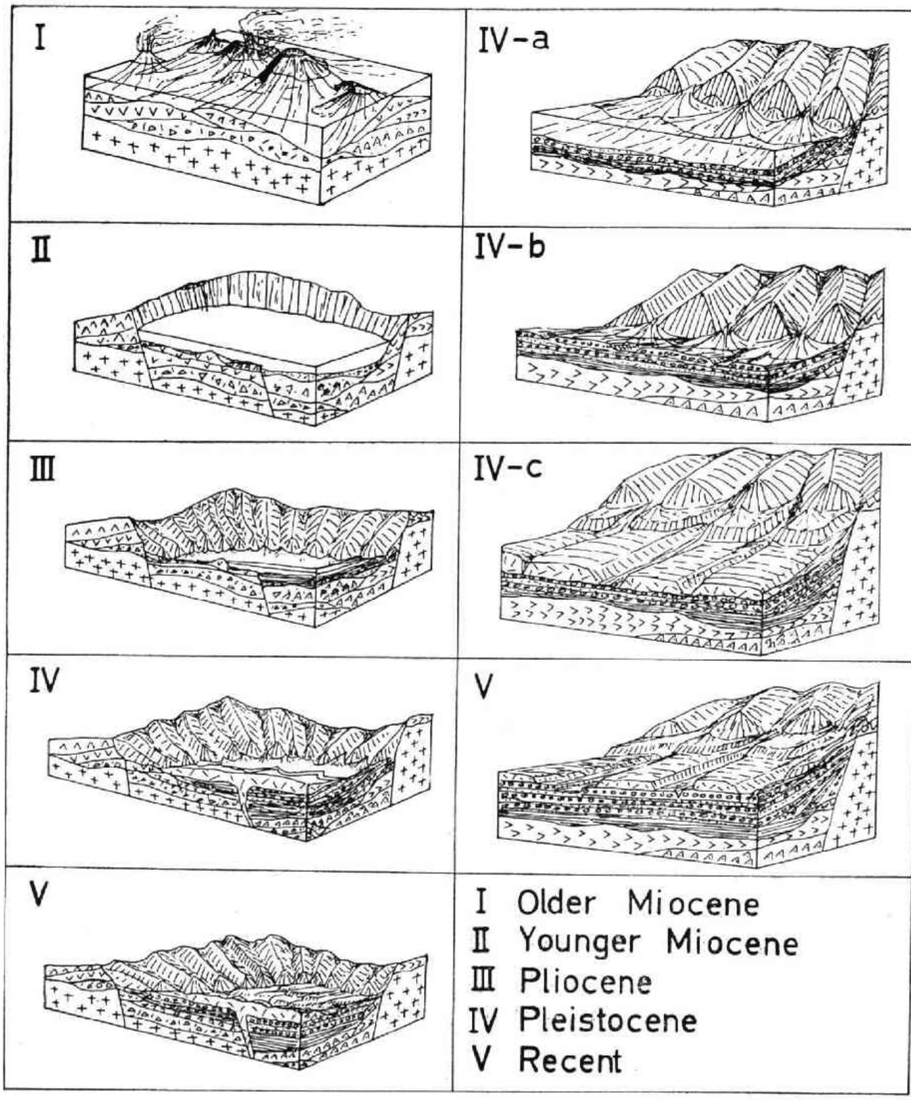

Figure 7. Ideal profiles showing the geomorphological development of the basin

According to Kuno, caldera is formed after the explosion of abundant pumice (partly welded tuff) more than 10 km³ in volume. Smith reported that the lower limit of the pyroclastics which formed caldera exceeded 3 km³. The minor scale of "Orogenic mass-circuits" of van Bemmeln (1957) will be applied in the tectonic development of this basin.

4. Geomorphological development

The geomorphological development of the Mukaimachi basin is summarized as follows (Fig. 7).

1) The Mukaimachi basin, surrounded by the green tuff, is a multi-cycled tectonic basin, after the green tuff activities. The tectonic movement was violent after the mid-Miocene, and uplifted the green tuff to make the crest of the Honshū island. But the depressed area kept the isolated level and the lacustrine deposited in the area. The trend of the upheaval axis in the backbone range is N-S direction in general, and sometimes E-W. The tectonic line of the NW-SE direction was formed in late Miocene and was active in the Pleistocene period. The latter controlled the Pleistocene volcanism and the present topography.

2) The drainage divide at Sakaida has been uplifted mostly and uniformly, but the amount of uplift decreases in accordance with the distance from here. The total upheaval since the beginning of the Pleistocene is 120 meters at least.

3) After the deposition of the Akakura formation, the Yamaya formation filled the basin in the Pleistocene. Without a long time break, the Mitsusawa dacite (dacite, partly welded tuff, dacitic tuff and pumiceous tuff) formed "tuff sheet." The mechanism of the explosion seems to have been originated from the NW-SE tectonic line of the Tertiary.

4) The Pleistocene volcanisms in this area succeeded the tectonic movements. The subsidence in the center of the basin began after the accumulation of the pyroclastic deposits and it is conspicuous in the southern half. The Mukaimachi basin is a "tectono-volcanic depression (K. Omoto 1967)"

5) Facies, stratigraphy and heavy mineral analysis of the Akakura, Yamaya and Mitsusawa formation suggest that the upper part of the Akakura formation may be correlated to the Pliocene in the Pacific Ocean side.

6) Several fluctuations of the local base level formed the flat summit accordance of the hill-land and river terraces. The most stable period was the formation of the Hatsugasawa surface, and the period of the formation of the Makinohara surface was the second one.

7) The Makinohara surface is correlative with the Shokubutsuen surface in the Nakayamadaira basin and the Myōsada surface of the Narugo basin, based on its continuity and related topography. But the accurate correlation will be established by the C-14 method.

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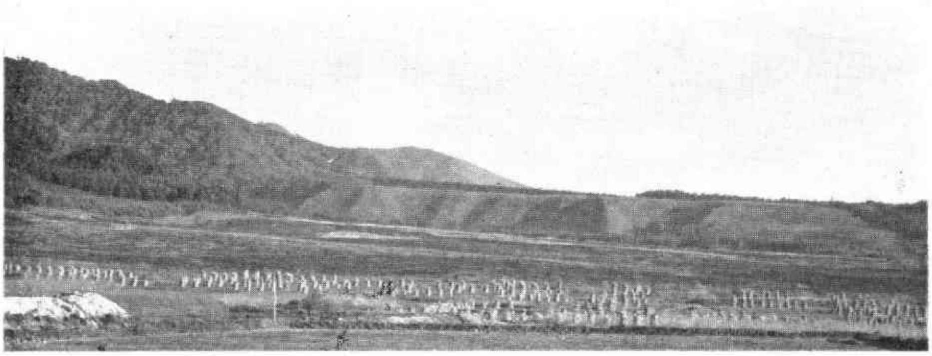
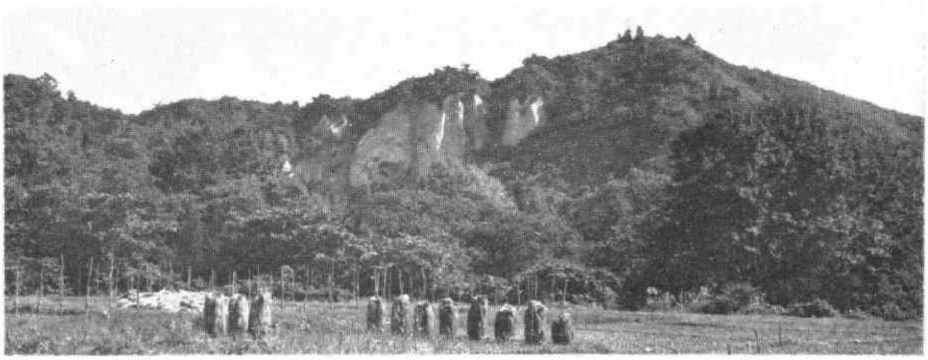
Pl. I-1 The northern half of the basin topography, viewed from the top of Mt. Kobuchi. Figure in lower middle shows the H1 (old Maemorihara fan), and T3 (young Maemorihara fan). The middle part shows H2 and H3 continuous from mountain spurs.

Pl. I-2. The southern half of the basin topography, viewed from Akakura ski-run. The flat surfaces covered with snow are H2 and H3. Figure in lower left shows settlement of Hitohane and the right settlement is Akakura. The dome-like mountain is Mt. Myōjin.



Pl. I-3. Young (lower) and old Maemorihara fan (The flat higher surface is H1), viewed from Shinnosawa.

Pl. I-4. Table topography ("tuff sheet") of the southern H2 and H3, viewed from Tomizawa.



Pl. I-5. "Shirasu" topography of Mitsusawa dacite at the east of Yakushihara.

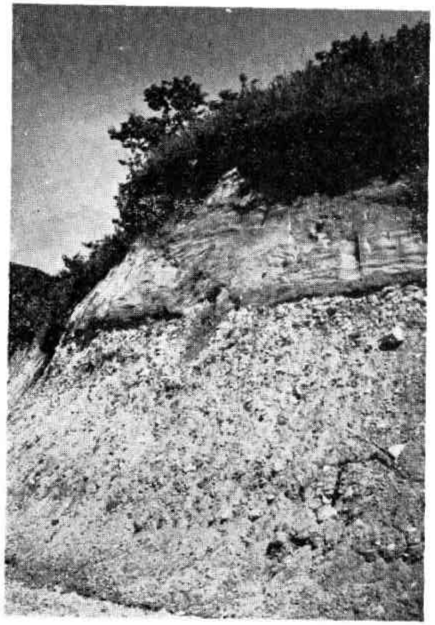
Pl. I-6. "*Leistenflur*" topography at the southwest of Akakura. This surface seems to continuous to the surface of T1.

Pl. II-1. Terrace deposits of T1 at Loc. 35.

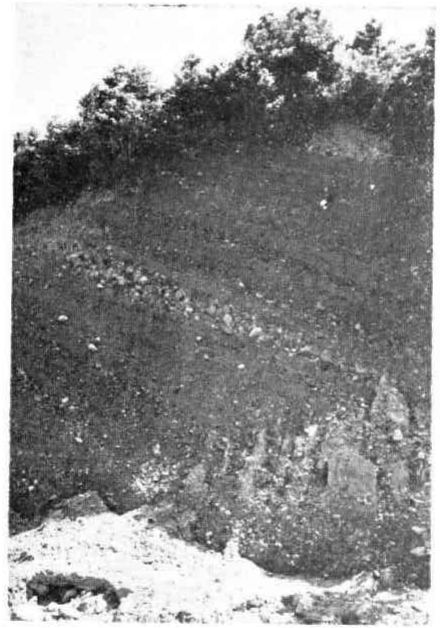
Pl. II-2

Pl. II-3

Pl. II-2. Terrace deposits of T2 at Loc. 34.
Pl. II-3. Terrace deposits of T1 at Loc. 1.



Pl. II–4. Pyroclastic deposits overlying Yamaya formation at Loc. 12.



Pl. II–5. Yamaya formation at the north of Wakamiya.

Pl. II–6. Akakura formation (lower) at Sugenodai.