551. 23/. 24 : 551. 782 (521. 61)

# Stratigraphy and Geological Structure of the Neogene Formations, Southeastern Part of the Izu Peninsula, Japan

Eizo YAMADA*

**Abstract**

The Neogene system in the area is composed mainly of shallow submarine volcanic products and their reworked deposits. They can be stratigraphically divided, based on the petrological character of dominant volcanic products and the lithological character of the reworked deposits, into the Oose Formation, the Nijo Formation, the Shimokamo Formation, the Aoichi Formation, the Ookamo Formation, the Kekurano Formation, the Itami Formation and the Harada Formation in roughly ascending order. The total thickness reaches about 2,500m.

These formations are in general gently folded with NE–SW axes gently plunging both to the NE and the SW. But in the northwestern part of the area, where several large intrusive bodies of dacite are exposed, the strata are more or less domed up around the intrusives and basin structures are formed between the domes.

The Neogene system in the area is cut by many faults. The predominant faults strike N0°–90°W and dip more than 60°. Among the predominant faults are included those having both nearly horizontal striations on the slicknesides and the same direction as the Irozaki fault, which moved on the occasion of the Izu-Hanto-Oki earthquake in May, 1974. Faults striking N40°–90°E and dipping more than 60° are next in frequency. Among them are included two faults with several meters of apparent reverse throw.

## 1. Introduction

### 1.1 Location and physiography

The studied area is located in the southeastern part of the Izu peninsula (Fig. 1). It is hilly land reaching in general 200 to 300 meters above sea level. It is steeply dissected by rivers and wide alluvial plains are developed in the bottoms of the valleys. On the alluvial and coastal plains villages are developed.

Warm and humid weather prevails most of the year and, therefore, the rocks have been deeply weathered. This fertile land is covered thickly by vegetation and even steep hill sides have been cultivated for orange orchards. Therefore, outcrops are very poor except along coastal cliffs or road-cuttings. Recently many resort villages have been developed in this area owing to the mild climate, beautiful coastal scenery and hotsprings.

This area is accessible in about four hours from Tokyo by train or by car.

### 1.2 Previous works and scope of the present work

The main published works on the stratigraphy and the geological structure of the Neogene formations in the area are by KOZU (1913), TAYAMA and NIINO (1931), WATANABE, MIKAMI and SUZUKI (1952), SAMESHIMA (1955), SUMI (1958), SAMESHIMA, IWAHASHI and KURODA (1968), KITAMURA *et al.*

* Geothermal Research Department

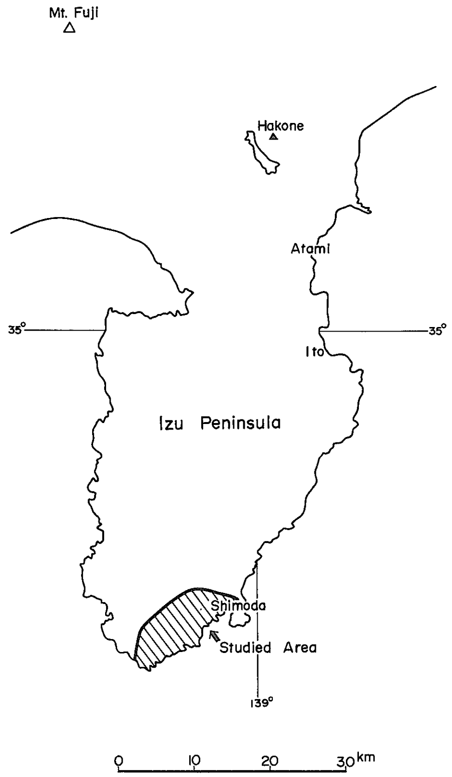



Fig. 1 Location map.

(1969), SAWAMURA *et al.* (1970), and ITO and HAYASHI (1970). The distribution of lithological facies of the area is gradually coming clear through these studies. Particularly, the geological sheet maps "Mikomotojima" (SUMI, 1958) and "Shimoda" (SAWAMURA *et al.*, 1970) describe the distribution of lithological facies in detail. As to the stratigraphical succession and the geological structure, however, there are many differences of opinion among the above works and many problems still remain.

The purpose of the present work is to clarify the stratigraphical succession and the geological structure of Neogene formations in order to better understand the distribution of thermal springs and the hydrothermal system in the area. To achieve the purpose, many stratigraphic columnar sections were made in and around the Shimokamo area and the lateral correlation of each bed was tried. Though the features of lateral changes of facies in these deposits were clarified in some detail, the lateral tracing of each bed was not successfully done because these formations consist mainly of thick piles of probably shallow submarine volcanic products, which abruptly change their facies in lateral directions, and also because of poor exposures and deep weathering. Many dips and strikes of beds and fault planes were measured throughout the area. Based on these data a map showing generalized strike lines and fracture patterns was made. Relying much on the generalized strike lines, the Neogene system in this area was divided into formations. The boundaries of formations in the present work were set roughly where the petrologic character of volcanic rocks or lithologic character of strata change substantially. Thus, though many problems still remain as to the details, the general stratigraphical succession and the geological structure of the Neogene system in the area were clarified.

## 2. Stratigraphy

The formations exposed in this area are solely of the Neogene period except for the Quaternary cinder cone and basalt lava distributed around the Ikenohara area (SUMI and MAEDA, 1974) and for local Quaternary sediments covering thinly the Neogene system. The Neogene system exposed in this area is divided into intrusive bodies and the following eight formations in roughly ascending order; the Oose Formation, the Nijo Formation, the Shimokamo Formation, the Aoichi Formation, the Ookamo Formation, the Kekurano Formation, the Itami Formation and the Harada Formation (Fig. 2).

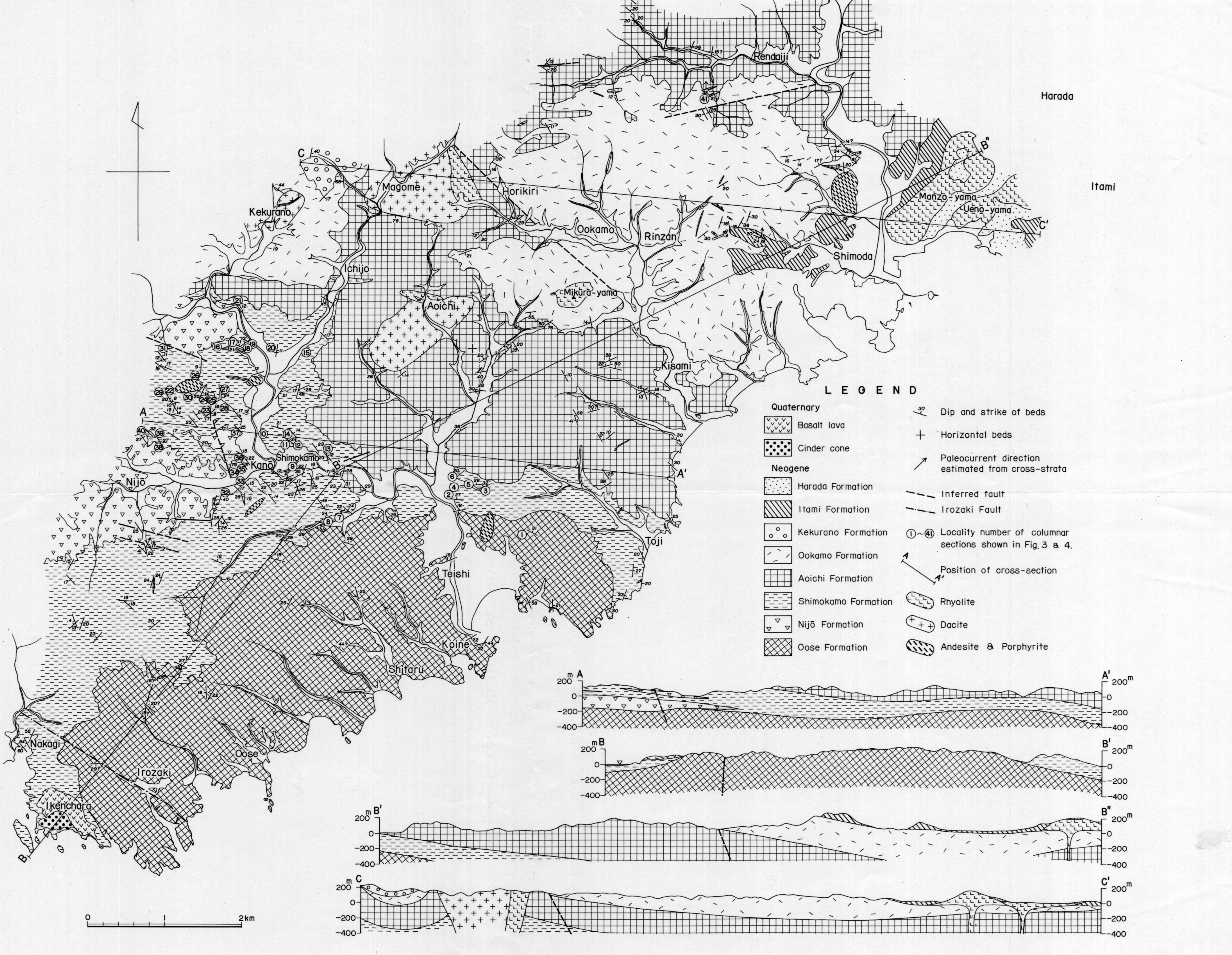



Fig. 2. Geological map of the southeastern part of the Izu peninsula.

### 2.1 Oose Formation

This formation is part of the Irozaki andesites and the Suzaki andesites (SUMI, 1958) but the stratigraphical horizon is greatly changed. It is typically exposed along roadcuttings from Irozaki village to Teishi village.

This formation consists mainly of augite-hypersthene-andesite lava (Pl. 20–1, 2), subaqueous autobrecciated lava (KUNO, 1968), andesitic hyaloclastite breccia (SILVESTRI, 1963) (Pl. 20–6, Pl. 21–1, 2), andesitic tuff-breccia, and andesitic volcanic conglomerate. Andesitic lapilli-tuff, and, rarely, conglomerate, sandstone and siltstone are intercalated in the upper half of this formation. Thick andesite lava flows characterize the lower half of this formation, which is exposed around Oose village. In some places clastic materials fill in the joints of lava flow (Pl. 23–5). In the areas between Irozaki village and Koine village this formation consists of exceptionally thick andesite lava flows which are intruded by many andesite dikes. Both the lava flows and dikes are altered extensively to white-colored rocks. These facts may suggest that the areas were in proximity to eruption centers.

This formation is the lowest part of the Neogene system exposed in the area. The exposed thickness ranges from 700 m to 1,400 m in this area. This formation is covered conformably by and partly interfingers with the Shimokamo Formation.

### 2.2 Nijo Formation

This formation is roughly the same as a formation called Dacite and its agglomerate (KOZU, 1913), or Nijo dacites (SUMI, 1958). But the author considers that parts of the Nijo dacites (SUMI, 1958) are probably intrusive bodies or stratigraphically different lava domes, which are, therefore, excluded from this formation. This formation is typically exposed around Nijo village.

This formation consists mainly of dacite lava, its subaqueous autobreccia, and dacitic volcanic conglomerate. It intercalates very rarely thin beds of white tuff and siltstone. The dacite is apt to be weathered deeply and appears as if it were whitish gray, sandy tuff when weathered. When fresh it is dark-gray, hard porphyritic dacite, containing corroded quartz, plagioclase, hornblende, and, in some places, hypersthene as the main phenocrysts. In the south of Kano village, large blocks of white tuff (Pl. 23–7) and in the southeast of Kekurano village siltstone blocks are embedded in the lava. They are probably blocks captured when the lava flowed over them.

This formation consists mainly of lava domes interposed within the Shimokamo Formation and is probably separated into two or three main lenses or sheets. Thus, the distribution is probably limited to narrow areas and therefore this formation may be regarded as a member of the Shimokamo Formation though in this paper it is called a formation. The maximum total thickness probably reaches more than 300 m.

### 2.3 Shimokamo Formation

This formation is part of the Shimokamo sandstone (SUMI, 1958) or part of the Kaden Formation (KITAMURA *et al.*, 1969). It is typically exposed around the Shimokamo area.

This formation consists mainly of sandstone, siltstone, and conglomerate. They are composed of volcanic materials redeposited from nearby volcanic piles. Essential volcanic products, *e.g.*, andesite lava, tuff-breccia, tuff, pumice flow deposits, are subordinately intercalated in this formation. This formation probably characterizes a relatively calm environment that existed between intense volcanic eruption centers.

In the western part of the area, the lower part of this formation consists of dacitic and andesitic debris-flow (CARTER, 1975) deposits, pumiceous sandstone, with minor intercalations of augite-hypersthene-andesite lava, hornblende-bearing andesite lava, andesitic tuff-breccia and acid pumice flow deposits; the upper part of this formation consists of well-sorted sandstone with local intercalations of siltstone, andesitic tuff-breccia, acid pumice flow deposits, and dacitic conglomerate (Pl. 22–7). Towards the east, andesitic lapilli-tuff and andesitic tuff-breccia gradually become dominant. In the eastern to central part of the area, this formation consists mainly of andesitic debris-flow deposits, (pyroclastic) tuff-breccia and andesitic hyaloclastite breccia with rare intercalations of air-fall tuff, scoria tuff and pumice tuff, mud-flow deposits, and augite-hypersthene-andesite lava. Thus the facies changes laterally in this formation (Fig. 3).

The decitic and andesitic debris-flow deposits usually contain cobble- to pebble-sized dacite and andesite in an ill-sorted sandy matrix, in which irregular trains of pumice lamina commonly are observed.

The pumice flow deposits of this formation consist of several eruption units. The lower part of each unit commonly contains andesite or dacite fragments in a pumiceous sandy matrix and the upper part becomes sandy pumice tuff. Each unit, however, does not show such regular vertical sequence of facies as reported in other areas, *e.g.*, the Onikobe area (YAMADA, 1973), and the upper finer divisions are almost lacking. This is probably due to the difference of sedimentary environment; that is, in this area a shallow marine condition existed while in other areas a deeper marine or a lacustrine condition existed. Pumice lumps are in general less than 10 cm in diameter and white-colored, but in the western part of the area rose-colored pumice lumps are observed in some places.

The sandstone of this formation is in general well sorted and commonly shows largescale cross-stratification. Planar cross-strata are common but wedge-shaped or lenticular-shaped cross-strata are also observed (Pl. 22–1, 2). This sandstone was probably deposited in a shallow marine environment. The flow directions, estimated from the cross-stratification, are from SW to NE and from WNW to ESE. Therefore, the sands were probably supplied to the area from SW and WNW directions. In some places cobble- to pebble-sized dacite fragments derived probably from the Nijo Formation are contained in comparatively coarser sandstone beds.

The andesitic debris-flow deposits (Pl. 22–7, 8, 9) contain cobble- to pebble-sized andesite in a matrix of granule- to sand-sized andesitic tuff. The upper part of a flow unit commonly becomes tuffaceous sandstone with parallel-laminae. In one outcrop (Pl. 21–8), ripple cross-laminae were observed. The paleocurrent direction estimated from them is form ESE to WNW. Thus, the andesitic debris-flow deposits were supplied probably form the opposite direction to the sands described earlier.

The andesitic hyaloclastite breccia (Pl. 20–5) contains only andesite fragments in a greenish yellow granule- to sand-sized matrix, which may be palagonite. The andesite fragments have a thick discolored margin. The (pyroclasitic) tuff-breccia (Pl. 21–3) usually contains andesite fragments in a scoriaceous tuff matrix. But a variety, which contains various accidental rock fragments, andesitic bombs and andesitic blocks in a sandy tuff matrix, was also found. In some places the andesitic bombs and blocks have a thick orange to brownish yellow margin, which may be a palagonitized chilled margin (Pl. 21–4).

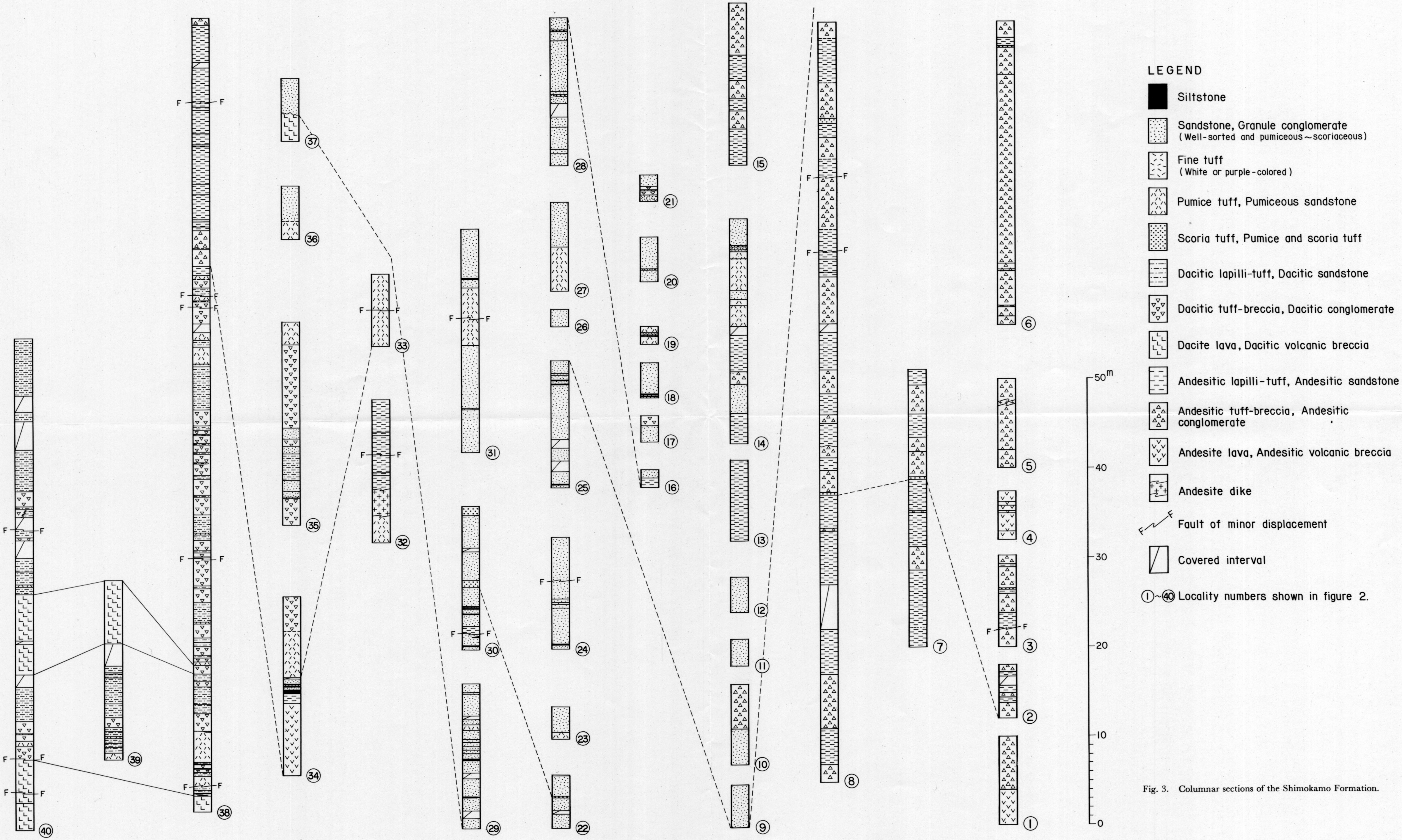



Fig. 3. Columnar sections of the Shimokamo Formation.

In the western part of the area this formation interfingers with and partly abuts against the Nijo Formation. Towards the east, andesitic tuff-breccia beds gradually predominate and the facies of this formation becomes similar to that of the underlying Oose Formation and the overlying Aoichi Formation, except the former is better stratified and richer in sandy intercalations than the latter. The thickness of this formation ranges from 200 to 600 m. This formation is overlain conformably by or partly interfingers with the Aoichi Formation.

### 2.4 Aoichi Formation

This formation is part of formations called Ichijo andesite, Aoichi basalts, and Suzaki volcanics (Sumi, 1958), Aoichi volcanics (Kitamura *et al.*, 1969), Aoichi Group (Tayama and Niino, 1931), or Propylite, its breccia and tuff, and Pyroxene andesite, its agglomerate and tuff (Kozu, 1916). It is typically exposed around the Aoichi area and along the coastal cliffs from Kisami village to Toji village.

This formation is composed of pyroxene-andesite lava (Pl. 20–7, 8), its hyaloclastite breccia, scoriaceous tuff-breccia, andesitic lapilli-tuff, andesitic debris-flow deposits (Pl. 21–5), and andesitic volcanic conglomerate (Pl. 21–6) with rare intercalations of basalt lava, fine tuff and scoria tuff. The upper part of this formation becomes dominantly dark-gray andesitic sandstone and conglomerate. The conglomerate locally shows largescale cross-stratification. Dark-gray, hard scoria tuff and thin beds of white pumice tuff or tuffaceous sandstone (Pl. 22–3) are very rarely intercalated.

The formation is not continuously exposed at the surface from the Rendaiji area to the other type areas described above. However, in a bluff at a quarry, which is 1 km southwest of Rendaiji town, andesitic tuff and conglomerate of this formation are overlain by rhyolitic tuff without marked unconformity (Fig. 4). The rhyolitic tuff belongs no doubt to the Ookamo Formation and, therefore,

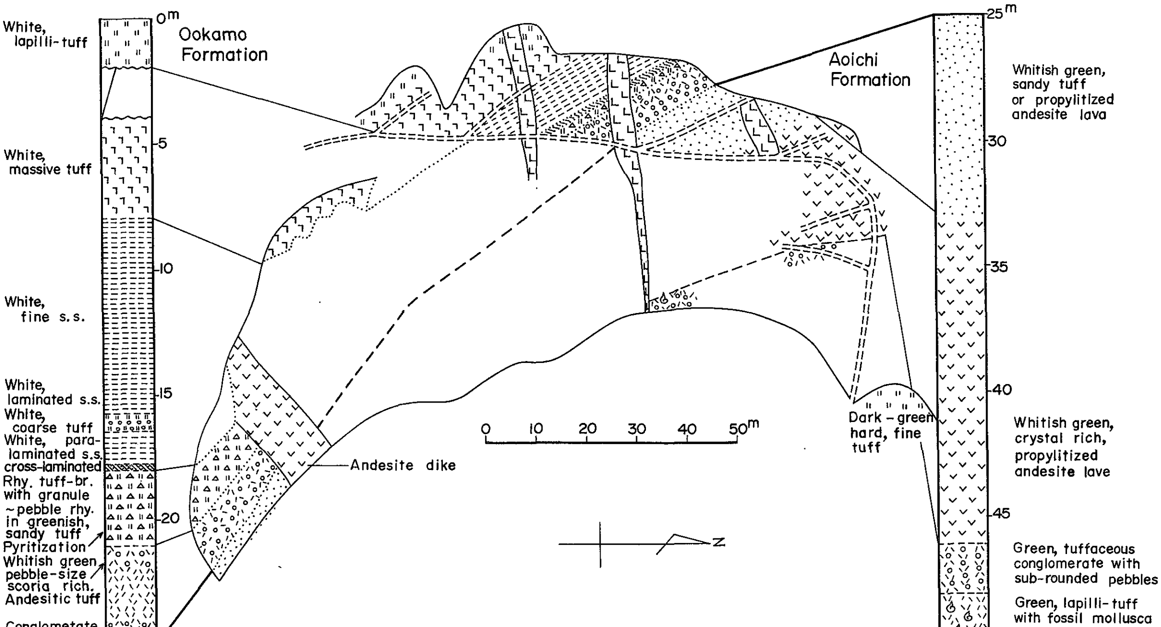



Fig. 4 Sketch of a bluff at a quarry to the south of Rendaiji.

the underlying strata will naturally be correlated to the Aoichi Formation. In the Rendaiji area this formation is composed of thick andesite lava flows, andesitic tuff-breccia and andesitic lapilli-tuff. There the upper part of this formation is conglomeratic as in the Aoichi area. Thus the strata in the Rendaiji area are similar to those of the Aoichi area, though in the former area they are locally silicified and mineralized and appear somewhat different in facies from those of the latter area.

This formation is overlain conformably by the Ookamo Formation so far as observed in the outcrops. However, the thickness of this formation reaches about 800 m in the eastern part but in the western part only several tens of meters. This fact along with the conglomeratic facies at the top of this formation suggests the possibility of a local uncomformable relationship with the overlying Ookamo Formation.

### 2.5 Ookamo Formation

This formation is part of Ogamo rhyolite and Isshiki tuff (SUMI, 1958), Ookamo tuff member, Horikiri Rhyolite, and Magome Pyroclastics (KITAMURA *et al.*, 1969), Tateiwa Group (TAYAMA and NIINO, 1931), or Plagioliparite (KOZU, 1913).

This formation is composed mainly of rhyolitic tuff-breccia and pumice tuff containing angular fragments of white rhyolite, white and dark-gray banded rhyolite, and dark-gray rhyolite obsidian. Near the base of a flow unit a pumice flow deposit locally contains abundant accidental rock fragments, mainly andesite and dacite. In some places at the top of a flow unit a thin layer of white sand- to silt-sized tuff is developed. White hard rhyolite lava, white sandstone, and siltstone are intercalated in some places. The rhyolitic sandstone exposed 1 km southwest of Rendaiji town shows cross-lamination, which indicates from S to N paleo-current direction. The rhyolite dikes and domes are mainly distributed in or immediately around the area presently covered by the Ookamo Formation and the strata of this formation contain many large rhyolite fragments. These facts may suggest that the pumice flows of this formation were erupted somewhere within or immediately around the area presently covered by this formation.

The pumice lumps and rhyolite fragments contain quartz, plagioclase, biotite, and, in some places, hornblende or hypersthene as the phenocrysts. Mafic phenocrysts are generally small in size and amount. Rose-colored pumice lumps are very rarely observed.

The relation between this formation and the overlying Itami Formation appears conformable in the road-cuttings at a resort village 1 km west of Shimoda. But in the area to the northeast of Shimoda this formation seems to be lacking and the Aoichi Formation is directly overlain by the Itami Formation. This is due either to the original ragged physiography and non-deposition or to the post depositional erosion of part of this formation. Judging from the borehole data, this formation may be interfingering with andesitic volcanic products of the Aoichi Formation in the northwestern part. In the Kekurano area this formation is unconformably overlain by the Kekurano Formation. The maximum thickness of this formation is about 400 m.

### 2.6 Kekurano Formation

This formation is proposed for the first time in this paper because it lies unconformably over the Ookamo Formation and has a characteristic lithofacies. This formation is typically exposed along the roadcuttings about 1 km west of Magome village. The distribution is very limited.

This formation consists mainly of conglomerate with subrounded to subangular dacite blocks several centimeters to a few meters large (Pl. 22–5). Its matrix is dark-gray, coarse sandstone with a vague stratification.

This formation unconformably overlies the Ookamo Formation. The unconformable erosional relation is clearly observed in the southern margin of this formation. But in the western margin this formation is apparently conformable with the underlying dark-gray, hard andesitic tuff (Pl. 22–4) which might belong to the Aoichi or the Itami Formation. The thickness of this formation is about 50 m.

### 2.7 Itami Formation

This formation was defined by WATANABE *et al.* (1952) and the type section at Itami cape was reported by them. In this paper the distribution of this formation was somewhat changed from that of the above work.

This formation is composed of purplish and greenish gray, variegated andesitic tuff-breccia and tuff, thick pyroxene-andesite lava (Pl. 20–3, 4), sandstone, and siltstone. In the area 1 km west of Shimoda, chocolate-colored siltstone and cross-laminated sandstone are intercalated (Pl. 22–6). The paleo-current direction at the locality estimated from the cross-laminae was towards N8°E.

### 2.8 Harada Formation

This formation was defined by WATANABE *et al.* (1952). The type locality given by them is along the Older Shimoda Road, west of the Shirahama Shrine.

This formation is composed of white tuffaceous sandstone, buff-yellow sandstone with rare intercalations of siltstone and volcanic breccia. The sandstone is commonly cross-laminated and contains abundant fossil mollusca shells. The thickness is around 125 m.

### 2.9 Intrusive Bodies

#### 2.9.1 Andesite

Several bodies of andesite are intercalated in the Oose Formation and the Shimokamo Formation. They are considered as intrusive rocks from such evidences as their characteristic cooling joints, their distribution pattern, or the disturbance of stratification near the bodies, though the very intrusive contacts were not observed except for the westernmost one. On the north of downtown Shimoda a large neck of porphyrite is exposed.

Several large porphyrite and basalt bodies are exposed in the northern part of the area and around Oose village. They have been regarded as intrusive bodies by SUMI (1958) and SAWAMURA *et al.* (1970). The body exposed 1 km northeast of Horikiri village is everywhere separated from white or greenish white pumice tuff of the Ookamo Formation by complicated faults with shear zones less than 1 m wide (Pl. 24–7). However, the intrusive relations were not evident for these bodies and therefore they were interpreted as thick lava flows in the present work.

Many thin dikes of andesite are intruding in the Ookamo, the Aoichi, the Shimokamo, and the Oose Formations. An about 4 m thick andesite dike of low inclination was observed near Rinzan village. It has an evident chilled margin and at the contact with the surrounding white pumice tuff, the tuff has been changed to black obsidian (Pl. 23–1). Cooling joints of andesite dikes become denser towards the contact surface (Pl. 23–3) and country rocks are often baked to black or darker color. In the southern part of the area the dominant dikes strike N60– 90°E; whereas in the northern part dikes striking NW–SE seem to predominate over those striking NE–SW.

**2.9.2** Dacites

Large bodies of dacite, exposed near Aoichi, Magome, and Kekurano villages are interpreted as intrusive ones, based on such evidences as their massive appearance, their distribution pattern, and the fact that the strata near the bodies become steeper and are domed up surrounding them. The very intrusive contacts were not observed, however, and their underground shapes and mode of emplacement are not known.

The dacites appear lithologically quite similar to those of the Nijo Formation. Under the microscope, the dacites contain plagioclase, quartz, augite, and hypersthene as the main phenocrysts, while very little amount of hornblende phenocrysts are contained. Thus, they are somewhat different from those of the Nijo Formation in that hornblende phenocrysts are meager.

**2.9.3** Rhyolite

Rhyolitic intrusive bodies are exposed in the Manzoyama, the Uenoyama, the Mikurayama, the Ichijo, the Aoichi, the west of Horikiri, and the east of Rinzan areas.

Manzoyama, Uenoyama, and Mikurayama bodies have been much studied and reported to comprise potash-liparite and plagio-liparite (Iwao and Hida, 1946; Watanabe *et al.*, 1952; Mikami, 1952; Ueno *et al.*, 1961). Parts of the bodies are lava domes, though described in this section.

Ichijo rhyolite is a dike of several tens of meters wide and of the E–W trend. The rhyolite exposed near Aoichi village may be the eastern extension of Ichijo rhyolite. The rhyolite exposed to the west of Horikiri village is locally intruded by siliceous mineralized veins. Narrow rhyolite dikes with characteristic flow bands (Pl. 23–2) are exposed to the east of Rinzan village. These rhyolite dikes contain plagioclase, quartz and biotite as the main phenocrysts.

## 3. Structure

### 3.1 Folds

In and around the Shimokamo area, where well stratified beds are developed, the dip and strike of beds were measured at many localities and the general trend of stratification became fairly clear. In the other areas, either due to the insufficiency of field work or the difficulty of measuring stratification in thick lava flows and pyroclastics the dip and strike of beds have not yet been sufficiently measured. However based mainly on the measured dips and strikes of beds and other available data, the generalized strike lines were drawn (Fig. 5). The large deviations of some measured dips and strikes of beds from the generalized strike lines are mostly due either to the measurement of cross-stratification or the measurement of slumped or structurally disturbed beds.

It is worthy to note that no clear structural gap was recognized from the base to the top of the Neogene system in this area. The beds in this area dip in general less than 30 degrees with its average around 20 degrees, though very steep dips, 70 degrees or so, are observed in some places near the faults (Pl. 24–1) and intrusive bodies. In other places the strike of beds abruptly changes on both sides of faults.

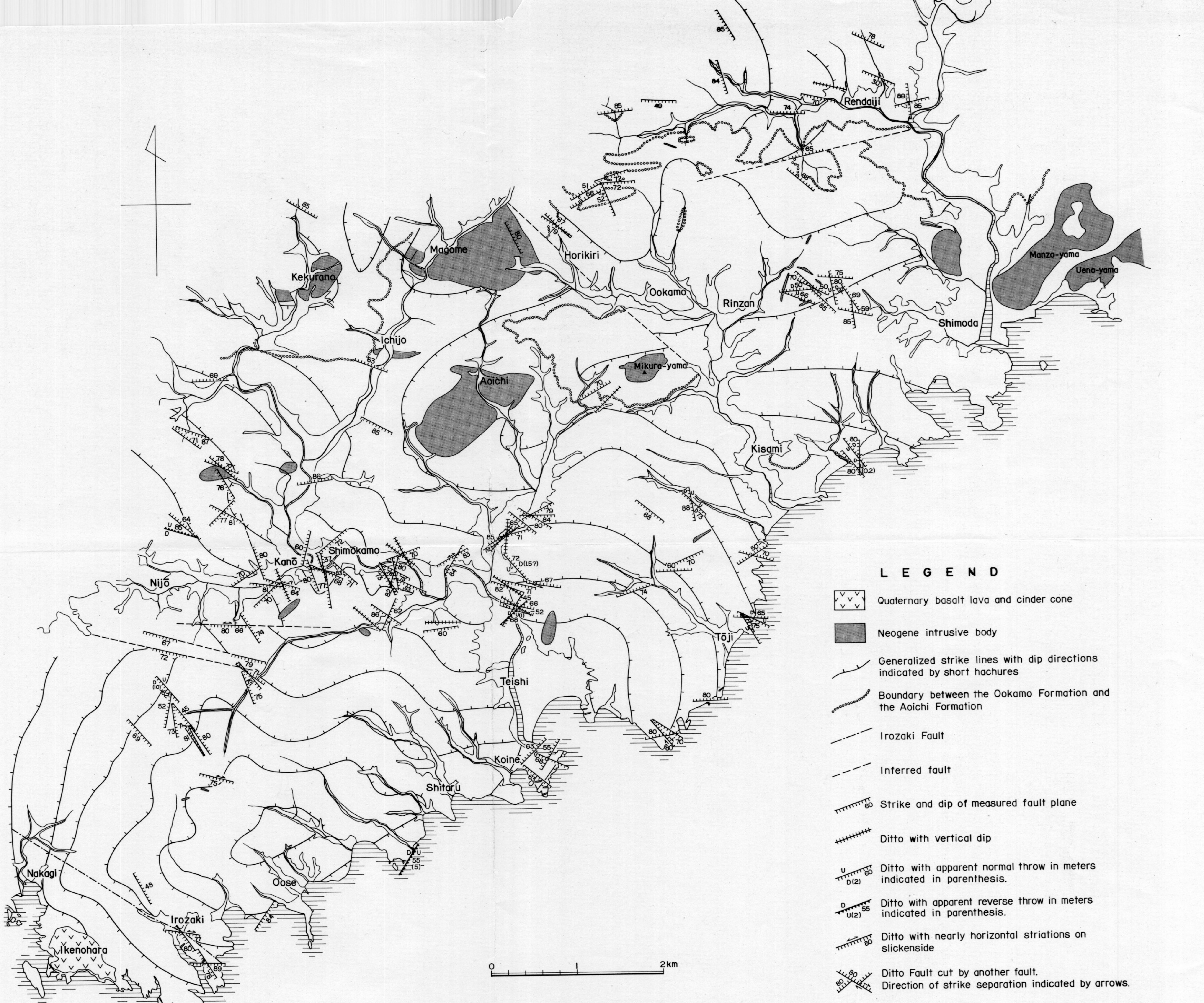



Fig. 5. Structural map of the southeastern part of the Izu peninsula.

According to the generalized strike lines (Fig. 5), a major broad anticline runs from Nakagi village to Kisami village roughly in a NE–SW direction, plunging gently away from Oose village both towards the northeast and the southwest; whereas a major syncline runs from Shimokamo town to Shimoda town roughly in a NE–SW direction plunging gently towards the northeast. In the Shimokamo area, the beds are undulated with synclines and anticlines of shorter wave lengths, the axes of which strike NNE–SSW and plunge towards the NNE. In the northern part of the area, the beds are domed up surrounding large intrusive bodies, resulting in basin structures without a fixed structural trend distributed between the domes.

### 3.2 Faults

The Neogene system in the area is commonly cut by faults and joints. The nature of fracture found in most places is a shear zone (Pl. 24–5, 7), a sharp shear plane (Pl. 25–4, 6), or a breccia zone; irregular cracks and wavy fractures are rarely observed. The fractures are commonly filled with siliceous veins or hydrothermally altered clay materials in the Shimokamo and the Rendaiji areas. The sense and the amount of displacement along the faults can only rarely be estimated, because of comparatively massive appearance of the Neogene system in the area. Faults are seldom densely enough developed in an outcrop to group them into conjugate pairs in the field.

A fault of NW–SE direction and of a fairly large displacement is inferred near Horikiri village in the geological map (Fig. 2), though it has not yet been confirmed. At that locality there seems to be a gap in the rock facies and in the strike of beds on both sides of the inferred fault. All of the other faults probably have comparatively small displacements. But parallel faults of the same sense of displacement

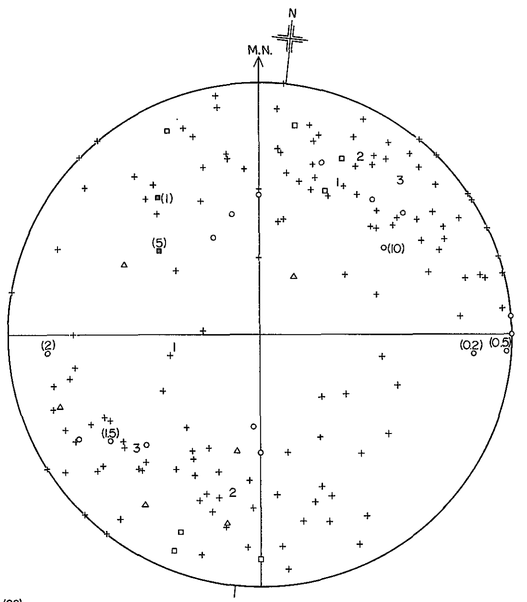



Fig. 6–a Poles of 172 fracture planes, plotted on the lower hemisphere of the Wulff net.

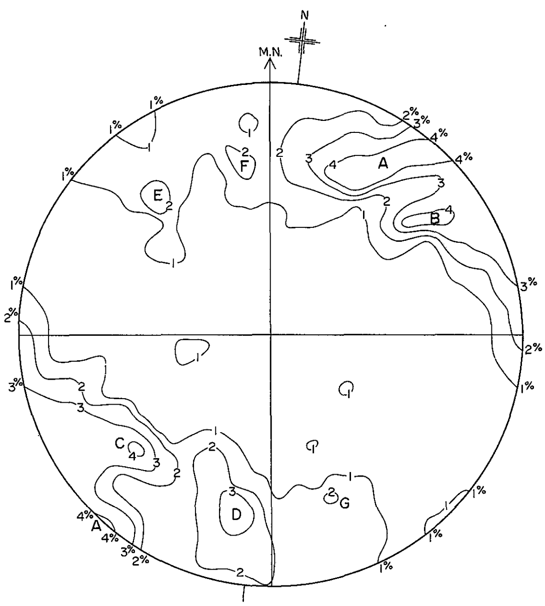



Fig. 6–b Contour diagram made from figure 6–a.

are commonly closely spaced. Therefore, by adding up the displacements of individual faults, the total displacement may reach a fairly large amount as in the southern part of Nijo village.

The poles of 172 fracture planes, mostly fault planes of minor displacement, were plotted on the Wulff net (Fig. 6–a) and statistically analysed according to the method reported by SHOJI and KOIDE (1975) (Fig. 6–b). It is evident that fractures with strikes N0°–90°W and dipping more than 60° north or south far predominate over those of other directions. They can further be subdivided into A, B, C, and D groups, according to the existence of point-maxima of more than 3- to 4-percent concentration. The fractures of the other directions are sporadically scattered and only three point-maxima of more than 2-percent concentration, *i.e.*, E, F, and G groups, are distinguishable (Fig. 6–b).

The most frequently observed fracture, group A, is centered around planes ranging from N50°W, 89°N to N78°W, 78°S but with a large scatter. Some of the faults of this group have nearly horizontal striations on the slickensides (P1. 24–2, 3) and they probably have a fairly large component of strike-slip. The direction of this fracture group coincides with the active right-lateral parallel fault set dominant in the Izu peninsula (MURAI and KANEKO, 1974) and with the Irozaki fault which moved on the occasion of the Izu-Hanto-oki earthquake of May 9, 1974 (MATSUDA and YAMASHINA, 1974; KAKIMI *et al.*, 1974). The direction of this fracture group also coincides with that of the dominant mineralized siliceous veins in the Rendaiji area (TAKEUCHI, 1968 in SAWAMURA *et al.*, 1970).

The fracture groups of B, C, and D are next in frequency and are also observed throughout the area. They are centered around planes of N38 W, 82°S to N48°W, 70°S; N43– 50°W, 70°N; and N84°W, 71°N respectively. Some of the northward dipping apparently normal faults, included in C and D groups, and some of the southward dipping apparently normal faults, included in A and B groups, may be conjugate systems of faults.

The fracture groups of E, F, and G are centered around planes of N45°E, 70°S; N75°E, 70°S; and N64°E, 70°N respectively. In the E group, two faults with several meters of apparent reverse throw are included.

## 4. Discussion and Summary

1) The Neogene system in the area is composed mainly of massive lava, autobrecciated lava, hyaloclastites, pyroclastic deposits, debris-flow deposits and subordinately conglomerate beds, cross-stratified sandstone beds, and rarely siltstone beds. The tracing of individual beds is very difficult even in a short distance, probably because they were deposited in an unstable shallow submarine volcanic environment.

The division of these rocks into stratigraphic units is not easy because of the rapid lateral changes of facies away from centers of volcanism, the existence of many source areas (centers of volcanism) at a given time, the rapid shifts of the centers in a short time, and also because of the probable existence of ragged paleotopography caused by the volcanic knolls. Moreover petrologically and lithologically similar beds occur repeatedly from the bottom to the top of the Neogene system and later hydrothermal alterations have changed the original lithological appearances at many localities.

In the present work the author relied much on the dip and strike of beds and the stratigraphic succession in making the stratigraphical division. As a result the Neogene system was divided into the Oose, the Nijo, the Shimokamo, the Aoichi, the Ookamo, the Kekurano, the Itami, and the Harada Formations in roughly ascending order. Each formation is composed of various kinds of beds, but as a whole is characterized by the dominance of particular petrological or lithological rocks: the Oose Formation is characterized by andesite lava and its pyroclastics, the Nijo Formation by dacite lava and its pyroclastics, the Shimokamo Formation by sandstone, the Aoichi Formation by andesite lava and its pyroclastics, the Ookamo Formation by rhyolitic pyroclastics, the Kekurano Formation by dacitic rubble conglomerate, the Itami Formation by andesite lava, its pyroclastics and siltstone, and the Harada Formation by sandstone. As to the exact boundary of each formation, however, many problems still remain. The total thickness of the Neogene system exposed in the area reaches about 2,500 m.

2) The Neogene system in the Izu peninsula has been divided into the Shirahama and the Yugashima Groups by the previous workers and the stratigraphic relations and the boundaries between the groups have been much discussed (SAWAMURA *et al.*, 1970; KITAMURA and TAKAYANAGI, 1972). In the present work, the author is inclined to set the boundary between the Shirahama and Yugashima Groups at the base of the Ookamo Formation. Because the Ookamo Formation is probably unconformable in the southern part with the underlying Aoichi Formation and the overlying Ookamo, Kekurano, Itami and Shirahama Formations seem to have been deposited in more or less restricted basins with local unconformable relations than the underlying formations.

There is, however, no evident structural discrepancy between the groups thus defined. All of the Neogene formations are slightly folded and have similar fold axes striking NE–SW with gentle plunges, except in the northwestern part of the area where the strata are commonly domed up surrounding large dacitic intrusive bodies. Basin structures are scattered between the domes.

If the boundary between the groups is set at the base of the Ookamo Formation as discussed above, the so-called Lepidocyclina beds are included in both groups; that is, in the Shimokamo Formation about 2 km west southwest of Nijo village, outside of the studied area (SAMESHIMA and MATSUI, 1960) and in the Ookamo Formation at 1.2 km north northeast of Rinzan village (HUJIMAGAI, 1975). The author considers that more detailed studies of the whole Izu peninsula are needed to define groups, and, therefore, in the present work the group names of the Shirahama and the Yugashima are not used.

3) The Neogene system in the area is cut by many faults and joints. Faults with strikes N0°–90°W and dipping more than 60° to the northeast or the southwest far predominate over those of other directions. They can further be subdivided statistically into a few subgroups. Genetically most of the northeast dipping and the southwest dipping faults are probably conjugate systems of normal faults.

Faults with strikes N40– 90°E and dipping more than 60° are next in frequency. Two faults, dipping southeast and having a fairly large reverse throw, are included in this group.

The maximum displacement along a fault is probably less than a few tens of meters. However, several parallel faults commonly are closely developed and then the total displacement along the fault zone may reach a larger amount.

The relations among these measured faults and the Irozaki fault, which moved on the occasion of the Izu-Hanto-oki earthquake (MATSUDA and YAMASHINA, 1974; KAKIMI *et al.*, 1974), and other active faults estimated by the study of air-photographs (MURAI and KANEKO, 1974) are worthy of especial consideration. The average direction of the Irozaki fault, which is N55°W, 75 –90°S (MATSUDA and YAMASHINA, 1974), coincides with that of the most dominant measured faults in this area. Moreover the striations on the slickensides of several faults are nearly horizontal and match well with the mainly right-lateral slip of the Irozaki fault.

The directions of the fault plane of the Irozaki fault, actually measured on the outcrops at various points, deviate from the average one namely N55°W, 75– 90°S. This may be due either to the wavy or the zigzag nature of the fault surface as in many well investigated faults (GZOVSKY *et al.*, 1969) or to the fact that the Irozaki fault is only a zone of pre-existing minor faults which moved slightly on the occasion of the Izu-Hakone-oki earthquake and possibly on the occasion of the other earthquakes of Quaternary times.

Based on a topographical examination a right-lateral slip of about 200– 300 m is suggested along the Irozaki fault during the late Quaternary Period (MURAI and KANEKO, 1974; MATSUDA and YAMASHINA, 1974). Geologically the amount of displacement along the fault has not yet been determined.

Many active faults of the same direction and the same sense of movement as the Irozaki fault have been estimated in this area based on the study of air-photographs (MURAI and KANEKO, 1974). In the field apparently minor faults are found at many places where the existence of faults was suggested by MURAI and KANEKO (1974). The measured directions, however, commonly deviate from that of the estimated faults.

Based on the movement of the Irozaki fault on the occasion of the Izu-Hanto-oki earthquake, another fault set which may constitute a conjugate system with the active fault set was estimated to have N40°E, 60°NW direction (MATSUDA and YAMASHINA, 1974). Faults of this direction, however, are rather rare in this area.

## Acknowledgements

The author is indebted to Dr. Kiyoshi Sumi, Dr. Toshihiro Kakimi, Dr. Koji Ono and Dr. R. O. Fournier for reading the manuscript and giving many valuable suggestions. Dr. Yasumoto Suzuki, and Dr. Kisaburo Kodama kindly furnished the author with their unpublished data on the geology of the southwestern part of the Izu peninsula.

## References cited

CARTER R. M. (1975) A discussion and calssification of subaqueous mass-transport with particular application to grain-flow, slurry-flow, and fluxoturbidites. *Earth-Science Reviews*, vol. 11, p. 145–177.

** GZOVSKY, M. V., LEKHTMAN, A. L. and HIRAYAMA, J. (1969) Experimental study on the influences of pre-existed cracks on the stress field. *Bull. Geol. Surv. Japan*, vol. 20, p. 657–667 (with Russian abstract).

** HUJIMAGAI, T. (1975) Geology of Rendaiji and its environs, Shimoda-shi, Shizuoka Prefecture. *Tohoku Univ.*, Graduation Thesis (MS).

** ITO, T. and HAYASHI, M. (1970) Stratigraphy of the Shirahama Group in the Shimoda District, southern Izu peninsula. *Shizuoka Univ., Geol. Institutes, Contr.*, vol. 2, p. 65–68.

** IWAO, S. and HIDA, N. (1946) Report on the potash quartz liparite of Mikura-yama, Izu. *Geol. Surv. Japan,* Unpublished report, no. 133, p. 1–7.

** KAKIMI, T., YAMADA, E. and MASAI, Y. (1974) First report on the Izu-Hanto-oki Earthquake of 1974. *Geol. Surv. Japan, Chishitsu News*, no. 240, p. 1–14.

* KITAMURA, N., TAKAYANAGI, Y., MASUDA, K., HAYASAKA, S., MITSUI, S., SUGAWARA, K. and

TAKAHASHI, K. (1969) On some geological problems concerning the Tertiary strata of the Izu peninsula, Japan. *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 68, p. 19–31.

* ——— and ——— (1972) Yugashima Group and Shirahama Group. *The Izu Peninsula*, Tokai Univ. Press, p. 189–201.

** KOZU, S. (1913) Résumé on the geology of southern part of the Province of Izu. *Geol. Surv. Japan, Report*, no. 38, p. 1–19.

* KUNO, H. (1968) Subaqueous autobrecciated lava. *Volc. Soc. Japan, Bull., 2nd Ser.*, vol. 13, p. 123–130.

* MATSUDA, T. and YAMASHINA, K. (1974) Surface faults associated with the Izu-Hanto-oki Earthquake of 1974, Japan. *Earthquake Research Institute, Prompt Report*, no. 14, p. 135–158.

MIKAMI, K. (1952) On the so-called potash-liparites from Manzo-yama, Shimoda, Izu Peninsula. *Yokohama National Univ., Sci. Report, Sec. II*, no. 1, p. 55–67.

* MURAI, I. and KANEKO, S. (1974) The Izu-Hanto-oki Earthquake of 1974 and the earthquake faults, especially, the relationships between the earthquake faults, the active faults, and the fractures ystems in the earthquake area. *Earthquake Research Institute, Prompt. Report*, no. 14, p. 159–203.

** SAMESHIMA, T. (1955) Geology of southern part of the Izu Peninsula. Chigaku Shizuhata, no. 8, p. 15–18.

** ——— and MATUI, T. (1960) Geology around Sashida, Minami-Izu-cho, Kamo-gun, Shizuoka Prefecture. (Preliminary report). Chigaku Shizuhata, no. 23, p. 16–18.

** ———, IWAHASHI, T. and KURODA, N. (1968) *Report of the basic research on the geothermal energy development in the Izu peninsula*. Shizuoka Prefectural Government. 88p.

* SAWAMURA, K., SUMI, K., ONO, K. and MORITANI, T. (1970) *Geology of the Shimoda district*. 41p., Quadrangle Series, scale 1: 50,000, Geol. Surv. Japan (in Japanese with English abstract 5p.).

* SHOJI, T. and KOIDE, H. (1975) On the method of analysis of structural directions by the Wulff's net. *Mining Geology*, vol. 25, p. 39–42.

SILVESTRI, S. C. (1963) Proposal for a genetic classification of hyaloclastites. *Bull. Volcanol.*, vol. 25, p. 316–321.

* SUMI, K. (1958) *The geological sheet map "Mikomotojima", scale 1: 50,000 and its explanatory text*. 33p., Geol. Surv. Japan (in Japanese with English abstract 6p.).

** ——— and MAEDA, K. (1974) Finding of alkali olivine basalt from the southern part of Izu peninsula. *Ceol. Soc. Japan, Jour*, vol. 80, p. 137–140.

** TAYAMA, R. and NIINO, H. (1931) Outline of the geology of the Izu peninsula. *Saito Ho-on-kai, Report*, no. 13, p. 1–30.

* UENO, S., TAKESHI, H., KAWADA, S., OMORI, E. and YAMADA, T. (1961) On the so-called potash-liparite of Shimoda District, Shizuoka Prefecture (Especially for row material of potash-fertilizer). *Bull. Geol. Surv. Japan*, vol. 12, p. 839–850.

* WATANABE, K., MIKAMI, K. and SUZUKI, S. (1952) Sedimentation of the Shirahama Group—geology of the eastern region of Shimoda town—. *Geol. Soc. Japan, Jour.*, vol. 58, p. 93–100.

YAMADA, E. (1973) Subaqueous pumice flow deposits in the Onikobe Caldera, Miyagi Prefecture, Japan. *Geol. Soc. Japan, Jour.*, vol. 79, p. 585–597.

* In Japanese with English abstract.
** In Japanese.

# 伊豆半島南東部の新第三系の層序と地質構造

山田 営三

## 要 旨

調査地域の新第三系は，おもに浅海域の火山活動による噴出物とその再堆積物からなっている．これらの地層はおもな火山噴出物の岩質的特徴および地層の岩相上の特徴により，およそ下位から上位に向かって大瀬層，二条層，下賀茂層，青市層，大賀茂層，毛倉野層，板見層および原田層に区分できる．全層厚は約2,500mに達する．

これらの地層は一般に北東－南西方向の長軸をもつゆるやかな褶曲構造ないしドーム・ベーズン構造を呈している．貫入による石英安山岩質の大きな岩体が多数発達する北西部地域では，それらをとりまいてドーム構造が発達しそれらのドーム構造の間に不規則にベーズン構造が発達する傾向がある．

地域の新第三系は多数の小断層により切られており，特に走向 N0°-90°W で60°以上傾斜している小断層が卓越しており，それらのなかには，1974年5月の伊豆半島沖地震の時に動いた石廊崎断層のような活断層と同じ方向を持ち，断層鏡面上に水平に近い条線を残しているものが含まれる．その次にはN40-90°E方向で60°以上傾斜している小断層が多く，その中には，見かけ上数mの上り落差を持つ逆断層が2つ見いだされた．

(受付：1976年9月24日；受理：1977年2月18日)

Plate 20

1. Closely spaced cooling joints, probably developed in the interior of a thick subaqueous andesite lava. The Oose Formation, 1.5 km west of Toji village.
2. The same andesite lava as Pl. 20–1, showing the thin discolored margin developed from the surface of joints.
3. The same as Pl. 20–1. The Itami Formation, 1.2 km west of Shimoda city.
4. Irregularly autobrecciated andesite lava, probably subaqueous origin. The Itami Formation, 1.2 km west of Shimoda city.
5. Subaqueous autobrecciated andesite lava, or hyaloclastite breccia containing angular andesite fragments in a greenish yellow, lapilli- to sand-sized palagonitic matrix. The bedding is probably from upper left to lower right of the photograph as shown by a thin non-brecciated lava bed which seem to extend discontinuously in that direction. The Shimokamo Formation, 1.2 km north of Teishi village.
6. The same as Pl. 20–5, except a thick massive lava part is observable in the upper part of the photograph. The Oose Formation, 1.4 km southwest of Toji village.
7. Slightly spheroidal joints; developed in the interior of subaqueous andesite lava. The Aoichi Formation, 1 km southwest of Kekurano village.
8. The same andesite lava as Pl. 20–7. This is a marginal part of the lava and is blended with the overlying pumice flow deposits on the right side of the photograph.

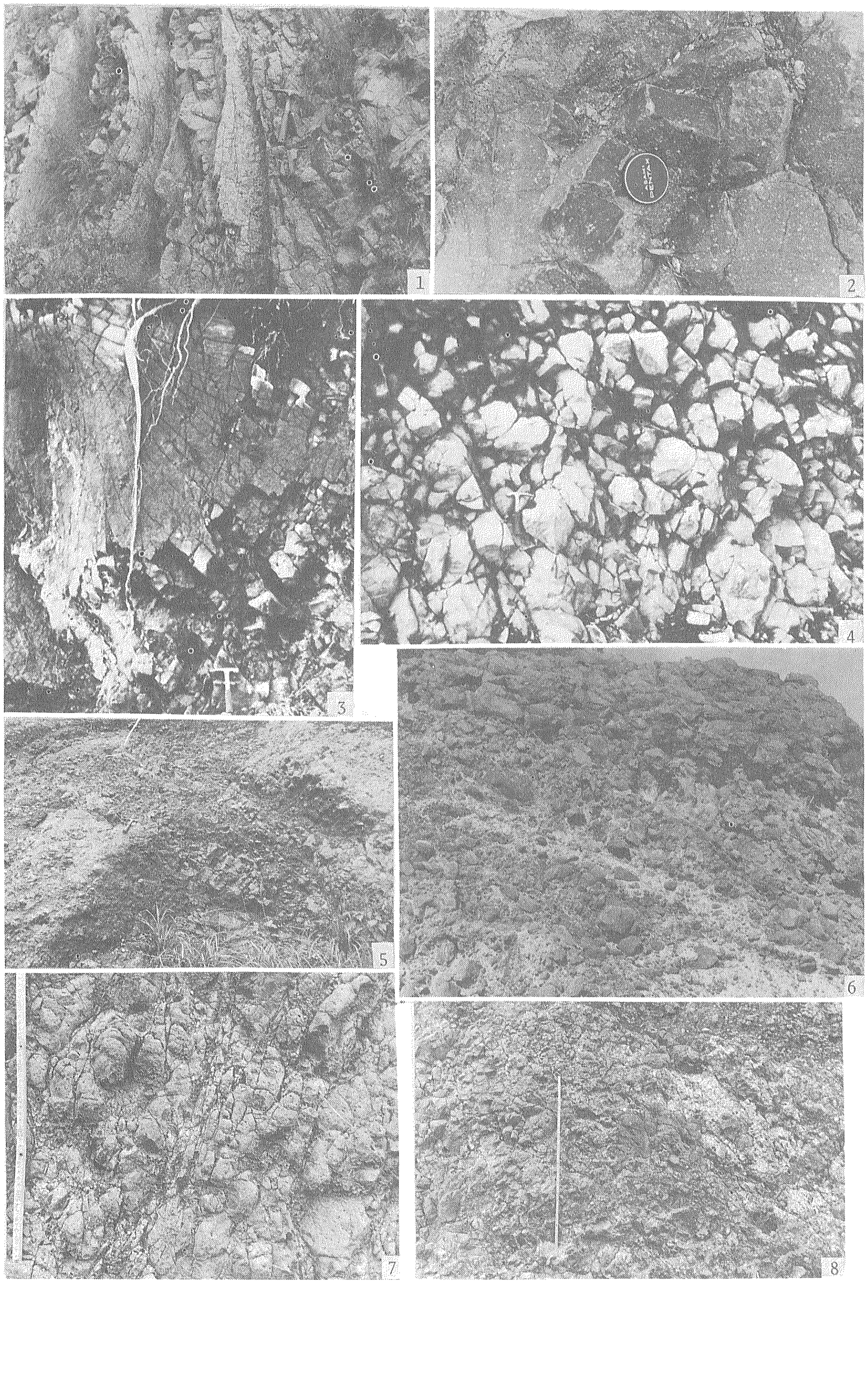

1
2
3
4
5
6
7
8

Plate 21

1. Subaqueous autobrecciated andesite lava or hyalocalstite breccia and the overlying slightly reworked hyaloclastite breccia. The bedding is from upper right to lower left of the photograph. The Oose Formation, 1.5 km west of Toji village.
2. The same as Pl. 21–1, except that the fragments are more angular and blocky in this autobrecciated lava. The Oose Formation, 1.5 km west of Toji village.
3. Andesite fragments having discolored margins of various thicknesses, embedded in a matrix of red scoria, yellow pumice, and volcanic sand. Subaqueous andesitic tuff breccia of the Shimokamo Formation, 1 km north of Teishi village.
4. Subaqueous pyroclastic tuff breccia, containing fragments of various kinds of rocks. Note the andesite bomb in the center of the photograph, which has thick orange to brownish yellow, palagonitic amgrin. The Shimokamo Formation, 0.8 km south southeast of Shimokamo town.
5. Volcanic conglomerate probably of subaqueous debris-flow origin. Basal part of a flow unit comprises finer fragments than the middle part, thus reversely graded. The Aoichi Formation, 1.0 km south of Aoichi village.
6. Andesitic volcanic conglomerate with a well sorted sand matrix and an overlying possibly subaqueous autobrecciated andesite lava or hyaloclastite breccia. The Aoichi Formation, 1.6 km northwest of Rendaiji town.
7. Poorly-sorted subrounded conglomerate, probably deposited by a subaqueous debris-flow. The Shimokamo Formation, 0.8 km south southeast of Shimokamo town.
8. Alternated beds of mainly andesitic conglomerate and sandstone, which were deposited probably by subaqueous debris-flows. In general each flow unit is composed of: a thin finer-grained basal part; a massive, coarse, poorlysorted central part; and a horizontally bedded or laminated sandto gramulesized upper part. The Shimokamo Formation, 0.8 km south southeast of Shimokamo town.
9. Alternated beds of poorly-sorted andesitic conglomerate and sandstone. Sporadically large andesite blocks are embedded. The Shimokamo Formation, 0.8 km south southeast of Shimokamo town.


1
2
3
4
5
6
7
8
9

Plate 22

1. Well-sorted sandstone with wedge-shaped cross-stratification. The Shimokamo Formation, 1.2 km northeast of Kano village.
2. Part of lenticular-shaped cross-stratification. White streaks consist of pumice shreds and the dark gray part is coarse sand. The Shimokamo Formation, 2.0 km northeast of Kano village.
3. Dark-gray hard andesitic tuff breccia and overlying white rhyolitic tuff in which a wedge-shaped, dark-gray andesitic tuff-breccia bed is intercalated. The Aoichi Formation, 0.4 km south of Magome village.
4. Dark-gray hard andesitic lapilli-tuff, which has a thin finer sandy part at the top, is overlain apparently conformably by a conglomerate bed containing blocks of porphyritic dacite. The Kekurano Formation, 0.9 km northeast of Kekurano village.
5. Large porphyritic dacite blocks embedded in a sorted sand matrix, which has a vague stratification trending from upper right to middle left of the photograph. The Kekurano Formation, 0.9 km northeast of Kekurano village.
6. Alternated hard beds of parallel- and cross-laminated sandstone and chocolate-colored siltstone. The Itami Formation, 1.2 km west of Shimoda city.
7. Irregularly alternating beds of sandstone and conglomerate, consisting of subrounded dacite cobbles and pebbles in a pumice tuffaceous matrix. The Shimokamo Formation, 1.4 km west southwest of Ichijo village.

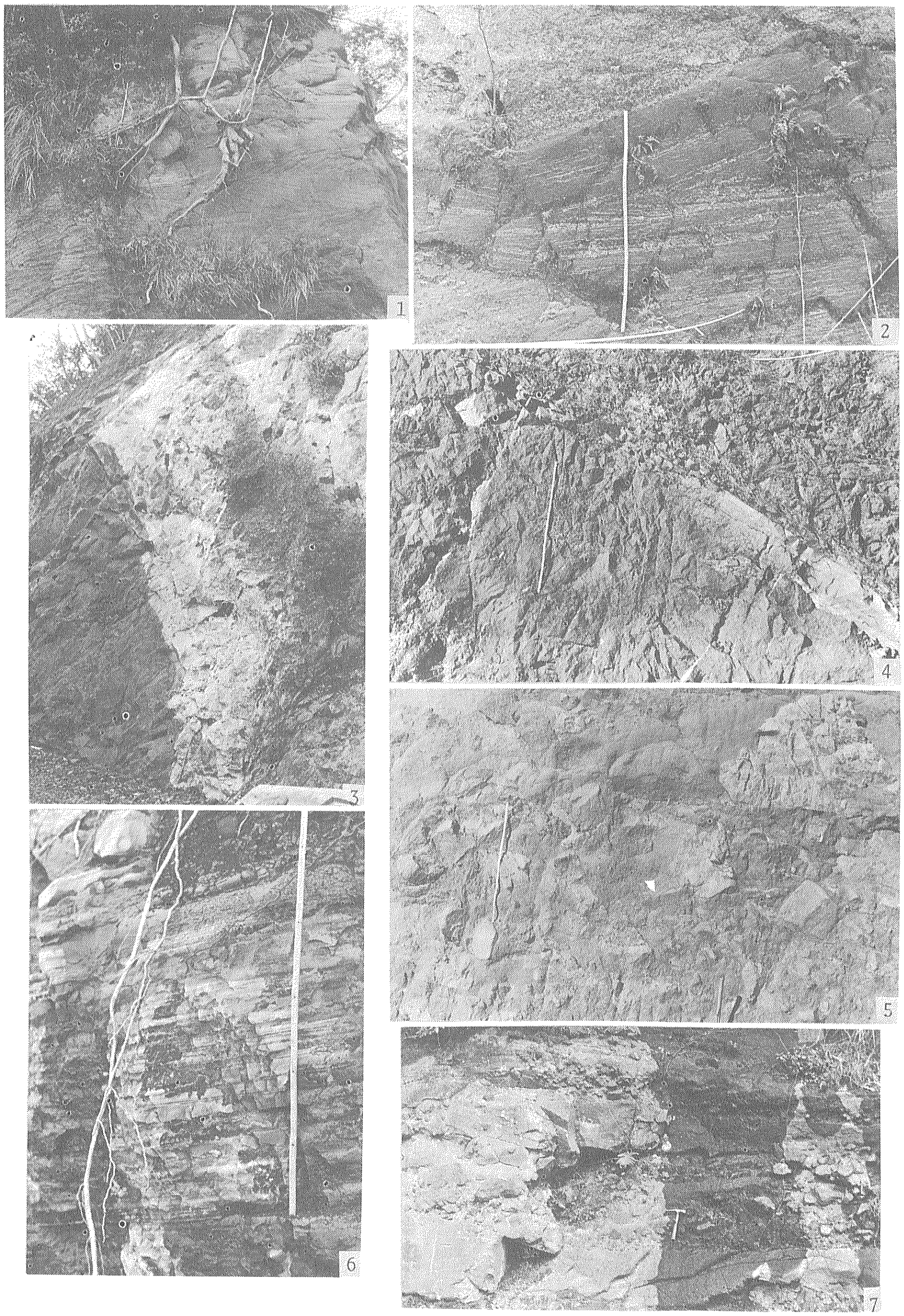

1
2
3
4
5
6
7

Plate 23

1. Intrusive contact between gently dipping andesite dike above and white rhyolitic pumice tuff-breccia below. Below the contact plane, the pumice tuff-breccia has been hardened by thermal effect for an interval of about 150 cm. The Ookamo Formation, 0.5 km east of Rinsan village.
2. Rhyolite dike with flow bands. 0.6 km east of Rinzan village.
3. Intrusive contact between gently dipping andesite dike below and andesitic volcanic breccia above. Cooling joints of the andesite dike are closer spaced nearer the contact surface. The andesite dike has a darker-gray zone a few tens of centimeters thick along the contact surface. The Oose Formation, 0.6 km southeast of Irozaki village.
4. Probably an intrusive contact between siltstone to the left and andesite dike to the right. The andesite dike is autobrecciated near the contact surface. The Shimokamo Formation, 1.4 km northwest of Kano village.
5. Clastic dikes intruded into joints of andesite lava. The Oose Formation, 0.4 km southeast of Oose village.
6. A probable intrusive contact between white acid tuff to the left and andesite dike to the right. The Ookamo Formation, 1.0 km west southwest of Rendaiji town.
7. A large white-gray acid tuff block, probably embedded in dark-gray, weathered dacite lava. The Nijo Formation, 0.8 km southwest of Kano village.

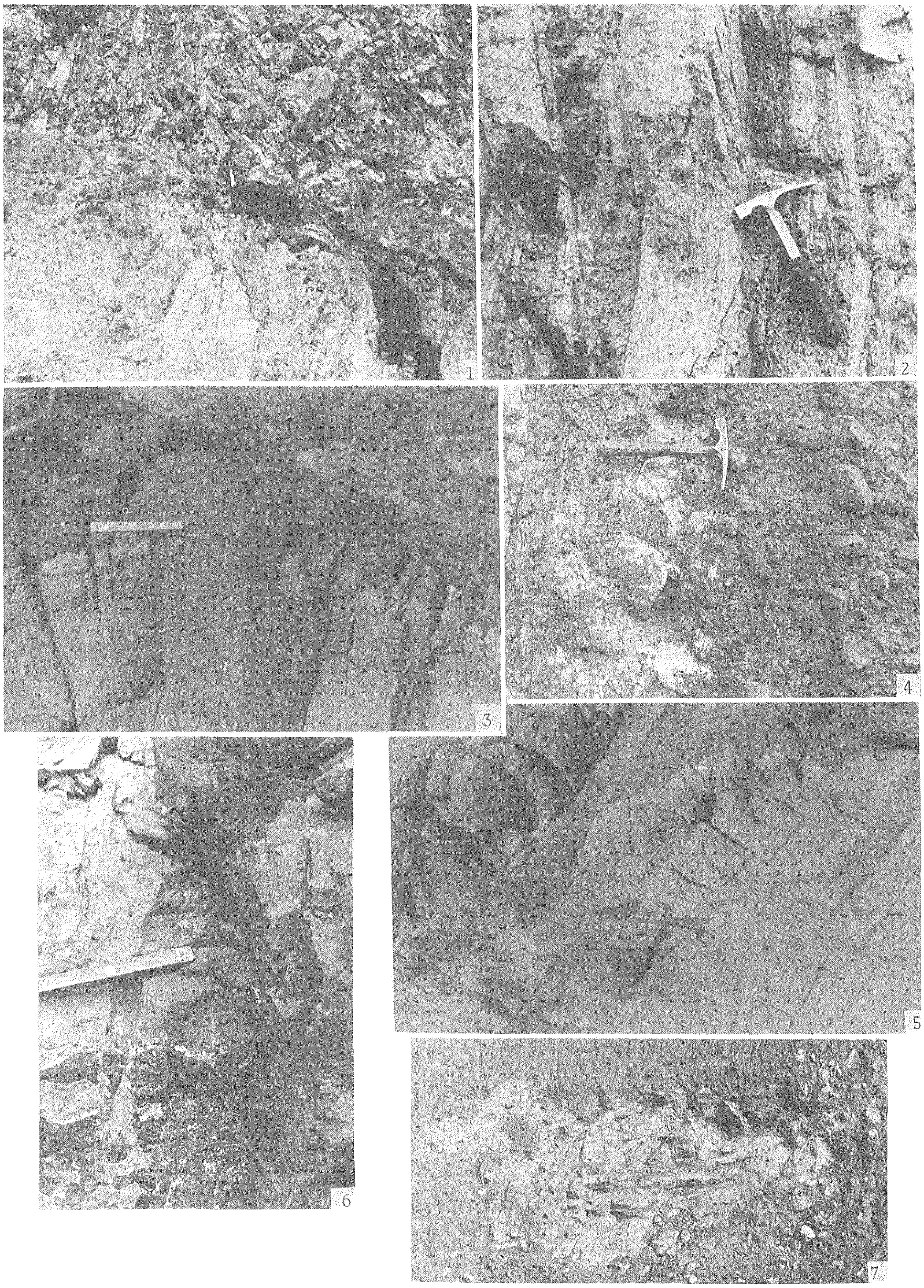
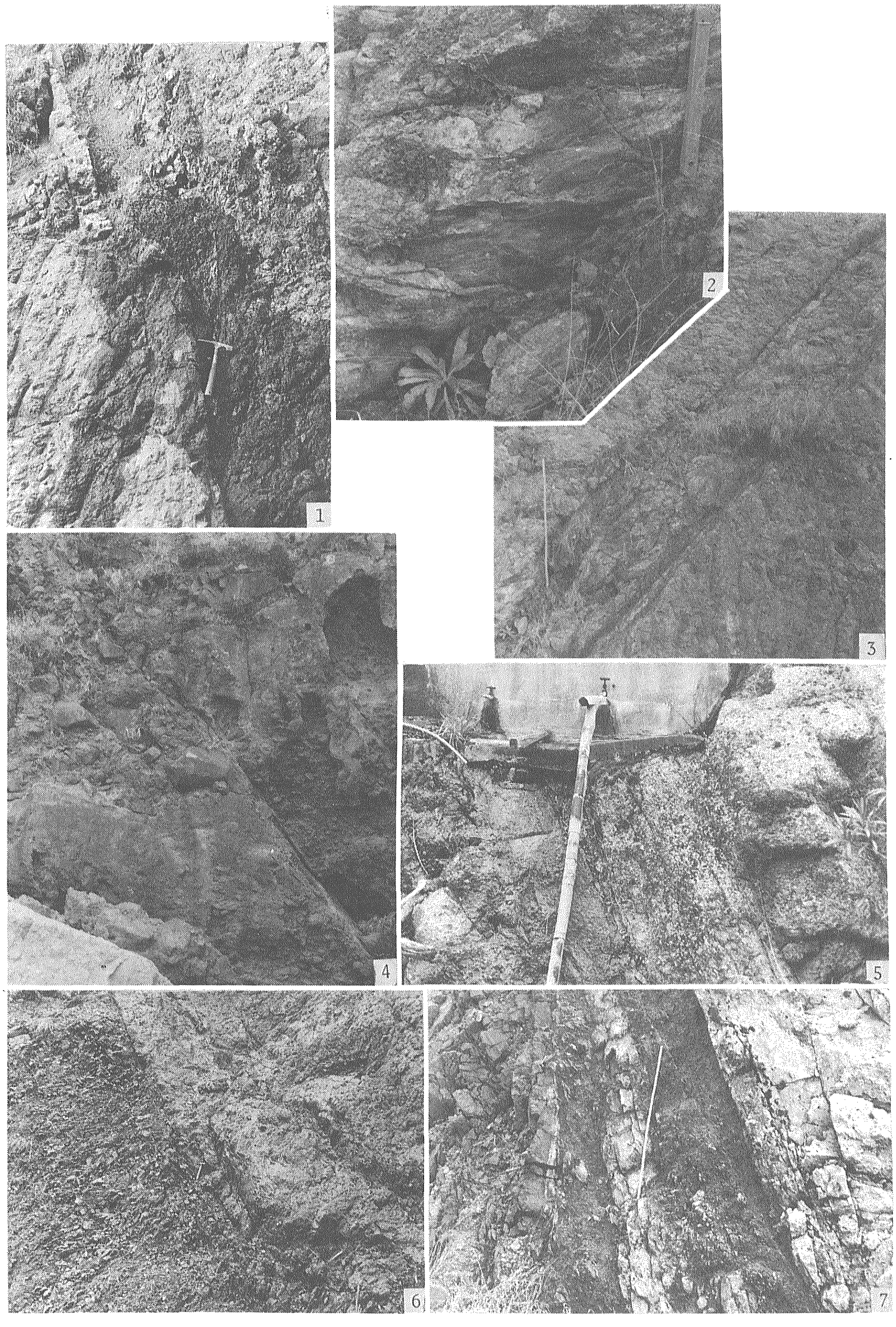

1
2
3
4
5
6
7

Plate 24

1. Fault contact between dacite lava of the Nijo Formation to the left and steeply dipping autobrecciated andesite lava of the Shimokamo Formation to the right. The fault strikes N21°E and dips 80°E and is slightly crooked in the middle part of the photograph. 0.3 km west of Kano village.
2. Nearly horizontal striations on the slickenside of a fault. This is a closer view of the lower left corner of Pl. 24–3.
3. Fault contact between dacite lava of the Nijo Formation to the right and andesitic lapilli-tuff of the Shimokamo Formation to the left. The two closely spaced parallel faults strike N86°W and dip 80°S. 1.0 km southwest of Kano village.
4. An apparently reverse fault with a throw of 5m, cutting andesite lava and autobreccia of the Oose Formation. The fault surface is sharp and strikes N34°E and dips 55°E. 1.0 km southwest of Shitaru village.
5. Fault with a shear zone, cutting pumice flow deposits of the Shimokamo Formation. Thermal water is tapped from the sheared zone which is slightly altered by the hydrothermal activity. The trend of the fault surface is N82°W and it dips 81°S. 0.4 km south southwest of Kano village.
6. Fault cutting hyaloclastic andesite breccia of the Shimokamo Formation. The fault is a sharp shear plane and strikes N78°W and dips 71°S. 1.2 km north of Teishi village.
7. Fault contact between andesite lava probably of the Aoichi Formation to the left and altered pumice tuff of the Ookamo Formation to the right. The fault has a wide shear zone, and the direction is E–W, 72°S. 1.0 km north northeast of Horikiri village.

   (Full length of the six-fold scale, the rock hammer, and the diameter of the lens cap in the photographs are 100 cm, 28 cm and 5 cm respectively).


1
2
3
4
5
6
7