# LARGE *DECKE* STRUCTURES AND THEIR FORMATIVE PROCESS IN THE SAMBAGAWA-CHICHIBU, KUROSEGAWA AND SAMBOSAN TERRAINS, SOUTHWEST JAPAN

By

**Akihiro MURATA**

**Abstract**

Many large overthrusts have moved Paleozoic and Mesozoic strata toward south or southeast, producing *decke* structures in the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains in Southwest Japan. The *decke* structures and their thrusting process in Kyushu, through Shikoku, to Kii Peninsula have been clarified by the detailed analyses of geologic structures.

Four large *deckes*, all trending in the ENE-WSW to NE-SW direction, are arranged from north to south in Kyushu to Shikoku; the Kashimine-Kitatada-Ikegawa, Nanokawa-Onoyama, Shiraiwayama-Uonashi-Kambaradani, and Gomayama-Unomachi *deckes*, which moved along the Kashimine-Kitatada-Ikegawa, Nanokawa-Onoyama, Shiraiwayama-Uonashi-Kambaradani, and Butsuzo thrusts respectively.

The four large overthrusts have south- or southeastward vergence and are accompanied with smaller thrusts. The overthrusts observed in the earth surface probably join to form a master *decollement* in a deeper level of the crust. A northern thrust was always formed after the formation of a southern thrust. The master *decollement* or the Butsuzo thrust formed probably at first, and then the northern thrusts formed successively, branching off the master *decollement*. Along the master *decollement*, strata of the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains moved southward over the Shimanto supergroup at certain ages between Late Cretaceous and Paleogene.

## I. INTRODUCTION

The Sambagawa-Chichibu, Kurosegawa, Sambosan, Shimanto and Setogawa-Nakamura terrains, all trending in the E-W direction, are zonally arranged from north to south in Southwest Japan (Fig. 1). Carboniferous to Jurassic strata which were deposited in the southern part of the Chichibu geosyncline are distributed in the Sambagawa-Chichibu terrain. The strata of the Sambagawa terrain in the north have undergone the high pressure-type Sambagawa metamorphism, whereas those of the Chichibu terrain in the south are weakly or not metamorphosed.

Carboniferous to Permian geosynclinal strata, Late Triassic, Late Jurassic and Early Cretaceous shelf facies strata are distributed in the Kurosegawa terrain (ICHIKAWA *et al.*, 1956). Granitic rocks, metamorphic rocks and Silurian strata which had been the basement rocks of the Carboniferous to Triassic strata are also distributed there. Minor geosynclinal strata are distributed in the Sam-

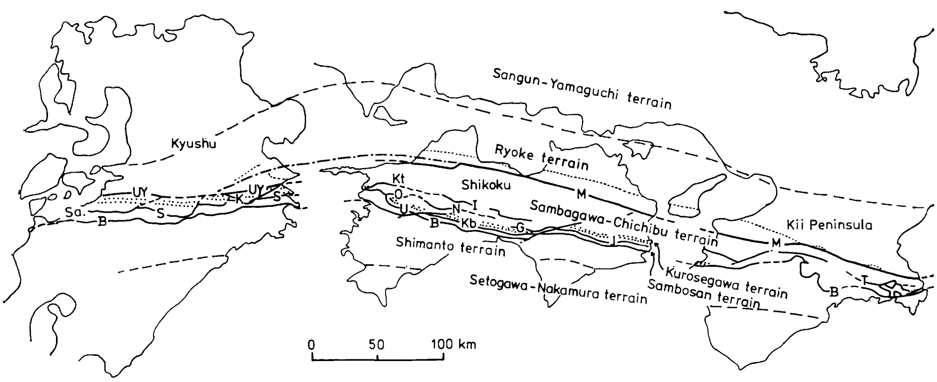
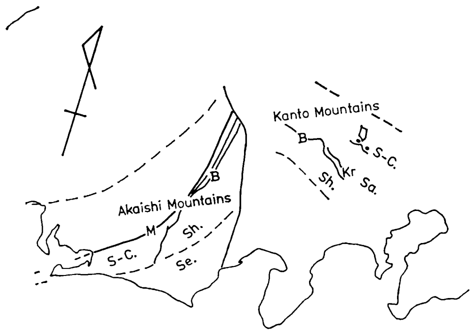



Fig. 1. Large overthrusts in the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains. M: Median Tectonic Line, UY: Usuki Yatsushiro Tectonic Line, S: Shiraiwayama thrust, K: Kashimine thrust, B: Butsuzo Tectonic Line (Butsuzo thrust), Kt: Kitatada thrust, O: Onoyama thrust, U: Uonashi thrust, I: Ikegawa thrust, N: Nanokawa thrust, Kb: Kambaradani thrust, G: Gozaishoyama thrust, J: Junisha thrust, T: Takihara thrust, Kr: Kurasawa thrust.

bosan, Shimanto and Setogawa-Nakamura terrains. The Sambosan geosyncline is of Carboniferous to early Jurassic, and the Shimanto geosyncline and Setogawa-Nakamura geosyncline are of Jurassic to Cretaceous and of Paleogene respectively (KIMURA, 1974).

The Sambagawa-Chichibu, Kurosegawa and Sambosan terrains are recently interpreted by means of "subduction tectonics". For example, OGAWA (1978) considered that the Sambagawa terrain was an ancient subduction zone. HORIKOSHI (1972) considered that the Kurosegawa terrain was an ancient trench, into which the "Kurosegawa islands" had fallen. HADA *et al.* (1979) and MARUYAMA (1978) regarded the Sambosan terrain as an accretionary prism, in which trench-fill sediments were accreted against the Kurosegawa terrain. These interpretations, however, failed to take the Permian to Triassic paleogeography into account.

The Kurosegawa terrain had sialic basements, and formed chain of islands or shallow submarine swells from Carboniferous to Triassic. These islands and surrounding of shallow sea were called the Kurosegawa islands-area (KIMURA *et al.*, 1975; MURATA, 1981b). The Chichibu geosyncline, 200 to 300 km wide, was present between the Hida continent (the Hida terrain) and the Kurosegawa islands-area. It was similar to present-day marginal sea (KIMURA, 1980). The Sambosan minor geosyncline was situated in the southeastern side (oceanic side) of the Kurosegawa islands-area. The Sambosan geosyncline was a narrow sedimentary basin and had shallow submarine swells along its southern margin (KIMURA *et al.*, 1975; MURATA, 1981a). A subduction zone and a trench must have been present on the oceanic side of the Sambosan minor geosyncline (KIMURA, 1980). The Sambagawa-Chichibu, Kurosegawa and Sambosan terrains are interesting and important areas to understand Paleozoic to Mesozoic tectonic developments of Southwest Japan, because those terrains were situated near the




subduction zone and trench at that time.

Large overthrusts such as the Kambaradani thrust, (KOBAYASHI, 1931), the Uonashi thrust (IKEBE, 1936) and the Butsuzo thrust (KOBAYASHI, 1941) exist in and along the southern margin of the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains (Fig. 1). KOBAYASHI (1941) clarified that these large overthrusts formed the imbricate structure of large scale in Shikoku. KIMURA (1957) and SHIIDA (1962) also clarified *decke* structures in Eastern and Central Kii Peninsula respectively. Large overthrusts in the Sambagawa-Chichibu and Sambosan terrains in Shikoku, however, are not sufficiently clarified on their significance, except for the Nanokawa thrust (KIMURA and HORIKOSHI, 1959).

MURATA (1981a, b) clarified that there exist large overthrusts such as the Shiraiwayama thrust and the Kashimine thrust in the Kurosegawa and Sambosan terrains in Kyushu. MURATA *et al.* (1980) also clarified that a large overthrust, called the Onoyama thrust, exists in the Chichibu and Sambosan terrain in Western Shikoku. On the basis of those results, I made investigation of the Sambagawa-Chichibu and Sambosan terrains from Kyushu to western Central Shikoku. As a result, many facts have made clear the presence of the large overthrusts and their thrusting process.

Analyses of geologic structures with conodont biostratigraphy have clarified that many thrusts of smaller scale also exist in the Chichibu and Sambosan terrains. These thrusts form the imbricate structure of small scale. In addition, analyses of the stratigraphy revealed that Permian to Triassic strata change their lithofacies from the Chichibu geosyncline, through the Kurosegawa islands-area, to the Sambosan geosyncline.

I will describe the stratigraphy and geologic structures of the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains from Kyushu to western Central Shikoku. On the basis of them, I will discuss chiefly the thrusting process of the large overthrusts in those terrains of Southwest Japan.

## II. KUROSEGAWA AND SAMBOSAN TERRAINS IN KYUSHU

Stratigraphy and geologic structures of the Kurosegawa and Sambosan terrains in Kyushu have already been described in detail elsewhere (MURATA, 1981a, b). These results are briefly summarized here. The most parts of the terrains are occupied by two large *deckes*. They are the northern Shiraiwayama *decke* moved along the Shiraiwayama thrust (MURATA, 1981b), and the southern Gomayama *decke* along the Butsuzo thrust (Fig. 2). The Shiraiwayama *decke* thrusts itself southeastward over the Gomayama *decke*, which also thrusts itself southeastward over the Shimanto supergroup. The Kashimine *decke* thrusts itself over the Shiraiwayama and Gomayama *deckes* along the Kashimine thrust in Eastern Kyushu (Fig. 2).

The Shiraiwayama *decke* consists of two geologic units, the strata of the Kurosegawa terrain in the north and those of the northern Sambosan terrain in the south. The Kashimine *decke* is characterized as the Kurosegawa terrain. The Gomayama *decke* consists of the strata of the southern Sambosan terrain in the north and those of the southern marginal Sambosan terrain in the south

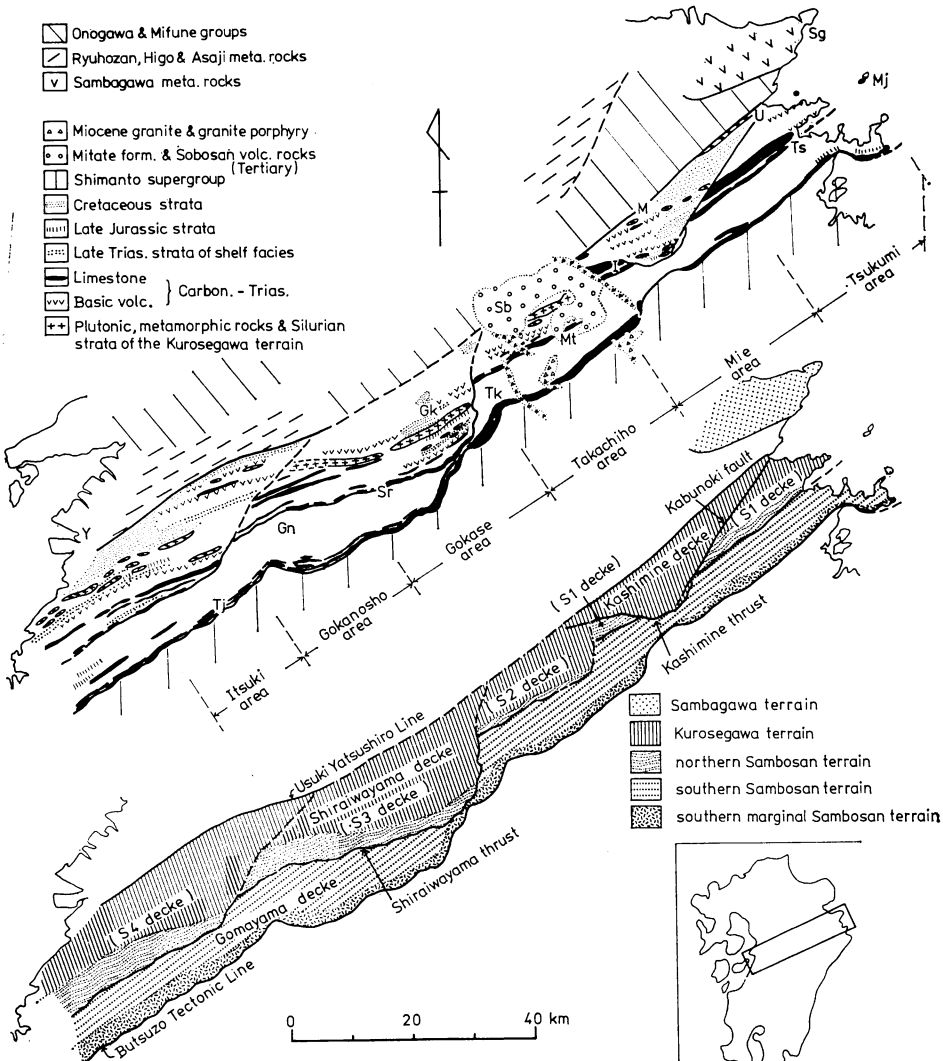



Fig. 2. Geologic and structural maps of the Kurosegawa and Sambosan terrains in Kyushu. Sg: Saganoseki Peninsula, Mj: Mukujima Island, U: Usuki, Ts: Tsukumi, M: Mie, Mt: Mitate, Sb: Mt. Sobo, Tk: Takachiho, Gk: Gokase, Sr: Mt. Shiraiwayama, Gn: Gokanosho, Tj: Toji, Y: Yatsushiro.

Table 1. Main lithologic characters of the Kurosegawa and Sambosan terrains in Kyushu.

| terrain \ age | Carbon. | Permian | Triassic Low. | Triassic Mid. | Triassic Up. | Jura. |
|---|---|---|---|---|---|---|
| Kurosegawa terrain | Basic volc., chert, limestone, sandstone & slump congl. | | | | cgl., ss, ms, alt. ss & ms | |
| northern Sambosan terrain | | limestone, chert, calcareous sandstone & slump congl. | | | | |
| southern Sambosan terrain | | | chert, sandstone & alternation of ss & ms | | | |
| southern marginal Sambosan terrain | | | | limestone, basic volcanics, chert & slump congl. | | |

(Fig. 2). Lithologic characters of the strata in each terrain are summarized in Table 1.

**1. The Shiraiwayama thrust and the Shiraiwayama *decke*.**

The Shiraiwayama thrust runs along the southern margin of the Permian limestone layers of the northern Sambosan terrain in Kyushu. Not only the strata of the northern Sambosan terrain, but also those of the Kurosegawa terrain thrust themselves southeastward. The thrust is inferred to dip fairly gently under the Kurosegawa terrain (MURATA, 1981b).

The Shiraiwayama *decke* measures about 10 km in width and 150 km in length (Fig. 2). The Shiraiwayama *decke*, however, is not a single *decke*, but consists of four *subdeckes*, each of which is about 10 km in width and 25 to 50 km in length. They are, from northeast to southwest, S 1 *decke* in the Tsukumi and Mie areas, S 2 *decke* in the Takachiho area, S 3 *decke* in the Gokase and Gokanosho areas and S 4 *decke* in the Itsuki area. The S 1 *decke* is covered by the S 2 *decke* on the west, the S 2 *decke* by the S 3 *decke* on the west, and the S 3 *decke* by the S 4 *decke* on the west (Fig. 2).

The strata of the Kurosegawa and northern Sambosan terrains are arranged in a left-handed *echelon* pattern as a whole. Any *subdecke* in the west is thrust further southeastward than a neighbouring *subdecke* in the east. Each *subdecke* is inferred to have moved southeastward with a slight clockwise rotation. The Shiraiwayama thrust is not a single thrust, but a set of four thrusts having moved the S 1, S 2, S 3 and S 4 *deckes*.

**2. The Kashimine thrust and the Kashimine *decke*.**

The Kashimine thrust in Eastern Kyushu moved the strata of the Kurosegawa terrain toward southeast over those of the northern Sambosan terrain which had also thrust themselves southeastward along the Shiraiwayama thrust, and further over those of the southern Sambosan terrain (MURATA, 1981b) (Fig. 2). The southern Sambosan terrain of about 5 km wide in Eastern Kyushu narrows to 2.5 km in the central part of the Mie area. The Permian limestone layers of the northern Sambosan terrain are distributed across Kyushu except for in the central part of the Mie area, where they are covered by the Kashimine *decke*. The *decke* is bordered on the eastern side by the high-angled

Kabunoki fault. The Cretaceous Onogawa group and the Sambagawa metamorphic rocks in the Saganoseki Peninsula have probably been moved southeastward along the Kashimine thrust (MURATA, 1981b) (Fig. 2).

## III. CHICHIBU AND SAMBOSAN TERRAINS IN WESTERN SHIKOKU

Stratigraphy and geologic structures of the Chichibu and Sambosan terrains in Western Shikoku were studied by HIRAYAMA & KAMBE (1956) and KASHIMA (1967, 1969). KASHIMA (1967) tried to correlate several formations in Western Shikoku with those in Eastern Kyushu. In the present study, the Kurosegawa terrain was successfully traced from Western Shikoku to Eastern Kysuhu, and lithology in both areas was reasonablly correlated.

The Sambagawa-Chichibu, Kurosegawa and Sambosan terrains in Western Shikoku are occupied by four large *deckes*. They are, from north to south, the Kitatada *decke* (western portion of the Kitatada-Ikegawa *decke* in Fig. 3), the Onoyama *decke* (western portion of the Nanokawa-Onoyama *decke*), the Uonashi *decke* (western portion of the Uonashi-Kambaradani *decke*) and the Unomachi *decke*, which moved along the Kitatada thrust, the Onoyama thrust (MURATA *et al.*, 1980), the Uonashi thrust (IKEBE, 1936), and the Butsuzo thrust (KOBAYASHI, 1941) respectively (Fig. 3).

The Onoyama *decke* consists of the strata of the Chichibu terrain. The Uonashi *decke* consists of the strata of the Kurosegawa terrain in the north and those of the northern Sambosan terrain in the south. The Unomachi *decke* consists of the strata of the southern Sambosan terrain in the north and those of the southern marginal Sambosan terrain in the south (Fig. 3). The Kitatada *decke* is described in the Chapter V.

### 1. Stratigraphy.

*Chichibu terrain.*

Succession and lithology: Strata of the Chichibu terrain, here described, are correlative with the Kume, Saitaro, Futaiwa and Uwagawa formations of KASHIMA (1969). Carboniferous to Permian strata of the terrain consist of basic submarine volcanics, cherts, limestones, sandstones, mudstones, alternations of sandstone and mudstone, slump breccias*, and chert-laminites (YOSHIDA, 1981) (Fig. 4). Triassic strata consist mostly of cherts, slump breccias, siliceous mudstones and chert-laminites. The lithofacies characterized by chert-laminites and sandstones which are distributed near Kitatada in the northwestern part of the area change toward east into cherts, sandstones and slump breccias. Weak schistosities are observed in the sandstones and cherts of the northern marginal Chichibu terrain.

The basic volcanics are dark green to dark reddish purple in color, and consist of tuffs and lavas; reddish purple tuffs 100 m thick near Torikubi, pillow lavas to the northeast of Mikame. They contain chlorite, epidote and pumpellyite

* "Slump conglomerates" in the previous paper (MURATA, 1981 b).

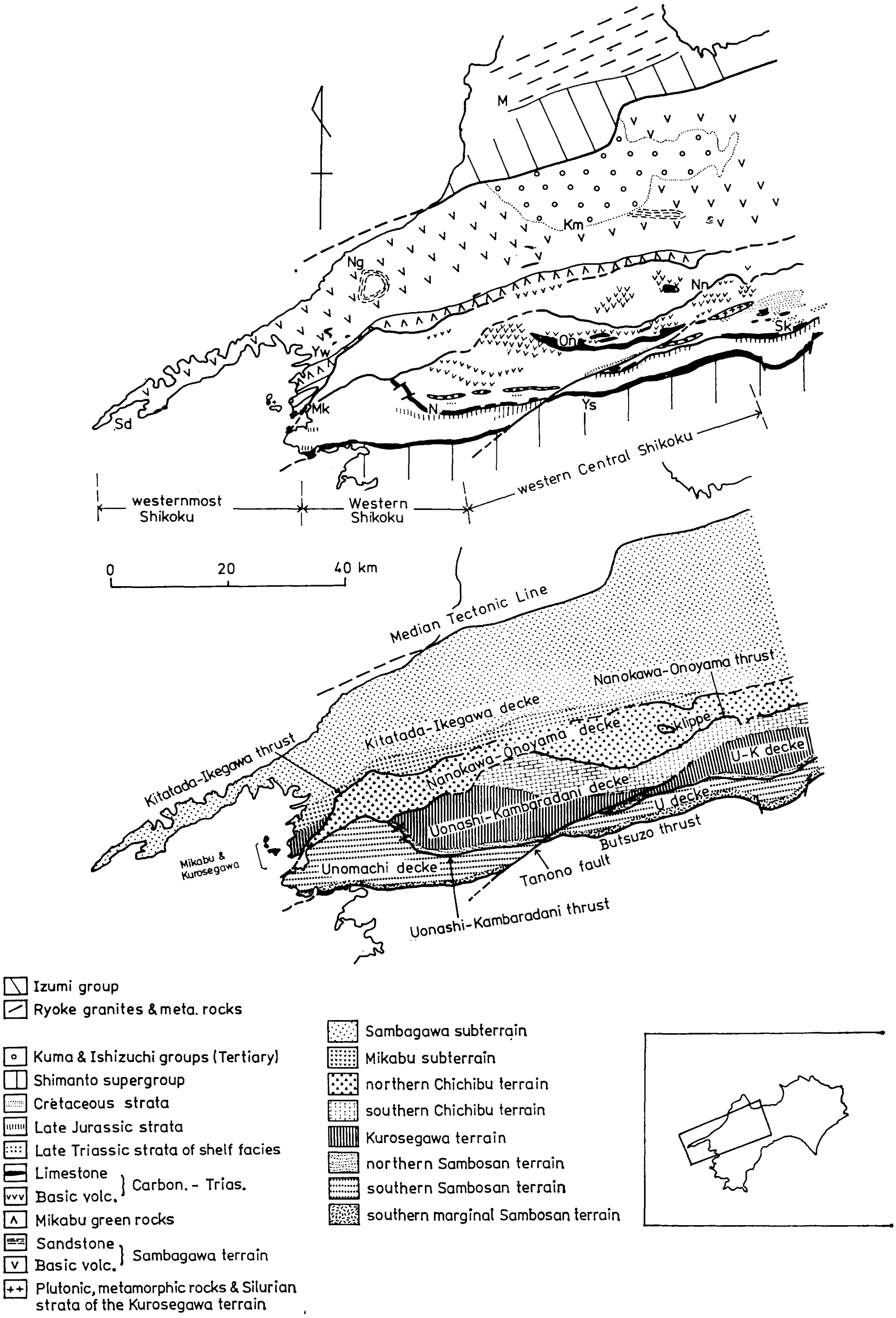



Fig. 3. Geologic and structural maps of the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains in Shikoku. Sd: Sadamisaki Peninsula, Ng: Nagahama, Yw: Yawatahama, Mk: Mikame, M: Matsuyama, N: Nomura, Km: Kuma, On: Onogahara, Ys: Yusuhara, Nn: Nanokawa, Sk: Sakawa,

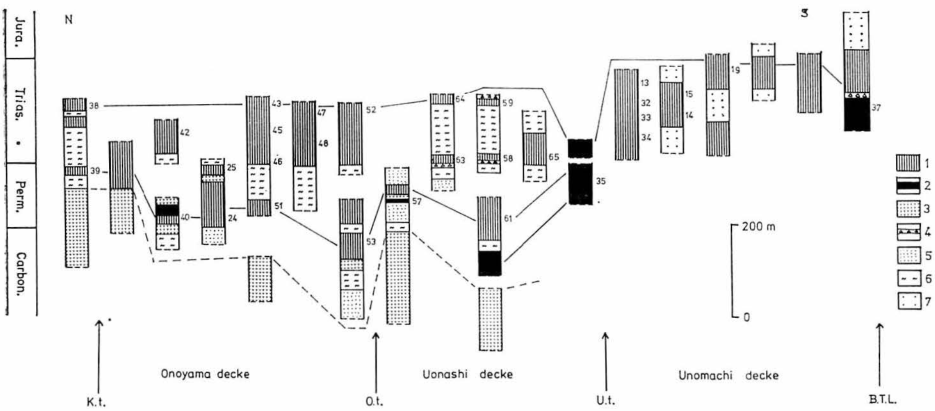



Fig. 4. Successions of layers in the Chichibu and Sambosan terrains in Western Shikoku. K.t.: Kitatada thrust, O.t.: Onoyama thrust, U.t.: Uonashi thrust, B.T.L.: Butsuzo Tectonic Line. 1: chert, 2: limestone, 3: basic volcanics, 4: acid tuff, 5: sandstone, 6: slump breccia and mudstone, 7: sandstone, alternation of sandstone & mudstone.

as metamorphic minerals, and titanaugite as relict phenocryst.

The cherts are bluish gray, gray, light reddish purple or red, and bedded. They yield Carboniferous to Triassic conodonts. The limestones are distributed to the north of Torikubi, west of Kanogawa, north of Mt. Onoyama and southwest of Kitatada, and dolomitic in places (MIYAHISA and KASHIMA, 1967). The limestones near Torikubi and Mt. Onoyama accompany bedded cherts closely, and in places alternate with them.

The sandstones are widely distributed to the north of Kanogawa and along the Kume River. They are medium to coarse grained. Grains are angular to subangular, and are made of quartz, feldspar, chert and mudstone fragments. The matrix is small in amount. Some sandstone beds show graded bedding. The mudstones are black colored and have sandstone laminae.

The slump breccias consist of angular to subangular clasts of S-size (KIMURA, 1980) and mudstone or microbreccia matrix. Clasts consist of sandstone, chert and basic volcanics. The siliceous mudstones are light greenish gray and very fissile, and are of the late Scythian like those of the Kurosegawa and Sambosan terrains in Kyushu. The chert-laminites (YOSHIDA, 1981) are thinly alternated beds of chert 0.1 mm to 1 mm thick, and claystone 0.1 to 0.5 mm thick.

Age: Some cherts yield Carboniferous to Permian conodonts such as *Neogondolella* sp. and *Hindeodella* sp. at Locs. 40 & 51 near Torikubi and at Loc. 24 to the southwest of Kitatada, and Permian conodonts such as *Neogondolella* sp. at Kanogawa (Loc. 53) (Table 2). Some cherts and siliceous mudstones yield Triassic (Scythian to Norian) conodonts such as *Neospathodus homeri*, *N. timorensis*, *Neohindeodella benderi* (Locs. 25, 26, 27 & 46), *Neogondolella foliata*, *N. polygnathiformis* (Locs. 29, 41, 42, 47 & 48) and *Epigondolella bidentata*, *E. abneptis*, *E. primitia* (Locs. 28, 42, 43) (Table 3). The strata of the Chichibu terrain extend in age probably to Jurassic, because those of Eastern Shikoku and Western

Table 2. Permian conodonts in Shikoku.

| Species \ Locality | 5 | 24 | 39 | 40 | 51 | 53 | 61 | 69 | 70 | 71 | 73 | 75 | 79 | 80 | 81 | 82 | 83 | 88 | 91 | 92 | 95 | 96 | 97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Anchignathodus* sp. | | | | | | | | | | | | | | | | ? | | | | | | | |
| *Cypridodella* sp. | X | | | | | | X | | | | | | | | | | | | | | | | |
| *Diplognathodus* sp. | | | | | | | | | | | | X | | | | | | | | | | | |
| *Gondolella* sp. | | | | | | | | | | | | | | | X | | | | | | | | |
| *Hindeodella* sp. | X | | | | X | | X | X | | | X | | | | X | | | X | | | | X | X |
| *Idiognathus* sp. | | | | | | | | | | | | | | | ? | | | | | | | | |
| *Neogondolella* sp. | | X | X | X | X | X | X | X | X | X | X | X | X | X | | | X | X | X | X | X | X | X |
| *Neostreptognathodus* sp. | ? | | | ? | | | | ? | | | | | | | | | | X | | | | | |
| *Xaniognathus* sp. | X | | | | X | | X | | | X | | | | X | | | | | | | X | | |

Kii Peninsula yield Jurassic-type radiolarians (ISOZAKI *et al.*, 1981 ; SUYARI *et al.*, 1982).

*Kurosegawa terrain.*

Carboniferous to Triassic strata of the Kurosegawa terrain consist of basic volcanics, bedded cherts, limestones, slump breccias, sandstones, calcareous sandstones and acid tuffs (Fig. 4). Besides them, Late Triassic *Monotis*-bearing strata occur to the north of Nomura (HADA, 1974).

The basic volcanics are distributed near Kanogawa, and consist of pillow lavas 200 m thick. The limestones are distributed to the southwest of Kanogawa. The slump breccias consist of clasts of S-size (KIMURA, 1980) and mudstone or microbreccia matrix. Clasts consist of sandstone, chert, basic volcanics and limestone. The sandstones are distributed near Kanogawa, and quartz-feldspathic. The calcareous sandstones are distributed to the east of Mt. Onoyama, and contain much calcite in the matrix. The acid tuffs, distributed along the Kanogawa River, are massive and light blue to light green in color. They gradually change into bedded cherts vertically.

The pillow lavas are overlain by the Permian fusulinid-bearing limestones, and is possibly of late Carboniferous to early Permian age. The limestones yield *Pseudofusulina regularis* and *P. kaerimizensis* at Locs. 55, 56, 57 & 62 to the west of Kanogawa (KASHIMA, 1969). The cherts yield Permian conodonts such as *Neogondolella* sp. and *Hindeodella* sp. at Loc. 61 to the west of Kanogawa. The cherts also yield *Neospathodus homeri* (Locs. 58 & 65) (Scythian) and *Neogondolella polygnathiformis* (Locs. 59 & 63) (Carnian) near Kanogawa (Table 3).

*Northern Sambosan terrain.*

The Permian to Triassic strata of the northern Sambosan terrain consist mostly of limestones and slump breccias. Some limestones are dolomitic (MIYAHISA and KASHIMA, 1967). Some limestones yield Permian fusulinids such as *Pseudoschwagerina minatoi* and *Neoschwagerina craticulifera* (KASHIMA, 1969). Some limestones, called the Tao limestone, yield Triassic ammonoids (BANDO, 1964) and Scythian to Norian conodonts (KOIKE, 1979). The Tao limestone is correlative with the Kamura formation (KAMBE, 1963) of Central Kyushu and the Gobangatake formation (KAMBE and TERAOKA, 1968) of Eastern Kyushu, judging from their age and tectonic position.

*Southern Sambosan terrain.*

The Permian (?) to early Jurassic (?) strata of the southern Sambosan terrain are widely distributed in the southern part of the area, and consist mostly of bedded cherts, sandstones, and alternations of sandstone and mudstone. The lithologic characters of the southern Sambosan terrain are similar in both areas, Western Shikoku and Kyushu. Basic lavas are rare and exceptionally distributed to the east of Unomachi. Most of sandstones are gray to grayish black, angular to subangular grained and quartz-feldspathic. Many of sandstone beds in the alternations of sandstone and mudstone show graded bedding.

The cherts yield Ladinian to Norian conodonts such as *Carinella mungoensis* (Loc. 32), *Neogondolella foliata* (Locs. 14, 32, 33, 34 & 36), *N. polygnathiformis* (Locs. 13, 15 & 22), *Misikella hernsteini* (Loc. 19) (Table 3). Some cherts are probably of the Permian and Early Triassic, as well as the cherts of the southern Sambosan terrain in Kyushu. The strata of this terrain contain probably early Jurassic strata, because strata of the Yusuhara subarea, 80 km east of Nomura, yield Jurassic-type radiolarians (TAIRA *et al.*, 1979).

*Southern marginal Sambosan terrain.*

The strata of the southern marginal Sambosan terrain consist mostly of limestones, bedded cherts, sandstones, basic volcanics, acid tuffs and slump breccias (Fig. 4). The lithologic characters of this terrain are similar in both areas, Western Shikoku and Kyushu. The limestones are grayish white, and sparry in general. The sandstones are mostly quartz-feldspathic, and some contain many basic volcanic fragments. The acid tuffs are distributed near Takayama in the southwestern margin of the area, and gray to light green. Acid tuff breccias also occur there (KIMURA *et al.*, 1975).

The limestones yield *Epigondolella abneptis* of Norian age (SAKAGAMI and WATANABE, 1972). A thick chert layer overlies the conodont-bearing limestones. The chert is possibly of Jurassic age. Late Jurassic strata, correlative with the Torinosu group, are distributed in the southern and southern marginal Sambosan terrains (KASHIMA, 1969; NAGAI and KASHIMA, 1963).

## 2. The Kitatada thrust.

The Kitatada thrust (western portion of the Kitatada-Ikegawa thrust in Fig. 3) runs from Ozu through Kitatada to Mikame in the northern marginal part of the area. The thrust runs nearly along the southern margin of the Mikabu green rocks in its eastern and central portions, and along the southeastern margin of the strata of the Kurosegawa terrain in its western portion. The trace of the thrust in its western portion nearly accords with the traces of the "Mikabu Tectonic Line" of HIRAYAMA and KAMBE (1956), and with the "Ozu-Mikame fault" of TAKEDA *et al.* (1977). Since the thrust does not always run along the southern margin of the Mikabu green rocks, it should not be called the Mikabu Tectonic Line.

The Kitatada thrust strikes northeast in its western portion. The Mikabu green rocks, ultrabasic rocks, the Maana sandstone beds (HIRAYAMA and KAMBE, 1956) and gabbroic rocks, all trending in the ENE-WSW direction, are distributed on the northwest of the thrust (Fig. 5), whereas sandstones, cherts, chert-laminites, slump breccias, and subordinate basic volcanics, striking E-W, are distributed on the southeast.

The Kitatada thrust strikes east in its eastern and central portions. The Mikabu green rocks near Anai in the western part extend continuously to Mt. Kannanzan, to the east of Ozu, in the northeastern part (Fig. 5). The Mikabu green rocks with subordinate cherts are distributed on the north of the thrust, whereas cherts, chert-laminites, mudstones and basic volcanics, called the Kume formation, (SUZUKI, 1935; KASHIMA, 1969), are distributed on the south (Fig. 5). The Mikabu green rocks in their western and eastern portions are about 5 km wide, whereas those in their central portion are 0.5 km wide. From this distributional pattern, most of the Mikabu green rocks in the central portion, which thrust themselves southward, are considered to have been eroded out.

The trace of the Kitatada thrust curves slightly, and are not affected by topography (Fig. 5), suggesting that it is a high angled fault at present. The Mikabu green rocks of the western marginal part thrust themselves southeastward, and cover most part of the Onoyama *decke* which is about 5 km wide on a geologic map in its central and eastern portion. From this fact, the horizontal displacement of the thrust is estimated to be at least 5 km. Its vertical displacement is inferred to be fairly small, because the Carboniferous to Triassic strata at most 2,000 m thick are widely distributed on the both sides of the thrust. The thrust is inferred to have been originally low-angled, although it is high-angled at present. The very point of the thrust is not yet found.

### 3. The Uonashi thrust.

The Uonashi thrust (IKEBE, 1936, western portion of the Uonashi-Kambaradani thrust in Fig. 3) runs nearly along the southern or southwestern margin of the Permo-Triassic limestone layer of the northern Sambosan terrain (Figs. 3 & 5). The limestone layer is distributed from Uonashi to Nomura, striking E-W, and then changes its strike toward northwest, extending to Mt. Onoyama. It is a little displaced by NNE-SSW trending faults (Fig. 5).

The strata on the north of the thrust consist of Permo-Triassic limestones, slump breccias, calcareous sandstones, cherts and subordinate basic volcanics, whereas the strata on the south consist of Permo-Triassic cherts, sandstones, alternations of sandstone and mudstone, and the Late Jurassic Torinosu group (Fig. 5). The lithologic characters on the north are quite different from those on the south, although the geologic age is correlative with each other. The strata on the south of the thrust strike east, whereas those on the north strike southeast in the area between Nomura and Mt. Onoyama; the limestone layer just on the north cuts the strata on the south (Fig. 5).

The Uonashi thrust has a bow-shaped trace convex toward the southwest, as described by KASHIMA (1969). Thus, the width of the southern Sambosan terrain narrows from Unomachi (9 km) to Uonashi (4 km) (Figs. 3 & 5). The evidence suggests that the Uonashi thrust has a horizontal displacement of at least 5 km. The strata on both sides of the thrust are nearly of the same geologic age, and are at most 2,000 m thick and therefore the vertical slip along the thrust is quite less than the horizontal one; the Uonashi thrust is inferred to dip fairly gently beneath the Kurosegawa terrain, although it dips at about 30° to 60° toward north near the earth surface. The granitic rocks and the Silurian strata of the Kurosegawa terrain near Nomura are probably rootless at present together with the strata of the northern Sambosan terrain as the case in Kyushu.

## 4. The Onoyama thrust.

The Onoyama thrust (western portion of the Nanokawa-Onoyama thrust in Fig. 3) is a large overthrust striking ENE in the middle part of the Western Shikoku (MURATA *et al.*, 1980). Its trace runs from Kanogawa, through Mt. Onoyama, to Mikame (Fig. 5). The thrust cuts the Uonashi thrust and the strata of the Uonashi *decke* sharply; the strata of the Unomachi *decke* including the Permo-Triassic limestone layer and the basic volcanic layers never extend northwestward beyond the Onoyama thrust (Fig. 5). The ENE-trending strata on the Onoyama thrust intersect diagonally the NW-trending strata on the Uonashi thrust (Fig. 5). The western half of the Onoyama thrust juxtaposes strata of slump breccia facies on the north with strata of chert-sandstone facies on the south. The trace of the thrust sinuates on the geologic map, affected by topography, and the thrust is inferred to dip toward north gently.

The Onoyama *decke*, which is moved along the Onoyama thrust, covers the

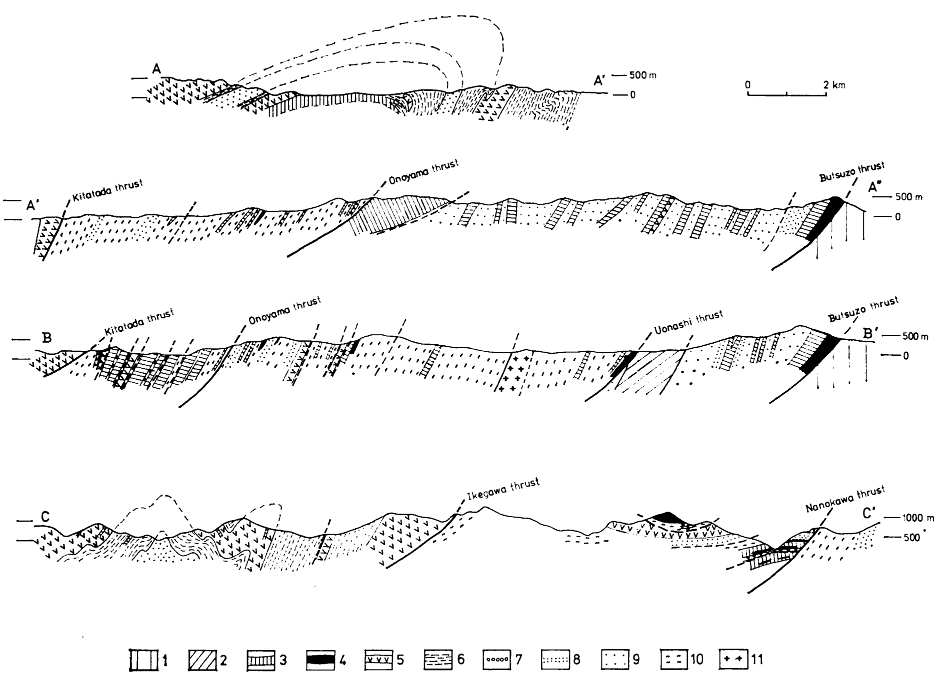



Fig. 6. Cross sections of the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains in Shikoku. A-A′, A′-A″, B–B′: Western Shikoku, C-C′: western Central Shikoku. 1: Shimanto supergroup, 2: Torinosu group, 3: chert, 4: limestone, 5: basic volcanics, 6: chert-laminite with slump breccia, 7: conglomerate, 8: sandstone, 9: alternation of sandstone & mudstone, mudstone, 10: slump breccia with chert-laminite, 11: granites & Silurian strata of the Kurosegawa terrain.

Uonashi *decke* in the east, and covers the Unomachi *decke* in the west (Figs. 3, 5 & 6). The metamorphic isograd which was clarified by HASHIMOTO and KASHIMA (1970), does not cut across the thrust, and the metamorphism ceased before thrusting. Outcrops of the Onoyama thrust have not been found yet.

### 5. Imbricate structure.

Many thrusts of smaller scales were ascertained in the northeastern part of the area. A pillow basalt layer about 200 m thick at Kanogawa shows northward facing, and is inferred to be of the late Carboniferous to early Permian. Triassic cherts (Fig. 5, Locs. 58 & 63) and slump breccias are distributed on the south of the basalt layer. A north-dipping thrust is inferred to occur between the basalt and chert layers.

A chert layer of Carnian (Loc. 47), a slump breccia layer, and a late Scythian chert layer (Loc. 46), all striking E-W, are distributed from south to north near Torikubi in the northeastern marginal part of the area (Fig. 5). The late Scythian layer overlies the slump breccia layer conformably, and therefore the late Scythian layer and slump breccia are inferred to thrust themselves southward over the Carnian chert layer.

A basic volcanic layer near Torikubi in the northeastern marginal part is Permian by conodonts (Loc. 40) in cherts intercalted in the volcanic layer. The volcanic layer is inferred to thrust itself southward over the Triassic chert layer (Locs. 41 & 42). Many other thrusts of smaller scales besides them are developed in the Chichibu and Kurosegawa terrains, and form an imbricate structure. The imbricate structure is inferred to be also developed in the northern and southern Sambosan terrains like those in Kyushu.

## IV. CHICHIBU AND SAMBOSAN TERRAINS IN WESTERN CENTRAL SHIKOKU

Stratigraphy and geologic structures of the Chichibu and Sambosan terrains in western Central Shikoku are studied by KOBAYASHI (1941), KIMURA & HORIKOSHI (1959), ISHIZAKI (1962), KASHIMA (1969), and TSUKUDA *et al.* (1981). These terrains are bounded on the north by the Ikegawa thrust (TAKEDA *et al.*, 1977), and on the south by the Butsuzo thrust (Fig. 3).

The Chichibu and Sambosan terrains in western Central Shikoku are occupied by three large *deckes*. They are, from north to south, the Nanokawa *decke* (eastern portion of the Nanokawa-Onoyama *decke* in Fig. 3) which is moved along the Nanokawa thrust (KIMURA and HORIKOSHI, 1959), the Kambaradani *decke* (eastern portion of the Uonashi-Kambaradani *decke*) moved along the Kambaradani thrust, and the Unomachi *decke* moved along the Butsuzo thrust (Flg. 3). The Sambosan terrain is separated into the northern Sambosan, southern Sambosan and southern marginal Sambosan terrains, like in Kyushu. The Chichibu terrain is separated into the northern Chichibu and southern Chichibu terrains by the Nanokawa thrust. The Kurosegawa terrain is not strictly separated from the southern Chichibu terrain in places. The Nanokawa *decke* consists of strata of

Table 3. Triassic conodonts in Shikoku.

| Species \ Locality | 10 | 12 | 13 | 14 | 15 | 17 | 19 | 22 | 25 | 26 | 27 | 28 | 29 | 32 | 33 | 34 | 36 | 38 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 52 | 58 | 59 | 63 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Carinella mungoensis* (Diebel) | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| *C. hungarica* (Kozur & Vegh) | | | | X | | | | | | | | | | X | | | ? | | | | | | | | | | | | | |
| *Epigondolella abneptis* (Huckriede) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *E. bidentata* Mosher | | | | | | | | | | | | | | | | | | | | | ? | | | | | | | | | |
| *E. nodosa* (Hayashi) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| *E. primitia* Mosher | | | | | | | | | | | | X | | | | | | | | X | | | | | | | | | | |
| *E.* sp. | | | | | | | | | | | | | | | | | | ? | | | | | X | | | | X | | | |
| *Gladigondolella tethydis* (Huckriede) | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *Neogondolella bulgarica* (Budurov & Stefanov) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *N. foliata* (Budurov) | | | | X | | | | | | | | | X | X | X | ? | ? | | | | | | | | | | | | | |
| *N. polygnathiformis* Budurov & Stefanov | | | X | | X | | | X | | | | | | | | | | | ? | ? | | | | | X | ? | | | X | ? |
| *N. navicula steinbergensis* (Mosher) | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| *N.* sp. | | | | | X | | | | | | | | | | | | | | | | | X | | | | | | | | |
| *Cornudina breviramulis minor* Kozur | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cypridodella mediocris* (Tatge) | | | | | | | | | | | | | X | X | | X | | | | | | | | | X | X | | | X | |
| *C. muelleri* (Tatge) | | | | X | X | X | X | X | | | | X | X | | X | X | | | | | X | | | | | | | | X | |
| *C. norika csopakensis* Kozur & Mostler | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | |
| *C. unialata* Mosher | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | |
| *C.* sp. A Koike | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| *C.* sp. | | | | | | | | | | | | | | X | | | | | | | | | | X | | | | | | |
| *Diplododella acroforme* (Mosher & Clark) | | | | | | | | | | | | | | | ? | | | | | | | | | | | | | | | |
| *D.* sp. | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | |
| *Enantiognathus ziegleri* (Diebel) | | | | X | | | | | | | | X | | X | X | | | X | X | | | | | | | | | | X | X |
| *E.* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Grodella delicatura* (Mosher) | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | |
| *Didymodella alternata* (Mosher) | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *Neohindeodella aequiramosa* Kozur & Mostler | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *N. benderi* (Kozur & Mostler) | | | | | | | | | X | | X | | | | | | | | | | | | | X | | | | X | | |
| *N. multihamata* (Huckriede) | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | |
| *N. suevica* (Tatge) | | | | X | X | | X | | | | | | | X | X | X | | | | | X | | | | | | | | | |
| *N. triassica* (Muller) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *N.* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Misikella hernsteini* (Mostler) | | | | | | | X | | | | | | | | | | | | | | ? | | | | | | | | | |
| *M. posthernsteini* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Neospathodus homeri* (Bender) | | | | | | | | | | | X | | | | | | | | | | | | | | | | | X | | |
| *N. timorensis* (Nogami) | | X | | | | | | | | ? | | | | | | | | | | | | | | | | | | | | |
| *N. triangularis* (Bender) | | | | | | | | | ? | | | | | | | | | | | | | | | | | | | | | |
| *N.* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pollognathus kochi* (Huckriede) | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| *Xaniognathus saginatus* (Huckriede) | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| *X. tortilis* (Tatge) | X | | | | | | | | | | | | | | X | | | | | | | | | | | | | X | | |
| *X.* sp. | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |

the northern Chichibu terrain. The Kambaradani *decke* consists of the southern Chichibu, Kurosegawa and northern Sambosan terrains. The Unomachi *decke* consists of southern Sambosan and southern marginal Sambosan terrains (Fig. 3).

## 1. Stratigraphy.

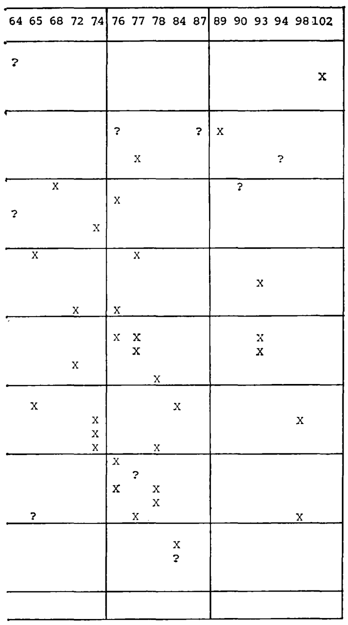
*Northern Chichibu terrain.*

Succession and lithology: Flat-lying or gently dipping strata are distributed in the northern Chichibu terrain of the Nanokawa subarea (Fig. 5). However, the sequence of the strata is not stratigraphic but "tectonic succession" (Fig. 7). The strata of the same stratigraphic horizon are repeatedly piled up by several thrusts, which dip very gently, nearly parallel to the strata.

The Carboniferous to Jurassic strata are divided into the a-, b-, c-, d- and e-formations in ascending order. The a-formation consists of sandstones, and the b-formation of submarine basic volcanics with cherts, the c-formation of cherts and chert-laminites with dolostones and mudstones, the d-formation of cherts, and the e-formation of sandstones and slump breccias with chert conglomerates. The total thickness is about 900 m.

The sandstones of the a-formation are mostly massive, and partly alternate with mudstones. They are grayish black to grayish brown and medium- to coarse-grained. Grains are made up of angular to subangular quartz, chert, and feldspar. The matrix is 10% at maximum in volume. Weak foliation, probably schistosity, is observed in them. Recrystallized muscovite is observed in the matrix.

The submarine basic volcanics of the b-formation consist of pillow lavas,



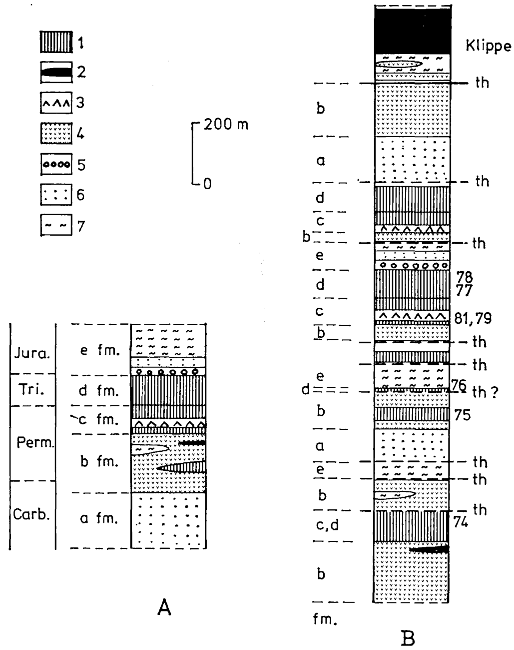



Fig. 7. Successions of layers in the Nanokawa *decke*. Probable stratigraphic succession (left) and "tectonic succession" (right). 1: chert with mudstone and chert-laminite, 2: limestone, 3: dolostone, alternation of dolostone & chert, 4: basic volcanics, 5: conglomerate, 6: sandstone, alternation of sandstone & mudstone, 7: slump breccia, mudstone. th: thrust, 74-81: fossil locality.

tuffs and tuff breccias. Chlorite, epidote, pumpellyite, albite and actinolite are present in them as metamorphic minerals. To the east of Ochide, alkali amphibole is also present (IWASAKI, 1960). Phenocrysts of clinopyroxene and olivine are present in them. Olivine is completely altered. Dark green sandstone, which consists mostly of sand-sized detrital clinopyroxene, occurs to the south of Funado. The tuff breccias consist of rock fragments of basalt and tuff, and tuff matrix.

The cherts in the c-formation are bluish gray, gray and red, and bedded. Some chert beds alternate with basic tuff beds. The chert-laminites are alternating chert and claystone laminae with a thickness less than a millimeter per laminae. The dolostones are massive and 80 m thick at maximum. They are light gray, and consist of dolomite crystals of 1 to 2 mm in diameter. Dolostone beds several to several tens of centimeters thick frequently alternate with chert beds several centimeters thick. The dolostones in the alternations are light pink to reddish pink, and have white laminae. In some dolostones, the size of dolomite crystals decrease upward from 2 mm to 0.5 mm gradually, similarly to graded bedding in sandstones. Some dolostones are included in cherts as nodule. The mudstones have sandstone laminae, and some include radiolarians.

The cherts in the d-formation are bluish gray, gray and greenish gray and bedded. They are accompanied with late Scythian siliceous mudstones. The sandstones in the e-formation are fine- to coarse-grained. The grains consist of quartz, chert, mudstone and feldspar. Some sandstones include many chert fragments. The sandstones include more mudstone matrix than those of the a-formation. The chert conglomerates consist of chert clasts and mudstone matrix. Dolomite crystals are present in the chert clasts. The slump breccias of the e-formation consist of clasts of S-size and mudstone or microbreccia matrix. The clasts are made up of sandstone, chert and basic volcanics.

Age: The cherts interbedded in the basic volcanics of the b-formation yield Permian conodonts such as *Diplognathodus* sp. and *Neogondolella* sp. (Loc. 75) (Table 2.) The cherts of the c-formation yield Permian conodonts such as *Gondolella* sp., *Hindeodella* sp., and *Idiognathodus* sp. (Locs. 79, 80, 81 & 82) (Table 2). The cherts of the d-formation yield Triassic Scythian to Norian conodonts such as *Neohindeodella benderi* (Loc. 74), *Neospathodus homeri* (Loc. 77) and *Misikella hernsteini* (Locs. 76 & 78) (Table 3). The a-formation is probably of the Carboniferous or early Permian. The e-formation is possibly of the Jurassic because the formation overlies the Norian strata conformably. The mudstones of the b-formation yield trace fossils such as *Chondrites.*

*Southern Chichibu terrain.*

The strata of the southern Chichibu terrain are characterized by the Carboniferous to Permian Onogahara-Torigatayama limestones. They are correlative with those of the Shirakidani group (SUYARI, 1961), considering their tectonic position. The strata include submarine basic volcanics, bedded cherts, quartz-feldspathic sandstones, calcareous sandstones, and slump breccias (Fig. 5). The limestones yield various fusulinids of Carboniferous to Permian age (ISHIZAKI, 1962). The cherts (Loc. 83) interbedded in the basic volcanics yield *Neogondolella* sp. of Permian age (Table 2). The cherts near Odo, to the south of Nanokawa, yield Triassic *Neospathodus homeri* (Table 3).

*Kurosegawa and Sambosan terrains.*

The lithologic characters of the terrains are same in both areas, western Central Shikoku and Kyushu. Radiolarites in the southern Sambosan terrain yield Jurassic-type radiolarians to the north of Funado and to the south of Ochimen (TAIRA *et al.*, 1979).

## 2. The Ikegawa thrust.

The Ikegawa thrust (TAKEDA *et al.*, 1977) (eastern portion of the Kitatada-Ikegawa thrust in Fig. 3) runs nearly along the southern margin of the Mikabu green rocks, which are distributed in the northern margin of the area (Figs. 3 & 5). Strata on the north of the thrust consist of the Mikabu green rocks, limestones, cherts, and chert-laminites, whereas strata on the south of the thrust consist of cherts, sandstones, chert-laminites, and acid tuffs. The limestones on the north and the cherts on the south yield Late Triassic conodonts (MATSUDA, 1978; KUWANO, 1979; HASEGAWA, 1980). The strata on the north of the thrust have quite different lithologic characters from those on the south, although they are of the same geologic age with each other.

The thrust is inferred to dip at 40° to 60° toward north near Kamidoi, and dip fairly gently toward north to the west of Kamidoi. The Mikabu green rocks thrust themselves southward along the Ikegawa thrust over the Nanokawa *decke*. Horizontal displacement is inferred to be much greater than vertical one because the strata on both sides of the thrust are nearly of the same geologic age in spite of quite different lithologic characters between the two.

### 3. The Nanokawa thrust in the Nanokawa subarea.

The Nanokawa thrust (KIMURA and HORIKOSHI, 1959) (eastern portion of the Nanokawa-Onoyama thrust in Fig. 3) runs from Osaki, through Nanokawa, to south of Funado (Fig. 5). The strata on the northwest of the thrust dip gently or nearly horizontal, whereas those on the southeast strike in the E-W direction and dip toward north steeply (Fig. 5). The thrust runs along the southern margin of the chert layers of the c- and d-formations, which strike in the NE-SW direction near Nanokawa and Osaki. The strata on the southeastern side of the thrust, on the other hand, strike in the E-W direction, and are diagonal to those on the northwestern side (Fig. 5). The Nanokawa thrust is inferred to dip at about 30° toward northwest near Osaki and Odo, judging from the geometrical relationship between its trace and topography. The thrust dips toward northwest steeply to the west of Odo (KIMURA and HORIKOSHI, 1959). An outcrop of the thrust is observed at Nanokawa (HASHIMOTO, 1955).

The strata of the Nanokawa *decke* have undergone metamorphism, and have weak schistosity, whereas the strata of the underlying mass, the Kambaradani *decke*, have no schistosity (KIMURA and HORIKOSHI, 1959); the strata with weak schistosity thrust themselves southeastward along the Nanokawa thrust over those without schistosity.

The weak schistosity is recognized in mudstones by preferred orientation of dusty opaque minerals (called dusty part by OHO, 1981) and muscovite; such mudstones are called phyllites. Crenulation cleavage, kink bands (Plate 23-1), and kink folds are observed in mudstones and chert-laminites of the Nanokawa *decke* near Nanokawa and Funado. No phyllites are present on the south of the thrust. Chert clasts in the chert conglomerates and rock fragments in the tuff breccias of the Nanokawa *decke* near Funado are deformed into oblate shape whose short axes are arranged perpendicular to the schistosity.

In the Nanokawa subarea, sandstones on the both sides of the thrust are studied in the similar way to that used by ABE (1978); he clarified sandstones into several types, based on bedding schistosity, grain boundary texture of detrital grains, size of recrystallized quartz grains, and so on. Samples were collected from sandstone beds more than one meter thick which include no minor folds. Calcareous sandstones are excluded. The sandstones are medium- to coarse-grained. The detrital grains are mostly made up of quartz, feldspar, epidote, and rock fragments such as chert and mudstone. The matrix of non- or less-foliated sandstones is less than 10% in volume. The matrix of foliated ones is 10 to 60% in volume. It comprises aggregates of mica and fine-grained quartz, 10 to 20 $\mu$m in diameter. Recrystallized quartz and mica are treated to be matrix.

Foliation and lineation are present in some samples. Foliation is recognized by the parallel arrangement of mica, dusty opaque minerals, and lenticular detrital grains. Lineation is indicated by preferred orientation of elongate detrital grains and the pressure shadow on the foliation. The following description is made on the basis of observation in b-c section which is a section including b- and c-axes. In this paper b-axis is denoted as the direction parallel to lineation, and c-axis is as the direction perpendicular to foliation. Non foliated samples are observed in a section of an arbitrary direction.

On the microstructural observation, special attention is paid on five characteristics; (1) spacing of dusty part and intensity of its preferred orientation, (2) intensity of preferred orientation of mica, (3) presence of subgrains around the margin of detrital quartz grains, (4) presence of pressure shadow, and (5) presence of micro-boudinage of detrital grains. Sandstones in the subarea are classified into five groups on the basis of difference of the characteristics mentioned above. They are named type-0, -1, -2, -3 and -4 sandstones respectively. Each type is described in the following.

Type-0 sandstones. No planar structure is discernible with the naked eye. Preferred orientation of mica and dusty part are absent even under the microscope (Plate 24-1). Pressure shadow, subgrains around detrital quartz grains and micro-boudinage of detrital grains are absent.

Type-1 sandstones. Weak foliation is present with the naked eye. Dusty part is present at intervals of several times of grain-scale spacing. The dusty part, parallel to the foliation, curves slightly (Plate 24-2). Preferred orientation of the dusty part is poorly developed. Preferred orientation of mica in the matrix is absent.

Type-2 sandstones. Foliation is conspicuous with the naked eye. Dusty part is present at intervals of a grain-scale spacing, and is more densely developed than in the type-1 sandstones. Preferred orientation of the dusty part is well developed (Plate 24-3). The dusty part in places penetrates detrital chert grains.

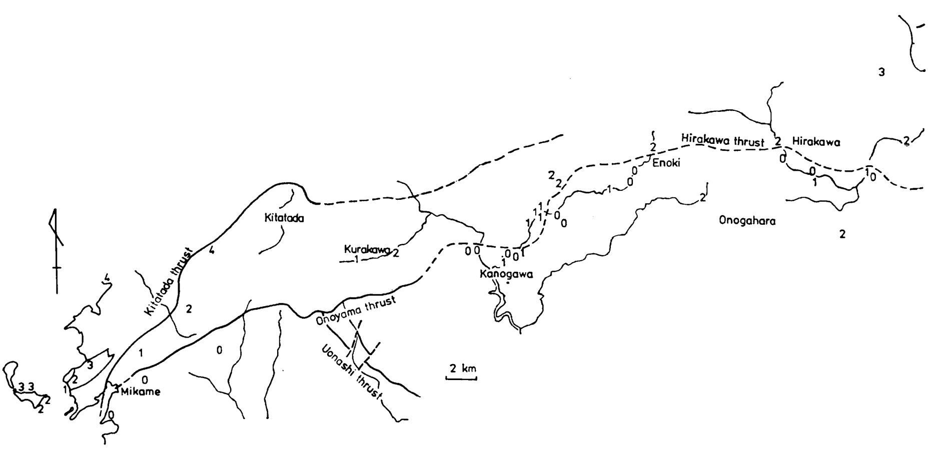



Fig. 8. Distribution of sandstones of each type in Western to western Central Shikoku. 0: type-0 sandstones, 1: type-1, 2: type-2, 3: type-3, 4: type-4.

These chert grains are displaced along the dusty part (Plate 24-4). Preferred orientation of mica in the matrix is poorly developed. Lenticular quartz and feldspar grains are arranged with their longest axes parallel to the lineation. Pressure shadow is rarely observed. Subgrains around detrital quartz grains and micro-boudinage of detrital grains are absent.

Type-3 sandstones. Foliation is conspicuous. Dusty part is present at intervals of a grain-scale spacing. Preferred orientation of dusty part is well developed (Plate 25-1). Some detrital grains are penetrated by the dusty part and separated into a few small "grains". Some detrital quartz grains show subgrain structure around their margin. Micro-boudinage of detrital feldspar and epidote grains is sporadically observed, and they are separated into a few "grains". These "grains" are pulled apart along the b-axis (cf. Plate 25-3). Preferred orientation of mica, probably muscovite, in the matrix is developed. Pressure shadow is present. It comprises aggregates of mica and fine-grained quartz (10 to 20 $\mu$m) growing on opposite sides of a host detrital grain, thereby producing an elongate structure.

Type-4 sandstones. Foliation and lineation are conspicuous. The foliation can be called schistosity, because it is recognized by parallel arrangement of recrystallized muscovite. The matrix is 20 to 60% in volume, and comprises aggregates of muscovite (10 to 100 $\mu$m in length along the long axis) and fine-grained quartz (10 to 20 $\mu$m). Subgrains around detrital quartz grains are hardly distinguishable from the original matrix. Many fine quartz grains in the matrix are lenticular and are arranged with the longest axis parallel to the lineation. Preferred orientation of muscovite in the matrix is very well developed (Plate 25-2). Dusty part is present, but is not so densely developed as those in the type-3 sandstones. Micro-boudinage of detrital feldspar and quartz grains is common. Some "grains" which are pulled apart by the micro-boudinage are all rotated in the same direction. This is ascertained by the direction of the plagioclase twin and "grain" shape (Plate 25-3). Pressure shadow is common. The type-4 sandstones are considered to be more intensely deformed than the type-3 ones, because micro-boudinage of detrital grains and pressure shadow are more densely developed in type-4 than in type-3.

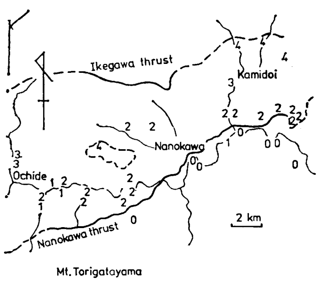



Fig. 8 shows the distribution of sandstones of each type in western Central Shikoku. The sandstones on the north of the Nanokawa thrust are more highly deformed than those on the south. The type-2 sandstones are mostly distributed on the north of the thrust, and the type-3 and type-4 sandstones are distributed in the northern part of the area. The type-0 sandstones, on the other hand, are mostly distributed on the south of the thrust.

Thus, the weakly schistose sandstones are distributed on the north of the Nanokawa thrust, and non-schistose sandstones are distributed on the south. Furthermore, the sandstones on the north become highly deformed toward north, and grade into psammitic schists of the Sambagawa metamorphic rocks. This occurrence means that the Nanokawa thrust is the southern boundary fault of the Sambagawa metamorphic rocks as mentioned by KIMURA (1980).

**4. Geologic structures of the Nanokawa subarea.**

The strata of the Nanokawa *decke* dip very gently toward east, and nearly horizontal from Ochide to Nanokawa. The sequence of the strata was formerly considered to be of true depositional order (KIMURA and HORIKOSHI, 1959). Now it has become clear that the sequence is not stratigraphic, but "tectonic" as pointed out by SANO (1980) because conodont fossils indicate that the layers are not successive and not conformable. Fig. 7 shows the "tectonic succession" of the layers of the Nanokawa *decke*.

The chert layers with dolostones of the c-formation and the chert layers of the d-formation are of Permian and Triassic ages respectively (Chapter IV-1). There are at least five bedded chert layers in the "tectonic succession". They are, in "ascending" order, Triassic d-formation, Permian to Triassic c- and d-formation, Permian c-formation, and Permian to Triassic c- and d-formations. A chert layer of the same stratigraphic horizon appears repeatedly. Furthermore, thick sandstone layers appear in the lower and upper "horizons", and both of them probably belong to the a-formation. Thick basic volcanic layers of b-formation appear also repeatedly in the lowest and the upper "horizons" in the "tectonic succession".

AIBA (1981) recently clarified that the limestone layer with basic volcanics in the uppermost "horizon" of the "tectonic succession" is more highly metamorphosed than the basic volcanic layers of the lower "horizons". According to him, the metamorphic grade of the former layer is equivalent to that of the Mikabu green rocks, which are situated 5 km north of the layer. The highly metamorphosed limestone layer with basic volcanics in the uppermost "horizon" thrusts itself along the Nakatsu thrust over the basic volcanic layers of the lower "horizons". Furthermore, the sandstones above the Nakatsu thrust are deformed into the type-4 like those near the Mikabu green rocks (Fig. 8). The Nakatsu thrust is inferred to be the southern extension of the Ikegawa thrust. The limestone layer above the Nakatsu thrust is considered to be a *klippe* which rests on the Nanokawa *decke* (Fig. 3). TSUKUDA *et al.* (1981) considered that the Nakatsuyama *nappe*, which is correlative with the Nanokawa *decke* in part, had rested on the Sambagawa metamorphic rocks originally, and that it had been thrust southward over the Mikabu green rocks and over the autochthonous strata of the Chichibu terrain. This opinion is not in accordance with the facts described above.

Geologic structures just to the south of the thrust are not yet clarified sufficiently. The basic volcanic layer near Nanokawa is accompanied with the Permian cherts (Loc. 83). A Triassic chert layer (Loc. 93) is distributed to the north of the volcanic layer, and the former overlies the latter conformably. The slump breccia layer occurs to the south of the volcanic layer, and is accompanied with Triassic cherts (Loc. 84) (Fig. 5). The steeply-dipping thrust is inferred to run along the southern margin of the volcanic layer.

The Kuroiwa thrust (KOBAYASHI, 1941) is a steeply-dipping one. The thrust runs nearly along the northern margin of the Cretaceous strata which overlie Permo-Triassic strata unconformably, like the Gozaishoyama thrust in Central Shikoku (IKUMA, 1980). The Kuroiwa thrust is not a large and low-angled thrust such as the Nanokawa thrust.

A large overthrust is inferred not to exist along the southern margin of the Onogahara-Torigatayama limestones. Slump breccias and calcareous sandstones with limestones are distributed on the south of the limestones. The Onogahara-Torigatayama limestones with subordinate slump breccias change their lithology gradually toward south.

Serpentinites are distributed along the Ochimen-Shimagawa Line (KIMURA and HORIKOSHI, 1959). They are characteristic of the Kurosegawa terrain, but not the Chichibu terrain. The Line is considered to be the probable northern limit of the Kurosegawa terrain.

**5. Connection between the Nanokawa and the Onoyama thrusts.**

The Nanokawa thrust near Nanokawa is inferred to extend westward to Hirakawa, where the thrust is called the Hirakawa thrust (KASHIMA, 1969). Alternations of dolostone and chert which are characteristic of the Nanokawa *decke*, occur on the north of the Hirakawa thrust (Fig. 5). In addition, the type-2 sandstones are distributed on the north of the Hirakawa thrust, and type-0 and -1 sandstones are on the south.

The Nanokawa thrust runs in the E-W direction near Hirakawa and Enoki. The thrust changes its strike into the NE-SW direction to the west of Enoki. Cherts, chert-laminites, dolostones and slump breccias are mostly distributed on the north of the thrust, and thick basic volcanic layer, which extends to those near Onogahara, are distributed on the south (Fig. 5). The basic volcanic layer does not extend westward because it is covered by the Nanokawa *decke* (Figs. 5 and 3). To the west of Machimura, the type-2 and type-1 sandstones are distributed on the northern side of the thrust, and the type-1 and type-0 sandstones are on the southern side (Fig. 8).

The Onoyama thrust is probably the western extension of the Nanokawa thrust. The type-4, -2, and -1 sandstones are distributed near Kitatada, Mikame and Kurakawa on the north of the Onoyama thrust, and the type-0 sandstones on the south (Figs. 8 & 5). Furthermore, deformed slump breccias which are weakly metamorphosed, occur near Torikubi, on the north of the thrust (KIMURA, 1980). Deformed and weakly metamorphosed sandstones are distributed on the north of the Nanokawa and Onoyama thrusts, and non-schistose sandstones are distributed on the south. Thus the Onoyama thrust is probably the western extension of the Nanokawa thrust. They should be called Nanokawa-Onoyama thrust.

The Nanokawa-Onoyama thrust strikes in the E-W direction near Nanokawa, and extends eastward to Tosayama (Figs. 5 & 9). Dolostones which are one of the characteristics of the northern side of the thrust are distributed from Uchiki to Kashigatoge Pass (HASHIMOTO, 1955). In addition, the type-2 and type-1 sandstones are generally distributed on the north of the thrust, and the type-0 ones on the south except near Tosayama (Fig 9).

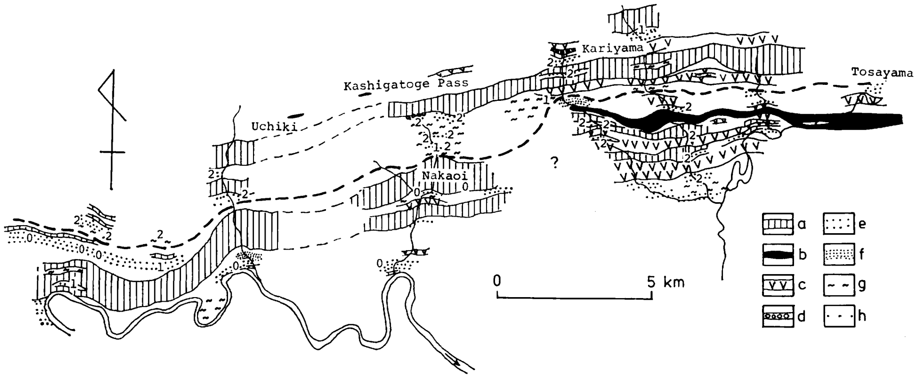



Fig. 9. Geologic map of Tosayama subarea in Central Shikoku and distribution of sandstones of each type. a: chert, b: limestone & dolostone, c: basic volcanics, d: conglomerate, e: sandstone, f: calcareous sandstone, g: slump breccia, mudstone, h: alternation of sandstone & mudstone, 0: type-0 sandstones, 1: type-1, 2: type-2.

## 6. Relation among the Uonashi-Kambaradani thrust, the Butsuzo thrust and the Tanono fault.

The Uonashi thrust runs from Uonashi to the Tsukumomagari Pass in the western part of the Yusuhara subarea, and the Kambaradani thrust runs from Tanono to Taroda in the eastern part (Figs. 5 & 3). The Uonashi thrust and the Kambaradani thrust have the same characteristics with each other as follows. They strike in the E-W direction, and run nearly along the southern margin of the Permian limestone layers. Permo-Triassic limestones, cherts, slump breccias and sandstones occur on the north of the thrusts. Those strata thrust themselves southward over the Late Jurassic Torinosu group which consists of limestones, conglomerates, sandstones, mudstones, and alternations of sandstone and mudstone (Fig. 5). Thus the Kambaradani thrust is inferred to be originally the eastern extension of the Uonashi thrust, and they are called Uonashi-Kambaradani thrust.

The Butsuzo thrust and the Butsuzo Tectonic Line are strictly distinguished from each other in the following discussion. The Butsuzo thrust (KOBAYASHI, 1941) is a thrust fault which has moved the strata of the Sambosan terrain over the Shimanto supergroup. Its trace runs along the southern margin of the limestone-rich strata of the southern marginal Sambosan terrain in Central Shikoku. The Butsuzo Tectonic Line, on the other hand, means only a boundary fault between the Chichibu or Sambosan terrain and the Shimanto terrain on a geologic map.

Formerly, the Butsuzo Tectonic Line in Western Shikoku was called the "Gozaisho thrust" by KOBAYASHI (1941), and was thought to be distinguished from the Butsuzo thrust. The "Gozaisho thrust" runs from Takayama to Mt.

Gozaishoyama in the western part of the Yusuhara subarea (Fig. 5). Its trace runs in the E-W direction along the southern margin of the southern marginal Sambosan terrain. The Butsuzo thrust in the eastern part of the Yusuhara subarea runs from the Tsukumomagari Pass to Taroda. It is correlative with the "Gozaisho thrust" because both of the thrusts run along the southern margin of the southern marginal Sambosan terrain. The "Gozaisho thrust" in Western Shikoku is originally the western extension of the Butsuzo thrust in Central Shikoku, and they are called the Butsuzo thrust unitely.

The Tanono fault runs from Mt. Gozaishoyama through Tanono to Mt. Torigatayama, striking NE-SW in the central part of the Yusuhara subarea. The fault cuts and displaces the Uonashi-Kambaradani thrust and the Butsuzo thrust (Fig. 5). It is nearly vertical, considering its straight trace independent of topography. The Tanono fault is inferred to have a left-lateral component similarly to the Kaminirogawa fault (IKUMA, 1980). The horizontal separation along the Tanono fault is about 8 km. This value does not necessarily represent a net slip; it probably moved strata on the northwestern side downward relatively to those on the southeastern side because Cretaceous strata, the youngest strata in the Yusuhara subarea, lie only on the northwestern side of the fault. Thus the Tanono fault between Mt. Gozaishoyama and the Tsukumomagari Pass is the Butsuzo Tectonic Line, which is the boundary fault between the Sambosan terrain and the Shimanto terrain. The southwestern portion of the Tanono fault nearly accords with the Takagawa fault of KASHIMA (1968).

## V. SOUTHERN SAMBAGAWA TERRAIN IN WESTERN TO WESTERN CENTRAL SHIKOKU

Stratigraphy and geologic structures of the Sambagawa terrain in Western to western Central Shikoku are studied by HIDE (1972), HARA *et al.* (1977), TAKEDA *et al.* (1972), and KASHIMA & TOKIWAI (1972). HIDE (1972) reported that there exists the "Nagahama recumbent fold" in the Ozu-Nagahama area in Western Shikoku. However, it still remained in question whether the "fold" really occurs or not. SUYARI *et al.* (1980) recently discovered Late Triassic conodonts from calcareous schists of the Sambagawa metamorphic rocks. Detailed geologic mapping, laying stress on the stratigraphic evidence, has led to the following conclusions, not in accordance with previous opinions expressed by some workers. The area, here described, is to the north of the Kitatada-Ikegawa thrust.

### 1. Stratigraphy.

The Sambagawa terrain is divided into the Mikabu subterrain in the south and the Sambagawa subterrain in the north. Stratigraphy of each subterrain is described as follows.

*Sambagawa subterrain.*

Succession and lithology: The Sambagawa metamorphic rocks of Western to western Central Shikoku have generally been weakly metamorphosed. The

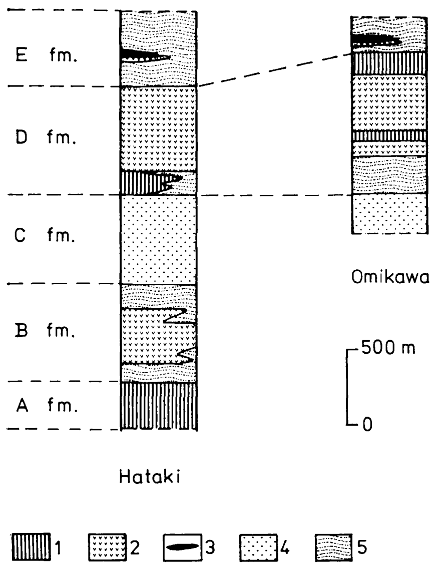



Fig. 10. Successions of the Sambagawa metamorphic rocks in Western to western Central Shikoku. 1: chert, 2: basic volcanics, 3: limestone, 4: sandstone, 5: chert-laminite & mudstone.

stratigraphy is here described by using original rock names before metamorphism. The Sambagawa metamorphic rocks are divided into five formations, A, B, C, D and E formations in ascending order (Fig. 10). The A and B formations occur near Hataki to the north of Ozu in Western Shikoku. The A formation consists of cherts and chert-laminites (YOSHIDA, 1981). The B formation consists of submarine basic volcanics and chert-laminites. The C formation is distributed near Hataki in Western Shikoku and near Omikawa in western Central Shikoku. The C formation consists of sandstones, alternations of sandstone and mudstone, and chert-laminites. The D formation is widely distributed, and consists mainly of basic volcanics and cherts. The E formation occurs to the north of Yawatahama in Western Shikoku and near Sozu in western Central Shikoku. It consists of limestones, basic volcanics, cherts and chert-laminites (Fig. 10).

Basic volcanics of the B, D and E formations are mostly composed of tuffs with subordinate pillow lavas and tuff breccias. The tuffs are thinly alternating beds of light green and dark green colored layers of 1 mm to 1 cm thick. The pillow lavas and tuff breccias occur near the Nakayama Pass (MARUYAMA *et al.*, 1976), near the coast to the west of Yawatahama (Loc. 2) (KIMURA, 1980), and at Loc. 99 to the east of Sozu (Plate 23-2) (Fig. 5). The rock fragments of basalt in the tuff breccias are strongly stretched to form a rod-shape. The basic volcanics include chlorite, epidote, actinolite, pumpellyite, albite, and quartz as metamorphic minerals, and clinopyroxene as relict minerals.

The cherts of the A, D and E formations are red, bluish gray and greenish gray, and bedded. The chert-laminites consist of chert laminae 0.1 to 1 mm thick and claystone laminae 0.1 to 1 mm thick. The chert-laminites of the C formation frequently intercalate thin sandstone laminae 1 to 10 mm thick.

The sandstones of the C formation are gray to grayish black, and medium- to coarse-grained. Grains are made up of quartz, feldspar and rock fragments. The matrix is made up of recrystallized quartz and muscovite. The limestones of the E formation are composed of dark gray and light gray laminae 0.5 to 5 mm thick. The color difference reflects the grain size of calcite, and coarser grains are dominant in the light gray colored layers.

Age: SUYARI *et al.* (1980) discovered conodonts such as *Epigondolella abneptis* and *Neogondolella* sp. cf. *N. Polygnathiformis* of Late Triassic age in the limestones of the E formation (Locs. 1 & 66). The sandstones of the C formation are correlative with those of the a-formation of the northern Chichibu terrain in the Nanokawa subarea. The basic volcanics of the D formation are correlative with those of the b-formation of late Carboniferous to early Permian age of the northern Chichibu terrain (for example, KANMERA, 1971; KIMURA, 1978). The original rocks of the Sambagawa metamorphic rocks of the area are inferred to be probably of Carboniferous to Triassic (early Jurassic ?) age.

*Mikabu subterrain.*

The Mikabu green rocks in Western to western Central Shikoku are described in detail by SUZUKI (1967, 1972) and SUZUKI *et al.* (1972). The rocks consist mainly of gabbros, dolerites, hornblendites, basic lavas, tuffs and tuff breccias. The relation between the Mikabu green rocks and associate sedimentary rocks is particularly described in this section.

Basic massive tuffs, included in the Mikabu green rocks, are overlain by red and gray cherts conformably to the north of Torikubi in Western Shikoku. To the south of Ikazaki, a chert-laminite layer with cherts (Loc. 39), and a chert layer (Loc. 38) occur on the north of the Mikabu green rocks. The former cherts yield *Neogondolella* sp. of probably Permian age (HASEGAWA, 1980), and the latter ones yield *Epigondolella* sp. of probably Late Triassic age. The cherts and chert-laminites of Permian to Triassic age probaby overlie the Mikabu green rocks.

MATSUDA (1978) and KUWANO (1979) discovered conodonts such as *Metapolygnathus abneptis* and *Epigondolella primitia* in the limestones of the Mikabu subterrain in the northeastern part of western Central Shikoku. The limestones alternate with the basic tuffs which are considered to belong to the uppermost horizon of the Mikabu green rocks. Near Machimura in western Central Shikoku, conodont-bearing limestones of Late Triassic age (Loc. 67) (SUYARI *et al.*, 1980) are accompanied with minor basic volcanics. The basic volcanics which are considered to belong to the Mikabu green rocks, are partly of Triassic age.

Tuff breccias of the Mikabu green rocks occur to the south of Mimido in western Central Shikoku as described by SUZUKI (1967). The tuff breccias are composed of rock fragments of basic lava and tuff, pebble to boulder size, and tuff matrix. Some of lava fragments have amygdule texture. Chlorite, actinolite, alkali amphibole, quartz, and albite are present as metamorphic minerals, and clinopyroxene as relict minerals in the matrix of the tuff breccias. The tuff breccias alternate with the tuffs. Tuff breccias similar to those near Mimido occur near Anai (Locs. 3 & 4, Fig. 5) in westernmost Shikoku, and are intruded by dolerite dikes which are petrologically identical to the breccias. One of the dikes, about 80 cm wide, has chilled margin at Loc. 3 (Plate 23-3); the tuff breccias are inferred to have been deposited in a volcanic site and not to have been redeposited in a place far away from the volcanic site.

## 2. Fold structures.

Some folds are ascertained in the Sambagawa terrain. An anticlinorium exists near Omikawa in western Central Shikoku (Figs. 5 & 6). The sandstones of the C formation (Chapter V-1) occur in the axial part of the anticlinorium, and the basic volcanics and cherts of the D formation occur on the limbs. A synclinorium occurs near Sozu, to the south of the anticlinorium. The Triassic chert-laminites with the limestones of the E formation occur in the axial part of the synclinorium, and the basic volcanics and cherts of the D formation occur on the limbs.

The axial traces of the anticlinorium and synclinorium strike nearly in the E-W direction. Their half-wavelengths are about 1.5 to 2 km. There are many folds of various wavelengths, several tens of centimeters to several hundreds of meters, in the area. The axis of the anticlinorium is inferred to plunge east at a low angle because the sandstones of the C formation, the lowest horizon in the eastern part of the area, occur near Omikawa, and not near Tsubayama, to the east of Omikawa. The axial surfaces of the anticlinorium and synclinorium dip at 45° to 80° toward north near Omikawa, and at 20° to 30° toward north near Sozu. To the south of the synclinorium, the probable Triassic limestones appear repeatedly, and they are inferred to be folded.

A dome-like structure is ascertained near Hataki, to the north of Ozu in Western Shikoku. The sandstones of the C formation form doughnut-like distribution on the map (Fig. 5). The sandstones are enclosed by the basic volcanics of the D formation. Strata of the C and D formations dip toward north in the northern and southern portions of the dome-like structure. The strata dip toward east and west in its eastern and western portions respectively. The strata of its southern portion are probably overturned. Axes of minor folds in the dome-like structure trend in the nearly ENE-WSW direction. The dome-like structure is probably formed by the superposition of ENE-WSW trending anticlinorium and N-S trending anticline, as pointed out by HASEGAWA (1980).

A synclinorium exists to the south of the dome-like structure. Its axial surface dips gently toward north. The D and E formations on the northern limb of the synclinorium are overturned to the north of Yawatahama. A thrust is inferred to run along the southern margin of the overturned D formation. Overturned minor folds are frequently observed near Yawatahama.

Spotted schists occur near Nagahama in the northernmost part of Western Shikoku. They are inferred to belong to the D formation, which is the upper horizon of the Sambagawa metamorphic rocks in the area, although they are more highly metamorphosed than the strata of the lower horizon. HIDE (1972) considered the presence of the "Nagahama recumbent fold", whose axial part is in the horizon of the spotted schists, because he supposed that the highly metamorphosed rocks belong to the lower horizon originally. The Sambagawa metamorphic rocks in Central Shikoku are not overturned as a whole, judging from the analyses of geologic structures (KIMURA, 1980). The spotted schists, there, occur only in the upper stratigraphic horizon (KOJIMA and MITSUNO, 1966). Furthermore, the metamorphic grade (temperature) increases stratigraphically upward in Central Shikoku (HIGASHINO, 1975). There is no evidence that the spotted schists near Nagahama belong to the lowest stratigraphic horizon. The "Nagahama fold" is inferred not to exist.

### 3. Relation between the Sambagawa terrain and the Kurosegawa terrain.

The sandstones and chert-laminites of the Sambagawa metamorphic rocks, the basic volcanics and hornblendites of the Mikabu green rocks, the Maana sandstone beds and ultrabasic rocks, the gabbroic rocks, and the Early Cretaceous strata are distributed from Yawatahama to Mikame in westernmost Shikoku (Fig. 5).

MASUDA (1977) discovered sheared granitic rocks, which are characteristic of the Kurosegawa terrain, near Mikame in westernmost Shikoku. He inferred that the area to the west of Mikame belongs to the Kurosegawa terrain by reason of the presence of the granitic rocks, large ultrabasic bodies, and the Early Cretaceous strata. SHIKANO (Kanazawa University, personal communication) recently discovered garnet amphibolities and dioritic rocks in Oshima Island. Such rocks are characteristic of the Kurosegawa terrain, but not in the Mikabu subterrain. Furthermore, pale green acid tuffs at Susaki and Birijima Island to the west of Mikame are similar to the Silurian acid tuffs. Thus it is certain that the strata near Mikame belong to the Kurosegawa terrain.

The Maana sandstone beds (HIRAYAMA and KAMBE, 1956) are distributed in the area between the Mikabu subterrain and the Kurosegawa terrain (Plate 23-4) (Fig. 11). The Maana sandstones are composed mostly of quartz and feldspar, and some include a large amount of rock fragments. They have been considered to be of the Late Cretaceous by TERAOKA (1970), and to be of the Paleozoic by KASHIMA and TOKIWAI (1972). Recent study, however, revealed that the Maana beds probably belong to the Sambagawa metamorphic rocks as described in the following.

Weak schistosity is present in the Maana sandstone beds. Preferred orienta-

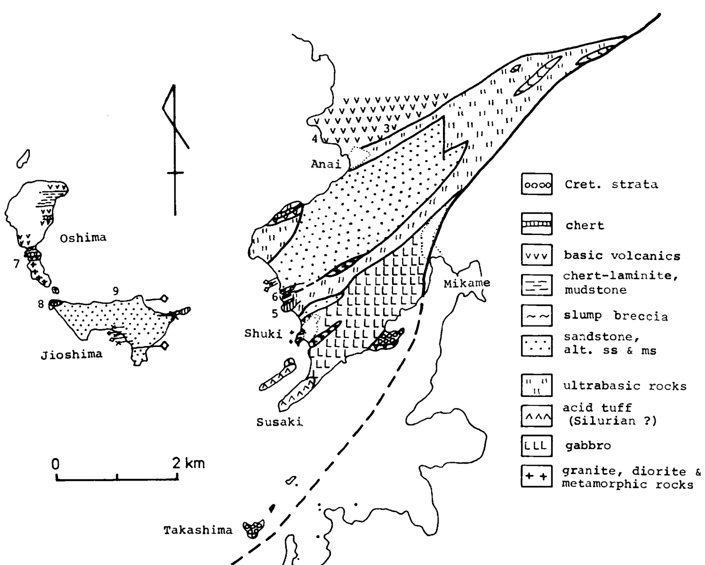



Fig. 11. Geologic map of Mikame-Oshima subarea.

tions of mica in the matrix and dusty part are present in the b-c section. In addition, the micro-boudinage of the detrital grains is common (Plate 25-4). The sandstones are deformed into the type-2 to type-3 sandstones, described in the Chapter IV-3. The deformation grade decrease toward south and becomes type-1 or type-2.

Conglomerates including large dioritic clasts, several tens of centimeters in diameter, are intercalated in the Maana sandstone beds on the northern coast of Jioshima Island (Loc. 9) (Plate 23-5). The conglomerates consist of clasts of dioritic rocks, cherts and mudstones, and sandstone matrix. Weak schistosity and lineation are observed in the sandstone of the matrix. Long axes of detrital sand grains are arranged parallel to the lineation. Grains in the dioritic clasts are also arranged with their longest axes parallel to the lineation of the sandstone matrix. The dioritic clasts were deformed probably after the deposition of the Maana beds.

The Maana beds are overlain by cherts, chert-laminites and basic volcanics conformably at the western extremity of Jioshima Island (Plate 23-6). They are all schistose, and certainly belong to the Sambagawa metamorphic rocks like those in Oshima Island, considering their lithologic characters. The basic volcanics in Oshima Island certainly belong to the Sambagawa metamorphic rocks as well, because they include tuff breccias which are identical to those of the Mikabu green rocks near Anai.

The Maana sandstone beds are overturned at Loc. 6 near Shuki, judging from graded bedding. They are overlain by cherts with basic volcanics conformably (Plate 23-7). The cherts, correlative with the D formation, are of the Permian. The Maana sandstones are probably of the Carboniferous or Permian. Cretaceous strata in the Chichibu and Kurosegawa terrains in Shikoku and the Cretaceous Onogawa group in Eastern Kyushu are not so deformed as the Maana beds. The Maana sandstone beds are not inferred to be of the Cretaceous. The beds are probably correlative with the C formation of the Sambagawa terrain (Chapter V-1) and with the Oboke-Koboke formation in Central Shikoku.

The Mikabu green rocks, ultrabasic rocks, the weakly metamorphosed Maana sandstones, and ultrabasic rocks with gabbros are distributed in this order from Anai to Mikame (Fig. 11). The ultrabasic rocks on both sides of the Maana beds join together in their eastern portion. The gabbros include granitic rocks (MASUDA, 1977) and the Silurian (?) acid tuffs as xenolith; the ultrabasic rocks and gabbros probably belong to the Kurosegawa terrain. In other words, the Sambagawa metamorphic rocks and the Kurosegawa rocks are distributed from north to south, alternating with each other on the map (Fig. 11). Just boundary between the Sambagawa metamorphic rocks in the north and the Kurosegawa rocks in the south is observed at Loc. 7 in Oshima Island; Sambagawa basic tuffs are in contact with the Kurosegawa dioritic rocks there. Only a minor fault exists along the boundary (Plate 23-8). A few small bodies of ultrabasic rocks occur also in the Mikabu subterrain (Fig. 5). In summary, the Sambagawa terrain is not clearly distinguished from the Kurosegawa "terrain" in westernmost Shikoku.

## VI. SEDIMENTARY FACIES AND PALEOGEOGRAPHY OF THE SAMBAGAWA-CHICHIBU AND SAMBOSAN TERRAINS

Sedimentary facies and paleogeography of the Kurosegawa islands-area and Sambosan geosyncline were clarified in Kyushu (MURATA, 1981a, b). Sedimentary facies of the Sambagawa-Chichibu terrain are now clarified in Western to western Central Shikoku. The Sambagawa-Chichibu terrain is divided into three areas, the Sambagawa-area, northern Chichibu-area and southern Chichibu-area in the following discussion. The Sambagawa-area is divided into the Sambagawa-subarea and the Mikabu-subarea. The upper Paleozoic and lower Mesozoic strata of the southern Chichibu geosyncline change their lithofacies laterally across the geosyncline (Fig. 12).

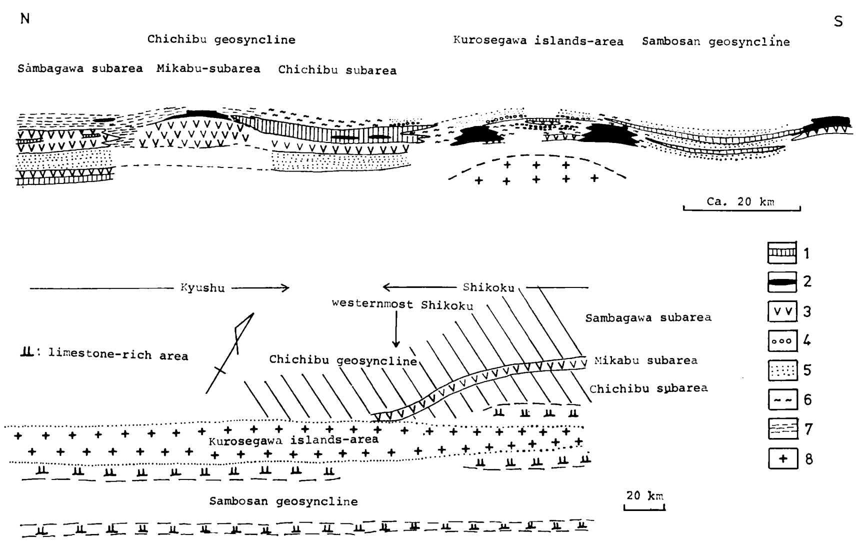



Fig. 12. Above; Schematic stratigraphic profile of the Chichibu geosyncline, Kurosegawa islands-area and Sambosan geosyncline. 1: chert, 2: limestone, 3: basic volcanics, 4: conglomerate, 5: sandstone, 6: slump breccia, 7: chert-laminite and mudstone, 8: basements of the Kurosegawa terrain. Below; Connection between the Kurosegawa islands-area and the Mikabu subarea.

Carboniferous to Permian strata of the southern Chichibu-area on the north of the Kurosegawa islands-area have a similar lithology to that of the northern Sambosan-area on the south, although the Late Triassic strata change their lithofacies from the Chichibu through the Kurosegawa to the Sambosan. For example, Permo-Carboniferous limestones (e. q. the Onogahara-Torigatayama limestones), basic volcanics, and slump breccias in the southern Chichibu-area are correlative with those in the northern Sambosan geosyncline (Fig. 12). The Sambagawa rocks in Western Shikoku intercalate a conglomerate which includes clasts of biotite gneisses and granites possibly derived from the Kurosegawa islands-area (TAKEDA *et al.*, 1981). These occurrences of strata imply that the zonal disposition of Chichibu-Kurosegawa-Sambosan existed already in Permo-Carboniferous time in Western Shikoku. A speculation that the Kurosegawa terrain and the Sambosan terrain were accreted to the Chichibu terrain in or after Jurassic time is not possible.

The Mikabu green rocks are situated about 10 km north of the Kurosegawa terrain in western Central Shikoku. They were probably situated more than 10 km north of the terrain originally, because many large and small thrusts exist between Mikabu and Kurosegawa at present. In westernmost Shikoku, on the other hand, the Mikabu subterrain and the Kurosegawa terrain were originally adjacent to each other or occupied the same area (see Chapter V).

The Kurosegawa islands-area, where the Silurian strata are distributed, existed already before the basic volcanism of the Mikabu green rocks because the volcanism occurred during the late Carboniferous to early Permian (for example, KANMERA, 1971; KIMURA, 1980). The basic volcanism of the Mikabu green rocks took place along a diagonal line to the Kurosegawa islands-area (Fig. 12). In other words, the Chichibu terrain between the Sambagawa terrain and the Kurosegawa terrain did not exist originally in westernmost Shikoku. A similar relation between the Sambagawa and Kurosegawa terrains is ascertained in Eastern Kyushu, where the Usukigawa igneous rocks (KAMBE and TERAOKA, 1968) of the Kurosegawa terrain, are distributed just to the south of the Sambagawa metamorphic rocks near the Saganoseki Peninsula (Fig. 2).

## VII. *DECKE* STRUCTURES OF THE SAMBAGAWA-CHICHIBU, KUROSEGAWA AND SAMBOSAN TERRAINS

### 1. Correlation of the thrusts in Kyushu and Shikoku.

The thrust sheets in Kyushu and Shikoku are correlative with each other on the basis of lithologic successions. On the other hand, a thrust in Shikoku does not always extend to a thrust in Kyushu continuously, because thrust sheets consisting of a particular lithologic succession were moved by several thrusts; for example, the Shiraiwayama thrust is not a single thrust, but is a set of four thrusts.

The Butsuzo thrust in Kyushu and Shikoku runs along the southern margin of the limestone layer of the southern marginal Sambosan terrain. The Unomachi *decke* in Western Shikoku and the Gomayama *decke* in Kyushu are probably continuous, because they are situated in the strike side to each other (Fig. 13). They are called the Gomayama-Unomachi *decke*.

The trace of the Shiraiwayama thrust runs nearly along the southern margin of the Permian limestone layers of the northern Sambosan terrain. The thrust has moved the strata of the Kurosegawa and northern Sambosan terrains. The Uonashi-Kambaradani thrust in Shikoku has the same characteristics as the Shiraiwayama thrust as described already, so they are here called the Shiraiwayama-Uonashi-Kambaradani thrust.

The trace of the Kitatada-Ikegawa thrust runs along the southern margin

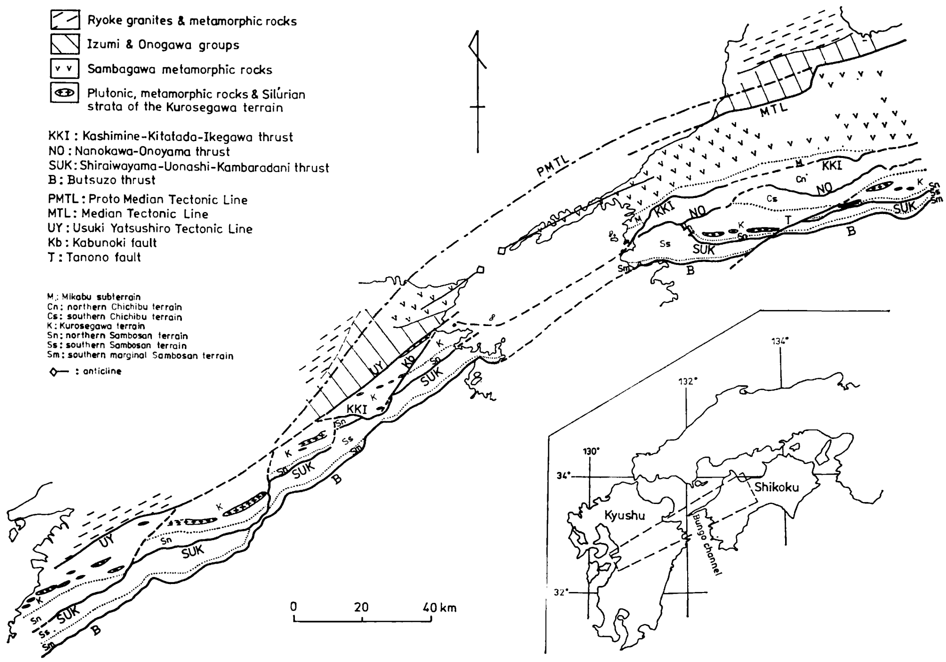



Fig. 13. Structural map of the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains in Kyushu and Shikoku.

of the Kurosegawa terrain which is located just on the south of the Mikabu subterrain in westernmost Shikoku (Fig. 13, Chapter V). The Kashimine thrust, on the other hand, has moved the strata of the Kurosegawa terrain and the Sambagawa metamorphic rocks of the Saganoseki Peninsula. It has the same characteristics as the Kitatada-Ikegawa thrust. The strata in the Kitatada-Ikegawa and the Kashimine *deckes* strike parallel to each other. An anticline exists in the Sambagawa terrain in the Sadamisaki Peninsula (KANWO, 1972; EHIME EARTH-SCIENCE ASSOCIATION, 1980). Its axial trace runs in the NE-SW direction, and its wavelength is more than 10 km. In the Sambagawa metamorphic rocks in the Saganoseki Peninsula also exists an anticline with a wavelength of more than 10 km, and its axial trace runs in the NE-SW direction (MATSUMOTO *et al.*, 1962). The two axial traces are situated on the strike side to each other (Fig. 13), and are probably continuous. From these facts, the Kitatada-Ikegawa thrust probably extend to the Kashimine thrust, and they are here called the Kashimine-Kitatada-Ikegawa thrust. Along the thrust, the Sambagawa metamorphic rocks of the Sadamisaki and Saganoseki Peninsulas and the strata of the Kurosegawa terrain moved southward as a single thrust sheet (Fig. 13).

The trace of the thrust runs probably to the south of Takashima and Mukujima Islands (Fig. 13) where Albian strata (Takashima formation, NAGAI *et al.*, 1965; Mukujima formation, KAMBE and TERAOKA, 1968) are distributed, because Albian strata are characteristically distributed on the north of the thrust in the Mie area (Haidateyama group, TERAOKA, 1970) and near Mikame (Nigyu fomation, NAGAI and NAKANO, 1961). The Nanokawa-Onoyama thrust is not traceable to Kyushu. Thus the *decke* structures in Kyushu and Shikoku are well correlative with each other.

**2. Thrusting process of the large overthrusts.**

The Kashimine-Kitatada-Ikegawa thrust, the Nanokawa-Onoyama thrust, the Shiraiwayama-Uonashi-Kambaradani thrust, and the Butsuzo thrust, trending in the E-W to NE-SW direction and having south- to southeast-ward vergence, are arranged from north to south in Kyushu to western Central Shikoku. The Nanokawa-Onoyama thrust formed after thrusting of the Shiraiwayama-Uonashi-Kambaradani thrust, because the former truncates the latter in Western Shikoku (III-4). The Kashimine-Kitatada-Ikegawa thrust truncates the Shiraiwayama-Uonashi-Kambradani thrust in Eastern Kyushu, so the former formed after thrusting of the latter. The Kashimine-Kitatada-Ikegawa *decke* covers the Nanokawa-Onoyama *decke* in Shikoku and covers the Shiraiwayama-Uonashi-Kambaradani *decke* and the Gomayama-Unomachi *decke* in Kyushu (Figs. 13, 2 & 3). The latter three *deckes* are fundamentally arranged from north to south. This occurrence suggests that the Kashimine-Kitatada-Ikegawa thrust formed after the thrusting of the Shiraiwayama-Uonashi-Kambaradani thrust and the Nanokawa-Onoyama thrust. The Kashimine-Kitatada-Ikegawa thrust is younger than the Nanokawa-Onoyama thrust, and the latter is younger than the Shiraiwayama-Uonashi-Kambaradani thrust.

The order of thrusting of the Butsuzo thrust and the Shiraiwayama-Uonashi-Kambaradani thrust is not directly ascertained because the two do not meet each other in any place. The traces of the two thrusts, run along the southern margin of limestone layers. Furthermore, many thrusts of smaller scale are developed in both *deckes,* forming imbricate structures (Chapter II). Attitudes of smaller thrusts are nearly parallel to those of the larger thrusts. The smaller thrusts formed probably during thrusting of the large overthrusts. A similar occurrence is well known in the Valley and Ridge Province in the Appalachian Mountains (for example, KING, 1977). The Shiraiwayama-Uonashi-Kambaradani thrust and the Butsuzo thrust are inferred to have been formed by the same genesis, judging from their common characteristics. The Shiraiwayama thrust was probably formed after the formation of the Butsuzo thrust, because the Shiraiwayama *decke* covers many smaller thrusts in the Gomayama *decke* in Kyushu (MURATA, 1981a, b).

In summary the Butsuzo thrust formed at first, then the Shiraiwayama-Uonashi-Kambaradani thrust, the Nanokawa-Onoyama thrust, and the Kashimine-Kitatada-Ikegawa thrust formed successively; a northern thrust is always younger than a southern one.

According to SUYARI (1961) and ISHIDA (1977, 1979), the trace of the Butsuzo thrust in eastern Central to Eastern Shikoku runs along the southern margin of the Triassic limestone layers of the southern marginal Sambosan terrain (MURATA, 1981a). The Kambaradani thrust and the Junisha thrust, also do not have the characteristics of the Butsuzo Tectonnic Line, which means a boundary fault between the Sambosan terrain and the Shimanto terrain (Fig. 1).

The trace of the Butsuzo thrust in Kanto Mountains is inferred also to run nearly along the southern margin of the limestone layers, although the very location of the thrust has not been fixed yet. The Kurasawa thrust (KIMURA, 1980), a large overthrust in the Sambosan terrain, is possibly the boundary fault between the Sambosan and Shimanto terrains, that is, the Butsuzo Tectonic Line, in its western portion, but not in its eastern portion (KIMURA *et al.*, 1976). The Kurasawa thrust is possibly younger than the Butsuzo thrust.

The Butsuzo Tectonic Line in Eastern Kii Peninsula is high-angled one. The Nomisaka *decke*, the Ichinose *decke* and the Ryusenzan *decke* are bounded on the south by the Butsuzo Tectonic Line. They are correlative with the Gomayama-Unomachi *decke*, the Shiraiwayama-Uonashi-Kambaradani *decke* and the Nanokawa-Onoyama *decke* respectively. However, it is unknown yet whether the low-angled thrusts which moved the Ryusenzan and Ichinose *deckes*, are younger than the Butsuzo thrust. The low-grade Sambagawa metamorphic rocks thrust themselves southward along the Takihara thrust in Eastern Kii Peninsula (KIMURA, 1957). The Takihara *decke* covers both of the Nomisaka *decke* and the Ichinose *decke*. This occurrence means that the Takihara thrust formed after thrusting of the Ichinose and Nomisaka *deckes*. A northern thrust probably is younger than a southern one in Eastern Kii Peninsula as well.

The Butsuzo Tectonic Line in Central Kii Peninsula is very low-angled (SHIIDA, 1962). The Butsuzo Tectonic Line from Kyushu to Western Kii Peninsula is nearly straight on the map. On the other hand, the Line in Central Kii Peninsula has a convex trace facing north (Fig. 14). According to SHIIDA (1962), strata belonging to the "northern belt of the Chichibu belt" occur just on the north of the convex, lacking strata of the "middle and southern belts". On the west and east sides of the convex, strata of the "middle and southern belts" are distributed striking ENE-WSW approximately.

The strata of the "middle and southern belts" that once thrust themselves over the Shimanto supergroup at the convex area, are considered to have been eroded out. The strata of the "northern belt", "middle belt" and "southern belt" are lithologically correlative with those in the Nanokawa-Onoyama *decke*, the

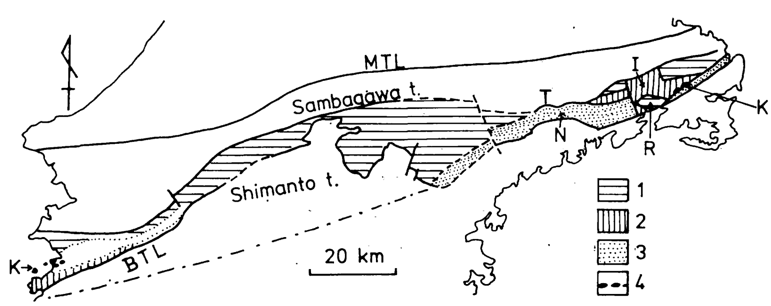



Fig. 14. Structural map of Kii Peninsula. After SHIIDA (1961) and KIMURA (1957). 1: "northern belt of the Chichibu belt", 2: "middle belt", 3: "southern belt", MTL: Median Tectonic Line, BTL: Butsuzo Tectonic Line, T: Takihara thrust, K: Kurosegawa rocks, I: Ichinose *decke*, R: Ryusenzan *decke*, N: Nomisaka *decke*, — — —: inferred extension of the "southern belt".

Shiraiwayama-Uonashi-Kambaradani *decke* and the Gomayama-Unomachi *decke* respectively. The strata of the "northern belt" in Shikoku have moved southward along the Nanokawa-Onoyama thrust. Thus the Butsuzo Tectonic Line in Central Kii Peninsula corresponds probably to the Nanokawa-Onoyama thrust though the former occupies the position of the Butsuzo thrust. The occurrence of the thrusts in Shikoku and Central Kii suggests that the Butsuzo thrust and other large thrusts join together in a deeper level of the crust to form a master *decollement* (Fig. 15). Since a northern thrust always formed after a southern thrust as described before, it is concluded that the master *decollement* or the Butsuzo thrust formed at first, and then the northern thrusts formed successively as listric faults, branching off the master *decollement*. It is well known in the Valley and Ridge Province in Appalachian Mountains (HARRIS and BAYER, 1979) and in the thrust belt in Canadian Rocky Mountains (PRICE, 1973) that many thrusts observed in the earth surface join together in a deeper level in the crust to form a master *decollement*.

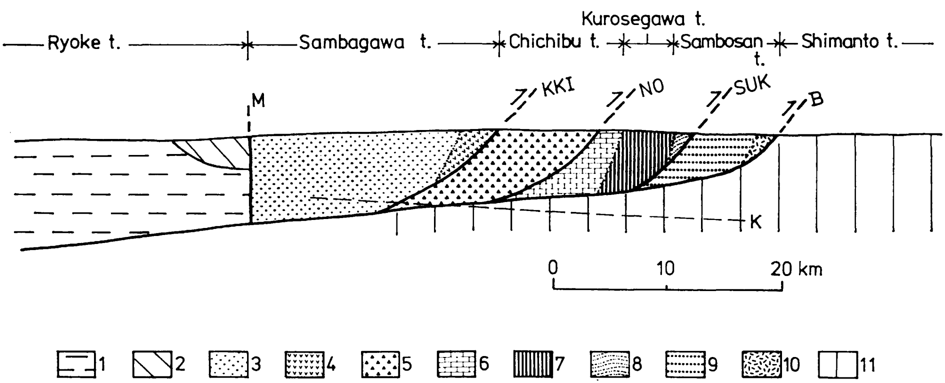



Fig. 15. Schematic cross section of the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains. This section is drawn on the supposition that overthrusting occurred in post-Izumi time. 1: Ryoke granites and metamorphic rocks, 2: Izumi group, 3: Sambagawa metamorphic rocks, 4: Mikabu green rocks, 5: strata of northern Chichibu terrain, 6: southern Chichibu terrain, 7: Kurosegawa terrain, 8: northern Sambosan terrain, 9: southern Sambosan terrain, 10: southern marginal Sambosan terrain, 11: Shimanto supergroup, M: Median Tectonic Line, KKI: Kashimine-Kitatada-Ikegawa thrust, NO: Nanokawa-Onoyama thrust, SUK: Shiraiwayama-Uonashi-Kambaradani thrust, B: Butsuzo thrust. Dashed line (K) is an erosional surface of Central Kii Peninsula.

It is notable that the overthrusts in the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains were not formed by the accretion process from the oceanic side (KARIG and SHARMAN, 1975). In case of the accretionary process, a northern (continental side) thrust is expected to be older than a southern (oceanic side) one.

### 3. Age of thrusting and "root zone" of overthrusts.

The Shiraiwayama-Uonashi-Kambaradani thrust has moved the Shibanomoto formation (KAMBE, 1957) of Neocomian to Albian age in Central Kyushu, and the Yatsushiro and other formations (MATSUMOTO and KANMERA, 1964) of Neocomian to Cenomanian age in Western Kyushu. The thrust has moved the Permo-Triassic strata over the Imaidani formation of Late Jurassic age and the Ryoseki series of earliest Cretaceous age (KASHIMA, 1969) in Western Shikoku. The thrust is overlain unconformably by the Mitate formation of possible Paleogene (Eocene ?) age (MATSUMOTO and HASHIMOTO, 1963) in Central Kyushu (Fig. 2). The thrust formed probably at a time from Turonian to Eocene.

The Kashimine-Kitatada-Ikegawa thrust has moved the Haidateyama formation, the Tano group and the Onogawa group of Albian to Santonian age (TERAOKA, 1970) in Eastern Kyushu, and the Nigyu formation (NAGAI and NAKANO, 1961) of Albian age in westernmost Shikoku. The thrust is intruded by the Miocene granite porphyry (ONO *et al.*, 1977) in Eastern Kyushu. The thrust formed probably at a time from Santonian to Miocene.

The Nanokawa-Onoyama thrust formed at a time from Jurassic to Miocene. The Butsuzo thrust has moved the Permo-Triassic strata over the folded Shimanto supergroup of Neocomian to Santonian age (YANAI, 1981). The Nakaoku formation of probably Eocene age, occurs on the northern side and the southern side of the Butsuzo thrust or a master *decollement* in Central Kii Peninsula (SHIIDA, 1962). The Butsuzo thrust formed probably at a time from Santonian to Eocene. The thrusting of four large overthrusts occurred at times from Late Cretaceous to Miocene time.

The Kashimine-Kitatada-Ikegawa thrust has moved the Sambagawa metamorphic rocks and the Onogawa group which contains large clasts of the metamorphic rocks (MATSUMOTO, 1936; KOBAYASHI, 1941), in Eastern Kyushu. Namely, the thrusting occurred after uplift of the Sambagawa metamorphic rocks. OGAWA (1978) considered that recumbent folds of the Sambagawa metamorphic rocks are genetically related to the thrusts in the Kurosegawa and Sambosan terrains. The folds, however, formed probably before the uplift of the metamorphic rocks.

The root zone of the overthrusts is not known yet. It is inferred by the following reason to be located to the north of the Median Tectonic Line and the Usuki Yatsushiro Tectonic Line. The Usuki Yatsushiro Line in Western Kyushu separates the Kurosegawa terrain in the south from the Ryuhozan metamorphic rocks, the Miyanohara granodiorite and the Higo gneisses in the north, which are correlative with the Ryoke metamorphic rocks (MATSUMOTO and KANMERA, 1964). The Usuki Yatsushiro Line is not a root zone from which the Shiraiwayama thrust emerged, because just on the south of the Line occur Cretaceous strata, that are youngest in the Shiraiwayama *decke*, but occur no older deformed rocks indicating a root zone. The Line in Eastern Kyushu is also not a root zone of the Kashimine thrust as described before (II-2). The rocks of the Ryoke terrain, therefore, moved probably southeastward along the Shiraiwayama and Kashimine thrusts. The Usuki Yatsushiro Tectonic Line is a fault of a later age.

Paleogeography of the Sambagawa-Chichibu and Ryoke terrains during the thrusting is not sufficiently clarified. The Izumi group was deposited in the southern marginal area of the Ryoke terrain during Campanian to Maastrichtian time. The group contains no clasts from the Sambagawa metamorphic rocks (NISHIMURA *et al.*, 1980). The Kuma group of shallow marine facies (NAGAI, 1972) unconformably overlies the Sambagawa metamorphic rocks at Western Shikoku in Eocene time. It is therefore concluded that no large mountains or intense uplift zones in the southern area of the Ryoke terrain and in the Sambagawa terrain during thrusting. Alternative timing for the overthrusting is possible; pre-Izumi or post-Izumi. If the overthrusting occurred in pre-Izumi time, the narrow Izumi basin was formed possibly in association with the earth movement that generated the overthrusting, and the Izumi group is autochthonous. If the overthrusting occurred in post-Izumi time, the Izumi group is allochthonous. It is certain that the overthrusting occurred after deposition of the Turonian-Santonian Onogawa group which is similar to the Izumi group in lithology. I believe the overthrusting occurred in post-Izumi time.

As the strata of the Ryoke, Sambagawa-Chichibu and Sambosan terrains moved together southward along the overthrusts, the root zone is believed to exist to the north of these terrains. In Central Kii Peninsula, the Shimanto supergroup occurs closely on the south of the Sambagawa metamorphic rocks. Strata of the Chichibu and Sambosan terrains about 20 km wide, which once covered the Shimanto supergroup, have mostly been eroded out there. This fact suggests that the Butsuzo thrust has at least 20 km horizontal displacement (Fig. 15). In addition, the Chichibu and Sambosan terrains are fairly shortened by the overthrusts and smaller thrusts, and therefore the Ryoke terrain is roughly estimated to have moved southward about 100 km relative to the Shimanto terrain. This value corresponds roughly to the width of the Tsushima channel which formed originally as a Paleogene sedimentary basin. The *deckes* were possibly pushed from north in association with the opening of the Japan Sea (KIMURA, 1978).

## VIII. SUMMARY

(1) The Mikabu-subarea was situated more than 10 km to the north of the Kurosegawa islands-area in Western to western Central Shikoku, but they were adjacent to each other in westernmost Shikoku. The basic volcanism of the Mikabu green rocks took place with diagonal trend to the Kurosegawa islands-area. The Chichibu terrain between the Sambagawa terrain and the Kurosegawa terrain did not exist originally in westernmost Shikoku to Kyushu.

(2) The trace of the Butsuzo thrust in Kyushu to Shikoku runs along the southern margin of the southern marginal Sambosan terrain. Along the thrust, the strata such as cherts and sandstones in the southern Sambosan terrain, and those such as limestones and basic volcanics in the southern marginal Sambosan terrain, thrust themselves southward over the Shimanto supergroup, and constitute the Gomayama-Unomachi *decke*. The Butsuzo thrust in Shikoku is cut off and displaced by the Tanono fault with NE-SW trend.

(3) The Uonashi thrust in Western Shikoku is originally the western extension of the Kambaradani thrust in Central Shikoku, and they should be called

the Uonashi-Kambaradani thrust, which is cut off by the Tanono fault. The trace of the Uonashi-Kambaradani thrust runs along the southern margin of the Permian limestone layer of the northern Sambosan terrain. Along the thrust, the strata of the southern Chichibu, Kurosegawa and northern Sambosan terrains thrust themselves southward over the Gomayama-Unomachi *decke*, and constitute the Uonashi-Kambaradani *decke*. The *decke* is correlative with the Shiraiwayama *decke* in Kyushu.

(4) The Onoyama thrust in Western Shikoku is the western extension of the Nanokawa thrust in western Central Shikoku, and they should be called the Nanokawa-Onoyama thrust. Along the thrust, the strata which underwent the Sambagawa metamorphism thrust themselves southward over the Uonashi-Kambaradani *decke* and the Gomayama-Unomachi *decke*.

(5) The trace of the Kitatada-Ikegawa thrust runs along the southern margin of the Mikabu green rocks in Western to western Central Shikoku, and runs along the southern margin of the Kurosegawa terrain in westernmost Shikoku. Along the thrust, the Sambagawa metamorphic rocks in Shikoku thrust themselves southward over the Nanokawa-Onoyama *decke*, and constitute the Kitatada-Ikegawa *decke*. The Kitatada-Ikegawa thrust in Shikoku is the eastern extension of the Kashimine thrust in Kyushu.

(6) In conclusion, the four large overthrusts, all trending in the E-W to NE-SW direction, are ascertained in the Sambagawa-Chichibu and Sambosan terrains in Kyushu to western Central Shikoku. They are from south to north, the Butsuzo thrust, the Shiraiwayama-Uonashi-Kambaradani thrust, the Nanokawa-Onoyama thrust and the Kashimine-Kitatada-Ikegawa thrust. Among those thrusts, the northern thrust is always formed after the thrusting of the southern one. They are inferred to unite together into a master *decollement* in the deeper part under the ground. It is inferred that the master *decollement* or the Butsuzo thrust was formed at first, and that the northern thrusts were successively formed, branching off the master *decollement*. This fact means that those overthrusts and smaller thrusts, producing the imbricate structure, were not formed by the accretion.

(7) The overthrusts were formed from Santonian to Paleogene time. The thrusting has no direct relation with the Sambagawa metamorphism and following uplift of the metamorphic rocks. Along the overthrusts, the strata and rocks of the Ryoke, Sambagawa-Chichibu, Kurosegawa and Sambosan terrains have moved southward over the strata of the Shimanto terrain.

**Acknowledgements**

I wish to express my sincere gratitude to Emeritus Professor Toshio Kimura of the University of Tokyo for his guidance, instructive suggestions and critical reading of the manuscript. I am deeply indebted to Associate Professor Toshio Koike of the Yokohama National University who kindly identified all the specimens of conodonts reported in this paper. I wish to express my gratitude to Associate Professor Shizuo Yoshida of the Nagoya University, who read the manuscript and suggested improvements. I wish also to express my gratitude to Professor Azuma Iijima of the University of Tokyo for his instructive suggestions on dolostones. Thanks are also extended to Associate Professor Tomowo Ozawa of the Hyogo University of Teacher Education and Associate Professor Kiyotaka Chinzei of the University of Tokyo for their identification of fossils. Thanks are also extended to Associate Professor Yasuo Nakamura and Dr. Tanio Ito of the University of Tokyo and Dr. Toshiaki Masuda of the Shizuoka University for their critical discussion. I owe my study to many persons of the Geological Institute of the Faculty of Science, the University of Tokyo, to whom I wish express my thanks.

## REFERENCES

(J. ; in Japanese, J. E.; in Japanese with English abstract)

ABE, T. (1978), Stratigraphy and geologic structure of the Sambagawa-Chichibu System in the Yoshino district, central part of the Kii Peninsula, central Japan. Master thesis, Univ. Tokyo.

AIBA, K. (1981), Metamorphism of the northern belt of the Chichibu Belt in western Central Shikoku. *Collect. Abs. 88th meeting of Geol. Soc. Japan, in Tokyo*, 367. (J).

BANDO, Y. (1964), The Triassic stratigraphy and ammonite fauna of Japan. *Sci. Rep., Tohoku Univ., 2nd Ser. (Geol.)*, 36, 1-137.

EHIME EARTH-SCIENCE ASSOCIATION (1980), Geological map of Ehime Prefecture, 1: 200,000, (ed. by NAGAI, K. *et al.*).

HADA, S. (1974), Construction and evolution of the intrageosynclinal tectonic lands in the Chichibu belt of western Shikoku, Japan. *Jour. Geosci., Osaka City Univ.*, 17, 1-52.

———, SUZUKI, T., YOSHIKURA, S. and TSUCHIYA, N. (1979), The Kurosegawa Tectonic Zone in Shikoku and tectonic environment of the Outer Zone of Southwest Japan. *"The basement of the Japanese Islands—Professor Hiroshi Kano Memorial Volume". ed. by Editorial Committee of the "Professor Kano Memorial Volume"*, 341-368. (J. E.)

HARA, I., HIDE, K., TAKEDA, K., TSUKUDA, E., TOKUDA, M. and SHIOTA, T. (1977), Tectonic movement in the Sambagawa belt. *In "The Sambagawa Belt" (ed. by K. Hide)*, 307-390. (J. E.).

HARRIS, D. L. and BAYER, K. C. (1979), Sequential development of the Appalachian orogen above a master decollement—A hypothesis. *Geology*, 7, 568-572.

HASEGAWA, S. (1980), Stratigraphy and geologic structure of the Sambagawa-Chichibu system in central and western Shikoku. Master thesis, Univ. Tokyo.

HASHIMOTO, M. and KASHIMA, N. (1970), Metamorphism of Paleozoic greenstones in the Chichibu belt of western Shikoku. *Jour. Geol. Soc. Japan*, 76. 199-204. (J. E.)

HASHIMOTO, K. (1955), Geological study of the Paleozoic strata in Shikoku. *Kyoikugeppo* (The education board of Kochi Prefecture), 7, 25-26. (J.)

HIDE, K. (1972), Significnce of the finding of two recumbent folds in the Sambagawa metamorphic belt of the Nagahama-Ozu district, western Shikoku. *Mem. Fac. Gen. Educ., Hiroshima Univ.*, III, 5, 35-51.

HIGASHINO, T. (1975) Biotite zone of Sambagawa metamorphic terrain in the Shiragayama area, central Shikoku, Japan. *Jour. Geol. Soc. Japan*, 81, 653-670. (J. E.)

HIRAYAMA, K. and KAMBE, N. (1956), Geological Map of Japan, Scale 1 : 50,000, Yawatahama and Iyo-Takayama sheets, and their explanatory text. Geol. Survey, Japan, (J. E.).

HORIKOSHI, E. (1972), Orogenic belt in Japanese Islands and plate tectonics. *Kagaku*, 42, 665-673. (J).

ICHIKAWA, K., ISHII, K., NAKAGAWA, C., SUYARI, K. and YAMASHITA, N. (1956), Die Kurosegawa-Zone. *Jour. Geol. Soc. Japan*, 62, 82-103. (in Japanese with German abstract).

IKEBE, N. (1936), On the Uonashi thrust. *Chikyu*, 25, 399-408. (J).

IKUMA, T. (1980), Deformation of the Cretaceous strata of the Chichibu belt in the Ryoseki-Monobegawa area, Kochi Prefecture, Shikoku. *Jour. Geol. Soc. Japan*, 86, 389-407. (J.E.).

ISHIDA, K. (1977), Reexamination of the Paleozoic and Mesozoic formations in the Southern Zone of the Chichibu Belt in eastern Shikoku by means of conodonts and fusulinids. *Jour. Geol. Soc. Japan*, 83, 227-240. (J.E.)

——— (1979), Study of the South Zone of the Chichibu Belt in Shikoku, Part 2, Stratigraphy and structure around Nagayasu-guchi Dam, Tokushima Prefecture. *Jour. Sci. Coll. Gen. Educ., Univ. Tokushima*, 12, 61-92. (J.E.)

ISHIZAKI, K. (1962), Stratigraphical and paleontological studies of the Onogahara and its neighbouring area, Kochi and Ehime Prefectures, Southwest Japan. *Sci. Rep., Tohoku Univ., 2nd Ser.*, 34, 95-185.

ISOZAKI, Y., MAEJIMA, W. and MARUYAMA, S. (1981), Occurrence of Jurassic radiolarians from the pre-Cretaceous rocks in the northern subbelt of the Chichibu Belt, Wakayama and Tokushima Prefectures. *Jour. Geol. Soc. Japan*, 87, 555-558. (J.)

IWASAKI, M. (1960), Glaucophanic amphibole in the weakly metamorphosed schalstein from Yanadani-mura, Ehime Prefecture. *Jour. Japan. Assoc. Miner. Petr. Econ. Geol.*, 44, 189-193. (J.E.)

KAMBE, N. (1957), Geological map of Japan, Scale 1:50,000, Kuraoka sheet, and its explanatory text. Geol. Survey, Japan. (J.E.).

——— (1963), On the boundary between the Permian and Triassic systems in Japan. *Japan. Geol. Surv. Rep.*, 198, 1-66. (J.E.).

——— and TERAOKA, Y. (1968), Geological map of Japan, Scale 1:50,000, Usuki sheet, and its explanatory text. Geol. Survey, Japan. (J.E.).

KANMERA, K. (1971), Palaeozoic and early Mesozoic geosynclinal volcanicity in Japan. *Mem. Geol. Soc. Japan*, 6, 97-110. (J.E.).

KANWO, S. (1972), Study of the major and minor structure in the Sanbagawa crystalline schist, Sadamisaki Peninsula and the neighbouring area, north Shikoku, Japan. Master thesis, Univ. Tokyo.

KARIG, D.E. and SHARMAN, G.F. (1975), Subduction and accretion in trenches. *Geol. Soc. Am. Bull.*, 86, 377-389.

KASHIMA, N. (1967), The arrangement of strata in the Chichibu terrain in western Shikoku, Japan—A study of the Chichibu terrain in western Shikoku V—. *Jour. Geol, Soc. Japan*, 73, 281-289. (J.E.)

——— (1968), The Butsuzo tectonic line in western Shikoku, Japan. *Jour. Geol. Soc. Japan*, 74, 459-471. (J.E.)

——— (1969), Stratigraphical studies of the Chichibu belt in western Shikoku. *Mem. Fac. Sci., Kyushu Univ., Ser. D, Geology*, 19, 387-436.

——— and TOKIWAI, M. (1972), Geology and structure in the Maana area, southern Yawatahama City, Shikoku. *Mem. Ehime Univ., Sci., Ser. D (Earth Sci.)*, 7, 45-50. (J.E.).

KIMURA, T. (1957), The geologic structure and the sedimentary facies of the Chichibu Group in the Eastern Kii Peninsula; a contribution to the geotectonic study of southwest Japan. *Sci. Pap. Coll. Gen. Educ., Univ. Tokyo*, 7, 243-272.

——— (1974), The ancient continental margins of Japan. *In "The geology of continental margins" (ed. C.A. Burk and C.L. Drake)*, 817-829.

——— (1978), Japanese Islands—the geological history—, I, Kokon-shoin. Tokyo. (J).

——— (1980), Japanese Islands—the geological history—, II. Kokon-shoin, Tokyo. (J).

——— and HORIKOSHI E. (1959), On the geologic structure of the Chichibu terrain in western Central Shikoku. *Sci. Pap., Coll. Gen. Educ., Univ. Tokyo*, 9, 329-342.

———, YOSHIDA, S. and TOYOHARA, F. (1975), Paleogeography and earth movements of Japan in the Late Permian to Early Jurassic Sambosan stage. *Jour. Fac. Sci., Univ. Tokyo, Sec. II*, 19, 149-177.

———, TOKUYAMA, A. and YOSHIDA, S. (1976), On the grand Decken structure—Kawanoridani Decke. *Collect. Abs. 83th meeting of Geol. Soc. Japan, in Matsumoto*, 146. (J).

KING, P.B. (1977), The Evolution of North America. Princeton University Press.

KOBAYASHI, T. (1931), Geologic structure and Paleozoic strata in the Sakawa basin. *Jour. Geol. Soc. Japan*, 38, 497-519. (J.)

——— (1941), The Sakawa orogenic cycle and its bearing on the origin of the Japanese Islands. *Jour. Fac. Sci., Univ. Tokyo*, 5, 219-578.

KOIKE, T. (1979), Conodont biostratigraphy of the Tao limestone (Triassic) in Shirokawa-cho, Higashiuwa-gun, Ehime Prefecture. *In "Biostratigraphy of Permian and Triassic Conodonts and Holothurian Sclerites in Japan"*, 21-77. (J.).

KOJIMA, G. and MITSUNO, C. (1966), Geological map of Japan, Scale 1:50,000, Kawaguchi sheet, and its explanatory text. Geol. Survey, Japan. (J.E.).

KUWANO, Y. (1979), Triassic conodonts from the Mikabu greenrocks in central Shikoku. *Bull. Nat. Sci. Mus., Ser. C*, 5, 9-24.

MARUYAMA, S. (1978), Dismembered ophiolite in the Kurosegawa Tectonic Zone. *Marine Sciences*, 10, 287-296. (J).

———, YOSHIKURA, S. and SATO, K. (1976), Structure of pillow lava flow in Sanbagawa belt, western Shikoku. *Jour. Geol. Soc. Japan*, 82, 607-608. (J.)

MASUDA, T. (1977), Discovery of crushed granitic rock in the Chichibu Terrain at westernmost Shikoku. *Jour. Geol. Soc. Japan*, 83, 821-822. (J.)

MATSUDA, T. (1978), Discovery of the Middle-Late Triassic conodont genus *Metapolygnathus* from calcareous schist of the Sambagawa southern marginal belt in central Shikoku. *Jour. Geol. Soc. Japan*, 84, 331-333. (J).

MATSUMOTO, T. (1936) Study on the geologic history of the Onogawa Basin, I, II. *Jour. Geol. Soc. Japan*, 43, 758-786, 815-852. (J.E.)

——— and KANMERA, K. (1964), Geological map of Japan, Scale 1:50,000, Hinagu sheet, and its explanatory text. Geol. Survey, Japan. (J.E.)

———, NODA, M. and MIYAHISA, M. (1962), Kyushu District. Asakura-shoten, Tokyo. (J.)

MATSUMOTO, Y. and HASHIMOTO, I. (1963), Unconformity below the Mitate formation in Kyushu. *Jour. Geol. Soc. Japan*, 69, 378-387. (J.E.)

MIYAHISA, M. and KASHIMA, N. (1967), Geological studies on the dolomite deposits of Chichibu terrain, western Shikoku, Japan. *Jour. Soc. Min. Geol. Japan*, 17, 214-227. (J.E.)

MURATA, A. (1981a), A large overthrust and the paleogeography of the Kurosegawa and Sambosan Terrains—in the case of the Gokase area in central Kyushu. *Jour. Geol. Soc. Japan*, 87, 353-367. (J.E.)

——— (1981b), Large *decke* structures in the Kurosegawa and Sambosan terrains, in Kyushu, Southwest Japan. *Jour. Fac. Sci., Univ. Tokyo, Sec. II*, 20, 277-293.

———, HASEGAWA, S. and HATA, S. (1980), Stratigraphy and major geologic structures of the Chichibu-Sambosan terrains in western Shikoku. *Collect. Abs. 87th meeting of Geol. Soc. Japan, in Matsue*, 361. (J.)

NAGAI, K. (1972), The Eocene Kuma Group, Shikoku. *Mem. Ehime Univ., Sec. II, Ser. D. (Earth Sci.)*, 7, 1-7. (J.E.).

——— and NAKANO, M. (1961), On the newly discovered Lower Cretaceous Nigyu formation from Nigyu in Mikame-cho, Nishiuwa-gun, Ehime Prefecture, Shikoku, Japan. *Mem. Ehime Univ., Sec. II, Ser. D. (Earth Sci.)*, 4, 1-6. (J.)

——— and KASHIMA, N. (1963), The Upper Jurassic Tanohama Formation in Akehama-cho, Higashiuwa-gun, Ehime Prefecture. *Mem. Ehime Univ., Sec. II Ser. D (Earth Sci.)*, 4, 11-16. (J.E.)

———, NAKANO, M. and FUKUROSE, R. (1965), Geology of the Taka-shima and its associated islands, offing Mikame, Nishiuwa-gun, Ehime Prefecture, Shikoku, Japan.

*Mem. Ehime Univ., Sec. II, Ser. D (Earth Sci.)*, 5, 23-28. (J.E.)

NISHIMURA, T., IIJIMA, A. and UTADA, M. (1980), Zeolitic burial diagenesis and basin analysis of the Izumi Group in Shikoku and Awaji Islands, Southwest Japan. *Jour. Geol. Soc. Japan*, 86, 341-351. (J.E.).

OGAWA, Y. (1978), Structural characteristics and tectonisms around the microcontinent in the outer margin of the Paleozoic-Mesozoic geosyncline of Japan. *Tectonophysics*, 47, 295-310.

OHO, Y. (1981), Slaty cleavage textures in the Ojika Peninsula, the South Kitakami Mountains. *Jour. Geol. Soc. Japan*, 87, 657-673. (J.E.)

ONO, K., MATSUMOTO, Y., MIYAHISA, M., TERAOKA, Y. and KAMBE, N. (1977), Geological Map of Japan, scale 1:50,000, Taketa sheet, and its explanatory text. Geol. Survey Japan. (J.E.)

PRICE, R.A. (1973), Large-scale gravitational flow of supracrustal rocks, Southern Canadian Rockies. *In "Gravity and Tectonics", ed. by De Yong, J.A. and Scholten, R.*. John Wiley & Sons, New York, 491-502.

SAKAGAMI, S. and WATANABE, C. (1972), The conodont fauna from the so-called Sanbosan Group in Ehime Prefecture, Japan. *Mem. Ehime Univ. Sec. II, Ser. D (Earth Sci.)*, 7, 17-22. (J.E.)

SANO, H. (1980), Stratigraphy of the northern belt of the Chichibu belt in the upper stream of the Niyodo River, Kochi Prefecture. *Collect. Abs. 87th meeting of Geol. Soc. Japan, in Matsue*, 130. (J.)

SHIIDA, I. (1962), Stratigraphical and geotectonic studies of the Paleozoic Chichibu and the Mesozoic Hitaka (Shimanto) terrains in the central part of the Kii Mountainland, southern Kinki, Japan. *Res. Bull. Dept. Gen. Educ., Nagoya Univ.*, 16, 1-58. (J.E.)

SUYARI, K. (1961), Geological and paleontological studies in central and eastern Shikoku, Japan, Part 1, Geology. *Jour. Gakugei, Tokushima Univ., Nat. Sci.*, 11, 11-76.

———, KUWANO, Y. and ISHIDA, K. (1980) Discovery of the Late Triassic conodonts from the Sambagawa Metamorphic Belt proper in western Shikoku. *Jour. Geol. Soc. Japan*, 86, 827-828. (J.)

———, ——— and ——— (1981), Stratigraphy and structures of the Chichibu Belt, and connection between the Chichibu and Sambagawa Belts. *Studies on Late Mesozoic Tectonism in Japan*, 3, 99-113. (J.)

———, ——— and ——— (1982), Stratigraphy and geological Structure of the Mikabu Green-rock Terrain and its environs. *Jour. Sci., Univ. Tokushima*, 15, 51-71. (J.E.)

SUZUKI, TAKASHI (1967), The Mikabu greenrocks in Shikoku—with special reference to distribution and occurrence of agglomeratic rocks—. *Jour. Geol. Soc. Japan*, 73, 207-216. (J.E.)

——— (1972), Volcanism and metamorphism of the Mikabu Greenrocks in central and western Shikoku. *Res. Rep. Kochi Univ.*, 21, 39-62. (J.E.)

———, KASHIMA, N., HADA, S. and UEMURA, H. (1972), Geosynclinal volcanism of the Mikabu Green-Rocks in the Okuki area, Western Shikoku, Japan. *Jour. Japan. Assoc. Min. Pet. Econ. Geol.*, 67, 177-192.

SUZUKI, TATSUO (1935), Geological map of Japan, Scale 1:75,000. Unomachi sheet, and its explanatory text. Geol. Survey, Japan.

TAIRA, A., NAKASEKO, K., KATTO, J., TASHIRO, M. and SAITO, Y. (1979), New observations on the "Sambosan group" in the western part of Kochi Prefecture. *Chishitsu News*, 302, 22-35. (J).

TAKEDA, K., TSUKUDA, E., TOKUDA, M. and HARA, I. (1977), Structural relationship between the Sambagawa and the Chichibu belts. *In "The Sambagawa Belt" (ed. by K. Hide)*. 107-151. (J.E.).

———, HIDE, K. and HARA, I. (1981), Discovery of crystalline schists containing clastics of amphibolite, biotite-gneiss and granite in the Sambagawa Belt, western Shikoku, Japan. *Jour. Geol. Soc. Japan*, 87, 689-692. (J.)

TERAOKA, Y. (1970), Cretaceous Formations in the Onogawa Basin and its vicinity, Kyushu, Southwest Japan. *Japan. Geol. Surv. Rept.*, 237, 1-84. (J. E.)

TSUKUDA, E., HARA I. and TOMINAGA, R. (1981), On the geologic structures of the Chichibu terrain in the western Shikoku. *Bull. Tectonic Research Group in Japan*, 26, 127-134.

YANAI, S. (1981), The stratigraphical and palaeogeographical situations of the Upper Cretaceous Uwajima Group of the shelf-facies within the Shimanto Supergroup, western Shikoku, Japan. *Jour. Geol. Soc. Japan*, 87, 339-352. (J. E.)

YOSHIDA, S. (1981), Chert-laminite: its petrographical description and occurrence in Japanese geosynclines. *Jour. Geol. Soc. Japan*, 87, 131-141. (J. E.)

## Postscript

While this paper was in review, I was informed of recent work about the Butsuzo Tectonic Line of Western to Central Kii Peninsula (KURIMOTO, 1982). According to him, the Sambagawa metamorphic rocks are in contact with the Shimanto supergroup by the Aridagawa Tectonic Line. Dashed line (K) in Fig. 15 of my paper should be placed at a lower level so that the Sambagawa metamorphic rocks are in contact with the Shimanto supergroup. The Sambagawa metamorphic rocks are thrust over the strata of the Chichibu and Sambosan terrains along the low-angled Takihara thrust in Eastern Kii Peninsula (KIMURA, 1957). The high-angled Aridagawa Tectonic Line is considered to be late generated fault after thrusting.

KURIMOTO (1982), "Chichibu System" in the area southwest of Koyasan, Wakayama Prefecture—Upper Cretaceous Hanazono Formation—. *Jour. Geol. Soc. Japan*, 88. 901-914. (J. E.)

A. MURATA

Large *decke* structures and their formative process in the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains, Southwest Japan

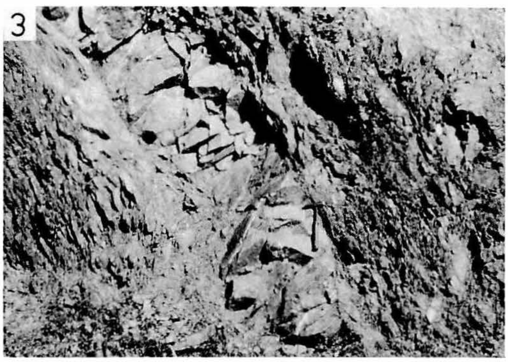
# Plate 23

## Explanation of Plate 23

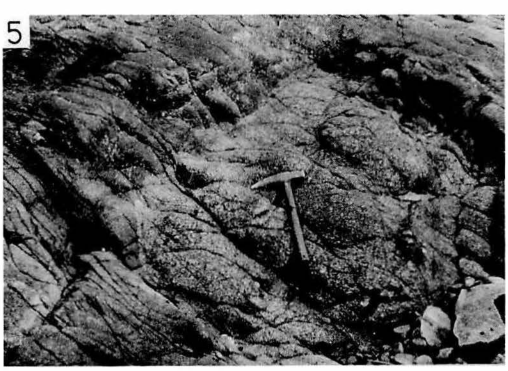
1. Kink band observed in chert-laminites of the c-formation at Funado.
2. Pillow lava in the Sambagawa terrain at Loc. 99 to the east of Sozu. It is slightly elongated.
3. Dolerite dike intruding tuff breccias of the Mikabu green rocks at Loc. 3 near Anai.
4. The Maana sandstone beds at Loc. 6 to the north of Shuki. The beds are overturned.
5. Huge dioritic clast in the Maana sandstone beds at Loc. 9 at the northern coast of the Jioshima Island.
6. The Maana sandstone beds (ss) overlain by cherts (ch) and basic volcanics (bv) at the western extremity of the Jioshima Island. Cliff is 20 m in height.
7. Boundary between the Maana beds and cherts at Loc. 6 near Shuki. Slump breccia (left) of the Maana beds are overlain by cherts (right).
8. Boundary between basic tuffs (left) of the Mikabu subterrain and dioritic rocks (right) of the Kurosegawa terrain.

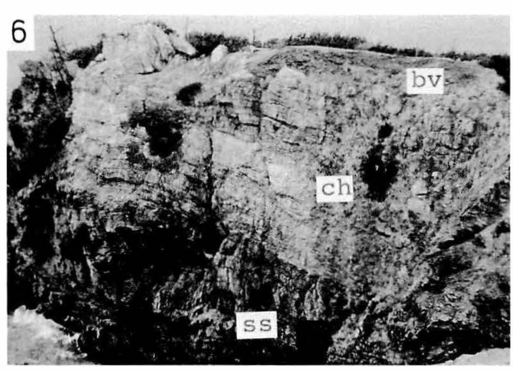

1

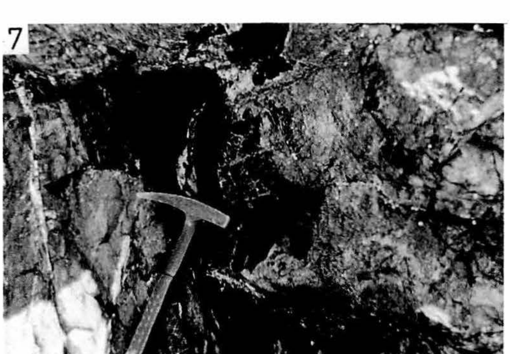

2


3


4


5


6
bv
ch
ss


7


8

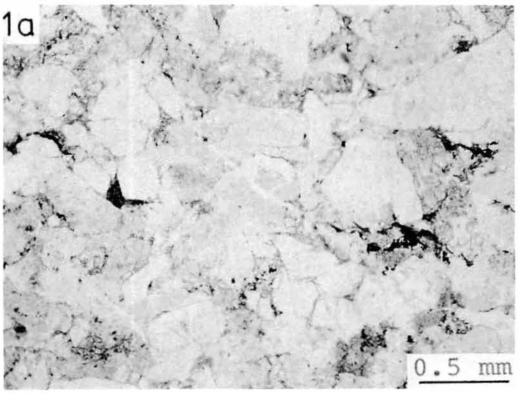
A. MURATA

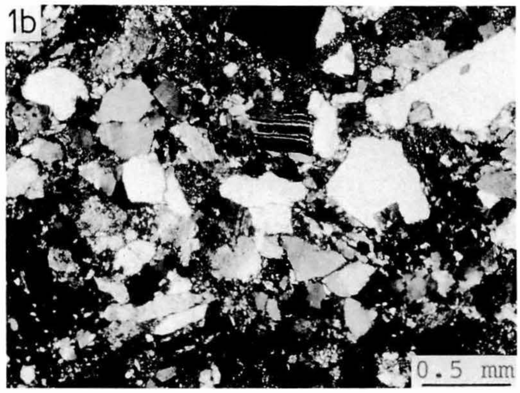
Large *decke* structures and their formative process in the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains, Southwest Japan

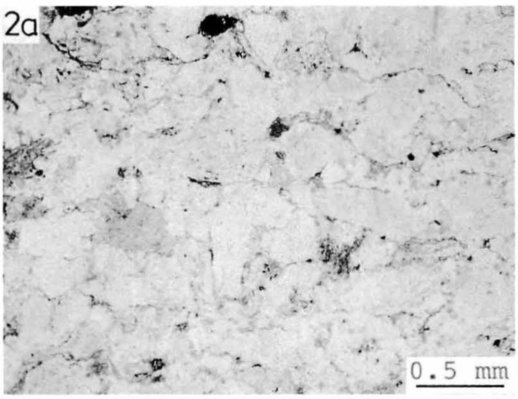
# Plate 24

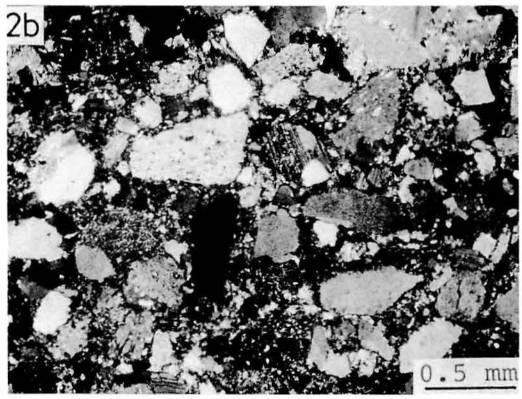
## Explanation of Plate 24

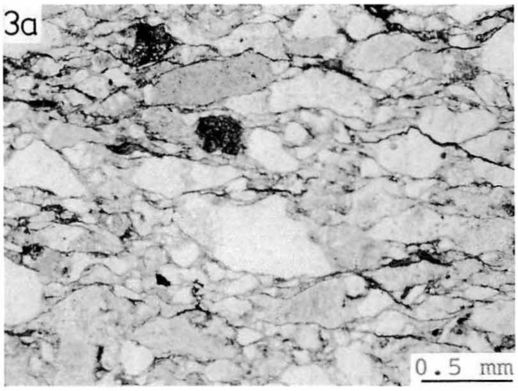
1. Type-0 sandstones near Osaki. a; open nicol, b; crossed nicols.
2. Type-1 sandstones to the west of Funado. b-c section. a; open nicol, b; crossed nicols.
3. Type-2 sandstones near Osaki. b-c section. a; open nicol, b; crossed nicols.
4. Detrital chert grain cut by dusty part in the type-2 sandstones near Osaki. b-c section. a; open nicol, b; crossed nicols.

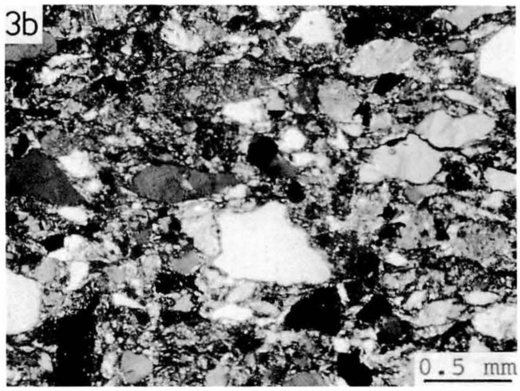

1a
0.5 mm

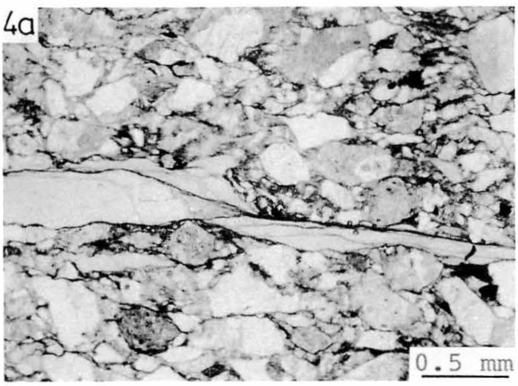

1b
0.5 mm

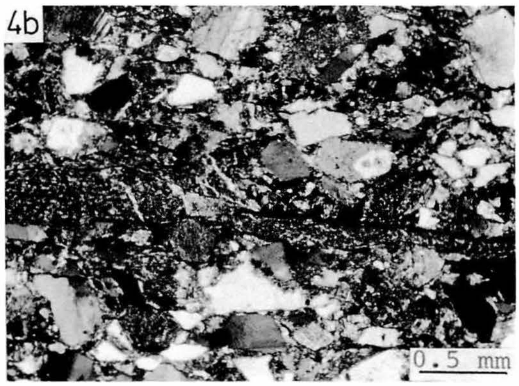

2a
0.5 mm


2b
0.5 mm


3a
0.5 mm


3b
0.5 mm


4a
0.5 mm


4b
0.5 mm

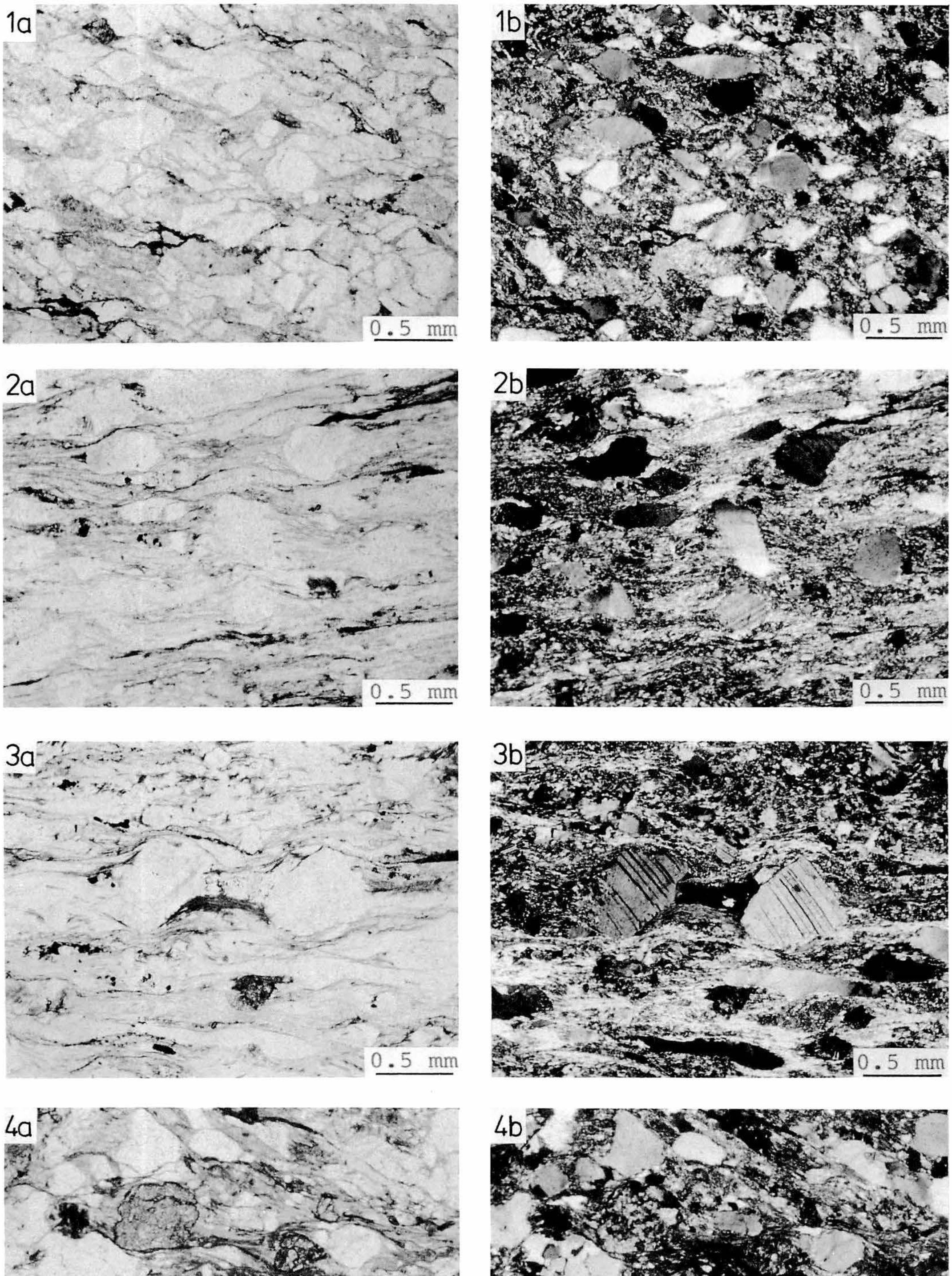
A. MURATA

Large *decke* structures and their formative process in the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains, Southwest Japan

# Plate 25

## Explanation of Plate 25

1. Type-3 sandstones near Ochide. b-c section. a; open nicol, b; crossed nicols.
2. Type-4 sandstones to the north of Kamidoi. b-c section. a; open nicol, b; crossed nicols.
3. Micro-boudinage of detrital feldspar grain in the type-4 sandstones to the north of Kamidoi. b-c section. a; open nicol, b; crossed nicols.
4. Micro-boudinage of detrital epidote grain in the sandstones of the Maana beds. b-c section. a; open nicol, b; crossed nicols.


1a
0.5 mm
1b
0.5 mm
2a
0.5 mm
2b
0.5 mm
3a
0.5 mm
3b
0.5 mm
4a
0.5 mm
4b
0.5 mm