LARGE *DECKE* STRUCTURES IN THE KUROSEGAWA AND SAMBOSAN TERRAINS, IN KYUSHU, SOUTHWEST JAPAN

By

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Abstract

Many large overthrusts have moved Paleozoic and Mesozoic strata toward south or southeast, producing *decke* structures in the Chichibu, Kurosegawa and Sambosan terrains in Southwest Japan. The *decke* structures of the Kurosegawa and Sambosan terrains in Kyushu have been clarified by the detailed analyses of geologic structures and conodont biostratigraphy. Two large *deckes*, the Shiraiwayama *decke* and the Gomayama *decke* which moved along the Shiraiwayama thrust and the Butsuzo Tectonic Line (thrust) respectively, occupy the most part of the terrains in Kyushu. The Shiraiwayama *decke* thrusts itself southeastward over the Gomayama *decke* which also thrusts itself southeastward over the Shimanto supergroup.

The Gomayama *decke* is a single *decke*, in which strata are continuously distributed in general, whereas the Shiraiwayama *decke* consists of four *subdeckes*, S1, S2, S3 and S4 *deckes* from northeast to southwest. These four *subdeckes* have a common character that they have the Permian limestone layers at their southeastern frontal edges. Overlapping of *subdeckes* takes place in the area where two *subdeckes* adjoin. The western *subdecke* always overlie the eastern one there. Those four *subdeckes* moved southeastward with a slight clockwise rotation, and are arranged in a left-handed *en echelon* pattern as a whole.

The Kashimine *decke* moved along the Kashimine thrust in eastern Kyushu. The Kashimine *decke* covers both the Shiraiwayama *decke* and the Gomayama *decke*. Many minor thrusts are associated with the large overthrusts and produce an imbricate structure. Originally, therefore, these terrains must have been much wider.

The upper Paleozoic and lower Mesozoic strata change their lithofacies remarkably from the Kurosegawa islands-area to the Sambosan geosyncline. The sedimentary facies show that there were land masses and shallow submarine hills in the Kurosegawa islands-area and in the southern marginal Sambosan geosyncline, whereas there was a relatively "deep" sea-area between them. The geosyncline was a narrow sedimentary basin which lay probably on the continental side of a trench.

I. INTRODUCTION

The Chichibu geosyncline and the Sambosan minor geosyncline were present from Carboniferous to Jurassic in Southwest Japan. They were separated by the Kurosegawa terrain, which had sialic basements and formed islands or shallow submarine swells (KIMURA *et al.*, 1975). The Sambosan geosyncline was a long

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and narrow sedimentary basin, which had shallow submarine swells along the southern margin of it (KIMURA *et al.*, 1975; MURATA, 1981). A subduction zone, or a trench must have been present on its oceanic side.

The connection between the Chichibu and Sambosan terrains are tried to be recently interpreted by means of other subduction models by some workers. HADA *et al.* (1979) and MARUYAMA (1978) suggested that the Sambosan terrain is an accretionary prism to the Kurosegawa terrain. HORIKOSHI (1972), on the other hand, is of opinion that the Kurosegawa Tectonic Zone was a trench on the oceanic side of the Chichibu in the past. Although those opinions do not accord with the paleogeography, they presumed the presence of a subduction zone, or a trench, on or near the Kurosegawa and Sambosan terrains. Those terrains are interesting and important areas to understand Paleozoic to Mesozoic tectonic developments of Southwest Japan.

There is a large overthrust, the Shiraiwayama thrust (MURATA, 1981), in the Gokase area of central Kyushu, by which granitic rocks and Silurian strata of the Kurosegawa terrain were cut and the rootless masses were moved southeastward. The Permian and Triassic strata change their lithofacies laterally from the Kurosegawa terrain and the northern Sambosan geosyncline, the strata of the Shirawayama *decke*, to the southern Sambosan, the strata in the underlying mass (MURATA, 1981). In this paper, the sedimentary facies from the Kurosegawa terrain to the Sambosan geosyncline of eastern, central and western Kyushu are dealt with. Then the developments of the large overthrusts such as the Shiraiwayama and Kashimine thrusts are discussed.

II. GEOLOGIC SETTING

The most part of the Kurosegawa and Sambosan terrains in Kyushu is covered by two large *deckes*. They are the northern Shiraiwayama *decke* moved along the Shiraiwayama thrust, and the southern Gomayama *decke* moved along the Butsuzo Tectonic Line (thrust) (Fig. 1). The Shiraiwayama *decke* thrusts itself southeastward over the Gomayama *decke*, which also thrusts itself southeastward over the Shimanto supergroup. Besides them, the Kashimine *decke* moved along the Kashimine thrust in eastern Kyushu (Chapter **VI**).

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 (MURATA, 1981) (Fig. 1). The Kashimine *decke* consists of the strata of the Kurosegawa terrain. Sheared granites, gneisses and Silurian strata which are correlative with those of the Kurosegawa Tectonic zone in western Shikoku (ICHIKAWA *et al.*, 1956) crop out also in the Kurosegawa terrain in Kyushu. They are the Kuraoka igneous rocks (KAMBE, 1957), the Usukigawa igneous rocks (KAMBE and TERAOKA, 1968), the Yatsushiro gneisses (MATSUMOTO and KANMERA, 1964), the Gionyama formation (HAMADA, 1964), the Fukami formation (MATSUMOTO and KANMERA, 1964), and the Okuhata formation (NODA, 1961) (Fig. 1). Besides them, Carboniferous to Middle Triassic strata, which include basic volcanics, cherts and limestones, and Late Triassic, Late Jurassic

and Early Cretaceous strata of the shelf facies, crop out in the Kurosegawa terrain (MATSUMOTO and KANMERA, 1964; KAMBE and TERAOKA, 1968; TAMURA, 1965; MURATA, 1981). Permian limestones and Triassic cherts and slump conglomerates* crop out in the northern Sambosan terrain (Fig. 1).

The Gomayama *decke* consists of strata of the southern Sambosan terrain and of the southern marginal Sambosan terrain (MURATA, 1981) (Fig. 1). Permian to Triassic (to early Jurassic) strata, which consist mostly of cherts,

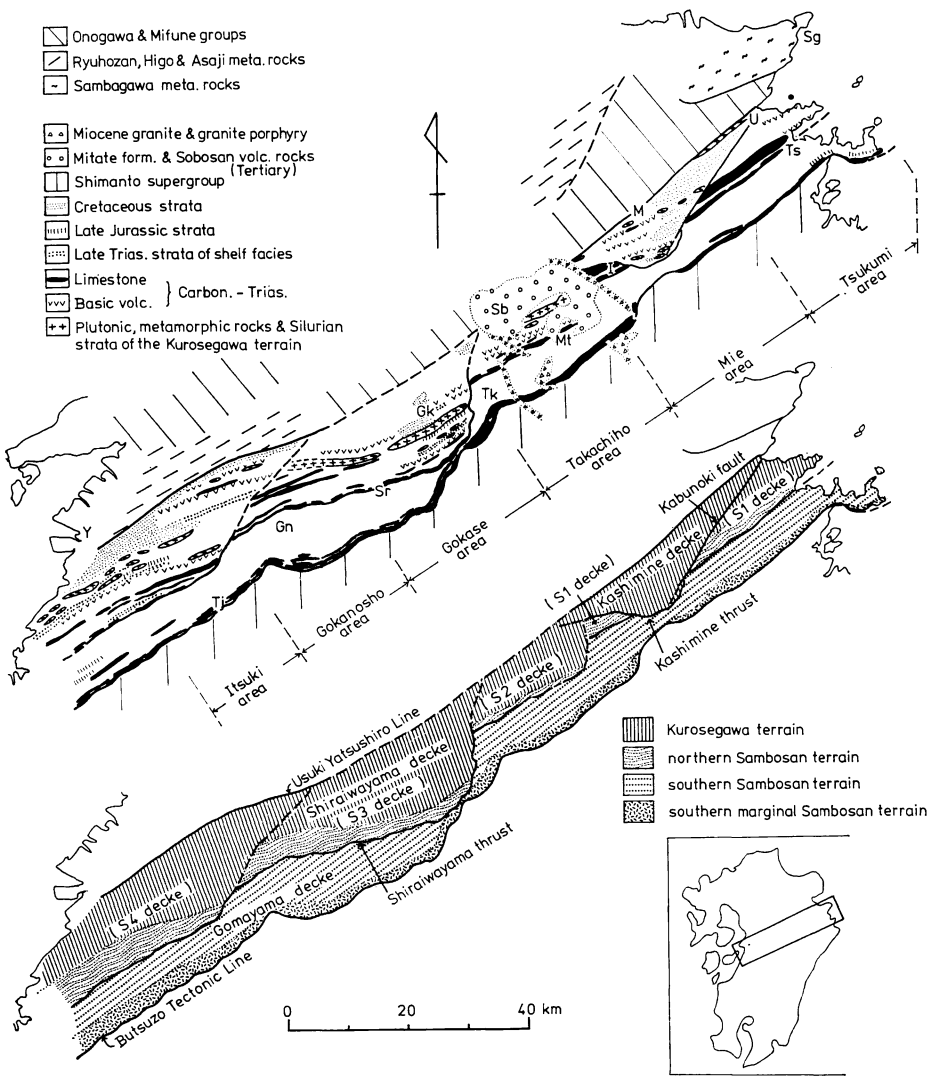


Fig. 1. Geological and structural maps of the Kurosegawa and Sambosan terrains in Kyushu. Sg; Saganoseki, U; Usuki, Ts; Tsukumi, M; Mie, Mt; Mitate, Sb; Mt. Sobo, Tk; Takachiho, Gk; Gokase, Sr; Mt. Shiraiwayama, Gn; Gokanosho, Tj; Toji, Y; Yatsushiro.

* Conglomerates formed by submarine slumping and sliding are called slump conglomerates for simplicity in the paper.

sandstones and alternations of sandstone & mudstone, crop out in the southern Sambosan terrain. Triassic to Jurassic limestones, basic volcanics and cherts crop out in the southern marginal Sambosan terrain.

III. SEDIMENTARY FACIES AND PALEOGEOGRAPHY FROM THE KUROSEGAWA ISLANDS-AREA TO THE SAMBOSAN GEOSYNCLINE

Stratigraphy of the Kurosegawa and Sambosan terrains was surveyed in the Gokase, Itsuki and Tsukumi areas, in central, western and eastern Kyushu respectively. Sedimentary facies and paleogeography of the Kurosegawa and Sambosan terrains are dealt with in this paper on the basis of the stratigraphy of three areas. MURATA (1981) described already the stratigraphy of the Gokase area among them. Conodont fossils of the other two areas are reported briefly by KOIKE (1979). The stratigraphy of these two areas will be precisely mentioned in future in a separate paper. Stratigraphic diagram showing sedimentary facies and paleogeography is shown in Fig. 2. The areas of the Kurosegawa islands and surrounding of shallow sea (KIMURA *et al.*, 1975) are called the Kurosegawa islands-area in the following discussion.

Gokase area The upper Paleozoic and lower Mesozoic strata change their lithofacies laterally from the Kurosegawa islands-area to the Sambosan geosyncline. Basic volcanics occurred in late Carboniferous and early Permian times and limestones, cherts, and slump conglomerates occurred in Middle and Late Permian times in the Kurosegawa islands-area. Cherts, basic volcanics, siliceous mudstones, and slump conglomerates were deposited in Early to Middle Triassic times and conglomerates including many large granitic clasts, *Monotis*-bearing sandstones, and alternations of sandstone & mudstone in Late Triassic time there. Limestones, calcareous sandstones, cherts and slump conglomerates, on the other hand, were mainly deposited in Permian time, and chert and slump conglomerates in Triassic time in the northern Sambosan geosyncline. Cherts, sandstones and alternations of sandstone & mudstone occurred in Permian and Triassic times in the southern Sambosan geosyncline. Those geosynclinal strata range in age possibly even to early Jurassic, because those of western Shikoku yield Jurassic-type radiolarian fossils (TAIRA *et al.*, 1979). Limestones, cherts, and slump conglomerates occurred in Late Triassic and Jurassic times in the southern marginal Sambosan geosyncline.

The Late Triassic strata change most remarkably their lithofacies from the Kurosegawa islands-area to the Sambosan geosyncline. The strata are of the shelf facies in the Kurosegawa islands-area, cherts and slump conglomerates in the northern Sambosan, cherts, sandstones and alternations of sandstone & mudstone in the southern Sambosan, and limestones and cherts with basic volcanics in the southern marginal Sambosan geosyncline.

Itsuki area The Permian to Triassic strata of the Itsuki area also change their lithofacies from the Kurosegawa islands-area to the Sambosan geosyncline (Fig. 2). The Kozaki and Kuma formations which consist of conglomerates

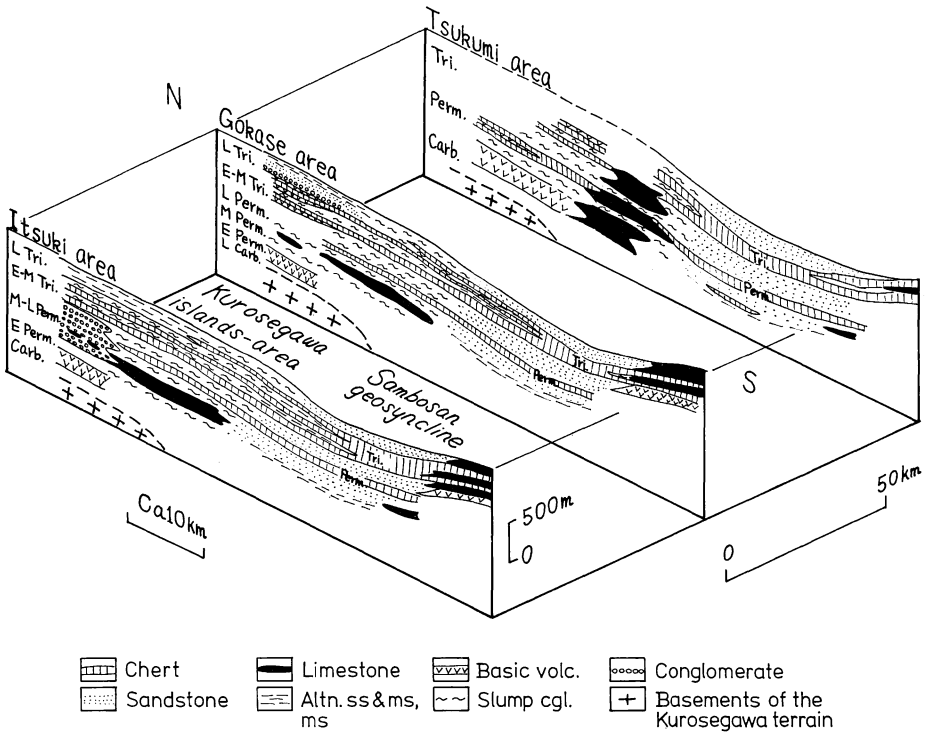


Fig. 2. Stratigraphic diagram showing sedimentary facies and paleogeography.

including granitic and limestone clasts and sandstones occurred in Middle and Late Permian times in the Kurosegawa islands-area (KANMERA, 1953, 1961), and change their lithofacies into limestones, cherts and slump conglomerates, which are correlative with the Yonaku formation and a part of the Yoshio formation by MATSUMOTO and KANMERA (1964), in the northern Sambosan geosyncline. The Early to Middle Triassic strata in the Kurosegawa islands-area consist of cherts and slump conglomerates which are correlative with the Hashirimizu formation by MATSUMOTO and KANMERA (1964). The Late Triassic *Monotis*-bearing strata were found not only in the Kurosegawa islands-area, where they are called the Arase beds (MATSUMOTO and KANMERA, 1964), but also in the area to the south of it, northern Sambosan geosyncline, where they are called the Misaka beds (MATSUMOTO and KANMERA, 1964). Thus, the *Monotis*-bearing strata extend from the Kurosegawa islands-area toward the northern Sambosan geosyncline in the Itsuki area.

Tsukumi area Nearly the same lithofacies change is observed in the Tsukumi area from the Kurosegawa islands-area to the Sambosan geosyncline as those in the Gokase and Itsuki areas (Fig. 2). The Late Carboniferous to Triassic strata in the northern Sambosan geosyncline consist mostly of limestones (KAMBE and TERAOKA, 1968; FUJII, 1954).

The Permian to Triassic strata, on the other hand, seldom change their lithofacies in the direction parallel to the geosynclinal axis, except for in the

Kurosegawa islands-area (Fig. 2). The northern, southern and southern marginal Sambosan geosynclinal strata have nearly the same lithologic characters through the Tsukumi, Gokase and Itsuki areas. The Middle to Late Permian strata in the Kurosegawa islands-area consist mostly of conglomerates in the Itsuki area, and cherts, basic volcanics and slump conglomerates in the Gokase and Tsukumi areas, and change their lithofacies from southwest to northeast.

The sedimentary facies described above revealed the paleogeography from the Kurosegawa islands-area to the Sambosan geosyncline (MURATA, 1981). The Kurosegawa islands-area was land masses in part and shallow water areas in part. The land masses supplied granitic boulders in Late Triassic time. There were shallow submarine hills or mounds in the southern marginal Sambosan geosyncline, where limestones and cherts with basic volcanics were deposited in that time. The submarine hills are inferred from the presence of fossil soils in the limestones in eastern Kyushu (KIMURA *et al.*, 1975; IWAO, 1972). The main part of the geosyncline, on the other hand, was a relatively "deep" sea-are a, where cherts, sandstones and alternations of sandstone & mudstone were deposited. These facts show that the Kurosegawa islands-area and the Sambosan geosyncline were not a trench from Permian to Triassic time, and the *Monotis*-bearing strata within the northern Sambosan geosyncline show that the strata in the geosyncline are not accretionary ones against the Kurosegawa terrain where the similar strata occur. The geosyncline was a narrow sedimentary basin between the Kurosegawa islands-area and the southern marginal submarine hills which lay probably on the continental side of a trench.

An angular unconformity called the Uminoura unconformity (ORITA, 1962) was formed to the west of the Itsuki area, and the strata in the Kurosegawa islands-area change their lithologic characters with age, where there were land masses and shallow water areas through the Permian and Triassic times. The Permian and Triassic strata in the main part of the Sambosan geosyncline, which was a relatively "deep" sea-area, are conformable with each other, and do not change their lithologic characters with age.

Basic volcanics of the Kurosegawa islands-area and the Sambosan geosyncline include titanaugite as phenocrysts (MURATA, 1981), so they are probably alkali basalts. It is notable that submarine basic volcanisms seldom occurred in the main part of the Sambosan geosyncline, but occurred in the Kurosegawa islands-area which had a sialic basements, and in the southern marginal geosyncline, just like the case pointed out by AUBOUIN (1965) in the Hellenides.

IV. THE SHIRAIWAYAMA THRUST

The Shiraiwayama thrust was ascertained for the first time in the Gokase area in central Kyushu, and was precisely investigated by MURATA (1981).

Gokase area The Shiraiwayama thrust in the Gokase area runs along the southern margin of the Permian limestone layer. Its trace runs continuously from the Iiboshi Pass, through the Obarai Pass and Takaragi, to Mt. Shiraiwayama (Fig. 3). The Permian and Triassic strata on the northern side (northern

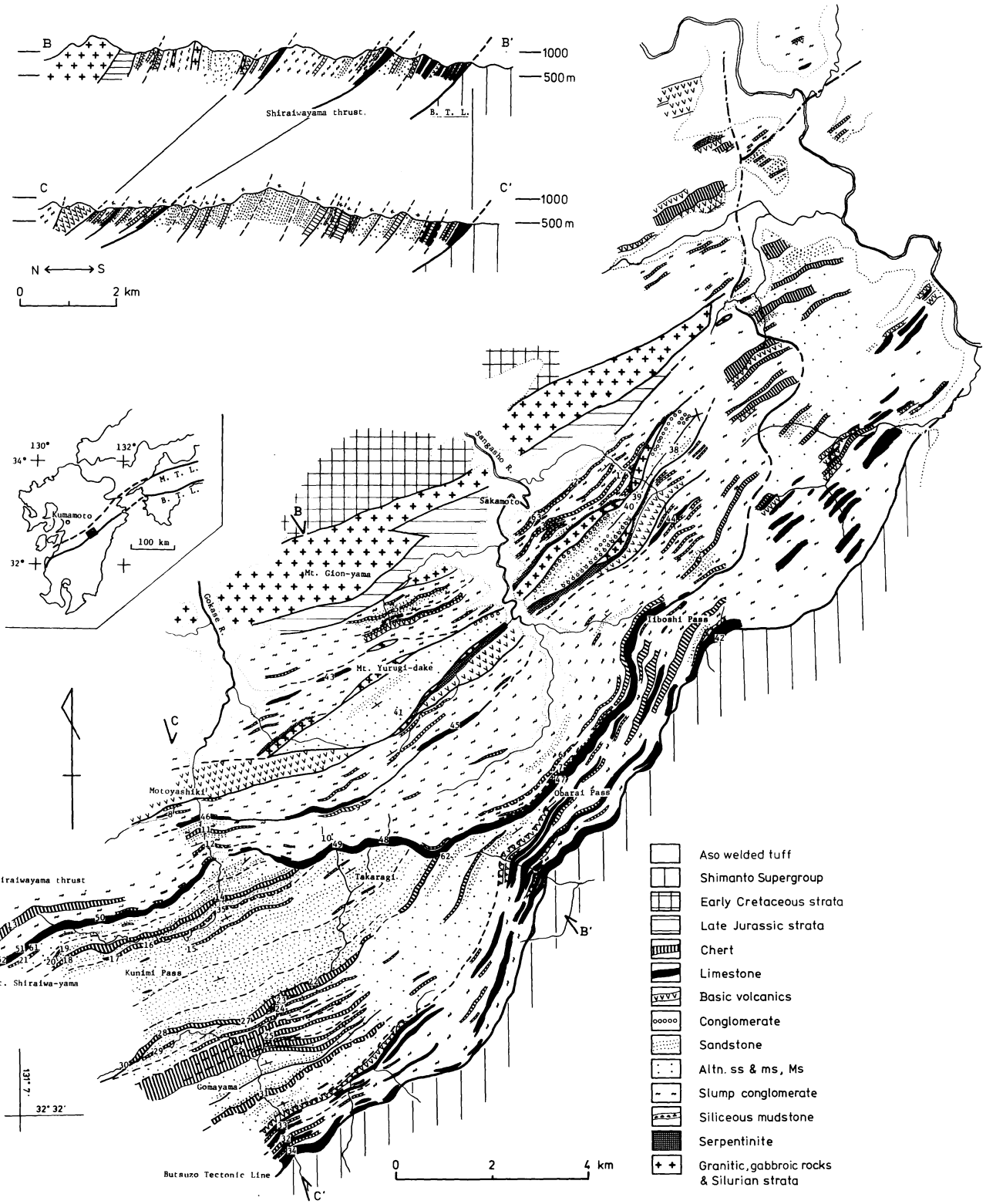


Fig. 3. Geological map and cross sections of the Gokase area. Arrows in the cross sections show the facings of the strata.

Sambosan terrain) of the thrust are characterized by limestones, slump conglomerates and calcareous sandstones, whereas those on the southern side (southern Sambosan terrain) are characterized by cherts, sandstones and alternations of sandstone & mudstone (Fig. 3).

The limestone layers of the northern Sambosan terrain on the northern side of the thrust were originally situated to the north of the strata of the southern Sambosan terrain on the southern side, although the former at present overlies by thrusting the latter which is about 5 km wide in Kyushu generally. The trace of the thrust in the Gokase area is convex toward the southeast (Fig. 3), and almost all parts of the southern Sambosan terrain is covered with the thrust sheet at the southeastern most part of the convex (Fig. 1). In other words, the southern Sambosan terrain, 5 km wide in the western part of the Gokase area, narrows toward east and is not distributed in the central part. The evidence suggests that the Shiraiwayama thrust has at least 5 km horizontal slip toward southeast in the central part of the Gokase area.

The strata of the northern Sambosan terrain and those of the Kurosegawa terrain including tectonic blocks of the granitic rocks and Silurian strata strike parallel to each other. The Shiraiwayama thrust runs from north to south and dips toward west gently in the eastern part of the Gokase area. The thrust strikes diagonally not only to the strata of the foot wall but also to those of the hanging wall. That is, it cuts the strata and rocks of the Kurosegawa terrain. In other words, not only the strata of the northern Sambosan terrain but also those of the Kurosegawa terrain, including the granitic rocks and Silurian strata, thrust themselves southeastward as one body, the Shiraiwayama *decke*. This means that they are rootless at present. The Shiraiwayama thrust dips, and/or is inferred to dip, at 30° to 45° toward north in its western portion and toward west in its eastern portion at or near the earth surface. The rather steep dip of 30° to 45° may show that vertical slip of the thrust is nearly equivalent to horizontal one, more than 5 km. The strata on both sides of the thrust, however, are of the same geologic age (Permian and Triassic), and are at most 1500 m thick. This indicates that the vertical slip of the thrust is fairly less than the horizontal one. Thus the Shiraiwayama thrust is inferred to dip fairly gently, nearly horizontally, under the Kurosegawa terrain (Fig. 4).

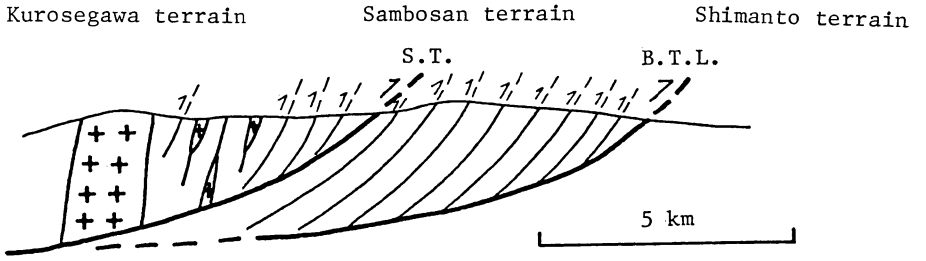


Fig. 4. Schematic cross section of the Kurosegawa and Sambosan terrains.

The Shiraiwayama thrust extends northeast and southwest from the Gokase area, and runs across Kyushu. As mentioned above, the trace of the thrust runs along the southern margin of the Permian limestone layer of the northern Sambosan terrain, and the strata on both sides of the thrust have quite different lithologic characters from each other.

Tsukumi area The Shiraiwayama thrust runs along the southern margin of the Permian limestone layers (Tsukumi limestone). Its trace runs from Tsukimi through Mt. Gobangatake to Sozubaru (Fig. 6). The Permian and Triassic strata on the northern side of the thrust in the area consist mostly of limestones, calcareous sandstones, cherts, basic volcanics and slump conglomerates, whereas those on the southern side consist mostly of cherts, sandstones and alternations of sandstone & mudstone (Fig. 6).

Mie area The Shiraiwayama thrust runs along the southern margin of the limestone layers near Mt. Inazumiyama (Fig. 6). The strata on the both sides of the thrust strike roughly parallel or slightly diagonally.

Takachiho area The Shiraiwayama thrust runs along the southern margin of the Permian limestone layer which is distributed from Mitate to Takachiho (Fig. 1).

Gokanosho area The Shiraiwayama thrust runs from Haki to Mt. Shiragayama. It does not run along the Permian limestone layer. Three limestone layers, howevr, are distributed to the north of the thrust, and the strata on both sides of the thrust have quite different lithologic characters from each other as those in other areas (Fig. 5).

Itsuki area The Shiraiwayama thrust runs along the southern margin of the Permian limestone layer which is distributed from Sakashita to Kawaradani (Fig. 5). Its trace in the area corresponds mostly to a fault which was considered to be the boundary fault between the Yonaku and Torinosu belts by OHTANI (1926, 1927).

Outcrops of the Shiraiwayama thrust are observed near Mt. Shiraiwayama (Loc. 61) and near Takaragi (Loc. 62) in the Gokase area (MURATA, 1981) (Fig. 3), near Hoguchi (Loc. 51) in the Gokanosho area, and near Uchitani (Loc. 52) in the Itsuki area (Fig. 5).

V. OVERLAPPING OF *SUBDECKES* CONSTITUTING THE SHIRAIWAYAMA *DECKE*

The Shiraiwayama *decke* moved along the Shiraiwayama thrust has a shape of a long and slender plate, on a map, about 10 km in width and 150 km in length (Fig. 1). 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 (more than 50 km in length), S 2 *decke* in the Takachiho area (25 km in length), S 3 *decke* in the Gokase and Gokanosho areas (45 km in length) and S 4 *decke* in the Itsuki area (more than 30 km in length) (Fig. 1). The S 1 *decke* among them occupies a narrower area because it is covered with the

Kashimine *decke* described in the next chapter. The S 1 *decke* is covered with the S 2 *decke* on the west, the S 2 *decke* with the S 3 *decke* on the west, and the S 3 *decke* with the S 4 *decke* on the west (Fig. 1).

Detailed relationship between adjacent *subdeckes* was observed for the S 2 and S 3 *deckes* at the eastern margin of the Gokase area (Figs. 1 & 3). Permian limestone layers are situated at the frontal edge of the S2 *decke* and the southern part of the frontal edge of the S 3 *decke*, and they are correlative with each other. The Permian limestone layers on the both edges, however, are not continuous, although they strike generally at N 60°E in both *subdeckes*. In other words, two Permian limestone layers of the Takachiho and Gokase areas break off in the eastern marginal part of the Gokase area. The limestone layers of the both frontal edges of the S 2 *decke* and S 3 *decke* are arranged in a left-handed *en echelon* pattern (Fig. 1). The strata and the tectonic blocks such as the

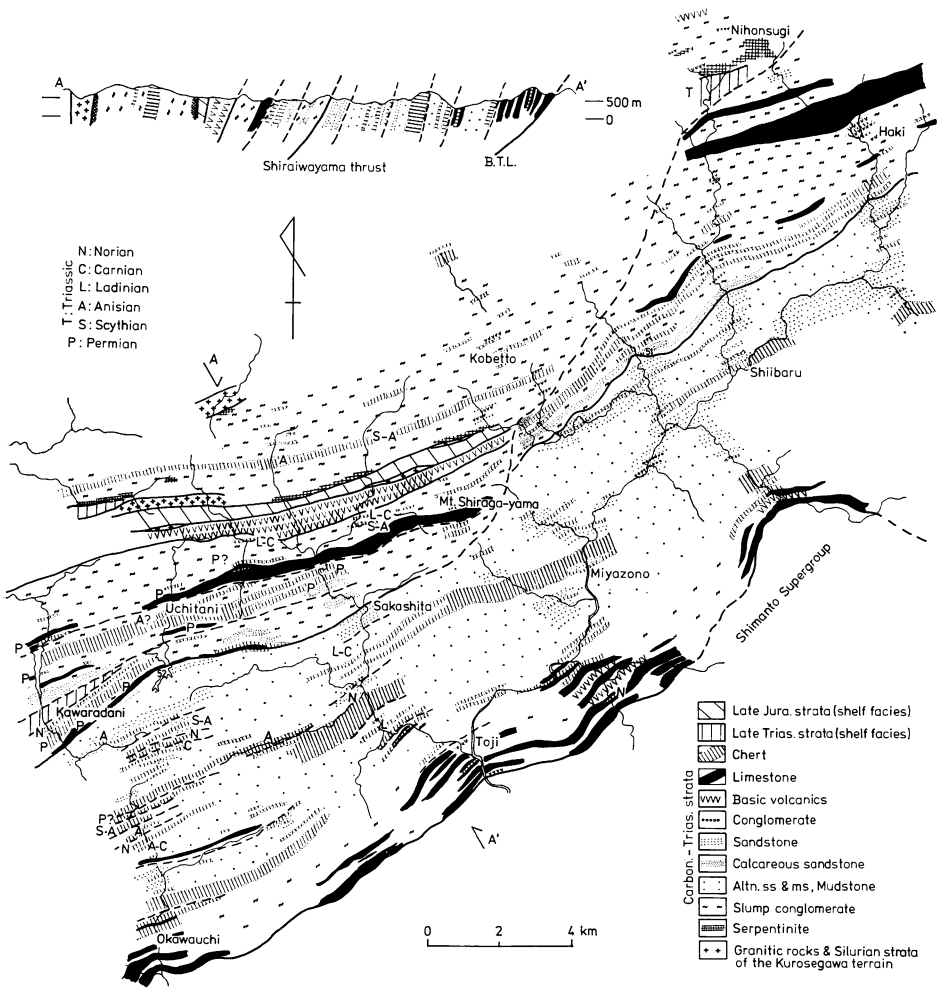


Fig. 5. Geological map and cross section of the Gokanosho and Itsuki areas. Ages of cherts and limestones were determined by fossils (Murata, to be published).

sheared granites and the Silurian strata in the Kurosegawa terrain strike in the same direction both in the S 2 *decke* and in the S 3 *decke*, but are not continuously distributed from the S 2 *decke* to the S 3 *decke*. Those of the Kurosegawa terrain in both *subdeckes* are arranged in a left-handed *en echelon* pattern (Fig. 1).

The limestone layers of the southern marginal Sambosan terrain in the Gomayama *decke*, which is situated to the south of the S 2 and S 3 *deckes*, on the other hand, are almost continuously distributed from the Takachiho area to the Gokase area (Fig. 3). The strata of the southern Sambosan terrain in the Takachiho area are situated in the strike side of those in the Gokase area, and those in the both areas strike in the same direction (Fig. 3). As mentioned above, the Shiraiwayama thrust strikes from north to south in the eastern marginal part of the Gokase area, and is diagonal to the strikes of the strata of the Kurosegawa and northern Sambosan terrains. This thrust extends northward and separates the S 2 *decke* from the S 3 *decke* (Fig. 1). These facts show that overlapping of the *subdeckes* was probably formed by discrete movements of the S 2 *decke* and the S 3 *decke*, and that the S 3 *decke* is thrust further southeastward than the S 2 *decke*.

The overlapping of the *subdeckes* takes place also in the eastern marginal part of the Itsuki area, where the S 3 *decke* is covered with the S 4 *decke* on the west (Figs. 1 & 5). The strata of the Kurosegawa and northern Sambosan terrains are not continuous from the S 3 *decke* to the S 4 *decke*, but break off there. They strike nearly at the same direction in the both *subdeckes*, and are arranged in a left-handed *en echelon* pattern. The strata of the southern Sambosan and southern marginal Sambosan terrains in the Gomayama *decke*, which is situated to the south of the S 3 and S 4 *deckes*, on the other hand, are continuously distributed from the Gokanosho area to the Itsuki area (Fig. 5). The strata in the S 4 *decke* are thrust further southeastward than those in the S 3 *decke*. A boundary fault between the S 3 *decke* and the S 4 *decke* runs from Mt. Shiragayama to Nihonsugi (Figs. 1 & 5). The strata in the S 4 *decke* arrange in a different way from those in the S 3 *decke*.

The Mitate formation and the Sobosan volcanic rocks of Tertiary age are extensively distributed in the eastern marginal part of the Takachiho area (SAITO *et al.*, 1958), whereas the Permian and Triassic strata arer estricted in the distribution (Fig. 1). The overlapping of the *subdeckes* is inferred to take place there, because the Permian limestone layer of the frontal edges of the S 1 *decke* and S 2 *decke* are arranged in a left-handed *en echelon* pattern. The western S 2 *decke* is probably thrust further southeastward than the eastern S 1 *decke*.

The strata of the Kurosegawa terrain are arranged in the parallel direction to those of the northern Sambosan terrain. A *subdecke* on the western side is always thrust further southeastward than that on the eastern side, and the overlapping of the *subdeckes* occurs (Fig. 1). As a natural consequence, it follows that the strata of the Kurosegawa and northern Sambosan terrains are arranged in a left-handed *en echelon* pattern as a whole. Each *subdecke* is inferred to have moved southeastward with a slight clockwise rotation.

Each *subdecke* has a tongue-like shape whose convex side faces toward southeast. Each *subdecke*, on the western side, covers an adjacent *subdecke*, on the eastern side, and the trace of each thrust which moved *subdecke* southeastward trends in NE-SW direction in the area where two *subdeckes* adjoin.

The sheared granites and the Silurian strata of the Kurosegawa terrain not only in the S 3 *decke* but also in the S 1, S 2 and S 4 *deckes* are probably rootless at present. The strata of a *subdecke* arrange in a different way from those of the other *subdeckes* in a small scale. However, the Kurosegawa terrain is situated to the north of the northern Sambosan terrain, keeping its tectonic position in a large scale.

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*. Those four thrusts, however, have common characters that they run along the southern margin of the Permian limestone layers, and that have moved the strata and rocks of the Kurosegawa as well as northern Sambosan terrains southeastward. A set of four thrusts are called the Shiraiwayama thrust in Kyushu from these facts.

VI. THE KASHIMINE THRUST AND THE KASHIMINE *DECKE*

A large overthrust—the Kashimine thrust—occurs in the Mie area in eastern Kyushu. The Kashimine thrust runs from Shinkai, through Kashimine and Okuhata, to near Mt. Inazumiyama (Fig. 6). The thrust trends in the E-W direction to the west of Kashimine, and in the NE-SW to N-S direction to the east. The Kashimine *decke*, moved along the Kashimine thrust, has a tongue-like shape with convex side toward southeast. The Kashimine *decke* covers both the Shiraiwayama *decke* (the S 1 *decke*) and the Gomayama *decke* (Figs. 1 & 6). The Kashimine thrust was ascertained by following facts.

The Permian limestone layers, 2 km in width, of the northern Sambosan terrain in the S1 *decke* (Tsukumi limestone) are continuously distributed from Tsukumi in the eastern extremity of Kyushu, through Mt. Gobangatake to Sozubaru in the eastern Mie area, and strike at N 60°E. However, the limestone layers are not distributed in the central part of rhe Mie area. They are again distributed near Mt. Inazumiyama in the western part of the Mie area with a width of about 2 km, and strike at N 60°E (Fig. 6). The Tsukumi limestone is correlative with those near Mt. Inazumiyama, because both of them are mainly of Permian age, have the same distributional width, and are situated at the frontal edge of the S 1 *decke*. Furthermore, the limestone layers near Mt. Inazumiyama are just situated in the strike side of the Tsukumi limestone, and strike in the nearly same direction as the Tsukumi limestone (Fig. 6).

No Permian limestone layers are distributed in the central part of the Mie area, whereas Carboniferous to Triassic strata which consist mostly of basic volcanics, cherts and slump conglomerates, Jurassic and Cretaceous strata, and the sheared granites and the Silurian strata of the Kurosegawa terrain are distributed, and strike at N 70° to 75°E (Fig. 6). On the other hand, the Permian and Triassic strata of the southern Sambosan terrain which consist of cherts, sand-

stones and alternations of sandstone & mudstone are distributed to the south of those strata, and strike at N 55°E diagonally to those on the northern side. These two sets of the strata are in contact with each other by a sharp boundary. This boundary runs from Shinkai to Kashimine, and dips toward northwest gently. Since this boundary has a bow-shape with convex side toward southeast, the southern Sambosan terrain of about 5 km wide in the eastern and western part of the Mie area narrows to 2.5 km in the central part (Figs. 1 & 6).

These facts probably indicate that a large overthrust occurs in the Mie area, and displaced the strata of the Kurosegawa terrain over those of the northern Sambosan terrain which had also thrust itself southeastward along the Shiraiwayama thrust, and further over those of the southern Sambosan terrain. 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 with the Kashimine *decke* (Fig. 1).

The Kashimine *decke* is bordered on the eastern side by the high-angled Kabunoki fault (FUJII, 1954; TERAOKA, 1970) striking at N 40°E. The strata to the southeast of the Kabunoki fault do not belong to the Kashimine *decke*, but to the Shirawayama *decke*, because they strike with diagonal trend to the strata in the Kashimine *decke*. It is probable that the NE-SW trending Kabunoki fault was formed after thrusting and has chiefly moved the strata on the northwestern side downward relatively to those on the southeastern side.

VII. LARGE OVERTHRUSTS AND IMBRICATE STRUCTURE IN THE SHIRAIWAYAMA, KASHIMINE AND GOMAYAMA *DECKES*

The Kurosegawa and Sambosan terrains of the Gokase area are occupied by two major *deckes*, the Shiraiwayama *decke* and the Gomayama *decke*. Many thrusts of smaller scales are observed in the Gomayama *decke* and in the southern part of the S 3 *decke*, and they produce an imbricate structure (MURATA, 1981).

The strata of the southern Sambosan terrain in the Gomayama *decke* strike at N 60° to 80°E and dip at 40° to 80° toward north. Cherts yield conodont fossils at many localities, and their ages are determined in detail. Sandstone layers in the alternations of sandstone & mudstone frequently show graded bedding. There are many cases that the succession of the strata inferred from the facing of the beds indicated by graded bedding is contradictory to the succession inferred from the ages of the strata indicated by fossils. Thrusts which moved hanging walls toward southeast were ascertained to occur in these cases (Fig. 3).

The Permian limestone layers are repeatedly appeared by the north-dipping thrusts in the northern Sambosan terrain of the S 3 *decke*. There are many thrusts in the Kurosegawa terrain too (Fig. 3).

Many thrusts of smaller scales are observed in the southern part of the S 4 *decke* and in the Gomayama *decke* of the Itsuki area. They produce the imbricate structure (Fig. 5). The strata to the west of the Itsuki area are

considered to be intensely isoclinally folded with faults, and the structure is called the "Sandwich structure" (KANMERA, 1950). However the structure there has more north-dipping thrusts than KANMERA (1950) has thought.

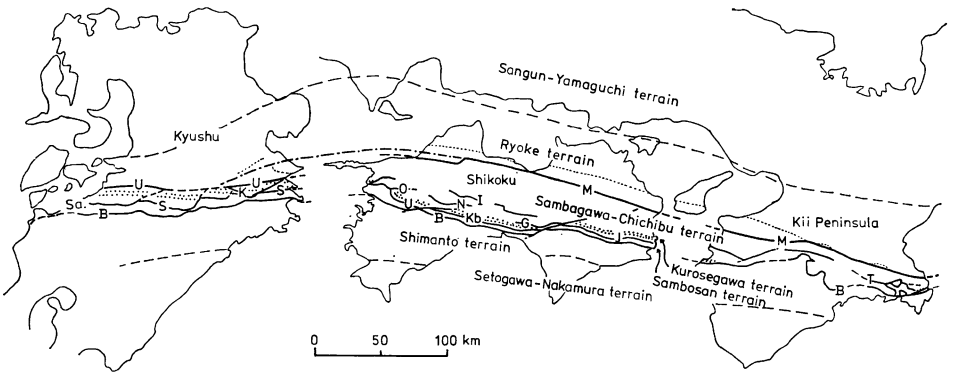
The imbricate structure also occurs in the southern part of the S1 *decke* and in the Gomayama *decke* of the Tsukumi area (Fig. 6). A synclinorium is ascertained in the Kurosegawa terrain of the Tsukumi area (KAMBE and TERAOKA, 1968). North-dipping thrusts and normal faults are observed in the Kashimine *decke* (Fig. 6).

Although folds with wavelength of several to several tens of meters occur in every *decke*, the imbricate structure is considered to be fundamental structure of the Sambosan terrain, but not the folds. The Shiraiwayama thrust, the Kashimine thrust, the Butsuzo Tectonic Line (thrust) and many thrusts producing the imbricate structure show southeastward vergence. Many smaller thrusts are probably related to the large overthrusts described above in origin.

The Butsuzo Tectonic Line has moved the Permo-Triassic strata over the folded Shimanto supergroup of Neocomian to Santonian age (YANAI, 1981) in the Chikanaga area in western Shikoku, and is considered to be overlain by the Nakaoku formation of possibly Paleogene age (SHIIDA, 1962) in the Kii Peninsula. The Shiraiwayama thrust has moved the Togawa, Kasabe, Shibanomoto and Takahata formations (TERAOKA, 1970) of Neocommian to Albian age in the Gokase area in central Kyushu, and is considered to be overlain by the Mitate formation of possibly Paleogene age (MATSUMOTO and HASHIMOTO, 1963) in the Takachiho area. The Kashimine thrust has moved the Haidateyama group of Albian age and the Tano group of Turonian age (TERAOKA, 1970), and is intruded by the Miocene granite porphyry (ONO *et al.*, 1977). The Butsuzo Tectonic Line (thrust) the Shiraiwayama thrust and the Kashimine thrust in Kyushu are inferred to be formed from Santonian to Paleogene time, from Albian to Paleogene time and from Turonian to Miocene time respectively.

The Kashimine *decke* covers both of the Shiraiwayama *decke* and the Gomayama *decke*. The Kashimine thrust was formed after or at nearly the same time as the formation of the Shiraiwayama thrust. The Shiraiwayama *decke* and the Kashimine *decke* do not thrust themselves over the Shimanto supergroup. In other words, the Shiraiwayama thrust and the Kashimine thrust do not become the Butsuzo Tectonic Line which is defined to separate the Sambosan or Chichibu terrains from the Shimanto terrain. The Butsuzo Tectonic Line in Kyushu is a single overthrust. The Butsuzo Tectonic Line, the Shiraiwayama thrust and the Kashimine thrust have the similar features with one another that all of them have moved their *deckes* southeastward, and that they are accompanied by many small thrusts. Furthermore, both the Shiraiwayama thrust and the Butsuzo Tectonic Line run along the southern margin of the limestone layers. Thus, these large overthrusts probably have a close genetic relation with one another.

The Usuki Yatsushiro Tectonic Line which separates the Kurosegawa terrain from the Ryuhozan belt in western Kyushu (MATSUMOTO and KANMERA, 1964) and the Kurosegawa terrain from the Onogawa group in eastern Kyushu



(TERAOKA, 1970), is not a root zone from which the large overthrusts emerged, because just on the southern side of the Usuki Yatsushiro Tectonic Line there occur the Cretaceous strata, the youngest of the Shiraiwayama and the Kashimine *deckes*, but not older deformed rocks indicating a root zone. The Usuki Yatsushiro Line must be a fault of a later age. The Cretaceous Onogawa group and the Sambagawa metamorphic rocks in the Saganoseki Peninsula in eastern Kyushu have probably been moved southeastward along the Kashimine thrust.

The Shiraiwayama thrust is similar to the Uonashi thrust (IKEBE, 1936; KASHIMA, 1969) in western Shikoku, the Kambaradani thrust (KOBAYASHI, 1931) in central Shikoku, the Junisha thrust (ISHIDA, 1977) in eastern Shikoku and the Kurasawa thrust (KIMURA, 1980, p. 681) in Kanto Mountains in a respect that all of them have south or southeastward vergence and are situated in the Sambosan terrain (Fig. 7). The Uonashi and Kambaradani thrusts, especially, have the same characters as the Shiraiwayama thrust that they run along the southern margin of the Permian limestone layers to the south of the Kurosegawa terrain. It is, however, a characteristic structure in Kyushu that the Shiraiwayama *decke* is separated into four *subdeckes* and that they are arranged in a left-handed *en echelon* pattern as a whole.

VIII. CONCLUSION

(1) The Permian and Triassic strata change their lithofacies remarkably from the Kurosegawa islands-area to the Sambosan geosyncline. For example, the Late Triassic strata are of the shelf facies in the Kurosegawa islands-area, cherts and slump conglomerates in the northern Sambosan, cherts, sandstones and alternations of sandstone & mudstone in the southern Sambosan, and limestones and cherts with basic volcanics in the southern marginal Sambosan geosyncline. On the other hand, the Permian and Triassic strata do not change their lithofacies along the geosynclinal axis except for in the Kurosegawa islands-area.

(2) The sedimentary facies revealed the paleogeography from the Kurosegawa

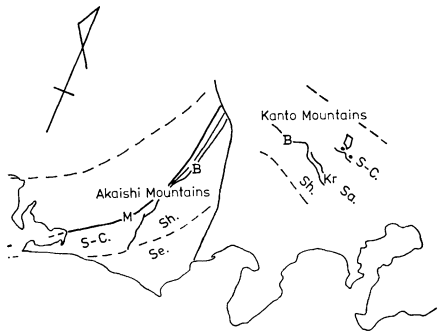


Fig. 7. Large overthrusts in the Sambagawa-Chichibu, Kurosegawa and Sambosan terrains in Southwest Japan. M; Median Tectonic Line, U; Usuki Yatsushiro Tectonic Line, S; Shiraiwayama thrust, K; Kashimine thrust, I; Ikegawa thrust, O; Onoyama thrust, U; Uonashi thrust, N; Nanokawa thrust, Kb; Kambaradani thrust, G; Gozaishoyama thrust, J; Junisha thrust, T; Takihara thrust, Kr; Kurasawa thrust, B; Butsuzo Tectonic Line.

islands-area to the Sambosan geosyncline. Land masses or shallow submarine swells existed in the Kurosegawa islands-area and in the southern marginal part of the Sambosan geosyncline in Late Triassic time, whereas a relatively "deep" sea existed in the area between them. The Sambosan geosyncline was not a trench, but a narrow sedimentary basin between the Kurosegawa islands-area and the southern marginal submarine hills which lay probably on the continental side of a trench.

(3) The Shiraiwayama thrust is traced nearly along the southern margin of the Permian limestone layers of the northern Sambosan terrain across Kyushu. Not only the strata of the northern Sambosan terrain but also those of the Kurosegawa terrain have moved southeastward along the Shiraiwayama thrust. The sheared granites and the Silurian strata of the Kurosegawa terrain are rootless at presesnt.

(4) The Shiraiwayama *decke* is not a single *decke*, but is separated into four *subdeckes*; the S 1, S 2, S 3 and S 4 *deckes* from northeast to southwest. Overlapping of the *subdeckes* takes place in an area where two *subdeckes* are adjoined. The western *subdecke* always thrusts itself further southeastward than the eastern one, in each area where the overlapping of *subdeckes* takes place. Each *subdecke* thrusts itself with a slight clockwise rotation. As a result, the four *subdeckes* are arranged in a left-handed *en echelon* pattern as a whole.

(5) The Kashimine *decke* occurs in eastern Kyushu and covers the Shiraiwayama *decke* and the Gomayama *decke*. The Onogawa group and the Sambagawa metamorphic rocks in the Saganoseki Peninsula have probably been moved southeastward along the Kashimine thrust.

(6) Many thrusts of smaller scales are developed in the Shiraiwayama, Kashimine and Gomayama *deckes*, and they produce the imbricate structure. The imbricate structure is probably related to the large overthrusts genetically. The Shiraiwayama thrust, the Kashimine thrust, the Butsuzo Tectonic Line (thrust) and mang thrusts of smaller scales are formed at some ages from Late Cretaceous to Paleogene time.

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