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The Baric Structures and Exhumation Processes of the Sogauchi Unit in the Sambagawa Belt

By

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with 9 Text—figures

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Abstract: The Sogauchi unit is developed as the Sogauchi nappe as a member of primary structure and as the Omogiyama nappe, Terano—Isozu nappe and Saredani—Kabayama—Izushi nappe as members of secondary structure. The baric structures of these nappes have been analyzed on the basis of chemical composition of amphibole in hematite—bearing basic schist. The Sogauchi nappe consists of three subunits as nappes, showing increase of pressure from the lower nappe to the upper nappe and northward increase of pressure for each nappe. The assumed isobaric lines appear to be running in WNW—ESE trend, which is slightly oblique to the general trend of mineral lineation (Lm), and the lower pressure part of each nappe appears to be placed on the western side on the line along Lm. The displacement of the nappes during their subcretion—exhumation appears to have been of westward sense judging from quartz microtextures. The Omogiyama nappe and Saredani—Kabayama—Izushi nappe have been assumed to have been derived as nappes from the northwestern extension (higher pressure parts) of the Sogauchi nappe. However, an alternative model has also been shown for the root of the Saredani—Kabayama—Izushi nappe.

Contents

I. Introduction

The Sambagawa schists in Shikoku consist of several subcretion units developed as nappes, Inouchi—Ojoin melange zone, Tsuji nappe, Omogiyama nappe, Terano—Isozu nappe, Saredani — Kabayama — Izushi nappe, Saruta nappes, Fuyunose nappe, Sogauchi nappe, Sakamoto — Niyodo nappe, Oboke nappe II and Oboke nappe I in descending order of structural level (Hara et al.,1992). The pilling structure of the latter six belongs to the primary structure (pre—Ozu phase structure) produced throughout the subcretion processes and the

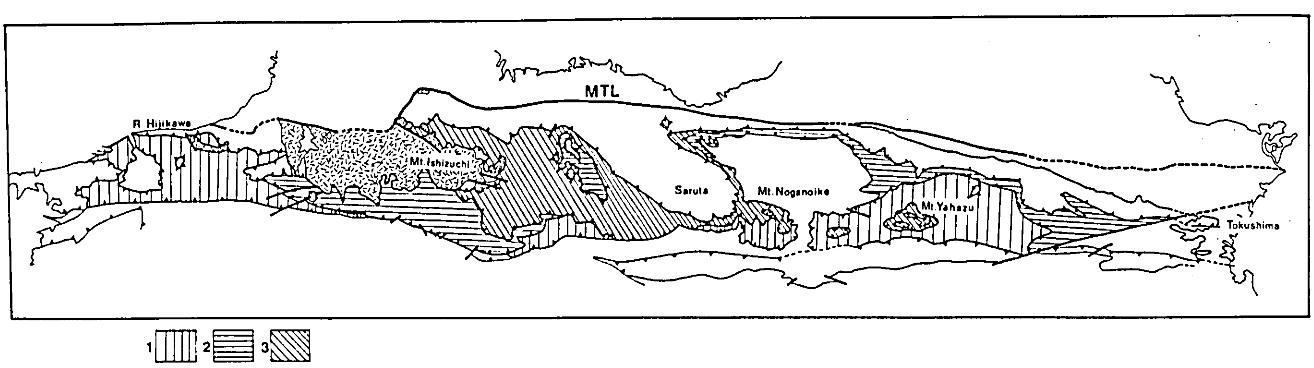

Fig. 1. Distribution of the Sogauchi nappe in the Sambagawa belt, Shikoku.
1: NOM subunit, 2: KAT subunit, 3: ST subunit, MTL:Median Tectonic Line, For fuller explanation see the Text.

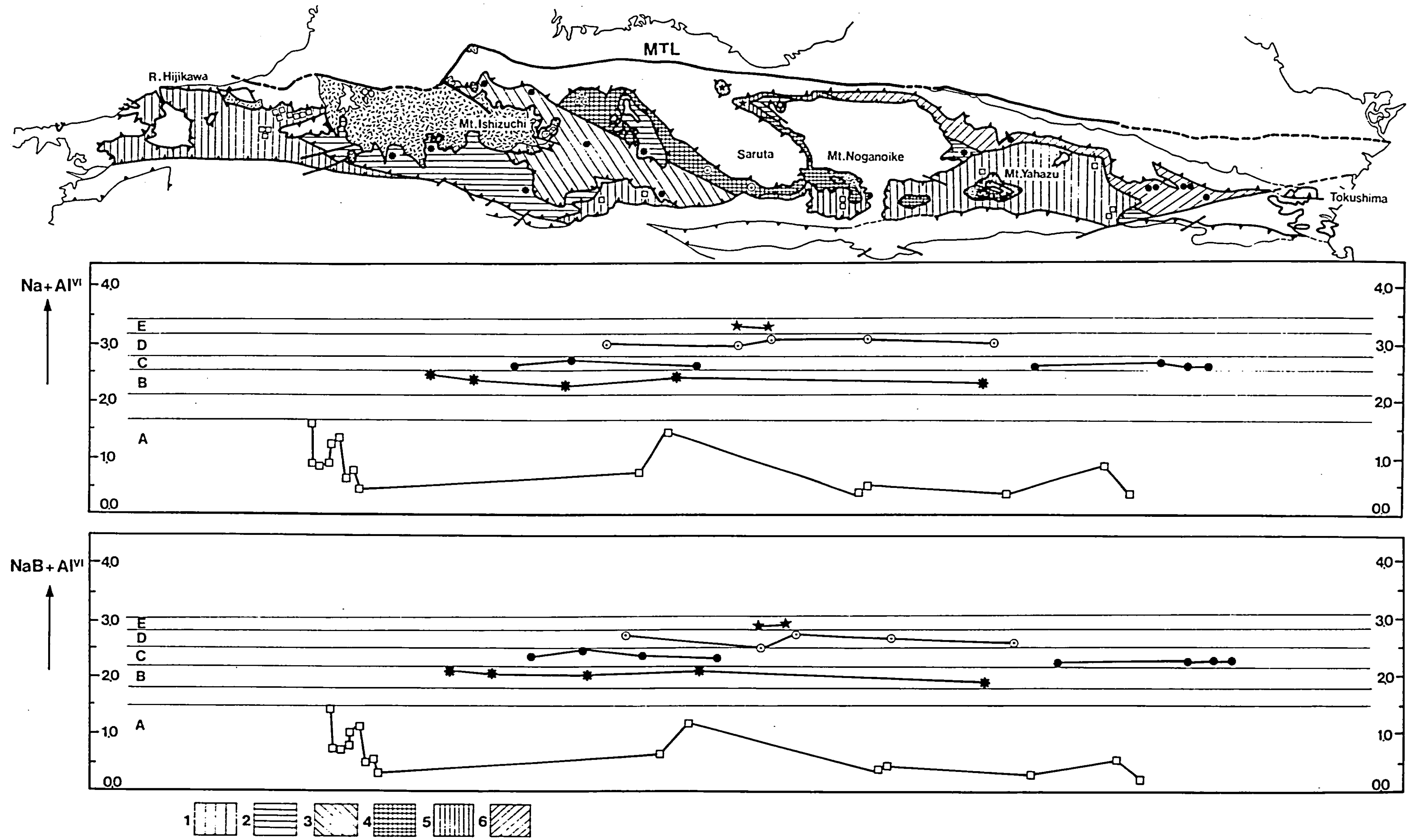

Fig. 2. Division of the Sogauchi nappe (ST subunit, KAT subunit and NOM subunit) based on the maximum values of ($Na+Al^{VI}$) and ($NaB+Al^{VI}$) contents of amphiboles in hematite–bearing basic schist.
solid stars, circled dots, solid circles, solid asterisks and open squares: sample localities, 1: A subzone, 2: B subzone in the KAT subunit, 3: C subzone in the ST subunit, 4: D subzone, 5: E subzone, 6: C subzone in the KAT subunit.

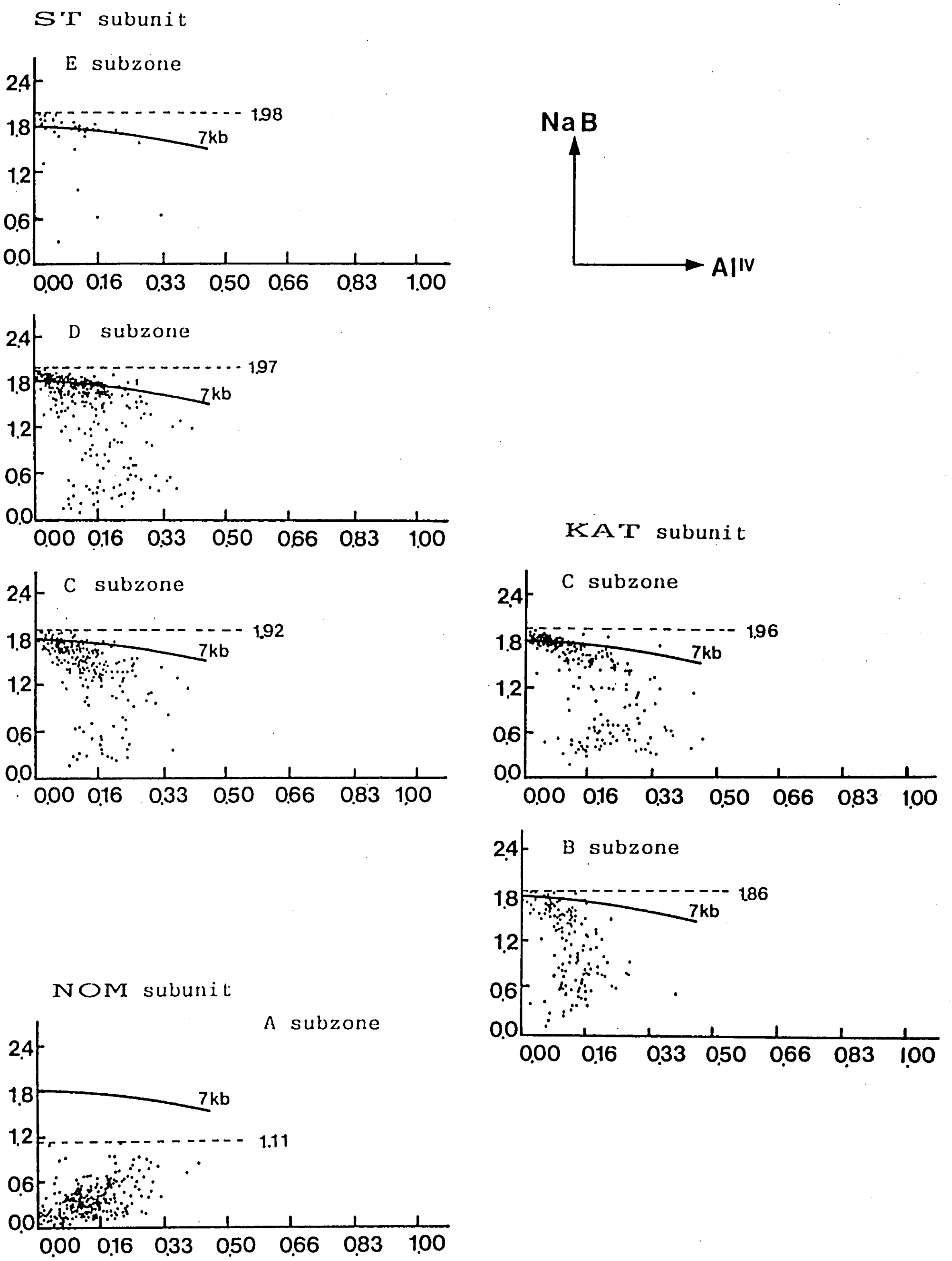

Fig. 3. NaB−Al^{IV} diagrams [Brown's (1977) diagrams] for amphiboles in hematite−bearing basic schist of the Sogauchi nappe (ST subunit, KAT subunit and NOM subunit in Fig. 2).

pilling structure of the former five belongs to the secondary structure (Ozu phase structure) for the exhumation of the Sambagawa schists (Hara et al.,1992; Seki et al.,1993). The Sogauchi unit appears to be involved in the Sogauchi nappe as a constituent of the primary structure and the Saredani−Kabayama−Izushi nappe, Terano−Isozu nappe and Omogiyama nappe probably as derivatives from the Sogauchi nappe. In this paper the geological and baric structures of the Sogauchi nappe will be first described and discussed, clarifying the movement picture throughout its subcretion−exhumation processes, and then the baric struc-

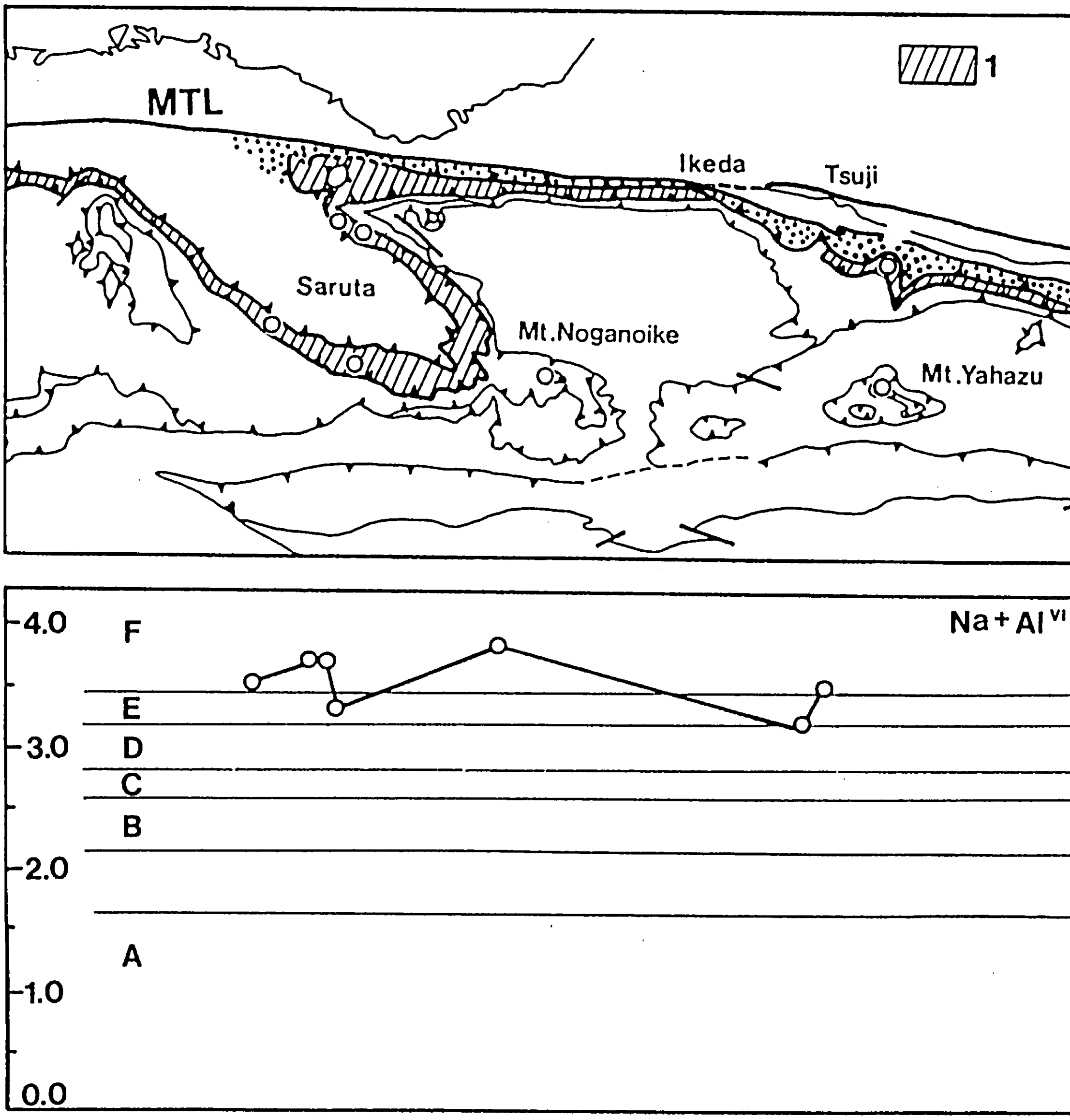

Fig. 4. Daigram showing the spatial variation of the maximum value of Na+Al^{VI} content of amphiboles in hematite–bearing basic schist in the Fuyunose nappe.
1: Fuyunose nappe, open circles: sample localities.

ture of the Sogauchi unit as constituents of the secondary structure will be described, discussing their movement pictures throughout the collapse of the primary structure.

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The authors' thanks are due to Mr. A. Minami of the Hiroshima University, who has kindly done a vast number of chemical analysis of metamorphic minerals. Their works have been partly supported by the Grant in Aid for Scientific Researches of the Ministry of Education of Japan.

II. Baric Structures and Exhumation Processes of the Sogauchi Nappe

The Sogauchi nappe appears to be developed in the greatest volume and extent among the subcretion constituents of the Sambagawa megaunit (Fig. 1). Hara et al.(1992) have first tried to clarify the geological and baric structures of this unit, showing that its lower member is developed in western Shikoku and amphibole in hematite–bearing basic schist may be of the lower pressure type in the lower member (magnesio–riebeckite – winchite – actinolite) than in the upper member (crossite). In the following paragraphs the mineralogical zonation of the Sogauchi nappe will be in further details analyzed with reference to amphiboles in he-

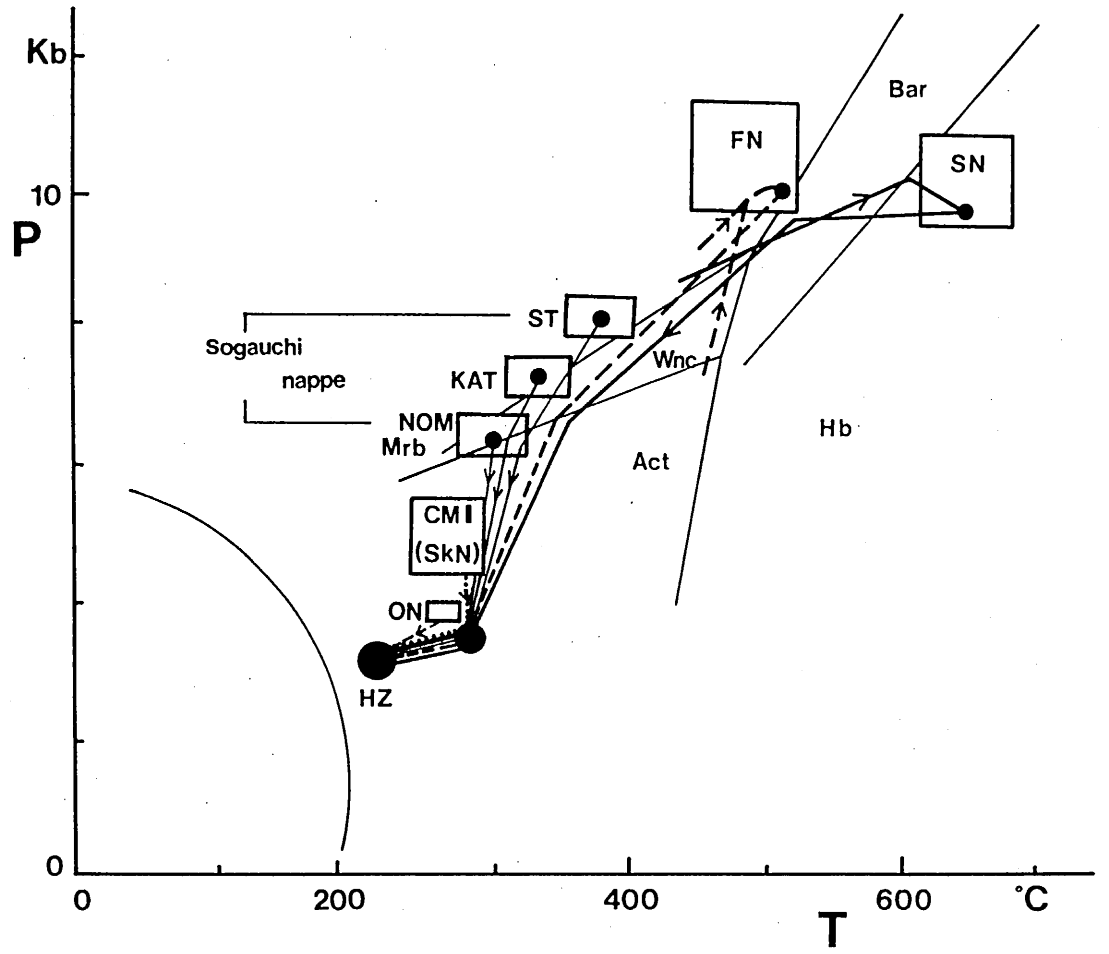


Fig. 5. P−T fields for three subunits of the Sogauchi nappe, which are for the highest−temperature phase of metamorphism (cf. Hara et al.,1992).
SN: Saruta nappes, FN: Fuyunose nappe, ST: ST subunit, KAT: KAT subunit, NOM: NOM subunit, CMI (SkN): Chichibu megaunit I (Sakamoto nappe), ON: Oboke nappes, HZ: Hijikawa−Oboke (Dh) phase, Hb: hornblende, Bar: barroisite, MrB: magnesio−riebeckite, Wnc: winchite, Act: actinolite, P: pressure, T: temperature.

matite−bearing basic schist.

The Sogauchi nappe is roughly divided into three subunits, Myoga−Sasagamine−Sogauchi−Toyosaka subunit (ST subunit), Kuma−Aguigawa−Takayabu−Kainayama−Kasidaira subunit (KAT subunit) and Nakayamagawa−Nekosako−Okuohta−Mibuchi subunit (NOM subunit) in descending order of structural level with reference to structural succession of constituent schists, as shown in Fig. 1. The chemical composition of amphiboles in hematite−bearing basic schist of these subunits has been analyzed, showing that the amphiboles, which grew during the highest−temperature phase of metamorphism, are glaucophane, crossite, magnesio−riebeckite, winchite and actinolite.

Regarding with such the highest−temperature phase amphiboles, thus, the ST subunit can be divided into two zones, glaucophane zone and crossite zone, the KAT subunit belongs to crossite zone and the NOM subunit belongs to magnesio−riebeckite − winchite − actinolite zone. Only in some places of the NOM subunit magnesio−riebeckite is found as amphibole cores, showing retrograde growth history of magnesio−riebeckite − winchite − actinolite. Thus it can be said that the magnesio−riebeckite − winchite − actinolite zone is found as the lower member of the Sogauchi nappe, while the upper member is defined by the crossite zone and glaucophane zone. The glaucophane zone is found only in the northernmost part of the uppermost member, which is placed in the Toyosaka−Urayamagawa district.

The above−mentioned amphibole zones can be further subdivided into five subzones, A, B, C, D and E, with reference to (Na+Al^{VI}) content and (NaB+Al^{VI}) content in constituent amphiboles as shown in Fig. 2. From these data, namely, it can be said that the magnesio−riebeckite − winchite − actinolite zone, the crossite zone and the glaucophane zone are divided into five subzones, A−subzone with (Na+Al^{VI}) content of less than 1.7 (magnesio−riebeckite − winchite − actinolite zone), B−subzone with (Na+Al^{VI}) content of 2.28−2.5,

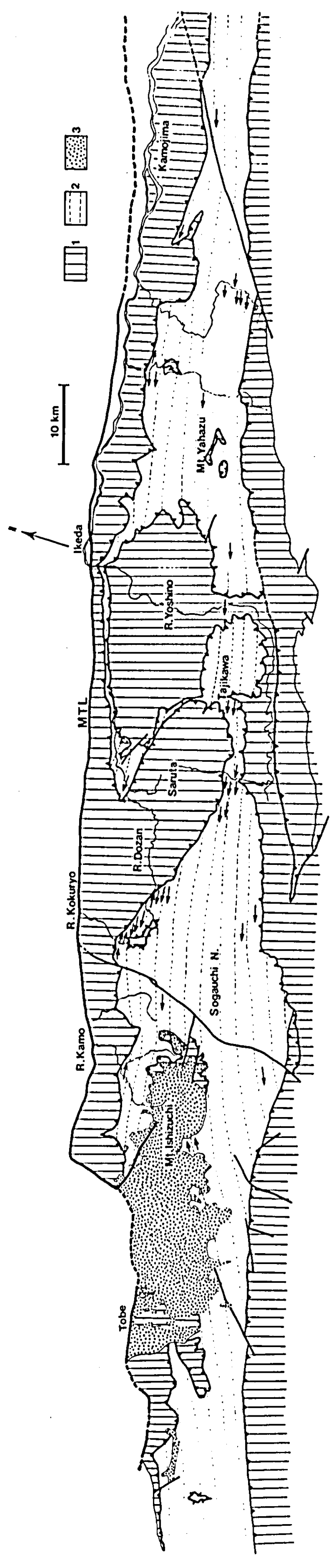


Fig. 6. Orientation direction of mineral lineation (Lm) in the Sogauchi nappe and shear sense assumed from Type III quartz microtexture in siliceous schist. dashed lines: trend of Lm, arrows: shear direction (displacement direction of the upper part), 1: other schists than the Sogauchi nappe schists, 2: Sogauchi nappe, 3: Ishizuchiyama Tertiary System.

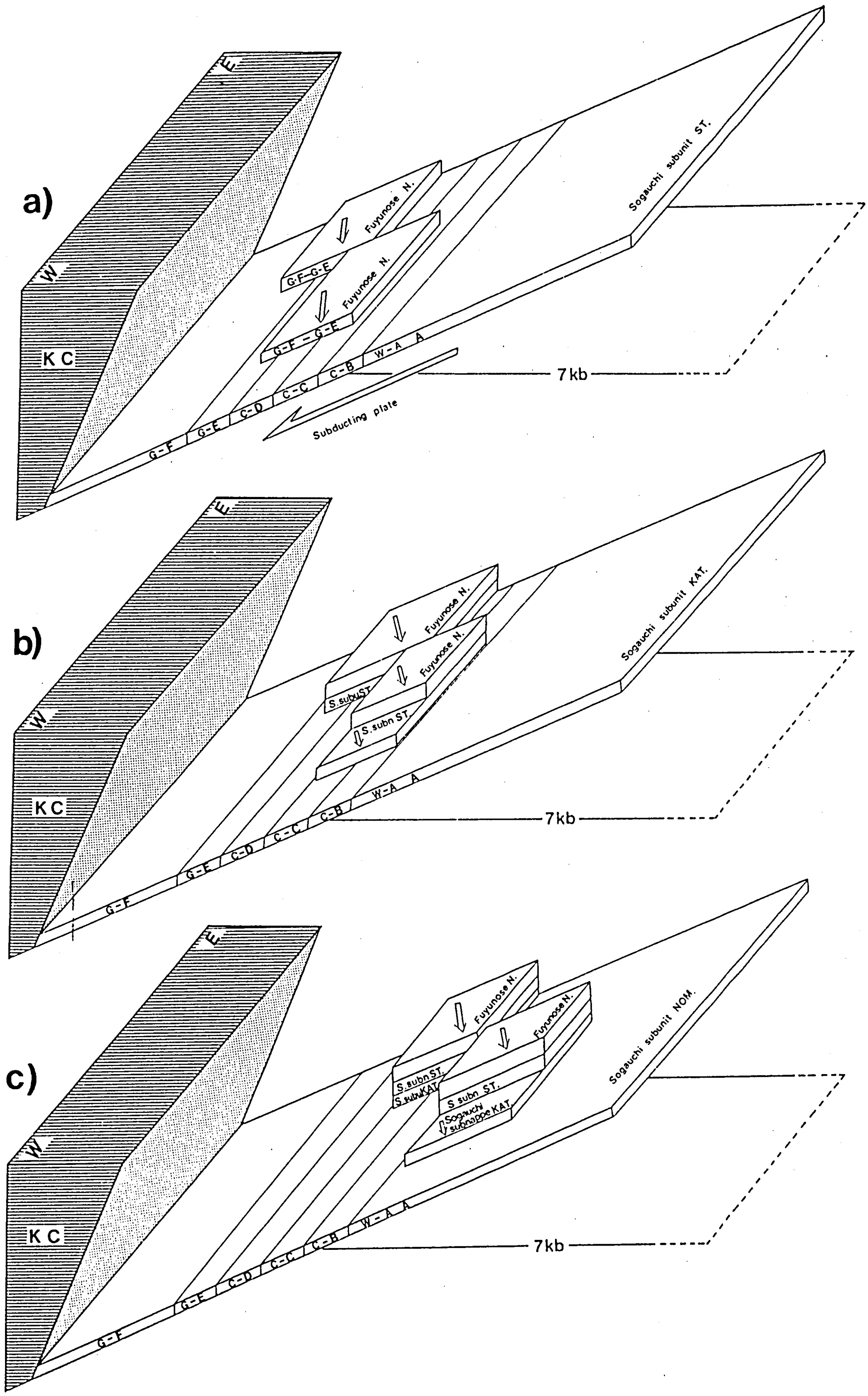
Fig. 7. Movement picrures of the Fuyunose nappe and Sogauchi nappe. a) exhumation of the Fuyunose nappe and subduction of the ST subunit (Sogauchi subunit ST), b) exhumation of the ST subunit and subduction of the KAT subunit (Sogauchi subunit KAT), c) exhumation of the KAT subunit and subduction of the NOM subunit (Sogauchi subunit NOM), G−F, G−E, C−D, C−C, C−B and W−A A: F subzone, E subzone, D subzone, C subzone, B subzone and A subzone respectively. For fuller explanation see the Text.

C−subzone with ($Na+Al^{VI}$) content of 2.51−2.8, D−subzone with ($Na+Al^{VI}$) content of 2.95−3.12 and E−subzone (glaucophane zone) with that of 3.25−3.27. The NOM subunit belongs to the A−subzone. The KAT subunit belong to the B−subzone in the southwestern part and to the C−subzone in the northeastern part (Fig. 2). The ST subunit belongs to the B−subzone in the southwestern part, the C−subzone in the central part and the D−subzone in the northeastern part, as shown in Fig. 2. These five subzones are also clearly recognized in Brown's (1977) diagram ($NaB-Al^{IV}$ diagram) as shown in Fig. 3. Amphiboles in hematite−bearing basic schist of the Fuyunose nappe, which crystallized during the high-est−temperature phase of metamorphism, are glaucophane, showing that the nappe as a whole belongs to the glaucophane zone (Hara et al.1990,1992). Fig. 4 illustrates also their ($Na+Al^{VI}$) content, clearly showing that it is greater in the Fuyunose nappe (F−subzone) than in the glaucophane zone of the ST subunit. According to Banno and Sakai (1989), the highest−temperature phase metamorphism of the Fuyunose nappe schists occurred under higher pressure and temperature condition than that of the Sogauchi nappe schists. The NaB content in amphibole appears to increase with increase of pressure following glaucophanic substitution (Robinson et al.,1982). It may be thus said that the data of Figs. 3, 4 and 5 roughly illustrate the baric structure of the Fuyunose and Sogauchi nappes.

From Figs. 2, 3 and 4 it may be said that during the highest−temperature phase of metamorphism there was the difference in pressure among the NOM subunit, the KAT subunit, the ST subunit and the Fuyunose nappe, showing discontinuous increase of pressure with upward migration of structural level, and that there was the difference in pressure among the C−subzone, the D−subzone and the E−subzone in the ST subunit and between the B−subzone and the C−subzone in the KAT subunit, showing increase of pressure toward the north, like the cases of the Saruta nappe and Fuyunose nappe (Hara et al.,1988,1990). The subzone boundaries in the ST subunit appear to be running in WNW−ESE trend. Analogous trend may be also for the subzone boundary in the KAT subunit. Hara et al.(1992) and Seki et al. (1993) clarified that the boundary between the crossite − winchite − actinolite path zone and the crossite − barroisite − winchite − actinolite path zone in the Fuyunose nappe, which may be regarded as an isobaric line, is running in WNW−ESE trend.

The Fuyunose unit (F−subzone) is underlain by the C−subzone, D−subzone and E−subzone of the ST subunit, showing the discontinuous relationship between the former and the latter (Fig. 2). In the Nakashichiban−Takayabu district the D−subzone of the ST subunit is in contact with the B−subzone of the KAT subunit, lacking the C−subzone. In the Tomisato−Sazare district the E−subzone of the ST subunit appears to be in contact with the C−subzone, lacking the D−subzone. In the Setogawa−Noganoike−Yahazuyama district the C−subzone of the ST subunit is directly underlain by the NOM subunit (A−subzone), lacking the KAT subunit (Fig.2). From these facts it would be said that the subunit boundaries are discontinuous ones with reference to pressure, like the cases of other nappe boundaries. The coupling of these subunits must also have been produced during the subcretion−exhumation processes as approximately illustrated by Fig. 5.

Fig. 6 is structural trend (mineral lineation = Lm) map of the Sogauchi


a)
E
W
K C
Fuyunose N.
G-F–G-E
Fuyunose N.
G-F – G-E
W-A
A
C-B
C-C
C-D
G-E
G-F
Subducting plate
7 kb
Sogauchi subunit ST.
b)
E
W
K C
Fuyunose N.
S.subuST
Fuyunose N.
S.subn ST.
W-A
A
C-B
C-C
C-D
G-E
G-F
7kb
Sogauchi subunit KAT.
c)
E
W
K C
Fuyunose N.
Fuyunose N.
S.subn ST.
S.subuKAT
S subn ST.
Sogauchi subnappe KAT.
W-A
A
C-B
C-C
C-D
G-E
G-F
7kb
Sogauchi subunit NOM.

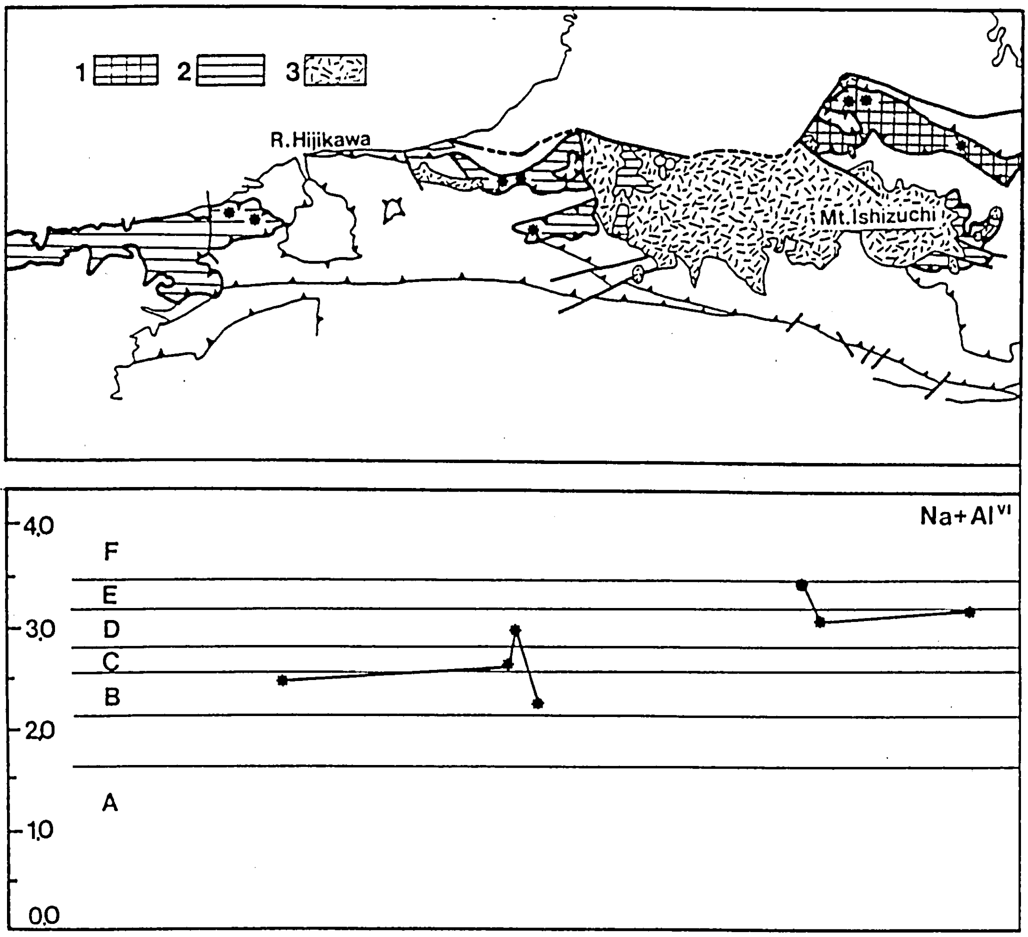


Fig. 8. Diagram showing the spatial variation of the maximum value of Na+Al^{VI} content of amphiboles in hematite–bearing basic schist of the nappes of the Ozu phase in western Shikoku in which the Sogauchi unit is involved.
1: Omogiyama nappe, 2: Saredani–Kabayama–Izushi nappe, 3: Ishizuchiyama Tertiary System, solid asterisks: sample localities.

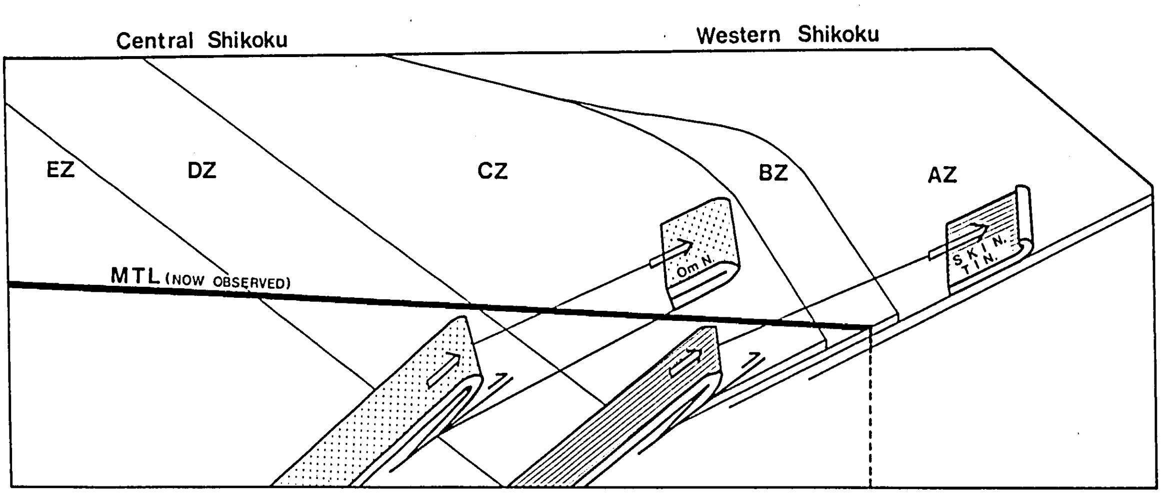


Fig. 9. Schematic block diagram illustrating the southward movement pictures of the Omogiyama nappe (Om N.) and Saredani–Kabayama–Izushi nappe (SKIN.)[Terano–Isozu nappe (TIN.)].
EZ, DZ, CZ, BZ and AZ: E subzon, D subzone, C subzone, B subzone and A subzone respectively. For fuller explanation see the Text.

nappe, which was partly reproduced from Hara et al.(1992). The trend of Lm appears to be slightly obliqe to the subunit boundaries, as is obvious in comparison between Fig. 2 and Fig. 6. If the subzone boundaries correspond to the isobaric lines, it can be said that the lower pressure part of each subunit is placed on the western side of the line along Lm. This is also the case for the Fuyunose nappe, which has been clarified by Hara et al.(1922). Fig. 6 also indicates that the deformation of the Sogauchi nappe schists, as assumed from Type III quartz microtextures [cf. Hara et al.,1990; = Type II S−C structure after Lister and Snoke (1984)], may roughly be explained in term of westward shear along Lm. Thus the subcretion−exhumation processes of the Fuyunose nappe, ST subunit, KAT subunit and NOM subunit would be schematically explained by Fig. 7.

Hara et al.(1992) have determined the exhumation velocity for the Saruta nappe(I+II), Fuyunose nappe and Sogauchi nappe schists to be ca. 2mm/year as assumed to be vertical movement. However, the exhumation of these Sambagawa schists appears to have occurred toward the west along Lm, which is slightly oblique to the assumed isobaric line, showing that the true exhumation velocity of the Sambagawa schists must be fairly greater than ca. 2mm/year.

III. Baric Structure of the Dismembered Sogauchi Unit and Its Movement Picture

The Sogauchi unit in western Shikoku is also involved in the Omogiyama nappe, Terano−Isozu nappe and Saredani−Kabayama−Izushi nappe (Fig. 8) as secondary structure (Hara et al.,1992). The Omogiyama nappe is underlain by the ST subunit. The Saredani−Kabayama−Izushi nappe, which is covered by the Terano−Isozu nappe, is underlain by the NOM subunit in the central−northern part and by the KAT subunit in the southernmost part (Figs. 2 and 8).

The thermal structure of the Sogauchi unit has been so far analyzed on the basic of measurement of graphitization degree of carbonaceous materials in pelitic schist. The constituent subunits of the Sogauchi nappe appear to show commonly upward increase of temperature for the highest−temperature phase of metamorphism: Tagiri's (1985) data are for the ST subunit in the River Asemi district, Takeda et al's (1987) data are for the NOM subunit in the Nakayama−Hijikawa district and Hara et al's (1992) data are for the KAT subunit in the Okuohta district. While, according to Takeda et al.(1987), the Terano−Isozu nappe and Saredani−Kabayama−Izushi nappe as the Sogauchi unit, which accompany garnet zone schists of less than ca.20m in thickness in their basal parts, show downward increase of temperature. The thermal structure of both nappes is against that of their underlying nappe (NOM sununit), showing a structural discontinuity between the former and the latter. The Omogiyama nappe contains a recumbent fold in which there is an increase of temperature toward the fold core(Hara et al.,1992).

The Saredani−Kabayama−Izushi nappe belongs to the crossite zone, which appears to be comparable with the B−subzone, C−subzone and D−subzone, suggesting that there is a discontinuity between this nappe and the underlying NOM subunit as the A−subzone (Figs. 2 and 8). It is clear that the Saredani−Kabayama−Izushi nappe was emplaced onto the NOM subunit from the depth part (B−subzone−D−subzone) of the Sogauchi unit partly accompanying the Fuyunose nappe. The B−subzone − D−subzone of the Sogauchi unit, which shows an upward increase of temperature, is widely developed with WNW−ESE trend as the Sogauchi nappe in central Shikoku (Figs. 2) accompanying the Fuyunose nappe as overlying nappe. The NW extension of such the Sogauchi−Fuyunose nappe complex must be the root of the Saredani−Kabayama−Izushi nappe. Namely, the former was overturned and emplaced as nappes onto the NOM subunit as schematically illustrated in Fig. 9. In the uppermost part of the NOM subunit there are some blocks (crossite zone schists) derived from the overlying nappes during the coupling of the former and the latter, as shown in Hara et al.'s (1992) data.

According to Hara et al.(1992), the geological structure of the Omogiyama nappe is characterized by the Omogiyama recumbent fold with southward closure. The Sogauchi unit involved in its mantle belongs to the glaucophane zone, which appears to be comparable with the D−subzone − E−subzone according to chemical data of amphibole in hematite−bearing basic schist (Fig. 8). The nappe is underlain by the C−subzone of the ST subunit. The D−subzone − E−subzone of the Sogauchi unit is developed with WNW−ESE trend as the northern part of the Sogauchi nappe in central Shikoku (Fig. 2) accompnaying the Fuyunose nappe. The NW extension of such the Sogauchi−Fuyunose nappe complex must be the root of the Omogiyama nappe. Namely, the former was transformed as a nappe toward the south forming a recumbent fold (Omogiyama recumbent fold) and emplaced onto the B−subzone of the ST subunit as schematically shown in Figs. 2 and 9. Such the movement picture of the Saredani−Kabayama−Izushi nappe and Omogiyama nappe is comparable with that of the Tsuji nappe with the Tsuji overturned fold, which has been clarified by Seki et al.(1993). The southward vergent deformation related to the formation of the nappes such as the Tsuji, Omogiyama, Terano − Isozu and Saredani − Kabayama−Izushi nappes is of the Ozu phase.

Recently Watanabe et al. (1993 & personal comunication) have reported that some basic schists of the Saredani−Kabayama−Izushi nappe show Rb−Sr ages of ca. 107−140Ma and the ages correspond to these of their peak metamorphism. According to their data and consideration, the Saredani−Kabayama−Izushi nappe, together with its overlying nappes such as Terano−Isozu nappe and Shiraki formation, Fukumizu formation and Isshakuya formation in Saganoseki Peninsula, is considered to belong to the Futami−Kuma nappe as high temperature−pressure parts of the Chichibu megaunit II (Hara et al., 1992) but not to the Sambagawa megaunit. It would be thus said that the high temperature−pressure parts of the accretionary complexs exhumed in the southern front of Kurosegawa−Koryoke continent are commonly placed in northern side than their low temperature−pressure parts as compared with each other for the single accretionary complex and further that the Sambagawa belt consists of the high temperature−pressure parts of the Chichibu megaunit II, high temperature−pressure parts (Sambagawa megaunit and Sakamoto nappe) of the Chichibu megaunit I and high temperature−pressure parts (Oboke nappes and Tatsuyama nappe etc) of the Shimanto megaunit. Hara et al. (1992) clarified that the high temperature−pressure schists (high temperature−pressure parts of the Chichibu megaunit I and Shimanto megaunit) in the Sambagawa belt exhumed after the Chichibu megaunit II (Mikabu unit) show an eastward younging age polarity, though low temperature−pressure parts are of the same ages between Shikoku and Kanto Mountains. This must be a quite important evidence in understanding the subcretion−exhumation processes of the high P/T schists in the subduction zone, judging from the subcretion−exhumation processes of the Sogauchi nappe schists mentioned in the preceding pages. It may namely be suggested that the exhumation of the high P/T schists are ascribed to the subduction of the Kula−Pacific ridge (Hara te al.,1992) and that occurred in restricted volume for the previously subcreted schists placed only just near the plate boundary. It would lastly be also pointed out thay many parts of the Ishizuchiyama Tertiary System was deposited on the Futami−Kuma nappe.

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