Title	Discovery of Biotite-Bearing Schists Blocks in the Garnet Zone of the Sambagawa Belt of theAsemi District: an Evidence of Tectonic Erosion of Hanging Wall Rocks by Subducting Sediments
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Discovery of Biotite-Bearing Schists Blocks in the Garnet Zone of the Sambagawa Belt of theAsemi District-an Evidence of Tectonic Erosion of Hanging Wall Rocks by Subducting Sediments

By

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with 15 Text-figures

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Abstract: Biotite-bearing schists have been discovered in the garnet zone (Fuyunose nappe) of the Sambagawa belt of the Asemi district, central Shikoku, which is covered by the biotite zone (Saruta nappe II and Saruta nappe I). The biotite-bearing schists (subunit II schists of the Fuyunose nappe) are pelitic schists, siliceous schists and basic schists and have plagioclase porphyroblasts, which crystallized during the prograde phase of metamorphism, like the case of the Saruta nappe (I+II) schists. They occur as lenses in the biotite-free schists (subunit I schists of the Fuyunose nappe) which have plagioclase porphyroblasts of the rerograde phase. Amphibole, which crystallized in hematite-bearing basic schists of the subunit I of the Fuyunose nappe during the peak metamorphism, is glaucophane. Biotite of the subunit II schists is commonly found only in plagioclase porphyroblasts, and the inclusion biotite in hematite-bearing siliceous schists of the subunit II occurs together with barroisite, katophorite and taramite. Barroisite of the subunit II schists, which crystallized together with biotite, have distinctly lower values of NaB content than that of the prograde phase of the Saruta nappe (I+II) schists (biotite zone schists) and than that of the retrograde phase of the subunit (I+II) schists, showing that the subunit II schists were derived from shallow tectonic positions of subduction zone. The subunit II schists had already been intermingled with the subunit I schists when the peak metamorphism of the latter had begun. It has been concluded in this paper that the origin of the subunit II schists is ascribed to the tectonic erosion and subduction of the hanging wall rocks [probably low pressure parts of the Saruta nappe (I+II) schists] of the subduction zone during the subduction of the original sediments for the subunit I schists,which induced great decrease of temperature along the subduction channel.

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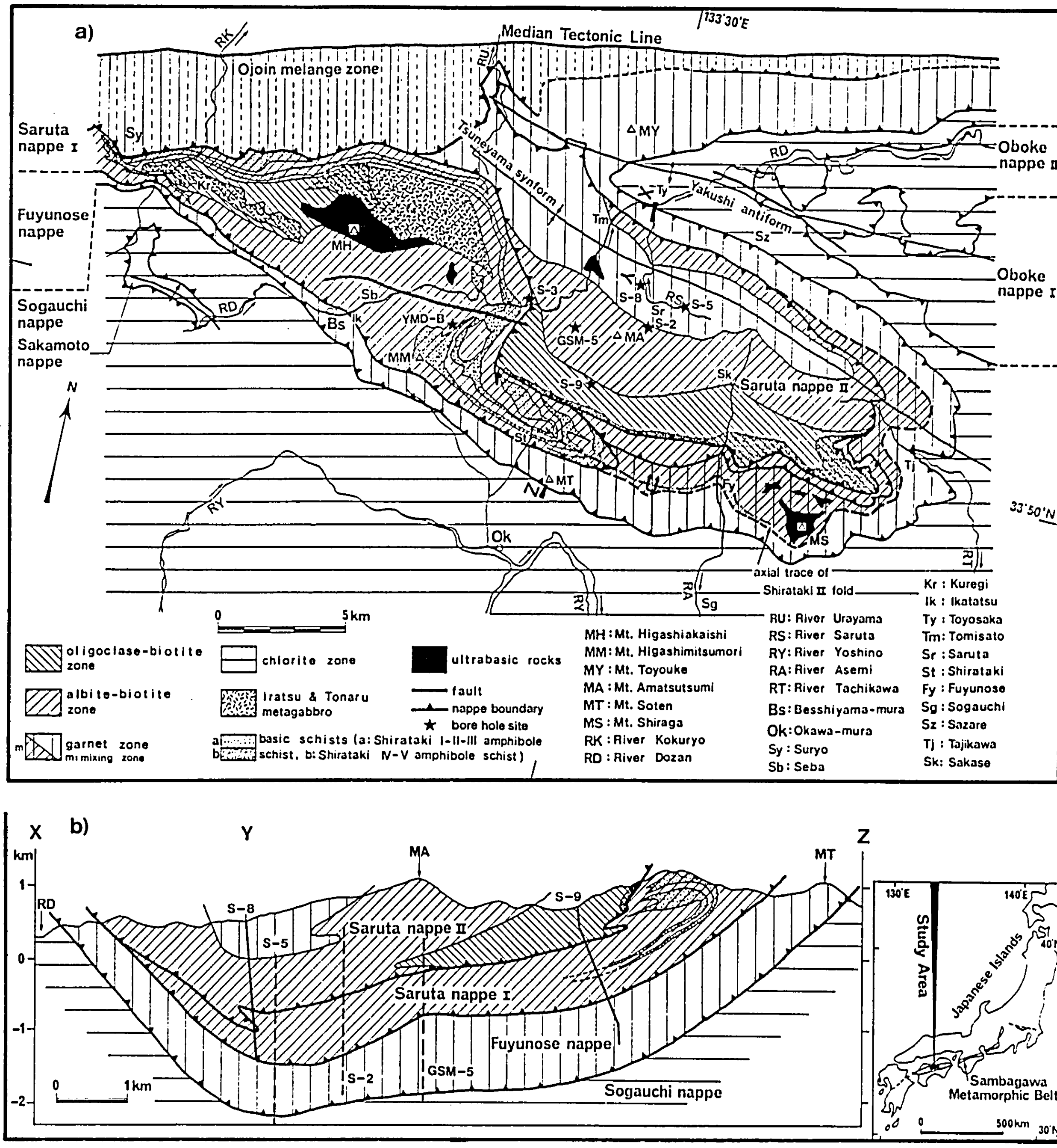


Fig. 1: Geological map (a) and profile (b:X-Y-Z line) of the Sambagawa belt in central Shikoku [partly modified from Hara et al.(1992)].

I. Introduction

The Sambagawa belt of central Shikoku consists of eight nappes, Ojoin-Inouchi melange, Saruta nappe II, Saruta nappe I, Fuyunose nappe, Sogauchi nappe, Sakamoto nappe, Oboke nappe II and Oboke nappe I in descending order of structural level, as shown in Fig. 1, (Hara et al.,1988,1990a,1992). Kurata and Banno (1974), Higashino (1975) and Enami (1983) have shown that the facies series of pelitic schists in the Sambagawa belt of central Shikoku, for the highest temperature phase of metamorphism, can be described in terms of a chlorite zone, garnet zone, albite-biotite zone and oligoclase-biotite zone. Fig. 1 illustrates the distribution relationship between these mineral zones and the nappes. The garnet zone has been considered to be developed in some parts of the Ojoin-Inouchi melange, the uppermost part of the Saruta nappe II and the whole part of the Fuyunose nappe. However, Hara et al.(1995) have clarified that the upper part of the Fuyunose nappe [garnet zone after Higashino (1975)] of the Asemi district, central Shikoku, contains biotite-bearing schists as tectonic blocks. In this paper, the biotite-bearing schists are described, clarifying the crystallization history and conditions of their constituent minerals, and their tectonic implication is discussed, showing that the blocks of

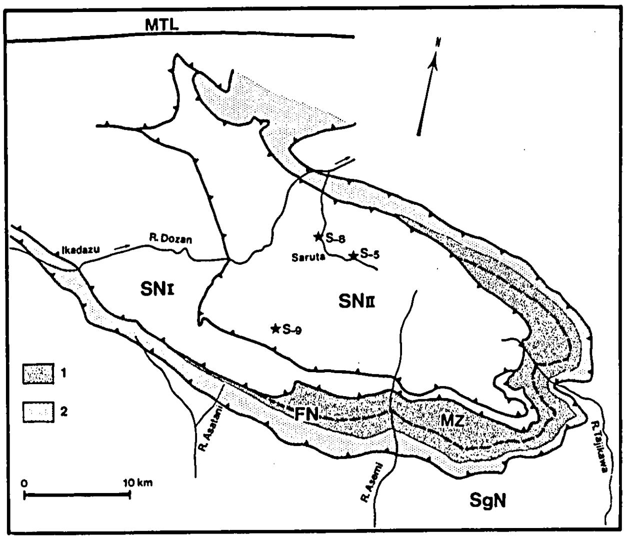


Fig. 2: Division of the Fuyunose nappe (FN).
1: part in which minimum Mn content of garnets in pelitic schists is less than 3%, 2: part in which minimum Mn content of garnets in pelitic schists is larger than 3%. MZ: mixing zone of the subunit I and the subunit II, SN I : Saruta nappe I, SN II : Saruta nappe II , SgN: Sogauchi nappe, S-5, S-8 and S-9: borehole sites.

biotite-bearing schists were derived from the shallow position of the hanging wall (= Saruta nappe schists) of subduction zone by tectonic erosion related to the subduction of their matrix schists.

Acknowledgements

The authors thank Mr. Minami of the Hiroshima University for chemical analysis of metamorphic minerals of the Sambagawa schists, which are described in this paper. The authors' works have been partly supported by the Grant in Aid for Scientific Researches of the Ministry of ducation of Japan.

II. Geological Setting

The Fuyunose nappe is just in contact with the Saruta nappe I in its southern half and with the Saruta nappe II in its northern half (Fig. 1). Such the juxtaposition of the Saruta nappes and the Fuyunose nappe appeared when the latter schists were subducted and underplated with the hanging wall of subduction zone: The former schists were a constituent of the hanging wall of subduction zone as a pre-existing subcretion unit (Hara et al., 1988,1990a,b,1992,1995).

The Fuyunose nappe shows an upward increase of temperature of the peak phase of metamorphism: Graphitization degree of carbonaceous materials in its pelitic schists shows an upward decrease of d(002) (Banno & Sakai,1989), and Mn content of rims of garnet in its pelitic schists shows an upward decrease accompanied with an downward decrease of Fe and Mg contents (Hara et al., 1990a; Suzuki et al., 1995). For example, garnet in pelitic schists near the uppermost horizon of the Fuyunose nappe along the River Saruta has Mn content of ca. 5% in rims, as measured on the Mn-Fe-Mg diagram, while that near its lowermost horizon has

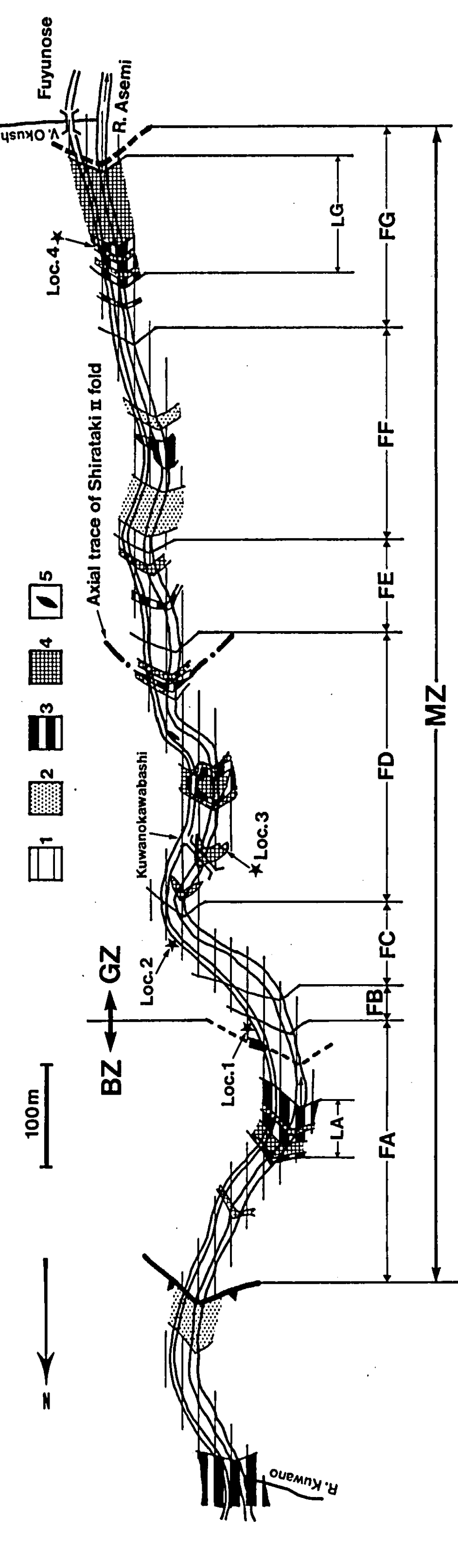


Fig. 3. Route map along the River Asemi.
1: pelitic schists, 2: psammitic schists, 3: siliceous schists, 4: basic schists, 5: ultrabasic rocks, BZ and GZ: biotite zone (BZ) and garnet zone (GZ), respectively, after Banno & Sakai (1989), Otuki & Banno (1990) and Wallis et al.(1992), SNI: Saruta nappe I , FN:Fuyunose napple, MZ: mixing zone of the subunit I and the subunit II , FA: Formation A, FB: Formation B, FC: Formation C, FD: Formation D, FE: Formation E, FF: Formation F, FG: Formation G, LA: layer A, LG: layer G.

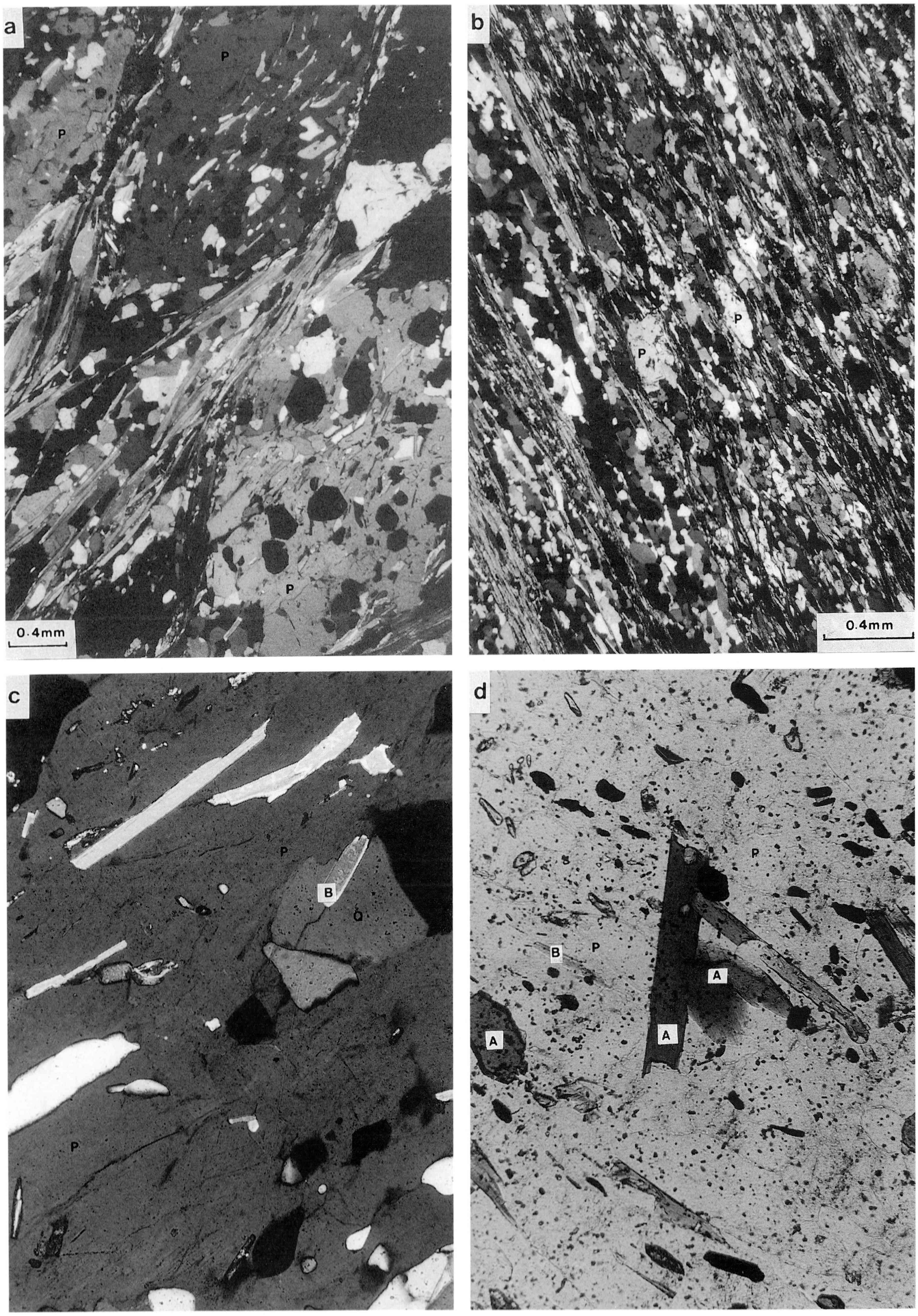


Fig. 4 : Microphotographs of the Sambagawa schists collected from three localities of the River Asemi.
a: pelitic schist (biotite zone schist) from the locaity 1 of Fig. 3, b: pelitic schist (garnet zone schist) of the Formation B of Fig. 3, c: biotite flake in plagioclase porphyroblast of pelitic schist of Fig. 4-a, d: biotite (B) and amphiboles (A) in plagioclase porphyroblast of hematite-bearing siliceous schist of the layer G in the Formation G from the locality 4 of Fig. 3, P: plagioclase porphyroblasts, Q: quartz. For fuller explanation see the Text.

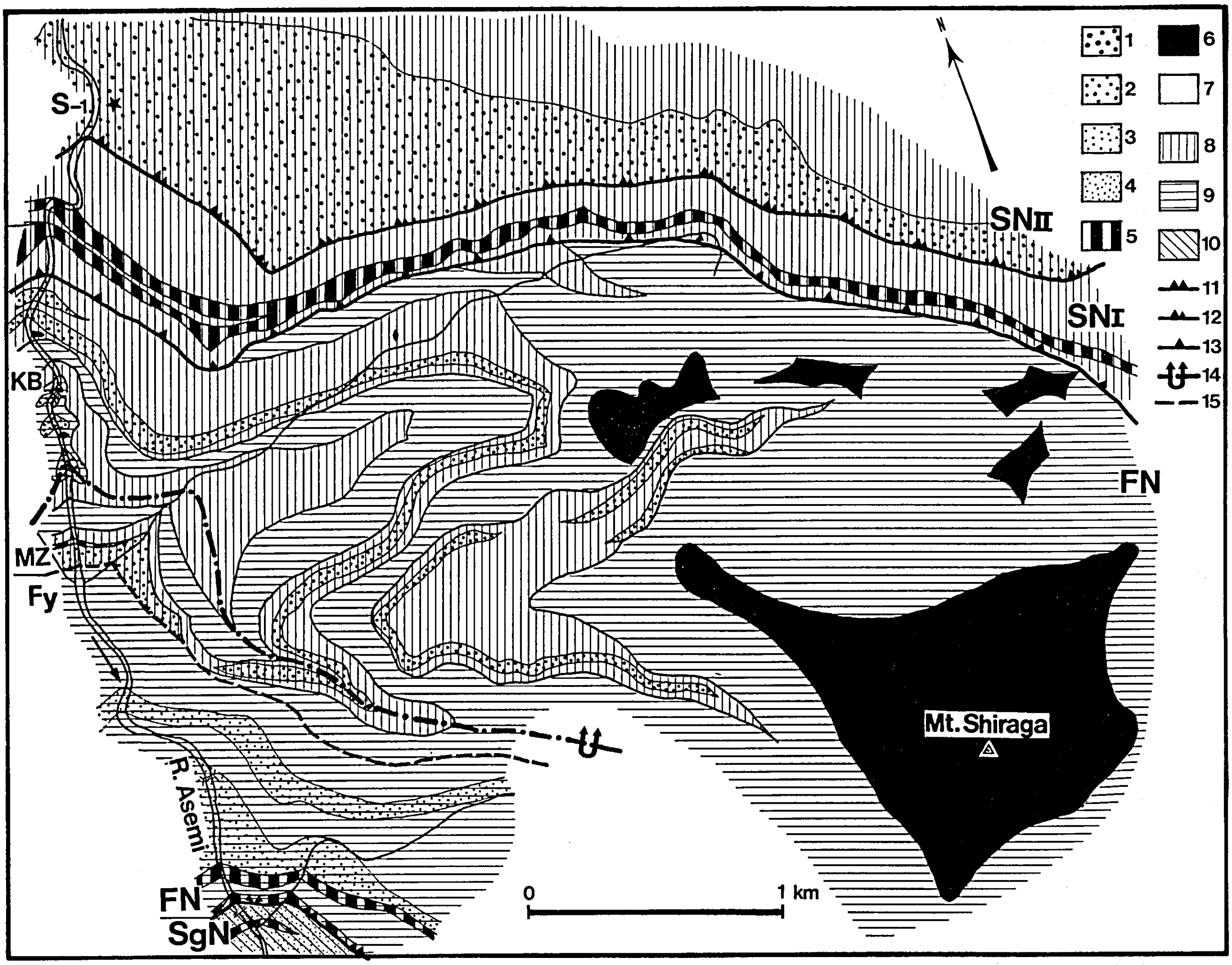
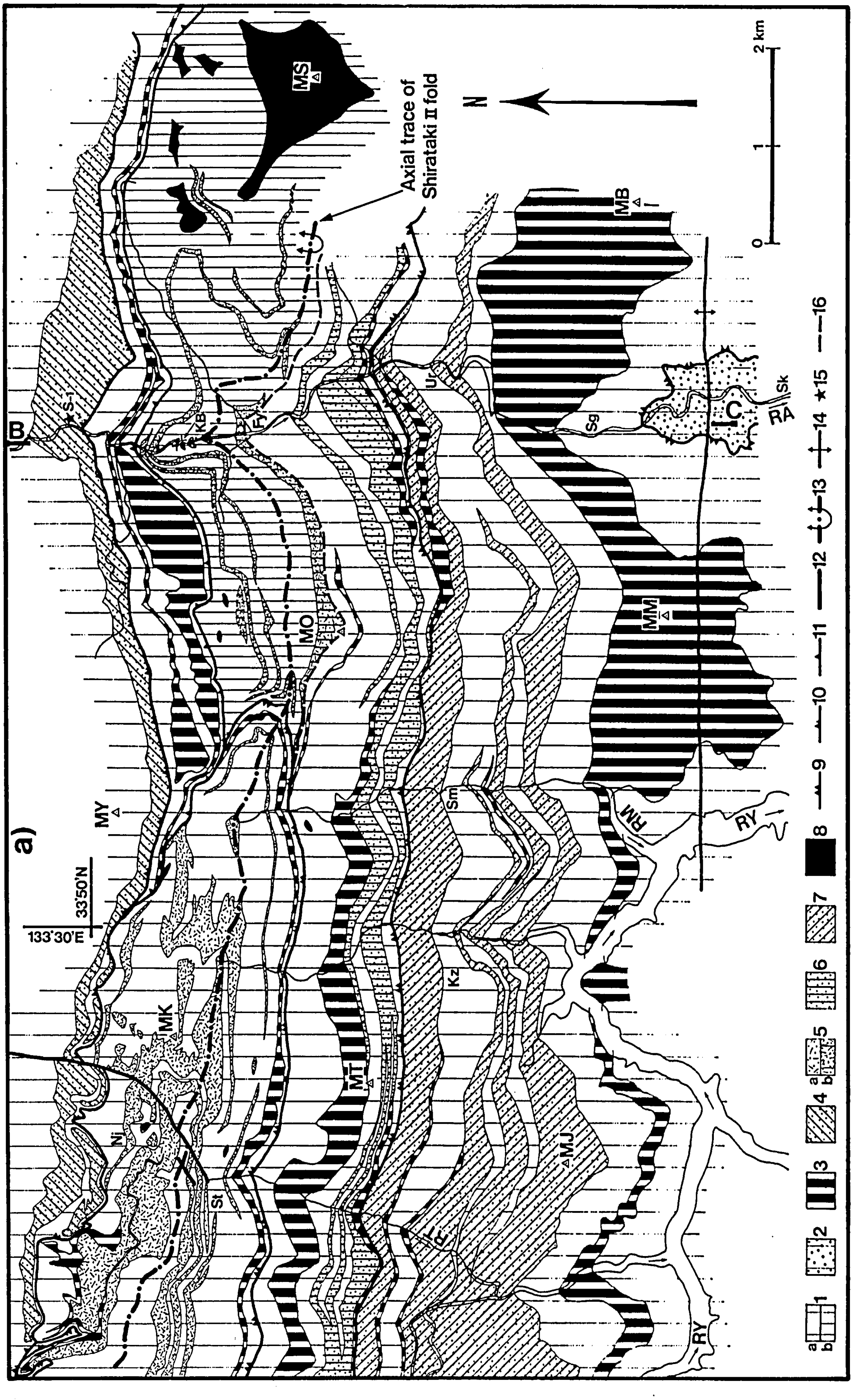


Fig. 5 : Geological map of the western slope of Mt. Shiraga.
1: Basic schists of the Saruta nappe II (SN II), 2: basic and siliceous schists of the mixing zone (MZ) of the Fuyunose nappe (FN), 3: basic and siliceous schists of the subunit I of the Fuyunose nappe developed on the south of the mixing zone, 4: basic schists of the Sogauchi nappe (SgN), 5: siliceous schists, 6: ultrabasic rocks, 7: pelitic schists, 8: biotite bearing schists, 9: garnet zone schists, 10: chlorite zone schists, 11: boundary between the Fuyunose nappe and the Sogauchi nappe, 12: boundary between the Saruta nappe II and the Saruta nappe I (SN I), 13: boundary between the Saruta nappe and the Fuyunose nappe, 14: axial trace of the Shirataki II fold, 15: basal line of the mixing zone, S-1: borehole site, KB: Kuwanokawabashi, Fy: Fuyunose.

Mn content of ca. 50% in rims (Suzuki et al.,1995). However, garnet in pelitic schists in which minimum Mn content is less than 3% as measured on the Mn-Fe-Mg diagram is not uniformly found in the upper part of the Fuyunose nappe as shown in Fig. 2: The distribution domain of such the garnet with low Mn content is absent or quite narrow in the western part of the Fuyunose nappe but broad in the eastern part (Hara et al.,1992). For convenience's sake, the former and the latter are named the W domain and the E domain respectively. The Shirataki district along the River Asatani and the River Saruta district (Figs. 1 and 2) are placed within the W domain, while the Asemi district belongs to the E domain. Namely, the boundary between the W domain and the E domain is drawn with reference to the above-described field data and the borehole data [data from S-8, S-5 and S-9 borehole sites described by Hara et al.(1990a)] as a N-S line which is placed just on the east of the River Asatani and River Saruta.

In hematite-bearing basic schists of the upper part of the W domain of the Fuyunose nappe, amphiboles crystallized during the peak phase of metamorphism are in general glaucophane and plagioclase porphyroblasts appeared during the retrograde phase of metamorphism when winchite was crystallizing (Hara et al., 1990a, b, 1992). The retrograde growth path of amphiboles is glaucophane-crossite-winchite-actinolite in the northern half and glaucophane-crossite-barroisite-winchite-actinolite in the southern half: Barroisite in the W domain crystallized in the whole part (upper to lower part) of its southern half during the retrograde phase (Hara et al., 1988, 1990a, 1992, 1995).

Banno & Sakai (1989), Otsuki & Banno (1990) and Wallis et al.(1992) pointed out that, as defined from mineral zones of the highest-temperature phase in hematite-bearing basic schists, the upper part of the garnet zone in the Asemi district (E domain of the Fuyunose nappe) belongs to the barroisite zone. However, Hara et


a)
Axial trace of Shirataki II fold
N
0
1
2 km
133°30'E
33°50'N
MS
MB
MM
MO
MY
MK
MT
MJ
Ni
St
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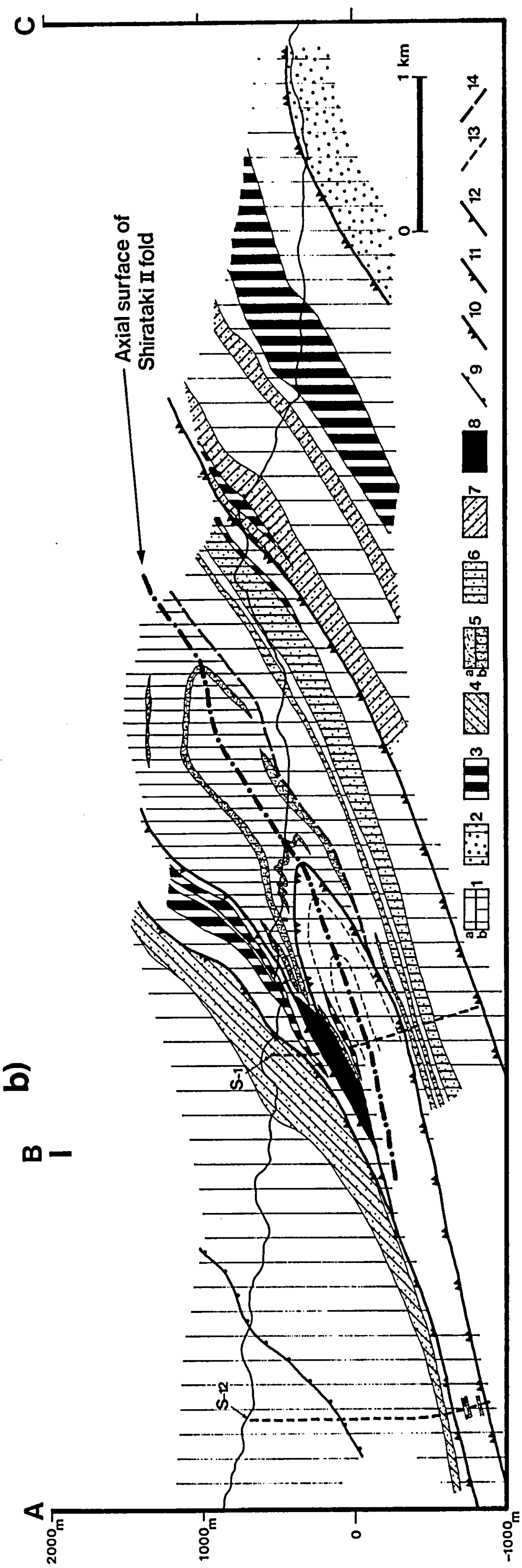

Fig. 6 : Geological map (a) and profile (b) of the Shirataki-Asemi district [partly modified from Hide et al.(1993)].
a) 1-a: pelitic schists of the Saruta nappes, Fuyunose nappe and Sogauchi nappe, 1-b: pelitic schists of the mixing zone of the subunit I and subunit II of the Fuyunose nappe, 2: pelitic schists with psammitic schists, 3: siliceous schists, 4: Shirataki IV-V amphibole schist (Saruta nappe II), 5: Shirataki I-II-III amphibole schist and other basic schists with siliceous schists (Saruta nappe I), 6: basic schists (Fuyunose nappe), 7: basic schists (Sogauchi nappe), 8: ultrabasic rocks, 9: boundary between subcretion units, 10: Saruta nappe I - II boundary [Sb1 phase after Hara et al.(1992,1995)], 11: Saruta nappe I -Fuyunose nappe boundary (Kuwanokawa thrust)[Sb2-1 phase after Hara et al.(1992,1995) and Hide et al.(1993)], 12: fault [post-Hijikawa phase after Hara et al.(1992)], 13: axial trace of the Shirataki II fold, 14: axial trace of the Hijikawa phase folds, 15: borehole site S-1, 16: basal line of the mixing zone, RY: River Yoshino, RT: River Asatani, RM: River Shimokawa, RA: River Asemi, MK: Mt.Kuroiwa, MT: Mt.Soten, MJ: Mt.Kamojiro, My: Mt.Toki, MO: Mt.Ogoya, MM: Mt. Kamataki, MS: Mt.Shiraga, MB: Mt.Kibisu, KB: Kuwanokawabashi, Nj: Nojimine, St: Shirataki, Kz: Kozuka, Sm: Shimokawa, Fy: Fuyunose, Ur: Uriuno, Sg: Sogauchi, Sk: Sakamoto, B-C: profile line
b) 1-a~8: see figure captions for 1-a~8 of Fig. 6-a, 9: boundary between the oligoclase-biotite zone and the albite-biotite zone in the Saruta nappe II , 10~12: see figure captions for 9-11 of Fig. 6-a, 13: borehole sites of S-1 and S-12, 14: see figure captions for 16 of Fig. 6-a.

Table 1. Representative analysis of biotite in plagioclase porphyroblasts of hematite-bearing siliceous schists of the subunit II of the Fuyunose napple.

	locality 2	locality 4
SiO_2	36.10	39.27
TiO_2	1.31	1.34
Al_2O_3	14.24	13.05
FeO	19.58	18.91
MnO	0.64	0.20
MgO	12.48	12.70
CaO	0.10	0.22
Na_2O	0.03	0.06
K_2O	8.84	8.16
Total	93.32	93.91
Formulae		
Si	6.19	6.20
Ti	0.22	0.15
Al^{IV}	1.81	1.79
Al^{VI}	0.63	0.63
Fe^{+2}	3.35	2.49
Fe^{+3}		
Mn	0.11	0.02
Mg	2.14	2.98
Ca	0.01	0.03
Na	0.00	0.01
K	1.51	1.64
	15.97	15.34

Total iron as FeO

al.(1990b,1992,1995) found out that a hematite-bearing basic schist, which was collected from an outcrop (= upper part of the garnet zone) just near the Kuwanokawabashi (bridge) of the River Asemi, shows the growth history such as crossite - glaucophane for the prograde phase and that such as glaucophane - crossite - barroisite - winchite - actinolite for the retrograde phase and has the retrograde phase plagioclase porphyroblasts, like the case of the W domain, and further that the E domain schists are divided into two subunits, subunit I consisting of schists with plagioclase porphyroblasts of the retrograde phase, and subunit II consisting of schists with the prograde phase ones. The lower part of the E domain corresponds as a whole to the subunit I and its upper part is a mixing zone of the subunit I and subunit II (Fig. 2). Biotite has been found in plagioclase porphyroblasts of pelitic schists and siliceous schists in the subunit II of the Asemi district (Hara et al.,1995).

III. Biotite-bearing schists in the Fuyunose nappe

Fig. 3 illustrates the route map from the lower part of the Saruta nappe I to the upper part of the Fuyunose nappe along the River Asemi. On the upper side of the route map is shown the boundary between the garnet zone and the biotite zone given by Banno & Sakai (1989), Otsuki & Banno (1990) and Wallis et al.(1992), while on the lower side are shown the data of Hara et al.(1995) and the present authors, indicating that biotite-bearing schists are also found in the garnet zone defined by Kurata & Banno (1974), Higashino (1975), Banno & Sakai (1989), Otsuki & Banno (1990) and Wallis et al.(1992), and the boundary between the Saruta nappe I and the Fuyunose nappe.

Biotite-bearing schist of the locality 1 (Fig. 3) is a pelitic schist with very coarse-grained plagioclase porphyroblasts (Fig. 4-a). Biotite is found in the plagioclase porphyroblasts (Fig. 4-c). In the upper part of pelitic schists of the Formation A, which is developed in the north of the Layer A (Fig. 3), biotite is also found in matrices. Hematite-bearing basic schists in the layer A have tschermakitic hornblende, magnesio-hornblende and barroisite as the bedding schistosity-forming amphiboles [also see Otsuki & Banno (1990)] and plagioclase porphyroblasts of prograde phase which contain barroisite as Si-forming amphiboles.

Plagioclase porphyroblasts in pelitic schists of the Formation B (Fig. 3) just on the south of the locality 1 is fine-grained, as well as other minerals (Fig. 4-c).Analogous textural types of pelitic schists are commonly found in the Fuyunose nappe of the W domain but not in the Saruta nappes.

Just on the south of the Formation B and on the north of the Kuwanokawabash there are pelitic schists, siliceous schists and basic schists with very coarse-grained plagioclase porphyrblasts. These schists are the Formation C in Fig. 3. Biotite-bearing schist, which has been found in the Formation C, is a hematite-bearing siliceous schist of the locality 2 (Fig. 3). Biotite is found together with barroisite and katophorite in plagioclase porphyroblasts. The plgioclase porphyroblasts are of the prograde phase. The chemical composition of such inclusion biotite is illustrated in Table 1.

Just on the south of the Formation C and around the Kuwanokawabashi there are basic schists and siliceous schists, together with pelitic schists, forming folds of southward vergence in mesoscopic scale. These schists are the Formation D in Fig. 3. It has been pointed out by Hide et al.(1993) that the mesoscopic folds of the Formation D are placed in the core of the Shirataki recumbent fold II as shown in Figs. 5 and 6. Biotite has not been found in the Formation D. As mentioned above, hematite -bearing basic schist of the Formation D (locality 3 in Fig. 3) shows such the growth history of amphiboles and retrograde phase plagioclase porphyroblasts that are in general developed in the Fuyunose nappe of the W domain (Hara et al., 1992).

Just on the south of the Formation D there are pelitic schists accompanying siliceous schists and basic schists in small amount (Fig. 3). These schists (Formation E) have very coarse-grained plagioclase porphyroblasts. Hematite-free basic schist of the Formation D has ferro-hornblende with Si content of 6.75, which forms the bedding schistosity, and its plagioclase porphyroblasts are of the prograde phase (Hara et al., 1995). From the fold shape of the Formation D which is placed in the core of the Shirataki fold II, the Formation E should be continuous with the Formation C which contains biotite-bearing schists, forming the southern limb and the northern limb of the fold respectively (Figs. 5 and 6).

Just on the south of the Formation E there is the Formation F consisting mainly of pelitic schists and psammitic schists (Fig. 3). The schists of the Formation F are fine-grained and have essentialy the same microscopic property as these of the Formation B. The Formation F should be continuous with the Formation B, forming the southern limb and the northern limb of the Shirataki fold II respectively (Figs. 5 and 6).

Hide et al.(1993) clarified from analysis of geological structure that the Formation G, which consists mainly of basic schists and siliceous schists with pelitic schists of small amount and is placed just on the south of the Formation F (Fig. 3), is continuous with the Formation A, forming the Shirataki fold II as shown in Figs. 5 and 6. All schists of the Formation G have very coarse-grained plagioclase porphyroblasts. In plagioclase porphyroblasts of a hematite-bearing siliceous schist of the Formation G (locality 4 in Fig. 3) have been found very fine-grained biotite flakes (Table 1) together with barroisite, katophorite ($Si=6.51$) and taramite ($Si=6.33$) (Fig. 4-d) and in the bedding schistosity-forming amphiboles of their matrix has also been found magnesio-hornblende. Hematite-free basic schist of the Formation G also contains magnesio-hornblende ($Si=6.77$) (Hara et al., 1995). Plagioclase porphyroblasts of the Formation G are of the prograde phase. It is clear that the Formation G is an equvalent to the Formation A, both containing biotite-bearing schists.

Fig. 5 illustrates the distribution of the Formations A to G on the western slope of Mt. Shiraga, which has been clarified by Hara et al.(1995). The schists, which overlie the Formation A, consist mainly of the garnet zone (Formation H) accompanying lenses of biotite-bearing schists (Formation I), which have been described

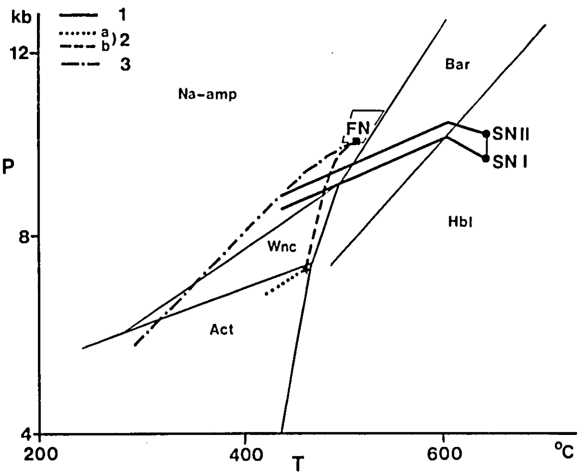

Fig. 7. P-T paths of the Saruta nappe II (SN II), Saruta nappe I (SN I) and Fuyunose nappe during the prograde phase. 1: data for the Saruta nappes, 2-a and 2-b: data for the first stage and that for the second stage of the subunit II of the Fuyunose nappe of the Tajikawa district respectively, 3: data for the subunit I of the Fuyunose nappe.

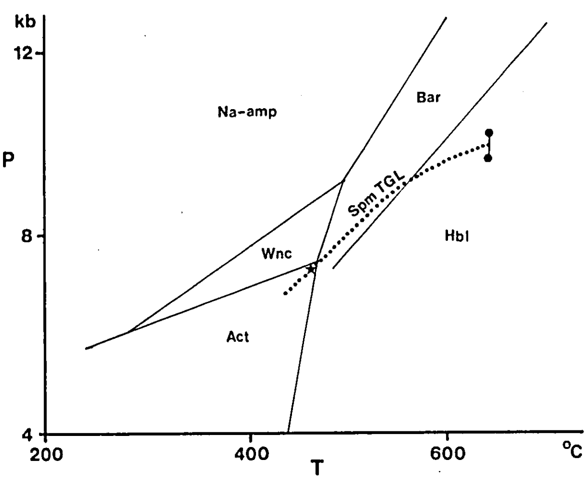

Fig. 8. P-T condition (SpmTGL) of the basal part of the hanging wall of subduction as inferred from data for the peak metamorphism of the Saruta nappe (I+II) schists and that of the first stage of the subunit II schists of the Fuyunose nappe of the Tajikawa district.

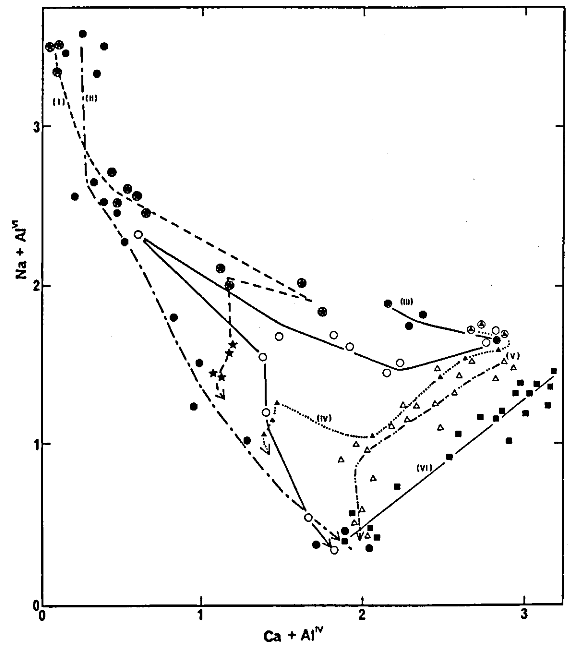

Fig. 9. Six types of retrograde phase chemical zoning of amphiboles in hematite-bearing basic schists [data from Hara et al.(1988,1990a)]. Arrows indicates the retrograde direction of chemical zoning. 1: data from the Fuyunose nappe of the Shirataki district, II : data from the Fuyunose nappe of the Tomisato district, III : data from the Saruta nappe II of the Tomisato district, IV : data from the Saruta nappe II of the Sazare district, V : data from the Saruta nappe I of the Shirataki district, VI : data from the Saruta nappe II of the Asemi district, circled stars, circled dots and circled solid triangles: data for amphibole grains included in plagioclase porphyroblasts.

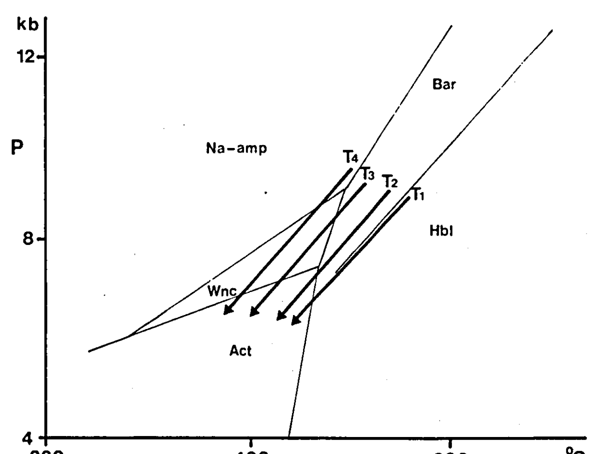

Fig. 10. Four types (Type 1, Type 2, Type 3 and Type 4) of retrograde growth path of amphiboles in hematite-bearing basic schists, which are developed through the Saruta nappe II , Saruta nappe I , Fuyunose nappe and Sogauchi nappe.

by Shiota (1991). The Formation H and Formation I are not developed along the River Asemi and cut across by the Saruta nappe I in the northern side and the subunit I in the southern side (Fig. 5). The Formation A = Formation G, Formation C = Formation E and Formation I belong to the subunit II of the Fuyunose nappe and the Formation B = Formation F, Formation D and Formation H belong to the subunit I .

IV. Discussion

Petrological implication of the nature of biotite-bearing schists as the subunit II and tectonic implication of the mixing of the subunit I and the subunit II in the Fuyunose nappe appear to be understood from the analysis of petrological characteristics of the Saruta nappe (I + II) schists and Fuyunose nappe schists and

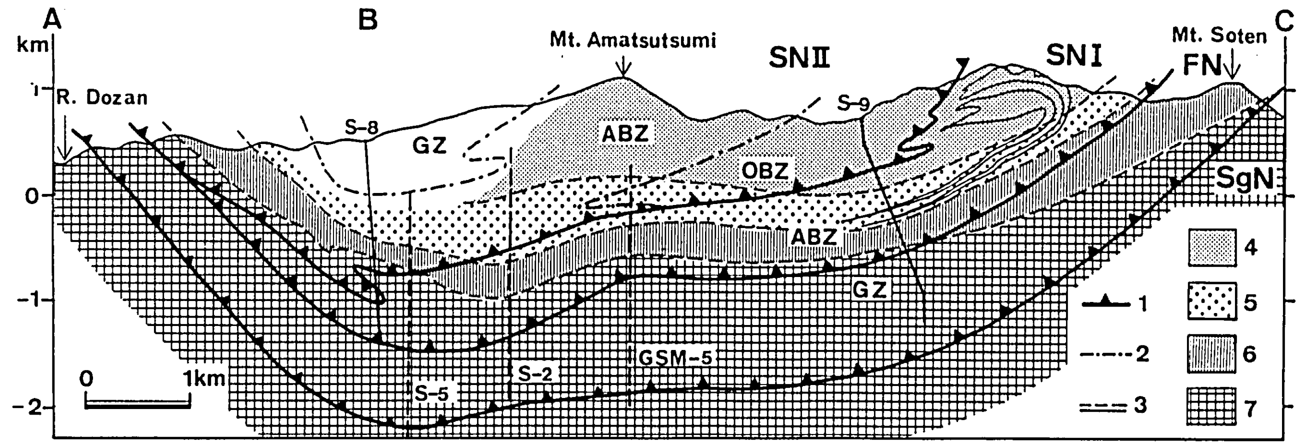

Fig. 11. Distribution of four types (Fig. 10) of retrograde growth path of amphiboles in hematite-bearing basic schists on the profile along the X-Y-Z line in Fig. 1 [data from Hara et al.(1988,1990a)]. 1: nappe boundary, 2: mineral zone boundary, 3: boreholes, 4: Type 1, 5: Type 2, 6: Type 3, 7: Type 4, GZ: garnet zone, ABZ: albite-biotite zone, OBZ: oligoclase-biotite zone, SN II : Saruta nappe II , SNI: Saruta nappe I , FN: Fuyunose nappe, SgN: Sogauchi nappe.

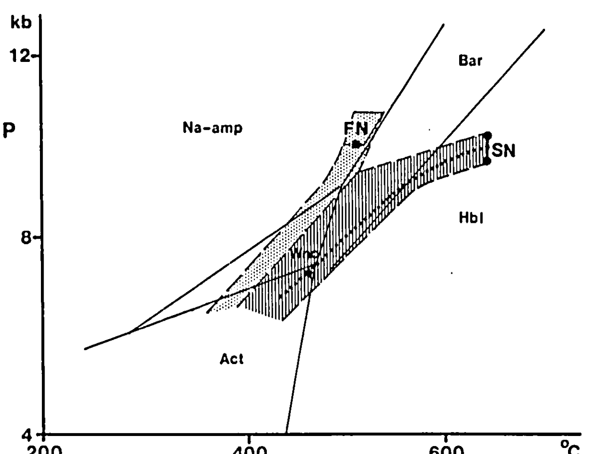

Fig. 12. Retrograde phase P-T path of the Saruta nappes (SN) and that of the Fuyunose nappe (FN) in the Shirataki-Asemi district. dotted line: Spm phase TG line.

of tectonic relationship between the Saruta nappes and the Fuyunose nappe. Hara et al. (1990b,1992,1995) clarified that the prograde growth path of amphibole of the Saruta nappe I and that of the Saruta nappe II are crossite-(winchite-barroisite)-barroisite-hornblende and crossite-barroisite-hornblende, respectively, showing nearly isobaric temperature increase (Fig. 7) and further showed that the nearly isobaric temperature increase of the progrdae metamorphism of the Saruta nappes is ascribed to the thrusting of the hanging wall (Kurosegawa-Koryoke continent and pre-existing accretionary complexes) in the subduction zone which was induced by the collision of the Kurosegawa-Koryoke continent with the Hida continent: The highest-temperature metamorphism for the Saruta nappe (I + II) schists, which occurred under the intermediate high-pressure type condition (Fig. 7), was a contact metamorphism by the Kurosegawa-Koryoke continent which thrust up from the depth of ca. 17kb to that of ca. 10kb.

The subunit II schist of the Fuyunose nappe has been first described by Hara et al. (1990b,1992) from the Tajikawa district. It is a hematite-bearing schist in which amphiboles in plagioclase porphyroblasts are actinolite, actinolitic hornblende and winchite whose composition is quite near to that of barroisite, and these in their outer mantles and matrix are crossite-glaucophane as the prograde phase amphiobles. The schist occurs as lense in the subunit I schists. The P-T path as assumed from such amphibole data of the subunit II schist is reproduced in Fig. 7, showing that it has two stages, the first prograde stage from acinolite to actinolitic hornblende and the second prograde stage from winchite to glaucophane. During the first prograde stage crystallized plagioclase porphyroblast cores (Hara et al., 1990b,1992). Crossite-glaucophane as the second stage amphiboles form the bedding schistosity and lineation, which appear to be oriented parallel to those of the surrouning subunit I schists. This fact suggests that the bedding schistosity-forming crossite-glaucophane of the subunit II schist are of the same generation as those of the subunit I .

Hara et al.(1992) clarified that the P-T path of the prograde phase for the subunit I is actinolite-winchite -crossite-glaucophane as schematically shown in Fig. 7. This P-T path is quite different from that of the second stage for the subunit II , which is nearly isothermal (Fig. 7). The metamorphism of the first prograde stage for the subunit II schist, which the subunit I schists had not experienced, appears to have occurred under the condition for the high-pressure intermediate type facies series, like the case of the Saruta nappe schists (Fig. 7). As mentioned above, plagioclase porphyroblasts in the subunit II schists are of the prograde phase, like the case of the Saruta nappe schists. Thus it has been assumed by Hara et al. (1990b,1992) that the subunit II schist of the Tajikawa district was tectonically eroded from the low-pressure part of the Saruta nappe schists,

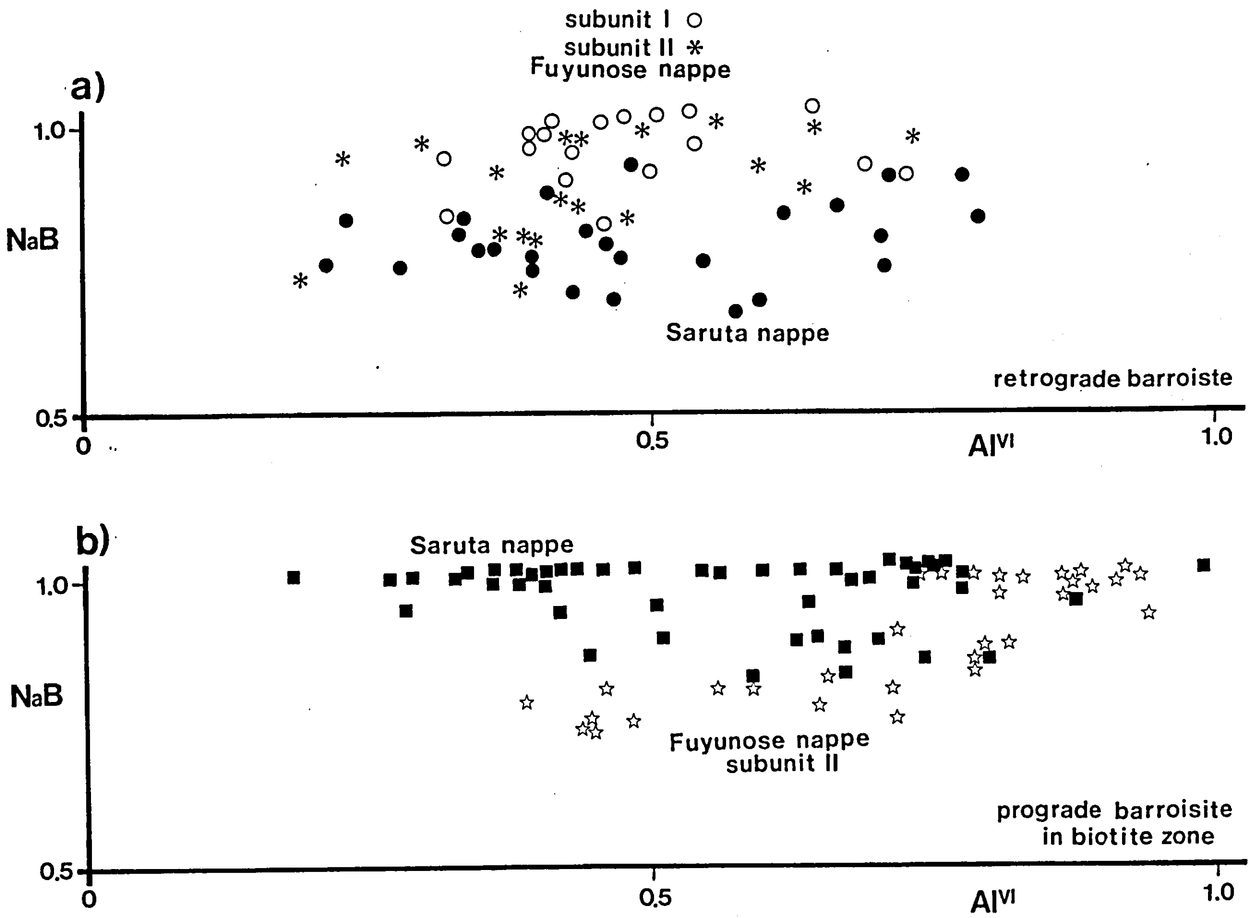

Fig. 13. Chmical composition of barroisite in hematite-bearing basic schists of the Saruta nappe I and Fuyunose nappe of the Ikadatsu-Shirataki-Asemi district. Prograde barroisite of the Saruta nappe I is found as inclusions in garnet, and that of the subunit II of the Fuyunose nappe as those in plagioclase porphyroblasts. For fuller explanation see the Text.

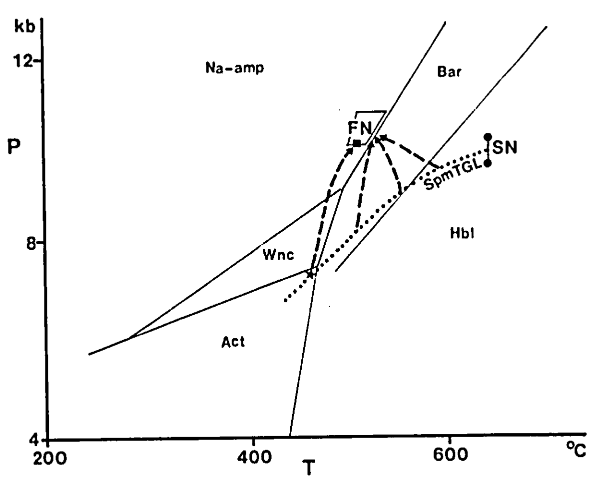

Fig. 14. P-T condition (dotted lines = SpmTGL) for the peak metamorphism of the first stage and P-T path for the metamorphism of the second stage (dashed lines) of the subunit II schists of the Fuyunose nappe. FN: P-T condition for the peak metamorphism of the subunit I schists and that of the second stage of the subunit II schists of the Fuyunose nappe, SN: P-T condition for the peak metamorphism of the Saruta nappe (I + II) schists. For fuller explanation see the Text.

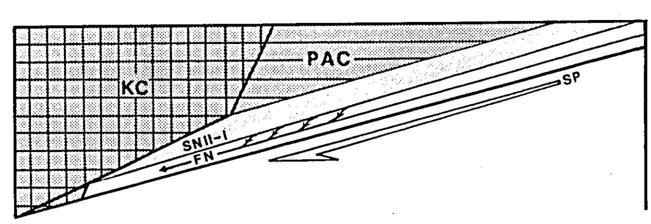

Fig. 15. Tectonics related to the formation of the subunit I and subunit II of the Fuyunose nappe, showing that the latter is ascribed to tectonic erosion and subduction (arrows) of the hanging wall rocks [Saruta nappe (I + II) schists (SN II- I)] of the subduction zone during the subduction (dashed line) of original sediments for of the former. KC: Kurosegawa-Koryoke continent (cf. Hara et al.,1992), PAC: accretionary complexes developed in the southern front of the KC continent, which which were developed along the hanging wall of subduction zone, and subducted together with the subunit I schists of the Fuyunose nappe as a newly subducted sediments, and therefore that the P-T condition along the plate boundary of the subduction zone during the beginning stage of the subduction of the original sediments for the subunit I schists is approximately shown by a tie line (Spm TG line) between the P-T

condition of the peak metamorphism of the Saruta nappe (I + II) schists and that of the peak metamorphism of the first stage for the subunit II schists of the Tajikawa district (Fig. 8). This assumption suggests such a possibility that the subunit II schists of the Asemi district were derived from the various parts of the Saruta nappe schists of the hanging wall of subduction zone, whose tectonic positions are mainly placed within the barroisite field on the Spm TG line of Fig. 8. This possibility will be examined in the next paragraphs.

The retrograde phase growth paths of amphiboles in hematite-bearing basic schists of the Saruta nappes, Fuyunose nappe and Sogauchi nappe have been clarified by Hara et al. (1988,1990a,b,1992), showing that these are divided into such types as shown in Fig. 9, and their parts, which are common to all of the nappes, are illustrated by four types, Type 1, Type 2, Type 3 and Type 4, in Fig. 10 and, that the four types of Fig. 10 are developed through the nappes as shwon in Fig. 11. Such the data indicate that the P-T path of the retrograde phase for the Saruta nappes and that for the Fuyunose nappe (subunit I and subunit II) in the Ikadatsu-Shirataki-Asemi district are illustrated by Fig. 12 (Hara et al., 1988, 1992, 1995). The P-T path of the retrograde phase for the Saruta nappes (Fig. 12) appears to be approximately running through the Spm TG line of Fig. 8. Therefore, if the above-mentioned assumption for the origin of the subunit II schists of the Fuyunose nappe of the Asemi district is available, then barroisite in plagioclase porphyroblasts of the subunit II schists should have essentialy the same property of chemical composition as that of the retrograde phase of the Saruta nappe I schists. While, from Figs. 7 and 10 (Fig. 12), barroisite of the retrograde phase in the Fuyunose nappe schists [subunit (I + II) schists] should have essentially the same property of chemical composition as that of the prograde phase in the Saruta nappe I schists. Fig. 13 illustrates the chemical composition of these barroisites, which is described by the relationship between NaB content and Al^{VI} content. The difference in crystallization condition between barroisite of the prograde phase and that of the retrograde phase is mainly noted in term of pressure (Figs. 7, 10 and 12). The NaB and Al^{VI} contents are commonly related to the glaucophanic substitution.

Fig. 13 indicates that barrosite in plagioclase porphyroblasts of the subunit II schists of the Fuyunose nappe of the Asemi district has essentially the same property of chemical composition as that of the retrograde phase in the Saruta nappe I schists and that of the retrograde phase in the Fuyunose nappe schists [subunit (I + II) schists] has essentially the same property of chemical composition as that of the prograde phase in the Saruta nappe I schists. Thus it can be said that the above-mentioned assumption for the origin of the subunit II schists of the Fuyunose nappe of the Asemi district is available, showing such tectonics as illustrated in Figs. 14 and 15. The tectonics for the origin of the subunit II schists illustrates that for the subduction of the original sediments for the subunit I schists, which is accompanied with the tectonic erosion and subduction of the hanging wall rocks (probably low-pressure part of the Saruta nappe schists) of the subduction zone and great decrease of temperature along the subduction channel.

Biotite in plagioclase porphyroblasts of the subunit II schists of the Fuyunose nappe occurs together with barroisite (data from the Asemi district) but not with actinolitic hornblende and winchite (data from the Tajikawa district). But, when barroisite of the retrograde phase crystallized, biotite had not crystallized in the Fuyunose nappe schists [subunit (I + II) schists]. From the above-described data it can also be said that the stability field of biotite is approximately illustrated by Hara et al's (1992) Fig. 32.

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