Jour. Sci. Hiroshima Univ., Ser. C, Vol. 9, No. 4, 715−720 (1993)

Nappe Boundary Migration during the Subcretion−Exhumation Processes of the Sambagawa Schists

By

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with 3 Text−figures

(Received, April 25, 1993)

Abstract: The Sambagawa schists consist of some successively subcreted units as nappes, Saruta unit as Saruta nappe II and Saruta nappe I, Fuyunose unit (Fuyunose nappe) and Sogauchu unit (ST subunit, KAT subunit and NOM subunit) etc. in descending order of structural level. The coupling of the Saruta nappe II and the Saruta nappe I occurred accompanying the underplating of the Fuyunose unit schists. When the underplating of the Sogauchi unit occurred accompanying the exhumation of the previously subcreted units, the latter was highly deformed, accompanying the formation of large−scale recumbent folds such as Shirataki II fold and Suryo fold and the nappe boundary migration from the Saruta I−II boundary and Saruta I − Fuyunose boundary to the Kuwanokawa thrust.

Contents

I. Introduction

The thermal structure of the Sambagawa schists in central Shikoku, which is shown by minerals produced during the highest temperature of metamorphism, can be described as having the highest grade schists in the middle part of their structural pile (e.g. Hide, 1961; Banno, 1964; Kurata & Banno, 1974). According to Kurata and Banno (1974), Higashino (1975) and Enami (1982, 1983), it is defined by the orientation pattern of a chrolite zone, garnet zone, albite−biotite zone and oligoclase−biotite zone, which correspond to the facies series of pelitic schist for the highest temperature of metamorphism, as shown in Fig. 1. This figure is essentially the same as that given by Higashino (1975) and Banno and Sakai (1989). Only on the basis of the now−observed distribution pattern of the mineral zones for the highest temperature phase of metamorphism (Fig. 1), they said that such the thermal structure was produced by the development of a recumbent fold with southward closure and the highest grade schists are placed in its fold core. However, Hara et al.(1990a) said that the distribution pattern of the mineral zones (Fig. 1) favours the assumption of a recumbent fold with northward closure, because the oligoclase−biotite zone shows a tendency to thin out toward the north. Hara et al.(1977, 1988, 1990a, 1992) and Furuyama et al.(1985) clarified that such a recumbent fold is not developed in the biotite zone, garnet zone and chlorite zone schists in question but their geological structure is explained in term of four nappes, Saruta nappe II, Saruta nappe I, Fuyunose nappe and Sogauchi nappe (ST subunit, KAT subunit, and NOM subunit) in descending order of structural level, as shown in Fig. 1, and that the Saruta nappe II consists of a garnet zone in the upper part, an albite−biotite zone in the middle part and an oligoclase−biotite zone in the lower part, the most part of the Saruta nappe I belongs to an albite−biotite zone, the Fuyunose nappe as a whole consists of a garnet zone and the Sogauchi nappe consists of a chlorite zone. Hara et al.(1988,1990a,b,1992) have assumed that the coupling of the Saruta nappe II with the Saruta nappe I occurred together with the new subcretion of the Fuyunose nappe schists during the Sb_1 phase and the structural pile consisting of the Saruta nappe II, Saruta nappe I and Fuyunose nappe was coupled with the newly subcreted Sogauchi nappe schists during the Sb_{2-1} phase when the exhumation of the former began. The deformation style of the exhuming structural pile during the Sb_{2-1} phase, with special reference to the formation of the Shirataki II fold (cf.Hide, 1954, 1961, 1965; Hara et al., 1990a,b), will be described and discussed in this paper.

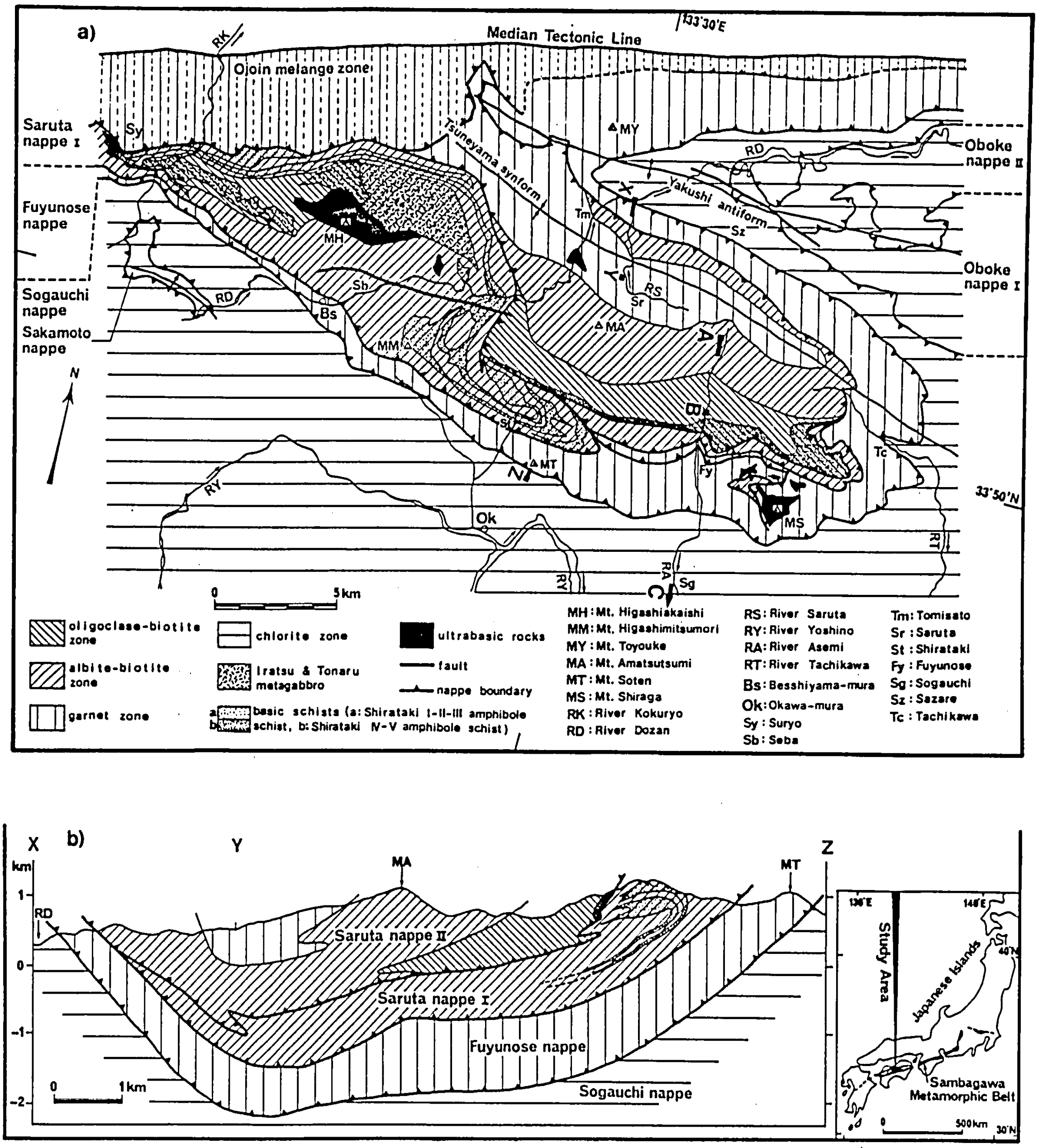


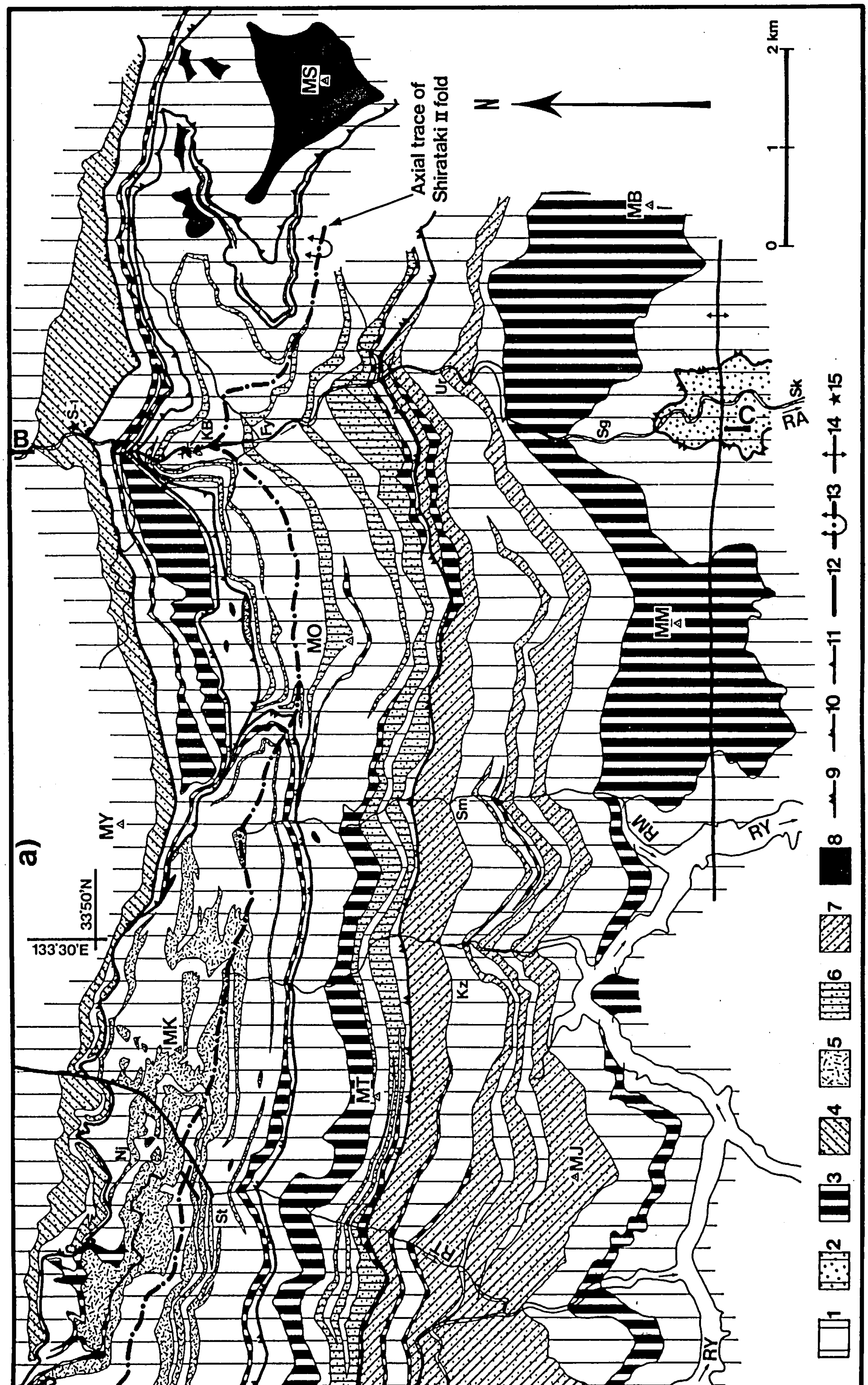
Fig. 1. Geological map (a) and profile (b: X−Y−Z line) of the Sambagawa belt in central Shikoku [partly modified from Hara et al.(1992)]. A−B−C line: geological profile line for Fig. 2−b.

Acknowledgements

The author's works have been partly supported by the Grant in Aid for Scientific Researchs of the Ministry of Education of Japan.

II. Analysis of the Shirataki II Fold

Fig. 2 illustrates the geological structure of the Sambagawa schists in the Shirataki−Asemi district, which contain the Saruta nappe II, Saruta nappe I, Fuyunose nappe and Sogauchi nappe. That is especially characterized by the folds of the Shirataki I−II−III amphibole schist in the Saruta nappe I. These comprise two large−scale recumbent folds produced by two phases deformations, Shirataki I fold and Shirataki II fold (Fig. 2) (Hide, 1965: Hara et al., 1990a, b). The former is for the Shirataki I amphibole schist and its fold axis appears to be parallel to mineral lineation (Lb_1) defined by preferred shape orientation of hornblende grains, which crystallized together with outer mantles of plagioclase porphyroblasts during the earliest phase (Sb_1 phase) of retrograde metamorphism, while its axial plane and Lb_1 are folded around the axis of the latter fold, showing that Lb_1 on the lower limb is in



a)
133°30'E
33°50'N
MY
MK
MT
MO
MS
MB
MM
MJ
Kz
Sm
St
Sg
Sk
RA
RY
RM
B
Axial trace of Shirataki II fold
N
0
1
2 km
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

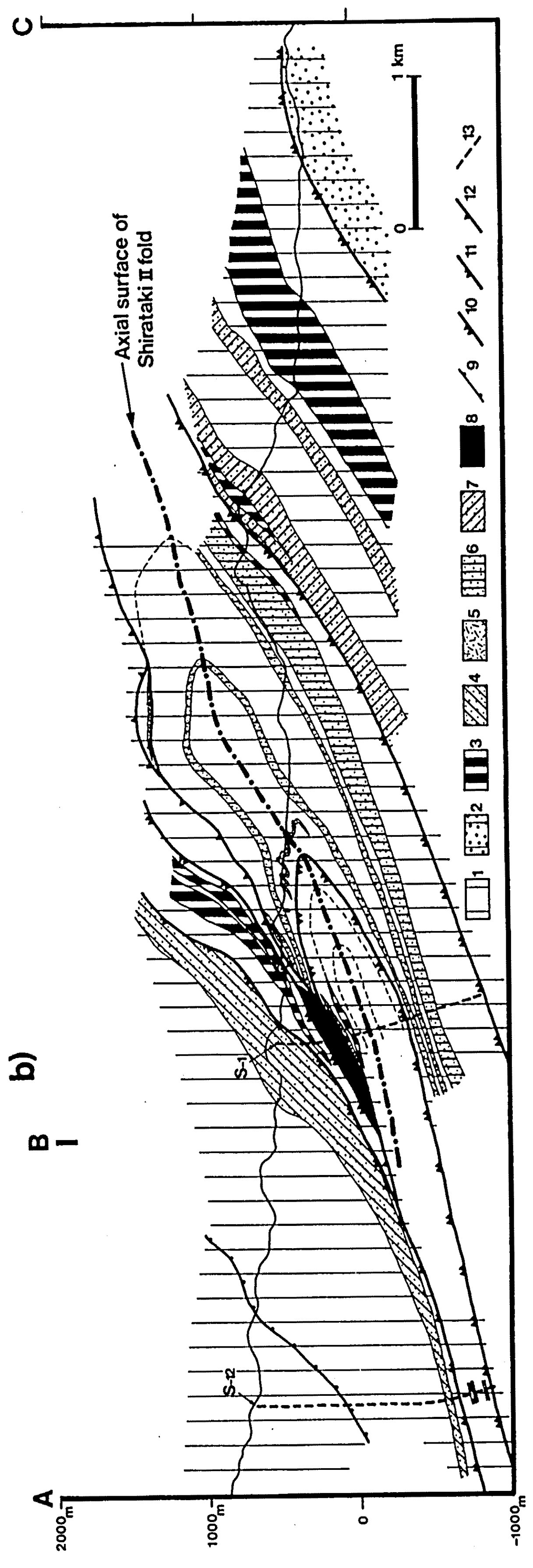


Fig. 2. Geological map (a) and profile (b) of the Shirataki–Asemi district [compiled from the data after Hide (1954, 1961, 1965), Iwata (1963), Kawachi (1968), MMEAJ (1968, 1971) Hara et al.(1990a, b, 1992), Shiota (1991) and the present authors]
a) 1: pelitic schist, 2: pelitic schist with psammitic schist, 3: siliceous schist, 4: Shirataki IV–V amphibole schist (Saruta nappe II), 5: Shirataki I–II–III amphibole schist and other basic schist with siliceous schist (Saruta nappe I), 6: basic schist (Fuyunose nappe), 7: basic schist (Sogauchi nappe), 8: ultrabasic rocks, 9: boundary between subcretion units, 10: Saruta nappe I–II boundary (Sb_1 phase), 11: Kuwanokawa thrust (Sb_{2-1} phase nappe boundary), 12: fault (post–Dh phase), 13: axial trace of the Shirataki II fold, 14: axial trace of Dh phase antiform, 15: borehole site of S–1, 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: Uryuno, Sg: Sogauchi, Sk: Sakamoto, B–C: profile line (see also Fig. 1).
b) 1~8: see figure captions for 1~8 of Fig. 2–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. 2–a, 13: borehole sites of S–1 and S–12

NNW–SSE trend and that on the upper limb is in EW trend. Thus it has been pointed out by Hara et al. (1990a,b) that the Shirataki I fold was produced during the Sb_1 phase and the Shirataki II fold postdated the Sb_1 deformation.

The retrograde growth histories of amphibole in hematite–bearing basic schist are recognized as four paths forming four path zones, hornblende–actinolite path zone (zone I), hornblende–barroisite–actinolite path zone (zone II), X–barroisite–winchite–actinolite path zone (zone III) and X–crossite–winchite–actinolite zone (zone IV), which are developed in descending order (Hara et al.,1988,1990a,b). The Shirataki II fold in the Shirataki district is cut across by the zone I and the zone II, showing that the folding occurred just before the separation of the retrograde growth history of amphibole into the above–mentioned four zones began (Hara et al.,1990a).

The oligoclase–biotite zone is placed in the basal part of the Saruta nappe II and is cut across by the Saruta I–II boundary between the Saruta nappe II and the Saruta nappe I (Hara et al.,1990a). The coupling of both nappes occurred during the Sb_1 phase. The pelitic schist involved in the core of the Shirataki I fold, which is also of the Sb_1 phase, belongs to the oligoclase–biotite zone (Furuyama, 1985, Fig. 3). Thus it would be said that the Shirataki I folding occurred involving the Saruta I–II boundary into the fold core and as a drag folding along this boundary during the coupling of the Saruta nappe II with the Saruta nappe I.

Fig. 2 illustrates the overall picture of the Shirataki II

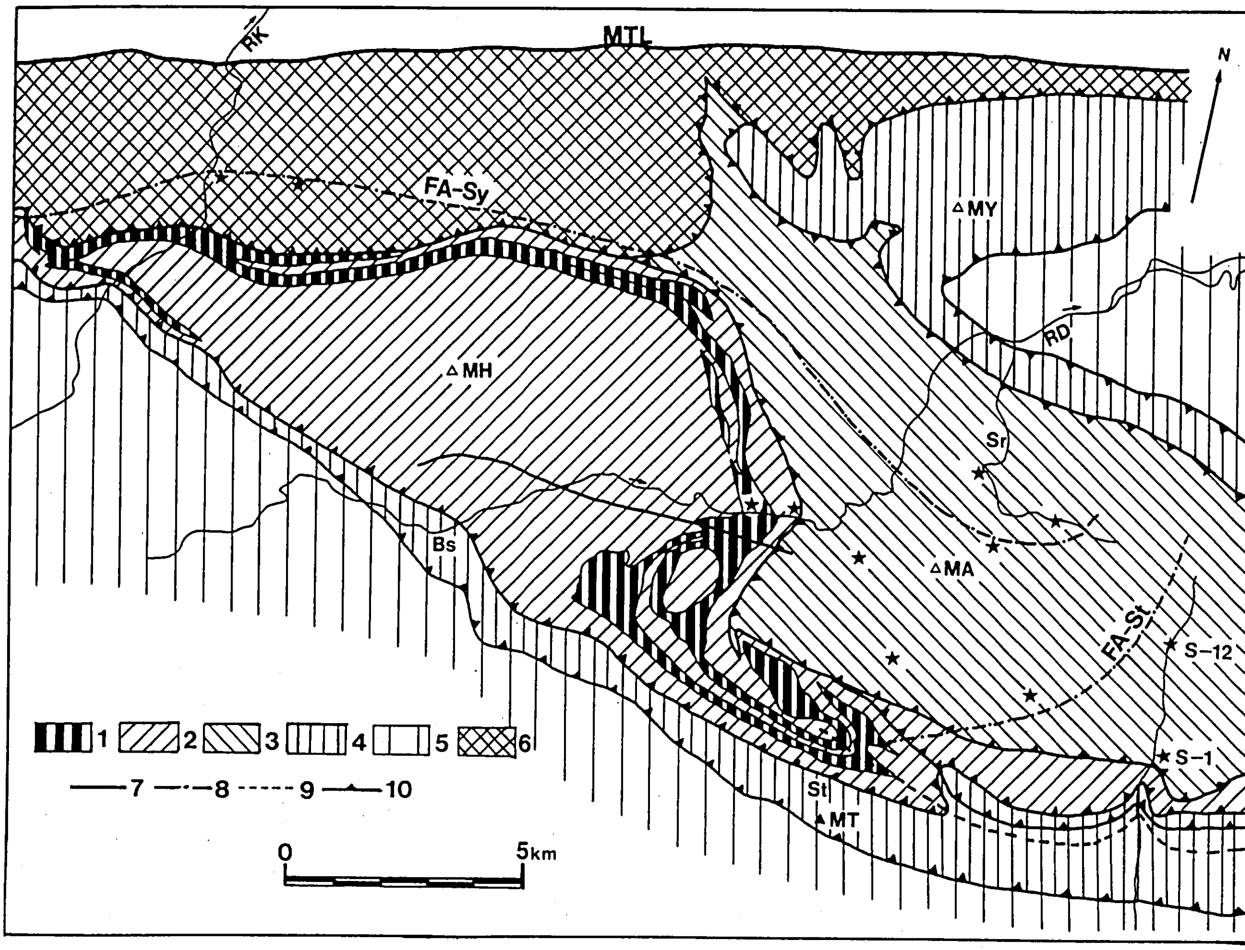


Fig. 3. Diagram showing the major structure of the Sambagawa megaunit in central Shikoku.
1: Shirataki I–II amphibole schist, 2: Saruta nappe I, 3: Saruta nappe II, 4: Fuyunose nappe, 5: Sogauchi nappe, 6: Inouchi–Ojoin melange zone, 7: fault (post–Dh phase), 8: fold axis [Suryo fold (FA–Sy) and Shirataki II fold (FA–St)], 9: axial trace of the Shirataki II fold, 10: nappe boundaries, solid stars: borehole sites (S–1, S–12 and others), RK: River Kokuryo, RD: River Dozan, Bs: Besshiyamamura, St: Shirataki, Sr: Saruta, MH: Mt. Higashiakaishi, MT:Mt. Soten, MA: Mt. Amatsutsumi, MY: Mt. Toyouke, MTL: Median Tectonic Line.

fold. This figure indicates that the Saruta I–Fuyunose boundary (boundary between the Saruta nappe I and the Fuyunose nappe) and the Fuyunose nappe schists, as well as the Saruta nappe I schists, are also involved in the Shirataki II fold. The mesoscopic parasitic folds of this fold are commonly found along the River Asemi and River Asatani, showing a fan–like arrangement of their axial planes converging toward its fold core. The Kuwanokawabashi fold developed along the River Asemi (Hara et al.,1992) is the parasitic folds on the upper limb and the mesoscopic folds with northward vergence in siliceous schist (Sotenyama siliceous schist) of the horizon 12 after Hide (1954,1961) found along the River Asatani correspond to these on the lower limb of the Shirataki II fold. Such a orientation pattern of minor folds had been also already described in the borehole data of S–I after MMEAJ (1968), defining the position of the axial plane of the Shirataki II fold on the schist pile. The data also indicated that there is a difference in trend of Lb_1 between the upper limb and the lower limb and Lb_1 on the lower limb is in NW–SE trend also in the S–I site. From the data of the S–12 borehole, MMEAJ (1971) pointed out that the axis of the Shirataki II fold for the Shirataki I–II–III amphibole schist is placed just on the west of this borehole site. The upper limb of the Shirataki II fold is cut across by a thrust fault (Kuwanokawa thrust) and any synform is not found just on the north of this fold (antiform) (Fig. 2). The large–scale lenses of the biotite–zone schists, which have been described by Shiota (1991), occur along the Kuwanokawa thrust. The retrograde growth history of amphibole in these lenses is comparable with that in their host Fuyunose nappe schists, showing that the emplacement of the lenses along the thrust occurred during the Sb_{2-1} phase. The geological profile of Fig.2 has been drawn on the basis of the above–described data.

Hara et al.(1992) clarified that the formation of the Kuwanokawabashi fold occurred during the Sb_{2-1} phase just before crystallization of plagioclase porphyroblasts in the Fuyunose nappe schists. The Sb_{2-1} phase is the phase for the coupling of the Fuyunose nappe with the

Sogauchi nappe schists (Hara et al.,1988, 1990a, b, 1992). Thus it would be said that the Shirataki II folding occurred as a drag folding along the Kuwanokawa thrust during the Sb_{2-1} phase, showing that, when the Sogauchi nappe schists were coupled with the Fuyunose nappe, the deformation of the previously subcreted schists [Saruta nappe (I+II) schists and Fuyunose nappe schists] occurred forming the Kuwanokawa thrust and Shirataki II fold. The Sb_{2-1} phase deformation in the Besshi−Suryo district on the west of the Shirataki−Asemi district formed the Suryo recumbent fold in the basal part of the Saruta nappe I (Fig. 3) (Hara et al., 1990a, 1992). It would be said that nappe boundary migration occurred in the previously subcreted structural pile during the subcretion−exhumation processes of the Sambagawa schists.

References

Banno,S.,1964: Petrologic studies on Sanbagawa crystalline schists in the Besshi−Ino district, central Shikoku, Japan. Jour. Fac. Sci. Univ. Tokyo, Sec.II, 15, 203−319.

Banno,S. and Sakai,C.,1989: Geology and metamorphic evolution of the Sanbagawa belt. In Daly,J.S., Cliff,R.A. and Yardley,B.W.D. eds, Evolution of Metamorphic Belts. Geol. Soc. Spec. Pub. 43, 519−532.

Enami,M.,1982: Oligoclase−biotite zone of the Sanbagawa metamorphic terrain in the Besshi district, central Shikoku, Japan. Jour. Geol. Soc. Japan. 88, 887−990.

Enami,M.,1983: Petrology of pelitic schists in the oligoclase−biotite zone of the Sanbagawa metamorphic terrain, Japan: Phase equilibria in the highest grade zone of a high−pressure intermediate type of metamorphic belt. Jour. Metamorphic Geol. 1, 141−161.

Furuyama,K., Hara,I. and Hide,K.,1985: Geological structure of the Sambagawa belt in the Besshibashi district, Central Shikoku. Mem. Vol. Prof. H. Yoshida. Hiroshima Univ., 386−390.

Hara,I., Hide,K., Takeda,K., Tsukuda,E., Tokuda,M. and Shiota,T.,1977: Tectonic movement in the Sambagawa belt. In Hide K. ed, The Sambagawa Belt. Hiroshima Univ. Press, Hiroshima, 309−390.

Hara,I., Shiota,T., Takeda,K. and Hide,K.,1988: Tectonics of the Sambagawa Terrane. The Earth, Monthly, 10, 372−378.

Hara, I. , Shiota, T. , Takeda, K. , Okamoto, K. and Hide, K. ,1990a: The Sambagawa Terrane. In Ichikawa et al. eds, Pre−Cretaceous Terranes of Japan. Publication of IGCP, 224, 137−163.

Hara,I., Shiota,T., Hide, K., Okamoto,K. and Takeda, K., 1990b: Nappe structure of the Sambagawa belt. Jour. Metamorphic Geol. 8, 441−456.

Hara,I., Shiota,T., Hide,K., Kanai,K., Goto,M., Seki,S., Kaikiri, K., Takeda, K., Hayasaka, Y., Miyamoto,T., Sakurai,Y. and Ohotomo,Y.,1992: Tectonic evolution of the Sambagawa schists and its implications in convergent margin processes. Jour. Sci. Hiroshima Univ. Ser. C, 9, 495−595.

Hide,K.,1954: Geological structure of the Shirataki mining district, Kochi Prefecture. Geol. Rept. Hiroshima Univ. 4, 47−83.

Hide,K.,1961: Geologic structure and metamorphism of the Sambagawa crystalline schists of the Besshi−Shirataki mining district in Shikoku, Southwest Japan. Geol. Rept. Hiroshima Univ. 9, 1−87.

Hide,K.,1965: Geological structure of the Shirataki mining district. Jour. Assoc. Jap. Struc. Petrol., 7, 23−24.

Higashino,T.,1975: Biotite zone of Sanbagawa metamorphic terrain in the Shiragayama area, central Shikoku, Japan. Jour. Geol. Soc. Japan. 81, 653−670.

Iwata,T.,1963: Geology and petrology of the eastern slope of Mt. Ogoya, Kochi Prefecture. Grad. Th. (MS) Hiroshima Univ.

Kawachi,Y.,1968: Large−scale overturned structure in the Sambagawa metamorphic zone in central Shikoku, Japan. Jour. Geol. Soc. Japan. 74, 607−616.

Kurata,H. and Banno,S.,1974: Low−grade progressive metamorphism of pelitic schists of the Sazare area, Sanbagawa metamorphic terrain in central Shikoku. Jour. Petrol. 15, 361−382.

MMEAJ,1968: Detailed geological survey Report 1966, Mt. Shiraga district. 1−428.

MMEAJ,1971: Detailed geological survey Report 1969, Mt. Shiraga district. 1−102.

Shiota,T.,1991: Nappe structure of the Sambagawa belt in the Mt. Shiraga district, central Shikoku. Natural Sci. Research, Tokushima Univ., 4, 29−44.

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