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# Prelithification shear structures of mélange unit in Shiofuki-iwa area, the upper Cretaceous Shimanto Belt, Wakayama Prefecture, Japan

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**Abstract**

Analyzing of sedimentary facies and structure together with regional field mapping were studied in the mélange unit, upper Cretaceous Shimanto Belt, Wakayama Pref., SW Japan. The field survey was concentrated in the coast of Shiofuki-iwa, Miyama Complex, Hidakagawa Belt where soft deformations penetrate throughout the mélange unit. Brittle to ductile faults associated as later deformations are excluded. The mélange unit is subdivided into the Y-shear zone (YSZ) and P-foliation zone (PFZ). The YSZ is composed of thick lenticular sandstone (trends subparallel to the direction of the mélange), intense shear band (thin layer with concentrated prelithification shear deformation) and mudstone dominant mélange. The PFZ is composed of mudstone dominant mélange (associated with foliations which slightly oblique to the direction of the YSZ) and lenticular sandstone (slightly oblique to the direction of the YSZ). The intense shear band separates the YSZ and PFZ. Preserved radiolarian fossils free from deformation in the intense shear band is the evidence of the prelithification shear deformation in the mélange. A remarkable-fact is that the structures of mélange unit are formed under sinistral sense of shear. The mélange unit in the Shiofuki-iwa is ascribed to be formed by sinistral sense of shear during sediments were prelithified.

**Keywords:** mélange, Shimanto Belt, Y-shear zone, P-foliation zone, intense shear band, prelithification structures

## Introduction

The Shimanto Belt is distributed along the Pacific side of southwest Japan. A thick sequence comprises of deformed complicated succession, however, rather monotonous in lithology which is dominated by unfossiliferous flysch had been regarded as “Mysterious Formations” because of little controlled age and uniquely deformed structural style (Taira *et al*., 1988). Fossils occurred as molluscs and calcareous planktonic microfossils which had been considerably limited. Scattered recovery of molluscan fossils including Ammonoidae and *Inoceramus* had been only biostratigraphic age indicators until early 1970s. This situation changed dramatically in 1980s depend on the new method using radiolarian biostratigraphy.

Now the Shimanto Belt became one of the most extensively studied and dated sequences in Japan (Taira *et al*., 1988, Suzuki and Hada, 1979; Kumon, 1983). It is widely accepted that the early deformation of accretionary processes of oceanic plate subduction in the circum pacific region is preserved (Fig.1-a). Plate-tectonics model has been adapted to interpret geology of the Shimanto Belt. Mélange in the Shimanto Belt is considered to be formed under subduction (e.g., Taira *et al*.,1992). Structures of tectonic mélange regarded to a “block-in-matrix” texture as Franciscan Complex (Cowan, 1985; Hsü, 1968), mélange unit in Shimanto Belt which is characterized by “successive lenses” and the surrounding argillaceous matrix were described. Recently studies depend on the basis of subducted plate-tectonics of two-dimension models of the Shimanto Belt (e.g., offscraping and underthrust, underplating) were proposed by using seismic reflection profiles at present-day convergent margins (McCarthy and Scholl, 1985; Lundberg and Moore, 1986; Sample and Fisher, 1986; Sample and Moore, 1987). In this connection with the models mentioned before, mélange also is suggested to be formed in tectonics of subducted plate (Moore and Byrne, 1987; Fisher and Byrne, 1987; Kimura *et al*.,2012). Tectonic mélange structures described in previous studies are brittle to ductile deformations which were formed under lithified condition. (Moore *et al*., 1986; Raymond, 1984). These structures could be later and deeper facies of deformation of the subduction process. Accretion model suggests that soft sediments on the oceanic crust are accreted at the subduction zone. However, the earliest structural of mélange unit is poorly known. Therefore, we described deformation structures, earliest synsedimentary deformations of mélange. Study area is Shiohuki-iwa, Mihama Town, Wakayama prefecture where is belong to the Miyama Accretionary Complex, the upper Cretaceous Hidakagawa Belt (Fig.1-c). A regional field mapping, sedimentary facies and structural analyses has been studied. Using these methods structural styles and characteristics of sheared argillaceous rocks and sandstone were delineated.

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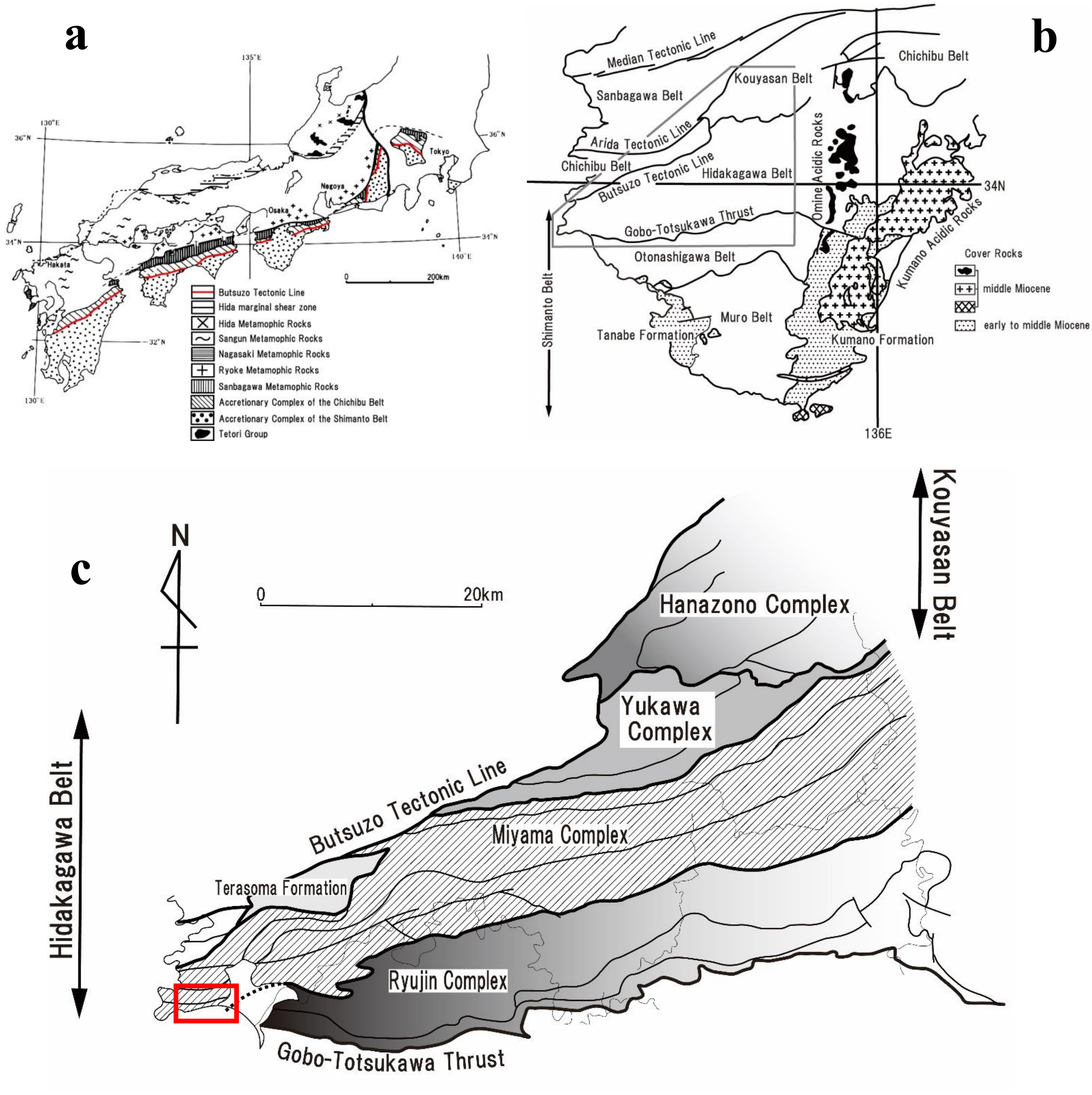



Fig.1 a) Distribution of Shimanto belt in south west Japan. b, c) Location of study area (modified Kishu Shimanto Research Group, 2012).

In this paper, we present mélange from regional scale to microscopic scale that argue for the layer-parallel-shearing during sediments were prelithified.

**The Cretaceous Shimanto Belt**

The Shimanto Belt is separated from the Jurassic accretionary terrane of the Chichibu Belt to the north by a major fault, Butsuzo Tectonic Line (Taira, 1985) (Fig.1-a). It shows an overall younging distribution to the south. In Wakayama Prefecture, the Shimanto Belt is subdivided into three subbelt, the Cretaceous accretionary complex (Kouyasan Belt and Hidakagawa Belt) to the north, the Eocene accretionary complex (Otonashigawa Belt) and the Oligocene to the lower Miocene accretionary complex (Muro Belt) from the north to the south (Fig.1-b).

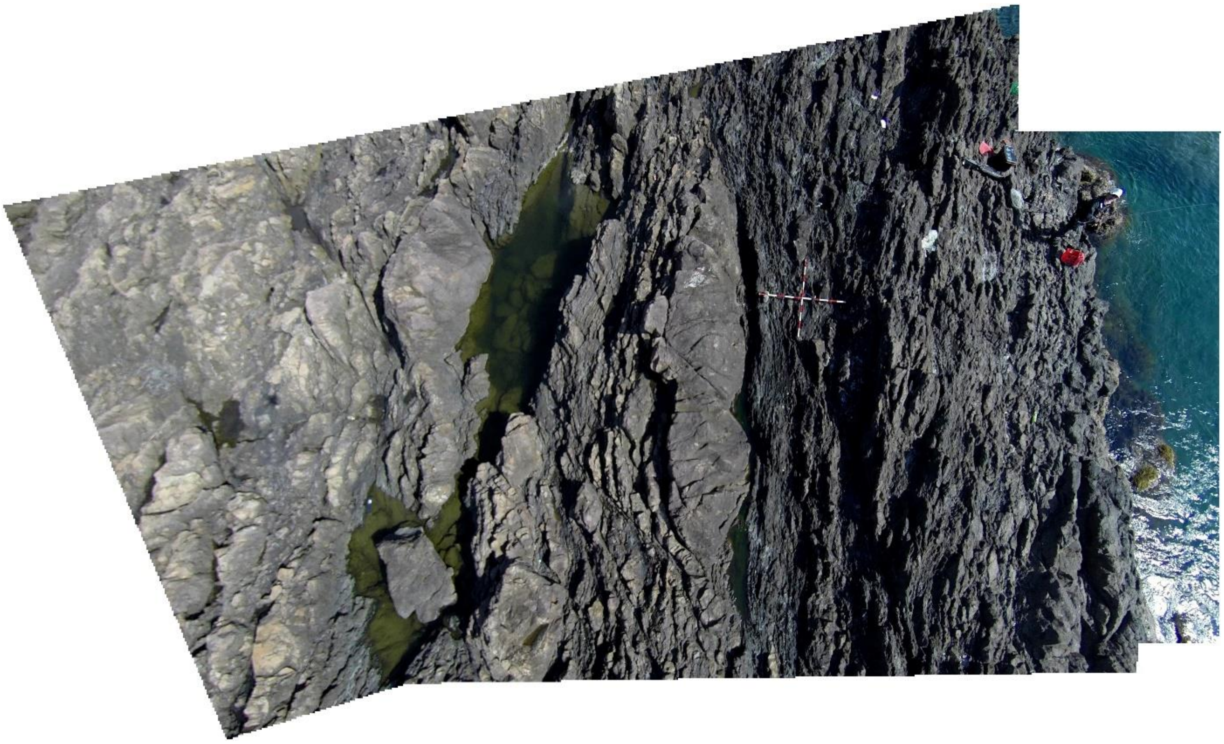


Fig.2 Drone photo showing the geologic sketch mapped outcrop of Figure.4-c (crossed scale bar is 2m long)

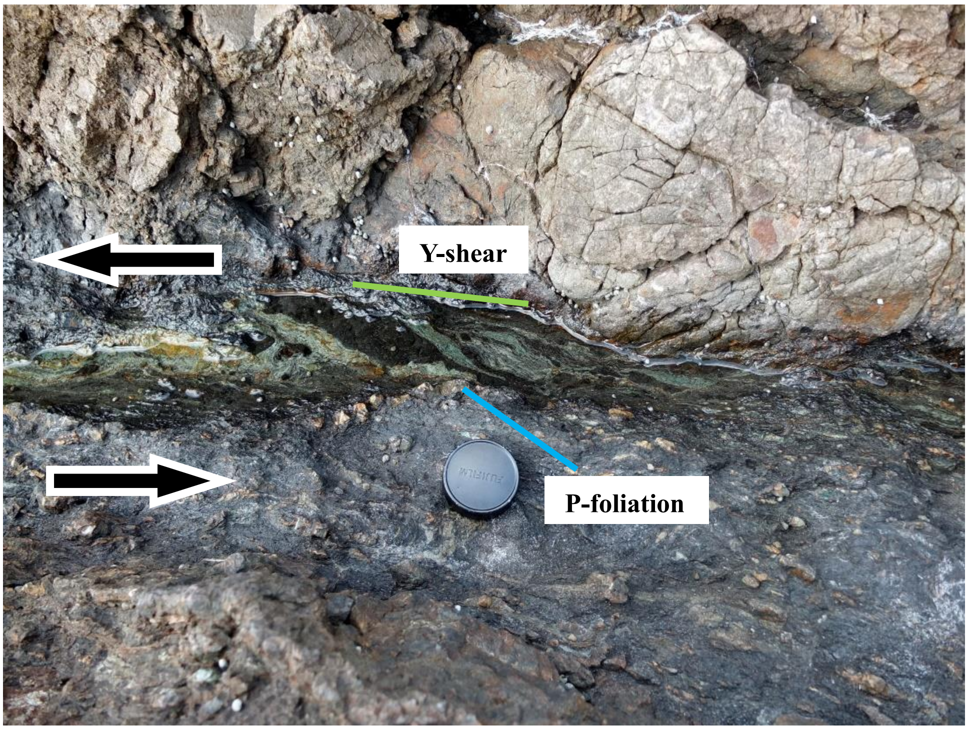
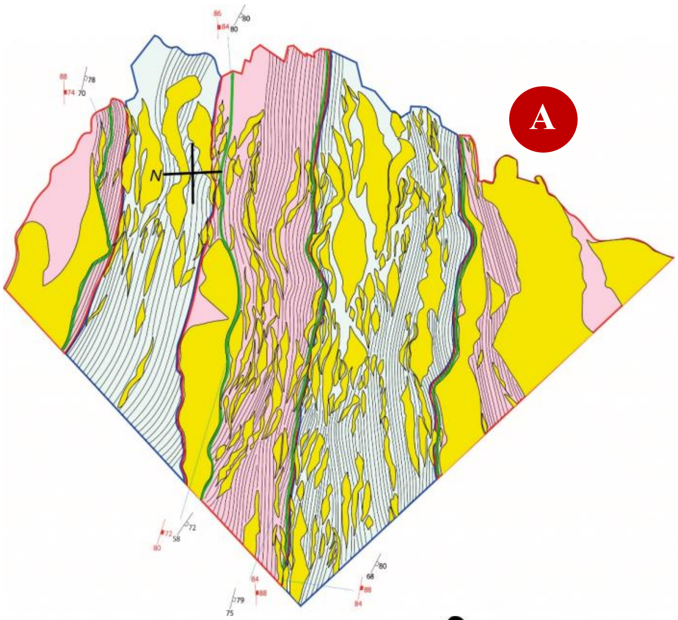
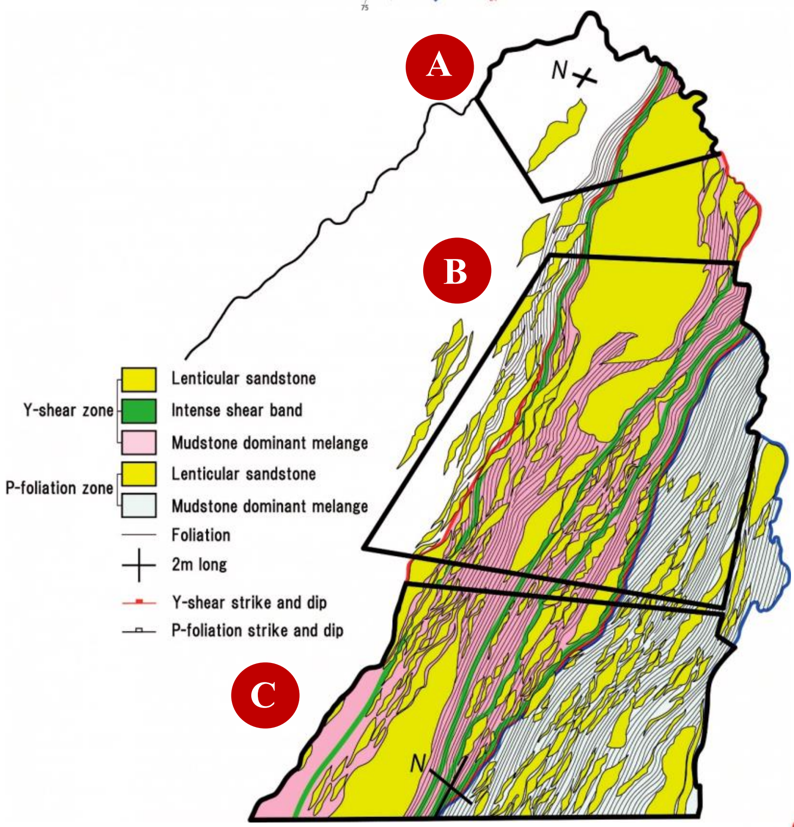



Fig.3 Composite planar fabric in the intense shear band. Green taffaceous mudstone indicate sinistral sense of shear.







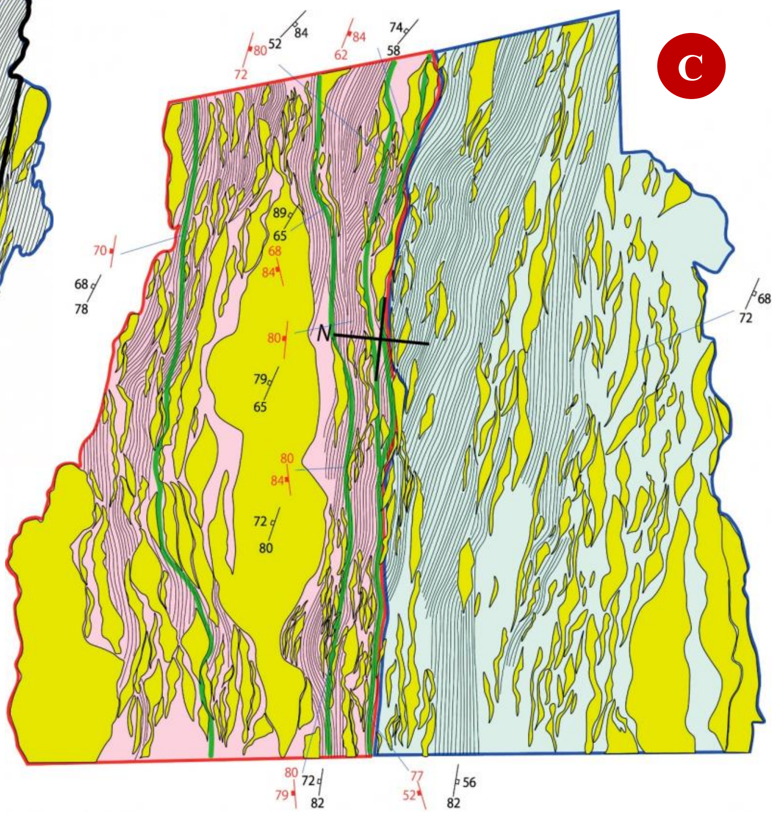




Fig.4 Geologic sketch maps of mélange unit. Intense shear band extending along thick lenticular sandstone.

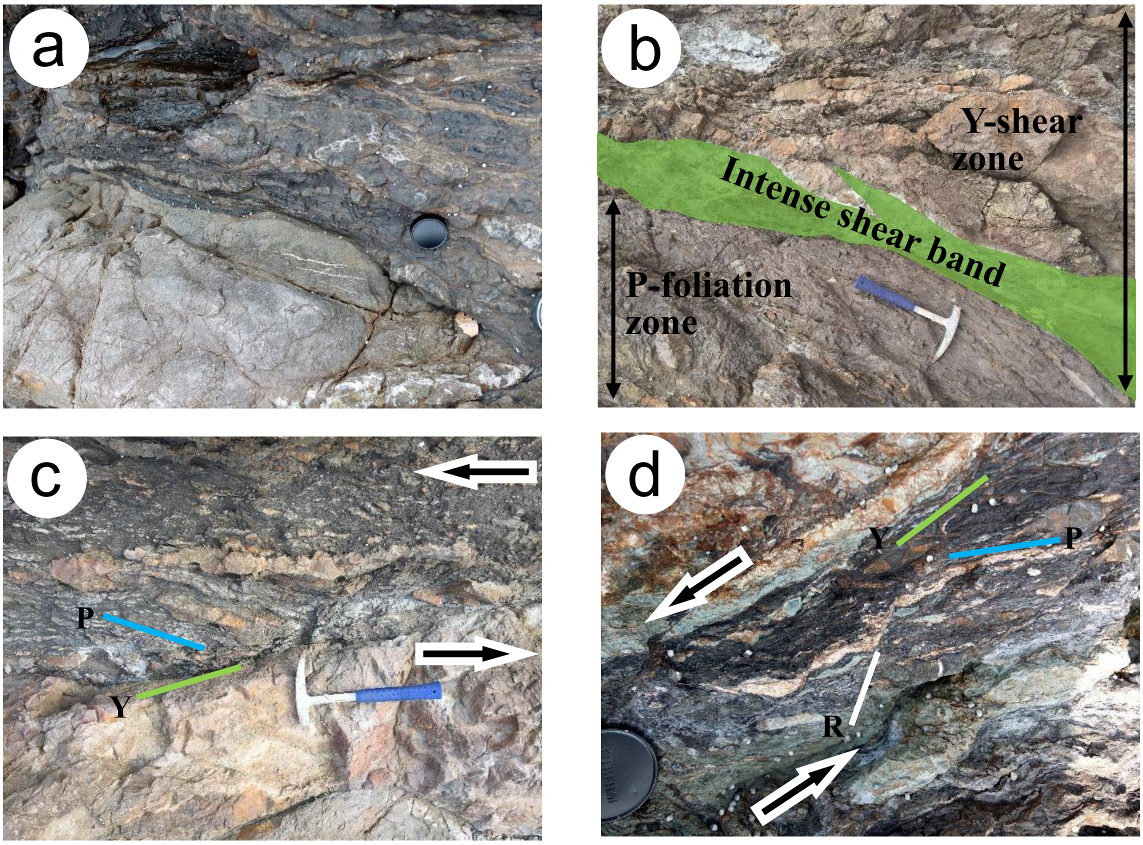



Fig.5 a) Argillaceous matrix with thin sandstone layer in the intense shear band wraps smoothly around sandstone lenses. b) Intense shear band divides the YSZ and PFZ. c) The intense shear band is concentrated narrow zone associated with composite planar fabric. d) Composite planar fabric of Y-shear, P-foliation and Riedel shear.

The Hidakagawa Belt is composed of the Yukawa Complex, Miyama Complex, Ryujin Complex from the north to the south (Kishu Shimanto Research Group, 59, 2012) (Fig.1-c). The Miyama Complex indicates that the successions of Turonian to early Campanian by radiolarian biostratigraphy (Kishu Shimanto Research Group, 59, 2012). These data suggest depositional age but the age of accretion has not been known.

**Outline of mélange unit of the Miyama Complex**

The upper Cretaceous mélange unit is mainly composed of the Miyama Complex. The mélange unit is composed of a sheared argillaceous "matrix" in which various sizes of tectonic lenses are incorporated as "elongated fish" and "balls" (Fig.2). The tectonic lenses are of intensely disrupted sandstones, varicolored mudstones, which are dominated asymmetric structure. The asymmetric structure is characterized by boudin structure, pinch & swell structure and composite planar fabric (Byrne,1994).

This study focused to detect deformation structures under prelithified condition. The structures allow us to identify the earliest stage of deformation and sense of shear in the mélange unit. Our discussions and interpretations are based on observations made mostly on NE facing sections, cut perpendicular to the Y-shear, P-foliation which developed during sediments were prelithified (Fig.3). The mélange unit is subdivided into the Y-shear zone (YSZ) and P-foliation zone (PFZ) (Fig.4).

**Y-shear zone and P-foliation zone**

The Figure 4 is the geologic sketch maps displaying a typical distribution and structural relationship between the YSZ and PFZ.

The YSZ is composed of thick lenticular sandstone, intense shear band and mudstone dominant mélange (Fig.4). The thickness of the lenticular sandstone layers is generally 1 to 3m. The layers are subparallel to the direction of the YSZ. The intense shear band is characterized by Y-shear planes (N80 to 90°E) and P-foliation planes (N70 to 80°W) (Fig.3). Riedel shear planes with echelon displaced P-foliations are associated (Fig.5-d). The thickness of the band is several centimeters to 20cm. The majority of the intense shear band accomplish layer-parallel-shearing that is associated with Y-shear. Resulted from the succeeded deformation, concentrated composite planar fabric in narrow zone were formed that are elongated parallel to the thick lenticular sandstone (Fig.5-c). In intense shear band, thin layers of sandstone and argillaceous matrix wrap smoothly around thick lenticular sandstone (Fig.5-a). An asymmetric orientation of the tales of the lenticular

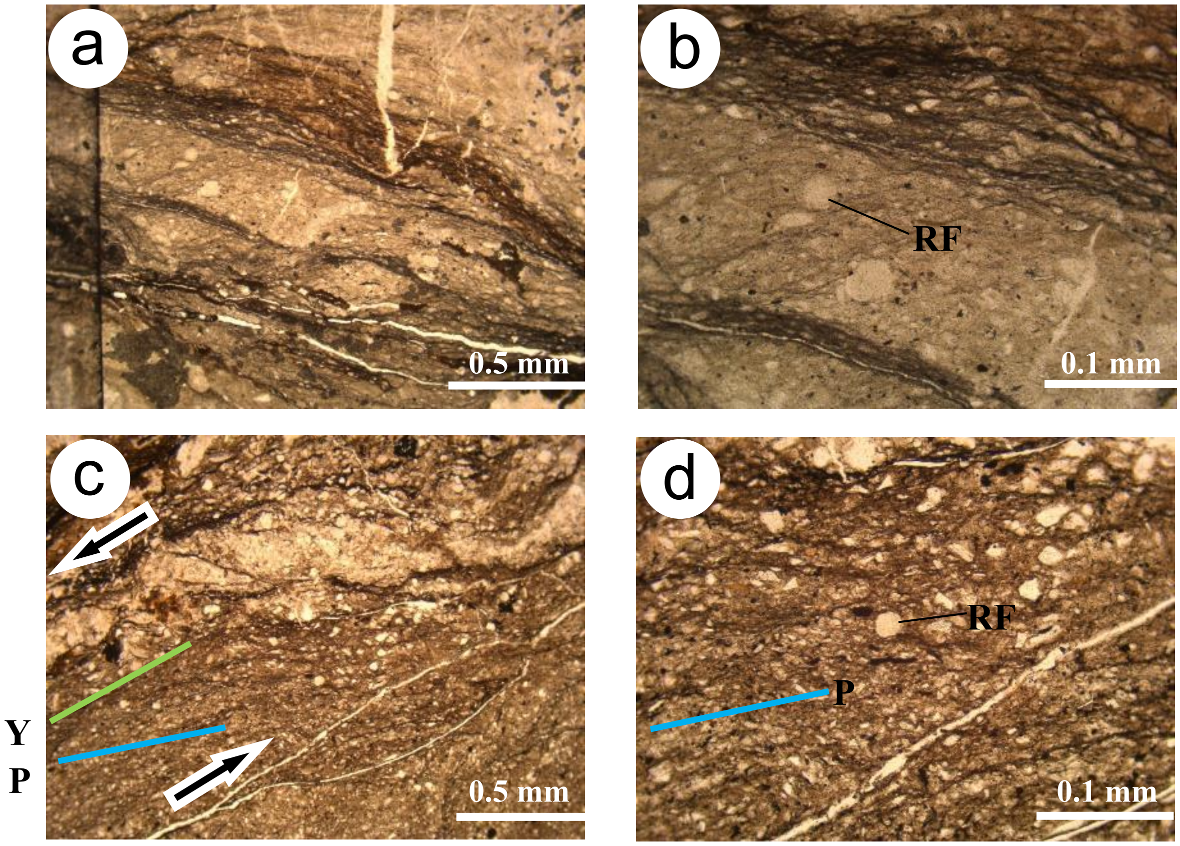



Fig.6 Texture of the mélange under microscope. a) Pale colored sandy layer (contains radiolarian fossils) is elongated in direction of Y-shear. The sample from the intense shear band. b) Close up of Fig.6-a. Radiolarian fossils (RF) are not deformed. c) Prelithification composite planar fabric in the intense shear band (Y: Y-shear, P: P-foliation). d) Close up of Fig.6-d. Radiolarian fossil(RF) incorporated in P-foliation is preserved and not deformed.

sandstone surrounded by argillaceous matrix and asymmetric lenses of varicolored mudstone indicate the sinistral sense of shear (Fig.5-d). The boundary of the YSZ and PFZ is bounded by intense shear band (Fig.5-b). The mudstone dominant mélange comprises mudstone and relatively thin lenticular sandstone layers (Fig.4). The mudstone has foliation defined by thin layers of varicolored mudstone or silty to sandy layer which is slightly oblique to the direction of the YSZ and subparallel to the direction of P-foliation (Fig.4). The PFZ is composed of mudstone dominant mélange and lenticular sandstone (Fig.4). The lenticular sandstone and the foliation of mudstone dominant mélange are subparallel and the direction defines P-foliation which gently oblique to the direction of the YSZ.

**Evidences of prelithification shear deformation**

Overall sandstone lenses are consistent with WNW to EW trending extension, which is contrary to ENE trending intense shear band. Near the boundary of YSZ, sandstone lenses are elongated and dragged in the direction of the intense shear band. These lenticular and pinched sandstone layers are also common in slump deposits as soft clasts.

In microscopic scale, there is significant evidence that the earliest deformation of mélange underwent during sinistral sense of shear. Composite planar fabrics are observed in microscopic scale (Fig.6-c). Competent layers have a tendency to elongate direction of the Y-shear plane (Fig.6-a, c). Foliation of incompetent part define the P-foliation (Fig.6-c). The fabrics are interpreted to be prelithification structures. Sandstone layers elongated in the direction of Y-shear suggest that fluid flow in the sediments controlled the deformation (Bolton, 1998). Deserving special mention is that interstitial radiolarian fossils within the sediments in intense shear band have survived against deformation (Fig.6-b, d). If the sediments underwent deformation after lithification, the radiolarian fossils might suffer brittle or ductile deformation. The survived radiolarian fossils suggest that the deformation in the mélange unit originated during prelithified condition.

**Discussion and Conclusion**

As mentioned before, the mélange unit is profoundly concerned with sinistral sense of shear which developed during sediments were prelithified. This result agrees with the Taira's opinion that the Shimanto Belt was drifted by the left lateral movement (Taira *et al*., 1992). Mélange unit is classified YSZ and PFZ by the difference of deformation structures. Zone boundary is decided by intense shear band.

Micro scale to macro scale structures of intense shear band are corresponded with structural relationship between YSZ and PFZ. Moreover, preserved radiolarian fossils within intense shear band are not deformed. In consequence of the texture, intense shear band has behavior as the heat of shear that the prelithified condition of deformation formed YSZ and PFZ. Remarkable facts are

1) The mélange unit of study area is composed of YSZ and PFZ.
2) The prelithification shear deformation and the structures are preserved typically in the intense shear band.
3) Overall mélange was formed by prelithification shear deformation of sinistral sense of shear in macro scale to micro scale.

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