Serpentine dominated tectonics around the southern Philippine Sea boundaries-Tectonics of Yap, Palau and Mariana Trenches-

Kantaro Fujioka

Deep Sea Research Department, Japan Marine Science and Technology Center

Abstract The arc-trench systems in the world may be divided into two major types: accretionary and erosional. The latter may be further subdivided into serpentine dominated or non serpentine dominated. We found serpentine dominated forearc systems distributed around the eastern and southern boundary of the Philippine Sea Plate, that is, Izu-Bonin, Mariana, Yap and Palau trenches.
Serpentine dominated forearc lithologic units found along the eastern and southern boundary of the Philippine Sea Plate may play a key role for better understanding the tectonic erosion processes under sediment starved subduction zones and to realize the existence of the serpentinite mass in the Orogenic belt on land such as Alps, Himalayas and Japanese metamorphic terranes.

Introduction

The arc-trench-backarc system in the world is divided into simply two types by Uyeda (1982), Chilean and Mariana types. The former is dominated under the compressional stress field whereas the latter under the extensional stress field. Japan Marine Science and Technology Center, JAMSTEC started deep sea research with submersible Shinkai 6500 from 1991, mainly on the subduction zones in the Western Pacific region. The dives were planned as an across island arc scheme from deep sea trench, magmatic arc and backarc basin under the framework of "TRANSARC" program. Recent results of the submersible Shinkai 6500 dives make it possible to divide the subduction zones into three types depending on their various forearc features: Accretionary Prism (AP), Tectonic Erosion (TE) and Serpentine Diapir (SD) types, respectively. AP type is dominant in the Nankai, Suruga, Sagami Troughs, and Ryukyu Trench in the western Pacific and Aleutian and Barbados in the Pacific and Atlantic Oceans. TE type is dominant in the Japan Trench, Peru and Chile Trenches in the world. The third SD type is only dominant in the western Pacific, Izu-Bonin, Mariana, Palau, Yap as well as Tonga Trenches (Figure 1).

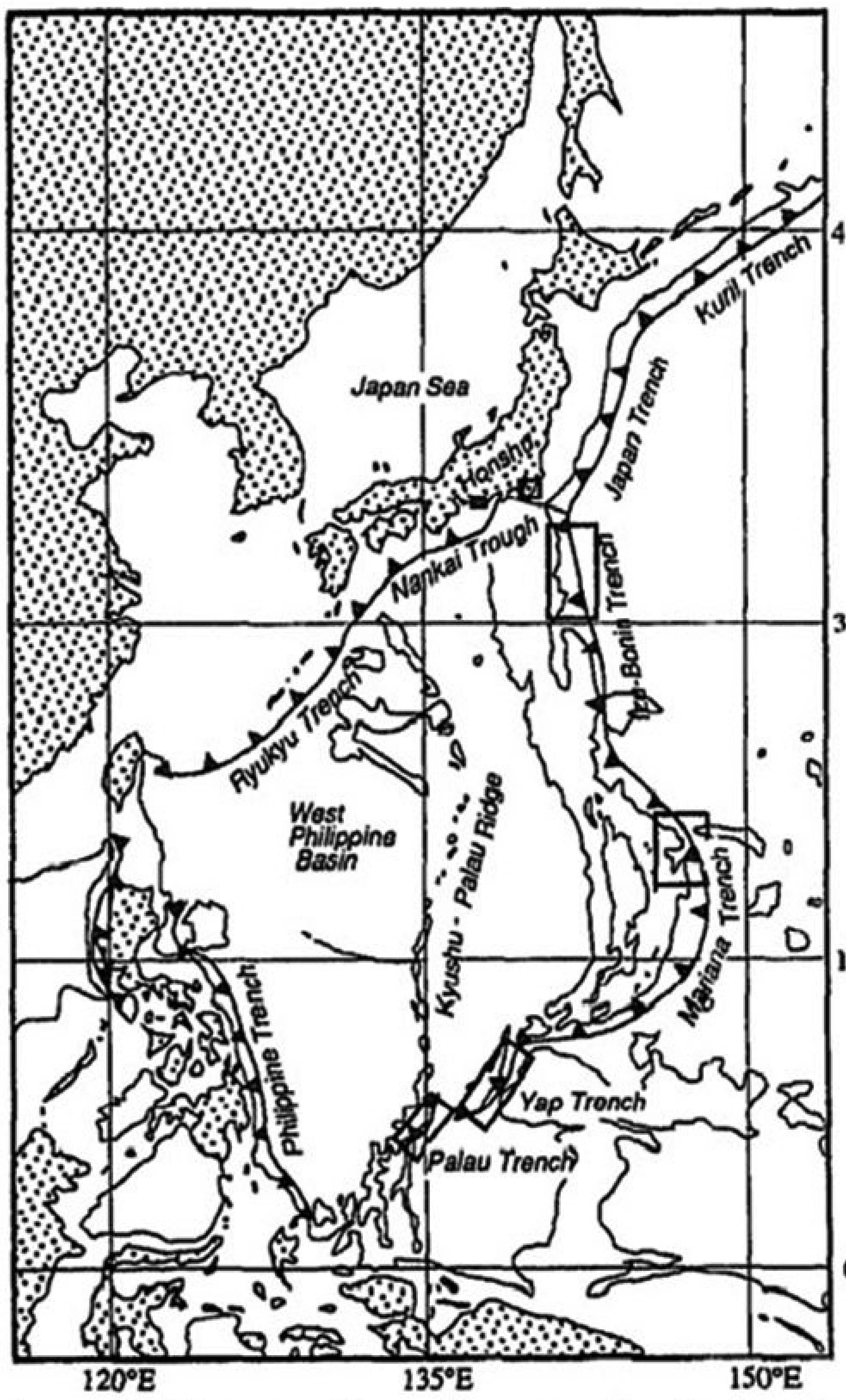

Figure 1. Topographic outline map for the Izu-Bonin, Mariana, Yap and Palau Trenches. Boxes show the location of the serpentine diapirs descried in the text

Typical examples of these three types around the Japanese Islands are the Nankai Trough, Japan Trench and Mariana Trench. SD type is significant for better understanding of the orogenic belt as to the serpentinites in relation to their tectonics.

Here the nature of the present day examples of the seafloor serpentine belts will be described and discussed in relation to the on land serpentinite belts in the orogenic belt.

Serpentine Diapir forearc

Here is a brief geologic description on the serpentine dominated forearc in the Izu-Bonin, Mariana, Yap, and Palau areas. The areas surveyed are shown in Figure 2.

Izu-Bonin forearc, Sedimented serpentine flows

Serpentine flow forming large seamounts were recognized along the Izu-Bonin forearc region. Along the Izu-Bonin trench forearc, there is a regular distribution of the seamounts only several tens of km west of the trench axis. The seamounts lie at even intervals from Aogashima Seamount to Torishima Seamount, north to south, almost parallel the trench axis. The seamounts have almost 18 km regular spacing, just twice that of the volcanoes on the volcanic front. The seamounts were named from north to south after the name of the nearby volcanic islands. They are Aogashima, Meisei, Myojin, Sumyo, Sumisu, Torisu and Torishima seamounts (SMT), respectively (Figure 2).

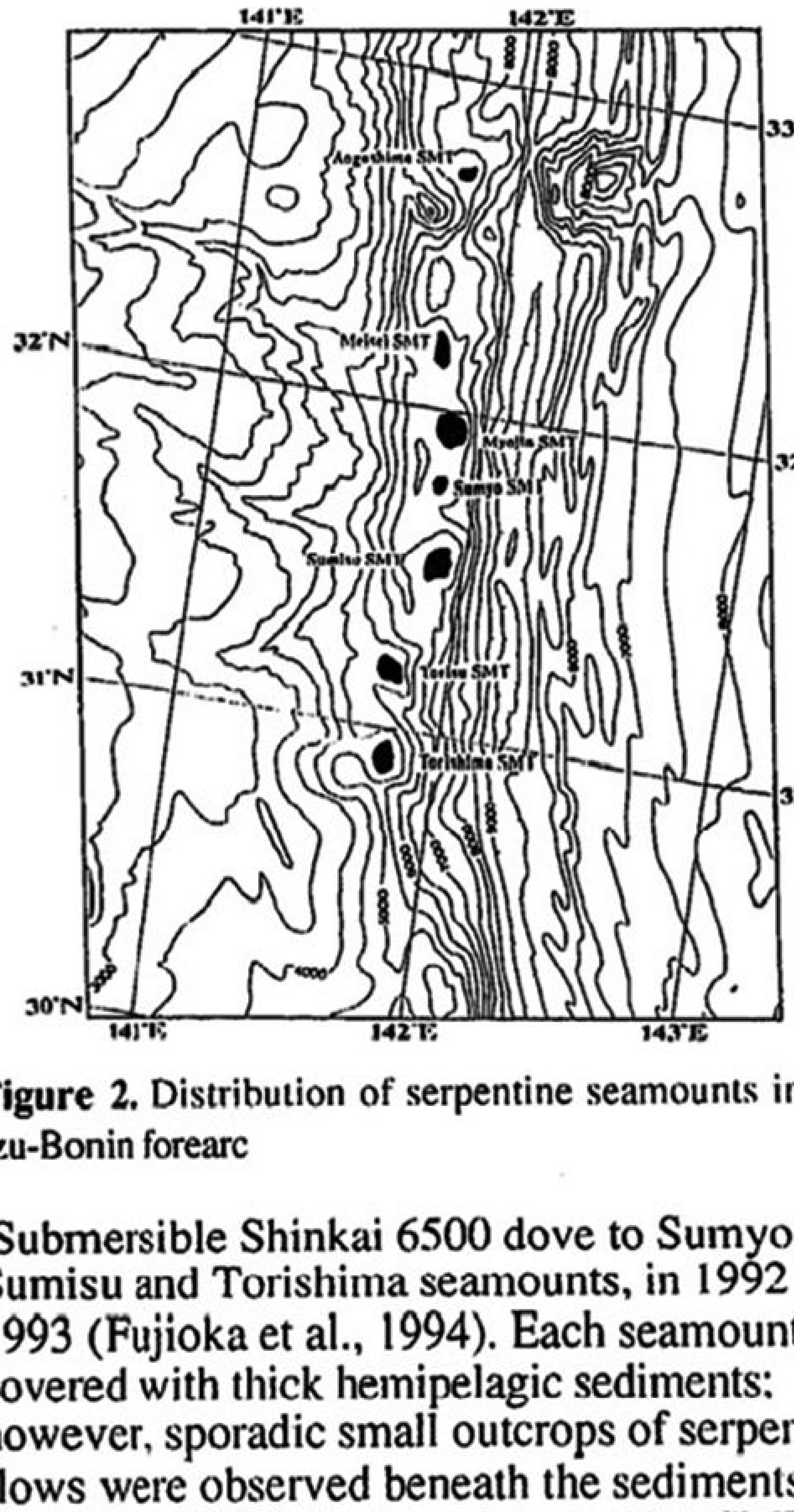

Figure 2. Distribution of serpentine seamounts in the Izu-Bonin forearc

Submersible Shinkai 6500 dove to Sumyo, Sumisu and Torishima seamounts, in 1992 and 1993 (Fujioka et al., 1994). Each seamount is covered with thick hemipelagic sediments; however, sporadic small outcrops of serpentine flows were observed beneath the sediments. Torishima SMT, the largest serpentine SMT and 150 km east of volcano Torishima, was mostly covered with hemipelagic sediments (Figure 3). Near the summit of the SMT, sporadic outcrops of serpentinites and rubbles and pebbles of serpentinites were recognized and sampled. White carbonate rich sediments were also collected together with serpentinites. These observations may indicate the Torishima SMT is now quiescent as to the serpentine flow eruption and mostly buried with sediments

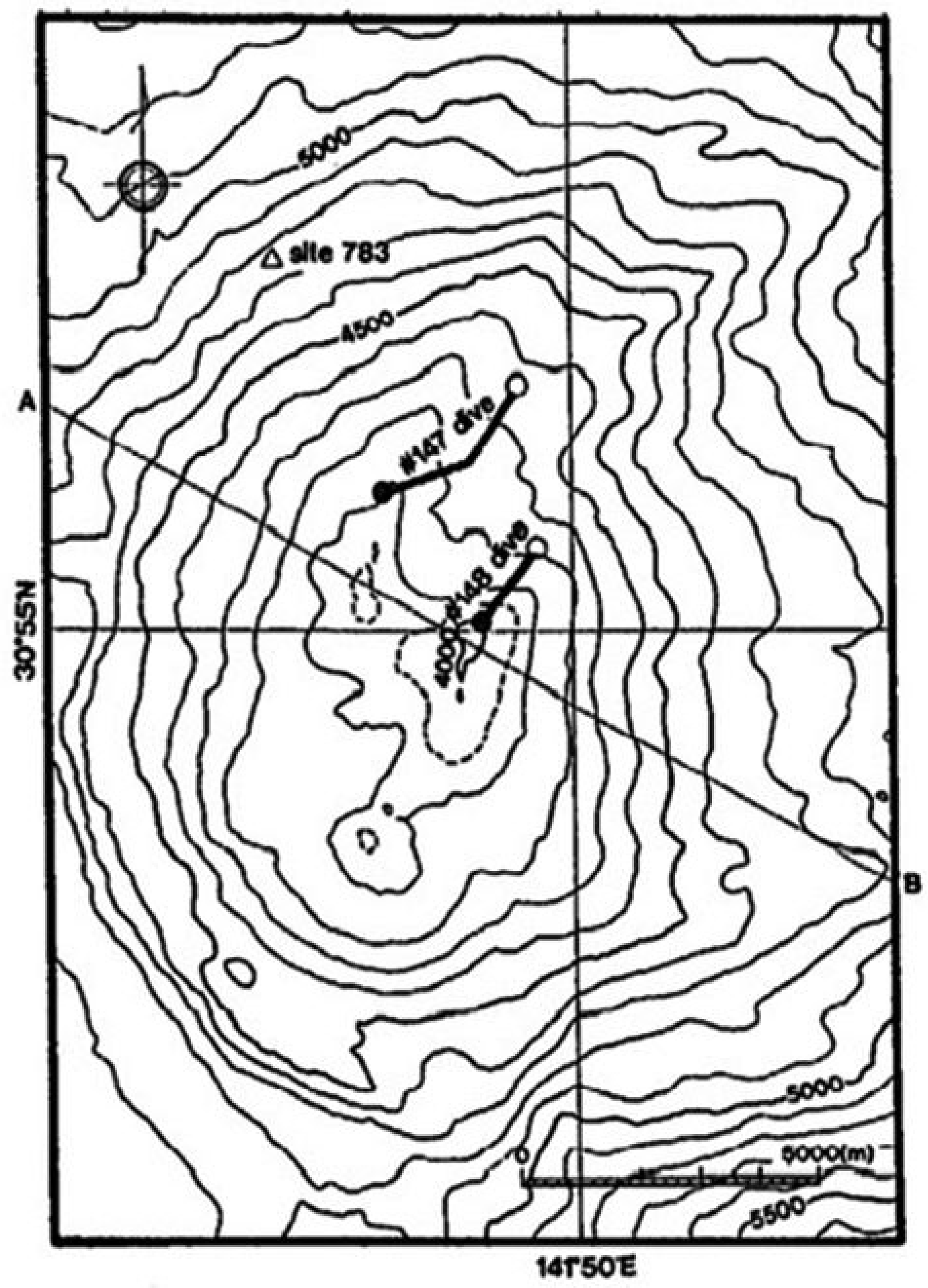

Figure 3. Topography of the Torishima Seamount

Mariana forearc, Active serpentine flow with carbonate chimney

Just 7 km west of the Mariana Trench axis are distributed many seamounts (Figure 4)

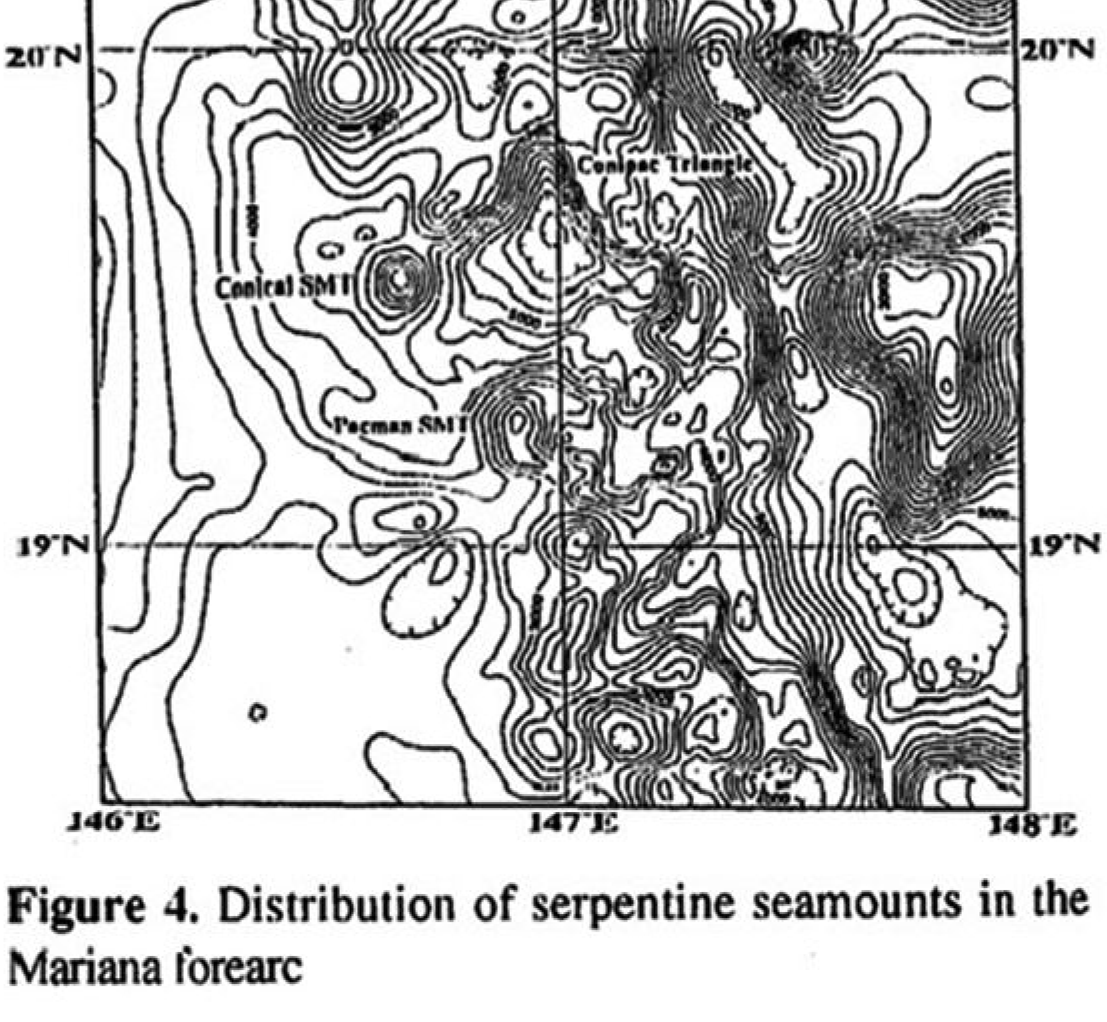

Figure 4. Distribution of serpentine seamounts in the Mariana forearc

These seamounts were found for the first time during a SeaMARC survey of the University of Hawaii, 1983. Bloomer and Hawkins (1983) and Fryer et al. (1989) described these seamounts for the first time as to the serpentine seamount instead of ordinary seamounts consisting mostly of volcanic materials. Two major seamounts were noted and named as Conical and Pacman by the shape of the seamounts. Conical SMT shows conical shape whose summit is more steep than the foot. Deep-tow survey confirmed sinuous distribution of the well refractive layers which were recognized to be of the serpentine flows. Pacman SMT has a huge collapse structure at eastern slope which shows the horseshoe shape by a huge slope failure.

Alvin dives confirmed the various serpentine flows from the summit of the Conical seamount in 1987 (Figure 5).

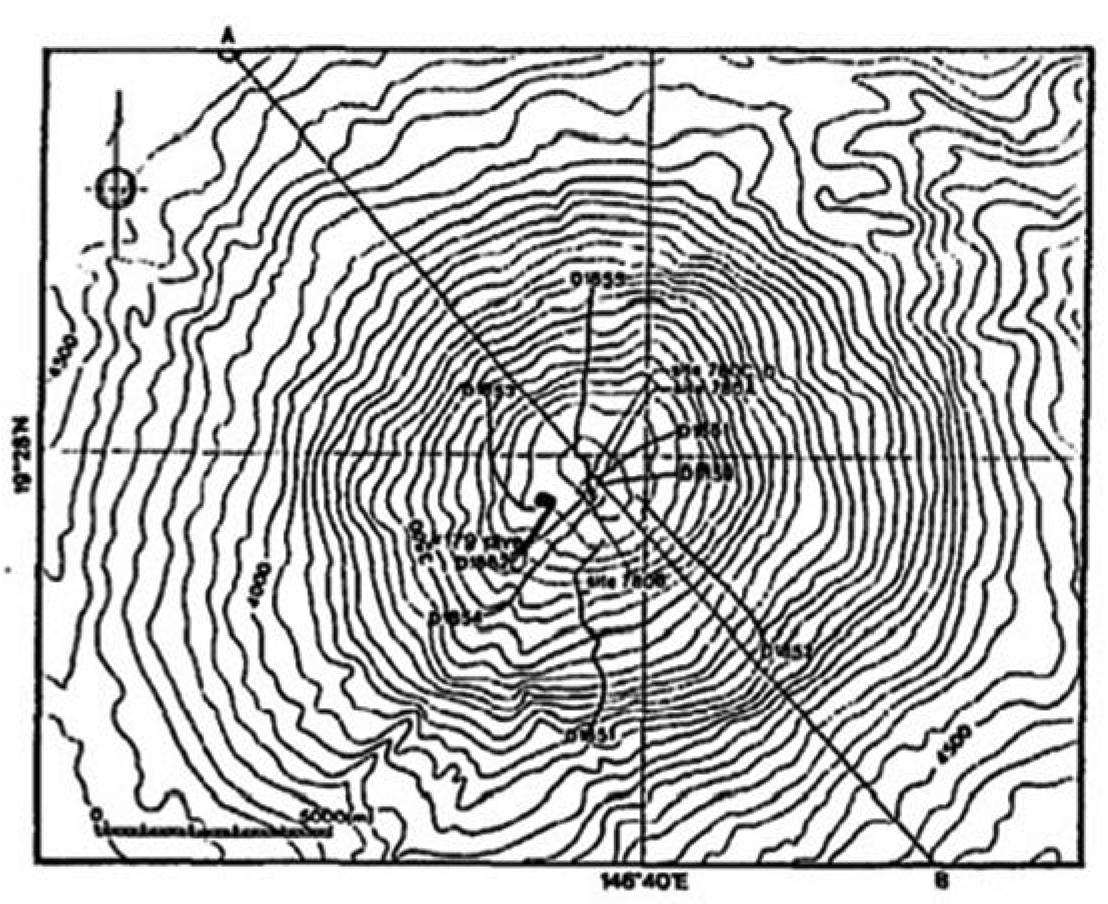

Figure 5. Topography of the Conical Seamount and the dive tracks of the submersible Alvin

Carbonate chimneys were also found on the summit of the seamount. They are 2 to 3 m high with pale green bacteria on their surface.

ODP Leg 125 drilled these seamounts and obtained facoidal serpentinites below the thin pelagic sediments blanket (Fryer et al., 1989). Fryer et al (1985, 1989) concluded that the metamorphic sponge model well explained the origin of serpentine diapir for the formation of this seamounts. Maekawa and others (1994) found the low temperature and high pressure type metamorphic mineral assemblage such as Quartz plus Jadeite from the meta-basalt which is included in the serpentine matrices. This evidence shows the origin of the serpentine flow is deeper than 30 km in the wedge of the mantle.

Shinkai 6500 dives observed various amounts of peridotite blocks in the serpentine flows. Some blocks exceed 5m in diameter (Figure 6a).

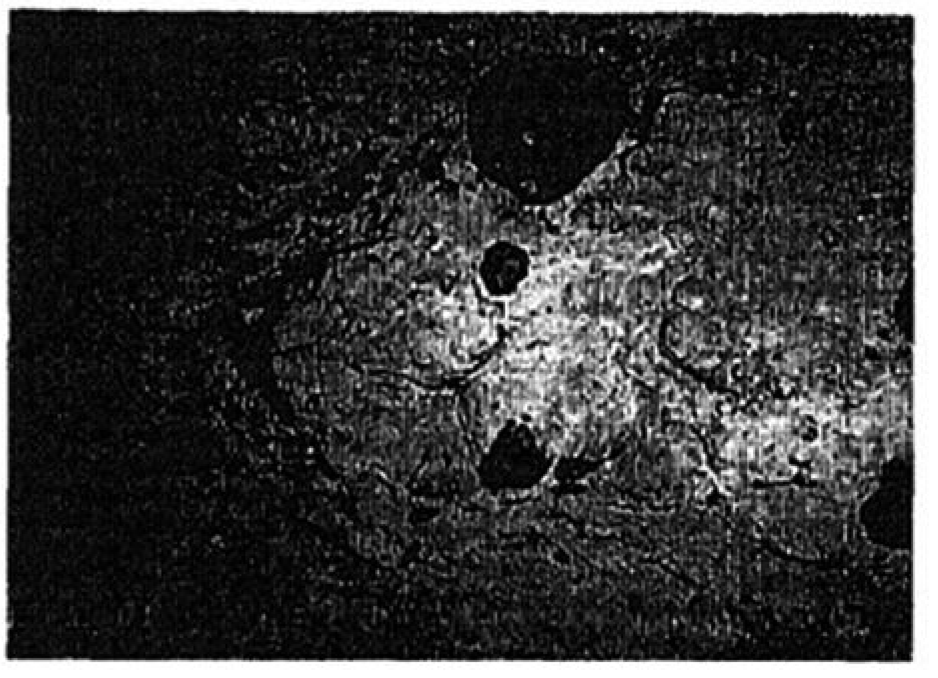

Figure 6a Photograph of the outcrop of the serpentine flow at the Conical Seamount

This makes it difficult to transport these heavier blocks together with lighter serpentine mud from the deeper part of the mantle by the process of slow diapiric uplift. One serpentine flow shows the small ridge like structure, several meters high (Fujioka et al., 1994, 1995). Baby carbonate chimneys were found near the summit of the southern wing of the Pacman seamount (Figure 6b).

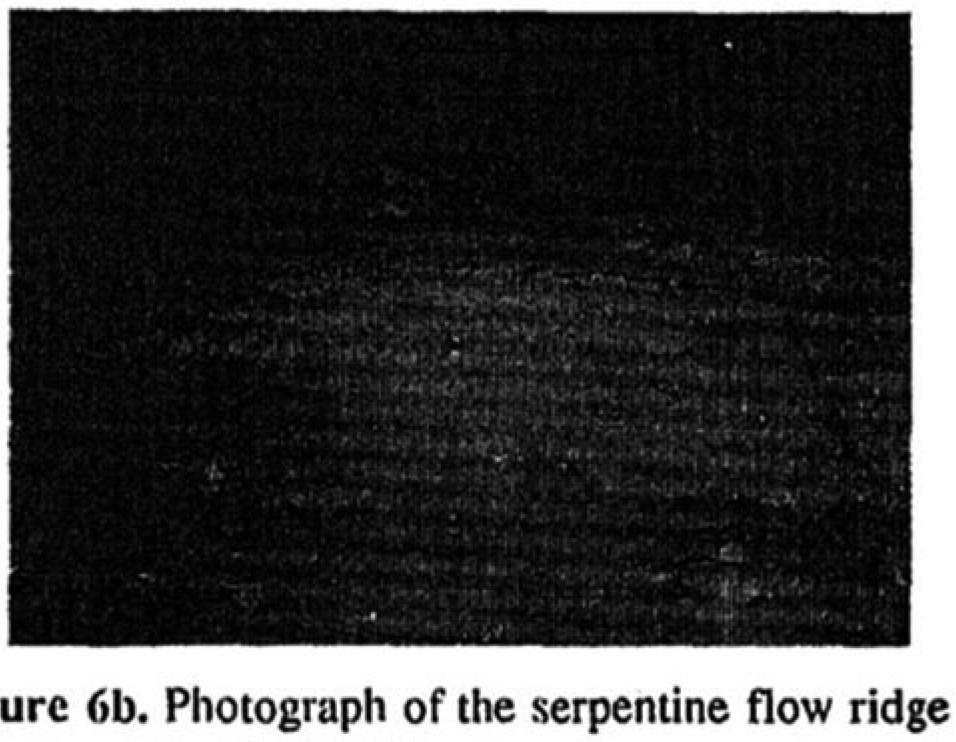

Figure 6b. Photograph of the serpentine flow ridge structure at the Conical Seamount

This seems the primary stage of the formation of the carbonate chimneys.

Apart from these two seamounts, a triangle basin developed in between Conical and Pacman SMT and was named as ConiPac triangle. The steep eastern wall of the ConiPac triangle were composed mostly of thin serpentine flow deposits (Fryer, 1993).

Figure 6c. Photograph of the carbonate chimney with giant sea anemone at the Conical Seamount

Figure 6d. Photograph of the carbonate baby chimney at the soutehrn wing of the Pacman Seamount

Yap (Moho exists in the forearc)

Yap forearc shows notable inflection points, at 4500m and 6000 to 6500m by a conventional PDR, 3.5KHz and other acoustic measurement (Fujioka et al., 1986, 1989a, b). A flat and gentle landward dipping thrust plane was recognized at a water depth of 6000m to 6500m by multi-narrow beam survey (Fujioka et al., 1994). If we take into account the evidence that the metamorphic rocks such as greenschist and amphibolite facies are exposed on land Yap and Map formations, these two inflection points or planes are equivalent to the boundary of upper and lower crust, and lower crust and upper mantle, respectively (Fujioka et al, 1986, 1989a).

Shinkai 6500 dived from the 6500 m to 5700 m crossing the lower inflection plane and obtained ultramafic rocks beneath and gabbroic rocks above this lower inflection plane. This means that the plane is more likely to be petrologic Moho discontinuity.

Palau (Newly discovered serpentinites)

The northern part of the Palau Trench axis has a huge limestone block exposed on the bottom of the trench. The Shinkai 6500 dive made clear the distribution and thickness of the limestone body in 1996. The block fell down to the trench bottom from the surface by a huge collapse. Inside the limestone block, ultramafic and related rocks were observed and collected (Fujioka et al., 1996). This may indicate that upper mantle materials are also exposed on the forearc slope just like Yap forearc. This finding indicates the serpentine dominated forearc is the eastern and southern boundary of the Philippine Sea Plate.

Continental and Oceanic Arcs

Island Arcs will be also divided into continental and oceanic by their existence of the granitic layers. For example, the Honshu Arc was examined by the explosion seismographic works and confirmed the existence of a thick crust and the 6 km/s layer. On the other hand Izu-Bonin Arc shows thinner crust, shallower Moho and thinner 6 km/s layer compared with the Honshu Arc. Sedimentation rate of the forearc areas of these two arcs is quite different because of the supply rate of the terrigenous input. The Continental type has a much higher rate of terrigenous and volcanogenic materials than the Oceanic type.

Sediment rich or sediment starved forearc is one of the characterizations of Continental and Oceanic arc also.

Discussion

What is the critical control to characterize the forearc nature. We recognized three different type of forearc around the Japanese Islands. High sedimentation rate and young descending slab is critical for the formation of the accretionary prism. If so, what is the key role to divide the TE and SD type? What is the major difference between SD and TE type forearc?

Along the Japan Trench forearc dehydration veins were recognized at shallow formations at DSDP Site 434 in the lower trench slope. Two huge earthquakes occurred off Sanriku area in 1896 and 1933. The stress field in the northern Honshu is compressional compared with Mariana area. The strength of the coupling of the two plates in the Japan Trench and Mariana Trench is different. The degree of coupling, continental or oceanic and the sedimentation rate are most critical for the determination of the two different forearcs. Is forearc serpentine seamount a prototype of serpentinites of the orogenic belt? Does the orogenic serpentinite mass have a flow structure inside? Mariana active serpentine flow shows a clear flow structure like a mud volcano. ODP Leg 125 cores show the diagnostic flow structure with peridotite blocks.

Mineoka Belt in the Boso Peninsula has dismembered serpentinite blocks exposed within Mineoka tectonic zone (Figure7).

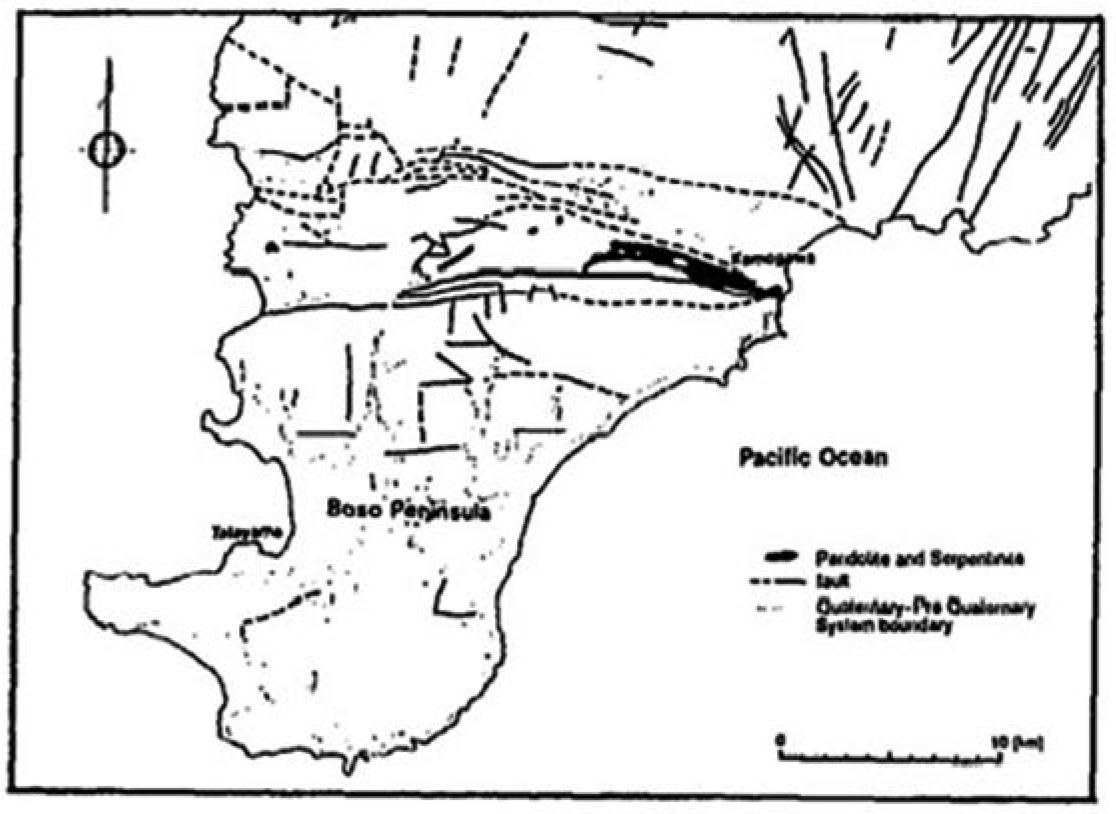

Figure 7 Geologic outline of the Mineoka serpentinite belt, Boso Peninsula

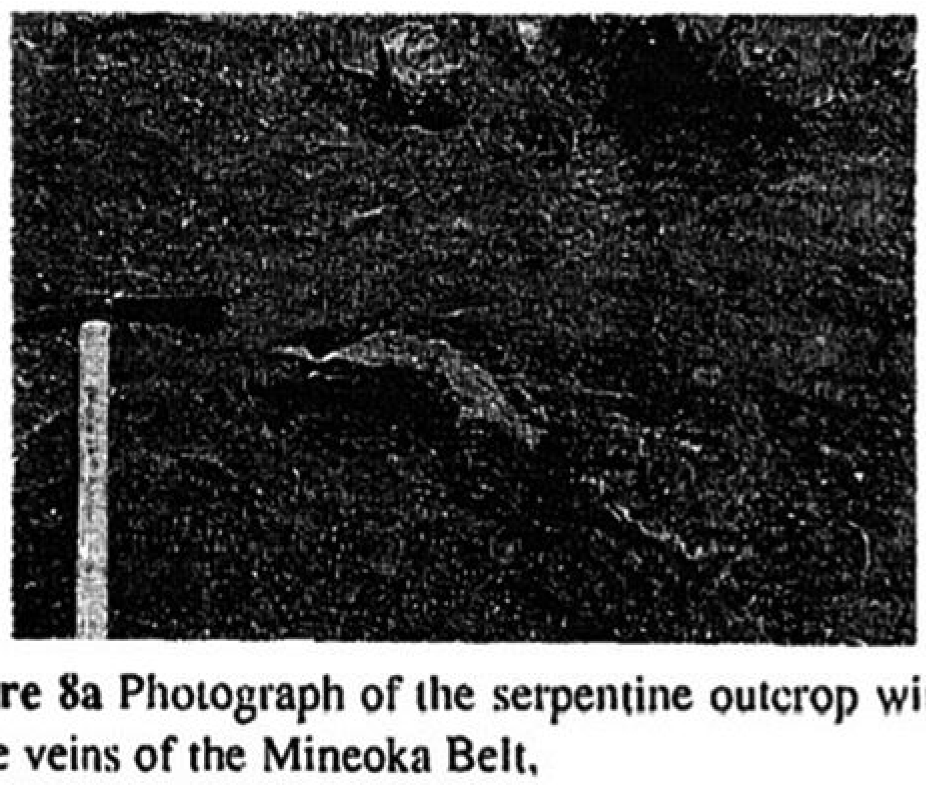

Figure 8a Photograph of the serpentine outcrop with white veins of the Mineoka Belt,

The serpentinite mass shows a clear sedimentary structure and sometimes includes white carbonate materials. The situation is quite similar with the forearc serpentine seamount. Sanbagawa metamorphic belt yields isolated serpentines blocks (Figure 8a, 8b).

Sedimentary structures with white carbonate-like material are also found within the serpentine belt of the Permian Sanbagawa high pressure and low temperature metamorphic belt (Figure 9).

Figure 8b Photograph of the serpentine outcrop with white veins of the Mineoka Belt

The grade of the metamorphism of this region is higher in this serpentine part compared with surrounding meta pelites. Photographs of the serpentinite outcrops are quite similar those obtained from the Mariana serpentine flows (Figure 10a, 10b).

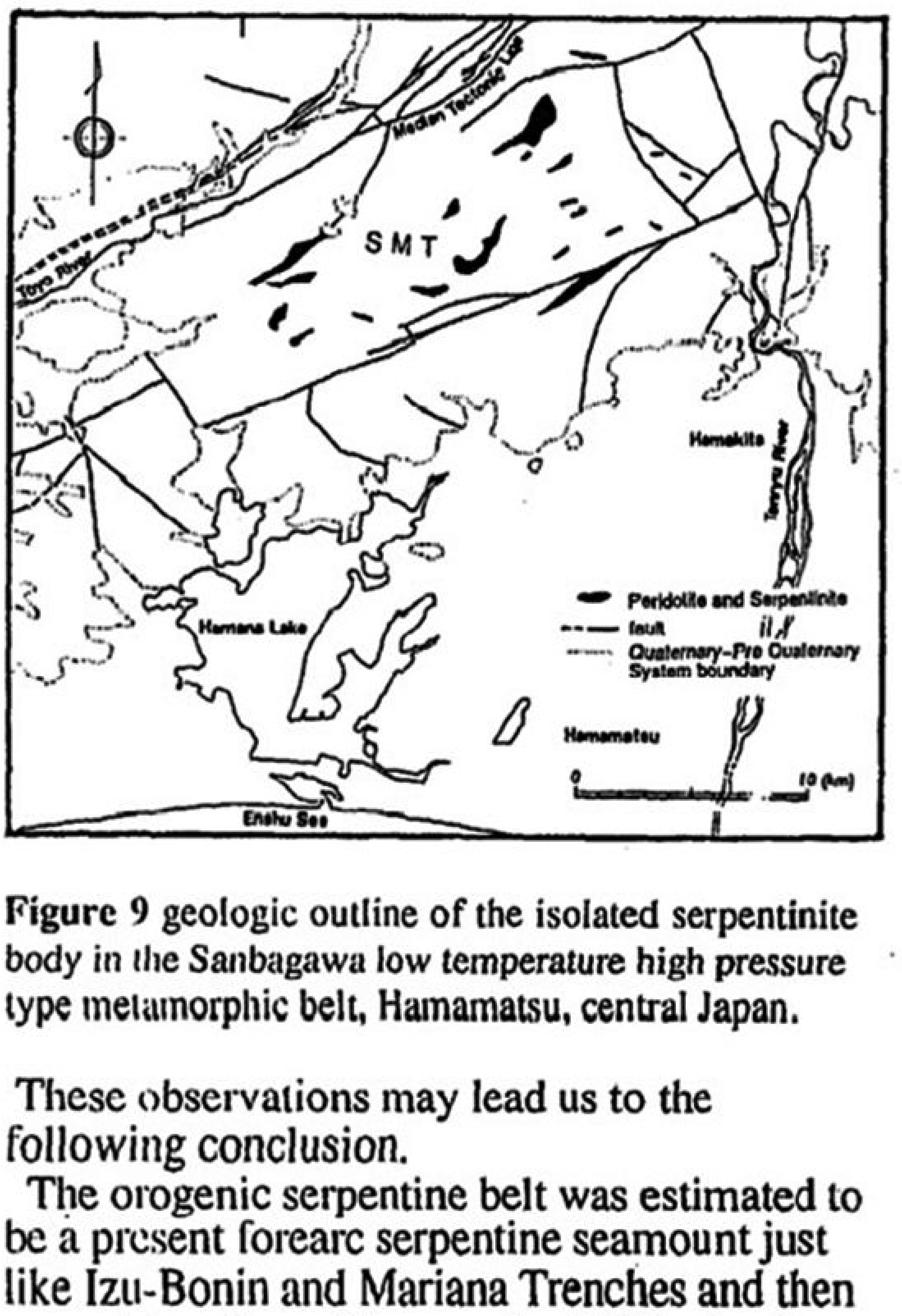

Figure 9 geologic outline of the isolated serpentinite body in the Sanbagawa low temperature high pressure type metamorphic belt, Hamamatsu, central Japan.

These observations may lead us to the following conclusion.

The orogenic serpentine belt was estimated to be a present forearc serpentine seamount just like Izu-Bonin and Mariana Trenches and then moved together with a moving Philippine Sea Plate and collided and uplifted into the orogenic belt during the formation of the orogenic belt. That is, the serpentine seamount is a critical key to understanding the past tectonic and depositional environment of the orogenic belt.

Figure 10a Photograph of the serpentine outcrop of the Sanbagawa metamorphic terrain

Figure 10a Photograph of the serpentine outcrop of the Sanbagawa metamorphic terrain

Summary

Serpentine dominated forearc is a key to understanding the tectonics of the emplacement and evolution of ultramafic rocks and high pressure/low temperature type of metamorphic belts in Orogenic Belts, Circum Pacific and Alpine type peridotites

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