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Depositional Cycles and Paleocurrent in Pelagic Condition from Example of Middle Permian Bedded Cherts, Southwest Japan

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Depostional cycles of the Middle Permian bedded chert sequence are examined in view point of lithology, composition and mode of occurrence of microfossils. Cyclic compositional change was veryfied by alternating occurrence of two distinct type of chert beds which are one biogenic called siltite, and the other fine siliceous ones called lutite. Thickness of beds forms cyclic peaks and of which composition of alternatively change between siltites and lutites. This points change of radiolarian blooming and deposition are intimately related to that in low-stand in sea level when activated circulation on botton surface was dominated, while in high-stand in sea level slow flux of coarse siliceous materials with varied biomass fertilized conodonts. These two oceanic conditions were clearly recorded in the lower to middle Middle Permian but it gradually became unclear in upper Middle Permian, prior to Upper Permian regression. Prefered orientation of *Follicucullus* shell characterized by elongated conical shape indicates bottom currents were regular in direction almost through the Middle Permian and an asymmetry in arrangement of shell vertical to the supposed current alludes possibly inclined paleoslope of the depositional basin and current parallel to this slope.

Introduction

In '80th standards of radiolarian biostratigraphy have been proposed from the Meso-Paleozoic bedded cherts and associated siliceous rocks of Japan. This progress brought great examples for stratigraphic, ecologic, geochemical, and tectonic and interdiciplinary research for environmental change of the global systems. Bedded cherts regarded to be deposited in pelagic condition, are usually free from the local event but record global change in geochemical aspect (Hori and Maruyama, 1991) and its resulted plankton production-depositional cycles (Ishiga et al., 1993, a, b). Bedded cherts have long been investigated in many ways, but still no consensus has not been attained on the formational mechanism. Elongated or conical shaped particles comprising these cherts tell about paleocurrent (Imoto, 1984), and in case indicate expected current velocity of reflection of changing bottom current through geologic events and by rhythms of the earth (Douzen and Ishiga, 1993, a, b). These biostratinomy with of course sedimentology of the bedded cherts takes long time to read records in the rocks, but it is to be the best example for estimation of oceanic cycles. Because of the geologic events and rhythms were intimately concerned to the earth systems (Masuda, 1989, 1990; Kaiho, 1991; Minoura, 1991 etc.). The possible rhythm recorded in Middle Permian bedded cherts is presented and sedimentary and oceanic environment is examined on the basis of conical shaped radiolarian biostratinomy.

Examined bedded cherts and its geologic setting

Bedded cherts reported here is at the Tajiri-dani section in Kyoto Prefecture, Japan which overlies Permian greenstones forming small lens in geological map (Ishiga and Imoto, 1980). Total thickness of the bedded cherts is about 5 m due to their exposure. Permian radiolarians were reported from this outcrop (Ishiga and Imoto, 1980) and later series of radiolarian faunas were examined in detail (Ishiga et al., 1982), of which biozonation is given taking account of recent review of radiolarian zonation by Ishiga (1991). According to reexamination of radiolarian faunas, the sequence covers the *Pseudoalbaillella longtanensis* to *Follicucullus japonicus* Zones corresponding to almost Middle Permian. This is because lower part of the *Pseudoalbaillella longtanensis* is absent in this section, and *F. charveti* of the characteristic species of the radiolarian zone overlying *Follicucullus japonicus* Zone has not been yielded.

Bedded cherts of this sequence are composed mostly of light greenish grey to grey in color, and a single bed of chert usually varies from 1 cm to 4 cm in thickness and a few excess 4 cm. Distinction of a single bed is in case unclear, but after treatment by diluted HF acid, etched surface of the vertical plane of the strata shows apparent set of chert beds and mudstone beds. And this also indicates two distinct type of chert is recognizable. One biogenic and the other resulting from very fine, approximately less than 1 μm siliceous particles. The latter can be distinct from mudstone beds because its whity color of etched surface indicating high silica content. According to nomenclature of lithology of cherts by Imoto (1984), biogenic type is called "B-type", while very fine type is "F-type". The cherts of the "B-type" in this section are composed of radiolarians of 200 to 500 μm in length and they are condensely gathered in the beds. Thus "siltite" is used for notation of the "B-type" chert and "lutite" is for "F-type". Lutite means clay size materials in case including calcareous clays, but here this is applied as descriptive word. Siltite and lutite are discriminated and indicated in Fig. 1 with their thickness. As for sedimentary structures, pull-a-part and injection occurred because of probable difference of viscosity between siltite and lutite in early stage of diagenesis.

In Fig. 1 occurrence of conodonts, mainly of *Gondolella* spp. and small amount of *Hindeodus minutus* are indicated. In the lower horizons some smaller foraminiferas occurred, which are discoidal shape. Examination of orientation of conical shaped radiolaria *Follicucullus* is reported from samples 49 to 78, of which results are indicated by rose diagrams in Fig. 2.

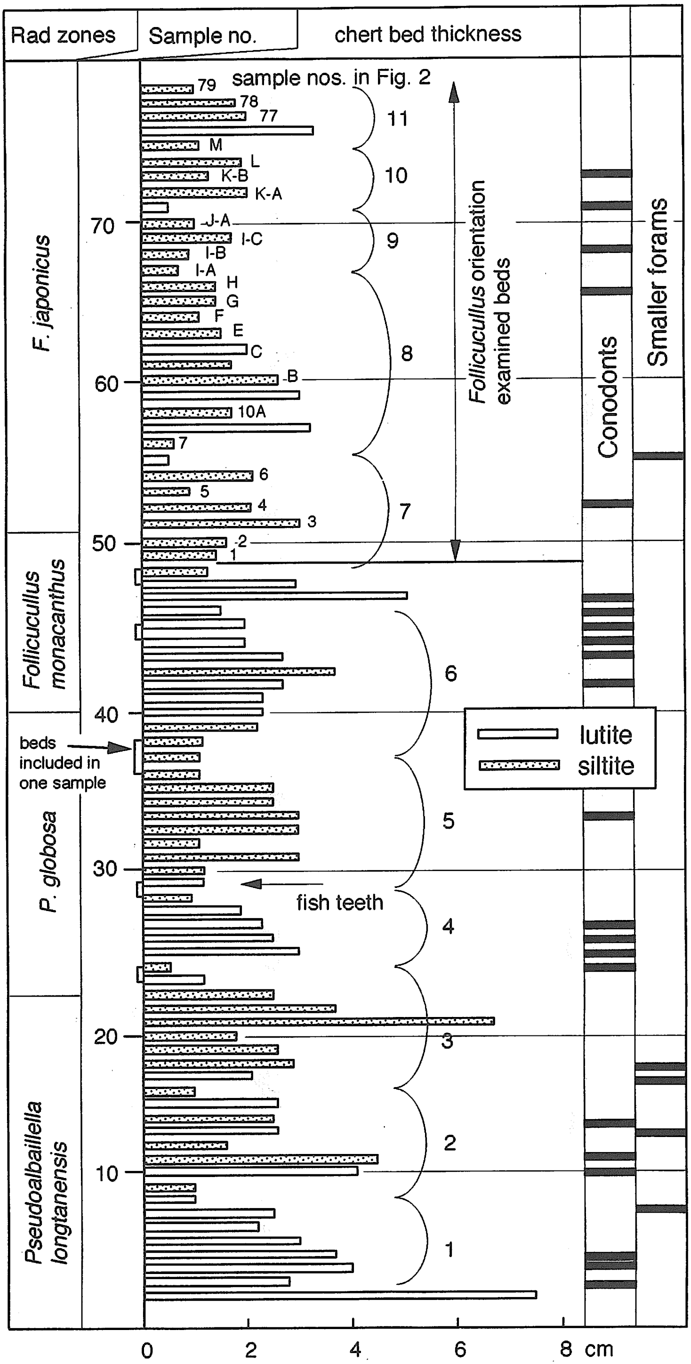

Fig. 1. Middle Permian bedded chert sequence indicating bed thickness, composition (discrimination of siltite and lutite), occurrence of microfossils, and depositional cycles. For detail see text.

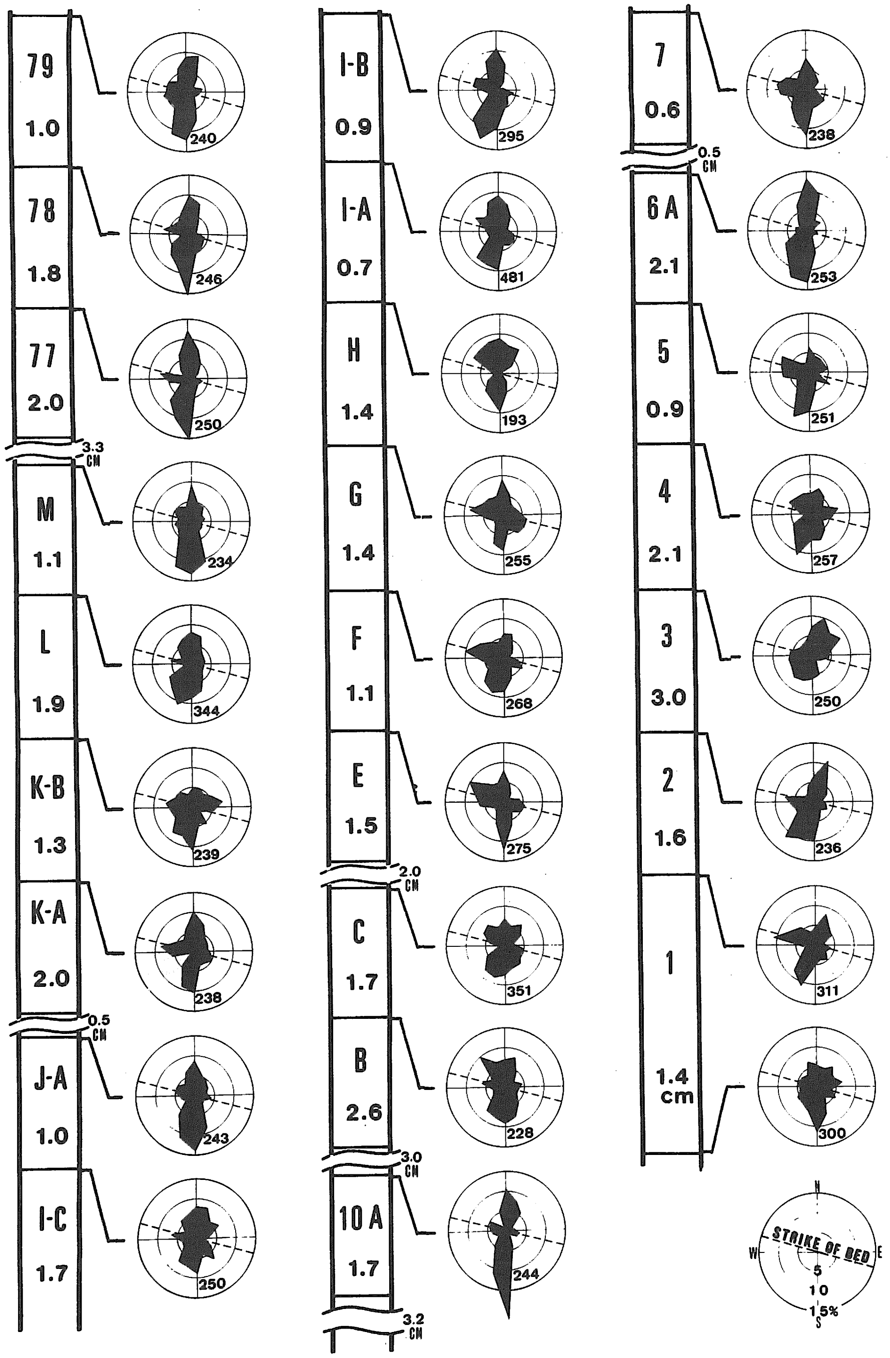

Fig. 2. Rose diagram showing prefered orientation of *Follicucullus* shells (Middle Permian elongated conical shells).

Sedimentary feature of bedded cherts

As is apparent in Fig. 1 thickness of chert beds varies with cyclicity, namely they form a peak when several to ten beds are combined into a unit. For example sample 2 to 8 and succeeding unclear peak from 9 to 16 and very sharp peak from 16 to 24, and so on. Approximately 11 peaks can be recognized whose shapes show variation, are given in figure.

Noteworthy is the composition of chert beds of each peak. Chert beds forming these peaks are composed of usually uniform lithology whether siltite or lutite. Thus the peak of siltite beds and that of lutites are repeated three times in range of peaks 1 to 7. Peak 2 and peaks from 8 to 11 consist of both type. Peak 2 is probably transitinal from peak 1 to 3 because of this shape and component, and peaks of the latter, including in radiolarian zone *F. japonicus*, lutite beds seemingly randomly occurred.

Orientation of *Follicucullus* shell

As indicated in Imoto (1984) prefered orientation of *Follicucullus* shell is one of the characteristic feature of the siltite cherts. Examined silite occurred in upper two beds of *F. monacanthus* (sample nos. 49 and 50 in Fig. 1) and beds in the *F. japonicus* (sample nos. 51 and 79). Sample nos. given in Fig. 2 differs from those in Fig. 1 which is due to reexamination of the beds but approximately correspond to those nos. judging from sedimentologic feature, and both series of numbering are given in Fig. 1.

Both *Follicucullus monacanthus* and *F. japonicus* are characterized by conical and elongated shells with imperforated smooth surface of them. They are bilaterally symmetrical in shape and apex of shell is slightly curved in this plane. Shell has apertural part with asymmetric spines of which proximal part connecting to the aperture is flattened, called flaps, and ditally tapered like spine. Inner side of shell is hollow and no internal construction was preserved. *F. monacanthus* differs from *F. japonicus* in having small spine at the boundary between shell apex (apical cone) and middle portion of shell (pseudothorax).

Rose diagram indicates clear concentration of orientation of shell apex. Namely they are almost concentrated in north and south in most examples, and weakly in west. Some show concentration in east. And apparently two directional concentration in north-south is increased in samples from I-A to 79. As for change in a single bed, sample 1 of Fig. 2 indicates that on top is rather well concentrated than that of the bottom. Strange thing is this concentration is bimodal but they show asymmetry in samples 10A, E, F, I-B, J-A, L. M, 77, 79. Bimodal direction (north and south) is opposite thus orientation of conical shell could be occurred by peculiar mechanism of current or basin structure as discussed later.

Discussion

Depositional cycles in Middle Permian bedded cherts

As described above, siltite and lutite beds of several numbers are repeatedly deposited in the lower to middle part of the section corresponding to the *P. longtanensis* to *F. monacanthus* Zones. As is reasonable understanding, fine grained material were deposited under condition of relatively slower current than those of coarser materials. If lutites were deposited under calm condition with slow current velocity and occasional supply of small amount of radiolarians, then cyclic change of oceanic circulation occurred in lower Middle Permian. Such condition might be caused by change of sea level, and supposition that lutites were deposited in high-stand in sea level is preferable to understanding cyclic deposition of siltite and lutite. Of course lutites could represent distal part of the siltite depositional basin as the proximal part, both lithology could be regarded to be horizontal facies change in this hypothesis. But in this case siltites and lutites were deposited at the same time and probably with same sedimentation rate. Moreover, conodonts usually over 0.5 mm, larger than radiolarians and their fragments are same in size to radiolarians could be gathered in siltites not in lutites. Conodont evidence indicates opposition to this expectation, because they usually occurred in lutites (Fig. 1). Thus depositional environment of lutites is favarably related to ecologic condition of conodont production, such as variety of biomass at the time of high flux and enchiched nutrient supply. If this supposition is reasonable condition of the ocean, lutite could be deposited in high-stand in sea level. On the other hand siltite deposition is influenced by radiolarian deposition, which is regarded to be activated at the time of low-stand in sea level (see Ishiga et al., 1993a). In conclusion alternative change of siltite beds and lutite beds in the lower to the middle part of the section reflects sea level change and related event of the biomass, of which at least seven times can be estimated. In the upper part, siltites are dominated and this indicates relatively low-stand in sea level appeared prior to the worldwide Upper Permian regression.

Prefered orientation formed by current in upper Middle Permian

Conical shaped radiolarian orientation indicates current direction and also relative current velocity (Douzen and Ishiga, 1993a). *Follicucullus* shows same phenomena in Middle Permian cherts and tendency of preferred shell orientation gradually became clear in upper Middle Permian as described already. This coincides the change of depositional environment reduced from feature of bed forms, composition of chert beds that cyclic change of siltite bed and lutite bed groups. In Jurassic conical shaped radiolarians shell apex facing to upstream dominates than that of other shell attitude, but their orientation is regularly arranged in flume experiment (Douzen and Ishiga, 1993b).

Namely shell apex facing to upstream, vertical to the current and shell apex facing down stream. Although *Follicucullus* and Jurassic conical radiolaria (mainly *Parahsuum*) differs from each other in proportion of shell, *Follicucullus* could be arranged in same manner to those of *Parahsuum*. But rose diagram is somewhat different in both fossils, because *Follicucullus* is more elongated shape which is likely arranged in attitude vertical to the current. Rose diagram of *Follicucullus* is characterized by beak shaped peak which indicates direction of upstream. Thus in the section for a long time, about 3 Ma, very steady condition of depositional basin and regular direction of current were expected to occur. As for the asymmetric arrangement of shell in north and south directions, other effect could be supposed to trace to its origin. When *Follicucullus* shell were directed vertical to the current, their asymmetry might be formed by physical effect of basin such as inclined depositional surface. Gravity position of *Follicucullus* shell occurs not at the middle portion of shell but at apertural portion from the center of shell. They rolled on slightly inclined surface with their apex pointing head of slope. Bottom currents transported *Follicucullus* shells along the northerly inclined slope is a scenario of the Middle Permian bedded chert depositional mechanism which should be inspected by other geologic evidence. But occurrence of the chert lens on the greenstones and that the shape is small and lenticular is consistent to this story.

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