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Depositional cycles in Permian and Triassic bedded cherts from Tanba Belt, Southwest Japan

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Rhythm recorded in bedded chert sequence has been examined by compositional set of chert and mudstone beds, and a newly proposed fundamental unit of the bedded cherts is indicated. Thick chert bed with following thinner chert beds clearly appeared in the Upper Triassic bedded cherts, and some part of the Permian sequence. These chert beds and intercalating mudstone beds are set all together, and this set is repeated several times in the Upper Triassic. Stratigraphic recomposition of bedded chert sequence in this manner, 52 sets are recognized in the Middle to Upper Triassic, although those in the Middle Triassic are incomplete and unclear. Additional cycle formed by the first large set and following rather small three set can be distinguished in the Upper Triassic. This newly proposed diagram suggests that thickness of chert beds shows regular with some cyclic peaks, while thickness of mudstone beds gradually decrease. Mudstone beds also have some peakes correspond to those of the chert beds. In the Permian sequence, styles of set recognized in the Lower Permian and Upper Permian are different mutually, namely those of the Lower Permian are characterized by rhythmic and steady sets while those in the Upper Permian are series of thinner chert beds and succeeding clear set of bedded cherts are repeated.

A set could be formed by dominant radiolarian blooming characterized by a thick chert bed and consequent drop of blooming indicated by some thinner chert beds. Two orders of cycle recorded in bedded chert sequence could indicate rhythmic change of nutrient supply or surface current velocity related to a circulation of the occean.

Introduction

Formational mechanism of bedded cherts has long been deputed, because their rhythmic stratification could not be explained by any simple ideas. Bedded cherts here we discuss are one of typical pelagic sediments free from the direct supply of terrigenous materials, comprise thick siliceous layers (chert beds) of about several cm in thickness and thinner mudstone partings (mudstone beds) of usually one to ten times to the chert beds. Chert beds are composed mostly of radiolarian shells and their fragments with other siliceous biogenic materials, while mudstone beds are chiefly of aeolian clay minerals. These two compositions of bedded cherts are regarded to represent mutually different source and their thickness depends on volume of source materials controlled by some rhythm or cycle of the earth, and depositional environment caused by or originated by a tectonic movement.

One of the authors, Imoto (1984) examined vertical change of thickness of both chert and mudstone beds in several sequences which indicated change of depositional environment related to the movement and subsidence of ridge basalts. Many other works concerning the cycles of bedded cherts are also subconscious to the thickness change of a single bed of chert bed and mudstone bed (see Hori and Cho, 1991).

The authors were stimulated by the work on Milankovitch cycles recorded in Tertiary turbidite sequence of Japan (Masuda et al., 1989). This work has given an image of a set of several beds of bedded cherts which involves cyclic change of bed thickness. Review of the cycles to be read in bedded cherts sequence in this method is a new view of understanding the rhythm of bedded cherts and additionally it leads to elucidation of oceanic environment.

Measured section and brief geologic setting

Triassic and Permian bedded chert sequences are reexamined based on the data given in Imoto (1984).

Triassic bedded cherts

Bedded cherts in the lower Tanba nappe of the Tanba Terrane (or type I suite of the Tanba Group of Ishiga, 1983) is reexamined, which is cited in Fig. 1 from Imoto (1984, column A in figure 15, on page 50). The section situated at the middle stream of the Ashmi-dani river, Keihoku-cho, Kitakuwada-gun, Kyoto Prefecture, and is embedded in Jurassic melange complex (Tanba Belt Reseach Group, 1979; Imoto et al., 1989). The bedded cherts of the horizon 13 in the lower part yielded conodont *Gondolella foliata* (Budurov) of characteristic occurrence from the Upper Ladinian to Lower Carnian (Koike, 1982), while those of horizon 1-g *Epigondolella postera* occurred which is generally regarded to occur from the Middle to Upper Norian (Isozaki and Matsuda, 1982). These bedded cherts in the lower Tanbe nappe usually consist of the sequence ascendingly from Lower Triassic siliceous claystones with organic mudstones, bedded cherts, siliceous mudstones and sandstones of which lithologic change indicates pelagic to terrigenous via hemipelagic environments. Bedded cherts range from possible Lower Triassic (but mostly Anisian) to lower Middle Jurassic. The sequence here consists of three parts (lower, middle and upper parts), and lower and the middle parts are probably Ladinian-Carnian age and the upper part includes Norian age.

Bedded cherts of this section is typified in GB-type chert which means grey in color and biogenic clasts in composition (Imoto, 1984). Thickness of chert beds shows less than 6 cm and is a uniform pattern, while thickness of mudstone beds vaires over wide range. In the lower part of the sequence, thickness of mudstone beds is thick regardless of the relatively uniform thickness of chert beds. Thickness of both chert

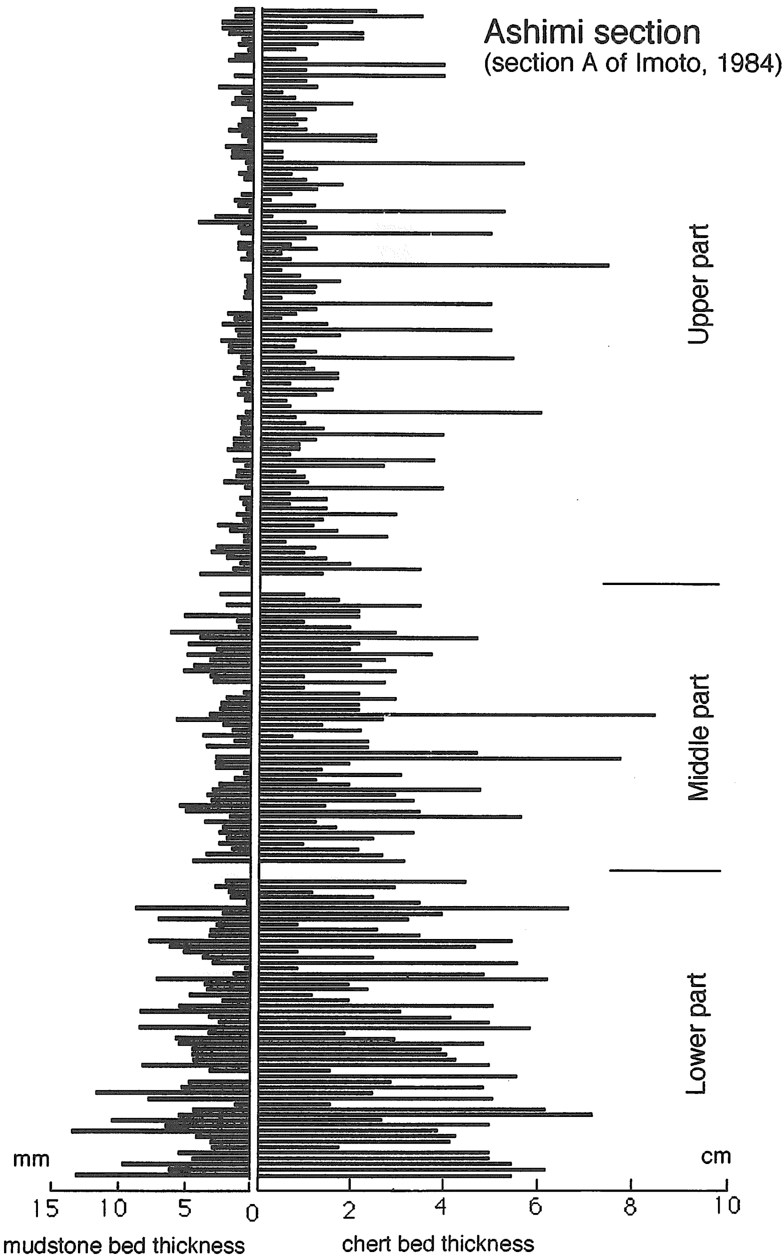

Fig. 1. Relationship between the thickness of chert beds and mudstone beds in the Triassic Ashimi-dani section (redrawn from the data of section A of Imoto, 1984).

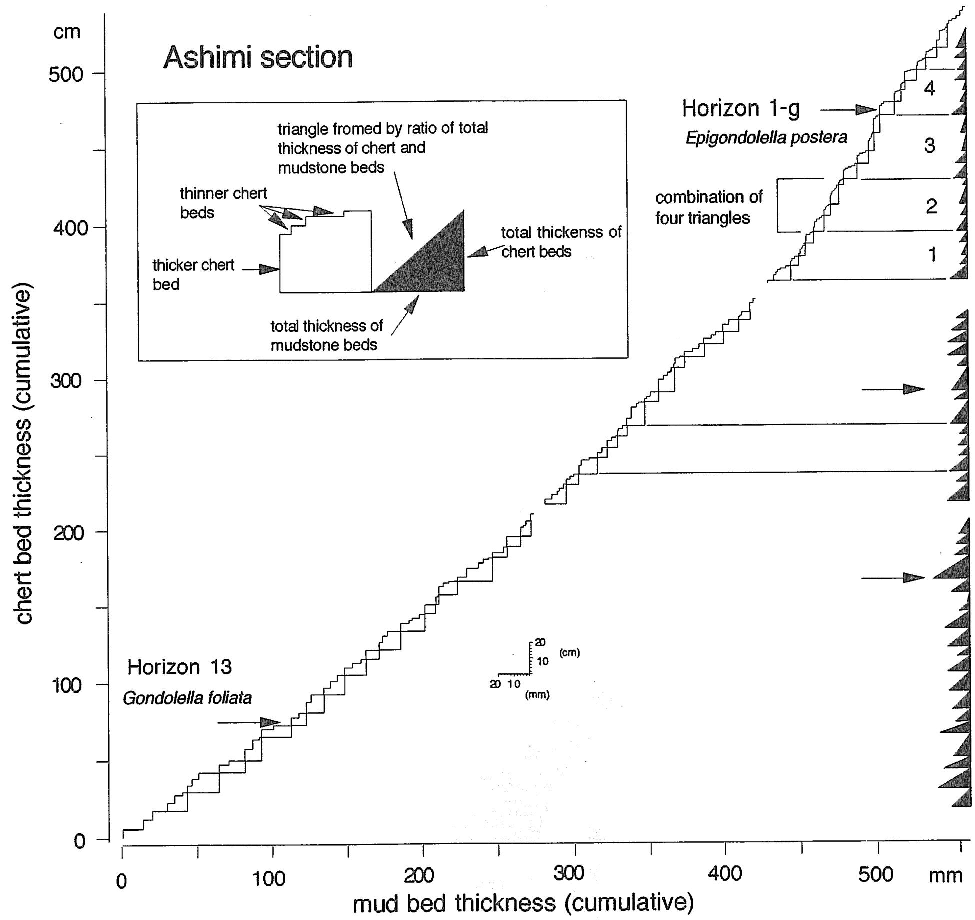

Fig. 2. Diagram indicating thickness of chert and mudstone beds in the Ashimi-dani section (data of section A of Imoto, 1984) and a set formed by thicker chert bed and following thinner chert beds is indicated. Dense triangles indicate total length of chert beds vertically, and that of mudstone beds horizontally in a set. Numbers 1–4 indicate other cycles formed by larger tringle and consequent three smaller ones. An arrow points possible larger triange.

beds and mudstone beds shows tendency to become thinner and thinner in upward direction, but in the upper part of the section, thicker chert beds occur in places with cyclicity. Adapting from the data of thickness of both chert bed and mudstone bed, cumulative diagram is drawn in Fig. 2, where thickness of chert beds in cm is given vertically, and that of mudstone beds in mm is horizontally.

Permian bedded cherts

Permian bedded cherts in the upper Tanba nappe of the Tanba Terrane (or type II suite of the Tanba Group of Ishiga, 1983) is reexamined, which is cited in Fig. 4 from Imoto (1984, column C in fig. 15, on page 50). The section is situated in Fujioka-oku, Sasayama-cho, Hyogo Prefecture, Japan in which radiolarian and conodont biostratigraphy was engaged in detailed (Ishiga and Imoto, 1980; Ishiga et al., 1982). The section consists of four parts of which the lower two are Lower Permian and the upper two are Upper Permian. Between the upper and lower part, although bedded cherts are apparently continuous, Middle Permian was missed to form a big hiatus.

Bedded cherts of the lower three parts are RB-RF type chert meaning red in color and biogenic in composition and red in color and fine grained siliceous materials (matrix) less than 0.7 μm in diameter with a small amount of well preserved biogenic

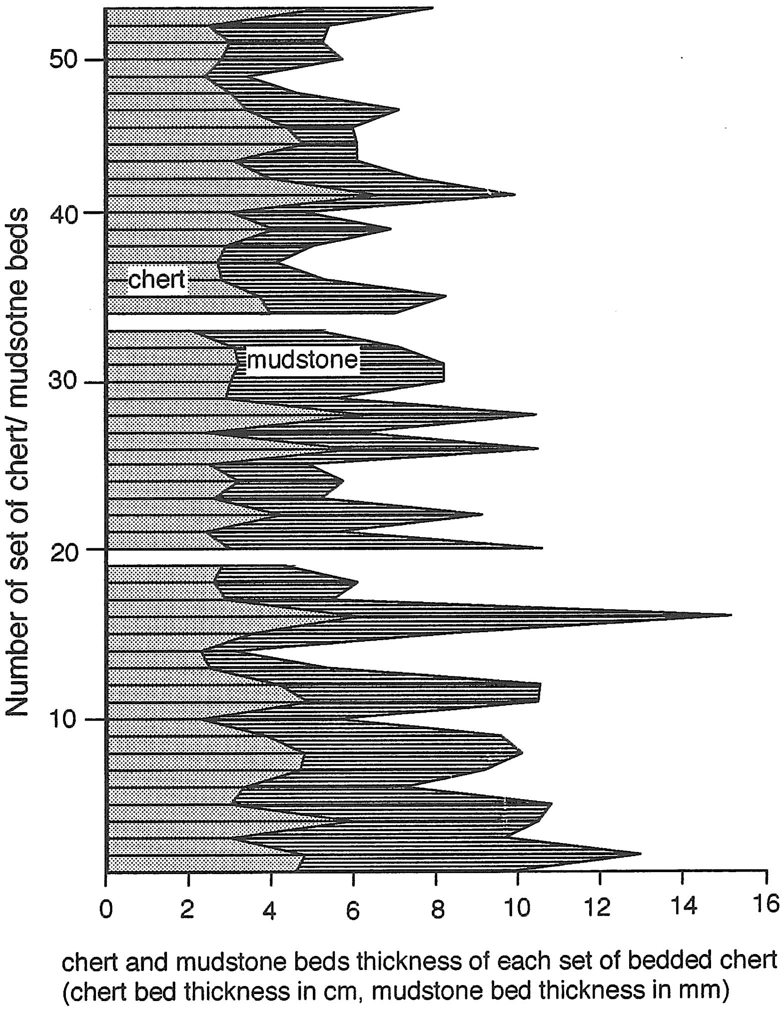

Fig. 3. Diagram indicating correlation of thickness of chert and mudstone beds of a set.

tests sporadically contained in the matrix.

Thickness of the chert beds of the lower part varies widely from 13 cm to about 1 cm in an irregular manner, while other three parts that of the chert beds commonly less than about 3 cm showing regular stratification. Cumulative diagram of chert beds and mudstone beds is given in Fig. 4 in the same manner to that of the Triassic one. Numbers given in this diagram indicate examined horizons yielding well-preserved radiolarians in Ishiga and Imoto (1980).

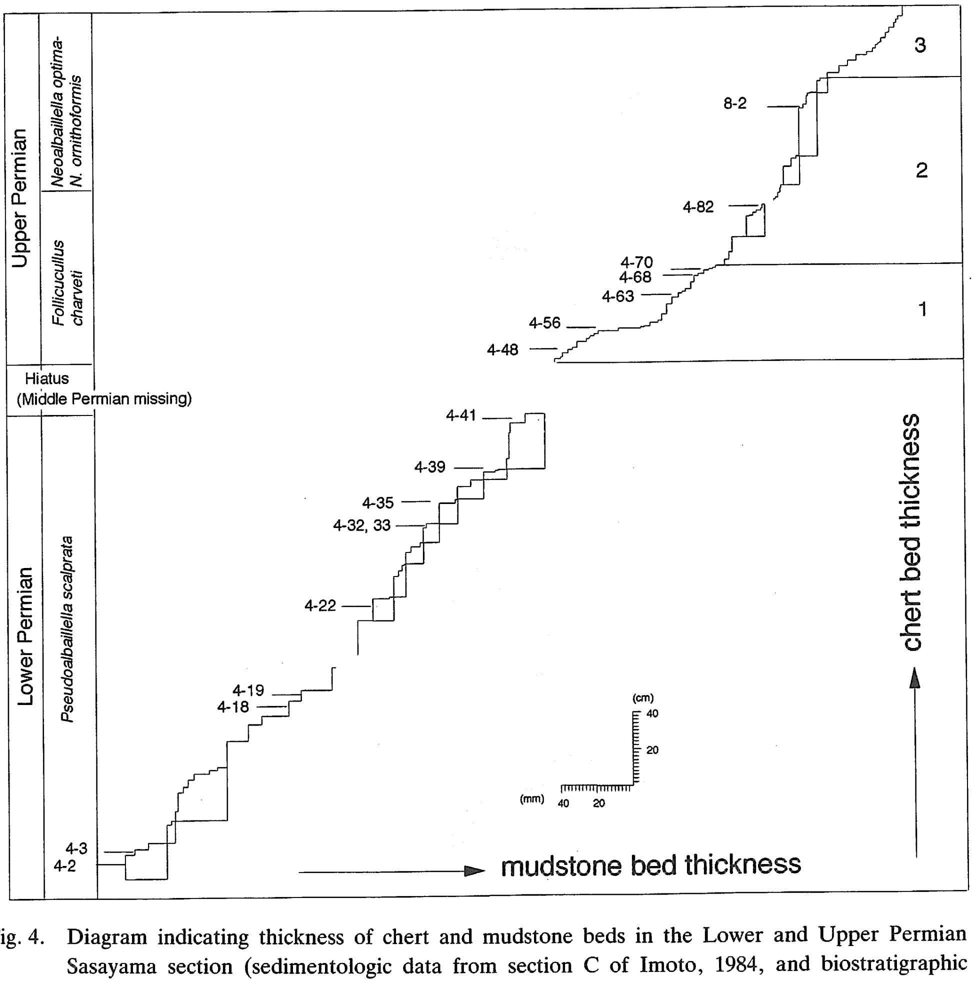

Fig. 4. Diagram indicating thickness of chert and mudstone beds in the Lower and Upper Permian Sasayama section (sedimentologic data from section C of Imoto, 1984, and biostratigraphic division modified from Ishiga and Imoto, 1980; Ishiga et al., 1982).

Results

Triassic bedded cherts

In the upper part of the section, as indicated in Imoto (1984) thicker chert layers occur with cyclicity and above this thick layer thinner several chert layers are usually accompanied. In forming a set composed of one and/or a few thicker chert layers and thinner chert layers, cyclic change of thickness of cherts can be apparent (Fig. 2). Dense tringles arrayed on right side of the graph indicate ratio of total thickness of chert layers and mudstone films of these sets of layering. In this array rather large triangles occur every four triangles and this is also indicative cyclicity. Characteristically thicker mudstone film is accompanied to the last bed or near last bed of this larger triangle. Thus the set of the chert beds proposed here is characterized by thicker chert layers in the first part and thicker mudstone films in the last part. If this packaging is tentatively applied to the Middle and Lower parts of the section, 52 sets can be recognized in whole section. In the middle part one cyclic change of triangles is recognized but the rest is unclear. In the lower part apparent cycle of triangles cannot be found and packaging a set of beds in some horizons is hard to be able. Possible large triangles are indicated by arrows.

Fig. 3 indicates relation of thickness of chert bed and mudstone bed in the sets of the bedded cherts. In taking account of set of bedded cherts, change of total thickness of chert beds and mudstone beds show intimate correlation.

Permian bedded cherts

A set found in Upper Triassic bedded cherts is rarely distinguished in the Permian section, but in the middle part of the Upper Permian and upper part of the Lower Permian, some sets could be recognized. Especially in the middle part of the Upper Permian three sets are resonably distinguished. Incomplete set which usually is composed of thick chert bed and one or two thinner chert beds occurred in the upper part of the Lower Permian. Noteworth is continuous occurrences of thinner chert beds in the lower and upper one third of the Upper Permian section.

Discussion

Cyclicity in Triassic bedded cherts

Two kinds of cyclicity recognized in the upper part of the section show similarity to those proposed in Tertiary turbidites by Masuda et al. (1989). Although the geologic situation of bedding of turbidites and bedded cherts is different mutually, some understanding of the formation of rhythmic bedding is indicative. Namely mudstone films of bedded cherts were deposited by aeolian dust, thus the sedimentation rate of pelagic clays is supposed to be constant. Cause of formation of cycles of bedded cherts can be reduced from cyclic deposition of siliceous materials of cherts. They are mainly radiolarians which show blooming in high primary production and they themselves yielding commensal algea (see Matsuoka, 1992). Nutrient supply and active circulation of surface current affect radiolarian blooming which in turn thick chert layers could be formed. In Fig. 3 thickness of chert layers and mudstone films in a set is given and the graph indicates, 1) total thickness of chert layers are rather constant, 2) thickness of total mudstone films in a set gradually decreased upward except for several strong peaks of chert layers and mudstone films. These strong peaks occurred cyclically and they correspond each other. This coincidence in thickness of chert and mudstone layers suggests radiolarian blooming is related to a high nutirent supply in relatively high-stand in sea level.

In the turbidite sequence, according to Masuda et al. (1989), deposition of thick sandstone is activated in the low-stand in sea level during the glacial period, while a mudstone dominant part formed in the high sea level period. If this idea of radiolarian blooming by the high supply of nutient, is applied to the bedded cherts in the upper part, the thick chert layer could be formed in the high sea level when river born nutrient materials could be trasported easily to the oceans and be spread out by active surface oceanic circulation. This phenomena could be clearly recorded in the high sea level of non-glaciation period (Masuda, 1991). And consequent thinner chert layers were in the low-stand in sea level. The nutrient supply is of course affected by other factors such that the cycles in the middle and lower parts of the section are unclear. They were under influence of other cycles of nutrient supply such as bottom currents and circulation of the ocean. When some incomplete cycles in the middle and lower parts are taking into consideration, sedimentary record of bedded cherts was possibly under influence of erosion by such currents.

Other possibility of an appearance of clear cycle of bedded cherts in the upper part of the section could be under the circumstances of relatively lower sea level in which an effect of sea level change could apparently recorded in sediments. If a sea level was relatively in high-stand of such as greenhouse state, a change of sea level could not be effectively appeared in the deposits both in terrigenous and in pelagic envidonments. As for the sea level change in Triassic time, it gradually became high towards Late Triassic and in turn lowered towards Triassic/Jurassic boundary at which a rifting occurred (Hallam, 1992). Thus in general Late Triassic occean could be relatively in the low-stand of sea level. This may explain also incomplete records of cycles of bedded cherts in the middle and lower parts of the section, which were probably deposited in the high-stand in sea level of greenhouse state.

Cyclicity of Permian bedded cherts

A set of bedded chert was roughly estimated in the section of Upper Permian and the clear difference of thickness patterns between the Lower and Upper Permian is recognized. That is incomplete, but steady rhythm of bedded cherts occurred in the Lower Permian while rather long thythmic change of thickness of bedded chert layers in the Upper Permian. Some relatively complete sets distinguished in the middle part of the Upper Permian can indicate rather high-stand of sea level appeared in this time. Continuous occurrences of the thin bedded cherts both below and above this part, may suggest reduction of radiolarian blooming towards the terminal Permian. As is well known Late Permian is the time of regression although glaciation was ceased already and it was in Green house stage. The active ciculation of oceanic surface supporsed to have occurred at this time stimulated radiolarian blooming and an evolution of new taxas. *Neoalbaillella* of the last radiolarian genera in the Paleozoic appeared in such time, where thick bedded cherts were formed (below the horizon 8–2). Noteworth is that horizons including well preserved radiolarians indicated by numbers almost coinside to the thinner bedded cherts above the thicker chert beds in a set. This may indicate thinner chert beds were formed under low sedimentation rate and complete radiolarian form could have been preserved in a fine siliceous matrix. If thicker chert beds were deposited during a same time span to those of thinner chert beds, thickness of chert depends on sedimentation rate.

Acknowledgements

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