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Straigraphic Correlation by Depositional Cycles of Bedded Cherts, Southwest Japan

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Upper Triassic bedded cherts are good example of recorded depositional cycles corresponding to the Milankovitch cycles, 100,000 years and 400,000 years, because radiolarian blooming was effected by nutrient supply in high-stand of sea level. Thus reading these cycles in bedded chert sequence by combination of thicker chert beds (activated radiolarian blooming and rapid deposition) and following thinner chert beds (weakened blooming) could be a new method for global correlation. This cycles clearly can be read in the Upper Triassic especially upper Carnian to lower Norian of relatively oceanic regression, while in the Middle Triassic, chert beds were deposited steady and evenly because of less effect of geologic cycles to radiolarian blooming at the time of relative transgression.

Introduction

Bedded cherts accreted to the Japanese Islands were originally deposited on greenstones of sea mounts and are typical example of pelagic sediments. Thus they are free from the direct supply of terrigenous materials, whose geochemical records reflect global change (Hori and Maruyama, 1991). Bed forms of bedded cherts also are indicative of the sedimentologic cycles in relation to the siliceous microplankton supply caused by blooming of those biomasses. Recent work on bedded cherts has been pointed to this fundamental problem, how the bedding of chert and mudstone was formed and reading the recorded cycles in alternation (Ishiga et al., 1993). The cycles in bedded cherts are represented by repetition of changing thickness of chert beds or sedimentation rate of chert beds, possibly reflecting radiolarian blooming. However this cyclicity in the beds appeared in particular age, such as Upper Triassic and some of the Permian, Japan. This is because cycles here discussed are due to the cyclic change in rather short term appeared in several beds of cherts, and probably occurred in regression of sea level which depressed radiolarian blooming (Ishiga et al., 1993). On the other hand mudstone beds were formed by steady and by regular deposition of aeorian clays, although they show gradual change in the long term like that of a period suffered a shifting between Ice house-Green house state. The Triassic is a time of recovery from the Permian/Triassic boundary oceanic deterioration and mass extinction, thus the bedded chert record could give an important information on environmental change and condition of the ocean.

Material studied

The examined sections of bedded chert sequence from the Tanba Belt and its extensions are well documented by conodonts and radiolarians. The sections are the Kuga section in Yamaguchi Prefecture belonging to the western extension of the Tanba Belt, and the Ashimi and Hozukyo sections in Kyoto Prefecture, of the Upper Tanba nappe of the Tanba Belt (or Type I suite of the Tanba Terrane of Ishiga, 1983), Southwest Japan. These three sections consist of black to grey bedded cherts of which thickness of chert beds varies from 1 to several cm and that of mudstone beds changes from less than 1 mm to 1 cm. Cyclic change of thickness of both beds is in part easily recognized in outcrop, namely a thicker chert bed followed overlying two to several thinner chert beds with intercalated mudstone beds (Ishiga et al., 1993).

Kuga section

This section consists of grey bedded cherts of about 20 m thichness which gradually change into Jurassic siliceous mudstones (Nishimura and Isozaki, 1986). The section was cut by fault accompanied by carbonaceous mudstones with 20 cm thickness and was tectonically underlain by other sequence of bedded cherts. Measured part is lower part of the section (about 4 m thickness), which shows regular stratification. *Epigondolella nodosa* from the lower horizon of the section, *E. abneptis* from the middle horizon and *E. postera* and *E. bidentata* from the upper horizon were reported (Nishimura and Isozaki, 1986). Thus the measured section included the Upper Carnian to Lower Norian, for the upper horizon of the section yielding *E. bidentata* which is indicative of the Upper Norian. Although the microfossil indicates biostratigraphic continuation of the bedded chert sequence, in the middle to upper horizon of the section, bedded cherts show microfolding interrupted by slip plane.

Ashimi section

The section consists of grey bedded cherts of about 7 m thickness and is intercalated in the Jurassic melange unit. The section consists of 3 parts interrupted by lack of exposure, but they are regarded to be continuous sequence.

Conodonts occurred from the sequence are, *Gondolella foliata* from sample no. 13 of the lower part of the sequence and *Epigondolella postera* from sample no. 1-g of the upper part of it, thus the sequence includes the upper Ladinian to Norian (Ishiga et al., 1993).

Thickness of each bed was measured by Imoto (1984), and the data was reorganized to be drawn in cumulative curve in Ishiga et al. (1993) is adopted from the literature.

Hozukyo section

The section consists of grey bedded cherts of about 33 m thickness and conodont biostratigraphy was examined in detailed (Isozaki and Matsuda, 1982). The examined section of about 12.5 m thickness is horizons from 11 to 26 of Isozaki and Matsuda (1982), fig. 2 on page 106 and this part covers Ladinian to Lower Norian according to the series of occurrence of conodonts. The horizon 20 characterized by occurrence of conodont *G. mungoensis* possibly corresponds to Ladinian to lower Carnian and the horizon 25 of *E. nodosa* and *E. abneptis* to Carnian and Norian boundary.

Feature of depositional cycle of bedded cherts

Cumulative curve of bedded cherts is drawn where thickness of chert bed is plotted vertically and overlying mudstone bed horizontally in each bed of the bedded cherts, of which method is indicated in Ishiga et al. (1993).

Kuga section (Fig. 1)

The attitude of cumulative curve changes in the lower horizon and in the upper horizon. Change of inclination of the curve is appeared by the series of alternation of thickness of both chert and mudstone beds. Thicker mudstone beds form gentle inclination while that of thicker chert beds with rather thinner mudstone beds form steeper curve. The cycles are recognized by a set of thick chert beds with following thinner chert beds. In the lower part of the section, these sets are not so clear, which are tentatively set by combination of a thicker chert bed and one or two following beds. But in the middle to upper part, chert beds following to the first thicker chert bed are very thin several beds (for example below the horizn of condont *E. abneptis*), which form a clear set of the chert and mudstone beds. In the range of this conodont, very thick mudstone bed occurred in two horizons and the cyclicity of bedded cherts seems to be changed from this horizon, i.e. rather thinner chert beds occupy the sequence and small triangle of cycle can be recognized. As a whole of the section, clear cycle of bedded chert appeared in middle to upper part of the section which could correspond to the upper Carnian to Norian on the basis of conodont.

Ashimi section (Fig. 2)

Feature of set of bedded cherts gradually changes upward. Those in the lower part, set is not so clear, but it comprises the first thick chert bed and following couple of or three apparently thinner chert beds. Tendency of forming clear distinctive set actually occurred in the middle and that are most distinctive in the upper part. In the upper part, thick chert bed followed by several thinner chert beds and finally rather thicker mudstone bed covered the chert bed, of which set is easily recognized in this part. Moreover as indicated in Ishiga et al. (1993), larger triangle is overlain by three small triangles, and second order cycle is recognized in the upper part. *Epigondolella*

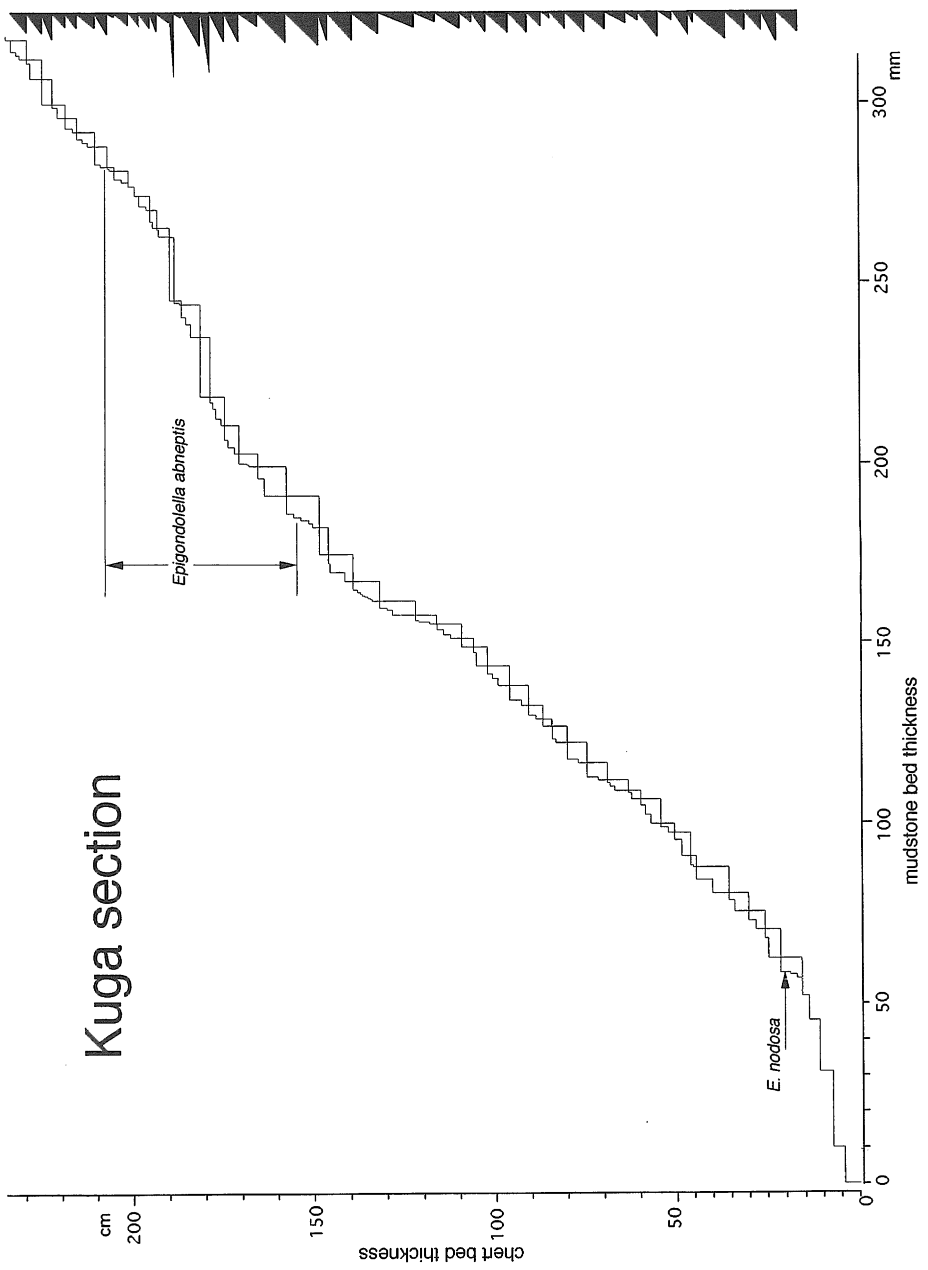

Fig. 1. Cumulative curve of bedded chert sequence of the Kuga section, Yamaguchi Prefecture, Japan. Conodont data from Nishimura and Isozaki (1986), p. 45.

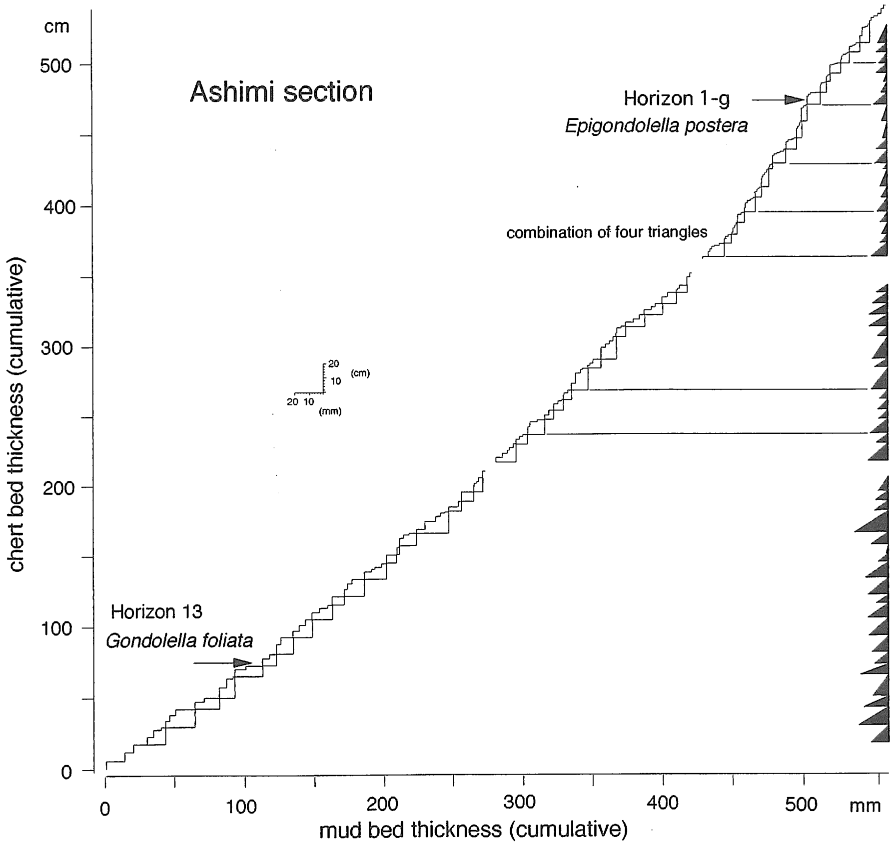

Fig. 2. Cumulative curve of bedded chert sequence of the Ashimi section adopted from Ishiga et al. (1993) and original data from Imoto (1984), Kyoto Prefecture, Japan.

potera occurred from the forizon 1-g and the bedded chert of the upper part of the Ashimi section includes Carnian/Norian boundary. On the basis of occurrence of conodonts from upper and lower parts of the section mentioned above, cycles in the section gradually become clear from lower to upper part of the sections and first and second order cycles appeared in the upper part.

Hozukyo section (Fig. 3)

The lower part of the section was occupied by gentle curve formed by thicker mudstone beds and which gradually become steeper and steeper in the middle part of the section. Clear cycle comprised by a series of set can be recognized in the upper part nearly from the conodont horizon 20 to the top of the section. However in the lower and middle part, such set is not distinguished except some horizons indicated in the figure. According to the occurrence of conodonts, the upper part of the section

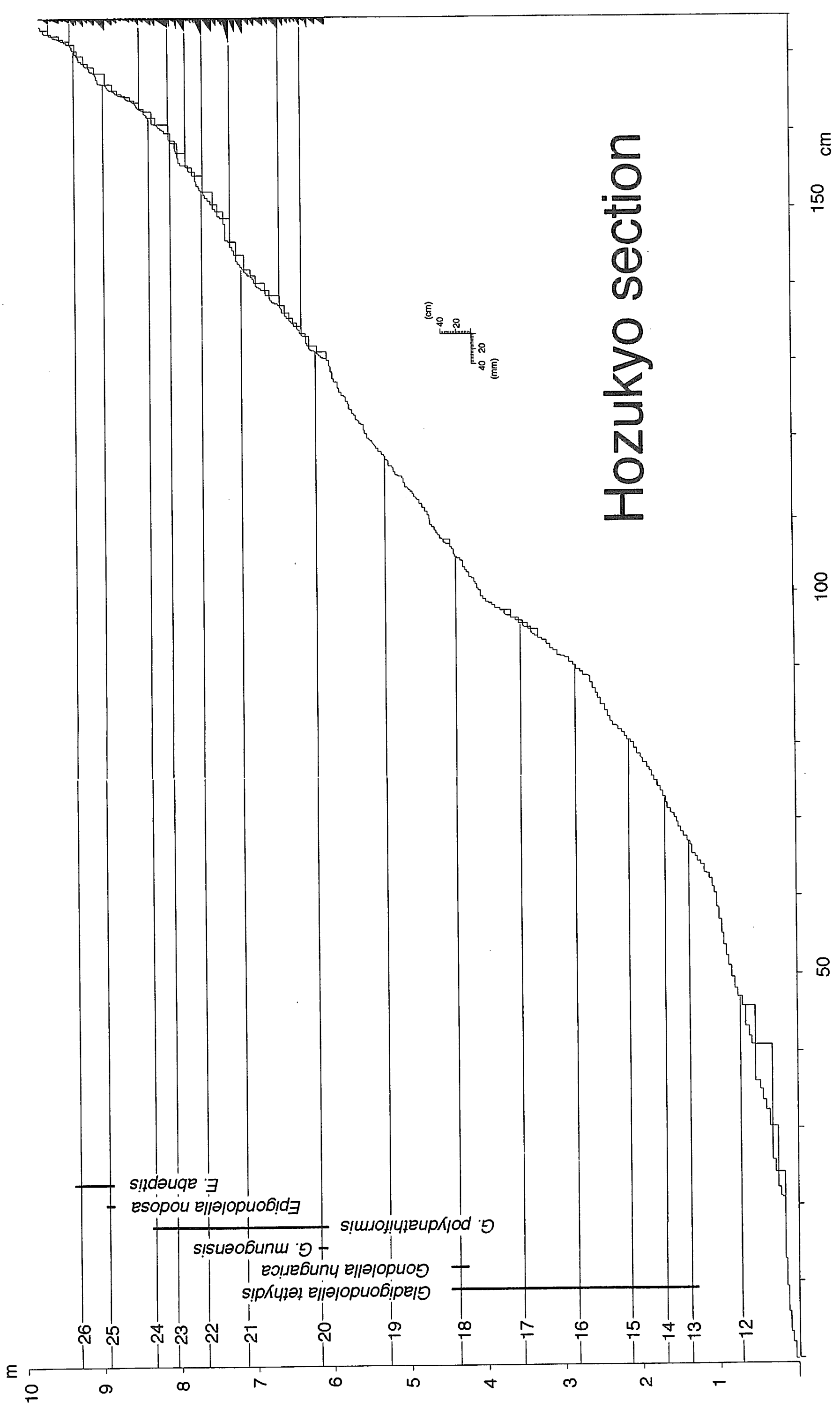

Fig. 3. Cumulative curve of bedded chert sequence of the Hozukyo section, Kyoto Prefecture, Japan. Conodont data from Isozaki and Matsuda (1986), p. 106, figure 2.

covers Carnian to lower Norian and this is concordant to other two sections mentioned above, which means clear cycles were recorded in the bedded chert of possible Carian and lower Norian.

Correlation of bedded chert sequences by depositional cycles—a new method of stratigraphic correlation—

Depositional cycles in bedded cherts and environmental change

Despite some depution on the tectonic setting of depositional basin, bedded cherts were formed in pelagic environment in which global change of continental geochemical composition was expected to be recorded (Hori and Maruyama, 1991). This is because bedded cherts are free from the detritus materials, which comprise mainly of biogenic silica such as radiolarians and clay minerals, and the latter were apparently transported as aeorian clays or dusts. It is seeming that voluminous change of main components of the chert beds, i.e. radiolarian blooming was greatly indebted to environmental change of ocean, especially nutrient supply in high-stand in sea level. The current change occurred in supposed sea-level change, which was controlled by the earth's rotation, ridge volume and glaciation (for example Hallam, 1981, 1991). If radiolarian blooming depends on active circulation of ocean current, depositional rate of cherts was accelerated in high-stand in sea level as discussed in Ishiga et al. (1993). Cycles recorded in bedded cherts can be read clearly in the Carnian to Lower Norian as examined in three sections. And noteworthy is typical and distinct sets appeared in the Upper Carnian and Lower Norian. As is known in this age, Norian is the time of relatively low-stand in sea level (Hallam, 1992) and mass extinction occurred (Berger et al., 1984). If cycles of bedded cherts recorded rhythm of global change, then the cycles in pelagic sediments could be a new tool of international correlation. And lacking of cyclicity in the Middle Triassic cherts as indicated in the possible Ladinian of the Hozukyo section points an idea that radioalrian blooming could not be effected by these cycles when depositional basin was relatively in condition of transgression.

Correlation by depositional cycles of bedded chert

Correlation of bedded chert sequence by cycles formed by a set of bedded cherts is tentatively done in three sections described here. Sets represented by dense triangles on left side and probable combination of four triangles are indicated in Fig. 4. As for patterns in the Ashimi and Hozukyo sections, characteristic changes of size of triangles seem to be similar each other. Correlation of both section is indicated in the figure with numbers of triangles which will help understanding of comparison. Set of four triangles usually is composed of ascendingly largest triangle and small three ones. But in Hozukyo section fourth triangle becomes rather large in size than third or second ones for examole no. one and seven. Triangle one consists of ascendingly, largest

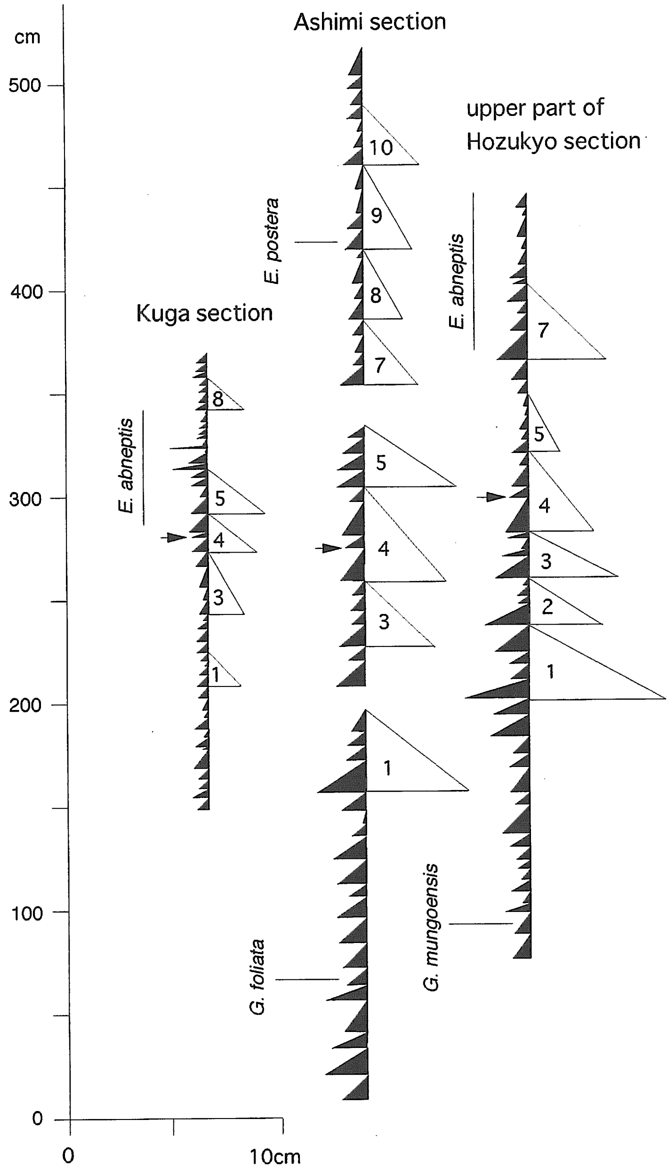

Fig. 4. Correlation diagram of three sections. Possible set of four trangles is indicated.

triangle and two small and one rather larger triangles in the Hozukyo section, and in the Ashimi section largest and small three triangles. And that of no. seven in both section is quite similar constitution and proportion.

Through recognition of compositional set of four triangles, peculiar combination of triangles was recognized in no. 4. This is characterized by second small triangle and same propotional change among four triangles can be seen in both Ashimi and Hozukyo sections. To correlate this horizon, 7 combination of triangles in Hozukyo and 10 combination in the Ashimi sections were discriminated, although they have lacked combination or fundamental triangles. This correlation is extended to those of the Kuga section, and possible five combination numbered as 1, 3, 4, 5, 8 are recognized. As for no. 4 second small triangle is apparent but here small triangle occupying in top of the triangles in other two sections is lacking. Triangle size variation among three sections could be understood local difference of radiolarian blooming, and correspondance of each of four triangles set could be a reflection of cyclic change of radiolarian biotic event from active blooming and rapid deposition to ceasing of fertility. A cycle formed by combination of four triangles could be caused by a long termed change of oceanic environment.

Time span and sedimentation rate deduced by cycles of bedded cherts

Masuda et al. (1989) indicated cycles of sandstone and mudstone beds in Tertiary tubidite are 100,000 years and about 400,000 years which coinside to Milankovitch cycles. If this time span is comparative to those of the bedded cherts, then one triangle included 100,000 years and composite set of four triangles 400,000 years. In the Ashimi section 37 triangles are set from conodont horizon *G. foliata* to *E. postera* (Fig. 4) of which dated conodont occurred and possibly Carnian is included. Thus 3.7 Myr is calculated from numbers of triangles. In this section no. 6 (whole four triangles) and two triangles of no. 2 are lacking, therefore at least 43 triangles are expected to occur in this range. Estimated time span for this range is then 4.3 Myr, which is unexpectedly close to the time range of the Carnian which is given for 5 Myr (Harland et al., 1989). This strongly supports that radiolarian blooming could be effected by nutrient supply current (Ishiga et al., 1993), which was activated in high-stand of sea level in regressional time. Clear cycles read in upper Carnian to lower Norian could be formed by sea level change, nutrient supply and activation of current coincidencial to the Milankovitch cycles. Hetherto the Milankovitch cycles in bedded cherts were examined through investigation of thickness of beds, geochemical components and extra-terrestrial metarials (Hori and Cho, 1991) all of which fundamental unit was based on a single bed. Set of chert and mudstone beds and four triangle sets are significantly useful for reading rhythm of the oceanic environment and for understanding formational mechanism of bedded cherts.

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