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Discussion

Upper Cretaceous stable carbon-isotope stratigraphy of terrestrial organic matter from Sakhalin, Russian Far East: a proxy for the isotopic composition of paleoatmospheric CO_2

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1. Introduction and overview

We are very grateful to see a comment on our results and discussion, and happy to have an opportunity to reply the comment. We must say, however, that most of the comments by Yazykova and Zonova (Y&Z) are based on their misreading and personal scientific opinion that may contradict with ours. That may also come from their misunderstanding of basic standpoint of Hasegawa et al. (2003). We try to solve each of them after explanation about the status of biostratigraphy in Hasegawa et al. (2003) in order to offer the comment authors correct information that we really want to let them understand.

First of all, Y&Z require a detailed biostratigraphy incorporating previous Russian studies. As Hasegawa et al. (2003) documented, it is not our final destination. Poyarkova (1987) showed comprehensive biostratigraphy of Naiba area; however, locality information for the outcrops are inadequate to extrapolate them onto our composite section. Biostratigraphy in Hasegawa et al. (2003) played just a role of rough age assignment in order to tune and correlate the obtained carbon isotope profile to internationally well known carbonate profile (Jenkyns et al., 1994). Our biostratigraphy established with specimens *collected with geochemical samples* at the same time by single research group was worth enough for it rather than the extrapolation of previous data.

Our biostratigraphic scheme established in Japan including Hokkaido grounds on hundreds of works published in English since 1930th with Tatsuro Matsumoto as the leader (e.g. Matsumoto, 1942–1943). Carefully selecting common and widespread taxa in the North Pacific realm, the scheme covers wide area extending 1000 km or more. The applic-

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ability has been already confirmed not only in major 10 sections in Hokkaido but also in three sections in Sakhalin (Shigeta et al., 1999). To enhance the accuracy for international correlation, the Japanese scheme has been repeatedly cross-checked by occurrence of internationally stage-diagnostic taxa. For example, the Cenomanian/Turonian boundary is cross-checked by LAD of *Rotalipora cushmani* (Hasegawa, 1997) and FAD of *Pseudaspidoceras* in Hokkaido (Hasegawa and Saito, 1993). Introducing satellite photography, detailed plan maps in the Naiba area are also open to the public so as to show the exact sampling points (see Kodama et al., 2002, Figs. 4–7). Therefore, the scheme summarized by Toshimitsu et al. (1995) seems much reliable than that of Poyarkova (1987, age assignment shown in Fig. 1 of the comment by Y&Z) in terms of testability, and the best for our purpose to give international stage assignment for the Cretaceous in Naiba area where we can rarely collect internationally age-indicative species. We avoid discussing availability of Poyarkova (1987) age assignment simply because it is not our purpose.

2. Counter-arguments

2.1. Cenomanian/Turonian (C/T) boundary

2.1.1. Zone lacking macrofossils in Fig. 2

It means the "zone lacking stage-diagnostic macrofossils". We obtained many macrofossils near the estimated C/T boundary, but we excluded non-diagnostic taxa from our discussion.

2.1.2. Positive C/T boundary spike

Actually, the horizon of the prominent C-isotope spike is located in the middle of member B1 (Kodama et al. 2002) and just below the member 3 (see far right of Fig. 1 of the comment) that is really concordant with Y&Z's opinion. In spite of this, they think middle Cenomanian is more plausible for assigning the δ^{13}C spike. It may be their misunderstanding of our information. Probably Y&Z confused the Shadrinka sandstone in the lower Bykov Formation (at lower part of member B1 of Kodama et al., 2002 but not shown in their figures) with upper sandstone member (N3 of Kodama et al., 2002) of Naiba Formation. Even though the prominent positive C-isotope spike is encompassed by zone lacking age indicative fossils, the values and pattern of C-isotope profile are unique enough (as we explained as segments NB0–NB2 in Hasegawa et al., 2003) to identify and correlate with other published profiles with a chronological limitation by fossil record from above and below this zone. The spike marks −22.7‰, the most positive value throughout the Naiba section followed by stable segment ~−23.5‰. This is the only feature for the C/T boundary and no other part of the Cenomanian and Turonian have this characteristic C-isotope profile. That's why we cannot agree the opinion by Y&Z.

2.2. Turonian/Coniacian (T/C) boundary

2.2.1. Position of the T/C boundary

Kodama et al. (2002, Figs. 3 and 4, Table 2) placed the T/C boundary between LAD of *Inoceramus teraokai* and *I. tenuistriatus* and FAD of *I. uwajimensis*. We agree their conclusion and followed them.

2.2.2. Positive spike at the base of Coniacian

Based on biostratigraphy by Kodama et al. (2002), we stratigraphically place a positive broad excursion in the lower Coniacian. Good consistency with the isotope profile and biostratigraphy (Fig. 5 in Hasegawa et al., 2003) supports our view. Such a long-term wave of δ^{13}C value as through Coniacian is interpreted to reflect fluctuation of steady state of global carbon cycle and not a spike-like sharp horizon marker. A modest positive excursion near the top of Turonian in East Kent (Jenkyns et al., 1994) that is also observed in other areas (Wiese and Kaplan, 2001) cannot be identified in the Naiba section probably because of our sparse sampling across the horizon.

2.3. Campanian, Maastrichtian and Cretaceous/Tertiary (K/T) boundary

2.3.1. Santonian/Campanian boundary

This boundary was magnetostratigraphically identified at the base of C33r (Kodama et al., 2000) as clearly mentioned in Hasegawa et al. (2003) on the basis of most reliable time-stratigraphic chart compiled and established by Hardenbol et al. (1998). Because the issue of boundary definition between Santonian and Campanian have not been resolved yet, we believe that following Hardenbol et al. (1998) is the best objective way to draw the boundary. Y&Z seem to pick up papers preferentially to criticize us writing down as we confused the age of *Sphenoceramus schmidti*. We cannot accept such non-scientific insistency by Y&Z.

2.3.2. "Lower" or "upper" Campanian

Without considering faunal provincialism during Campanian time, it is barren to debate whether "lower" or "upper" only by endemic taxa. Otherwise, common axes are needed. Kodama et al. (2002) first provided the common axis, magnetostratigraphy, for correlation of the upper Cretaceous in Sakhalin. Hasegawa et al. (2003) and many other studies on carbon isotope stratigraphy can offer another common axis for the correlation in East Asia region. These forerunning results will be challenged by various ways, but critics should show new original data of magneto- or carbon-isotope stratigraphy before debate.

2.3.3. Position of Campanian/Maastrichtian (C/M) boundary

Y&Z assumed the C/M boundary between the members 3 and 4 (Fig. 1 of the comment). However, it is rejected because abundant upper Campanian fauna, e.g., *Canadoceras multicostatum* and *Menuites soyaensis*, occur continuously from the members 3 and 4 (see Kodama et al., 2002, Figs. 4 and 8, Table 3; Matsumoto, 1984). Y&Z appear to understand that Hasegawa et al. (2003) located a negative excursion of δ^{13}C value at the C/M boundary in Figs. 4 and 5; however, careful reading can allow them to find the most negative value of the excursion is actually located in the upper part of C31r that is *above* the C/M boundary (Hardenbol et al., 1998). We emphasize that the result from carbon isotope stratigraphy is well concordant with the interpretation of magnetostratigraphy (Kodama et al. 2000). Majority of middle to upper Maastrichtian is represented by normal chrons (C31n and C30n; Hardenbol et al., 1998) those never allow us to correlate this negative δ^{13}C excursion to upper Maastrichtian broad trough.

2.3.4. Danian

We never deny the possibility that the Sinegorsk Formation is the Danian. Our study could not substantiate it, however. In usual, the upper Maastrichtian "*Inoceramus*" *awajiensis* zone covers the underlying *Zelandites varuna* zone. The former is not observed even in the top part of the Krasnoyarka Formation in the Naiba area (Kodama et al., 2002). These facts makes us hesitate to recognize the K/T boundary now. Therefore, we simply followed the interpretation based on magnetostratigraphy (Kodama et al., 2000). Our results do not show any incoherency with it.

3. Epilog

The purpose of Hasegawa et al. (2003) was to reveal time-stratigraphic profile of δ^{13}C value of terrestrial organic carbon from Naiba section, to compare the profile with well known carbonate profiles, and to discuss driving factors for these carbon isotope values through time. We did not intend to achieve detailed chronostratigraphic calibration with Hasegawa et al. (2003) only.

Discrepancy of biostratigraphic schemes between Russia and Japan is partly attributable to miss-identification of the taxa by Russian paleontologists. As shown in Yazykova et al. (2004), most of the zone-indexing taxa, particularly ammonoids, were originally described by Japanese paleontologists since Yokoyama (1890), and Japanese institutes house most of the types. Russian paleontologists have never investigated these types although these are open to public. Identification only by literatures may sometimes cause poor result. From the viewpoint of population concept, unnaturally split taxa, e.g., *Schmidticeramus*, should be excluded. We actually hope close collaborative work with Russian paleontologists. Exact identification of taxa will be great help to establish the Cretaceous stratigraphy in the Far East Russia.

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