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POSSIBLE APPLICATION OF CARBON-ISOTOPE STRATIGRAPHY FOR EAST ASIAN CLASTIC SEQUENCES: A TOOL FOR CORRELATION OR PALEOENVIRONMENTS

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ABSTRACT

Previous studies demonstrate that carbon-isotope stratigraphy established with whichever terrestrial organic carbon or marine carbonate provides a tool for inter-regional correlation. Globally synchronous fluctuation of $\delta^{13}C$ value in the oceanic/atmospheric CO_2 reservoir through time provides such opportunity. However, carbon isotope ratio of terrestrial organic matter in sedimentary rocks could be biased by some local environmental factors. Such biased feature is expressed as a decoupling from stratigraphic profiles of $\delta^{13}C$ value for marine carbonate. It may obscure $\delta^{13}C$ profile for terrestrial organic matter making a non-marine/marine correlation by $\delta^{13}C$ profiles difficult. However, we could take advantage of the decoupling between $\delta^{13}C$ profiles from these two carbon species in order to understand the terrestrial paleoenvironment that caused the $\delta^{13}C$ profile biased. Recent innovation of analytical technology for mass spectrometry, such as organic compound-specific measurement will refine on this strategy based on carbon-isotope stratigraphy for both interregional correlation and regional paleoenvironmental reconstruction of non-marine sequences.

Keywords: paleoclimatology, paleoenvironment, carbon, isotope, correlation, Cretaceous, Yezo Group

長谷川 卓（2003）東アジアにおける炭素同位体層序の応用可能性： 陸成層における国際対比・古環境解析．福井県立恐竜博物館紀要 2：149–152.

最近の研究で炭素同位体比($\delta^{13}C$)の変動パターン比較により国際対比が可能なことが分かってきた．特定期の際立つ $\delta^{13}C$変動は化学的鍵層となる．この対比法は $\delta^{13}C$変動が大気海洋系の炭素循環の状態を示し，世界中同時に同規模で記録されたという前提に基づく．陸成層では有機物の $\delta^{13}C$値を測定するが，様々なバイアスを考慮すべきだ．有機物の起原（藻類，高等植物等），高等植物内でも個々の種の生理作用の差，植物体にかかる塩分，湿度，温度，CO_2分圧等の環境圧が $\delta^{13}C$値に影響する．一方，環境によるバイアスを含む $\delta^{13}C$層序から陸上古環境が解読可能かもしれない．蝦夷層群では陸上植物の $\delta^{13}C$が欧州の炭酸塩のそれに対して相対的に負にずれる期間がある．地球の平均気温と海水準が極大となったその時期，同層群の有機物供給場でも広域的温暖・湿潤化が生じ，植物群集がこれに反応したとすると現象をよく説明する．

有機分子毎の $\delta^{13}C$測定を可能にする技術は， $\delta^{13}C$層序に基づく国際対比・古環境解析を陸成層でも可能にするだろう．

INTRODUCTION

Carbon-isotope stratigraphy allows us an interregional correlation on the basis of time-stratigraphic fluctuation of carbon isotope ratio (e.g. Jenkyns et al. 1994; Beerling and Jolley, 1998; Menegatti et al., 1998; Gröcke et al., 1999). Because of inapplicability of magnetostratigraphy, carbon-isotope stratigraphy has been well studied for Upper Cretaceous strata in order to provide an independent time scale to supplement biostratigraphy.

On the other hand, Hasegawa (2003) found a consistent decoupling in the long-term $\delta^{13}C$ profiles between terrestrial organic carbon from Hokkaido sections, northern Japan and

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those of the European marine carbonate carbon based on a series of his studies for the last decade. Similar excursion diagnostic for terrestrial organic carbon profile is also observed in the northern stretch of the Yezo fore-arc basin (Sakhalin, Far East Russia; Hasegawa et al., 2003).

The purpose of the present paper is to review these recent studies briefly though critically and discuss our future prospects of these approaches.

CARBON-ISOTOPE STRATIGRAPHY AS A TOOL FOR CORRELATION

Carbon-isotope events specific for certain time intervals, e.g. Cenomanian/Turonian positive excursion, can be applied as chemostratigraphic "key beds". We must remind it as employed that this method based on assumption of both global ocean-atmospheric carbon cycle with its long-term fluctuations of steady state and short-term disturbances, and of each isotopic event being recorded in rocks contemporaneously around the world with same magnitude. A lot of potential factors masking the original carbon-isotopic signals of non-marine organic carbon should be considered for the application of this method when we select non-marine organic carbon for analysis. First of all, type of organic matter and its origin should be clarified. Even different species within a category of higher terrestrial plants may have different isotopic fractionation because of each specific physiological character. A variety of environmental pressures (e.g. salinity, humidity, temperature and pCO_2) may bias the original isotopic fluctuation of the atmospheric CO_2. Table 1 summarizes factors that could affect on carbon-isotopic ratio fluctuation recorded in terrestrial organic carbon and marine carbonate (See Arens et al., 2000; Beerling and Royer, 2002; Gröcke, 2002; Hasegawa, 2003, in press for details). Mechanisms of transportation, sedimentation and diagenesis may also mask original carbon-isotopic signals. Nevertheless, recent efforts showed a successful correlation between East Asian Cretaceous fore-arc basin (Yezo fore-arc basin) sediments (Hasegawa, 1997; Takahashi et al. 1997; Hasegawa and Hatsugai, 2000; Ando et al., 2002 and Hasegawa et al., 2003) and well-known European marine carbonate sections. In order to evaluate the terrestrial origin of organic carbon, Hasegawa (1997), Hasegawa and Hatsugai (2000), Ando et al. (2002), Shimizu et al. (2001) and Hasegawa et al. (2003) employed petrographic analysis of visual kerogen. Rock Eval pyrolysis and biomarker analysis (Hasegawa and Saito, 1993; Takahashi et al., 1997) can provide indirect information of organic composition to confirm the terrestrial origin. The terrestrial materials used in these studies are composed exclusively of plant fragments. Hasegawa (2001) inferred that they have been highly mixed during transportation to the Yezo fore-arc basin. Moreover, each carbon isotope value from a sample can be interpreted to have been averaged by post-depositional bioturbation representing approximately hundred years. In other words, the analysis of bulk rock terrestrial organic carbon isotope ratios in these samples dampens the influence of local effects although some differences are ascribed to minor stratigraphic missing and/or differences in sedimentation rates between the sections. These studies demonstrate that the primary carbon-isotopic fluctuations of atmospheric CO_2 have been recorded in higher plants in East Asia and can potentially provide a powerful tool for inter-regional correlation of inland basin sequences, too. Gröcke et al. (1999) analyzed hand-picked plant fragments in order to get $\delta^{13}C$ value of pure terrestrial higher plants from marine strata. Beerling and Jolley (1998) used monospecific pollen assemblage for carbon isotope analysis to discuss $\delta^{13}C$ fluctuations of paleoatmospheric CO_2. When we establish carbon-isotope stratigraphy for inland basin sediments, we need careful studies on organic petrology and organic geochemistry to select the best material for carbon isotope analysis.

TABLE 1. Factors affecting carbon-isotopic signals for two carbon species. **SST**: Sea surface temperature.

Factors affecting carbon-isotopic signals			Terrestrial organic carbon from C3 higher plants	Marine pelagic carbonates
Carbon-isotopic fluctuation of the ocean-atmosphere system			○	○
Fluctuation of SST			○+	○
$\delta^{13}C$ of local water mass				○
Global pCO_2 change			○?	
Global pO_2 change			○?	
Change of vertical structure of the ocean			○+	○
Terrestrial factors	Temperature		Under extreme condition	
	Local salinity		○	
	Humid climate-induced canopy effect of forest	local pCO_2	○?	
		CO_2 recycle	○	
	Water stress-induced stomatal effect		○	
	C4 plant incorporation		○	
Taxonomy of organisms (vital effect)			●	●
Differential degradation / diagenesis			● *	○

● May resolved by compound-specific (biomarker) / taxon-specific isotopic analysis
* No existence of precursor should be certified
\+ If the phenomenon is global

CARBON-ISOTOPE STRATIGRAPHY FOR PALEOENVIRONMENTAL RECONSTRUCTION

It is suggested that terrestrial paleoenvironment can be estimated from carbon-isotope stratigraphy only if the paleoenvironmental pressure is the only factor that affects on $\delta^{13}C$ value of terrestrial organic carbon except for the $\delta^{13}C$ value fluctuations of global atmospheric CO_2 (Table 1). It requires the assumption of constant effects from other factors mentioned above through time and same "taphonomical" condition through each sequence. Some sections of the Yezo

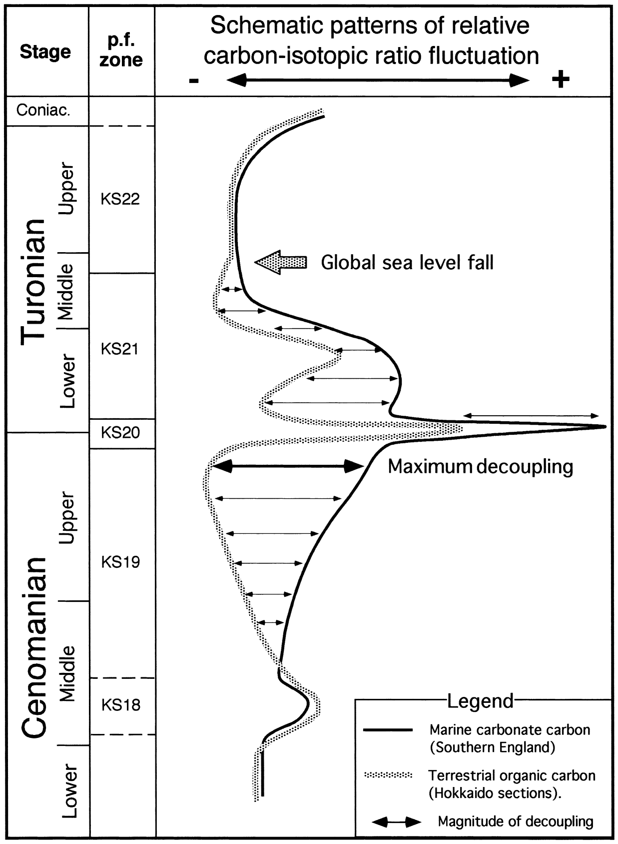

FIGURE 1. Schematic patterns of relative carbon-isotopic fluctuations of marine carbonate and terrestrial organic carbon. The curve of marine carbonate carbon from Southern England was simplified after Jenkyns et al. (1994). The curve of terrestrial organic carbon was drawn based on Hasegawa and Saito (1993), Hasegawa (1997) and Hasegawa and Hatsugai (2000). The magnitude of decoupling observed between terrestrial organic carbon and marine carbonate carbon is indicated with arrows. Note that maximum decoupling is located at the uppermost Cenomanian. **p.f.**: planktonic foraminifer.

Group, in which organic carbon are predominantly terrestrial, may satisfy the prerequisite. Hasegawa (2003) compared carbon-isotope curves from three Hokkaido sections (Oyubari, Tappu and Kotanbetsu sections) with those from carbonate sections in Europe (East Kent, England; Jenkyns et al., 1994) and North America (Pueblo, Colorado, USA; Pratt, 1985). The comparison reveals a long-term decoupling between the terrestrial organic carbon and carbonate carbon. The middle Cenomanian through middle Turonian sequences in Hokkaido show systematic negative shift of carbon isotope ratio for the terrestrial organic matter relative to European marine carbonate. Figure 1 simplifies the difference in the $\delta^{13}C$ profiles between the Japanese terrestrial organic carbon and English carbonate. Hasegawa (2003) discussed the relationship between this phenomenon and regional paleoenvironmental changes that may have controlled the plant communities in the provenance of the Hokkaido sediments. He assumed that only terrestrial factors modified the original $\delta^{13}C$ curve that reflects $\delta^{13}C$ fluctuations of ocean-atmospheric CO_2 reservoir (Table 1). This phenomenon can be best explained when the global higher temperature and high-stand sea level are supposed as the driving forces leading to regional warm and humid climate around the continental East Asia, the provenance of the Yezo Group.

FUTURE PROSPECTS

Discussions on carbon-isotope stratigraphy had been limited to carbonate sequences until 1992. After Hasegawa and Saito (1993), who analyzed carbon isotope ratio of terrestrial organic matter from the Yezo Group, methods using carbon isotope stratigraphy as a correlational tool and for paleoenvironmental discussions have been extended to Cretaceous clastic sequences in Japan. The Yezo fore-arc basin sediments have great advantage for establishing carbon-isotope stratigraphy of terrestrial organic carbon on the basis of simple bulk rock analysis. However, the application of the method to inland basin sediments may not be simple. For example, each sample from such sediments would represent narrower provenance and limited plant communities and, therefore, would be prone to be controlled by complex local factors. Nevertheless, the author believes optimistically that similar approaches will be available for inland basin sediments by recent innovations on analytical techniques and equipments (e.g. Hasegawa and Yoshida, 1999). Compound-specific isotope ratio analysis that enables us obtaining $\delta^{13}C$ values for each organic molecule (see Naraoka et al. 1997 for detailed explanation) will play an important role for our forthcoming breakthrough.

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