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STUDY OF CARBON-ISOTOPE STRATIGRAPHY OF THE TETORI GROUP, CENTRAL JAPAN : A TRIAL TO CORRELATE BETWEEN NON-MARINE AND MARINE STRATA OF THE JURASSO-CRETACEOUS

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ABSTRACT

Preliminary study of organic carbon-isotopes in a non-marine section of the middle and upper subgroups of the Tetori Group shows characteristic distribution of the carbon-isotopic values. Its stratigraphic profile has some features comparable to those compiled from many Tethyan marine carbonate sections in the Upper Jurassic and Lower Cretaceous. A long-term profile for the $\delta^{13}C$ values through the subgroups exhibits a fluctuation around the middle part with a single short-term excursion. This long-term pattern and a confined distribution of the $\delta^{13}C$ values within three permil appear to be features comparable with that of carbonate profile in the Tethyan region. The distribution of the $\delta^{13}C$ values between −25‰ and −22‰ well matches with the range previously reported for terrestrial higher plants from the Lower Cretaceous in Japan and Europe. This first data set of carbon isotope study for the Tetori Group does support the idea of correlation between non-marine and marine strata with carbon-isotope stratigraphy.

Key words: Toyama, Tetori Group, carbon-isotope, organic carbon, Cretaceous, non-marine, correlation

長谷川　卓・日比野　剛（2006）手取層群の炭素同位体比層序：ジュラ－白亜系の非海成－海成層対比の試み．福井県立恐竜博物館紀要５：15－24.

手取層群の中，上部の二亜層群についての有機炭素の同位体比を予察的に検討した結果，テチス海域の上部ジュラ－下部白亜系の炭酸塩セクションについての総括結果と類似する特徴を確認した．立山セクションにおける二亜層群の炭素同位体比の長周期変動は，セクション中部で明瞭な一つの短期的な正のエクスカーションを持つ．この長期的な炭素同位体比のパターンと，変動幅が約３‰に限定されるという事実は，テチス海域の炭酸塩プロファイルと共通する特徴のようである．－25‰と－22‰の間の値の分布は，これまで日本やヨーロッパの下部白亜系から報告されている陸上高等植物の値によく対応している．炭素同位体比のデータは手取層群から初めて報告されたが，炭素同位体比層序は非海成層と海成層との対比に使用できる可能性があるといえる．

INTRODUCTION

Non-marine Cretaceous strata including the major part of the Tetori Group are widely distributed around East Asia (e.g., Shen and Mateer, 1992 ; Krassilov et al., 1992 ; Badamgarav et al., 1995 ; Matsukawa, Takahashi et al., 1997). Their correlation and age assignment have been mainly based on non-marine mollusks (e.g., Chen, 1996 ; Matsukawa et al., 1997b) and plant communities (e.g., Kimura, 1987). The Tetori Group is composed of three subgroups, namely Kuzuryu, Itoshiro and Akaiwa Subgroups in ascending order. The middle and upper subgroups distributed around Hokuriku and Hida regions are composed of non-marine strata and are known to yield vertebrate fossils including dinosaur (e.g., Matsukawa, et al., 1997a ; Manabe and Barrett, 2000 ; Unwin and Matsuoka, 2000 ; Azuma

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et al., 2002 ; Hirayama, 2002 ; Goto et al., 2002 ; see also Table 1 of Matsukawa and Obata, 1994, for a list of dinosaur fossils from the Tetori Group). In spite of such occurrences of dinosaur fossils, few studies on interregional relationships of phylogeny and migration pathways for these dinosaur taxa (e.g., Manabe, 1999 ; Manabe and Barret, 2000) have been performed because of the poor age control for these subgroups. More detailed intra- and interregional correlations are required to advance paleontological and paleoenvironmental research on non-marine Cretaceous formations of East Asia.

Recent studies on carbon-isotope stratigraphy of the Cretaceous and Tertiary show that terrestrial organic carbon derived from higher plants basically records carbon-isotope value fluctuations of paleoatmospheric CO_2 (Hasegawa and Saito, 1993 ; Hasegawa, 1997 ; Beerling and Jolley, 1998 ; Gröcke et al., 1999 ; Ando et al., 2002 ; Gröcke, 2002). Without index fossils in a section of Hokkaido, Hasegawa and Hatsugai (2000) applied the carbon-isotope stratigraphy to locate the Cenomanian/Turonian boundary and discussed interregional correlation based on the pattern of the isotopic profile through the section. If carbon-isotope stratigraphy for a non-marine sequence is established, it enables the sequence to correlate directly to marine sequences and leads to variety of discussions about land-ocean climatic interactions. In order to be acceptable, a basic prerequisite should be satisfied for this approach to correlation : substantially identical origin of organic matter throughout the section studied. Some authors have analyzed taxon-specific fossils of pollen (Beerling and Jolley, 1998) or fragments of plant tissues (Gröcke et al., 1999). However, these methods can only be used when such materials are available and seem to be impractical for general use.

In this study we intend to show the first data set of organic carbon-isotopes from the Tetori Group (Itoshiro and Akaiwa Subgroups) with the simplest methodology, namely a whole rock analysis. The purpose of this study is to discuss the potential of carbon-isotope stratigraphy for interregional correlation of the subgroups. We checked the kerogen composition of selected samples to confirm the unique organic character of samples. Vitrinite and/or inertinite are expected as the major components of the kerogen for our non-marine samples. We understand that various taxa of organisms generate a single type of kerogen ; many terrestrial woody plant species can be transformed into vitrinite, for example. We employed this approach for initial evaluation of the organic matter. It tells us whether carbon-isotope stratigraphy has potential for correlation of the subgroups. The validity of our $\delta^{13}C$ values and of the distribution range (magnitude of fluctuation) among the data from various regions of the world is another basic view point to test the potential of carbon-isotope stratigraphy on the subgroups for inter-regional correlation . Carbon-isotope stratigraphy of terrestrial organic matter generally reflects fluctuations of carbon-isotopic composition for CO_2 in the ocean-atmospheric reservoir (e.g., Hasegawa, 1997 ; Gröcke et al., 1999 ; Hasegawa et al., 2003). If the carbon-sotope stratigraphy of the subgroups has potential for the correlation, the $\delta^{13}C$ values and their distribution range should be concordant with previous data.

To collect mudstones from the sequence of the Itoshiro and Akaiwa Subgroups, we selected the Tateyama section in Tateyama Town, Toyama Prefecture (Fig. 1).

GEOLOGIC SETTING

In spite of its limited exposures, we interpreted the Tateyama section to be substantially continuous, as Yamada's (1988) geological map around this section supports (Fig. 2). Potential faults or folds that cause minor duplication or lack of the strata may exist. If any exist, they do not affect general long-term trends of carbon-isotope values through the section.

According to Maeda (1956), the Tetori Group in northeastern Toyama Prefecture is composed of four lithologic units : the Joganjigawa Alternation of conglomerate and sandstone, the Shidakadani Alternation, the Nagaoyama Alternation of conglomerate and sandstone, and the Shiroiwagawa Alternation of tuff, shale and sandstone, in ascending order. Maeda initially named each of these units with "locality name + lithology" as an equivalent of a "formation", and correlated the units to formations of the Itoshiro and Akaiwa Subgroups, which are generally recognized in Ishikawa and Fukui Prefectures. Yamada (1988) treated these lithologic units as members in order to keep these names after applying some formation names to the Tateyama area. To avoid a confusion of nomenclature, we adopted "members" for the lithologic units originally described by Maeda (1956), but do not use Yamada's (1988) formations defined in Jinzu area because of difficulty in applying them to the study area. Yamada (1988) summarized the Tetori Group in our study area based on published and unpublished data, and interpreted that the upper two "members" represent the uppermost part of the Tetori Group in Toyama Prefecture. Similar tuffaceous features of the uppermost part of the Tetori Group in Ishikawa and Fukui Prefectures (See Maeda, 1961 and Yamada, 1988 for summaries) support this contention.

The Tateyama section has intercalations of fine-grained mudstone available for carbon-isotope study throughout the section. This is an advantageous character of the Tateyama section to this study over stratigraphically equivalent sections around the Kuzuryu and Tedori Valleys, which have intervals of less or no intercalations of mudstone.

The Tetori Group in the study area strikes NE-SW and dips 25 to 40 degrees northward. At the lowest part of the section, sandstone and conglomerate are predominant with minor intercalation of shale layers (<20 cm in thickness) and are assigned to the Joganjigawa Altnernation Member of conglomerate and sandstone (JAM). The sandstone and shale-dominated Shidakadani Alternation Member (SdAM) overlies JAM. The thickness of the SdAM, which is estimated to be ～340 m, does not change significantly in the study area (Fig. 2).

The Nagaoyama Alternation Member of conglomerate and sandstone (NAM) is distinguished from the underlying member by a predominance of conglomerate relative to sandstone and mudstone. The tuffaceous feature represented by intercalations of sandy tuff and tuffaceous shale layers characterizes this member. The lithology of the NAM gradually shifts into more tuffaceous facies with higher frequency of tuff, tuffaceous shale and tuffaceous sandstone intercalations exhibiting gradual contact with overlying Shiroiwagawa Alternation Member of tuff, shale and sandstone (SgAM).

AGE CONTROL FOR THE ITOSHIRO AND AKAIWA SUBGROUPS

Ammonite biochronology for the upper part of the Kuzuryu Subgroup has been believed to be Oxfordian age (Sato et al., 1963). Sato and Yamada (2005) recently reported newly discovered Early Tithonian ammonite from the Kamihambara Formation of the Itoshiro Subgroup indicating the lower limit of the Itoshiro Subgroup should be lower Tithonian or below. This restricts the basal age of the unconformably overlying Itoshiro Subgroup to Ealy Tithonian or older (Fig. 3).

Kawai (1961), Matsuo and Ohmura (1966) and Kimura (1975) discussed floral communities of the Itoshiro Subgroup and suggested Late Jurassic and Early Cretaceous for their age (Fig. 3). Kimura's (1975) interpretation well matches with the early Neocomian (Berriasian and Valanginian) age suggested from molluscan fauna of the Itoshiro Subgroup (Matsumoto et al., 1982). Fujita (2002) obtained bivalve specimens from Itsuki Formation, Itoshiro Subgroup, suggesting Hauterivian or Berriasian as the sedimentary age, which is younger than previously proposed.

Recently, Matsumoto et al. (2005) reported radiometric age for tuff layers of the Kuwajima Formation, Itoshiro Subgroup in Ishikawa Prefecture (Fig. 3). Their result was 130.7 ± 0.8 Ma indicating upper Hauterivian or lower Barremian. They also obtained similar 129.8 ± 1.0 Ma to 130.2 ± 1.7 Ma as the age for the Mitarai Formation, Kuzuryu Subgroup, and 132.9 ± 0.9 Ma to 117.5 ± 0.7 Ma for the overlying Okurodani Formation, Itoshoro Subgroup in Shokawa region. This fact suggests that the lower limit of the Itoshiro Subgroup is assigned to be ～130 Ma that contradicts the discussion above. We interpret the radiometric ages from the Shokawa region by Matsumoto et al. (2005) rather imply as follows : The Mitarai Formation is assigned to be Itoshiro Subgroup, not the Kuzuru Subgroup ; Kuwajima and Mitarai Formations are contemporaneous heterotopic facies. The lower limit of the Itoshiro Subgroup can be assigned to be below ～130 Ma and do not contradict to the age mentioned above.

For the Akaiwa Subgroup, Kimura (1975) interpreted the Akaiwa flora as late Neocomian (Hauterivian and Barremian), and the Tamodani flora as Aptian in age. Furthermore, the Kitadani Formation is assigned to be late Neocomian based on the molluscan Kitadani Fauna (Matsumoto et al., 1982).

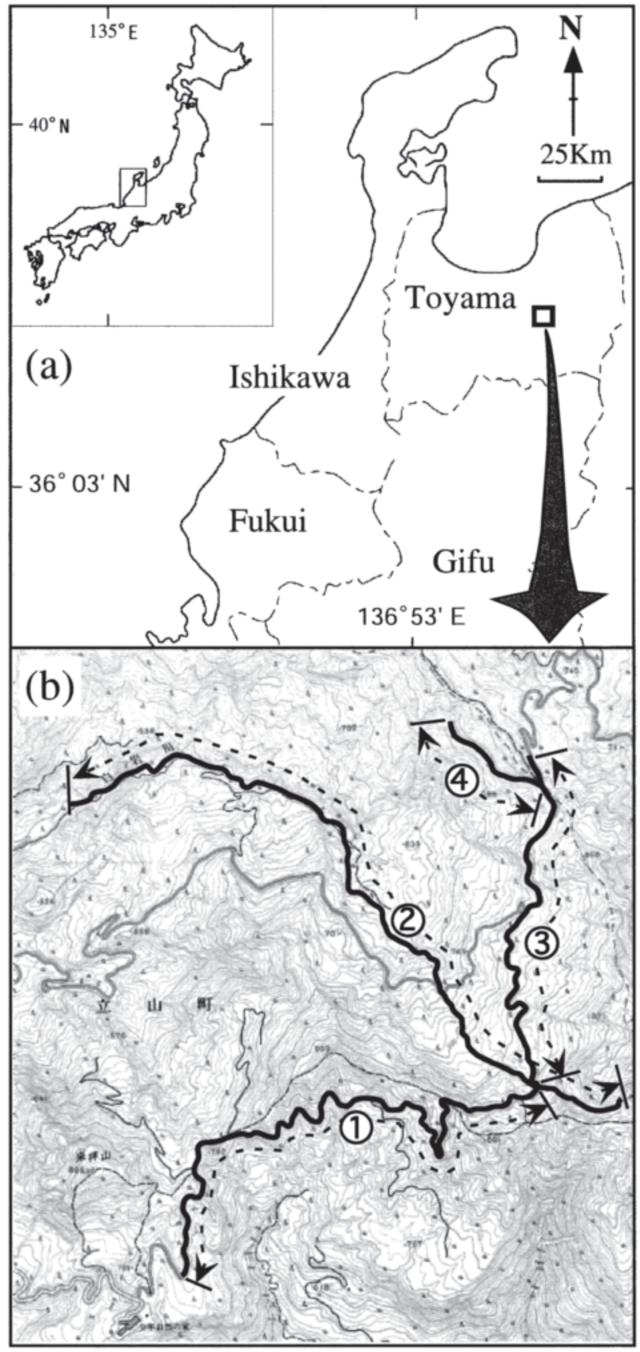

FIGURE 1. **a**, Map showing locality of the studied area ; **b**, Map showing routes from which samples are collected in Tateyama Town, Toyama Prefecture (from 1 : 25,000 topographic map "O'oiwa" published by Geographical Survey Institute of Japan). Number indicates a geologic column for each route in Figure 2.

Geological data from some igneous rocks constrain the age for the upper limit of the Akaiwa Subgroup. Radiometric ages for diorite that intruded Akaiwa Subgroup about 30 km SE from the

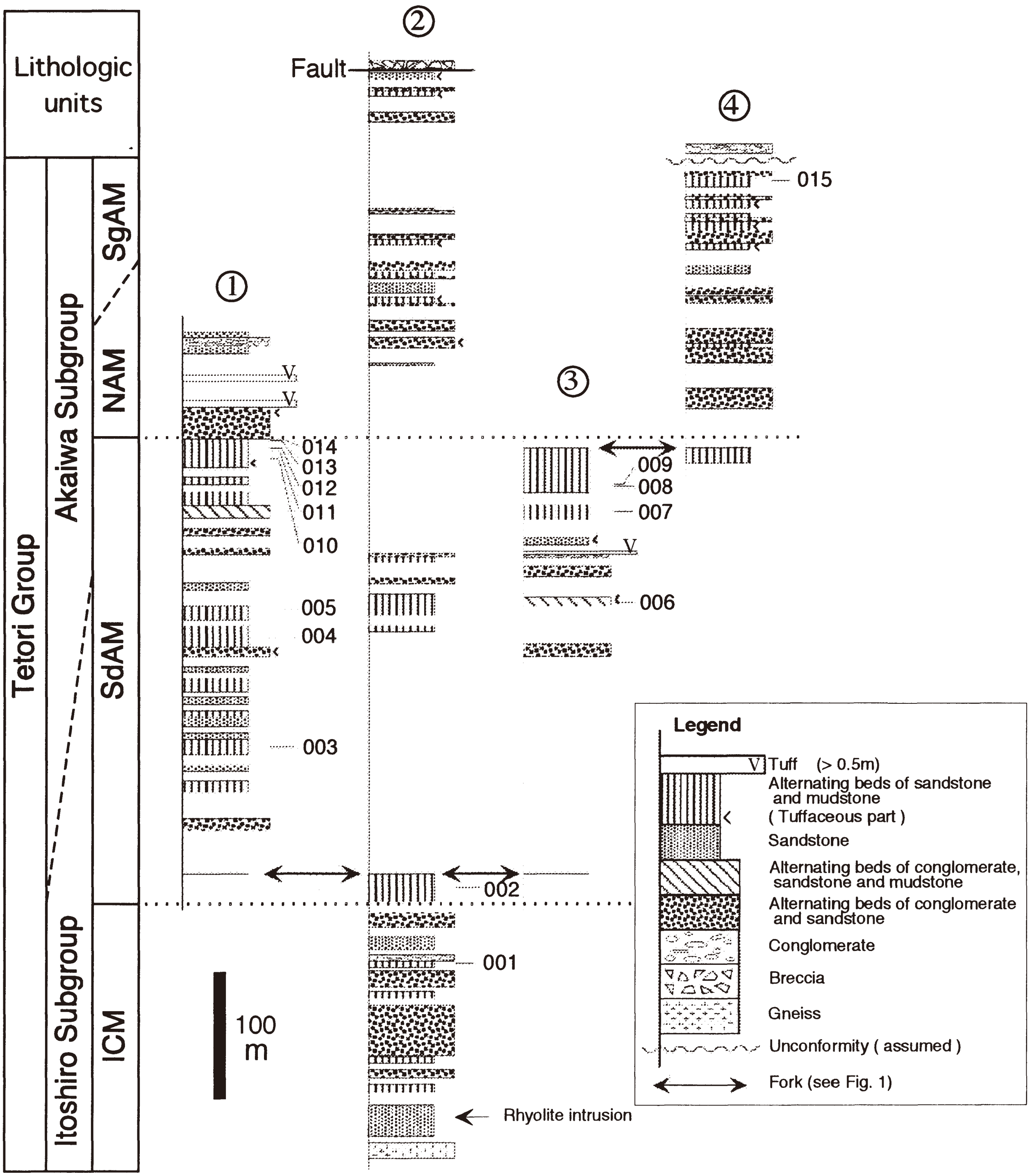

FIGURE 2. Geologic columns for the routes from which samples are collected. A number above each column indicates its locality shown in Figure 1. Members are tentatively identified based on previous descriptions, however, some boundaries between members are unclear and impossible to designate. For such case, boundary is expressed with an oblique broken line. JCM : Joganjigawa Conglomerate Member ; SdAM : Shidakadani Alternation Member ; NAM : Nagaoyama Alternation Member of conglomerate and sandstone ; SgAM : Shiroiwagawa Alternation Member of tuff, shale and sandstone.

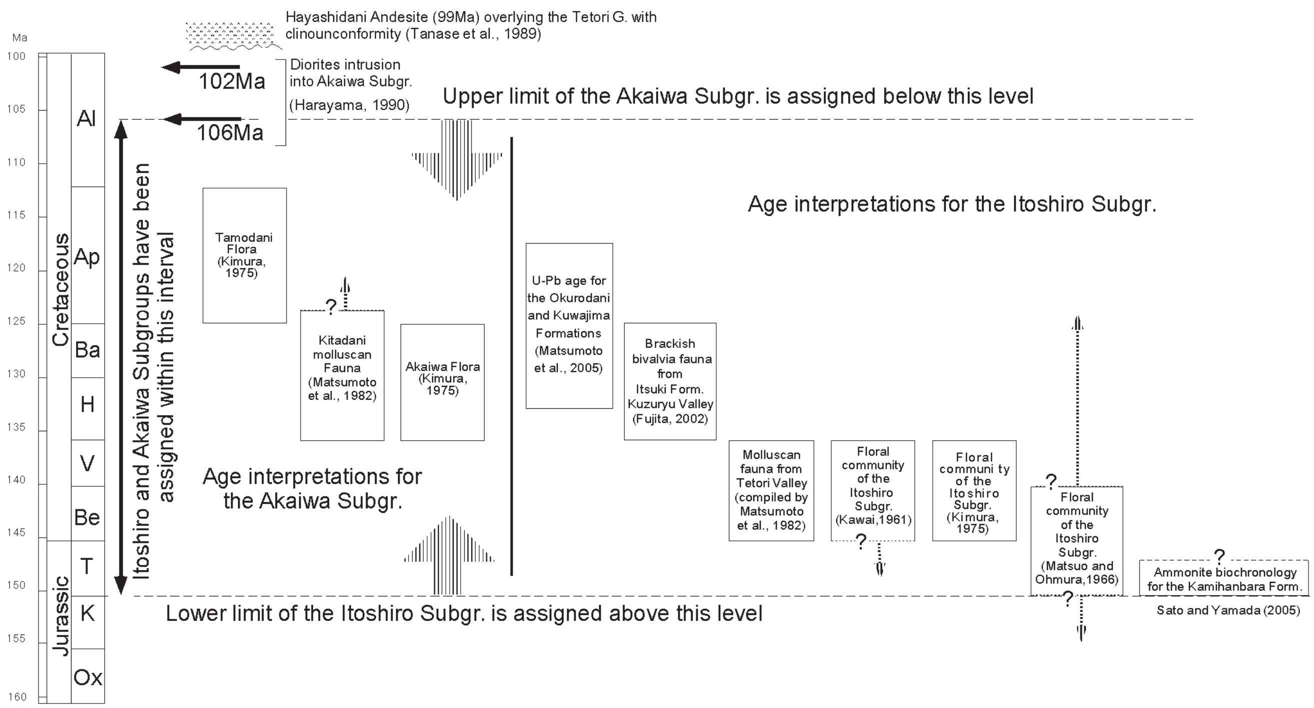

FIGURE 3. Age assumption for the Tetori Group based on previous studies. Relationship between stage boundary and absolute age is from Gradstein et al. (2004). Cl : Callovian ; Ox : Oxfordian ; K : Kimmeridgian ; T : Tithonian ; Be : Berriasian ; V : Valanginian ; H : Hauterivian ; Ba : Barremian ; Ap : Aptian ; Al : Albian. See also Fujita's (2003) summary for further discussion on age assignment of the Tetori Group.

study area indicate 102 Ma and 106 Ma (Albian), demonstrating the age for the Akaiwa Subgroup to be older than these ages (Harayama, 1990 ; see Fig. 3). Tanase et al. (1989) also reported 99 Ma for the Hayashidani Andesite that overlies the Tetori Group with clinounconformity in the Kuzuryu area. These ages form a general agreement that the upper limit of the Akaiwa Subgroup is Albian or older.

Age control for the Itoshiro and Akaiwa Subgroups around the Hokuriku region suggests that they encompass almost entire Early Cretaceous and possibly the Late Jurassic, ranging from Tithonian to Albian (Fig. 3). The Tateyama section is interpreted to represent a part of this time range. Board of Education of Toyama Prefecture (2003) reported fission track (FT) ages that support the interpretation above from the Tetori Group in Toyama Prefecture. They analyzed a volcanogenic gravel from NAM located ～1 km north of our route 4 (Fig. 1) and obtained 141 ± 6 Ma restricting the age of NAM near the Jurassic/Cretaceous boundary (145.5 ± 4.0 Ma ; Gradstein et al., 2004) or younger. Board of Education of Toyama Prefecture (2003) also reported 111 ± 6 Ma and 116 ± 6 Ma as FT ages for tuffaceous mudstone of the Tetori Group distributed in Jinzu Valley, Toyama Prefecture, suggesting that the age for the upper limit of the Tetori Group in Toyama Prefecture reaches to Aptian/Albian Period boundary or younger. It must be noted that any fossils available for age interpretation have not been reported from the Tateyama section.

METHODS

Because the majority of mudstone (shale) is too weathered for isotope study, sample intervals vary and are very sparse. Each of the samples used for this study was collected as a lump (>3 cm in diameter), cut into a cubic centimeter, then crushed and powdered in an agate mill. Samples those could not be collected as a lump or were broken before trimming into a cube were eliminated.

Powdered mudstones were treated with a 5 N solution of HCl for 12 hours to remove carbonate minerals. After repeated rinsing with deionized water to remove Cl^-, each neutralized sample was sealed in a tube under vacuum together with CuO and then baked in an oven at 850℃ for 8 hours to convert organic carbon into CO_2 gas. After purification of CO_2 gas on a cryogenic vacuum line, carbon-isotope analyses were performed with a Finnigan MAT 252 mass spectrometer at Biogeochemical Laboratories, Indiana University. The results reported herein are obtained using reference CO_2 calibrated by NBS standards. All isotopic values are expressed in the standard delta notation with respect to the PDB standard, where $\delta^{13}C = \{(^{13}C/^{12}C)_{sample}/(^{13}C/$

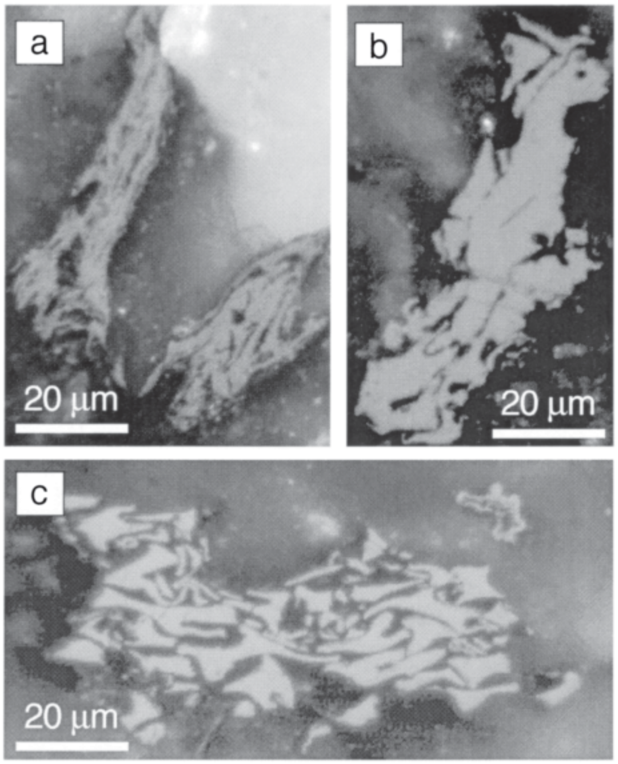

FIGURE 4. Kerogen derived from terrestrial woody plant in origin from the Tetori Group. **a**, Semifusinite from sample 006 ; **b**, Semifusinite from sample 008 ; **c**, Fusinite from sample 007.

$^{12}C)_{standard}-1\}$ X1000. The isotopic values were checked by an isotopically well-characterized laboratory standard (triphenylamine). Total organic carbon content (TOC) for these samples was analyzed with a CS elementary analyzer LECO instruments.

Organic compositions of ten selected mudstone samples (indicated with * on table 1) were checked by visual observation of kerogen under reflected light and in fluorescent light. When the samples are concentrated stratigraphically within 8 m, a single sample was selected for the observation as representative of that interval. Crushed mudstone was made into polished blocks following the standard preparation procedure (Bustin et al., 1983). Polished pellets were examined under microscope to identify organic particles.

RESULTS

Composition of kerogens on all selected samples shows predominance of semifusinite, vitrinite and fusinite (Fig. 4). Associated with these kerogens, minor (<<1%) content of sporinite and cutinite is observed in some samples.

The carbon-isotope ratios obtained from 15 samples are plotted as a single profile based on Figure 2. All values through

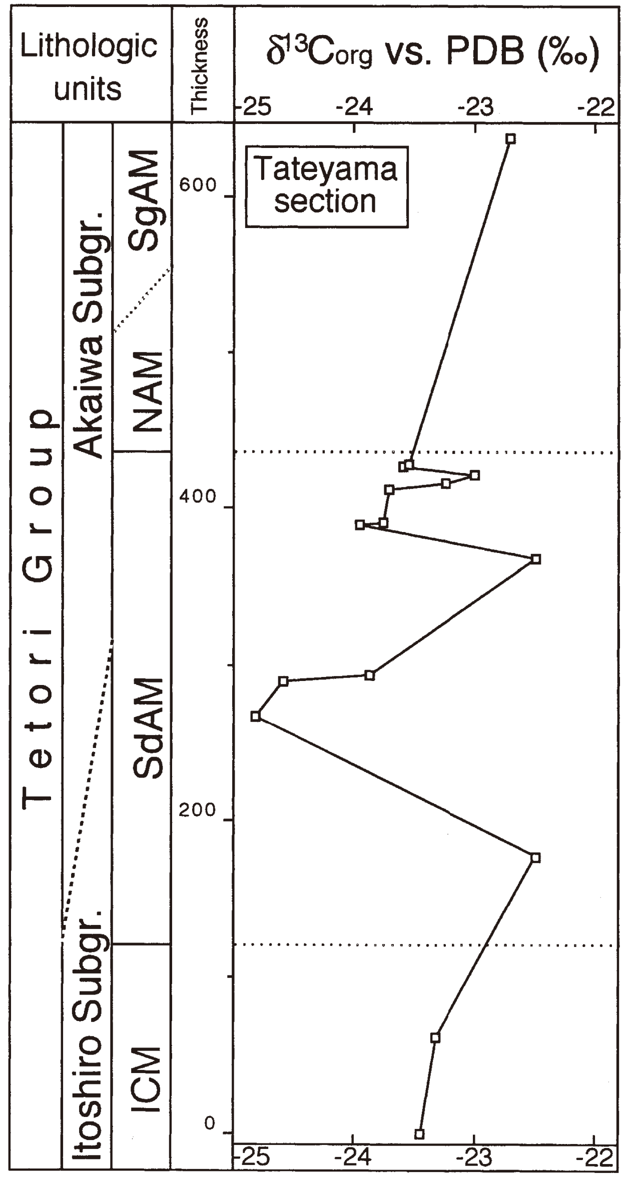

FIGURE 5. Stratigraphic distribution of carbon-isotope value through the Tateyama section. Broken lines indicate top and bottom of the Shidakadani Alternation Member.

the Tateyama section are distributed within a range of three permil between −25‰ and −22‰ (Fig. 5, Table 1). Near the bottom of the profile, medium values (−23.5‰) shifted toward one of the most positive values in the section (−22.5‰), followed by a negative shift in the lower half of SdAM. The most ^{13}C-depleted values throughout the section (−24.6, −24.8 ‰) are followed by a short-term excursion in the upper part of SdAM, in the middle of the section. Above the excursion with one of the most positive values throughout the section (−22.5‰), the value dropped back to ～24.0‰ followed by a positive migration through the upper part of the section. A remarkable

TABLE 1. Carbon isotope ratio of the Tetori Group

Sample ID	Sample horizon (m)	δ13C org vs. PDB (‰)	Total organic carbon content (%)
015*	637	-22.71	0.64
014	428	-23.55	1.62
013	426	-23.60	1.63
012*	421	-22.99	0.65
011	416	-23.24	1.30
010*	412	-23.71	1.17
009	391	-23.76	2.96
008*	389	-23.96	1.49
007*	368	-22.48	0.43
006*	293	-23.88	0.12
005	289	-24.60	0.90
004*	267	-24.82	1.74
003*	176	-22.49	0.07
002*	61	-23.31	0.07
001*	0	-23.45	4.41

Sample horizon is indicated by vertical separation from the lowest sample.

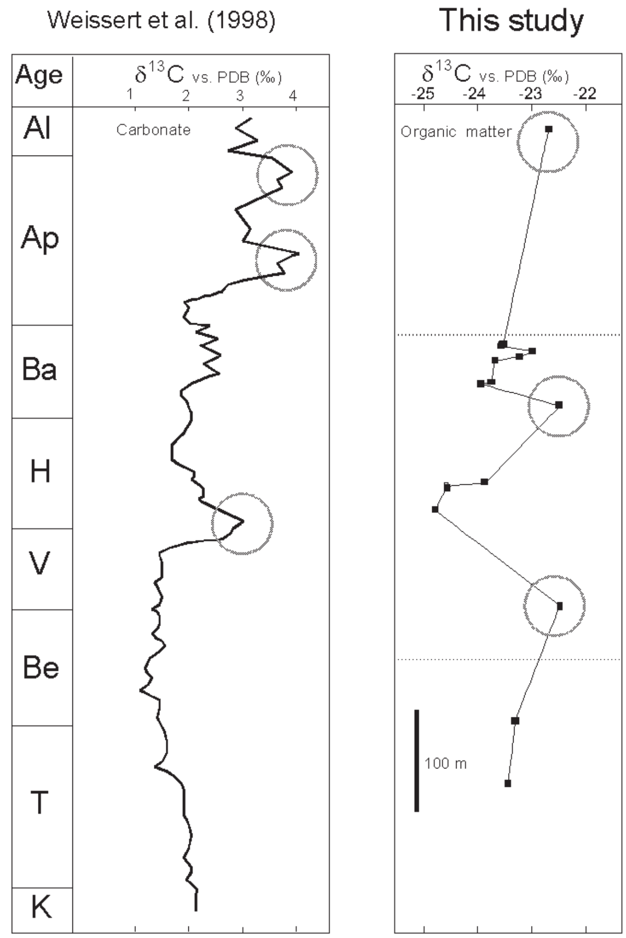

FIGURE 6. Comparison of the fluctuation of carbon-isotope value between Tethyan carbonate carbon (Weissert et al., 1998) and studied organic carbon from the Tateyama section. Amplitude for the value fluctuations confined within three permil in range is a common feature for both curves. K : Kimmeridgian ; T : Tithonian ; Be : Berriasian ; V : Valanginian ; H : Hauterivian ; Ba : Barremian ; Ap : Aptian ; Al : Albian.

value (−22.7‰) close to the most positive value characterizes the top of this section.

TOC shows extended range of distribution from 0.07% to 4.41% without any systematic correlation with $\delta^{13}C$ values.

DISCUSSION

The organic matter in each sample examined under microscope has conformed that it is predominantly derived from terrestrial woody plants. We interpreted that all samples for isotopic analysis in this study have a consistent origin of terrestrial woody plants. General field observation on shales and associated sandstones that often yield abundant fossils of woods, leaves, stems and indeterminable plant fragments supports this interpretation. Even though photosynthesis of C3 terrestrial higher plants is mediated by a single enzyme, ribulose biphosphate calboxylase oxygenase (RuBisCO), and the isotopic fractionation of RuBisCO is known to be unique (−29‰ ; Roeske and O'Leary, 1984), we should pay attention to forest canopy effect (Broadmeadow et al., 1992), humidity (Farquhar et al., 1989 ; Tieszen, 1991 ; O'Leary, 1993) and other environmental factors those could bias $\delta^{13}C$ values of each plant (See Arens et al., 2000 ; Hasegawa, 2003).

The $\delta^{13}C$ values and their distribution range (magnitude of fluctuation) are another point of view as the organic matter is evaluated. Gröcke et al. (1999) studied fossil woods from Isle of Wight sequence spanning upper Barremian through lowermost Albian. Their $\delta^{13}C$ values are mainly distributed between −27‰ and −21‰. For the same time span, Ando et al. (2002) also reported $\delta^{13}C$ values between −25‰ and −22‰, which have almost identical range with those from Cenomanian-Turonian strata in Japan (Hasegawa, 1997). The $\delta^{13}C$ values for our samples from the Tetori Group show similar distribution between −25‰ and −22‰, supporting the predominant terrestrial origin of the organic materials in our samples.

Weissert et al. (1998) compiled $\delta^{13}C$ values of marine carbonates from Kimmeridgian through Albian strata around the Tethyan region and drew a generalized $\delta^{13}C$ value profile for marine carbonate carbon. Recently, Weissert and Erba (2004) updated the $\delta^{13}C$ reference curve incorporating newly published data sets exhibiting high frequency short-term fluctuation. Because general outline of time-stratigraphic pattern has been unchanged, we adopted the simple figure of Weissert et al. (1998) on Figure 6 rather than Weissert and Erba (2004) that is too detail for our discussion on long-term fluctuation of the $\delta^{13}C$ value. Weissert et al. (1998) shows a long-term gradual negative shift from Kimmeridgian through Berriasian, and a gradual positive shift above it through the Albian, with three positive short-term excursions at the Valanginian-Hauterivian boundary, lower Aptian and upper Aptian, respectively (Fig. 6). The most negative value throughout this profile is marked at the lower Berriasian, whereas the most positive values are in the Aptian. Previous studies indicated that time-stratigraphic fluctuations of $\delta^{13}C$ value for both terrestrial organic matter and marine carbonates generally reflected contemporaneous fluctuation of that for CO_2 in the ocean-atmospheric reservoir (e.g., Hasegawa, 1997 ; Menegatti et al., 1998 ; Gröcke et al., 1999 ; Hasegawa et al., 2003).

If our Tateyama section represents a major part of the time interval of the Tethyan carbonate curve (Fig. 3), general stratigraphic trends of $\delta^{13}C$ values for this section of the Tetori Group is comparable to those of the Tethyan carbonates. The rate of sedimentation for the Tateyama section, which is composed of a variety of clastic sediments, should not be uniform and is difficult to estimate. However, no regionally traceable unconformity or discontinuity through the Tateyama section has been reported. The distribution of $\delta^{13}C$ values for the Tetori Group restricted within three permil is comparable to that of the carbonate values between 1‰ and 4‰ (Fig. 6). These conditions suggest a general pattern of long-term $\delta^{13}C$ profile could be preserved in the Tateyama section. The carbon-isotope profile including a pair of negative and positive excursions in SdAM implies that the section preserves short-term excursions in it. Each of circled horizons in the Tateyama section may represent a short-term positive excursion and potentially be correlated with either of circled short-term excursion shown in Tethyan curve (Weissert et al., 1998). Further study with densely collected samples is required to identify each short-term event as a globally correlative excursion with certainty. Nevertheless, our result indicates that such time-diagnostic short-term excursions are possibly identified in the Tetori Group.

CONCLUSION

The preliminary study on carbon-isotopes of organic matter from bulk-rock mudstones of the Itoshiro and Akaiwa Subgroups in Toyama, Japan revealed the following aspects of carbon-isotope stratigraphy of the subgroups : (1) microscopic observation on organic matter demonstrates the origin of organic matter in the mudstone samples to be terrestrial woody plants. The $\delta^{13}C$ values for the organic matter between −25‰ and −22‰ well match to that of terrestrial plants during the Early Cretaceous ; (2) the distribution of $\delta^{13}C$ values restricted within three permil is comparable to that of Tethyan carbonate values between 1‰ and 4‰ ; (3) short-term excursions appear to be preserved in the Tateyama section.

Carbon-isotope stratigraphy may offer a tool for interregional correlation of the Tetori Group providing stratigraphically dense samples are collected from less weathered continuous sequences. It can potentially be applied to any inland basin sequences yielding no index fossil. Bulk-rock analysis for carbon-isotope values of organic carbon may pick up some local environmental signals that mask global signature of $\delta^{13}C$ (see Arens et al., 2000). Nevertheless, carbon-isotope stratigraphy with this simplest method still appears to offer valuable information for chronological interpretation of the Tetori Group.

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* : in Japanese with English abstract
** : in Japanese

< 地名・地層名 >

Kuzuryu Subgroup ······九頭竜亜層群
Itoshiro Subgroup ······石徹白亜層群
Akaiwa Subgroup ········赤岩亜層群
Shidakadani Alternation Member ·······················志鷹谷互層
Nagaoyama Alternation Member of conglomerate and sandstone ················長尾山礫岩砂岩互層
Shiroiwagawa Alternation Member of tuff, shale and sandstone ··········白岩川凝灰岩頁岩砂岩互層
Kamihambara Formation······上半原層
Kuwajima Formation ··········桑島層
Mitarai Formation ··········御手洗層
Okurodani Formation ········大黒谷層
Tateyama ······················立山