In Search of the Cretaceous – Tertiary Boundary in Heilongjiang River Area of China

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Abstract Abstract A new geological section recognized in Baishantou of Jiayin, Heilongjiang Province, China, was studied preliminarily in searching for the K/T boundary. An early Paleocene florule characterized by abundant Tiliaephyllum tsagajanicum leaves and its associated plants, was collected from the Baishantou Member (new member representing the lower part of the Paleocene Wuyun Formation) overlying the possible K/T boundary. A tuff bed was found from the upper part of the Furao Formation (uppermost Cretaceous) in this section. The new findings imply that the K/T boundary is probable lying in the interval between the base of the Baishantou Member and the tuff bed, based on the correlation of the present strata with the stratotype of the Tsagajan Group spanning the K/T boundary in "Belaya Gara" of the Bureya Basin, Russia. The early Paleocene florule from the Baishantou Member and the early-middle Maastrichtian dinosaurs found from the Yuliangzi Formation underlying the Furao Formation suggest that the Baishantou section is more promising for searching for the K/T boundary in this area. Further studies of the section is needed, integrating paleontological, biostratigraphic, geochemical, paleomagnetic, and sedimentary research would benefit our understanding the mass extinction event and biotic recovery in the Heilongjiang River area, China, and even all of northeast Asia during the K/T bonndary interval.

Key words K/T boundary, Early Paleocene, Baishantou Member, Jiayin, Heilongjiang River

1 Introduction

The event taking place during the Cretaceous (K)-Tertiary (T) boundary interval has been much debated in scientific circles. Many hypotheses were proposed for explaining the worldwide event which caused the mass extinctions and biotic recoveries which occurred about 65 million years ago. The hypotheses include, the event resulted from an impact of an extraterrestrial body (Alvarez et al., 1980; Hildebrand et al., 1991), perturbation in the global carbon cycle by Deccan Traps volcanism (McLean, 1985), major global fires followed by a bolide impact at the K/T boundary (Scott et al., 2000), and a global fall in sea level at the end of the Cretaceous (Haq et al., 1987).

Although there are no such records (e.g. the impact of an extraterrestrial body) in China, or even

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in northeastern Asia, it is certain that the large scale mass extinctions and biotic recoveries might exist in these areas at the K/T boundary time. The unexpected faunal extinction marked by sudden disappearance of dinosaurs and ammonites, and the extensive biotic recoveries represented by the emergence of a great number of new taxa of organisms after the K/T boundary interval, appear to suggest the existence of the global event in this region.

In China, the majority of Cretaceous and Tertiary deposits are non-marine in origin except those distributed in Tibet and western Xinjiang with marine in origin. Comparatively, non-marine Cretaceous-Tertiary continuous outcrops in China are known only in Jiayin of Heilongjiang Province along the right bank of the Heilongjiang River (BGMRH, 1993) and Nanxiong of northern Guangdong (Zhao et al., 1991; Erben et al., 1995; Ashraf, 1995). However, the recognition of the K/T boundary in Nanxiong has been debated, and that the definition of the K/T boundary has not been confirmed.

The Jiayin is located in northeastern Heilongjiang Province of China, about 48°52′N and 130°23′E (Fig.1). In the beginning of the 20th century, the first dinosaur fossil *Mandschurisaurus amurensis* Riabinin was found in this area (Xing, 1999; Miao, 2000). Later, a lot of geologists or paleontologists came here for geological mapping (Luo et al., 1983; Li. 1986; BGMRH, 1993), studying dinosaurs (Xing et al., 1994), plant fossils (Zhang, 1983; Xiong, 1986), or biostratigraphy (Li, 1986; Chen et al., 1998). Although some of the publications mentioned above discussed the K/T boundary in some aspects of this area, it is still controversial in the Jiayin area (BGMRH, 1993; Xiong, 1986; Li, 1986; Chen et al., 1998; Tao, 2000). The reason might be due to insufficient continuous stratigraphic sections spanning the K/T boundary and thus a lack of the confirmation of the existence of the uppermost Cretaceous or the lowest Paleocene in this area.

However, in the Zea-Bureya Basin of Russian opposite Jiayin, China by the Heilongjiang (Amur) River, there are several sites with good outcrops and

Fig. 1 Geographical position of Jiayin, Heilongjiang, China and its adjacent areas of Russia

continuous K/T boundary strata which have been studied precisely. Among them, the stratotype of the K/T boundary in "Belaya Gara" (Tsagajan) yielding Maastrichtian and Danian floras associated with the Maastrichtian dinosaurs represented by *Amurosaurus riabinini* Bol. et Kurz, appears to be the best one for correlation of the K/T boundary (Krassilov, 1976; Kamaeva, 1990; IBP FESBRAS et al., 2001). Since these researches in the Zea-eya Basin were favored by the biostratigraphic standards established mainly in Sakhalin and its adjacent areas with marine alternating with non-ine sediments (Akhmetiev; 1973; Akhmetiev et al., 1978;

Golovneva, 1994; Kodrul, 1999), the K/T boundary stratotype from the "Belaya Gara" (Tsagajan) is more convincing. It is important to mention that the IBP FESBRAS et al. (2001) re-studied the stratotype and subdivided the Tsagajan Group (Formation) into three new formations, mainly based upon detailed palynological research. The new formations include (in descending order): the Darmakan Formation (i.e. Upper Tsagajan Group Danian in age, and consisting of two subformations), the Bureya Formation (Middle Tsagajan Group, upper Maastrichtian) and Udurchukan Formation (Lower Tsagajan Group with the main dinosaur zone, early-middle Maastrichtian in age) (Tab. 1). The new Russian research not only improved the precision for biostratigraphic correlation on the K/T boundary strata, but also benefits the K/T boundary study in China, particularly in the Jiayin area. In order to find the K/T boundary on the Chinese side, the present authors made field investigations in the Jiayin area, for which preliminary results are briefly presented in this paper.

2 Baishantou Section and the Possible K/T Boundary

The geological section of the Baishantou is located on the right side of the Heilongjiang River, near the town of Wuyun, about 60 km northwest from Jiayin (Fig. 1). The Baishantou section appears to show continuous non-marine deposits from the uppermost Cretaceous to the lower Paleocene (Figs. 2, 3). The deposits in this section consist of two parts including the Furao Formation (here showing probably its uppermost part, i.e. the Beds 1-3 in the section) and the Baishantou Member of the Wuyun Formation (maybe from the Beds 4 to Bed 10). The Baishantou Member is a new stratigraphic unit named by the authors, representing the lower part of the Wuyun Formation.

According to the preliminary investigation of

Tab.1 Correlation of Upper Cretaceous-eocene biostratigraphy between The Jiayin of Heilongjiang, China and the Zea-Bureys Basin of Russia

<table>
<tr><th colspan="3">Region / Formation (Fm) & Group / Chronological Stratigr.</th><th colspan="4">RUSSIA
Zea-Bureya Basin</th><th colspan="2">CHINA
Jiayin of Heilongjiang</th></tr>
<tr><td rowspan="2">Paleocene</td><td rowspan="2">Danian</td><td>U</td><td rowspan="4">Tsagajan Group</td><td rowspan="2">U</td><td rowspan="2">Darmakan Fm</td><td>Coal-bearing Sub-Fm</td><td rowspan="2">Wuyun Fm</td><td>Coal-bearing Member</td></tr>
<tr><td>L</td><td>Sandstone Sub-Fm</td><td>Baishantou Member</td></tr>
<tr><td rowspan="5">Upper Cretaceous</td><td rowspan="3">Maastrichtian</td><td>U</td><td>M</td><td colspan="2">Bureya Fm</td><td colspan="2">Furao Fm</td></tr>
<tr><td>M</td><td rowspan="2">L</td><td colspan="2" rowspan="2">Udurchukan Fm
(main dinosaur horizon)</td><td colspan="2" rowspan="2">Yuliangzi Fm
(main dinosaur horizon)</td></tr>
<tr><td>L</td></tr>
<tr><td colspan="2">Campanian</td><td colspan="3" rowspan="2">Kundur Fm</td><td rowspan="3">Upper Zavitin Fm</td><td colspan="2" rowspan="2">Taipinglinchang Fm</td></tr>
<tr><td colspan="2">Santonian</td></tr>
<tr><td colspan="2">Coniacian</td><td colspan="3" rowspan="2">Boguchan Fm</td><td colspan="2" rowspan="2">Yong'ancun Fm</td></tr>
<tr><td colspan="2">Turonian</td></tr>
<tr><td colspan="2">Cenomanian</td><td colspan="4">Lower Zavitin Fm</td><td colspan="2">?</td></tr>
</table>

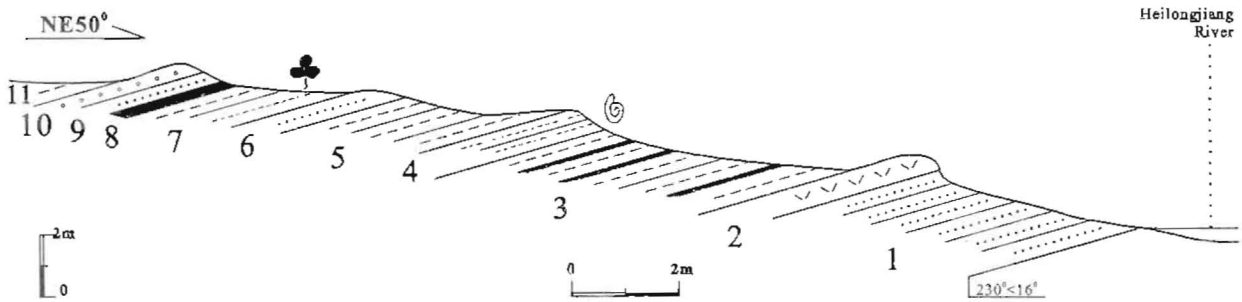

Fig.2 Geological section of the strata spanning possible K/T boundary in Baishantou of Jiayin

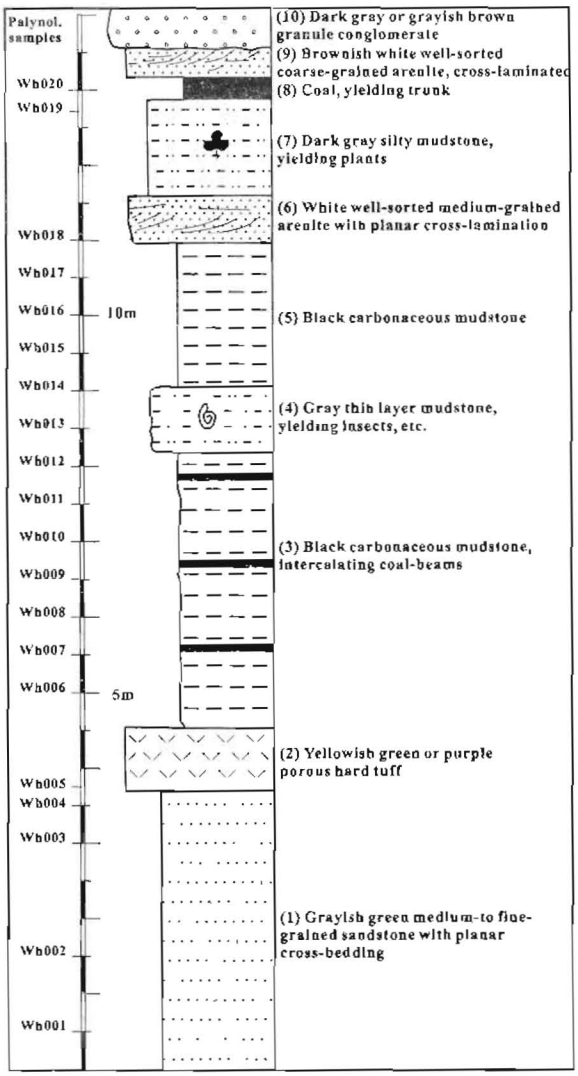

Fig.3 Stratigraphic column concerned in Baishantou section of Jiayin

the Baishantou section made by the authors, the stratigraphy of the section can be described briefly as follows (in descending order):

10. Dark gray or grayish brown granule conglomerate 0.52m
9. Brownish white well-sorted coarse-grained arenite, cross-laminated 0.48m
8. Coal, yielding trunk 0.30m
7. Dark gray silty mudstone, yielding plants 1.37m
6. White well-sorted medium-grained arenite with planar cross-lamination 0.67m
5. Black carbonaceous mudstone 2.01m
4. Gray thin layer mudstone, yielding insects, plants 0.93m
3. Black carbonaceous mudstone, intercalating coal-beams 3.85m
2. Yellowish green or purple porous hard tuff 0.90m
1. Grayish green medium- to fine-grained sandstone with planar cross-bedding 3.95m

It is amazing that the biostraigraphic characteristics of this section are quite similar to the stratotype section of the Tsagajan Group in the "Belaya Gora" (Tsagajan) (IBP FEBRAS et al., 2001, p.39, Fig. 2.16). In the present Baishatou section we found a rich florule in the Bed 7, including *Ginkgo* ex gr. *adiantoides* (Ung.) Heer, *Taxodium olrikii* (Heer) Brown, *Tiliaephyllum tsagajanicum* (Krysht. et Baik.) Krassilov, *Trochodendroides* ex gr. *arctica* (Heer) Berry, *Nyssa* sp., *Platanus raynoldsii* Newb., *Platanus*. sp., *Ampelopsis acerifolia* (Newb.) Berry, *Acer*? sp. The florule is characterized by the dominance of *Tiliaephyllum tsagajanicum*. According to the correlation of the

present section to the "Bellaya Gora" stratotype section, *Tiliaephyllum tsagajanicum* has been found only in the lower part of the Upper Tsagajan Group where they are dominate, and below the Kivda Bed (upper Upper Tsagajan Group), and the taxon is one of the indicators for the early Danian age (IBP FEBRAS et al., 2001; Krassilov, 1976, p. 22). The plants associated with *Tiliaephyllum tsagajanicum*, e.g. *Platanus raynoldsii*, *Trochodendroides* ex gr. *arctica*, *Ampelopsis acerifolia* in the Baishantou section are common in the Tsagajan flora ranging basically from Maastrichtian to Danian. Besides, in Bed 4 of the Baishantou section, one of the authors (Bugdaeva) found insect fossils including Homoptera, *Plateumaris* sp., Curculionidae, (identified by Rasnitsyn et al.), which seems to show similar biostratigraphic characters to those of the Upper Tsagajan Group that the main insect-bearing bed was just overlying the K/T bonndary. Therefore, the upper part of the strata in the present section (Beds 4-10) perhaps corresponds to the lower Paleocene Sandstone Subformation of the Karmakan Formation (lower Upper Tsagajan Group). The authors name this strata (Beds 4-10) the Baishantou Member belonging to the lower part of the Wuyun Formation (Tab. 1).

In the lower part of deposits in the present section (from Bed 1 to Bed 3), the authors found a tuff bed (i.e. Bed 2) composed of yellowish green or purple porous hard tuff, about 0.9 m in thickness. The tuff bed can be correlated to the tuffite bed (i.e. the Bed 6, about 0.2 m in thickness) from the stratotype of the K/T boundary in the "Belaya Gora"(Tsagajan). The tuffite bed belongs to the Bureya Formation (Middle Tsagajan Group) with late Maastrichtian age (IBP FEBRAS et al., 2001, p. 40; Fig. 2.16). The extraordinary similarity of the two volcano-originated beds in sequential and lithological characteristics, implies that the present tuff bed is perhaps belonging to the uppermost Cretaceous (the Furao Formation in the Jiayin area) and not far from the K/T boundary.

On the basis of the early Paleocene florule in the present section and the biostratigraphic correlations between the Chinese and Russian uppermost Cretaceous – Paleocene strata, it suggests the idea that the K/T boundary would be lying in this section, and probably between Bed 4 and Bed 3 in the Baishantou section. The tuff or tuffite beds occurring along the Heilongjiang River imply that there was volcanic activity before the K/T boundary, which might be responsible for the mass extinction in the Heilongjiang River area covering the Jiayin and the Zea-Bnreya Basin. Of course, more precise research work is needed on the Baishantou section in the near future, integraring the paleontological, isotopic, paleomagnetic and geochemical examinations of all the strata of the section. However, in any case, the present Baishantou section is very promising for searching for the K/T boundary in this area.

3 Discussion

3.1 The Yuliangzi Formation with dinosaurs

The Yuliangzi Formation is underlying the Furao Formation in the Jiayin area along the Heilongjiang River, China (Tab. 1). The Yuliangzi Formation has been well-known because it yields abundant dinosaur fossils (Xing et al., 1994; Nessov, 1995; Xing, 1999; Miao, 2000) (Fig. 4). Up to now, there are, at least, four dinosaur taxa that have been reported from this formation, e.g. *Mandschurosaurus amurensis* Riabinin (Hadrosauria), *Albertosaurus periculosus* Riab. (Tyrannosauriadae), Caelurosauria and Ornithopoda (Li, 1986; Xing, 1999; Miao, 2000). Among them, *Albertosaurus* was found from the Upper Cretaceous of Alberta Province, Canada and referred to lower Maastrichtian. *Mandschurosaurus* is one of typical Hadrosauria dinosaurs and similar to *Trachodon* and *Edmontonsaurus*, and all the three taxa can be re-

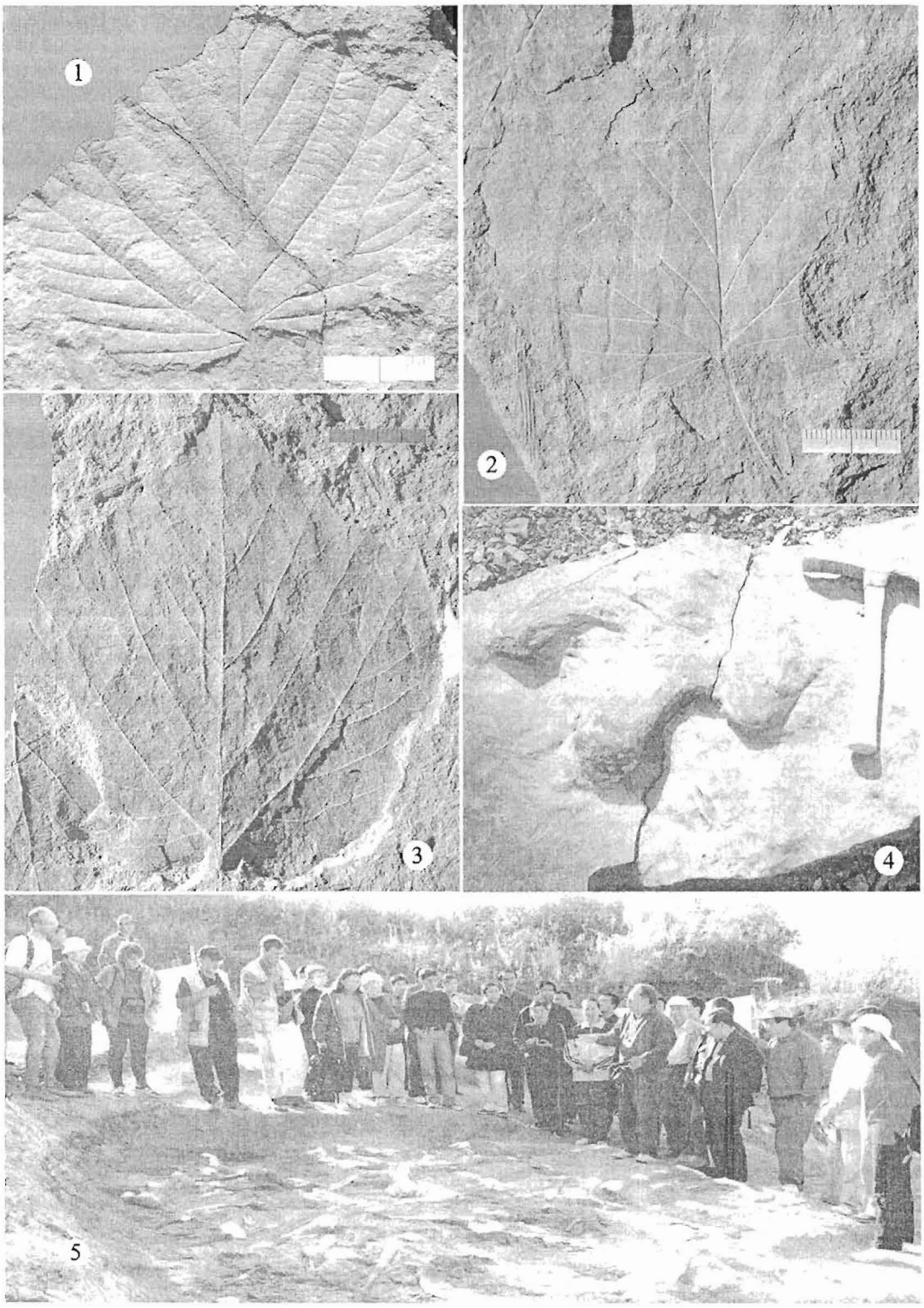

Fig. 4 1-3 Plants from the lower Paleocene Baishan Member of Wuyun Formation in Baishatou of Jiayin
1, 2 *Tiliaephyllum tsagajanicum* (Krysht. et Baik.) Krassilov; 3. *Platanus raynoldsii* Newberry; 4. **Dinosaur foot print (Hadrosauria) newly found from the Yong'ancun Formation** (Upper Cretaceous) at the right bank of Jiayin, Heilongjiang by one of the authors (K. R. Johnson); 5. **Scientists in the dinosaur fossil locality** (Yuliangzi Formation) in Wulaga of Jiayin

garded as the remains of the upper Upper Cretaceous. A significant fauna of dinosaurs characterized by *Tyrannosaurus* – *Triceratops* from the Lance Formation (upper Maastrichtian) in North America, has not been found in Asia, so far. The Lance Formation can be correlated to the lower – middle Tragajan Group yielding Hadrosauria from the Bureya Basin of Russia. On the other hand, abundant dinosaur fossils were found from the lower Maastrichtian in the Kundur of the Bureya Basin, including Tyrannosauridae, Ornithomimidae, Dromaesauridae, Troodontinae, Hadrosauridae and Nodosauridae, in which abundant Hadrosauridae (e.g. *Amurosaurus*) were found also from the middle Maastrichtian in the Blagoveschesk and its adjacent area of the Zea Basin along the Heilongjiang River (IBP FEBRAS, et al., 2001). All the dinosaur material from the Zea-eya Basin of the Russian side of the river appear to have close relationships to those found from the Jiayin, China. Therefore, we suggest the Yuliangzi Formation with *Albertosaurus*-*Mandschurosaurus* dinosaur fauna from the Jiayin area, could be considered the late Late Cretaceous and at least, early – middle Maastrichtian age. Thus, its overlying Furao Formation might he regarded as late Maastrichtian in age.

3.2 The Wuyun Formation and its new subdivision

The Wuyun Formation and its flora have been studied for a long time (Zhang. 1983; BGMRH, 1993; Xiong, 1986; Manchester et al., 1999; Tao, 2000). However, the age of the Wuyun Formation and its flora has heen debated in paleobotanical circles. Most researchers consider the Wuyun Formation and its flora to be Paleocene (Xiong, 1986; Manchester et al., 1999; Feng et al., 2000). But, some researchers considered the age as Maastrichtian – Paleocene(Tao, 2000).

Based on the authors' recent investigation on the formation and its flora in the Jiayin-Wuyun area, and considering the correlation of the Wuyun main flora to the Upper Tsagajan flora of Russia, the authors have recognized that the Wuyun Formation (and flora) is composed, actually, of two members (assemblages). The upper member (the Coal-bearing Member) is the main coal-bearing strata which are well exposed in the Wuyun Open-Cut Coal-Mine and with a very rich flora (BGMRH, 1993; Xiong, 1986; Tao, 2000). In this member, the authors recently collected a great number of plants including *Tallites* sp., *Ginkgo* ex gr. *adiantoides* (Ung.) Heer, *Glyptostrobus nordenskioldii* (Heer) Brown, *Metasequoia accidentalis* (Newb.) Chaney, *Ampelopsis acerifolia* (Newh.) Brown, *Beringiaphyllum cupanioides* (Newb.) Manchester, Crane et Golovneva, *Myrica* sp., *Nuphar burejense* Krassilov, *Nyssidium arcticum* (Heer) Iljinskaja, *Platanus* sp., *Trochodendroides arctica* (Heer) Berry, *Trochodendrospermum arcticum* (Brown) Krassilov, *Ulmus furcinervis* (Borsuk) Ablajev, etc. Comparing the flora with the Upper Tsagajan flora of the Bureja Basin (Krassilov, 1976), the flora of the Coal-bearing Member of the Wuyun Formation is very similar to that from the Kivda Beds (the Coal-ring Suhformation of the Karmakan Formation, i.e. the upper Upper Tsagajan Group) late Danian in age (IBP FEBRAS er al., 2001).

While in the lower member (i.e. the Baishantou Memher, see section 2 as above), the authors found a new florule dominated by *Tiliaephyllum tsagajanicum*. Based on the comparison with the Upper Tsagajan flora, the florule of the member is considered early Paleocene, i.e. early Danian in age.

Therefore, since the main floristic horizon from the Wuyun Open-Cut Coal-Mine perhaps not covers the early Paleocene in age, the type section of the "Furao Formation", as previously understood from the Xiaoheyan of Furao along the Heilongjiang River (BGMRH, 1993; Chen et al., 1998; Sun & Zheng, 2000), should be restudied and suhdivided.

Because the "Furao Formation" may contain two parts: the upper part belonging to the Baishantou Member (lower Paleocene), while the lower part may be uppermost Cretaceous. The strata outcrop in the Baishantou section and its equivalents in the Wuyun-Baishantou area, previously named "Furao Formation", would be a very promising place to search for the K/T boundary in the Jiayin area.

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