

Radiometric Dating of Ignimbrite from Inner Mongolia Provides no Indication of a Post-Middle Jurassic Age for the Daohugou Beds

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Abstract: Lacustrine deposits exposed at Daohugou, Inner Mongolia, China, have yielded superbly preserved vertebrate fossils. The fossil beds were first misinterpreted as of Early Cretaceous age, based on alleged occurrences of key fossils of the Jehol Biota. Compelling evidence revealed by more rigorous research involving regional biostratigraphy, radiometric dating, and paleontology supports the Middle Jurassic age of the fossil beds. Despite the awesome evidence for the Middle Jurassic age of the Daohugou beds, the age dispute has been resurrected recently by invoking an overturned stratigraphic sequence. A careful review of the data, however, found no evidence that this sequence has been overturned. In addition, many of the assumptions, on which the conjecture of the fossil beds being post-Middle Jurassic is imprudently based, are self-contradictory or otherwise misleading. Thus, the post-Middle Jurassic age of the Daohugou beds as an unfounded conclusion can readily be dismissed.

Key words: Daohugou beds, Inner Mongolia, Middle Jurassic, age dispute, radiometric dating

1 Introduction and Background

Along with stunning paleontological discoveries from the world-renowned fossil beds in western Liaoning Province of China, recent findings from the lacustrine deposits exposed at the Daohugou village (Fig. 1) near Ningcheng, Inner Mongolia, include superbly preserved pterosaur, salamander, insect, and plant fossils (Ji and Yuan, 2002; Wang et al., 2002; Gao and Shubin, 2003; Zheng et al., 2003; Rasnitsyn and Zhang, 2004). The Daohugou fossil beds consist of a set of intercalated, fine-grained lacustrine deposits and fine volcanic ash that unconformably overlay pre-Cambrian rocks (Liu and Jin, 2002; Ren et al., 2002). At first, the fossil beds were incorrectly correlated with the Early Cretaceous Yixian Formation (Wang Xiaolin et al., 2000). This erroneous correlation was primarily based on the purported occurrences of *Lycoptera* fish and *Ephemeropsis* (insect larva) fossils at the Daohugou site, and the alleged superposition of the Daohugou beds on top of the Tuchengzi Formation, which normally underlies the Yixian Formation. Work by Ren et al. (2002), however, has provided undeniable evidence showing that the Daohugou fossil beds are the volcanic deposits of the Middle Jurassic Jiulongshan Formation (called Haifanggou Formation in Liaoning) in northern China, and the beds in fact rest

directly on pre-Cambrian rocks at an unconformable contact (Fig. 2). Liu and Jin (2002) have independently demonstrated this same point, i.e., no deposits of the Tuchengzi Formation are exposed at Daohugou Village in contact with the fossil beds, which are underlain by pre-Cambrian rocks. Moreover, *Lycoptera* (a key member of the Jehol Biota) fossils have never been found from the Daohugou beds, and the so-called *Ephemeropsis* fossils found at the site are of misidentified *Mesoneta* (an euephemeropteran insect commonly known from Middle Jurassic deposits).

Consequently, both the stratigraphic correlation of the Daohugou beds with the lower Yixian Formation of Liaoning and a contact of the fossil beds with the supposedly underlying Tuchengzi Formation at the Daohugou site are unfounded allegations that lack any evidence in their support. The age of the Daohugou beds as a focal topic was extensively discussed at a conference organized by the China Geological Survey (October of 2004, Shenyang). The flawed correlation of the Daohugou fossil beds with the lower Yixian Formation was widely criticized at the conference, and a correlation of the Daohugou beds with the Middle Jurassic Haifanggou (Jiulongshan) Formation was widely accepted based on evidence from several sources, including regional stratigraphy, radiometric dating, and paleontological studies (see discussion below).

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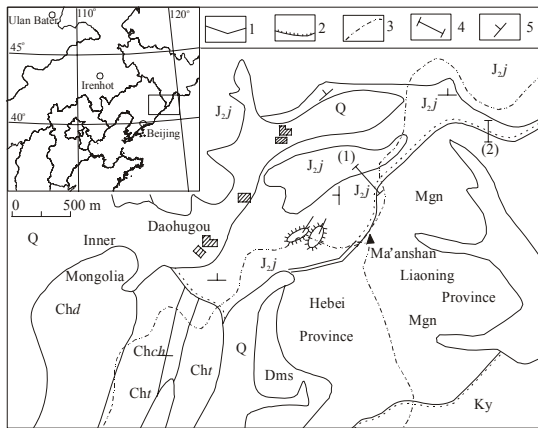


Fig. 1. Simplified geological map of Daohugou area at the juncture of three provinces of Liaoning, Hebei, and Inner Mongolia.

1. Stratigraphic boundary; 2. unconformity; 3. provincial boundary; 4. location of geological section; 5. strike and dip; Chc – Changchougou Fm; Chch – Chuanlinggou Fm; Chd – Dahongyu Fm; Cht – Tuanshanzi Fm; Dms – Dalaiyingzi erosion surface; J.j – Jiulongshan Fm; J.j_f – Tiaojishan Fm; Ky – Yixian Fm; Q – Quaternary; Mgn – Maanshan gneiss.

More recently, both $^{40}\text{Ar}/^{39}\text{Ar}$ and SHRIMP U-Pb dating of trachyte and trachytic ignimbrite rock samples from the Daohugou area (N41°18.979', E119°14.318') some 20 m above the fossil-bearing shales yielded a date of 164 Ma (Chen et al., 2004), a Middle Jurassic (Bathonian) age. Before this, the stratigraphically higher Lanqi (=Tiaojishan) Formation in western Liaoning has yielded a K-Ar date of 158 Ma (Wang Si'en et al., 2000), providing an indirect support for the Middle Jurassic (Bathonian) age of the underlying Haifanggou (Jiulongshan) Formation (including the fossil beds exposed at the Daohugou area).

In spite of all of the above, He et al. (2004) have reopened this dispute, challenging the Middle Jurassic age of the Daohugou fossil beds and alleging that these beds are no older than Early Cretaceous. They base their astonishing conclusion mostly on a remarkably unparsimonious interpretation of the stratigraphy at the Daohugou fossil site, namely that this sequence has been overturned and that the ignimbrite, which now overlies the fossil beds in outcrop at the site, is actually older than the fossil beds beneath, which therefore must be deposited after the ignimbrite was emplaced. Furthermore, He et al. (2004, 2005) attempt to support this imprudent argument by biostratigraphic inferences that can only be characterized as irrational (see comments below).

2 Comments and Discussion

He et al. (2004) claim that the fossil beds at Daohugou must have been deposited after the ignimbrite (dated as 159.8 Ma) was in place because there is no evidence of baking of the fossiliferous shales at their contact with the

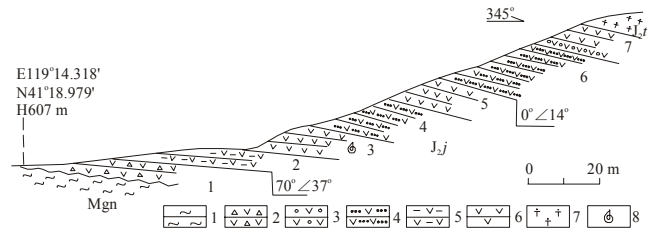


Fig. 2. Stratigraphic section measured at Daohugou near Ningcheng, Inner Mongolia.

Mgn – Maanshan gneiss; 1. gneiss; 2. tuffaceous grand conglomerate; 3. tuffaceous conglomerate; 4. tuffaceous siltstone; 5. tuffaceous mudstone; 6. tuffaceous shale; 7. volcanic breccia; 8. fossil locality.

ignimbrite; hence, the entire stratigraphic sequence must have been overturned, and the observed overlying ignimbrite was deposited before the underlying shales. This interpretation is fallacious on several counts:

1) Ignimbrites, which by definition are igneous rocks formed by lithification of volcanic ash and breccia (Press and Siever, 1982), are pyroclastic in origin. Pending on the actual temperatures and depositional environments, the underlying rocks may or may not be extensively baked when the ignimbrites are deposited, contrary to what He et al. (2004) assume. Moreover, the fossiliferous shales exposed at Daohugou represent volcanic ash deposited in a lake; if the lake was still extant at the time, the ignimbrites would have settled on the lake bottom sediments in a cool aqueous environment, and no baking of sediments already in place could have taken place.

2) He et al. (2004: fig. 2) claim to recognize weathering of the ignimbrite at the contact with the shale, implying that this surface was subaerially exposed before the shales were deposited and subsequently overturned; However, such a bold claim lacks any supporting evidence: He et al. (2004) provided no data neither on the diagnostic features (e.g., root traces, soil horizons, soil structures; see Retallack, 1988) nor on the geochemical nature of their “weathered layer”. By the same token, the so-called “reversed sequence” as a key point in He et al. (2004), also lacks of any evidence from structural geology (e.g., folding and associated faults). Moreover, what they have identified as the “weathered ignimbrite” (as arrow pointed in their figure 2) in the outcrop at this site is laterally continuous with the shales themselves and hence is obviously part of those deposits, and not part of the main body of the ignimbrites above.

3) He et al. (2004) also took the absence of baking of the shale at its contact with the ignimbrites as evidence “excluding the possibility of the ignimbrite having intruded later” [sic]. As it is commonly understood that ignimbrites are formed from pyroclastic debris (ash and breccia) violently ejected from a volcanic source, how would

anyone with a basic geology background expect to have an intrusion of the ignimbrites into volcanic ash already in place as lake bottom sediments?

4) He et al. (2004) provided no evidence to challenge the results of Ren et al. (2002) and Liu and Jin (2002), who, as noted above, independently concluded that the fossiliferous volcanic shales at Daohugou rest unconformably on pre-Cambrian rocks. No known geological process could have completely overturned the ignimbrite+fossiliferous shale sequence at Daohugou while leaving no evidence of such a disruptive event on the pre-Cambrian rocks beneath. He et al. (2004) also claim that, contrary to Ren et al. (2002) and Liu and Jin (2002), “at the Daohugou locality, the fossil-bearing sediments are also found to overlie the Tuchengzi Formation at a few sites”, but they have not cited the coordinates of the sites where this occurs nor have they documented this contact in a photograph of these sites. Moreover, if, as He et al. (2004) claim, the Daohugou fossil beds do overlie the Tuchengzi Formation (dated as 139.4 ± 0.2 Ma, Swisher et al., 2002), this is unambiguous evidence that the sequence at Daohugou has not been overturned, in direct contradiction with their own argument.

Contrary to He et al. (2004), more thorough field investigation by Liu et al. (2004, fig. 2) has revealed compelling evidence showing that the Tuchengzi Formation disconformably overlies the volcanic rocks of the Lanqi (Tiaojishan) Formation (observation site: $N41^{\circ}22.91' E119^{\circ}10.03'$), stratigraphically some 270 m above the Daohugou fossil beds. Liu et al.'s (2004) publication included detailed description of the stratigraphic successions, measured geological sections, and clearly marked stratigraphic and GPS positions from where rock samples have been collected for radiometric dating.

He et al. (2004) attempted to invoke radiometric dates to support their argument that the sequence of fossiliferous shales and ignimbrites has been overturned. They dated the ignimbrites exposed above the fossil-bearing shale at the Daohugou locality (coordinates given as $119.24^{\circ}E, 41.32^{\circ}N$), while the illustrated contact zone (He et al., 2004, fig. 2) was from another site (coordinates given as $119.22^{\circ}E, 41.32^{\circ}N$). Why? Naturally, the question is: why is the contact of the dated ignimbrite with the fossil beds at the Daohugou locality not illustrated? More interestingly, why did He et al. (2004) only present the date of the ignimbrite and not a date for the shales beneath? The stratigraphic sequence in question can only be shown to have been overturned if the lower beds (the fossiliferous shales) are younger than those that are higher (the ignimbrites) in the same outcrop; He et al. (2004) have presented no evidence at all that this is the case. In contrast, the fossiliferous shale has yielded a U-Pb SHRIMP date of 165 Ma (Yang and Li,

2004). In a more recent discussion, however, He et al. (2005) expressed concern on contaminations of their rock samples from the “same tuff as by Yang and Li”. In fact, the thickness of the Daohugou shales varies from some 50 m to more than 500 m (Ren et al., 2002; Liu et al., 2004) under the control of tectonic subsidence and sedimentary supply at the time. Neither group of authors (Yang and Li, 2004; He et al., 2005) has provided data on GPS positions or actual stratigraphic horizons of their rock samples. Unless the rock samples dated by the two different work groups can be verified as from the same section and horizon, the radiometric date by Yang and Li (2004) provides the ultimate evidence for the Middle Jurassic (Bathonian) age of the fossil beds, supported by paleontological evidence from conchostracans (Shen et al., 2003) and insects (Rasnitsyn and Zhang, 2004).

Attempting to use vertebrate fossils as evidence supporting their age argument, He et al. (2004) made an outrageous allegation: “the Daohugou salamander assemblage is generally comparable to that of the Late Jurassic Karatau Formation in Kazakhstan”. Such an invalid assertion can be easily dismissed, as the Late Jurassic (Kimmeridgian) salamander “assemblage” from Kazakhstan consists of one fossil taxon, *Karaurus*, known from a single specimen. *Karaurus* is classified as a stem-caudate (Milner, 2000), while the fossil salamanders from the Daohugou beds are all crown-group urodeles. *Karaurus* and the true salamanders from the Daohugou beds are morphologically so distinctive from one another, and their phylogenetic relationships are so remote that any comparison for the purpose of yielding a biostratigraphic conclusion as to the relative age of the beds in Kazakhstan and China is entirely invalid.

He et al. (2004) claimed that fieldwork in 2002 at the section near Daohugou village “resulted in discoveries of hundreds of fossils including lizards, ...” This is another incorrect claim like the previously alleged occurrence of *Lycoptera* and *Ephemeropsis* in the Daohugou beds (Wang Xiaolin et al., 2000). The two authors of this paper (Gao and Ren) have been intensively working on the fossil salamanders and insects from this site and we made frequent visits to the site in the past few years. We have never seen or heard of a single occurrence of lizard fossils from the Daohugou site, although lizard fossils are commonly known from several fossil sites (e.g., Jingangshan near Yixian, Dawangzhangzi near Lingyuan) of the Yixian Formation.

3 Conclusions

As shown above, the conclusions that He et al. (2004) have made about the post-Middle Jurassic age of the

Daohugou beds as based on unfounded assumption of an overturned geological sequence can readily be dismissed; their use of biostratigraphic evidence to support their conclusions commands even less respect. In contrast, radiometric date of 165 Ma directly from the fossil-bearing shale, supported by paleontological evidence from conchostracans and insects, provides the most definitive evidence for the Middle Jurassic (Bathonian) age of the Daohugou fossil beds.

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