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Stratigraphy of deep-water Cretaceous deposits in Gyangze, southern Tibet, China

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Abstract

Extensive tectonic activity in southern Tibet (Tibetan Tethys Himalayas) resulted in overthrusting and tectonic deformation of Cretaceous strata, which in the study area was not recognized by earlier researchers. Field studies of three typical cross-sections in southern Tibet has led to the revision of previous stratigraphy. The thickness of the Cretaceous in Gyangze varies between 300 and 700 m, but is not over 2000 m as previously estimated at Gyabure and Weimei, where the strata are overturned and repeated owing to previously unrecognized thrusts. In upward stratigraphic order four lithological markers were used in the field study: belemnite and black marker, lenticular limestone and white marker, red marker, and olistolith marker. The first two of these are associated with the fine-grained clastic shelf sequence of the Gyabula Formation, which is of Berriasian–early Santonian age. The third is the deep-sea red-beds marker of the Chuangde Formation, dated as middle Santonian–early Campanian. The fourth depicts the slump facies and olistolith of the middle Campanian–Paleocene Zongzhuo Formation. The revised Cretaceous stratigraphy provides a framework for studies of the pelagic red beds of the Chuangde Formation, which is intermittently exposed in southern Tibet.
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Keywords: Stratigraphy; Lithostratigraphic markers; Pelagic red beds; Cretaceous; Gyangze; Southern Tibet

1. Introduction

Mesozoic strata deposited on the distal shelf and slope of the northern Indian continental margin are well exposed in southern Tibet (central north Tethyan Himalayas; Fig. 1), especially in the Gyangze area. The deep-water Cretaceous sequences crop out south of the Yarlung Zangbo suture zone (Fig. 1). It is a mountainous area, with the chains having an elevation of 1200–1500 m above the Tibetan plateau. As the mountains are not covered by vegetation, the sedimentary strata are well exposed on the slopes. Several groups of Chinese geologists (Yang and Wu, 1962; Wang et al., 1976; Xu et al., 1990; TBGMR, 1993, 1994, 1997) have studied the Cretaceous strata in the north Tethyan Himalayas, in which Upper Cretaceous, Tethyan, pelagic red beds are found, although they are less common than in the southern Himalayas in shelf sediments of the Tethyan succession (e.g., Wan et al., 1993; Willems and Zhang, 1993a,b; Willems et al., 1996). Our studies have shown that several major errors were made by previous investigators, mainly as a result of the complex tectonics of the region. In this paper, we attempt to correct the general geological and stratigraphic interpretation of the Cretaceous in the study area (Fig. 1).

During field studies in 1998–2001 we examined three structural cross-sections and measured two new sections (Fig. 2) in the Gyangze area where Cretaceous strata are exposed. For each of the cross-sections, we tried to

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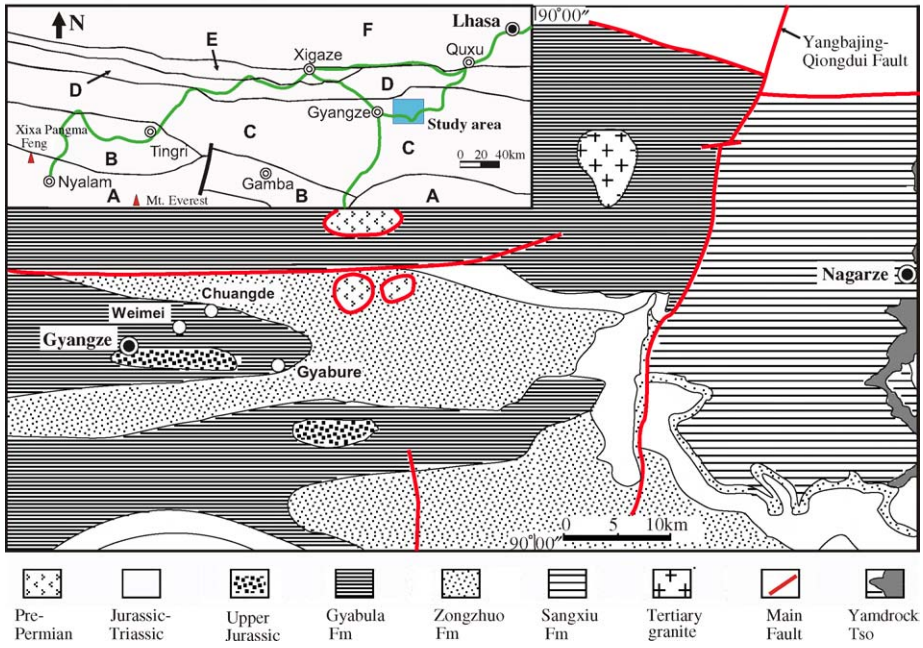

Fig. 1. Geological sketch map of Gyangze and Nagarze areas. The inset at the top left shows tectonic/stratigraphic zonations of the Tibetan Tethyan Himalayas: A, Higher (Crystalline) Himalayas; B, south Tethyan Himalayas; C, north Tethyan Himalayas; D, Indus-Yarlung Zangbo suture zone; E, Xigaze forearc basin; F, Gandese Arc. The Chuangde Formation does not appear on the map because it is less than 30 m thick. Both the Gyabula and Zongzhuo formations can be subdivided into members on a smaller-scale map (1:250,000).

determine the stratigraphic sequence and thickness of the Cretaceous by excluding strata that are repeated as a result of extensive tectonic deformation and late thrusting. The faults and folds were identified using a combination of sedimentary structures (upward orientation), changes in dip angles, lithostratigraphic markers, stratigraphic correlation and biostratigraphic information. Samples were collected and processed for foraminifera and radiolaria, which were studied subsequently for their biostratigraphic implications.

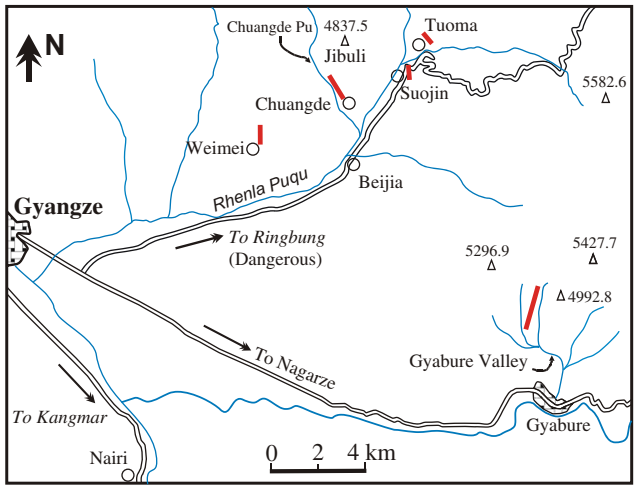

Fig. 2. Locations of measured Cretaceous sections in the Gyangze area. Elevations of peaks are in metres.

2. Results

2.1. Stratigraphic succession and thickness

Previous mapping by Chinese geologists reported the Cretaceous succession in the northern Himalayas to be 2000–3000 m thick. Their measurements did not take into account tectonic repetition of strata by thrust faults, probably because the original determination of thickness was derived from the type section at Gyabure (also named the Gyabula cross-section) described by Wang et al. (1976) and Xu et al. (1990). The Gyabure section lies in a narrow valley north of Gyabure village, ca. 20 km east-south-east of the town of Gyangze (Figs. 1, 2). Wang et al. (1976) and Xu et al. (1990) considered the entire section to be a monocline and inferred that the strata become younger northwards (Fig. 3A, B). However, the presence of at least eight thrust faults (F1–8), three anticlines, and two synclines (Fig. 3B) result in duplication of the strata.

According to our interpretation, we consider that the first anticline is composed of sandstones and shales of the Upper Jurassic Weimei Formation. Following the fault F1, the first syncline incompletely crops out between faults F1 and F3, and the second anticline is constrained by faults F3 and F5 (Fig. 3B). All of the strata in the second anticline are the counterpart of bed 6 of Wang et al. (1976) and beds 8, 9 and lower part of 10 of Xu et al. (1990). Thus, it is a composite syncline in

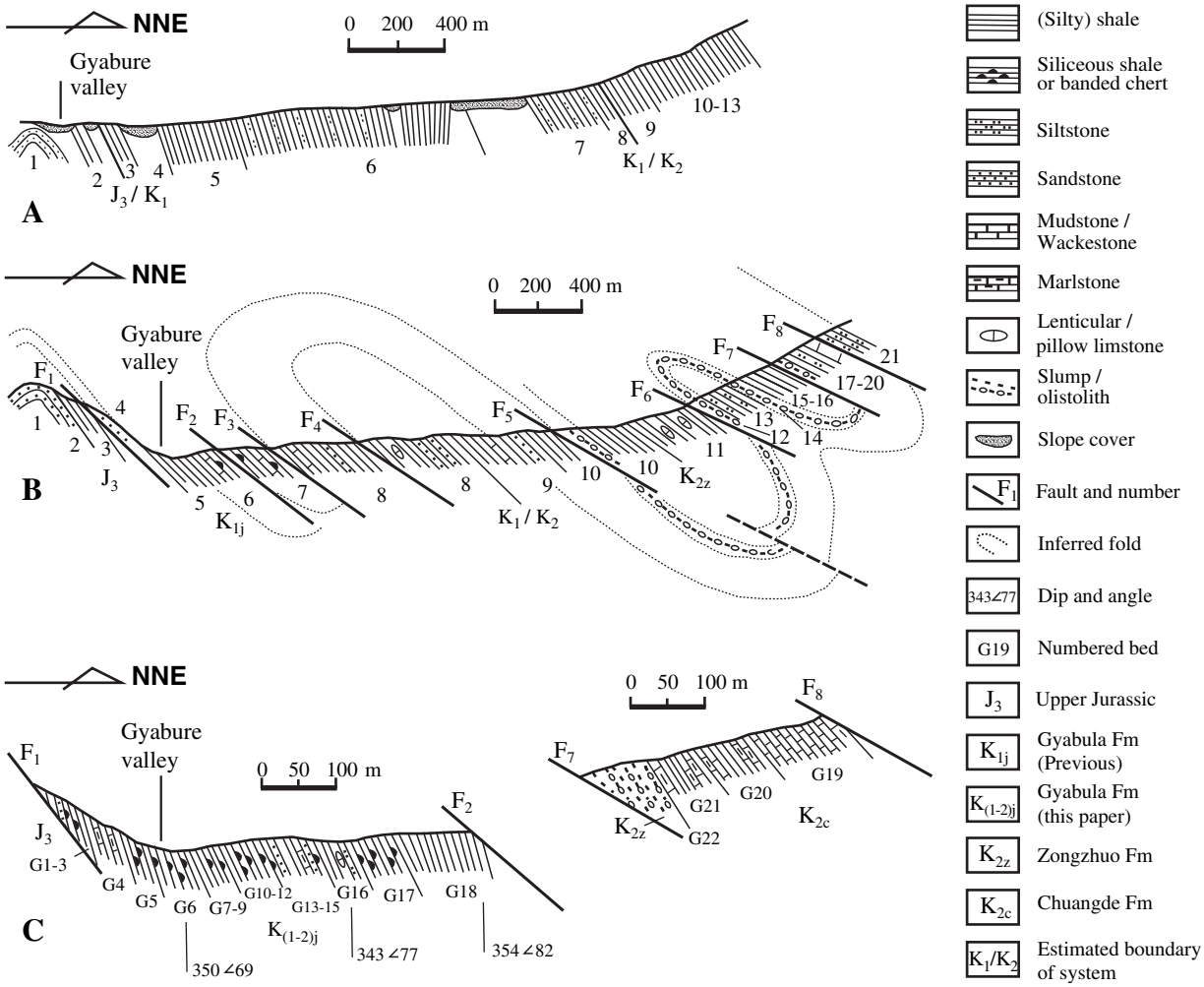

Fig. 3. Re-interpretation and comparison of the Gyabure section as measured by different authors: A, Wang et al. (1976); B, Xu et al. (1990) with our structural interpretation; C, this paper.

which the strata involved are equivalent to beds 7–13 of Wang et al. (1976) and beds 10–21 of Xu et al. (1990).

Fossils indicate that the strata between faults F1 and F2 are of Early Cretaceous age, and the sedimentary structures (sole marks) show a normal succession northwards, i.e., it becomes younger from bed 5 to 6 (Fig. 3B). We found Late Cretaceous strata in the upper part of the cross-section that lies between faults F7 and F8 (Fig. 3B), which contradicts the interpretation (Fig. 3A, B) of Wang et al. (1976) and Xu et al. (1990). We also carried out more detailed measurements of the succession between faults F1 and F2 and F7 and F8 (Fig. 3B, C). By adding the thicknesses we obtained, and allowing for corrections for duplication of strata by thrust faulting, we arrived at an average thickness of 300–500 m for the Cretaceous strata, although at several sections we measured almost 700 m.

Another erroneous interpretation of the thickness and sequence of the Cretaceous succession was also identified at the locality of Weimei, which is not far from the Gyabure section (Fig. 2). Wu et al. (1977) interpreted it as becoming younger northward (Fig. 4), and estimated it to be more than 1000 m thick. We have revised the interpretation of beds 9–4 of Wu et al. (1977), using sole mark orientations and renumbered beds W1–6 (Fig. 4), correlating them with strata in the Gyangze area. As a result, we obtained a thickness of less than 300 m for the Cretaceous of the Weimei section.

The stratigraphic succession at Chuangde was interpreted by Wu (1987) to be overturned, and has frequently been cited as a key reference section for the deeper water Cretaceous exposed in the north Tethyan Himalayas (southern Tibet). The section is near the village of Chuangde, about 15 km east-north-east of Gyangze (Figs. 1, 2). This area is much easier to study than the Gyabure cross-section. Wu (1987) considered the north-westward (from right to left in Fig. 5A) sequence to be progressively younger and dated most of the strata as Late Cretaceous–Eocene, although there is no fossil evidence for the Palaeogene. We assume that his interpretation was partly influenced by a comparison

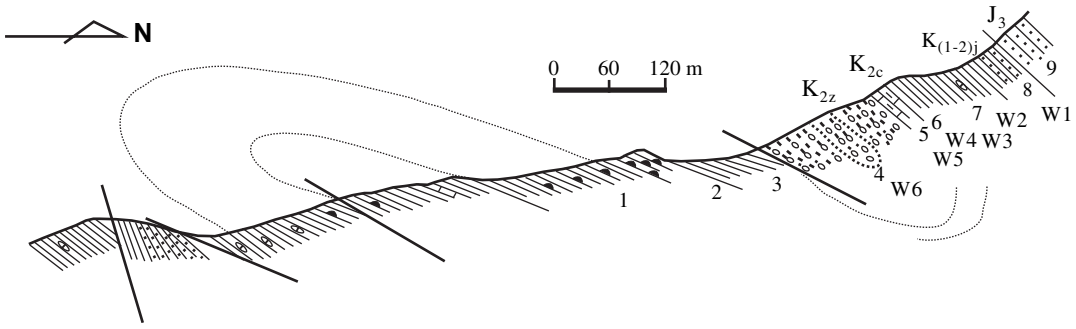

Fig. 4. Re-interpretation of the Weimei section, originally measured by Wu et al. (1977). We have subdivided beds W1-6. For legend, see Fig. 3.

with Cretaceous–Palaeogene sequences in Tingri and Gamba, which belong to a shallower development of the south Tethyan Himalayas (Willems et al., 1996). However, our results lead us to a quite different interpretation.

Many sedimentary structures in the lower part (left part of Fig. 5B) of the Chuangde section indicate that the top of the sequence is in the opposite direction, i.e., south-eastward. The indicators include scours, sole marks, graded bedding and basal conglomerates in beds C12 and C15, in the lower part of the section (Fig. 5B). Ages suggested by the fossils also indicate that strata become younger towards the south-east. Foraminifera and radiolaria indicate that beds C26–30 are Cenomanian–Turonian in age, and beds C33–35 are Santonian–Early Campanian (Fig. 5B, Section 3). The presence of an andesite and a basalt in the lowest part of the section (Fig. 6), dated as Middle Jurassic (Xu et al., 1990), provides additional support for our interpretation.

Because the strata in the Gyabure and Weimei sections are repeated by reverse faults, we recommend that the Chuangde section serve as a type section for the deep water Cretaceous stratigraphy of the north Tethyan Himalayas.

2.2. Lithostratigraphic markers

There are at least four lithostratigraphic markers within the Cretaceous strata in the Gyangze area.

Belemnite bearing and black marker (BBM). Most of the Lower Cretaceous is composed of dark grey shale intercalated with siliceous shale and sandy turbidite beds. The dark colour of this unit persists throughout the area (Fig. 7A), and is further characterized by the occurrence of belemnites, which are mostly widely scattered but in some beds concentrated to the extent that they form up to 80% of the rock (Fig. 7B). The strata with belemnites are chiefly in beds G4 of the Gyabure section, where they may be up to 50 m thick (Fig. 2), and C27 of the Chuangde section.

Lenticular limestone and white marker (LWM). The lower part of the Upper Cretaceous is characterized by pale grey shale that is readily distinguishable from the dark coloured strata in the field. The shale encloses many limestone concretions (Fig. 7C), some of which are up to 500 cm in diameter. The presence of large lenses of the limestone together with the light grey colour of the strata makes them easily recognizable in the field.

Red marker (RDM). Red sediments crop out locally in the Gyangze area and are rare in all of the north

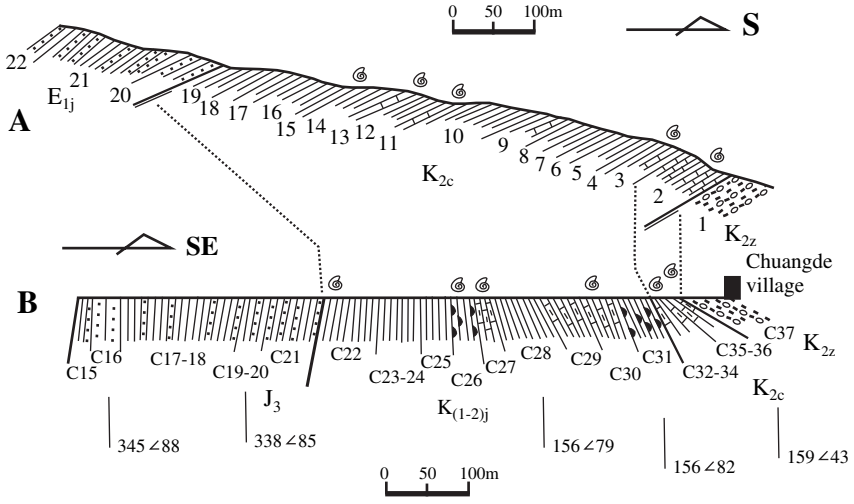

Fig. 5. Re-interpretation and comparison of the Chuangde section: A, Wu (1987); B, this paper. For legend, see Fig. 3.

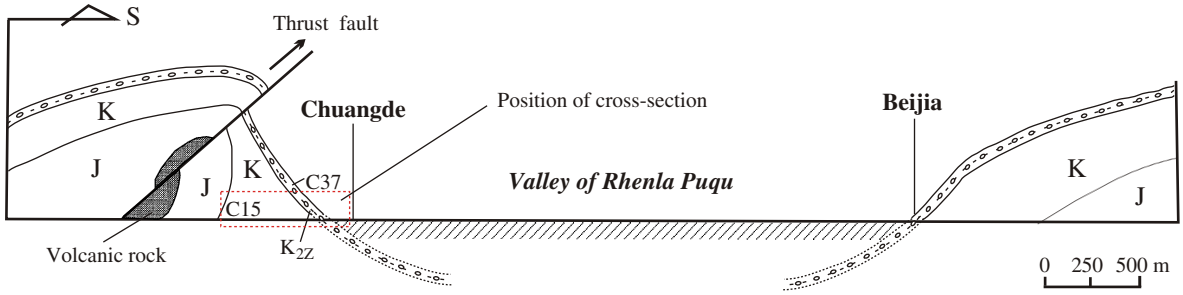

Fig. 6. Location of the Chuangde section and structural background interpretation. For legend, see Fig. 3.

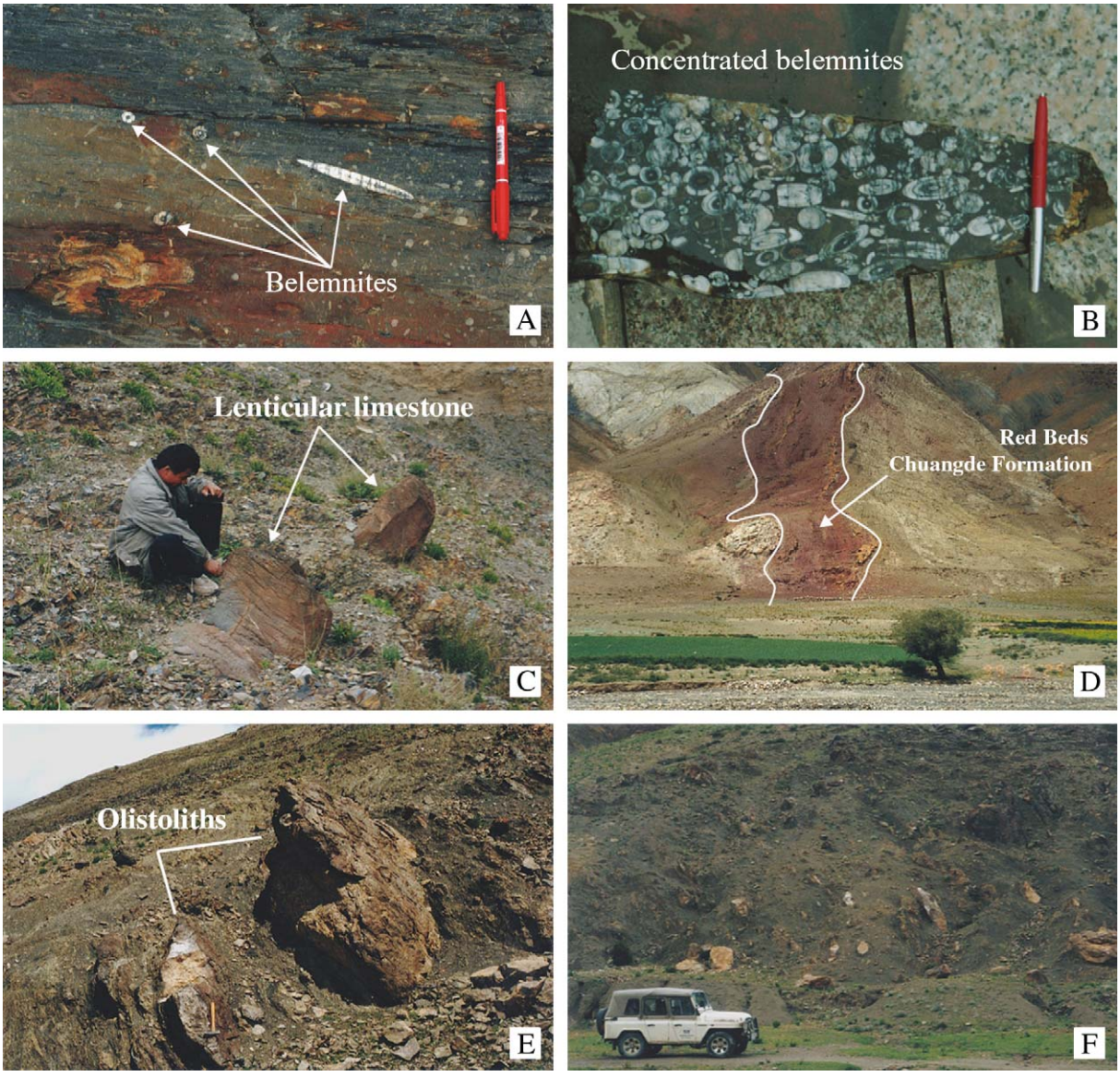

Fig. 7. Photographs showing Cretaceous deposits in the Gyangze area. A, belemnites in the Chuangde Pu Member of the Gyabula Formation, Gyabure Valley; the marker pen on the right is 14 cm long. B, belemnite lumachelle in the Chuangde Pu Member of the Gyabula Formation, Gyabure Valley; the pen at the right is 13.5 cm long. C, lenticular limestones in the Jibuli Member of the Gyabula Formation, Gyabure Valley. D, pelagic red beds, the counterpart of the Chuangde Formation that crops out at Chuangde village, ca. 500 m west of the typical Chuangde section shown in Fig. 8B. E, olistoliths in the Zongzhuo Formation, Chuangde section; the hammer is 34 cm long. F, photograph showing the whole of the Zongzhuo Formation, Chuangde section.

Tethyan Himalayas. The marker is cardinal/violet-red shale intercalated with pale red marlstone and/or greyish green siliceous mudstone and shale (Fig. 7D). There are also a few debris and deformed red limestones enclosed in red shales. The age of the marker is constrained by the presence of Santonian–early Campanian microfossils (see below).

Olistolith marker (OLM). This lithologic marker is widespread over the whole area. Along the road from Nagarze to Gyangze, olistoliths of different sizes and abundances are entrenched within the shales and siltstones, particularly south-west of Yamdrock Tso. The size of olistoliths varies from 30–100 cm (Fig. 7E, F) to over 20 m in maximum dimension. Hence, this unit is designated as a stratigraphic marker for field mapping in the study area.

3. Stratigraphic framework

Many Chinese geologists established the stratigraphic framework of the Cretaceous in the Tethyan Himalayas used hitherto (Yang and Wu, 1962; Wang et al., 1976; Xu et al., 1990; TBGMR, 1993, 1997: Table 1). However, there are numerous problems with it. According to the revised stratigraphic thicknesses and sequences, the lithological markers described above, and biostratigraphic determinations, we revise the stratigraphic classification here.

The Cretaceous strata in the Gyangze area can be subdivided into three main formations. In an upward stratigraphic order they are: Gyabula, Chuangde and Zongzhuo (Table 1; Fig. 8A, B). All three are easily correlatable in the study area (Fig. 9) and can be mapped.

3.1. Gyabula Formation

The Gyabula Formation has been mapped near the village of Gyabure (Wang et al., 1976). It is composed of dark grey siliceous/calcareous shale, siltstone, and turbidite beds with a few carbonate concretions. It is 160–400 m thick and conformably overlies the Weimei Formation, and in turn is overlain with a gradational contact by the Chuangde Formation. However, in Yamdrock Tso, the contact with the overlying Zongzhuo Formation may be paraconformable. Belemnites, ammonites, foraminifera and radiolaria indicate a Berriasian–Early Santonian age for the formation (this differs from previous interpretations), which is subdivided here into two members, as follows.

3.1.1. Chuangde Pu Member

This member is the counterpart of the lithological marker BBM and is composed of dark grey shale intercalated with turbiditic sandstone beds (Figs. 7A, 8B). Pyrite concretions are common, and belemnites, radiolarians and planktonic foraminifera have been found in these beds. The member is 100–350 m thick and conformable with the overlying Jibuli Member. Three fossil assemblage zones have been recognized: A Zone, the belemnite *Hibolites* Assemblage Zone, composed of the fossils *Belemnopsis* cf. *sinensis*, *Hibolites jiabulensis*, *H. jiangziensis*, *H. parahastatus*, *H. subfusiformis* and *H. verbeeki* (Valanginian); B Zone, the radiolarian *Artocapsa* Zone, characterized by the presence of *Artocapsa*, *Cyrtocapsa*, *Pseudodicyonitra* and *Stylophaera* (Albian); C Zone, characterized by the presence of the radiolarians *Eucyritium* sp., *Hemicryptocapsa* sp., *Pseudocaulophacus floresensis* and *Theocape tina*, and the foraminiferan *Glomospira* sp. (early Cenomanian). The age of the member is, therefore, Berriasian–early Cenomanian.

Table 1
Lithostratigraphic subdivision and dating of Cretaceous deposits in the Gyangze area of southern Tibet

Series	Stage	Yang and Wu, 1962	Wang, et al., 1976	*	Wu, 1987	This study		
Upper Cretaceous	Maa	Zongzhuo Formation	Zongzhuo Formation	Zongzhuo Formation	Chuangde Formation	Zongzhuo Formation		Olistolith marker (OLM)
	Cmp					Chuangde Formation		Red marker (RDM)
	San				Zongzhuo Fm	Gyabula Formation	Jibuli Member.	Lenticular limestone and white marker (LWM)
	Con							
	Tur		Gyabula Formation					
	Cen						Chuangde Pu Member	Belemnite bearing and black marker (BBM)
Lower Cretaceous	Alb | Ber			Gyabula Formation	?			

* Wu, 1984; Xu et al., 1990; TBGMR, 1993, 1997.

3.1.2. Jibuli Member

This unit corresponds in part to lithological marker LWM. It is a dark grey to black, calcareous shale up to 100 m thick, which characteristically weathers greyish white. Two fossil assemblage zones have been recognized in this member: D Zone, *Dictyomitra* Zone, with sparse *Dictyomitra* sp. and *Stichocapsa* sp. in the lower part of the member (probably middle–late Cenomanian); E Zone, *Whiteinella-Pseudotheocampe* Zone,

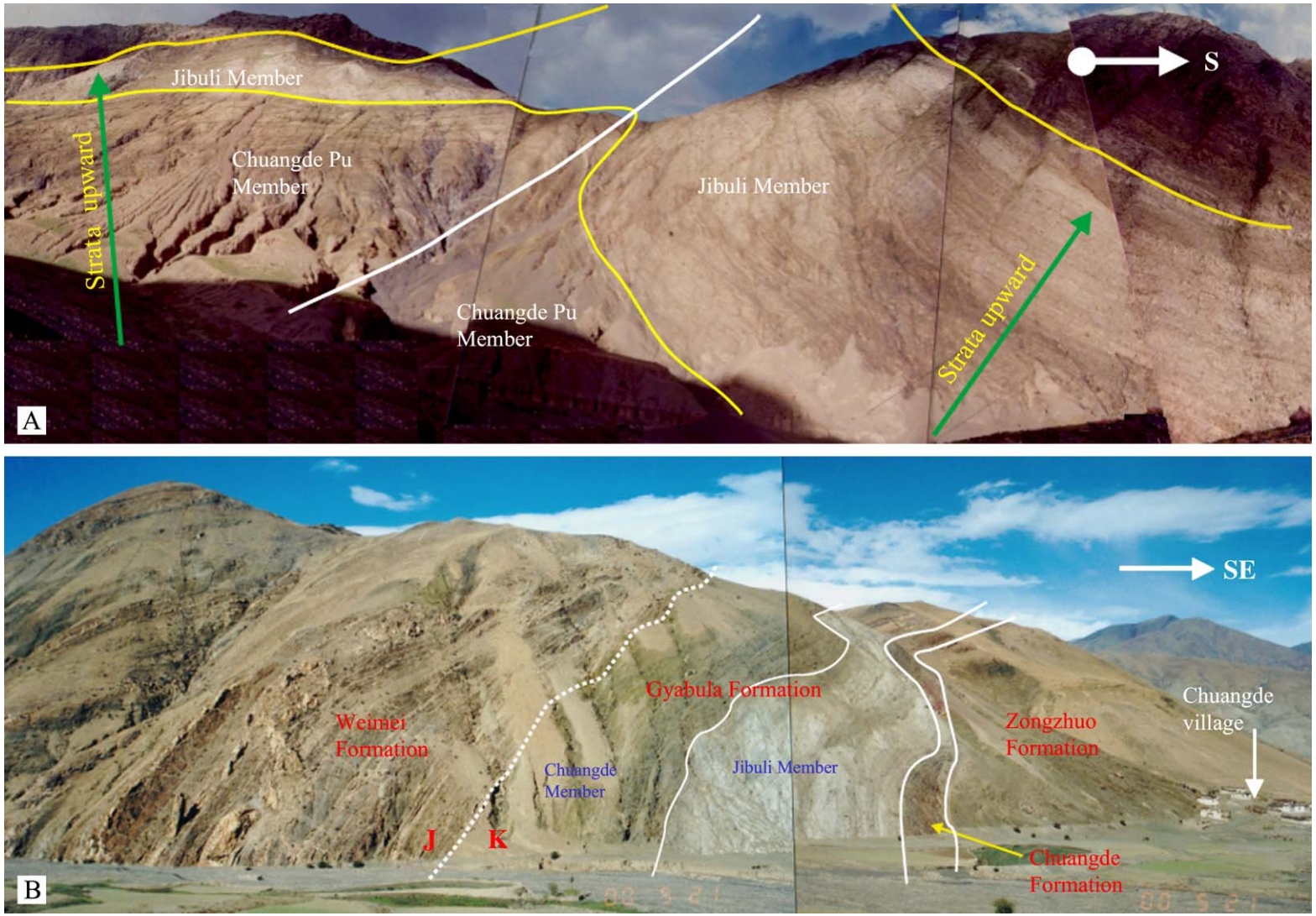

Fig. 8. Photographs of sections in Gyangze. A, the Chuangde Pu and Jibuli members of the Gyabula Formation between the village of Gyabure and the Gyabure Valley. B, the Cretaceous and upper Jurassic successions of the Chuangde section.

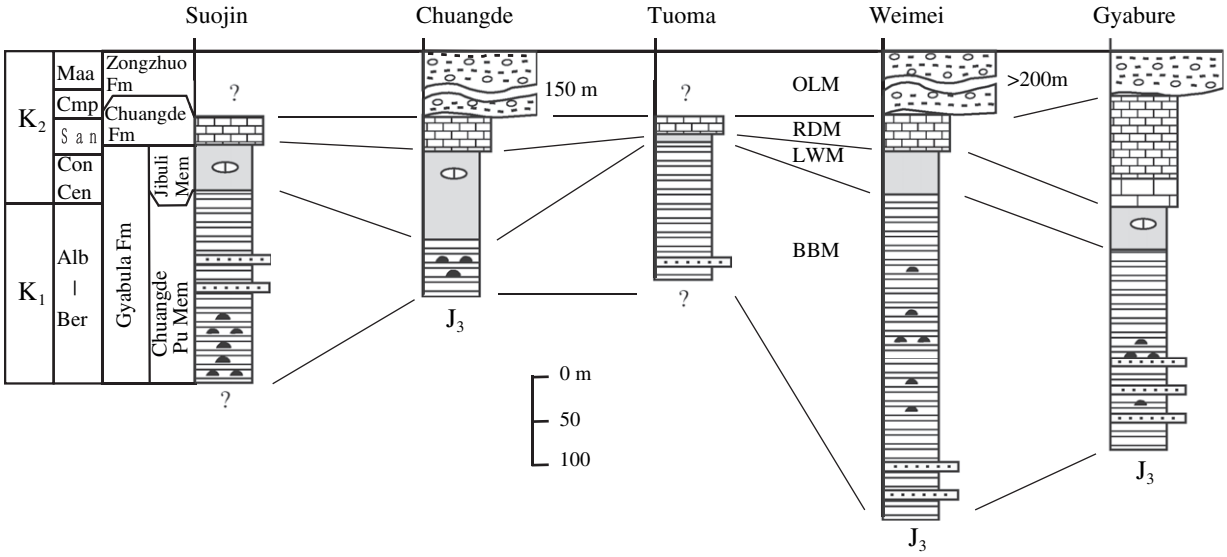

Fig. 9. Correlation of Cretaceous sections in the Gyangze area. For locations and legend, see Figs. 2 and 3 respectively.

yields the radiolarians *Gravidiscus*, *Grongylothorax*, *Obesacapsala*, *Theocampe* and *Tricolocapsa*, and the foraminifera *Hedbergella* spp., *Rotalipora* sp. and *Whiteinella archaeocretacea* (latest Cenomanian–Turonian). The age of the Jibuli Member is, therefore, middle Cenomanian–Turonian.

3.2. Chuangde Formation

As discussed above, the stratigraphic sequence at the Chuangde locality becomes progressively younger south-eastwards rather than, as Wu (1987) indicated, in the opposite direction. We redefine it because it was misinterpreted to represent the top of the Cretaceous succession. The formation corresponds to the RDM and is characterized by violet-red and pale red siliceous shales, marls and siliceous limestones intercalated with greyish green, pale grey and red radiolarian silicates and foraminiferal packstones. It is conformable with both the underlying and overlying formations. In most places it is less than 20 m thick. Abundant planktonic foraminiferal and radiolarian fossils, *Globotruncana linneiana*, *G. stuartiformis*, *G. ventricosa*, *Globotrancanita elevata*, *Heterohelix* sp. and *Marginotruncana stuarti*, and *Theoscapsa amphora* respectively, constrain the age to middle Santonian–early Campanian.

3.3. Zongzhuo Formation

The Zongzhuo Formation, also called "Beijia Melange" (Wu et al., 1977), is characterized by the presence of a great number of olistoliths (Fig. 7E, F) in a dark grey–black shale and siltstone matrix. The olistoliths vary in size and composition; some are up to 20 m in diameter, and composed of sandstones, limestones, bedded chert silicates, and even volcanic rocks. There are almost no exposures of rocks above it. The revised thickness of this unit is 200–ca. 500 in Gyangze. By implication of its stratigraphic position above the conformable Chuangde Formation, the age of the Zongzhuo Formation is estimated to be middle Campanian–Paleocene (Liu and Aitchison, 2002). It is synonymous with the OLM marker.

4. Conclusions

Studies of several cross-sections of Cretaceous strata in the Gyangze area has led to a revision of the stratigraphy of the deep-water Tibetan Tethyan Himalayas, because some tectonic repetition and tectonically-overturned strata had not been recognized previously. The Cretaceous strata of Gyangze are between 300 and 700 m thick, not 2000 m thick as previously estimated. In the Chuangde section they become progressively younger towards the south-east rather than towards the north-west. This section is recommended to be the type section of Cretaceous deep-water deposits in southern Tibet because it is not affected by tectonic repetition and strata overturn, unlike the Gyabure and Weimei sections.

Four Cretaceous lithostratigraphic markers were found to be helpful for stratigraphic analysis in the tectonically complex Gyangze region. Two of these, the members of the Gyabula Formation, and the other two are equivalent to the Chuangde and Zongzhuo formations. Foraminiferal and radiolarian assemblages have enabled the dating of these units. This revised Cretaceous stratigraphy provides a general framework for detailed studies of Late Cretaceous pelagic red beds variably exposed in the Gyangze and Yamdrock Tso areas of southern Tibet.

Many questions on the Cretaceous stratigraphy of southern Tibet remain unanswered. Additional studies are needed to determine the contact relationships between lithostratigraphic units and to test their isochroneity. The scarcity of fossils is puzzling. More finds of macro- and microfossils are needed for more precise biostratigraphic determination, and more detailed stratigraphic studies are necessary on the Cretaceous of the north Tethyan Himalayas.

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