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Jurassic ammonites of the Wulong area, Tingri County, Tibet

Nicol MORTON [1], Christian MEISTER [2], Louis RULLEAU [3], Xiaoying SHI [4]

Key words: ammonites, Jurassic, Tibet, systematic, biostratigraphy.

Abstract. The Jurassic succession west of Wulong village, Tingri County, southern Tibet, is described. Lithostratigraphical classification uses pre-existing terminology for formations, and an informal subdivision into members is proposed. An important structural dislocation, in the form of a small-scale flower structure, affects the Zhamure Formation straddling the Triassic/Jurassic boundary but does not affect the underlying Derirong Formation (Rhaetian) or the overlying Wulong Formation (Lower Jurassic). No other major structural discontinuities could be recognised. New finds of ammonites *in situ* include a new genus and species of possible schlotheimiid, *Womalongiceras inflatum*, with a probable age of Sinemurian or slightly younger. Two separate beds yielded rich assemblages of crushed ammonites identified as *Nyalamoceras nyalamensis* Chao and Wang (1956) here interpreted as a hammatoceratid. The age of these is reinterpreted as uppermost Aalenian on the basis of an accompanying specimen of ?*Pseudolioceras (Tugurites)* sp. nov. and poorly preserved ammonites from higher beds identified as graphoceratids (?*Graphoceras*).

INTRODUCTION

The Jurassic of Tibet was almost unknown until the second half of the 20th Century, as indicated by there being only two pages on Tibet and Nepal in Arkell (1956, p. 413–414). There had been indications of the presence of marine Jurassic in Tibet based on accounts by explorers, but very little useful information emerged. However, one resulted in a description of Bajocian ammonites from Tibet by Arkell (1953).

The first detailed information resulted from expeditions to the Mount Jolma Lungma (Qomolangma in Tibetan, Everest in English) region in 1966–1968 under the auspices of Academica Sinica. Reports of these expeditions, published in the mid-1970s in Chinese, included a monograph with 18 plates on Jurassic and Cretaceous ammonites by Chao Ping-Koo and Wang Yi-gang (1976). A summary of the expedition's results in English was published by Mu An-tze *et al*. (1973). However, complexities of structure meant that stratigraphical information was limited and the palaeontological work, including new genera and species, was little known outside China.

In this paper we describe the succession in the Wulong area of Tingri County in southern Tibet (Figs 1A, B) and describe the ammonites found, nearly all collected *in situ*.

GEOLOGICAL BACKGROUND

The geographical, geological and historical context of southern Tibet is discussed in detail in Li and Einsele (1994), Shi *et al*. (2006) and Jadoul *et al*. (1998). Briefly, the Himalayan

[1] Formerly Birkbeck College, University of London, Le Chardon, 180 Chemin Brugière, 07200 Vogüé, France; e-mail: nicol.morton@orange.fr.
[2] Natural History Museum of Geneva, Department of Geology and Paleontology, 1 Rte de Malagnou, CP 6434, 1211 Geneva 6, Switzerland; e-mail: christian.meister@ville-ge.ch.
[3] Ch. de l'Herbetan, 69380 Chasselay, France; e-mail: louis.rulleau@wanadoo.fr.
[4] Department of Geology, China University of Geosciences, 29 Xueyuan rd, Beijing 100083, China; e-mail: shixyb@cugb.edu.cn.

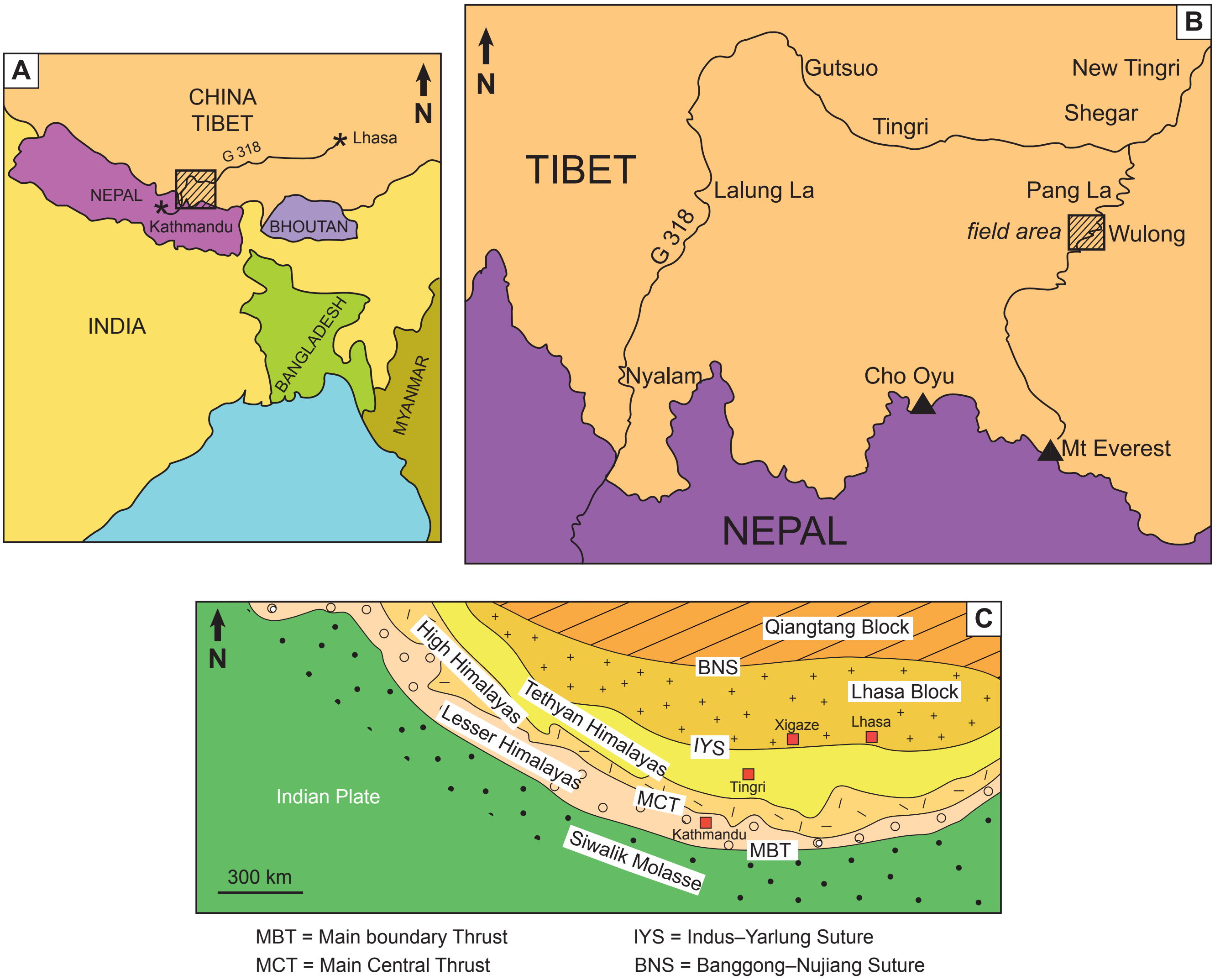

Fig. 1. A. Map of part of southern Asia showing location of southern Tibet and the Kathmandu to Lhasa road. B. Map of part of southern Tibet, Nyalam and Tingri Counties, showing key localities, the Kathmandu – Lhasa road G318, and the tourist route to Mt Everest base camp. The study area at Wulong is situated south of the Pang La. C. Geological framework of the Himalayas and Tibetan Plateau with their major tectonic units: MBT Main Boundary Thrust; MCT Main Central Thrust; IYS Indus–Yarlung Suture; BNS Banggong–Nujiang Suture (from Liu, Einsele, 1994)

Chain, formed by the collision of the Indian Plate with the Eurasian Plate, is one of the largest mountain ranges and represents the eastern part of the Alpine-Himalayan orogenic belt. Southern Tibet is situated on the Indian Plate, part of the Gondwana continent during the Jurassic Period. More precisely the area studied is part of the Tethyan Himalayan tectonic zone or belt (Ganser, 1964; Windley, 1988; Liu, 1992; Shi *et al.*, 2006) (Fig. 1C).

Marine Jurassic sediments crop out widely in this area between the Lesser Himalayan and Higher Himalayan belts to the south and the Indus–Yarlung suture to the north. The rocks have been subject to strong transpression, with tight folding, thrusts and many strike-slip faults. In general, the degrees of deformation and metamorphism increase towards the north, reaching blueschist facies near the suture.

In recent years numerous studies have been carried out on the Jurassic of Tibet, sometimes involving collaboration between Chinese and non-Chinese geologists [for example, see Shi *et al*. (1996), Shi *et al*. (2006), Yin *et al*. (2007), Yin and Fürsich (2009) and Yin (2010)]. In 2010 the 8th International Congress on the Jurassic System was held in China and field guides were published for most regions. Unfortunately the proposed field trip to Tibet had to be cancelled so no guide-book for Tibet was published.

FIELDWORK

In June and July 1999 an expedition including two of the authors (NM and XS) carried out fieldwork in Tingri, Nyalam and Gamba Counties, with seven working days in the Wulong area of Tingri County. This involved travelling each day from the base in Shegar village into the Qomolangma National Park and over the 5200 m high Pang La to the Wulong area [GPS readings 28°28'N 87°01'E altitude 4350 m] (Fig. 1B). The main section studied is in the valley leading from the ruins of Dzongkog Pongdro up the Gara valley to Womalong village to the west of Wulong village (Fig. 2A). A second section north-east of Wulong, in the valley north of Yongjia where the road from Shegar to Mt. Everest Base Camp crosses the stream is not discussed here, because the structural and stratigraphical relationships of the two sections are not clear.

Note that the names and orthography of Tibetan villages are not always consistent; those used here are from Google Earth, but correspond closely to those used in the field.

This paper describes one section in the Wulong area of Tingri County, along the road that leads from the tourist route to Mt Everest base camp just south of Wulong village and follows a narrow valley leading to Womalong village (Fig. 2A). The section continues along the stream in a broader valley north-west and north of Womalung village (not shown in Fig. 2A).

The succession is summarized in Figure 3, showing the beds where ammonites were found. The field log recorded by NM is given in Appendix 1. Parts of the section, especially those with ammonites, could be measured in reasonable detail, but for other parts there was insufficient time and thicknesses are estimated.

There is no apparent evidence in the field for significant stratigraphical or structural breaks in the succession other than that affecting the Zhamure Formation (Fig. 2B). The outcrops of the Derirong and Wulong Formations, respectively to the south and north, were observed in the field to be continuous across the valley. The structure is interpreted here as a narrow flower structure associated with two thrust faults within the less competent strata of the Zhamure Formation.

The main purpose of this paper is to give a summary description of the succession and to describe and discuss ammonites that were found for the first time. They include a new genus, *Womalongiceras*, and *in situ* assemblages dominated by the genus *Nyalamoceras*, first described in Chinese and figured by Chao and Wang (1976). The highest specimens in the sequence are interpreted to be ?*Graphoceras*, although preservation is poor.

STRATIGRAPHY

Information on the sequence stratigraphy is given by Shi (2001). This contribution will discuss the stratigraphy and ammonites found in the Jurassic section between the Wulong and Womalong villages.

The lithostratigraphical scheme of formations used here is based on Shi *et al*. (1996) because this seems more appropriate to this section than the generalised one in Shi *et al.* (2006); informal subdivision into members is suggested here. Thicknesses of members are mostly estimated rather than measured in detail (Fig. 3).

In the wider setting of southern Tibet large faults are observed that result in interleaving of units that are stratigraphically unrelated, with partial repetition or omission of succession. However, in the Wulong section no significant faults of this type were observed between the base of the Wulong Formation and the top of Member 3 of the Kangdui Formation. In the higher parts of the section some faults with brecciation were observed but the structural and stratigraphical consequences were unclear. Faults at high angles to the strike of the beds are common but have small displacements of less than five metres. There are abrupt lithological changes from coarser beds to black mudstones between the top of the Wulong Formation to the base of Member 1 of the Kangdui Formation and from the top of Member 2 to the base of Member 3 of the Kangdui Formation.

SUMMARY DESCRIPTION OF SECTION

The section studied extends from the entrance to the narrow Gara valley where it meets the main route to Mt. Everest base camp, near the ruined village of Dzongkog Pongdro, and follows both sides of the valley, but mainly beside the road on the east side of the valley to Womalong village. It continues following up the stream west of the village and to the north. Approximately 450 m north of the village the valley becomes broader and shallower and the section ends in a vertical wall of breccia trending 032–042 degrees. There appeared to be few outcrops further upstream. A more detailed field log is given in the Appendix 1.

Stream section north-west and north of Womalong:

Large fault with vertical wall of breccia, trend 032–042 degrees.

- *Kangdui Formation, Member 9*: Thinly-bedded limestones, mudstones, siltstones and sandstones;
- ammonites (J1K5) *c*. 10 m and *c*. 40 m above base (**90.0 m**).

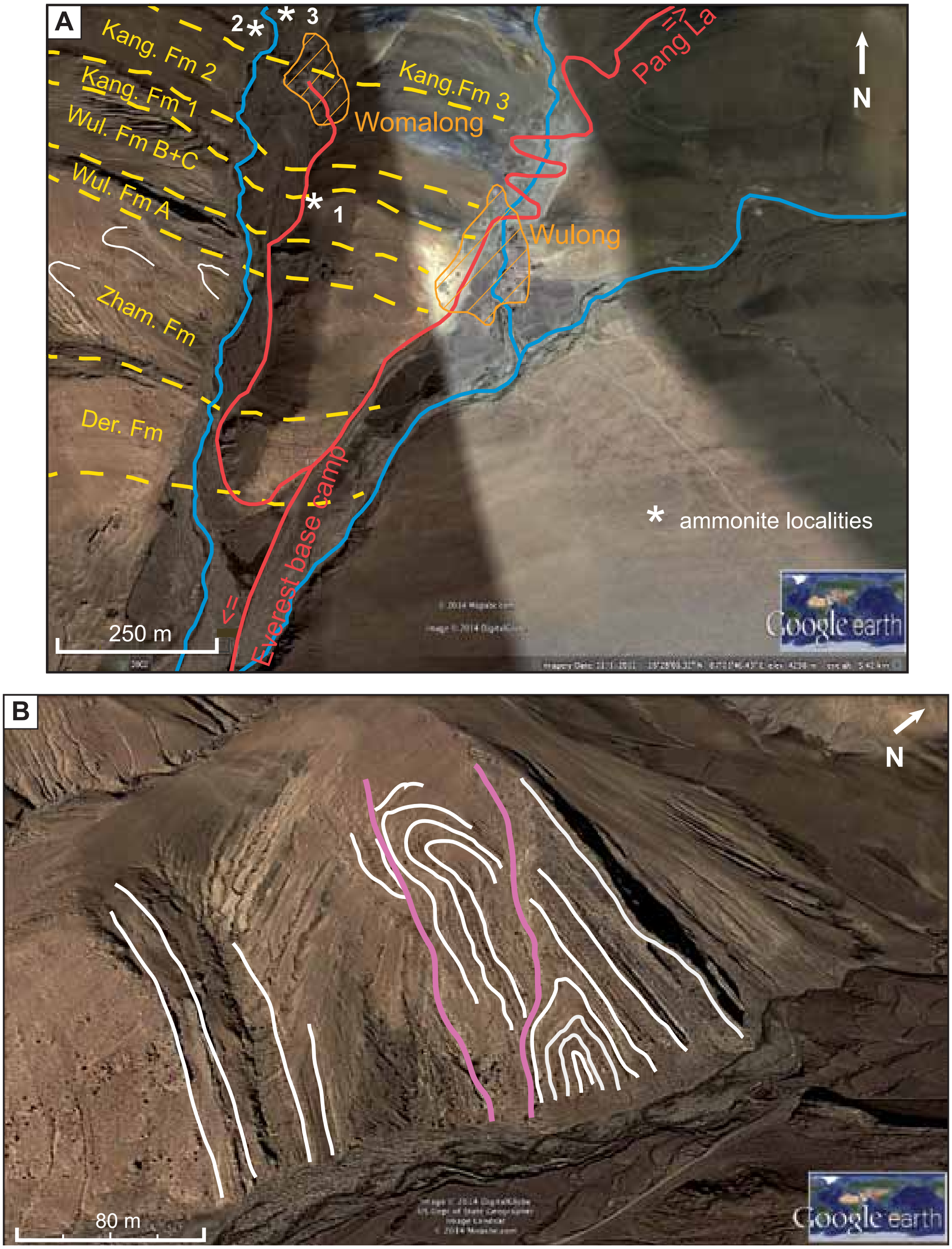

Fig. 2. A. Geological sketch map of the Wulong–Womalong area, Tingri County, southern Tibet, based on a Google Earth image with streams (blue) and roads/tracks (red) added. Stratigraphical boundaries (yellow dashed lines) are based on field notes and recognition of topography. B. Oblique Google Earth image looking north-west at the western side of Gara valley south of Womalong village, showing deformation of the Zhamura Formation between the undeformed Derirong Formation (to left) and Wulong Formation (to right)

Abbreviations: Kang. Fm. – Kangdui Formation (members 1–9); Der. Fm. – Derirong Formation; Zham. Fm. – Zhamure Formation with folding picked out; Wul Fm. – Wulong Formation, members A, B and C; Kang. Fm. – Kangdui Formation, members 1, 2 and 3 (members 4 and higher crop out to north of Womalong village). **Localities where ammonites were found are indicated by white stars:** 1 – Ammonite J1W1; 2 – Ammonite fauna J1K2; 3 – Ammonite fauna J1K3. The field log (Appendix 1) starts from the road to Everest base camp and follows the road to and through Womalong village and then the stream north-west and north of the village

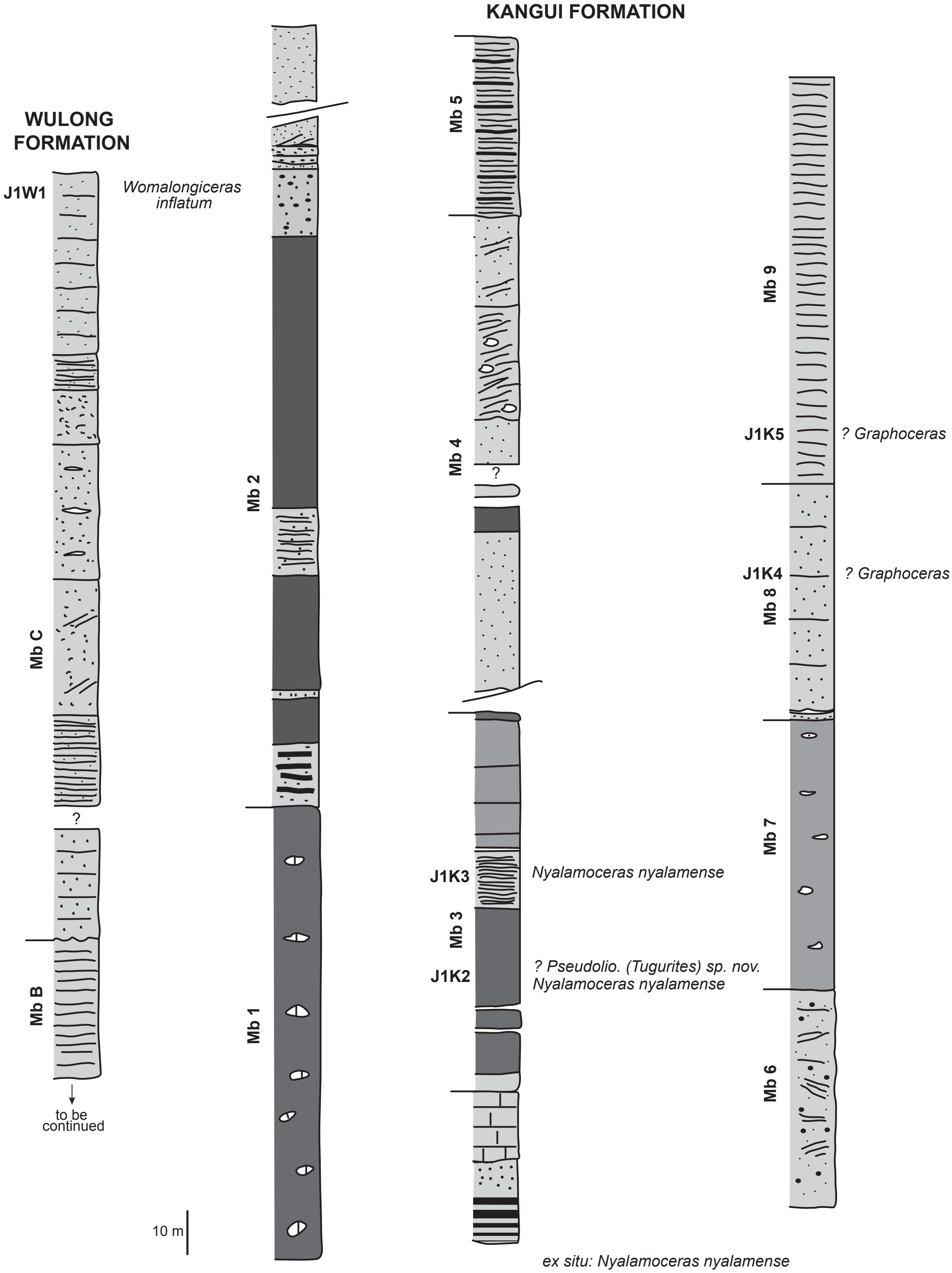

Fig. 3. Lithologic profiles of the Wulong Formation and of the Kangdui Formation in Wulong–Womalong area showing ammonite occurrences found

- *Kangdui Formation, Member 8*: Greenish sandstones, volcaniclastic, and some black mudstones, ammonites (J1K4) (**52.6 m**).
- *Kangdui Formation, Member 7*: Black mudstones with nodules (**60.0 m**).
- *Kangdui Formation, Member 6*: Grey harder sandstones, channel bases with pebbles (**50.0 m**).
- *Kangdui Formation, Member 5*: Black mudstones and siltstones, plant fragments (**40.0 m**).
- *Kangdui Formation, Member 4*: Pale sandstones with dark grains, trace fossils and bivalves, channel sandstones and siltstones; structurally complex, fault zone at base (**113.5 m**).
- *Kangdui Formation, Member 3*: Black mudstones with siltstones and sandstones; ammonites found *c.* 20 m (J1K2) and *c.* 45 m (J1K3) above base (**88.0 m**).
- *Kangdui Formation, Member 2*: Hard calcareous sandstone; bivalves and brachiopods, forms waterfall (**15.0 m**).

Section beside road to Womalong village:

- *Kangdui Formation, Member 2 (contd.)*: Interbedded sandstones, some with channelled bases, siltstones and black mudstones, generally coarsening upwards; minor faulting (**208.5 m**).
- *Kangdui Formation, Member 1*: Dark grey mudstones with scattered calcareous nodules (occasionally fossiliferous) (est. **90–100 m**).
- *Wulong Formation, Member C*: Massive to bedded coarse- to medium-grained sandstones, calcareous with lenses of fossils, interbedded with siltstones and mudstones; ammonite (J1W1) near top, bivalves and plant fragments (**140.0 m**).
- *Wulong Formation, Member B*: Interbedded limestones, siltstones and mudstones with occasional greenish sandstones (**126.9 m**).
- *Wulong Formation, Member A*: Thickly-bedded shelly limestones with brachiopods at top, underlain by mixed limestone and sandstone beds (**112.5 m**).
- *Zhamure Formation*: Upper part interbedded sandstones, siltstones and limestones, strongly folded (Fig. 2B) and structural relations not clear, separated by major fault zone from lower part of red-coloured sandstones, siltstones and mudstones (>**170 m**).
- *Derirong Formation*: Quartzitic sandstones, white to red-weathering, thickly bedded with cross-bedding and vertical burrows; some calcareous beds with bivalves near base (>**120 m**).
- *Norian and Carnian*: Not examined; strata crop out towards main road and to south.

PALAEONTOLOGY

SYSTEMATIC PART

Class CEPHALOPODA Cuvier, 1798

Subclass **Ammonoidea** Zittel, 1884

Order **Psiloceratida** Houša, 1965

Superfamily **Psiloceratoidea** Hyatt, 1867

Family ?**Schlotheimiidae** Spath, 1923

Genus ***Womalongiceras*** gen. nov.

Type species. – *Womalongiceras inflatum* sp. nov.
Derivatio nominis. – From the nearby village Womalong.

Diagnosis. – Diagnostic features are (1) planorbicone-subcadicone coiling in the inner whorls with suboval less inflated whorls and well-developed simple almost straight ribs clearly interrupted on the venter, as in schlotheimiids, and (2) subsphaerocone – discocone coiling in the outer whorls with massive thick whorls and rounded venter are particularly diagnostic of the new genus and are unknown in any other schlotheimiid.

Affinities. – A schlotheimiid affinity was first suggested by Desmond Donovan in verbal discussions in 2000, noting the ribbing on the inner whorls. He thought it may be a late endemic schlotheimiid and we concur with his suggestions.

Womalongiceras inflatum sp. nov.

Figs 4A–I, 5A–C

Derivatio nominis. – From Latin *inflatus* = full, puffy suggesting the subsphaerocone coiling.

Diagnosis. – Same as for the genus. The simple ribbing interrupted (at least in the inner whorls) on the venter as in *Schlotheimia* characterizes this species together with the inflated outer whorls.

Type locality. – Wulong area, Tingri County, approx 300 m south of Womalong village, *c.* 10 m up hill from road; *c.* 5 m below the top of Wulong Formation Member C, bed 99 in Appendix 1 [28°28'19.93"N 87°01'37.49"E, elev. 4360 m].

Material. – Only one specimen (the holotype) was found and is illustrated in Figs 4 and 5.

Dimensions (mm).

	D	U	Wh	Ww	U/D	Ww/Wh
Inner whorls	~24	~6	~9.3	10	0.25	1.07
Outer whorls	~100	–	43	38	–	0.88

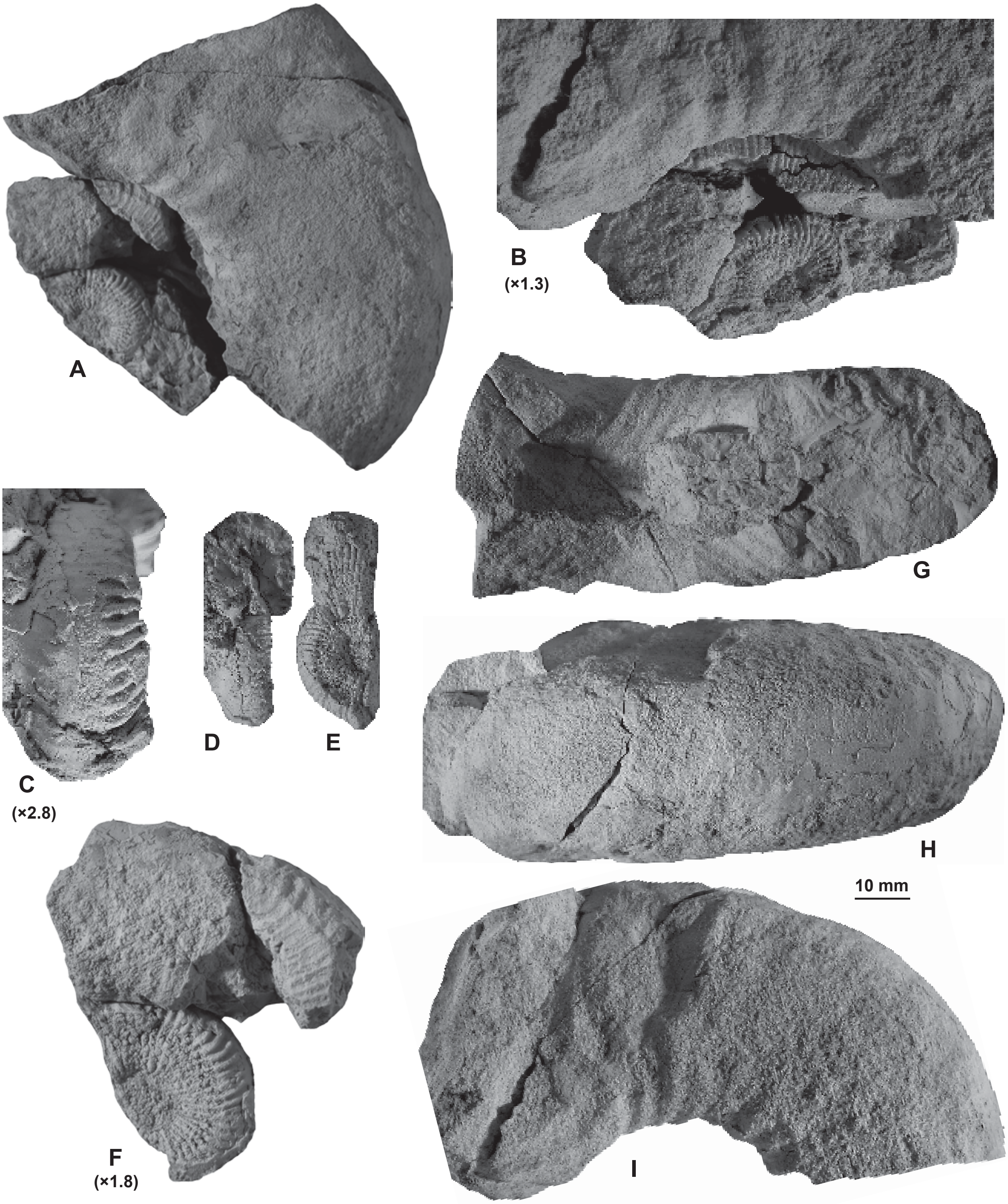

Fig. 4. *Womalongiceras inflatum* gen. and sp. nov.

A, B. Complete specimen as preserved. **C–E.** Inner whorls. **F.** Inner and intermediate whorls. **G–H.** Outer whorl (body chamber) [JIW1]. Ammonite from Wulong area

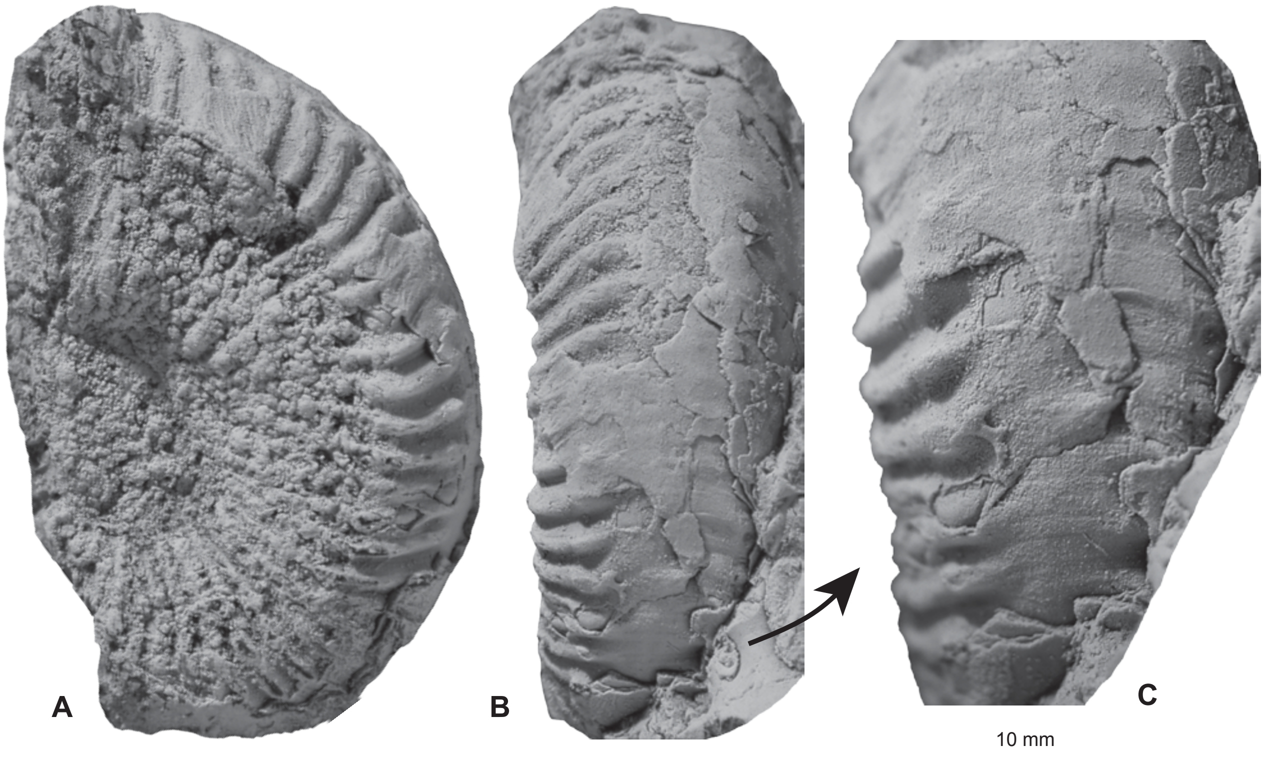

Fig. 5. *Womalongiceras inflatum* **gen. and sp. nov. (juvenile whorls), enlarged**

A. Side view. **B.** Ventral view. **C.** View of venter showing smooth band [JIW1]. Ammonite from Wulong area

Description. – This specimen, with about 100 mm diameter, is characterized by a subsphaerocone-discocone coiling. Only a short part of the body chamber is preserved, approximately one third of a whorl. The umbilicus is deep and rather small with a ratio of U/D of 0.25. The whorls are suboval, with a relatively constant ratio from inner whorls (Ww/Wh = 1) to outer whorl (Ww/Wh = 0.97). The umbilical wall is deeply convex and the umbilical edge rounded.

On inner whorls (Figs 4C–E, 5A–C) the ribbing is simple, rarely fasciculate, slightly rursiradiate. These whorls are less inflated with suboval whorls associated with broad, flat to slightly convex venter on which a distinctive, smooth and narrow siphonal band (furrow) is present. This feature is typical of Schlotheimiidae. On inner-intermediate whorls (Fig. 4F) ribs are fine and acute, very dense and becoming a little sharper towards the venter, forming small nodes on the edge of the venter and with a smooth siphonal band. On the outer whorl (Fig. 4G–I), the ribs are confined to the lower part of the whorl sides, where they become stronger and more widely spaced and clearly rursiradiate. The ribs may be subdivided on the whorl sides as far as can be discerned from the preservation. On the umbilical wall the ribs are stronger and clearly rursiradiate.

Discussion. – The style of ribbing and the coiling of the inner whorls evoke Schlotheimiidae morphology, especially some small *Angulaticeras* [e.g. *A.* (*Boucaulticeras*) *rumpens* (Oppel) or *A.* (*Sulciferites*) *ventricosum* (Sowerby) in Canavari, 1888, pl. 4, fig. 10], even if the massive and less high outer whorl is very different and does not fit with any known Schlotheimiidae. Indeed in large *Angulaticeras* the whorls are very high and compressed with a clearly suboxycone coiling. It is only on the basis of the inner whorl morphology that the new taxon is attributed to this family.

The *Schlotheimia* sp. in Chao and Wang (1976, pl. 2, fig. 8) has coarser and more widely spaced ribs.

Age and distribution. – Only recorded from this locality in Tibet in the Wulong Formation, it is suggested here that *Womalongiceras inflatum* belongs to the Schlotheimiidae. The total range of this family including the *Phricodoceras* as recently discussed by Meister *et al*. (2011, p. 82) and Dommergues and Meister (2013) corresponds to the Middle Hettangian – Upper Pliensbachian. It is not possible to give a precise age for this new taxon, but a Sinemurian age or even later seems probable, following Donovan's suggestion that this may be a late form.

Superfamily **Hildoceratoidea** Hyatt, 1867

Family **Hildoceratidae** Hyatt, 1867

Subfamily **Harpoceratinae**, 1875

Genus *Pseudolioceras* Buckman, 1889

Type species. – *Ammonites compactilis* Simpson in Buckman, 1889, OD.

Subgenus **Tugurites** Kalacheva et Sey, 1970

Type species. – *Pseudolioceras* (*Tugurites*) *tugurensis* Kalacheva and Sey, 1970.

Remarks. – These middle sized platycone involute ammonites are characterized by a coarse subfalciform ribbing sharply curved on the middle of the flank and a high keel. They represent the last *Pseudolioceras* at the top of the Aalenian and the base of Bajocian. According to Contini *et al*. (1997), the genus *Pseudolioceras* has a long range at least in the Arctic Domain up to the Lower Bajocian. The subgenus *Tugurites* ranges from Aalenian to Lower Bajocian.

?*Pseudolioceras* (*Tugurites*) sp. nov.

Fig. 6O

Material. – One crushed specimen (J1K2-5); from lower part of Kangdui Formation, Member 3, bed 120 in Appendix 1.

Dimensions. – Given in Appendix 2.

Description. – This keeled suboxycone ammonite (U/D = 12.5%) is characterized by a pronounced, rather dense and fine parvicostate ribbing. In detail the ribs are strongly prorsiradiate from the umbilicus until the mid-flank then abruptly rursiradiate until the uppermost part of the flank where it is slightly arched forward. On the mid-flank the angle is relatively closed and on the body chamber near the aperture, a kind of a spiral crenulation is developed ending with a long and narrow lappet.

Discussion. – This specimen shares affinities with two groups of ammonites belonging to the last representatives of the *Pseudolioceras* [*P.* (*Tugurites*)] and with some *Graphoceras*.

All the closest *Pseudolioceras* come from the Arctic Province. *P.* (*Tugurites*) *tugurensis* Kalacheva and Sey is similar with its parvicostate ribbing, but this Siberian ammonite remains more evolute and the ribbing of the Tibet specimen is stronger even than the closest form *P.* (*Tugurites*) *tugurensis* Kalacheva and Sey *in* Sey *et al*. (1986, fig. 3N). In contrast, the Alaskan *Pseudolioceras* like *P.* (*T.*) *m'clintocki* (Haughton) in Frebold (1960) and *P.* (*T.*) *whiteavesi* (White) in White (1889) show a similar coiling but the ribbing is sinuous to slightly falciform. For *P.* (*T.*) *fastigatum* Westermann (1992, pl. 25, fig. 6) and *P.* (*T.*) *costistriatum* Westermann (1992, pl. 25, fig. 7) from the Alaskan Lower Bajocian, the ribbing also remains different. In fact our specimen has a combination of characters of both Siberian and Alaskan *P.* (*Tugurites*). The interpretation of Westermann (1992, pl. 23, figs 7, 8) for *P.* (*T.*) *whiteavesi* (White) fits well with our specimen. However, the distinctive feature of this Tibetan form is that the angularity of the ribs is more accentuated at mid-flank and the ribs are more arched forward on the topmost part of the flanks. Because of the poor preservation our specimen is left in open nomenclature. Note that our specimen comes from southern Tibet *i.e.* the southern Tethys margin and is morphologically related to a Boreal form like *Tugurites*. This original form so raises the problems of convergence of morphology or parallel evolution.

Our specimen superficially has also some similarities to *Graphoceras* like *G. arcitenens* Buckman (1902, pl. 4, figs 1, 2) or *G. rudis* (Buckman, 1898, pl. 15, figs 11–13) that also show well-developed parvicostate ribbing but these forms remain more evolute and more coarsely ribbed than the Tibetan specimen. Of the same group, *G. stigmosum* Buckman and *G. decorum* Buckman also show some similarities of ribbing but are less tightly coiled. For discussion of *Graphoceras* we refer to Morton (1975, 1976), Chandler (1997) and Rulleau (2011).

Age and distribution. – The range of ?*P*. (*Tugurites*) is Aalenian – Middle Bajocian (see Howarth, 2013), and the age of our specimen seems to be Aalenian, but without more precision. Noting that ?*Graphoceras*, which occurs stratigraphically higher ranges from Upper Aalenian to basal Bajocian (see below).

Family **Hammatoceratidae** Buckman, 1887

Genus *Nyalamoceras* Chao et Wang, 1976

Type species. – *Nyalamoceras nyalamense* Chao et Wang, 1976.

Nyalamoceras nyalamense Chao et Wang, 1976

Figs 6C–N, P–R

1973. *Nyalamoceras nyalamense* (Gen. and sp. nov.): Mu *et al*., p. 107, fig. 5 (only cited).
1976. *Nyalamoceras nyalamense* Chao and Wang, p. 516, pl. 3, figs 1–3 (formally described).
1994. *Nyalamoceras*: Liu, Einsele, p. 37, tab. 1.
1996. *Nyalamoceras*: Shi *et al*., p. 19, tab. 2 (Cretaceous).
1997. *Nyalamoceras*: Wang, Li, p. 284.
2006. *Nyalamoceras nyalamense*: Wignall *et al*., p. 181.

Material. – 15 crushed specimens from two separate beds *c.* 14 m apart; Kangdui Formation, Member 3, beds 120

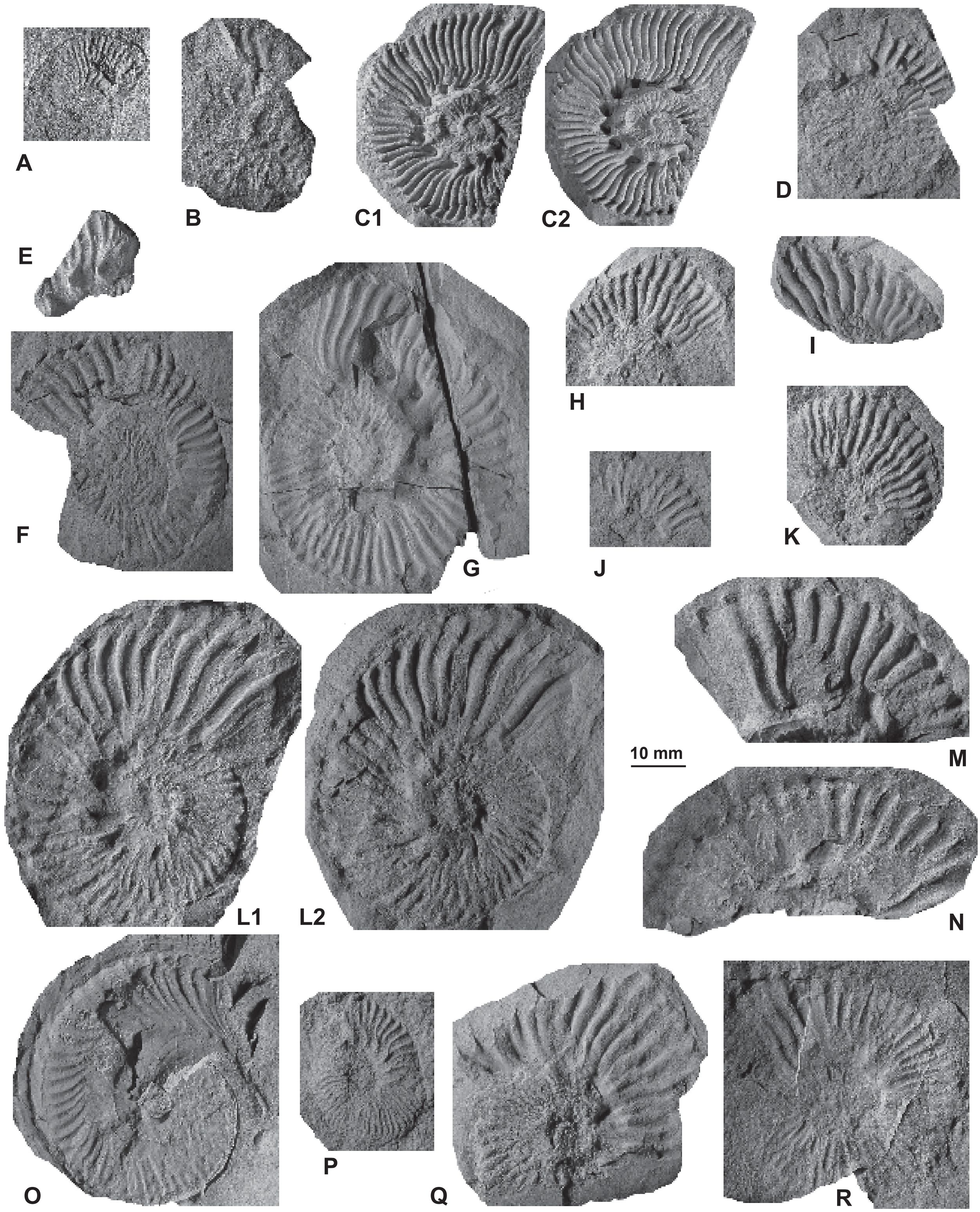

Fig. 6. A, B. ?*Graphoceras* [1 = JIK4 and 2 = JIK5]. C–N, P–R. *Nyalamoceras nyalamense* Chao et Wang, 1976 (C = *ex situ*, D–K = JIK3, L–N, P–R = JIK2). O. ?*Pseudolioceras* (*Tugurites*) sp. nov. [JIK2]

(J1K2) and 128 (J1K3) in Appendix 1. Bed 128 is especially fissile, making recovery of complete specimens difficult; also one better preserved *ex situ* specimen.

Measurements. – see Appendix 2 giving also specimen numbers to relate to Figure 6. Bivariate plots of umbilical diameter and secondary rib density are shown in Figure 7.

Description. – This rather small sized platycone ammonite (D ~60 mm for the largest) is characterized by a sharp ornament with a row of peri-umbilical nodes from which arise fine and dense secondary ribbing crossing the venter without interruption (Fig. 7). From each node arise 3 to 5 ribs showing a fasciculate style. Ribs are slightly sinuous, prorsiradiate and slightly projected forward on the ventrolateral part becoming slightly blunt on the venter. Only one specimen [J1K2-3 (Fig. 6L)] shows part of a rather rounded ventral area and no keel is present. The specimens are crushed so whorl section is not preserved.

Discussion. – Despite the poor preservation there seems to be two distinct morphotypes: one more involute and with more complex curved ribbing and elongate nodes on the lower parts of the whorls [*e.g.* J1K2-2 (Fig. 6L) and *ex situ* specimen (Fig. 6C)]; the second morphotype, of smaller size, is more evolute with simpler, mainly unbranched ribbing [*e.g.* J1K3-5 (Fig. 6J]. It probably corresponds to a di-

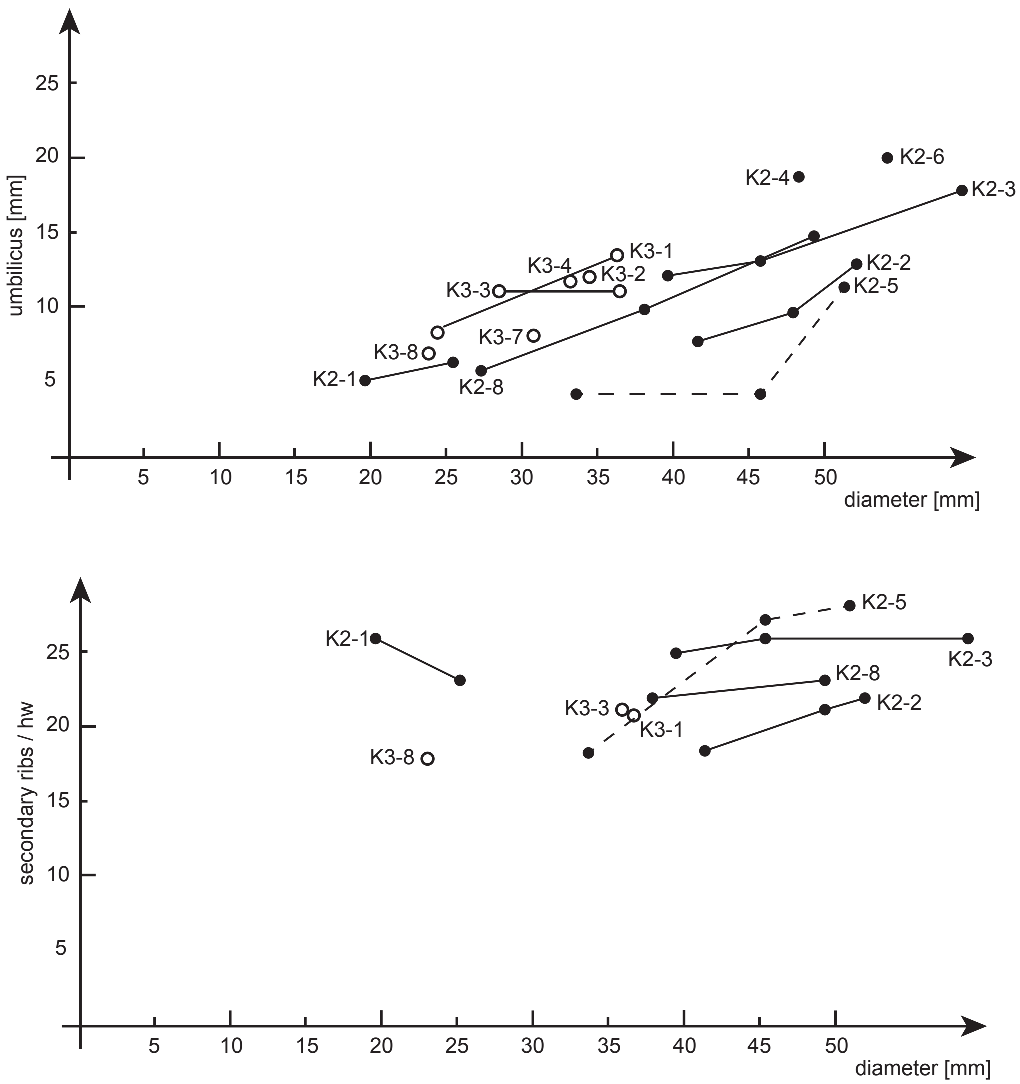

Fig. 7. Ontogenetic variations of the umbilicus (U) and of the secondary rib numbers (sR) per half whorl versus the diameter (D) for *Nyalamoceras nyalamense* Chao et Wang, 1976 (see Appendix 2) and for ? *Pseudolioceras* (*Tugurites*) sp. nov. as dashed line to show that it is more involute than *Nyalamoceras*

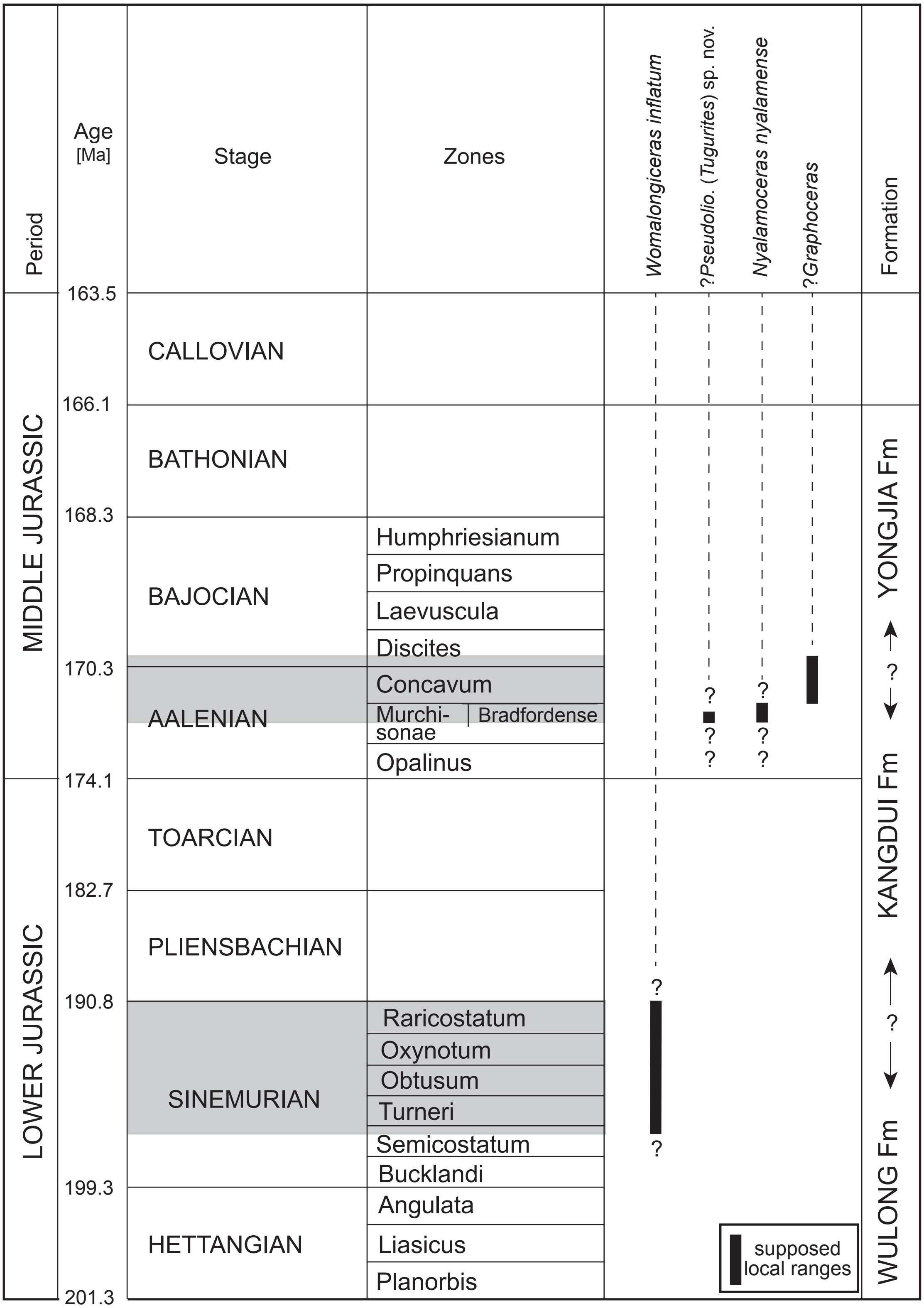

Fig. 8. Ammonite ranges with their local supposed ages

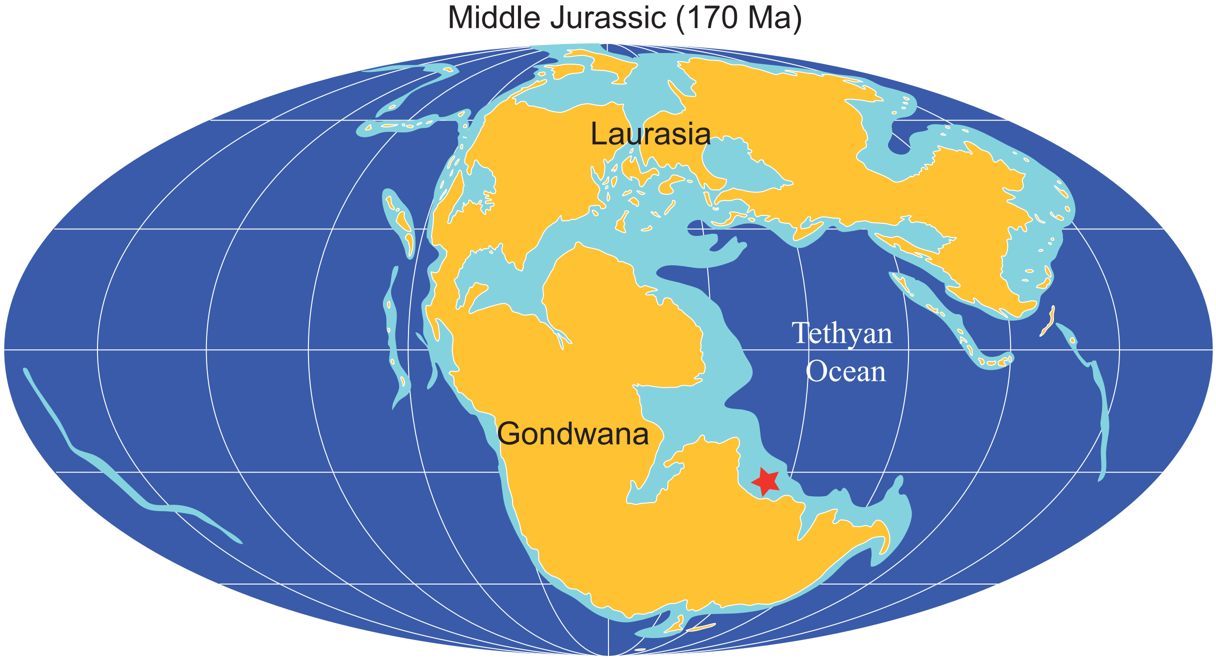

Fig. 9. Paleogeographical framework for the Middle Jurassic (Blakey, 2011 modified) and location of the studied area

morph couple of the same species. This is more clear with the better preserved population illustrated by Yin (unpublished, personal communication) in which a hypothesis of microconch and macroconch can be formulated.

This newly discovered fauna corresponds well to *Nyalamoceras nyalamense* Chao et Wang (1976). Note that the whorl section of the holotype is suboval with flat flank slightly convergent to the rounded and weakly convex venter.

Age and distribution. – Endemic to Tibet, the age of this taxon has been much discussed (Jurassic or Cretaceous). In the original description (Chao, Wang, 1976), this taxon was considered as a Lower-Middle Jurassic ammonite without any precision or supporting documentation. In Mu *et al*. (1973, fig. 5) *Nyalamoceras* is shown as above *Gleviceras* (Sinemurian) and below *Dorsetensia* (Bajocian). However, some authors (Shi *et al*., 1996) attribute a Lower Cretaceous age (Hauterivian) for this taxon. On the basis of our data, we prefer to give a Jurassic age because the association of *Nyalamoceras nyalamense* Chao and Wang with ? *Pseudolioceras* (*Tugurites*) which has an Aalenian age and below ?*Graphoceras* (see below).

Remarks. – It is necessary to note also morphological similarities between *Nyalamoceras* and *Phymatoceras* (?) *collignoni* Blaison, 1963 from the Late Toarcian of Madagascar; moreover palaeogeographically they were relatively closer. Similarities should also be noted with *Yakounia* and other "*Phymatoceras*" of the Circum-Pacific domain (North and South America, Japan, Indonesia) which are also attributed to Late Toarcian (*e.g.* Jakobs, Smith, 1996; Jakobs, 1997). These convergences of form would plead more in favour of an older age (topmost Toarcian to Aalenian) for *Nyalamoceras*. Is it only simple convergence of forms of different ages or does it rather indicate closely related forms of the same age ? In our case the presence of ?*P*. (*Tugurites*) is determining for the age of *Nyalamoceras* and indicates more certainly an Aalenian age.

Family **Graphoceratidae** Buckman, 1905

Genus *Graphoceras* Buckman, 1898

Type species. – *Lioceras concavum* var. *v.-scriptum* Buckman, 1888.

?*Graphoceras*

Figs 6A, B

Remarks. – From the upper part of the section, four poorly preserved specimens have been collected. Despite the preservation some features can be seen such as a small lappet on one specimen just like on microconch Graphoceratidae and more curved ribbing on the whorl sides that those on all underlying *Nyalamoceras* specimens. On the basis of these observations, they are attributed to the graphoceratids, probably ?*Graphoceras*.

BIOSTRATIGRAPHY AND PALEOGEOGRAPHY

Biostratigraphical information is limited in the Wulong area. Nevertheless three successive bio-stratigraphic units corresponding to two different intervals can be highlighted (Fig. 8):

- In the Lower Jurassic, the presence of a new Schlotheimiidae (*Wumalongiceras inflatum*) indicates a Sinemurian or Early Pliensbachian age.
- The association of ?*Pseudolioceras* (*Tugurites*) sp. with *Nyalamoceras nyalamense* corresponds to a period in the Middle Jurassic, more precisely from about the uppermost. The presence of ?*Graphoceras* higher in the section indicates Late Aalenian to basal Bajocian for overlying strata. This restricts the age of *Nyalamoceras* / ?*P.* (*Tugurites*) in the Wulong section, to Aalenian.

During Jurassic time, as shown in the paleogeographical map (Fig. 9), the area studied was part of the southern Tethys margin. For the Early Jurassic, the ammonite data remain very rare and remote on this margin extending from Madagascar, Somalia and Oman to the west to Indonesia (*partim*), New Caledonia and New Zealand to the east.

CONCLUSIONS

1. A new taxon is described from the Lower Jurassic series: *Wumalongiceras inflatum* gen. and sp. nov.

2. The presence of one specimen of ?*Pseudolioceras* (*Tugurites*) nov. sp. allows us to give a Jurassic age (Aalenian) to the Tibetan ammonite *Nyalamoceras nyalamense* Chao and Wang, the age of which was recently in discussion.

3. Poorly preserved specimens attributed to ?*Graphoceras* found in higher strata supports this interpretation.

4. The originality of the fauna, the rarity of paleontological studies in this area and geographical isolation make precise correlations with other fossiliferous areas difficult.

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The specimens will be housed in the Palaeontology Museum of Université Claude Bernard, Lyon I.

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Appendix 1

FIELD LOG OF SUCCESSION IN WULONG – WOMALONG AREA, TINGRI COUNTY, TIBET

The succession was described upwards from the lowest beds seen at the entrance to the valley leading to Womalong village from the main road to Mt. Everest base camp. Fieldwork was carried out over several days; dates are indicated.

Stream section north of womalong village 27/06/1999

Fault breccia, trend 032–042 degrees

KANGDUI FORMATION, MEMBER 9:

149. 90.00 m – thinly-bedded calcareous mudstones/limestones and siltstones/fine-grained sandstones; nodules, both calcareous (moderately large) and ?marcasite (very small); belemnite *c.* 20 m above base, ammonites (J1K5) *c.* 10 m above base and 30–40 m higher

KANGDUI FORMATION, MEMBER 8:

148. *c.* 50.00 m – volcaniclastic (?) sandstones, greenish, massive; one bedding surface with trace fossils and ammonite (J1K4), next bedding surface with ?*Rhizocorallium*; forms waterfall
147. 0.80 m – Dark mudstones and coarse-grained sandstones (volcaniclastic)
146. 1.80 m – Dark medium-coarse grained sandstone; ? some volcanis debris

KANGDUI FORMATION, MEMBER 7:

145. 60.00 m – black mudstones with nodules

KANGDUI FORMATION, MEMBER 6:

144. 50.00 m – grey-weathering harder sandstones with pebbles marking channel; ammonites observed; overlain by grey siltstones/mudstones with pebbles marking further channels

KANGDUI FORMATION, MEMBER 5:

143. 40.00 m – black mudstones and siltstones, medium-bedded; vague plant fragments observed

KANGDUI FORMATION, MEMBER 4:

142. 20.00 m – massive pale-weathering sandstone, medium-grained with numerous (15–20%) dark mineral grains; trace fossils and bivalve *Weyla*
141. 25.00 m – silty sandstone with rounded pebbles and boulders in darky silty mudstone matrix; appears to be channel cutting into underlying bed

[beds 141–142 probably submarine fan complex ?]

140. *c.* 10.00 m – sandstone

[nature of strata obscured by structurally complex zone; equivalent thickness 15.00 m]

139. 2.50 m – siltstone

[beds affected by structural complexity]

138. 6.00 m – black mudstone
137. 35.00 m – massive rather sheared silty sandstone

----------------------------- [fault]----------------------------------

KANGDUI FORMATION, MEMBER 3:

136. 2.00 m – black mudstones
135. 8.00 m – black mudstones, slightly silty
134. 4.00 m – silty mudstones, slightly harder than above
133. 8.00 m – black mudstones
132. 7.50 m – siltstones
131. 2.50 m – silty mudstones
130. 1.00 m – black mudstones
129. 2.00 m – silty fine-grained sandstone
128. 8.00 m – black fissile mudstones with ammonites near base (J1K3)
127. 0.50 m – siltstone
126. 0.50 m – mudstone
125. 0.80 m – siltstone
124. 1.00 m – mudstones
123. 0.50 m – siltstone
122. 10.00 m – mudstones
121. 1.00 m – siltstone
120. 11.00 m – dark mudstones, ammonites in lower part (J1K2)
119. 0.30 m – siltstone
118. 5.00 m – mudstones
117. 0.40 m – siltstone
116. 14.00 m – mudstones

KANGDUI FORMATION, MEMBER 2

115. 15.00 m – thick sandstone, hard and calcareous forming small waterfall under water pipeline, uppermost part very calcareous with bivalves and brachiopods

Section along track and passing through Womalong village 28/06/1999

114. 7.00 m – massive sandstone, medium-grained; cut by fault seen
113. 12.00 m – thinly-bedded mudstones and siltstones

112. *c.* 17.00 m – siltstones and fine-grained sandstones, coarsening–up into medium-grained sandstones

-----section faulted but apparently not large displacement-----

111. up to 6.00 m – sandstones, with channel base
110. 2.00 m – siltstones
109. 1.50 m – sandstone
108. 1.00 m – siltstones
107. 15.00 m – sandstones
106. *c.* 60.00 m mudstones, total thickness estimated for faults [faults displace beds to right up the hill; also cross-faults cut out most of bed alongside track]
105. 15.00 m – sandstones and mudstones
104. 25.00 m – black mudstones
103. 2.00 m – sandstone
102. 15.00 m – black mudstones
101. 15.00 m – mudstones, siltstones and thin sandstones

KANGDUI FORMATION, MEMBER 1

100. 90.00–100.00 m – same lithology as below; total thickness estimated but probable fault not allowed for

Section along track to Womalong village 22/06/1999 and 23/06/1999

100. *c.* 50.00 m – dark grey mudstones with calcareous nodules (up to 1 m long by 25 cm thick; ribbed pectinid bivalve 45.00 m above base

[same beds seen over hill towards Wulong on 20/06/1999]

WULONG FORMATION, MEMBER C

99. *c.* 35.00–45.00 m – massive medium- to coarse-grained sandstones, sometimes with low-angle cross-bedding, calcareous; with occasional large thick bivalve shells, patches (lenses or nodules) of small well-preserved bivalves (including *Astarte, Nucula*), oyster fragments; one ammonite (vertically embedded) (J1W1) found and patch, 15.00 cm across, of echinoderm debris with pentameral symmetry found in top sandstone bed (*c.* 5.00 m below top of formation), plant fragments

[same beds seen (28/06/1999) across hill towards Wulong village, opposite the school:

coarse-grained sandstones with high proportion of dark-colour minerals; some shell beds with shells mostly unbroken but single valves, sometimes decalcified, incl. *Astarte*, *Plagiostoma, Modiolus, Cardinia*, gastropod, echinoderm fragments]

98. 8.00 m – thinly-bedded green mudstones, siltstones and sandstones
97. *c.* 12.00 m – massive medium- to coarse-grains sandstones with lenses of coarse shell debris (sometimes decalcified) and large shells (?*Gryphaea*) in upper part; small fault cuts across section

[same beds opposite Wulong school (28/06/1999), thick beds >1 m with sphaeroidal weathering]

96. *c.* 30.00 m – medium- to fine-grained dark sandstones with beds and lenticles of laminated (?dolomitised) siltstones in lower part, becoming paler in colour in top 10 m; possible channels

------------------------small fault parallel to road----------------

95. *c.* 20.00 m – soft, apparently tectonically messy, unit; thinly-bedded to laminated mudstones, siltstone and sandstones with sideritic limestone beds and nodules; fossil plants, including one bed with conifer shoot and two types of fern
94. 5.00 m – gap, obscured by talus; ?mudstones
93. 25.00 m – thickly-bedded sandstones (litharenites), medium-grained and with dark minerals; irregular base

WULONG FORMATION, MEMBER B

92. *c.* 30.00 m – siltstones, mudstones and limestones; tectonically broken section [thicker on other side of hill towards Wulong]
91. 0.50 m – thinly-bedded limestones and siltstones; ripple-drift cross-bedding
90. 1.00 m – thickly-bedded coarser limstones with numerous bivalves, intraclasts
sharp change
89. 8.50 m – thinly-bedded limestone, bedding becomes thicker upwards
88. 9.00 m – mudstones, greenish, and thin sandstones
87. 3.00 m – thinly-bedded grey limestones
86. 7.00 m – thinly-bedded mudstones and siltstones
85. 4.50 m – sandstones and thin mudstones
84. 1.00 m – mudstones, greenish in colour
83. 4.00 m – mudstones and thicker sandstone beds
82. 4.00 m – mudstones and thin siltstones

sharp boundary

81. 2.20 m – thinly-bedded siltstones, fine-grained sandstones and mudstones
80. 0.20 m – limestone bed with numerous thick-shelled bivalves
79. *c.* 16.00 m – thinly-bedded siltstones, fine-grained sandstones and mudstones; some bedding plane trace fossils

sharp boundary

78. 6.00 m – thinly-bedded dark grey fine-grained limestones with numerous orange-weathering (?dolomitic) nodules; bivalves in some beds
77. *c.* 30.00 m – gap, obscured by talus (siltstones near top of hill)

WULONG FORMATION, MEMBER A

76. 40.00 m – thickly-bedded massive limestones, with medium-bedding in places; some beds seen to be shelly, with brachiopods; forms high scarp and cliff [ruins of castle at top of hill]
75. *c.* 30.00 m – grey limestones with sandstone patches, including possible fissure fills; some beds with intraclasts; forms broad shallow gully
74. *c.* 35.00 m – interbedded and interspaced coarse-grained calcareous sandstones and fine-grained dark grey limestones; evidence of fissures in limestone filled by sandstone and of lenses of varying sizes of limestone in sandstones; thickly-bedded, forms promontory
73. 1.50 m – fine-grained grey calcareous sandstones and thin limestones interbedded; latter with shelly debris of bivalves but nothing recognizable
72. 2.00 m – thinly-bedded, partly nodular, grey fine-grained limestones; no shells seen for most part

[beds 72 and 73 form a broad shallow gully]

71. 4.00 m – coarse-grained brown-weathering sandstones with cross-bedding and thin lenses of dark grey fine-grained limestone; some bivalve shells in sandstones, limestones are sometimes continuous

[? Erosion surface cutting down into underlying bed]

ZHAMURE FORMATION

70. *c.* 1.00 m – brown-weathering grey fine-grained carbonaceous sandstones, very strongly bioturbated
69. 0.30 m – brown-weathering grey fine-grained carbonaceous sandstone

sharp lithological boundary

68. ???? – white sandstones, very closely jointed

-------------------------------major fault---------------------------

section continued by track and stream below Womalong village 21/06/1999

67. *c.* 10.00–12.00 m – pale brown-weathering sandstones
66. 3.00 m – purplish mudstones/siltstones
65. 1.00 m – thinly-bedded coarser sandstone, plant fragments
64. 1.00–4.00 m – brown-weathering limestones
63. *c.* 2.00 m brown-weathering sandstone with herringbone cross-bedding
62. *c.* 1.00 m – purplish thinly-bedded sandstones ans siltstones
61. 3.00 m – soft brown sandstones
60. 0.80 m – limestone
59. *c.* 6.00 m – sandstones; upper beds with Skolithos lower beds with cross-bedding; ripple marks
58. 1.20 m – grey limestone
57. *c.* 20.00 m thinly-bedded unit (not accessible)
56. 30.00 m thickly- bedded limestones
55. 1.00 m sandstone
54. ???? m – underlying beds broken up, not measurable

overlying beds folded, structural relations not clear

---------------------section cut by faults--------------------------

53. *c.* 15.00–20.00 – greenish-grey mudstones and siltstones
52. *c.* 2.00 m – slightly harder brown-weathering bed
51. *c.* 12.00 m – greenish mudstones and siltstones

passing up into

50. 1.00 m – thinly-bedded red-weathering sandstones, beds thinning upwards
49. 8.00 m – thinly-bedded red weathering sandstone and dark grey siltstones

[section obscured by complicated structure]

48. gap
47. 8.00 m – thinly-bedded softer and harder sandstones, shelly in places, occasional burrows
46. 6.00 m – sandstone beds became thicker and harder, purplish-red in colour, medium- to thick beds
45. 4.00 m – thinly-bedded grey and red sandstones, shelly in places
44. 0.50 m – orange-red weathering pebbly sandy ?dolomite, thickness variably, possibly channel
43. 4.00 m – thinly-bedded dark grey mudstone, mostly as thin partings, and sandstones; thicknesses vary
42. 0.60 m – purplish-weathering sandstone, middle part very shelly (decalcified)
41. 1.20 m – thinly-bedded siltstones and sandstones, some contortion of bedding
40. 1.00 m – red-weathering sandstone, much less quartzose than below
39. 0.70 m – thinly-bedded siltstones and sandstones
38. ??? m – poorly exposed interval along stream, partly covered but includes three beds of purplish-weathering conglomerate interbedded with thin sandstones
37. 7.00 m – medium- to thinly-bedded sandstones, thinly-bedded especially towards top; some strange features on bedding surfaces
36. 5.00 m – obscured interval
35. 4.00 m – thickly-bedded sandstones

DERIRONG FORMATION

34. 3.50 m – largely obscured, some medium grey slightly purplish sandstones
33. 10.00 m – hard white sandstone, as below, top 30 cm with decalcified bivalves, especially in some layers
32. 4.00 m – thickly-bedded soft white sandstones
31. 1.00 m – very soft white sandstone

section continued upwards on south-west side of valley

30. 16.00 m – thickly-bedded white sandstones, medium-grey occasionally large doggers, slightly brown-weathering, of sandstone with coarse crystalline calcite cement
29. 1.00 m gap, no exposure
28. 8.00–9.00 m – thickly- and medium-bedded white sandstones
27. 4.50 m – massive thickly-bedded sandstones, red spots towards top
26. 20.00 m – thickly-bedded white sandstone, medium-grained, massive, cross-bedding; four or five major internal bedding surfaces; forms large feature; ends in prominent bedding surface
25. 0.50 m – thinly-bedded medium-fine-grained white sandstone
24. 1.00 m – thinly-bedded calcareous fine-grained sandstone; occasional shell fragments
23. 0.50 m – white sandstones, medium-grained, cross-bedded, vertical burrows; two internal bedding surfaces
22. 2.00 m – gap
21. 6.00 m – massive coarse-grained white sandstone; forms prominent pinnacle
20. 0.70 m – white medium-grained sandstones, as below
19. 1.50 m – gap
18. 1.00 m – thick quartzitic sandstone, vertical burrows; four internal bedding surfaces
17. 0.20 m – gap
16. 0.30 m – sandstone, as 14 but less clear burrows
15. 0.40 m – thinly-bedded sandstone, as 13
14. 0.50 m – massive white sandstone with frequent vertical burrows
13. 0.30 m – grey silty sandstone, weathering orange, thinly-bedded
12. 3.00 m – massive sandstone, as 9
11. 0.20 m – gap
10. 7.00 m – very massive sandstone, as below

[prominent bedding surface]

9. 8.00 m – massive, very thick-bedded quartzose sandstones, medium-grey, some dark laminae bring out cross-bedding
8. 10.00 m – gap, covered
7. 4.00 m – white sandstones, medium-bedded (10 cm) becoming thicker-bedded (50 cm)

upwards

6. *c.* 1.00 m – orange-weathering calcareous (?dolomitic) sandstone with occasional fragments of thick shells
5. 0.20 m – gap ? silty mudstones
4. 2.75 m – medium- to thick-bedded orange-weathering sandstones, some parts (at least) very white and quartzose when fresh; on closer look upward change to thicker beds and purer sandstones
3. 0.50 m – thinly-bedded grey sandy limestone with occasional thick-shelled bivalves
2. 3.00 m – reddish-weathering, medium- to thick-bedded sandstones, fine- to medium-grained, occasional reddish-brown calcareous nodules; cross-bedded, sometimes herring-bone pattern

OULONG GONGBA FORMATION

1. *c.* 10.00–15.00 m – thinly-bedded limestones and purplish-weathering sandstones, grey slightly greenish when fresh; some fossils, including shrimp

continuation observed to west of main road where this crosses river near ruins of abandoned village (Dzongkog Pongdro)

[Rhaetian: cliff of sandstones, Deriromg Formation, described above]

Norian: thinly-bedded mudstones and limestones, Oulong Gangba Formation

?? not distinguished, Norian: thinly-bedded mudstones and limestones, Yazhi Formation

Carnian: cliff of folded thinly-bedded limestones, Kangshare Formation

Appendix 2

DIMENSIONS OF TIBET AMMONITES

The specimens are nearly all crushed more or less flat in a fissile mudstone, so that preservation is generally poor. Measurements have often had to be estimated.

D = diameter (mm), Wh = whorl height, Wh/D as percentage, U = umbilical diameter, Ud/D as percentage, pR or sR = primary or secondary ribs, hw or qw = half or quarter of whorl

	Fig. 6	D	Wh	Wh/D [%]	U	U/D [%]	pR	sR
J1-K2-1	P	25.2	9.7	38.5	6.4	25.4	12/hw	23/hw
[?M]		19.3	8.4	43.5	5.2	26.9	–	26/hw
J1-K2-2	L1, L2	A51.9	27.5	53.0	13.4	25.8	?10/hw	22/hw
[?M]		47.7	23.1	48.3	10.0	21.2	11/hw	21/hw
		41.2	19.4	47.1	8.1	19.7	9/hw	23/hw
J1-K2-3	E, G	A58.5	26.5	45.3	18.4	31.5	14/hw	26/hw
[?M]		45.3	18.1	40.0	13.5	29.8	10/hw	26/hw
		39.5	17.3	43.8	12.5	31.6	11/hw	25/hw
J1-K2 -4	Q	e48.1	e26.6	54.9	9.2	19.1	–	12/qw
[??M]								
J1-K2-6	N	e54.0	23.2	43.0	e20.5	38.0	–	11/qw
[?m]								
J1-K2-7	M	–	22.0	–	–	–	–	12/qw
[?m]								
J1-K2-8	R	49.2	e23.0	46.7	14.8	30.1	–	23/hw
[??]		37.9	16.5	43.5	10.3	27.2	–	22/hw
		27.1	14.9	55.0	6.1	22.5	–	–
J1-K2-9	[fragment of part of one whorl]							
J1-K2-10	[fragment with coarse ribbing]							
J1-K2-11	[fragment with curved ribbing]							
J1-K2-5	O	A50.8	27.7	54.5	5.9	11.6	–	28/hw
		45.3	24.8	54.7	4.6	10.2		27/hw
		33.5	18.1	54.0	4.6	13.7		e18/hw
J1-K3-1	F	e36.2	14.9	41.2	e13.6	37.6	–	21/hw

	Fig. 6	D	Wh	Wh/D [%]	U	U/D [%]	pR	sR
[?m]		e24.6	9.9	40.2	8.7	35.4	–	–
J1-K3-2		34.1	12.3	36.1	12.2	35.8	–	–
[?m]								
J1-K3-3		e36.2	e14.4	39.8	11.5	31.8	9/hw	e21/hw
[??]		e28.1	12.6	44.8	11.2	39.9	5/qw	11/qw
J1-K3-4		e32.9	14.6	44.4	12.2	37.1	5/qw	13/qw
[?m]								
J1-K3-5		e21.0	10.2	48.6	–	–	4/qw	11/qw
[?m]								
J1-K3-6			10.5	–	–	–	5/qw	10/qw
J1-K3-7		e30.5	e15,7	51.5	8.5	27.9	–	e9/qw
[?m]								
J1-K3-8		e23.7	e11.8	49.8	7.0	29.5	–	18/hw
[??]		no photo						
J1-Y	specimen obtained from villagers							
[?M]	C1, C2	A39.3	16.0	40.7	12.8	32.6	e10/hw	33/hw
		34.8	13.6	39.1	11.9	34.2	7/hw	33/hw
		27.4	10.7	39.1	10.1	36.9	8/hw	13/qw
J1-K4-1	A	e17.8	8.7	43.9	e4.9	27.5	8/qw	12/qw