

# A new occurrence of silicified wood from the Early Cretaceous (Berriasian) Kagbeni Formation of north central Nepal

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## ABSTRACT

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During recent fieldwork a second occurrence of silicified wood has been discovered from the Early Cretaceous Kagbeni Formation of north central Nepal. The wood exhibits anatomical features which are well in accordance with *Araucarioxylon nepalense* described from another locality in the Kagbeni Formation near Kagbeni in the Thakkhola Valley in central Nepal. It is a pycnoxylic wood with mostly uniseriate and rarely biseriate bordered pits on radial tracheid walls. According to recent taxonomic opinions this type of wood should not be treated as *Araucarioxylon*, but as *Agathoxylon* Hartig. Thus, we propose the name *Agathoxylon nepalense* comb. nov. for this type of wood. The sandstones of the Kagbeni Formation have been interpreted as delta–deposits, with a major flow direction from the south. This suggests that the wood originated from the northern margin of Gondwana (i.e. the Indian Plate).

**Key–words**—Cretaceous, Nepal, Permineralized wood, *Agathoxylon nepalense*.

उत्तर मध्य नेपाल के प्रारंभिक चाकमय कागबेनी शैलसमूह से सिलिकीभूत काष्ठ की एक अभिनव प्राप्ति

खुम पौडयाल, लालू पौडेल एवं डाइटर उहल

## सारांश

उत्तर मध्य नेपाल के प्रारंभिक चाकमय कागबेनी शैलसमूह से हाल ही के क्षेत्रीय कार्य के दौरान सिलिकीभूत काष्ठ की एक दूसरी प्राप्ति खोजी गई है। काष्ठ शारीर रचना संबंधी अभिलक्षण प्रदर्शित करती है जो मध्य नेपाल की थक्कोला घाटी में कागबेनी के निकट कागबेनी शैलसमूह में दूसरी उपबस्ती से वर्णित *एरौकैरीऑक्सीलॉन नेपालेन्से* के समनुरूप हैं। यह अरीय दारु वाहिनिका भित्तियों पर अधिकांशतः एकल पंक्तिबद्ध व दुर्लभ द्वि पंक्तिबद्ध सीमांकित गर्तों सहित घनदारुक काष्ठ है। अभिनव वर्णिकीय मतानुसार इस प्रकार की काष्ठ को *एरौकैरीऑक्सीलॉन* के रूप में नहीं मानना चाहिए। अतैव इस प्रकार की काष्ठ के लिए हम *अगाथॉक्सीलॉन नेपालेन्से* नव संयोग नाम प्रस्तावित करते हैं। कागबेनी शैलसमूह के बलुआपत्थर दक्षिण से विशाल प्रवाह दिशा सहित डेल्टा–निक्षेपों के रूप में व्याख्यायित किए जा चुके हैं। यह सुझावित करता है कि काष्ठ गोंडवाना (अर्थात् भारतीय आधार पट्टिका) के उत्तरी पार्श्व से उद्गमित हुई।

**सूचक शब्द**—चाकमय, नेपाल, पर्मियनीकृत काष्ठ, *एरौकैरीऑक्सीलॉन नेपालेन्से*।

## INTRODUCTION

THE Nepal Himalaya has been a focus of geoscientific research within the Himalaya range for more than 60 years and numerous studies about a wide variety of topics have been published during this period (cf. Dhital, 2015). Despite these big efforts only a few studies have provided detailed information about the Mesozoic palaeobotany of this region. For central Nepal only a single fossiliferous outcrop from the Early Cretaceous Kagbeni Formation at Kagbeni–Muktinah in the Thakkhola Valley found its way into the palaeobotanical literature (cf. Barale *et al.*, 1978; Dhital, 2015).

First reports on plant fossils from this particular outcrop have been published by Bordet *et al.* (1964, 1967, 1971). These authors reported the occurrence of *Nilssonia orientalis* Heer, *Ptilophyllum pecten* Phillips, *Otozamites abbreviatus* Feistmantel, as well as araucarian wood remains, without providing detailed descriptions. Later on Barale *et al.* (1978) described silicified wood and other plant remains from the same locality (Fig. 1). These authors identified leaf remains as *Ptilophyllum acutifolium* Morris and *Ptilophyllum* sp. cf. *Ptilophyllum cutchense* Morris as well as a single remain as *Taeniopteris* sp. cf. *T. spatulata* McClelland, the latter taxon may be corresponding to *Nipaniophyllum* Sahnii, a member of the order Pentoxylales (Sahnii, 1948; Howe & Cantrill, 2001). Additionally these authors described permineralized wood fragments from this locality as the new species *Araucarioxylon nepalensis* Barale *et al.*

Here we report a second occurrence of this taxon from a different outcrop a few kilometres south of Kagbeni, also located within the Early Cretaceous Kagbeni Formation.

According to current nomenclatural policy we propose the new combination *Agathoxylon nepalense* (Barale *et al.*) nov. comb. for this type of wood.

## GEOLOGY AND STRATIGRAPHY

A recent summary and overview of various geological aspects of Cretaceous strata in Nepal is provided by Dhital (2015). In the Kagbeni area folded Mesozoic formations of the Tethyan Himalayan sequence crop out in an anticlinal structure. The rocks belong to the Early Cretaceous Chukh Group (Gradstein *et al.*, 1991) which has been divided into the Kagbeni Formation (150 m thick sandstones) and the (at most localities) conformably overlying Dzong Formation (about 600 m green sandstones and shales, with some intercalating limestones) (Bassoullet & Mouterde, 1977). During sedimentation of the Chukh Group major geodynamic events, like the breakup of parts of Gondwana, as well as volcanic eruptions to the south affected sedimentation (Gradstein *et al.*, 1991; Liu & Einsele, 1994; Garzanti, 1999). This led to an increased deposition of clastic silicates and these sandstones of the Kagbeni Formation have been interpreted as delta-deposits, with a major flow direction from the south, i.e. the Northern margin of the Indian Plate (Dürr & Gibling, 1994).

Evidence for a Berriasian age is given for the major part of Kagbeni Formation (Chukh Formation sensu Gibling *et al.*, 1994) based on marine marker fossils, i.e. cephalopods, foraminifera and dinoflagellate cysts (Gradstein *et al.*, 1991; Gibling *et al.*, 1994). Only the most basal sediments of the formation are assumed to belong to the Tithonian by these authors.

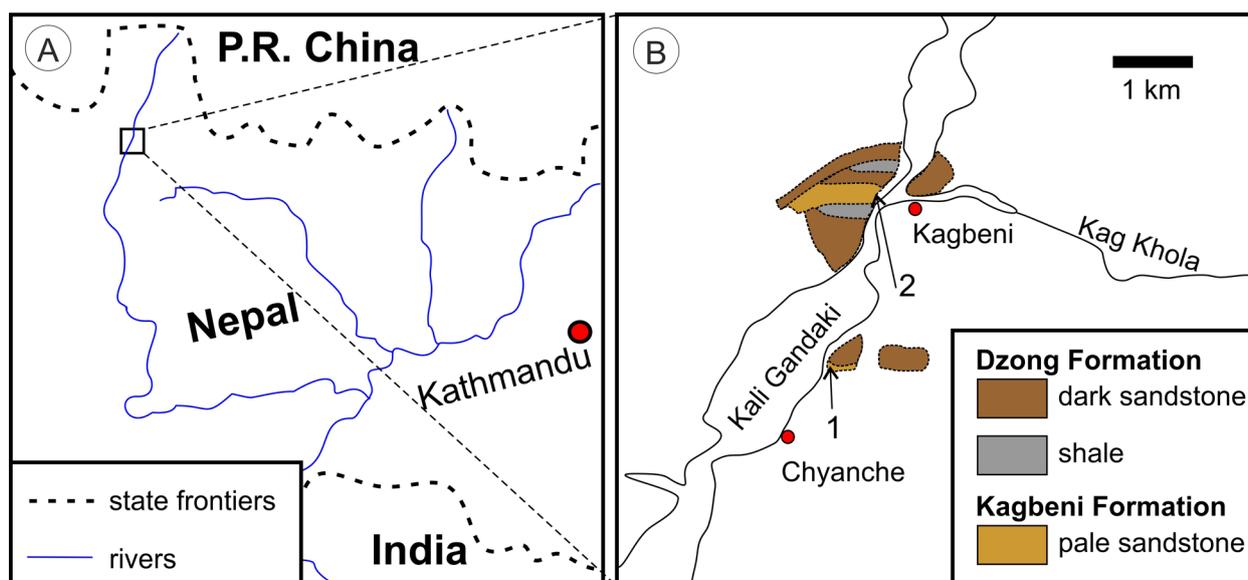


Fig. 1—Geographic position of the sampling locality. (A) Overview map of the central part of Nepal, (B) Geological sketch map of the Cretaceous strata in the surrounding of the sampling locality in the Thakkhola Valley in Nepal. Based on Gibling *et al.* (1994) and modified according to Barale *et al.* (1978) and Dhital (2015).

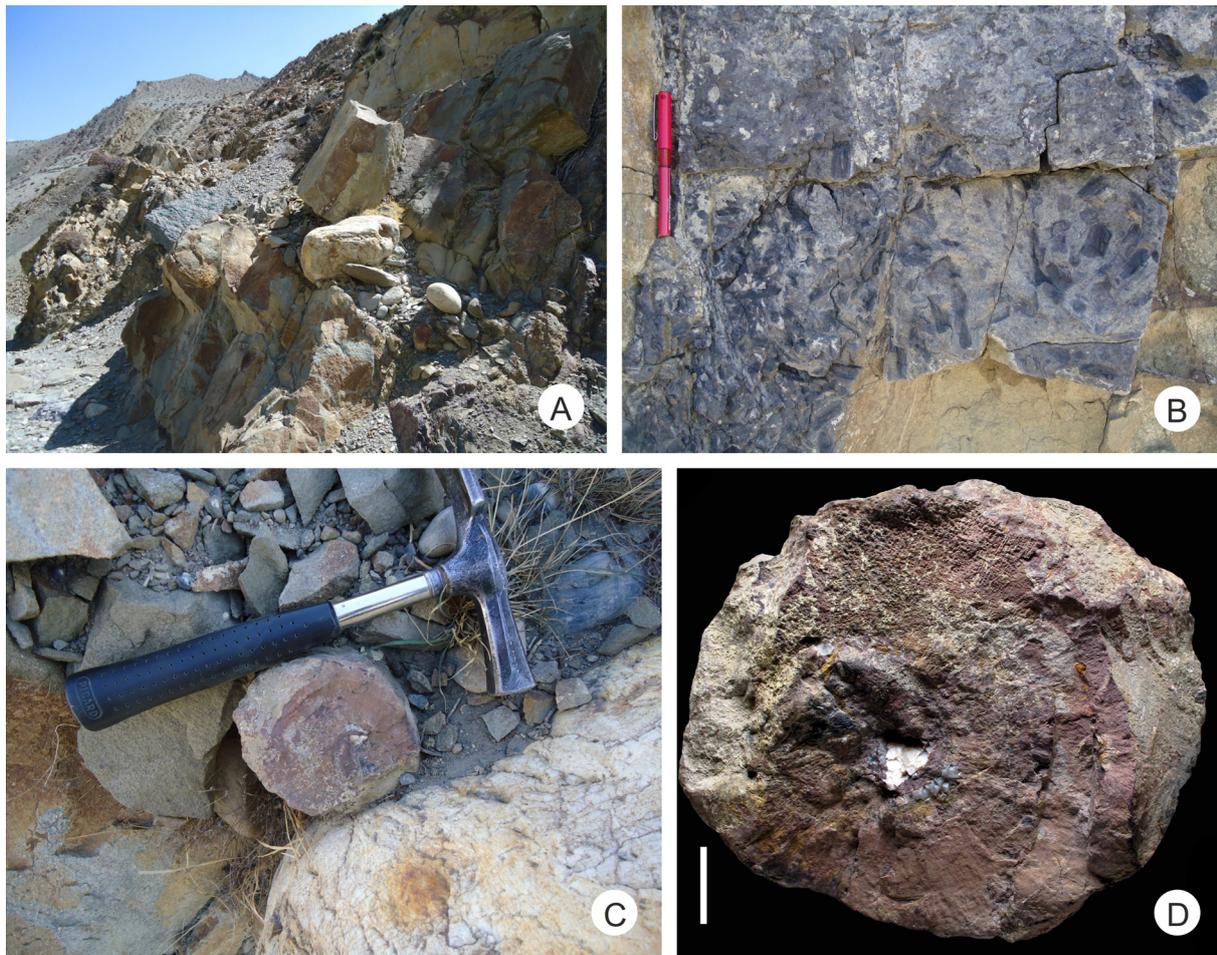


Fig. 2—Photographs of sampling locality and permineralized stem. (A) View of sampling locality, (B) surface of a sedimentary layer, exhibiting numerous plant fragments, (C) permineralized plant stem *in situ* in sediment, (D) overview on slab of permineralized stem; Inv.-Nr. SM.B 21541; scale bar = 2 cm.

## MATERIAL AND METHODS

### Material

A large piece of permineralized wood (ca. 20 x 14 x 12.5 cm) has been collected from sandstones of the Kagbeni Formation (*sensu* Bassoullet & Mouterde, 1977) in April 2012 by Khum Paudyal and Lalu Paudel during a fieldtrip to Thakkhola Valley. The locality is located approx. 2 km south of the village Kagbeni (Fig. 1) at the left bank of the Kali Gandaki River; it corresponds to locality KA4 of Gibling *et al.* (1994; Fig. 4). The specimen is permineralized with silicates, of brownish color and edges of the specimen are only slightly abraded (Fig. 2). Outer tissues like bark and phloem are also abraded, pointing to some transport of the specimen prior to burial.

At Kagbeni the plant-bearing horizon is approx. 50 m below the boundary between the Kagbeni Formation and the (at most localities) conformably overlying Dzung Formation (Barale *et al.*, 1978). However, at the new locality the contact

between both formations is unconformable (Gibling *et al.*, 1994), thus it is not possible to verify the exact position of this horizon in relation to the top of the Kagbeni Formation.

According to Dhital (2015) the plant bearing horizon is about 10 m thick on the right bank of the Kali Gandaki River, upstream of a bridge near Kagbeni. The material described in the present study, most likely originates from the same horizon rich in fossil plants, indicating that this plant bearing horizon stretches over a considerable distance, but exact correlation of both localities is unfortunately not possible at the moment.

### Methods

Three oriented (cross-section, tangential, radial) thin sections of the wood were made at the Senckenberg Forschungsinstitut und Naturmuseum Frankfurt, Germany, from a slice of the wood which has been cut off at the Central Department of Geology, Tribhuvan University, Kirtipur, Kathmandu, Nepal. Microphotographs of the thin sections were taken with an OLYMPUS BX41 microscope and an

Altra-20 digital camera. The macrophotograph of the wood slice from which thin sections were made, was taken with a Canon Powershot G11 camera. Contrast and brightness of the images were adjusted with Corel Photopaint X4.

The slab of the wood and the three oriented thin sections used in this study are stored in the palaeobotanical collection of the Senckenberg Forschungsinstitut und Naturmuseum Frankfurt, Germany under accession number SM.B 21541.

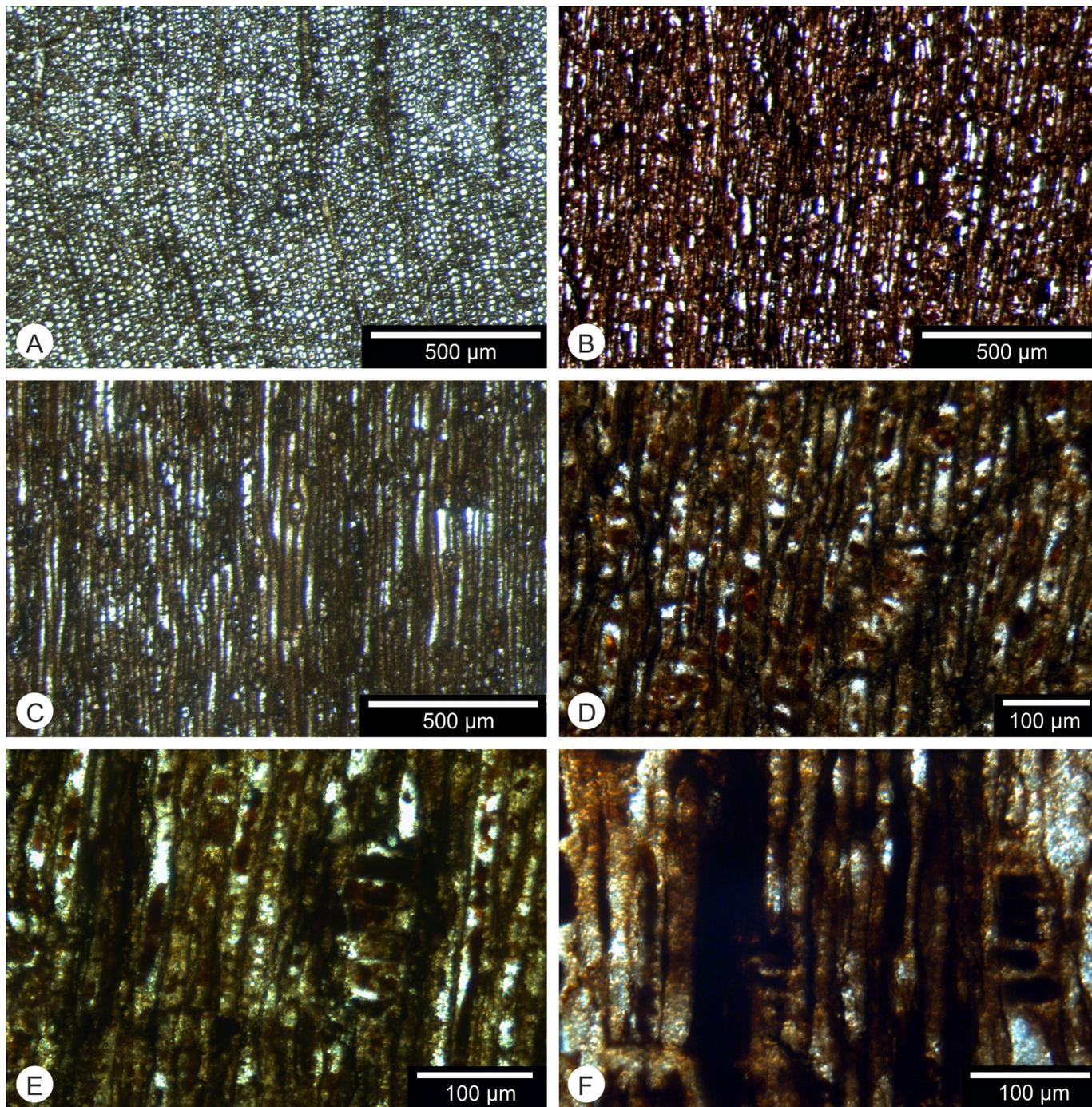


Fig. 3—Microphotographs of permineralized wood from the Kagbeni Formation in central Nepal. Inv.-Nr. SM.B 21541. (A) cross section showing no evidence of growth rings; (B) slightly oblique radial section in overview; (C) tangential section, exhibiting numerous rays; (D) radial section, exhibiting uniseriate pitting; (E) radial section, exhibiting partly biseriate pitting; (F) radial section, with badly preserved ray.

**SYSTEMATICS****GYMNOSPERMS****Order—PINALES**

**Genus—AGATHOXYLON** Hartig, Bot. Zeitung (Berlin) 6: 190. 10 Mar 1848.

**Type—*A. cordaianum*** Hartig

**Species—*Agathoxylon nepalense*** (Barale *et al.*) comb. nov.

**Basionym:**

1978 *Araucarioxylon nepalensis* Barale *et al.*, 1978. The Palaeobotanist 25, 34; Pl. 2, Figs 7–12.

**Synonyms:**

2004 *Araucarioxylon nepalense*; Philippe *et al.*, 2004. Review of Palaeobotany and Palynology 129, 157.

**Type Locality**—Thakkhola River Section at right bank of Kali Gandaki River, near Kagbeni, Nepal.

**Horizon**—Bed No. 6 of Khagbeni sandstones (sensu Barale *et al.*, 1978), Kagbeni Formation; Early Cretaceous (Berriasian).

**Type Specimen**—No. JM 144/1 of Laboratoire de Paléobotanique, University of Lyon I, France.

**Descriptions**—Permineralized wood of moderately preserved, pycnoxylic wood without visible growth rings. Bordered pits on radial tracheid walls contiguous, uni- to (rarely) biseriate (than alternating), with circular to oval pori (Fig. 3). No pits on tangential tracheid walls visible. Rays uniseriate 1–8(10) cells high. 1–5 cupressoid (?) pits per crossfield (mostly very badly preserved).

**DISCUSSION**

The recently discovered wood exhibits anatomical features which agree with *Araucarioxylon nepalensis*, as described by Barale *et al.* (1978) from the same plant bearing horizon about 2 km to the North of the new locality. The only significant difference is the absence of growth rings in the new specimen. As in many taxa the formation of growth rings is dominantly controlled by physiological reactions to environmental factors (e.g. *Araucaria angustifolia* from Brazil; Philippe, 2011), we are of the opinion that this difference is not of taxonomic relevance, as it could just reflect different environmental and/or climatic conditions during growth of the source trees. All the other characteristics are well in agreement with the description of the wood from Kagbeni by Barale *et al.* (1978).

According to current taxonomic and nomenclatural concepts (Philippe & Bamford, 2008; Philippe, 1993, 2011; Rößler *et al.*, 2014) the generic name *Araucarioxylon*, should

no longer be used for this type of wood, thus we propose the new combination *Agathoxylon nepalense* for this wood from the Early Cretaceous of Nepal. This is in agreement with Philippe *et al.* (2004), who already commented in their Appendix A, that this species probably belongs to *Agathoxylon* according to the system proposed by Philippe and Bamford (2008). Nevertheless Philippe *et al.* (2004) did not formally propose a new combination for this taxon. As such a formal combination is required to validate the new name in terms of botanical nomenclature (McNeill *et al.*, 2012), we made this formal new combination to validate the new name.

The sandstones of the Kagbeni Formation have been interpreted as coastal or delta-deposits, with a major flow direction from the south (Gibling *et al.*, 1994; Dürr & Gibling, 1994). This suggests that the wood originated from the northern margin of Gondwana (i.e. the Indian Plate). The plant bearing horizon(s) near Kagbeni can thus be considered a unique source of information about the palaeo-vegetation during the Early Cretaceous at the Northern margin of Gondwana. However, own observations in the field at different localities of the Kagbeni Formation, which yield abundant plant remains, suggest that the potential of this horizon has so far been underestimated and/or underexplored.

In the light of current nomenclatorial and taxonomic advances it is also clear, that previous determinations of leaf remains (Bordet *et al.* 1964, 1967, 1971; Barale *et al.*, 1978) are in need of revision. This and additional field work (i.e. collection of additional plant material) will help to increase our knowledge about this interesting flora from an area which is so far largely unexplored from a palaeobotanical point of view.

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