1661-8726/08/020546-16
DOI 10.1007/s00015-008-1274-0
Birkhäuser Verlag, Basel, 2008

Swiss J. Geosci. 101 (2008) 547–562

Anisian ammonoids from Qingyan, southwestern China: biostratigraphical implications for the age of the Qingyan Formation

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Key words: ammonoids, Anisian, Qingyan Formation, southwestern China, taxonomy, biostratigraphy

ABSTRACT

The Upper Qingyan Formation in the northeastern vicinity of Qingyan, Guizhou Province, southwestern China, yields an ammonoid sequence comprising a latest middle Anisian assemblage in its lower part followed by an earliest late Anisian assemblage in its middle and upper parts. Age-diagnostic genera of the lower assemblage include *Bulogites* and *Acrochordiceras*; additional genera comprise *Proarcestes*, *Sageceras*, and Beyrichitinae gen. indet. This assemblage well correlates with the *Bulogites mojsvari* Subzone in northwestern Nevada and the *Bulogites zoldianus* Zone in Lombardy and Hungary. The upper assemblage comprises the age-diagnostic genera *Rieppelites* and *Judicarites*; additional characteristic genera include *Ptychites* and *Gosauites*. This assemblage correlates with the *Billingsites cordeyi* Subzone in northwestern Nevada and the *Rieppelites cimeganus* Zone in Lombardy. The middle/late Anisian boundary is situated in the upper middle part of the highly fossiliferous section at Leidapo. Judging from re-study of available and figured specimens, reports of stratigraphically younger taxa such as *Paraceratites trinodosus* from the Upper Qingyan Formation of this area are based on misidentifications. The time interval represented by the Qingyan Formation at its type locality is not equal to the Anisian as has long been supposed in Chinese stratigraphy. An earliest late Anisian age for the uppermost strata of the Qingyan Formation in this area is the only available, well-documented age-constraint.

Introduction

The northeastern vicinity of Qingyan, a small town about 30 km south of Guiyang, the capital of Guizhou Province in southwestern China, has been known for more than 100 years as an important site for Anisian (early Middle Triassic) marine fossils (Figs. 1a, b). Anisian fossils from this area have been described or mentioned in many publications (e.g. Koken 1900; Hsu & Chen 1943; Yang & Xu 1966; Nanjing Institute of Geology and Palaeontology 1974; Guizhou Work Team on Stratigraphy and Palaeontology 1978; Kristan-Tollmann 1983a; Yin & Yochelson 1983; see Stiller 2001a for an overview). The main locality, which yielded most fossil specimens reported in the literature, is the highly fossiliferous section at the small hillock called Leidapo (sometimes also referred to as Bangtoupo) (Fig. 1c). Similar strata are present at Wachangpo (hillock), a few hundred metres south of Leidapo; however, exposures at Wachangpo are very poor. The high taxonomic diversity and the generally good preservation of the fossils, especially from Leidapo, are the reason for the great and supra-regional importance of this locality.

The taxonomically unusually diverse fossil assemblages of Leidapo provide information about the main early Mesozoic post-extinction radiation of benthic invertebrates, with regard to taxonomy as well as palaeoecology. They comprise numerous taxa of great phylogenetic significance, e.g. some of the earliest known scleractinian corals (Deng & Kong 1984; Qi 1984; Qi & Stanley 1989) and isocrinid as well as millericrinid crinoids (Stiller 2000a, 2001a). Bivalves, gastropods, and brachiopods are the most common groups. They also include taxonomically, phylogenetically, and palaeoecologically significant taxa (Stiller 2001a; Stiller & Chen 2004, 2006; Chen et al. 2006). Compared to benthic invertebrates, ammonoids are generally rarely found in the fossil assemblages of Qingyan. Palaeogeographically situated at the transition between the extensive carbonate platform of the Yangzi Platform and the open deep-water basin with mainly siliciclastic sedimentation of the Youjiang region, the Qingyan area is also of importance with regard to palaeogeography and palaeoecology. For detailed information on the geology, fossil assemblages, and palaeoecology of Leidapo and the vicinity of Qingyan see Stiller (1997, 2001a).

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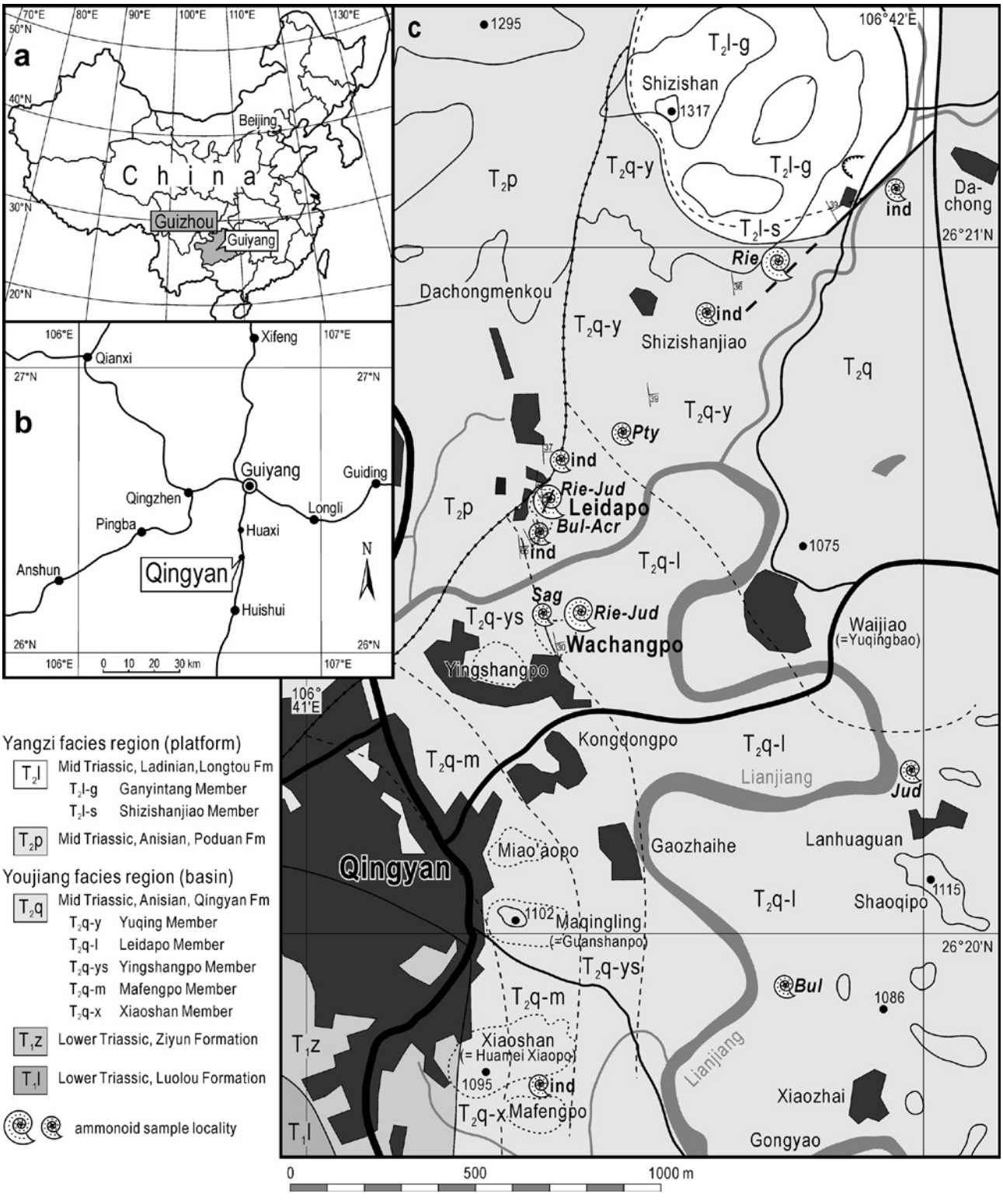


Fig. 1. Geographical location of Qingyan in Guizhou Province, southwestern China, and Middle Triassic fossil sample localities near Qingyan. a) General map of China with location of Guiyang marked. b) Map of central Guizhou Province with location of Qingyan south of Guiyang. c) Map of the northeastern vicinity of Qingyan with ammonoid sample localities; geology after Guizhou Geological Team 108 (1976b: geological map and fig. 75), altered and emended, including the member boundaries of the Qingyan Formation, after Stiller (2001a) and personal field observations (Stiller); Anisian/Ladinian boundary according to traditional Chinese stratigraphy. Abbreviations: *Rie-Jud*, *Rieppelites-Judicarites* assemblage; *Bul-Acr*, *Bulogites-Acrochordiceras* assemblage; *Sag*, *Sageceras*; *Bul*, *Bulogites*; *Rie*, *Rieppelites*; *Jud*, *Judicarites*; *Pty*, *Ptychites*; ind, ammonoids gen. et sp. indet.; Fm, Formation. For taxa list see Figure 2.

In the northeastern vicinity of Qingyan, a succession of Olenekian to lower Ladinian strata stretches from the town to Shizishan (mountain) (Fig. 1c). The marly part of the succession between the town and the foot of Shizishan is the type section of the Qingyan Formation. In Chinese stratigraphy, the Qingyan Formation is considered to be equivalent to the Anisian. The ammonoid zonation established in this succession has been used for a long time as the biostratigraphical standard for the marine Anisian in southwestern China and also in other regions of China. In Chinese stratigraphy, the marine Anisian recently has even been named Qingyanian, after the Qingyan Formation (Yang et al. 2000; National Stratigraphical Commission of China 2001, 2002; see below).

Despite their great biostratigraphical importance, the Middle Triassic ammonoids of Qingyan hitherto have only been studied very superficially. The aim of the present contribution is a taxonomic revision of the available ammonoid specimens from the Anisian of Qingyan and an improved biostratigraphical correlation of the Upper Qingyan Formation and especially the strata at Leidapo.

The present study is based on the specimens used by Stiller (2001a) and some additional samples collected during recent years. The specimens figured herein are deposited in the collections of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, in Nanjing, P.R. China. Additional specimens not figured herein are housed in the Institute and Museum of Palaeontology of the University of Zürich, Switzerland (research collection of H. Bucher).

Institutional abbreviations: NIGP, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, in Nanjing, P.R. China.

Research history

In the first publication on fossils from Qingyan, Koken (1900) described some specimens from this locality. However, among these were no ammonoids. Koken noticed that the marly facies and the fossil faunule available to him fairly resembled those of St. Cassian (Dolomites, northernmost Italy) in the southern Alps, and therefore estimated the age of the Qingyan fauna to be Ladinian to Carnian. During the following decades, no new data became available, and Koken's data were repeated in several publications addressing the Chinese Triassic (Philippi 1903; Noetling 1905; Frech 1911; Grabau 1928).

More intensive investigation of the Triassic in southern China commenced during the thirties and fourties of the twentieth century. Hsu & Chen (1943) published a fairly extensive list of Triassic fossils from Qingyan, which comprised the first mention of ammonoids from this locality. Unfortunately, they provided no figures and only very short remarks on a few new taxa. However, they correctly concluded from their studies that the Qingyan fauna is of Anisian age. Hsu (1944, 1945) also mentioned ammonoids from Qingyan.

During the second half of the twentieth century, the study of the Triassic fossils, stratigraphy, sedimentology, and palaeogeography of the Qingyan region was intensified, and numerous publications also included palaeontological descriptions [see Stiller (2001a) for detailed information]. The Qingyan Formation became the standard for the marine Anisian in southwestern China. Although used as a biostratigraphical standard for about 50 years and referred to in many publications, the ammonoids have not been dealt with in detail. Only very few ammonoids from Qingyan were described and illustrated, and most descriptions solely repeated data that had been published earlier. Descriptions and figures of Middle Triassic ammonoids from Qingyan are included in Yu & Zhao (1957), Institute of Geology and Palaeontology (1962), Zhao et al. (1965), Zhao & Wang (1974), and Liao (1978), and altogether comprise only four species. Recently, an ammonoid specimen was figured by Komatsu et al. (2004a). A fairly extensive list of ammonoids from the northeastern vicinity of Qingyan was published by Guizhou Geological Team (1976a, b). Stiller (2001a) listed numerous ammonoid taxa he collected from the Upper Qingyan Formation of Qingyan and provided taxonomic remarks and extensive synonymy lists, but he gave neither descriptions nor figures.

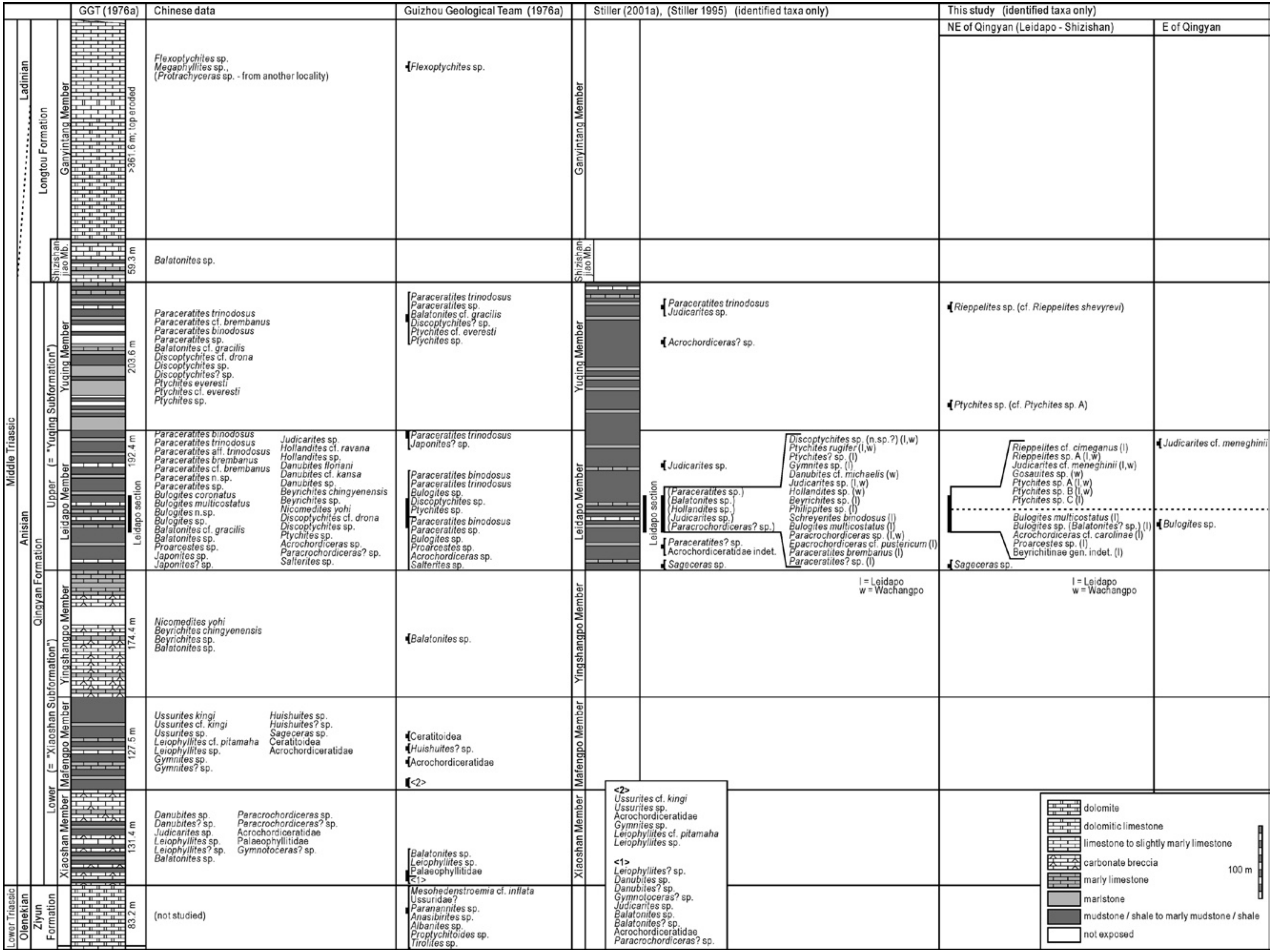
The Middle Triassic of Qingyan

The Middle Triassic of Qingyan comprises Anisian and lower Ladinian strata and is approximately 1250 m thick. It is subdivided into two lithostratigraphical formations, the Qingyan Formation (829 m thick) and the Longtou Formation (more than 421 m thick, top eroded). Figure 2 gives a summary of the lithology, local stratigraphy, and ammonoid data of the Middle Triassic of the northeastern vicinity of Qingyan.

The Qingyan Formation consists of marly mudstones and shales, marlstones, marly limestones, and carbonate breccias. In Chinese stratigraphy it is subdivided into (in ascending order) the "Xiaoshan Subformation" including the Xiaoshan, Mafengpo, and Yingshangpo members and the "Yuqing Subformation" comprising the Leidapo and Yuqing members. The Longtou Formation is formed by limestones and dolomite. It is subdivided into the Shizishanjiao and Ganyintang members.

The term "subformation" used in this Chinese stratigraphy, however, is not an official lithostratigraphical term [and in German, "Subformation" is equivalent to the English term "member" (Steininger & Piller 1999)]. Therefore, the Chinese nomenclature is somewhat unfortunate, and the Xiaoshan and Yuqing "subformations" herein are referred to as the Lower and Upper Qingyan Formation, respectively.

The Xiaoshan Member is formed by an alternation of carbonate breccias, limestones, and marly mudstones/shales. The overlying Mafengpo Member is dominated by marly mudstones/shales; mostly thin layers of marlstones to limestones occasionally are intercalated. The limestone-dominated Yingshangpo Member consists of marly limestones and carbonate breccias with comparatively few and mostly thin intercalations of mudstones/shales to marlstones. The Leidapo and Yuqing members are dominated


GGT (1976a)
Chinese data
Guizhou Geological Team (1976a)
Stiller (2001a), (Stiller 1995) (identified taxa only)
This study (identified taxa only)
NE of Qingyan (Leidapo - Shizishan)
E of Qingyan
Middle Triassic
Lower Triassic
Ladinian
Anisian
Olenekian
Longtou Formation
Qingyan Formation
Ziyun Formation
Upper (= "Yuqing Subformation")
Lower (= "Xiaoshan Subformation")
Ganyintang Member
Shizishan-jiao Mb.
Yuqing Member
Leidapo Member
Yingshangpo Member
Mafengpo Member
Xiaoshan Member
>361.6 m; top eroded
59.3 m
203.6 m
192.4 m
174.4 m
127.5 m
131.4 m
83.2 m
Leidapo section
Flexoptychites sp.
Megaphyllites sp.,
(Protrachyceras sp. - from another locality)
Balatonites sp.
Paraceratites trinodosus
Paraceratites cf. brembanus
Paraceratites binodosus
Paraceratites sp.
Balatonites cf. gracilis
Discoptychites cf. drona
Discoptychites sp.
Discoptychites? sp.
Ptychites everesti
Ptychites cf. everesti
Ptychites sp.
Paraceratites binodosus
Paraceratites trinodosus
Paraceratites aff. trinodosus
Paraceratites brembanus
Paraceratites cf. brembanus
Paraceratites n.sp.
Paraceratites sp.
Bulogites coronatus
Bulogites multicostatus
Bulogites n.sp.
Bulogites sp.
Balatonites cf. gracilis
Balatonites sp.
Proarcestes sp.
Japonites sp.
Japonites? sp.
Judicarites sp.
Hollandites cf. ravana
Hollandites sp.
Danubites floriani
Danubites cf. kansa
Danubites sp.
Beyrichites chingyenensis
Beyrichites sp.
Nicomedites yohi
Discoptychites cf. drona
Discoptychites sp.
Ptychites sp.
Acrochordiceras sp.
Paracrochordiceras? sp.
Salterites sp.
Nicomedites yohi
Beyrichites chingyenensis
Beyrichites sp.
Balatonites sp.
Ussurites kingi
Ussurites cf. kingi
Ussurites sp.
Leiophyllites cf. pitamaha
Leiophyllites sp.
Gymnites sp.
Gymnites? sp.
Huishuites sp.
Huishuites? sp.
Sageceras sp.
Ceratitoidea
Acrochordiceratidae
Danubites sp.
Danubites? sp.
Judicarites sp.
Leiophyllites sp.
Leiophyllites? sp.
Balatonites sp.
Paracrochordiceras sp.
Paracrochordiceras? sp.
Acrochordiceratidae
Palaeophyllitidae
Gymnotoceras? sp.
(not studied)
Flexoptychites sp.
Paraceratites trinodosus
Paraceratites sp.
Balatonites cf. gracilis
Discoptychites? sp.
Ptychites cf. everesti
Ptychites sp.
Paraceratites trinodosus
Japonites? sp.
Paraceratites binodosus
Paraceratites trinodosus
Bulogites sp.
Discoptychites sp.
Ptychites sp.
Paraceratites binodosus
Paraceratites sp.
Bulogites sp.
Proarcestes sp.
Acrochordiceras sp.
Salterites sp.
Balatonites sp.
Ceratitoidea
Huishuites? sp.
Acrochordiceratidae
<2>
Balatonites sp.
Leiophyllites sp.
Palaeophyllitidae
<1>
Mesohedenstroemia cf. inflata
Ussuridae?
Paranannites sp.
Anasibirites sp.
Albanites sp.
Proptychitoides sp.
Tirolites sp.
Paraceratites trinodosus
Judicarites sp.
Acrochordiceras? sp.
Judicarites sp.
Paraceratites sp.
Balatonites sp.
Hollandites sp.
Judicarites sp.
Paracrochordiceras? sp.
Paraceratites? sp.
Acrochordiceratidae indet.
Sageceras sp.
Discoptychites sp. (n.sp.?) (l,w)
Ptychites rugifer (l,w)
Ptychites? sp. (l)
Gymnites sp. (l)
Danubites cf. michaelis (w)
Judicarites sp. (l,w)
Hollandites sp. (w)
Beyrichites sp. (l)
Philippites sp. (l)
Schreyerites binodosus (l)
Bulogites multicostatus (l)
Paracrochordiceras sp. (l,w)
Epacrochordiceras cf. pustericum (l)
Paraceratites brembanus (l)
Paraceratites? sp. (l)
l = Leidapo
w = Wachangpo
<2>
Ussurites cf. kingi
Ussurites sp.
Acrochordiceratidae
Gymnites sp.
Leiophyllites cf. pitamaha
Leiophyllites sp.
<1>
Leiophyllites? sp.
Danubites sp.
Danubites? sp.
Gymnotoceras? sp.
Judicarites sp.
Balatonites sp.
Balatonites? sp.
Acrochordiceratidae
Paracrochordiceras? sp.
Rieppelites sp. (cf. Rieppelites shevyrevi)
Ptychites sp. (cf. Ptychites sp. A)
Rieppelites cf. cimeganus (l)
Rieppelites sp. A (l,w)
Judicarites cf. meneghinii (l,w)
Gosauites sp. (w)
Ptychites sp. A (l,w)
Ptychites sp. B (l,w)
Ptychites sp. C (l)
Bulogites multicostatus (l)
Bulogites sp. (Balatonites? sp.) (l)
Acrochordiceras cf. carolinae (l)
Proarcestes sp. (l)
Beyrichitinae gen. indet. (l)
Sageceras sp.
l = Leidapo
w = Wachangpo
Judicarites cf. meneghinii
Bulogites sp.
dolomite
dolomitic limestone
limestone to slightly marly limestone
carbonate breccia
marly limestone
marlstone
mudstone / shale to marly mudstone / shale
not exposed
100 m

by marly and sometimes silty mudstones and shales. Mostly thin layers of marlstones to marly limestones occasionally occur, but generally are rare. The Leidapo section and the fossil site at Wachangpo stratigraphically are situated in the lower middle part of the Leidapo Member. At Leidapo, calcareous intercalations are more abundant than in the successions of the Leidapo and Yuqing members below and above [see detailed columnar section of Leidapo/Bangtoupo in Stiller (2001a)]. Marly siltstones rarely occur in the Yuqing Member. The uppermost part of the Yuqing Member is formed by an alternation of marly mudstones/shales and generally thin layers of marly limestones. The mudstones and shales of the Yuqing Member on average contain more carbonate than those of the Leidapo Member. However, the Leidapo Member and the Yuqing Member are fairly similar lithologically and not readily distinguished in the field. Therefore, it would be more convenient to regard the entire Upper Qingyan Formation as a single member. In contrast to the Lower Qingyan Formation, no carbonate breccias occur in the Upper Qingyan Formation and the Shizishanjiao Member. The latter mainly consists of thin-to-thick layers of marly limestones with generally thin to very thin intercalations of marly mudstones/shales. The Ganyintang Member is formed by generally thickly-bedded to massive carbonate rocks. Dolomite (dolomitised limestone) dominates in its basal part, followed upwards by dolomitic limestone and finally limestone.

The generalised columnar section in the left part of Figure 2 was drawn after Guizhou Geological Team (1976a). This publication contains the most detailed lithological data available. Later Chinese publications, e.g. Guizhou Geological Team [1976b: especially fig. 78 (Guiyang Formation), fig. 91 (Qingyan Formation)] or Guizhou Bureau of Geology and Mineral Resources (1987), also used this source but strongly schematised and simplified the data. Own observations of the Leidapo and Yuqing members (e.g. Stiller 1997, 2001a), which have been corroborated by studies of Komatsu et al. (2004a, b), led to a somewhat different characterisation of the lithology of the Upper Qingyan Formation, which is shown in the generalised columnar section in the right part of Figure 2. According to these more recent investigations, less limestone and marlstone are intercalated in the mudstones/shales than documented in the earlier Chinese reports, and the mudstones and shales of the Yuqing Member are marly, but they do not represent marlstones as supposed in the Chinese publications.

The Qingyan Formation was deposited on the slope between an extensive carbonate platform and a deep-water basin with mainly siliciclastic sedimentation [see Stiller (2001a) for detailed discussion and references]. The lower part with its characteristic carbonate breccias was deposited in deeper water on the (probably lower) slope. With regard to the depositional environments of the Upper Qingyan Formation, opinions somewhat vary. Stiller (e.g. 1997, 2001a) interpreted the facies as developing from deeper water slope conditions below the Leidapo section to shallow-marine and partly storm-influenced at Leidapo and then back to conditions of somewhat deeper water in the upper Leidapo Member and the Yuqing Member. Komatsu et al. (2004a, b), on the other hand, interpreted the Leidapo Member as consisting of basin floor deposits in its lower and upper parts and slope deposits at Leidapo; the Yuqing Member was interpreted to comprise storm-influenced inner shelf deposits and mudstones deposited in somewhat deeper, outer shelf environments. The Shizishanjiao Member represents shallow-marine conditions, and then the lithofacies changes to shallowly subtidal and intertidal to supratidal platform carbonates of the Ganyintang Member, mirroring the progradation of the carbonate platform (see Stiller 2001a).

Ammonoids of the Upper Qingyan Formation and biostratigraphical correlation

Figure 2 provides a synopsis of the ammonoids hitherto reported from Middle Triassic rocks exposed just northeast of Qingyan. New data from the same area were obtained during the course of this study and are listed in the right column of Figure 2. Many of the earlier taxonomic assignments evidently require revision. Identifications given in previous lists are lacking descriptions and illustrations in most cases.

Fig. 2. Synopsis of the ammonoids and their stratigraphical occurrences reported from the Middle Triassic in the northeastern vicinity of Qingyan; after Chinese data (left part) and own observations (right part); data from earlier publications without revision. Columns from left to right: Stratigraphical subdivision of the Middle Triassic in the Qingyan region. – Generalised columnar section, after Guizhou Geological Team (1976a) (see text); limestone layers in the Qingyan Formation and the Shizishanjiao Member are often separated by thin layers of mudstone/shale, which are not shown in the generalised columnar section; uppermost limestone unit of the Ganyintang Member not drawn to scale; remark: the thickness of the Yingshangpo Member is generally given as 176.4 m or 176 m, also in Guizhou Geological Team (1976a, b), but re-evaluation of the metric data and the columnar section published by Guizhou Geological Team (1976a) showed that this figure is based on a miscalculation and that the thickness of the Yingshangpo Member is 174.4 m. – Ammonoids reported from the different members of the Middle Triassic of Qingyan in Chinese and international publications, mainly based on Chinese data; compiled after Hsu & Chen (1943), Hsu (1944, 1945), Wang et al. (1956), Yu & Zhao (1957), Institute of Geology and Palaeontology (1962), Zhao et al. (1962), Zhao et al. (1965), Yang & Xu (1966), Zhao & Wang (1974), Guizhou Work Team (1975), Guizhou Geological Team (1976a, b), Guizhou Province Work Team (1977), Liao (1978), Chen et al. (1979), Rao (1979), Wang & He (1980), Yang & Li (1980), Wang et al. (1981), Yang et al. (1982), Zhao et al. (1982), Kristan-Tollmann (1983a, b), Kristan-Tollmann & Tollmann (1983), Yin & Yochelson (1983), Deng & Kong (1984), Qi (1984), Guizhou Bureau of Geology and Mineral Resources (1987), Wang (1988), Qi & Stanley (1989), Wang & Westermann (1993), Wei (1993), Wei et al. (1996). – Ammonoids and their stratigraphical occurrences in the Triassic of Qingyan after Guizhou Geological Team (1976a). – Generalised columnar section of the Leidapo and Yuqing members after personal observations (e.g. Stiller 1997, 2001a), corroborated by studies of Komatsu et al. (2004a, b) (see text). – Ammonoids (identified taxa only) and their stratigraphical occurrences in the Leidapo, Yuqing, and Shizishanjiao members after Stiller (1995 [in brackets ()], 2001a); these data were referred to in more recent publications as well (e.g. Stiller & Chen 2004; Komatsu et al. 2004a, b; Chen et al. 2006). – Ammonoids (identified taxa only) and their stratigraphical occurrences, this study; Stiller & Chen (2006) already referred to preliminary data of this new study.

Some reported associations even contain genera that are well known to be mutually exclusive in all other sections of Anisian age. For instance, reported occurrences of *Japonites* and *Paracrochordiceras*, both of early Anisian age, within the late middle and early late Anisian dominated faunas of the Leidapo Member appear rather dubious. Similarly, the stratigraphically older assemblage from the Xiaoshan Member also contains unrealistic reported associations such as the early Anisian *Paracrochordiceras* together with the early late Anisian *Judicarites*. Finally, the stratigraphically younger Yuqing Member is reported to yield the late Anisian *Paraceratites trinodosus* together with the late middle Anisian *Balatonites*.

Newly collected material essentially comes from the Leidapo and Yuqing members. Bedrock-controlled samples were mainly obtained from the approximately 50 m thick Leidapo section and the upper Yuqing Member. In the section at Leidapo, the ammonoid sequence comprises a latest middle Anisian assemblage followed by an earliest late Anisian assemblage.

Bulogites-Acrochordiceras assemblage

Age-diagnostic taxa of the lower assemblage are *Bulogites multicostatus* WANG, in Zhao et al. (1965) and *Acrochordiceras* cf. *carolinae* MOJSISOVICS 1882 (Fig. 3). Additional taxa include *Proarcestes* sp. and Beyrichitinae gen. indet. This assemblage compares well with that of the *Bulogites mojsvari* Subzone of the *Balatonites shoshonensis* Zone from northwestern Nevada as defined by Monnet & Bucher (2005). It also correlates with the *Bulogites zoldianus* Zone from eastern Lombardy-Giudicarie as revised by Monnet et al. (2008) and from the Balaton Highland (Vörös 2003) (Fig. 7). All known species of *Bulogites*

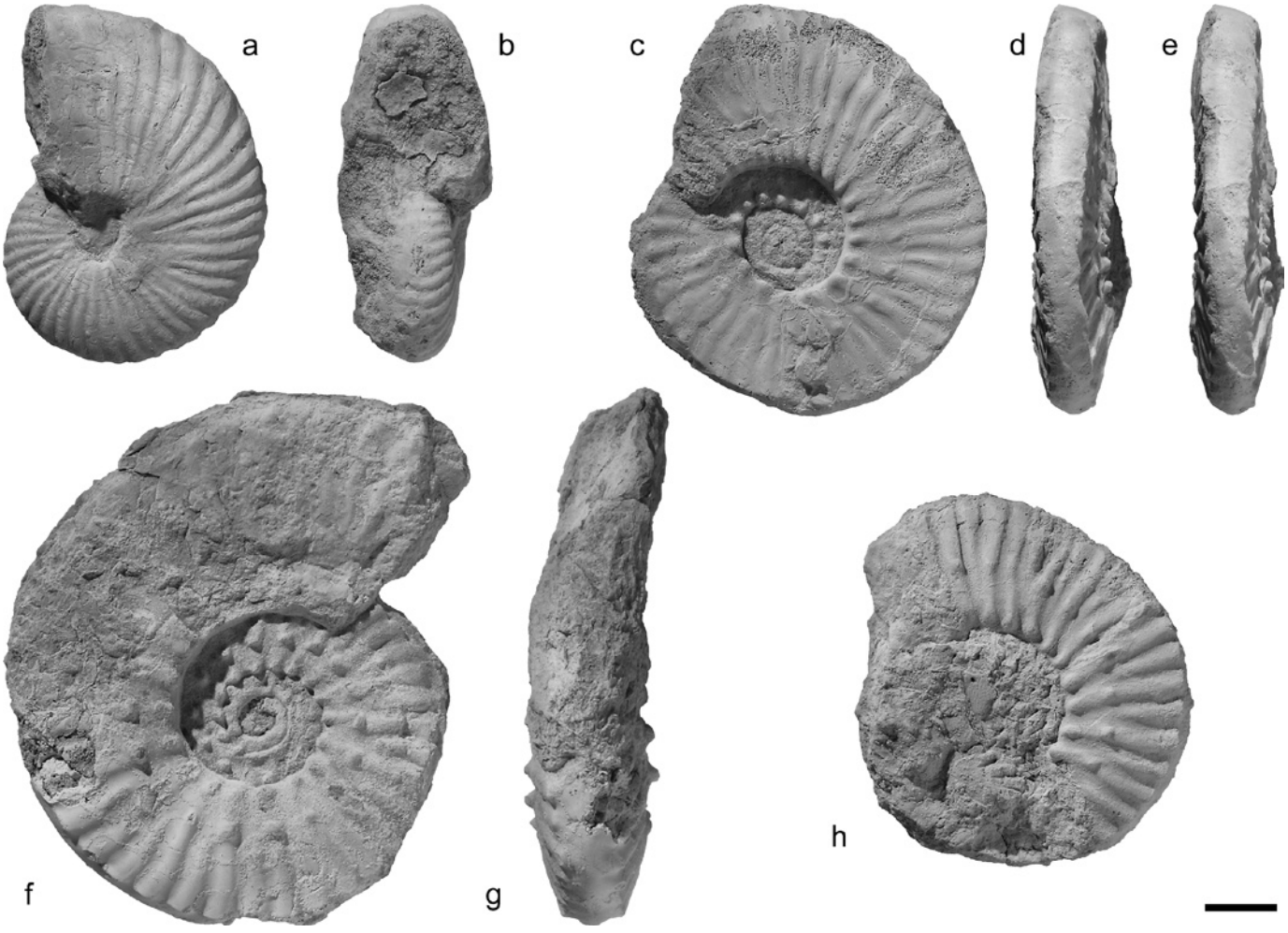


Fig. 3. Age-diagnostic ammonoids of the *Bulogites-Acrochordiceras* assemblage from the lowermost part of the Upper Qingyan Formation. All specimens from the lower middle Leidapo Member (latest middle Anisian, early Middle Triassic) of the lower portion of the Leidapo section, northeast of Qingyan, Guizhou Province, southwestern China. a, b) *Acrochordiceras* cf. *carolinae* MOJSISOVICS 1882; NIGP 143730. c–e) *Bulogites multicostatus* WANG, in Zhao et al. (1965); NIGP 143731. f, g) *Bulogites multicostatus* WANG, in Zhao et al. (1965); NIGP 143732. h) *Bulogites multicostatus* WANG, in Zhao et al. (1965); NIGP 143733. All figures natural size; scale bar: 10 mm.

are restricted to this latest middle Anisian age, thus making the genus *Bulogites* a worldwide index within the low-palaeolatitude belt. From the basal Leidapo Member, *Sageceras* sp. was collected; however, this genus is long-ranging.

Taxonomic remarks on Bulogites multicostatus

The holotype of *Bulogites multicostatus* (NIGP 22045) is a poorly preserved and fragmentary specimen as can be seen from the illustration given by Wang (in Zhao et al. 1965: 266, pl. 85: 12), and, unfortunately, could not be found in the Nanjing collection. The same photograph was published in Yu & Zhao (1957 [*Paraceratites trinodosus*]), Institute of Geology and Palaeontology (1962 [*Paraceratites trinodosus*]), Zhao & Wang (1974), and Liao (1978) (see Appendix). However, the holotype comes from the same Leidapo section, from where new material is now available. The herein illustrated and relatively well-preserved new specimens (Figs. 3c–h) are therefore most likely conspecific with *B. multicostatus*. This new material also provides a reliable basis for comparing the Chinese species to other congeneric species. *Bulogites multicostatus* is trituberculated, thus differing from the quadrituberculated *Bulogites multinodosus* (HAUER 1892). *Bulogites multicostatus* also differs from *Bulogites zoldianus* MOJSISOVICS 1882 by its more evolute coiling and more robust umbilical and lateral rows of nodes, and from *Bulogites mojsvari* (ARTHABER 1896) by its more evolute coiling. The suture line of *B. multicostatus* (see illustrations in the Chinese publications cited above) compares well with that of *B. mojsvari* (see Monnet & Bucher 2005: fig. 30).

Rieppelites-Judicarites assemblage

The next overlying ammonoid assemblage comprises *Rieppelites* cf. *cimeganus* (MOJSISOVICS 1882), *Rieppelites* sp. A, *Judicarites* cf. *meneghinii* (MOJSISOVICS 1882), *Gosauites* sp., *Ptychites* sp. A, *Ptychites* sp. B., and *Ptychites* sp. C (Figs. 4, 5). The genus *Rieppelites* is known to be restricted to the basal late Anisian in Nevada (Monnet & Bucher 2005), the Dolomites (Kustatscher et al. 2006), and Lombardy-Giudicarie (Monnet et al. 2008). In the Prezzo Limestone of Lombardy-Guidicarie, the stratigraphical occurrence of *Judicarites* is bracketed by the *Rieppelites cimeganus* fauna below and the *Schreyerites*

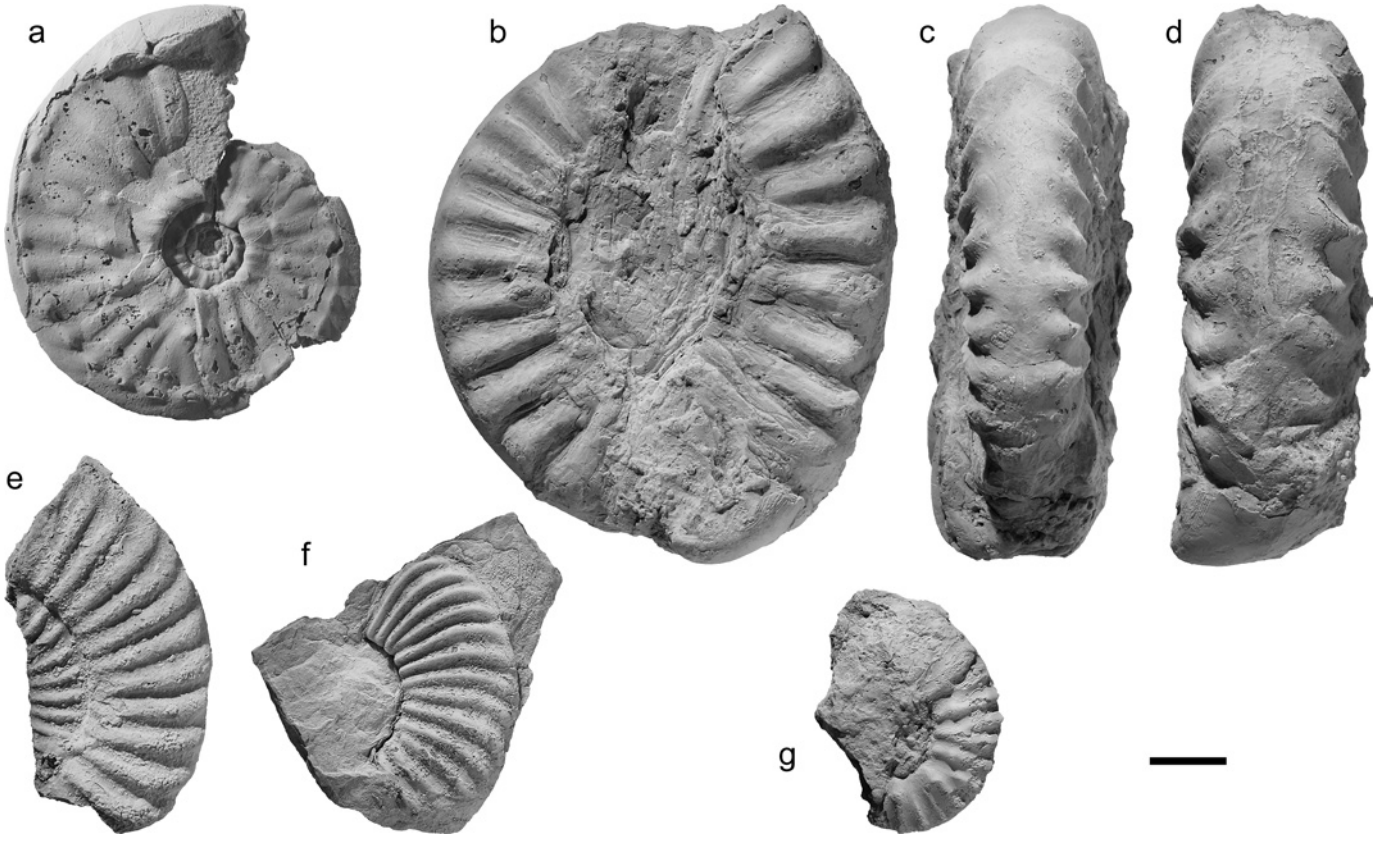


Fig. 4. Ammonoids of the *Rieppelites-Judicarites* assemblage from the lower part of the Upper Qingyan Formation. All specimens from the upper middle and upper Leidapo Member (earliest late Anisian, early Middle Triassic) of the northeastern vicinity of Qingyan, Guizhou Province, southwestern China. a) *Rieppelites* sp. A; NIGP 143735; upper middle Leidapo Member, upper portion of the Leidapo section. b–d) *Gosauites* sp.; NIGP 143738; upper middle Leidapo Member, Wachangpo. e) *Judicarites* cf. *meneghinii* (MOJSISOVICS 1882); NIGP 143736; upper middle Leidapo Member, Wachangpo. f) *Judicarites* cf. *meneghinii* (MOJSISOVICS 1882); NIGP 143737; upper Leidapo Member, northwest of Lanhuaguan. g) *Rieppelites* cf. *cimeganus* (MOJSISOVICS 1882); NIGP 143734; upper middle Leidapo Member, upper portion of the Leidapo section. All figures natural size; scale bar: 10 mm.

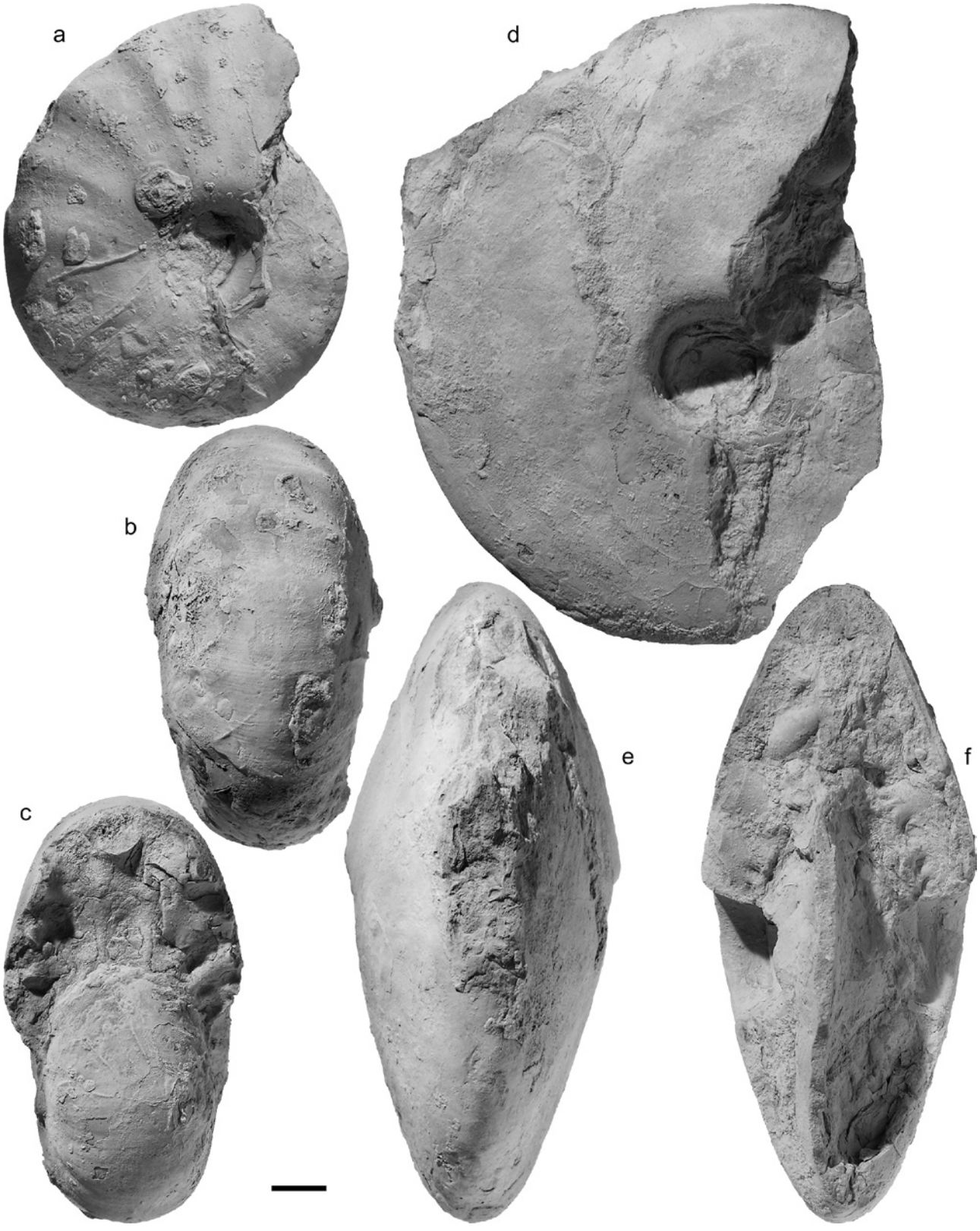


Fig. 5. Ammonoids of the *Rieppelites-Judicarites* assemblage from the lower part of the Upper Qingyan Formation. All specimens from the upper middle Leidapo Member (earliest late Anisian, early Middle Triassic) of the upper portion of the Leidapo section, northeast of Qingyan, Guizhou Province, southwestern China. a–c) *Ptychites* sp. A; NIGP 143739. d–f) *Ptychites* sp. B; NIGP 143740. All figures nearly natural size; scale bar: 10 mm.

abichi and *Paraceratites trinodosus* faunas above. Only in the Dolomites (Dont) is *Judicarites* documented in association with the basal late Anisian *Rieppelites cimeganus* fauna. It is not known whether the several species of *Judicarites* described by Mojsisovics (1882) from the middle part of the Prezzo Limestone represent a highly variable species or whether these have any chronological significance within the 10 m or so of strata in which they occur. Nevertheless, the co-occurrence of *Rieppelites* and *Judicarites* clearly indicates an earliest late Anisian age for this assemblage from Qingyan (Fig. 7).

The *Rieppelites-Judicarites* assemblage well correlates with the *Billingsites cordeyi* Subzone of the *Gymnotoceras weitschati* Zone from northwestern Nevada as defined by Monnet & Bucher (2005). *Rieppelites* is restricted to this subzone, but *Judicarites* is not known from Nevada. It also compares well with the *Rieppelites cimeganus* Zone from eastern Lombardy-Giudicarie as revised by Monnet et al. (2008) (Fig. 7). In the latter zone, *Rieppelites* and *Judicarites* co-occur.

Ptychites is apparently represented by three distinct forms. *Ptychites* sp. A shows affinities with *Ptychites stachei* MOJSISOVICS 1882 in sharing a broadly rounded venter crossed by regularly spaced folds. *Ptychites* sp. B evidently differs from *Ptychites* sp. A by its smooth shell and triangular whorl section, suggesting some affinities with *Discoptychites domatus* (HAUER 1851) and *Ptychites gradinarui* (BUCHER 1992). *Ptychites* sp. C differs from the two previous forms in having a much more compressed and involute shell shape, with a narrowly rounded venter and distant, weak lateral folds, morphologically somewhat resembling the genus *Flexoptychites*.

Only very few identifiable ammonoids were recovered from the overlying Yuqing Member. Among these, the only available age-diagnostic forms are referred to *Rieppelites* sp. (Fig. 6), which also indicates an earliest late Anisian age for this member. *Rieppelites* sp. from the upper Yuqing Member somewhat resembles *Rieppelites shevyrevi* MONNET & BUCHER 2005 from northwestern Nevada. Stiller (2001a: 522) reported *Judicarites* to co-occur with *Rieppelites* sp. (formerly assigned to *Paraceratites trinodosus*); however, the generic identification of this specimen is not certain.

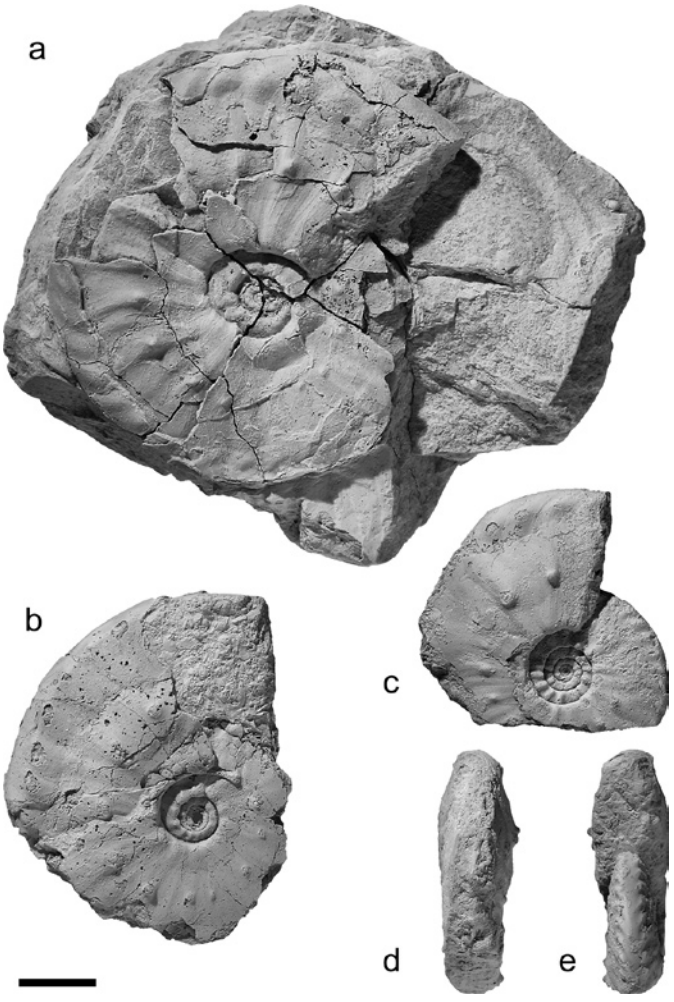


Fig. 6. Age-diagnostic ammonoids of the *Rieppelites-Judicarites* assemblage from the uppermost part of the Upper Qingyan Formation. *Rieppelites* sp. (cf. *Rieppelites shevyrevi* MONNET & BUCHER 2005) from the upper Yuqing Member (earliest late Anisian, early Middle Triassic) of Shizishanjiao, northeast of Qingyan, Guizhou Province, southwestern China. a) NIGP 143741. b) NIGP 143742. c–e) NIGP 143743. All figures natural size; scale bar: 10 mm.

Remarks on earlier taxonomic identifications

In earlier publications, ammonoids from the Upper Qingyan Formation, i.e. from the Leidapo and Yuqing members, have been assigned to *Paraceratites trinodosus* (MOJSISOVICS 1882) and other species of late late Anisian age, and the stratigraphical correlation was based on these identifications. However, the present re-study of the ammonoids shows that no *Paraceratites* occur in the Upper Qingyan Formation. Probably all specimens from the Leidapo and Yuqing members assigned to various *Paraceratites* species in earlier publications do not belong to this genus. Among the figured specimens (Yu & Zhao 1957; Institute of Geology and Palaeontology 1962; Zhao et al. 1965; Zhao & Wang 1974; Liao 1978; Komatsu et al. 2004a), those assigned to *P. trinodosus* belong to either the latest middle Anisian *Bulogites multicostatus* or the earliest late Anisian *Rieppelites* sp. A and *Rieppelites* sp., and those assigned to *Paraceratites binodosus* (HAUER 1851) also to *Rieppelites* sp. A (see Appendix). The specimen assigned to *P. trinodosus* in Zhao & Wang (1974) and Liao (1978) (NIGP 22037) has been re-studied, that assigned to *P. binodosus* in these publications was not available for study. *Rieppelites* differs from *Paraceratites* in the absence of a ventral keel.

From the "Qingyan Formation" (Anisian) of the Anshun region, Guizhou Province, *Judicarites primordius* ZHAO & WANG 1974 was described (Zhao & Wang 1974; Liao 1978; NIGP 22035, specimen could not be found in the Nanjing collection). According to the description, it has a distinctly protruding keel on the venter, on both sides delimited by a shallow groove. However, without an illustration of the venter and with the sample not being available, the generic assignment of this

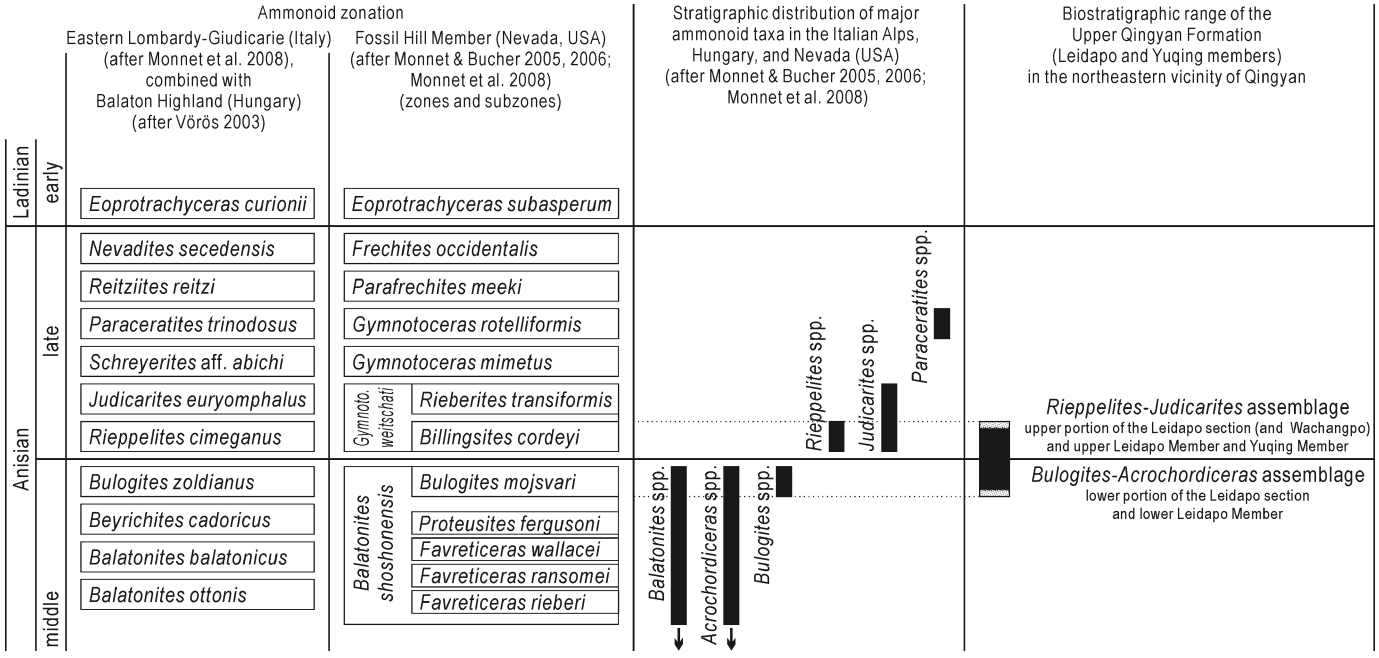


Fig. 7. Correlation between the Upper Qingyan Formation in the northeastern vicinity of Qingyan and the ammonoid zonations in the Italian Alps, Hungary, and Nevada (USA), and stratigraphical distribution of major, correlation-relevant ammonoid taxa in these regions. Exact biostratigraphical ages of the lower and upper boundaries of the Upper Qingyan Formation unknown; proven range in black, possible maximum range in grey.

specimen is doubtful. It differs from *Judicarites* cf. *meneghinii* from Qingyan in its coarser and more irregular ribbing.

Palaeobiogeographical remark

From a palaeobiogeographical point of view, the Anisian ammonoid fauna from Qingyan significantly expands the distribution of *Judicarites* to the east and bridges the previously known low-palaeolatitude occurrences of *Rieppelites* between the southern Alps and Nevada. These new occurrences support and strengthen the broad palaeolatitudinal distribution of middle and late Anisian ammonoid faunas.

Stratigraphy

The Anisian age of the marly succession near Qingyan, later named the Qingyan Formation, was first established by Hsu & Chen (1943). In Chinese stratigraphy, the Qingyan Formation is regarded to represent the Anisian, i.e., to be equal to the Anisian, and the Anisian stage (marine facies) has recently been named the Qingyanian stage (Yang et al. 2000; National Stratigraphical Commission of China 2001, 2002; Yin & Tong 2002; Tong & Yin 2005). The stage name Qingyanian is derived from the Qingyan Formation, and the stratotype section is that near Qingyan (National Stratigraphical Commission of China 2002: 32). Because the outcrop conditions near Qingyan nowadays are insufficient, the Guandao section near Bianyang, Luodian, southern Guizhou Province, has been chosen as an alternative type section (Yin & Tong 2002; Tong & Yin 2005). However, no ammonoid data are available for the Guandao sections. Only the stratigraphical distribution of conodonts was given by Lehrmann et al. (2005), and obvious internal contradictions highlighted by Bucher et al. (2007) have led to substantial shifts in the position of some conodont first occurrences and in the re-assessment of the U-Pb zircon ages of some volcanic ash layers bracketing the Early/Middle Triassic boundary, as well (see Lehrmann et al. 2007; Ramezani et al. 2007).

The Longtou Formation (in some, especially earlier, publications on the Qingyan region also referred to as Guiyang Formation or Falang Formation) is regarded to be Ladinian (late Middle Triassic) in age. The Shizishanjiao Member originally was included in the Qingyan Formation and regarded to be of latest Anisian age (Yang & Xu 1966; Guizhou Work Team 1975; Guizhou Province Work Team 1977; Yin & Yochelson 1983). In Guizhou Geological Team (1976a, b) and almost all later publications, it was included in the Guiyang/Longtou Formation and thus regarded to represent lowermost Ladinian strata.

Wei (1993) and Wei et al. (1996) included the Qingyan Formation (platform slope to basin margin facies) in the Xinyuan Formation (basin facies) and correlated the Xiaoshan and Mafengpo members with the Lower Xinyuan Formation, the Yingshangpo Member with the Middle Xinyuan Formation, and the Leidapo and Yuqing members with the lower Upper Xinyuan Formation. However, because the Qingyan Formation represents a fairly well-defined facies belt stretching along the external slope of the extensive carbonate platform, it appears more convenient to keep the Qingyan and Xinyuan formations separated.

The ammonoid zonation of the Anisian of Qingyan used in Chinese stratigraphy was established by Wang Yigang (e.g. Guizhou Geological Team 1976b: 228; Yang et al. 1982). Yang et al. (1982: 11) referred to an unpublished manuscript as "Wang Yigang (1964): Ammonoids from central and southern Guizhou" [translated from Chinese]. Unfortunately, this study of Wang was not published due to the Cultural Revolution, and the fate of the manuscript as well as the specimens is unknown (He Guoxiong pers. comm. 2004). In the Qingyan section, Wang recognised three ammonoid zones (in ascending order): *Nicomedites yohi* Zone, *Paraceratites binodosus* Zone, and *Paraceratites trinodosus* Zone. He correlated these with the European *Nicomedites osmani*, "*Paraceratites*" *binodosus* (*Schreyerites binodosus*), and *Paraceratites trinodosus* zones, respectively. For the lower part of the Lower Qingyan Formation, he did not define an ammonoid zone, but in the lower Anisian of Anshun (about 70 km west of Qingyan) he recognised the "*Parapopanoceras nanum* Zone", which he thought to represent the basal Anisian. These horizons in Anshun may be correlated with the lower Lower Qingyan Formation of Qingyan (Yang et al. 1982).

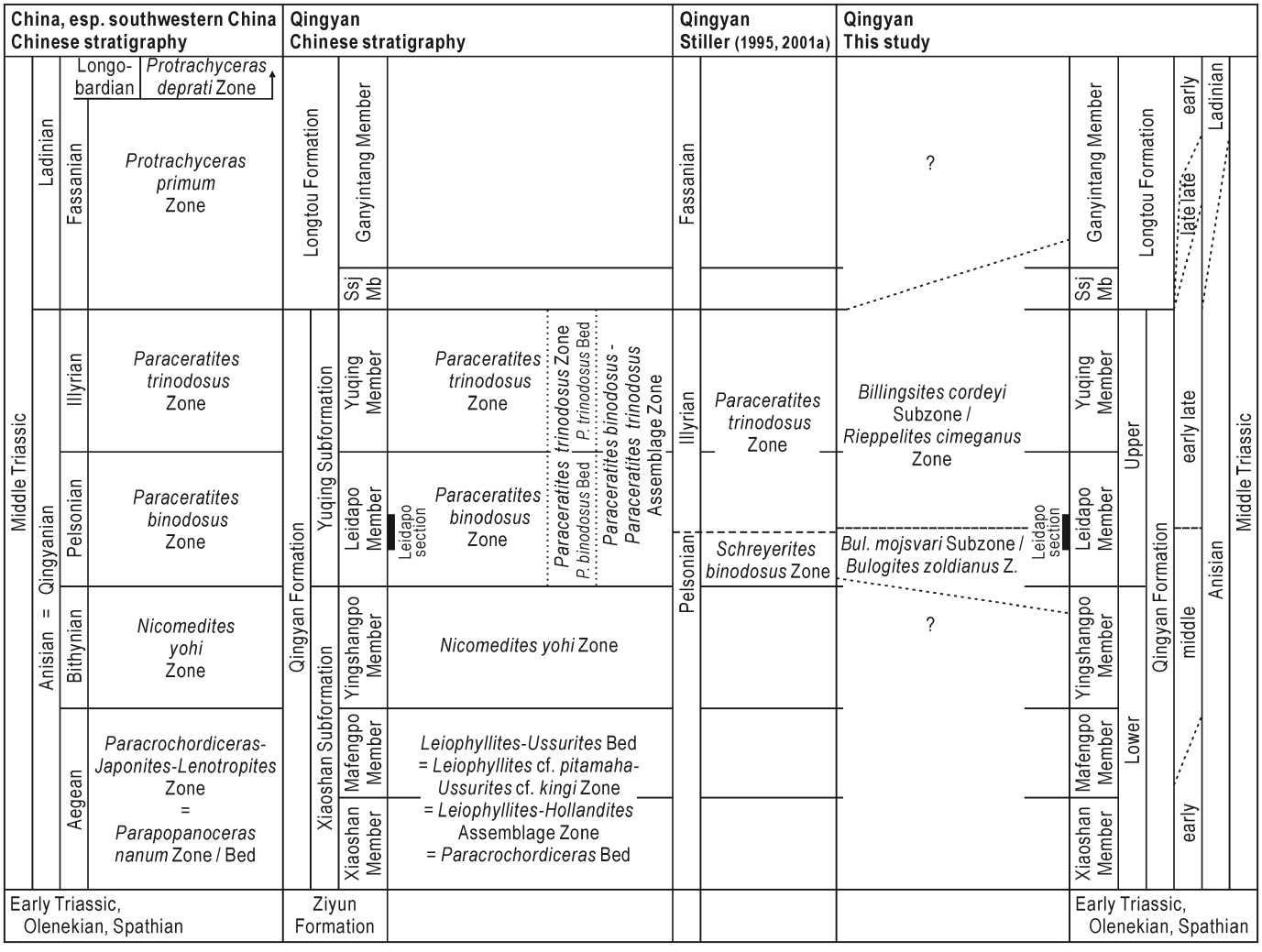


Fig. 8. Comparative synopsis of the stratigraphical correlation of the Middle Triassic of the Qingyan region. Chinese data for China (especially southwestern China) and the Qingyan region after Wang (1964, unpublished manuscript, see text), Guizhou Geological Team (1976b), Chen et al. (1979), Rao (1979), Wang & He (1980), Yang & Li (1980), Wang et al. (1981), Yang et al. (1982), Zhao et al. (1982), Yin & Yochelson (1983), Yang (1986), Guizhou Bureau of Geology and Mineral Resources (1987), Huang & Chen (1987), Meyerhoff et al. (1991), Yin (1997), Chen et al. (2000), Yang et al. (2000), National Stratigraphical Commission of China (2002), Yin (2003). [The *Protrachyceras primum* Zone occasionally has been referred to as *Xenoprotrachyceras primum* Zone; in some publications, the species name *primum* was misspelled as "*prinum*". Yin (1997) placed *Protrachyceras primum* not in the lower Ladinian but in the uppermost Anisian; in Yin (2003) it is placed on the Anisian/Ladinian boundary.] The correlation of Stiller (1995, 2001a) was used in all his (single- and co-authored) publications on Qingyan fossils until Chen et al. (2006). Stiller & Chen (2006) already referred to preliminary data of our new study. For discussion of the revised correlation (this study) see text. Abbreviation: Ssj Mb, Shizishanjiao Member.

Wang's correlation for the Qingyan Formation has been used in Chinese stratigraphy until today and even became the standard for the Anisian of the whole of southwestern China and adjacent regions (e.g. Chen et al. 2000; Yang et al. 2000; National Stratigraphical Commission of China 2002; Yin 2003). In the Qingyan region, the Leidapo Member is correlated with the "*Paraceratites*" *binodosus* Zone and the Yuqing Member with the *Paraceratites trinodosus* Zone (e.g. Guizhou Geological Team 1976b; Guizhou Bureau of Geology and Mineral Resources 1987). Only minor nomenclatorial changes have been proposed for the Qingyan area. Guizhou Geological Team (1976b) regarded the entire Upper Qingyan Formation ("Yuqing Subformation") as *Paraceratites trinodosus* Zone, subdivided into *Paraceratites binodosus* and *Paraceratites trinodosus* beds (Leidapo and Yuqing members, respectively), and defined for the Xiaoshan and Mafengpo members a *Leiophyllites* cf. *pitamaha-Ussurites* cf. *kingi* Zone (*Leiophyllites-Ussurites* Bed in later publications). Guizhou Bureau of Geology and Mineral Resources (1987) named the "Yuqing Subformation" *Paraceratites binodosus-Paraceratites trinodosus* Assemblage Zone ("*Paraceratites binodosus-Paraceratites trinodosus* Zone" in Chen 2004: 656) and referred to the Xiaoshan and Mafengpo members as *Leiophyllites-Hollandites* Assemblage Zone. This lower part of the Lower Qingyan Formation was called *Paracrochordiceras* Bed by Chen et al. (2000).

Based on his own observations and in slight deviation from the Chinese stratigraphical division, Stiller (1995, 2001a) regarded the Leidapo/Bangtoupo section biostratigraphically to be approximately at the transition between the "*Paraceratites*" [*Schreyerites*] *binodosus* and *Paraceratites trinodosus* zones, i.e., at the transition from the Pelsonian to the Illyrian substages. This stratigraphical correlation was also used by Stiller (1997, 1998, 1999a, b, 2000a, b, 2001b, c, 2002), Chen et al. (2001, 2006), Stiller et al. (2002), Komatsu et al. (2004a, b), Stiller & Chen (2004). Stiller & Chen (2006) already referred to preliminary data of our new study. Figure 8 gives a summary of the stratigraphical correlations proposed for the Middle Triassic of Qingyan and southwestern China.

The taxonomic revision of the available ammonoid specimens from the Upper Qingyan Formation (Leidapo and Yuqing members) shows that this succession is of latest middle to earliest late Anisian age and thus distinctly older than the *Paraceratites trinodosus* Zone (Fig. 7). The boundary between late middle and early late Anisian strata is positioned in the upper middle part of the Leidapo section, approximately at bed F45 (above F40 and below F50) of Stiller (2001a). The exact position of the biostratigraphical boundary is uncertain due to the relative scarcity of ammonoids in the fossil assemblages and thus the relative scarcity of bedrock-controlled ammonoid specimens. The fossil site at Wachangpo biostratigraphically can be correlated with the earliest late Anisian upper portion of the Leidapo section.

In the entire Yuqing Member as well, no *Paraceratites* was found, and the known specimens assigned to this genus in earlier publications have to be re-assigned to *Rieppelites*. Specimens of *Rieppelites* are fairly common in the upper part of the Yuqing Member, proving its earliest late Anisian age.

The exact biostratigraphical ages of the lower and upper boundaries of the Upper Qingyan Formation are somewhat uncertain. However, the lower boundary of the Upper Qingyan Formation most probably is situated within the equivalent of the *Bulogites mojsvari* Subzone (*Balatonites shoshonensis* Zone; Nevada) and of the *Bulogites zoldianus* Zone (Lombardy; Balaton Highland). Near the upper boundary of the Upper Qingyan Formation, ammonoids of the *Rieppelites-Judicarites* assemblage occur, especially *Rieppelites* sp. Therefore, the upper formation boundary lies within the equivalent of the *Billingsites cordeyi* Subzone (*Gymnotoceras weitschati* Zone; Nevada) and of the *Rieppelites cimeganus* Zone (Lombardy) (Figs. 7, 8).

No ammonoid specimen is available from the Shizishanjiao Member. In Chinese publications, only *Balatonites* sp. was mentioned very rarely (but not described or figured) from this member (Yang & Xu 1966; Guizhou Work Team 1975; Guizhou Province Work Team 1977; in all these publications, the Shizishanjiao Member was regarded to represent the uppermost part of the Qingyan Formation). However, *Balatonites* certainly is a misidentification. The benthic fauna of the Shizishanjiao Member mainly comprises taxa also known from the Leidapo section (Stiller 2001a). The Shizishanjiao Member thus most probably is of early late Anisian age and possibly belongs to the same ammonoid zone as the upper part of the Upper Qingyan Formation.

The Ganyintang Member probably contains upper Anisian strata in its lower part. Its upper part is of early Ladinian age as indicated by the occurrence of the ammonoid genus *Protrachyceras* at another locality in the Guiyang region (Guizhou Geological Team 1976b). In the Qingyan section, *Flexoptychites* sp. was reported from the upper Ganyintang Member (Guizhou Geological Team 1976a, b). The exact position of the Anisian/Ladinian boundary in the Ganyintang Member succession near Qingyan is unknown.

The Yingshangpo Member in Chinese stratigraphy is regarded to represent the *Nicomedites yohi* Zone and is correlated with the European *Nicomedites osmani* Zone and the Bithynian (e.g. Yang et al. 1982; Chen et al. 2000; Yin 2003). The holotype of the index fossil *Nicomedites yohi* Hsu, in Hsu & Chen (1943) represents the only published specimen of this taxon (Hsu & Chen 1943: 133, 136 [*Nicomedites yohi* Hsu, *Beyrichites chingyenensis* Hsu]; Yu & Zhao 1957: 246, pl. 135: 11 [*Beyrichites chingyenensis*]; Institute of Geology and Palaeontology 1962: 144, pl. 85: 14 [*Beyrichites chingyenensis*]; Zhao et al. 1965: 265, pl. 60: 7; Zhao & Wang 1974: 348, pl. 182: 12; Liao 1978: 434, pl. 140: 9; [same specimen and figure in all publications]). The specimen was not available for study. However, judging by the repeatedly published figure, its generic assignment appears questionable.

In Chinese publications *Balatonites* sp. was mentioned from the middle Yingshangpo Member. Ammonoids are

scarce in this member, and no specimen was available for study. The Yingshangpo Member probably is of middle Anisian age. The Mafengpo and Xiaoshan members probably comprise middle and lower Anisian strata. However, based on the ammonoid taxa reported from these members (see Fig. 2) and the few specimens available for study, it is not possible to differentiate between lower and middle Anisian in this succession.

Conclusions

The Upper Qingyan Formation in the northeastern vicinity of Qingyan contains latest middle Anisian and earliest late Anisian ammonoid assemblages. Age-diagnostic genera include *Bulogites* and *Acrochordiceras*, and *Rieppelites* and *Judicarites*, respectively. These assemblages correlate well to typical ammonoid assemblages at the middle/late Anisian boundary in northwestern Nevada (latest middle Anisian *Bulogites mojsvari* Subzone, earliest late Anisian *Billingsites cordeyi* Subzone) as well as in the Italian Alps and Hungary (latest middle Anisian *Bulogites zoldianus* Zone, earliest late Anisian *Rieppelites cimeganus* Zone). The middle/late Anisian boundary is situated in the upper middle part of the highly fossiliferous section at Leidapo.

The time interval represented by the Qingyan Formation at its type section thus is not equal to the Anisian as has long been supposed in Chinese stratigraphy. The uppermost strata of the Qingyan Formation in this area are of earliest late Anisian age. The Qingyan Formation at this locality does not encompass middle late or late late Anisian strata. As far as can be concluded from re-study of available and figured specimens, reports of stratigraphically younger taxa such as *Paraceratites trinodosus* from the Upper Qingyan Formation are based on misidentifications. At least in this area, the whole Qingyan Formation is distinctly older than the *Paraceratites trinodosus* Zone.

These findings do not affect the naming of the Anisian stage (marine facies) as Qingyanian in Chinese stratigraphy. However, it should be kept in mind that the name-giving Qingyan Formation, at least as hitherto defined with the stratotype section being that near Qingyan, is not equivalent to the entire Anisian.

Acknowledgements

We are grateful for constructive review comments by L. Krystyn (Wien), S.G. Lucas (Albuquerque), and A. Morard (Lausanne) that improved the manuscript. Field work of F. Stiller in Guizhou, southwestern China, was financially supported by Studienstiftung des deutschen Volkes (1992, 1994), Alfried Krupp von Bohlen und Halbach-Stiftung and Stiftung Bildung und Wissenschaft (1992), National Natural Science Foundation of China and Deutsche Forschungsgemeinschaft (2002), Heinrich Hertz-Stiftung and Gesellschaft zur Förderung der Westfälischen Wilhelms-Universität zu Münster (2003). This work was also partially supported by the Swiss National Science Foundation (project 200020-113554 to H. Bucher). Technical support for mechanical preparation and photography was provided by Markus Hebeisen and Rosi Roth (University of Zürich).

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Manuscript received July 12, 2007
Manuscript accepted May 13, 2008
Published Online first July 23, 2008
Editorial Handling: Alain Morard (Guest) & J.-P. Billon-Bruyat

Appendix

The following synonymies for the ammonoid taxa from the Upper Qingyan Formation mentioned in this study solely include references to Stiller (2001a) and to publications with figured specimens. Extensive synonymy lists critically reviewing the earlier data on Qingyan ammonoids were provided by Stiller (2001a). For fossil sample localities see Figure 1.

***Bulogites-Acrochordiceras* assemblage**

Bulogites multicostatus WANG, in Zhao et al. (1965)

. 1957 *Paraceratites trinodosus* (MOJS.) – Yu & Zhao: 247, pl. 136: 1.
. 1962 *Paraceratites trinodosus* (MOJSISOVICS) – Institute of Geology and Palaeontology: 144, pl. 85: 13 [same specimen and figure as in Yu & Zhao (1957)].
*. 1965 *Bulogites multicostatus* WANG n. sp. – Wang in Zhao et al.: 266, pl. 85: 12 [same specimen and figure as in Yu & Zhao (1957)].
. 1974 *Bulogites multicostatus* (sp. nov.) – Zhao & Wang: 349, pl. 183: 15 [same specimen and figure as in Yu & Zhao (1957)].
. 1978 *Bulogites multicostatus* WANG – Liao: 435, pl. 140: 1 [same specimen and figure as in Yu & Zhao (1957)].
v. 2001a *Bulogites multicostatus* WANG in Zhao, Liang, Zou, Lai & Zhang 1965 – Stiller: 257.
vp. 2001a *Paraceratites brembanus* (MOJSISOVICS 1882) – Stiller: 259.
vp. 2001a *Paraceratites*? sp. indet. – Stiller: 261.
Provenance: Leidapo; lower middle Leidapo Member.

Bulogites sp. (*Balatonites*? sp.)

vp. 2001a *Paraceratites brembanus* (MOJSISOVICS 1882) – Stiller: 259.
Provenance: Leidapo and northwest of Xiaozhai; lower middle Leidapo Member.

Acrochordiceras cf. *carolinae* MOJSISOVICS 1882

v. 2001a *Epacrochordiceras* cf. *pustericum* (MOJSISOVICS 1882) – Stiller: 259.
vp. 2001a *Paracrochordiceras* species A – Stiller: 258.
Provenance: Leidapo; lower middle Leidapo Member.

Proarcestes sp.

vp. 2001a *Ptychites rugifer* (OPPEL 1865) – Stiller: 255.
Provenance: Leidapo; lower middle Leidapo Member.

Beyrichitinae gen. indet.

?v. 2001a *Beyrichites* species A – Stiller: 256.
v. 2001a *Philippites* species A – Stiller: 257.
Provenance: Leidapo; lower middle Leidapo Member.

Sageceras sp.

v. 2001a *Sageceras* species A – Stiller: 255.
Provenance: Wachangpo; lowermost Leidapo Member.

***Rieppelites-Judicarites* assemblage**

Rieppelites cf. *cimeganus* (MOJSISOVICS 1882)

vp. 2001a *Paraceratites brembanus* (MOJSISOVICS 1882) – Stiller: 259.
Provenance: Leidapo; upper middle Leidapo Member.

Rieppelites sp. A (Leidapo Member)

1956 *Ceratites* (*Paraceratites*) *trinodosus* MOIS. – Wang et al.: 576, 1 fig. (a–d) [sketch drawing; Qingyan Formation, locality not mentioned].
v. 1974 *Paraceratites trinodosus* (MOJSISOVICS) – Zhao & Wang: 348, pl. 182: 7.
. 1974 *Paraceratites binodosus* (HAUER) – Zhao & Wang: 348, pl. 182: 10–11.
v. 1978 *Paraceratites trinodosus* (MOJSISOVICS) – Liao: 432, pl. 140: 3 [same specimen and figure as in Zhao & Wang (1974)].
. 1978 *Paraceratites binodosus* (HAUER) – Liao: 435, pl. 140: 4 [same specimen and figures as in Zhao & Wang (1974)].
v. 2001a *Hollandites* species A – Stiller: 256.
v. 2001a *Schreyerites binodosus* (HAUER 1851) – Stiller: 257.
vp. 2001a *Paraceratites brembanus* (MOJSISOVICS 1882) – Stiller: 259.
vp. 2001a *Paraceratites*? sp. indet. – Stiller: 261.
Provenance: Leidapo and Wachangpo; upper middle Leidapo Member.

Rieppelites sp. (cf. *Rieppelites chevyrevi* MONNET & BUCHER 2005; Yuqing Member)

v. 2001a *Paraceratites trinodosus* (MOJSISOVICS 1882) – Stiller: 260.
v. 2004a *Paraceratites trinodosus* MOJSISOVICS – Komatsu et al.: fig. 6–1.
Provenance: Shizishanjiao; upper Yuqing Member.

Judicarites cf. *meneghinii* (MOJSISOVICS 1882)

vp. 2001a *Judicarites* species A – Stiller: 256.
Provenance: Leidapo and Wachangpo; upper middle Leidapo Member. Northwest of Lanhuaguan; upper Leidapo Member.

Gosauites sp.

v. 2001a *Danubites* cf. *michaelis* (MOJSISOVICS 1882) – Stiller: 255.
Provenance: Wachangpo; upper middle Leidapo Member.

Ptychites sp. A

vp. 2001a *Ptychites rugifer* (OPPEL 1865) – Stiller: 255.
Provenance: Leidapo and Wachangpo; upper middle Leidapo Member.

Ptychites sp. B

v. 2001a *Discoptychites* species A (n. sp.?) – Stiller: 254.
Provenance: Leidapo and Wachangpo; upper middle Leidapo Member.

Ptychites sp. C

Provenance: Leidapo; upper middle Leidapo Member.

Ptychites sp. (cf. *Ptychites* sp. A)

Provenance: Northeast of Leidapo; lower Yuqing Member.

Ammonoids gen. et sp. indet.

v. 2001a *Ptychites*? sp. indet. – Stiller: 255.
v. 2001a *Gymnites* species A – Stiller: 255.
vp. 2001a *Judicarites* species A – Stiller: 256.
vp. 2001a *Paracrochordiceras* species A – Stiller: 258.
v. 2001a *Acrochordiceras*? species A – Stiller: 259.
v. 2001a Acrochordiceratidae gen. et sp. indet. – Stiller: 259.
vp. 2001a *Paraceratites*? sp. indet. – Stiller: 261.
v. 2001a Ammonoidea gen. et sp. indet. – Stiller: 261.
Provenance: Leidapo, Wachangpo, and other localities in the northeastern vicinity of Qingyan; Leidapo and Yuqing members.

Ammonoid gen. et sp. indet. (new taxon?)

Provenance: East of limestone quarry at Shizishan; Leidapo Member.