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Palaeontology of the 1985 Tibet Geotraverse, Lhasa to Golmud

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[One plate]

Palaeontological collections made on the 1985 Geotraverse are used to date the associated strata and provide information about palaeoenvironments. A biostratigraphical and palaeoenvironmental framework for the Tibetan plateau is constructed. The crucial stratigraphical and palaeontological evidence for dating volcanic sequences, flysch basins, open oceanic sediments, latest marine sediments and terrestrial red beds in each terrane is reviewed. A quantitative palaeobiogeographical analysis from the Carboniferous to early Triassic is presented for the Tibetan fauna and flora, to establish the biotic relationships between the various terranes. This is based largely on coral, brachiopod and fusulinid distributional data, but other groups have also been analysed, including the Permian terrestrial flora. This analysis demonstrates a clear diversity gradient from equatorial or sub-equatorial biotas in the north to temperate biotas in the south during the late Palaeozoic. No suture line consistently marks the position of a faunal/floral break during the late Palaeozoic and there appears to have been no physical barrier (such as a large ocean) to biotic dispersal between Tibetan terranes at this time. Climate is seen as the most likely factor dominating biotic distribution in this region and the early Permian glaciation had a profound effect on marine faunal distributions in Tibet.

1. INTRODUCTION

Palaeontology provides three kinds of evidence which are crucial to our understanding of Tibetan geology. *Firstly, fossils provide a biostratigraphical framework.* Competent taxonomists can use the stratigraphical succession of evolving biotas to construct a highly resolved and refined time framework, without which it would be more or less impossible to place data from other geological subdisciplines in relative context. The time resolution achievable using fossils, even in remote parts of the world such as Tibet, is generally in the order of 5 Ma, and may sometimes be considerably less. *Secondly, fossils provide a great deal of evidence concerning palaeoenvironments.* By using a knowledge of an organism's functional morphology, trace fossil data and general concepts of community structure, a considerable amount can be deduced about the palaeoenvironment in which the fossils once lived. A knowledge of palaeoenvironments is important in making palaeogeographical reconstructions and therefore in placing constraints on plate tectonic models. Usually the palaeontological data are combined with facies analysis of the sediments to build up a detailed picture of the evolution of environments, as we have done here. Leeder *et al.* (this volume) combine palaeontological evidence concerning palaeoenvironments with sedimentological data to provide an overall synthesis. *Thirdly, fossil distributions provide*

biogeographical data. The geographical distribution of fossil taxa can be analysed rigorously to determine the degree of effective biotic exchange between regions; this places constraints on palaeogeographical and palaeomagnetic reconstructions and plate tectonic models.

2. BIOSTRATIGRAPHICAL FRAMEWORK

Details of the regional biostratigraphical setting have largely been outlined by Yin *et al.* (this volume), but a few additional points are worth stressing here. Approximately 2500 specimens of macrofossil and several hundred microfossil samples were collected during this expedition. These have been studied in both the Nanjing Institute of Palaeontology and in the British Museum (Natural History) and, indeed, work is still proceeding on the mammoth task of identifying this material. The Appendix lists those fossils that have been identified to date, together with notes on their occurrence and palaeoenvironmental setting. The approximate position for all localities for which palaeontological data have been collected is shown later in figure 15. Some age-diagnostic Permian and Cretaceous foraminifera are shown in plate 1.

The geological subdivisions that have been adopted in this chapter follow Harland *et al.* (1982), with the exception of the Permian. International correlation of Permian strata has been problematic until recently, but there is now emerging a general broad consensus of opinion (viz. Waterhouse 1976; Kanmera *et al.* 1976; Iranian–Japanese research group 1981; Ross 1970, 1982*a*; Toriyama 1984; Dickins 1985*b*). In the Chinese literature, the Asselian and Sakmarian stages are placed as Upper Carboniferous, whereas throughout Europe and North America the Permian is considered to start at the base of the Asselian with the first appearance of the fusulinid *Pseudoschwagerina* as a useful marker. Higher stages in the Permian are often referred to Russian type sections, but there is still some dispute as to their correlation outside Russia. In this paper, therefore, we have adopted the Chinese subdivisions of the Permian, since there is a broad similarity between the total fauna of China and Tibet, and because these stages have been widely applied in the Chinese literature of this region. There are four stages, the Qixian, Maokouan, Longtanian and Changxinian, defined largely on the larger benthic foraminifera (see Wang, Sheng & Zhang 1981). Broadly speaking, the Qixian is equivalent to the Artinskian, the Maokouan to the Ufimian and Kungurian, the Longtanian to the Kazanian and the Changxinian to the Tartarian. In figure 1, each of the four stages is given the nominal duration of 5 Ma.

For the aims of this expedition, there are certain rocks whose dating is more critical than others for constructing plate tectonic models. These are volcanic sequences, flysch sequences, oceanic sediments, fluvial red beds and the latest marine sediments present in each terrane. The evidence for dating these strata is outlined below.

Volcanic strata

(a) *Lhasa Terrane*

(i) *Dagze volcanics.* A relatively thick sequence of sheet-flow basalts and pyroclastics with interbedded mudrocks is found to the south of Lhasa towards the southern margin of the Lhasa Terrane. The interbedded mudrocks have yielded simple fern palynomorphs (see Appendix: locality M15) indicating a late Carboniferous or Permian age. Previously, these volcanics had been considered as probably Triassic in age.

(ii) *Chisan volcanics.* In the Chisan district, north of Lhasa, volcanics overlie a sequence of

limestones, which at one horizon yield a late Anisian (Triassic) marine fauna of ammonoids (Gu, He & Wang 1980; see also Appendix, loc. B12). This would suggest a Ladinian (Middle Triassic) age for these volcanics.

(iii) *Takena Formation*. In the northern part of the Lhasa Terrane, around Naqu, Amdo and Jang Co, there is an extensive sequence of volcanics and associated intrusive sheets. These have been dated radiometrically as between 110 and 75 Ma (i.e. Upper Cretaceous) by Coulon *et al.* (1986).

(iv) *Jienong Group*. Wang (1983*a*) has recorded the presence of andesitic volcanics interbedded in the Jienong Group, dated as Lower to Middle Jurassic on the evidence of ammonites. We have not been able to confirm this as the only volcanics of Jurassic age that we examined were in the Damqiao area associated with oceanic chert beds.

(v) *Sangri Group*. This is a thick 'eugeosynclinal' sequence found along the southern margin of the Lhasa terrane. The stratigraphical sequence is complex and includes thick and extensive volcanics. Interbedded sediments have yielded Tithonian to Aptian (latest Jurassic to Lower Cretaceous) faunas (Yang & Wang 1985). This sequence was not examined by our expedition.

(vi) *Linzizong Formation*. North of Lhasa a sequence of calcalkaline volcanics is interbedded with continental clastics. There is no fossil evidence for the age of these red beds, but the succession unconformably overlies folded and eroded Upper Cretaceous strata of the Takena Formation and can be no older than latest Cretaceous. Radiometric dating of the interbedded volcanics (Maluski *et al.* 1982) suggests a late Cretaceous/early Palaeocene age.

(b) *Qiangtang Terrane*

(i) *Kaixinling Group*. Basaltic and andesitic flows within this sequence at Kaixinling lie within a sequence that includes limestones yielding Maokouan fusulinids (early Upper Permian) and a fluvial sequence with an Upper Permian flora [see Appendix, locs B59 and B60]. This suggests that the volcanics are late Permian in age. Volcanics are found at a similar horizon in the Qamdo region further to the east (Dong & Mu 1984).

(ii) *Batang Group*. At Zhakongjian, in the northern part of the Qiangtang terrane, there is a thick sequence of andesitic volcanics overlying a fluvial sequence of conglomerates and sandstones and themselves directly overlain by a marine clastic and carbonate sequence of Norian age (Upper Triassic) [see Appendix, loc. B67]. These volcanics are probably therefore early late Triassic (Carnian or early Norian) in age.

(iii) *Yanshiping Group*. Near Wenquan, just north of the Tanggula Pass, there is a sequence of basaltic volcanics which lies at the base of an enormously thick fluvial red bed sequence. Within this red bed sequence there are occasional marine incursions which date the succession as Bathonian/Calloviaian (Middle Jurassic). The age of the volcanics is therefore likely to be early mid Jurassic.

(c) *Kunlun Terrane*

(i) *Juchishan and Dagangou Formations*. In the Dagangou valley, to the north of Naj Tal in the northern Kunlun Shan, there is a series of volcanic outcrops that has been mapped previously as two formations, one Devonian in age, the other Carboniferous. Although there is a fossiliferous sequence of late Viséan/early Namurian (mid Carboniferous) fluvio-deltaic sediments [see Appendix, loc. B108], the stratigraphical relationship between this fossil-bearing sequence and both groups of volcanics is problematic. The 'Devonian' volcanic sequence appears to

underlie a thick basal sequence of conglomerates and arkosic sandstones which themselves are conformably overlain by the fossiliferous mid Carboniferous strata, suggesting that there is a genuine late Devonian or early Carboniferous volcanic sequence here. However, the so-called 'Carboniferous' volcanics show fault-bounded contacts with the Carboniferous sequence where examined by us and we suspect them to be fault-bounded blocks of Devonian volcanics. Alternatively, they may be younger volcanics (?Permo-Triassic) downfaulted into this area.

(ii) *Permian Volcanics*. In the north Kunlun Mountains a number of local stratigraphical names has been applied to early Permian (Asselian–Sakmarian) volcanics that are found interbedded with fusulinid-bearing limestones (Qinghai Stratigraphical Working Group 1980: see also Yin *et al.*, this volume). Unfortunately, no volcanics interbedded with dateable Permian sediments were seen by our expedition. However, we suspect that the thick sequence of volcanics seen to the southeast of Naj Tal (the Wanbaogou Group) may be Permian in age.

The Wanbaogou Group, outcropping from Wanbaogou in the west to the Kunlun bridge in the east, comprises a thick sequence of resedimented tuffs and basaltic volcanics, with occasional crystalline limestones. This sequence has been attributed to the pre-Cambrian on account of the discovery of *Conophyton*, a supposedly pre-Cambrian stromatolite, within one of the limestones in the Wanbaogou valley (Zhu, Zhao & Zheng 1985). However, this identification needs confirmation since in the same paper they assign a Jurassic/Cretaceous age to Upper Ordovician strata on the misidentification of platyceratid gastropods as Mesozoic bivalves. At one locality (B88 – see Appendix), one of these limestones contained badly recrystallized crinoidal debris indicating an age no older than Ordovician. As this sequence of resedimented tuffs, volcanics and limestones appears to grade up into late Permian limestones in the Wanbaogou valley, they are tentatively assigned to the early Permian.

Flysch basins

(a) *Lhasa terrane*

(i) Flysch type sequences interbedded with volcanics (the Jienong Formation) occur in the Jang Co region in the northern part of the Lhasa Terrane. Wang (1983*a*) records ammonites from this succession which range in age from Sinemurian to Callovian (Lower to Middle Jurassic) while Girardeau *et al.* (1984) report an Aalenian (Middle Jurassic) age on the basis of gastropods. Our sparse evidence suggests a slightly younger age. At locality B48, near Amdo close to the line of the Banggong Suture, we logged a continuous sequence which commenced with shallow fluvio-marine sediments, with periodic bands of *Cladocoropsis*, mostly broken and transported. This graded upwards into a fine sand/shale turbiditic flysch sequence containing derived nerineid gastropod and other shelf faunas, similar to those occurring at Jang Co (locs B32 and B33). The occurrence of *Cladocoropsis* (Upper Jurassic) in the underlying beds places this flysch sequence as late Jurassic or possibly even early Cretaceous.

(ii) In the very south, adjacent to the Zangbo Suture, flysch-type sediments are intermixed with volcanics (the Sangri Formation). From these sediments Yang & Wang (1985) have discovered latest Jurassic (Tithonian) to Lower Cretaceous (Aptian) fossils.

(b) *Qiangtang and Kunlun Terranes*

(i) *Bayan Kalā Group*. A thick sequence of turbidites and contourites occurs extensively over the northern part of the Qiangtang Terrane. Its precise thickness is impossible to gauge due

to the considerable repetition produced by tectonic slicing. No fossil evidence was found by us to date this sequence. However, further to the east, previous Chinese geological teams have been more successful (He & Yin 1983). According to their work, the sequence commences with sandstone-dominated clastics that have yielded species of the bivalve *Claria* indicative of an early Induan age (basal Triassic). Proper flysch-type sedimentation does not appear to have commenced until slightly later, in the late Induan or Olenian. Fossil evidence for a mid Triassic age has also been found; the highest beds in this sequence have yielded the bivalves *Halobia* and *Daonella* and are late mid Triassic or early late Triassic in age. Thus the whole flysch sequence appears to be entirely Triassic in age.

Oceanic sediments

(a) *Zangbo Suture*

Distal fan turbidites and radiolarian cherts are found along the line of the Zangbo Suture, but were not examined by our expedition. Wang & Sheng (1982) have described Upper Triassic radiolaria from cherts associated with deep water clastics in the Gyirong district, as well as Upper Jurassic radiolaria from shales with lentiform limestones in the Gyangze district. Wu & Li (1982) and Wu (1984, 1986, and unpublished manuscript) have described latest Jurassic (Tithonian), Berriasian, late Valanginian and late Albian–?Cenomanian (all Cretaceous) radiolaria from cherts along this suture. Deep water clastics of Valanginian and Albian to Cenomanian age have also been proved (Wu 1984, 1986). The formation of the olistostrome associated with the Zangbo Suture has been dated on the basis of radiolaria in the sedimentary matrix as Turonian (Upper Cretaceous) (Wu *et al.* 1982), but there may also have been olistostrome formation as late as Maastrichtian to produce the intermixing of *Globotruncana*-bearing limestones of Campanian/Maastrichtian age and Triassic strata. It is, however, not yet clear whether this is syndepositional or post-depositional mixing.

There is thus evidence for oceanic sediments associated with the Zangbo Suture from the late Triassic to the end of the early Cretaceous (the majority being early Cretaceous in age). There is also evidence that ophiolite emplacement and olistostrome formation had started by the Turonian (Upper Cretaceous).

(b) *Banggong Suture*

Oceanic cherts and fine clastics associated with the Dongqiao ophiolite sequence along the Banggong Suture were examined, but unfortunately samples collected proved to have no determinable radiolaria. However, Wang (1984) reported a radiolarian assemblage from these cherts which he suggested was probably late Jurassic in age and Li (1986) has recently described an early Tithonian (Upper Jurassic) radiolarian fauna from cherts in this suture zone.

The timing of obduction for the ophiolite and chert sequence is bracketed by an apparently conformable (though faulted) sequence just to the west of Dongqiao (loc. B41) previously described by Girardeau *et al.* (1984). Here the ophiolite suite is overlain unconformably by a three metre palaeosol followed by a fluviomarine sequence with the alga *Cladocoropsis* and other fossils. This dates the overlying sediments as Upper Jurassic and no later than Tithonian (latest Jurassic).

At another locality near Dongqiao (loc. B39), a deep water clastic sequence with thin limestones contains a melange horizon with chert, pillow lava and limestone olistoliths. The age of the clastic sequence is unknown, since only indeterminate radiolaria were collected, but the

limestone blocks in the melange are fossiliferous and yield a fauna of corals, stromatoporoids and echinoid spines, including ?*Pseudocidaris maresi* (Cotteau). The fauna from these limestone blocks exactly matches that found from late Jurassic (Kimmeridgian) to early Cretaceous (?Valanginian) reef limestones of the Xiaqiong Co region to the west [see Appendix, locs B28–B30]. Erosion of emplaced ophiolitic material was obviously taking place after lithification of this late Jurassic/early Cretaceous limestone, possibly in the latter part of the Lower Cretaceous.

Latest marine strata

Dating of the latest marine strata in each terrane helps to bracket the timing of final closure of epicontinental seas following collision. There is a progressive increase in the age of the latest marine strata from south to north.

(a) *Himalayan Terrane*

South of the Zangbo Suture, in the Himalayan Terrane, the youngest marine strata appear to be Lutetian (early mid Eocene), to judge by the occurrence of foraminifera including *Orbitolites complanatus* (Zhang 1981, Wang 1983*a*). Pan *et al.* (1984) report Palaeogene marine sediments from immediately north of the Zangbo Suture to the west of our traverse, but this clearly represents deposition associated with the closing seaway along this suture zone.

(b) *Lhasa Terrane*

In the Lhasa Terrane, strata as young as Maastrichtian (uppermost Cretaceous) have been reported from the Bange region (Wang 1983*b*; Wang & Bassoullet 1984; Pan 1985), but this is decidedly questionable. The one locality that our expedition visited from which Wang (1983*b*) reported Upper Cretaceous fauna (loc. B31 – see Appendix) turned out to have Albian/Cenomanian orbitoline foraminiferans, and the gastropods described by Pan (1985) are not by themselves convincing evidence for a late Cretaceous age. The highest marine strata in this region are therefore late early Cretaceous in age, though there is the possibility that marine conditions may have continued into the lower Upper Cretaceous. Previous suggestions that the Langshan Formation extended into the Cenomanian have recently been shown to be wrong (Zhang 1986).

(c) *Qiangtang Terrane*

In the Qiangtang Terrane, the youngest fully marine strata found are seen around Amdo and are late Jurassic (Kimmeridgian) in age [Appendix, loc. B50]. Marine incursions into a predominantly continental red bed sequence occurred in the Middle and possibly Upper Jurassic of the Amdo region, but to the north of Yanshiping no marine strata younger than Norian (Upper Triassic) are found, suggesting that the marine incursions were coming from the south. This deduction is supported by sedimentary studies (Leeder *et al.*, this volume).

(d) *Kunlun Terrane*

Finally, in the Kunlun Terrane, the oldest marine beds encountered by our expedition are late Permian in age. The section in the Wanbaogou Valley, west of Naj Tal, originally considered to be early Triassic in age (e.g. Li & Lin 1982; Chang *et al.* 1986) is now known to have an Upper Permian fauna (Appendix, loc. B91). It is clear that there are outcrops of Induian to Anisian (Lower to Middle Triassic) marine strata to the north in the South Qilian

Mountains, where a diverse ammonoid and brachiopod fauna has been reported (Yang *et al.* 1983). Whether similar aged beds exist in the Kunlun Shan remains to be proved.

The record of marine Mesozoic (Jurassic or Cretaceous) by Zhu, Zhao & Zheng (1985) has also been disproved by our expedition, as these beds are late Ordovician in age (see Appendix, loc. B98).

Continental red beds

These are the most difficult to date accurately.

(a) *Lhasa Terrane*

(i) *Linbuzong Formation*. Extensive fluvial red bed sequences with occasional marine incursions occur to the north of Lhasa [e.g. Appendix, loc. B16]. Fossils from these marine to brackish horizons indicate a latest Jurassic (Tithonian) to early Cretaceous age (Bassoulet *et al.* 1984, Wang & Sun 1983) near the base of this sequence. Plant fossils from higher in the sequence [Appendix, loc. B16a] suggest an early Cretaceous age. The whole succession is overlain by clastics and limestones yielding Aptian to Albian (upper Lower Cretaceous) orbitoline foraminiferans, the transition being seen in the Baingoin district by our expedition.

(ii) *Lhunzhub Member of the Takena Formation*. The major marine incursion of Aptian/Albian age, the Pembo Group, which overlies the Linbuzong Formation, is itself overlain by a sequence of variegated clastics known as the Lhunzhub Member. As these are folded and overlain unconformably in turn by the possibly Palaeocene Linzizong Formation, they are likely to be early late Cretaceous in age, although we have no internal faunal or floral data to support this.

(iii) *Linzizong Formation*. These volcanics, with intercalated red beds, unconformably overlie the Upper Cretaceous Takena Formation. There is no independent fossil evidence as to their age, but radiometric dating of some basal volcanics suggests they are Palaeocene (see Maluski *et al.* 1982).

(b) *Qiangtang Terrane*

(i) *Kaixinling Group*. In the Kaixinling district of the central Qiangtang Terrane, a sequence of continental clastics overlies limestones with a Maokouan (early Upper Permian) fauna of fusulinid foraminiferans [Appendix, locs B59 and B60] and themselves contain an Upper Permian plant flora. These red beds, which have intercalated volcanics, are late Permian in age.

(ii) *Batang Group*. At Wuli, near the northern margin of the Qiangtang Terrane, a thick sequence of Upper Triassic volcanics is underlain by a red clastic sequence of continental origin. A precise age for these beds cannot be proposed, but their conformable relationship with overlying Norian strata suggests that they are probably early late Triassic (Carnian) in age. Late Upper Triassic (Norian) red beds cap the sequence and have yielded plant fossils from further east around Qamdo (Wu 1982).

(iii) *Yanshiping Group*. From around Amdo to just north of Wenquan, on either side of the Tanggula Mountains, there is an extensive sequence of red beds (over 2 km in thickness) with occasional brackish to marine incursions. The fauna from the marine horizons ranges in age from Bathonian to Kimmeridgian [Appendix, locs B49, B50, B51, B56, B57 and B58]. A probable equivalent succession is seen at Wuli, to the north, where continental clastics with thin coal seams, previously attributed to the Permian, yielded Middle Jurassic non-marine bivalves belonging to the genus *Pseudocardinia*.

(iv) *Fenghuoshan Group*. Around Erdaogou, to the north of the Qiangtang Terrane, is another thick sequence of continental red beds. There are no marine incursions within this sequence, but thin lacustrine limestones yielded charophytes and palynomorphs [Appendix, locs B69 and B74] which indicate a ?Palaeocene or early Eocene age for these beds.

(c) *Kunlun Terrane*

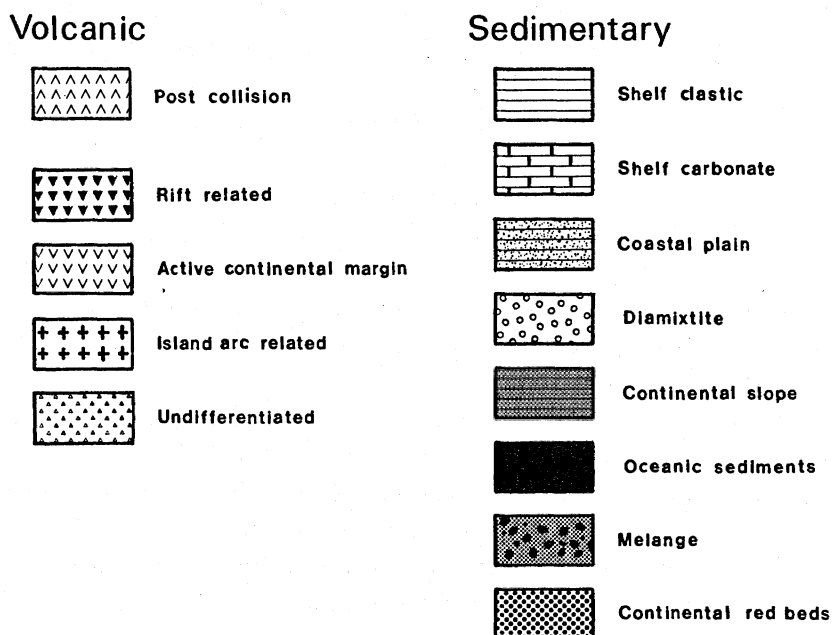
(i) *Juchishan Formation*. In the region of Dagangou, in the northern Kunlun Mountains, red siltstones and fine sands are overlain by fluvial arkosic sandstones and gravels. These reach several kilometres in thickness and are conformably overlain by a marine limestone/shale sequence of latest Visean or early Namurian age (mid Carboniferous) [Appendix, loc. B108]. They are therefore most likely to be early Carboniferous in age.

(ii) Lower Jurassic red beds are also reported from this region (Qinghai Stratigraphical Working Group 1980), based on the identification of palynomorphs. However, no positive evidence for Jurassic red beds was found by our team. A sizeable outcrop of continental clastic sediments was examined in the north Kunlun Shan, at localities B103 and B104. No fossils were obtained from these strata to provide a clue as to their age, but they are probably post-Carboniferous, since they are not cut by any dykes or sills, in stark contrast to the immediately adjacent Carboniferous sequence. These have previously been mapped as Jurassic, but are best considered as late Palaeozoic or Mesozoic.

(iii) A small outcrop of continental, plant-bearing clastic sediments is found in the Xidatan valley at locality B88. There are no diagnostic palynomorphs in our samples and the macrofossil material is scrappy. However, it does hint at a Mesozoic rather than Palaeozoic age for these beds.

The biostratigraphical data is summarized in figure 1. This shows the distribution of broad

FIGURE 1. Biostratigraphy of the Tibetan plateau. This diagram summarizes the distribution of broad rock types and facies from Carboniferous to Recent across the Tibetan plateau. Areas left blank represent time spans for which there is no record of deposition.



PALAEONTOLOGY

MATHEMATICAL,
PHYSICAL
& ENGINEERING
SCIENCES

PHILOSOPHICAL
TRANSACTIONS
OF
THE ROYAL
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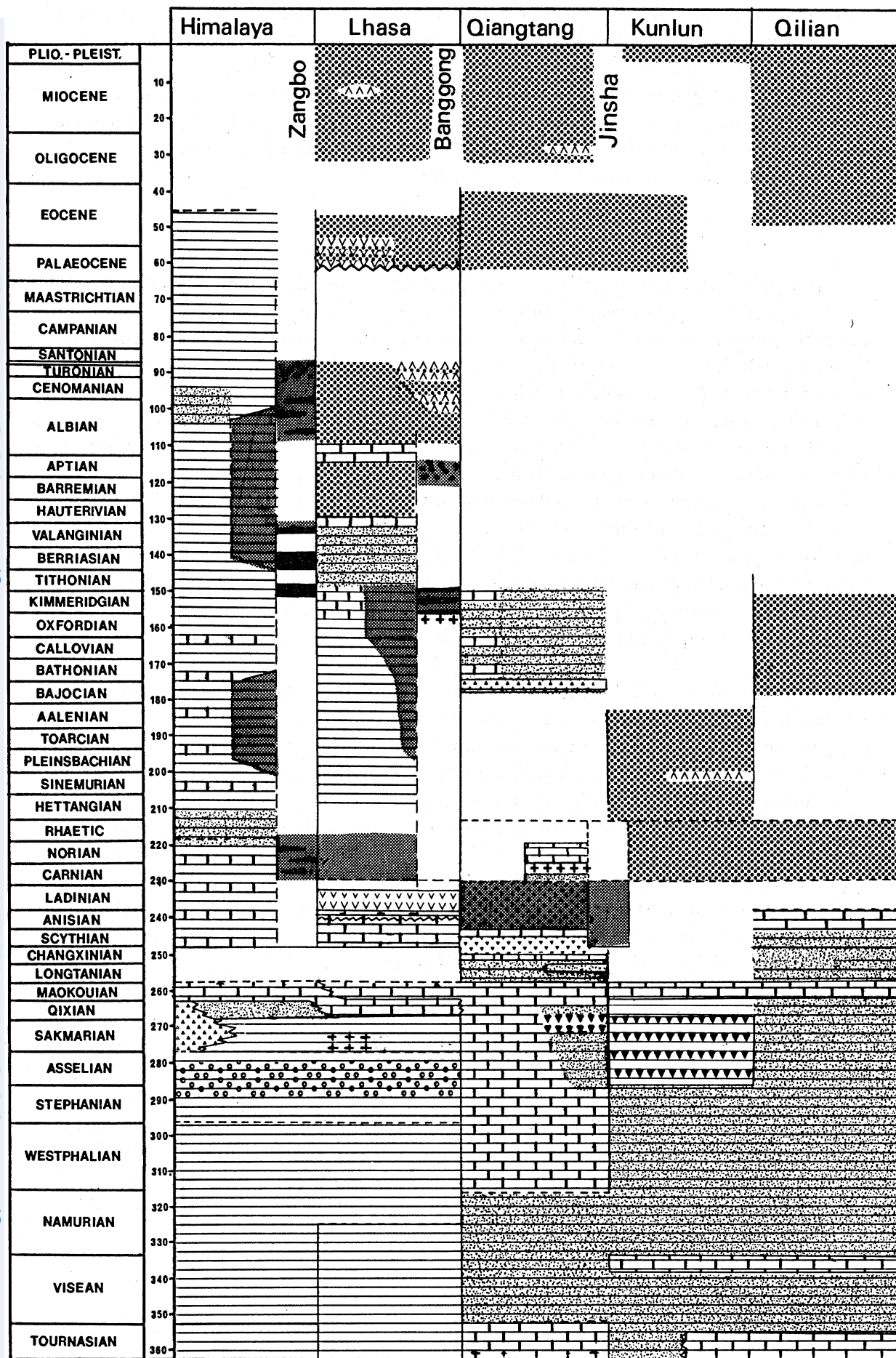


FIGURE 1. For description see opposite.

palaeoenvironments and rock types across the Tibetan plateau and has been compiled from our own observations, supplemented where necessary with data from published sources. Facies are distinguished on faunal and lithological grounds, and divided into the following types: fluvial; coastal plain; clastic marine shelf; carbonate marine shelf; continental rise and oceanic. Volcanics are separated into rift, active continental margin and post collisional on the basis of data presented by Pearce (this volume). Palaeoenvironments and geological history are discussed more fully by Leeder *et al.* (this volume).

3. BIOGEOGRAPHICAL ANALYSIS

In principle it should be possible to use a knowledge of the distribution of fossil biotas to set some constraints on palaeogeographical reconstructions. The underlying rationale is that, in comparing the biotas from a number of regions, those with many members in common come from areas which maintain (or maintained until relatively recently in the past) a large degree of biotic exchange and migration with one another, whereas conversely those with few members in common have been isolated from one another for a relatively greater length of time. Temperature also plays a role in restricting the distribution of taxa and distributions of fossil taxa may help define climatic belts.

However, in practice several problems enter into any biogeographical analysis which make the task much less simple than would first appear, and which are sometimes overlooked. First there is the problem of the vagaries of the fossil record. For example, the absence of a fossil taxon from one region may be genuine, or may be a pseudo-absence produced by collection failure or the absence of exposures of rocks of the right facies. This is clearly a particularly pressing problem in palaeobiogeographical studies of poorly studied regions of the world such as Tibet.

A second problem arises because all taxa are to a greater or lesser extent facies-restricted. Within the same region, adjacent facies may support quite different biotas. To avoid this problem, either the region's biota must be sampled over as broad a range of facies as possible, or the biotas of very specific facies only must be compared. In practice, because of the sheer impossibility of recognizing subtle, yet important, differences in habitat within the fossil record, by far the best approach is to sample as widely as possible within one broad habitat (such as 'shallow marine' or 'terrestrial').

A third problem arises from diversity gradients. In most rigorous methods of analysis, variation in biotic diversity for whatever cause (genuine diversity gradient or sampling problems) will affect the result. Thus evidence of a depleted biota is not sufficient by itself to establish provinciality; only endemism is significant.

Finally, there are very many different methods of analysis which do not necessarily produce the same results. The more rigorous and explicit the method, the easier it is for others to assess.

Biogeographical analysis of the fossil biota of the Tibetan plateau is particularly difficult for the following three reasons.

(1) Despite the tremendous effort over the last decade, primarily by Chinese scientists, to understand the geology of the Tibetan plateau and record its fossil biota, our knowledge of the fossil fauna and flora of this region is still at an elementary stage. A great deal of field and laboratory work remains to be done.

(2) Consequently, there remain some fairly serious problems in correlation both within the

region and also with other parts of the world. A broad picture has emerged over the last decade but the biostratigraphical time scale in many places is still very coarse and in need of refinement.

(3) Because fossil taxa from this region are generally neither abundant nor well preserved, there are serious taxonomic difficulties. The small sample sizes mean that variation within populations is rarely established, which has had the unfortunate result that there has been a great deal of taxonomic oversplitting at all levels. Poor preservation also makes systematic determinations difficult. We have strong reservations about the quality of the taxonomic data, but have expertise in only a small proportion of the Tibetan fauna and flora. Published taxonomic determinations have therefore had to be taken on trust without the possibility of checking for accuracy or consistency.

Because of the numerous problems mentioned above, one might wonder whether it was not premature to attempt a biogeographical analysis in a region such as Tibet where sampling is poor and taxonomy uncertain. Whether or not this is correct, there have already been numerous attempts to define past biogeographical provinces and reconstruct palaeogeographies on the data that is available, (*viz.* Allègre *et al.* 1984; Dickins 1985*b*; Dickins & Shah 1981; Fan 1985; Gu *et al.* 1980; He & Zhang 1984; Jin 1985; Li, Yao & Deng 1982; Liang & Wang 1983; Liao & Xia 1985; Lin 1983, 1984; Liu 1981; Liu & Cui 1983; Ross & Ross 1985; Wang 1984; Wang & Mu 1984; Waterhouse & Bonham Carter 1975; Xia 1983; Yang & Fan 1983; Zhang & He 1985; Zhang & Wu 1983; Zhang *et al.* 1985). These have largely been descriptive and anecdotal in form and for this reason are difficult to assess or compare with rival hypotheses. Furthermore, in many cases it has been only a small proportion of the total biota that has been used. It is therefore necessary to undertake a more rigorous analysis of the data as it stands, with all its inconsistencies and limitations, in order to discover precisely what the available data really does imply about Tibetan palaeogeography. This analysis must be considered as a very preliminary attempt to investigate Tibetan palaeobiogeography.

4. APPROACH

Our primary interest is to discover the historical pattern of relationships of the biotas from the three strip-like terranes that constitute the Tibetan Plateau, with respect to biotas of the Indian and Eurasian plates between which they now lie sandwiched. We specifically wish to ask the question 'at a particular time, is the biota of terrane x closer in character to that of the Himalayas (Indian Terrane) or of the Qilian (Eurasian Terrane)?'

Methods of biogeographical analysis currently employed to probe such questions in a rigorous way are vicariance biogeography, multivariate analysis and parsimony analysis of endemism. Unfortunately, vicariance biogeography is not an option in this case because the method requires a taxonomic group whose relationships have been determined cladistically and which has at least one species unique to each terrane. No single taxon from Tibet fulfils these criteria. Left with the choice of multivariate analysis or parsimony analysis of endemism, we have chosen to adopt the latter (for details of this method see Rosen & Smith (1988)). The advantage of parsimony analysis of endemism is that it produces a cladogram of sample areas directly interpretable in terms of relative recency of biotic contact between sample areas. The method nests sample areas hierarchically according to the taxa that are shared between them. A dichotomously branching tree is calculated relating the areas which requires the fewest reversals and parallelisms of data (maximum parsimony).

(a) Choice of sample areas

The often difficult and subjective choice of sample areas for analysis is made simple in this case because of the highly specific problem that we are investigating, namely the relationships of the three suture-bounded terranes that compose the Tibetan Plateau. Geological boundaries delimit our sample areas (figure 2). Thus the region to the south of the Zangbo Suture is the Himalayan Terrane (H); that between the Zangbo and Banggong Sutures, the Lhasa Terrane

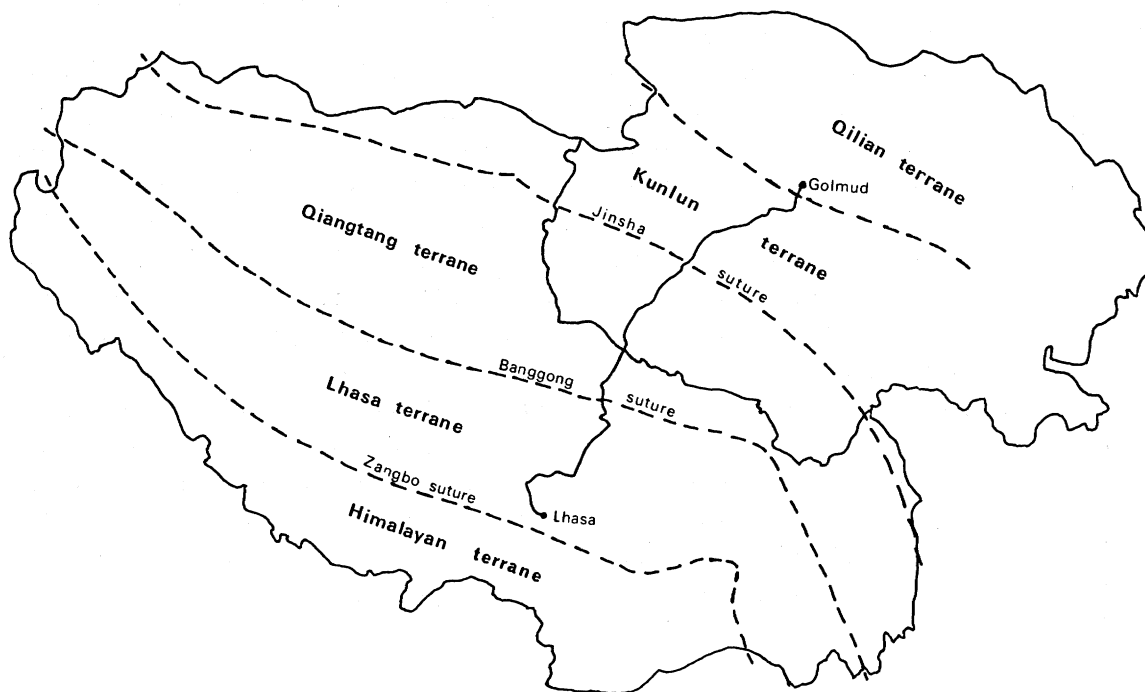


FIGURE 2. Outline map of Xizang and Qinghai provinces (Tibetan Plateau), China, showing the sample areas (terranes) used in the biogeographical analysis and their boundaries (suture zones).

(L); that between the Banggong and Jinsha Sutures, the Qiangtang Terrane (Qa); that between the Jinsha Suture and the major fault marking the northern margin of the Kunluns, the Kunlun Terrane (K); and the area to the north of the Qaidam basin in Qinghai Province, the Qilian Terrane (Qi). The biota within each terrane is treated as a single entity and data from different localities within it are amalgamated. Note that the western part of the Qiangtang Terrane of previous authors (e.g. Wen 1984: Rutog district, etc.) is omitted from consideration here, since it appears to be part of the Lhasa Terrane, both lithologically and faunally, and ought to be treated as a separate sample area in analysis.

(b) Level of analysis and data set

Biogeographical analyses were attempted for biotas from the Lower Carboniferous through to the Middle Triassic. No analyses were attempted for geological periods before the Lower Carboniferous because rocks of the appropriate ages are not represented in each terrane. The pattern of plates after the Triassic is little disputed and there is sufficient independent evidence

on which to base palaeogeographical reconstruction. Thus the prime aim of this analysis is to establish the relationships of terranes prior to the establishment of a large Tethyan ocean represented now by the Zangbo Suture. Faunal and floral lists of genera were compiled for specific geological periods (generally a single stage) for each terrane, based largely on the published Chinese literature, but supplemented wherever possible with our own data. We chose to work at the taxonomic level of genus for practical reasons. As noted above, species level taxonomy appeared to us to be oversplit, with few species apparently found outside their type area, let alone in more than one terrane. Genera appeared to be somewhat more consistently used and provided sufficient endemism to be of use.

Taxa that are unique to just one terrane are uninformative about how that area relates to others. It is only those taxa that are recorded from two or more terranes that can provide the necessary data from which to assess area relationships. The full taxonomic lists for each sample area were thus culled to remove all taxa unique to a single area. In practice only a few major groups were abundant enough to analyse with this method.

(c) *Interpolation of ranges*

Because our knowledge of the fossil biota of Tibet is still very preliminary, the problem of pseudo-absences in the data is acute. In order to try to minimize this, we have made one assumption, namely that the five sample areas remain in their same relative positions through time. Although major barriers to biotic exchange could appear and disappear between adjacent terranes, it is assumed that no terrane switched position ('leap-frogged') relative to its neighbours along the north/south transect. This seems eminently reasonable since the three terranes form long narrow strips running east/west. Accepting this, then a taxon's range can be interpolated between its most southerly and northerly records. Where a taxon is present in two non-adjacent terranes, then its absence in the intervening terranes is ascribed to collection failure or absence of the appropriate facies.

The culled data set of taxonomic ranges was then analysed following the parsimony analysis of endemism method outlined by Rosen & Smith (1988). For each time period analysed, only a few major groups were used, those being the most important and best studied. The results for each taxonomic group were kept separate and then compared to check for congruence. Where there is a high degree of congruence between the results from different taxonomic groups then more reliance can be placed on the results. In most cases the data matrixes were small enough to carry out a parsimony analysis empirically, without the aid of computer programs.

5. RESULTS

(a) *Late Dinantian (Visean)*

(i) *Correlation*

This is the first period for which there is a good record of fossiliferous marine strata across the plateau. Correlation within the Qiangtang, Kunlun and Qilian Terranes is well established on the brachiopod and coral faunas (Jin & Sun 1981; Chen 1984), which are closely comparable in all three regions. Correlation into the Lhasa and Himalayan Terranes is less well established and no detailed stratigraphy is yet available.

(ii) *Corals* (figure 3)

The Qiangtang, Kunlun and Qilian Terranes share a very similar coral fauna dominated by Eurasian elements. It is a high diversity fauna dominated by compound rugose corals or large solitary rugose corals with complex dissepimentation, typical of a shallow marine carbonate shelf environment. Stromatoporoids and chaetetids are also common. Many of the genera are part of a fairly cosmopolitan equatorial fauna (e.g. *Lithostrotion*, *Lonsdaleia*), but there are also genera which are found only in the South China Block (e.g. *Yunnanophyllum*, *Kueichophyllum*).

There is a marked drop in diversity to the south of the Qiangtang Terrane and corals from the Lhasa and Himalayan Terranes are on first sight very different. This is solely due to the loss of compound genera. The sparse fauna of small solitary rugose corals without dissepiments or thickened axial edges and of tabulate corals is composed of genera that have also been reported as present in the Qiangtang–Kunlun–Qilian biota. Notably, there are no endemic forms unique to the Lhasa–Himalaya region.

Visean - corals

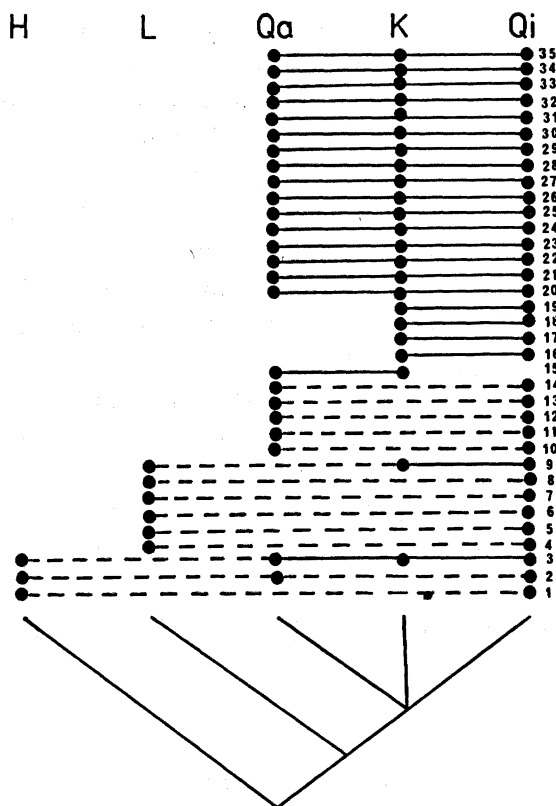


FIGURE 3. Taxon/area matrix of late Dinantian coral distribution across the Tibetan Plateau. H = Himalayan Terrane; L = Lhasa Terrane; Qa = Qiangtang Terrane; K = Kunlun Terrane; Qi = Qilian Terrane. Only genera found in two or more terranes are included: each line represents the range of a genus; black circles = presence recorded; dashed lines = interpolation of range through a terrane from which the taxon has not yet been recorded. Summary cladogram of sample areas is shown at the base. Data from many sources. Taxa are as follows: 1, *Zaphrentoides*; 2, *Caninophyllum*; 3, *Caninia*; 4, *Cyathaxonia*; 5, *Barrandeophyllum*; 6, *Meniscophyllum*; 7, *Zaphrentites*; 8, *Rhopalolasma*; 9, *Amplexus*; 10, *Zaphriphyllum*; 11, *Neoclisiophyllum*; 12, *Clisiophyllum*; 13, *Stelechophyllum*; 14, *Lophophyllum*; 15, *Hunanoclisia*; 16, *Qinghaiphyllum*; 17, *Chaetetes*; 18, *Michelinia*; 19, *Ekvasophyllum*; 20, *Kueichouphyllum*; 21, *Kueichoupora*; 22, *Lithostrotion*; 23, *Heterocaninia*; 24, *Syringopora*; 25, *Hexaphyllia*; 26, *Dibunophyllum*; 27, *Lonsdaleia*; 28, *Aulina*; 29, *Palaeosmia*; 30, *Syphonophyllia*; 31, *Carcinophyllum*; 32, *Gangamophyllum*; 33, *Arachnolasma*; 34, *Yunanophyllum*; 35, *Diphyphyllum*.

(iii) *Brachiopods* (figure 4)

The brachiopod data produce a result congruent with that from corals. Brachiopods are rather more widespread in their distribution, with a less marked drop in diversity between the Qiangtang and Lhasa Terranes. As with corals, there appears to be a continuous decline in diversity from north to south, with no genus endemic to the Lhasa–Himalaya region.

Visean - brachiopods

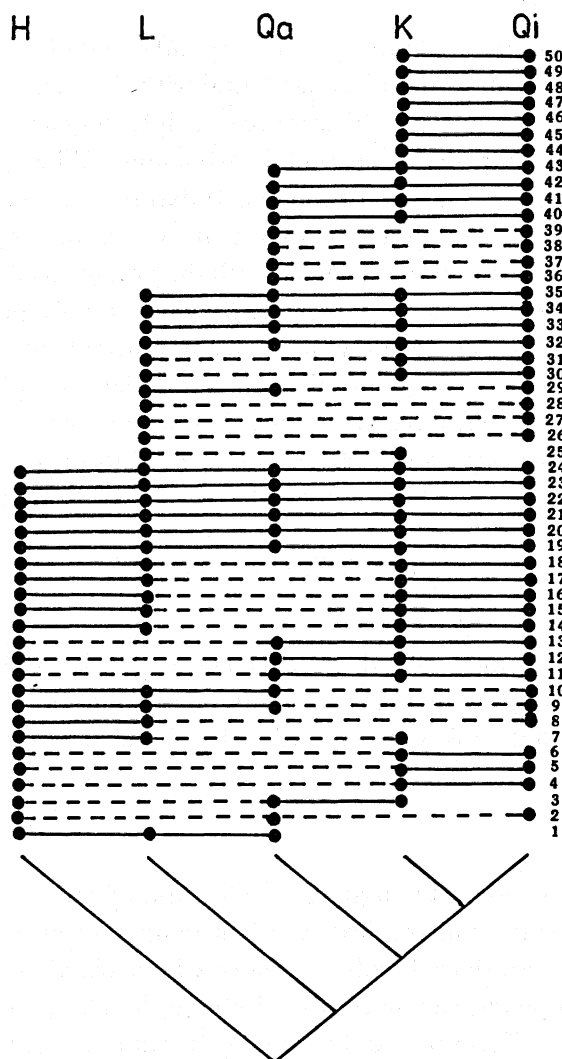


FIGURE 4. Taxon/area matrix and cladogram of late Dinantian brachiopods. Symbols as in figure 2. Taxa are as follows: 1, *Fusella*; 2, 'Chonetes'; 3, *Waagenoconcha*; 4, *Pugilis*; 5, *Delepinea*; 6, *Schuchertella*; 7, *Rotaia*; 8, *Balakhonia*; 9, *Tylothyris*; 10, *Ectochoeristites*; 11, *Striatifera*; 12, *Gigantoproductus*; 13, *Linoproductus*; 14, *Syringothyris*; 15, *Ovatia*; 16, *Neospirifer*; 17, *Marginatia*; 18, *Composita*; 19, 'Spirifer'; 20, *Eomarginifera*; 21, *Dictyoclostus*; 22, *Dielasma*; 23, *Buxtonia*; 24, *Brachythyris*; 25, *Marginifera*; 26, *Pugnax*; 27, *Hustedia*; 28, *Fluctuaria*; 29, 'Productus'; 30, *Plicatifera*; 31, *Rhipidomella*; 32, *Punctospirifer*; 33, *Phricodothyris*; 34, *Martinia*; 35, *Overtonia*; 36, *Schellwienella*; 37, *Semiplanus*; 38, *Crurithyris*; 39, *Camaratoechia*; 40, *Megachonetes*; 41, *Echinoconchus*; 42, *Cleiothyridina*; 43, *Antiquatonia*; 44, *Uncinella*; 45, *Rugosochonetes*; 46, *Pustula*; 47, *Leptagonia*; 48, *Kansuella*; 49, *Grandispirifer*; 50, *Cancrinella*.

(iv) *Interpretation*

The marine fauna of this period can be divided into a highly diverse, shallow carbonate shelf community dominated by compound rugose corals, solitary rugose corals with dissepiments, stromatoporoids and brachiopods in the north, and a low diversity, deeper water clastic community dominated by brachiopods, fenestellid bryozoans, crinoids and small simple solitary rugose corals to the south. Clearly the faunas of the Qiangtang, Kunlun and Qilian Terranes are closely comparable, and indeed show the same detailed biostratigraphical succession. The coral data suggest that these three areas also maintained a close connection with the South China Block at this time.

The differences between the two faunas are striking but cannot be taken as evidence for there being a major palaeogeographical break coincidental with the Banggong Suture at this period as some have suggested (e.g. Fan 1985). This is because different facies are being compared (off-shore deeper shelf clastics with shallow subtidal carbonates). What is clear from this analysis is that there is a decrease in diversity southwards and that in both taxonomic groups the Lhasa Terrane shares more fauna in common with areas to the north than it does with the Himalayan region. This may be a genuine latitudinal effect, with the progressive loss of tropical/subtropical faunas southwards into more temperate regions. But it is equally possible that it is a depth-related phenomenon, with diverse shallow water communities being replaced to the south by reduced diversity deeper water communities. In particular, the absence of a single genus endemic to the Lhasa–Himalaya region at this time argues strongly against there being a separate ‘Gondwanan’ province south of the Banggong Suture. Faunal analysis provides no evidence for there having been provinciality of biotas across this region at this time.

(b) *Early Permian*

(i) *Correlation*

Where they occur, we have used the occurrence of fusulinids belonging to the *Pseudoschwagerina* assemblage to define this period. In the Lhasa and Himalayan Terranes, there are no larger benthic foraminiferans and correlation has been done on the basis of brachiopod faunas (Wang & Mu 1984).

(ii) *Fusulinids* (figure 5)

Fusulinids are found only in the Qiangtang, Kunlun and Qilian Terranes. They are generally thought to be shallow water and tropical to warm temperate in distribution (Ross 1982*b*). Many of the genera are also shared with the South China Block. Their distribution matches that seen for Visean compound rugose corals. Although there are slightly more genera shared in common between the Kunlun and Qiangtang Terranes, there is no real evidence for separation of these three areas.

(iii) *Corals*

The number of coral genera known from this period is relatively small and few genera are known from more than one terrane, therefore no quantitative analysis is possible. Broadly speaking, however, coral distribution appears much as it was in the Visean, with compound rugose corals restricted to the Qiangtang, Kunlun and Qilian Terranes and small solitary

Early Permian - fusulinids

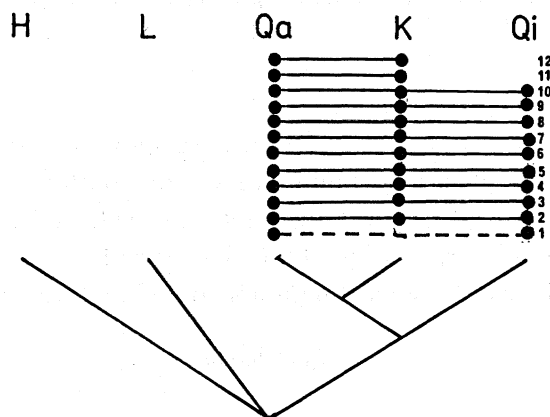


FIGURE 5. Taxon/area matrix and cladogram of early Permian (Asselian/Sakmarian) fusulinid genera. Symbols as in figure 2. Data from many sources. Genera are as follows: 1, *Paraschwagerina*; 2, *Schwagerina*; 3, *Schubertella*; 4, *Pseudofusulina*; 5, *Quasifusulina*; 6, *Ozawainella*; 7, *Triticites*; 8, *Rugosofusulina*; 9, *Eoparafusulina*; 10, *Pseudoschwagerina*; 11, *Boultonia*; 12, *Sphaeroschwagerina*.

rugose corals dominating in the Lhasa and Himalayan Terranes. Simply on number of taxa, there does appear to have been a southward shift in peak coral diversity from the Qilian Terrane in the mid Carboniferous to the Qiangtang Terrane in the early Permian. This may be due to collection failure or may be genuine and result from the increasingly more fluviatile conditions that apparently developed towards the north.

(iv) *Brachiopods* (figure 6)

Only relatively few taxa are recorded from the Qiangtang–Kunlun–Qilian region making interpretation of results difficult. The Lhasa Terrane has a fauna that has shared elements both

Early Permian - brachiopods

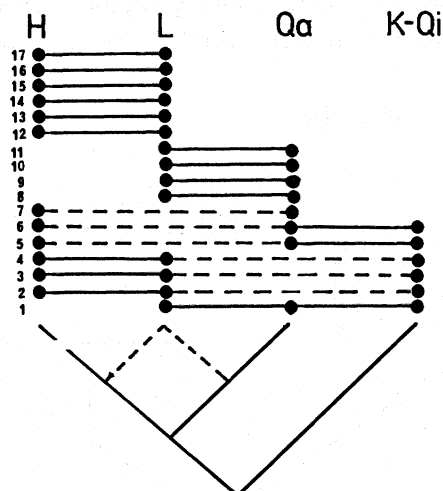


FIGURE 6. Taxon/area matrix and cladogram of early Permian brachiopods. Symbols as in figure 2. Data from many sources. Taxa are as follows: 1, *Dictyoclostus*; 2, *Neospirifer*; 3, *Linoproductus*; 4, *Martinia*; 5, *Canocrinella*; 6, *Orthotetes*; 7, *Orthotichia*; 8, *Marginifera*; 9, *Chaoiella*; 10, *Choristites*; 11, *Punctospirifer*; 12, *Stenoschisma*; 13, *Stepanoviella*; 14, *Brachythyris*; 15, *Syringothyris*; 16, *Trigonotreta*; 17, *Paekmannella*.

with the Himalayan Terrane to the south (six genera) and with terranes to the north (five genera). Clearly Lhasa holds an intermediate position with the possibility of faunal exchange in both directions.

(v) *Interpretation*

The dichotomy between shallow carbonate marine communities to the north of the Banggong Suture and deeper water shelf clastics communities to the south seen during the Carboniferous continues here into the early Permian. Our sparse knowledge of the fauna from north of the Banggong Suture hampers interpretation of the biogeography at this time, but there is at least some hint of faunal similarity between Lhasa and the Himalayas.

(c) *Qixian*

(i) *Correlation*

Larger benthic foraminiferans provide a sound basis for correlation between most regions, the only exception being the Himalayan Terrane, from which they are absent. Here brachiopods are once again used, although the precise correlation is somewhat tentative.

(ii) *Fusulinids*

For the first time fusulinids extend into the carbonate facies of the Lhasa Terrane (*Parafusulina*, *Pseudofusulina*, *Nankinella*, etc.). They are most diverse in the Qiangtang Terrane, becoming less numerous further north, possibly because of the predominance of near-shore fluvio-deltaic conditions.

(iii) *Corals* (figure 7)

Here we find corals are relatively uncommon in the Qiangtang–Kunlun–Qilian region; those that are present are predominantly compound rugose forms (e.g. *Wentzellophyllum*, *Polythecalis*) or large solitary rugose corals with well developed dissepimentation (e.g. *Caninia*). Some small solitary rugose forms also occur. To the south, in the Lhasa and Himalayan Terranes, there are many genera of small, solitary rugose corals, (though this may to some extent be a product of taxonomic oversplitting), some of which are not present to the north.

Qixia - corals

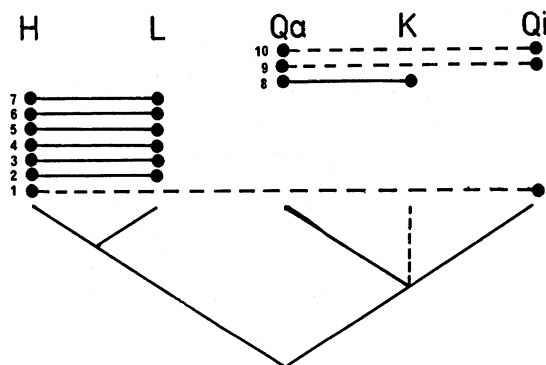


FIGURE 7. Taxon/area matrix and cladogram of Qixian coral genera: data from many sources. Symbols as in figure 2. Genera are as follows: 1, *Lophophyllidium*; 2, *Wannerophyllum*; 3, *Cyathocarina*; 4, *Verbeekiella*; 5, *Trachylasma*; 6, *Plerophyllum*; 7, *Lytvolasma*; 8, *Protomichelina*; 9, *Sechuanophyllum*; 10, *Yatsengia*.

(iv) *Brachiopods* (figure 8)

As for the corals, there appears to be close links between the brachiopods of the Lhasa and Himalayan regions at this time, with several genera and even species (e.g. *Calliomarginata*, *Costiferina indica*, *Stenoschisma purdoni*) uniquely shared between these two regions. There are also a couple of genera shared uniquely between the Qiangtang, Kunlun and Qilian Terranes (*Uncinunella*, *Neoplicatifer*), though the fauna of this area is still relatively poorly known.

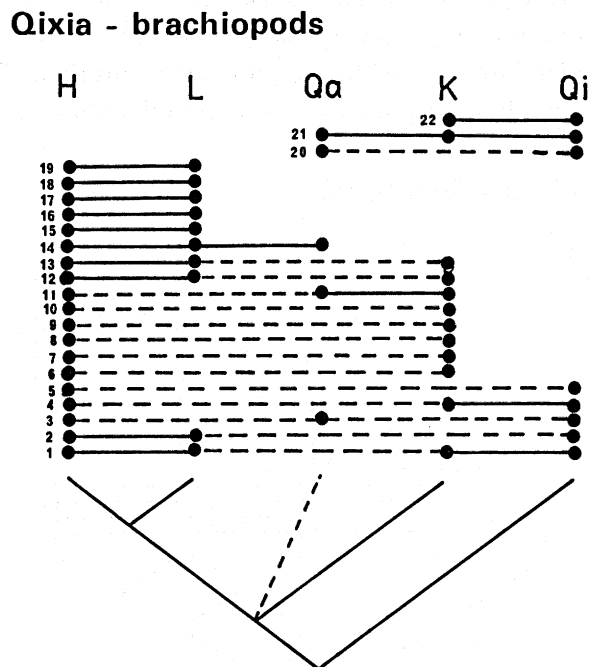


FIGURE 8. Taxon/area matrix and cladogram of Qixian brachiopods: data from many sources. Symbols as in figure 2. Genera are as follows: 1, *Dielasma*; 2, *Spiriferellina*; 3, *Streptorhynchus*; 4, *Linoproductus*; 5, *Squamularia*; 6, *Waagenoconcha*; 7, *Punctospirifer*; 8, *Dictyoclostus*; 9, *Marginifera*; 10, *Cancrinella*; 11, *Athyris*; 12, *Martinia*; 13, *Neospirifer*; 14, *Stenoschisma*; 15, *Costiferina*; 16, *Stepanoviella*; 17, *Cleiothyridina*; 18, *Calliomarginata*; 19, *Anadanthus*; 20, *Neoplicatifer*; 21, *Uncinunella*; 22, *Haydenella*.

(iv) *Interpretation*

The marine fauna of the Qixian provides some good evidence from coral and brachiopod data in support of a faunal tie between the Lhasa and Himalayan Terranes. This, however, is unsupported by the distribution of fusulinids. This suggests that the Lhasa Terrane occupied a somewhat intermediate position between the Himalayas and the Qiangtang–Kunlun–Qilian regions, and the faunal distribution pattern is probably best explained as a product of latitudinal gradient, or facies change.

(d) *Maokouan*(i) *Correlation*

The larger benthic foraminiferans provide the key to correlation from the Lhasa Terrane northwards (*Verbeekina* assemblage), but once again correlation into the Himalayan Terrane is somewhat tentative and based on brachiopods.

(ii) *Fusulinids* (figure 9)

As in the Qixian, fusulinids occur from the Lhasa Terrane northwards, though they are most abundant and diverse in the Qiangtang–Kunlun terranes. There is a hint that the fauna from the Qiangtang and Kunlun Terranes is more closely comparable than either is to the Qilian Terrane at this time.

(iii) *Corals* (figure 10)

Compound rugose corals (e.g. *Wentzellites*, *Lonsdaleastraea*) and larger solitary rugose corals with complex dissepimentation (e.g. *Iranophyllum*), generally considered to be part of the Tethyan equatorial reefoidal fauna, are widely distributed at this time. They are present to the north of the Banggong Suture, but are also now known from the Lhasa Terrane, where a diverse

Maokou - fusulinids

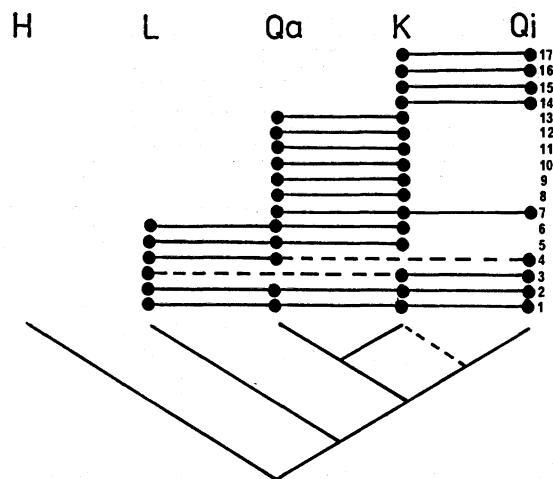


FIGURE 9. Taxon/area matrix and cladogram of Maokouan fusulinids: data from many sources. Symbols as in figure 2. Genera are as follows: 1, *Verbeekina*; 2, *Neoschwagerina*; 3, *Rugososchwagerina*; 4, *Chusenella*; 5, *Yangchienia*; 6, *Nankinella*; 7, *Sumatrana*; 8, *Yabeina*; 9, *Schubertella*; 10, *Parafusulina*; 11, *Pseudofusulina*; 12, *Ozawainella*; 13, *Khalerina*; 14, *Monodiexodina*; 15, *Polydiexodina*; 16, *Schwagerina*; 17, *Afghanella*.

Maokou - corals

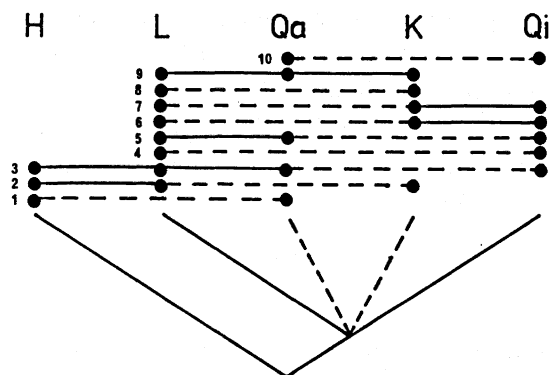


FIGURE 10. Taxon/area matrix and cladogram of Maokouan coral genera: data from many sources. Symbols as in figure 2. Genera are as follows: 1, *Wannerophyllum*; 2, *Amplexocarina*; 3, *Trachylasma*; 4, *Tomasiphyllum*; 5, *Wentzelella*; 6, *Waagenophyllum*; 7, *Iranophyllum*; 8, *Syringopora*; 9, *Ipciphyllum*; 10, *Duplophyllum*.

reefoidal community has been described by Lin (1983, 1984). This fauna is accompanied by other corals and stromatoporoids. In the Himalayan Terrane only small solitary rugose corals without dissepimentation are known (e.g. *Trachylasma*, *Lytvolasma*), some of which are also found in the more diverse faunas to the north. The affinities of the Lhasa Terrane at this period lie clearly with the Qiangtang Terrane and the South China Block.

(iv) *Brachiopods* (figure 11)

The brachiopod fauna is relatively large and the analysis shows a rather complex mosaic of overlapping ranges. However, the predominant clustering suggests that the strongest faunal affinity lies between the Lhasa, Qiangtang and Kunlun Terranes. This region has several

Maokou - brachiopods

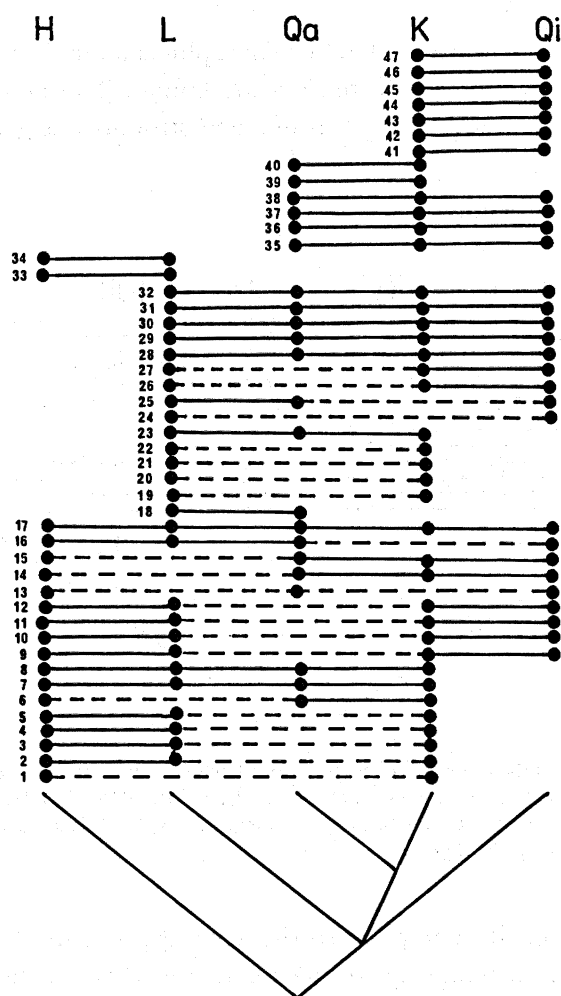


FIGURE 11. Taxon/area matrix and cladogram of Maokouan brachiopod genera: data from many sources. Symbols as in figure 2. Genera are as follows: 1, *Chonetes*; 2, *Phricodothyris*; 3, *Waagenoconcha*; 4, *Stenoschisma*; 5, *Neospirifer*; 6, *Anidanthus*; 7, *Spiriferella*; 8, *Chonetella*; 9, *Haydenella*; 10, *Dielasma*; 11, *Marginifera*; 12, *Martinia*; 13, *Orthotetina*; 14, *Linoproductus*; 15, *Streptorhynchus*; 16, *Spiriferellina*; 17, *Leptodus*; 18, *Composita*; 19, *Spirigerella*; 20, *Chonetinella*; 21, *Terebratuloida*; 22, *Notothyris*; 23, *Hustedia*; 24, *Cancrinella*; 25, *Spinomarginifera*; 26, *Waagenites*; 27, *Derbyia*; 28, *Araxathyris*; 29, *Neoplicatifera*; 30, *Dictyoclostus*; 31, *Squamularia*; 32, *Enteleles*; 33, *Costiferina*; 34, *Calliomarginata*; 35, *Oldhamia*; 36, *Compressoproductus*; 37, *Neowellerella*; 38, *Uncinunellina*; 39, *Gefonia*; 40, *Tyloplecta*; 41, *Alexania*; 42, 'Echinoconchus'; 43, *Urushtenia*; 44, *Punctospirifer*; 45, *Buxtonia*; 46, *Megaderbyia*; 47, *Compressoproductus*.

genera in common (e.g. *Spinomarginifera*, *Neoplicatifera*, *Araxathyris*). There are also some genera restricted to the Qiangtang–Kunlun–Qilian region. Diversity is lower both in the Qilian and the Himalayan Terranes. Apart from *Cleiothyridina*, there is no evidence for taxa shared uniquely between the Lhasa and Himalayan terranes.

(v) *Interpretation*

There is little doubt that the faunal affinities of the Lhasa Terrane now lie strongly with the region north of the Banggong Suture, and with the South China Block, where a similar coral and fusulinid fauna is recorded. The brachiopod data also support this, although the distribution of taxa is much less internally congruent.

(e) *Permian flora*

(i) *Floral distributions* (figure 12)

The Permian flora has been much used in biogeographical analysis, but suffers from the same sorts of problems as are encountered in the marine faunas. The material from the Tibetan Plateau, though sometimes well preserved in detailed structure, is generally rather scrappy,

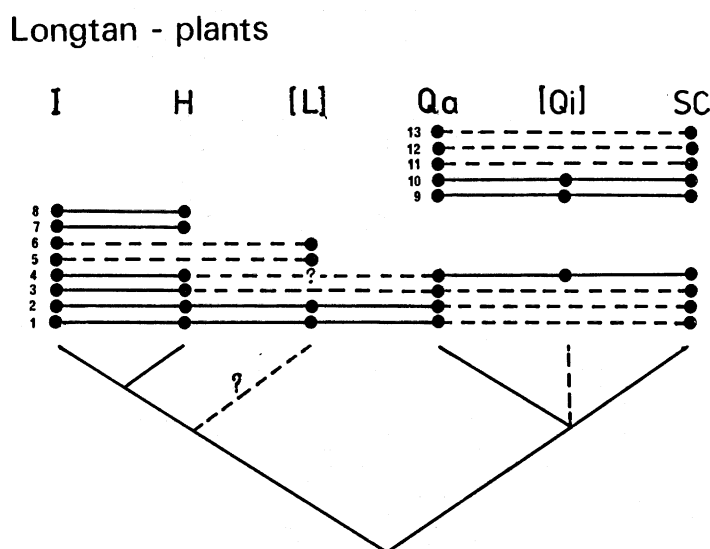


FIGURE 12. Taxon/area matrix and cladogram of early Upper Permian plant genera: see table 1 for sources of data. Symbols as in figure 2. Genera are as follows: 1, *Pecopteris* s.l.; 2, *Chladophlebis*; 3, *Sphenophyllum*; 4, *Lobatannularia*; 5, *Phyllothea*; 6, *Noeggerathiopsis*; 7, *Glossopteris*; 8, *Gangamopteris*; 9, *Lobatannularia sinensis*; 10, *Lepidodendron*; 11, *Gigantopteris*; 12, *Gigantonoclea*; 13, *Rajahia*.

making determination difficult. There is also the general problem of correlating non-marine beds. Thus there has been a tendency to talk about the Permian flora as a whole without ensuring that more or less contemporary floras are being compared. Floral lists for the principal localities are listed in table 1. From this it is seen that the Gondwanan flora of the Himalayas is Qixian in age, whereas the Cathaysian floras of Qiangtang and Qilian are Longtanian or later in age. However, there is a reasonable flora reported from the Mamal Formation (= Kazanian; early Upper Permian) of Kashmir that can be compared (Singh *et al.* 1982).

The results of the analysis are presented in figure 12. This suggests that the Qiangtang flora

TABLE 1. PERMIAN FLORA (GENERA) OF THE QINGHAI-XIZANG PLATEAU AND ADJACENT REGIONS

(Regions and source for data are as follows: 1, South China Block (a = Longtanian; b = Changxinian); Li, Yao & Deng 1982. 2, Qilian Mountains (Longtanian); Liu 1984. 3, Qiangtang Terrane (a = Maokouan, b = Changxinian); He & Zhang 1984, Li, Yao & Deng 1982, this expedition. 4, Lhasa Terrane (stage uncertain); Li *et al.* 1985. Southern Tibet, S of Zangbo suture (Qixian); Li 1983; 6 Kashmir (a = Qixian, b = Maokouan); Singh *et al.* 1982.)

	Regions									
	1		2		3		4	5	6	
	a	b	.	.	a	b	.	.	a	b
<i>Lepidodendron</i>	x	x	x	x	.	.	.	.	.	.
<i>Sphenophyllum</i>	x	x	.	x	x	.	x	.	.	x
<i>Annularia</i>	.	x	.	x	x	.	.	.	.	.
<i>Paracalamites</i>	.	.	.	x	.	.	.	.	x	x
<i>Lobatannularia</i>	x	x	x	x	x	.	.	.	.	x
<i>Schizoneura</i>	x	.	.	x	?	.	.	.	x	.
<i>Rajahia</i>	x	x	.	x	x	.	.	.	.	x
' <i>Pecopteris</i> '	x	x	.	x	x	x	x	x	x	x
<i>Chladophlebis</i>	.	.	.	x	x	.	?	.	.	.
<i>Fascipteris</i>	x	x	x	x	x	.	.	.	.	.
<i>Compsopteris</i>	x	x	.	x	x	.	.	.	.	.
<i>Gigantopteris</i>	x	x	.	x	x	.	.	.	.	.
<i>Gigantonoclea</i>	.	x	.	x	x	.	.	.	.	.
<i>Sphenopteris</i>	.	.	.	x	.	x	x	x	x	.
<i>Taeniopteris</i>	x	.	.	.	.	.	.	.	.	.
<i>Rhizamopteris</i>	x	.	.	x	x	.	.	.	.	.
<i>Rhipidopsis</i>	x	x	.	x	.	.	.	.	.	.
<i>Selaginellites</i>	.	.	.	.	x	.	.	.	.	.
<i>Alethopteris</i>	.	.	.	.	x	?	.	.	.	.
? <i>Neuropteridium</i>	.	.	.	x	x	.	.	.	.	.
? <i>Pterophyllum</i>	.	.	.	.	x	.	.	.	.	.
<i>Calamites</i>	.	.	x	.	.	.	.	.	.	.
<i>Cordaites</i>	.	.	x	.	.	.	.	.	.	.
<i>Glossopteris</i>	.	.	.	.	.	.	x	x	x	x
<i>Gangamopteris</i>	.	.	.	.	.	.	.	.	x	x
<i>Stellotheca</i>	.	.	.	.	.	.	x	.	.	.
<i>Noeggerathiopsis</i>	.	.	.	.	.	x	.	.	.	.
? <i>Plagiozamites</i>	.	.	.	.	.	x	.	.	.	.
<i>Cardiocarpus</i>	.	.	.	.	.	x	.	.	.	.
<i>Carpolithus</i>	.	.	.	.	.	x	.	.	.	.
<i>Phyllotheca</i>	.	.	.	.	.	x	.	.	.	.
<i>Odontopteris</i>	.	.	.	x	.	.	.	.	.	.

at this time shared a number of elements in common with the Qilian Terrane and the South China Block. Thus we find *Rajahia*, *Compsopteris*, *Gigantopteris* and *Gigantonoclea* in Qiangtang, all of which are considered to be elements of the south Cathaysian flora (see He & Zhang 1984). The sparse flora reported from Qilian has taxa that are either widespread or suggest Cathaysian affinities.

In the Himalayas there is a reduced diversity flora with *Gangamopteris* and *Glossopteris* as endemic elements of a Gondwanan flora. Some taxa are common to both areas (*Pecopteris s.l.*, *Sphenopteris*, *Sphenophyllum*) and are cosmopolitan in distribution. *Lobatannularia* is generally considered to be a Cathaysian genus, but Singh *et al.* (1982) has reported this genus from Kashmir, and Li *et al.* (1985) have suggested that *Stellotheca* from the Himalayan region of Tibet is also synonymous with *Lobatannularia*. *Lobatannularia* does not extend southwards into more typical Gondwanan floras of India.

The reported flora from the Lhasa Terrane (Li *et al.* 1985) is very poorly preserved and determinations are tentative. It includes none of the characteristic elements of either the Gondwanan or Cathaysian floras and is therefore difficult to place. Li *et al.* (1985) interpreted some elements of the flora as *Noeggerathiopsis* and *Phyllothea*, which are elements of the Indian Gondwanan flora. They also claimed that there were Cathaysian elements in the flora, namely *Pecopteris* spp., but this form genus is best considered as more cosmopolitan in distribution. The remainder of the flora is inconclusive as to its affinities.

(ii) *Interpretation*

The floral distribution supports the hypothesis that the Qiangtang Terrane and areas to the north were in close biotic contact at this time with the South China Block. Clearly some genera are more restricted in their range (e.g. *Gigantopteris*) while others have a broader range (e.g. *Lobatannularia*) and are less geographically restricted. This flora is considered by palaeobotanists to be characteristic of humid tropical to subtropical regions. The Himalayan Terrane flora on the other hand is characteristic of the more southern temperate regions. The flora from the Lhasa Terrane may have closer affinities with the Gondwanan flora, but the evidence for this is at present exceedingly tenuous and cannot be relied upon. The clear dichotomy in terrestrial flora between India to the south and the Qiangtang Terrane to South China Block region to the north may well have been maintained by the broad shelf sea that existed across the Lhasa Terrane at this time.

(f) *Upper Anisian ammonoids*

Ammonoids form the basis for subdividing the Triassic in the Tibetan Plateau and there is no real problem in correlating across this region. The Lhasa Terrane has only an Upper Anisian fauna, and so the analysis is restricted to this time period. No marine fauna of this age is known from the Qilian region and the Kunlun fauna comes from the Bayan Kala Group (see He & Yin 1983). The analysis (figure 13) shows clear evidence for the Lhasa Terrane sharing closer faunal relations with the Qiangtang and Kunlun Terranes rather than with the Himalayan

Upper Anisian - ammonoids

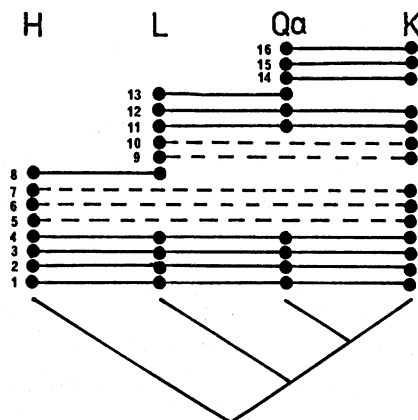


FIGURE 13. Taxon/area matrix and cladogram of Upper Anisian (Middle Triassic) ammonoids: data from many sources. Symbols as in figure 2. Genera are as follows: 1, *Gymnites*; 2, *Hollandites*; 3, *Leiophyllites*; 4, *Japonites*; 5, *Buddhaites*; 6, *Anagymnites*; 7, *Ussurites*; 8, *Anacrocordiceras*; 9, *Paraceratites*; 10, *Reiflingites*; 11, *Balatonites*; 12, *Acrocordiceras*; 13, *Aristoptychites*; 14, *Paracrochordites*; 15, *Procladiscites*; 16, *Cuccoceras*.

Terrane. Xia & Liao (1986) have previously suggested that the Qiangtang ammonoids are European in appearance, and a similar conclusion has been drawn from coral data (Xia & Liao 1986). The ammonoid fauna from Lhasa also shows a preponderance of European (Tethyan) genera and species, with more similarity to the faunas of the Alps than to those of the Himalayan region (Gu, He & Wang 1980).

6. DISCUSSION AND INTERPRETATION

The analyses presented above, covering the period from early Carboniferous to Middle Triassic, provide a rigorous assessment of the available taxonomic data on the biotic relationships of the Tibetan terranes. The changes in area relationships through time are summarized in figure 14, and what now remains to be done is a synthesis of this data to provide an overall picture.

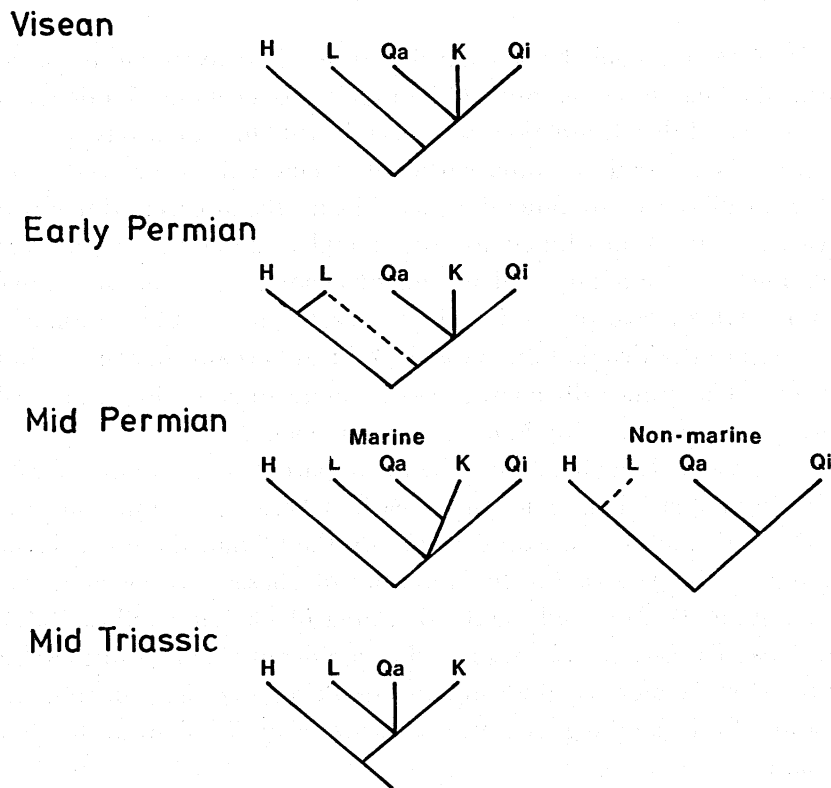


FIGURE 14. Summary diagram of area cladograms showing the changing relationships of sample locality areas through time. Note the change in position of the Lhasa Terrane in the early Permian. Symbols as in figure 2. For further discussion see text.

Firstly, what undoubtedly stands out is the cohesiveness of the Qiangtang–Kunlun–Qilian region throughout the late Palaeozoic. In the later part of the Permian, the Kunlun–Qilian biotic connection appears to become less strong, but this is just as likely to be due to sampling problems as to any genuine biogeographical divergence between these regions. The overall similarity of the biota is demonstrated by marine coral, brachiopod and fusulinid data, and by non-marine plant data. Furthermore, the fauna and flora of this large region also have close

connections with that found in the South China Block, as demonstrated by the shared endemic genera of corals.

What is also clear is that for most of the late Palaeozoic there was a diversity gradient in the marine fauna from north to south, with taxa becoming progressively lost southwards. In the Permian there is an unambiguous dichotomy in the flora between the temperate flora of the Himalayas and the more humid equatorial flora of Qiangtang and Qilian, but the position of the Lhasa Terrane remains unclear.

Less clear is the question of whether there was a significant faunal break coincidental with one of the sutures that might indicate the presence of an oceanic barrier. Different workers have at different times argued that one or other of the suture zones represent the remains of a large Prototethyan ocean. For example, initially the Zangbo Suture zone was considered to mark the northern margin of Gondwanaland, but Chinese work to the north of this suture in the 1970s has tended to disprove this theory. Currently, argument seems to centre around whether the Banggong Suture or the Jinsha Suture marks the Palaeotethys Ocean (viz. Yang & Fan 1983; Wang 1984).

A major oceanic break could only be positioned at either the Zangbo Suture or the Banggong Suture if we accept the Qiangtang–Kunlun–Qilian region as a cohesive biotic region. Previous claims as to the position of this disjunction have been based almost entirely on comparisons of faunas from different facies (shallow water carbonate facies with deeper water clastic facies). Thus although facies differences are potentially significant, the apparent differences in marine faunas could just as easily be attributed to, for example, changes in depth across a broad continental shelf. The absence of any evidence for two centres of endemism in marine faunas across the Tibetan Plateau, except possibly in the early part of the Permian (Asselian to Qixian), does not support the idea that there was a significant oceanic barrier to biotic exchange in the late Palaeozoic. The supposedly characteristic Gondwanan marine fauna of the southern terranes is simply a reduced diversity fauna in a clastic facies.

The problem is most acutely demonstrated by the apparent switch in faunal affinities of the Lhasa Terrane during the late Palaeozoic. In the earliest Permian, the marine fauna of Lhasa shows strongest ties with the Himalayan Terrane. By the Qixian there is evidence of mixed faunal affinities and by the Maokouan the fauna of the Lhasa Terrane shows unambiguous links with the Qiangtang Terrane and the South China Block. This well established fact (see for example Lin 1984; Dickins 1985*b*) has posed a significant problem to those searching for a place in Tibet to insert a major ocean during the late Palaeozoic, since the boundary appears to migrate with time: from the Banggong Suture in the early Permian, to the Zangbo Suture by the late Permian.

However, the change in marine faunas and their affinities is also correlated with a change in lithofacies. Where offshore clastic facies like those of the Himalayan region prevail, the fauna resembles that of the Himalayan region, but with the onset of carbonate ramp toe conditions a mixed fauna is found. The establishment of shallow water carbonate shelf facies in the Lhasa Terrane, similar to contemporary facies in the Qiangtang Terrane, results in similar faunas being present in these two areas. A double oscillation in affinities is also demonstrated within a single section in the Ali district of the southern Karakoram Mountains (Liang *et al.* 1983) where it again appears to be facies-related.

What then are the possible explanations to account for the distribution of faunas in the late Palaeozoic, and for the change in affinities of the biota of the Lhasa Terrane in particular? We

think that there are three possibilities worth considering; plate migration, sea level changes, and shifts in climatic belts.

(i) *Plate migration*

Under this model the Lhasa Terrane is initially part of the marginal shelf platform of the Gondwanan complex during the early Permian, and then migrates northwards during the Qixian stage to become part of the Qiangtang–Kunlun complex by the Maokouan.

This model can be rejected on several grounds. There is no independent evidence to suggest that subduction and collision took place between the Lhasa and Qiangtang Terranes during the Permian; all available evidence suggests that the Banggong Suture was a Jurassic creation. Furthermore, it is more or less impossible to explain why the Qiangtang Terrane should have both kinds of facies/faunas under this model (mixtites and Himalayan fauna to the west around Rutog and Ali, shelf carbonates with a diverse 'warm water' fauna in central and eastern Xizang). Even if we assume that the western portion of the Qiangtang Terrane is in reality part of the Lhasa Terrane and that the Banggong Suture has been wrongly traced eastwards in Xizang, there is still the problem of the double oscillation of faunal affinities noted in Ali.

(ii) *Sea level changes*

Under this model a southward-prograding shore face would bring a carbonate platform across the continental shelf producing a migration of depth-related facies southwards. Only when suitable shallow water conditions were established were diverse coral/brachiopod/stromatoporoid communities able to flourish.

Although there may be some evidence that marine conditions were progressively lost through the Carboniferous and Permian in the northern part of the Tibetan Plateau, and that shelf carbonate platforms were initiated in the Lhasa region in the Permian (see Leeder *et al.*, this volume), this model cannot explain all the features. Clearly the fauna is to some extent depth-related, but there is evidence of tidally-influenced clastic sediments at Chisan Ka (see Leeder *et al.*, this volume) which show that it is not a simple dichotomy between deep water and shallow water communities, and thus the model is rejected.

(iii) *Shift in climatic belts*

Under this model the faunas would be controlled to a large extent by latitudinal variation in climate (which would also control the development of carbonate shelf facies). During the end-Carboniferous glaciation the climatic gradient would be at a maximum and the equatorial belt of high diversity faunas would be relatively restricted, but with amelioration of conditions the gradient would decrease and the equatorial high diversity belt expand southwards. Dickins (1977, 1978, 1984, 1985 *a, b, c*) has provided a very strong case in favour of significant climatic changes taking place during the late Carboniferous and Permian.

This is to some extent supported by the observation that the maximum evidence for regionalization of the marine fauna coincides with the period of glaciation and that immediately following. It could also account for variation within a single plate, for example, by assuming that the Qiangtang region is orientated at a high angle to the climatic belts during the Permian (Wang 1984) or by invoking an appropriate pattern of oceanic circulation. [A more simple explanation, however, would be that the mixed fauna in the Qiangtang Terrane during the Permian reflects bathymetric differences across the region.] It would also explain the diversity gradient so obviously picked up in the biogeographical analysis outlined above.

This last explanation, probably in conjunction with sea level changes, is our favoured model. Note then that this carries with it certain implications about late Palaeozoic palaeogeography.

(i) The various terranes from Qilian to northern India extended from an equatorial or subequatorial position in the north to a temperate position in the south during the late Palaeozoic. This is based on diversity gradients of the total fauna, coral distribution and floral distribution, but also receives independent confirmation from the limited palaeogeomagnetic data available (see Lin & Watts, this volume, who place the Kunlun Shan at approximately 20° south of the palaeoequator) and from the occurrence of late Carboniferous/early Permian glacio-marine facies in the southern block (see Leeder *et al.*, this volume).

(ii) The boundary between these two climatic regions fluctuated through time across the Qiangtang and Lhasa Terranes according to global conditions. There can be little doubt that significant changes in climate were taking place in the late Palaeozoic (see Dickins 1984, 1985 *a, b, c*) which affected the distribution of the biota.

(iii) Because the biotas from equatorial and temperate zones appear to cross terrane boundaries (suture zones) without impediment as global climatic conditions changed, no single suture zone can be recognized as the location of a 'Palaeotethyan' ocean on faunal (or facies) evidence.

(iv) The overlapping nature of faunal and lithological ranges through time (e.g. the extension of a compound rugose coral fauna into the Lhasa Terrane in the Maokouan; the extension of mixtite facies into the Qiangtang Terrane in the Asselian) suggests that there was no consistent physical barrier other than climate across this region. Specifically, we see no evidence for significant oceanic barriers within this region during the late Palaeozoic. The continuity of both faunas and lithofacies across suture zones at different times is more in keeping with the idea of a continuous epicontinental shelf. The alternative of having a series of island terranes is possible, but less appealing because of the absence of firm evidence of continental rise or deep ocean sediments of this age on any of the terranes. Whatever break there was between island terranes under this model was not significant enough to affect the fauna and left no record in the sedimentary succession.

Wang (1984) has previously suggested that the regions to the south of the Jinsha Suture all formed one large continuous plate with India (the Qingzangindia Plate), and recently Dickins (1985 *b*) and Dickins & Shah (1981) have also hinted that the Tibetan Plateau was all one region continuous with India in the late Palaeozoic. Our evidence not only supports this view, but also raises doubts about supposing that any major oceanic barrier existed between the Qilian/South China Block and India in the late Palaeozoic. This view was also put forward by Crawford (1974) who argued that the entire Tibetan Plateau was contiguous with India and Gondwanaland and that the boundary lay to the north along the Tien Shan.

7. SUMMARY

1. The late Palaeozoic biota ranged from equatorial or sub-equatorial in the north to temperate (southern) in the south.

2. Climatic fluctuation on a global scale controlled the distribution of the biota of this region during the late Palaeozoic and no suture zone can be identified as a consistent boundary between 'Gondwanan' (i.e. temperate southern) and 'Cathaysian' (i.e. equatorial) biotas.

3. It is therefore suggested that either the whole region formed one continuous shelf region

at this time, or that, under an island terrane model, the terranes formed 'island' platforms spread out across the region more or less uniformly. There is no evidence for any consistent dichotomy at one particular suture zone, nor for any one suture zone marking a significant barrier to faunal dispersal.

4. There is no evidence for any Upper Palaeozoic continental rise or oceanic sediments on the Tibetan plateau. The earliest evidence is of early Triassic turbidites and late Triassic radiolarian cherts. This is contrary to the expectations of an island terrane model.

5. The breakup of this region may date from the Permian.

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APPENDIX 1. PALAEOLOGICAL DATA

The following determinations represent the combined work of a large number of experts, not only in the British Museum (Natural History) and Nanjing Institute of Palaeontology, but also in Universities and Research Establishments of Britain, Europe and the United States of America. These experts and their addresses are listed beneath. The initials of each expert are given wherever appropriate to indicate the source of the determination and any comments that may accompany it.

The localities are not listed in stratigraphical order, rather for each prefix letter they are in order of collection during the expedition, starting with localities in the south and ending with those in the north. The alphabetical prefixes identify the various working groups of the expedition. Figure 15 shows the approximate position for all localities for which we have collected palaeontological data. The map names and grid references refer to the 1:100000 scale geographical maps used as field maps during the expedition. A set of these is lodged in the British Museum (Natural History). No field maps were available for the Baingoin region and reference should be made to our field maps (Kidd *et al.*, this volume: microfiche 2 in pocket) for precise locations of fossil samples.

Each locality number generally refers to a section that was logged. In many cases simplified stratigraphical logs of these sections are presented in Leeder *et al.*, (this volume) where the precise horizons from which samples were collected are sometimes marked. In other cases, where the section is small or unimportant, there is no accompanying sketch log to consult. Where fossils were found from more than one horizon in the section, individual sample numbers are also given, thus, for example, under locality B50 there are a number of sample horizons, each one designated by its bed number in the field logs (e.g. B50.118).

For each entry there is a brief statement about geographical locality, age, and, where appropriate, palaeoenvironment. Many determinations, such as those of Foraminifera, are at a provisional (generic) level pending further work. In other cases (notably amongst the corals) the work of identifying the material has only just commenced and only the occurrence of such material is noted. Some age-diagnostic Permian and Cretaceous foraminifera are illustrated in plate 1.

A complete suite of macrofossils from this expedition is housed in the Nanjing Institute of Palaeontology, Academia Sinica, Nanjing, China, together with micropalaeontological samples determined by Chinese workers. Where duplicate material was collected a representative sample is also housed in the British Museum (Natural History), London, where there is also a complete set of micropalaeontological samples determined by British scientists. A duplicate set of palynological samples is held by the British Geological Survey, Keyworth, Nottinghamshire.

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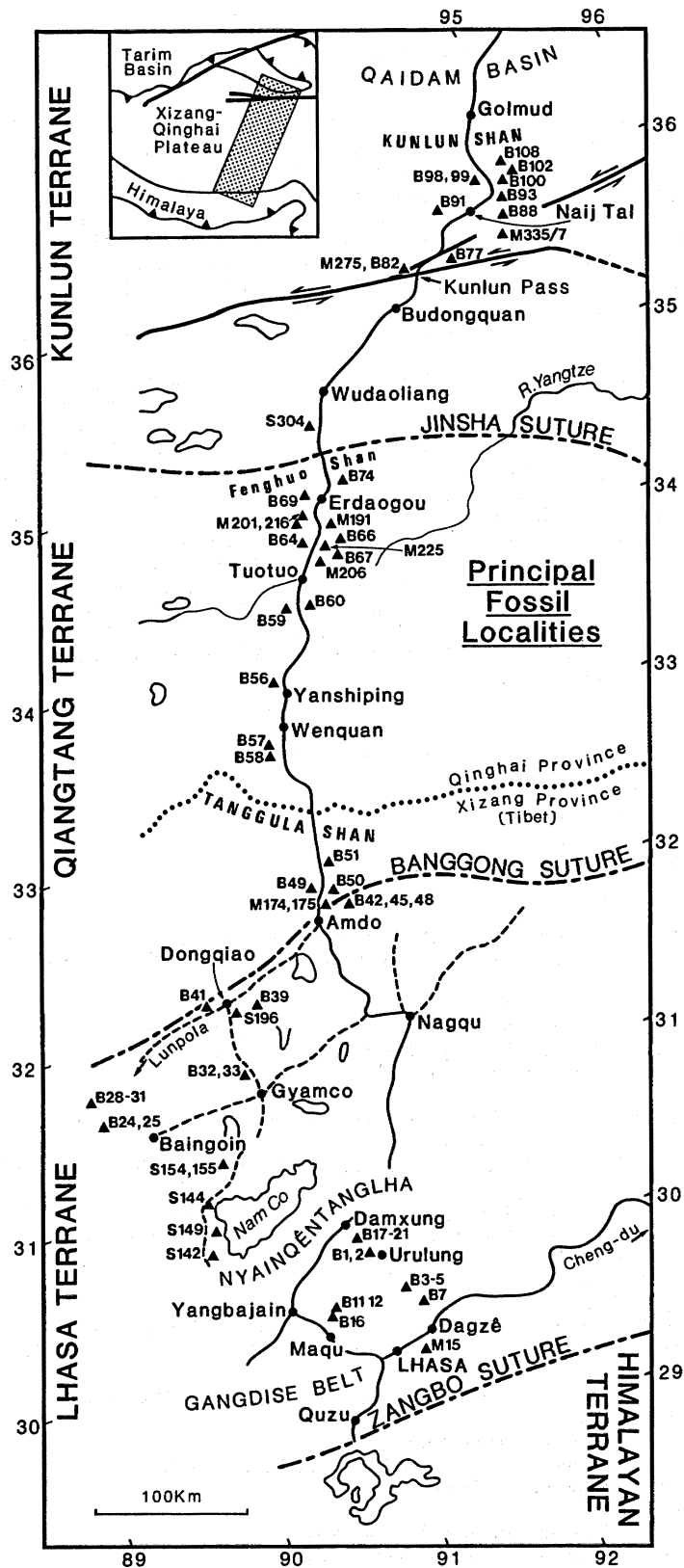


FIGURE 15. Strip map of the Geotraverse route showing the principal fossil localities listed in the Appendix.

XJT Dr Xue Juntao, Nanjing Institute of Palaeontology.
 YCH Dr Ye Chunhui, Nanjing Institute of Palaeontology.
 YW Dr Yu Wen, Nanjing Institute of Palaeontology.
 ZLJ Dr Zhang Lujing, Nanjing Institute of Palaeontology.
 ZLX Dr Zhang Linxin, Nanjing Institute of Palaeontology.
 ZZK Dr Zhu Zhikang, Nanjing Institute of Palaeontology.

Locality B1. Section at Urulung, north east of Lhasa (Pangduo sheet, grid ref. 63,328E 33,624N). Near the top of the Pondo Group: Early Permian (Asselian/Sakmarian). The fossils come from a thin calcareous sandstone bed and represent an allochthonous assemblage probably of storm deposit origins at or near wave base.

Brachiopoda (CHCB)

Mucrospiriferinella cf. *undulosa* Waterhouse
 cf. *Cancrinelloides monticulus* Waterhouse
 cf. *Chonetes ambiensis* Waagen

Locality B2. Section at Urulung, north east of Lhasa (Pangduo sheet, grid ref. 66,324E 33,626N).

B2.11. Thin storm deposit bed of allochthonous bryozoan debris within the Urulung Formation: Qixian Stage, Lower Permian. About 50 m below base of limestones.

Bryozoa (PDT)

Meekopora sp.
Goniocladia sp.
 ?*Girtypora* sp.
Streblotrypa sp.
Polypora sp.
 'Fenestella' sp.

Loose limestones derived from the Lobadoi Formation which here forms a steep cliff face: *Neoschwagerina* Zone, Maokoan, Upper Permian. These are micritic limestones with a sparse derived fauna of corals and fusulinids, interpreted as carbonate ramp facies.

Foraminifera

'Contains the fusine *Rugososchwagerina* (see plate 1, figures 1, 6) and specimens of the smaller benthic foraminifer, *Pachyphloia*. Species of the former have previously been recorded from Tibet by Wang *et al.* (1981) from the Lobadoi Formation (Majula Member) and the Ombo Formation. According to Kanmera *et al.* (1976), *Rugososchwagerina* is restricted to the *Neoschwagerina* Zone of the Maokouan 'stage' (JEPW).

(ZLX)

Rugososchwagerina x zangica (Wang, Sheng & Zhang)
Nankinella inflata (Colani)
Schwagerina sp.

Corals

Locality B3. Exposures near the roadside approximately 1 km south of the village of Qibulung, Lhasa Terrane (Pangduo sheet, grid ref. 63,3'2E 33,306N). Limestone/shale turbidite sequence interpreted as shelf-basin or shelf-margin facies. Qibulung Formation, Chaqupu Group; ?Carnian, Upper Triassic.

Bivalves (NJM)

Halobia cf. *charlyana* Mojsisovics (probably Carnian but just possibly Lower Norian: common).

Locality B4. 600 m south of locality B3. Well bedded micritic limestones with shales. Allochthonous fauna includes recrystallised branched ?stromatoporoid, crinoidal debris, micromorphic gastropods, fragmentary pieces of scleractinian coral and bivalve. Interpreted as carbonate ramp facies. Mailonggang Formation; Carnian, Upper Triassic.

Crinoids (ABS)

'*Isocrinus*' *candelabrum* Bather (columnals); a species from the Carnian of southern Europe.

Locality B5. 1 km south of locality B3. Limestone/shale sequence with transported shelf fauna of corals and bivalves, probably shelf basinal facies. Mailonggang Formation; Carnian/Norian, Upper Triassic.

Bivalves and Corals

Locality B11. Outcrops on the hillside approximately 500 m east of Chisan Ka hot springs, Lhasa Block: (Maqu sheet, grid ref. 62,882E 33,255N). See Leeder *et al.* (this volume) figure 6 for logged section. Here Permian cross-bedded sands of shoreface facies are overlain by thick-bedded sparsely fossiliferous micritic limestones.

B11, bed 9: Tuffaceous quartz sand, slightly calcareous within cross-bedded sand unit interpreted as distal shoreface sand. ?Urulung Formation, Lower Permian.

Brachiopods (CHCB).

Badly preserved productacean; marginiferid
 ?*Chaoiella latisinuata* Jing & Sun
 ?*Rectimarginifera* sp.

Bryozoans (PDT)

Indet. fenestellids

B11, bed 23: Basal bed of limestone sequence. Permo-Triassic.

Indeterminate crinoid stem fragments.

B11, bed 37: Thick bedded fossiliferous micritic limestone approximately 40 m above the base of the limestone sequence.

Foraminifera (JEPW)

'A dolomite with abundant macrofossil shell fragments [mostly rhynchonellids, but also some ostracodes and crinoid debris]. There are a few, poorly preserved foraminifera belonging either to *Angulodiscus* or *Glomospira*. Age, probably Triassic.'

Locality B12. Outcrop on hillslope 100 m east of Chisan Ka hot springs, Lhasa Terrane (Maqu sheet, grid ref. 62,876E 32,256N). Black micritic limestone overlying prominent disconformity; Chaqupu Group, Upper Anisian, lower Middle Triassic.

Ammonoids (MKH)

Paraceratites elegans Mojsisovics

Brachiopods (SDL)

Nudirostralina subtrinodosi (Yang & Xu)

Costirhynchopsis cf. *sinensis* (Yang & Xu)

Bivalves (NJM)

Indet. pteriomorph

Locality B16. Outcrops forming cliff to the south of Chisan monastery, Lhasa Terrane (Maqu sheet, grid ref. 62,850E 33,236N). Plant-bearing sandstones in a fluviatile red bed sequence; Lingbuzong Formation, late Jurassic or early Cretaceous.

B16; near the base of the succession.

Plants (CRH)

'*Ptilophyllum cutchense* Morris. There is no exact match in the regional literature, but very similar leaves also referred to this species are known from the Jurassic of Kazakhstan. *P. caucasicum* Doludenko & Svanidze from the Upper Jurassic of Georgia, U.S.S.R., is very similar and has preserved cuticles, but the venation appears to be much more dense. The Japanese Upper Jurassic to Lower Cretaceous specimens figured by Oishi (1940, pl. 32 figs 1-3) as *P. pecten sensu lato* also look very similar and have a comparable vein density. The Indian type material described by Morris includes a broader range of leaf and pinna form than this Tibetan collection but amongst them are some more or less identical leaves.

'*P. cutchense* is a broadly defined and probably rather artificial species, now used mainly as a catch-all for material with short pinnae of which the cuticle is unknown. It is a suitable provisional determination for the Tibetan specimens until much larger samples showing more detail become available. Age: Mesozoic. The most closely comparable material from elsewhere ranges from Middle Jurassic through to Lower Cretaceous.

'*Ptilophyllum* sp. A, cf. *P. cutchense* Morris. Differs from the above species mainly in its smaller size. Broadly similar material from the Gondwanan Mesozoic has been referred directly to *P. cutchense* Morris. Material from the Jurassic of the Kazakhstan, also referred to *P. cutchense*, is more similar than the Gondwanan material but is larger. Age: Middle Jurassic to Lower Cretaceous.

'?*Ptilophyllum* sp. B: leaf fragment. The general appearance of the pinnae is of *Pterophyllum* but the pinna base (based solely on one or two of the better preserved pinnae) appears rounded acropically and slightly decurrent basiscopically, as in *Ptilophyllum*. I know of no other species of *Ptilophyllum* which exactly resembles this leaf and none referred to *Pterophyllum* that resembles it closely. Age; Permian to Middle(?) Cretaceous. The most similar material comes from the late Triassic and Lower Cretaceous.

'Indeterminate bennettitalean leaf fragments. Though often described as *Ptilophyllum* or *Zamiophyllum*, leaf fragments such as these are not sufficiently well preserved to identify securely to genus or species.

'*Pagiophyllum* sp. A, cf. *P. astrachanense* Doludenko. Similar material has been identified in the Chinese literature as *Sphenolepis* sp., a characteristically Cretaceous genus, but there is an equal or greater resemblance to several other species worldwide that have been given various generic names with little justification. Because of lack of epidermal detail and absence of attached or associated cones the present material is placed in the form genus *Pagiophyllum* following Harris (1979). This species lies at or near the boundary of *Pagiophyllum* with *Geinitzia*, but has a leaf shape closer to the former. The genus ranges from Triassic to Recent but is most characteristic of Jurassic and Lower Cretaceous floras.

'*Geinitzia* sp. A. Branching coniferous shoots of which the epidermal details are unknown. Shoots of this form are typical of the Mesozoic taxodiaceae genus *Elatides*. *E. harrisii* Zhou from the Lower Cretaceous of Liaoning differs in its longer and straighter leaves. Similar material from East Asia has been named *E. curvifolia* (Dunker), but full comparison of the Tibetan material with other species is precluded by the lack of epidermal detail. Age (of genus) Late Triassic to Lower Cretaceous.

'**Age of the flora.** Duan *et al.* (1977) previously recorded from this locality the fern *Weichselia reticulata*, a highly characteristic member of Lower Cretaceous floras worldwide, but extending back into the Middle Jurassic in some localities. The advanced fern *Onychiopsis*, also recorded by them, is similarly characteristic of Lower Cretaceous floras, but the photographs of this material (as published) are not entirely convincing. The present sample considerably augments botanical knowledge of the flora as a whole but adds little to estimating its age. The sample could equally on palaeobotanical grounds be ?Middle to Late Jurassic as well as Lower Cretaceous. In general the flora is composed of cosmopolitan elements, although if *Geinitzia* sp. A does turn out to be a species of *Elatides*, this genus has never previously been reported from Gondwana.'

B16b; approximately 100 m above the base.

Plants (CRH)

'Indet. cycad or cycadophyte leaf: it could be *Nilssonia* (in which the pinnules do not meet over the rachis) or one of a number of bennettitalean genera such as *Pterophyllum* or *Zamiophyllum* seen from the abaxial surface. The material is insufficient to identify'.

Locality B17. Outcrops along track running southeast of Damxung, immediately southeast of the summit of the pass, 3 km southeast of Damxung, Lhasa Terrane (Damxung sheet, grid ref. 63,232E 33,772N). Cleaved mudrocks of offshore marine shelf facies. Pondo Group, beds within mixtite sequence; ?late Carboniferous – Asselian, Lower Permian.

Brachiopods (CHCB)

Punctospirifer cf. *tamugangensis* Zhang

?*Phricodothyris* sp. cf. *asiaticus* (Chao)

mucronate spiriferid – ?*Alispirifer* sp.

large productacean – ?*Chaoiella* cf. *grundwaldti* (Krotov)

?Linoproductid fragments

?*Spinatrypa khalfni* Alekseeva

Rhipidomellid

Bryozoans (PDT)

Fenestella s.l.

?*Polypora* sp.

? '*Thamniscus*'

Indet. trepostome bryozoans

Indet. rhabdomesine cryptostome bryozoans

Bivalves (NJM)

Paleyoldia sp. (common)

Gastropods (RJC)

Peruvispira sp.

Indet. crinoid debris

Locality B18. As above, 20 m southeast from the summit: at top of mixtites.

Brachiopods (CHCB)

Schuchertella sp.

A chonetid with no external ribbing – cf. *Tornquistia tropicalis* Grant

Mucronate spiriferid – ?*Alispirifer* sp.

Lochengia [= *Cyrtospirifer*] sp. cf. *L. lochengensis* Grabau & Yoh

Davidsoniacean indet.

Bryozoans (PDT)

Fenestella sp. s.l.

?*Reteporida* sp.

Indet. trepostome bryozoans

Bivalves (NJM)

Ptychopteria sp.

Indet. crinoid debris

Locality B19. As for locality B17, 50 m southeast of the summit. Beds within the mixtite unit.

Brachiopods (CHCB)

Large spiriferid – ?*Alispirifer* sp.

Indet. Davidsoniacean

cf. *Chaoiella grundwaldti* (Krotov)

Conulariid (ZZK)

cf. *Notoconularia tenuistriata* (McCoy)

Bivalves (NJM)

Deltopecten sp.

Indet. crinoid debris

Locality B20. Outcrops along valley side approximately 6 km southeast of Damxung along a trackway (Damxung sheet, grid ref. 63,260E 33,749N). Finely laminated mudrock with thin calcareous bands, interpreted as offshore clastic shelf facies. Pondo Group, ?Upper Carboniferous.

Brachiopods (CHCB)

Chonetid sp. – ?anopliid

Martiniid indet.

cf. *Crurithyris* sp.

Gastropods (RJC)

Peruvispira sp.

Locality B21. Outcrop forming small cliff on the northern side of the valley, 8.5 km southeast of Damxung, along the trackway running from Damxung southeastwards (Damxung sheet, grid ref. 63,275E 33,734N). Pondo Group, ?early Upper Carboniferous.

Brachiopods (CHCB)

Sculptospirifer cf. *acutiplicatis* (Su)

?Martiniid

Crinoids (ABS)

Cyphostelechinus sp. (columnals)

Indet. crinoid and bryozoan debris

Locality B24. Outcrop forming a steep cliff to the south of Duoba village, Baingoin District, Lhasa Block. Limestones and calcareous shales of shallow marine facies. Langshan Formation; Aptian/Albian, Lower Cretaceous. [The sequence is apparently inverted].

Foraminifera (JEPW & MDS) [From first massive limestone approximately 50 m above top of red beds].

'An *Orbitolina* Limestone which contains good large embryos with alveolae indicating the subgenus *O.* (*Mesorbitolina*). Other foraminifera include *Daxia*. Age; Early Cretaceous, Albian.' (see plate 1, figure 10).

Bivalves (NJM & PS) [B24, bed 99; approximately 25 m above start of limestones]

Praeradiolites sp.

Locality B25. Outcrops up the left bank of a north/south gully in the north-facing Lang Shan scarp face, approximately 2 Km ESE of Duoba Village, Baingoin District, Lhasa Terrane. A thick sequence of shallow marine calcareous shales and limestones of lagoonal facies, with rudist reefs. There is one clastic horizon in the sequence that is ?hypomarine. The sequence is inverted, based on foraminiferan dating of the beds. Langshan Formation; Aptian/Albian, Lower Cretaceous. Individual beds are as follows:

B25, beds 15 & 17.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone. The embryos show alveolae, which according to Shroeder (1975) would place them within the subgenus *Orbitolina* (*Mesorbitolina*). Other foraminifera include *Pseudocyclamina* and *Cuneolina*. Age; early Cretaceous, Middle to Late Albian.'

B25, bed 30.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone with *O.* (*Mesorbitolina*). Other foraminifera include *Trochospira* and miliolids. Age; early Cretaceous, late Albian.'

B25, bed 32.

Gastropods (NJM & YW)

Tylostoma sp. (common)

Bivalves (NJM)

'Concentrically ribbed infaunal bivalves, badly preserved; possibly small *Asartidae*. Also a fragment of ?*Liopistha*.'

B25, bed 33.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone with *O.* (*Mesorbitolina*) and *Palorbitolinoides*. Age; early Cretaceous, late Aptian to Albian.' (see plate 1, figure 7).

B25, bed 38.

Bivalves (NJM & PS)

Offneria sp. [top Lower Aptian]

'*Praeradiolites* *hedini* Douville. This species was first described from Aksai Chin in Western Tibet, associated with orbitolines. On the basis of the general similarity of this species with *P. fleuriani* from the Cenomanian of Aquitaine, Douville suggested that this species might be Cenomanian. In fact the two species are hardly similar at all and there is no reason to believe that Douville was correct. Yang *et al.* described further material attributed to *Praeradiolites* from the Ngari area of western Tibet; it was here associated with Requenidae and again orbitolines. *P. hedini* was identified as occurring in Lower Albian to Cenomanian deposits, but it would appear that the Cenomanian age was based on Douville's assertion, rather than on independent evidence. In the area around Gilgit and another locality in Western Afghanistan '*Praeradiolites* *gilgitensis* (a probable synonym of '*P.* *hedini*) occurs with *Horiopleura lamberti*, a species restricted to near the Aptian - Albian boundary. There seems little doubt that all this material is of late Aptian to early Albian age.'

B25, bed 44.

Bivalves (NJM & PS)

'*Praeradiolites* *hedini* Douville

B25, bed 45.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone. Good, very large embryos are preserved, suggesting *O.* (*Mesorbitolina*). Other foraminifera include *Ammobaculites* and *Palaeodictyoconus*. Age; early Cretaceous, probably Albian.'

Algae (MDS)

Neomeris budaense Johnson**B25, bed 54.**

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone containing *O. (Mesorbitolina)* and *Praeorbitolina* and other foraminifera including *Cuneolina* and *Daxia*. Age; early Cretaceous, Aptian or Albanian.' (See plate 1, figures 12.)

B25, bed 66.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone. Good embryos are available and these show a primitive condition of the genus *O. (Mesorbitolina)*. Other foraminifera include *Cuneolina* sp., *Vercorsella* and miliolids. Age; early Cretaceous, late Aptian.' (See plate 1, figures 9 and 11.)

B25, bed 72.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone with *Eopalorbitolina*: an interesting find as this genus was thought to be endemic to western Europe. Age, early Cretaceous, Late Barremian'. (See plate 1, figure 8.)

B25, bed 77.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone. The embryos are rather primitive and indicate *Praeorbitolina*. Age; early Cretaceous, early Aptian.'

B25, bed 87.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone. Both matrix-free and random thin sections show good embryos referable to a primitive species of *O. (Mesorbitolina)*. The foraminifer *Cuneolina* is also present. Age; early Cretaceous, Aptian.'

B25, upper beds (loose).

Gastropods

Trocharia sp. (YW): indet. nerineid (PV)

Locality B28. Outcrops on the north side of Xiaqiong Lake, approximately 50 km northwest of Baingoin, Lhasa Terrane (see Kidd *et al.*, field maps on microfiche; also logged section, Leeder *et al.* figure 9). Massive dolomitised limestones separated by siltstone sequences. Three main reefoidal limestones form prominent sharp features and are of immediately subtidal marine shelf facies. The interbedded siltstone facies represents back-reef mud flats and beachrock environments. Xiaqiongc Formation; late Jurassic (Upper Oxfordian/Kimmeridgian) to Lower Cretaceous (Valanginian).

First limestone

Foraminiferans (PDT)

Placopsilina – type encrusting species.

Sclerosponge (PDT)

Neuropora sp.

Chaetetid (BRR & RW) [from top bed]

Blastochaetetes angoulensis Fischer [Kimmeridgian species]

Scleractinian corals (BRR) [from top beds]

Pseudocoenia sp.*Fungiastraea arachnoides* (Parkinson)*Stylosmilta* cf. *micelini* Milne Edwards & Haime*Stylina bangoinensis* Liao*Stylosmilta* sp.*Myriophyllia* cf. *rastellina* (Michelin): this coral differs from *M. rastellina* in being lamellar rather than massive.

'This fauna mostly indicates a Late Oxfordian or Kimmeridgian age.'

Octocoral (BRR)

? *Polytremacis* sp.

Bryozoans (PDT)

Berenicea sp.? *Discosparsa* sp.*Proboscina* sp.

Gastropods (PV)

Phaneroptyxis sp. (common)*Eunerinea* sp.*Adicopyxis* sp. cf. *A. valdensis* (Pictet & Campiche). This genus is typically Lower Cretaceous.

Bivalves (NJM)

Indet. oysters

Echinoids (ABS) [from top bed]

Trochotiara sp.

Saleniid; either *Salenia* or *Hyposalenia*, but details of apical disc not seen and determination not possible. Age; Saleniids similar to this range from Kimmeridgian to late Cretaceous.

Second limestone

Brachiopods (terebratulids), stromatoporoids and bivalves.

Beachrock between second and third limestones

Serpulid-encrusted surface.

Third limestone

Stromatoporoids

Bivalves (NJM)

Lophid oyster, genus indet.

Echinoids (ABS)

Pseudocidaris ?maresi (Cotteau). Large, club-shaped spines similar to these have been reported from the Neocomian of Algeria, the Valanginian/Hauterivian of Portugal and the Bau Formation of Kutching, Borneo (Lower Cretaceous). They are also probably synonymous with spines reported as 'late Jurassic' from Japan, under the name *Firmacidaris neumayri* Nisiyama.

Locality B29. Outcrop of massive limestone 1 km to the southeast of locality B28. Xiaqiongco Formation, late Jurassic – early Cretaceous. For locality see field map (Kidd *et al.*, this volume: microfiche 2, in pocket). Shallow reefoidal limestone.

Chaetetes (BRR & RW)

Blastochaetetes angoulensis Fischer [Kimmeridgian species]

Coral (BRR)

Stylina bangoensis Liao [late Jurassic species]

Locality B30. Siltstones above the main limestone sequence of locs B28 & B29, conformably underlying a fluviodeltaic sequence 1.5 km east of locality B28 and 0.5 km north of locality B29, north side of Xiaqiong Lake, Baingoin district, Lhasa Terrane (see field maps, Kidd *et al.*, this volume: microfiche 2, in pocket) for a log of this section see Leeder *et al.*, this volume, fig. 11). Very shallow back reef marine lagoonal facies, with strand-line deposits. Xiaqiongco Formation; Lower Cretaceous, Valanginian to Hauterivian.

Foraminifera (JEPW & MDS)

A fine sandstone containing a species of *Pseudocyclamina*. Age; Valanginian to ?Aptian. (See plate 1, figure 14.)

Serpulids (ABS)

Serpula sp. s.s.

Gastropods

Cryptaulax sp. (YW). 'The overall shell shape and lack of internal folds are characteristic of *Aphanoptyxis*'. (PV)

Echinoids (ABS)

Numerous specimens, all badly crushed and distorted, of a heart-shaped atelostomate echinoid. The apical disc is not seen in any specimen but appears to be compact rather than elongate, indicating it is a spatangoid, rather than a holasteroid. There are no fascioles developed thus it belongs to the family Toxasteridae. The frontal ambulacrum is sunken and shows no evidence of two forms of pore pairs (hence it is not *Heteraster*). The petals also are not sunken and the anterior pair are curved anteriorly. This is almost certainly *Toxaster* sp., closest to the Neocomian *T. cordiformis* Breynius. The unsunken nature of the petals is a primitive feature and suggests an earlier rather than later species within the range of this genus (Berriasian – Hauterivian).

Also plates and spines of a cidarid. The spines are very large (10 cm) and coarsely thorned, with a flattened shaft. These come from the genus *Rhabdocidaris* and are indistinguishable from those of *R. tuberosa* (Gras) from the Valanginian of southern Europe.

Locality B31. Scarp face exposures near base of hill approximately 5 km NNE of locality B28, on the north side of Xiaqiong Lake (see field map (Kidd *et al.*, this volume: microfiche 2, in pocket for locality). Biosparite limestones with shell beds of oysters, rudists and stromatoporoids, and with some terebratulids. Hanshan Formation [= Langshan Formation]; Albian, early Cretaceous.

Foraminifera (JEPW & MDS)

Orbitolina sp. Age; Albian – Cenomanian.

Stromatoporoids and Brachiopods

Bivalves (MDS)

'In thin section radiolitic rudist bivalve debris is seen. Age; must be Albian or younger.'

Locality B32. Cleaved mudrock with thin calcareous sandy horizons exposed on the end of a narrow spit extending from the northern margin into Jang Lake (Jang Co sheet, grid ref. 62,960E 34,984N). Continental slope turbidites with transported shallow shelf fauna. Lake Area Flysch; probably late Jurassic.

Fragmentary scleractinian compound corals and stromatoporoids including *Stylosmilia* sp. (LWH)

Gastropods

'There are at least three different genera present in this material. (1) *Aptyxiella* or *Nerinella* (long, thin tapering shells are characteristic of both genera and the fold structure which would distinguish between them is not seen). (2) ?*Trochalia*. (3) *Eumerinea*.' (PV)

'*Aptyxis* sp.' (YW)

Bivalves (NJM)

Camptonectes sp. (badly distorted)

Cirripedes (SFM)

'A single valve of a scalpellid cirripede in which the lateral margins and apex are ill preserved. It can be identified as a tergum from the apico-basal ridge which is wide, flat and increases in width towards the basal angle. This is characteristic (though not exclusively so) of the genera *Archaeolepas* and *Eolepas*, both Upper Jurassic in age, and is much rarer at other times.'

Locality B33. As for locality B32; exposures along the north edge of Jang Lake (Jang Co sheet, grid ref. 62,955E 34,995N).

Algae (GE)

Indet. cyanophyte algae (common)

Gastropods

As at locality B32 (PV & YW)

Locality B39. Outcrop on the northwest side of a small valley 7 km southeast of Dongqiao village, Banggong Suture zone (Dongqiao sheet, grid ref. 63,045E 35,384N). Silts and fine sands with thin bedded calcarenitic limestones; ?distal fan turbidite shelf facies. Latest Jurassic or Lower Cretaceous.

Trace fossils (ABS) [in silts]

Chondrites (abundant)*Laminaria**Rhizocorallium*

Radiolaria (EAP) [calcarenite]

'The single specimen appears to be a yet unnamed Jurassic/Cretaceous Spumellarian'

WHR records the following genera:

*Paronaella**Pseudodictyomitra**Patulibrachium**Praeconocaryomma**Crucella*? *Hemicryptocapsa**Archaeospongoprunum***Fauna from limestone blocks within a bedded olistostrome, composed predominantly of chert and basalt.**

Stromatoporoids and Corals

Echinoids (ABS)

Large club-shaped spines identical to those found in the third limestone at locality B28, and referable to ?*Pseudocidaris maresi* (Cotteau).

Locality B41. Outcrop on the hillside southwest of Zige Tang Lake approximately 10 km northwest of Dongqiao village, Banggong Suture zone (Zige Tang Co map, grid ref. 62,916E 35,504N). Sequence overlying ophiolite; for log see Leeder *et al.*, this volume, figure 9. Includes shore-facies shallow marine limestones at top. Late Jurassic.

B41, bed 19. [plant bed]

Plants (CRH)

'Gross form is poorly preserved but preservation of leaf cuticles is good. Material includes *Cyprissidium* sp., a poorly preserved, branching shoot fragment with needle-like leaves and poorly preserved shoots which most probably belong to *Brachyphyllum* but might possibly turn out to belong to *Pagiophyllum* or even *Cyprissidium*. These forms are most commonly found in Middle to Upper Jurassic floras.'

B41, beds 26–28.

Sclerosponge (BRR)

Cladocoropsis sp.

Corals

Gastropods (NJM & RJC)

Eunerinea sp.*Ampullella* sp.? *Nerinea (Ptygmatis)* sp.

Pseudomellaniid genus indet.

Bivalves (NJM)

Arcomytilus sp.

'The bivalves and gastropods suggest a Middle or Upper Jurassic age.'

Locality B42. Outcrop forming prominent conical hill, approximately 15 km northeast of Amdo, Banggong Suture Zone (112th Station sheet, grid ref. 63,920E 35,888N). Oolitic limestones, shallow marine shelf facies. Zhamunaqu Formation; Lower/Middle Jurassic.

Basal oolitic/oncolitic limestone.

Brachiopods (CHCB)
Koninckinacean, ?*Cadomella* sp.

Higher massive oolitic limestones.

Gastropods (RJC)
Procerithium (*Xystrella*?) sp.

Bivalves (NJM)
Pernopecten or *Propeamussium* sp. The distinguishing feature which is the ribbing on the inner shell surface of the latter is not exposed.

Crinoids (ABS)
Pentagonal isocrinid stem ossicles with smooth latera and simple petaloid crenulariae – ?*Balanocrinus* or *Isocrinus*.

Locality B45. Outcrop along the floor of a small valley immediately to the south of the conical hill of loc. B42, approximately 15 km northeast of Amdo, Banggong Suture Zone (112th Station sheet, grid ref. 63,928E 35,868N). Black shale with thin bands of calcareous nodules, interpreted as offshore shelf basinal facies. Zhamunaqu Formation; Middle Jurassic (Bajocian; *sauzei* Zone in part).

Bivalves (NJM)
Ceratomya cf. *bajociana* d'Orbigny
Propeamussium sp.
Chlamys-like pectinacean
Astartidae sp. A: possibly *Nicaniella* sp.
Small *Gryphaea*-like oyster
? *Gervillella* sp. (fragment)
? *Palaeonucula* sp.
? *Mesosacella* sp.
? *Isocybrina* sp.

Corbulidae fragment resembling *Corbulamima* sp.

Ammonites (MKH)
Euhoplceras adicra (Waagen); Lower Bajocian, *discites* Zone or *sauzei* Zone.
Dorsetensia sp. indet. (2 small fragments); Lower Bajocian *sauzei* Zone.
Phylloceras sp. indet.

Fontannesia cf. *luculenta* Buckman; Lower Bajocian, *discites* Zone. [the precise location of this specimen within the sequence is uncertain. If it is much lower than the other specimens then it could be the Upper Toarcian *Dumortieria*].

Crustacean (JC)
Protocarcinus ?*hebes* Meyer: carapace

Locality B48. Outcrops along the east bank of a small stream, approximately 4 km southeast of the conical hill of loc. B42, some 15 km northeast of Amdo, Banggong Suture Zone (112th Station sheet, grid ref. 63,945E 35,852N). Cross-bedded sands with shale and thin bioclastic limestones of shallow fluvio-marine facies. ?Zhamunaqu Formation; Upper Jurassic.

Lower beds in sequence

Sclerosponge (BRR)
Cladocoropsis sp.
Stromatoporoid

Top beds at bend in stream: at start of flysch sequence.

Gastropods (PV)
Aptyxiella or *Nerinella*; similar to locality B32/33

Locality B49. Material excavated in a marmot burrow from immediately above a submarine lithified surface, outcropping on the hillside 800 m north of the road, approximately 17 km ENE of Amdo, Qiangtang Terrane (112th Station sheet, grid ref. 63,875E 35,918N). Yanshiping Group; Bathonian/Callovian, Middle Jurassic.

Gastropods (NJM)
Internal mould of a small ?Naticacea
Bivalves (NJM,WSX & XJT)
Lophid oyster, possibly *Actinostreon* sp.
Ceratomya concentrica (Sowerby)
Camptonectes yanshipingensis Wen
Modiolus imbricatus (Sowerby)
Pteroperna sp.
Arcomytilus sp.
? *Catinula* sp.
Indeterminate heterodont bivalve

Brachiopods (SDL)

Burmihynchia sp. [Large numbers of specimens were collected attributable to the following nominal species – *B. asiatica* Buckman, *B. cf. lobata* Ching, Sun & Ye, *B. parva* Buckman, *B. luehngensis* Reed, *B. quinquiplicata* Ching, Sun & Ye, *B. nyainrongensis* Ching, Sun & Ye, *B. shanensis* Buckman, ?*B. namtuensis* Buckman, *B. lobata* Ching, Sun & Ye].

Echinoids (ABS)

Holcetypus depressus (Leske) (Bathonian/Callovian)

Locality B50. Cliff outcrop on the east bank of the river, approximately 18 km northeast of Amdo, Qiangtang Terrane (112th Station sheet, grid ref. 63,895E 35,935N). Grey mudrock of shelf basinal facies; Sewa Formation, Kimmeridgian, Upper Jurassic.

Dinoflagellates (Nanjing Institute scientists) [from near the base of the section]

Pareodinia ceratophora Deflandre

Meiourogonyaux rioultii Sarjeant

Ctenidodinium mosaicum Dodekova

Mendicodinium ? *reticulatum* Morgenroth

Dapcodinium (*Macodinium*) *semitabulatum* (Morgenroth) Dorhofer & Davies

Yalkopodinium (*Cyclomephelium*) cf. *areolatum* (Cookson & Eisenack) Morgan

Paragonyaulacysta ? *calloviensis* Johnson & Hills

?*Meiourogonyaux valensii* Sarjeant

Ambonosphaera cf. *jurassica* Gitmez & Sarjeant

Subtilisphaera sp.

Dichadogonyaulax sellwoodii Sarjeant

Bivalves (NJM, WSX & XJT)

Pholadomya cf. *hemicaredia* Roemer

Entolium sp.

Arcticidae, genus indet.

Radulopecten sp.

Exogyriiform oyster cf. '*Gryphaea*' *hennigi* Dietrich

Chlamys sp.

'*Exogyra*' cf. *forteai*

Inoperna sp.

Actinostreon sp.

Brachiopods (SDL)

Indet. rhynchonellids

Ammonites (MKH)

'Many large fragments of indeterminate perisphinctids, probably Upper Jurassic. The largest specimen and the Kodachromes are probably *Torquatisphinctes* of Lower Middle Kimmeridgian age. The coarse ribbed and tuberculate ammonites are *Katroliceras* sp. indet. from the Middle Kimmeridgian.'

Locality B51. Roadside cutting by Highway Station 114, approximately 22 km northeast of Amdo, Qiangtang Terrane (112th Station sheet, grid ref. 63,907E 35,965N). Restricted marine sequence with black, fossiliferous shales, cross-bedded sands and a coalified plant bed. Yanshiping Formation; Middle Jurassic.

Bivalves (CPP)

Protocardia sp. cf. *stricklandi* (Morris & Lycett)

Tancredia? sp.

Corbulimima sp. cf. *attenuata* Lycett

Pleuromya sp.

Ceratomya sp. cf. *concentrica* Lycett

Thracia sp.

Locality B56. Exposures at the northeast end of the road cutting immediately to the northeast of Yanshiping village, Qiangtang Terrane (Yanshiping sheet, grid ref. 64,176E 37,232N). Fine sands and silts with rippled and mudcracked horizons indicative of very shallow lacustrine or hypomarine conditions. Lower part of the Yanshiping Group; Middle Jurassic (pre-Bathonian).

Bivalves (WSX)

Psilunio spp. including *P. ovalis* Mu, *P. chaoi* (Grabau), *P. thailandicus* (Hayami), *P. henanensis* Gu and *P. aff. guangyuanensis* Mu. ['The genus *Psilunio* as used in the Chinese literature is probably not the same as *Psilunio* Gabbe. Some smaller specimens within this sample show the sculpturing of *Protocardia*. This suggests that the beds may contain a mixture of non-marine and marginal marine forms. All are Middle Jurassic species.' (NJM)]

Locality B57. Outcrop in east/west valley just south of kilometre post 1000, approximately 3 km to the east of the road, 15 km south of Wenquan station, Qiangtang Terrane (Wenquan sheet, grid ref. 63,938E 36,825N). Brackish to marine limestones within a red bed fluvial sequence (a lower and upper limestone sequence was studied). Yanshiping Group; Bathonian, Middle Jurassic.

Upper marine limestone.

Brachiopods (SDL)

Holcathyris sp. [conforming to the morphotypes *H. trigonalis* Buckman, *H. subovalis* Buckman and *H. acuminata* Buckman]

Burmihynchia sp. [conforming to the morphotypes *B. praestans* Reed, *B. globulus* Buckman and ?*B. gutta* Buckman]

Cererithyris sp.

Gastropods (NJM)

Naticid gastropod

Bivalves (NJM)

Praeexogyra cf. *hebredica* (Forbes) [? = *Ostrea davaiacensis burmanica* Reed]. Probably Bathonian in age, though Tibetan and other Far Eastern occurrences could have a different range to those in Europe, where the species is not known outside the Bathonian. Marginal marine species.

Modiolus sp.*Camptonectes* cf. *auritus* (Schlotheim)*Camptonectes* sp. (smooth or exfoliate specimen)? *Sphaeriola* sp.*Ceratomya* sp.

Echinoids (ABS)

Badly preserved regular euechinoid. Tall globular test with uniserial columns of ambulacral pores and one primary tubercle on each interambulacral plate. Ambulacra relatively narrow. Either an Acrosalenidae or a Hemicidaridae.

Locality B58. A section logged through approximately 2 km of predominantly red bed facies exposed up the hill slope in a southwesterly directed valley approximately 3 km due west of the road near kilometre marker number 1004, 18 km south of Wenquan army station, Qiangtang Terrane (Wenquan sheet, grid ref. 63,935E 36,800N to 63,905E 36,793N). Coastal plain facies with marine incursions and some lacustrine horizons (for a log of this section see Leeder *et al.*, this volume, figure 9). Yanshiping Group; Middle Jurassic ?Bathonian/Callovian – Upper Jurassic, Kimmeridgian.

Dinoflagellates [from 'Lower Shales'] (Nanjing Institute scientists)

Pareodinia groenlandica Sarjeant*P. prolongata* Sarjeant*P. ceratophora* Deflandre*P. ceratophora* var. *pachyceras* (Sarjeant) Lentin & Williams*Dapcodinium* (*Mancodinium*) *semitabulatum* (Morgenroth) Dorhofer & Davies*Mendicodinium reticulatum* Morgenroth*Wanaea* ? *digitata* Cookson & Eisenack*Polysphaeridium* sp.*Ctenidodinium* aff. *arnatum* (Eisenack) Deflandre

Bivalves (NJM, WSX & XJT)

B58, beds 37/38*Camptonectes yanshipingensis* Wen*Protocardia* sp.? *Praeexogyra* cf. *hebredica* (Forbes)**B58, beds 41 & 45***Corbula* sp.

Protocardia sp. Here and in other beds *Protocardia* forms monospecific masses suggestive of low salinity environments. This form has clear ribbing on the corcelet not known on other taxa with comparable morphology except a single undescribed arcticacean from the Bajocian of Madagascar, and identification must remain slightly tentative until details of hinge structure can be determined.

B58, bed 59*Undulatula tanggulaensis* Gu (an Upper Jurassic species in China).*Pseudocardinia* or Neomiodontid*Protocardia* sp.**B58, bed 63**

Dinoflagellates (JBR)

Systematophora areolata Klemant. A Late Oxfordian to Kimmeridgian species.

Palynomorphs (GW)

Abundant organic debris with some spores, but largely indeterminate. Material includes a questionable circumpollen group pollen and *Cyadopites*.

B58, bed 71

Ostracods (YCH)

Darwinula sarytirmenensis Shanapova

Bivalves (NJM, WSX & XJT)

B58, bed 103*Protocardia* sp.

Unionid

B58, bed 106*Undulatula tanggulaensis* Gu (an Upper Jurassic species in China).*U. perlonga* Gu? *Pseudocardinia* sp.

B58, bed 118

Bivalves (NJM)
Radulopecten sp.
Protocardia sp.
 ?*Liostrea* sp.
 ?*Antiquicyprina* sp.

B58, bed 139

Bivalves (NJM)
Placunopsis sp.
Protocardia sp. (as before)
Radulopecten sp.
Anisocardia sp.
 'Modiolus' sp.
 ?*Antiquicyprina* sp.
 Gastropods (NJM)
 Naticacean – ? *Ampullospira* sp.
 Trace fossils (ABS)
Zoophycos

Locality B59. Outcrops at Kaixinling coal field, approximately 12 km southwest of Tuotuo station, Qiangtang Terrane (Tuotuo River sheet, grid ref. 64,404E 37,806N). Succession of fluvio-marine clastics with drift coal beds, overlain by thick-bedded micritic limestones; marginal marine to shallow marine shelf facies. Kaixinling Group; Maukouan, early Upper Permian.

From shales immediately underlying the drift coal beds.

Brachiopods (CHCB)
Orthotichia cf. *waterhousei* Grant
 Davidsoniacean – cf. *Perigeyerella tricola* Grant
 new genus cf. *Bilotina*, superficially like *Spinomarginifera* in external form.

Bivalves (NJM & MD)

Leptodesma sp.
Aviculopecten sp.
 ?*Guizhopecten* sp.
 ?*Etheripecten* sp.
 ?*Pernopecten* sp.
 ?*Pseudomonotis* sp.
 Aviculopectenid, genus indet.
Mytilus s.l.

Plants (LXX)

Compsopteris contracta Gu & Zhi var. *punctinervis* Li & Yao
Rajahia (Pecopteris) calceiformis Li & Yao
Pecopteris sp. cf. *P.?* *tobaensis* Li et al.
Pecopteris spp.
Gigantonoclea or *Gigantopteris* sp.

[RW also identified the following

Odontopteris sp.
Pecopteris orientalis Schenk]

Massive micritic limestone exposed above and immediately to the east of the coalfield.**Fusuline foraminifera (JEPW)**

'Contains a large fusuline with schwagerinid wall structure, probably a *Parafusulina*. The range of the genus according to Kanmera et al. (1976) is *Cancellina* to *Lepidolina* Zone, Maokouan, Upper Permian.' (See plate 1, figure 2.)

(ZXL) recognized:

Parafusulina dainelis (Skinner & Wilde)
P. yabei Hanzawa
Nankinella sp. indet.
Staffella sp. indet.

Locality B60. Massive micritic limestone outcropping to the east of the road opposite the track leading to Kaixinling coal field, approximately 11 km WSW of Tuotuo River station (Tuotuo River sheet, grid ref. 64,460E 37,775N). Carbonate ramp facies. Maokouan, Upper Permian.

Fusuline foraminifera (JEPW)

'A fusuline limestone containing the genera *Verbeekina*, *Parafusulina* and *Nankinella*. According to Kanmera et al. (1976), *Verbeekina* is restricted to the Maokouan Stage.' (See plate 1, figures 3, 4.)

(ZXL) recognized the following:

Parafusulina gigantia (Deprat)
P. dainelii (Skinner & Wilde)
P. multiseptata (Schellwien)
Verbeekina verbeeki Geinitz
Neoschwagerina craticulifera (Schwager)
N. haydeni Dutkevich & Khabokov
N. sp. nov.
Yangchienia cf. haydeni Thompson

In addition an apparently older assemblage of fusulines, including

Schwagerina pseudocervicalis Sheng & Sun
Quasifusulina cf. longissima Moeller
Rugosofusulina cylindrica Sheng & Sun
Pseudofusulina sp.

were found in this vicinity. These were studied by ZXL and dated as Asselian/Sakmarian (early Permian).

Corals

Locality B64. Outcrop approximately 3 km west of the highway northwest of the abandoned '85th Service Station', approximately 25 km WSW of Erdaogou Station, Qiangtang Terrane (Erdaogou sheet, grid ref. 64,710E 38,130N). Fluvial sequence with drift coal deposits and non-marine shales. Yanshiping Group (previously mapped as Permian); Middle Jurassic.

Bivalves (NJM & FZZ)

Pseudocardinia sp. cf. P. jennisensis (Lebegev)
 'Tutuella' ? *rotunda* Ragozin
 Astartid, indet.
 Unionid – *Unio sp. s.l.*

Locality B66. Outcrop to the southeast of a small lake, approximately 6 km southeast of '85th Service Station' (abandoned), some 25 km south of Erdaogou Station, Qiangtang Terrane (Erdaogou sheet, grid ref. 64,795E 38,075N). Shale/siltstone sequence with thin fossiliferous sandy packstone limestones interpreted as offshore (basinal) marine shelf facies. Wuli Group; Lower Permian.

Brachiopods (CHCB)

Orbiculoidea sp.
 Davidsoniacean – ?*Streptorhynchus sulcatulum* Grant
Chonetinella cf. convexa (Yang & Fang) or *irregularis* (Lee & Sun)
 ?Rugosochonetid
 Productacean – cf. *Bilobina acantha* Waterhouse & Piyasin
 Productacean cf. *Avonia echidniformis* Chao
Perigeyerella sp.

Gastropods (NJM & RJC)

?*Naticopsis sp.*
 Belleriphontidae (two species, both indet.)

Echinoids (ABS)

Large club-shaped spine with a relatively long shaft. ?Undescribed genus: nothing comparable has been described from the Palaeozoic, except *Nortonechinus*, which has much shorter spines.

Locality B67. Outcrops forming a low ridge, approximately 50 km east of the Highway near Zhakongjian, about 30 km due south of Erdaogou Station, Qiangtang Block (no map reference). Blue coloured biomicrites interpreted as carbonate platform facies, approaching shallow subtidal towards the top where large oncolitic structures are found. All four fossil horizons are near the top of the sequence. Batang Group; Norian, Upper Triassic.

From a limestone bed 25 m below the top.

Brachiopods (SDL)
Yidunella magna Ching, Sun & Ye
Aulacothyropsis sp.
Omolonella sp.
Amphiclina intermedia Bittner

From a limestone bed about 75 m below the top.

Brachiopods (SDL)
Yidunella pentagina Ching, Sun & Ye
Y. yunnanensis (Ching & Fang)
Amphiclina intermedia Bittner

From a bed 85 m below the top.

Brachiopods (SDL)
Yidunella yunnanensis (Ching & Fang)
Rimirhynchopsis sp.

Amphiclina intermedia Bittner
Lobothyris sp.

Bivalves (NJM)
Oxytomidae indet.

From a bed 10 m above the volcanics at the base of the limestone sequence.

Brachiopods (SDL)
Terebratuloids indet.

Corals

From limestones in the upper half of the main limestone.

Conodonts (WCY)
Diplodondella sp.
Neogondolella hallstattensis
N. cf. steinbergensis
N. sp.
Epigondolella postera
E. abneptis
Lonchoidina sp.
Enatignathoidus zeigleri

Foraminifera (JEPW)

'A fine grained bioclastic limestone with a few smaller benthic foraminifera which are difficult to determine with certainty. Similar to forms identified by Salaj *et al.* (1983) from the Norian of the West Carpathians and referred by them to the genera *Nodosaria*, *Agathammina/Ophthalmidium* and *Glomospirella*. Age; probably late Triassic.'

ZLX also identified *Plagiographs* and *Ammodiscus*.

Locality B69. Outcrops on the south flank of the hill to the north of the valley leading northwestwards from Erdaogou, some 2.5 km northwest of Erdaogou Station (Erdaogou sheet, grid ref. 64,830E 38,382N). Shallow pond limestones in red bed sequence. Fenghuoshan Group; early Eocene.

Charophytes (MF)

'One species, belonging to the family Characeae, and genus *Stephanochara* (Lower Eocene to Recent). Species belonging to this genus with this type of ornamentation have not been found in beds younger than the Middle Oligocene. With reference to the numerous species described from the Palaeogene of China, this most closely resembles '*Naedlella*' *nanxiangensis* Huang from the Lower Eocene.'

WZ identified the following:

Rhabdochara ? sp.
Peckichara subsphaerica? Lin & Z. Wang
Harrisichara yunlongensis? Z. Wang, Lin & S. Wang

These indicate an early Palaeocene (Palaeocene or Lower Eocene) age.

Locality B74. Outcrop on the east side of the highway at the northern end of the Fenghuoshan Range, approximately 28 km north of Erdaogou Station, Qiangtang Terrane (Fenghuoshan sheet, grid ref. 64,940E 38,522N). Thin limestones within a clastic sequence, interpreted as shallow freshwater pond deposits: Fenghuoshan Group, Palaeogene (Palaeocene/early Eocene)

Palynomorphs (ZLJ)

Triporopollenites? nactonodus Zhao, Sun & Wang
Polyodiaceasporites sp.
Cyathidites sp.
Schizosporis sp.
Pediastrum sp.

(MCB) A single specimen of a well preserved bisaccate pollen (*Pityosporites sylvestris* type) and one specimen of a monolet spore (*Polyodiaceasporites*) were found. Black debris is oxidized to amorphous matter and degraded bundles (see Boulter & Riddick 1986) suggesting an organic-rich freshwater deposit.

Charophyta (MF & WZ)

Gyrogoneae, gen. indet.

Ostracods (YCH)

Cypreid

Gastropods (YW)

Ammicola sp.
Bithynia sp.

Locality B77. Coal bed outcropping by a stream in the South Kunlun Shan, 9 km northeast of Kunlun Pass, Kunlun Terrane (63rd Station sheet, grid ref. 65,095E 39,548N). Interpreted as a allochthonous coal within a fluvial sequence with volcanoclastic debris. Babaoshan Group; ?Triassic or Jurassic.

Plants (LXX & CRH)

Plectopteris s.l. or *Sphenopteris*. One badly preserved pinna of a fern, Permian or Triassic. The widely spaced pinnules suggest a Mesozoic age.

? Associated beds (XJT Collection)

Holothurian sclerites [indicative of a Triassic or younger age]

Theelia zawidzkae

Kuehnites spinioformis

Sponge sclerites

Locality B82. Finely laminated silts beneath a varve sequence, interpreted as lake beds. Pliocene/Pleistocene. Exposure 100 m to the west of the highway, 300 m north of the Kunlun Pass summit (63rd Station sheet, grid ref. 65,995E 39,495N).

Palynomorphs (MCB)

About 20 pollen were recovered and are either bisaccates, similar to modern *Pinus* species, or triporate, of the *Corylus* – *Myrica* type. Palynodebris is abundant and consists of cuticle and tracheids. This together with the evidence of a badly preserved *Pediastrum* colony, common in the Tertiary, shows that deposition was in a freshwater lake. With and without oxidation the plant cells are a pale yellow and very well preserved. The very limited palynological evidence supports a Plio-Pleistocene age.

Gastropods (YW)

Limnaea sp.

Ostracods (JWN)

Cypridaeidae

Locality B88. Outcrop forming a small mound on the north side of the Xidatan valley, approximately 20 km southwest of Kunlun bridge (along a trail leading southwards from beside the small works east of Najj Tal), central Kunlun Shan (Najj Tal sheet, grid ref. 66,775E 39,648N). Fluvialite red beds with silts; age uncertain – ?Mesozoic.

Plants (CRH)

'Sphenopsid stems – linear leaf and pinna fragments and cone scales which are indeterminate. Could be Permian, Triassic or younger.'

Locality B91. Limestones from relatively high in the thick carbonate sequence forming the higher outcrops on West Mountain, Wanbaogou valley, approximately 15 km westnorthwest of Najj Tal Station, North Kunlun Shan (Qingbanshu sheet, grid ref. 65,250E 39,850N). Shelf carbonate facies. Hongshuichuan Formation; Upper Permian [originally considered to be Lower Triassic].

Brachiopods (CHCB)

'There are six or seven species in the sample. Two species show well preserved laminar shell, characteristic of strophomenaceans. One, with a wide hinge and strong ribs is the chonetid *Waagenites*, a characteristic Permian genus well-known from Timor, South Himalayas, Thailand, etc. Especially well known from late Lower Permian through to Upper Permian. The other strophomenacean might be a productid, such as a small marginiferid, not known above the Permian.

'A smooth-shelled, elongate, anteriorly folded species with impunctate coarse fibres is also present. This has internal structures suggestive of Stenosismatacea and externally resembles *Camarophorina*, a Permian Timor/Malaysia genus extending up into the Upper Permian. There is also a ribbed stenoscismatacean, possibly *Stenosisma* itself, a Carboniferous through to Late Permian genus.

'There is a ribbed, rounded species which externally looks like *Rhipidomella* (Carboniferous – Permian). The shell is poorly preserved and it is not possible to see the expected fine endopunctae of this genus, but it does not resemble any Triassic genus that I know.

'There are a couple of small, rounded specimens which might be *Crurithyris* sp., a long-ranging genus that extends into the Triassic.

'Finally, there is an (?) impunctate shell with a ventral median septum, low profile ribbing and a ?well developed ventral umbo. I think this is some sort of spire-bearer, but these few characters do not allow determination. In conclusion, the sample is Permian in age and probably Late Permian rather than early Permian.'

Locality B93. Large cliff face close to Shuinchang, just to the northeast of Najj Tal, on the north side of the river approximately 24 km eastnortheast of Najj Tal Station, Kunlun Shan (Najj Tal sheet, grid ref. 66,695E 39,820N). Massive micritic limestones of shelf facies. Shuinchang Formation (? = Shihuichang Formation); Upper Ordovician/Lower Silurian.

Stromatoporoids

Corals (CS)

?*Pycnolithus* sp. (Lower Silurian genus)

Gastropods

Locality B98. Outcrop to the north of a large valley, approximately 1 km west of the river and 2 km north of a working quarry, 24 km ENE of Najj Tal Station, Kunlun Shan (Najj Tal sheet, grid ref. 66,655E 39,860N). Micritic limestone bed with transported fossils of shelf facies. Shihuichang Formation; Upper Ordovician.

Stromatoporoids (CS)

Labechia sp.

Clathrodictyon sp.

Corals (CS)

Agetolites sp. cf. *A. varitabulatus* Lin – *A. aequabilis* Lin & Chow group

Gastropods (NJM)

?*Lophospira* sp.

?*Lovonemetrída* sp.

[specimens housed in Nanjing Institute of Palaeontology from this limestone proved to be platyceratid gastropods – ABS & XJT]

Locality B99. Limestone exotic block within a ?Triassic or younger sequence of tuffs and conglomerates, identical to the limestone exposed at locality B98. Outcrop on south face of small promontory ridge approximately 600 m west of the river and 3 km north of a working quarry some 24 km eastnortheast of Naij Tal (Naij Tal sheet, grid ref. 66,656E 39,868N). Derived from the Shihuichang Formation limestone, Upper Ordovician.

Stromatoporoids (CS)

Labechia sp.

Clathrodictyon sp.

Corals (CS)

Agatolites sp.

Wormsipora sp.

The corals suggest an Upper Ordovician age.

Locality B100. Oolitic limestone on the north slope of a ridge, 150 m east of the highway approximately 4 km due north of a working quarry and some 24 km east of Naij Tal Station, north Kunlun Shan (Naij Tal map, grid ref. 66,676E 39,876N). Shallow marine shelf, Halabayigou Formation; late Cambrian – early Ordovician.

Trilobite (RAF)

'A single cranidium which can be determined only as a leiostegeacean. I do not believe it is an *Annmitella* because the internal mould shows no sign of glabeller furrows. Elongate unfurrowed glabellae of this type are more usual among late Cambrian and early Ordovician (Tremadoc) leiostegeaceans. I would go no further on the basis of this specimen.'

Locality B102. Limestone exposed on the west side of a gully on a prominent ridge of hills approximately 9 km northeast of a working quarry some 5.5 km east of a major loop in the highway across a dry gully (Naij Tal sheet, grid ref. 66,742E 39,906N). ?Shihuichang Formation; Ordovician.

Conodonts (WCY)

Panderosus gracilis

Locality B108. Section up a north/south running dry gully at Dagangou, north Kunlun Shan, approximately 10 km east of the highway and approximately 12 km eastnortheast of a large working quarry (Dishantuo sheet, grid ref. 66,760E 39,955N). Marine limestone units within a thick fluvial sequence (For a log of this section see Leeder *et al.*, this volume, figure 2). Dagangou and Diaosu Formations; late Visean to early Namurian.

First Limestone unit, beds in lowest 3 m.

Conodonts (WCY)

Neognathodus dilatus

Stromatoporoids and chaetetids

Corals (LWH)

Lithostrotion

Dibunophyllum

Clisiophyllum

(BRR)

Actinocyathus floriformis crassiconus (McCoy)

Siphonodendron pauciradiale (McCoy)

Siphonodendron intermedium (Poty)

Bryozoans (PDT)

Fenestella sp. s.l.

?*Septopora* sp.

?Anisotrypid trepostome cystoporates

Brachiopods (CHCB)

'*Overtonia*' *transversus* (Wang)

cf. *Ovatia* sp.

cf. *Flexaria* sp.

?*Rugosochonetes kansuensis* Chao

?*Cleiothyridina* sp.

?*Ucinella* cf. *minor* Grabau

Rhipidomella cf. *plana* Yang

"*Gigantoproductus*" cf. *rectestrius* (Grabau)

Echinoconchus fasciatus (Kutorga) or *E. parafascifera* Wang

'*Antiquatonia*' cf. *taiguanfuensis* (Grabau)

Davidsoniacean cf. *Pseudorthotetes borodencovensis* Sokolskaya

?*Punctospirifer tamugangensis* Zhang

?*Dielasma dieneri* Grabau & Yoh

?*Beecheria* sp.

'*Echinoconchus*' *transversus* Wang

Protoniella sp.

Productacean – cf. *Diaphragmus* sp.

?Linoproductid fragments

cf. *Marginifera chuchuhuai* Grabau & Yoh

Reticulariacean – cf. *Martinia* sp.

?*Derbyia* sp.

Small ?spiriferellinids

?*Hystriculina* sp.

Small dictyocloid

Trilobite (RO)

Linguaphillipsia sp. (glabella & pygidium)

Limestone bed near the top of the section, just below fault contact with volcanics. Upper Carboniferous.

Corals

Brachiopods (CHCB)

cf. *Liraplecta richthofeni* (Chao)

Martinia cf. *kunlunia* Zhang

Coledium cf. *trigonalis* (Wang)

cf. *Choristites jigulensis* Stuckenberg

Limestone band towards the top of the section in a neighbouring gully to that above. Upper Carboniferous.

Conodonts (WCY)

Idiognathoides corrugatus

I. cf. *sinuatus*

Neognathodus dilatus (Stauffer & Plummer)

Corals

Brachiopods (CHCB)

?*Rugosochonetes* sp.

Echinoconchus cf. *fasciatus* (Kutorga)

Hystriculina cf. *sinica* Wang

Martinia sp.

Pleuropugnoides wangenheimi (Pander)

Locality M15. Mudrock with volcanics intercalated outcropping at the base of a ridge 1.2 km south of the Lhasa–Dagze road on the east side of the valley which trends south from the main Kyu-Chu river valley: about 13 km ESE of Lhasa [Lhasa sheet, grid ref. 63,344E 32,345N]. From the base or within a thick volcanoclastic and volcanic sequence, ?Chaqupu Group, Dagze Formation; Late Palaeozoic: Upper Carboniferous or Permian.

Palynomorphs (GW)

Poorly preserved miospores, mostly trilete spores but also one poorly preserved bisaccate spore, indicative of a Late Palaeozoic age (Upper Carboniferous or Permian). Genera include:

Densosporites

Lycospora

?*Convolutispora*

?*Dictyotriletes*

?*Knoxisporites*

Locality M174. Grey shaly limestone outcrop in the east bank of the river 10 km WNW of the army station at Amdo [Amdo sheet, grid ref. 63,698E 35,781N]. Bioclastic limestone with almost monotypic accumulation of oyster shells, probably *Nannogyra* (NJM). Jurassic or Cretaceous brackish marine facies [?Zhamunaqu Formation].

Locality M175. As above, slightly upstream. Bioclastic limestone with large erect in situ colony of *Cladocoropsis* (BRR). Upper Jurassic ?Zhamunaqu Formation. Shallow but protected marine facies.

Locality M191.1. Tan mudstone blocks in pink marble outcrops in gullies above the east bank of the river adjacent to and below the thrust plate of red arenites 12.3 km SSW of Erdaogou Station [Erdaogou sheet, grid ref. 64,786E 38,242N].

Palynomorphs (MCB)

Osmundacidites, *Tsugaepollenites*, *Classopollis* and Mesozoic bisaccates suggest a Jurassic – early Cretaceous age.

Locality M201. Pale concretionary (?freshwater) limestones loose on the south slope of an east/west trending ridge, about 16 km SW of Erdaogou Station [Erdaogou sheet, grid ref. 64,786E 38,242N].

Locality M206.5. Low outcrops of pale sands and marls in gullies on west bank of dry stream bed 1.8 km due north of main Lhasa–Golmud road, 17 km NE of the bridge over the Tuotuo River [Yaxicuo sheet, grid ref. 64,625E 38,038N].

Locality M216. Pale concretionary (?freshwater) limestone forming a low outcrop adjacent to the west side of the main Lhasa–Golmud road on south slope of low hill, about 23.2 km WSW of Erdaogou Station [Erdaogou sheet, grid ref. 64,772E 38,071N]. All Neogene lake bed deposits, probably Pliocene in age.

Palynomorphs (MCB)

'These three samples are from different localities but are treated together here because their origin, preservation and taxonomic composition shows they are from the same sequence of deposition, though M201 has very few angiosperms. M216 has the most abundant pollen and the most diverse assemblage. Palynodebris is very rare in all three samples.

'More than 10 specimens of each of the following form genera have been identified in the oxidized preparations (see Jansonius & Hills 1976 for descriptions of these taxa):

Polyodioidites

Pityosporites spp.

Abiespollenites

Piceapollenites

Cedruspollenites

Tsugaepollenites

Inaperturopollenites

Cycadopites

Monocolpopollenites

Graminidites

Tricolpopollenites spp.

Ilexpollenites

Tricolporopollenites spp.

Polyvestibulopollenites

Trivestibulopollenites spp.

Myricipites spp.

Momipites spp.

Chenopodipollis spp.

Ericipites

'As indicated, some of these form genera are represented by many different form species, and there are rarer specimens of other form genera not listed. Comprehensive studies of Neogene pollen and spores have been published from two regions in Asia, N.E. India and eastern China. Though neither is sufficiently close to these Tibetan deposits for ideal geographical comparison, there is sufficient palynological similarity to suggest that these intervening Tibetan samples contain fossils from the same floristic province.

'The Indian and Chinese Neogene assemblages are described by Baski (1971) and Song *et al.* (1985) respectively. These Neogene assemblages have a temperate aspect, lacking sub-tropical taxa, and show surprising similarities with the relatively well described Neogene palynology of Europe. Although there is a distinct Neogene character to the palynology, and an absence of equally distinctive Palaeogene forms, most assemblages have a strong facies-related element, as might be expected for terrestrial deposits. These three deposits may record stages in the development of an inland lake deposit. Upland conifers whose bisaccate pollen were distributed by wind and rivers to the very young lake (M201) were later joined by pollen from plants growing at the edge of the larger lake (M206). It is in this sample that the most diverse assemblage of pollen is preserved. As well as numerous bisaccate pollen from the hinterland conifers, the assemblage includes pollen from plants such as the Taxodiaceae, Betulaceae, Fagaceae and Myricaceae, which may have grown at the edge of the lake.

'The multiporate pollen referred to here as *Chenopodipollis* is enigmatic within such a reconstruction, despite its abundance both in these samples and in those described by Liu & Tang (1980), Song (1981), Sun (1981) and Zheng *et al.* (1981). Zheng *et al.* (1981), Horowitz (personal communication) and others assign such fossil pollen to the Chenopodiaceae, a family whose 75 modern genera are nearly all halophytic. Such plants are abundant today on the salt steppes of eastern Asia and the Himalayas, usually in xerophytic conditions. This is an enigma, because plants from such environments are rarely fossilized. If *Chenopodipollis* really does come from plants of this family, either the pollen was transported some distance from the dry steppes to this lake bed or the Neogene species enjoyed wet habitats just as some modern species (e.g. *Chenopodium rudrum* and *C. botryodes*) do today.

'On the basis of this evidence any age determination more accurate than 'Neogene' is speculative. However, comparing the overall character of these samples with the results of recent Chinese work shows a clear similarity with Pliocene material. Assemblages described by Sun (1981), Liu & Tang (1980), Song (1981) and Song *et al.* (1985) also have a high proportion of Chenopodiaceae-type pollen, which these authors assign to the Pliocene, rather than the Miocene. If this feature is genuinely stratigraphical and not facies related, then it suggests that the above assemblage is also Pliocene in age.'

Locality M225. Grey limestone outcropping as loose fragments on the west shoulder of the hill on the east/west trending ridge, 2 km due south of the main Lhasa-Golmud road, about 32 km SW of Erdaogou Station [Erdaogou sheet, grid ref. 64,686E 38,071N].

Foraminifera (JEPW)

A dolomite with poorly preserved Triassic foraminifera, including *Angulodiscus* (*Involutina auct.*) and *Trochonella* (*Trocholina auct.*). Similar faunas are known from the late Triassic (Norian) of the West Carpathians (Salaj *et al.* 1983) and elsewhere. Age; late Triassic, probably Norian.

Locality M275. Pale lake bed marls outcropping in interfluvium 17.5 km ESE of the Kunlun Pass (just south of the trace of the Kunlun Pass fault) [63rd Station map, grid ref. 66,170E 39,476N]. Probably Pliocene.

Palynomorphs (MCB)

'There is no palynodebris but there are single specimens of *Compositipollenites*, *Pityosporites* and *Graminidites* present. These taxa are also present in the Pliocene assemblages of M201-M206 (see above) and may have come from the northern part of the same lake deposit.'

Locality M335/7. Loose limestone blocks derived locally from mountains 1–3 km to the north in a side valley on the north side of the Dongdatan, 56 km ESE of Naj Tal Station [Reshui sheet, grid ref. 67,007E 39,653N].

Foraminifera (JEPW)

'A bioclastic limestone with abundant smaller Permian foraminifera, including *Hemigordius*, *Pachyphloia*, and *Glomospira*. *Pachyphloia* is not known in earliest Permian and similar species to these are known in Murgabian or equivalent strata of the Tethyan realm. Age; Permian, probably Late Permian but of a different facies than the fusuline-bearing limestones.' (See plate 1, figure 5).

'Another sample contains the fusulines *Kahlerina* and *Nankinella* with an associated foraminiferal fauna including *Bradyina* and *Climacammina*. According to Ross (1967), *Kahlerina* is restricted to the Murgabian; similar species are figured from Tibet by Wang *et al.* 1981 from the Lasaila Limestone. Age; Late Permian, Murgabian [= Kazanian/Ufimian of western workers: = Maokouan of Chinese workers].'

Bryozoans (PDT)

'Thin sections show rhabdomesine cryptostomes, hexactinellid? cystoporates and fistuliporid cystoporates including – *Fenestella* sp. s.l., *Polypora* sp., *Streblotrypa* (*Streblotrypa*) sp. and a cystodictyonid cystoporate cf. *Filiramoporina*. This tends to indicate a Permian age, possibly Lower Permian'. [?Equivalent to the Wanbaogou valley Hongshuichuan Formation].

Locality N20.4. Outcrop of pale marls and silts on eroded eastern face of low hill, 200 m north of dirt road, about 76 km directly WSW of Dongqiao [Dongkaco sheet, grid ref. 62,230E 35,345N].

'Pharyngeal tooth of a Barbine fish, Family Cyprinidae' (CP) and indeterminate fresh water ostracods.

Locality S2.31. A biomicritic, slightly brecciated limestone overlying ophiolites to the west of Nam Lake and south of Gyanco village [no map reference]. In thin section a biomicrite wackestone with oyster and echinoderm debris (including echinoid spines), much of it algal coated and bored, and micromorphic gastropods.

Foraminifera (JEPW & MDS) – 'some large agglutinating foraminifera: a cyclamminid and/or *Haplophragmoides*, and algae. A second specimen contains the foraminifera *Buxicrenata*, *Neotrocholina* and a *Nautiloculina* similar to forms described by Bayliss (1966) from the Bau Limestone of Sarawak (late Jurassic – early Cretaceous).

This specimen also contains algae, determined by GFE and MDS. The algae are a profusion of a *Permodiculus* sp. (very uniform and finely pored, probably a new species), rare *Thaumatoporella parvovesiculifera* (Raineri) Pia and an indet. dasyclad, possibly *Salpingoporella* sp. Age: the algae suggest early Cretaceous but the top Jurassic cannot be ruled out. The foraminifera, on the other hand, support an early Cretaceous pre-Barremian age.'

Locality S2.33. Grey, fine-grained *Orbitolina* limestone 1 km north of the northwest edge of Nam Lake [no map reference]. Langshan Formation; Lower Cretaceous.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone. Embryons are large and advanced with well developed alveolae suggesting *O. (Mesorbitolina)*. Age: early Cretaceous, Albian.' (See plate 1, figure 13).

Locality S2.34. Grey, fine-grained *Orbitolina* limestone outcropping as a shore cliff on the northwestern corner of Nam Lake [no map reference]. Langshan Formation, Aptian/Albian, Lower Cretaceous.

Foraminifera (JEPW & MDS)

'An *Orbitolina*-limestone. Embryons of both *O. (Mesorbitolina)* and *O. (Orbitolina)* are present (species superficially similar to *O. concava*). Age: early Cretaceous, late Albian.'

Locality S2.43. Dense light grey conchoidally fractured limestone lenses in volcanics, probably of a melange type, 1 km south of Amdo.

Foraminifera (JEPW & MDS)

'Contains some foraminifera but preservation is poor; they are probably *Pseudocyclammina* and *Everticyclammina*. Age: late Jurassic or early Cretaceous.'

Locality S142. Limestone 'above' ophiolite in sequence of intersliced and imbricated units by track running N–S on western side of Nam lake [no map reference].

An algal-bound micritic limestone with numerous indeterminate ostracode valves, some indeterminate small foraminifera and algal fragments of *Halimeda* or a related genus (determination by GFE). Age: Not older than Lower Cretaceous.

Locality S144. Limestone near the northwestern corner of Nam lake [no map reference]. Late Jurassic.

A large *in situ* colony of *Cladocoropsis* (BRR).

Locality S149. Outcrop of limestone about 500 m to the east of the track running N–S approximately 5 km due west of Nam lake [no map].

Corals

Locality S154. Bioclastic limestone with foraminifera outcropping 3 km north of the NW edge of Nam Co, overlying red beds. Early Cretaceous: Albian.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone containing *O. (Mesorbitolina)* and *O. (Conicorbitolina)*. Other larger foraminifera include *Daxia*, *Cuneolina*, and *Buccicrenata*. Age: Early Cretaceous, late Albian.'

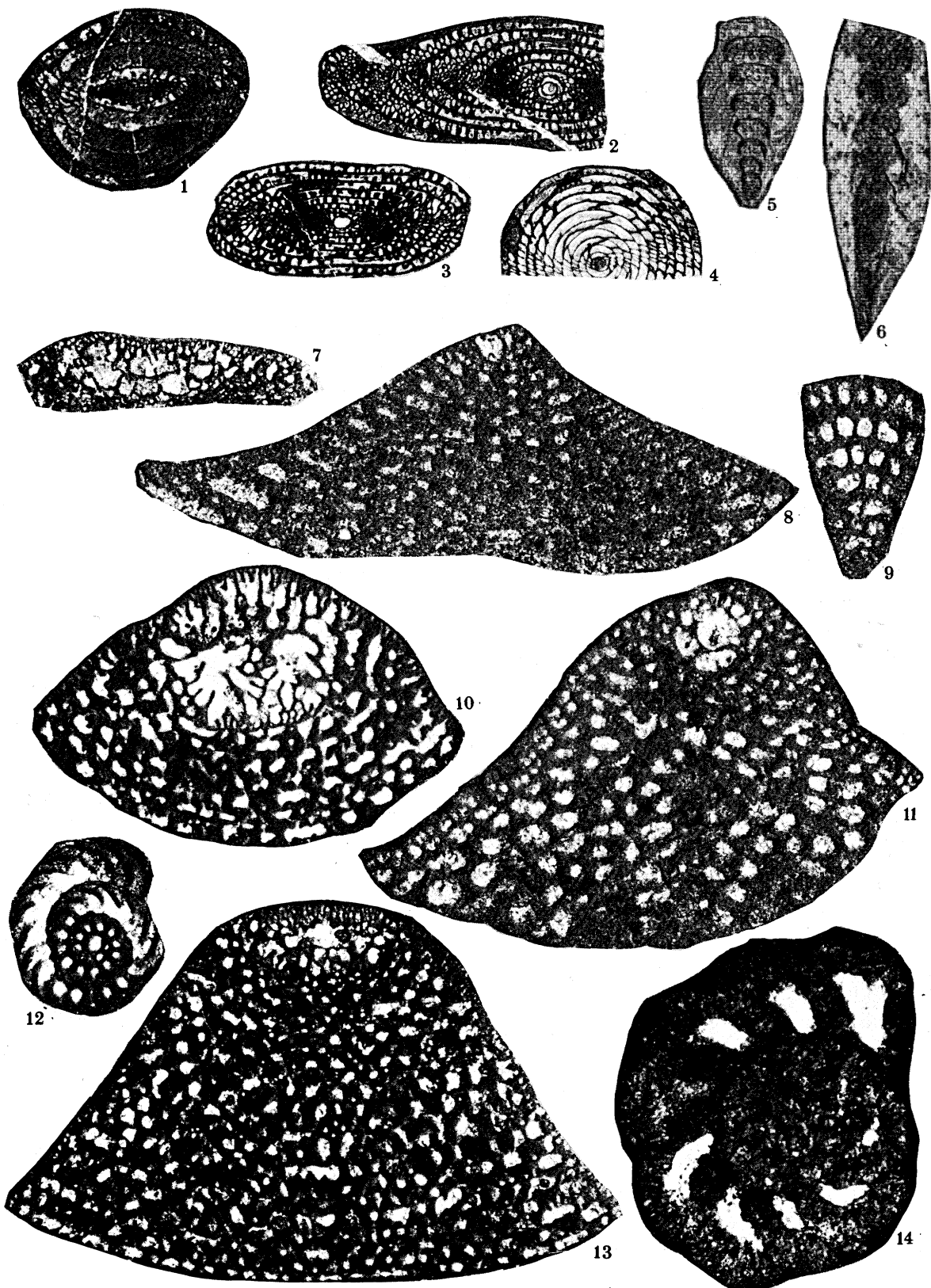


PLATE 1. Some age-diagnostic foraminifera. Late Permian (Maokao stage) fusuline foraminifera. Figure 1. *Rugososchwagerina*. Lobadoi Formation, locality B2, $\times 5$. Figures 2, 3. *Parafusulina* s.l. Kaixinling Group, localities B59 (fig. 2) and B60 (fig. 3), both $\times 5$. Figure 4. *Verbeekina*. Kaixinling Group, locality B60, $\times 5$. Smaller benthic foraminifera. Figure 5. *Pachyphloia*. Dongdatan Valley, Kunlun, locality M335/7, $\times 65$. Figure 6. *Pachyphloia*. Lobadoi Formation, locality B2, $\times 65$.

Some age-diagnostic Cretaceous (late Barremian to late Albian) foraminifera. Figure 7. *Palorbitolinoides*: (embryonic apparatus only). Langshan Formation, locality B25.33, $\times 32$. Figure 8. *Eopalorbitolina*. Langshan Formation, locality B25.72, $\times 80$. Figure 9. *Cuneolina*. Langshan Formation, locality B25.66, $\times 80$. Figure 10. *Orbitolina* (*Mesorbitolina*). Langshan Formation, locality B24, $\times 32$. Figure 11. *Orbitolina* (*Mesorbitolina*). Langshan Formation, locality B25.66, $\times 80$. Figure 12. *Daxia*. Langshan Formation, locality B25.54, $\times 32$. Figure 13. *Orbitolina* (*Mesorbitolina*). Langshan Formation, Nam Co area, locality S2.33, $\times 32$. Figure 14. *Pseudocyclamina*. Xiajiongcuo Formation, locality B30, $\times 32$.

Locality S155. Bioclastic limestone outcropping 6 km north of the NW edge of Nam Co lake and about 3 km south of Shen lake. Early Cretaceous.

Foraminifera (JEPW & MDS)

'An *Orbitolina* limestone; no embryos seen. Age, early Cretaceous.'

Locality S196. A dolomite containing many small foraminifera in a brecciated limestone sequence 4 km SE of Dongqiao [Dongqiao sheet, grid ref. 63,020E 35,415N].

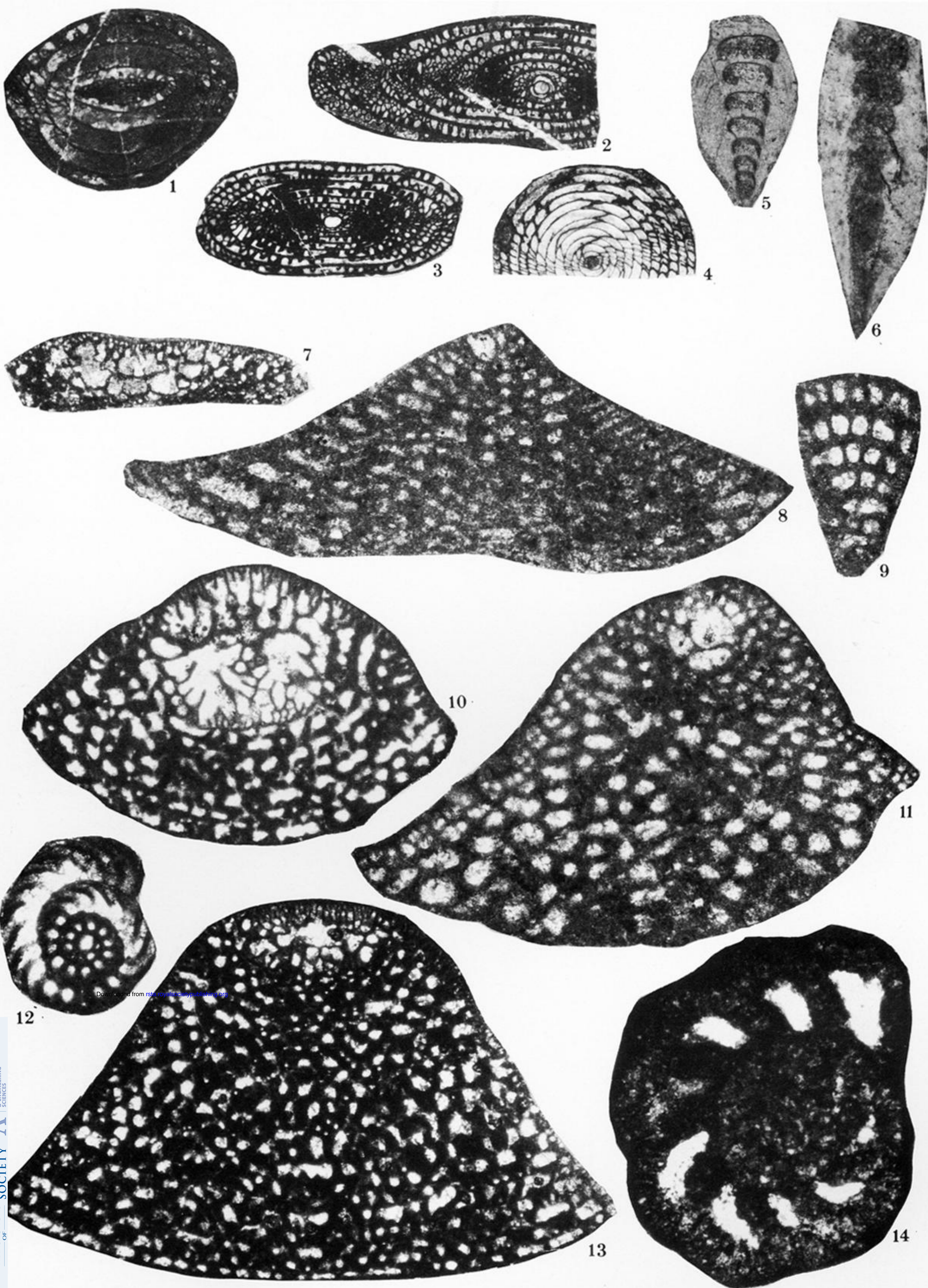
Foraminifera (JEPW)

'Abundant specimens of *Glomospira*. Although this genus has a long range, monotypic faunas like this are usually indicative of early or mid Triassic (see Zaninetti & Whittaker 1980). Age: early or mid Triassic, Scythian or Anisian.'

Locality S304. Outcrop of marl on the western side of the road at a low limestone ridge [Fenghuoshan sheet, grid ref. 65,014E 38,762N]. ?Pliocene lake beds.

Palynomorphs (MCB)

'The oxidized preparation yielded 10 badly preserved bisaccates, most likely Neogene, but no other palynomorphs and more or less no palynodebris. The unoxidized preparation yielded two well preserved specimens of Neogene *Pityosporites* and three or four badly preserved palynomorphs of what may be reworked taxa.'



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Some age-diagnostic Cretaceous (late Barremian to late Albian) foraminifera. Figure 7. *Palorbitolinoidea*: (embryonic apparatus only). Langshan Formation, locality B25.33, $\times 32$. Figure 8. *Eopalorbitolina*. Langshan Formation, locality B25.72, $\times 80$. Figure 9. *Cuneolina*. Langshan Formation, locality B25.66, $\times 80$. Figure 10. *Orbitolina* (*Mesorbitolina*). Langshan Formation, locality B24, $\times 32$. Figure 11. *Orbitolina* (*Mesorbitolina*). Langshan Formation, locality B25.66, $\times 80$. Figure 12. *Daxia*. Langshan Formation, locality B25.54, $\times 32$. Figure 13. *Orbitolina* (*Mesorbitolina*). Langshan Formation, Nam Co area, locality S2.33, $\times 32$. Figure 14. *Pseudocyclammina*. Xiaqiongcuo Formation, locality B30, $\times 32$.