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Endemic Devonian spores from South China, Saudi Arabia and Australia

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Abstract

A spore assemblage from Maoshanxiang, Yunnan, South China includes well known Mid Devonian spores including *Archaeozonotriletes variabilis*, *Cirratriradites monogrammos*, *Grandispora libyensis*, *Geminospora lemurata*, *Cymbosporites magnificus* and *Ancyrospora* spp. which constrain the age to Givetian (late Mid Devonian). There are also elements that occur in the Givetian of South China and Australia such as *Archaeoperisaccus indistinctus* (senior synonym of *A. rhacodes*) that also occur very rarely in Saudi Arabia. The Maoshanxiang assemblage also contains species of *Rotaspora*. In the Adavale Basin of Australia and Saudi Arabia there is a similar plexus of endemic species of *Rotaspora* but of Emsian age. In addition, there is a species of the morphologically distinct spore *Tribojasporites*, a genus that is was only known previously from the Emsian of Australia. The converse also occurs with spores such as *Dictyotriletes biornatus*, only previously known from the late Pragian to mid Emsian of Saudi Arabia, found as rare specimens in Maoshanxiang. This demonstrates that the Maoshanxiang spore assemblage contains spores that are endemic to the northern margin of Gondwana but with younger ranges and represent relict populations that survived in isolation on the South China terrane. Blooms of the hydrodictyacean chlorococcalean alga *Musivum gradzinskii* previously known only from Poland are also present at Maoshanxiang.

Keywords: Devonian, miospores, stratigraphy, China, Saudi Arabia, Australia, biogeography

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1. Introduction

Present day China is an amalgam of terranes. During the Palaeozoic a group of these terranes (e.g., Indochina, North and South China; Xiao et al., 2010 and Fig. 1) were spread across the Palaeo-Asian Ocean including a series of volcanic arcs (the Altaids) that intermittently linked through to Siberia and Kazakhstan (Xiao and Santosh, 2014). These terranes coalesced as part of a continuing series of collisions during the Palaeozoic and early Mesozoic. The distribution of these dispersed terranes and their palaeofloras is of some significance as they acted as gateways (Xu et al., 2012, 2014) for the migration of Devonian plants during the global spread of the first forests.

One key characteristic of the Devonian faunas on these terranes was endemicity that was particularly demonstrated by the highly unusual early Devonian fossil fish from South China (Zhao and Zhu, 2007). Similar endemicity in the plants and spore microfloras is not so obvious although the floras are clearly different (Wang et al., 2007, 2010), generally lacking some major Devonian plant groups (e.g. progymnosperms) and are very much dominated by lycopods.

This contribution focuses on Devonian deposits in Yunnan on the South China Block. Here the younger Mid Devonian (Givetian) spore floras were described in a number of monographs by Lu and Ouyang (1978) and Lu (1980a, 1988) but with few unique morphotypes that are unknown elsewhere in the Devonian. Here we introduce the spore microflora from a new section of the Haickou Formation at Maoshanxiang (Fig. 2) in Yunnan. These are also late Mid Devonian in age but contain a number of distinct morphotypes. We can now understand their significance following the recent publications by colleagues (Al-Ghazi, 2007; Breuer et al., 2007; Breuer and Steemans, 2013; Breuer et al., 2015) on the CIMP Saudi Aramco Project that has filled an information gap on the Arabian Plate. This enables a more detailed comparison of spore ranges and biogeography between Arabia, China and Australia.

2. Material and methods

In 2006 a small set (14) of Haickou Formation samples were collected from a section at Maoshanxiang. When these proved to contain a very interesting assemblage the locality was revisited (2014) and a closely spaced set of 43 samples collected through a measured (Fig. 3) and internally correlated section. These samples were processed by standard palynological methods of 30% HCl to remove carbonates, followed by decant washing to neutral then demineralisation with 60% cold HF. The samples were again washed to neutral and then sieved at 15 μm. Any remaining neoformed fluorides were removed with a single treatment in hot 30% HCl followed by rapid dilution in water and then resieving at 15 μm before storage in a vial. Residues were then mounted in Elvacite 2044 (RI=1.483). Some residues were found to contain AOM so this was preferentially fragmented with a 15 second treatment with a Sonics and Materials ultra-sonic probe followed by resieving at 15 μm to separate the palynomorphs. All the material was at a low level of thermal maturity (generally yellow and orange spore colours) and did not require any oxidation. Selected samples were also top sieved at 150 µm for megaspores which were picked in water under a low power stereoscopic microscope. These picked megaspores were also mounted in Elvacite 2044.

3. The Palynological Assemblage

The palynological assemblage contains a number of distinctive spores that occurred very widely across the Devonian continents. Many of these spores have been used zonally. Although most of their inceptions have only been conodont calibrated in Europe their sequential occurrence (e.g. broadly in the same order between Canada and Australia; McGregor and Playford, 1992) demonstrates that they form the basis of an international zonation. In Maoshanxiang these zonally important spores include *Grandispora libyensis* (Plate 1, Fig. 3) mid Eifelian to ?early Frasnian; Breuer and Steemans, 2013); *Cirratriradites monogrammos* (Plate 1, Fig. 5) with a late Eifelian inception and a range into the mid Givetian (Avkhimovitch et al., 1993); *Archaeozonotriletes variabilis* (Plate 1, Fig. 2) which has an early Givetian inception in Poland calibrated with conodonts (Turnau and Narkiewicz, 2011) and *Cymbosporites magnificus* (Plate 1, Fig. 8) which has an inception within the Givetian (see discussion in Xu et al., 2014). Another important species is *Geminospora lemurata* (Plate 1, Fig. 4; the microspore of the archaeopteridalean progymnosperms) which occurs widely across Euramerica and Gondwana. Although its inception in Euramerica is early Givetian, its conodont/ammonoid calibrated first occurrence in Australia is late Givetian (Grey, 1991, 1992). It occurs very rarely in China, as most assemblages are dominated by a diversity of lycopods to the exclusion of progymnosperms. Also present are both microspores and megaspores with bifurcate tipped processes that belong within *Ancyrospora* spp (Plate 1, Fig. 1). Such bifurcate tipped spores are entirely characteristic of the Mid and Late Devonian. These selected taxa demonstrate a Givetian (~mid-late) age for the Maoshanxiang section.

In addition to these cosmopolitan Devonian spores, there are also local endemics such as *Cereusisporites mirabilis* (Plate 1, Fig. 7) which has a very distinctive sculpture and is only known from Yunnan (Lu and Ouyang, 1978).

Another endemic, but with a broader regional distribution, is *Archaeoperisaccus indistinctus* (Plate 1, Fig. 6) that is not only widely distributed across China (Lu, 1980b; Gao, 1988) including the Altaid Arcs of Xinjiang (Zhu et al., 2008) but also occurs in Australia (Hashemi and Playford, 2005) as both *A. distinctus* and *A. rhacodes*. The latter species can be included within the intraspecific variation of *A. distinctus* found in assemblages from the Haickou which is the type formation for the species (Lu, 1988). *Archaeoperisaccus* has also been reported very rarely from Saudi Arabia (as *A.* cf. *rhacodes*, Breuer and Steemans, 2013) and Iran (Hashemi and Tabe, 2009).

The final group of endemics are those that were only previously recorded from single areas. These include examples from both Saudi Arabia and Australia, the two areas that represent the geographically closest monographed Devonian spore floras to China. Perhaps the most distinctive of these endemic species is *Dictyotriletes biornatus* (Plate 1, Fig. 10) which has the unique characteristic of mural rings being formed from discrete coni. This species has only ever been reported from Saudi Arabia (Breuer et al., 2007; Breuer and Steemans, 2013) where its stratigraphic age range is late Pragian to mid Emsian.

A persistent spore type found within the Maoshanxiang assemblage has a tricrassate morphology (Plate 1, Figs. 15, 16) and, as such, is generally placed within *Rotaspora* spp. These are known from Australia in the Adavale Basin (Hashemi and Playford, 2005) where they form a distinctive element within their Assemblage I that was dated by spores as being Emsian in age. They were also present within Assemblage II (age estimated as Eifelian and early Givetian) when they co-occur with both *Ancyrospora* and *Archaeoperisaccus* but disappear before the inception of *Geminospora lemurata*. A complex of *Rotaspora* species (but placed in *Camarozonotriletes,* e.g. *C. filatoffii* etc.) is also present in the Pragian and Emsian of Saudi Arabia (Breuer and Steemans, 2013) further increasing the regional comparison.

Another very distinctive morphology found in the Maoshanxiang assemblage is a species of *Tribojasporites* (Plate 1, Fig. 11). The genus, previously known only from the Adavale Basin in Australia (Hashemi and Playford, 2005), is characterized by the presence of three annular thickenings centred on the proximal faces. The Australian type species, *T. sajjadiae*, is separable from the new Yunnan species on the detail of the sculpture and occurs only in Adavale Assemblage I of Emsian age.

A common spore within the Maoshanxiang assemblage is *Zonotriletes* sp A (Plate 1, Figs 12-14). This is very variable in morphology and size. It has a flange and typically a distal annulus, on smaller specimens this can be a distal boss. The spore wall within the distal annulus can become detached to give an operculum. This is similar to *Z. armillatus* from the Givetian of Saudi Arabia (Breuer, et al., 2007; Breuer and Steemans, 2013) but is more variable with a less developed flange and the presence of the operculum.

There is a minor marine component present within some samples in the Maoshanxiang assemblage and these are rare acritarchs and much more common scolecodonts. However, at the base of the Haickou Formation (Fig. 3, sample MSX 14/8) there is a thin interval that is dominated by coenobial algae. These (Plate 1, Fig. 9) have the morphology of planar sheets of thin walled equant cells that have a primary element of a 4 coenocyte cluster. As such, they are identical to *Musivum gradzinskii* (Wood and Turnau 2001) a hydrodictyacean chlorococcalean alga described from the late Givetian of Poland. This range was subsequently extended from the Emsian to ?Frasnian (Filipiak, 2014; Turnau, 2011, 2012) but still has only be recognised from Poland. So, the specimens from Maoshanxiang represent a considerable geographical extension. From their local abundance, position within the sequence and presence within a minor mudstone interval in fluvial sediments they represent the results of a coenobial algal bloom within a ‘fresh-water’ pool.

4. Conclusion

The cosmopolitan elements in the assemblage demonstrate that the age is clearly Givetian. In addition, there are regional endemics such as *A. indistinctus* that are present in China, Australia and Saudi Arabia and appear to have similar age ranges. However, it is the new occurrences of endemic spores that are the most interesting. These include spores that were only known previously from either the Adavale Basin in Australia (*Tribojasporites*) or Saudi Arabia (*Dictyotriletes biornatus*) where they have restricted and older ranges that do not overlap with the age of the Maoshanxiang assemblage.

These endemics from Maoshanxiang are not regarded as reworked since they are compatible in spore colour and preservation with the other elements in the Maoshanxiang assemblage. They also contrast in colour to spores from the underlying early Devonian Cuifengshan Formation.

This can be understood in the context of the Devonian palaeogeography of South China (Fig. 4). Previous studies of palynology in South China compared to Xinjiang (Xu et al., 2012, 2014) has shown there was limited ability of the plants to migrate between the different isolated terranes. Given that in both Australia and Saudi Arabia these endemic spores do not occur in the overlying Eifelian and Givetian sequences that occur in both areas then the Maoshanxiang records represent range extensions, i.e. these are rare forms that have survived in relative isolation into the Givetian. These endemic spores have also not yet been reported from other Givetian palynological assemblages from South China so have a restricted distribution within Yunnan and represent rare ‘Emsian’ relicts both within the flora and within the region. The immediate palaeogeography of the field locality (Fig. 4, Cai and Zhang, 2009) was a carbonate shelf with isolated islands (on basement highs) surrounded by an apron of clastic sediments. The geographical pattern of these islands also changed through the Devonian (Cai and Zhang, 2009) when it was driven by the interplay of tectonic movements, sediment supply and Devonian sea level. Fig. 4 can only be a time-averaged imperfect synthesis and, in reality, there would be many smaller islands. It is such a setting that populations of the relict plants would survive on these isolated islands. Our understanding is further complicated by the fact that most of the Devonian sections in South China are relatively thin and hence we don’t yet have a single section succession that demonstrates the complete sequence of palynological events through the Mid Devonian.

However, these results clearly emphasise the need to undertake systematic studies of pre-Givetian sections within South China to track the inception, development and decline of these endemics in comparison to the related East Gondwana sections in Saudi Arabia and Australia. Importantly it shows that the hitherto unknown Emsian spore assemblages from South China are likely to resemble those of both Australia and Saudi Arabia. The palynological assemblages from Australia and Saudi Arabia are all from sub-surface material and the macroplant floras are essentially unknown. Conversely in South China there are many described Early Devonian fossil plants (e.g., Hao and Gensel, 2001) but few co-preserved palynofloras. This at least gives some clues as to the identity of these unknown Australian and Saudi Arabian floras.

In addition, these emerging similarities in Emsian palynofloras between Saudi Arabia, South China and Australia show that the latter is not an isolated endemic microflora but part of a distinct floral province with shared palynological elements.

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Fig. 1. Location of Maoshanxiang (MSX) on the South China Block. It is one of a series of isolated terranes within Palaeotethys that links northern Gondwana to Siberia. The location of the Devonian spore assemblages from Australia (Adavale Basin) and Saudi Arabia are also shown. Kaz, Kazakhstan; T, Tarim. Map from Domeier and Torsvik (2014).

Fig. 2. Location of Maoshanxiang in Yunnan, China. The locality is off the X027, Luda Road. The insert map of China has Yunnan shaded grey.

Fig. 3. Simplified stratigraphic section for the Haickou Formation from Maoshanxiang, showing location of selected samples.

Fig. 4. Mid Devonian palaeogeography of Yunnan from Cai and Zhang (2009). Land is shaded grey with the clastic apron stippled. The carbonate facies are not shown for simplicity. Maoshanxiang is MSX. Other studied sections with Mid Devonian spores are shown: Yangliuhe, YLH; Longhuashan, LHS; Xujiachong, XJC; Yuguangcun, YGC.

Plate 1. Mid Devonian spores from Maoshanxiang, Yunnan, China. The scale bars represent 10 µm. All spores are followed by a sample and slide number and England Finder reference. All figured specimens are in the collections of NIGPAS, Nanjing. Fig. 1. *Ancyrospora* sp, MSX14-24, pick 1, G21/1. Fig. 2. *Archaeozonotriletes variabilis*, MS09, V46. Fig. 3. *Grandispora libyensis*, MS12, F31/2. Fig. 4. *Geminospora lemurata* MS09, S49/4. Fig. 5. *Cirratriradites monogrammos*, MS09, X41/4. Fig. 6. *Archaeoperisaccus indistinctus*, MS09, U48/1. Fig. 7. Ceres, MSX14-25 pick 1, E25/2. Fig. 8. *Cymbosporites magnificus*, MS09, R35/1. Fig. 9. *Musivum gradzinskii*, MSX14-8, Q35/1. Fig. 10. *Dictyosporites biornatus*, MS09, O41/2. Fig. 11. *Tribojasporites* sp, MS09, L46. Fig. 12. MS12, F32/2. Fig. 13. MS09, V35. Fig. 14. MS09, G30/4. Fig. 15. *Rotaspora* sp, MS09, Q38. Fig. 16. *Rotaspora* sp, MS09, X33/3.

Appendix Cited spores and alga
Archaeoperisaccus rhacodes Hashemi and Playford 2005
Archaeoperisaccus indistinctus Lu 1988
Archaeozonotriletes variabilis (Naumova) Allen 1965
Camarozonotriletes filatoffii Breuer et al., 2007
Cereusisporites mirabilis Lu and Ouyang 1978
Cirratriradites monogrammos (Arkhangelskaya) Arkhangelskaya 1985
Cymbosporites magnificus (McGregor) McGregor and Camfield 1982
Dictyotriletes biornatus Breuer et al., 2007
Geminospora lemurata (Balme) Playford 1983
Grandispora libyensis Moreau-Benoit 1980
Rotaspora spp.
Tribojasporites sajjadiae Hashemi and Playford 2005
Zonotriletes armillatus Breuer et al., 2007

Musivum gradzinskii Wood and Turnau 2001