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PALYNOLOGICAL EVENTS IN THE MISSISSIPPIAN (LOWER CARBONIFEROUS) OF EUROPE, NORTH AFRICA AND NORTH AMERICA

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ABSTRACT

Mississippian miospore assemblages are strongly affected by floral provincialism, resulting in major compositional differences between the various regions in the Northern Hemisphere. Nevertheless, six major palynological events can be recognised which may be relevant to the correlation of the Mississippian. In ascending order, these are: 1-the extinction of *Retispora lepidophyta* approximately at the Devonian/Carboniferous boundary, 2-the first appearance of *Spelaeotriletes pretiosus* in the middle Tournaisian, 3-the first appearance of *Lycospora pusilla* (uppermost Tournaisian - basal Viséan), 4-the first appearance of *Tripartites vetustus* (upper Viséan), 5-the first appearance of monosaccate pollen (lowermost Namurian), and 6-the extinction of *Tripartites vetustus* and *Rotaspora* spp. (lower Namurian - E_{2b}). Limited, independent, biostratigraphic control suggests that the six events are essentially synchronous over considerable distances.

INTRODUCTION

The establishment of floral provinces during the Early Mississippian resulted in major differences among miospore assemblages of similar age from the various regions of the Northern Hemisphere (SULLIVAN, 1965, 1967; CLAYTON 1985). The Lower Mississippian *Vallatisporites* Microflora has been recognised in the Midcontinent U.S.A., Atlantic Canada, Western Europe, southern and central Poland, the Donets Basin, Tibet and northern China. The broadly contemporaneous *Lophozonotriletes* Microflora encompassed western Canada, Spitsbergen, Bear Island, northern Poland and the northwestern parts of the U.S.S.R. The *Vallatisporites* and *Lophozonotriletes* microfloras are succeeded in the same regions by the Upper Mississippian *Grandispora* and *Murospora* microfloras, respectively. The latter microflora also occurs in the Canadian Arctic Archipelago.

A very different Mississippian microflora, the *Spelaeotriletes balteatus* Microflora, was described from North Africa and the Middle East (CLAYTON, 1985), though its name should now be changed to the *Aratrisporites saharaensis* Microflora, following the erection of this taxon by LOBOZIAK *et al.* (1986) to accommodate spores which had previously been incorrectly assigned to *Spelaeotriletes balteatus*. The Mississippian Kazakhstan microflora is poorly known, and is not considered further here.

In the following discussion of significant events in the Mississippian, emphasis is placed on the *Vallatisporites* and *Grandispora* microfloras. Events which can be recognised within these microfloras may permit correlation of the Dinantian and lower Namurian regional stages of Western Europe, and of sequences in Atlantic Canada, Eastern Europe, Tibet and central China with Mississippian reference sections once the latter have been studied in sufficient detail.

This paper briefly outlines the main changes in palynological associations through the Mississippian in Europe, North Africa and North America, based mainly on detailed investigations in Canada, Western Europe, Poland and North Africa. The locations of the sections discussed are shown in Fig. 1. Many of the palynological events described are first appearances of species rather than genera or suprageneric groupings, and are subjective in nature. They are described in the following section in ascending stratigraphic order.

PALYNOLOGICAL EVENTS

1. Extinction of *Retispora lepidophyta* (KEDO) PLAYFORD. This event, which can be recognised worldwide and appears to be totally independent of facies, is one of the most prominent breaks in the Upper Palaeozoic miospore succession. Other taxa which disappear at this

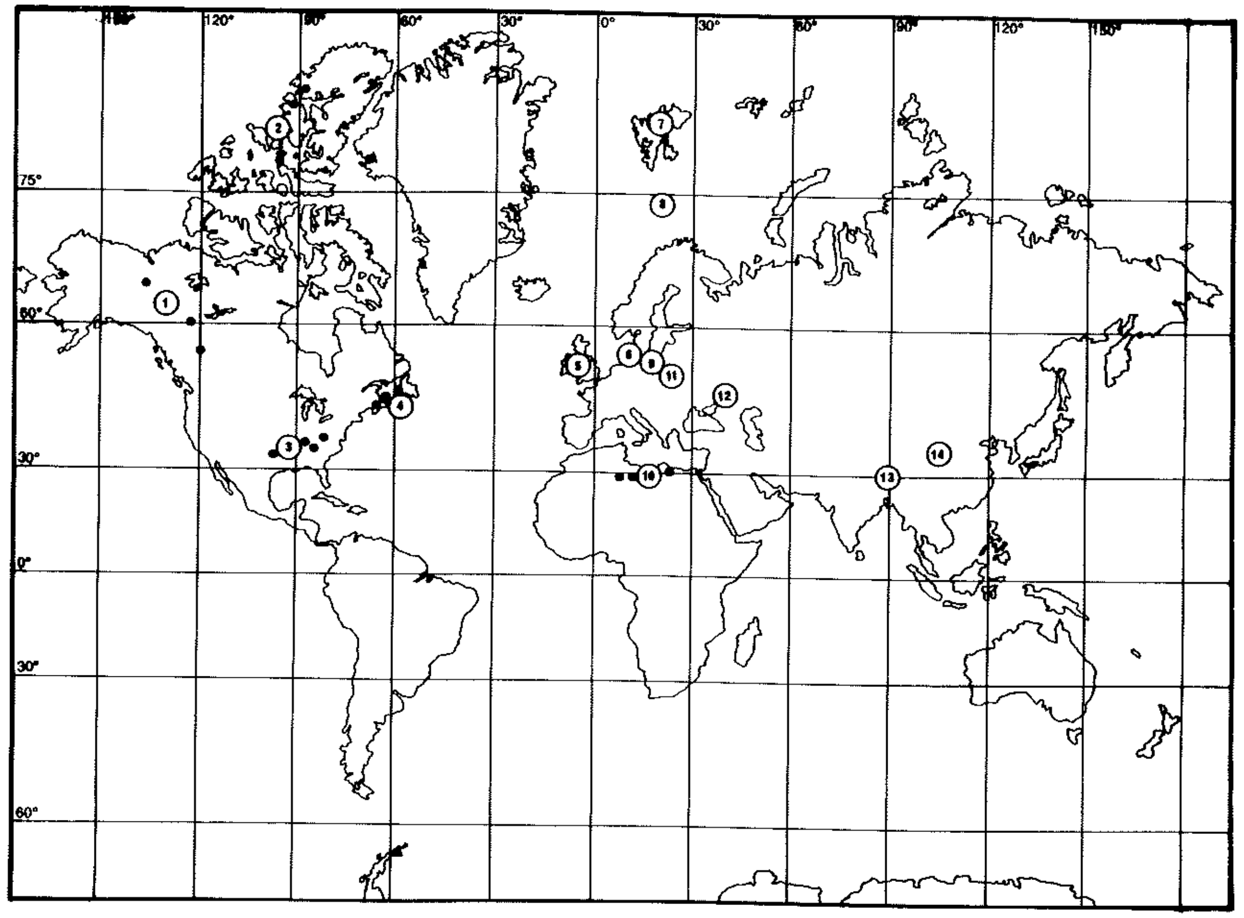

Fig. 1. Localities discussed in the text: (1) western Canada, (2) Canadian Arctic Archipelago, (3) midcontinental U.S.A., (4) Atlantic Canada, (5) British Isles, (6) Falster (Denmark) and Rugen (Germany), (7) Spitsbergen, (8) Bear Island, (9) northern Poland, (10) North Africa, (11) Warsaw - Lublin area, (12) Donets Basin, (13) Nyalam (Tibet), and (14) Gansu Province (China). Widely separated locations or basins discussed collectively (*e.g.*, western Canada) are shown by dots on the map.

level include *Vallatisporites hystricosus* (WINSLOW) BYVSHEVA, HIGGS & STREEL 1984. In Western Europe, the disappearance of *R. lepidophyta* appears to be more or less coincident with the Devonian/Carboniferous boundary (PAPROTH & STREEL, 1972; BYVSHEVA *et al.*, 1984; HIGGS & STREEL, 1984). In other regions, independent biostratigraphic control is more limited, or totally absent, but there is nothing to suggest that the timing of this event differs substantially in age from Europe.

Basal Carboniferous miospore assemblages (VI Biozone of CLAYTON *et al.*, 1977) in Western Europe are typically impoverished in composition, consisting of relatively long-ranging taxa which survived from the Strunian (HIGGS *et al.*, 1988). Similar assemblages of low diversity have been recorded from the Kinderhookian in Kentucky (COLEMAN & CLAYTON, 1987).

2. First appearance of *Spelaeotriletes pretiosus* (PLAYFORD) NEVES & BELT emend. UTTING. In Western Europe, *Spelaeotriletes pretiosus* first appears within the middle Tournaisian (CLAYTON *et al.*, 1978). This taxon also appears in Atlantic Canada in sections dated as middle or possibly upper Tournaisian (UTTING, 1987; UTTING, KEPPIE & GILES, 1989) and in the Kinderhookian/lower Osagean of the midcontinental United States (COLEMAN & CLAYTON, 1987).

In northern Poland, *S. pretiosus* first appears in deposits assigned to the middle Tournaisian (TURNAU, 1975, 1978; CLAYTON & TURNAU, in press). In North Africa, the first appearance of *S. pretiosus* immediately follows the disappearance of *R. lepidophyta*, suggesting a condensed section in the uppermost part of the lower Tournaisian and in the lower middle Tournaisian, though independent dating is lacking (LOBOZIAK & CLAYTON, 1988; COQUEL & LATRECHE, 1989).

3. First appearance of *Lycospora pusilla* (IBRAHIM) SOMERS. *Lycospora pusilla* and morphologically related species of the same genus were microspores produced by the arborescent lycophyte *Lepidodendron*. The first appearance of *Lycospora pusilla* is undoubtedly one of the most significant events in terms of Mississippian plant evolution.

The species first appears at, or close to, the Tournaisian/Viséan boundary in the British Isles (NEVES *et al.*, 1972; CLAYTON *et al.*, 1978), and in the uppermost Tournaisian in the Donets Basin of the U.S.S.R. (OWENS *et al.*, 1978). Macrofaunal and microfaunal correlation of the successions in these regions with the Belgian stratotype is, however, extremely tenuous. *L. pusilla* is present in strata dated as early Viséan in the Baltic islands of Falster, Denmark (BERTELSEN, 1972) and Rügen, Germany (BURMANN, 1975). In northern Poland, it first appears in sections poorly dated as early Viséan, though in this region its initial occurrences are very rare (TURNAU, 1978). The first appearance of *L. pusilla* in Spitsbergen is in rocks which lack any stratigraphically diagnostic fauna (PLAYFORD, 1962, 1963). *Lycospora pusilla* is not present in reasonably diverse miospore assemblages from the lower Osagean of Kentucky (COLEMAN & CLAYTON, 1987), but was recorded from the upper Osagean (Keokuk Limestone equivalent) of Tennessee (HOROWITZ *et al.*, 1979).

The species first appears at the base of the Naxin Formation in Nyalam, Tibet, which is dated on faunal evidence as late Tournaisian to early Viséan (GAO, 1989). In Gansu Province, northern China, *L. pusilla* first occurs in the lowermost Viséan (GAO, 1985).

In Atlantic Canada, *L. pusilla* first appears in rocks of late middle to late Viséan age, though these are separated from the underlying late Tournaisian by an hiatus or by red beds lacking palynomorphs (UTTING, 1987; UTTING, KEPPIE & GILES, 1989). It occurs commonly in the late Viséan of western Canada and the Canadian Arctic Archipelago (BAMBER *et al.*, 1989; UTTING, JACHOWICZ & JACHOWICZ, 1989). In western Canada this species has also been recorded in early to middle Viséan rocks (BRAMAN & HILLS, 1977; RICHARDS *et al.*, in press), although early Viséan beds in this region have yet to be studied in detail.

In North Africa, the first appearance of *L. pusilla* was considered by MASSA *et al.* (1980), COQUEL *et al.* (1988), LOBOZIAK & CLAYTON (1988) and COQUEL & LATRECHE (1989) to occur only in the late Viséan. However, there is no reliable palaeontological evidence to prove the existence of middle Viséan strata in this region.

4. First appearance of *Tripartites vetustus* SCHEMEL. *Tripartites vetustus* appears to be restricted geographically to the *Grandispora* Microflora, but its first appearance is nevertheless considered significant since it may enable correlation between the Midcontinent U.S.A., Western Europe, Donets Basin and Gansu, China. The species first appears at the base of the late Viséan Brigantian Stage in Scotland and northern England (CLAYTON *et al.*, 1978). Other taxa which typically first appear with *T. vetustus* are *Rotaspora fracta* (SCHEMEL) SMITH & BUTTERWORTH, *R. knoxi* BUTTERWORTH & WILLIAMS, *Grandispora spinosa* HOFFMEISTER, STAPLIN & MALLOY, and *Savitrisporites nux* (BUTTERWORTH & WILLIAMS) SMITH & BUTTERWORTH. In the Warsaw - Lublin area, *T. vetustus* and *R. fracta* first appear in the late Viséan, though older Carboniferous rocks are absent (KMIECIK, 1979, 1986).

In Atlantic Canada *Grandispora spinosa* appears in rocks believed to be late Viséan (UTTING, 1987). *Rotaspora fracta* occurs in the late Viséan of western Canada and the Canadian Arctic archipelago (BAMBER *et al.*, 1989; UTTING, JACHOWICZ & JACHOWICZ, 1989).

5. First appearance of monosaccate pollen. The Dinantian/Silesian boundary cannot easily be recognised on palynological evidence in Europe, since no taxa consistently appear or disappear precisely at the boundary. However, several taxa do appear sporadically in basal Namurian sections including *Crassispora kosankei* (POTONIE & KREMP) BHARADWAJ, *Cirratriradites saturni* (IBRAHIM) SCHOPF, WILSON & BENTALL, *Proprisporites laevigatus* NEVES and the monosaccate pollen *Florinites* spp. and *Potonieisporites elegans* (WILSON & COE) WILSON & VENKATACHALA. Of these, the monosaccate pollen taxa are considered the most significant, since they first appear at broadly comparable stratigraphic levels (lower Namurian or lower Serpukhovian) in the *Monilospora* and *Aratrisporites saharaensis* microfloras.

In Western Europe, *Potonieisporites elegans* first appears at the base of the Pendleian Stage, with *Florinites* spp. first occurring within the Arnsbergian. The latter first appear together with *Cirratriradites saturni* and *Proprisporites* spp. in the Donets Basin, though *Crassispora kosankei* is present in the late Viséan (OWENS *et al.*, 1978). *Florinites* spp. occur in the late Chesterian part of the Springer Formation of Oklahoma together with *Rotaspora fracta* (FELIX & BURBRIDGE, 1967).

In the Rhadames Basin of Libya, *P. elegans* and *Florinites similis* KOSANKE first appear together in early Serpukhovian strata correlated with the Pendleian (COQUEL *et al.*, 1988). Monosaccate pollen also appear within the

Serpukhovian of Atlantic Canada (*P. elegans*) and western Canada (*Florinites* spp.) (NEVES & BELT, 1971; UTTING, 1987; BAMBER *et al.*, 1989; RICHARDS *et al.*, in press).

Slightly contradictory reports have been published on the lower Namurian palynology of Gansu Province, northern China. According to GAO (1987), *Potonieisporites elegans* first appears with *Florinites millotii* BUTTERWORTH & WILLIAMS within the upper part of the E_2 Zone at the type section of the Yushuliang Formation in Jingyuan County. Other taxa present in this unit include *Crassispora kosankei, Proprisporites laevigatus* and *Tripartites vetustus*. LI *et al.* (1987) recorded *T. vetustus* through E_1 and E_2 in the Tsingyuan (Jingyuan) Formation at Ciyao, also in the Jingyuan area, but noted the absence of gymnosperm pollen (including *P. elegans* and *Florinites* spp.). The Yushuliang and Tsingyuan formations are possibly synonymous, and the sections described in the above two publications may be the same, or at least in close proximity to each other (P. BRENCKLE, 1990, personal communication). In both studies the sections appear to have been firmly dated by means of ammonoids and/or conodonts.

6. Extinction of *Tripartites vetustus* and *Rotaspora* spp. In Western Europe, the typically upper Viséan taxa *Tripartites vetustus* and *Rotaspora* spp. disappear abruptly within the Arnsbergian Stage (E_{2b}). The youngest published records of these taxa in North America are from the late Chesterian Hardinsburg Formation of southern Illinois and western Kentucky (HOFFMEISTER *et al.*, 1955) and from the Springer Formation of Oklahoma (FELIX & BURBRIDGE, 1967).

CONCLUSIONS

Approximate correlation of the Devonian/Carboniferous boundary can be effectively achieved using the extinction of *Retispora lepidophyta*. The mid-Tournaisian (upper Kinderhookian/Osagean) first appearance of *Spelaeotriletes pretiosus* has potential for inter-regional correlation at this stratigraphic level, though independent control is limited. The first appearance of *Lycospora pusilla* is an important palaeobotanical event which approximates to the Tournaisian/Viséan boundary. Occurrences of *Tripartites vetustus* are geographically restricted to the U.S.A., Western Europe, Eastern Europe and China, but its first and last appearance in the upper Viséan and lower Namurian (E_{2b}), respectively, may prove valuable for correlation of Chesterian divisions among these regions. The incoming of monosaccate pollen, notably *Florinites* spp. and *Potonieisporites elegans*, in the basal Namurian is an event which can be recognised in all of the regions discussed. The main obstacle to further progress in palynological correlation of the Mississippian is the current lack of data from the U.S.A., especially from the type Mississippian.

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AUSTRALIAN LOWER CARBONIFEROUS MIOSPORES RELEVANT TO EXTRA-GONDWANIC CORRELATIONS: AN EVALUATION

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ABSTRACT

In this Australian-based survey of globally distributed Early Carboniferous (Mississippian) miospores, a number of taxa are identified, in terms of their consistency of stratigraphic appearance or disappearance, as being of actual or potential significance in correlating Southern Hemisphere strata beyond the Gondwana realm. The exit of *Retispora lepidophyta* (KEDO) PLAYFORD 1976 appears to be a ubiquitous palyno-event, consistently marking the Devonian–Carboniferous boundary. Within the Mississippian, the ranges of the following are regarded as chronologically significant in both Northern and Southern Hemispheres: *Dibolisporites distinctus* (CLAYTON) PLAYFORD 1976, *D. acritarchus* (NEVILLE) PLAYFORD & SATTERTHWAIT 1986, *Tricidarisporites* spp., *Diatomozonotriletes* spp., *Cordylosporites papillatus* (NAUMOVA) PLAYFORD & SATTERTHWAIT 1985, *Knoxisporites ruhlandii*/cf. *ruhlandii* DOUBINGER & RAUSCHER 1966, *Raistrickia clavigera* (SULLIVAN) PLAYFORD & SATTERTHWAIT 1986, *Tumulispora rarituberculata* (LUBER) PLAYFORD n. comb., *Retusotriletes mirabilis* (NEVILLE) PLAYFORD 1978, and *Waltzispora polita* (HOFFMEISTER, STAPLIN & MALLOY) SMITH & BUTTERWORTH 1967. The palynological data are suggestive of floral regionalism during the Early Carboniferous, while still providing evidence of cosmopolitan distribution of some elements of the spore-producing land vegetation. In the systematic section of the paper, the widespread, Strunian-lower Visean species *Hymenozonotriletes explanatus* (LUBER) is newly combined with *Indotriradites* TIWARI 1964, and several other new combinations are instituted. The acavate apiculate/biformate genus *Umbonatisporites* HIBBERT & LACEY 1969 is reaffirmed as a junior synonym of *Dibolisporites* RICHARDSON 1965.

INTRODUCTION

This paper was originally solicited by the Chairman of the SCCS Lower Carboniferous/Mississippian Boundaries Working Group (Dr. Paul BRENCKLE) as a survey of palynomorph taxa that occur in Southern Hemisphere Lower Carboniferous (Mississippian) strata and offer scope for international correlation (*i.e.*, of and within that interval). The focus of the paper is on Australian palynofloras, inevitably so because very little has been forthcoming from the older part of the Carboniferous System elsewhere in the Southern Hemisphere. Moreover, the palynomorphs discussed are entirely miospores. Many of the Australian sequences that have been studied palynologically are of marine origin (and hence dated on independent faunal grounds), but their acritarch content is minimal in comparison with the profuse miospore component. Megaspores, too, are of rare occurrence (PLAYFORD, 1986b).

In the systematic section, the taxonomy and morphological characteristics of 23 widely distributed miospore taxa (all but two of specific rank) are reviewed and illustrated on Plates 2–4; complete synonymy listings (or references to same) are provided, together with distribution (geographic/stratigraphic) summaries for each of the taxa. Figs. 1 and 2 depict known vertical ranges of the miospore taxa in Australian and Northern Hemisphere deposits, respectively. A selection of species that are not certainly known outside the Australian Lower Carboniferous is illustrated on Plate 1 to emphasize the predominantly endemic complexion of the Australian palynofloras.

The combination of attributes that places spore–pollen palynomorphs at the forefront of stratigraphically important microfossils, in the correlation of both continental and nearshore marine sedimentary rocks, needs no reiteration here. So far as the Carboniferous is concerned, miospores are well-established as zonal indices, particularly in western and northern Europe, in the Soviet Union, and in North America. In Australia, Carboniferous palynological studies were inaugurated appreciably later (BALME, 1960) than in the Northern Hemisphere, but have since progressed considerably,