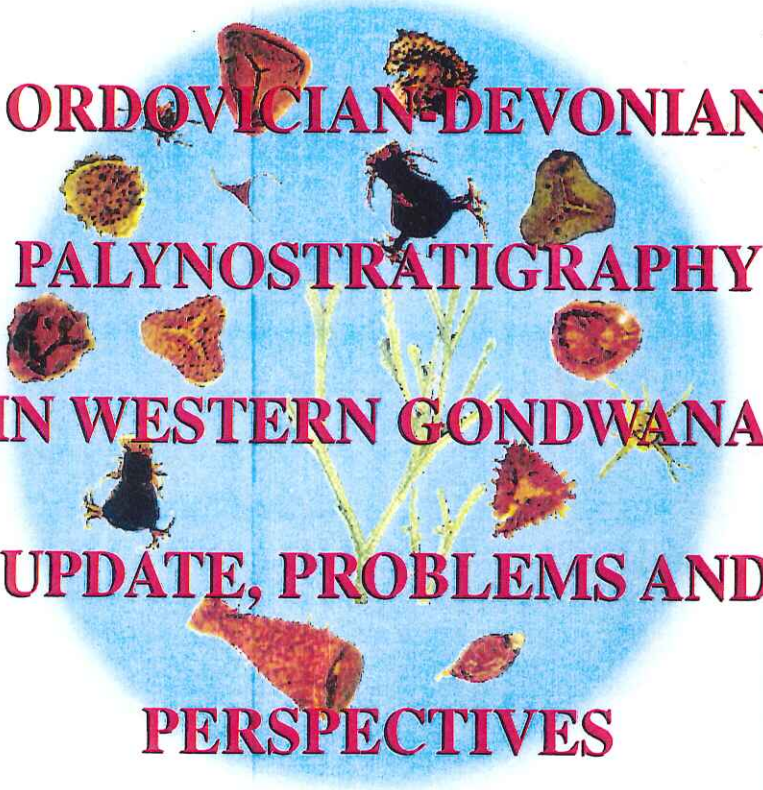
ORDOVICIAN-DEVONIAN PALYNOSTRATIGRAPHY IN WESTERN GONDWANA: UPDATE, PROBLEMS AND PERSPECTIVES



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Ordovician - Devonian Palynostratigraphy in Western Gondwana

Chapter 1

Ordovician to Lower Devonian cryptospore/trilete spore stratigraphy in Western Gondwana and correlation with type sequence in Western Europe.

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The most convincing evidence of the presence of flora on the continents, or/and at the edging of the continents, since the Ordovician is currently given by the sporomorphs - the cryptospores and the spores. On the other hand, the oldest plant remains are not known below the Llandovery (Edwards and Selden, 1993). These plants are increasingly abundant through the Silurian, but they start really to be diversified since the Devonian.

The oldest cryptospores, in the Llanvirn, were found in Saudi Arabia (Strother *et al.*, 1996) and in Tchekia (Vavrdova, 1984; Vavrdova, 1990). All morphological types of cryptospores are already there: monads, dyads and tetrads, enclosed or not enclosed in a membrane. Then, both stratigraphically, from the Caradocian to the Llandovery, and geographically, from high to low latitudes, the sporomorph assemblages are all very similar in composition

(Richardson, 1996b; Steemans, in press). The capacity of the first plants which produced these palynomorphs to survive under very different climatic conditions seemingly allowed them to be moderately affected by the Hirnantian glaciation, contrariwise to the majority of the other fossils groups.

The cryptospore biodiversity is decreasing through the Llandovery to reach a minimum value during the Telychian and the Sheinwoodian (fig. 1). Again, the cryptospores are diversified during the Homerian. Then, their biodiversity decreases progressively until the Lochkovian, with a minimum value during the Gorstian. The cryptospores almost completely disappear during the Lochkovian, where only the most primitive species survive.

The oldest trilete spores income during the Ashgillian in Turkey (Steemans *et al.*, 1996) and rare species appear during the Thelychian (Al-Ameri, 1980; Richardson, 1996b; Wellman *et al.*, 1998a). As the cryptospores during the Homerian, the trilete spores increase in biodiversity. This biodiversification is increasingly amplified during the Late Silurian and the Devonian.

The cryptospores evolved rapidly during the post-Llandoverian periods, contrariwise to previous periods. The cryptospores and trilete spores respect the same evolution scheme but with a lag. The cryptospores develop first new morphologies. The morphology of some cryptospores and trilete spores is identical excepted the presence of a trilete mark in the case of the trilete spores. The biodiversity curve of the cryptospores is approximately parallel to the global sea level curve (Kaljo *et al.*, 1995). The impoverishment in species during the Llandovery corresponds to a highstand. The diversification of the spores and the cryptospores during the Homerian corresponds to a lowstand. The Gorstian transgression corresponds to an impoverishment in species. The data are too inaccurate to distinguish stratigraphically the assemblages of highstand and lowstand during the Ludfordian. In return, though the oceans regress during the Pridoli and the Lochkovian, most of the cryptospores are disappearing during the Lochkovian, contrariwise the trilete spores.

Lacustrian sediments from UK, close to the Siluro-Devonian boundary, contain an assemblage rich in cryptospores and poor in trilete spores (Wellman

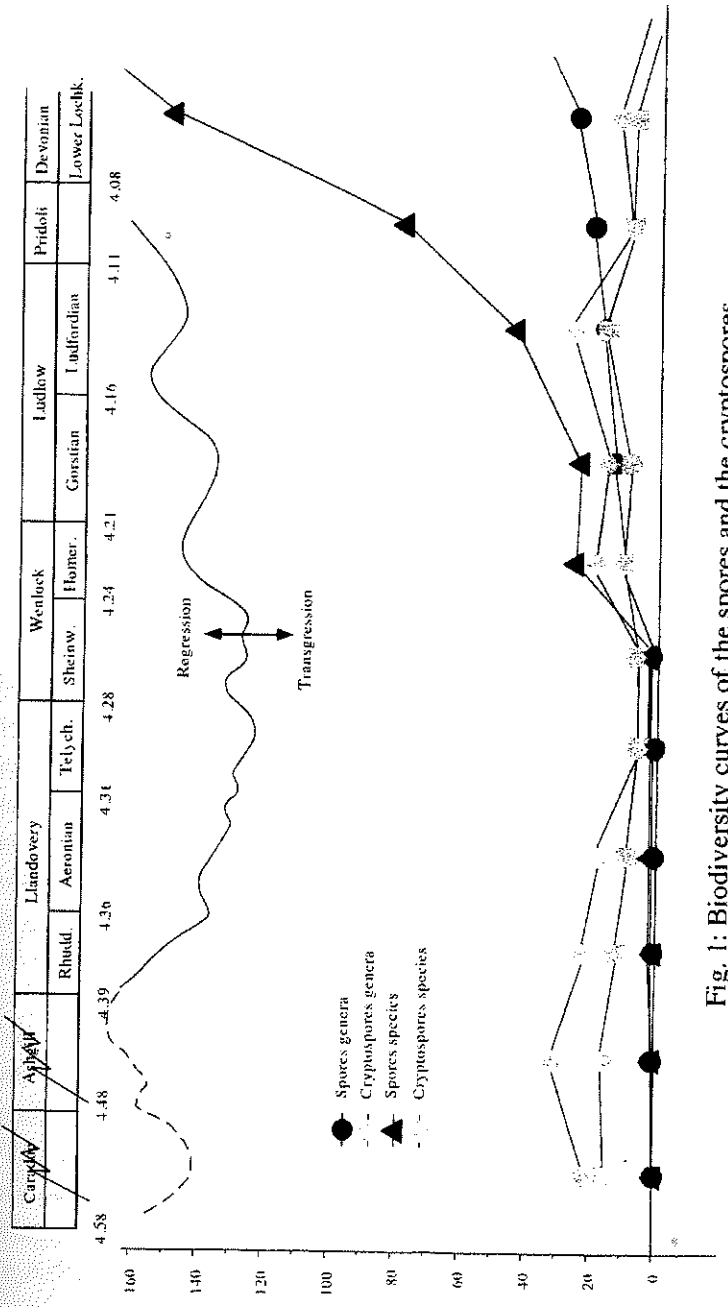

Fig. 1: Biodiversity curves of the spores and the cryptospores compared with the global sea level curve.

and Richardson, 1996). This observation is in contradiction with the general biodiversity curve. Marine coeval sediments from Libya contain a similar assemblage in which the trilete spores are largely dominant (Rubinstein *et al.*, in preparation). These contradictory data, associated to the biodiversity curve, allow to suggest a model for the terrestrialization of the first plants. The cryptospore producing plant would be dependent to the sea level, because they stay associated to the coastal aquatic biotopes. The trilete spores producing plants would be progressively independent from this environment.

Thanks to these cryptospores and spores it is possible to propose a stratigraphic scale from the Late Ordovician to the Lower Devonian. Meanwhile, the stratigraphic resolution of the biozones and the possibility to do correlations by means of them are very different during this range of time. Indeed, the Lower Devonian is studied since the sixties in many different regions, whereas the sporomorphs from the Ordovician and the Silurian are studied only since twenty years and the number of publications on that matter is still low.

There is too few data in the Early Ordovician to propose biostratigraphic data in this range of time. Except for minor changes, the assemblages of cryptospores and spores are very similar from the Caradocian to the middle part of the Llandovery (Richardson, 1996b; Steemans, in-press; Wellman, 1996). These assemblages are largely dominated by cryptospores: monads, dyads and tetrads. These sporomorphs can be enclosed in a membrane, ornamented or not. A same ornamentation can occur on each of these three type of cryptospores. The relative proportion of cryptospores enclosed in a membrane is decreasing throughout the Llandovery and they become very rare in younger sediments. Generally, the cells of the tetrads and dyads are tightly adpressed and do not dissociate as in younger Silurian sediments. The only monads observed, *Rugosphaera* excepted, are those where the monads result of physically broken polyads

The Ordovician - Silurian boundary is included in the *Nodospora* sp. A - *murusdensa* (Richardson, 1988) or in the *murusdensa - murusattenuata* Assemblage Biozone (Richardson and Edwards, 1989). This biozone ranges from the Ashgill to the Rhuddanian (fig. 2). This biozone is overlain by the

avitus - dilutus Biozone (Burgess, 1991; Richardson, 1988; Richardson and McGregor, 1986),? late Rhuddanian to early Telychian, and by the *chulus - nanus* Biozone (Burgess and Richardson, 1991; Richardson, 1996b; Richardson and McGregor, 1986; Wellman *et al.*, 1998a), late Telychian to Homerian. These two last biozones are characterized respectively by the incoming of the genera *Ambitisporites* and *Archaeozonotriletes* and the absence of cryptospores enclosed in a membrane.

Rare true trilete spores (*Ambitisporites avitus - dilutus*) were discovered in the Ashgillian from Turkey (Steemans *et al.*, 1996) but associated with abundant cryptospores enclosed in a membrane contrary to UK assemblages. On that base, the *Velatitetras - Ambitisporites* Biozone, Hirnantian to the Early Aeronian, has been created. Above this biozone, a new *avitus - dilutus* Biozone was defined by the presence of *Ambitisporites* and the absence of cryptospores enclosed in a membrane. However, new data demonstrated that these cryptospores enclosed in a membrane are also known in younger sediments, until the early Lochkovian (Burgess and Richardson, 1995; Richardson, 1996a; Wellman and Richardson, 1996; Wellman *et al.*, 1998b). These cryptospores are progressively less abundant throughout the Llandovery.

Therefore, existing biostratigraphical scales should not be used anymore. Two of the most important events, in the range of time here considered, are the appearance of *A. avitus - dilutus* in the Hirnantian and true *L. divellomedia* in the Rhuddanian. The oldest *A ? vavrdovae* incomes in the Ashgillian from Turkey and Libya (Richardson, 1988 ; Steemans *et al.*, 1996) below the first incoming of *A. avitus-dilutus*. *A ? vavrdovae* is also observed in the Caradocian from Libya, from the Melez Chograne Formation, but the age provided by the authors is based on poor data (Gray *et al.*, 1982).

As said before, the base of the *vavrdovae* Interval Biozone is not well known. Likewise, the base of the Subbiozone ß of this Interval Biozone is unclear because based on the incoming of the very rare first trilete spore : *Ambitisporites*. There is no type outcrop to define the base of the *divellomedia* Interval Biozone, dated as Hirnantian or Rhuddanian. The Subbiozone α of this Interval Biozone is characterized by the presence of abundant cryptospores enclosed in a membrane and rare trilete spores. On the contrary, in the

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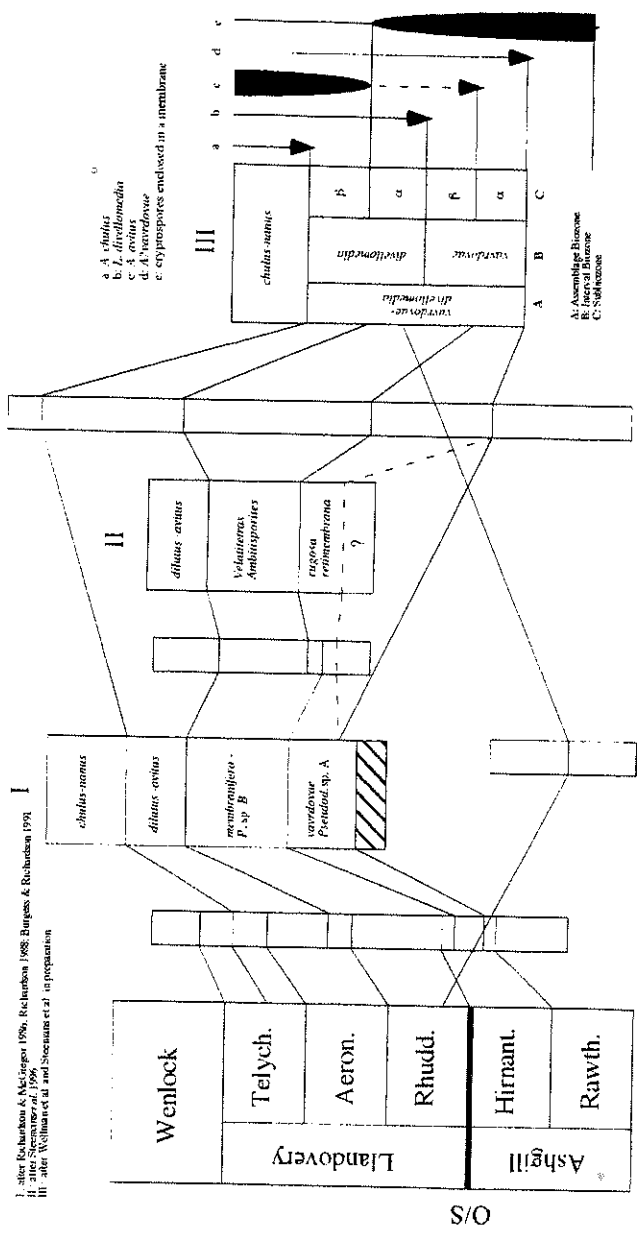

Fig. 2 : Biostratigraphic scale around the O/S boundary

Subbiozone ß, the trilete spores are more abundant and cryptospores enclosed in a membrane rare. These last data are still unpublished but based on results from the literature (Steemans *et al.*, 1998 ; Wellman *et al.*, 1998a).

The *chulus-nanus* Biozone (Richardson and McGregor, 1986) is characterized by these two trilete spores species and by rare cryptospores enclosed in a membrane. There are few species in this biozone. Its base is probably Hirnantian.

The *brevicosta- verrucatus* Biozone (Richardson and McGregor, 1986) is characterized by the incoming of these two nominal cryptospores. Three sub-zones can be recognized. The base of the *brevicosta* Assemblage Sub-Zone (Burgess and Richardson, 1995), in the type Wenlock area, is situated in the *lundgreni* Graptolite Biozone. The base of the *lamontii* Assemblage Sub-Zone (Burgess and Richardson, 1995), in the type Wenlock area, is situated in the earliest *nassa* Graptolite Biozone. The base of the *protophanus* Assemblage Sub-Zone (Burgess and Richardson, 1995) is not well known but there is some evidence in favor of a latest Homerian age.

The *downiei - saggitarius* Assemblage Zone (Burgess and Richardson, 1995) is characterized by the disappearance of the nominal species of the *brevicosta - verrucatus* Assemblage Biozone and the appearance of the nominal species of this new biozone. The age of the base of this biozone is either latest Homerian or Gorstian.

The *libycus - poecilomorphus* Assemblage Zone (Richardson and McGregor, 1986) is subdivided in four Assemblage Sub-Zones. The base of the *obscura* Assemblage Zone is probably Gorstian in age. The base of the *cambrensis* , *asperata* and *inframurinata* Assemblage Sub-Zones are Gorstian or Ludfordian in age. None of the Assemblage Sub-Zones in the *brevicosta-verrucatus* and *libycus-poecilomorphus* have been verified elsewhere than in the regions where they were defined.

The base of the *tripapillatus - spicula* Assemblage Zone (Richardson and McGregor, 1986) is usually considered as characterizing the Ludlow-Pridoli boundary but this interpretation is not substantiated by good biostratigraphic data (fig. 3).

The Biozones A and *Apiculiretusispora* sp. E (Richardson and

Edwards, 1989) are not clearly defined and their stratigraphical range has still to be precised. Both are probably Pridolian in age. The top of the last one could be Lochkovian. A considerable gap in recovery separates both.

The base of the MN Biozone in the Old Red Sandstones region (Richardson and McGregor, 1986 ; Steemans, 1989; Streel *et al.*, 1987) characterized the lower part of the Lochkovian. But data obtained in Libya (Al-Ameri, 1980 ; Rubinstein *et al.*, in preparation) show that some species on which this biozone is based could appear earlier, in the late Pridoli of the Gondwana plate.

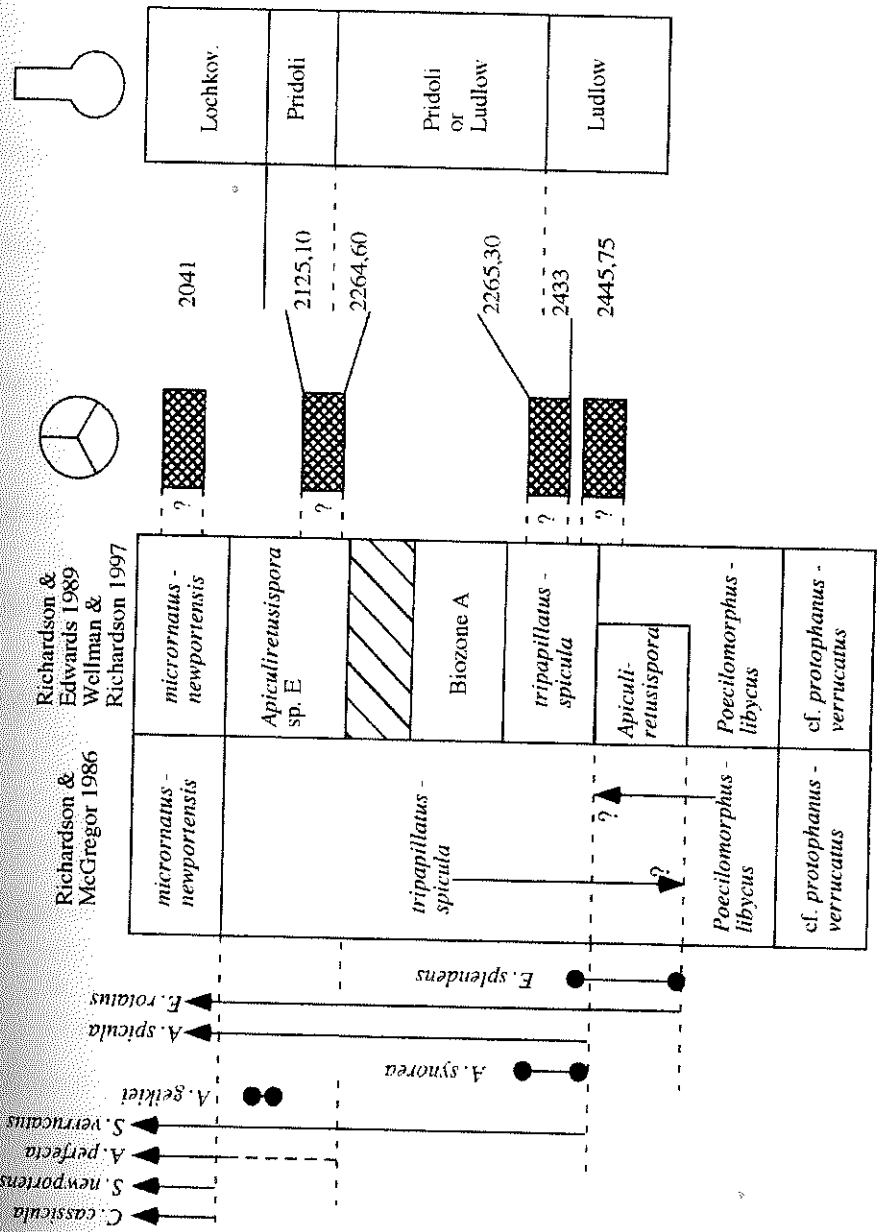

Fig. 3 : Biostratigraphic scale around the S/D boundary (Rubinstein et al., in preparation)

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