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Limitations on the application of the Devonian standard conodont zonation

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The most commonly used Lower and Middle Devonian conodont zonations that sometimes have been presented as standard zonations are evaluated. The author questions whether the Frasnian standard conodont zonation based on a phylogenetic succession of species belonging to the pelagic genera *Mesotaxis*, *Palmatolepis* and *Siphonodella* can be used for worldwide correlation. He favours the idea of an international conodont reference scale based on a synthesis of well established and documented conodont successions (with figured specimens of first and last occurrences of index-species) from key areas representing a variety of facies. Graphic correlation is likely to be the most objective and precise method to provide such a synthesis represented by the composite standard. Such standards have been already elaborated for the Frasnian and the Middle Devonian. This point of view does not imply that classical biozonations should be abandoned.

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INTRODUCTION

"… in the case of biostratigraphic units, it must be kept in mind that out of the almost limitless number of overlapping biozones that could be proposed, the first to be described is not necessarily the most useful. This means that workers must continually be free to propose new zones or to improve previous proposals in both scope and nomenclature..." (Salvador, 1994).

The second edition of the IUGS International Stratigraphic Guide (Salvador, 1994) does not mention the term "standard zonation". However, a glossary includes the term "standard zone" but this is considered as a biostratigraphic term with limited or no acceptance. In Devonian biostratigraphy the terms standard zonation/standard zone are most commonly used by conodont workers (e.g. Ziegler and Sandberg, 1990) and ammonoid workers (e.g. Becker and House, 2000). In these two papers a standard zonation implies, to a greater or lesser degree, that standard zone-defining fossils occur worldwide or at least have an interbasinal distribution. The methods for establishing a standard zonation and the opinion on the palaeogeographic dispersal potential of the index-species are different in the two papers. Strictly speaking, for the Devonian there is only a formally named and described standard conodont zonation for the uppermost Givetian and the Upper Devonian, from the *disparilis* to the *praesulcata* Zone (Ziegler and Sandberg, 1990, text-fig. 1) and these authors also stress that it is a zonation for the pelagic biofacies. Sandberg and Ziegler (1996, text-figs. 1a, b) clearly indicate that they only recognize standard zones in the uppermost Givetian and Upper Devonian and not in the other parts of the Middle Devonian and in the Lower Devonian. However, in the past, commonly used Lower and Middle Devonian conodont zones have been assembled in zonations, occasionally headed "standard zonation" (e.g. Clausen *et al*., 1993).

THE DEVONIAN STANDARD CONODONT ZONATION

LOWER DEVONIAN

The Lower Devonian part of the standard zonation in Clausen *et al*. (1993) should certainly not be considered as such. This is clearly demonstrated by several new Lower Devonian zones that have been introduced since 1993 (e.g. Yolkin *et al*., 1994, Emsian; Valenzuela-Rios and Murphy, 1997, Lochkovian; Bardashev *et al*., 2002, Pragian–Emsian; Slavik, 2004, Pragian; Murphy, 2005, Pragian). The two last-mentioned authors introduced new zonations because the application of the 1993 standard zonation to the areas that they studied, the Barrandian and Nevada, is problematic. The zonally defining species of these two new Pragian zonations have a limited inter-regional distribution. Application on a global scale of the zonations introduced by Yolkin *et al.* (1994) and Bardashev *et al.* (2002) is also problematic because there is no general agreement between conodont workers on the taxonomy of the upper Pragian–Emsian polygnathid index-species they used (e.g. Mawson, 1997; Murphy, 2005). Considering a specific Lower Devonian standard zone, Valenzuela-Rios (1997) stressed that the precise stratigraphic level of the base of the upper Pragian *pyreneae* Zone is unknown and that the species is not well characterized. So it is obvious that there is at present no global Lower Devonian zonation on which there exists a large agreement, as would be a normal requirement for employing the term "standard".

MIDDLE DEVONIAN

Several zonally defining Middle Devonian species (e.g. *Polygnathus partitus*, *P. costatus*, *Tortodus australis*, *T. kockelianus, P . ensensis*, *P. timorensis*) have a wide geographical distribution, occur in deeper pelagic and shallower neritic sequences and were used to establish a Middle Devonian standard zonation (Weddige, 1988). In the same contribution, however, Weddige wrote that these standard zones are useful for inter-regional correlations but are too "rough" for detailed correlations in smaller areas with similar facies as for instance the neritic Ardenno-Eifelian area. So he introduced alternative zonations for that area as refinements of the standard zonation (ibidem, text-fig. A14-18/11).

Graphic correlation of 9 neritic Middle Devonian successions from the Ardenne area (Gouwy and Bultynck, 2003) and 9 successions from the Mader (pelagic to neritic facies) — Tafilalt (pelagic-hemipelagic facies) region in Southern Morocco (Belka *et al*., 1997; Gouwy and Bultynck, 2002) resulted in the construction of an Ardenne and a Mader-Tafilalt regional composite (RC). The graphic correlation of the Ardenne RC with the Mader-Tafilalt RC (Gouwy and Bultynck, 2002) demonstrates that first occurrences of some conodont species, including also zonally defining species, can be diachronous comparing the first occurrences in the two regional composites. Klapper (1997) had stressed already through graphic correlation of Frasnian sequences in Montagne Noire (MN, France) and Western Canada that the entries of some zonally defining species of the classic-biostratigraphic Frasnian MN zones can be "diachronous to a considerable degree in different sections of the Frasnian Composite Standard".

Bultynck (1987, fig. 9) introduced an alternative zonation for the *varcus* Zone as defined and subdivided by Ziegler *et al.* (1976). This alternative zonation is based on a hemipelagic succession in the northern Tafilalt (Southern Morocco) and in ascending order consists of the *timorensis* Zone (= lower part of Lower *varcus* Subzone), *rhenanus*/*varcus* Zone (= upper part of Lower *varcus* Subzone), *ansatus* Zone (= Middle *varcus* Subzone minus uppermost part) and *semi-alternans*/*latifossatus* Zone (= uppermost part of Middle *varcus* Subzone and Upper *varcus* Subzone) (Fig. 1).

The use of Lower, Middle and Upper *varcus* subzones is well established in Devonian conodont literature. But in my view, the alternative zonation provides a higher stratigraphic resolution than the *varcus* Zone and its subdivisions and reflects better the most important changes in the conodont species of that part of the Givetian.

In the first place, *Polygnathus varcus* itself is not the critical species for recognizing the base of the Lower *varcus* Subzone. According to the definition of Ziegler *et al.* (1976) it is defined by the first occurrence of *Polygnathus timorensis*. From the distribution tables in that paper it appears that *P. varcus* first occurs well above the base of the zone, in the North American sections studied it occurs only in a few samples and there is not any figured specimen of the species in the paper. Huddle (1981) did not recognize it in the Givetian of New York. This was the main reason for replacing the Lower *varcus* Subzone by the *timorensis* Zone and the *rhenanus*/*varcus* Zone. Ziegler *et al.* (1976) regarded *P. timorensis* as a senior synonym of *P. rhenanus* " because the latter seems to have been based on a juvenile specimen of *P. timorensis*". I agree that the holotype of *P. rhenanus* is not a fully adult specimen but Bultynck (1987, pl. 7, figs. 13–15) figures adult specimen of *P. rhenanus* that can be easily separated from adult specimens of *P. timorensis* (ibidem, pl. 7, fig. 9) by the very long blade and the short, clearly asymmetrical platform, due to the prominent outward bowing of the outer anterior trough margin. Johnson *et al*. (1980) and Klapper (1981) introduced a late form of *P. timorensis*, specifying that it corresponds exactly with *P. rhenanus* as established by Klapper *et al*. (1970). However, the latter species is still used by several conodont workers and figured e.g. Sparling (1999, including synonym list), García-López and Sanz-Lopez (2002) and Kaufmann (1998). So the use of *P. rhenanus* is preferred herein to the long-winded wording " *P. timorensis* late form".

In North America the late form of *Polygnathus timorensis* vel *P. rhenanus* first occurs in the "Middle *varcus* Subzone" (Johnson *et al*., 1980; Sparling, 1999).

Johnson *et al.* (1980) recorded the "late form of *P. timorensis*" and *P. ansatus* in the uppermost part of the Lower Member of the Denay Limestone in central Nevada, assigned to the "Middle *varcus* Subzone". However, there is an important interval without conodont records that may belong either to the "Middle *varcus* Subzone" or to the "Lower *varcus* Subzone". This interval corresponds to the "Lower *varcus* Subzone regression (upper If)" recognized in the upper part of the Lower Member of the Denay Limestone in central Nevada and consists of dolomites.

In north-central Ohio, Sparling (1999) recorded *P. rhenanus* and *P. ansatus* from the Prout Dolomite, assigned to the "Middle *varcus* Subzone". However, in that area there is an important disconformity between the Prout Dolomite and the Plum Brook Shale assigned to the *ensensis* Zone. The delayed first occurrence of *P. rhenanus* in North America may be due to the unfavourable dolomite rocks in central Nevada and the disconfomity in north-central Ohio.

Rogers (1998, fig. 7) recognized the "Middle *varcus* Subzone" in Iowa by the presence of the zonally defining *Polygnathus ansatus* and was not able to recognize specifically *P. varcus* and only mentioned "*P. varcus* group", a bucket term that is commonly used in the Givetian for polygnatids with a small platform and long blade. In the "Middle *varcus* Subzone" of north-central Ohio Sparling (1999) recognized *P. ansatus* and *P. rhenanus*, both figured, but no *P. varcus*. So in my view "*ansatus* Zone" is a more appropriate name for that biostratigraphical interval than "Middle *varcus* Subzone".

Ozarkodina semialternans first occurs in the uppermost part of the "Middle *varcus* Subzone" and the first occurrence of *Schmidtognathus latifossatus* defines the base of the "Upper *varcus* Subzone". However, in the southern Moroccan sections *O. semialternans* is common to abundant and *Schm. latifossatus* is rare. This is also the case in other areas (Aboussalam, 2003, p. 13). For that reason Bultynck (1987) introduced the *semialternans*/*latifossatus* Zone, its base being only slightly older than the base of the "Upper *varcus* Subzone". Moreover, in the Middle Devonian Composite Standard resulting from graphic correlation of sections in Southern Morocco (Gouwy and Bultynck, 2002), there is little difference in composite standard units for the entries and last occurrences of *O. semialternans* (139, 19–140, 11) and *Schm. latifossatus* (139, 50–140, 42).

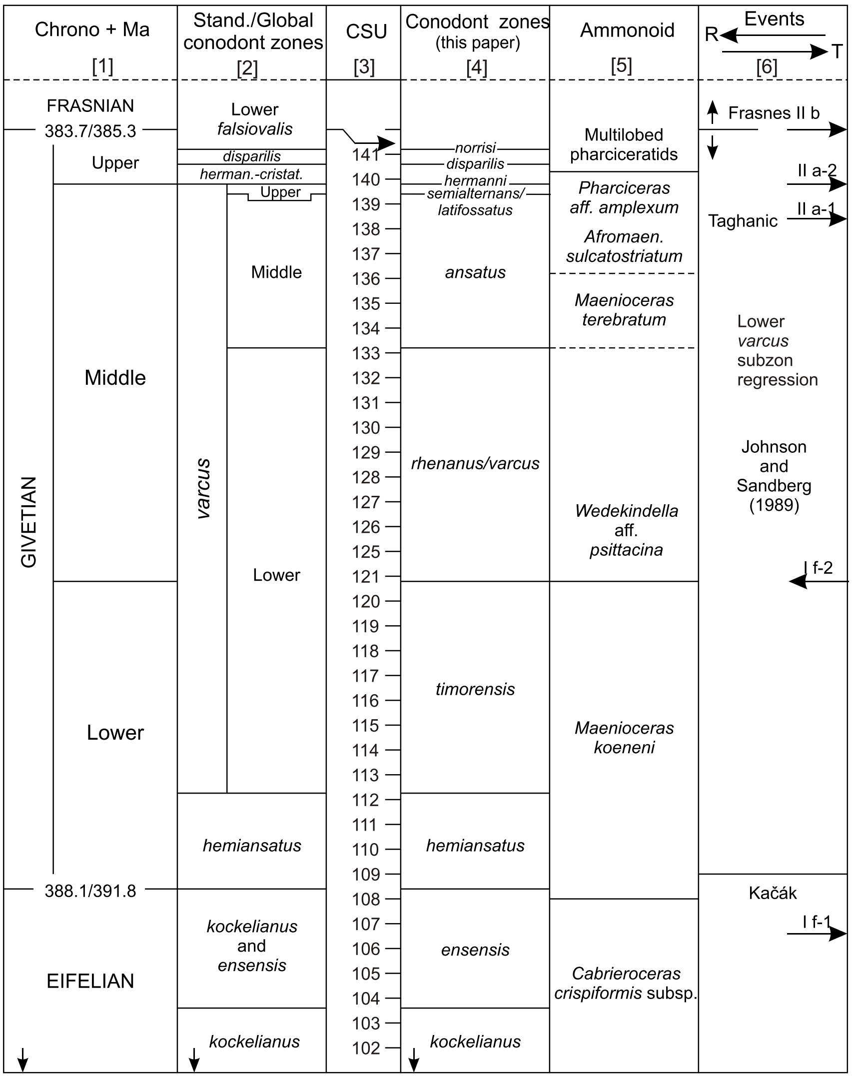

Fig. 1. Chronostratigraphic subdivision of the Givetian, correlation of Givetian conodont zonations and correlation with the composite standard units of a Middle Devonian Composite Standard, ammonoid zones, transgressive-regressive cycles and events

1 — subdivision of the Givetian adopted by the Subcommission on Devonian Stratigraphy (Leicester meeting, 2006); age of the stage boundaries: left number, Gradstein *et al*. (2004); right number, Kaufmann (2006); 2 — zonation based on Clausen *et al*. (1993) and Weddige and Ziegler (1996); 3 — scale in composite standard units based on Belka *et al*. (1997), Gouwy and Bultynck (2002, 2003); the reference section for the Givetian CS is Bou Tchrafine in the northwestern Tafilalt, Southern Morocco (Bultynck 1987; Bultynck and Walliser 2000); 4 — the *semialternans*/*latifossatus*, *ansatus*, *rhenanus*/*varcus*, *timorensis* and *hemiansatus* zones have been introduced by Bultynck (1987); the index-species have been illustrated in Bultynck and Hollard (1980) and Bultynck (1987); 5 — after Becker and House (2000); Bou Tchrafine; 6 — trangressive–regressive (T–R) cycles after Johnson *et al*. (1985) and Johnson and Sandberg (1989)

FRASNIAN

Ziegler and Sandberg (1994) emphasized the advantages of using species belonging to the pelagic genera *Mesotaxis*, *Palmatolepis* and *Siphonodella* for their "Late Devonian standard conodont zonation" (1990). (1) These evolved and could be distributed worldwide in such a short time that they seemed to appear synchronously in the geological record; (2) they are less affected by physico-chemical influences; (3) they evolved more rapidly and produce a finer time scale than do species belonging to shallower water species.

The two first-mentioned assertions are at least partly contradicted by more recent studies on Devonian ammonoids, a group with a pelagic lifestyle (Becker and House, 2000). They stressed that only a few Devonian ammonoid species are really cosmopolitan and that generally, the occurrence of Devonian ammonoids shows more facies influence than was recognized in the past. They also referred to the historical German Devonian ammonoid succession that was used as a standard for worldwide correlation and that actually "has hindered biostratigraphic progress significantly and for long time". As a result of their observations Becker and House (2000) recognized different regional zonations on the basis of which they reconstructed an idealized scheme of standard zones, which may not occur in all regions.

In a comment on the Devonian Standard Conodont Scale (Clausen *et al*., 1993), Johnson (1993) wrote: "This mode of expression, employing the term "Standard", has become commonplace in the absence of critical review, the very thing that could validate its use".

Constraints on the Frasnian standard conodont zonation (FrSCZ) for the pelagic biofacies are discussed herein under four items.

RECOGNITION OF THE STANDARD ZONATION IN PELAGIC FACIES

In pelagic facies the FrSCZ cannot be recognized worldwide. Conodont workers who have tried to apply the FrSCZ to pelagic successions in different parts of the world have been faced with the same problems as mentioned by ammonoid workers, e.g. an absence of marker species of the standard zonation, different ranges for some marker species, endemic species and so on. They established alternative zonations not exclusively based on *Mesotaxis* and *Palmatolepis*.

The best known is the Montagne Noire conodont succession (S France) established by Klapper (1989), and including the MN zones 1 to 13. The pelagic characteristics of the Frasnian deposits in the area are summarized in Feist and Klapper (1985) and Morzadec *et al*. (2000). The Montagne Noire zonation has been applied with success to successions in widely separated areas: the Eastern Canadian Cordillera (Uyeno, 1991); Western New York (Kirchgasser, 1994; Kralick, 1994); the Timan-Pechora region of the East European Platform (Klapper *et al*., 1996; House *et al*., 2000); the Canning Bassin, Western Australia and Alberta Rockies (Klapper *et al*., 1995); Western Canada (McLean and Klapper, 1998); the Rhenish Slate Mountains-Martenberg, the reference section for the FrSCZ from the *punctata* Zone to the Lower *rhenana* Zone (Klapper and Becker, 1999); northern Tafilalt, Southern Morocco (Bultynck and Walliser, 2000; Becker and House, 2000).

Ovnatanova *et al*. (1999) established a succession of 11 conodont assemblages for the entire Frasnian of the southern Timan-Pechora Province belonging to the northeastern part of the East European Platform. The middle Frasnian (base corresponding to the base of their Assemblage IV with *Palmatolepis punctata*, *Palm*. *gutta*, *Ancyrodella gigas*, *Mesotaxis johnsoni*, *Polygnathus timanicus* and *P. vjalovi*) and upper Frasnian are represented by slope and basinal deposits with rich palmatolepid and goniatite faunas. *Palmatolepis hassi* does not occur and *Palm*. *jamieae* only occurs in an interval above the last occurrence of *Palm*. *semichatovae* and below the first occurrence of *Palm*. *linguiformis*, so in a younger stratigraphic position than it should be according to the FrSCZ. In the southern Timan-Pechora Province there occur also several *Palmatolepis* species that are unknown from the FrSCZ. House *et al*. (2000) proposed a correlation with the MN zonation. The correlation with the MN zones 1, 2 and the boundary between MN zones 12 and 13 are problematic.

BIOSTRATIGRAPHIC RESOLUTION OF *MESOTAXIS* AND *PALMATOLEPIS*

Species belonging to the genera *Mesotaxis* and *Palmatolepis* do not always provide the highest biostratigraphic resolution. The uppermost Givetian–lower Frasnian (*falsiovalis* Zone/*norrisi* Zone and MN zones 1 to 4) are characterized by the evolutionary radiation of the genus *Ancyrodella* (e.g. Bultynck, 1983; Klapper, 1985; García-López, 1986; Sandberg *et al*., 1989; Kralick, 1994). In this part a dozen short-ranging valid *Ancyrodella* species can be recognized (*binodosa*, *pristina*, *rotundiloba*, *crosbiensis*, *alata*, *rugosa*, *recta*, *triangulata*, *pramosica*, *africana*, *gigas*) and in some of the species different morphotypes can be distinguished. Their succession provides a much higher stratigraphic resolution than the succession within the genera *Mesotaxis* and *Palmatolepis*. *Mesotaxis ovalis*, *falsiovalis* and *asymmetricus* range from the uppermost Givetian/lowermost Frasnian into the middle Frasnian and the radiation of *Palmatolepis starts* well above the base of the middle Frasnian. Another advantage of *Ancyrodella* taxa is that they occur in both pelagic and neritic facies. So for the uppermost Givetian–lower Frasnian a zonation based on and named after *Ancyrodella* taxa provides a better international biostratigraphic reference scale than the FrSCZ and reflects the most striking event of conodont evolution in that period. Bultynck (1986, p. 276) advocated the replacement of the Lower *asymmetricus* Zone by *Ancyrodella* zones.

TAXONOMIC PROBLEMS

The potential for reliable correlations of some Frasnian standard conodont zones can be questioned due to inconsistent taxonomic concepts and the insufficient range-documentation of the index-species. This is especially true for the *hassi* and the *jamieae* Zones. Ziegler and Sandberg (1990) include in the range of variation of *Palmatolepis hassi* quite different Pa element morphotypes (compare on plate 2 their figure 3 with figure 2 = holotype). Klapper and Foster (1993) and Bultynck *et al*. (1998) used a more restricted variation around the holotype. *Palm*. *hassi s.s.* appears in the Upper *rhenana* Zone/upper part or MN Zone 12. However, the Lower *hassi* Zone of the FrSCZ is directly above the *punctata* Zone and Ziegler and Sandberg (1990) only figure specimens from the Lower and Upper *rhenana* Zone and one specimen from the *jamieae* Zone. So we do not know the morphology of the earlier specimens from the Lower and Upper *hassi* Zone that they assigned to *Palm*. *hassi*, and whether they really can be included within *Palm*. *hassi*. Ziegler and Sandberg (1990) distinguished two morphotypes within the range of variation of *Palm*. *jamieae*, the index-species of the *jamieae* Zone. In my view the holotype of the species belongs to the second morphotype in which the outer lobe is poorly demarcated and the general outline of the platform tends to be pyriform (e.g. Ziegler and Sandberg, 1990, pl. 6, figs. 9, 10). The holotype and other figured specimens close to the holotype are from the Lower *rhenana* Zone. The only figured specimen from the *jamieae* Zone belongs to the first morphotype with a well demarcated lobe, anteriorly and posteriorly. Bultynck *at al*. (1998) preferred to exclude such forms from the range of variation of *Palm*. *jamieae*. Klapper and Becker (1999) also discussed *Palmatolepis jamieae* in comparison with *Palm*. sp B Klapper and Foster 1986. For them it is unclear to which morphotype the holotype of *Palm*. *jamieae* belongs.

CORRELATION WITH SHALLOWER SHELF DEPOSITS

According to Salvador (1994) "...in setting up new biozones or in selecting for use biozones that already have been proposed, practicability in identification and correlation should be considered...".

Practicability in correlation with the FrSCZ is seriously limited by the fact that it has been established for the pelagic biofacies. Looking at a global scale, areas with shallower shelf deposits largely predominate in the geological record, as also in the Devonian (e.g. Ziegler, 1989, fig. 5). Although *Palmatolepis* taxa occur in shallower shelf environments, they are rather rare and only well represented during periods of important eustatic sea-level rises. Consequently the earliest occurrence of the index-taxa of the FrSCZ can be diachronous to a considerable degree, resulting in inaccurate and speculative correlations. I agree that there is a need for a kind of reference scale providing a common basis for Devonian conodont workers. However, such a reference scale should not be only based on successions in pelagic facies but on a synthesis of well established and documented (with figured specimens of first and last occurrence) conodont successions from key areas representing the most common facies/conodont biofacies. Graphic correlation is likely to be the most objective and precise method to provide such a synthesis represented by the Composite Standard (CS) subdivided into Composite Standard Units (CSU). Klapper *et al*. (1995) elaborated a Frasnian CS subdivided into 34.5 CSU. This Frasnian CS is based on data from 64 sections in different areas including the Montagne Noire (France), the Alberta Rockies and the Hay-Trout Rivers (Canada), the Mid-continent and western New York (US), the Canning Basin (Western Australia) and the Central Devonian Field and the Timan-Pechora region of the East European Platform. The sections represent different biofacies. Klapper (1997) established more detailed correlations between the Montagne Noire and Alberta Rockies with a polygnathid biofacies.

Gouwy and Bultynck (2000) developed a Frasnian regional composite for the Ardenne Area (Belgium–northeastern France) on the basis of 10 sections and using data mainly from conodonts but also from corals and brachiopods. The Ardenne Frasnian regional composite has been correlated with the Frasnian CS of Klapper (1997). On page 341 and Figure 1 of the present contribution information on a Middle Devonian CS based on a neritic succession in the Ardenne Area and pelagic and pelagic-neritic successions in Southern Morocco is provided. The Middle Devonian CS is subdivided into 98.6 composite standard units.

CONCLUSIONS

During the last two decades a Frasnian and Middle Devonian Composite Standards have been elaborated. The Frasnian CS is in a more advanced stage of development than the Middle Devonian CS because it is based on more sections that are spread across North America, Europe and Australia.

The Frasnian, Givetian and Eifelian composite standards better meet the requirements of what an international conodont reference scale should be. They provide a higher resolution for stratigraphic correlations than the Frasnian standard conodont zonation and the most frequently used Eifelian (*partitus*, *costatus*, *australis*, *kockelianus*, *ensensis*) and Givetian conodont zones (*hemiansatus*, Lower, Middle and Upper *varcus*, Lower and Upper *hermanni*, Lower and Upper *disparilis* and lowest part of *falsiovalis*). Moreover, the composite standards integrate data from successions with different biofacies. So their applicability is more universal than a classical standard biozonation.

However, this point of view does not imply that classic biozonations should be abandoned. They should, though, receive a more appropriate heading referring to the geographical area and facies in which they were established and the name of the biozones should emphasize the most important species change(s) that took place. One should also realize that in classical biozonations the first occurrence of the index-species of a zone in the reference section is not necessarily isochronous with its first occurrence in other sections and there are reliable and less reliable species for correlation, even in the genus *Palmatolepis* (Klapper, 1997, p. 120).

A disadvantage of a composite standard may be its nameless numerical scale, hampering easy communication in presentations and debates and frightening the uninitiated. The name of a taxon is more informative and can be linked immediately to a specific stratigraphic level. A good solution can be to indicate also the base of a classical biozone in a specific section by its CSU as has been done for the Frasnian conodont zonation in the Montagne Noire and the Alberta Rockies and the biostratigraphic intervals recognized in the Hay and Trout Rivers (e.g. Klapper, 1997, fig. 5).

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