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Early Pragian conodont-based correlations between the Barrandian area and the Spanish Central Pyrenees

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Occurrences and distribution of extremely scarce eognathodontids do not facilitate reliable correlation across the European regions. The correlation of the traditional early Pragian of the Prague Synform (a part of the classical Barrandian area) and the Spanish Central Pyrenees (section Segre 1) is based on conodont taxa of the *Icriodus steinachensis* and the *Pelekysgnathus serratus* stocks. This correlation has the potential to be extended to other peri-Gondwanan regions where this scarcity of eognathodontid faunas exists as well. Application of the morphotype subdivision in *I. steinachensis* enables approximation of the beginning of the Pragian in the Pyrenees. It is based on the entry of *I. steinachensis* beta morphotype; it enters together with early eognathodontid taxa in the Barrandian sections. These correlations show that routine application of certain zonal concepts can lead to misleading conclusions. Copyright © 2007 John Wiley & Sons, Ltd.

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1. INTRODUCTION

The global correlation of the Pragian is still a problem in Early Devonian stratigraphy. The difficulties are not confined only to the boundaries and their definitions, but the recognition of any part of the Pragian is at present extremely difficult, in spite of recent detailed work by Murphy (2005). Recently, effort has been made to consider all data available to improve the Early Devonian correlation of the Barrandian sections. The resulting integrated stratigraphy will also involve physical methods such as magnetostratigraphy and gamma-ray spectrometry in order to upgrade the correlation potential of the studied sections. The successful application of these physical methods for juxtaposition of carbonate sequences has been proven already in several studies (e.g. Hladil 2002; Ellwood *et al*. 2006). In spite of present advance in physical methods, fossil distribution still remains as the crucial guide for the matching of the gamma-ray and magneto-susceptibility logs and for global stratigraphy. The definition of many Palaeozoic stages and their subdivision is based principally on conodont faunas. Accordingly, there is a permanent need for functional conodont correlation, based on well defined easily recognizable, and, if possible, 'cosmopolitan' taxa. This is particularly significant, especially at a time of ongoing discussions on the future subdivision of stages and redefinition of several Devonian boundaries (notably the base of the Emsian). Although conodont zonation for the Pragian has had a long and complex history, we still do not have any universally

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applicable biostratigraphic 'scale' for this stage. At the same time, based on our experience, it cannot be excluded that due to many objective constraints (e.g. faunal differences) we would not ever arrive at an ideal working scale—the successive-appearance conodont zonation for the Pragian with worldwide application. The question remains: Is it really necessary to establish a kind of 'partially working substitute'? In order to try to answer the question, we have initiated a study based on conodont successions from two Gondwana-derived areas—the Barrandian area in the Czech Republic and the Spanish Central Pyrenees—both in biofacies with off-shore faunas. The purposes of this paper are to present a correlation of both areas and to discuss refinements in Pragian conodont biostratigraphy.

2. MAJOR DIFFICULTIES IN THE PRAGIAN CONODONT CORRELATION

The former threefold Pragian zonal subdivision, including *sulcatus*, *kindlei* and *pireneae* zones, has been in use since its introduction by Lane and Ormiston (1979) based on sequences in Alaska. Lane and Ormiston supplemented and refined the former scale (e.g. by Klapper 1977). Even though segments of the zonation have been questioned, it has been largely used worldwide. Unfortunately, misleading parts of the zonation are still being used in recent papers (e.g. in the valuable calibration of the Devonian time scale by Kaufmann 2006). The parts of the Pragian global zonal scale have been discussed and criticized during recent years, for example, in papers by Mawson (1995), Valenzuela-Ríos (1997), Carls and Valenzuela-Ríos (1999), Slavík (2004a, 2004b) and Murphy (2005). The latter author discussed thoroughly the former zonation and proposed a new zonal scale based on evolution of eognathodontids, as well as the lowest occurrence of distinct taxa such as *Pedavis mariannae* and *Profunda brevicauda*. However, this subdivision is applicable, so far, only in western North America.

In a previous study, Bardashev *et al*. (2002) revised the taxonomy of many Devonian taxa based on published figures and erected a host of new taxa. Their concept has been criticized first by Mawson and Talent (2003) and recently by Murphy (2005), who pointed out serious discrepancies of this concept of taxonomy and zonation. Herein, we join the critique. Especially, we cannot accept the procedure of Bardashev *et al*. (2002) of selecting only single figured specimens, while disregarding the composition of whole collections recorded in different parts of the world that may represent again only a sample of polymorphic populations. We think such a procedure that disregards intraspecific variability cannot be applied for reconstruction of phylogenetic lineages. A serious problem is the introduction of errors in the stratigraphic position of individual taxa, because of unclear occurrences of selected specimens (e.g. suggested range of their new *Polygnathus pireneae* sspp.) Their revised zonation of the Pragian involves refinements of the former *sulcatus* and *kindlei* zones through splitting of the genus *Eognathodus* and through proposing many new eognathodontid index taxa without control of stratigraphic or evolutionary position. Their proposed zones lack important information such as the reference to time relationship to other stratigraphically significant conodont taxa and/or faunal groups (e.g. dacryoconarids and graptolites). According to Bardashev *et al*. (2002), the validity and sense of the former late Pragian *pireneae* Zone is acknowledged again; but in the zonation it is assigned to mark the base of the Emsian, beside the *kitabicus* Zone and to consider both isochronic. This appears to be a particularly serious problem because sequences in Zinzilban (Yolkin *et al*. 1994) and in other places (e.g. in the Pyrenees) show different ranges and because it restricts the Pragian even more. Herein, we want to stress that application of the former (Lane and Ormiston 1979) or recently modified zonation by Bardashev *et al*. (2002) is neither globally nor regionally possible.

We briefly summarize the major problems regarding the Pragian conodont correlation as follows:

(1) Uncertainty about the origin of the genus *Eognathodus* in Europe and its earliest representatives, as well as the scarcity of eognathodontid conodonts in most European regions, makes the correlation extremely difficult. Accordingly, there is a problem with locating and establishing the position of the earliest '*sulcatus*' that was selected to be crucial for the identification of the beginning of the Pragian (Weddige 1987, see comments in Slavík and Hladil 2004, p. 150). In the type section for the Lochkovian/Pragian boundary, even older eognathodontids occur below the Global Stratotype Section and Point (GSSP) of the Pragian base (Slavík and Hladil 2004, p. 142). The morphological variability within the '*sulcatus*' stock appears to be very high in some

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regions. Murphy (2005) has recently worked out this aspect and has proposed a new '*branching pattern*' for explaining the Pragian evolution of eognathodontids. He proposed that *Eognathodus irregularis*—a taxon still without '*sulcus*' is the crucial conodont for the Lochkovian–Pragian boundary definition; however, records from the stratotype section show that the index taxon could appear before the beginning of the Pragian (see below).

(2) Herein, we concur with the doubts expressed about the value of the *kindlei* Zone for global stratigraphic correlations of the middle part of the Pragian. Although Murphy (2005) has demonstrated that forms with a 'partially sulcate branch' belonging to the species *kindlei* have a late early Pragian origin in Nevada, the exact stratigraphic relationship between *Pseudogondwania kindlei* (= *Eognathodus sulcatus kindlei*, = *Eognathodus sulcatus lambda* morph part) and the earliest eognathodontid is still not clear. The unique record of the morphotype lambda (= *P. kindlei* or *Gondwania profunda*) from the TO-I section in Central Nevada that coincides with the entry of *E. irregularis* (= *E. s. eosulcatus* (Murphy 1989, p. 69, table 2) is not in contradiction to the assumed age because *E. irregularis* (including various morphotypes) in Nevada has a long range that overlaps with the range of some morphotypes of *P. kindlei* (see Murphy 2005, figures 2 and 5). However, in the new taxonomic assignment (Bardashev *et al*. 2002) the former morphotype lambda may belong to both *G. profunda* and *P. kindlei*; the lack of illustrations in Murphy (1989) precludes definitive identification. The presence of morphotype kappa (= *G. profunda*) in the same bed (Murphy 1989, table 2) certifies the presence of *G. profunda*, but as *G. profunda* and *P. kindlei* overlap, uncertainty about reliable attribution of the specimen identified as morphotype lambda arises. The interval that could show the connection between the earliest eognathodontids and the index for the *kindlei* Zone in the Salmontrout River Area is covered (upper part of the Road River Fm. is not available; cf. Lane and Ormiston 1979, figure 2a). The range of the *kindlei* Zone in the Salmontrout starts together with that of *Icriodus steinachensis*—an early Pragian conodont (sample 30, 215 feet (65.53 m) in the Type Salmontrout exposure, cf. Lane and Ormiston 1979, table 1). It all suggests a rather early Pragian age for the beginning of the former *kindlei* Zone, whose range thus might be not relevantly younger than the traditional earliest Pragian zone—the *sulcatus* Zone (= *irregularis* sensu Murphy 2005, figure 1). We agree with Murphy (2005) that *P. kindlei* is not relevant as an index for a middle Pragian zone.

(3) The latest Pragian conodont zone—*pireneae*—has been discussed and criticized thoroughly by Valenzuela-Ríos (1997) and found absolutely unsubstantiated: there is scarce knowledge about the ancestry of *Polygnathus pireneae*, and it is also very difficult to find the really oldest occurrence. Moreover, *Po. pireneae* occurs in Nevada close to the entry of the *kindlei* Zone (cf. Valenzuela-Ríos 1997). Murphy (2005, figure 1) shows also this situation by tracing the base of the *mariannae* Zone, which appears slightly later than *P. pireneae* in Nevada (Murphy 2005, figure 5), close to the base of the former *kindlei* Zone. However, in his new classification of eognathodontid forms, he documents the range of *Pseudogondwania kindlei* in Nevada from his *profunda-brevicauda* Zone (Murphy 2005, figure 5). But we have to take into account that following the original diagnosis of Lane and Ormiston (1979), in the new *kindlei* concept, Murphy (2005) includes forms previously assigned to *Eognathodus sulcatus kindlei* (with previous morphs lambda and mu) of *E. sulcatus* and *Eognathodus sulcatus juliae*.

In addition, there are also problems with the reconfirmation of the occurrence of *Polygnathus pireneae* in its type stratum (Boersma 1973), because the type stratum and nearby beds have been re-sampled in detail by Valenzuela-Ríos and have yielded no specimens of *pireneae*. The conodont correlation of the late Pragian is even more complicated because of the deficiency of relevant cosmopolitan forms. Furthermore, the situation in the late Pragian–early Emsian stratigraphy has been, especially for the last dozen years, a subject of endless discussion within the stratigraphic community (e.g. Yolkin *et al*. 1994; Mawson 1995; Carls and Valenzuela-Ríos 1999, 2002a, 2002b; Bardashev *et al*. 2002; Slavík 2004b). The placement of the GSSP for the Lower Emsian boundary in a bed low down in the Zinzilban Section (Uzbekistan) results in huge discrepancies between the GSSP and both the volume of the original Pragian in the stratotype area and the base of the original Emsian. Unfortunately, it seems we are still too far from an international consensus that should be underpinned by reliable taxonomic and

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biostratigraphic data. In general, it seems, there are many constraints for the desired universally applicable conodont correlation scale. Besides the global eustatic conditions (Pragian lowstands)—that strongly affected the characters of the biota, there are also taxonomic complications (partly mentioned above) that also imply uncertainty in correlation with other faunal groups, as well as with geochemical and physical events. There exist large faunal differences especially between the North American, the European and the Australian conodont faunas. Diversity and abundance of stratigraphically relevant conodonts are seemingly higher in the Alaskan and Nevadan sections (cf. Lane and Ormiston 1979; Murphy *et al*. 1981; Murphy and Matti 1982; Murphy 2005). As seen from many European (hemi)pelagic regions (e.g. Barrandian, Carnic Alps, Pyrenees), there were probably rather unfavourable environments for conodonts during Pragian time. They are reflected through relatively low numbers of widespread taxa and of more endemic forms and through low conodont yields in general (cf. 'conodont crisis' of Carls 1987 and low-diversity episode of Ziegler and Lane 1987). In the Pragian of Europe, there are certain taxa belonging to *Icriodus* and *Pelekysgnathus* that are more important for European correlation than their counterparts in North America. Conodont successions from the Barrandian area and Spanish Central Pyrenees may exemplify this fact. Moreover, conodont data from both regions (Schönlaub in Chlupáč *et al*. 1985; Valenzuela-Ríos 1994, 2002; Slavík 2004a) show striking similarities and prospects for an alternative correlation. Accordingly, we draw a comparison of the Pragian conodont faunas between both regions.

3. INTRODUCTION OF THE STUDIED REGIONS

3.1. Barrandian area

The Lower Devonian stratal successions in the Prague Synform (in the classical Barrandian area, central Bohemia, SW of Prague) are characterized by the absence of major hiatuses (with an exception for the Koněprusy segment in the SW, e.g. Chlupáč *et al*. 1998), and by medium sedimentation rates (~20–25 m/Ma) (with the exception of the extremely shallow-water Koněprusy Limestone), which are typical for the open-marine carbonate environments, slopes and prevailing deposition below the storm weather wave-base. Limestone of various facies were documented (e.g. Hladil *et al*. 1996; Velebilová and Šarf 1996; Čáp *et al*. 2003) where extensive pelagic and calciturbidite systems alternate with deposition around several seafloor highs. The abundance of planktonic and widespread reliably correlated faunas in combination with a rather moderate detrital input is indicative of significant influence of oceanic conditions. These features of the Lower Devonian sediments in the Barrandian area facilitate biostratigraphic and palaeoenvironmental/lithological correlations with many peri-Gondwanan basins (typical successions in lithologies, distribution of dacryoconarids and even the long migration paths of several benthic faunas—e.g. corals, brachiopods and trilobites). The correlation potential of the Barrandian sections is enhanced by its extraordinary high degree of reconnaissance that dates back to the pioneering monographs of J. Barrande, published in the later half of 19th century, but is equally demonstrated by the most recent papers and monographs by I. Chlupáč (e.g. Chlupáč *et al*. 1998). This high standard and progress in palaeobiology and biostratigraphy was reflected also by the selection of GSSPs that were placed in this classical Barrandian area (Silurian-Devonian (S-D), Lochkovian/Pragian (L/P) and the Lower/Middle Devonian parastratotype). In the Barrandian area, the correlation of the early Pragian presented herein is based on conodont data from eight sections that cross the L/P boundary: Čertovy schody, Pod Barrandovem, Branžovy, Karlík Valley, Požáry, Velká Chuchle, Černá rokle (near Kosoř) and Cikánka. The traditional base of the Pragian is recognized through the onset of deposition of the Praha Fm. that is often marked by a moderate lithological change (often highlighted by lighter coloured, bioclastic or biomicritic limestones). With the exception of the Koněprusy area, there is no apparent tectonic distortion or stratigraphic gap below the Lower Pragian boundary. The selected Barrandian sections cover all three tectonically shaped stripes of outcrops (NE–SW oriented) in the main part of the Prague Synform as well as a separate tectonic segment in the SW (see Figure 1) and thus they comprise a miscellaneous facies development ranging from deeper-water facies (e.g. Pod Barrandovem section) up to extremely shallow-water limestones (e.g. Čertovy schody section in the Koněprusy area). Detailed descriptions of the sections with the complete conodont distribution can be found in Slavík (2004a),

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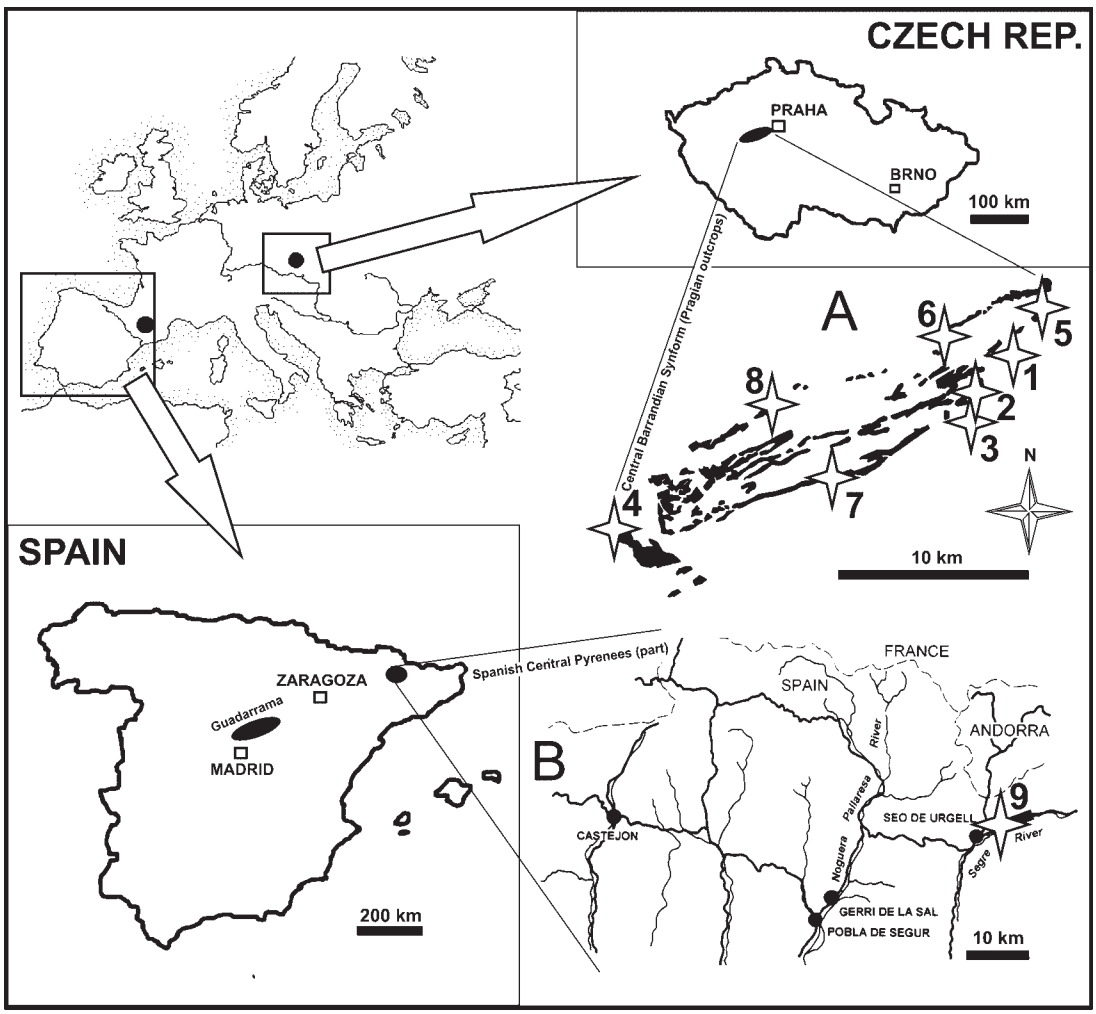

Figure 1. Location scheme of the studied regions with marked localities: (**A**) Central Barrandian (Prague) Synform with outcrops of limestones of Praha Formation (= Pragian in its oldest classical concept). The eight Barrandian sections are marked by four-pointed stars: 1: VC, Velká Chuchle; 2: Ci, Cikánka; 3: CR, Černá rokle (Kosoř); 4: CS, Čertovy schody, 5: Ba, Pod Barrandovem; 6: Po, Požáry; 7: Ka, Karlík Valley; 8: Br, Branžovy; (**B**) Spanish Central Pyrenees (part): 9: Se, Segre 1.

the section Černá rokle (near Kosoř) is described, for example, in Chlupáč *et al*. (1985). Biostratigraphically, the boundary is defined in the GSSP of the Velká Chuchle section and it is based on a non-figured eognathodontid specimen found in bed 12 (Weddige 1987, see comments by Slavík and Hladil 2004). Because of the scarcity of eognathodontids in the Barrandian, the boundary is also approximated by other taxa in some sections.

3.2. Spanish Central Pyrenees

The character of sedimentation in the Spanish Central Pyrenees also reflects the Hercynian (Bohemian) type of facies development with a prevalence of pelagic carbonates. In spite of intense tectonic deformation that affected most of the Devonian rocks in the Pyrenees, it is possible to find several tectonically undisturbed sections that are appropriate for stratigraphic studies. Despite the dearth of macrofossils and the unsatisfactory state of their preservation, conodonts play an exceptional role and are pivotal in stratigraphic correlations. Their importance and

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relative abundance stimulated detailed conodont studies in the 1960s and 1970s. Early Devonian conodonts were studied first by Boersma (1973), who established, among others, the taxon *Polygnathus pireneae* that was later selected by Lane and Ormiston (1979) as the index for the latest Pragian conodont Zone. Comprehensive work on Lower Devonian conodonts was carried out by Valenzuela-Ríos (1994) who described in detail a number of Lower Devonian sections. As regards the Pragian, there are three well-described sections in the Pyrenees—Isábena 1, Baliera 6 and Segre 1. The sections Isábena 1 and Baliera 6 show the upper parts of the Pragian and cross the Lower Emsian boundary. These upper Pragian–Lower Emsian sections are easily correlated by the presence of characteristic icriodontid and polygnathid faunas such as *Icriodus curvicauda*, *Icriodus celtibericus* and *Polygnathus excavatus* Carls and Gandl 1969 (cf. Valenzuela-Ríos 1994, 2001; Martínez-Pérez and Valenzuela-Ríos 2005). The most instructive section for the correlation purposes of the early Pragian is the section Segre 1, where one stratigraphically important subspecies of *Pelekysgnathus* has been introduced. The Lower Pragian succession belongs to the Rueda Fm.; it is developed as light grey-brownish limestone beds alternating with marly and argillaceous limestones with claystone intercalations; nodular levels are frequent. The Castanesa Fm. begins just below the entry of *Po. pireneae* and consists mostly of grey crinoidal wackestones and packstones and nodular limestones. For a detailed description see Valenzuela-Ríos (2002).

4. EARLY PRAGIAN CONODONT CORRELATION

The detailed revision of Pragian conodont biostratigraphy shows that we are faced with the following problems: (1) the global correlation of the base of the Pragian Stage is difficult due to its problematic definition (stratotype vs. biostratigraphical index), (2) the position (regarding time) of the earliest *sulcatus* morph, that up to now globally corresponds to the eta morph of Murphy *et al*. 1981 = *E. s. eosulcatus* Murphy 1989 which turned out to be a junior synonym of *E. irregularis* (Murphy 2005), (3) the beginning of the *kindlei* Zone, (4) the beginning of the *pireneae* Zone and (5) the correlation of the historical Emsian. The recent paper by Bardashev *et al*. (2002) considering *Po. pireneae* as another index for the base of the Emsian (and therefore the Pragian would be even more reduced) has added more confusion to this item. Certain progress in points 3 and 4 has been achieved (Murphy 2005, figure 2); however, the sequence established in Nevada cannot be applied in Europe yet, mainly due to the scarcity of eognathodontids, but also because of the occurrence of very peculiar forms in Europe. Regarding points 1 and 2 (point 2 applies to the Prague Synform) we have obtained the following results: An eognathodontid specimen showing a clear sulcus has been found below the L/P GSSP in the Velká Chuchle section (bed 11) (see Slavík and Hladil 2004, Plate 1, figure 7); it may belong to some younger morphotype of *Eognathodus irregularis* in the sense of Murphy (2005). According to the phylogenetic interpretation of the 'sulcatus group' (Murphy *et al*. 1981; Weddige 1987; Murphy 1989, 2005), the entry of the L/P boundary defining index (the oldest *E. irregularis*) proposed by Murphy (2005) with irregular dentition but without a sulcus, developed from the ancestral *Masarella pandora* stock and should be found even lower. Re-sampling of the auxiliary stratotype section (Černá rokle near Kosoř) furnished an *Eognathodus* (figures 3–9) with a clear sulcus from bed 76—in the position of the redefined L/P boundary by Weddige (1987). The specimen is broken in upper view, however, it is remarkable that the sulcus reaches almost to the anterior tip of the unit. The basal cavity is distinctly sub-rectangular and the blade, if complete, would have been rather long. Of course, it is hazardous to rely on an incomplete specimen, but it could be related to *Gondwania profunda* Murphy 2005; according to him, *G. profunda* is the index of the second Pragian conodont Zone in Nevada. The evidence that this fairly developed specimen cannot be the oldest in the stock is supported by the appearance of another eognathodontid specimen from bed 72 (about 0.7 m below the redefined L/P boundary in the Černá Rokle (near Kosoř) section that already shows an incipient but not really developed sulcus. This specimen is very close to *Eognathodus irregularis*. The record of an eognathodontid specimen that is very close to *Gondwania profunda* near the base of the Praha Formation in the Požáry section, thus, confirms the very early appearance of these 'morphologically advanced' eognathodontids in the Barrandian sections. As a consequence, we cannot be sure neither about the biostratigraphic base of the Pragian according to faunal characterization (whether to use the original 'sulcate' or the recently proposed 'unsulcate' forms by Murphy (2005)

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as the biostratigraphical criterion), nor about the stratigraphic position of the really oldest eognathodontid in the Barrandian. If we adopt the 'unsulcate' concept—the Lower Pragian boundary should be then moved down deep into the Lochkovian. Biostratigraphical orientation by means of eognathodontids in the Barrandian is problematic because both the specimens with incipient sulcus and morphologically advanced forms occur stratigraphically very close to the traditional Pragian base. Fortunately, in the Barrandian there are other controls besides the lithological change—for example, dacryoconarids (*Nowakia* (*Turkestanella*) *acuaria*) and the distribution of typical Pragian macrofauna that help to locate the Lower Pragian boundary. If we look at the distribution of significant conodont taxa in the Barrandian sections, we can infer the stratigraphical importance of the *Icriodus steinachensis* stock (see Figure 2). The morphotypes of *Icriodus steinachensis* are present in all sections with the exception of reefal

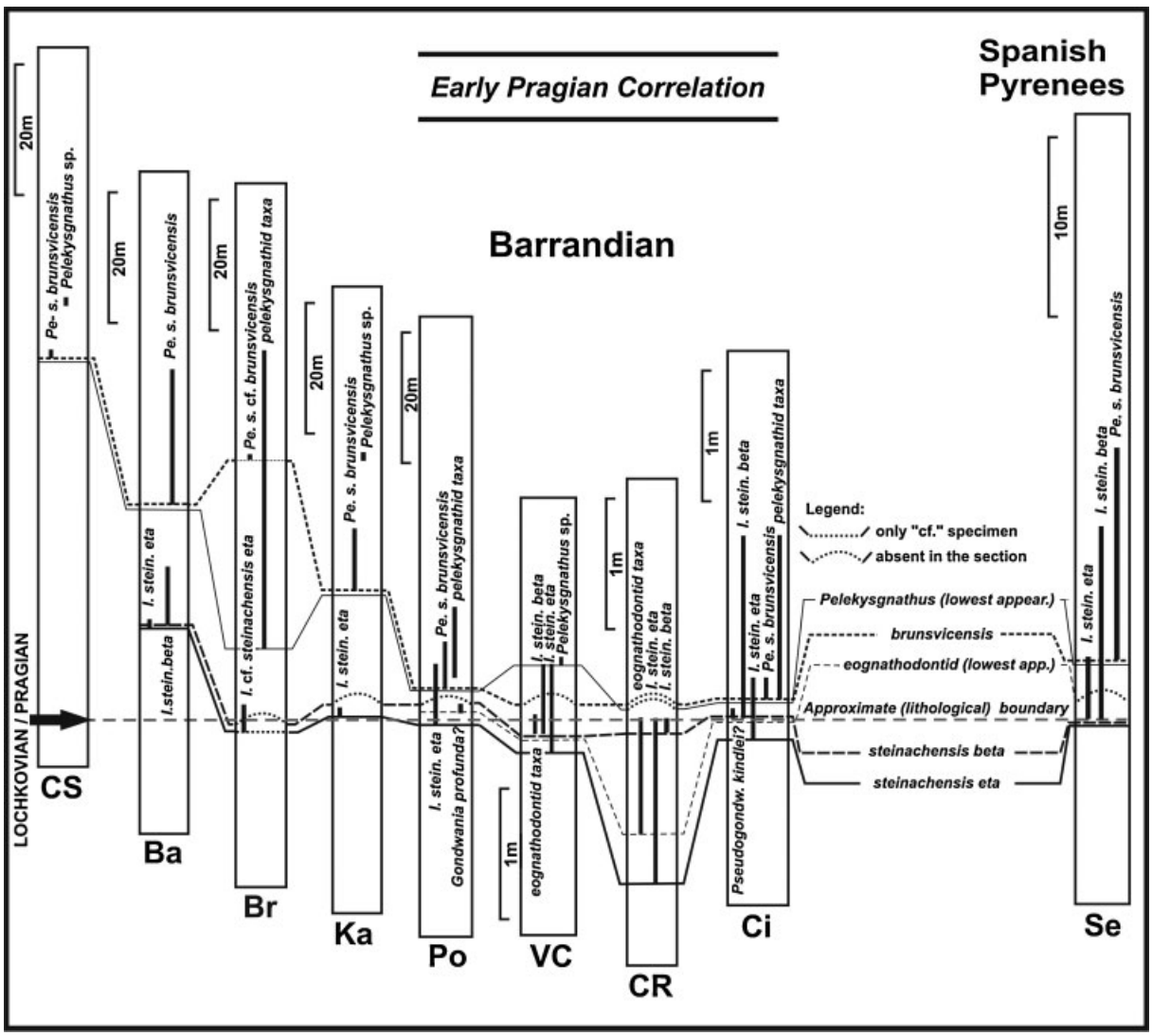

Figure 2. Early Pragian correlation of stratigraphically most significant taxa in the Barrandian and Pyrenean sections: The sections are aligned with approximate position of the lithological boundary between the Lochkov Fm. and the Praha Fm. (central dashed line). Only upper Lochkovian–Early Pragian parts of the sections are represented herein. Abbreviations (from left to right): Barrandian: CS = Čertovy schody; Ba = Pod Barrandovem; Br = Branžovy; Ka = Karlík Valley; Po = Požáry; VC = Velká Chuchle; CR = Černá rokle (Kosoř); Ci = Cikánka; Pyrenees: Se = Segre 1.

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limestones of Čertovy schody in the Koněprusy area. The presence of *I. steinachensis* in the Koněprusy area, which is located in the south-western part of the Central Barrandian Synform (area around the Čertovy schody section, cf. Figures 1–4) is, however, inferred only from an adjacent locality (Bacín Hill, cf. Slavík 2004a). Morphotypes of *I. steinachensis* occur in many regions of the world, for example, Frankenwald (Al-Rawi 1977), Sardinia (Mastandrea 1985), Nevada (Murphy and Matti 1982), East-Central Alaska (Lane and Ormiston 1979), Tajikistan (Bardashev and Ziegler 1992), Pyrenees (Valenzuela-Ríos, 1994, 1997), Carnic Alps (Schönlaub 1985), Morocco (Benfrika 1999) and others. Distinct morphotypes eta and beta were defined by Klapper and Johnson (1980, p. 448) and were subsequently used by many authors (e.g. Murphy and Matti 1982; Murphy and Berry 1983; Schönlaub in Chlupáč *et al*. 1985). Murphy and Cebecioglu (1984), however, rejected the distinction of morphotypes due to their interfering range in Nevada. It contrasts with the former data of Klapper and Johnson (1980, tables 3 and 4) who pointed out that eta morphotype is older than beta morphotype. Based on the material from Barrandian and Pyrenees, we think that the stratigraphical meaning of both morphotypes is useful in Europe, as they have distinctly different ranges in several European sections. The morphotype eta with the 'spindle-like' outline of the spindle has been documented in many places (e.g. Barrandian, Carnic Alps, Frankenwald, Moroccan Meseta, Victoria, New South Wales) to occur very close to the anticipated local L/P boundaries. In sections of the Barrandian and Carnic Alps morphotype eta enters earlier than the morphotype beta. In Nevada the earliest forms of *I. steinachensis* (*I. steinachensis* H) may co-occur with the late Lochkovian taxa (cf. Murphy and Matti 1982, table 3). The morphotype beta with a triangular ('carrot') shape of the spindle has never been recorded to enter below the morphotype eta anywhere. It has been proved that the younger morphotype follows the older one rather soon. This eta—beta stratigraphic sequence is seen in the Carnic Alps (Oberbuchach II, Schönlaub in Chlupáč *et al*. 1985; Schönlaub 1985) and in the Barrandian (Černá rokle, Velká Chuchle, Cikánka; Schönlaub in Chlupáč *et al*. 1985; Slavík 2004a). Both in the Barrandian and the Pyrenees, the specimens of *I. steinachensis* are abundant and they occur in the lowermost portions of the Pragian sequences, not reaching very high above the boundary (see Figure 2). Very important is the striking co-occurrence of the eognathodontid specimens with incipient, but clear sulcus with the first beta morphotype of *I. steinachensis* in the Velká Chuchle and Cikánka sections. As it has been pointed out above, we cannot consider the known Barrandian entries of eognathodontid specimens to be necessarily the oldest because of their advanced morphology. Murphy (2005) has demonstrated the origin of *Eognathodus* from *Masaraella*, and its coincidence with the L/P boundary (as this is the biostratigraphic criterion approved by the Subcommission on Devonian Stratigraphy (SDS)). However, eognathodontid specimens were recorded below the stratotype in Velká Chuchle and in the parastratotype at Černá Rokle near Kosoř. Following the western North American evolution (Murphy 2005), the eognathodontid taxon recorded from bed 12 at Velká Chuchle (stratotype) is morphologically younger then the first *E. irregularis*, as it has already developed a sulcus (cf. Slavík and Hladil 2004, plate 1, figure 9) and is more comparable to the early representatives of the *Gondwania profunda* stock that according to Murphy (2005) first appears in the 'lower middle' Pragian. Therefore, there is a clear discrepancy between the earliest *Eognathodus* and the beginning of the Pragian. This is clearly shown in the stratotype area, where the taxonomical criterion for the boundary interpreted by Murphy (2005) as the earliest '*Eognathodus sulcatus*' and stratotype do not match. The earliest eognathodontids in Nevada (e.g. the unsulcate forms, *Eognathodus epsilon* and *E. irregularis*) are thus, by means of correlation with the stratotype, of late Lochkovian age. This is a logical consequence of the original procedure during the boundary definition made by Weddige (1987): it is necessary to bear in mind that the GSSP boundary definition in the Barrandian was based on the first '*Eognathodus sulcatus*'—in the late 1980s under this name were meant for specimens with a clearly developed sulcus. Of course, this cannot now be in accordance with the recent concept of 'unsulcated' boundary defining specimens (Murphy 2005) that still had to undergo a time-demanding evolution towards this morphological advance—the development of a sulcus.

We cannot also be sure about the origin of the eognathodontid stock and its oldest representative in Europe because of the scarcity of representatives of this stock, as stated earlier. The concurrent entry of *I. steinachensis* beta and a kind of early eognathodontid with a developed sulcus might be, in the meantime, an alternative mark of the beginning of the Pragian regarding the stratotype until more data about the *steinachensis* and *eognathodontid* lineages in Europe are available. Following this criterion, the base of the Pragian in the Pyrenees can thus be very

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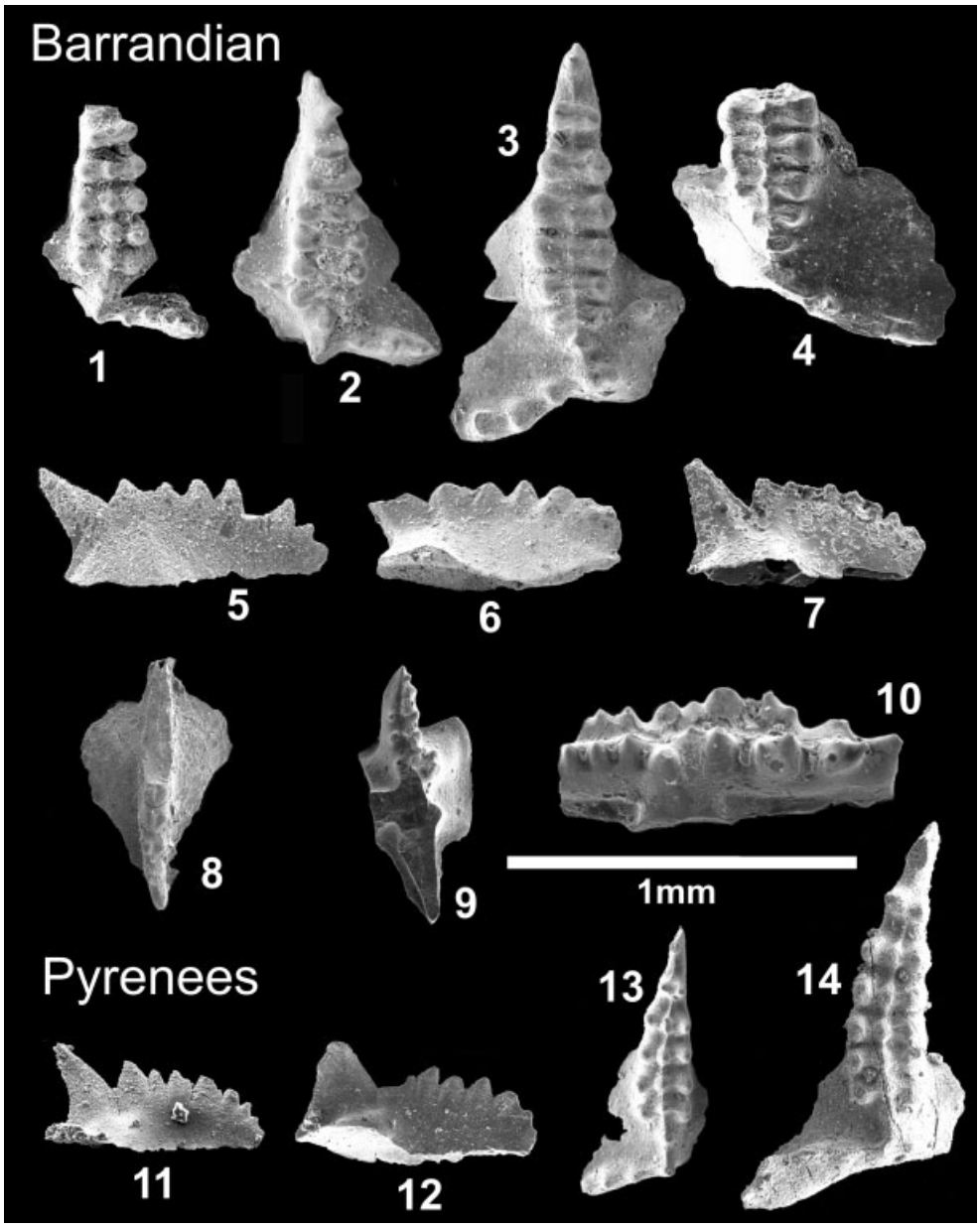

Figure 3. SEM-figures of selected early Pragian conodonts. All specimens are at the same scale (cf. 1 mm bar). Barrandian specimens: 1: *Icriodus steinachensis* Al-Rawi, beta morphotype Klapper and Johnson 1980, upper view of I element Sp.No.312BA, sample 5BA, Pod Barrandovem section; 2–4: *Icriodus steinachensis* Al-Rawi, eta morphotype Klapper and Johnson 1980, 2: Upper view of I element Sp.No.011BC, sample BC11, Locality Bacín (Koněprusy area), 3: Upper view of I element Sp.No.202CI, sample 5CI, Cikánka section, 4: Upper view of I element Sp.No.816VC, sample 4VC, Velká Chuchle section; 5: *Pelekysgnathus serratus* cf. *brunsvicensis* Valenzuela-Ríos, lateral view of Sp.No.208BC, sample BC8, Lokality Bacín (Koněprusy area), 6–7: *Pelekysgnathus serratus brunsvicensis* Valenzuela-Ríos, lateral view of Sp.No.086PO, sample 14PO, Požáry section, 7: Lateral view of Sp.No.314Ba, sample 13BA, Pod Barrandovem section; 8: *Pseudogondwania kindlei?* Lane and Ormiston 1979 (? = *Eognathodus sulcatus kindlei* Lane and Ormiston 1979), upper view of Sp.No.205CI, sample 6CI, Cikánka section; 9–10: *Gondwania profunda?* Murphy 2005, 9: Upper view of Sp.No.MGUV 5961, bed 76, Černá rokle (Kosoř) section, 10: Upper-lateral view of Sp.No.115PO, sample 6PO, Požáry section. Pyrenean specimens: 11–12: *Pelekysgnathus serratus brunsvicensis* Valenzuela-Ríos 1994, 11: Lateral view of specimen from bed 49, Segre 1 section, 12: Lateral view of specimen from bed 44d, Segre 1 section, 13–14: *Icriodus steinachensis* Al-Rawi, beta morphotype Klapper and Johnson 1980, 13: Upper view of I element from bed 41, Segre 1 section, 14: Upper view of I element from bed 39, Segre 1 section.

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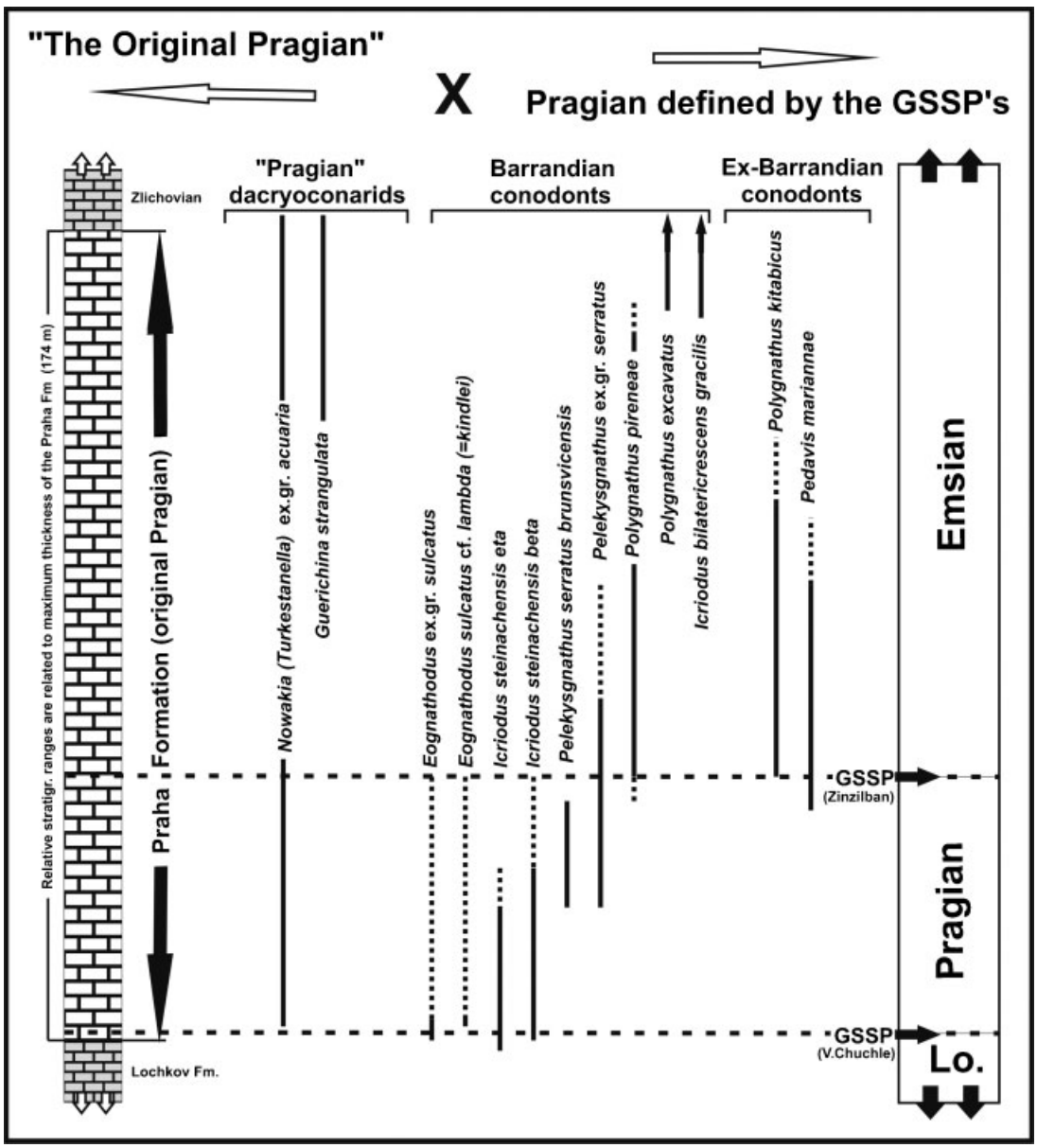

Figure 4. Praha Formation (Original Pragian) in its maximal thickness matched against summarized relative ranges of stratigraphically important conodont and dacryoconarid taxa. Documented ranges of taxa are marked by continuous line; dashed lines indicate supposed continuation of the range and arrows indicate continuation of the taxa into the Zlichovian. Ex-Barrandian taxa are represented in Zinzilban (GSSP section for the Pragian/Emsian boundary). According to detailed inter-regional correlation of crucial Zinzilban taxa, the beginning of the Emsian in the Barrandian can be expected close above the last occurrences of *Pelekysgnathus serratus brunsvicensis*. The original Pragian might thus be shortened to only 1/3 of its original volume.

close to bed 39 with the entry of *I. steinachensis* beta in sequence with eta morphotype and the absence of any Lochkovian taxa in the Segre 1 section (see Valenzuela-Ríos 1994). The correlation of the Lower Pragian boundary (according to the stratotype) can be extended to other regions where the eognathodontid specimens are scarce. It is obvious that the correlation of the lower parts of the Pragian successions in both regions cannot be based on eognathodontid morphotypes. In the Barrandian, they occur randomly, either close below the lithological boundary

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between the Lochkov Fm. and the Praha Fm. in Velká Chuchle, Černá rokle and Cikánka or slightly above this boundary (Požáry), and there is no record of eognathodontid conodonts in the Pyrenees.

A very important biostratigraphic correlation tool besides the earliest Pragian *steinachensis* stock is the *Pelekysgnathus serratus* lineage. The oldest Pragian pelekysgnathids occur as early as within the upper part of the range of *I. steinachensis* eta. Their known stratigraphic range in the Barrandian is longer than in the Pyrenees and can extend to several tens of metres (cf. Branžovy and Pod Barrandovem sections, see Figure 2). The representatives of the Pragian *Pelekysgnathus* recorded in many regions worldwide have been lumped under the name *Pelekysgnathus serratus* Jentzsch. In fact, the genus *Pelekysgnathus* displays a high variability during the Pragian, but many taxa have not yet been formally named. Several morphologically distinct forms were recorded in Barrandian sections under the name '*Pelekysgnathus* ex. gr. *serratus*' (Slavík 2004a). However, unless more specimens become available, the formal description of new species or subspecies is not possible. The only exception in the Pragian is *Pelekysgnathus serratus brunsvicensis* Valenzuela-Ríos 1994 that occurs in many sections in the Barrandian where it has an even longer stratigraphic range than in the Pyrenean type section, Segre 1. This relatively frequent occurrence outside its type area suggests a wider palaeogeographical distribution. It has been recorded in the Guadarrama, central Spain (Bultynck 1976, plate 5, figures 6–11; Figure 1). Wider inter-regional correlation of the stratigraphic range of *Pelekysgnathus serratus brunsvicensis* is, however, complicated mostly due to a dearth of figures and descriptions of many globally recorded pelekysgnathids. In brief, the early Pragian can be also correlated according to the distribution of representatives of the *steinachensis* and *serratus* stocks in several peri-Gondwanan regions, which also have a dearth of eognathodontids. The appearance of *Icriodus steinachensis* beta can be very close to the defined Lower Pragian boundary in these regions.

5. THE DURATION OF THE PRAGIAN IN ITS ACTUAL VERSION—A DISCUSSION

Late parts of the Pragian sequence (in the traditional sense) in both regions are difficult to correlate so far because of faunal differences. Accordingly, the late Pragian is not treated in this study. The stratigraphically important taxon *Pedavis mariannae* (present in the Pyrenees) is absent from the Barrandian and spotty records of *Polygnathus pireneae* cannot be a reliable control. *Icriodus celtibericus* and *Icriodus curvicauda* are rather long-ranging taxa that persist into the Emsian. The promising marker *Icriodus bilatericrescens gracilis* that was recorded in the uppermost part of the Praha Fm. (very late Pragian age in the traditional sense) in the Barrandian (Slavík 2004b) and in very early Zlichovian in the Iberian Chains (Carls and Valenzuela-Ríos 2002a) has not yet been recorded in the Pyrenees. Moreover, in the Pyrenees, there is a dearth of knowledge about the distribution of other late Pragian taxonomic groups (e.g. dacryoconarids, macrofauna). The impact of the former conodont correlation concept, based on unsatisfactory conodont zonation and especially GSSP definitions on the existence of the Pragian itself, well illustrates the present stratigraphic position of the Praha Fm. The typical traditional representative of the Pragian Stage in its stratotype area approximately coincides with the Praha Fm. The current GSSP concept of the Pragian/Emsian (P/E) boundary and the recent zonal concept of Bardashev *et al*. (2002, p. 451) have reduced the Pragian enormously, so that only a short lowermost part (if even any part!) of the sedimentary succession of the Praha Fm. belongs to the 'official' Pragian. Figure 4 shows the relative proportion of the Praha Fm. in relation to ranges of stratigraphically important conodont taxa, after P/E redefinition.

As already mentioned, *Polygnathus pireneae* has been shown to occur close to the beginning of the former *kindlei* Zone. According to Bardashev *et al*. (2002), *Po. pireneae* is the basal Emsian conodont having the same range as *Polygnathus kitabicus*. Both *Po. pireneae* and *Po. kitabicus* enter deep below the last occurrences of dacryoconarids—*Nowakia* (*Turkestanella*) *acuaria* and *Guerichina* sp. ex gr. *strangulata* (cf. Walliser and Kim 2001) in the Zinzilban section (the GSSP of the P/E boundary). The above-mentioned dacryoconarid is, however, a typical biostratigraphic marker for the duration of the original Pragian (i.e. the Praha Fm.). This is also shown in Murphy (2005, figure 5), where the range of *kindlei* in Nevada (according to the original diagnosis) starts close to the base of his new second Pragian zone (the *profunda-brevicauda* Zone). If his first zone (*irregularis-profunda* Zone) is, according to stratotype records, mostly Lochkovian (see above), the Pragian would be extremely

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shortened. All these data, however, have to be taken with caution, because in this operation 'zones' and not faunal sequences are correlated. It is necessary to document in one section the sequence of entries of all taxa involved and to robustly correlate different sections. In spite of the enormous effort recently done by Murphy (2005) in clarifying the Pragian conodont succession in western North America, we still need detailed studies in Europe that can correlate with these Nevadan data. The correlation potential of excellent conodont data from Nevada might be enhanced by providing other necessary correlation tools (e.g. dacryoconarids, macrofauna, physical stratigraphy). For instance, we are currently not sure about the beginning of *P. pireneae* in Europe in comparison with the western North America zonations. Considering all the above, it follows that the Pragian might be only a virtual stage because the majority of the original Pragian in the stratotype area belongs to the new concept of the Emsian. Thereafter, we would have an extremely long Emsian on the one hand and a Pragian Stage of almost insignificant duration on the other hand. It is obvious, that such a situation is not sustainable and the revision of the P/E boundary is urgently needed.

6. CONCLUSIONS

1. As the former threefold zonal subdivision of the Pragian is inapplicable worldwide, the global early Devonian conodont correlation is still extremely difficult.
2. The application of the recent excellent concept of the Pragian conodont zonation proposed in Nevada by Murphy (2005) cannot be applied in the European sections due to the scarcity and unreliability of eognathodontids.
3. The upper part of the Nevadan zonation based on *Pedavis* taxa is very promising for future correlation, however, more biostratigraphic or other controls from Nevada are needed. Without knowledge about the distribution of other faunal groups (e.g. dacryoconarids) combined with the conodont data, the evaluation of Nevadan sections as regards replacement of the stratotype of the Pragian Stage is impossible.
4. According to the correlation with the stratotype, the origin of the earliest eognathodontids lies in the Lochkovian. The Pragian Stage might thus be considerably reduced not only from above (through the *kitabicus* boundary), but also from underneath. The majority of the Praha Formation—a typical representative of the original Pragian—belongs to the Emsian in the current SDS sense.
5. The study of conodont faunas from the Barrandian and from the Pyrenees shows that the early Pragian correlation can be alternatively but successfully based on conodonts of the *Icriodus steinachensis* and the *Pelekysgnathus serratus* stocks. Especially in European regions this can be seen as progress in an otherwise unreliable global conodont correlation.
6. The correlation of the Lower Pragian boundary with respect to the stratotype can be approximated by the entry of *Icriodus steinachensis* beta in the Pyrenees and in other regions that lack reliable eognathodontid successions. *I. steinachensis* beta in the Barrandian appears with the sulcated eognathodontids.

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