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THE MIDDLE DEVONIAN KAČÁK EVENT

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There are over a dozen widely recognized sedimentary perturbations in the European Devonian, many of which are marked by anoxic or hypoxic events. The Kačák Event lies at about the Eifelian/Givetian boundary and has been claimed to be represented by a gap in Germany and Devon. The type section is the Kačák Member in Czechia, and a review is given of the type locality and equivalents in Germany, south-west England, France, Spain and North Africa. Some observations are made on probable equivalents in New York State, China and Australia. Comments are made on the faunal changes associated with the event and on the sequence of environmental changes over the event period and their relation to the new Global Stratotype Section and Point (GSSP) defining the Eifelian/Givetian boundary at Mech Irdane, Morocco, which has been ratified by the IUGS. Finally attention is drawn to the polyphase nature of the event and how it shares this feature with other Devonian events. Comments are made on their likely interpretation.

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INTRODUCTION

In 1985 eight events in the Devonian were named where extinction or change in ammonoid faunas appeared to be related to widespread hypoxic sedimentary events (House 1985). Many of these had already been recognised as local units, and their widespread association with the abundance of certain genera or species had also been noted (Walliser 1984, 1985). Several more events have been subsequently recognised and the current status is shown on Figure 1. One such event close to the Eifelian/ Givetian boundary was named the Kačák Event after a unit in the sucession of the Prague Basin (Chluáč and Kukal 1988) and some details of extinctions at this event were published (House, 1989). Since that time it has been possible to examine a number of the occurrences of the Kačák Event in Europe, North Africa and New York State. This account is intended to be a rather broad review of the developments in this geographic area and this includes the Global Stratotype Boundary and Point (GSSP) defining the base of the Givetian at Mech Irdane, Morocco (Walliser *et al*., 1995). In addition, attention is drawn to records at this level in other areas, especially in China and Australia. Comments are made on the interpretation of the event.

There is at present still fluidity in the terminology of conodont zones around the time here considered. Formerly the succession was: *kockelianus*, ensensis and *varcus* Zones. The recognition of the usefulness of *Polygnathus hemiansatus* was then recognised (and the entry was used to define the basal Givetian GSSP). For some *hemiansatus* now replaces ensensis as the basal Givetian conodont zone fossil (Walliser *et al*., 1995). However, there is an interval in the GSSP section after *kockelianus* has disappeared, and before *hemiansatus* enters and some use a restricted *ensensis* Zone for this interval (Bai *et al*., 1994).

REGIONAL REVIEW OF THE KAČÁK EVENT

A review of occurrences of sedimentary and faunal perturbations internationally at about the time of the Kačák Event is given below. An illustration of some typical boundary sequences across the Kačák Event and the Eifelian/Givetian boundary is illustrated here (Figures 2,3) and a brief review of the developments in several areas is summarised:

Prague Basin

The Kačák Event was named after the Kačák Member of the Sbskro Formation (House, 1985; Chluáč, 1960, 1995; Chluáč and Kukal, 1988; Hladil and Kalvoda, 1993). The member is developed as a black shale with marked contrast to the Chote Member of crinoidal packstones below. At the Hlubo epy railway cutting the Kačák Member (2.7 m thick) is bituminous below, with some thin limestone beds and a yellow-weathering accumulation of fossils at the top. The grey clays and silts of the Roblín Member lie above. Dacryoconarids referred to *Nowakia otomari* Boček, *Styliolina fissurella* (Hall), *Striatostyliolina* spp. and *Metastyliolina* occur. The goniatites *Cabrieroceras crispiforme* (Kayser), *Agoniatites costulatus* (Archiac and de Vemeuil) and *Holzapfeloceras* occur and conodonts in the lower part indicate an interval in the *Tortodus kockelianus* to *Polygnathus ensensis* Zone. A rich fauna of land plants occurs including *Rellina*, *Pseudosporochnus* and *Drepanophycus*. Rare benthos includes orbiculoidean brachiopods. The Kačák event in the Prague Basin has been studied by Budil who has published a detailed review (Budil, 1995).

Germany

Famous localities for the event in the Rhenish Schiefergebirge include the Ballersbacher Kalk in Ballersbach Steinbruch near Hebom, the Odershäuser Kalk in Steinbruch Benner and the Blauer Bruch section. Characterised by a condensed sequence of black limestones the units have yielded very rich faunas historically, including *Kokenia, Cabrieroceras, Sobolewia, Agoniatites, Parodiceras, Holzapfeloceras, Wedekindella* and *Maenioceras*. Unfortunately, collecting is not easy from these intractable limestones. Nevertheless the short-lived anoxic facies is clearly defined (May and Avlin, 1995).

The Middle Devonian sequence in the Eifel Mountains (Struve, 1982a) has been the subject of detailed biostratigraphical investigation by Weddige (1977, 1988a,b, 1989, 1990) and Weddige and Struve (1988) using conodonts; the GSSP level lies near the base of the Freilingen Beds and the suggestion is made that this is transgressive above a break. The shaly Giesdorf and Freilingen units seem to correspond to the Kačák Event. Earlier, in the Ahrdorf Schichten, *Pinacites* is known, and also *Foordites* (Becker and House, 1994a). Struve (1982b) argued for a great break in the Middle Devonian succession of the Eifel, and claimed that this could be recognised in many other areas also but documentation was not provided. An analysis of Sr isotope ratios through the Eifel Middle Devonian has been presented by Diener *et al*. (1996) which shows a marked excursion at the Kačák Event level.

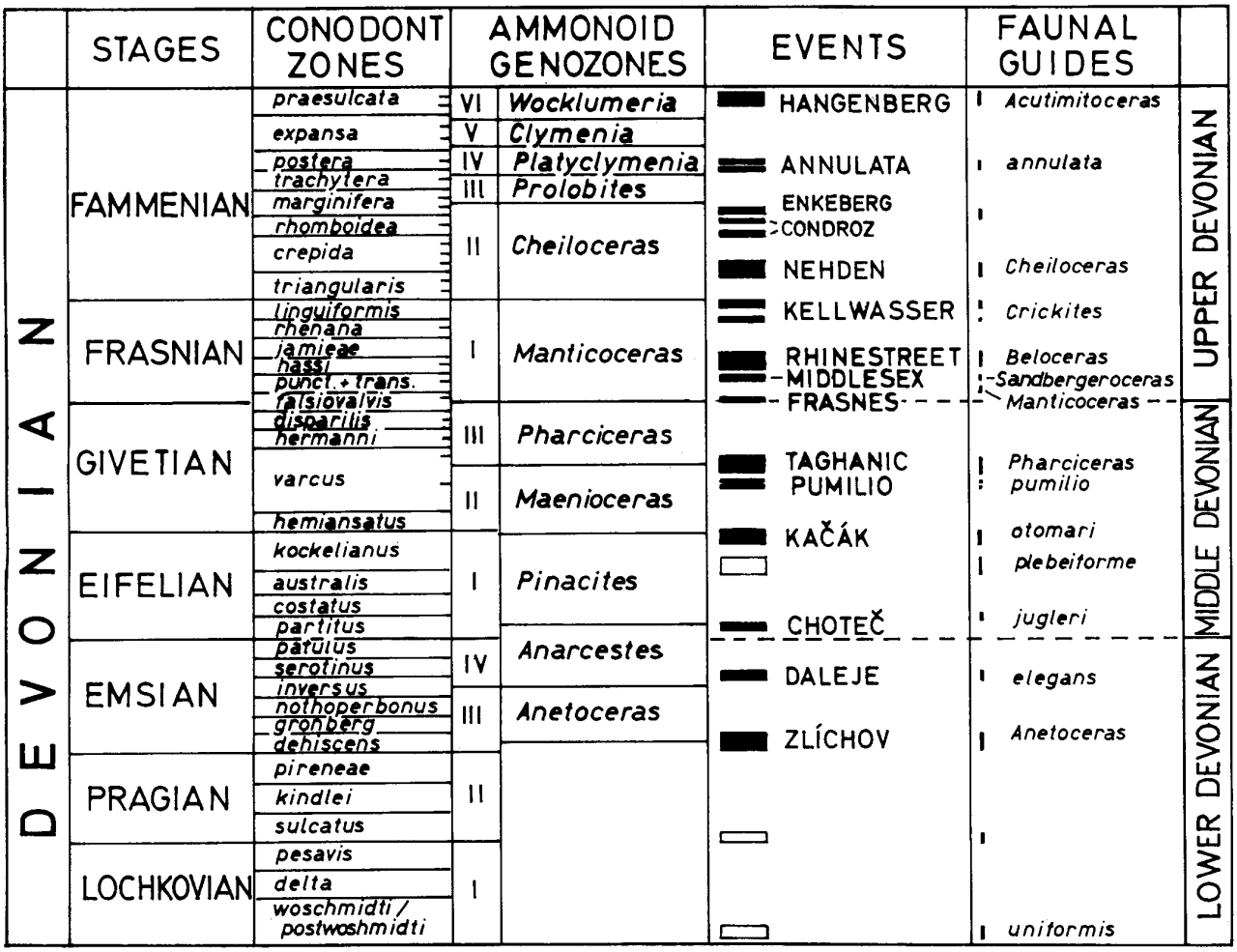

Figure 1. Diagram indicating the main event levels recognised in the Devonian and their correlation with the standard stages and conodont and ammonoid zonal divisions.

South-west England

So far the event has not been recognised in this area, but Struve (1982b) claimed his "Great Gap" was present, but gave no evidence. It is clear, however, that there are sections in Devon and Cornwall which cross the boundary and the Kačák Event. At the northern end of Redgate Beach, Torquay (Castle in Scrutton, 1978) there is a distinctive black limestone in the lower part of the Walls Hill Limestone which Castle (1982) assigned to the former *ensensis* Zone. This is the correct level to be a representation of the Kačák Event: unfortunately the cliffs are difficult to access. In the Brixham area south of Torbay *Latanarcestes* sp. and *Subanarcestes macrocephalus* occur in the St Mary's Bay Shale and so the Kačák Event is to be expected within the overlying Berry Head Formation, since both those goniatites occur below the GSSP level internationally. Perhaps the event is within in the St Mary's Bay Member (Austin *et al*., 1985, p. 106). In Cornwall the event has not been recognised, but attention should be drawn to an anomaly which may be associated with it. Beese (1982) has pointed to the evidence for an extraordinary thickness of Middle Devonian rocks along the North Cornish coast. Much of this seems to be Eifelian. House (1963, p.11) reported *Sobolewia* at a locality on the northern side of Booby's Bay and *Cabrieroceras* has since been found in the limestone concretions there. A late Eifelian date is suggested. Yet *terebratum* Zone levels which form a wrench-faulted outcrop from Trevose Head to Pentonwarra Point, Trevone, lie an anomalously short distance to the north: but this may have a tectonic, rather than a stratal gap explanation.

Scotland

Attention may be drawn to the suggestion by House (1991) that the Kačák Event is represented in the Old Red Sandstone facies by the Achanarras Fish Bed.

Southern France

The Montagne Noire (Feist 1983, 1985) has successions over this interval, of which that at the Pic de Bissous Marbrière is the best documented (Walliser, 1990) and the sequence has been used for analysis of Milankovitch rhythmicity across the boundary (House, 1995). The level of the Kačák Event is indicated by goniatite faunas (House and Chlupač 1987) including the typical goniatites *Cabrieroceras*, *Sobolewia* and *Agoniatites costulatus*. The microrhymic sequence of pelagic micrites however does not show anoxia at the expected level and it must be supposed that the area lay in a rather open sea oceanic location at the time.

Northern Spain

Probable recognition of the Kačák Event along the Asturian coast is owed to Professor Garcia-Alcalde (1992, 1995) in a section at El Tranqueru, west of Cabo Torres (Garcia-Lopez, 1987), where the succession is the most neritic of those examined. There is a level with *Paraspirifer* some 6 m below. Apart from hypoxic dark shales (1.0 m thick) with thin "tempestite" sandstone stringers, of particular interest is a 1.2 m-thick fine sandstone unit, the base of which cuts down into

the shales below and is characterized by load casts and near spherical fluidisation structures reminiscent of the spherical structures common in the Kellwasserkalk facies.

Another locality in the Cantabrian Mountains, described by Buggisch *et al*. (1982) is near the top of a col 300 m north of the Church at Portilla del Luna. Here the Kačák Event is represented by the shales of the Huergas Formation which contain, in the lower part a haematised fauna of *Holzapfeloceras* sp., *Parodiceras* sp. and *Cabrieroceras*. This represents the acme of the Kačák Event. The relationship with the underlying Santa Lucia Limestone Buggisch interpreted as marking an erosional and karstic break, but Professor Garcia-Alcalde has demonstrated that the karstic surface is not Devonian, but Recent, and the anomalous relationship between the two formations is due to disharmonic thrusting and not unconformity (Truyóls-Massoni *et al*., 1990).

Morocco

Good localities in southern Morocco for the Kačák level were described during the search for potential stratotype sections to define the base of the Eifelian. The best documented are at Ou Driss (Bultynck, 1989), Jebel Amelane (Becker and House 1991, 1994a), Bou Tchrafine (Walliser, 1991; Bultynck, 1987, Bultynck *et al*., 1991; House and Becker, 1994a) and Jebel Mech Irdane (Walliser, 1991). It was the last which was recommended as the Global Stratotype Section and Point (GSSP) for the base of the Givetian and this has now been ratified by the IUGS (Walliser *et al*., 1995). Jebel Mech Irdane lies 25 km south-south-west of Erfoud. The main Kačák shale interval lies below the entry of *Polygnathus hemiansatus*, the guide to the GSSP level. Within the shale is an interval of pyritic fauna which represents the anoxic acme of the event; *Maenioceras* enters a little later than this. Crick *et al*. (1994) reported a very marked magnetic susceptibility excursion at the Kačák level in both the Tafilalt and the Ma'der.

New York State

The Cherry Valley region of New York State exposes an upward succession comprising the *Wernerоceras* Bed (0.4 m) with *Cabrieroceras*, *Subanarcestes,* and *Parodiceras*, Upper Union Springs Shale (0.3 m) with *Agoniatites*, Cherry Valley Limestone (1.9 m) with *Agoniatites*, *Parodiceras* and "*Tornoceras*" and Chittenango Shale which shows the entry of the true *Tornoceras* 18.3 m above the base. Since the Wernerоceras Bed to lowest Cherry Valley Limestone succession is referred by Klapper to the *kockelianus* Zone, the level of entry of *hemiansatus* (which has not been found in New York) is to be expected rather higher, where the black shale spread of the Chittenango Shale suggests analogy with the Kačák Event shale.

China

The Devonian succession at Liujing, South China, is especially famous and a Middle Devonian event (undefined) was recognised there by Jin (1988). Subsequently the Kačák Event has been identified by Sun and Bai (1995) as a shale interval in the lower part of the *ensensis* Zone, that is, before the appearance of *Polygnathus hemiansatus* which would define the base of the Givetian: particular interest lies in their record from limestones within the shales of the giant brachiopod *Stringocephalus*, which in other patrs of the world is restricted to the Givetian (Frasnian records now also fall in the Givetian following the redefinition of the base of the Upper Devonian). Sun (in Bai *et al*., 1994) has described this early form as *Stringocephalus gubiense*. The shale level has been shown by Bai *et al*. (1995, p.121) to show a distinctive geochemical anomaly with nickel enrichment in the shales and they draw the *kockelianus/ ensensis* boundary below the intercalated limestone which first yielded *Stringocephalus gubiense*. It would appear, therefore that the entry of *Stringocephalus* is one of the characteristics of the Kačák Event.

Australia

Mawson Sr Talent (1989) have recognised levels of the Kačák Event in the Middle Devonian of the Broken River succession, Queensland. Using sections there in the Papilio Formation, Talent et al. (1993) have described significant isotopic excursions ford $\delta^{13}C$ and $\delta^{18}O$ in the late *kockelianus* Zone. The entry of *hemiansatus* is not recorded but the authors refer to the excursion as the Kačák Event.

TERMINOLOGY OF DEVONIAN EVENTS

Many of the Devonian events have names with historical roots in lithologically distinctive units. Thus the Kellwasser Limestone, Annulata Shales, and Hangenberg Shale were all named in the 19th Century. With the rise of an event terminology for the European Cretaceous, a similar pattern became applied in the Devonian. Thus Walliser (1983, 1984) gave names to particular genera or species which became abundant at such times, thus the *Annulata* Event, *pumilio* Event and so on. Following an analysis of faunal distributions around what has become known as the Taghanic Event (House, 1975) the writer was more impressed, not by the abundance of particular taxa at these events, but by the fact that they were associated with sharp extinction events and that there appeared to be a link between widespread sedimentary perturbations, and these extinction events. Thus a review was published (House, 1985) demonstrating in outline extinctions and radiations of ammonoids at events and, since the relation was with sedimentary perturbations, event names were given based essentially on type localities showing the perturbations, thus the Kačák Event, after the Kačák Member of the Sbskro Formation in the Czech Republic. Attention was drawn to the fact that such events were polyphase, and occupied a considerable time although they usually have a peak. Truyóls-Massoni *et al*. (1990) have pointed out that event terms have been applied loosely in recent years. But it seems better to keep a broad term for a polyphase event, and name or number stages within it as detailed work elucidates the history, as has been done, for example, by Schindler (1990) for the Kellwasser Events, and as indicated below is possible for the Kačák Event (developed from information in Becker and House, 1994).

SUCCESSION OF STAGES AROUND KAČÁK EVENT

Considering all faunal elements the following stages seem represented following the Chotec Event above the base of the Eifelian to the early Givetian:

A. International spread of *Pinacites*.

B. Entry of Subanarcestes macrocephalus.

C. Entry of *Cabrieroceras* and *Sobolewia*.

D. Entry of *Asgoniatites* and *Parodiceras*.

E. Onset of anoxic facies. Entry of *Nowakia otomari*.

F. Peak of anoxia. Pyritic faunas widespread.

G. Extinction of *Subanarcestes*, *Kokenia* and *Fidelites*. Loss of *Cabrieroceras* in most sections.

H. Entry of *Maenioceras*.

I. Entry of *Po. hemiansatus* defining base of Givetian.

J. Loss of anoxia.

K. Entry of *Po. timorense* Group.

Opinion may differ on what limits should be applied to the Kačák Event. However it was originally intended (House, 1985) that the type section would define the name so that the Event includes stages E to H.

INTERPRETATION OF DEVONIAN EVENTS

Since, as was demonstrated already in 1985, there is a similar sedimentary perturbation associated with most of the Devonian extinction intervals to which the named events have been applied, the interpretation of the Kačák Event cannot be considered in isolation.

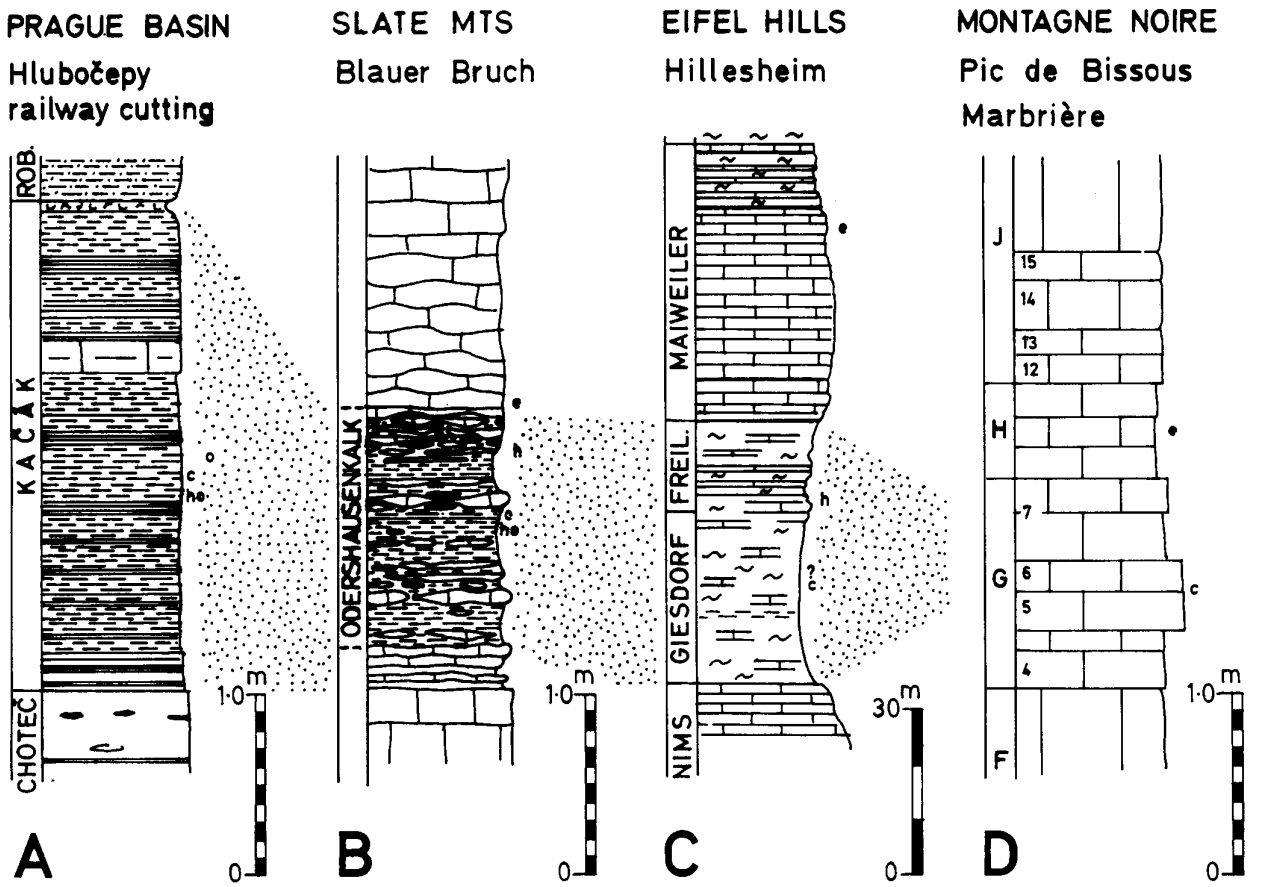

Figure 2. Sections across the Kačák Event in the Czech Republic, Germany and Montagne Noire of southern France. Key: e, entry of Polygnathus ensatus; h, entry of Polygnathus hemiansatus; C, Cabrieroceras faunas; o, occurence of Nowakia otomari.

All Devonian events seem associated with several of the following characteristics, although in all cases research is still at an early stage.

1. Hypoxic or anoxic sediments represented by black or dark grey shales or limestones.
2. Comparatively short interval of time within a stage, occupying one or two zones, or the boundary region of them.
3. International distribution. Most are recognised in Eurasia but many are significantly less well-documented in the Americas.
4. Association with specific faunal characteristics, often by the opportunistic spread of a single taxon.
5. Associated often with significant faunal changes. There are well documented extinctions for the Ammonoidea, but documentation for other groups still has to be refined.
6. Associated with significant geochemical anomalies, changes in Total Organic Carbon, Nickel, carbon and oxygen isotopes have been reported.
7. Associated with excursions in magnetic susceptibility reflecting changes in the lithoferric constituents.

As was pointed out some time ago (House, 1985) it is difficult to invoke bolide or meteorite impact to explain these events, mainly because it is clear their polyphase nature indicates development over a relatively long period of time. Even for the Kellwasser Events, among the shortest events, this is clear (Becker and House 1994b) and some sections in the Meseta of Morocco show several probably precessional microrhythms within this events, suggesting an age up to 100 ka at least for the perturbation. Earth-bound environmental changes are critical, in which sea level changes and the spread of anoxic waters with elemental and isotopic distinction are fundamental. It is possible that such events could be driven by mid-ocean ridge activity which alters ocean volume, leading to sea level changes and transgression. On the other hand, extreme climatic factors might have the same effect, although then the anoxia could be caused by sea-floor stagnation due to spreads of organic debris or suffocation by extreme plankton blooms. The suggestion that events have some periodicity was shelved earlier (House, 1985) for lack of evidence on period length. Bai (1995) resurrects these ideas but evidence that the events are periodic is still not forthcoming.

CONCLUSIONS

The hypoxic Kačák event level can be traced from the Czech Republic to North Africa and it may be represented by the early part of the Chittenango black shale in New York State. The perturbations at the Kačák Event level are well indicated in the areas reviewed by either sedimentary or faunal characteristics, although often biostratigraphic resolution is still crude. Element or isotope anomalies indicate possible occurrences in China and Australia. Some pelagic sequences (Pic de Bissous) show no evidence of anoxia, which suggests ocean anoxic turnover may not have affected open sea areas. The phased pattern of development is thought to be best interpreted as driven by earthbound processes of which climate may be the most significant, perhaps as "greenhouse"-type extremes.

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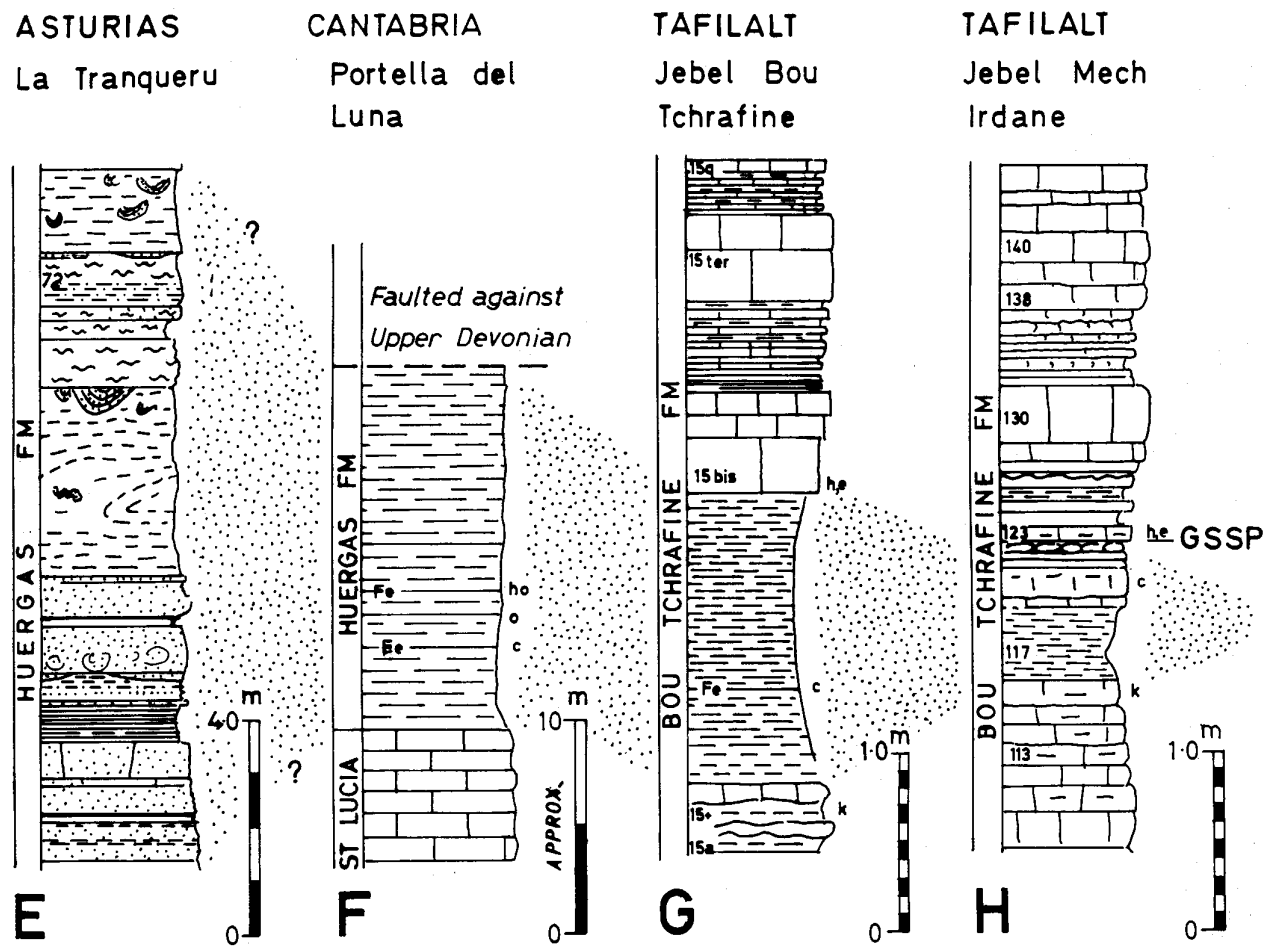

Figure 3. *Sections across the Kačák Event in Spain and Morocco. Key: e, entry of Polygnathus ensatus; h, entry of Polygnathus hemiansatus; C, Cabrieroceras faunas; o, occurence of Nowakia otomari.*

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