# Prospects for an upper Givetian substage

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With 3 figures, 3 plates, and 2 tables

## Abstract

New ammonoid and conodont data from Germany, the Montagne Noire (France) and southeastern Morocco document a complex sequence of sedimentary events and faunal changes within an extended Givetian (late Middle Devonian) Taghanic Event Interval or Taghanic Biocrisis. Direct association of supposed typical middle Givetian ammonoids, trilobites and corals with upper Givetian marker taxa such as pharciceratids have been found, for example, in Moroccan and French time equivalents of the New York Upper Tully Limestone. The initial and eustatic Taghanic Onlap level is not known to be characterized by the first appearance of any widespread index conodont, goniatite or other taxon. A future upper Givetian substage, therefore, might be based either on the entry of *Ozarkodina semialternans* or on the first appearance of *Schmidtognathus hermanni*. The *semialternans* Zone correlates with a third sedimentary cycle within the Tully Limestone and with the spread of the first Pharciceratidae, Eobeloceratidae (*Mzerrebites juvenocostatus*) and Archoceratidae n. fam. (*Atlantoceras*). The (Lower) *hermanni* Zone is marked by a post-event transgression which led to a significant conodont radiation and to a further diversification of Pharciceratidae and Eobeloceratidae (*Mz. erraticus*).

**Key words:** Middle Devonian, ammonoids, Archoceratidae, conodonts, trilobites, chronostratigraphy, global events, Morocco, France.

## Zusammenfassung

Neue Ammonoideen- und Conodonten-Daten aus Deutschland, Frankreich (Montagne Noire) und aus Südost-Marokko belegen eine komplexe Abfolge sedimentärer Ereignisse und von Faunenwechseln in einem längerfristigen Taghanic-Event-Intervall bzw. einer Taghanic-Biokrise des Givetiums (oberes Mittel-Devon). Direkte Vergesellschaftungen von Ammonoideen, Trilobiten und Korallen, die früher als typische Mittel-Givetium-Formen angesehen wurden, mit Leitformen des Ober-Givetiums (z. B. Pharciceraten) konnten in Marokko und Frankreich in Zeitequivalenten des Oberen Tully-Kalkes von New York nachgewiesen werden. Der initiale und eustatisch bedingte Taghanic Onlap ist bisher nicht durch das Einsetzen eines weit verbreiteten Index-Conodonten, -Goniatiten oder eines Vertreters anderer Fossilgruppen gekennzeichnet. Eine künftige Ober-Givet-Unterstufe sollte daher entweder durch das Einsetzen von *Ozarkodina semialternans* oder durch das erste Auftreten von *Schmidtognathus hermanni* definiert werden. Die *semialternans*-Zone korreliert mit einem dritten Sedimentations-Zyklus im Tully-Kalk und mit der Ausbreitung erster Pharciceratidae, Eobeloceratidae (*Mzerrebites juvenocostatus*) und Archoceratidae n. fam. (*Atlantoceras*). Die (Untere) *hermanni*-Zone ist durch eine Post-Event-Transgression gekennzeichnet, welche eine wichtige Conodonten-Radiation und eine weitere Diversifizierung der Pharciceratidae und Eobeloceratidae (*Mz. erraticus*) ermöglichte.

**Schlüsselwörter:** Mittel-Devon, Ammonoidea, Archoceratidae, Conodonta, Trilobita, Chronostratigraphie, Globale Events, Marokko, Frankreich.

## Introduction

In the classical subdivision of the German Upper Devonian by Wedekind (1913), the *Pharciceras lunulicosta* Zone or do Iα (originally to Iα) was taken as the base of the Upper Devonian. House (1982) correlated this with the *Pharciceras*-bearing (House 1962) Tully Limestone of New York and with the base of the Assise de Fromelennes, which mostly was taken as the base of the Upper Devonian in Belgium. This interpretation was adopted by subsequent authors (e.g., Johnson et al. 1985). When the revised Middle/Upper Devonian boundary was placed at the much younger base of the *Ancyrodella rotundiloba* Zone (Klapper et al. 1987, =

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Received May 2001, accepted July 2001

base of MN Zone 1 sensu Klapper 1989), almost all pharciceratid faunal levels or most of the *Pharciceras* Stufe (House 1985) fell into the late Givetian. This interval was of considerable duration (more than 2 ma following House 1995) and spans as many as 5 goniatite zones (House & Becker 1999) and 6 ½ zones of the traditional conodont zonal scheme: the upper part of the Middle *varcus* Zone, the Upper *varcus* Zone, the Lower *hermanni* Zone, the Upper *hermanni* Zone, the Lower *disparilis* Zone, the Upper *disparilis* Zone, and the *norrisi* Zone (lowest part of the Lower *falsiovalis* Zone = former Lowermost *asymmetricus* Zone).

With respect to the classical boundary and to significant global faunal differences (e.g., the boundary between the *Maenioceras* = MD II and *Pharciceras* Stufe = MD III) caused by the global Taghanic Event (House 1985), it seems logical to place the base of an upper Givetian substage at the position of the old Upper Devonian base. Recent detailed work on the Taghanic Event in North America (Brett et al. 1999), in Germany, the Montagne Noire and Morocco (Aboussalam 2000), including a lot of new conodont and goniatite data, however, showed that the sequence of faunal and sedimentary changes is rather complex (Fig. 1). It also should be noted that the term upper Givetian has been used in the past by various authors working on neritic successions of the western and eastern Rhenish Massive in rather different ways and including older levels (e.g., in the sense of the "Iserlohnium", see Struve 1992).

In all investigated areas it is evident that there is not just one level of global extinction, faunal change and of eustatic rise associated with the "Taghanic Onlap" (Johnson 1970), but a staged sequence of events (Fig. 1). For example, the New York Tully Limestone cannot only be divided into lower and upper members (Heckel 1973) but Brett et al. (1999) recognized three sedimentary sequences, with a second sequence boundary and start of a third division beneath the Bellona-West Brook Beds, within Heckel's upper member. Equivalents of 1st/2nd (lower member to lower half of upper member) and of the 3rd Tully sequence (Bellona-West Brook, Moravia and Fillmore Glen Beds) can be recognized in many European and Moroccan sections. Recognition of three Tully subdivisions with separation of a West Brook Member goes back to Cooper & Williams (1935) and Cooper (1967). The whole period from the sharp regression at the top of the Hamilton Group (from the sub-Tully sequence boundary of Brett & Baird 1996) to the base of the Geneseo Shale, the Tully Limestone time equivalents (compare House 1983, 1989), is taken as extended Taghanic Event Interval or Taghanic Biocrisis (Fig. 1).

Abbreviations: *Po.* = *Polygnathus*, *Schm.* = *Schmidtognathus*, *Oz.* = *Ozarkodina*, *I.* = *Icriodus*, *Ph.* = *Pharciceras*, *Maenio.* = *Maenioceras*. All illustrated material is deposited in the Museum für Naturkunde, Berlin.

## Investigated Sections with new Ammonoid and Conodont Data

Late Givetian sections have been described from around the world but none has been documented so far in sufficient detail to serve as a reference section for the middle/upper Givetian transition. It is recommended to search for a section in pelagic facies with good representation of several faunal groups, including diverse benthic organisms and, if possible, also miospores. Among the numerous European-North African localities studied by us in the last years in detail, none gave a perfect sedimentary and faunal sequence.

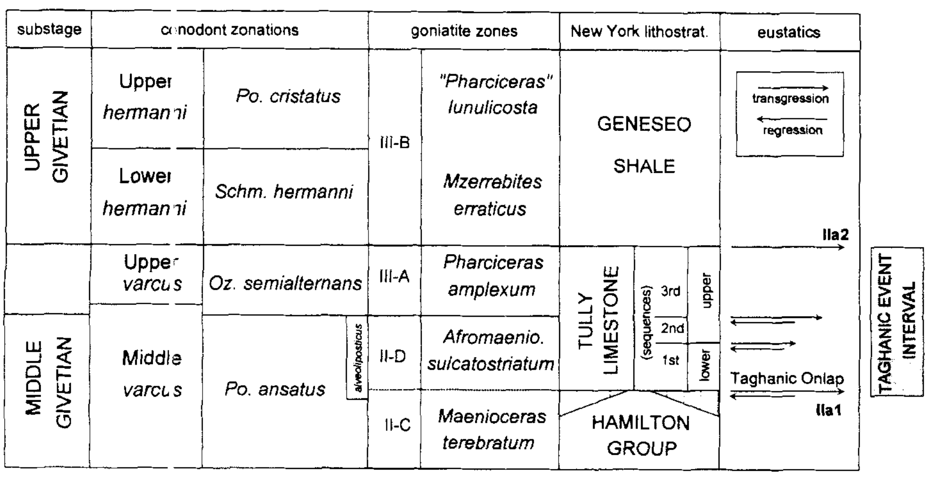


Fig. 1. Middle to upper Givetian chrono-, bio-, litho- and sequence stratigraphy.

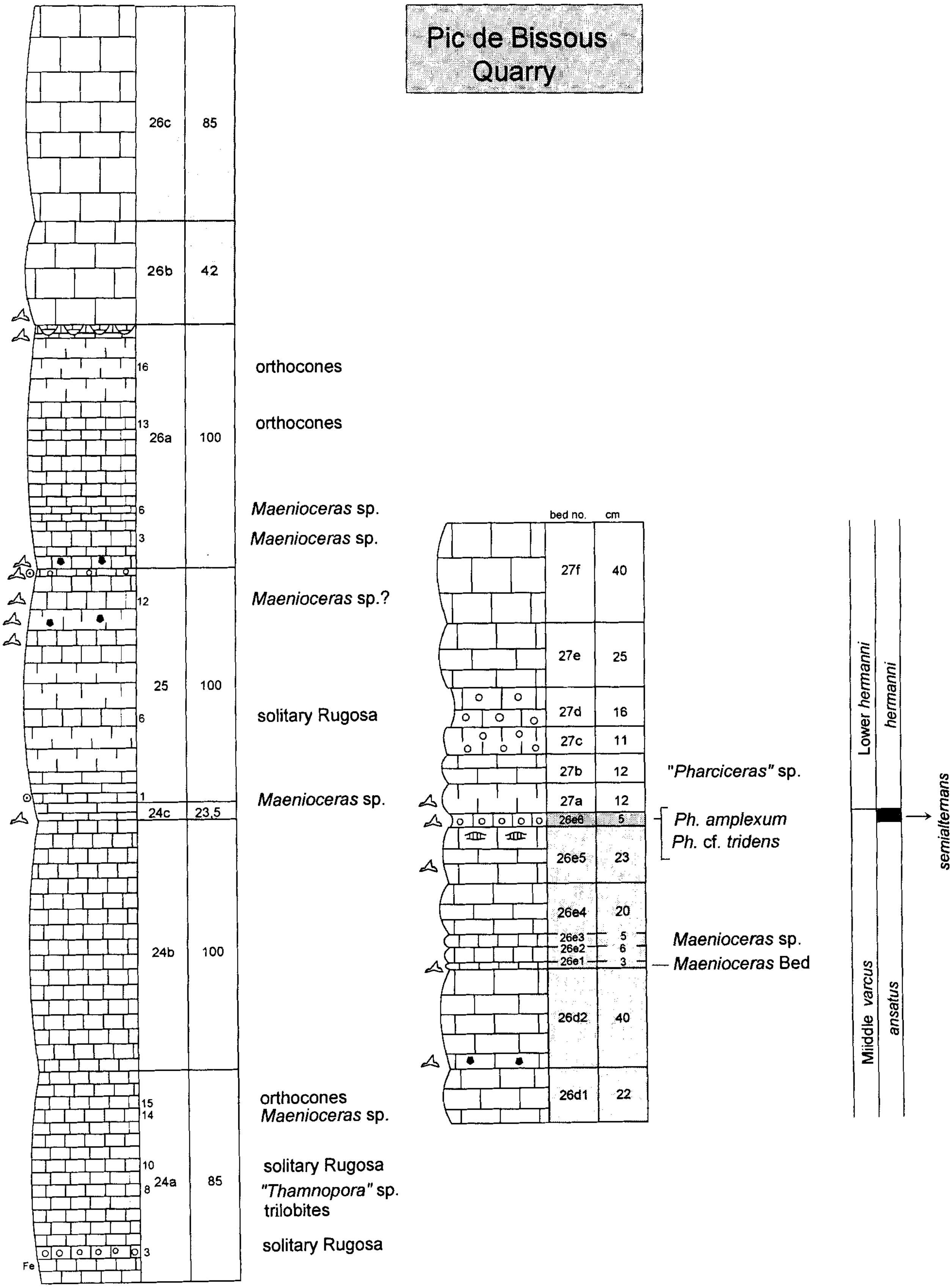



Fig. 2. Sedimentary and faunal succession in the middle to upper Givetian at Pic de Bissous Quarry (Marbriére Nord) showing the position of conodont samplex and of macrofaunal levels. The extended Taghanic Event Interval is shaded.

German sections in pelagic limestone facies (e.g., Syring and Blauer Bruch, Kellerwald, see Ebert 1993) are all very poor in macrofauna. Sealevel changes associated with the Taghanic Onlap and later regressive events often cause unconformities, for example along the Mont Peyroux and in the Cabrières area of the Montagne Noire (Feist & Klapper 1985), or on the central Tafilalt Platform of southeastern Morocco (Jebel Amelane, Jebel Mech Irdane, Seheb-el-Rhassal, Hamar Laghdad). More basinal and less condensed sections of southern Morocco are often incredibly rich in well preserved goniatites (Hassi Nebech, Tata region, Bensaid 1974) but the conodont record is very poor, even in intercalated limestone beds. Only two well-known sections currently have good goniatites and a sufficient record of important marker conodonts: Pic de Bissous Quarry of the Montagne Noire, and Bou Tchrafine in the Tafilalt.

**Pic de Bissous Quarry (Marbrière Nord)**

The marble quarry on the northern slope of Pic de Bissous, ca. 3 km N of Cabrières (Fig. 2; precise location see Feist & Klapper (1985: text-fig. 3), or Becker (1993: fig. 15), has been long known as an important Middle Devonian fossil locality. The succession is completely overturned but the succession is not disturbed by tectonics. Hematite-rich, red Givetian hemipelagic limestones are strongly cyclic (House 1995) and contain goniatites, orthocones, crinoid remains, trilo-

**Pic de Bissous Quarry**

| conodont zones | *ansatus* Zone | | | | | | | | | | *sem.Z.* | *her.Z.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bed and sample no. | 24c1 | 25 (1) | 25 (10) | 25 (11) | 26a(1) | 26a(18,19) | 26b(1) | 26d2 | 26e 1 | 26e 5 | 26e 6 | 27a |
| *Po. varcus* | 2 | * | 1 | 3 | 4 | 7 | 1 | 3 | * | 7 | * | 3 |
| *Po. ling. klapperi* | 1 | * | 2 | 1 | * | * | * | 3 | 1 | 3 | 1 | |
| *Po. ling. linguiformis* | 13 | * | 25 | 32 | 33 | 13 | 8 | 25 | 3 | 23 | 3 | |
| *Po. hemiansatus* | | W | | | | | | | | | | |
| *Po. ansatus* | * | W | * | * | * | * | * | * | W | | | |
| *Po. ling. mucronatus* | | | 1 | * | 1 | * | * | * | * | 2 | | |
| *Po. ling. weddigei* | | | | 1 | 3 | * | 1 | * | * | 1 | | |
| *Po. timorensis* | | | | | 2 | 1 | * | 1 | 1 | 4 | * | W |
| *I. difficilis* | | | | | 2 | | | | | | | |
| *Lateri. latericrescens* | | | | | 1 | | | | | | | |
| ***Oz. semialternans*** | | | | | W? | | | | | | 2 | 1 |
| *Tortodus* spp. | | | | | | | 1 | * | * | * | * | 2 |
| *I. obliquimarginatus* | | | | | | | | | W | cf. | * | cf. |
| *Po. xylus* | | | | | | | | | | 3 | * | 5 |
| *Po. ovatinodosus* | | | | | | | | | | 1 | * | 23 |
| *Schm. latifossatus* | | | | | | | | | | | | 4 |
| ***Schm. hermanni*** | | | | | | | | | | | | 2 |
| ***Schm. wittekindti*** | | | | | | | | | | | | 2 |
| ***Po. limitaris*** | | | | | | | | | | | | 4 |

Table 1. Conodont succession at Pic de Bissous Quarry. W = records of Walliser (1990). Shaded areas = extended Taghanic Event Interval.

bites, solitary rugose corals, rare tabulate corals, inarticulate brachiopods, bivalves, ostracods, dacryoconarids, agglutinating foraminiferans and moderately rich conodont assemblages. The dominating lithologies are internally layered and often styliolinid-rich bioclastic wackestones to packstones with ostracods, trilobites and crinoidal debris (Pl. 3: 8). Goniatites are enriched in specific thin units such as Beds $26e_1$ (*Maenioceras* Bed = youngest subunit of Bed R in House 1995) and $26e_6$ (Pl. 3: 7) which may reflect levels of minor deepening and of increased trophic level. Episodic coarse crinoidal debris limestones (e.g., Beds 25(11), 26a(1), 26d2(1), see Pl. 3: 5) were deposited during storms or short-termed shallowing phases.

Apart from some preliminary data of Walliser (1990), whose bed numbering has been mostly adopted and extended, the conodonts of the quarry have largely remained unstudied. Faunas from the upper part of Middle *varcus* Zone to basalmost Frasnian, however, were described from a nearby section at the western slope of Pic de Bissous (Feist & Klapper 1985: section VS-W; goniatites in House et al. 1985). Our conodont succession (Table 1) starts with Bed 24c which falls in the *ansatus* Zone (ca. middle part of Middle *varcus* Zone). *Po. ansatus* was found in Bed 25(1) but Walliser (1990) noted it at a much older level higher up in the quarry (youngest part of Bed 17). *Latericriodus* (Pl. 2: 18; compare records in Feist & Klapper 1985) forms a minor element of Montagne Noire *ansatus* (Middle *varcus*) Zone faunas. A significant unconformity with erosional contact at the boundary between Beds 26a and 26b has previously been unnoticed. In sequence stratigraphic terms, it seems likely that this sedimentary break correlates with the regression-transgression couplet of the initial Taghanic Event.

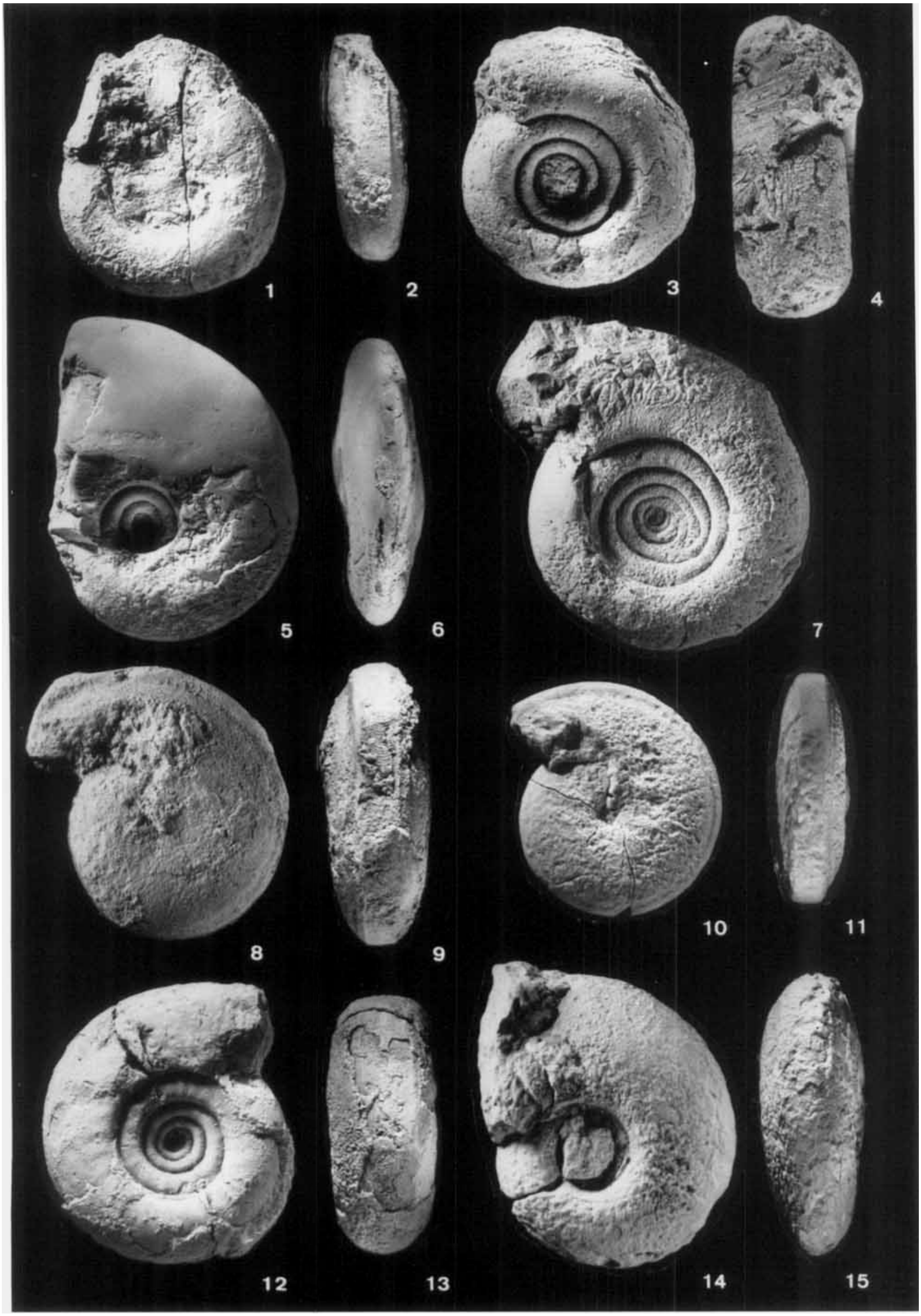
The mass occurrence of *Maenioceras terebratum* Group (e.g., MB.C.3607) in Bed $26e_1$ (= Bed 26c in Walliser 1990) at the floor of the quarry still falls in the *ansatus* (Middle *varcus*) Zone. It is tempting to correlate this unusual unit with the 2nd Tully transgression at the base of its upper member. There is evidence of an additional sedimentary break and erosional events within haematite-rich styliolinid wackestones of Bed $26e_5$ (Pl. 3: 6). The dark red and nodular Bed $26e_6$ is only exposed in the eastern quarry corner and yielded for the first time in Europe *Pharciceras amplexum* (Pl. 1: 1–2) together with rather evolute *Ph.* cf. *tridens* (Pl. 1: 7). As in the Moravia Bed of New York, this unit contains *Oz. semialternans* (Pl. 2: 9) and can be precisely correlated with the 3rd Tully sequence. The erosional unconformity of Bed $26e_5$ indicates a sequence boundary just below, still in the topmost *ansatus* Zone (Middle *varcus* Zone). The *semialternans* Zone, unfortunately, is very condensed since the following Bed 27a gave a typical and diverse *hermanni* Zone fauna with *Po. limitaris* (Pl. 2: 20), *Schm. latifossatus* and others. Pharciceratids from Bed 27b are too poorly preserved for identification.

The described sequence suggests that more efforts should be undertaken to investigate the Pic de Bissous rugose corals, trilobites and ostracods.

## Bou Tchrafine

The Bou Tchrafine section S of Erfoud in the central Tafilalt has been described by a wide range of authors. The middle to late Givetian conodont succession was investigated by Bultynck & Hollard (1980), Bultynck & Jacobs (1981), Ziegler & Klapper (1982), Bensaid et al. (1985), Bultynck (1987) and Ebert (1993). Goniatite data were included in Bensaid et al. (1985) and Ebert (1993); a more detailed summary was provided by Becker & House (1999). Based on this background we have specifically resampled the levels from below the Taghanic Event (upper *Maenioceras* Marls) to the Lower Marker Bed (Fig. 3) of the *Po. cristatus* Zone (= Upper *hermanni* Zone).

The sequence consists of yellowish-grey, nodular marls (Bed A0 = BT 30), massive and very solid, bluish-grey micrites with some goniatites, relative rich conodonts and bioturbated upper surfaces (*Sellagoniatites* Limestone and Lower Marker Bed), thin shale/marl interbeds, and yellowish, styliolinid-rich and somewhat argillaceous, fossiliferous, bioturbated, partly still layered micrites with goniatites, orthocones, *Pterochaenia*-like bivalves, brachiopods, crinoid remains, rare tabulate corals, foraminiferans (e.g., *Webbinelloidea*, Pl. 2: 16), smooth ostracods, phacopids, harpids and tentaculites (Beds A4 to B4). A microfacies analyses (Pl. 3: 1–4) showed that carbonates rather uniformly consist of styliolinid wackestones to packstones with ostracods, trilobites and rare crinoid remains. Mudstone intervals (Pl. 3: 2) indicate episodic deepening, packstones (Pl. 3: 1) formed during minor shallowing phases with increased bottom turbulance and removal of fine micritic matrix. It is obvious that most beds consist of several depositional units,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perhaps each representing one orbital cycle, and separated by inconspicuous unconformities. Bed boundaries reflect somewhat stronger signals of sedimentary cyclicity and sealevel fluctuations.

Beds A0 to A3 (BT 30–31c, Table 2) fall in the higher part of the *ansatus* Zone (Middle *varcus* Zone); Bultynck (1987) and Lotmann (1990) recorded *Po. ansatus* from well below the *Maenioceras* Marl (= Bed A0). An intermediate between *Po. ansatus* and *Oz. semialternans* was found by Bultynck (1987) in his sample 30bis near the top of Bed A0. *Po. ovatinodosus* (Table 2, Pl. 2: 1) is now locally first recorded from the middle part of the *Sellagoniatites* Limestone (Bed A2 = BT 31b) which contains the name-giving marker goniatite. At its top (top of Bed A3) there is a distinctive erosional surface and a thin shale unit. Based on sequence stratigraphy, we correlate the overlying styliolinid-rich Bed A4 (Pl. 3: 2, = BT 32 in Bensaid et al. 1985 and Ebert 1993), which has poor macrofauna and which consists of two subunits, with the 1st/2nd sequences of the Tully Limestone. Conodonts still fall in the *ansatus* Zone (Middle *varcus* Zone) and its top is also rather irregular suggesting another discontinuity surface.

Bed B1b (= BT 33a in Ziegler & Klapper 1982, Bensaid et al. 1985 and Ebert 1993; BT 32 in Bultynck & Jacobs 1981, includes Bed B2 of Becker & House 1999) is the famous unit with *Pharciceras* aff. *amplexum* (which will be placed in a new species, Pl. 1: 3–4). Detailed sampling showed that poorly preserved *Maenioceras* are still rather abundant (MB.C.3305.1–7) and associated with the last rare *Sellagoniatites* (Pl. 1: 5–6) and the first *Epitornoceras*. The presence of *Oz. semialternans* was confirmed (Pl. 1: 8) but conodont samples are not rich. The overlying Beds B2–B4 (= BT 33b–d) have a typical and rather diverse fauna of the *hermanni* Zone. At the base of the zone (Bed B2), *Schm. hermanni* (Pl. 2: 4), *Sch. pietzneri* (Pl. 2: 2–3), *Schm. wittekindti* (Pl. 2: 5), *Po. limitaris* (Pl. 2: 14a–b), *Schm. latifossatus* (Pl. 2: 13) and *Oz. proxima* (Pl. 2: 7) enter. Bed B2 (= BT 33b, including fauna placed in Bed B3 in Becker & House 1999), yielded *Mzerrebites erraticus* and a closely related, somewhat thicker form (compare specimen from Jebel Amelane, Pl. 1: 14–15) but no pharciceratids. In neighbouring sections (Seheb el Rhassal), the multilobate and evolute "*Pharciceras*" *lunulicosta* Group (Gen. nov.) enters in equivalents of Beds B3/B4.

The lower part of the Upper Marker Bed (Bed C1 = BT 34) has been dated by Bensaid et al. (1985) and Ebert (1993) as Upper *hermanni* Zone which is defined by the entry of *Po. cristatus* Hinde. As repeatedly noted (Kirchgasser 1970, Huddle 1981; compare discussion in Ziegler & Klapper 1982), the holotype of *Po. cristatus* differs from *Po. cristatus* sensu Bischoff & Ziegler (1957) in ornamentation (with partly fused nodes in two rows, the outer of which runs around the platform margin) and in its dorsal carina which does not reach the posterior tip of the platform. It is probably appropriate to restrict the name *Po. cristatus* to morphotypes resembling the holotype. In such a taxononomic concept, *Po. ectypus* Huddle becomes available as the correct name for *Po. cristatus* sensu Bischoff & Ziegler. The *cristatus* lectotype lies outside the variation of an Illinois population illustrated by Orr (1964) but he (text-fig. 4C), as well as Bultynck & Jacobs (1981, pl. VII, figs 11a–b), illustrated single specimens with *ectypus*-type nodation and *cristatus*-type short med-

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Plate 1. Goniatites from around the Taghanic Event Interval of Morocco and of the Montagne Noire. **1–2**. *Pharciceras amplexum* (Hall), MB.C.3300.1, Pic de Bissous Quarry, Bed 26e6, *semialternans* Zone, incomplete specimen, × 1; **1**, lateral view, and **2**, ventral view showing typical, strong ventrolateral furrows and cross-section with flat venter. **3–4**. *Pharciceras* aff. *amplexum* (Hall), MB.C.3151.3, Bou Tchrafine, Bed B1b, *semialternans* Zone, small specimen with sutures; **3**, lateral view, × 2.2, and **4**, ventral view, × 2.5, showing the rounded cross-section at ca. 20 mm diameter lacking prominent furrows. **5–6**. *Sellagoniatites discoides* (Waldschmidt), MB.C.3302.1, Bou Tchrafine, Bed B1b, *semialternans* Zone, × 1; **5**, lateral view showing rapid whorl expansion, and **6**, ventral view showing typical and strong shell compression. **7**. *Pharciceras* cf. *tridens* (Sandberger & Sandberger), MB.C.3301, Pic de Bissous Quarry, Bed 26e6, *semialternans* Zone, relative evolute and compressed morphotype (or subspecies) lacking furrows, × 1.5, lateral view. The irregular coiling of early whorls is an artefact of preparation. **8–9**. *Maenioceras* aff. *terebratum* (Sandberger & Sandberger), MB.C.3303.1, Col de Tribes South, Bed 45, *semialternans* Zone, × 1.5; **8**, lateral view showing strong ventrolateral furrows, and **9**, ventral view, showing thicker whorls than in the *terebratum* lectotype of Becker & House (1994). **10–11**. *Maenioceras terebratum* (Sandberger & Sandberger), MB.C.3306, Jebel Amelane, Section 1 (see Becker & House 1994), loose specimen from *Maenioceras* Marls (*terebratum* Zone), typical strongly compressed morphotype, × 1.5; **10**, lateral view, and **11**, ventral view showing thinner whorls than in *Maenio.* aff. *terebratum* (see Fig. 9). **12–13**. *Pharciceras* aff. *amplexum* (Hall), MB.C.3304.1, Col de Tribes South, Bed 45, *semialternans* Zone, × 1.5; **12**, lateral view showing biconvex growth lines, and **13**, ventral view showing broad whorl profile and weak ventrolateral furrows at 30 mm diameter. **14–15**. *Mzerrebites* aff. *erraticus* (Petter), MB.C.3166, Jebel Amelane, Section 1, loose specimen, probably from the *erraticus* Zone, × 1.5; **14**, lateral view, and **15**, ventral view showing wider whorls than in typical *Mz. erraticus*.

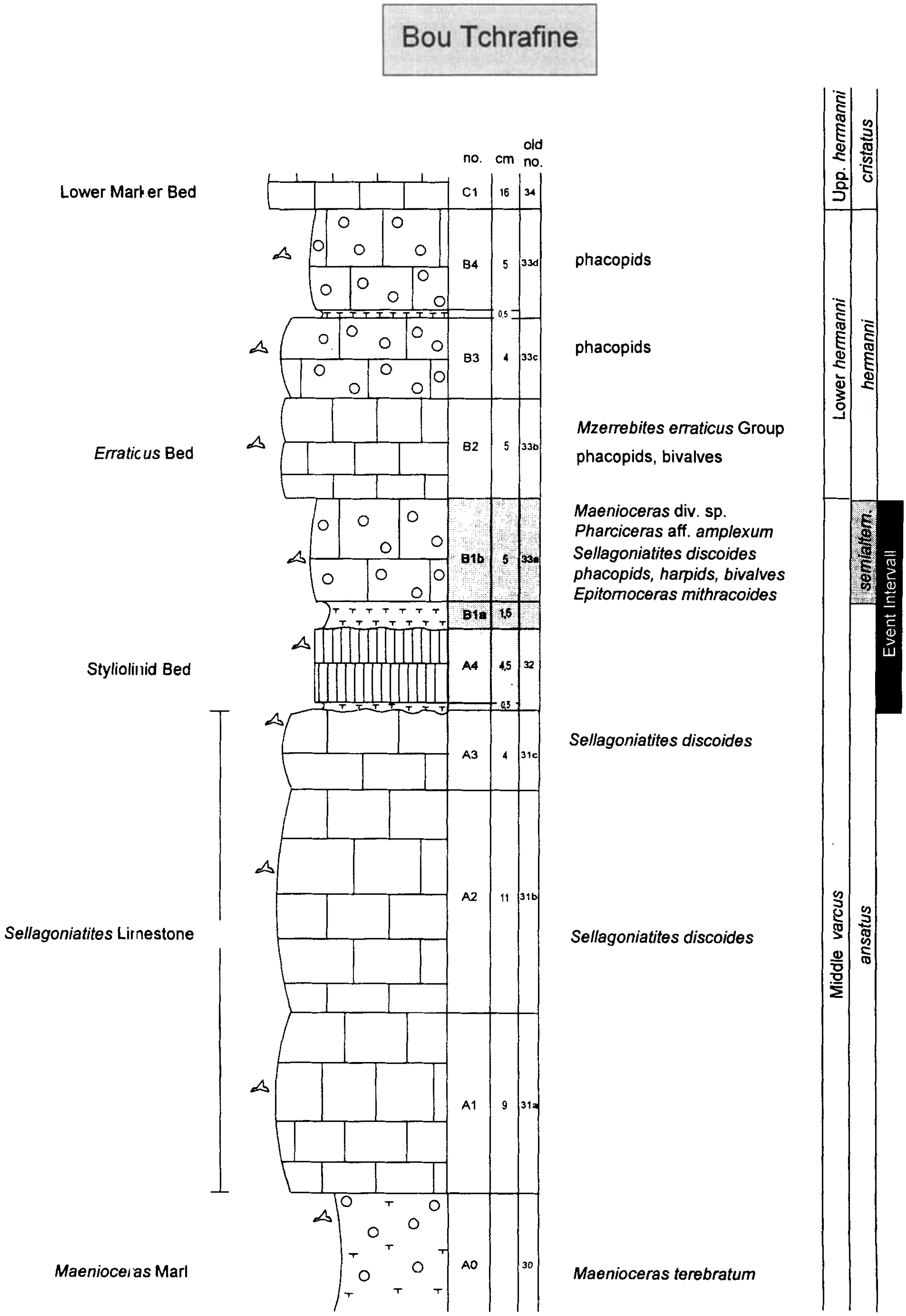



Fig. 3. Sedimentary and faunal succession in the middle to upper Givetian at Bou Tchrafine (section of Bultynck & Hollard 1980 and Bultynck 1987) showing the position of new conodont samples and the macrofaunal record. Shaded area = Taghanic Event Interval.

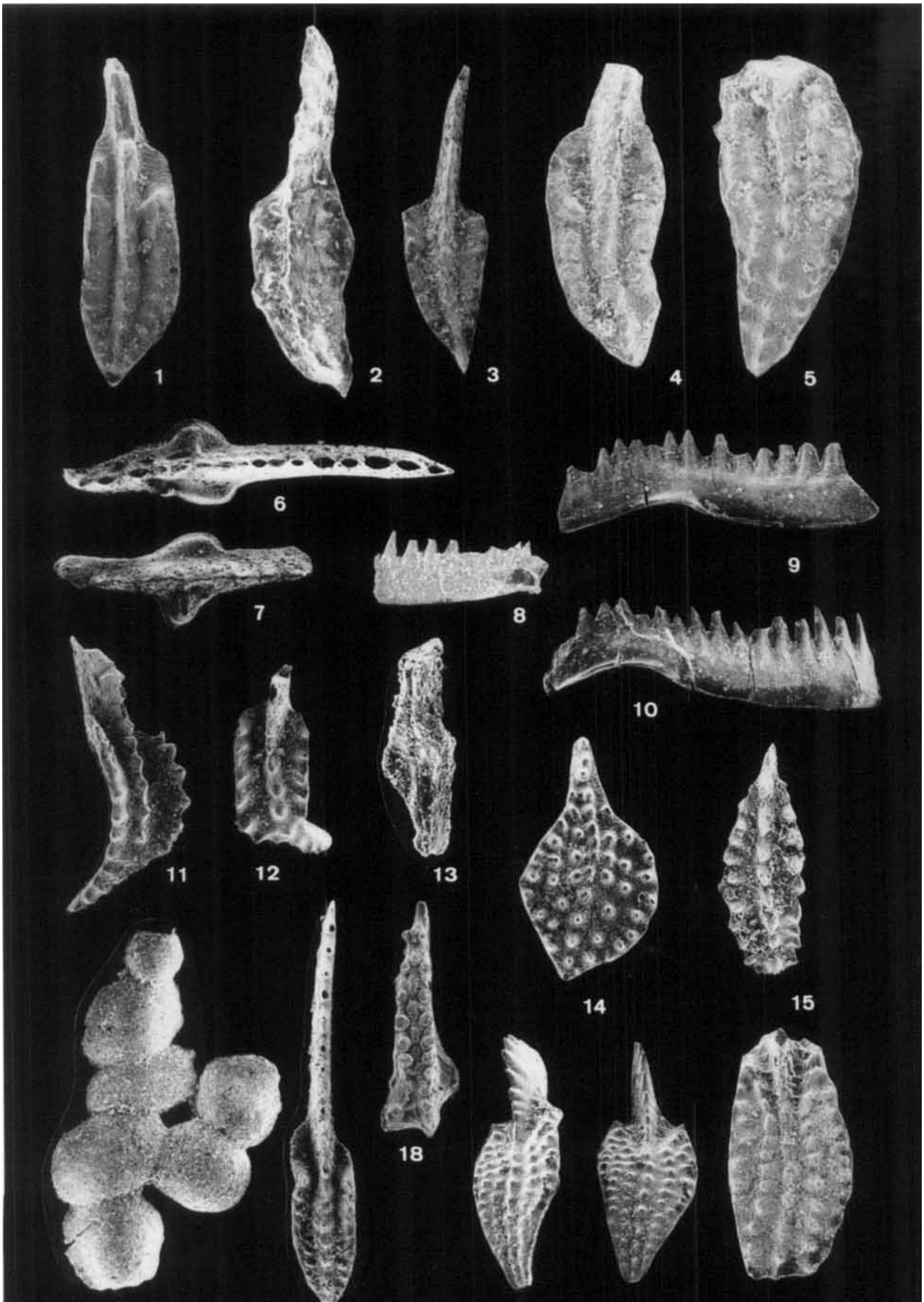
| Bou Tchrafine | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| conodont zones | *ansatus* Zone | | | | | *sem.Z.* | *hermanni* Zone | | | *cr. Z.* |
| bed and sample no. | A0 | A1 | A2 | A3 | A4 | B1b | B2 | B3 | B4 | C1 |
| *Po. varcus* | 1 | 2 | 30 | 39 | 4 | B | 13 | 9 | * | B |
| *Po. rhenanus* | B | * | B? | | | | | | | |
| *Po. ling. linguiformis* | 20 | 21 | 224 | 121 | 34 | 4 | | | | |
| *Po. ling. mucronatus* | 1 | 3 | 7 | 4 | 2 | | | | | |
| *Po. ling. weddigei* | 1 | 1 | 24 | 8 | 3 | 1 | | | | |
| *Po. timorensis* | B | * | 23 | 10 | 1 | E | 3 | | | |
| *Tort. beckmanni* | B | * | * | * | * | B | | | | |
| *Po. ansatus* | * | * | 27 | 7 | * | * | 8 | | | |
| *Po. xylus* | * | * | 20 | 9 | E | * | 3 | 6 | 4 | |
| *Po. ling. klapperi* | * | * | 7 | 6 | 1 | | | | | |
| *I. difficilis* | * | * | 2 | * | * | * | 8 | | | |
| ***Po. ovatinodosus*** | | | 12 | 1 | 2 | E | 8 | 8 | * | B |
| *Tortodus* spp. | | | | 4 | 1 | 1 | | | | |
| ***Oz. semialternans*** | | | | | | 1 | 2 | * | 1 | B |
| *Oz. proxima* | | | | | | | 3 | | | |
| *Oz. sannemanni* | | | | | | | 1 | | | |
| *Schm. latifossatus* | | | | | | | | 1 | * | B |
| ***Schm. hermanni*** | | | | | | | 27 | 11 | 2 | B |
| ***Schm. wittekindti*** | | | | | | | 4 | 6 | 1 | B |
| ***Schm. pietzneri*** | | | | | | | 1 | 1 | * | B |
| ***Po. limitaris*** | | | | | | | 1 | 4 | 2 | |
| *Elsonella rhenana* | | | | | | | | 1 | | |
| ***Po. cristatus*** | | | | | | | | | | B |

Table 2. Middle to late Givetian conodont succession at Bou Tchrafine, based on new samples and records of Bultynck (1987: B) and Ebert (1993: E). Shaded area = Taghanic Event Interval.

ian carina. Both taxa seem to have come from the same stratigraphical level (North Evans Limestone) of New York.

**Possible levels for the base of an upper Givetian substage**

The discovery of intermediate pelagic faunas with mixtures of previously supposed typical middle and upper Givetian taxa together with other data on ammonoid and conodont occurrences allow a critical evaluation of three levels which should be considered for a formal definition of an upper Givetian substage: the initial Taghanic Onlap, levels around the base of the traditional Upper *varcus* Zone, and the base of the *hermanni* Zone. Any decision should incorporate additional data based on miospores, vertebrates and neritic faunas but these have not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yet been used for detailed international correlation. It is worth mentioning that stringocephalid brachiopods range above all the levels under discussion.

## Base of Taghanic Onlap

The initial transgressive pulse at the base of the mostly unconformable Lower Tully Limestone (Fig. 1) has been correlated with the Belgian transgression of the Fromelennes Formation over the Calcaire de Givet and with many other regional deepening events of North America and Eurasia (House 1975, 1983, Johnson et al. 1989, Ebert 1993, Day 1996a). New data by Bultynck et al. (2001), however, indicate that the Fromelennes Formation began as early as in the upper part of the Lower *varcus* Zone (*timorensis* Zone). This is in conflict with a record of *Stringodiscus? birenheidei* in the basal Fromelennes Formation (Struve 1992), a species which otherwise is only known from Flinz limestones (Schleddenhof Beds) above the thick middle Givetian reef limestones (Massenkalk Formation) of the Iserlohn area in the northern Rhenish Massive.

Johnson et al. (1985, 1989) recognized the Taghanic Onlap as the start of their international Depophase IIa. The initial pre-Tully regression/Tully transgression couplet is assumed to have coincided with significant extinctions in ammonoids (House 1985, 1989, Becker & House 2000) and trilobites (Cheiruridae, Lichidae, Calmoniidae, Eremiproetinae, Cyphaspidinae, most Proetinae, many Dechenellinae, Otarioninae and Aulacopleurinae; Feist 1991, Chlupac et al. 2000). Many other faunal groups, such as rugose and tabulate corals (e.g., Oliver & Pedder 1994), brachiopods (Cooper & Williams 1935, Dutro 1981), stromatoporoids (e.g., Mistiaen in Brice et al. 1976) and ostracods (e.g., Lethiers in Brice et al. 1976) were affected by the Taghanic Event but the precise timing of their extinctions is either still unknown, was stepwise (Dutro 1981, Day 1996b), or much influenced by regional factors. A first range compilation of many faunal groups by Ebert (1993), unfortunately, needs considerable revision and elaboration. Despite the fact, that the Taghanic Onlap seems to be recognizable on a global scale, serious reasons speak against its use as substage boundary level:

a. The initial Taghanic Onlap falls within the Middle *varcus* Zone (*ansatus* Zone of Bultynck 1987) and currently there is no index conodont, ammonoid or any other international faunal marker available that allows an easy recognition of the onlap level. In many of our sections the identification of the onlap level had to be based on sequence stratigraphy. In North American interior basins, Day (1996a, 1996b) underlined the immigration of

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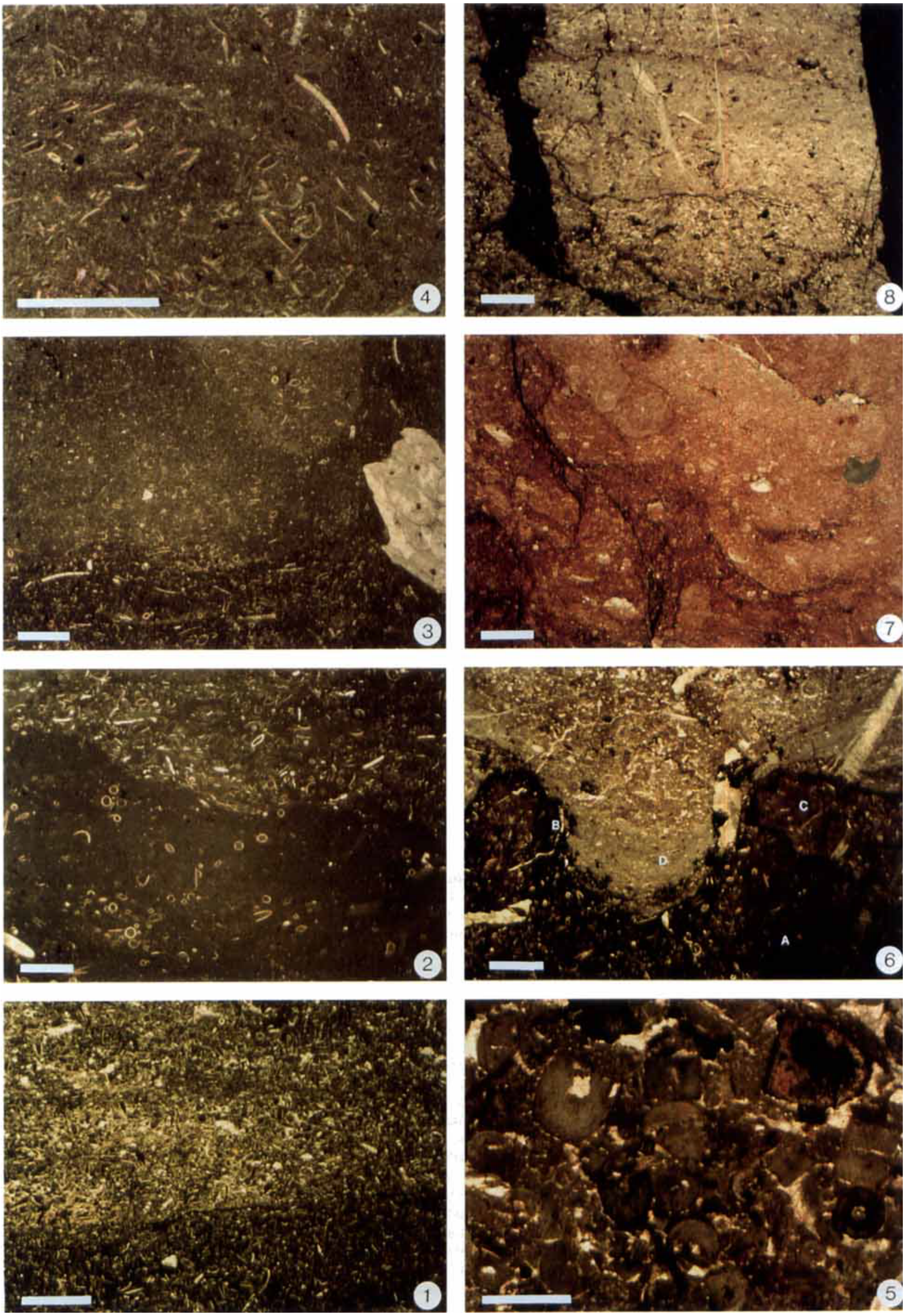
Plate 2. Conodonts and foraminiferans from around the Taghanic Event Interval of Morocco and of the Montagne Noire. **1**. *Polygnathus ovatinodosus* Ziegler, Klapper & Johnson, Bou Tchrafine, Bed A2, middle *Sellagoniatites* Limestone, upper part of *ansatus* Zone, incomplete and relatively weakly ornamented specimen, × 55. **2**. *Schmidtognathus pietzneri* Ziegler, Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, large specimen, × 50. **3**. *Schmidtognathus pietzneri* Ziegler, Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, small specimen, × 85. **4**. *Schmidtognathus hermanni* Ziegler, Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, incomplete specimen, upper view, × 85. **5**. *Schmidtognathus wittekindti* Ziegler, Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, incomplete specimen, × 85. **6**. *Ozarkodina sannemanni* Bischoff & Ziegler, Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, upper view, × 55. **7**. *Ozarkodina proxima* (Pollock) Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, upper view, × 55. **8**. *Ozarkodina semialternans* Wirth, Bou Tchrafine, Bed B1b, *Pharciceras* aff. *amplexum* Bed, *semialternans* Zone, fragmentary specimen, lateral view, × 55. **9**. *Ozarkodina semialternans* Wirth, Pic de Bissous Quarry, Bed 26e6, *Pharciceras amplexum* Bed, *semialternans* Zone, lateral view, × 85. **10** *Ozarkodina semialternans* Wirth, Col de Tribes South, Bed 46, *Pharciceras* aff. *amplexum* Beds, *semialternans* Zone, lateral view, × 85. **11**. *Polygnathus linguiformis mucronatus* Wittekindt, Bou Tchrafine, Bed A3, top *Sellagoniatites* Limestone, upper part of *ansatus* Zone, slightly oblique view, × 55. **12**. *Polygnathus linguiformis mucronatus* Wittekindt, Bou Tchrafine, Bed A3, top *Sellagoniatites* Limestone, upper part of *ansatus* Zone, upper view of a second specimen, × 55. **13**. *Schmidtognathus latifossatus* (Wirth), Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, lower view of incomplete specimen showing the *Schmidtognathus*-type large basal cavity, × 55. **14**. *Polygnathus alveoliposticus* Orr & Klapper, Seheb el Rhassal, top Bed D2, top *Sellagoniatites* Limestone, upper part of *ansatus* Zone, wide morphotype, × 55. **15**. *Polygnathus alveolipoticus* Orr & Klapper, Martenberg (Rhenish Massive), section at northern corner, top Bed –3B, *semialternans* Zone, narrow morphotype, × 55. **16**. *Webbinelloidea similis* Stewart & Lampe, unusually complex morphotype (= *Webb. disparicella* Summerson, see *similis* Subgroup IIIA in Conkin & Conkin 1970), Bou Tchrafine, Bed B1b, *Pharciceras* aff. *amplexum* Bed, *semialternans* Zone, × 30. **17**. *Polygnathus timorensis* Klapper, Bou Tchrafine, Bed A3, top *Sellagoniatites* Limestone, upper part of *ansatus* Zone, specimen with asymmetric platform, × 85. **18**. *Latericriodus latericrescens* (Branson & Mehl), Pic de Bissous Quarry, Bed 26a (1), *ansatus* Zone, incomplete specimen, × 85. **19**. *Polygnathus limitaris* Ziegler, Klapper & Johnson, Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone, slightly oblique (a) and upper view (b), × 50. **20**. *Polygnathus limitaris* Ziegler, Klapper & Johnson, Pic de Bissous Quarry, Bed 27a, basal (Lower) *hermanni* Zone, incomplete specimen, × 85.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longer-ranging Old World Realm and Eastern American brachiopod groups with the Taghanic Onlap but did not note important evolutionary innovation at that time.

b. In the Lower Tully, but not at its very base (in the Carpenter Falls Bed, Ziegler et al. 1976), and in various other North American regions (e.g., Dawson Bay Formation of Manitoba, Norris & Uyeno 1971; Bassett Member of the Little Cedar Formation, Iowa, Witzke et al. 1989; Buffalo River Member of the Pine Point Formation, Northwestern Territorries, Lantos 1983), *Po. alveoliposticus* is a useful index species but it occurs only very rarely outside America and not always at the same level. In the Tafilalt of southern Morocco, we have found one specimen (Pl. 2: 14) in the immediate pre-event interval (shallowing upwards *Sellagoniatites* Limestone, topmost MD II-C). At Martenberg in the Rhenish Massive, another specimen (Pl. 2: 15) was discovered in the *semialternans* Zone. The *disparillis* Zone in the age of most original material from the basal New Albany Shale and lower Antrim Shale of Indiana (Orr & Klapper 1968). Species such as *Po. ovatinodosus* and *Po. tuberculatus* experienced some blooms in the transgressive episode but also range into pre-onlap levels of the Middle *varcus* Zone (*ansatus* Zone). Conodonts show no significant extinction at all at the initial Taghanic Event (Aboussalam & Becker 2000).

c. The new data from Morocco (Bou Tchrafine, Ouidane Chebbi) and from the Montagne Noire showed that both *Maenioceras* and *Sellagoniatites*, supposed typical middle Givetian index goniatites, may still co-occur with the oldest *Pharciceras* in equivalents of the 3rd Tully sequence (MD III-A). Directly associated *Maenio.* aff. *terebratum* (Pl. 1: 8–9) and *Ph.* aff. *amplexum* (Pl. 1: 12–13) are illustrated from the *semialternans* Zone (see Pl. 2: 10) of Col de Tribes South, at the eastern slope of the Mont Peyroux of southern France, just N of section MP-E of Becker (1993). In more basinal sections of the Tafilalt (Hassi Nebech) and in the Dra Valley (Tata region: sections Oufrane, Tiguisselt, Oued Mzerreb), litho- and sequence stratigraphical correlations suggest that a deepening and black shale interval with *Afromaenioceras sulcatostriatum,* the last *Wedekindella brilonensis* and *Trevoneites* (MD II-D) correlates with the 1st/2nd Tully sequences. It is conformably overlain by black shales with the oldest *Pharciceras* (MD III-A).

d. A range of supposed typical middle Givetian trilobite groups survived the pre-Tully regression and initial onlap. The last representative of the Proetinae (*Gerastos*) was found at Ouidane Chebbi (eastern Tafilalt) in equivalents of the 1st/2nd Tully sequence (Bed 2). This has parrallels in a little noticed contemporaneous record of Crassiproetus from the Bassett

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Colour-Plate 3. Microfacies of beds around the Taghanic Event Interval at Bou Tchrafine and Pic de Bissous (Scale bars = 1 mm). **1.** Bou Tchrafine, Bed A3, top of *Sellagoniatites* Limestone, upper part of *ansatus* Zone: styliolinid-rich wackestone, followed above a haematite-encrusted small-scale discontinuity surface (ca. 1/3 above base of figure) by styliolinid packstone. The lower styliolinid wackestone contains some thick-shelled, benthic ostracods, crinoid debris, trilobite remains and disarticulated brachiopod shells. In the stylionid packstone the dark micrite was washed out pointing to episodically increased bottom turbulence and condensation. Towards the top of the bed the styliolinid abundancy decreases again. **2.** Bou Tchrafine, Bed A4, Styliolinid Bed, top part of *ansatus* Zone: bioturbated stylionid mudstone-wackestone with some tentaculites (middle left margin), small orthocones, trilobite remains and rare angular quartz grains, followed above an undulating and non-encrusted minor discontinuity surface by styliolinid-richer wackestone. **3.** Bou Tchrafine, Bed B1b, *Pharciceras* aff. *amplexum* Bed, *semialternans* Zone: styliolinid wackestone with brachiopods, trilobite remains and rare angular quartz grains, followed above an inconspicuouse undulating discontinuity surface by less fossiliferous, bioturbated styliolinid wackestone/mudstone with rare crinoid debris. Remains of large tabulate/stromatoporoid colonies form unusual shallow-water allochems in the otherwise typical pelagic microfacies. **4.** Bou Tchrafine, Bed B2, *erraticus* Bed, basal (Lower) *hermanni* Zone: detailed view of bioclastic wackestone with styliolinids, ostracod and brachiopod remains and some pyrite/(secondary) haematite. **5.** Pic de Bissous Quarry, Bed 26d2, *ansatus* Zone: crinoid grainstone/rudstone with some haematite coating and sparite and peloids between partly complete and partly broken ossicles. **6.** Pic de Bissous Quarry, Bed 26e5, (–), top *ansatus* Zone: lower part (A) composed of haematite-rich styliolinid wackestone with ostracods and shell filaments, truncated by an haematite-coated erosional channel (B) which has mostly removed a second wackestone unit (C) which is separated by an undulating stylolitic unconformity surface. The channel is filled by a shallowing upwards wackestone unit (D) with many styliolinids, intraclasts, crinoid debris, ostracods, filaments and trilobite remains. **7.** Pic de Bissous Quarry, Bed 26e6, *Pharciceras amplexum* Bed, *semialternans* Zone: haematite-rich, red, bioturbate and nodular wackestone with ostracods, styliolinids and intraclasts in microsparitic matrix. The original internal bedding has been largely destroyed by diagenetic overprinting. **8.** Pic de Bissous Quarry, Bed 27a, basal (Lower) *hermanni* Zone: styliolinid packstone with thin-shelled, pelagic ostracods, haematite and crinoid debris, followed gradually (in the middle part of the section) by less fossiliferous styliolinid wackestone.

Member of the Little Cedar Formation of Iowa; the genus may range even higher in Iowa (Witzke et al. 1989). Homalonotids (*Dipleura decayi*), Hamilton-type phacopids (*Geesops rana*), otarionids (*Harpidella*), asteropygids (*Greenops*) and Dechenellinae (*Monodechenella macrocephala, Pseudodechenella rowi*) re-appear in New York in the Upper Tully Limestone (Richter & Richter 1926, Cooper & Williams 1935). They are associated with various Hamilton-type brachiopods of the *Elytha fimbriata* Zone (see Heckel 1973). In the discussion of trilobite extinctions associated with the Taghanic Onlap little attention has been paid so far to the lower Callaway Formation of Missouri which has been correlated with the (post-onlap) lower part of the Cedar Valley Formation of Iowa (e.g., Witzke et al. 1989, Day 1996b). Faunas listed in Fraunfelter (1967) include brachymetopids (*Mystrocephala pulchra*), crassiproetines (*Crassiproetus calhounensis*), *Greenops*, *Phacops*, scutelluids, dechenellids (*Dechenella* aff. *nortoni*, *Pseudodechenella elevata*) and others. A single *Aulacopleura (Paraaulacopleura)* was mentioned by Basse (1998) from the Tentaculitenschiefer of the northern Rhenish Massive the drowning of most of the massive reefs of the region by this dark shale unit probably has been caused by the Taghanic deepening. On a global scale, there is a remarkable lack of well documented late Givetian trilobite faunas. But it seems clear that only ca. half of all middle Givetian trilobite genera ranged into the event interval.

e. Survival of the initial Taghanic Onlap is also true for some North American brachiopods (Dutro 1981) rugose and tabulate corals (Heckel 1973) which re-occur in the Bellona and West Brook Beds of the Upper Tully Limestone. In the Tafilalt (Ouidane Chebbi), the cladochonid *Bainbridgia alternans* was recently discovered to range into the level with oldest *Pharciceras*. It is expected that future work will show the presence of more typical middle Givetian faunal groups in Tully Limestone equivalents.

### Base of Upper *varcus* Zone

The base of the Upper *varcus* Zone is traditionally defined by the entry of *Po. latifossatus* (Ziegler et al 1976) which for phylogenetical and morphological reasons (large basal cavity, see Pl. 2: 13) is better placed in *Schmidtognathus*. Although the species has been recorded almost worldwide (Nevada, Iowa, New York, Morocco, Montagne Noire, Pyrenees, Northern Spain, Sardinia, Austria, Germany, South China: Guangxi, Yunnan, Australia: New South Wales, Queensland), several reasons argue against its use as upper Givetian index conodont:

a. The species enters within the Upper Tully Limestone (within the Moravia Bed of the 3rd sequence) and just postdates the entry of *Pharciceras amplexum* (Ziegler & Klapper 1982). A "*latifossatus*-boundary" would not include the earliest part of the *Pharciceras* Stufe and would not correlate precisely with significant faunal changes in other groups.
b. In all our investigated sections from Germany (but including none of the three described by Ziegler et al. 1976), the Montagne Noire and from Morocco, *Schm. latifossatus* is a rather rare species and it was mostly impossible to recognize the Upper *varcus* Zone in its strict sense. Much easier to place is the entry of its ancestor (see Bultynck & Hollard 1980), *Oz. semialternans*. We, therefore, propose to replace the Upper *varcus* Zone by a *semialternans* Zone in the standard zonal scheme. Already Bultynck (1987) has introduced a *semialternans-latifossatus* Zone. Rare oldest *Oz. sannemanni* (Wirth 1967) and *Elsonella rhenana* (new record from Ouidane Chebbi) enter at the same time as *Oz. semialternans*.

The base of the *semialternans* Zone correlates with the entry of first *Pharciceras* (base of international division MD III-A = *Pharciceras* Genozone) in New York, Morocco, and in the Montagne Noire (new fauna from Col de Tribes South). It coincided with the deepening phase of the 3rd Tully sequence in the type region and with transgressive episodes elsewhere. A range of middle Givetian "holdover taxa" amongst goniatites, corals, brachiopods and trilobites obviously did not overlap with *Oz. semialternans* in the Tully Limestone. In the Tata region of southern Morocco, the oldest simple-lobed *Pharciceras* are associated with first Eobeloceratidae (*Mzerrebites juvenocostatus*, Bensaid 1974). Regionally typical is also the appearance of *Atlantoceras*, the first member of the Archoceratidae n. fam. (Gephurocerataceae; also including *Archoceras* and a related new genus from Ouidane Chebbi) which are defined by only four mature lobes and with very deep, v-shaped ventral and dorsal lobes (true septal folds) as in juvenile Maenioceratidae, but unlike that found in any Anarcestina or Agoniatitina.

An upper Givetian substage defined by *Oz. semialternans* should be considered as a serious option since the species also has an almost worldwide record of first occurrences (Iowa, New York, Morocco, Montagne Noire, Pyrenees, Sardinia, Rhenish Massive, South China, Kolyma of eastern Siberia). A current disadvantage is the unclear ancestry since there are only very few true ozarkodinids in the preceding main Middle *varcus* (*ansatus*) Zone. Bultynck (1987) suggested that *Oz. semialternans* was derived from *Po. rhenanus* and documented an intermediate specimen with platform remains from an immediate pre-Taghanic level of Morocco (Bou Tchrafine). Consequently, he placed the species in *Polygnathus* which, however, comprises a number of widely different and not closely related lineages.

## Base of (Lower) *hermanni* Zone

The base of the zone is defined by the entry of *Schm. hermanni* or of alternative index conodonts such as *Schm. wittekindti, Schm. pietzneri* and *Po. limitaris. Po. dubius* and *Po. ordinatus* also enter within the zone. Using its base for the definition of an upper Givetian would have some advantages:

a. As just outlined, the base of the *hermanni* Zone is marked by a significant post-Taghanic conodont radiation and can be easily recognized by a number of index species belonging to different phylogenetic lineages.
b. The boundary between the *varcus* and *hermanni* Zones is also characterized by a small-scale global conodont extinction (Aboussalam & Becker 2000) which terminated, for example, *Po. linguiformis mucronatus* (compare Pl. 2: 11–12), *Po. linguiformis klapperi, Po. linguiformis transversus*, the last *Po. parawebbi*, and, perhaps, the last *Bipennatus*. In many sections, *Po. linguiformis linguiformis* became rare with the end of the *varcus* (*semialternans*) Zone.
c. The conodont extinction event coincided with the final extinction of Maenioceratidae and of the last Agoniatitidae; both were always regarded as typical middle Givetian groups. Similar Taghanic Onlap survivor extinctions may apply to some corals and brachiopods. Only ca. half of the known trilobite genera (*Phacops, Cyphaspis, Longicoryphe, Richterraspis, Scutellum, Harpes, Greenops, Bradocryphaeus, Heliopyge, Neometacanthus, "Gondwanapis"*) survived into the post-event late Givetian.
d. The base of the *hermanni* Zone correlates with the entry of easily recognizable goniatites such as *Mzerrebites erraticus* (in North Africa and in the Rhenish Massive) and of advanced (involute or multilobate) pharciceratids (MD III-B). Surprisingly, this significant gradual upper Givetian radiation is not known to have been parallelled in the trilobite evolution.
e. The base of the *hermanni* Zone coincided with a significant eustatic transgression. In New York this is well marked by the base of the Geneseo blackshale (House 1983) which sits on a post-Tully erosional unconformity (Brett & Baird 1996), partly marked by the oldest Leicester Pyrite (Huddle 1981). In Iowa the global sealevel rise was recognized as base of a middle subdivision of the eustatic Depophase IIa (IIa–2, Witzke et al. 1989), or as regional T-R cycle 3B (Day 1996b).

Disadvantages of a *hermanni*-defined substage would be as follows:

a. The basal part (first zone, MD III-A) of the *Pharciceras* Stufe as defined by House (1985) would be excluded from the upper Givetian.
b. The base of the substage would lie 1 ½ conodont zones and up to two ammonoid zones (Fig. 1) higher than the initial Taghanic Onlap.

## Conclusions

Two different conodont-goniatite levels are available which might be used to define an upper Givetian substage: the base of the *Oz. semialternans* Zone = base of *Pharciceras* Genozone (MD III-A), or the base of the *Schm. hermanni* Zone = base of *Stenopharciceras* Genozone (MD III-B, regional *Mzerrebites erraticus* Zone of SE Morocco, House & Becker 1999). Both levels correlate with eustatic transgressions subsequent to the initial and main Taghanic Onlap and can be recognized nearly worldwide, at least in pelagic facies.

## Acknowledgements

This study was conducted within the frame of the DFG-financed Graduiertenkolleg on "Evolutionary Transformations and Mass Extinctions" at the Museum für Naturkunde, Berlin. We appreciate the field company in Morocco by our friends Dr. V. Ebbighausen (Odenthal), J. Bockwinkel (Leverkusen), Prof. A. El Hassani (Rabat) and Prof. M. R. House (Southampton): the latter and Dr. D. Weyer (Berlin) also provided helpful comments on the manuscript. We like to express our thanks to Dr. M. Dahmani and others from the Ministére de l Industrie, du Commerce, de l'Énergie et des Mines who enable research in Morocco. Aspects of conodont taxonomy were discussed with our friends Prof. G. Klapper (Iowa City), Prof. W. T. Kirchgasser (Potsdam, New York) and Prof. P. Bultynck (Bruxelles). Ammonoid specimens were prepared by Mrs. E. Stenzel, many conodont samples were processed by Mrs. S. Salzmann. Mrs. W. Harre conducted photographic work. Dr. A. Greshake helped to photo thin sections, and Dr. E. Wäsch and P. Czaja assisted in the SEM laboratory. Dr. R. Feist led us to the Col de Tribes South section in the Montagne Noire.

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