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Devonian conodont and ammonoid succession of the eastern Tafilalt (Ouidane Chebbi section), Anti-Atlas, Morocco

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ABSTRACT:

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Devonian conodonts and ammonoids occurring in association in the Ouidane Chebbi section of the eastern Tafilalt (Anti-Atlas, Morocco) are described and analysed in terms of stratigraphy. The excellently exposed sequence spans the entire Devonian; it includes open-marine carbonates and shales deposited outside the tropical realm. Except for its Middle Devonian part, the Ouidane Chebbi section is not condensed. Although the sequence was only sampled in a preliminary fashion, most of it lithological units have been dated with some precision. The study is an attempt to enhance the precision in the correlation between the Devonian conodont and ammonoid sequences. Graphic correlation method was used for estimating the precise position of the zonal and stage boundaries for the Middle and Upper Devonian intervals. The stratigraphy of the Lower Devonian at Ouidane Chebbi is still poorly defined. The Eifelian/Givetian boundary is well constrained, especially by both conodonts and ammonoids. It occurs within the uppermost part of the Kačak Event-Level, a characteristic shale horizon that begins in the *ensensis* Zone and ranges into the *hemiansatus* Zone. Biostratigraphic indications from conodonts show that the top of the *Pharciceras* limestone unit is located within the *norrisi* Zone and the Givetian/Frasnian boundary should be placed within the characteristic black styliolinites level of the Frasne Event. The onset of the Kellwasser facies falls within the Zone 12 (*winchelli* Zone) of the Frasnian and it extends into the *rhomboidea* Zone. The combined evidence from ammonoid and trilobite data suggests that the marine deposition persisted at Ouidane Chebbi at least up to the time of the Upper *praesulcata* Zone.

INTRODUCTION

Excellent exposures, a great number of well-preserved fossils and apparently continuous sedimentation in the Anti-Atlas of southern Morocco make it one of the most important areas for study of the Devonian stratigraphy and palaeontology in the world. Unfortunately, the commercial collecting of fossils – economically significant for the population living in this marginal part of the Sahara desert – has resulted in devastation of many Devonian sections and exposures. Evaluating the biostratigraphy of the

Devonian sequence in this region requires base-line documentation of its faunas. As a contribution to this we describe the conodont and ammonoid fauna from the Ouidane Chebbi section (Text-fig. 1), a long and complete section representing all of Devonian time. Except for its Middle Devonian part, this section is not condensed. It is unique also because of the continuous exposure of strata including thick portions of soft rocks (shales and marls), which are generally not well exposed at other places in the eastern Anti-Atlas. Additionally, some single bedding planes are exposed over hundreds of square metres. The only disadvantage is the occurrence of a few dolerite sills within the sequence.

Although the value of conodonts and goniatites in the Devonian biostratigraphy is well established, correlation of conodont and ammonoid zonal schemes remains rather inaccurate (*see* BECKER & HOUSE 1994) and needs to be improved. The main objective of this study, therefore, was to attempt integration of conodont and ammonoid biostratigraphic data derived from the same non-condensed section. An additional goal has been to document and analyse the conodont fauna throughout a sedimentary sequence deposited outside of the tropics during Devonian times. This survey is important because the Devonian conodont biostratigraphy has come to be based primarily on conodont successions from areas lying within the equatorial belt at that time. In general, successions of Devonian conodont faunas from regions with temperate climate were not taken into account (*e.g.* ZIEGLER & SANDBERG 1990).

The Ouidane Chebbi section is situated in the eastern part of the Tafilalt, about 45 km southeast of Erfoud (Text-fig. 1), close to the geomorphological edge of the Hamada, where the Palaeozoic rocks are concealed under flat-lying Cretaceous-Tertiary cover (Pl. 1, Fig. 1). The Devonian sequence at Ouidane Chebbi (Text-fig. 3) was

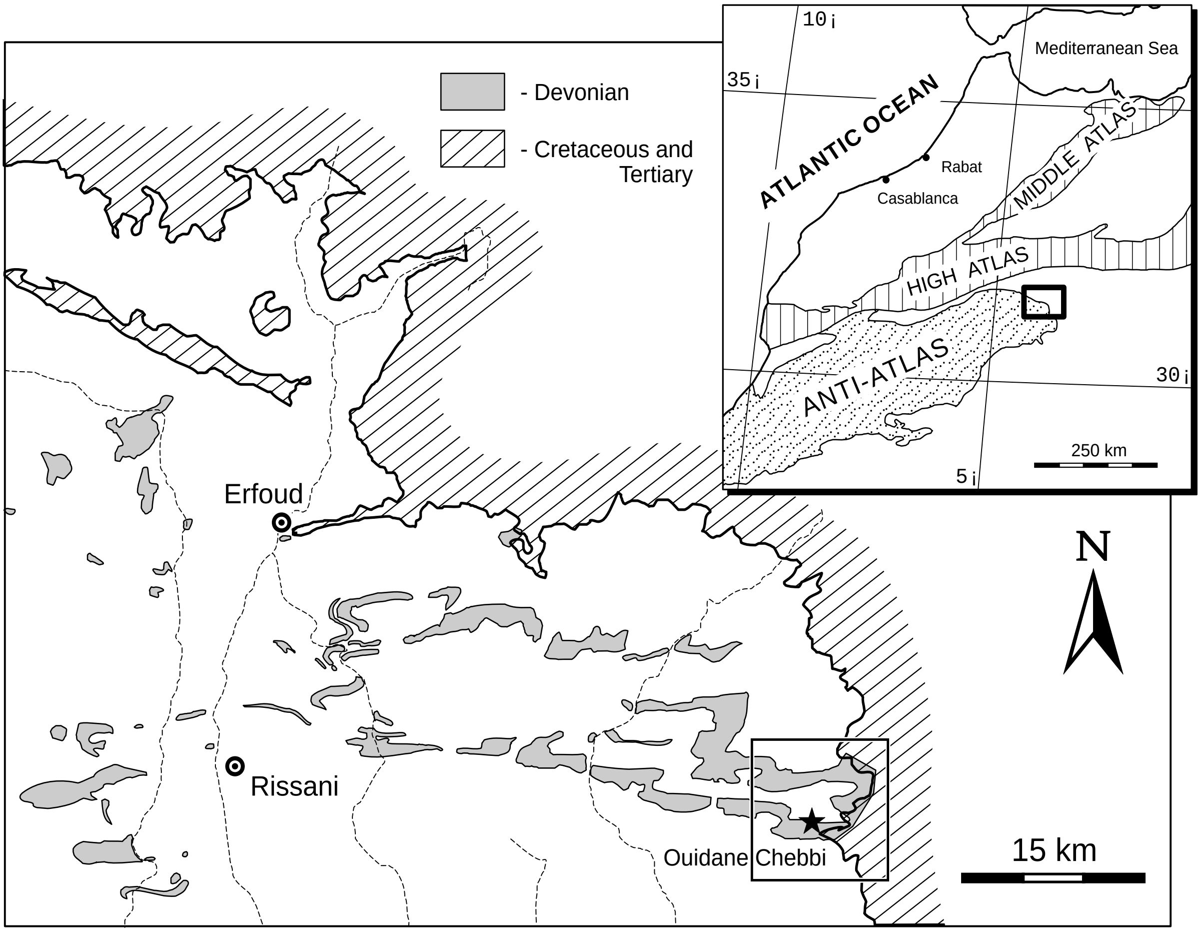


Fig. 1. Simplified geological map of the northeastern Anti-Atlas showing distribution of Devonian rocks and location of the Ouidane Chebbi section (*asterisked*); boxed area indicates field of Text-fig. 2; inset shows regional geology and location of the study area

studied by us along three measured sections located NW and N of the "Tower Rock", a conspicuous outlier left by erosion in front of the Hamada (Text-fig. 2; *and* Pl. 1, Fig. 1). The conodont, ammonoid, other megafossil, and lithological samples on which this report is based were collected between 1991 and 1998.

GEOLOGICAL BACKGROUND

The palaeogeographic position of the Anti-Atlas during the Devonian is still not satisfactorily constrained and thus remains a matter of debate. SCOTESE & MCKERROW (1990), for instance, placed the margin of North Africa at about 40° south of the equator during the Early Devonian, whereas TAIT & *al.* (1997), based on palaeomagnetic data, postulated a position at a much higher southern latitude of about 60° during this time. Taking no account of difference in the palaeolatitude position for Africa in those reconstructions, there is general agreement that the North African margin of Gondwana drifted northwards during the Devonian, but it did not reach the equatorial realm until Early Carboniferous times.

The Anti-Atlas area of southern Morocco lay within the passive continental margin of Gondwana during the Devonian. This passive margin had already formed during the Ordovician after the rifted Peri-Gondwana plates, such as Armorica and Avalonia, moved away from Gondwana. Its depositional and tectonic evolution were controlled by regional, E-W trending strike-slip faults. They were reactivated several times during Palaeozoic, influenced the subsidence pattern, and led to formation of sea-floor relief with carbonate platforms and small intracratonic marine basins during the Early Devonian (BELKA & *al.* 1997b). In the easternmost part of the Anti-Atlas, WENDT (1988) discriminated an asymmetric basinal realm, the Tafilalt Basin, bordered on the north and west by the pelagic Tafilalt Platform. The Devonian sequence of Ouidane Chebbi was deposited in the marginal zone of the Tafilalt Platform. The Lower and Middle Devonian underwent similar lithologic development to central parts of the platform (KAUFMANN 1998). During the Late Devonian, however, the eastern part of the Tafilalt Platform evolved into a south-trending carbonate ramp, sloping gently into the Tafilalt Basin. The sequence studied of Ouidane Chebbi represents a deep ramp setting at that time.

PREVIOUS STRATIGRAPHIC STUDIES

The fact that the Devonian rocks at Ouidane Chebbi have remained essentially unstudied for a long time was primarily because of distance from Erfoud (Text-fig. 1). Unlike other sections of the Tafilalt Platform, this locality is not readily accessible by car. WENDT & BELKA (1991) provided the first columnar section and the preliminary conodont stratigraphy of the Upper Devonian of Ouidane Chebbi. Frasnian and Famennian conodont fauna from this locality was used subsequently in analysis of conodont distribution within the Kellwasser facies of the Anti-Atlas (BELKA & WENDT 1992). More recently, BELKA (1995) presented a detailed conodont sequence through the Frasnian-Famennian boundary interval at Ouidane Chebbi.

Conodont faunas and associated records of ammonoids about the Middle/Upper Devonian boundary have been reported (ZIEGLER & KLAPPER 1982, BENSAID & *al.* 1985) from Achguig in the eastern Tafilalt (Text-fig. 2); this section is about 6 km N of Ouidane Chebbi. Much of the stratigraphical work in the Anti-Atlas related to Devonian conodonts and ammonoids, however, was done in the central part of the Tafilalt Platform where the Bou Tchrafine and the Hamar Laghdad sections received most attention (*e.g.* MASSA 1965; BULTYNCK & HOLLARD 1980; BULTYNCK 1985, 1987; BECKER & HOUSE 1994; BELKA & *al.* 1997a).

LITHOLOGY AND BIOTIC COMPONENTS

The Devonian sequence of Ouidane Chebbi is approximately 350-360 m thick. Neither the base nor the top of the Devonian, however, cannot be precisely identified (Text-fig. 3); neither conodonts nor ammonoids were found in the critical intervals. The sequence is dominated by rather monotonous shale, but it contains many very fossiliferous carbonate horizons (Text-fig. 3; Pl. 1, Figs 1-2). Details of conodont and ammonoid records are presented in separate sections (*see also* Text-figs 4-5 and 7-9) and therefore they will not be discussed here.

Lower Devonian

The Lower Devonian, about 240-250 m thick, is composed mainly of shales, in which there are several characteristic limestone intervals and concretions (Text-fig. 3). The first limestone key beds, about 2 m thick, contain abundant loboliths and isolated sclerites of *Scyphocrinites elegans* associated by bivalves, orthoconic cephalopods and rare gastropods. These beds, usually referred to as the *Scyphocrinites* limestone, are followed by an almost 60 m thick unit of dark grey shales which gradually become darker towards the top of the unit. Layers of limestone nodules and, in the middle and upper part, calcareous siltstones are intercalated. Fossils are restricted to the calcareous layers and are dominated by orthoconic cephalopods, bivalves and rare ostracods and dacryoconarids. Scarcity of benthic organisms and black colouration of sediments (presumably due to high organic carbon content) suggest a presence of anoxic conditions on the sea floor during middle to late Lochkovian times. The contact with the overlying Pragian rocks is marked by a conspicuous colour change of the shales from dark to light grey (Text-fig. 3), which was also documented by ALBERTI (1981) in the Bou Tchrafine and Jebel Amelane sections of the central Tafilalt.

The Pragian interval is about 35 m thick and begins with a 15 m thick unit of light grey shales intercalated with thin-bedded nodular limestones. It is followed by 14 m grey, fossiliferous, nodular limestones which form the first, small ledge in the section (Pl. 1, Fig. 2). These carbonates show textures from wackestone to packstone and contain trilobites (dominant), crinoids, orthoconic cephalopods, gastropods, bivalves, tabulate and solitary rugose corals, and occasionally brachiopods. The rich benthic fauna and trace fossils (*Fucoides*) indicate well-oxygenated bottom waters.

The Emsian part of the section is about 130 m thick and composed predominantly of monotonous, greenish shales containing very rare brachiopods, orthoconic cephalopods, trilobites,

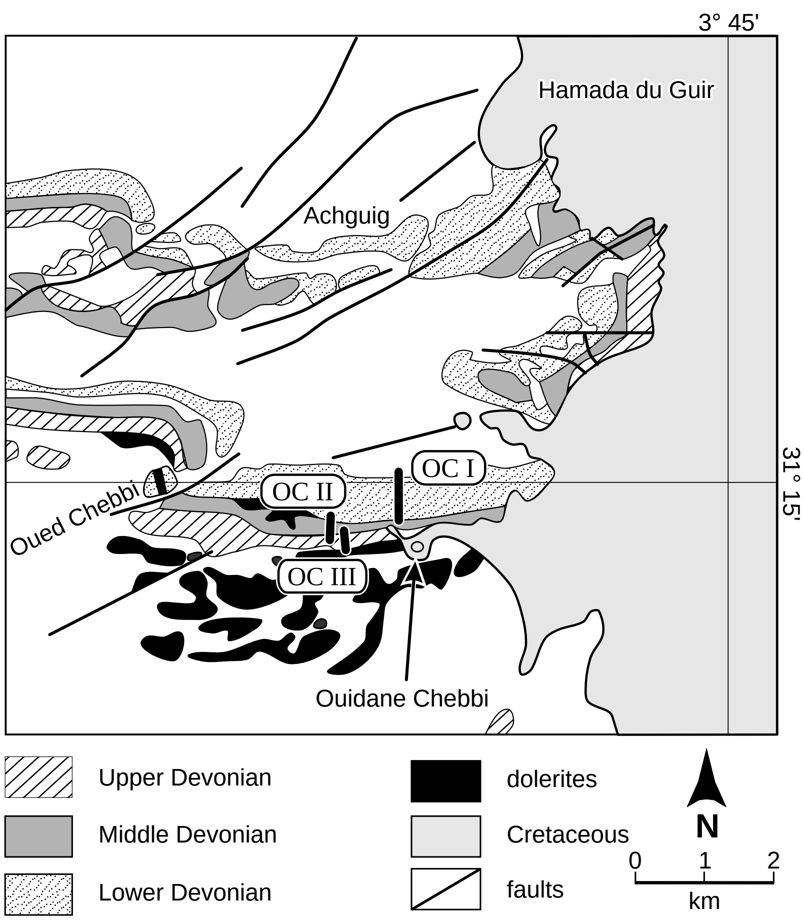
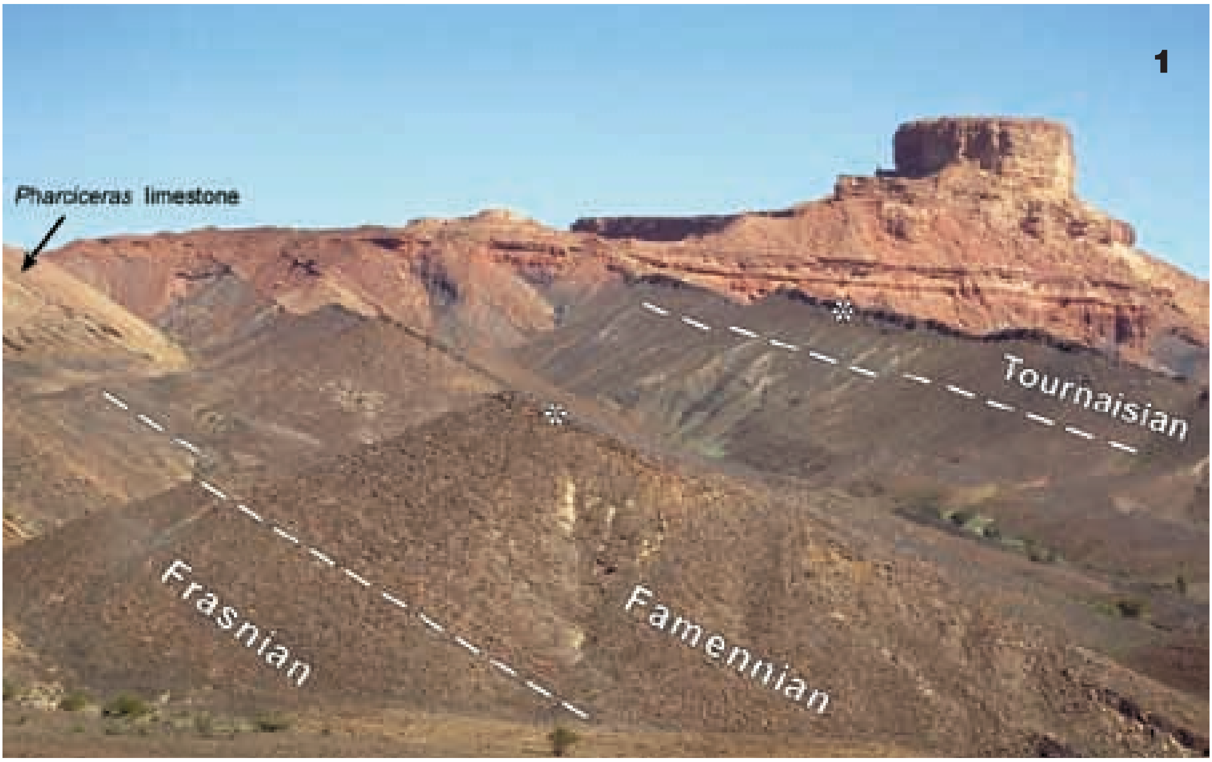
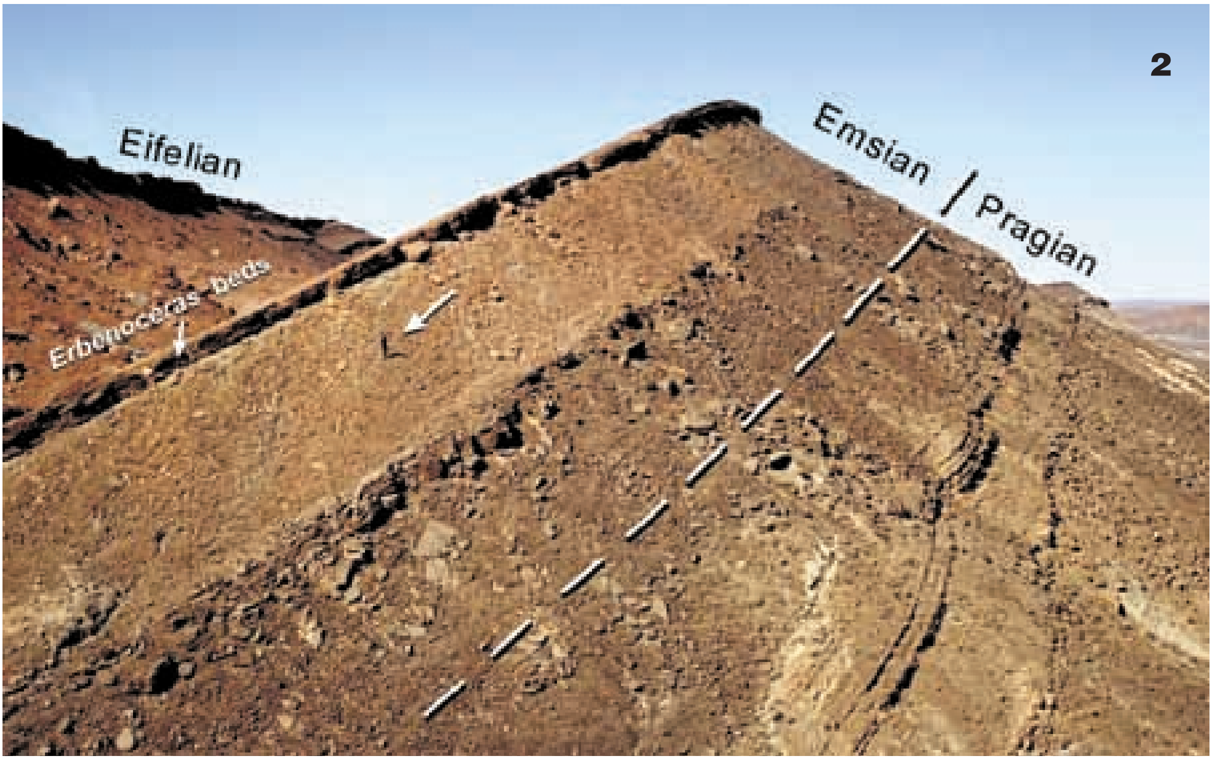


Fig. 2. Simplified geological map of the Achguig-Ouidane Chebbi area, to show the distribution of Devonian rocks and location of sampled sections (OC I, OC II and OC III)



1 – General eastward view of the Ouidane Chebbi area showing the continuous exposure of the Upper Devonian rocks dipping to the right, discordantly overlain by the Upper Cretaceous carbonates; the most prominent dolerite sills are asterisked; approximately 150 m of Devonian section is visible and the arrow indicates the upper part of the Givetian condensed carbonates bearing the rich ammonoid *Pharciceras* fauna



2 – Westward view of the Lower Devonian crest (section OC I); see a person (*arrowed*) for scale

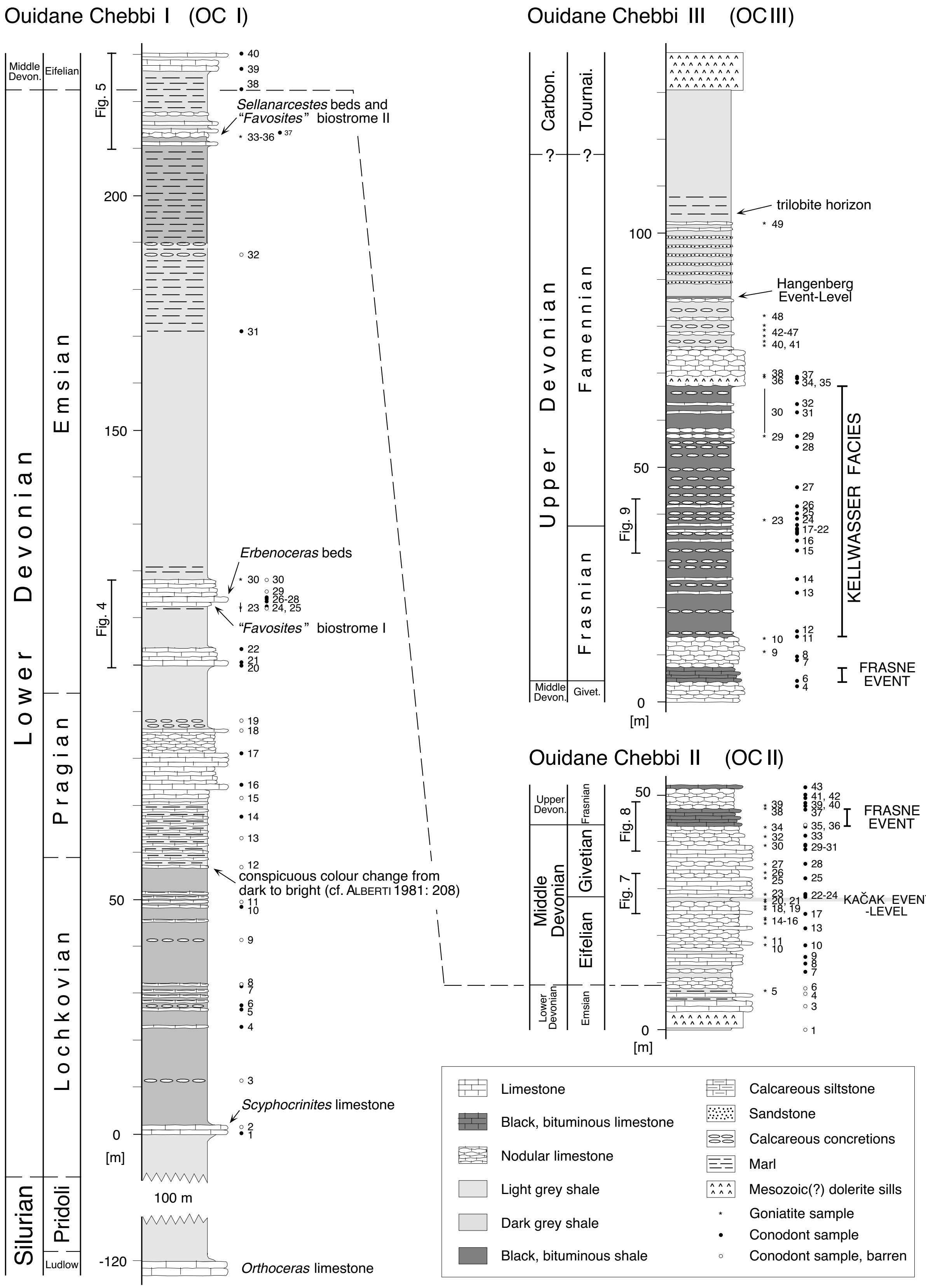


Fig. 3. Lithological column of the Devonian section at Ouidane Chebbi with sample distribution and general stratigraphy

crinoids, dacryoconarids and small solitary rugose corals. This sequence includes three carbonate units being very rich both in benthic and nektonic fossils (Text-fig. 3). The lower one consists of nodular, bioclastic wackestone. Its faunal content and diversity, are similar to those of the Pragian carbonates below (Text-fig. 4; Pl. 1, Fig. 2). The bioclastic limestones are followed by light grey shales bearing, in their upper part, the oldest ammonoid fauna found in the section, associated by gastropods and brachiopods. The shales are topped by a 0.6 m thick biostrome ("*Favosites*"-biostrome I, Text-figs 3 and 5) with a lateral extent of about 15 m. Apart from a highly diverse tabulate coral fauna, trilobites, solitary rugose corals, crinoids, brachiopods, orthoconic cephalopods, bivalves and gastropods are common. The coral boundstone is overlain by a 6 m thick, nodular and

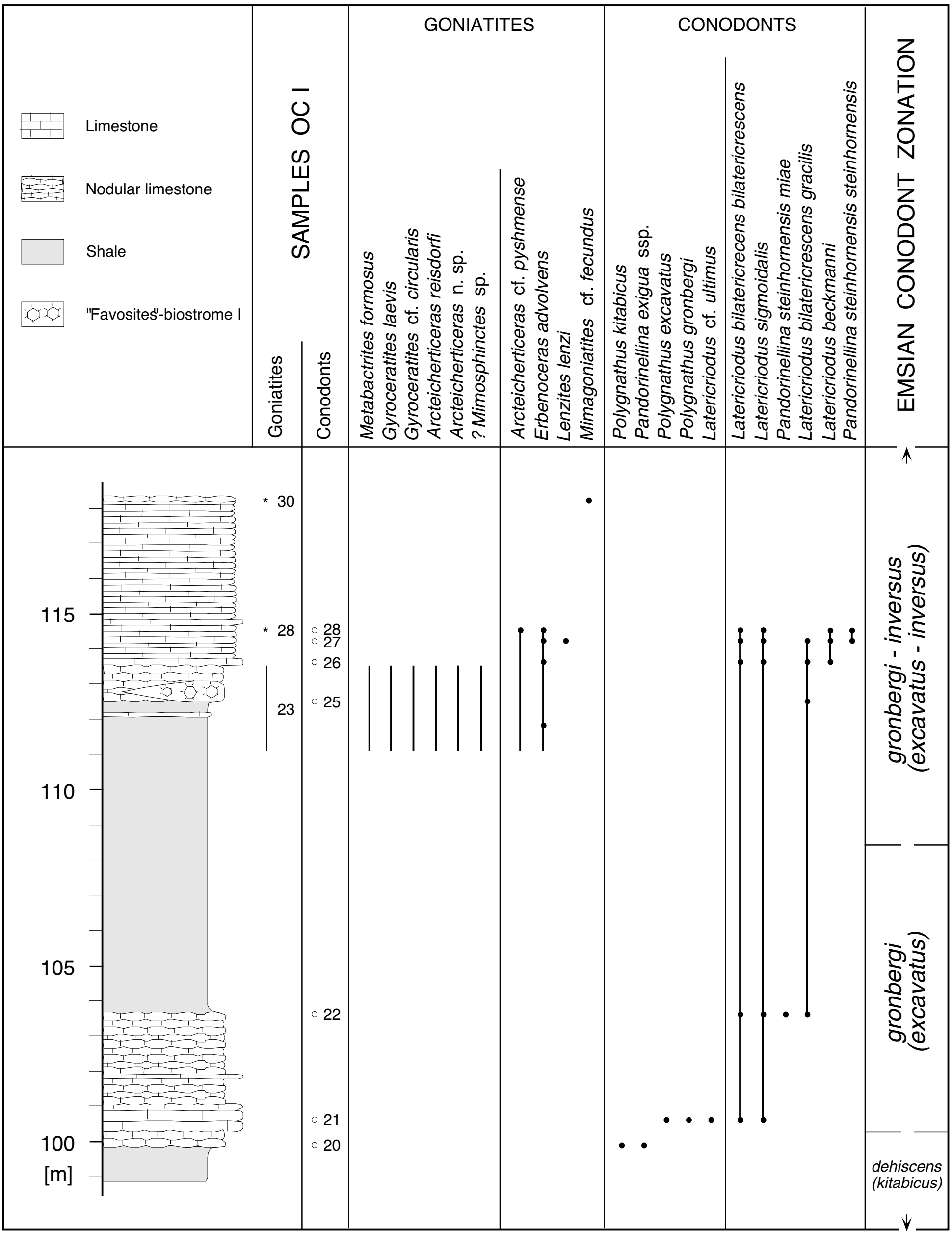


Fig. 4. Lower Emsian part of Ouidane Chebbi section (OC I) with goniatite and conodont distribution; conodont zonation in parentheses *after* YOLKIN & *al*. (1994)

thin-bedded carbonates represented by fossiliferous wackestones. This unit, known as the *Erbenoceras* beds, is very distinct morphologically, forming the first major crest of the Ouidane Chebbi section (Pl. 1, Fig. 2). The fauna contains cephalopods (various ammonoids and large orthoconic cephalopods), trilobites, dacryoconarids, and a few solitary rugose corals. One of its prominent features is a sharp contact between the *Erbenoceras* beds and the overlying shales. The abrupt lithological change can be observed in the Emsian sections over the entire eastern Anti-Atlas; it possibly correlates with the Daleje event, based typically on sequences in Bohemia (CHLUPAČ & KUKAL 1986). This event corresponds to an apparently global transgression (the younger of the two intra-Ib transgressions of JOHNSON & *al*. 1985, 1996) that occurred in the lower part of the *inver-*

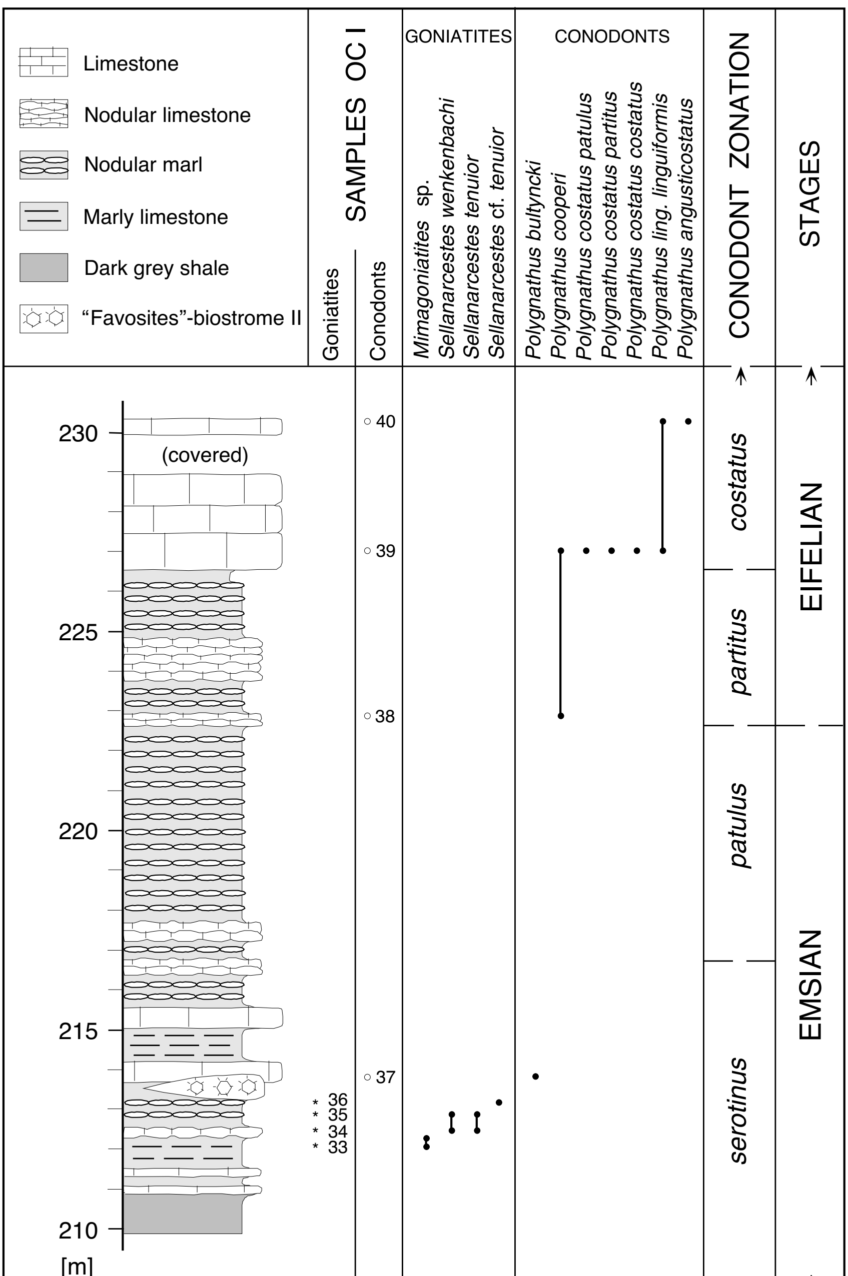


Fig. 5. Emsian/Eifelian boundary interval of Ouidane Chebbi section (OC I) with goniatite and conodont distribution

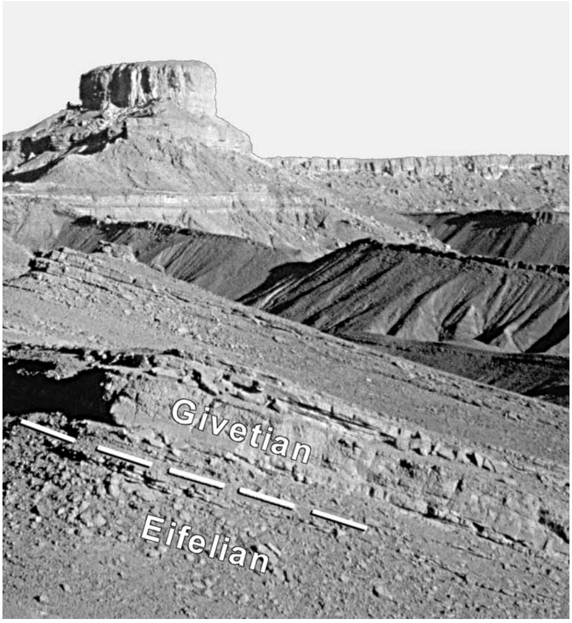


Fig. 6. View of the main crest of the Ouidane Chebbi section built up of the Middle Devonian condensed carbonates; eastern wall of Hamada with flat-lying Upper Cretaceous carbonates visible as an outlier in the background

sus Zone. The thick, overlying shales are poorly fossiliferous. They become almost black in their upper part and then pass gradually into the marl-limestone sequence. This third Emsian carbonate unit, called informally as the *Sellanarcestes* beds, is only 3 m thick. It includes several limestone interbeds, among which is another coral biostrome ("*Favosites*"-biostrome II; Text-figs 3 and 5). Its fauna of tabulate corals is here much less diverse when compared with the older biostrome, and consists almost exclusively of *Favosites* (*F. bohemicus* MAURER; *see* POTTHAST & OEKENTORP 1987).

Middle Devonian

As usual in the eastern Anti-Atlas, the highest Devonian crest of the Ouidane Chebbi section is made up of carbonates of the Middle Devonian age (Text-fig. 6). The sequence is only 27 m thick, condensed and very uniform in lithology. The Eifelian part of the section, about 12 m thick, is characterized by nodular, fossiliferous wackestones with intercalations by medium-bedded limestone. The rich fauna includes goniatites, orthoconic cephalopods, dacryoconarids, trilobites, brachiopods and bivalves. At the top, there is a 0.7 m thick shale intercalation forming a conspicuous cavetto; it contains a diverse haematitized ammonoid fauna (Text-fig. 7). It represents **The Kačak Event**, a deepening event recognized worldwide and having an unquestionably eustatic character (*cf.* HOUSE 1985, JOHNSON & SANDBERG 1988).

There is no significant lithological difference between the Eifelian and Givetian interval. However, the Givetian carbonates, about 15 m thick, has higher carbonate content and thicker bedding. The character of the fauna is very similar to that of the Eifelian carbonates. In the upper part, a very thin (about 5 cm), distinctive marker bed is present. It contains many small lenticular brachiopods (*Ambocoelia* aff. *mesodevonica*). This layer has also been identified in the adjacent section at Achguig by LOTTMANN (1990) and correlated with the upper part of the Upper *pumilio* horizon (Text-fig. 8). In the Middle Devonian at Ouidane Chebbi, as in the section at Achguig, other beds bearing the brachiopod *pumilio* fauna are not present.

Upper Devonian

The Upper Devonian sequence is at least 110 m thick and differentiated with respect to facies (Text-fig. 3). It begins with a 3.6 m black carbonate unit that is conspicuous due to its high organic carbon content (Text-fig. 8). The rocks are styliolinid/tentaculitid packstones and wackestones with thin shale intercalations. In addition to abundant styliolinids and tentaculites, entomozoan ostracods and small orthoconic cephalopods are present. We also found rare specimens of *Buchiola* (bivalve). This unit represents the so-called Frasne Event (*sensu* HOUSE 1985), the first episode during the Late Devonian characterized by oxygen-depleted water on the sea floor. It is widespread throughout the Tafilalt and is a useful key horizon for regional and intercontinental correlation (WENDT & BELKA 1991). Contact between these black carbonates and the overlying nodular limestones is sharp and marked by a distinct change in colour. The nodular limestones, about 5 m thick, are thick-bedded, light-coloured wackestones and mudstones. They are burrowed in places and contain relatively common cephalopods. This unit is generally well exposed in the whole Tafilalt region and is lithologically rather uniform.

In all localities, where the Frasnian nodular limestones appear, they are overlain by a very prominent sequence of black shales and/or limestones representing the Kellwasser facies in southern Morocco. At Ouidane Chebbi, this unit attains a thickness of about 50 m, ranges high into the Famennian, and consist of black shales with thin interbeds of black marly mudstones (Text-fig. 3). In contrast to the Kellwasser sediments of the Variscan Europe, these sediments are extremely fossiliferous containing predominantly nektonic and planktic fauna represented by goniatites, orthoconic nautiloids, conodonts, and styliolinids (for more details *see* WENDT & BELKA 1991). The contact between the black Kellwasser sediments and the overlying well-oxygenated carbonates is sharp but generally masked by rock waste of a dolerite sill. Together with igneous rocks, these limestones form the third major crest of the Ouidane Chebbi section (Pl. 1, Fig. 1).

The characteristically yellow-coloured limestones are about 8 m thick and characterized by a nodular fabric and textures from wackestone to packstone. They contain a relatively rich cephalopod fauna (ammonoids and orthoconic nautiloids), in places associated with scattered brachiopods. The unit consistently occurs above the Kellwasser sediments in the entire Tafilalt region (WENDT & BELKA 1991). It is lithologically variable, containing predominantly coarse crinoidal packstones in

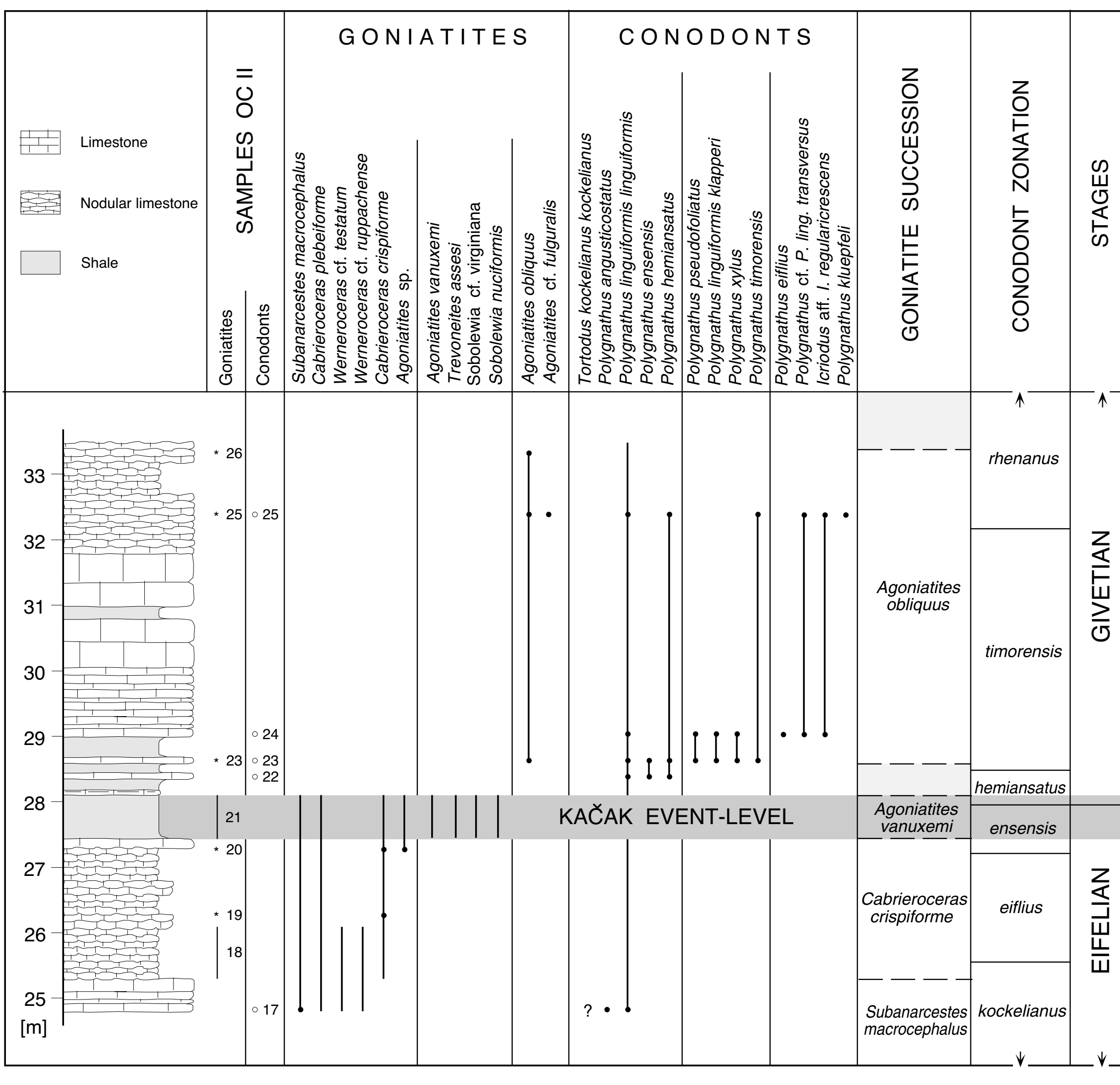


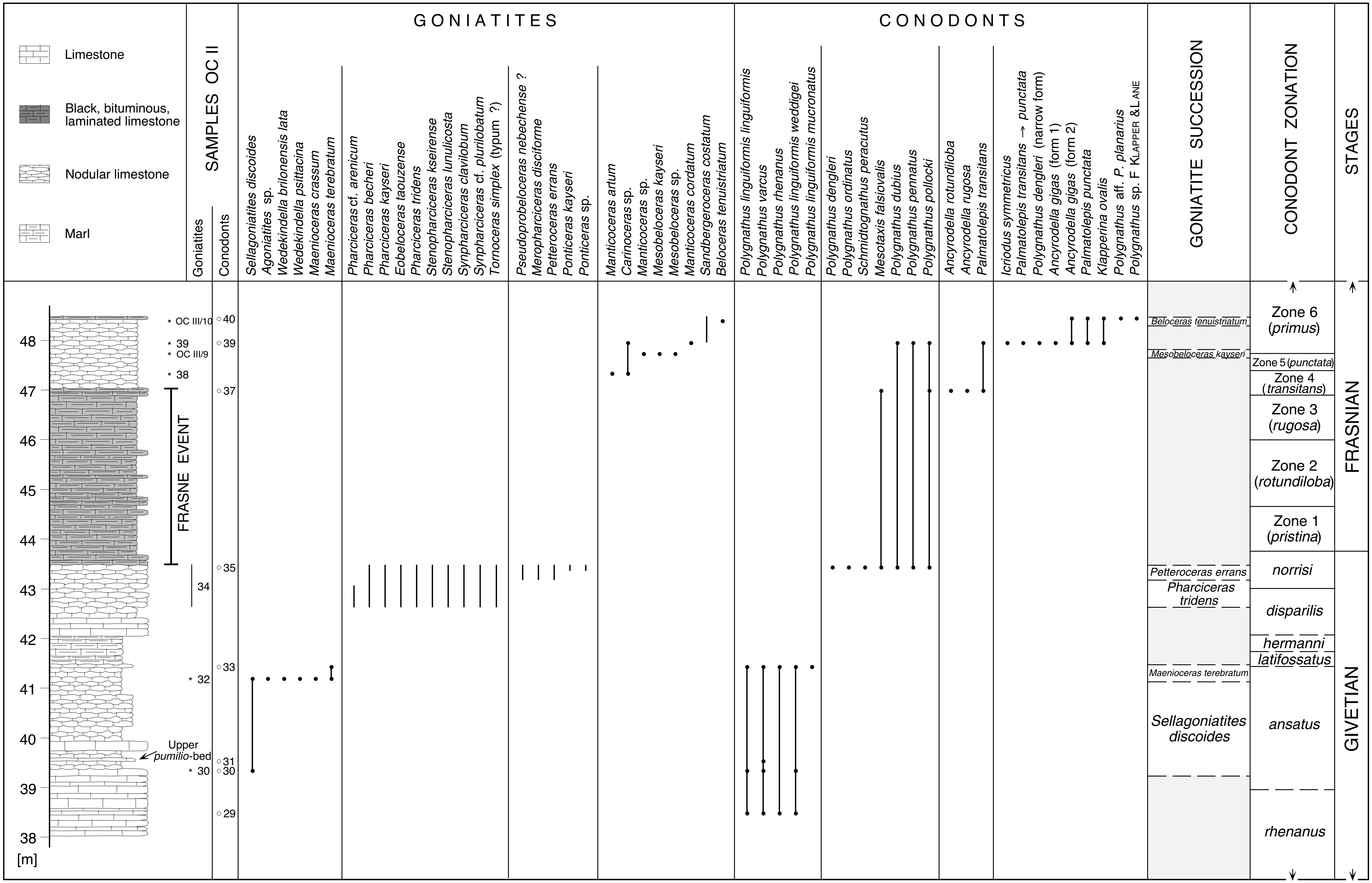
Fig. 7. Eifelian/Givetian boundary interval of Ouidane Chebbi section (OC II) with goniatite and conodont distribution; boundaries of conodont zones are calculated by graphic correlation with the Anti-Atlas regional composite (AARC; *see* BELKA & *al*. 1997a); conodont zonation *after* BELKA & *al*. (1997a)

the central, more shallow-water areas of the Tafilalt Platform, and fine-grained cephalopod wackestones to mudstones in marginal situations. In the Ouidane Chebbi section, this carbonate unit is followed by more than 50 m of light-coloured shales (Text-fig. 3).

In general way, the lower part of the overlying unit is composed of greenish shale with several limestone intercalations in which the carbonate layers are commonly disrupted into lenses and nodules. The common fossils include ammonoids, gastropods, brachiopods and placoderm skulls. The top of this interval is marked by a thin (about 0.5 m) black shale horizon that probably represents the Late Devonian Hangenberg Event (Text-fig. 3). The middle part of the interval is about 15 m thick, it consists of the most terrigenous-rich rocks of the entire Devonian section at Ouidane Chebbi. Trace fossils and sole marks are abundant in the siltstone and sandstone interbeds, whereas fossils are scarce and poorly preserved. The only exceptions are two prominent but thin sideritic intercalations. The first one, approximately 16 m above the Hangenberg Event horizon, has an ammonoid fauna with *Acutimitoceras intermedium*. The second intercalation, 2 metres higher, contains common trilobites: *Belgibole abruptrirhachis* and *Macrobole* aff. *funirepa*. Both taxa co-occur in many European sections; for instance, in the Carnic Alps (Grüne Schneid), Rhenish Slate Mountains (Drewer, Stockum), Franconia (Gattendorf) and Montagne Noire (Puech de la Suque). Their occurrence at Ouidane Chebbi is the first known outside Europe.

Ouidane Chebbi I **Conodonts** **Samples**	1	4	5	6	10	16	17	20	21	22	25	26	27	28	37	38	39	40
Latericriodus postwoschmidti	7																	
Latericriodus sp.	12	2						1	5	19	14	16	86					
Ozarkodina remscheidensis remscheidensis	1																	
Panderodus cf. *P. semicostatus*	2																	
Ozarkodina sp.			1															
Ancyrodelloides carlsi				1														
Pseudooneotodus beckmanni				1														
Ancyrodelloides transitans ?					1													
Pelekysgnathus serratus elongatus					4													
Bellodella resima						6	18	9										
Panderodus unicostatus						2												
Pandorinellina exigua ssp.								1										
Polygnathus kitabicus								2										
Latericriodus bilatericrescens bilatericrescens									3	1		3	14	4				
Latericriodus sigmoidalis									2	37		2	2	1				
Latericriodus cf. *L. ultimus*									3									
Polygnathus excavatus									2									
Polygnathus gronbergi									1									
Latericriodus bilatericrescens gracilis										4	1	6	16					
Pandorinellina steinhornensis miae										3								
Belodella devonica												2	3	7				1
Latericriodus beckmanni												2	9	8				
Panderodus sp.												2			4			
Pandorinellina steinhornensis steinhornensis													8	16				
Polygnathus sp.													1			2	8	2
Polygnathus bultyncki																1		
Polygnathus cooperi																2	2	
Icriodus sp.																	1	
Polygnathus costatus costatus																	2	
Polygnathus costatus partitus																	2	
Polygnathus costatus patulus																	4	
Polygnathus linguiformis linguiformis																	3	8
Polygnathus angusticostatus																		1

Table 1. Numerical distribution of conodont species in the Ouidane Chebbi I section (OC I)



Givetian/Frasnian boundary interval of Ouidane Chebbi section (OC II) with goniatite and conodont distribution; Givetian conodont zonation *after* BELKA & *al.* (1997a) and KLAPPER & JOHNSON (1990); Frasnian conodont zonation *after* KLAPPER & *al.* (1996); boundaries of conodont zones are calculated by graphic correlation with the Frasnian composite standard (KLAPPER 1997)

CONODONT FAUNA

Conodonts were recovered mainly from carbonate lithologies. The collection has been assembled from samples collected during several periods of fieldwork. For this study a total of 90 samples, each between 1-2 kg, was processed. From these, only 71 samples yielded identifiable conodont elements. It should be noted that all but one barren samples were from the Lower Devonian. In that part of the section, the recovery rate of conodonts was also rather low (generally below 50 elements/kg). The most abundant faunas were isolated from sediments of the Kellwasser facies. Occurrences of conodonts (listed in Tables 1-3) depict the abundance and ranges of Pa elements in the Ouidane Chebbi section. Although we have not noted sedimentary structures suggesting significant redeposition in the section, the platform (Pa) elements remarkably outnumber other elements (Pb, S and M) in the studied samples. Synsedimentary, posthumous transport of conodont elements seems most likely to be responsible for the unbalanced composition of the fauna. There is evidence, such as oriented fossils, indicating the presence of current activity, even in settings with an anaerobic depositional regime in the eastern Anti-Atlas during the Devonian (WENDT & BELKA 1991, WENDT 1995).

The low number of the Early Devonian conodonts obtained during this study does not allow reliable statistical comparison with coeval faunas known from other continents (*e.g.* CARLS & GANDEL 1969, KLAPPER 1969, KLAPPER & MURPHY 1975, AL-RAWI 1977, SCHÖNLAUB 1985, MAWSON 1987, VALENZUELA-RIOS 1990). It appears, however, that the fauna in the Anti-Atlas is both less abundant and less diverse, but it do not contain any endemic forms (*see also* BULTYNCK 1985). Possible ecological cause(s) of the paucity and low diversity of the fauna might have been the position of the Anti-Atlas at very high palaeolatitudes during Early Devonian time or local facies control.

Conodonts recovered from the condensed Eifelian and Givetian carbonates include taxa which were cosmopolitan during the Middle Devonian. It shows a similar level of diversity to that recognized in the localities of the marginal zone of the Mader Basin (BULTYNCK 1985, BELKA & *al.* 1997a). Both the conodont abundance and diversity at Ouidane Chebbi are lower than in the adjacent Bou Tchrafine section, although the Middle Devonian in both sections displays a similar lithological development and a comparable level of sediment condensation. We interpret this phenomenon as an effect of sampling because the Bou Tchrafine section was sampled several times (*see* BELKA & *al.* 1997a) and thus a large volume of rock was processed previously.

The conodont fauna of the Kellwasser facies is abundant but slightly less diverse than time-equivalent faunas in the Upper Devonian of the European Variscides. This feature can be observed throughout the whole area of the Anti-Atlas, both in basinal sequences and on carbonate platforms (BELKA & WENDT 1992). Typical is the lack of several late Frasnian species of *Palmatolepis* (e.g. *P. linguiformis*, *P. rhenana*) that are widespread in central Europe and North America. In terms of diversity, the Frasnian conodont fauna in the Anti-Atlas is similar to that of the Montagne Noire in France (*see* for comparison KLAPPER 1988), but it is dominated by polygnathids. In addition, the Frasnian portion of the Kellwasser sequence at Ouidane Chebbi yields lower numbers of taxa than equivalent sediments in the inner parts of the Tafilalt Platform. This pattern has been discussed by BELKA & WENDT (1992), who showed that a simple ecological model of conodont distribution involving distance from shore and water depth, as proposed by SANDBERG & *al.* (1988), is not valid in the Upper Devonian of the Anti-Atlas.

AMMONOID FAUNA

Compared to most of the Devonian successions of the eastern Anti-Atlas the Ouidane Chebbi section is very rich in ammonoids. More than 1100 specimens of over 100 species of ammonoids were collected. They were extracted from various lithologies and consequently are preserved in various ways: as calcareous, haematitic or sideritic internal moulds, sometimes with imprints of the external sculpture, and also as calcareous steinkerns with shell remains. All collected specimens are three-dimensionally preserved. Deformation as a consequence of tectonic stress or compaction is rare. Haematitic specimens are abundant in the Emsian shales, in the Kačak Event-Level (upper Eifelian), and in the black shales of the Kellwasser facies. Ammonoids preserved in sideritic nodules, however, occur only in the topmost part of the Famennian.

The Ouidane Chebbi section is rich in early Emsian (Zlichovian) ammonoids exhibiting the highest diversity observed in the Anti-Atlas. The fauna is predominantly composed of cosmopolitan

Ouidane Chebbi II **Conodonts** **Samples**	7	8	9	10	13	17	22	23	24	25	28	29	30	31	33	35	37	39	40	41	42	43
Icriodus corniger	2		1																			
Polygnathus bultyncki		1	13	4																		
Polygnathus cracens			4																			
Polygnathus sp.			2	13		5		19	3	2	3	4	4		3	25		9	4	20	11	1
Icriodus amabilis				1																		
Polygnathus costatus patulus				13	4																	
Polygnathus linguiformis pinguis				4	1																	
Polygnathus linguiformis linguiformis					6	14	5	27	33	5	14	10	25		13							
Polygnathus angusticostatus						1																
Tortodus kockelianus kockelianus ?						1																
Polygnathus ensensis							5	2														
Polygnathus hemiansatus							1	9		2												
Icriodus sp.								1														
Polygnathus linguiformis klapperi								1	4													
Polygnathus pseudofoliatus								2	3													
Polygnathus timorensis								8		2												
Polygnathus xylus								1	2													
Icriodus aff. *I. regularicrescens*									2	2												
Polygnathus eiflius									1													
Polygnathus cf. *P. linguiformis transversus*									1	1												
Polygnathus kluepfeli										1												
Polygnathus linguiformis ssp. b of Weddige											4											
Icriodus obliquimarginatus → *I. brevis*											1											
Polygnathus varcus											2	1	4	1	2							
Polygnathus linguiformis weddigei												3	3		1							
Polygnathus rhenanus												1			1							
Polygnathus linguiformis mucronatus															1							
Mesotaxis falsiovalis																1	2					
Polygnathus dengleri																20						
Polygnathus dubius																6		1				
Polygnathus ordinatus																4						
Polygnathus pennatus																6		1		1		
Polygnathus pollocki																18	1	154				
Schmidtognathus peracutus																6						
Ancyrodella rotundiloba																	1					
Ancyrodella rugosa																	2					
Ancyrodella sp.																	1	21	2	6		1
Palmatolepis transitans																	1	7				
Ancyrodella gigas (form 1)																		17				
Ancyrodella gigas (form 2)																		10	2			
Icriodus symmetricus																		6	8	44	9	1
Klaperina ovalis																		1				
Mesotaxis sp.																		1				
Ozarkodina sp.																		2				
Palmatolepis punctata																		1	8	21		
Palmatolepis transitans → *punctata*																		1				
Palmatolepis sp.																		9	5	12		
Polygnathus dengleri (narrow form)																		6				
Polygnathus aff. *P. planarius*																			3			
Polygnathus sp. F of Klapper & Lane																			11	6		
Ancyrodella lobata																				6	3	
Ancyrognathus sp. A of Wang & Ziegler																				7		
Ancyrognathus sp.																				1	1	
Palmatolepis bohemica																				1		
Palmatolepis mucronata																				1		
Palmatolepis aff. *P. proversa*																				1		
Polygnathus decororsus																				34	9	1
Ancyrodella curvata (early form)																					1	

Table 2. Numerical distribution of conodont species in the Ouidane Chebbi II section (OC II)

Ouidane Chebbi III Conodonts Samples	4	5	6	7	8	11	12	13	14	15	16	17	18	19	20	21	22	24	25	26	27	28	29	31	32	34	35	37
Ozarkodina sannemanni	3		1																									
Polygnathus dengleri	8	3																										
Polygnathus pennatus	3																											
Polygnathus pollocki	16	21	1	6																								
Polygnathus sp.	9	37	2	12	11	36		14	2	3		2		6	9	8	13	1	4	3		2	9		9	1	4	
Klapperina disparilis		2																										
Polygnathus cristatus		6																										
Polygnathus dubius		2																										
Polygnathus latifossatus		2																										
Polygnathus limitaris		2																										
Polygnathus cf. *P. ovatinodosus*		3																										
Mesotaxis falsiovalis			1																									
Skeletognathus norrisi			1																									
Ancyrodella rotundiloba				7																								
Ancyrodella sp.				12	12	1		1						1		5												
Icriodus subterminus				3																								
Icriodus sp.				1				6									2	1	2	4	2		2	2				
Klapperina ovalis				2																								
Mesotaxis sp.				1																								
Ancyrodella africana					4																							
Ancyrodella lobata					12																							
Ancyrognathus amplicatus					3																							
Ancyrognathus sp.					4	2		4	1								1											
Icriodus symmetricus					15			3	3																			
Palmatolepis punctata					30																							
Palmatolepis sp.					9	7	2	1	3	7	11	18	11	49	35	17	101	7	57	7	18	3	1		10	6	10	1
Polygnathus decorosus					234	8	7																					
Ancyrognathus asymmetricus						1							1															
Palmatolepis kireevae						8																						
Polygnathus webbi							1	14			3	10	6	25	19	5												
Ancyrodella curvata (late form)									9		1	5	1	5	12	6												
Icriodus alternatus alternatus									1					16	5	1	4	1		6			3					
Palmatolepis jamieae									1																			
Palmatolepis winchelli									1		1	14	6	12														
Palmatolepis aff. *P. bogartensis*									1	1	1	5	3	2	1													
Polygnathus alatus									1																			
Polygnathus politus									3				1	7					13	8								
Palmatolepis hassi											1	1			6	2												
Palmatolepis bogartensis												1	7		9	4												
Icriodus alternatus helmsi														11	2	1	5			5								
Ancyrognathus ubiquitus															4	5												
Icriodus iowaensis																	1					3						
Palmatolepis triangularis																	131	2	18	5								
Polygnathus brevilaminus																	2		1	1								
Palmatolepis clarki																		3	19									
Ancyrognathus sinelaminus																			1	2								
Icriodus cornutus																			10		2							
Palmatolepis delicatula																			95									
Palmatolepis minuta minuta																			1		1		1		18	3		
Palmatolepis tenuipunctata																			3	2	2							
Palmatolepis quadrantinodosalobata																				3	6	1						
Palmatolepis crepida																					1							
Palmatolepis minuta loba																					1							
Palmatolepis termini																					8							
Palmatolepis glabra lepta																						1?				1	6	
Palmatolepis glabra prima																						2						
Palmatolepis glabra pectinata																							7		3	9	12	
Palmatolepis minuta subgracilis																								1				
Palmatolepis rhomboidea																								5				
Branmehla sp.																									8			
Palmatolepis schindewolfi																									2	2	14	2
Polygnathus procerus																									14			
Palmatolepis quadrantinodosa inflexa																										1		
Polygnathus glaber medius																										2		
Polygnathus nodocostatus																										2	1	
Palmatolepis gracilis gracilis																											4	4
Palmatolepis marginifera marginifera																											1	
Polygnathus granulosus																											2	1

Table 3. Numerical distribution of conodont species in the Ouidane Chebbi III section (OC III)

Ouidane Chebbi I **Ammonoids** **Samples**	23	28	30	32	32 - 33	33	34	35	36
Arcteicherticeras reisdorfi	9*								
Arcteicherticeras sp. B	1*								
Arcteicherticeras cf. *pyshmense*	35*	6							
Erbenoceras advolvens	65*	15							
Gyroceratites laevis	4*								
Gyroceratites cf. *circularis*	4*								
? *Mimosphinctes* sp.	2*								
Metabactrites formosus	5*								
Lenzites lenzi		3							
Mimagoniatites cf. *fecundus*			1						
Paraphyllites cf. *tabuloides*				1					
Latanarcestes latisellatus					2*				
Latanarcestes noeggerathi					6*				
Latanarcestes sp.					6*				
Praewerneroceras hollardi					1*				
Mimagoniatites sp.						2			
Sellanarcestes tenuior							3	2	
Sellanarcestes wenkenbachi							2	1	
Sellanarcestes sp.							2		2
Sellanarcestes cf. *tenuior*									1

Table 4. Numerical distribution of ammonoid fauna in the Ouidane Chebbi I section (OC I); specimens collected from scree are asterisked

genera but it is generally less diverse than faunas known from regions located at lower latitudes during Emsian times such as Bohemia, North Ural, Guangxi (China), Bretagne, and Germany. A distinct biogeographic pattern, however, cannot be recognized at the generic level. The late Emsian (Dalejan) faunas are dominated by anarcestid ammonoids, *i.e.* the genera *Latanarcestes*, *Praewerneroceras*, *Sellanarcestes*, and *Anarcestes,* which are known to occur in the Rhenohercynian belt of Germany, and also in Bohemia.

The Eifelian ammonoids from Ouidane Chebbi are among the most diverse faunas of this time-slice worldwide (*see* Tables 4-6). Similar faunas are known especially from the Wissenbach Shale (Germany) and from the Chotec Limestone of the Barrandian (Czech Republic). During the Eifelian most of the ammonoid genera and possibly also some species were cosmopolitan. The species *Subanarcestes macrocephalus*, for instance, which is present in the faunas of the Anti-Atlas, is known from the Rhenohercynian belt of Germany, the Brittany, the Cantabrian Mountains, and the North Urals, but was not yet reported from the Barrandian.

The early Givetian ammonoid fauna of Ouidane Chebbi is relatively poor (Table 5). It shows the closest relationship to ammonoids occurring in the Rhenohercynian belt of Germany and England. The late Givetian ammonoid fauna, however, contains highly diverse populations and belongs to the richest faunas known from this time-span. Most of the genera are widely distributed throughout Variscan Europe. Faunas of other areas in the world (the Altay in Kazakhstan, eastern United States, and Guangxi) are considerably poorer in genera and species.

Despite the extremely large numbers of ammonoid specimens which can be collected in the Frasnian of the Tafilalt, only rather few genera and species are known. The fauna consists mainly of *Manticoceras* and the closely related genera (*Carinoceras*, *Crickites*), *Mesobeloceras*, as well as *Beloceras*. Compared with other regions (eastern United States, the Rhenohercynian belt, the Timan, the North Urals, and the Canning Basin), this fauna displays much lower diversity. It is conspicuous, however, that the largest known Frasnian ammonoids, attaining more than 60 cm in diameter, were observed in several localities of the eastern Anti-Atlas.

Ammonoids are also extremely frequent in the Famennian part of the Kellwasser facies, but unlike the Frasnian, the fauna is highly diverse (BECKER 1993) and comparable to those of other regions, e.g. the Rhenohercynian belt, the Montagne Noire, and the South Urals. Many of the genera appear to be cosmopolitan, but there are also endemic taxa, such as *Acrimeroceras*, which is very common in one distinct horizon across the Tafilalt. Interestingly, the *Prolobites* fauna is under-represented. Horizons rich in advanced tornoceratids as well as diverse faunas containing *Prolobites* and the earliest clymeniids, which are well known from the Rhenohercynian belt, the Holy Cross Mountains, and the South Urals, have not been found in North Africa at all. Clymeniid faunas of the Tafilalt are comparatively rich, but are less diverse than faunas known from Germany, Poland, Russia (South Urals) and Kazakhstan. Several taxa, however, such as *Platyclymenia annulata*, *Platyclymenia subnautilina*, *Prionoceras divisum*, and *Prionoceras frechi*, have a cosmopolitan distribution and are common.

STRATIGRAPHY

Conodont biostratigraphy already offers a high-resolution framework for the Devonian but the currently used zonal schemes still have potential for being made more precise (*see* Text-fig. 10). Moreover, there is no conodont zonal scheme for the Devonian which has obtained universal acceptance. Progress in recent years has been due not only to the abundance of new stratigraphic data but also because of introduction of new concepts in stratigraphical practice, including multielement taxonomy, shape analysis, and graphic correlation (*e.g.* MURPHY & BERRY 1983, KLAPPER & FOSTER 1993, KLAPPER & *al.* 1996, BELKA & *al.* 1997a). The fact that we do not yet have a "standard" conodont scheme for the Devonian is just a reflection of the current dynamics in development towards a high-resolution Devonian chronostratigraphic scale based on conodonts.

Because of the long stratigraphic range of the Ouidane Chebbi section, we were constrained to use various conodont zonal schemes in our study. For the Lochkovian and Pragian we applied the zonation established by KLAPPER (1977), KLAPPER & ZIEGLER (1979), and LANE & ORMISTONE (1979). The Emsian zonation follows a scheme proposed

Ouidane Chebbi II **Ammonoids** **Samples**	5	10	11	14	15	16	18	19	20	21	23	25	26	27	30	32	34	38	39
Anarcestes sp.	1																		
Fidelites fidelis		8	2	3	3														
Sobolewia sp.		1	1																
Fidelites cf. *fidelis*			2																
Subanarcestes macrocephalus			3	1	2	9													
Werneroceras cf. *testatum*			1			2	1												
Werneroceras cf. *ruppachense*				1			1												
Cabrieroceras plebeiforme					1		1			18*									
Cabrieroceras crispiforme							2	1	1	18*									
Agoniatites sp.									2	6*						3			
Agoniatites meridionalis										1*									
Agoniatites vanuxemi										15*									
Sobolewia nuciformis										2*									
Sobolewia cf. *virginiana*										1*									
Trevoneites assesi										9*									
Agoniatites obliquus											1	2	1	1					
Agoniatites cf. *fulguralis*												1							
Sellagoniatites discoides															1	5			
Maenioceras crassum																5			
Maenioceras terebratum																5			
Wedekindella lata																1			
Wedekindella psittacina																1			
Eobeloceras taouzense																	5*		
Pharciceras becheri																	8*		
Pharciceras kayseri																	2*		
Meropharciceras disciforme																	1*		
Petteroceras errans																	1*		
Pharciceras tridens																	2*		
Pharciceras cf. *arenicum*																	1*		
Ponticeras kayseri																	9*		
Ponticeras sp.																	2*		
Pseudoprobeloceras nebechense																	7*		
Stenopharciceras kseirense																	3*		
Stenopharciceras lunulicosta																	1*		
Synpharciceras clavilobum																	2*		
Synpharciceras plurilobatum																	2*		
Tornoceras simplex																	3*		
Beloceras sp.																		1*	
Carinoceras sp.																		2	1
Manticoceras intumescens																		1	
Manticoceras cordatum																			2

Table 5. Numerical distribution of ammonoid fauna in the Ouidane Chebbi II section (OC II); specimens collected from scree are asterisked

by YOLKIN & IZOKH (1988) and its refined version (YOLKIN & *al.* 1994). For the Middle Devonian and Frasnian intervals, we used the chronostratigraphic frameworks (the Anti-Atlas regional composite and the Frasnian Composite Standard) and the conodont zonations recently constructed by graphic correlation (BELKA & *al.* 1997a, KLAPPER 1997). Both frameworks provide much higher stratigraphic resolution than traditionally used conodont zonations. The Frasnian Composite Standard, incidentally, is based on several dozen sections worldwide located in different climatic settings during Late Devonian times (KLAPPER 1997); it offers an improved basis for intercontinental correlation.

There are a number of other advantages to biostratigraphy when it is based on graphic correlation and composite standards (*see* CARNEY & PIERCE 1995). Among the most important of these are simultaneous visual comparison of all fossil ranges available for the correlation and the ease with which the composite standard (CS) is enhanced each time. The zonal markers, in contrast with conventional biostratigraphy, do not have the status of bench marks to which the ranges of other species

Ouidane Chebbi III **Ammonoids** **Samples**	9	10	23	29	30	36	38	40	41	42	43	44	45	46	47	48	49
Beloceras tenuistriatum	1	7															
Manticoceras sp.		1															
Mesobeloceras kayseri		1															
Phoenixites frechi			11														
Cheiloceras subcostatum				1	21*												
Falcitornoceras bilobatum				5	5*												
Falcitornoceras falciculum				1	1*												
Oxynehdenites praelentiforme				1													
Oxynehdenites cf. *praelentiforme*				4													
Staffites cf. *afrispina*				58													
Staffites cf. *curvispina*				15													
Armatites beatus					10*												
Armatites cf. *beatus*					9*												
Armatites planidorsatus					16*												
Armatites cf. *planidorsatus*					2*												
Cheiloceras crassum					3*												
Cheiloceras evolutum					1*												
Cheiloceras subpartitum					5*												
Cheiloceras cf. *subpartitum*					6*												
Cheiloceras sp.					157*												
Nehdenites planilobum					52*												
Nehdenites undulosum					191*												
Planitornoceras gesinae					18*												
Puncticeras gastriforme					1*												
Acrimeroceras falcisulcatum						9											
Maeneceras biferum							10										
Platyclymenia sp.								5	30								
Prionoceras divisum									3								
Sporadoceras orbiculare										2	2	1					
Cyrtoclymenia sp.											1				1		
? *Clymenia* sp.													1				
Cymaclymenia sp.													4	1	1		
Gonioclymenia sp.													2	3	1		
Kosmoclymenia lamellosa														4	2		
Mimimitoceras lineare													1				
Gonioclymenia speciosa														2			
Mimimitoceras sp.														1			
? *Franconiclymenia* sp.															1		
Kalloclymenia sp.																1	
Sporadoceras sp.																1	
Acutimitoceras intermedium																	2

Table 6. Numerical distribution of ammonoid fauna in the Ouidane Chebbi III section (OC III); specimens collected from scree are asterisked

are compared. Thus, the impact of all species on a CS are similar and the result is certainly more objective. By biostratigraphic evaluation of new sections the position of zonal boundaries can be estimated with great precision. Based on data provided by KLAPPER (1997), we made use of this method, even for the lowest Famennian, although we used in fact the classical zonation proposed by ZIEGLER & SANDBERG (1990) for that stage.

Ammonoid stratigraphy differs conceptually from conventional conodont biostratigraphy, because ammonoid appearances provide a more stroboscopic rather than continuous picture of the fossil record. This is probably why the ammonoid zones, as defined by BECKER & HOUSE (1994) for the Lower and Middle Devonian, for instance, are in fact faunal intervals having in most cases the character of assemblage zones. Another problem in practice is that ammonoid faunas very often include specimens collected from scree; these do not allow the recognition of the precise stratigraphic range in the section. During our study, therefore, ammonoid records have been carefully documented (Tables 4-6) in order to achieve precise correlation with the conodont stratigraphy. In this way we are endeavouring to establish a detailed ammonoid stratigraphic sequence for the Devonian of the Anti-Atlas, which then can be applied independently where conodonts are absent.

Although ammonoids are generally very frequent in the Devonian of the eastern Anti-Atlas, the species on which the Devonian ammonoid zonation of Becker (*in* WEDDIGE 1997) is based are either relatively rare or absent. From the 59 index species of this scheme proposed for global use only 16 were found at Ouidane Chebbi. The global ammonoid zonation, which has been amalgamated from various local and regional ammonoid zonations around the world, is thus not readily applicable in southern Morocco. We discriminated therefore horizons based on the most characteristic ammonoid species occurring abundantly in the Anti-Atlas (Text-figs 7-8).

Lower Devonian

As already mentioned above, the Silurian/Devonian boundary cannot be precisely recognized at Ouidane Chebbi section, but it probably lies within the upper third of a 120 m thick shale unit that underlies the Lochkovian *Scyphocrinites* limestone. Conodonts isolated from these carbonates are indicative of the *eurekaensis* conodont Zone. Although the conodont record in the Lower Devonian is poor and we were not able to recognize any of the Pragian conodont zone, correlation with other sections in the region is facilitated by the conspicuous colour change (*see* Text-fig. 3) which probably correlates with the end-*pesavis* event (*sensu* TALENT & *al*. 1993) at the end of the Lochkovian. This event is manifested by a reduction in diversity of the conodont faunas. In eastern Australia, it is related to a regional regression, the global extent of which is still uncertain (TALENT & *al*. 1993).

The Pragian/Emsian boundary could not be determined but it must occur within the interval of light grey shales below the first Emsian carbonate unit (Text-fig. 3; Pl. 1, Fig. 2), which contains conodonts assignable to the *dehiscens* and *gronbergi* conodont zones. The ammonoid fauna is extraordinarily rich in this interval. Striking is the occurrence of the species *Gyroceratites laevis*, which makes its first appearance with the *Mimagoniatites* fauna. In the ammonoid zonation of BECKER (*in* WEDDIGE 1997), this taxon defines a zone (*Gyroceratites laevis* Zone) succeeding the *Mimagoniatites fecundus* Zone. Obviously the appearance of *Gyroceratites laevis* around the world was diachronous. It is thus not suitable for precise stratigraphic correlations.

The third last Emsian carbonate band bearing the *Sellanarcestes* ammonoid fauna lies evidently within the *serotinus* Zone. Due to scattered sampling the position of the Emsian/Eifelian boundary in the section cannot be precisely indicated. Taking into account the similar lithological development of the Bou Tchrafine section and its stratigraphy (BULTYNCK 1985), we place this boundary tentatively about 3-4 m below the base of the thick-bedded Eifelian limestones of the *costatus* conodont Zone (Text-fig. 5). Unfortunately, we have not found any ammonoids in this interval.

Middle Devonian

The Eifelian is very much condensed but our conodont data are insufficient to state whether the sequence is continuous or not. The ammonoid fauna documents only the upper part of the stage. The genus *Sobolewia* (Table 5) is stratigraphically important in the rich Eifelian *Subanarcestes* fauna; this is the oldest records of the genus globally (*cf.* BECKER & HOUSE 1994). The Eifelian/Givetian boundary is well constrained by both conodonts and ammonoids. Graphic correlation with the Anti-Atlas regional composite reveals its position within the uppermost part of the Kačak Event-Level (Text-fig. 7). This characteristic shale horizon begins in the *ensensis* conodont Zone and ranges into the *hemiansatus* conodont Zone of the Givetian. The first specimens of *Agoniatites* have been found in the limestone bed directly underlying the Kačak Event-Level. Thus, the entry of this

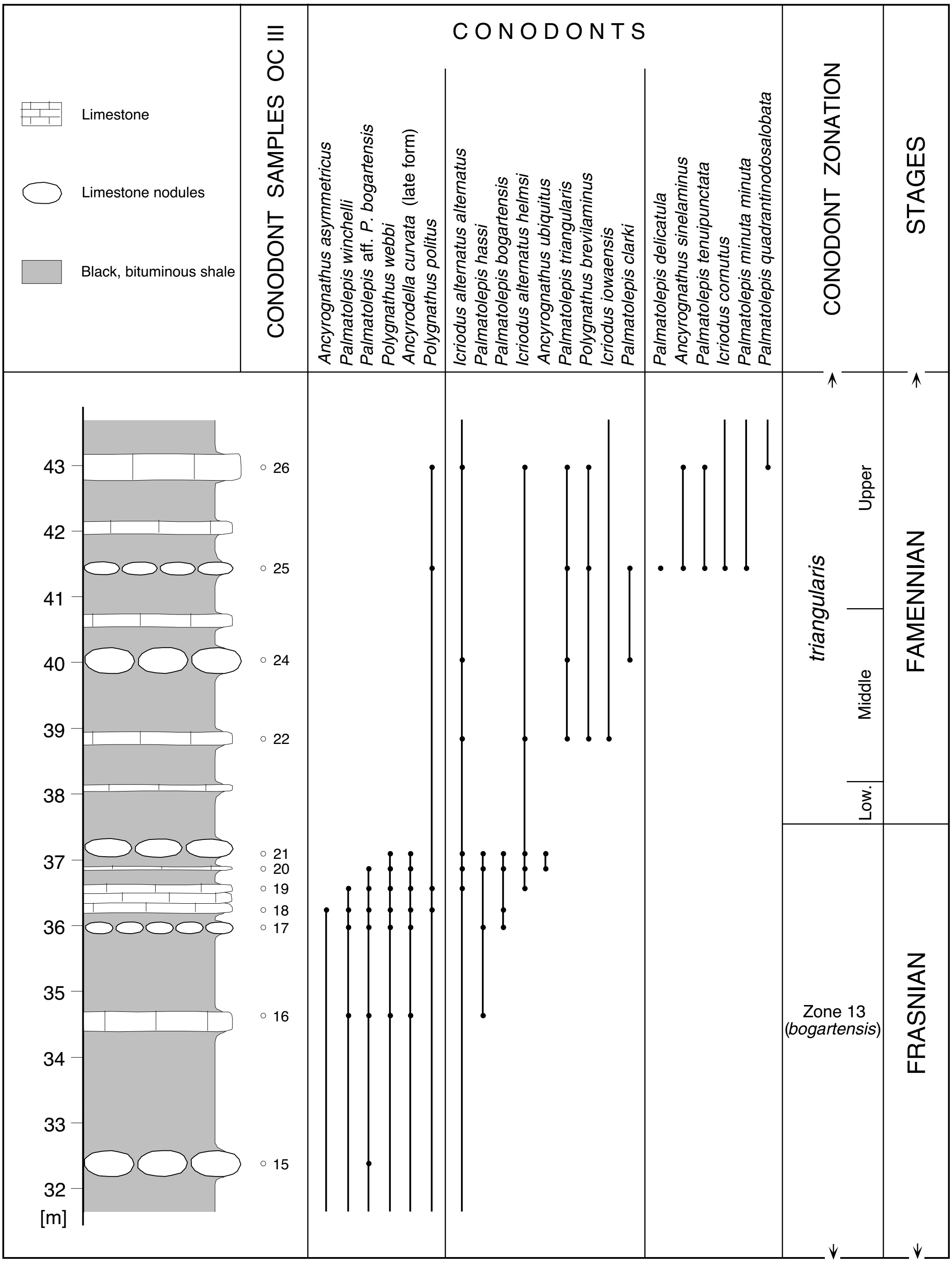


Fig. 9. Frasnian/Famennian boundary interval of Ouidane Chebbi section (OC III) with conodont distribution; Frasnian conodont zonation *after* KLAPPER & *al*. (1996); Famennian conodont zonation *after* ZIEGLER & SANDBERG (1990); boundaries of conodont zones are calculated by graphic correlation with the Frasnian composite standard (KLAPPER 1997)

genus can be correlated with the basal part of the *ensensis* Zone.

Conodonts and ammonoids provide evidence that, like the Eifelian, the Givetian sequence at Ouidane Chebbi is much condensed. Biostratigraphically diagnostic conodonts were recovered from the basal and uppermost parts of the Givetian only. Thus, we were able to identify unequivocally the *hemiansatus*, *timorensis*, *rhenanus*, and *norrisi* conodont zones (Text-figs 7-8). The fragment of the section, in which the *ansatus* to *disparilis* conodont zones are to be expected, is about 4 m thick; i.e. it constitutes only ca. 25% of the studied Givetian sequence. In contrast, the *timorensis* and *rhenanus* conodont zones together (formerly the Lower *varcus* Zone) comprise at least 60% of the measured thickness. HOUSE (1995) calculated the duration (in real time) of the Givetian conodont zones and showed similar time-proportions for these intervals, namely 30% and 58%, respectively. Therefore, we do not expect any significant stratigraphic gaps in the poorly constrained (by conodonts) *ansatus* to *disparilis* interval. Useful evidence here is the record of *Sellagoniatites discoides* which first appears immediately below the Upper *pumilio* level and ranges upwards to occur within the *terebratum* ammonoid fauna. The entry of *S. discoides* at Ouidane Chebbi is the oldest record of this species in southern Morocco (*cf.* BECKER & HOUSE 1994). The uppermost part of the Givetian has produced both rich ammonoid and conodont faunas. The detailed ammonoid sequence, however, is not completely straightforward because of great number of loose specimens collected from the *Pharciceras* limestone (Text-fig. 8 and Tab. 5). Conodont information obtained from the OC II and OC III sections shows evidently that the top of the light-coloured, pharciceratid-bearing carbonates is located within the *norrisi* conodont Zone. Using graphic correlation between the Ouidane Chebbi conodont succession and the Frasnian CS (KLAPPER 1997), the Givetian/Frasnian boundary should be placed about 20 cm above the base of the black styliolinites of the Frasne Event.

Upper Devonian

Currently, only conodonts offer useful evidence for dating sedimentary events in the Frasnian portion of the studied sequence. Biostratigraphic control is first of all confined to intervals close to the limits of lithological units; it provides no indication of stratigraphic gaps associated with those boundaries. The first black carbonate unit of the Frasne Event, the base of which almost coincides with the lower Frasnian stage boundary (Text-fig. 8), ranges into the Zone 4 (*transitans*). Detailed biostratigraphy of the overlying light-coloured cephalopod-bearing carbonates, in terms of conodont zones, remains unknown but the conodont fauna collected at its top (Table 3, sample OC-III-11) is diagnostic of the Zone 12 (*winchelli*). The first limestone band within the black shales of the Kellwasser facies (Text-fig. 3) has the same age. The Frasnian/Famennian boundary cannot be identified on the basis of lithology. It must occur within the 1.5 m thick shale interval between the sample OC-III-21 and OC-III-22 (Text-fig. 9) containing, respectively, the last Frasnian and the first Famennian conodont fauna. Graphic correlation of conodont data against the Frasnian CS place this boundary in the lower part of the interval, about 25 cm above the last Frasnian carbonate horizon. The first carbonate band with Famennian conodonts can be easy identified as it contains numerous specimens of the ammonoid *Phoenixites frechi* (Pl. 5, Figs 3-4). As already demonstrated by WENDT & BELKA (1991), the Kellwasser lithology at Ouidane Chebbi extends into the *rhomboidea* Zone. Of great significance for stratigraphic correlation is, however, the fact that the top of this unit is markedly diachronous through its area of distribution in the eastern Anti-Atlas. Contrary to that, the onset of the overlying nodular limestones dated as Lower *marginifera* conodont Zone marks a synchronous sedimentary event resulted from worldwide transgression at that time. Above this level, the biostratigraphy of the upper part of the Famennian at Ouidane Chebbi is based only on ammonoids and trilobites. The ammonoid fauna documents well the interval from the *biferum* to the *paradoxa* ammonoid Zone. Stratigraphically important is the occurrence of the goniatite *Acutimitoceras intermedium* (Pl. 5, Figs 7-8) above the last black shale horizon in the section (Text-fig. 3), indicating the Upper *praesulcata* conodont Zone. The trilobites (*Belgibole abruptrirhachis* and *Macrobole* aff. *funirepa*) found also in this interval represent the youngest Devonian trilobite association known from southeastern Morocco. In all European localities, where these taxa are present, they occur within the Upper *praesulcata* Zone. Thus, both trilobites and ammonoids strengthen the contention that the underlying black shales equate with the Hangenberg Shale developed in the Rhenish Slate

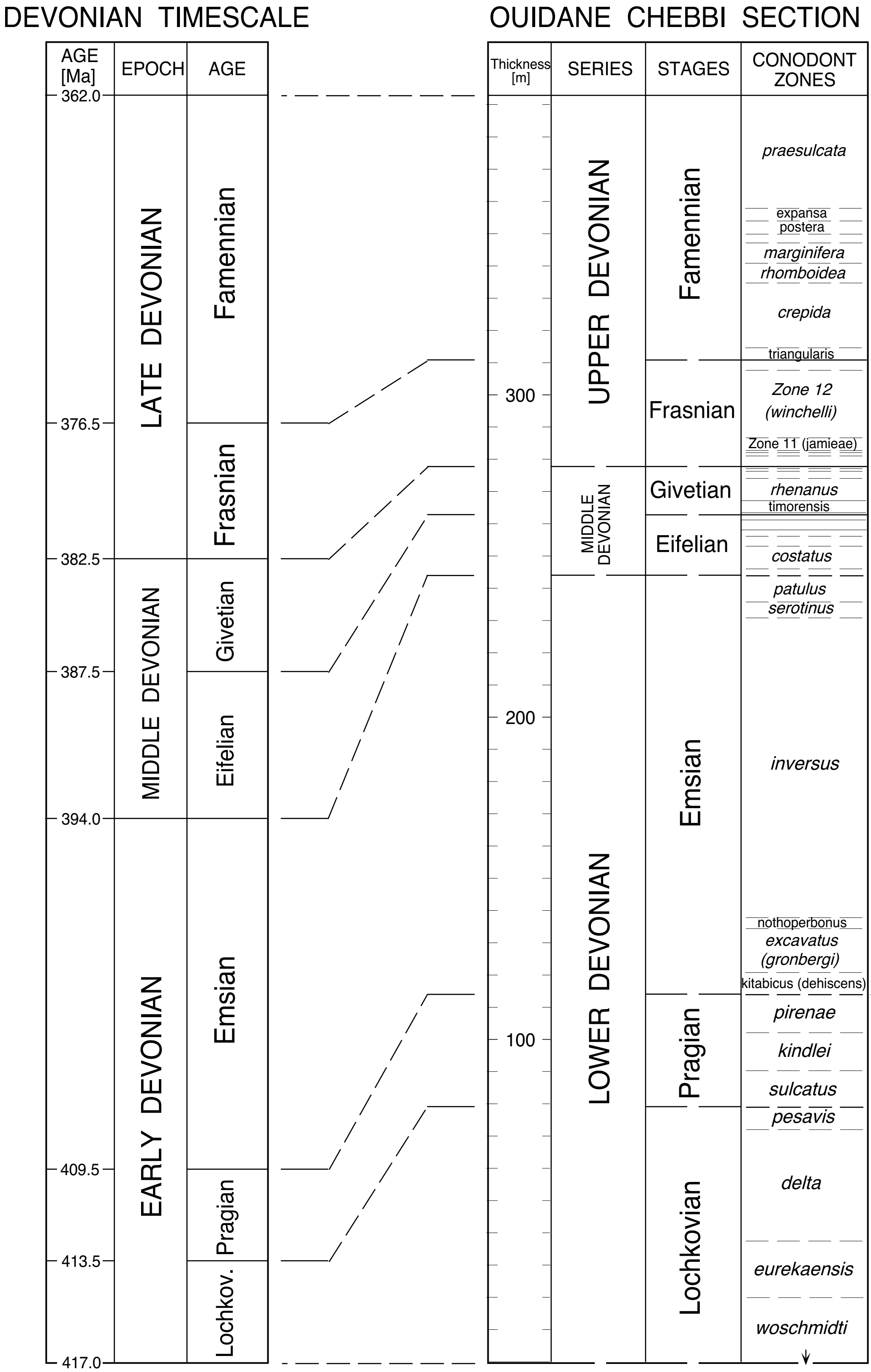


Fig. 10. Comparison of stage thicknesses in the Ouidane Chebbi section with the numerical Devonian timescale of TUCKER & *al*. (1998); note the stratigraphic condensation of the Middle Devonian

Mountains. Furthermore, it bears to continuous marine sedimentation continuing to the very top of the Devonian in the eastern Tafilalt. The widespread distribution of trilobites of the *abruptirhachis-funirepus* group makes these fossils as a useful biostratigraphic marker for the uppermost Famennian, immediately below the Devonian/Carboniferous boundary.

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PLATE 2

1-2 – *Latericriodus postwoschmidti* (MASHKOVA, 1968)
1 – Sample OC-I-1, × 50
2 – Basal cavity partly broken, sample OC-I-1, × 55

3 – *Latericriodus sigmoidalis* (CARLS & GANDEL, 1969); sample OC-I-22, × 55

4 – *Latericriodus beckmanni* (ZIEGLER, 1956); sample OC-I-28, × 55

5 – *Pandorinellina steinhornensis steinhornensis* (ZIEGLER, 1956); sample OC-I-28, × 70

6 – *Polygnathus bultyncki* WEDDIGE, 1977; sample OC-I-38, × 50

7 – *Polygnathus gronbergi* KLAPPER & JOHNSON, 1975; lower view, free blade broken, sample OC-I-21, × 80

8 – *Polygnathus costatus patulus* KLAPPER, 1971; sample OC-I-39, × 55

9 – *Polygnathus hemiansatus* BULTYNCK, 1985; sample OC-II-23, × 40

10 – *Polygnathus* aff. *planarius* KLAPPER & LANE, 1985; sample OC-II-40, × 40

11 – *Polygnathus* cf. *linguiformis transversus* WITTEKINDT, 1965; sample OC-II-25, × 40

12 – *Polygnathus linguiformis weddigei* CLAUSEN, LEUTERITZ & ZIEGLER; 1979, sample OC-II-29, × 50

Unless otherwise stated, all figures are upper views

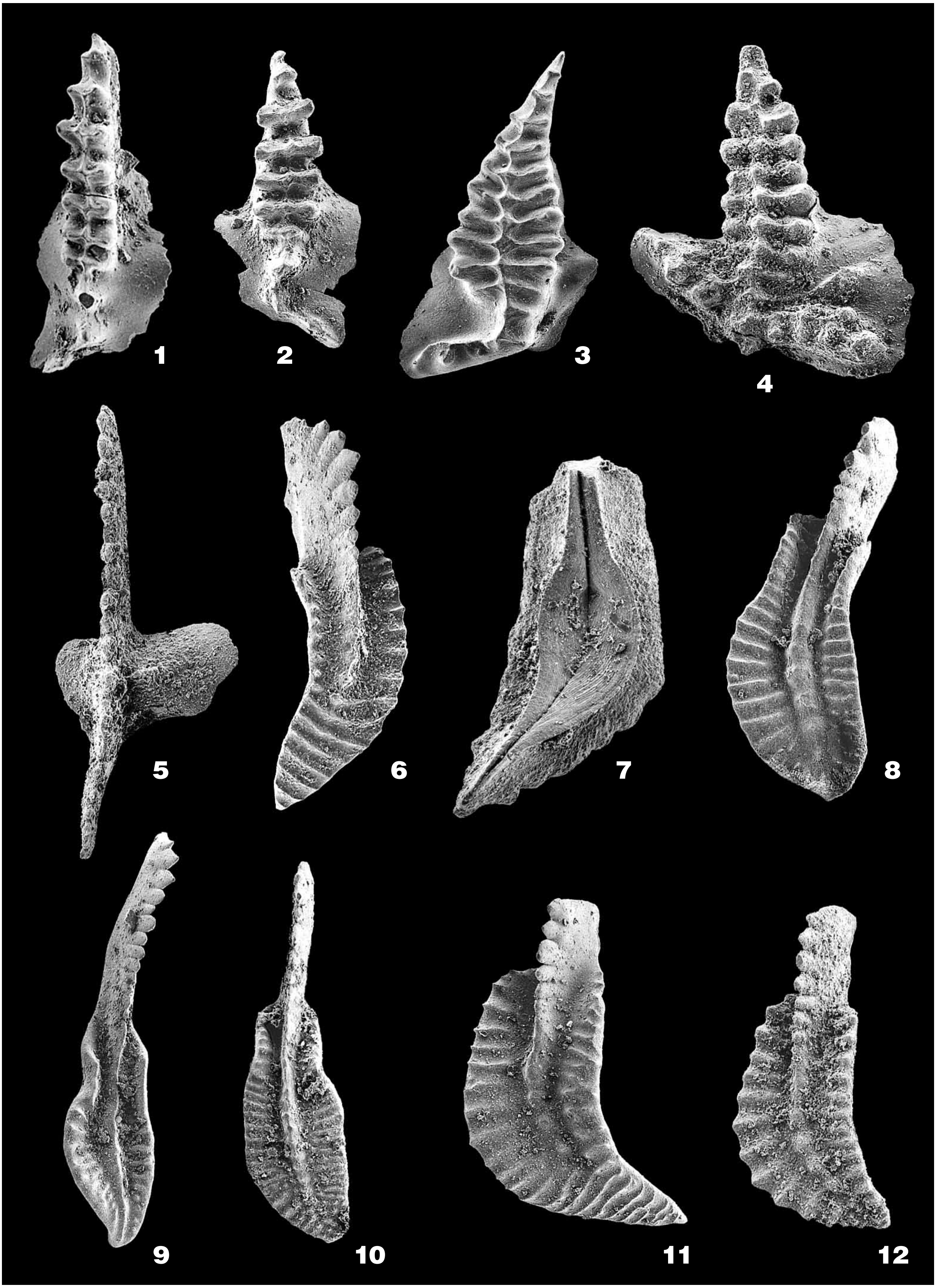
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PLATE 3

1-2 – *Palmatolepis punctata* (HINDE, 1879)
1 – Sample OC-II-39, × 50
2 – Sample OC-II-41, × 40

3 – *Palmatolepis* aff. *proversa* KLAPPER, 1988; sample OC-II-41, × 70

4 – *Palmatolepis bohemica* KLAPPER & FOSTER, 1993; sample OC-II-41, × 40

5 – *Palmatolepis mucronata* KLAPPER, KUZMIN & OVNATANOVA, 1996; oblique upper view, sample OC-II-41, × 40

6 – *Ancyrognathus* “sp. *A*” of WANG & ZIEGLER, 1983; sample OC-II-41, × 80

7 – *Polygnathus* aff. *pennatus* HINDE, 1879; sample OC-II-41, × 65

8 – *Polygnathus decorosus* STAUFFER, 1938; sample OC-II-41, × 65

9-10 – *Polygnathus* sp. *F* of KLAPPER & LANE, 1985
9 – Sample OC-II-41, × 65
10 – Oblique lateral view, sample OC-II-40, × 65

Unless otherwise stated, all figures are upper views

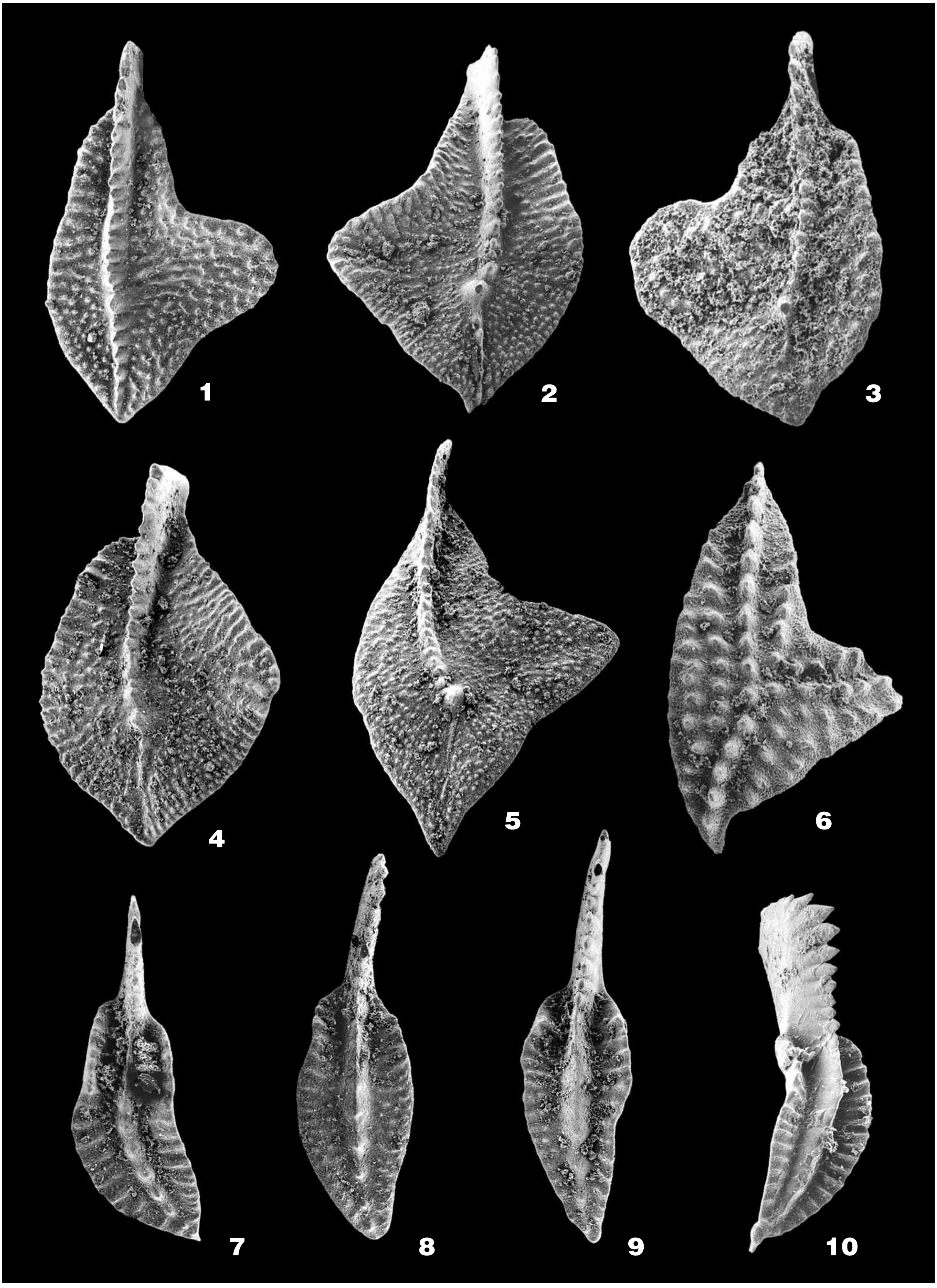
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PLATE 4

1-2 – *Latanarcestes noeggerathi* (VON BUCH, 1832); lateral and ventral view, loosely collected specimen from shales below the *Sellanarcestes* beds, GPIT 1849-145, × 1.1

3-4 – *Sellanarcestes wenkenbachi* WALLISER, 1965; lateral and ventral view, bed OC-I-35, GPIT 1849-758, × 1

5-6 – *Agoniatites obliquus* (WHIDBORNE, 1889); lateral and ventral view, bed OC-II-27, GPIT 1849-314, × 1.1

7-8 – *Maenioceras terebratum* (SANDBERGER & SANDBERGER, 1851); lateral and ventral view, bed OC-II-32, GPIT 1849-323, × 1

9-10 – *Petteroceras errans* (PETTER, 1959); lateral and ventral view, loosely collected specimen from the Upper Givetian *Pharciceras* limestone, GPIT 1849-780, × 1.1

11-12 – *Ponticeras kayseri* (WEDEKIND, 1918); lateral and ventral view, loosely collected specimen from the Upper Givetian *Pharciceras* limestone, GPIT 1849-388, × 1.1

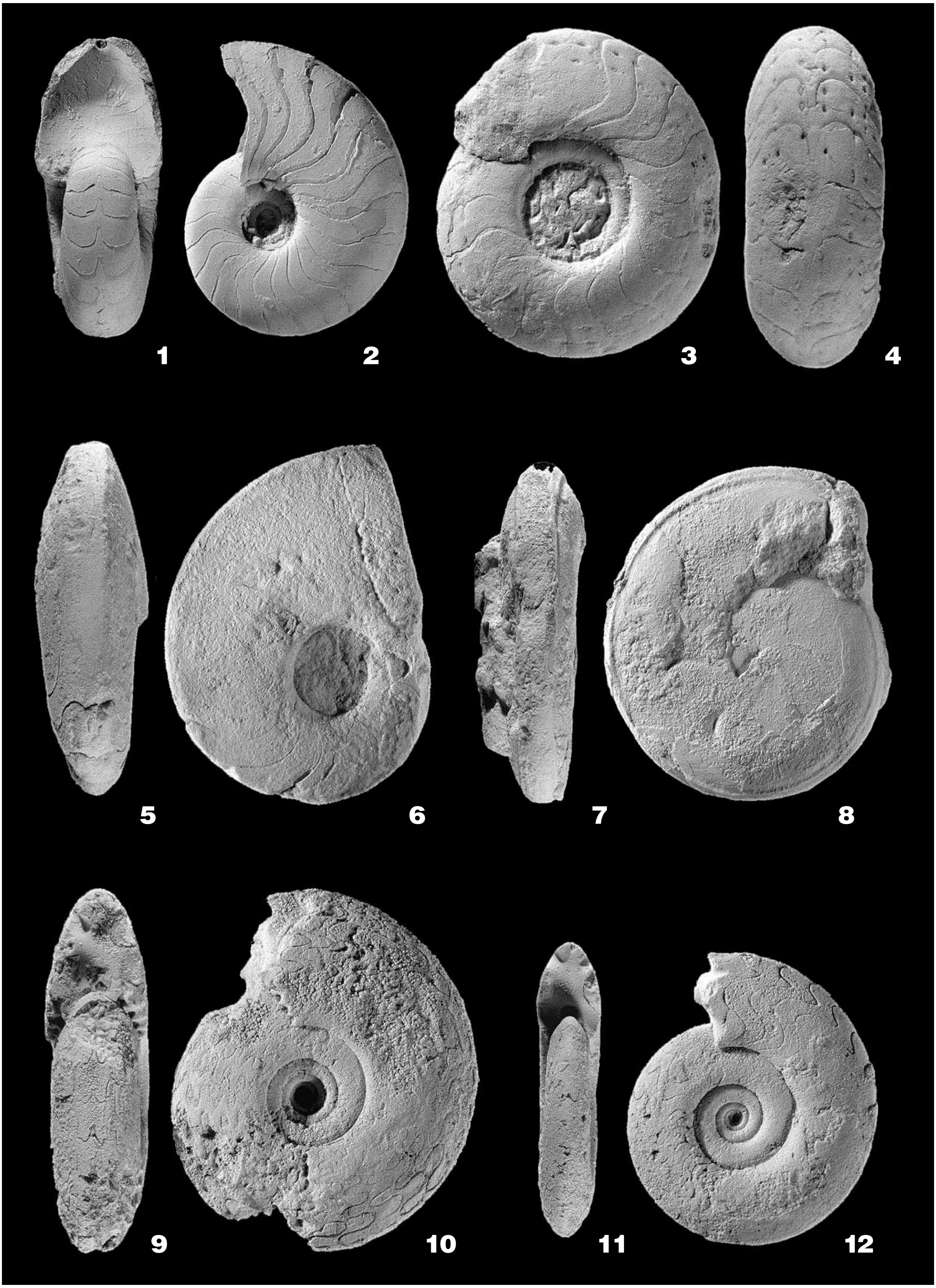
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PLATE 5

1-2 – *Triainoceras costatum* (D'ARCHIAC & DE VERNEUIL, 1842); lateral and ventral view, loosely collected specimen from the lower Frasnian nodular limestones below the Kellwasser unit, GPIT 1849-390, × 1

3-4 – *Phoenixites frechi* (WEDEKIND, 1918); lateral and ventral view, OC-III-23, GPIT 1849-530, × 1

5-6 – *Acrimeroceras falcisulcatum* BECKER, 1993; lateral and ventral view, loosely collected specimen from the middle Famennian nodular limestones overlying the Kellwasser unit, GPIT 1849-520, × 1.1

7-8 – *Acutimitoceras intermedium* SCHINDEWOLF, 1923; lateral and ventral view, OC-III-49, GPIT 1849-751, × 1.3

9-11 – *Macrobole* ex gr. *funirepa* FEIST, 1988
- 9 – Incomplete pygidium, partially external mould; trilobite horizon above sample OC-III-49, UM2-RF 123, × 7.5
- 10 – Incomplete pygidium, partially external mould; trilobite horizon above sample OC-III-49, UM2-RF 124, × 4.5
- 11 – Incomplete pygidium, partially external mould; trilobite horizon above sample OC-III-49, UM2-RF 122, × 8

12 – *Pseudowaribole conifer gibber* ALBERTI, 1975; fragmentary cranidium, external mould, sample OC-III-48, UM2-RF 127, × 6.5

13 – *Belgibole abruptirhachis* RICHTER & RICHTER, 1951; incomplete pygidium, latex cast of external mould, trilobite horizon above sample OC-III-49, UM2-RF 121, × 6

14 – *Phacops* (*Omegops*) "sp. *T*" of STRUVE, 1976; incomplete cephalon, plasticine cast of external mould, marlstone above sample OC-III-48, UM2-RF 125, × 1.5

15 – *Pseudowaribole conifer gibber* ALBERTI, 1975; pygidium with damaged axis, external mould, sample OC-III-48, UM2-RF 128, × 5.5