



## Famennian Ammonoid Stratigraphy of the Ma'der and Tafilalt (Eastern Anti-Atlas, Morocco)

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9 Text-Figures, 1 Table and 7 Plates



Morocco  
Anti-Atlas  
Devonian  
Famennian  
Cephalopods  
Ammonoids  
Stratigraphy

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## Ammonoideenstratigraphie der Famenne-Schichten des Ma'der- und Tafilalt-Gebietes (östlicher Anti-Atlas, Marokko)

### Zusammenfassung

Profile in Sedimentgesteinen des Mittel- und Oberfamenne im östlichen Anti-Atlas zeigen drei Schwarzschiefer-Horizonte, welche sich mit Hilfe von Ammonoideen-Faunen datieren lassen. Die beiden unteren Horizonte, der zweifache *Annulata*-Schwarzschiefer, ist durch *Platyclymenia annulata* und *Prionoceras divisum* gekennzeichnet, welche aus Profilen Mitteleuropas bekannt sind. Der obere Horizont kann mit dem weitverbreiteten Hangenberg-Schwarzschiefer korreliert werden (mit *Wocklumeria sphaeroides* darunter und *Acutimitoceras* sp. darüber). Die Ammonoideen-Stratigraphie des östlichen Anti-Atlas stimmt weitgehend mit derjenigen anderer Regionen, besonders dem Rheinischen Schiefergebirge, dem Heiligkreuzgebirge und dem Südrural überein.

Die folgenden Taxa werden im paläontologischen Abschnitt neu beschrieben: *Posttornoceras sapiens* n.sp., *Posttornoceras weyeri* n.sp., *Erfoudites* n.gen., *Erfoudites zizensis* sp.nov., *Erfoudites rherisensis* sp.nov., *Platyclymenia ibnsinai* n.sp., *Czarnoclymenia* n.gen., *Czarnoclymenia ibnrushdi* n.sp., *Sellaclymenia ibntufayli* n.sp., *Protoxycymenia wendti* n.sp.

### Abstract

The middle and late Famennian sedimentary sequences of the eastern Anti-Atlas have three black shale horizons which can be dated in terms of ammonoid faunas. The lower two horizons, the dual *Annulata* Black Shales, have a characteristic fauna consisting, inter alia, of *Platyclymenia annulata* and *Prionoceras divisum*, known also from sections in Central Europe. The upper horizon correlates with the widespread Hangenberg Black Shale (with *Wocklumeria sphaeroides* below and *Acutimitoceras* sp. above). The ammonoid stratigraphy of the eastern Anti-Atlas coincides broadly with those of other regions, notably the Rhenish Massif, the Holy Cross Mountains, and the South Urals.

The following taxa are newly described in the palaeontological section: *Posttornoceras sapiens* sp.nov., *Posttornoceras weyeri* sp.nov., *Erfoudites* gen.nov., *Erfoudites zizensis* sp.nov., *Erfoudites rherisensis* sp.nov., *Platyclymenia ibnsinai* sp.nov., *Czarnoclymenia* gen.nov., *Czarnoclymenia ibnrushdi* sp.nov., *Sellaclymenia ibntufayli* sp.nov., *Protoxycymenia wendti* sp.nov.

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## 1. Introduction

Famennian sections in various regions of the world can be subdivided according to their ammonoid faunas; these subdivisions may be correlated over great distances, and can help biostratigraphically date various environmental events that occurred during the middle and late Famennian, specifically the so-called *Annulata* and Hangenberg Events (BECKER, 1992, 1993a; CLAUSEN et al., 1994; KORN et al., 1994; LUPPOLD et al., 1994). Sedimentary indications of these anoxic events have probably not been published from North African sections. It will be shown here that they do occur, and closely resemble sections in other regions, such as in the Rhenish Massif.

Frasnian Kellwasser facies sediments are well known from the eastern Anti-Atlas (BUGGISCH & CLAUSEN, 1972; WENDT, AIGNER & NEUGEBAUER, 1984; WENDT, 1985, 1988; SCHINDLER, 1990; WENDT & BELKA, 1991). The last of these authors have shown that this facies is not restricted to the Frasnian but continued through into the early Famennian *crepida* Zone. By contrast, middle and late Famennian sediments have not previously been intensively studied. This may be due to poorer outcrops, but may also be due to their sedimentologically less spectacular character.

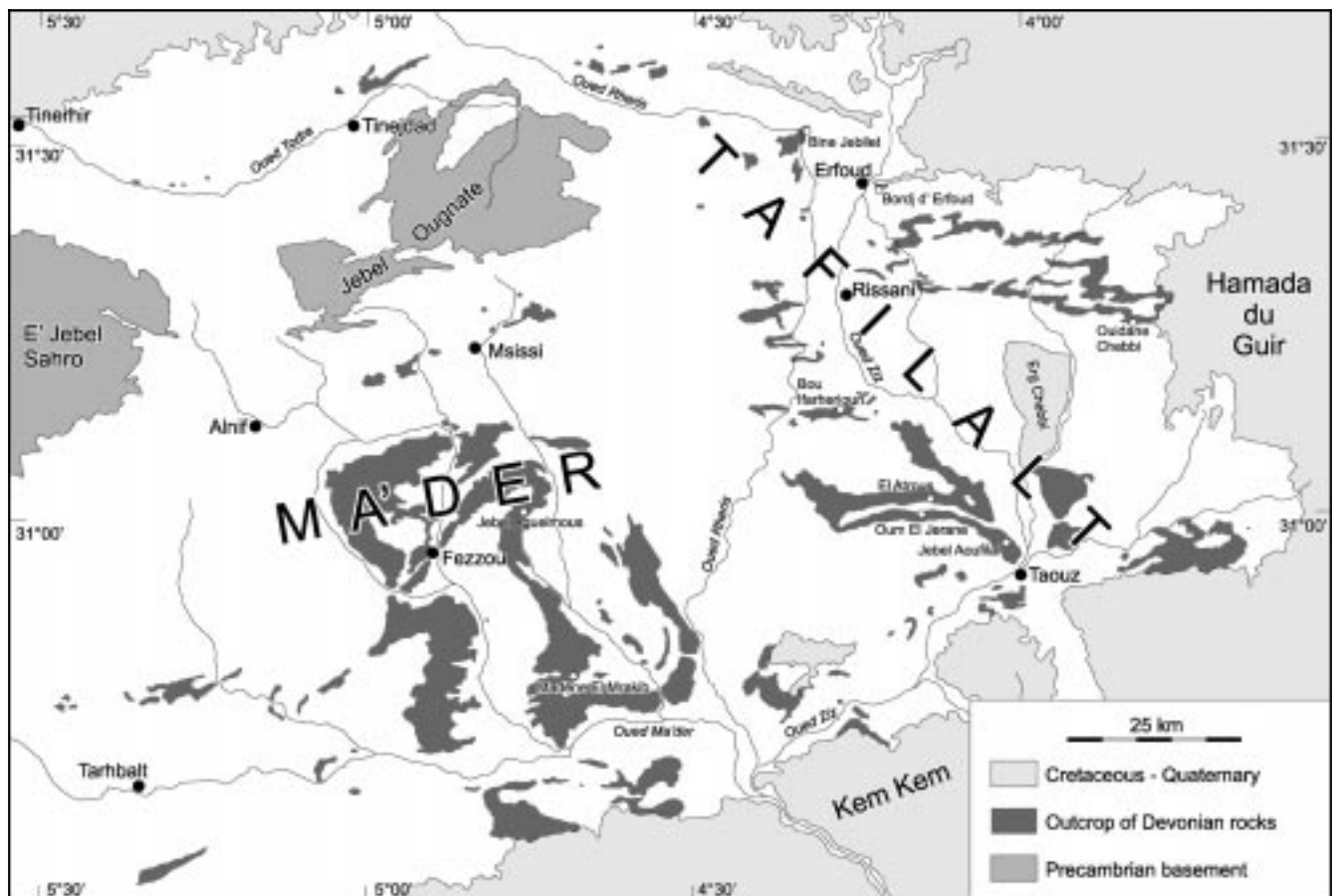
In spite of extremely large numbers of individuals, the middle and late Famennian ammonoid faunas of the eastern

Tabelle 1.

Late Famennian ammonoid zonation, mainly based on sections in the Rhenish Massif (after BECKER & KORN, 1997).

C = Carboniferous; Pr.-Pl. Stufe = *Prolobites-Platyclymenia* Stufe; G. St. = *Gattendorfia* Stufe; HBS = Hangenberg Black Shale; ABS = *Annulata* Black Shale.

C.	G. St.		
LATE FAMENNIAN	Wocklumeria Stufe	<i>subinvoluta</i> Zone	
		<i>prorsum</i> Zone	
		<i>nigra</i> Zone	HBS
		<i>sphaeroides</i> Zone	
		<i>paradoxa</i> Zone	
		<i>endogona</i> Zone	
		<i>lens</i> Zone	
		<i>parundulata</i> Zone	
	Clymenia Stufe	<i>sublaevis</i> Zone	
		<i>piriformis</i> Zone	
		<i>ornata</i> Zone	
		<i>laevigata</i> Zone	
	Pr.-Pl. Stufe	<i>serpentina</i> Zone	
		<i>dunkeri</i> Zone	
		<i>annulata</i> Zone	ABS
		<i>delphinus</i> Zone	
		<i>pseudogoniatis</i> Zone	



Text-Fig. 1.

Location map of the localities described from the Tafilalt and Ma'der in the eastern Anti-Atlas, Morocco.

Anti-Atlas are relatively poor in species compared with faunas from the Rhenohercynian and Saxothuringian Zones, the Holy Cross Mountains, and the South Urals. Biostratigraphical correlation using index species from other regions is thus usually difficult. Moreover, some of the ammonoid horizons in sections described in this paper have not been identified in other places.

For the middle and late Famennian, two stratigraphical schemes based on ammonoids have been proposed during the last 20 years, both building on subdivisions introduced by WEDEKIND (1918), SCHMIDT (1924), and SCHINDEWOLF (1937). On the basis of sections in the Rhenish Massif, KORN (1981, 1986) discriminated a lower and an upper *annulata* Zone, 4 clymenioid zones within the *Clymenia* Stufe, and 8 ammonoid zones within the *Wocklumeria* Stufe. Some of these zones were subsequently subdivided further without the subdivisions being named (KORN, 1992, 1995). BECKER (1995) reconsidered this scheme from the standpoint of another zonal scheme, suggesting there could be still finer subdivision between the *annulata* Zone and the *acuticostata* Zone. He based this on sections in the Rhenish Massif as well as other regions, e.g. the eastern Anti-Atlas. Both schemes are broadly compatible, differing primarily in terminology. The revised terminology introduced by BECKER & KORN (1997) will be used here (Tab. 1).

The present study is based on three sections (Text-Fig. 1): Madène El Mrakib (Ma'der Basin), Ouidane Chebbi (Tafilalt Basin), and Bordj d'Erfoud (Tafilalt Platform). These differ remarkably in thickness due to the different rates of influx of clastics, whereas the amount of carbonates appears to be similar. Materials from Bou Tchratine, Bou Ifarherioun, El Atrous, Jebel Aoufilal, Oum El Jerane, Bine Jebilet (all Tafilalt Platform), and Jebel Aguelmous (Ma'der Basin) were also examined, confirming the results obtained in the three major sections.

## 2. Investigated Sections

### Madène El Mrakib

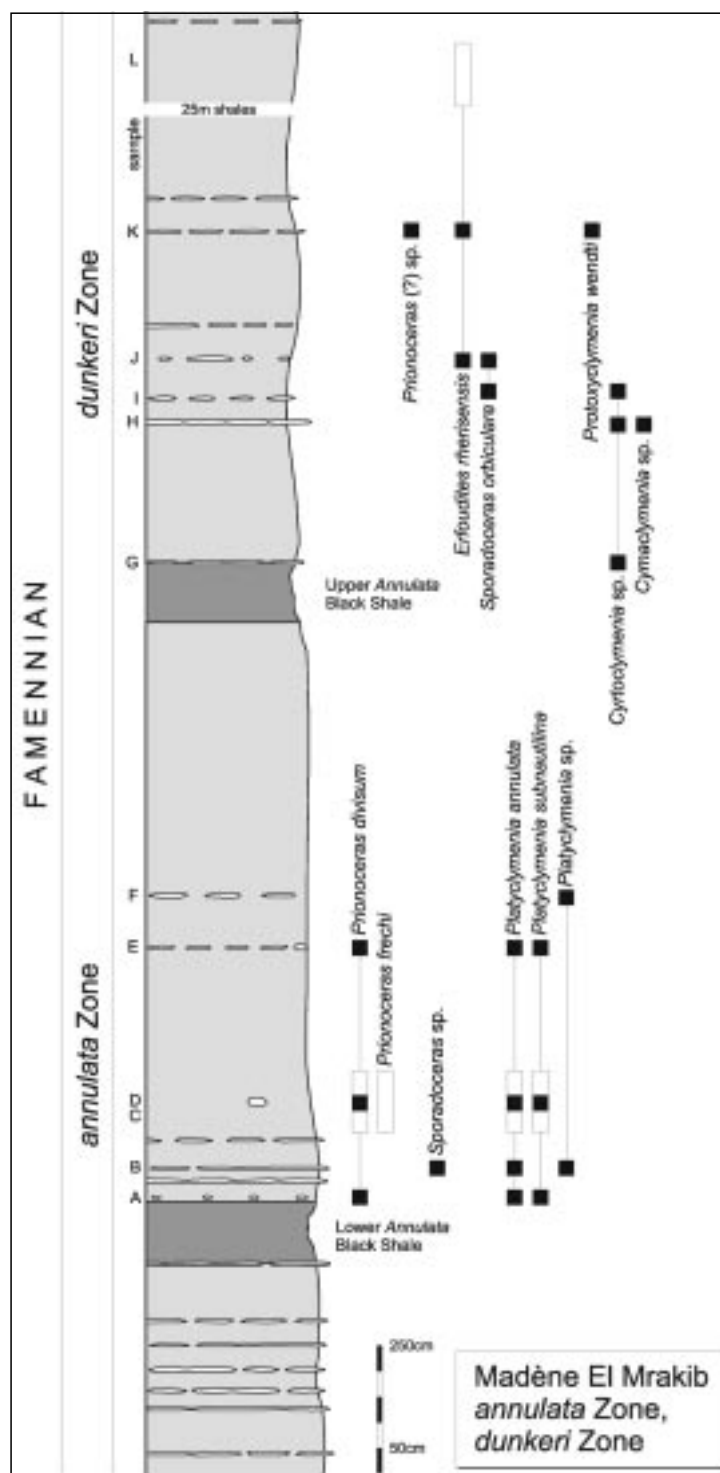
The Madène El Mrakib section is 30 km south-east of Fezzou, 80 km south-southwest of Erfoud, in the southern Ma'der.

In this area, the Famennian section consists mainly of fine clastics, usually greenish claystones, with thin intercalations of marly or calcareous nodular layers (Text-Fig. 2). The late Famennian, especially, is represented by a rather monotonous succession of claystones with interbedded thin carbonates and black shales. From this section, 600 ammonoid specimens were collected from strata between the *annulata* Zone and the top of the Devonian (coll. FEIST, 1992; KORN, 1998).

### Bordj d'Erfoud

The section is located beside the Erfoud Muslim cemetery, 500 metres east of the Ziz Valley, directly north of the road to Taouz.

It is a very condensed sequence of shales and nodular limestones (Text-Fig. 3) representing most of the Late Devonian except for the highest part, covered by boulders of Cretaceous sandstone.



Text-Fig. 2.  
The Madène El Mrakib section and its ammonoid content.

About 750 ammonoid specimens have been collected bed-by-bed; investigations focused mainly on the *annulata* Zone and the *Wocklumeria* Stufe (coll. WEYER, 1995; KORN, 1993, 1995).

### Ouidane Chebbi

The easternmost investigated section is close to the Hamada du Guir 45 km east-southeast of Erfoud.

The late Famennian here, represented by nodular limestones and greyish-greenish claystones (Text-Fig. 4), is intermediate in thickness between the condensed Tafilalt Platform and the thick Ma'der Basin sections. Investigations focused on the lower *Wocklumeria* Stufe and the highest Devonian *prorsum* Zone. Fossil collections were relatively small, 150 specimens, due to profound

Text-Fig. 3.  
The Ouidane Chebbi section and its ammonoid content.

weathering of the outcrop (coll. FEIST & KORN, 1993; WEYER & KORN, 1995; KLUG & KORN, 1998).

#### El Atrous

At the Frasnian/Famennian stratotype candidate (BECKER, HOUSE & ASHOURI, 1988) El Atrous 52 km south-southeast of Erfoud, the very condensed late Famennian strata are not well exposed due to quarrying of the *Gonioclymenia* limestone bed and covering of neighbouring beds with scree. The few ammonoid-bearing horizons examined are:

- 1) a 15 cm black limestone containing an abundant *annulata* Zone fauna, and
- 2) 80 cm higher, a 10 cm black limestone full of *Cymaclymenia* n.sp. A total of 350 ammonoids were collected (coll. KORN, 1995, 1998; KLUG, 1995).

#### Jebel Aoufilal

Like the El Atrous section, this section is in the Amessoui Syncline, 56 km south-southeast of Erfoud. Between a black limestone bed with *Platyclymenia annulata* and the nodular *Gonioclymenia* limestone, is an 8 m interval of claystone with abundant limonitic ammonoids. Unfortunately, not all of the latter are unequivocally from the same horizon. More than 800 specimens were collected (coll. KLUG, REISDORF, WALKER, MÜLLER & KORN, 1995).

#### Oum el Jerane

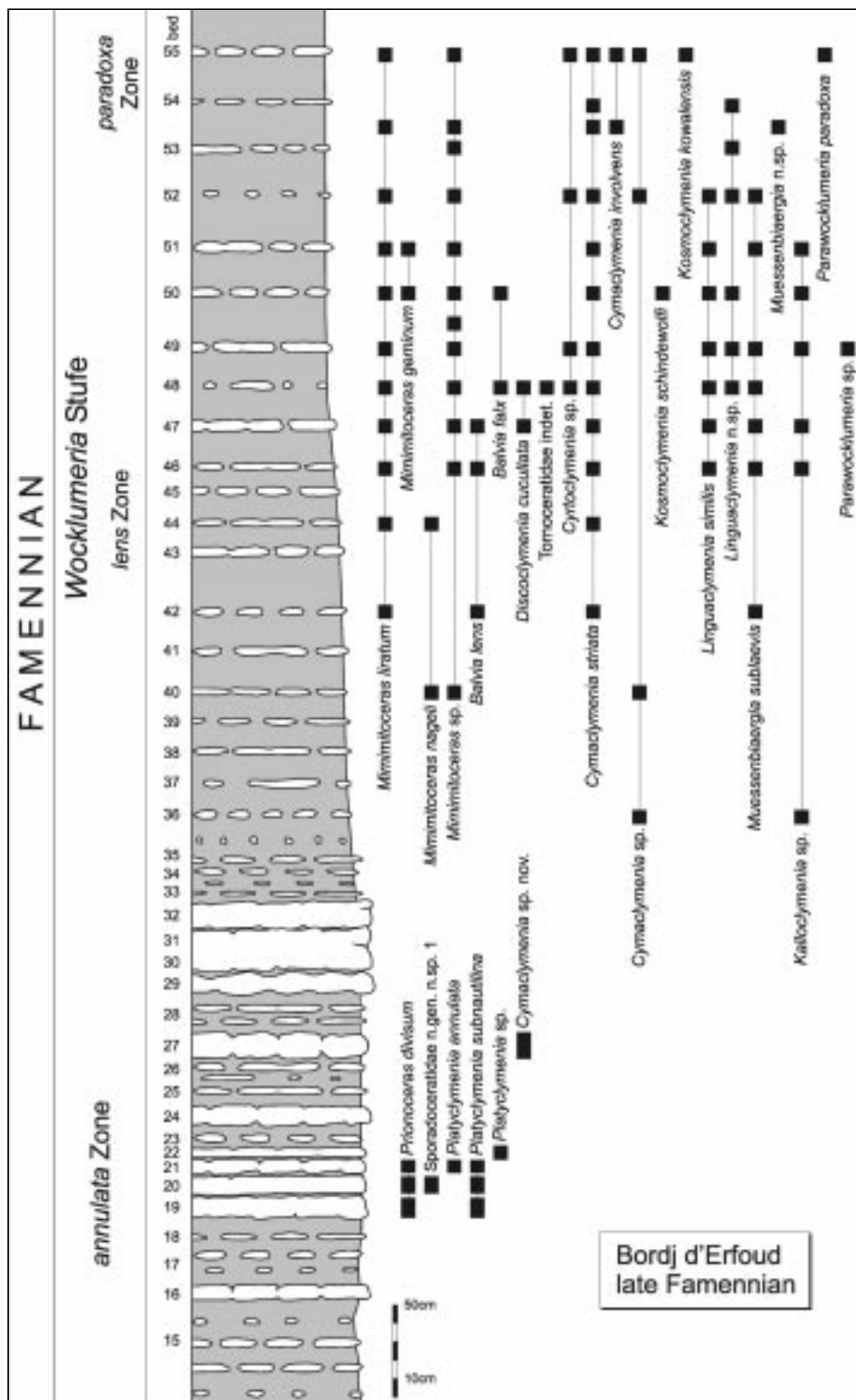
This section, also in the Amessoui Syncline, resembles the El Atrous and Jebel Aoufilal sections in whose vicinity it is located. Only one horizon has been exploited, a very fossil-rich black limestone between the *annulata* Zone and the *Gonioclymenia* limestone. Its rich fauna of 120 ammonoids (coll. KLUG, 1995, 1998) is a lower *Clymenia* Stufe horizon.

#### Bine Jebilet

This locality, 10 km west of Erfoud, produced 150 *annulata* Zone ammonoids from a single bedding surface (coll. KORN, 1993).

#### Jebel Aguelmous

This, the thickest section investigated, is in the Central Ma'der, 25 km west-northwest of Fezzou, and 55 km



southwest of Erfoud; it consists mainly of greyish shales with marly intercalations. The section starts above the *annulata* Zone and extends up into thick sandstones about the Devonian-Carboniferous Boundary.

#### Bou Tchrafine

This locality, 8 km southeast of Erfoud, is often described because of its Emsian to Givetian section (e.g. BECKER & HOUSE, 1996). The Famennian strata are not well exposed, but one *Gonioclymenia*-bearing horizon could be exploited and yielded 70 ammonoid specimens (coll. KORN, 1993).

Text-Fig. 4.  
The Bordj d'Erfoud section and its ammonoid content.

### Bou Ifarherioun

At Bou Ifarherioun, 33 km south of Erfoud, the late Famennian is extremely condensed, resembling the section at El Atrous. One extremely fossiliferous limestone bed immediately above the *annulata* Zone bed (which is represented here by a debrite) yielded 160 ammonoids, probably from the *dunkeri* Zone or lower *Clymenia* Stufe (coll. KORN, 1993).

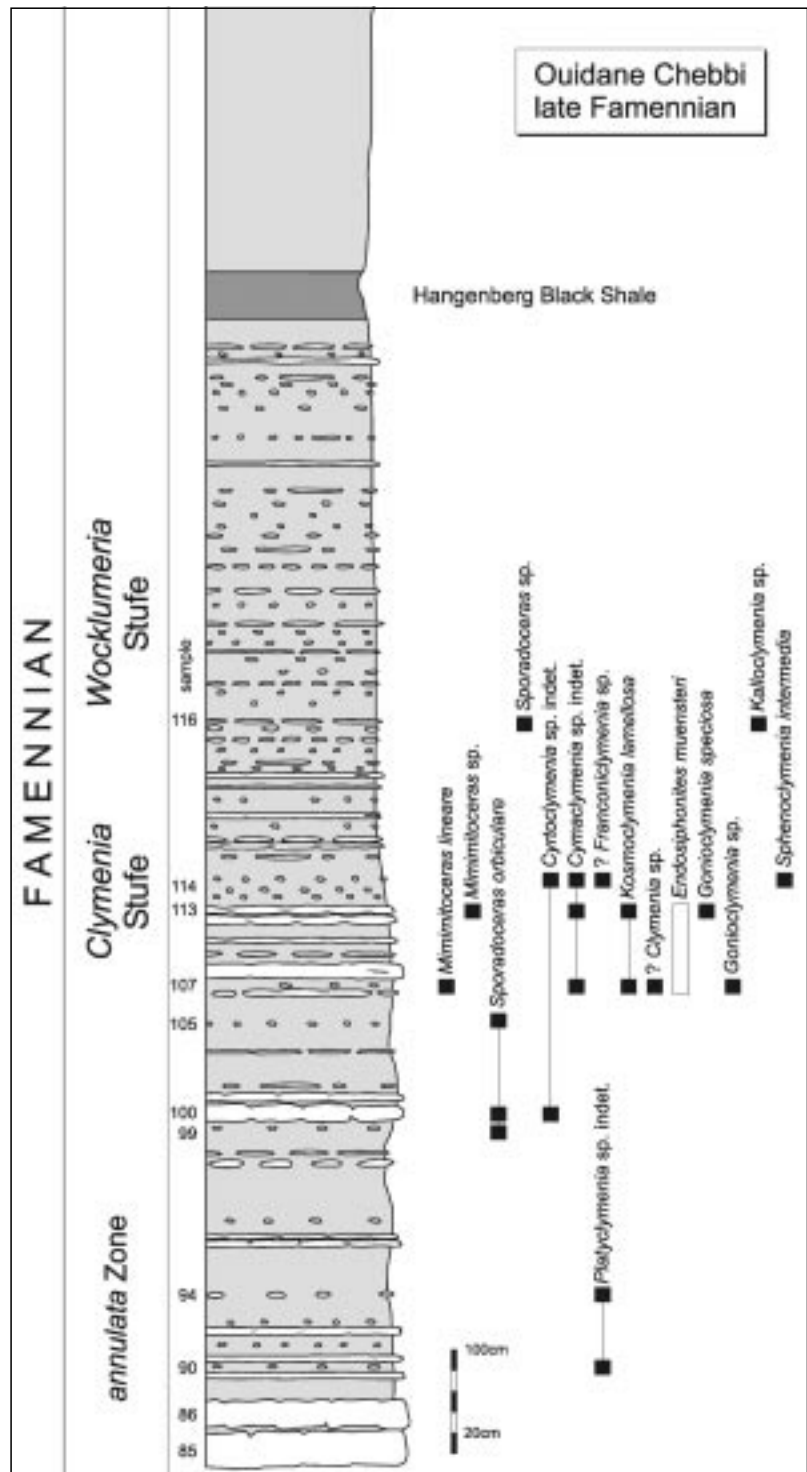
## 3. Middle and Late Famennian Ammonoid Stratigraphy in the Eastern Anti-Atlas

### 3.1. *Annulata* Zone

The *annulata* Zone, characterised by *Platyclymenia annulata* up to the first entry of *Protycliclymenia dunkeri*, is well developed in sections in the eastern Anti-Atlas. At Madène El Mrakib, two horizons of surficially multicoloured but otherwise black, extremely fine-grained shales are intercalated in an interval of claystones (Text-Fig. 2); both horizons are about 1.2 m thick. They are separated by 11.5 m of greenish shales with marly horizons at the base, above which a limonitized ammonoid fauna was obtained. In other more condensed sections, such as Ouidane Chebbi and Bordj d'Erfoud, these black shales are not discernible due to intense weathering.

The *Platyclymenia annulata* faunas from Madène El Mrakib, Ouidane Chebbi, Bordj d'Erfoud, etc. are less diverse in species and range of morphology than those from other areas, notably the Rhenish Massif and the South Urals. There is, however, no doubt that they are time equivalents. *Platyclymenia annulata* (MÜNSTER 1832) is a very common species in the eastern Anti-Atlas, but its variability has not been examined as yet. It occurs at Madène El Mrakib in several horizons and is usually accompanied by *Platyclymenia subnautilina* (SANDBERGER 1855), *Prionoceras divisum* (MÜNSTER 1832) and *Prionoceras frechi* (WEDEKIND 1913). The specific composition varies from horizon to horizon:

- Sample A: Small (up to 40 mm diameter), poorly preserved *Platyclymenia annulata*, *Pl. subnautilina*, and *Prionoceras divisum* occur in marls immediately above the lower black shale horizon.
- Sample B: Large (up to 10 cm in diameter) *Platyclymenia annulata* as well as another unidentified species of the genus were found in one marly nodular layer 70 cm above the black shale.
- Sample C: A 120 cm horizon of dark shales contains numerous small, limonitized but rather well preserved specimens of *Platyclymenia annulata*, the same number of



*Prionoceras frechi* (Pl. 2, Fig. 7), as well as rarer *Platyclymenia subnautilina* and *Prionoceras divisum*.

- Sample D: A dark limestone nodule from lithological unit C produced the same ammonoid fauna (except for *Pr. frechi*). The specimens are very well preserved; *Pr. divisum* is the most abundant form.
- Sample E: Another dark limestone nodule, 480 cm above the lower black shale, and 640 cm below the upper one, has the same ammonoid fauna as sample D, but *Pr. divisum* far outnumbers other components of this fauna.
- Sample F: Very large individuals (20 cm and larger; Text-Fig. 7G) of *Platyclymenia* occur 520 cm below the higher of the two black shales. This is probably the hori-

zon exploited commercially at El Haroun southeast of Erfoud, producing huge specimens of that genus.

The succession within the *annulata* Zone is less clear in other investigated sections. Badly preserved *Platyclymenia* were collected from beds 90 and 94 at Ouidane Chebbi. Very well preserved specimens of *Platyclymenia annulata* occur in a 25 cm interval at Bordj d'Erfoud, but the near absence of prominent clastic intercalations between the nodular limestones black shale horizons at that locality prevents tracing of horizons. At this locality, the *annulata* Zone is well represented by ammonoid faunas; 80 specimens were collected from beds 19–22. *Platyclymenia subnautilina* is the dominant species, constituting more than 70 % of the fauna, whereas *Pl. annulata* is very rare and was collected only from bed 21. In bed 22, the coarser ribbed *Pl. cf. richteri* was found, but further investigation is required to check if this species occurs stratigraphically above *Pl. annulata*. *Erfoudites zizensis* sp.nov., a species not found at Madène El Mrakib, occurs in bed 20 in well preserved individuals.

Sections in the Amessoui Syncline (e.g. El Atrous) are even more condensed. The *annulata* Zone is represented by a single black limestone bed approximately 15 cm thick, extremely rich in ammonoids. The fauna consists of *Platyclymenia annulata* and *Prionoceras divisum* in high numbers, as well as rarer *Pl. subnautilina*, *Erfoudites zizensis*, *Prionoceras frechi* and *Carinoclymenia beuelensis* (LANGE 1929); it appears to correlate with sample C of Madène El Mrakib and bed 20 at Bordj d'Erfoud. A fauna from Bine Jebilet west of Erfoud has a similar association of species, but the numbers are very different. *Pl. subnautilina* is by far the dominant species at that locality, *Prionoceras divisum* and *Pr. frechi* are much rarer; and only two specimens of *Erfoudites zizensis* were obtained; no specimens of *Pl. annulata* were found.

### 3.2. Dunkeri Zone

At Madène El Mrakib, lenses of fine-grained as well as detrital limestone up to a maximum thickness of 8 cm occur in several horizons:

- Sample G: one specimen of *Cyrtoclymenia* sp.
- Sample H: very fossiliferous lenses of dark grey detrital limestone, 3.5 m above the higher black shale, *Cymaclymenia* sp. as well as *Cyrtoclymenia* sp. (Pl. 3, Fig. 1). This horizon occurs also in the Amessoui Syncline where, at El Atrous, it is an 8 cm limestone bed packed with the two species, together with rarer *Erfoudites rherisensis* sp.nov., *Prionoceras* sp., and (?) *Protoxycymenia* sp. No equivalent fauna is known from the Rhenish Massif.
- Sample I: isolated nodules with large specimens of *Sporadoceras orbiculare* (MÜNSTER 1832) and *Cyrtoclymenia* sp.
- Sample J: *Sporadoceras orbiculare* is accompanied by *Erfoudites rherisensis*. At Ouidane Chebbi, large specimens of *S. orbiculare* occur together with *Cyrtoclymenia* sp. (attaining 30 cm in diameter and more) in beds 99 and 100; these beds may be time equivalents of samples I and J of Madène El Mrakib. Other faunal components have not been found.
- Sample K: lenticular nodules with *Protoxycymenia wendti* sp.nov. together with *Erfoudites rherisensis*. This fauna may correlate with the horizon with *Protoxycymenia dunkeri* (MÜNSTER 1840) reported from a few places in the Rhenish Massif and Franconia. At Bou Ifarherioun, a fauna with numerous *E. rherisensis* together with ?*Protoxycymenia* sp. have been found; it may represent fauna K at Madène El Mrakib. This fauna has not been found at Bordj d'Erfoud.

### 3.3. Clymenia Stufe

The exact stratigraphical position of the next younger ammonoid sample L at Madène El Mrakib is unclear. This locality produced only poorly preserved limonitic specimens of *Erfoudites* cf. *rherisensis*, together with a badly preserved *Prionoceras* and an undeterminable kosmoclymenioid. Most probably the same horizon was investigated at Jebel Aoufilal (Amessoui Syncline 5 km northwest of Taouz, Tafilalet), where the rich and diverse fauna consists of:

<i>Prionoceras divisum</i> (MÜNSTER 1832)	22 specimens
<i>Prionoceras frechi</i> (WEDEKIND 1913)	11 specimens
<i>Mimimitoceras</i> (?) sp.	5 specimens
<i>Erfoudites rherisensis</i> sp.nov.	598 specimens
<i>Posttornoceras</i> sp.nov.	2 specimens
<i>Posttornoceras</i> cf. <i>balvei</i> WEDEKIND 1910	3 specimens
<i>Discoclymenia cucullata</i> (VON BUCH 1839)	24 specimens
<i>Alpinites kayseri</i> (SCHINDEWOLF 1923)	1 specimen
<i>Gundolficeras</i> sp.	2 specimens
<i>Praeglyphioceras</i> sp.	41 specimens
<i>Cyrtoclymenia</i> sp.	35 specimens
<i>Cymaclymenia</i> sp.	2 specimens
<i>Platyclymenia</i> sp.	9 specimens
<i>Falciclymenia</i> sp.	2 specimens
<i>Endosiphonites muensteri</i> ANSTED 1838	22 specimens

This fauna came from an 8 m shale unit, but was not collected in situ; therefore it is uncertain whether it is from a single horizon. All specimens have similar limonitic preservation suggesting this may be the case. The fauna contains elements of the *annulata* Zone (*Prionoceras*, *Erfoudites*) as well as the *Clymenia* Stufe (*Discoclymenia*, *Endosiphonites*). It may therefore be close to the base of the latter.

A rich fauna from possibly the same horizon occurs in very fossiliferous dark limestone at Oum El Jerane, also in the Amessoui Syncline, 16 km northwest of Taouz. The fauna consists of:

<i>Prionoceras divisum</i> (MÜNSTER 1832)	9 specimens
<i>Erfoudites rherisensis</i> sp.nov.	53 specimens
<i>Discoclymenia cucullata</i> (VON BUCH 1839)	6 specimens (Pl. 1, Fig. 7)
<i>Cymaclymenia</i> sp.	19 specimens (Pl. 4, Fig. 6)
<i>Falciclymenia</i> sp.	1 specimen
<i>Kosmoclymenia</i> ? sp.	5 specimens (Pl. 6, Fig. 3, 4)
<i>Endosiphonites muensteri</i> ANSTED 1838	28 specimens (Pl. 7, Fig. 2, 3)

The presence of *Pr. divisum*, *Erf. rherisensis*, *D. cucullata*, and *End. muensteri* suggest correlation with the fauna from Jebel Aoufilal. The last species was also collected from Ouidane Chebbi (though not in situ), and from a single limestone nodule at Bou Ifarherioun.

*Franconicyclomenia serpentina* (MÜNSTER 1832), the index species of the *serpentina* Zone of the Rhenish Massif and Franconia, is not known from North Africa, thus unequivocal correlation cannot be made. The species-poor fauna of the *serpentina* Zone in the Rhenish Massif does not, however, have the species listed above.

The entry of *Gonioclymenia* is a spectacular marker horizon in many places of the eastern Anti-Atlas; it is conspicuous because of extensive mining for fossils by the local people. At Madène El Mrakib, such a horizon is not developed – *Gonioclymenia* occurs in sample L with two different species, *G. speciosa* (MÜNSTER 1831) and *G. sp.*, in nodules at the base of a 19 m thick series of greyish shales

with thin intercalations of nodular limestone and thin sideritic beds. They are accompanied by *Cymaclymenia* sp. and *Mimimitoceras* sp.

Bed 107 at Ouidane Chebbi is a shaly unit with small limestone nodules; it contains *Gonioclymenia* sp., *Clymenia* sp., *Mimimitoceras lineare* (MÜNSTER 1832), *Cymaclymenia* sp. and *Kosmoclymenia lamellosa* (WEDEKIND 1914). Because of the last species, this horizon is referred to the *laevigata* Zone of the Rhenish Massif; the other forms accord with its allocation. The *Gonioclymenia* level is rather poor in species of ammonoids.

The *Gonioclymenia* fauna from Bou Tchrafine produced:

<i>Mimimitoceras</i> cf. <i>lineare</i> (MÜNSTER 1832)	4 specimens
cf. <i>Tornoceratidae</i> indet.	2 specimens
<i>Kosmoclymenia inaequistriata</i> (MÜNSTER 1832)	7 specimens
	(Pl. 6, Fig. 7)
<i>Komoclymenia</i> sp.	6 specimens
<i>Gonioclymenia speciosa</i> (MÜNSTER 1831)	23 specimens
<i>Cymaclymenia cordata</i> WEDEKIND 1914	28 specimens
	(Pl. 4, Fig. 5).

The index forms of the *Gonioclymenia*-bearing beds of the Rhenish Massif are missing, namely *Clymenia laevigata* (MÜNSTER 1832), *Ornatoclymenia ornata* (MÜNSTER 1834), and *Piriclymenia piriformis* (SCHMIDT 1924). Correlation is therefore based on species of *Kosmoclymenia*. Assignment to the *ornata* Zone seems likely.

### 3.4. *Wocklumeria* Stufe

The rarity of index forms prevents exact determination of the base of the *Wocklumeria* Stufe in the eastern Anti-Atlas. This boundary may lie below richly fossiliferous nodules containing rather abundant species of *Muessenbiaergia* (Pl. 6, Fig. 6), *Mimimitoceras* (Pl. 3, Fig. 4), and rare *Kalloclymenia*.

At Bordj d'Erfoud, the *Wocklumeria* Stufe consists of greenish shales with intercalations of greenish and bluish limestone nodules, some of which produced rich ammonoid faunas. The base of the *Wocklumeria* Stufe could not be drawn exactly because the rather poor ammonoid faunas from these strata lack index forms. *Kalloclymenia* occurs in bed 36 and may indicate the *Wocklumeria* Stufe. The index fossils *Balvia lens* KORN 1992 and *Parawocklumeria paradoxa* (WEDEKIND 1918; Pl. 3, Fig. 2) demonstrate that younger parts of the *Wocklumeria* Stufe are represented. The generic composition of the *Wocklumeria* Stufe faunas differs between the various limestone beds, but there is a general pattern with *Cymaclymenia* as the predominant genus. Within that genus, *C. striata* (MÜNSTER 1832; Pl. 4, Fig. 1) is replaced by the weaker ornamented *C. involvens* LANGE 1929 (Pl. 4, Fig. 3) in the upper part of the succession. Another important genus is *Linguaclymenia*, followed by *Mimimitoceras*. It is striking that some of those clymeniid genera, such as *Kosmoclymenia*, important in time-equivalent horizons in other regions (e.g. the Rhenish and Thuringian Massifs), are relatively rare. For instance, *Kosmoclymenia* (Pl. 6, Fig. 8) is represented by only 2 individuals out of more than 660 collected specimens. Although *Muessenbiaergia* is more abundant (60 specimens), its frequency is much lower than in other regions. Minute forms – only *Parawocklumeria* and *Balvia* (16 specimens) – are also very rare, whereas *Kamptoclymenia* and *Glatziella* species appear to be absent.

*Wocklumeria sphaeroides* (RICHTER 1848) and *Lissoclymenia wocklumeri* (WEDEKIND 1914) are known from the highest carbonate nodules at Madène El Mrakib (Pl. 3, Fig. 3; Pl. 6, Fig. 9). The fauna, as presently known, is similar in composition to the *Wocklumeria* Stufe faunas of the Rhenish

and Thuringian Massifs, but is poorer in species. The discovery of *W. sphaeroides* at Madène El Mrakib allows correlation of the immediately overlying black shale horizon with the Hangenberg Black Shale. *W. sphaeroides* was not found at Ouidane Chebbi, but there is little doubt that the black shale occurring at this place is the same horizon. A 4 m black shale in the same stratigraphical position was also noted at Jebel Aguelmous.

Two localities, Madène El Mrakib and Ouidane Chebbi, yielded ammonoid faunas from above the supposed Hangenberg Black Shale. At the first locality, crushed and rather poorly preserved *Acutimitoceras* sp. could be found between the black shale and the following thick sandstone bed; at the latter, *Acutimitoceras subbilobatum* (MÜNSTER 1839) and *Acutimitoceras intermedium* (SCHINDEWOLF 1923) occur in three-dimensionally preserved specimens above 20 m above the black shale (Pl. 2, Fig. 8). Although there is no direct evidence for the *prorsum* Zone, lack of *Gattendorfia* and other genera typical of the *Gattendorfia* Stufe in the rich fauna can be taken as evidence for that horizon being present. Higher horizons at Ouidane Chebbi are again calcareous, but have so far produced only 3 specimens of *Acutimitoceras* sp. It is not if these beds already belong to the *Gattendorfia* Stufe. Another black shale horizon is exposed higher in the section. Its stratigraphical position is questionable, but it may be an equivalent of the Lower Alum Shale of the Rhenish Massif.

## 4. Conclusions

In summary, the three black shale horizons present at the Madène El Mrakib section represent the *Annulata* Black Shales (the lower two horizons) and the Hangenberg Black Shale (the upper horizon). Thus both events left their imprint on the northern Gondwana shelf as well as around Baltica; this testifies to the grand scale of these events.

The ammonoid succession in the middle and late Famennian, based on Central European occurrences, can be applied in part to the North African sections. Some zones, such as the *annulata* Zone and some zones within the *Clymenia* Stufe (*laevigata* and *ornata* Zones) and the *Wocklumeria* Stufe (*lens*, *paradoxa*, and *sphaeroides* Zones) have been recognised in the eastern Anti-Atlas, but other zones have not been discriminated. The interval between the *annulata* Zone and the *acuticostata* Zone, not well represented in the Rhenish Massif and Franconia, is much better represented in North Africa where there is potential for finer subdivision of this interval.

## 5. Systematic Palaeontology

Order:	Goniatitida
Suborder:	Tornoceratina WEDEKIND 1918
Superfamily:	Dimerocerataceae
	ARTHABER 1911
Family:	Posttornoceratidae
	BOGOSLOVSKY 1962
Genus:	<i>Posttornoceras</i> WEDEKIND 1910

Type species: *Posttornoceras Balvei* WEDEKIND 1910, by original designation.

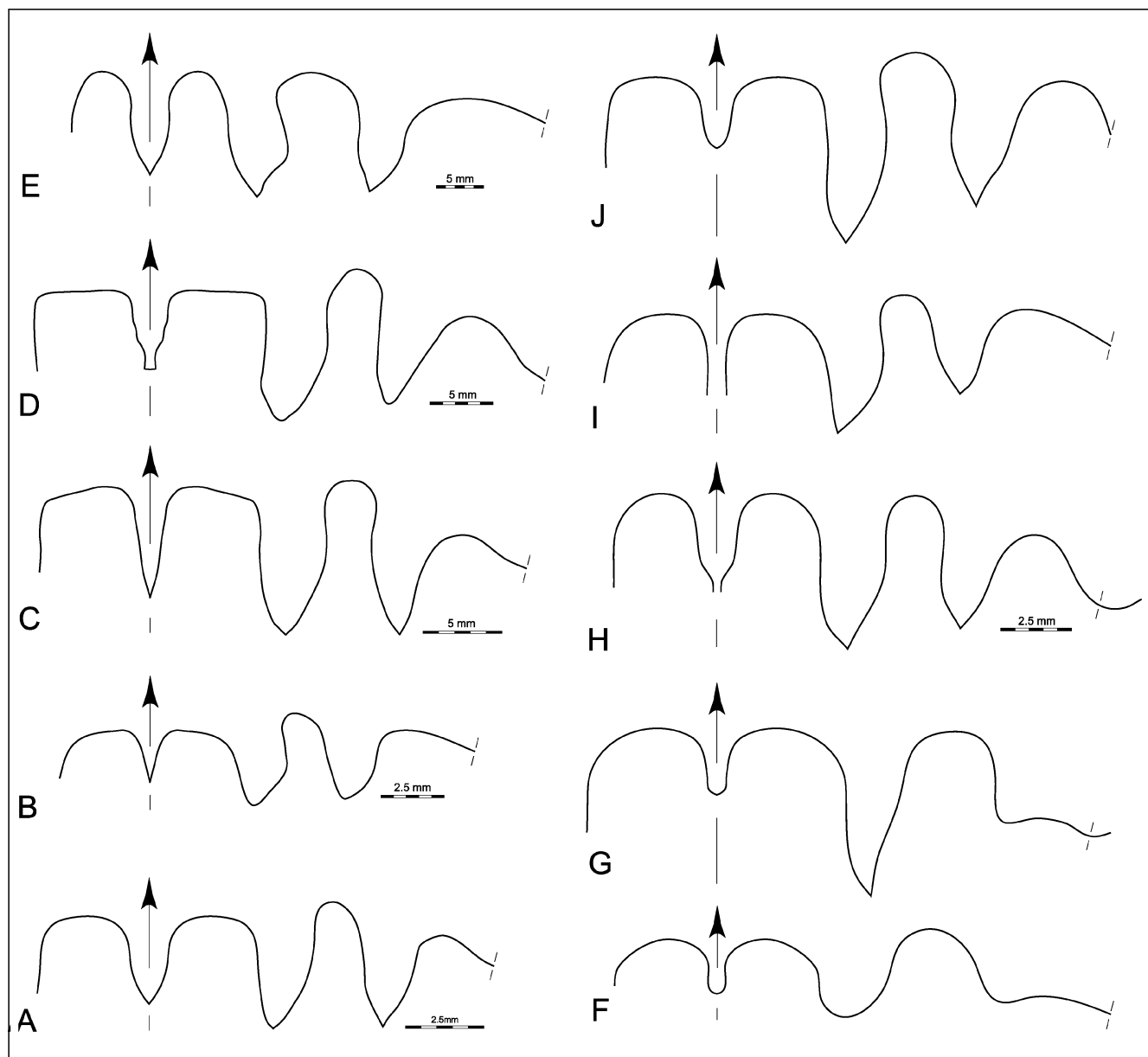
Genus definition: Typical genus of the family Posttornoceratidae with the following characters: conch thickly discoidal; ornament of fine growth lines with barely

visible dorsolateral and pronounced ventrolateral projection; external sinus deep; suture line with V-shaped and pointed A and L<sub>v</sub> lobe on the flanks; saddle between A and E broadly rounded or flattened; sutural formula E A L<sub>v</sub> L<sub>m</sub> L<sub>d</sub> I.

#### Generic composition:

*balvei*: *Posttornoceras Balvei* WEDEKIND 1910: 768. *Annulata* Zone, Rhenish Massif, Germany.

*contiguum*: *Gonialites contiguum* MÜNSTER 1832: 22. Uebergangskalk (probably *annulata* Zone), Franconia, Germany.



Text-Fig. 5.

Suture lines of various species of the family Posttornoceratidae and Sporadoceratidae.

- A) *Posttornoceras balvei* WEDEKIND 1910.  
Holotype GÖT 386–36; Beul near Balve (Rhenish Massif), probably *annulata* Zone; ×5; at dm 19.2 mm, ww 10.2 mm, wh 12.7 mm.
- B) *Posttornoceras sapiens* sp. nov.  
Holotype GPIT 1850-30; Rich Sidi Ali (southern Ma'der), bed 12H, probably *annulata* Zone; ×5; at dm 20.8 mm, ww 9.0 mm, wh 12.5 mm.
- C) *Posttornoceras* cf. *balvei* WEDEKIND 1910.  
GPIT 1850-46; Jebel Aoufilal, probably lower *Clymenia* Stufe; ×2.5; at ww 17.2 mm, wh 19.5 mm.
- D) *Posttornoceras weyeri* sp. nov.  
Holotype GPIT 1850-49; Jebel Aguelmous, probably lower *Clymenia* Stufe; ×2.5; at dm 42.4 mm, ww 26.0 mm, wh 26.5 mm.
- E) *Sporadoceras orbiculare* (MÜNSTER 1832).  
GPIT 1850-32; Madène El Mrakib, sample I, probably *dunkeri* Zone; ×1.5; at dm 64 mm, ww 36 mm, wh 36.5 mm.
- F) *Exotornoceras fezzouense* BECKER 1995.  
Fezzou area (Ma'der, Morocco), probably lower *Clymenia* Stufe; at wh 17 mm; after BECKER (1995, Fig. 5a).
- G) *Exotornoceras superstes* (WEDEKIND 1908).  
Nehden (Rhenish Massif, Germany), *Cheiloceras* Stufe; at wh 11.7 mm; after BECKER (1993b, Fig. 76a).
- H) *Posttornoceras sodalis* BECKER 1995.  
Man'ya River (Middle Urals, Russia), probably *annulata* Zone; ×4.5; at dm 18 mm, ww 11.5 mm; after BOGOSLOVSKY (1971, Fig. 23).
- I) *Posttornoceras posthumum* (WEDEKIND 1918).  
Hövel (Rhenish Massif, Germany), probably lower *Clymenia* Stufe; after WEDEKIND (1918, Fig. 47k).
- J) *Posttornoceras contiguum* (MÜNSTER 1832).  
Schübelhammer (Lower Franconia, Germany), probably *annulata* Zone or lower *Clymenia* Stufe; at wh 6.8 mm; after BECKER (1995, Fig. 7c).



*posthumum*: *Sporadoceras contiguum* var. *posthuma* WEDEKIND 1918: 149. Lower *Clymenia* Stufe, Rhenish Massif, Germany.

*sapiens*: *Posttornoceras sapiens* sp. nov. Probably *annulata* Zone, eastern Anti-Atlas, Morocco.

*sodalis*: *Posttornoceras sodalis* BECKER 1995: 621. *Prolobites* Stufe or *annulata* Zone, South Urals, Kazakhstan.

*weyeri*: *Posttornoceras weyeri* sp. nov. Probably *Clymenia* Stufe, eastern Anti-Atlas, Morocco.

(?) *cornwallense*: *Discoclymenia cornwallensis* SELWOOD 1960: 174. Stourscombe Beds (*Wocklumeria* Stufe), Cornwall, Great Britain.

**Comparisons:** *Posttornoceras* is intermediate between simpler tornoceratids, such as *Exotornoceras* BECKER 1993, and *Discoclymenia* HYATT 1884. From the latter genus, *Posttornoceras* is distinguished by the absent or only very shallow  $A_2$  lobe, which is V-shaped or pointed in *Discoclymenia*. *Exotornoceras* (of which *Gundolficeras* BECKER 1995 may be a junior synonym) has a shallow and rounded  $L_v$  lobe (see Text-Fig. 5F, 5G), and a broadly rounded saddle between A and E.

**Remarks:** *Posttornoceras* is an often misunderstood genus. Its species, apart from the type species *Pt. balvei*, have sometimes been interpreted as species of *Sporadoceras*, but this genus displays a different conch morphology, with low aperture and hence low whorl expansion rate.

It is not clear if *Goniolites contiguus* MÜNSTER 1832 belongs to *Posttornoceras*, since the original material appears to be lost. BECKER (1993b: 317) proposed a neotype for stabilising the species concept, but this opinion is not accepted here. The original material described by MÜNSTER was collected at Schübelhammer in Lower Franconia; the stratigraphically oldest ammonoid fauna known from this locality is *annulata* Zone. However, the proposed neotype comes from the Enken-Berg in the Rhenish Massif, from a considerable older horizon, i.e. the *contiguum* Zone of the upper *Cheiloceras* Stufe. Thus the proposal of this neotype implies that the species was a long-ranging taxon; this is not supported by empirical data. It would have been more reasonable to propose the specimen figured by BECKER (1995, Pl. 3, Figs. 12,13; housed in the Museum für Naturkunde, Berlin; refigured here in Text-Fig. 5K) under the species name *Sporadoceras posthumum* as neotype, since it comes from the type locality and was even regarded by MÜNSTER as belonging to *Goniolites contiguus*. This specimen is here interpreted as a *Posttornoceras* because of:

- 1) the conch shape with very high aperture, and a whorl expansion rate of approximately 2.45, and
- 2) the suture line with shallow external lobe and lanceolate asymmetric lobes on the flank.

*Sporadoceras contiguum* var. *posthuma* WEDEKIND 1918 is another problematic species; the type may be lost (BECKER 1995: 621). It appears from WEDEKIND's figure and sutural drawing (refigured here in Text-Fig. 5J) to be a species of *Posttornoceras*.

**Occurrence:** *Annulata* Zone and lower *Clymenia* Stufe of the Rhenish Massif (Germany), the Holy Cross Mountains (Poland), the eastern Anti-Atlas (Morocco), and the South Urals (Kazakhstan).

### ***Posttornoceras balvei* WEDEKIND 1910**

(Plate 1, Fig. 4, 6; Text-Fig. 5A,C, 6A,B)

1910 *Posttornoceras Balvei* WEDEKIND: 768.

?1995 *Posttornoceras* aff. *contiguum*. – BECKER: 620, Pl. 3, Fig. 1, 2.

**Type material:** The holotype, GÖT 386–36 (coll. WEDEKIND), a rather well preserved, completely chambered specimen showing the suture line and remains of ornament on the conch, was collected at the Beul near Balve, in a light brown limestone – according to the original label from beds with *Platyclymenia annulata*.

**Material:** In addition to the holotype, three septate limonitized specimens (GPIT 1850-46 to GPIT 1850-48) from Jebel Aoufilal may belong to this species; their diameters are between 17 and 37 mm. They display the suture line but no remains of shell.

**Species diagnosis:** A species of *Posttornoceras* with thickly discoidal conch ( $ww/dm = 0.50$ ) and with closed umbilicus; ornament of fine, smooth growth lines with a pronounced ventrolateral projection; suture line with equally deep, pointed A and  $L_v$  lobes.

**Description of the holotype:** The single specimen has a thickly lenticular conch, broadest near the funnel-shaped umbilicus. The aperture of the specimen is extraordinarily high, more than one-third of the conch diameter, and thus leading to a whorl expansion rate of more than 2.60. The ornament consists of fine, smooth growth lines with distances of 0.2 mm in the mid-flank area. They run with a barely visible dorsolateral, but pronounced ventrolateral projection over the flanks forming a moderately deep ventral sinus (Text-Fig. 6A). Some areas of the shell are covered by a wrinkled structure, particularly strong near the umbilicus where the wrinkles are spirally arranged. The suture line has been prepared already by WEDEKIND; it is characterised by almost equally deep, pointed  $L_v$  and A lobes, of which the A lobe is asymmetric with a steeper ventral prong. The external part of the suture cannot be followed with certainty in the specimen, but the saddle between A and E is wide and appears to be broadly rounded. The septal surface (Text-Fig. 6B) shows a very prominent septal pillar connecting the saddle between A and  $L_v$  as well between I and  $L_d$ .

**Description of additional material:** In conch dimensions, the specimens from the eastern Anti-Atlas resemble the holotype; the umbilicus is funnel-shaped with broadly rounded margin. Specimen GPIT 1850-47 shows, at 17 mm conch diameter, a suture line closely resembling that of the holotype; the saddle between A and  $L_v$  is broadly rounded. The larger specimen GPIT 1850-46 shows, at 36 mm diameter, that this saddle is flattened (Text-Fig. 5C); it displays an extremely shallow  $A_2$  lobe. Because of the box-shaped outline of the saddle between E and A, the material may represent another species of *Posttornoceras*.

**Dimensions in mm:**

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh
GÖT 386–36	29.0	15.0	18.9	0	11.3	2.68	0.52	0.79
GPIT 1850-46	36.4	18.6	22.8	0	13.9	2.62	0.51	0.82
GPIT 1850-47	17.3	10.6	10.7	0	6.5	2.56	0.61	0.99
GPIT 1850-48	17.6	10.7	10.8	0	6.6	2.56	0.61	0.99

**Comparisons:** *Posttornoceras balvei* is distinguished from *Pt. sodalis* BECKER 1995 by the slightly narrower conch which has in that species, at 38 mm diameter, a ratio  $ww/dm = 0.58$ ; it has, moreover, a much wider saddle between A and  $L_v$ , whereas in *Pt. sodalis* (Text-Fig. 5I) it is only little wider than the adventive lobe. *Pt. sapiens* sp. nov. has a narrower conch ( $ww/dm = 0.40$  at 20 mm diameter) than *Pt. balvei* as well as a pronounced subangular umbilical margin. *Pt. weyeri* sp. nov. is much thicker

( $ww/dm = 0.70$  at 35 mm diameter), and *Pt. posthumum* (WEDEKIND 1918) has much deeper, lanceolate lobes on the flanks.

**Stratigraphical and geographical distribution:** Probably *annulata* Zone of the northern margin of the Rhenish Massif, Germany. The specimens from Jebel Aoufilal are stratigraphically younger and may derive from the *dunkeri* Zone or lower *Clymenia* Stufe.

***Posttornoceras sapiens* sp. nov.**

(Plate 1, Fig. 1, 2; Text-Fig. 5B)

**Derivation of name:** After Christian KLUG (Tübingen) whose intensive collection of fossils contributed greatly to knowledge of the Famennian strata in the eastern Anti-Atlas.

**Holotype:** Specimen GPIT 1850-30 (coll. WENDT), figured in Pl. 1, Fig. 1.

**Type locality and horizon:** Rich Sidi Ali (southern Ma'ader), bed 12H (probably *annulata* Zone).

**Type material:** Two limonitized specimens of slightly more than 20 mm diameter are available for study, the holotype and a paratype (GPIT 1850-31). Both display the suture line, but shell material has not been preserved.

**Species diagnosis:** Species of the genus *Posttornoceras* with discoidal conch ( $ww/dm = 0.40$ ); umbilicus closed, funnel-shaped, bordered by an angular margin; internal mould with weak ventral constrictions; suture line with pointed  $L_v$  lobe and asymmetric subacute A lobe;  $L_v$  lobe slightly deeper than the A lobe;  $L_v/E$  saddle asymmetric, flattened.

**Description:** Both specimens have a similar conch and are lenticular in shape. The umbilicus is completely closed, with an oblique wall bordered by an angular contact towards the widely rounded flanks. The venter is narrowly rounded. Shell material is not preserved, but the holotype shows about 8 weak constrictions per whorl on the steinkern; these are restricted to the venter and form a deep sinus. The suture line (Text-Fig. 5B) shows an asymmetric and subacute A lobe with an almost vertical ventral and less steep dorsal side. The  $L_v$  lobe is also slightly asymmetric, but V-shaped and pointed.

**Dimensions in mm:**

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh
Holotype GPIT 1850-30	22.8	9.1	14.8	0	8.6	2.58	0.40	0.61
Paratype GPIT 1850-31	21.0	8.6	13.4	0	0.41	0.64		

**Comparisons:** *Posttornoceras balvei* WEDEKIND 1910 is distinguished from the new species by its thicker conch ( $uw/dm = 0.50$  in contrast to 0.40 in *P. sapiens*), by the rounded umbilical wall, and by the pointed adventive lobe in the suture line. It is readily distinguished from all other species of *Posttornoceras* by its subangular umbilical margin.

**Stratigraphical and geographical distribution:** Probably *annulata* Zone in the eastern Anti-Atlas, Morocco.

***Posttornoceras weyeri* sp. nov.**

(Plate 1, Fig. 3, 5; Text-Fig. 5D)

**Derivation of name:** After Dieter WEYER (Berlin), whose extensive collection of fossil material contri-

buted much to knowledge of Famennian strata in the eastern Anti-Atlas.

**Holotype:** Specimen GPIT 1850-49 (coll. WADE), figured in Pl. 1, Fig. 3.

**Type locality and horizon:** Jebel Aguelmous, probably lower *Clymenia* Stufe.

**Type material:** Two limonitized specimens, the holotype and a paratype (GPIT 1850-50), 47 respectively 41 mm in conch diameter, are available for study. Both display the suture line, but shell material has not been preserved.

**Species diagnosis:** Species of *Posttornoceras* with pachyconic conch ( $ww/dm = 0.60-0.65$ ) and closed umbilicus; umbilical margin rounded; interior (as displayed by internal mould) without constrictions; suture line with subacute  $L_v$  lobe and asymmetric subacute A lobe, the A lobe being larger and deeper than the  $L_v$  lobe; A/E saddle box-shaped.

**Description:** Both specimens show a pachyconic conch, widest at the umbilical margin, from whence the flanks converge towards the relatively narrow venter. The umbilicus is completely closed, and the umbilical wall is oblique, continuing by a round margin into the flanks. No shell material has been preserved. The suture line (Text-Fig. 5D) shows an asymmetric and subacute A lobe with an almost vertical ventral and a less steep dorsal side. The  $L_v$  lobe is almost symmetric, V-shaped and subacute.

**Dimensions in mm:**

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh
Holotype GPIT 1850-49	46.5	28.2	29.3	0	18.5	2.76	0.61	0.92
Paratype GPIT 1850-50	41.3	26.5	25.4	0		0.64	1.04	

**Comparisons:** *P. weyeri* is the thickest species so far known in *Posttornoceras*; its  $ww/dm$  ratio of more than 0.60 is greater than for all other species of the genus.

**Stratigraphical and geographical distribution:** Probably lower *Clymenia* Stufe in the eastern Anti-Atlas, Morocco.

**Superfamily: Dimerocerataceae HYATT 1884**

**Family: Sporadoceratidae**

MILLER & FURNISH 1957

**Genus: *Erfoudites* gen. nov.**

**Type species:** *Erfoudites zizensis* sp. nov.

**Generic composition:**

*zizensis*: *Erfoudites zizensis* sp. nov.; *annulata* Zone, eastern Anti-Atlas, Morocco.

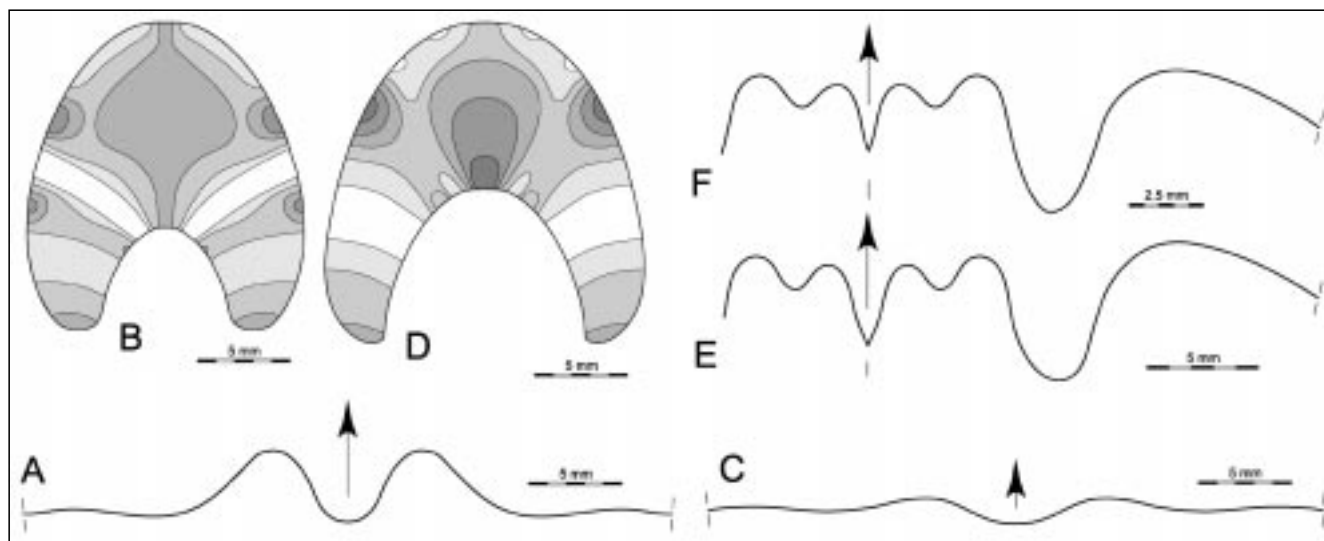
*rherisensis*: *Erfoudites rherisensis* sp. nov.; *dunkeri* Zone, eastern Anti-Atlas, Morocco.

*rotundolobatus*: *Sporadoceras rotundolobatum* SCHINDEWOLF 1924: 98; probably *dunkeri* Zone, Thuringia, Germany.

*spirale*: *Sporadoceras spirale* WEDEKIND 1918: 149. Lower *Clymenia* Stufe, Rhenish Massif, Germany.

*ungeri*: *Goniatis ungeri* MÜNSTER 1840: 107. Uebergangskalk, Franconia, Germany.

**Genus definition:** Genus of Sporadoceratidae with conch discoidal to thickly discoidal, involute in all stages; ornament of slightly biconvex growth lines and fine spiral lines; suture line with deep, broadly rounded  $A_1$  lobe, small, rounded  $A_2$  lobe and small, V-shaped E lobe.



Text-Fig. 6.

Growth line courses, septal shapes and suture lines of species of the families Posttornoceratidae and Sporadoceratidae.

A) Growth line course in *Posttornoceras balvei* WEDEKIND 1910.

Holotype GÖT 386–36 (coll. WEDEKIND); Beul near Balve (Rhenish Massif), probably *annulata* Zone;  $\times 2.5$ .

B) Septal surface with indications of septal pillars of the same specimen;  $\times 2.5$ .

C) Growth line course in *Erfoudites zizensis* sp. nov..

Holotype GPIT 1850-1; purchased in Erfoud, most probably *annulata* Zone;  $\times 2.5$ .

D) Septal surface with indications of septal pillars of the same specimen;  $\times 2.5$ .

E) Suture line of the same specimen;  $\times 3$  (at dm 24.2 mm, ww 15.6 mm, wh 13.2 mm).

F) Suture line of *Erfoudites rherisensis* sp. nov.

Paratype GPIT 1850-33; south-west of Taouz, most probably *dunkeri* Zone or lower *Clymenia* Stufe;  $\times 4$  (at dm 21.2 mm, ww 10.5 mm, wh 13.0 mm).

**Comparisons:** The conch form and suture line of *Erfoudites* are similar to those of *Maenoceras*, but the new genus is easily discriminated from other genera of Sporadoceratidae by the spiral ornament, and the bi-convex course of its growth lines. *Erfoudites* species superficially resemble species of *Posttornoceras*, but are different in conch parameters. The latter has an extremely high whorl expansion rate, the whorl height exceeding 65 % of the diameter. In *Erfoudites* it does not reach 60 %, falling inside the field of variation of typical sporadoceratids.

In contrast to *Erfoudites*, *Posttornoceras* does not display spiral ornament. The two genera differ strikingly in septal shape. In *Posttornoceras*, the two lobes on the flank most likely originated from subdivision of the lateral lobe, as in the early Famennian *Exotornoceras* BECKER 1993. Its sutural formula is  $E A L_v L_m L_d I$ . This can be assumed since, in the septum of *Posttornoceras*, the saddle between  $A$  and  $L_v$  in correspondence with the saddle between  $I$  and  $L_d$  build a prominent septal pillar (Text-Fig. 6C), known from other advanced tornoceratids such as *Lobotornoceras* and *Discoclymenia*. In *Erfoudites*, the suture and septal shape resemble those of *Sporadoceras*: the sutural formula is  $E A_2 A_1 L U I$ . Here, the saddles  $A_2/A_1$  and  $I/U$  are conjoined to form a septal pillar that is much weaker than in *Posttornoceras* (Text-Fig. 6D).

**Remarks:** *Sporadoceras rotundolobatum* SCHINDEWOLF 1924, based on a single internal mould, is a species inquerendum. According to D. WEYER (personal communication 9.5.1998) the specimen is lost from the Jena collection. It probably came from a horizon above the Wagner-Bank (probably *dunkeri* Zone) of Bohlen near Saalfeld (Thuringia). No new material has been obtained from that site and, moreover, specimens with ornament are unlikely to be obtained there. The species is therefore likely to remain problematic.

**Occurrence:** *Annulata* Zone as well as *dunkeri* Zone (and probably ranging into the *laevigata* Zone) of the Tafilalet of Morocco and the Rhenish Massif of Germany.

### *Erfoudites zizensis* sp. nov.

(Plate 2, Fig. 2, 3; Text-Fig. 5C–E)

**Derivation of name:** After the Ziz River in the Tafilalet.

**Holotype:** Specimen GPIT 1850-1 (purchased in Erfoud), figured in Pl. 2, Fig. 2.

**Type locality and horizon:** Locality unknown, but probably near Erfoud; type horizon is presumably the *annulata* Zone.

**Type material:** Additional to the holotype 3 specimens (among these the paratype GPIT 1850-2 (coll. KORN, 1993) from grey limestone nodules (bed 20) in the *annulata* Zone of Bordj. All display conch ornament; the holotype shows the suture. Further material comes from the *annulata* Zone of El Atrous (12 specimens, coll. KORN 1993), Bine Jebilet (2 specimens, coll. KORN 1993), and Jebel Aoufilal (4 specimens, coll. KLUG 1995).

**Diagnosis:** A species of *Erfoudites* with thickly discoidal conch (ww/dm = 0.55 at 25–35 mm dm) and with closed umbilicus; ornament of fine, crenulated growth lines and spiral lines, the latter ( $>200$ ) much coarser than the growth lines and occurring all over the conch at varying distances apart.

**Description:** The well preserved holotype is a fully chambered specimen with a thickly discoidal conch, broadest near the umbilicus. The ornament is very well preserved, consisting of very delicate, crenulated, bi-convex growth lines. Both dorsolateral and ventrolateral projections are weak, the external sinus being much deeper than the lateral sinus (Text-Fig. 6C). Much more

prominent than the growth lines are the spiral lines, of which 200 can be counted from umbilicus to umbilicus. They are unequally spaced and bear a fine granulation caused by growth lines crossing them. On the internal mould, about ten constrictions per whorl are present ventrally and ventrolaterally. The suture line (Text-Fig. 6E) is characterised by a large, bell-shaped and, at the bottom, broadly rounded first adventive lobe, a much smaller, rounded second adventive lobe, and a narrow, pointed and V-shaped external lobe.

Dimensions in mm:

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh
Holotype GPIT 1850-1	32.8	17.7	18.6	0	9.1	1.92	0.54	0.95
Paratype GPIT 1850-2	27.3	15.5	15.9	0	7.9	1.98	0.57	0.97

**Comparisons:** The species can be distinguished from *Erfoudites rherisensis* by the thicker conch ( $ww/dm = 0.55$  in *E. zizensis*;  $0.48$  in *E. rherisensis*), and the stronger spiral ornament. Additionally, in *E. zizensis* the spirals do not form a spider-web like pattern as they do in *E. rherisensis*.

**Stratigraphical and geographical distribution:** All in situ collected specimens came from the *annulata* Zone of the Tafilalt in south-eastern Morocco.

### *Erfoudites rherisensis* sp. nov.

(Plate 2, Fig. 4–6; Text-Fig. 6F)

(?)1959 *Sporadoceras rotundolobatum*. – PETTER: Pl. 21, Fig. 1.

(?)1959 *Sporadoceras biferum*. – PETTER: Pl. 21, Fig. 3, 4.

**Derivation of name:** After the Rheris River in the Tafilalt.

**Holotype:** Specimen GPIT 1850-3 (coll. KORN 1993), figured in Pl. 2, Fig. 4.

**Type locality and horizon:** Bou Ifarherioun 33 km south of Erfoud; limestone nodule from above the *annulata* Zone horizon, i.e. probably *dunkeri* Zone.

**Type material:** A large suite of about 925 specimens of all growth stages are available for study: 125 calcareous specimens from the type locality at Bou Ifarherioun (coll. KORN, 1993) between 4 and 46 mm conch diameter; 8 calcareous specimens from samples K and J of Madène El Mrakib (coll. KORN 1998); 6 calcareous specimens from El Atrous (coll. KORN, 1993); 24 calcareous specimens from 1 km south of the Amelane Pass (coll. WENDT); 53 calcareous specimens from Oum el Jerane (coll. KLUG 1998); 609 limonitic specimens from Jebel Aoufilal (coll. KLUG, REISDORF), 26 limonitic specimens from Madène El Mrakib (coll. FEIST; KORN, 1998); and 73 limonitic specimens from the localities El Kraouhia (north-west of Taouz), south-west of Taouz (containing the paratype GPIT 1850-33), north of Rich Bou Korazia, Rich Sidi Ali (southern Ma'der), and from Iferd Nou Harouar near Taouz (coll. WENDT).

**Diagnosis:** Species of the genus *Erfoudites* with thickly discoidal conch ( $ww/dm = 0.45$ – $0.50$  at 25–35 mm diameter) and with closed umbilicus. Ornament with fine, crenulated growth lines and spiral lines which are as fine as the growth lines and form a spider-web pattern. The number of spirals exceeds 300; they are distributed over the entire shell at varying distances apart.

**Description:** The conch is similar in form at all growth stages between 4 and 46 mm, but there is a trend from a thickly discoidal conch in juveniles towards a discoidal conch in adults. The umbilicus is always closed. The

shell ornament of the paratype GPIT 1850-5 from Bou Ifarherioun consists of very fine crenulated growth lines, running with two almost equally high projections over the flanks forming a deep ventral sinus. The spiral lines are so fine that they are difficult to count; they decrease near the umbilicus, but about 300 are present. Usually, they are as fine as the growth lines. The number of spirals increases during ontogeny. The suture line (described from specimen GPIT 1850-33 from south-west of Taouz; Text-Fig. 5F) closely resembles that of *E. zizensis*; but the first adventive lobe is narrowly rounded and more than twice as deep as the rounded, V-shaped secondary adventive lobe. The shape of the adventive lobe, however, is varying between populations of this species. As seen in the rich material from the Jebel Aoufilal (coll. KLUG and REISDORF 1995), the adventive lobe can be broadly rounded (as seen in *E. zizensis*), narrowly rounded (as in the figured specimen), as well as V-shaped and pointed.

Dimensions in mm:

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh
Holotype GPIT 1850-3	45.6	20.6	26.1	0	14.6	2.16	0.45	0.79
Paratype GPIT 1850-4	39.7	19.6	23.8	0	13.0	2.22	0.49	0.82
Paratype GPIT 1850-7	34.9	16.3	19.5	0	11.1	2.20	0.47	0.84
Paratype GPIT 1850-5	34.0	16.8	19.2	0	10.8	2.15	0.49	0.88
Paratype GPIT 1850-33	21.2	10.5	13.0	0.5	7.2	2.29	0.50	0.81
Paratype GPIT 1850-6	17.5	9.8	11.1	0	6.1	2.36	0.56	0.88

**Comparisons:** *E. rherisensis* has more (about 300) and much finer spiral lines than *E. zizensis* (200). This can best be seen in the ratio between the width of the spirals and the distances between them: In *E. zizensis*, the spirals are wider, and in *E. rherisensis* they are narrower than the spaces between them. Furthermore, the whorl expansion rate is higher in *E. rherisensis* (more than 2.15) than in *E. zizensis* (lower than 2.00).

**Stratigraphical and geographical distribution:** All specimens came probably from the *dunkeri* Zone and the lower *Clymenia* Stufe of the Tafilalt and Ma'der in south-eastern Morocco. They are accompanied by *Cymaclymenia* sp. nov. and *Kosmoclymenia* ? sp.

**Order:** Clymeniida EDWARDS 1849  
**Suborder:** Clymeniina EDWARDS 1849  
**Superfamily:** Clymeniaceae EDWARDS 1849  
**Family:** Platyclymeniidae WEDEKIND 1914

**Included genera**

*Platyclymenia* HYATT 1884

*Annulites* WEDEKIND 1914 (synonym of *Platyclymenia*)

*Choneclymenia* PERNA 1914 (synonym of *Platyclymenia*)

*Czarnockia* gen. nov.

*Gyroclymenia* CZARNOCKI 1989

(probable synonym of *Pleuroclymenia*)

*Fasciclymenia* KORN & PRICE 1987

*Pleuroclymenia* SCHINDEWOLF 1934

*Spinoclymenia* BOGOSLOVSKY 1962

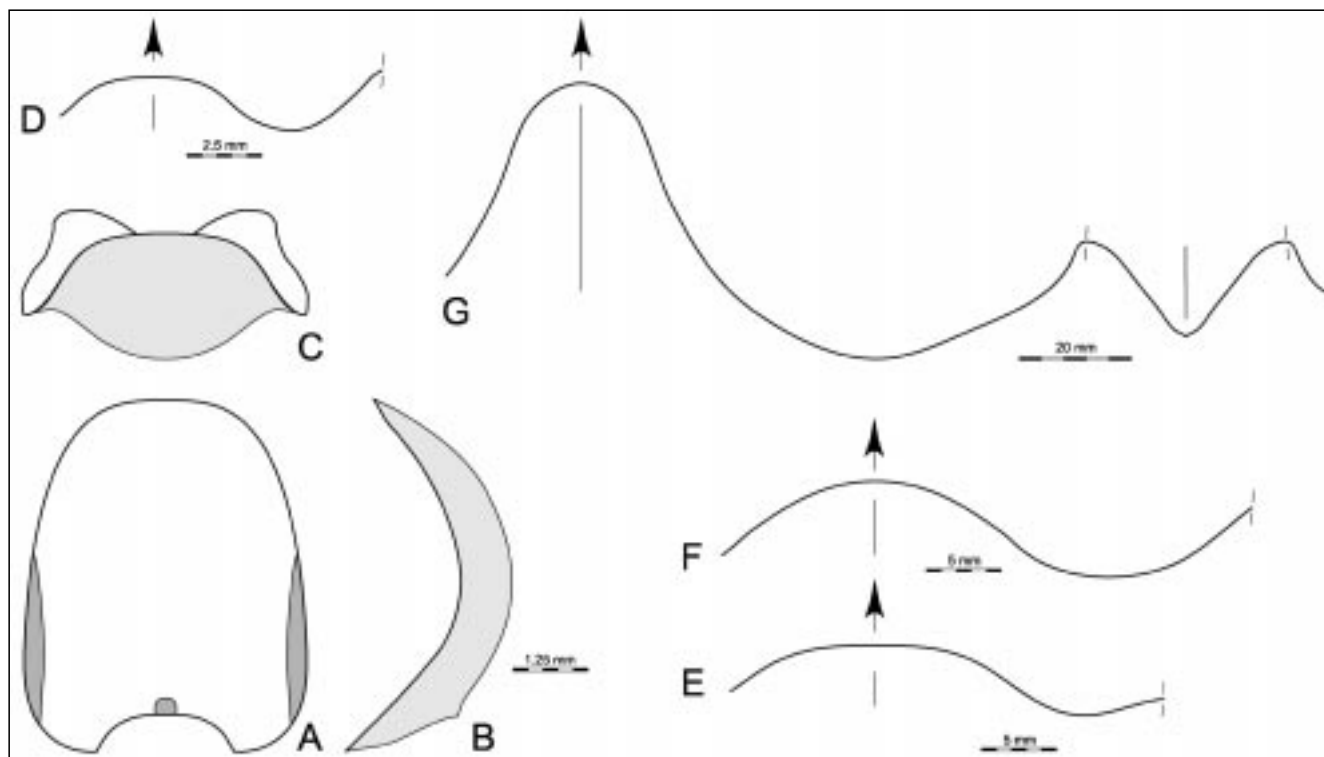
*Trigonoclymenia* SCHINDEWOLF 1934

*Varioclymenia* WEDEKIND 1908 (synonym of *Platyclymenia*)

**Genus:** *Platyclymenia* HYATT 1884

**Type species:** *Goniolites annulatus* MÜNSTER 1832.

**Genus definition:** Genus of Platyclymeniidae with thinly discoidal conch, flanks and venter rounded or flat-



Text-Fig. 7.

Septal projections and suture lines of species of *Platyclymenia* and *Cyrtoclymenia*.A–C) Septal projections of *Platyclymenia ibnsinai* sp. nov.Paratype GPIT 1850-44; north of Rich Bou Korazia;  $\times 8$ .D) Suture line of the same specimen;  $\times 4$  (at ww 5.0 mm, wh 6.2 mm).E) Suture line of *Cyrtoclymenia* sp.GPIT 1850-21; Madène El Mrakib, sample H;  $\times 2$  (at ww 18.5 mm, wh 17.8 mm).F) Suture line of *Platyclymenia ibnsinai* sp. nov.Holotype GPIT 1850-8; south-west of Oum El Hadj;  $\times 2$  (at ww 15.8 mm, wh 22.6 mm).G) Suture line of *Platyclymenia* sp.GPIT 1850-36; Madène El Mrakib, sample F;  $\times 0.75$  (at ww 47.5 mm, wh 71 mm).

tened, and evolute with wide umbilicus; ornament of fine or coarse growth lines concave-convex course, often with simple ribs; suture line with symmetric and moderately deep, broadly rounded L lobe and broadly rounded external lobe.

**Generic composition:** *Platyclymenia* is a genus for which numerous species have been erected. As already pointed out (PRICE & KORN 1989), many of these, based on minor differences in ornament, need to be synonymised – for which a comprehensive revision is necessary. Until this is done, no meaningful list of accepted and rejected species can be given.

### *Platyclymenia ibnsinai* sp. nov.

(Plate 5, Fig. 4, 5; Text-Fig. 7A–D,F)

**Derivation of name:** After IBN SINA (Lat. AVICENNA), \*980 Afschana (Bokhara), †1037 Hamadan; physician and philosopher, the most important transmitter of Greek philosophy to the Orient.

**Holotype:** Specimen GPIT 1850-8 (coll. WENDT), figured in Pl. 5, Fig. 5.

**Type locality and horizon:** South-west of Oum El Hadj; most probably *annulata* Zone.

**Material:** Additional to the holotype, 3 small limonitized specimens from the localities in Iferd Nou Harouar (specimen GPIT 1850-29) and from north of Rich Bou Korazia (specimens GPIT 1850-43, 1850-44).

**Diagnosis:** Species of the genus *Platyclymenia* with thinly discoidal conch (ww/dm = 0.30) and with moderately

wide umbilicus (uw/dm = 0.37); flanks broadly rounded; venter and umbilical wall rounded; whorl expansion rate 2.25. Ornament of fine growth lines and sharp ribs at conch diameter between 5 and 35 mm. Suture line with relatively deep, broadly rounded lateral lobe.

**Description:** The adult conch, as in the holotype (GPIT 1850-8), displays the characteristic conch morphology on which the new species is based. Unlike all other known species of the genus, the umbilical width is only little more than one-third of the diameter, and the whorl height is very prominent (0.40 of conch diameter). The flanks are broadly rounded converging towards the rounded venter. The inner whorls of the holotype are mainly covered with shell; the development of the ornament can therefore be observed during ontogeny. The innermost whorls are not well preserved but, up to approximately 5 mm conch diameter, no ribs are visible. Between 5 and 35 mm diameter, coarse and sharp ribs are present; they run with a shallow sinus over the flanks. One volution bears about 25 of these ribs; they are usually equally spaced, but are sometimes grouped in pairs. At 30–35 mm diameter, they decrease over a distance of less than half a volution; the last indications are weak umbilical nodes. The terminal volution of the holotype bears neither ribs nor umbilical nodes. The outer suture line of the holotype consists of a rather deep, slightly asymmetric lateral lobe, and a moderately high external saddle (Text-Fig. 7F).

The suture line of a smaller limonitized paratype (GPIT 1850-44) has the same outline as in the holotype; at a

whorl height of 5.5 mm, the septum is simply domed with conspicuous lateral deflexions caused by broad lateral tie points (Text-Fig. 7D); the lateral lobe is thus slightly asymmetric. One whorl earlier in the same specimen, at  $wh = 3$  mm, the lateral lobe is almost symmetric, and lateral deflexions are barely visible. In smaller limonitized specimens, the ribbed growth stage ends at a much smaller diameter. Paratypes GPIT 1850-29 and GPIT 1850-42, for instance, are ribbed up to approximately 11 mm diameter, the ribs disappearing first on the outer flank.

Dimensions in mm:

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh	uw/dm
Holotype GPIT 1850-8	92.5	26.0	37.2	34.0	31.0	2.26	0.28	0.70	0.37
Paratype GPIT 1850-23	27.4	8.1	10.8	11.0	9.3	2.29	0.30	0.75	0.40
Paratype GPIT 1850-29	22.3	5.8	8.8	8.9	7.5	2.28	0.26	0.66	0.40

**Comparisons:** *Platyclymenia ibnsinai* can easily be separated from all the other species of the genus by its prominent whorl expansion rate, ranging around 2.25, in contrast to about 2.00 in the other species, such as the similar *P. annulata* (MÜNSTER 1832). Modification of the conch geometry in this species also results in a narrower umbilicus ( $uw/dm$  less than 0.40, but more than 0.45 in other species).

**Remarks:** Introduction of another new species of *Platyclymenia* is justified by the remarkable conch geometry of the new material from the eastern Anti-Atlas. Populations of *P. annulata* from the Saxothuringian and Rhenohercynian Zones display variability in outline of the whorl cross-section; it can be circular to subquadrate, but in coiling values they are very similar, ranging from 1.95 to 2.00.

**Stratigraphical and geographical distribution:** *Annulata* Zone of the Tafilalt in the eastern Anti-Atlas of Morocco.

### Genus: *Czarnoclymenia* gen.nov.

**Type species:** *Nodosoclymenia subacuta* CZARNOCKI 1989

**Genus definition:** Genus of the family Platyclymeniidae with conch thinly discoidal, with subacute to acute venter, and evolute with a moderately wide to wide umbilicus; ornament of fine growth lines; suture line with asymmetric and very deep, broadly rounded L lobe and high external saddle.

**Generic composition:**

*subacuta*: *Nodosoclymenia subacuta* CZARNOCKI 1989: 59. Lower *Clymenia* stage, Holy Cross Mountains, Poland.

(?) *retrursa*: *Rectoclymenia retrursa* CZARNOCKI 1989: 51. Lower *Clymenia* stage, Holy Cross Mountains, Poland.

*ibnrushdi*: *Czarnoclymenia ibnrushdi* sp.nov. Probably lower *Clymenia* Stufe, Tafilalt, Morocco.

*acuta*: *Cyrtoclymenia acuta* SCHMIDT 1924: 128; late Famenian, Rhenish Massif, Germany.

**Comparisons:** The new genus cannot be confused with other genera because of the acute or subacute venter. Some species of *Platyclymenia*, such as *P. ibnsinai* sp. nov., develop strongly converging flanks in adult individuals, but possess a flat venter.

**Stratigraphical and geographical distribution:** *Czarnoclymenia* is thought to be restricted to the lower part of the *Clymenia* Stufe. The genus has a wide geographical distribution; it is known from the Holy Cross Mountains of Poland, the Rhenish Massif of Germany, and the eastern Anti-Atlas of Morocco.

### *Czarnoclymenia ibnrushdi* sp.nov.

(Plate 3, Fig. 5; Text-Fig. 8F)

**Derivation of name:** After IBN RUSHD (lat. AVERROES), \*1126 Córdoba, †1198 Marrakech; Arabian physician, philosopher, and commentator on Aristotle (Averroism – theory of the beginningless existence of the world).

**Holotype:** Specimen GPIT 1850-9 (purchased in Erfoud), figured in Pl. 3, Fig. 5.

**Type locality and horizon:** El Haroun (Tafilalt, Morocco); from dolomitized limestone, apparently from the lower *Clymenia* Stufe. The specimen is preserved with conch ornament and bears numerous epizoan serpulids.

**Diagnosis:** Species of *Czarnoclymenia* with conch thinly discoidal ( $ww/dm = 0.20$ ) with moderately wide umbilicus ( $uw/dm = 0.23$ ); flanks flattened dorsally as well as ventrally, bordered by subangular margins; umbilical wall oblique; venter tectiform and subacute; ornament of fine, concave growth lines forming a wide lateral projection.

**Description:** The general shape of the conch is a flat lens. The whorl cross-section has almost parallel flanks bordered – at the oblique umbilical wall – by an angular margin. The tectiform and subacute venter is also clearly separated from the flanks, but this border is less sharp. The ornament is very weak; the course of the very fine growth lines can be seen only in some places; they run with a shallow sinus over the umbilical wall and inner flanks, bending forward to form a wide and low projection occupying almost the entire flank. It can be seen, in the umbilicus, that the inner volutions possess strengthened growth lines.

Dimensions in mm:

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh	uw/dm
Holotype GPIT 1850-9	127.5	24.6	56.0	29.8	37.6	2.01	0.19	0.44	0.23
Holotype of <i>C. subacuta</i>	91	17	38	30			0.21	0.47	0.33
Holotype of <i>C.(?) retrursa</i>	80	16.5	29	31			0.21	0.57	0.39

**Comparisons:** *Czarnoclymenia subacuta* (CZARNOCKI 1989) is a rather similar species, but differs from *C. ibnrushdi* in its wider umbilicus ( $uw/dm = 0.33$  in *C. subacuta*; 0.23 in *C. ibnrushdi*). In *C. ibnrushdi*, the umbilical wall is separated from the flanks by an angular margin, whereas the umbilical margin in *C. subacuta* is rounded. Other species of the genus have much wider umbilici, i.e.  $ww/dm = 0.40$  in *C.(?) retrursa*.

**Stratigraphical and geographical distribution:** The stratigraphical origin of the only specimen is unclear, it may be from the basal *Clymenia* Stufe. The species is so far known only from the Tafilalt in south-eastern Morocco.

### Superfamily: Gonioclymeniaceae

HYATT 1894

### Family:

Costaclymeniidae

RUZHENCEV 1957

### Included genera:

*Costaclymenia* SCHINDEWOLF 1920

*Endosiphonites* ANSTED 1838

*Mesoclymenia* BOGOSLOVSKY 1981

*Nodosoclymenia* CZARNOCKI 1989

(?) *Stenoclymenia* LANGE 1929

## Genus: *Endosiphonites* ANSTED 1838

Type species: *Endosiphonites Münsteri* ANSTED 1838

Genus definition: Genus of Costaclymeniidae with thinly discoidal conch with flattened flanks and venter, and evolute with wide to moderate umbilicus; ornament of coarse growth lines; suture line with asymmetric and deep, broadly rounded L lobe, small, rounded U lobe and very shallow, broadly rounded external lobe.

### Generic composition:

*muensteri*: *Endosiphonites Münsteri* ANSTED 1838: 419. Pe-therwin beds, Cornwall, Great Britain.

*enodis*: *Costaclymenia enodis* SCHINDEWOLF 1926: 108. Famennian, Rhenish Massif, Germany.

*ornatus*: *Trochoclymenia ornata* PETTER 1960: 34; probably *Clymenia Stufe*, Tafilalt. (synonym of *E. muensteri*)

(?) *bowsheri*: *Falciclymenia bowsheri* MILLER & COLLINSON 1951: 601. Percha Shale, New Mexico, U.S.A.

Comparisons: The introduction of a tie-point-related L lobe occurred in *Platyclymenia* on the inner flank area near the umbilicus (see above). In the superfamily Gonio-clymeniaceae, this tie-point became modified from a broadly rounded to pointed one; additional tie-points, hence new lobes, were introduced. *Endosiphonites* can be regarded as one of the most ancestral form in the Gonio-clymeniaceae (PRICE 1982), possessing only two lobes, and lacking the E lobe seen in all the subsequent genera. *Endosiphonites* resembles, in its conch parameters, *Costaclymenia* SCHINDEWOLF 1920 (which may be a junior synonym of *Endosiphonites* ANSTED 1838) and *Nodo-*

*soclymenia* CZARNOCKI 1989, but lacks the ventrolateral nodes present in those genera. The suture line provides better characters for discriminating the genera. In *Nodo-soclymenia*, there is only a wide and slightly asymmetric L lobe, in *Endosiphonites* this lobe is deeper and accompanied by an U lobe, and in *Costaclymenia*, an E lobe is added. *Endosiphonites* occupies an intermediate position in this regard.

## *Endosiphonites muensteri* ANSTED 1838

(Plate 7, Fig. 1–3; Text-Fig. 8A–E)

1838 *Endosiphonites Münsteri* ANSTED: 419, Pl. 8, Fig. 1.

1855 *Clymenia Muensteri*. – MCCOY in SEDGWICK & MCCOY: 402, Pl. 2A, Fig. 12.

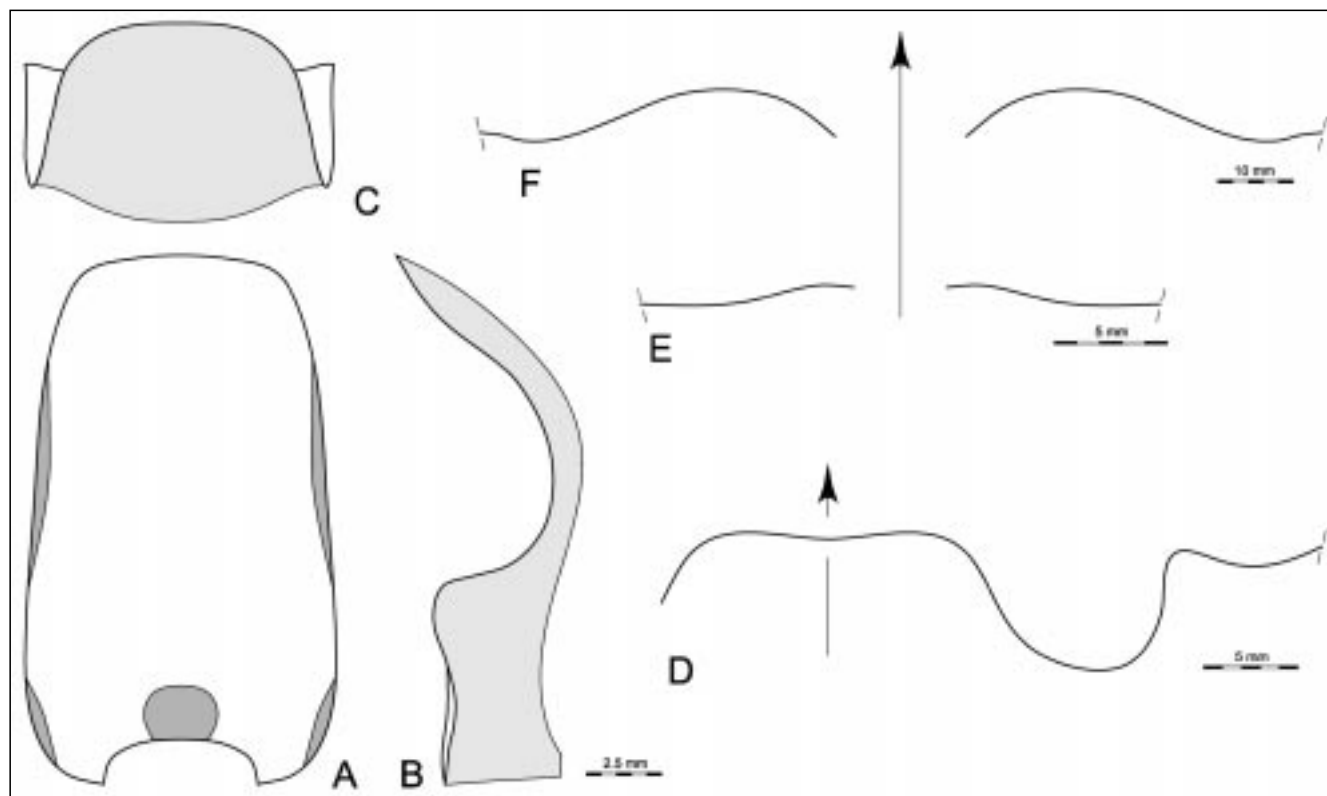
1960 *Costaclymenia binodosa*. – SELWOOD: 157, Pl. 26, Fig. 1.

(?) 1960 *Costaclymenia* cf. *enodis*. – PETTER: 12, Pl. 3, Fig. 10.

1960 *Trochoclymenia ornata*. – PETTER: 34, Pl. 3, Figs. 1,2,4,7,8.

Type material: Holotype is the complete specimen figured by ANSTED (1838, Pl. 8, Fig. 1), No. H4010 in the Sedgwick Museum, Cambridge. It came from the Pe-therwin Beds of Launceston, Cornwall, Great Britain.

New material: 28 calcareous specimens up to 40 mm diameter from Oum El Jerane (among these GPIT 1850-51 to 1850-53); 23 limonitic specimens, mostly fragments, from Jebel Aoufilal. One slightly corroded internal mould (GPIT 1850-10) was found loose at Ouidane Chebbi; it has a diameter of 76 mm and displays the adult suture line. One specimen of 73 mm diameter (GPIT 1850-45) from Bou Ifarherioun shows ornament and suture lines.



Text-Fig. 8.

Septal projections, suture lines, and growth line course of species of *Endosiphonites* and *Czarnockia*.

A–C) Septal projections of *Endosiphonites muensteri* (ANSTED 1838).

GPIT 1850-45; Bou Ifarherioun;  $\times 4$ .

D) Suture line of *Endosiphonites muensteri* (ANSTED 1838).

GPIT 1850-10; vicinity of Ouidane Chebbi;  $\times 2.5$  (at ww 11.5 mm, wh 20 mm).

E) Growth line and rib course of the same specimen;  $\times 1.5$  (at 70 mm conch diameter).

F) Growth line course of *Czarnockia ibnrushdi* sp. nov..

GPIT 1850-9; El Haroun,  $\times 1$  (at 120 mm conch diameter).

**Diagnosis:** Species of *Endosiphonites* with thinly discoidal conch ( $ww/dm = 0.20$ ), with wide umbilicus in juveniles ( $uw/dm = 0.60$  at 15 mm diameter), and moderately wide umbilicus ( $uw/dm = 0.40$ ) in adults at 80 mm diameter. Flanks flattened and ventrally bordered by an angular shoulder; venter flattened. Ornament of fine, concave-convex growth lines and very weak ribs.

**Description:** The conch shape changes during growth, best seen in specimen GPIT 1850-45. In early ontogeny, the conch has a very wide umbilicus and, at 20 mm diameter, the umbilicus is half of the conch diameter. At this stage, the whorls expand moderately – the whorl expansion rate is about 2.00. During ontogeny, the whorl expansion rate increases toward a value of 2.30, and at the same time, the umbilicus width decreases to a value of 0.40. At all stages, the whorl cross-section is rectangular with flattened flanks and an almost flat venter. The shell of this specimen bears weak growth lines running with a low ventrolateral projection over the flanks and forming a moderately deep ventral sinus. Spacing and strength of the growth lines is irregular. The general shape of the septum (GPIT 1850-45; Text-Fig. 8A-C) is concave, but two tie points, a large lateral and a smaller umbilical, lead to formation of a suture line that shows a rather deep and asymmetric lateral lobe (with almost vertical dorsal and slender ventral sides), and a shallow umbilical lobe. On the venter, a very low lobe exists which is caused by the geometry of the cross section, and not by a tie point.

**Dimensions in mm:**

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh	uw/dm
GPIT 1850-10	76.0	16.0	27.0	32.0	25.5	2.26	0.21	0.36	0.42
GPIT 1850-45	73.0	15.5	27.5	31.6	24.5	2.27	0.21	0.38	0.43
	48.5	9.8	16.0	23.2	15.2	2.12	0.20	0.33	0.48
	19.2	3.3	5.7	9.6	5.5	1.96	0.17	0.30	0.50
GPIT 1850-51	40.2	8.4	12.9	18.0			0.21	0.32	0.45
GPIT 1850-52	30.8		8.8	15.5				0.29	0.50
GPIT 1850-53	14.3	3.0	3.1	8.9			0.21	0.22	0.62
Holotype of <i>E. muensteri</i>	97.8	15.9	36.0	40.4	33.0	2.28	0.16	0.37	0.41

**Comparisons:** *Endosiphonites muensteri* differs from *E. enodis* (SCHINDEWOLF 1926), which is based on a very bad specimen, mainly in its much narrower umbilicus ( $uw/dm = 0.40$  in *E. muensteri*; 0.50 in *E. enodis*). The two forms may be conspecific.

**Stratigraphical and geographical distribution:** The Cornish holotype may have been derived from the basal *Clymenia* Stufe; the same applies to the materials from the Tafilalt in south-eastern Morocco.

## Family: Sellaclymeniidae SCHINDEWOLF 1923

### Included genera:

*Sellaclymenia* HYATT 1884

*Sellaclymenia* HYATT 1884

**Type species:** *Clymenia angulosa* MÜNSTER 1839 = *Goniatites planus* MÜNSTER 1832: 30.

**Genus definition:** Genus of Sellaclymeniidae with conch thinly discoidal with flattened flanks and flat venter, and evolute with a moderately wide umbilicus; ornament with coarse growth lines, sometimes with ribs and ventrolateral nodes; suture line with almost symmetric and deep, Y-shaped lateral lobe, small, V-shaped umbilical lobe and bifid external lobe.

### Generic composition:

*angulosa:* *Clymenia angulosa* MÜNSTER 1839: 40. Uebergangskalk (probably early *Wocklumeria* Stufe), Franconia, Germany. (synonym of *S. plana*)

*ibntufayli:* *Sellaclymenia ibntufayli* sp. nov. Lower *Wocklumeria* Stufe, eastern Anti-Atlas, Morocco.

*plana:* *Goniatites planus* MÜNSTER 1832: 30. Uebergangskalk (probably early *Wocklumeria* Stufe), Franconia, Germany.

*spinoda:* *Sellaclymenia spinoda* SCHMIDT 1924: 136. *Clymenia* Stufe, Rhenish Massif, Germany. (synonym of *S. torleyi*)

*torleyi:* *Gonioclymenia torleyi* WEDEKIND 1914: 58. *Clymenia* Stufe, Rhenish Massif, Germany.

(?) *roemeri:* *Goniatites Römeri* MÜNSTER 1839: 52. Uebergangskalk (probably early *Wocklumeria* Stufe), Franconia, Germany. (? synonym of *S. plana*)

(?) *interrupta:* *Clymenia interrupta* MÜNSTER 1842: 126. Uebergangskalk (probably early *Wocklumeria* Stufe), Franconia, Germany.

### *Sellaclymenia ibntufayli* sp. nov.

(Plate 7, Fig. 6)

**Derivation of name:** After IBN TUFAYL (lat. ABUBACER), \*1115 Guadix, †1185 Marrakech; Arab physician and philosopher (By observation and reflection up to the highest levels of natural and divine cognition).

**Holotype:** Specimen GPIT 1850-25 figured in Pl. 7, Fig. 6.

**Type locality and horizon:** Vicinity of Ouidane Chebbi; apparently from the lower *Wocklumeria* Stufe.

**Material:** 3 specimens are available for study. The holotype (GPIT 1850-25) is a calcareous shelled specimen of 48 mm diameter from the early *Wocklumeria* Stufe of Ouidane Chebbi; it is slightly corroded but displays the ornament. The first two of the paratypes (GPIT 1850-19) come from the type locality; it is an internal mould of 18 mm diameter. The second paratype (GPIT 1850-54) is a limonitic whorl fragment from Taourarht 12 km south of Fezzou; it displays the suture line and septal surface.

**Diagnosis:** Species of *Sellaclymenia* with thinly discoidal conch ( $ww/dm = 0.20$ ); umbilicus wide at 20 mm diameter ( $uw/dm = 0.45$ – $0.50$ ) and moderately wide at 48 mm diameter ( $uw/dm = 0.35$ – $0.40$ ); flanks flattened and dorsally as well as ventrally bordered by subangular margins; venter flattened; ornament of fine, concave-convex growth lines forming a wide lateral projection; juveniles with 10 ventrolateral spines per volution, adults with undulated flanks.

**Description:** The slightly corroded paratype GPIT 1850-19 shows, between 7 and 18 mm conch diameter, 10 conspicuous and equidistant ventrolateral nodes giving a polygonal appearance to the umbilicus. Sutural development can be observed in the inner whorls where it can be seen that deepening of the lateral lobe occurs rapidly in less than one volution. The holotype GPIT 1850-25 displays corroded inner whorls in which the ventrolateral nodes are still visible. The last volution, up to 48 mm conch diameter, bears fine growth lines strengthened at the ventrolateral projection lying adjacent to the angular ventrolateral shoulder separating the flattened flanks and the almost flat venter. Periodically, shallow radial lateral folds are visible, but ribs are



absent. The suture line of the third paratype (GPIT 1850-54) consists of a narrow and deep internal lobe, an asymmetric and V-shaped umbilical lobe, a deep Y-shaped lateral lobe, and a V-shaped external lobe divided by a low and broadly rounded median saddle. The septal surface is strongly anticlastic.

Dimensions in mm:

	dm	ww	wh	uw	ww/dm	ww/wh	uw/dm
Holotype GPIT 1850-25	48.0	9.6	18.9	18.3	0.20	0.39	0.38
Paratype GPIT 1850-19	17.2	3.8	5.6	8.1	0.22	0.33	0.47
Paratype GPIT 1850-54	6.8	11.8		11.1			

**Comparisons:** *Sellacyclomenia ibntufayli* differs from *S. plana* (MÜNSTER 1832) in the presence of ventrolateral nodes in juvenile specimens, and from *S. torleyi* (WEDEKIND 1914) in the absence of ribs in adult specimens.

**Stratigraphical and geographical distribution:** The specimens from Ouidane Chebbi came from the basal *Wocklumeria* Stufe where they are associated with *Muessenbiaergia sublaevis* (MÜNSTER 1832). The species is so far only known from the eastern Anti-Atlas of Morocco.

## Family: Kosmoclymeniidae KORN & PRICE 1987

### Included genera:

*Kosmoclymenia* SCHINDEWOLF 1949  
*Eokosmoclymenia* CZARNOCKI 1989  
*Lissoclymenia* KORN & PRICE 1979  
*Linguaclymenia* KORN & PRICE 1979  
*Muessenbiaergia* KORN & PRICE 1979  
*Franconicyclomenia* KORN & PRICE 1979  
*Protoxycymenia* SCHINDEWOLF 1923  
*Aktuboclymenia* BOGOSLOVSKY 1979

## Genus: *Protoxycymenia* SCHINDEWOLF 1923

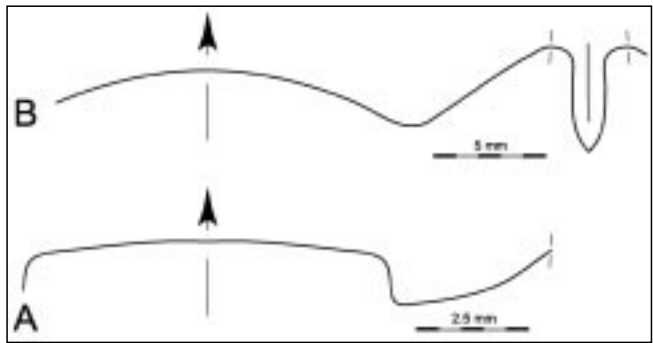
Type species: *Clymenia Dunkeri* MÜNSTER 1839: 15.

**Genus definition:** Genus of Kosmoclymeniidae with conch thinly discoidal with rounded flanks, rounded or flat venter, and evolute with a moderately wide to wide umbilicus; ornament of fine or coarse growth lines; external band present; suture line with very asymmetric and deep, angular L lobe, and broadly rounded external saddle.

### Generic composition:

*dunkeri*: *Clymenia Dunkeri* MÜNSTER 1839: 15. Uebergangskalk (most probably *dunkeri* Zone), Franconia, Germany.  
*galezicensis*: *Protoxycymenia galezicensis* CZARNOCKI 1989: 72. *Platyclymenia* Stage, Holy Cross Mountains, Poland (probably synonym of *Pr. dunkeri*).  
*tenuissima*: *Protoxycymenia tenuissima* CZARNOCKI 1989: 72. *Platyclymenia* Stage, Holy Cross Mountains, Poland.  
*wendti*: *Protoxycymenia wendti* sp. nov. Most probably *dunkeri* Zone, eastern Anti-Atlas, Morocco.

**Comparisons:** Species of *Protoxycymenia* have a conch and ornament similar to early species of *Kosmoclymenia*, but are readily discriminated by their angular lateral lobe, in contrast to the pointed one in *Kosmoclymenia*. *Franconicyclomenia* has a suture line resembling that of *Protoxycymenia*, but the latter has species with larger conch without an external band, but with prominent ventrolateral furrows. *Eokosmoclymenia* is also similar, but has a rounded and only slightly asymmetric lateral lobe.



Text-Fig. 9.

Suture lines of species of *Protoxycymenia* and *Clymenia*.

A) Suture line of *Protoxycymenia* sp. nov.

Holotype GPIT 1850-38; Madène El Mrakib, sample K; X6 (at ww 5.2 mm, wh 6.5 mm).

B) Suture line of *Clymenia* sp..

GPIT 1850-35; Ouidane Chebbi, bed 107; X1.5 (at ww 19.5 mm, wh 24.5 mm).

## *Protoxycymenia wendti* sp. nov.

(Plate 6, Fig. 1, 2; Text-Fig. 9A)

**Derivation of name:** After Jobst WENDT, in honour of his major contribution to knowledge of the Devonian succession in the eastern Anti-Atlas.

**Holotype:** Specimen GPIT 1850-38 (coll. KORN 1998).

**Type locality and horizon:** Madène El Mrakib, sample K, most probably *dunkeri* Zone.

**Type material:** 15 specimens in two states of preservation:

1. some specimens, including the holotype, extracted with difficulty from hard, brittle nodules, and
2. preserved as impressions in corroded limestone nodules, all from the type locality.

**Diagnosis:** Species of *Protoxycymenia* with the following characters: Conch thinly discoidal ( $ww/dm = 0.25$ ) with wide umbilicus ( $uw/dm = 0.50$ ); flanks rounded and ventrally bordered by subangular margins; venter flat; ornament of coarse, concavoconvex growth lines forming a moderately high ventrolateral projection; external band inconspicuous; number of growth lines on venter slightly reduced.

**Description:** The holotype (GPIT 1850-38) is a specimen for which the umbilicus could not be properly prepared. However, it is an evolute and lenticular conch with a whorl cross-section showing rounded flanks and an angular contact against the flat venter. The suture line (Text-Fig. 9A) has a rather deep and strongly asymmetric appearance with slender dorsal and vertical ventral side; the external saddle is broad and rounded. Shell material is not preserved, but the internal mould shows, at 25 mm diameter, a prominent constriction, deepest in the ventrolateral area.

The shell ornament can be seen better in moulds of the exterior in weathered nodules. Paratype GPIT 1850-39 is a specimen of 12 mm diameter displaying coarse growth lines with a shallow sinus and a low ventrolateral projection over the flanks. An external band is not well developed; the growth lines have a shallow external sinus.

Dimensions in mm:

	dm	ww	wh	uw	ww/dm	ww/wh	uw/dm
Holotype GPIT 1850-38	25.4	5.5	7.7	13.1	0.22	0.71	0.52
Lectotype of <i>Pr. dunkeri</i>	32		11.8	13.9			0.43

Comparisons: *Pr. dunkeri* (MÜNSTER 1839) has a much narrower umbilicus ( $uw/dm = 0.43$  in contrast to *Pr. wendti* with 0.52), and thus can be readily identified. *Pr. wendti* has a flat venter; *Pr. tenuissima* CZARNOCKI 1989 is more widely umbilicate than *Pr. wendti* and has a rounded venter.

Stratigraphical and geographical distribution: All the material comes from the Madène El Mrakib section, where the species occurs above nodules with *Sporadoceras orbiculare*. Its range may be *dunkeri* Zone. The species is so far known only from the Tafilalt in south-eastern Morocco.

## Acknowledgements

The sections described here were investigated during several field trips, and I wish to thank those people who helped in measuring sections and collect fossil material:

1993 field session – Raimund FEIST and Bernard ORTH (Montpellier);  
1995 field session – Christian KLUG, Achim REISDORF, Simone WALKER, and Cornelia MÜLLER (all Tübingen), as well as Dieter WEYER (Berlin) and Horst BLUMENSTENGEL (Jena);

1998 field session – Christian KLUG and Sascha DÖRING (Tübingen).

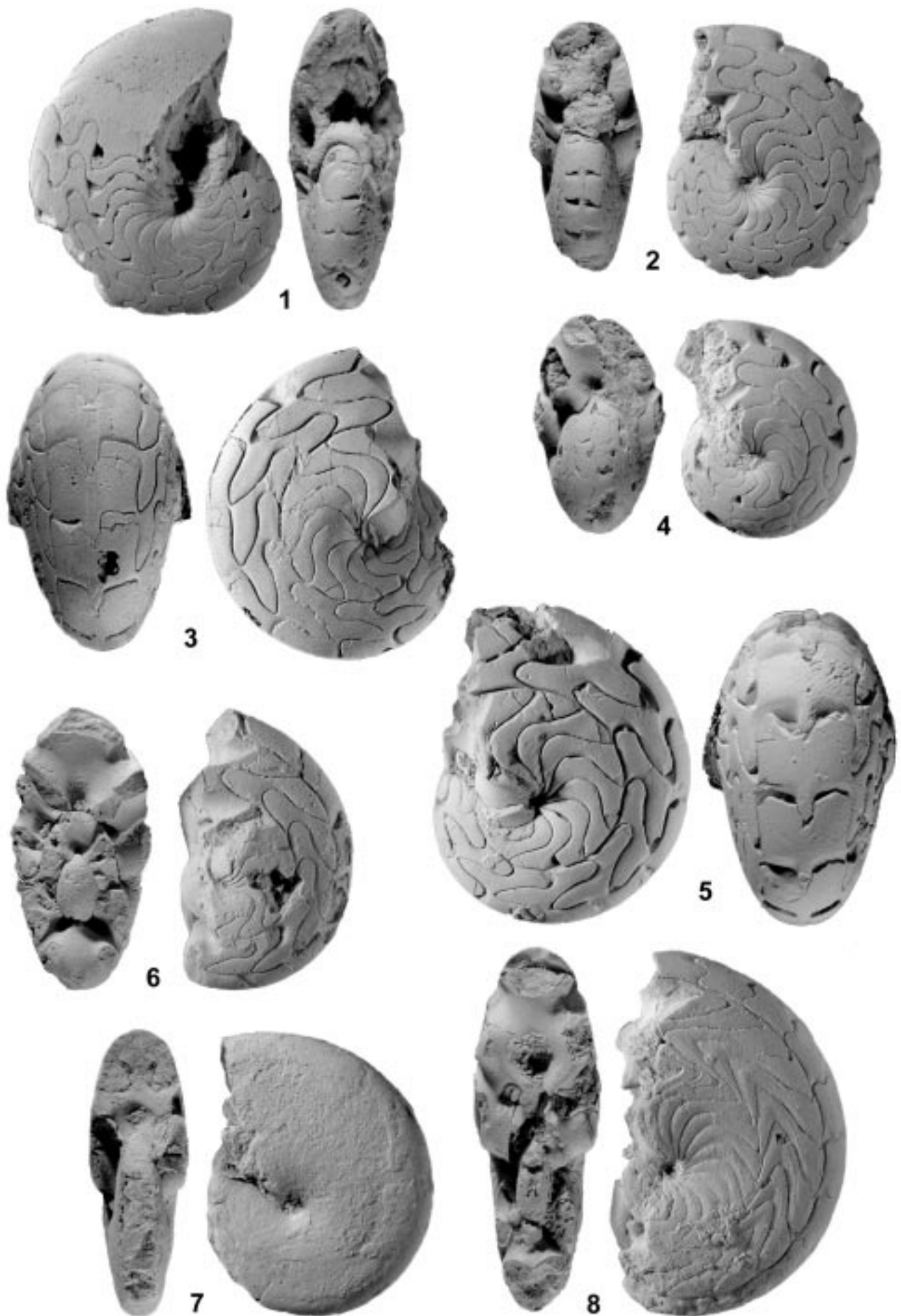
Very important additional material described in this paper was assembled by Geoff WADE (Llandudno), and particularly by Jobst WENDT (Tübingen) during numerous field trips, and I like to thank him for advice in the field.

I am also indebted to John TALENT (Sydney) for his careful review of the typescript. Wolfgang GERBER (Tübingen) patiently photographed the specimens.

## Plate 1

Tornoceratid ammonoids from the eastern Anti-Atlas.

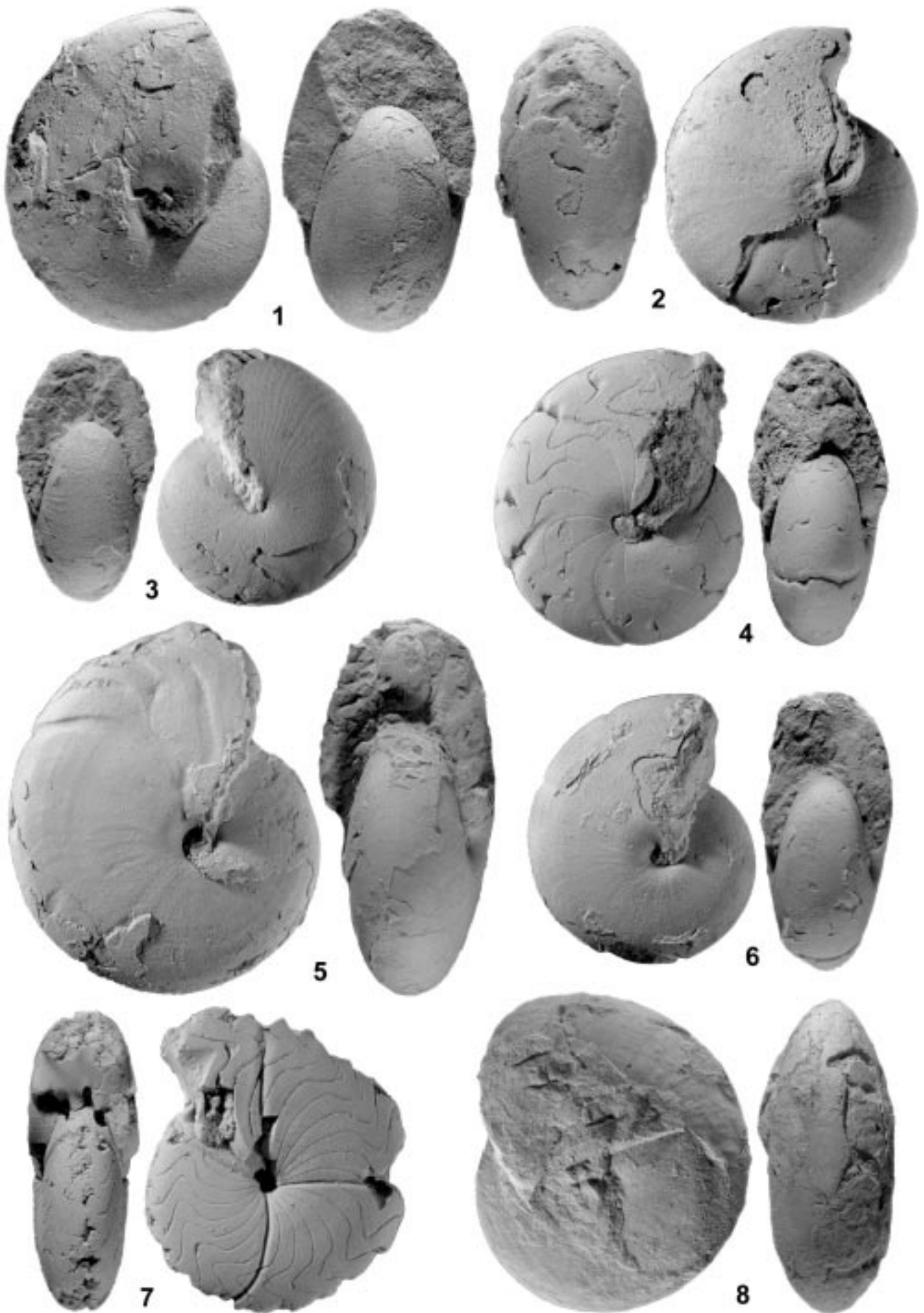
- Fig. 1: *Posttornoceras sapiens* sp. nov.  
Holotype GPIT 1850-30; Rich Sidi Ali (southern Ma'der), bed 12H, probably *annulata* Zone.  
× 2.5.
- Fig. 2: *Posttornoceras sapiens* sp. nov.  
Paratype GPIT 1850-31; Rich Sidi Ali (southern Ma'der), bed 12H, probably *annulata* Zone.  
× 2.5.
- Fig. 3: *Posttornoceras weyeri* sp. nov.  
Holotype GPIT 1850-49; Jebel Aguelmous, probably lower *Clymenia* Stufe.  
× 1.25.
- Fig. 4: *Posttornoceras* cf. *balvei* WEDEKIND 1910.  
GPIT 1850-47; Jebel Aoufilal, probably lower *Clymenia* Stufe.  
× 2.5.
- Fig. 5: *Posttornoceras weyeri* sp. nov.  
Paratype GPIT 1850-50; Jebel Aguelmous north-east of Fezzou, probably lower *Clymenia* Stufe.  
× 1.5.
- Fig. 6: *Posttornoceras* cf. *balvei* WEDEKIND 1910.  
GPIT 1850-46; Jebel Aoufilal, probably lower *Clymenia* Stufe.  
× 1.5.
- Fig. 7: *Discoclymenia cucullata* (VON BUCH 1832).  
GPIT 1850-55; Oum El Jerane, probably lower *Clymenia* Stufe.  
× 2.
- Fig. 8: *Discoclymenia cucullata* (VON BUCH 1832).  
GPIT 1850-37; Jebel Aguelmous, probably lower *Clymenia* Stufe.  
× 1.25.



## Plate 2

Sporadoceratid and prionoceratid ammonoids from the eastern Anti-Atlas.

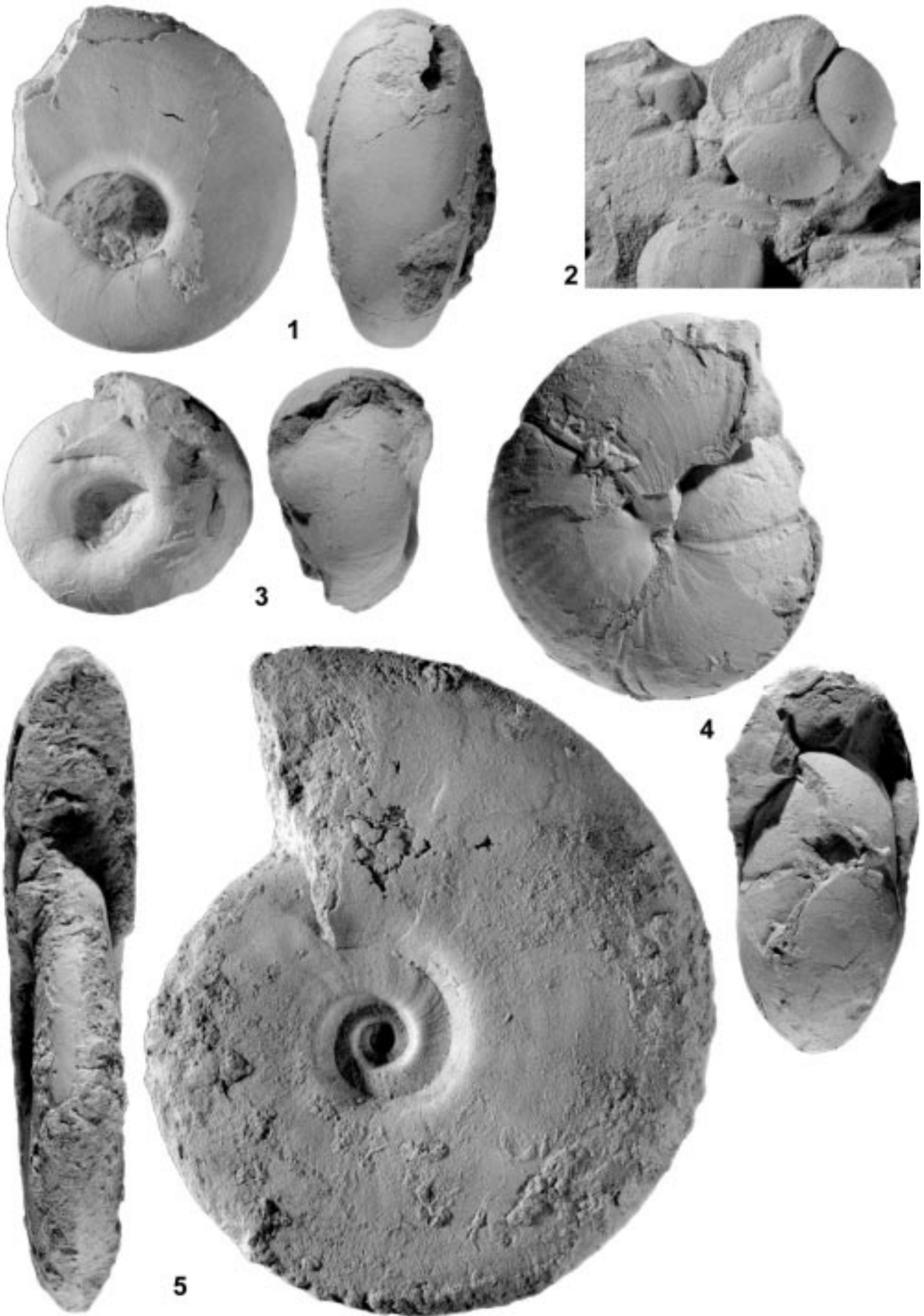
- Fig. 1: *Sporadoceras orbiculare* (MÜNSTER 1832).  
GPIT 1850-24; Ouidane Chebbi, bed 100, probably *dunkeri* Zone.  
× 1.25.
- Fig. 2: *Erfoudites zizensis* sp. nov.  
Holotype GPIT 1850-1.  
Purchased, most probably *annulata* Zone.  
× 2.
- Fig. 3: *Erfoudites zizensis* sp. nov.  
Paratype GPIT 1850-2; Bordj d'Erfoud, bed 20, *annulata* Zone.  
× 2.
- Fig. 4: *Erfoudites rherisensis* sp. nov.  
Paratype GPIT 1850-33; south-west of Taouz, *dunkeri* Zone or lower *Clymenia* Stufe.  
× 2.5.
- Fig. 5: *Erfoudites rherisensis* sp. nov.  
Holotype GPIT 1850-3; Bou Ifarherioun, *dunkeri* Zone.  
× 1.5.
- Fig. 6: *Erfoudites rherisensis* sp. nov.  
Paratype GPIT 1850-5; Bou Ifarherioun, *dunkeri* Zone.  
× 1.5.
- Fig. 7: *Prionoceras frechi* (WEDEKIND 1913).  
GPIT 1850-27; Madène El Mrakib, sample C, *annulata* Zone.  
× 2.5.
- Fig. 8: *Acutimitoceras intermedium* (SCHINDEWOLF 1923).  
GPIT 1850-23; Ouidane Chebbi, above Hangenberg Black Shale.  
× 1.25.



## Plate 3

Various ammonoids from the eastern Anti-Atlas.

- Fig. 1: *Cyrtoclymenia* sp.  
GPIT 1850-21; Madène El Mrakib, sample H (*Sporadoceras* Fauna).  
× 1.25.
- Fig. 2: *Parawocklumeria paradoxa* (WEDEKIND 1918).  
GPIT 1850-16; Bordj d'Erfoud, bed 49, *paradoxa* Zone.  
× 3.
- Fig. 3: *Wocklumeria sphaeroides* (RICHTER 1848).  
GPIT 1850-41; Madène El Mrakib, directly below Hangenberg Black Shale, *sphaeroides* Zone.  
× 2.
- Fig. 4: *Mimimitoceras liratum* (SCHMIDT 1924).  
GPIT 1850-26; vicinity of Ouidane Chebbi, lower *Wocklumeria* Stufe.  
× 1.25.
- Fig. 5: *Czarnoclymenia ibnrushdi* sp. nov.  
Holotype GPIT 1850-9; El Haroun (purchased in Erfoud), probably lower *Clymenia* Stufe.  
× 1.

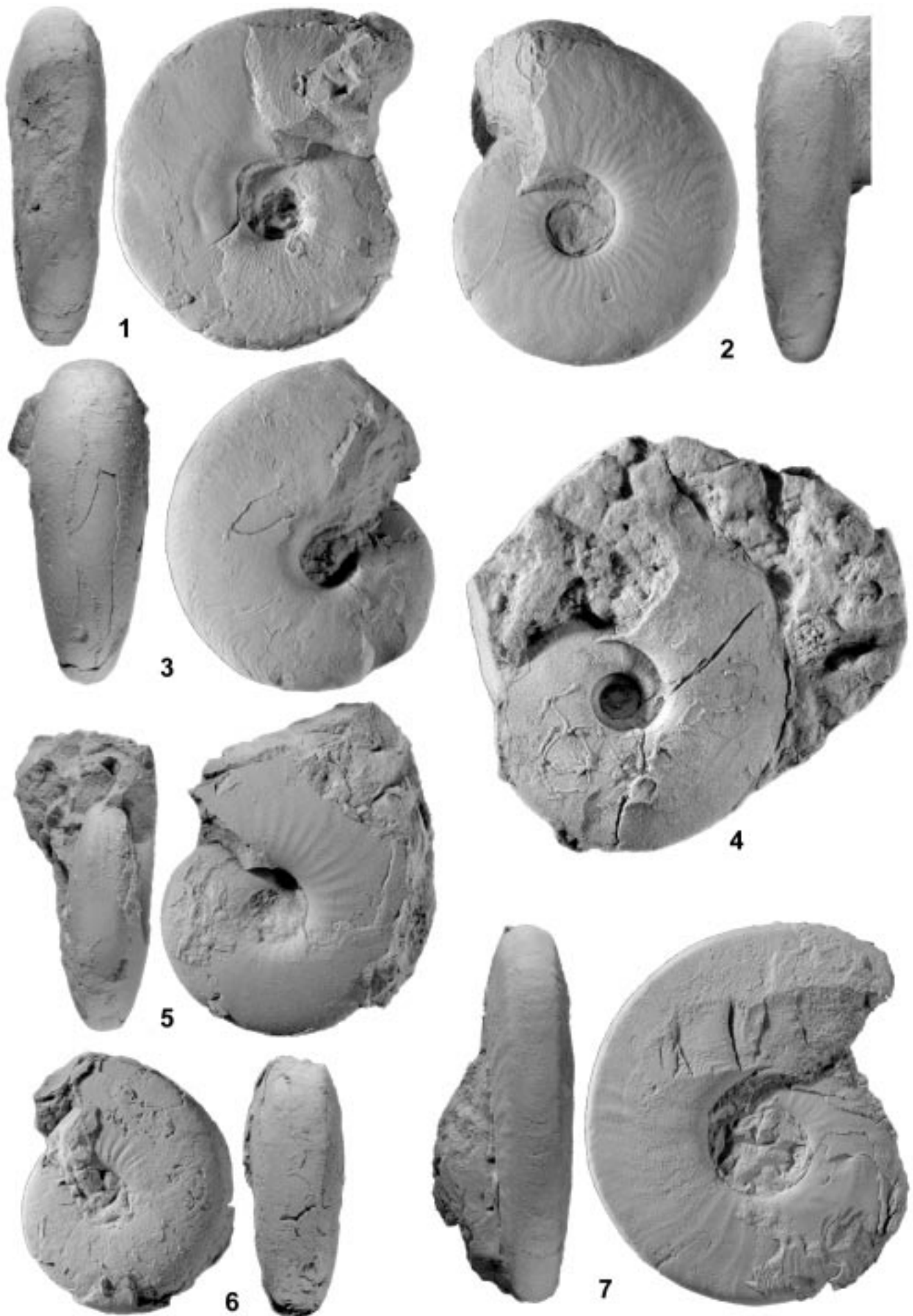


## Plate 4

*Cymaclymenia* from the eastern Anti-Atlas.

- Fig. 1: *Cymaclymenia striata* (MÜNSTER 1832).  
GPIT 1850-14; Bordj d'Erfoud, bed 55, *paradoxa* Zone.  
× 1.25.
- Fig. 2: *Cymaclymenia costellata* (MÜNSTER 1832).  
GPIT 1850-40; Jebel Zireg, *Wocklumeria* Stufe.  
× 1.25.
- Fig. 3: *Cymaclymenia involvens* LANGE 1929.  
GPIT 1850-13; Bordj d'Erfoud, bed 55, *paradoxa* Zone.  
× 1.25.
- Fig. 4: *Cymaclymenia involvens* LANGE 1929.  
GPIT 1850-22; Madène El Mrakib, directly below Hangenberg Black Shale, *Wocklumeria* Stufe.  
× 1.
- Fig. 5: *Cymaclymenia cordata* WEDEKIND 1914.  
GPIT 1850-57; Bou Tchrafine, *Gonioclymenia* Limestone (*Clymenia* Stufe).  
× 2.
- Fig. 6: *Cymaclymenia* sp.  
GPIT 1850-56; Oum El Jerane, probably lower *Clymenia* Stufe.  
× 2.
- Fig. 7: *Cymaclymenia* sp.  
GPIT 1850-14; Bordj d'Erfoud, bed 27, probably lower *Clymenia* Stufe.  
× 1.5.

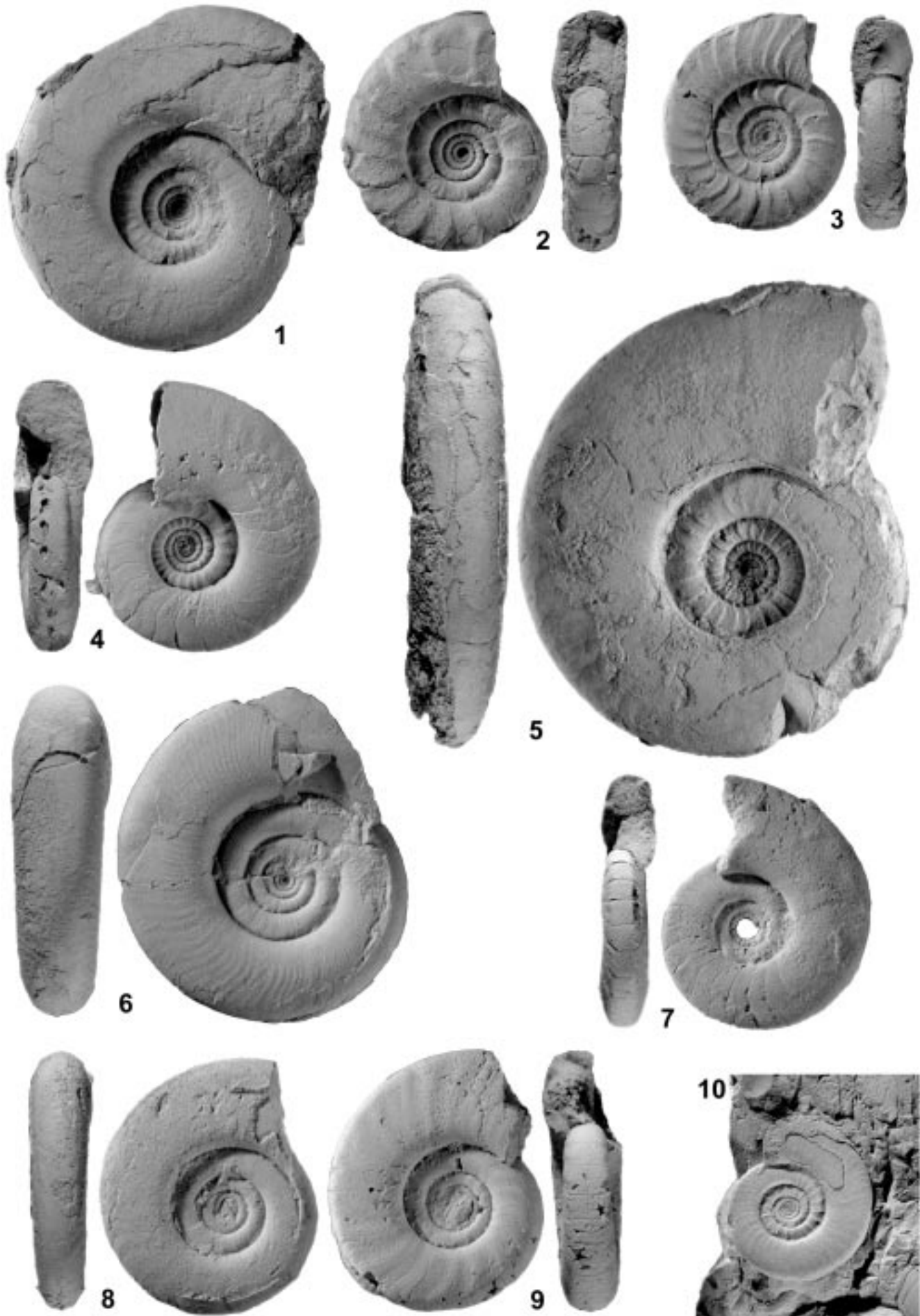




## Plate 5

Platyclymeniid ammonoids from the eastern Anti-Atlas.

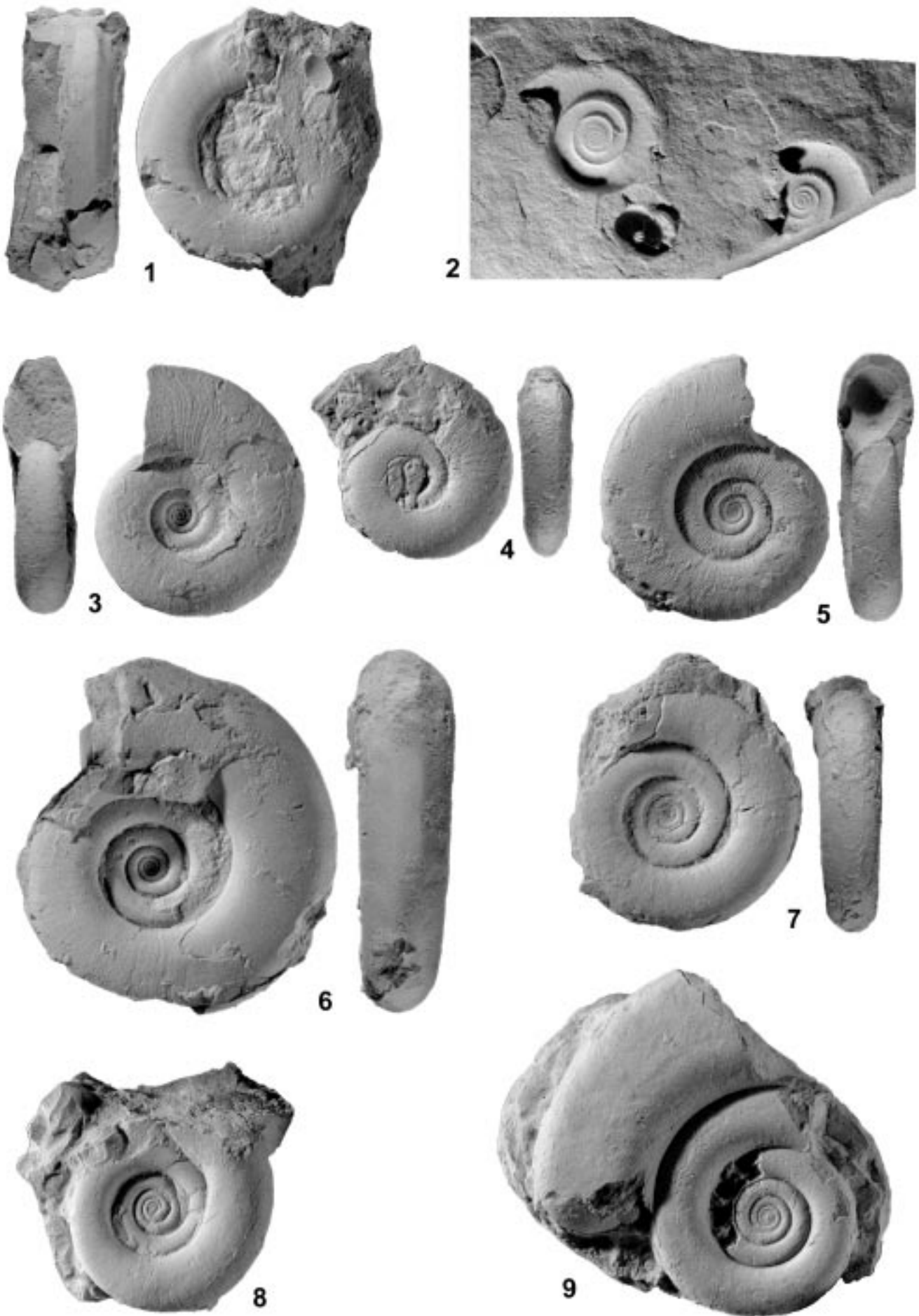
- Fig. 1: *Platyclymenia* sp.  
GPIT 1850-14; El Atrous, *annulata* Zone.  
× 1.5.
- Fig. 2: *Platyclymenia annulata* (MÜNSTER 1832).  
GPIT 1850-14; Madène El Mrakib, sample C, *annulata* Zone.  
× 2.5.
- Fig. 3: *Platyclymenia annulata* (MÜNSTER 1832).  
GPIT 1850-34; Bordj d'Erfoud, bed 21, *annulata* Zone.  
× 2.
- Fig. 4: *Platyclymenia ibnsinai* sp. nov.  
Paratype GPIT 1850-29; Iferd Nou Harouar near Taouz, probably *annulata* Zone.  
× 2.
- Fig. 5: *Platyclymenia ibnsinai* sp. nov.  
Holotype GPIT 1850-8; south-west of Oum El Hadj, *annulata* Zone.  
× 1.
- Fig. 6: *Platyclymenia subnautilina* (SANDBERGER 1855).  
GPIT 1850-59; Bordj d'Erfoud, bed 21, *annulata* Zone.  
× 2.
- Fig. 7: *Platyclymenia* sp.  
GPIT 1850-60; north of Rich Bou Korazia, *annulata* Zone.  
× 2.
- Fig. 8: *Platyclymenia* sp.  
GPIT 1850-61; El Atrous, *annulata* Zone.  
× 2.
- Fig. 9: *Platyclymenia* sp.  
GPIT 1850-62; south-west of Taouz, *annulata* Zone.  
× 2.5.
- Fig. 10: *Platyclymenia annulata* (MÜNSTER 1832).  
GPIT 1850-63; Bordj d'Erfoud, bed 21, *annulata* Zone.  
× 1.52.



## Plate 6

Kosmoclymeniid ammonoids from the eastern Anti-Atlas.

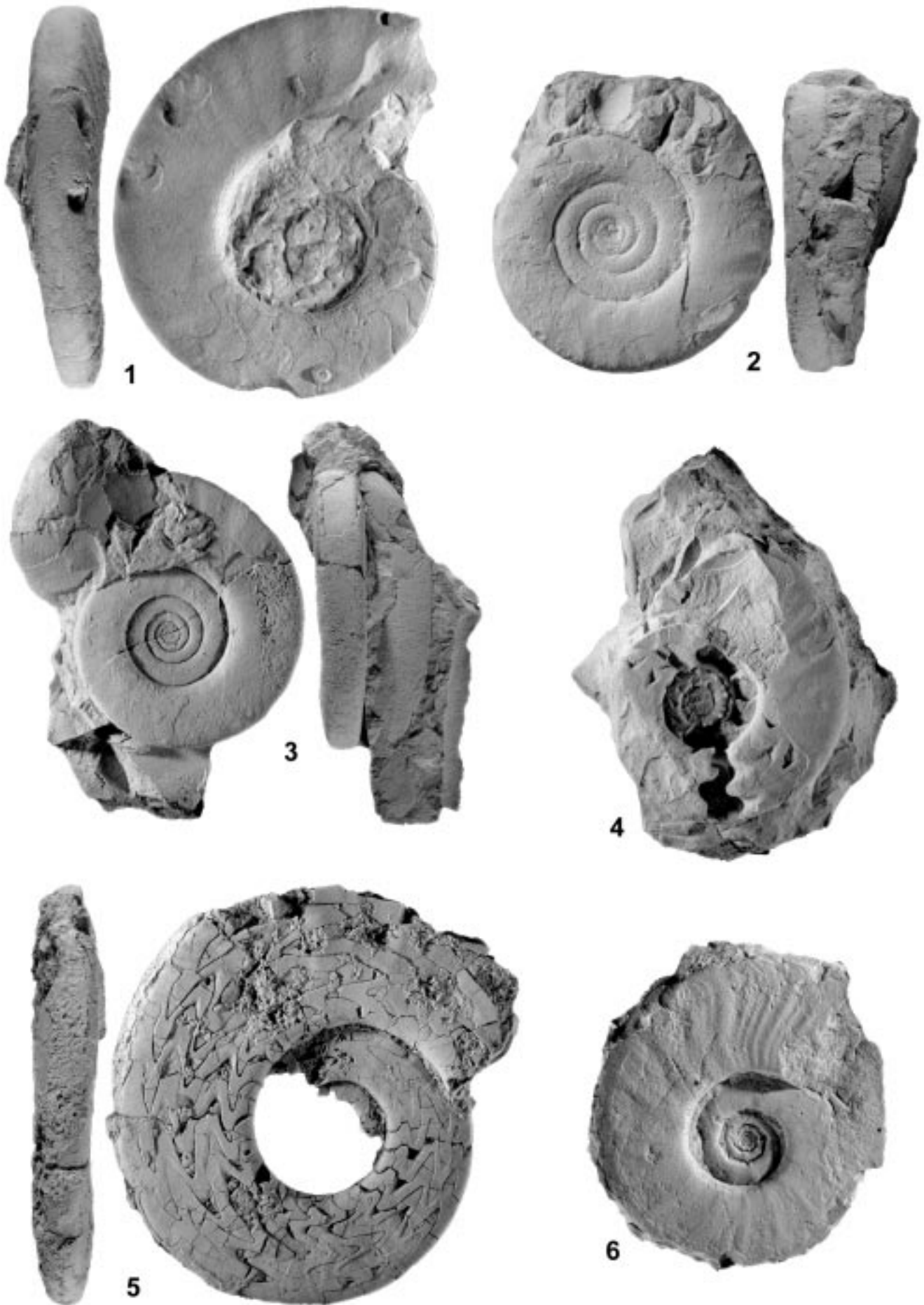
- Fig. 1: *Protoxycymenia wendti* sp. nov.  
Holotype GPIT 1850-38; Madène El Mrakib, sample K, *dunkeri* Zone.  
× 2.
- Fig. 2: *Protoxycymenia wendti* sp. nov.  
Paratype GPIT 1850-39; Madène El Mrakib, sample K, *dunkeri* Zone.  
× 2.
- Fig. 3: *Kosmoclymenia* (?) sp.  
GPIT 1850-64; Oum El Jerane, probably lower *Clymenia* Stufe.  
× 2.5.
- Fig. 4: *Kosmoclymenia* (?) sp.  
GPIT 1850-65; Oum El Jerane, probably lower *Clymenia* Stufe.  
× 2.
- Fig. 5: *Kosmoclymenia lamellosa* (WEDEKIND 1914).  
GPIT 1850-18; Ouidane Chebbi, bed 113, lower *Clymenia* Stufe.  
× 1.5.
- Fig. 6: *Muessenbiaergia sublaevis* (MÜNSTER 1832).  
GPIT 1850-66; Bordj d'Erfoud, bed 48, lower *Wocklumeria* Stufe.  
× 2.
- Fig. 7: *Kosmoclymenia inaequistriata* (MÜNSTER 1832).  
GPIT 1850-67; Bou Tchrafine, lower *Clymenia* Stufe.  
× 2.5.
- Fig. 8: *Kosmoclymenia kowalensis* CZARNOCKI 1979.  
GPIT 1850-15; Bordj d'Erfoud, bed 55, *paradoxa* Zone.  
× 1.5.
- Fig. 9: *Lissoclymenia wocklumeri* (WEDEKIND 1914).  
GPIT 1850-42; Madène El Mrakib, directly below Hangenberg Black Shale, *sphaeroides* Zone.  
× 1.25.



## Plate 7

Various clymeniids from the eastern Anti-Atlas.

- Fig. 1: *Endosiphonites muensteri* (ANSTED 1838).  
GPIT 1850-10; vicinity of Ouidane Chebbi.  
× 1.
- Fig. 2: *Endosiphonites muensteri* (ANSTED 1838).  
GPIT 1850-52; Oum El Jerane, probably lower *Clymenia* Stufe.  
× 2.
- Fig. 3: *Endosiphonites muensteri* (ANSTED 1838).  
GPIT 1850-51; Oum El Jerane, probably lower *Clymenia* Stufe.  
× 1.5.
- Fig. 4: *Gonioclymenia* sp. nov.  
GPIT 1850-17; vicinity of Ouidane Chebbi, lower *Clymenia* Stufe.  
× 1.25.
- Fig. 5: *Sphenoclymenia* sp.  
GPIT 1850-20; Jebel Aguelmous, lower *Clymenia* Stufe.  
× 1.25.
- Fig. 6: *Sellaclymenia ibntufayli* sp. nov.  
Holotype GPIT 1850-25; vicinity of Ouidane Chebbi, lower *Wocklumeria* Stufe.  
× 1.25.



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