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Macrocephalitinae (Ammonoidea, Middle Jurassic) from North and Central Iran

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With 12 figures and 1 table

Abstract: *Macrocephalites* is one of the most common and cosmopolitan ammonites of the Middle Jurassic and partially an important guide fossil in Europe and the Indo-East-African Province. The ammonites of this genus inhabited the shelf seas around the edges of the Tehtys Ocean from the Late Bathonian to the earliest Middle Callovian. In Iran *Macrocephalites* is rather rare, we only know a dozen of localities in the North Iran (Alborz and Binalud mountains) and Central Iran. Most of the specimens come from the locality named Talu near Dāmghān in the eastern Alborz, from the marls and limestones of the Dalichai Formation. The *Macrocephalites* fauna of Talu seem to belong to the middle part of the Bullatus Zone (Lower Callovian). Further collections from localities in Binalud, Koppeh Dagh and Tabas areas indicate horizons of other ages. Thus, a sequence of 8 ammonite assemblages can be proposed for the Upper Bathonian and Lower Callovian of Iran. In Iran *Macrocephalites* is only frequent in the Bullatus Zone, but also occurs in the Prahecquense Subzone. Only a single *Macrocephalites* was found in the Gracilis Zone at Kelariz. The *Macrocephalites gracilis* fauna, which is typical of the middle Gracilis Zone, and the *M. opis-semilaevis* fauna from the Lower-Middle Callovian boundary seems to be absent in Iran. Overall the Middle Jurassic ammonite fauna of North and Central Iran belongs to the Submediterranean Province.

Key words: Biostratigraphy, Ammonoidea, Macrocephalites, Middle Jurassic, Iran.

1. Introduction

The present study is part of a research project on the ammonite fauna of the Dalichai and Lar formations in eastern Alborz and Binalud Range (Seyed-Emami & Schairer 2010, 2011a, b; Seyed-Emami et al. 2013). The studied ammonites mainly come from the Dalichai Formation (late Bajocian – Oxfordian) N of Dāmghān.

The Dalichai Formation consisting of greyish marls, marlstones and limestones, is widely distributed along the Alborz Range. Nearly everywhere the Dalichai Formation overlies disconformably the dark coal-bearing and siliciclastic Shemshak Group (Upper Triassic – Lower Bajocian) and is followed conformably by the light and cliff building carbonates of the Lar Formation (Upper Jurassic). The bulk of the studied ammonites come from the upper part of the Dalichai Formation at Talu (N of Dāmghān; Fig. 1). Few further specimens come from Jajarm (Majidifard 2003), Fraizi (northwest Mashhad), Mayamey (east Mashhad) and N of Tabas (East- Central Iran; Fig. 2) (Seyed-Emami et al. 1997). Additionally, specimes from the Binalud Mountains collected by A. Raoufian are considered.

The aim of the present study is to give an overview of the Macrocephalitinae fauna of Alborz and Central Iran, which were hitherto little known. Macrocephalitiids are relatively rare in Iran, but their rather abundant occurrence at Talu is remarkable. Unfortunately most of them are either poorly preserved, small or juveniles, or have been collected loosely. Additionally, the high

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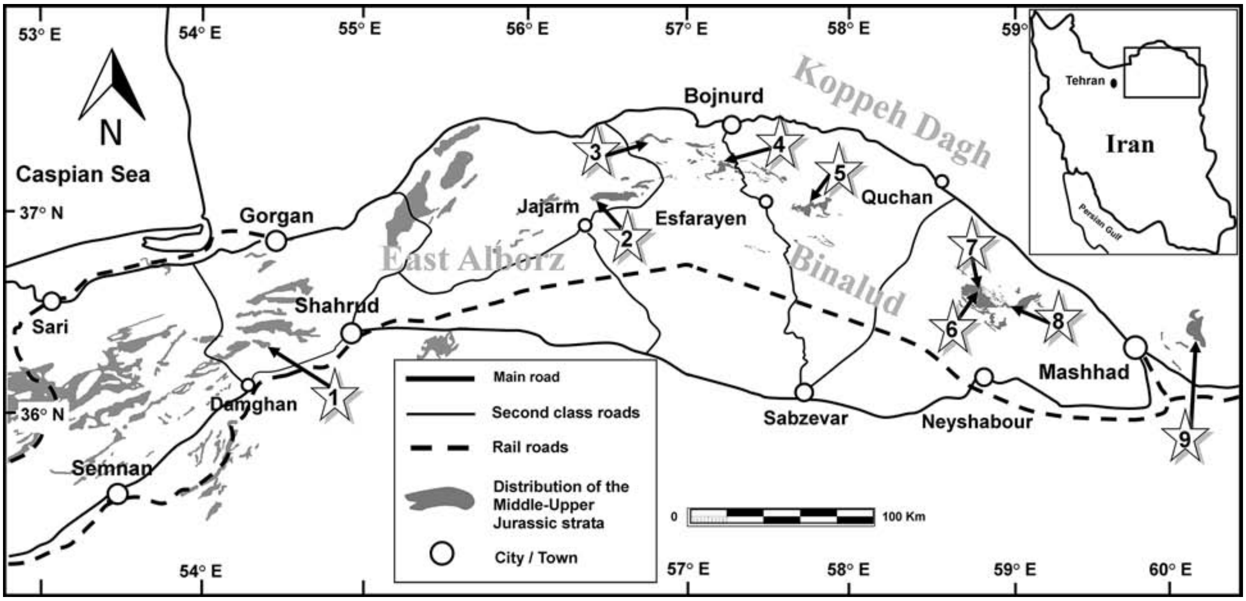

Fig. 1. Map of eastern Alborz, Binalud and Koppeh Dagh. Localities cited in text: 1. Talu; 2. Golbini; 3. Navia; 4. Chehar Borj; 5. Dahaneh Ojagh; 6. Ghoroneh; 7. Baghi; 8. Fraizi; 9. Mayamey.

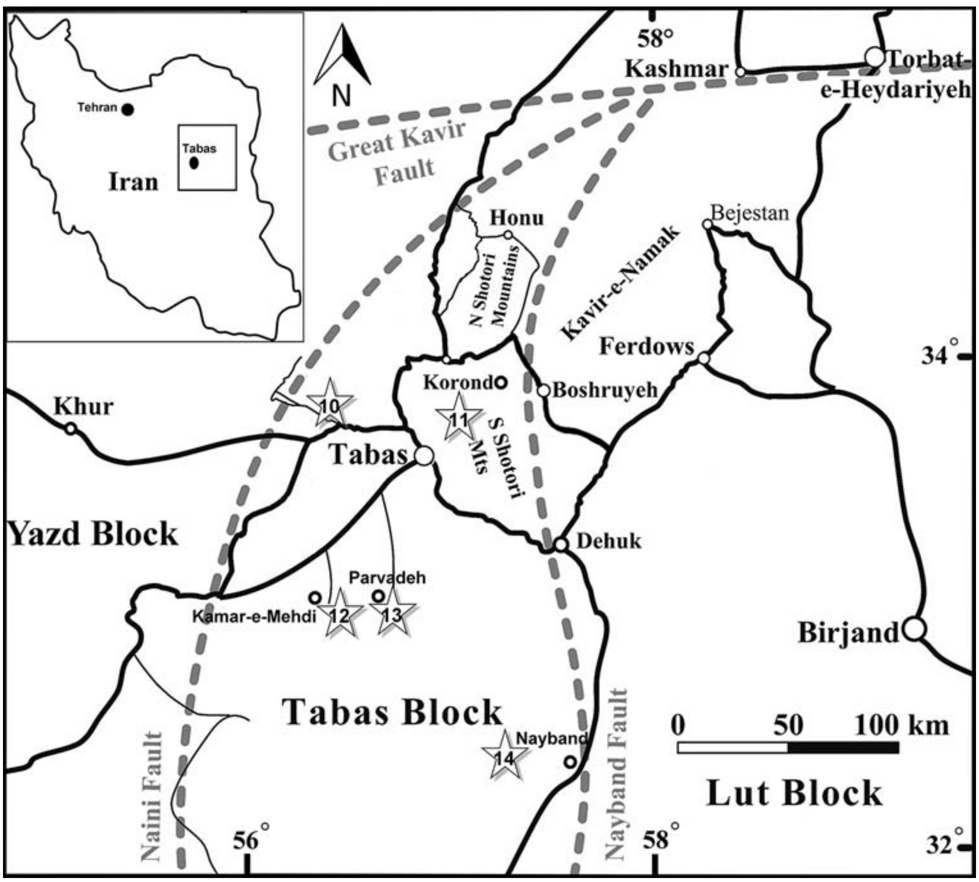

Fig. 2. Map of the Tabas area, east-central Iran (completed after Wilmsen et al., 2010). Localities cited in text: 10. Kuh-e-Echelon; 11. Khorow-Pain; 12. Kamar-e-Mehdi; 13. Parvadeh; 14. W Nayband.

variability and the taxonomic problems of the group, makes specific determinations very difficult. Nevertheless, we managed to associate the different ammonite assemblages to the standard zones and subzones, thus more statements about the paleobiogeography should be possible.

2. Geological setting

The studied ammonites come from five localities in northeast Iran (east Alborz, Binalud and Koppeh Dagh mountains) and Tabas area (east-central Iran). These are:

1. Talu, Dalichai Fm, ca 19 km NE of Dāmghān (36°19'06"N, 54°26'04" E).
2. Golbini: Dalichai Fm, ca 16 km N of Jajarm (37°05'13" N, 56°44'41" E) (Majidifard 2003).
3. Fraizi: Dalichai Fm, ca 58 km NW of Mashhad (36°29'55" N, 58°57'40" E) (Seyed-Emami & Schairer 2011b).
4. Mayamey, Chaman Bid Fm, Sarakhs road, 56 km E of Mashhad (36°10'31" N, 60°06' 4" E).
5. Kuh-e-Echelon, Baghamshah Fm, ca 45 km N of Tabas (33°50'17" N, 56°36'48" E) (Seyed-Emami et al. 1997).

Additional material from the Binalud Mountains (Fig. 1) and Tabas area (Fig. 2) is considered as well:
Fig. 1: 1 – Talu, 2 – Golbini (N Jajarm), 3 – Navia (37°23'04" N, 56°41'36" E), 4 – Chehar Borj (37°12'09" N, 57°10'32" E), 5 – Dahaneh Ojagh (37°01'41" N, 57°44'05" E), 6 – Ghoroneh (36°35'08" N, 58°41'36" E), 7 – Baghi (36°35'37" N, 58°42'1" E), 8 – Fraizi, 9 – Mayamey.
Fig. 2: 10 – Kuh-e-Echelon (33°0'17" N, 56°36'48" E), 11 – Khorow-Pain (33°48'07" N, 57°02'42" E), 12 – Kamar-e-Mehdi (33°06'20" N, 56°26'20" E), 13 – Parvadeh (33°01'15" N, 56°48'10" E), 14 – W Nayband (33°23' N, 57°08' E).
The following localities are also mentioned in the text: 1 – Kelariz (ca 25 km N Dāmghān (36°22'21" N, 54°17'11" E), 2 – Tazareh, NE Dāmghān (36°28'21" N, 54°30'49" E), 3 – Tooy (ca 30 km E of Jajarm, 37°09'4" N, 57°09'13" E; Majidifard 2003).

The bulk of the studied Macrocephalitinae come from Talu, north of Dāmghān (Geological map of Dāmghān 1:100000, prepared by Alavi & Salehi Rad 1975). The section at Talu was firstly studied within a MS-Thesis by Behfar in 2009, and later by Behfar et al. (2012). For the current study further sections at Talu were measured and sampled by A. Raoufian in the years 2012 and 2013. The section at Talu is of great importance because of the relatively frequent occurrences of *Macrocephalites*, being rather scarce within the Dalichai Formation. The Dalichai Formation at Talu has a thickness of about 170 m and can be roughly subdivided into four members (Fig. 3):

Member 1 (M1): About 15.5 m of dark redbrown, sandy to fine-conglomeratic limestone with intercalation of marls.

Member 2 (M2): Consists of about 60 m of greyish green, argillaceous and very soft marls, with intercalations of marly limestones in the upper part. This unit contains fragmentary sponges, pelecypods, gastropods, crinoid ossicles and belemnites.

Member 3 (M3): It has a thickness of 70 m and consists of an alternation of greyish marly limestones and marls, with varying content of ammonites. Three succeeding stratigraphic levels, of few meters of condensed, reddish nodular limestones and marls in "Ammonitico Rosso Facies" occur. The first red bed (I) is 1.5 m thick and contains Late Bajocian ammonites (*Oxycerites*, *Parkinsonia* and *Vermisphinctes* among others). The second red bed (II) has a thickness of 2 m and contains Early Bathonian ammonites (*Oxycerites*, *Cadomites*, *Parkinsonia* and *Morphoceras*). The third bed (III) is 4 m thick and contains Callovian ammonites (Hecticoceratinae, Reineckeidae and Pseudoperisphinctidae among others). *Macrocephalites* occurs in the beds ca 2 meters below the red-bed III (star in Fig. 3).

Member 4 (M4): The upper unit has a thickness of 27 m and consists largely of an alternation of light grey limestones and marls succeeding in the upper part into an intercalation of cherty limestone with Late Callovian to Early Oxfordian ammonites.

The following parameters are given: diameter (*D*) in mm; umbilical width (*U*), whorl height (*H*); whorl width (*W*), all in % of diameter; number of primary ribs (PR) per whorl; number of secondary ribs (SR) per whorl; [m] = microconch, [M] = macroconch. All figures are in natural size, if not otherwise indicated. The ammonite fauna is deposited in the collections of the Bayerische Staatssammlung für Paläontologie und Geologie in Munich, Germany, under the numbers BSPG-2013-XXIV-14 to 34.

3. Systematic palaeontology

Family Sphaeroceratidae Buckman, 1920
Subfamily Macrocephalitinae Salfeld, 1921
Genus *Macrocephalites* Zittel, 1884

Subgenera. – In some horizons the macrocephalids show a wide spectrum of relative whorl width, the different specimens ranging from compressed to inflated. This is typi-

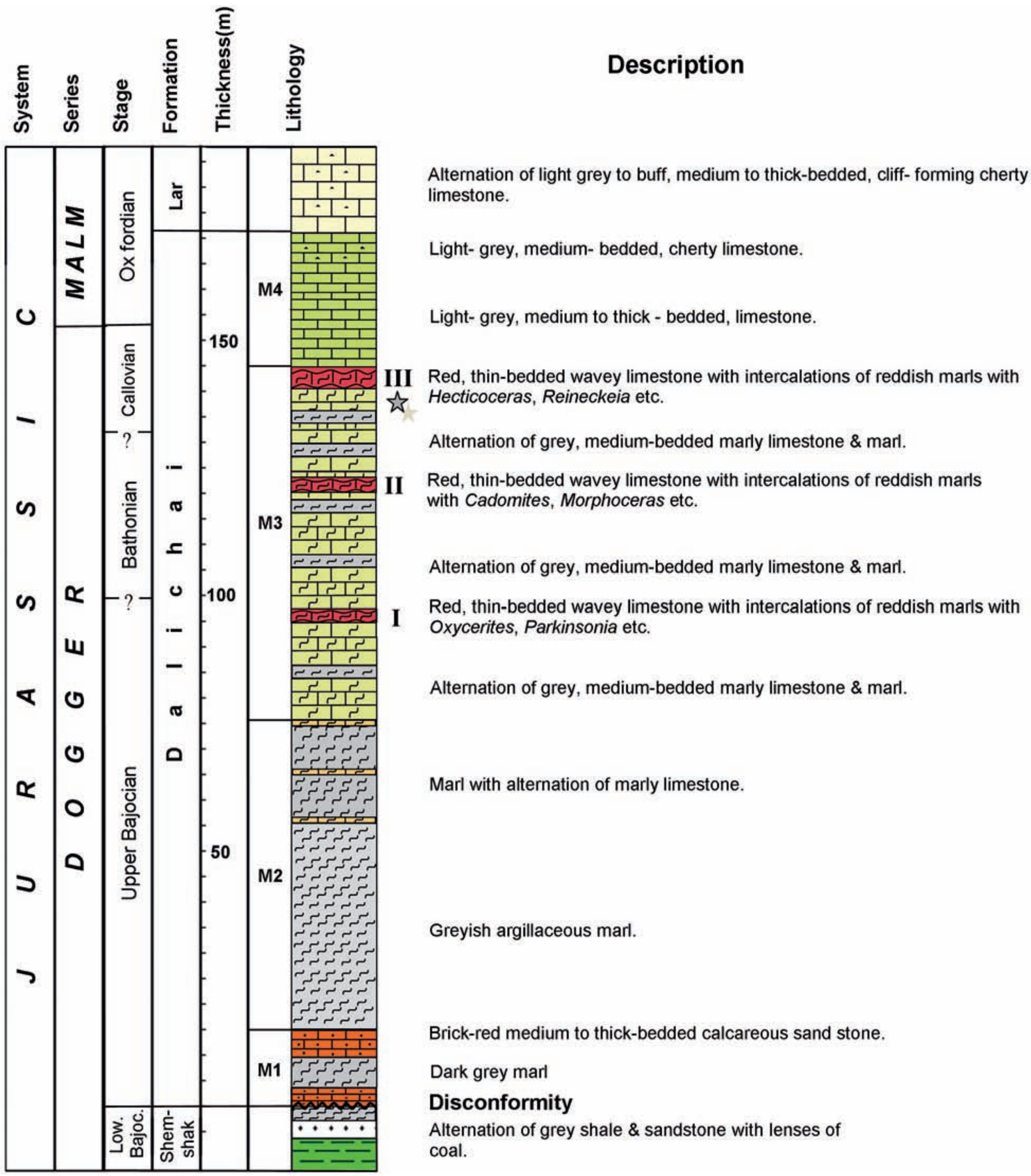

Fig. 3. Stratigraphic log-section of Talu (N Dāmghān); the grey star indicates the position of the *Macrocephalites*-bed.

cal of all “populations” of *Macrocephalites*. It is not clear whether this is related with a large variability within a single species, or there exist two or more parallel lineages with different species. The question can be answered only after a wide revision based on the comparative study of the ontogeny of stratigraphically well constrained samples with the support of statistical analysis. Pending such a revision, we follow the approach that several parallel lineages are present (according to Thierry 1978; Callomon et al. 1989, 1992; Krishna & Cariou 1993; Mönnig 1995). Krishna & Cariou

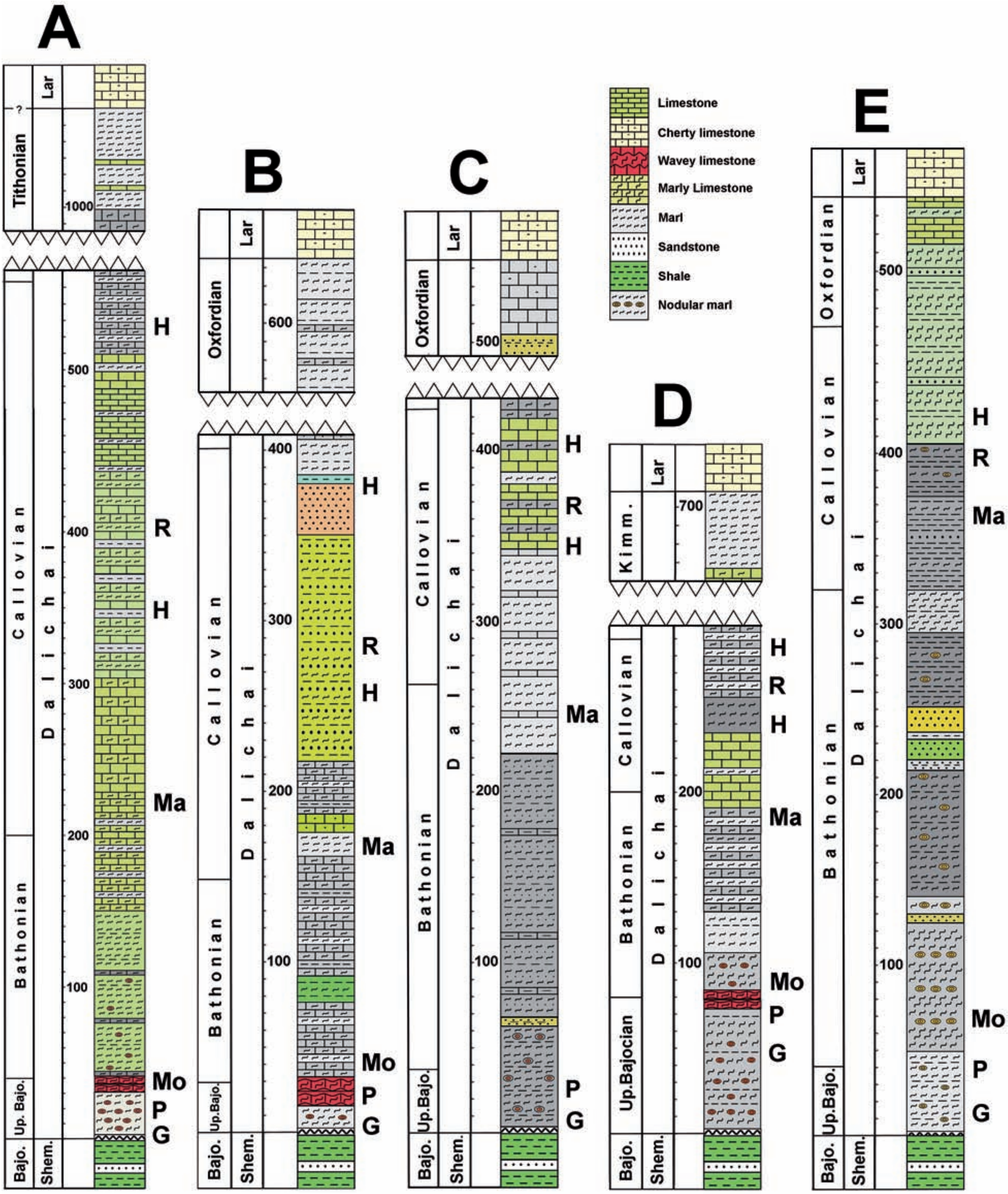

Fig. 4. Stratigraphic log-sections studied in the Binalud Mountains. A: Navia, B: Chehar Borj, C: Dahaneh Ojagh, D: Ghoroneh, E: Fraizi; G: *Garantiana*, P: *Parkinsonia*, Mo: *Morphoceras*, Ma: *Macrocephalites*, H: *Hecticoceras*, R: *Reineckeia*.

(1993) split the macrocephaliids – after their immigration to the shelf margins of the Tethys Ocean in the Late Bathonian – into two lineages, namely the Gracilis lineage in the Submediterranean Province and the Chrysoolithicus lineage in the Indo-East-African Province. The Gracilis Lineage in turn splits up into the Sphaericus-, Macrocephalus-, and Kamptus

Table 1. Upper Bathonian to Lower Callovian chronostratigraphic chart of the Submediterranean Province with faunal assemblages of Iran and Kachchh.

Submediterranean Province (Mangold & Rioult 1997, Thierry et al. 1997)					Indo-East-African Province (Krishna & Ohja 1996, Jain 2014)		
		Subzone	Western Europe	Iran	Kachchh	Subzone	
	Anceps	Stuebeli	M. tumidus	*Reineckeia* spp. *Hecticoceras* spp. *Indosphinctes* cf. *patina* (Golbini, Talu - Red Bed III))	*S. opis*; *M. semilaevis E. eucyclum*	Opis/ Eucyclum	Anceps
Lower Callovian	Gracilis	Patina	*M. tumidus*		*M. semilaevis E. eucyclum*	Semilaevis	Semilaevis
		Michalskii	*M. dicosmum M. gracilis*	*H. (Chanasia)* spp. *Reineckeia* spp. *Indosphinctes choffati/patina* ***Macrocephalites*** (1 spec.) (Kelariz, Talu - Red Bed III))	***M. formosus***	Formosus	
		Laugieri	*M. dicosmum M. gracilis*		***M. diadematus***	Diadematus	Chrysoolithicus
		Pictava		*Reineckeia* spp. *Hectioceras* spp. first *Indosphinctes* (Talu - Red Bed III)	CHRYSOOLITHICUS lineage *M. crysoolithicus M. elephantinus*	Chrysoolithicus	
		Grossouvrei					
		Prahecquense	SPHAERICUS lineage *M. cossmanni*; GRACILIS lineage *M. gracilis* ssp. A	***M. cossmanni*** (Fraizi, Baghi, Talu)	*M. transitorius M. habyensis*	Transitorius	
	Bullatus	Bullatus	*M. verus*; *M. verus/jaquoti*	***M.* cf. *madagascariensis M. caucasicus, Pleuroceph.*** (Kuh-e-Echelon, Navia) ***M. lamellosus*** (Golbini) ***Macrocephalites verus M. hoyeri, M. pila, Pleuro-cephalites*** (Talu, Tooy) ***M.* cf. *jaquoti M.* cf. *subcompressus*** (Myamay, Tazareh, Ghoroneh, Dahaneh Ojagh)	*M. madagascariensis M. lamellosus M. subcompressus*	Madagas-cariensis	Madagascariensis
Upper Bathonian	Discus	Discus	Southern Germany	*Clydoniceras, B. Kheraiceras) Homoeoplanulites* (Khorow-Pain)	*M. triangularis*	*Sivajiceras congener Choffatia* spp. *Homoeoplanulites*	Triangularis
		Angulicostatum (Hollandi)	*M. jaquoti M.triangularis M.* cf. *keeuwenis*			*Epistrenoceras B. (Kheraiceras)* cf. *hannoveranus Choffatia* spp.	
	Retrocostatum	Hannoveranus (Histricoides)				*Procerites* spp.	
		Blanazense/ Julii		*Oxycerites ssp. Paroecotraustes maubeugii B. (Kheraiceras) hermi Choffatia/Homoeoplanulites* (Parvadeh)	*M. apertum M.* cf. *etheridgei*	*Micromphalites clydocromphalus „Gracilisphinctes" arkelli*; *Clyd. triangulare B. (Kheraiceras)* sp.	Arkelli
	Bremeri	Fortecostatum		*Alcidellus tenuistriatus Prohecticoceras haugii B. (K.)* aff. *ymir Homoeoplanulites* or *Procerites, Wagnericeras* sp. *Cadomites* cf. *bremeri* (Kamar-e-Mehdi)			
		Bullatimorphus					

lineages during the upper Bullatus Chron. There is probably a fourth lineage on the Russian Platform.

In the Subboreal Province, at the end of the Koenigi Chron, the inflated ammonites of the Macrocephalus lineage became extinct, or at least very rare. Shortly after, at the end of the Koenigi Chron, *M. dicosmum* and *M. gracilis* as representatives of the Submediterranean Gracilis lineage immigrated to Germany (Mönnig 2010). Something very similar happens in the Indo-East-African Province. Here as well, the Chrysoolithicus lineage becomes extinct at the close of the Diadematus Subchrone and the depressed, coarse ribbed ammonites were also replaced by compressed, fine-ribbed forms (*M. semilaevis*) (Krishna & Westermann 1987). Whether *M. semilaevis* has derived from the sub-Mediterranean Gracilis line, is likely but not finally resolved (Krishna & Cariou 1993). The simultaneous *M. formosus* cannot be compared with any European species and appears to be confined to the Indo-East-African Province.

The development in the late Calloviense and Patina zones has not been understood in detail yet. It is possible that there is a mixing of previously separate lineages (*opis-semilaevis-gracilis* assemblage). Surely, it would be convenient to consider these lineages as subgenera. The associated nomenclatural problems have been discussed by Westermann & Callomon (1988) and Callomon et al. (1992).

Another problem is that the "populations" are divided into micro- and macroconchs, interpreted as males and females, respectively. Some authors (Thierry 1978; Page 1988; Westermann & Callomon 1988) were very consequent to consider both sexual dimorphs within a single species, as in the zoological nomenclature, that marked the difference only by an appropriate symbol (m & M or ♂ and ♀). This approach, however, can raise taxonomic difficulties if the dimorphic pair already has two different names, since one of them should be considered as a junior synonym. Therefore, other authors treat micro- and macroconchs as two different species, or even put them into different subgenera to avoid these complications (Callomon et al. 1989; Mönnig 1995). We will proceed under the following scheme, according to Krishna & Cariou (1993):

"Macroconch" subgenus	"Microconch" subgenus
GRACILIS Lineage:	
Tmetokephalites Buckman, 1923	*Dolikephalites* Buckman, 1923
MACROCEPHALUS and KAMPTUS lineages:	
Macrocephalites Zittel, 1884	*Kamptokephalites* Buckman, 1922
SPHAERICUS lineage:	
Platystomaceras Corroy, 1933	*Pleurocephalites* Buckman, 1922
CHRYSOOLITHICUS lineage:	
Indocephalites Spath, 1928	*Pleurocephalites* Buckman, 1922

Species. – As the diagram (Table 1) shows, we assume that the faunas of the Bullatus and Herveyi zones are identical or at least very similar in the different provinces, and that there occur the same morphospecies. But to asign the Iranian macrocephalitids to well-known species is difficult for several reasons. Often the material is collected ex-situ, so that we do not know from which bed or bench the fossils come, but we can specify the level within the formation to within a few meters. In addition, the ammonite associations of a certain locality are very homogeneous and probably come from only one subzone or one faunal horizon. A similar problem was faced by Westermann & Callomon (1988), having also only relatively roughly horizon-oriented material for their monograph of the Macrocephalitidae of the Sula Islands and New Guinea. Following the procedure of these authors we determined the stratigraphic age of an "assemblage" with the help of the accompanying fauna, and then we looked whether the determination of a species of *Macrocephalites* fits to the age of the type material.

Another reason for difficulties is the preservation. Unfortunately, only a few specimens are well-preserved. Most of them are only inner whorls or fragments. Concerning *Macrocephalites*, it is particularly unfortunate, because you need some well-preserved specimens to identify a subzone or a particular faunal horizon. The macroconchs have smooth or almost smooth body chambers. The consideration of relative whorl width (W/D or W/H)) can provide reliable results in classification. However, because of the large variability a large amount of specimens are necessary to get a representative average. By all means, certain morphotypes can occur virtually in all of the stratigraphic levels and in different faunal provinces too. Therefore, it makes no sense to determine the specimens purely in morphotypical terms. A good example is *Macrocephalites folliformis* (Buckman). The holotype comes from of the *metorchus* horizon (Koenigi Zone) of Chippenham (Wiltshire) and is possibly endemic there. Nevertheless, the species has been recorded from very different horizons and regions as Northern Germany (Keppleri/Terebratus Subzone; Mönnig 1995), Southern Germany (upper Koenigi Zone; Callomon et al. 1992), Western France (Gracilis Zone; Cariou 1984) or Tikong (Upper Bathonian; Westermann & Callomon 1988). The same is true for many other morpho-species of *Macrocephalites*, and there are over a hundred of them with at least ten different genera and subgenera in the literature. In order to produce a workable framework Krishna & Cariou (1993) have compiled the occurrence of important morphotypes of *Macrocephalites* in a chronostratigraphic chart, as a kind of family tree.

The often-cited monograph on *Macrocephalites* by Thierry (1978) suffers from a wrong approach. Thierry put together same morphotypes or apparently similar-looking specimens and arranged them as "species" into the zones and subzones of the corresponding faunal provinces. The result was a family tree of the Macrocephalitinae with 16 species including their dimorphic pairs. As already mentioned, some of the morphotypes of *Macrocephalites* have a long stratigraphic range, and so many of "species" of Thierry are a mixture of ammonites from completely different levels. For example he shows *Macrocephalites macrocephalus* Zittel 1884 (non Schlothheim = *verus* Buckman) ranging from the Kamptus Subzone through the lower half of the Koenigi Zone, even though the type comes from the *keppleri* horizon at the base of the Callovian stage. To avoid such mistakes, it is important to firstly clarify the biostratigraphy and only then to compare the present material with already known species, as we approach.

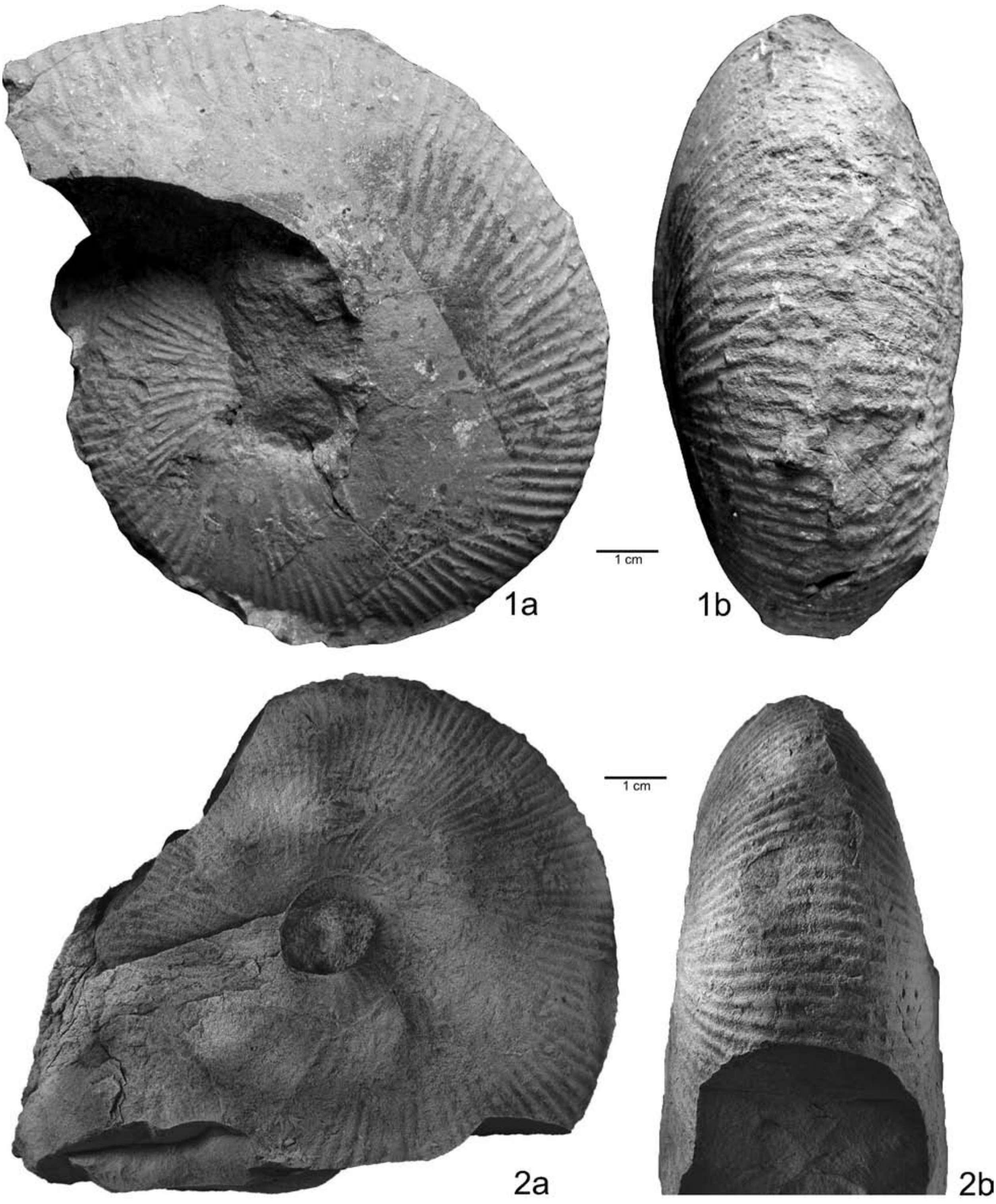

Fig. 5. 1a, b. *Macrocephalites* (*Tmetokephalites*) *jacquoti* H. Douvillé [M], resembling *Macrocephalites keeuwensis* α Boehm, 1912, D 4112 from Dahaneh Ojagh. **2a, b.** *M. (Tmetokephalites) verus* Buckman [M], BSPG 2013 XXIV 28, from Talu.

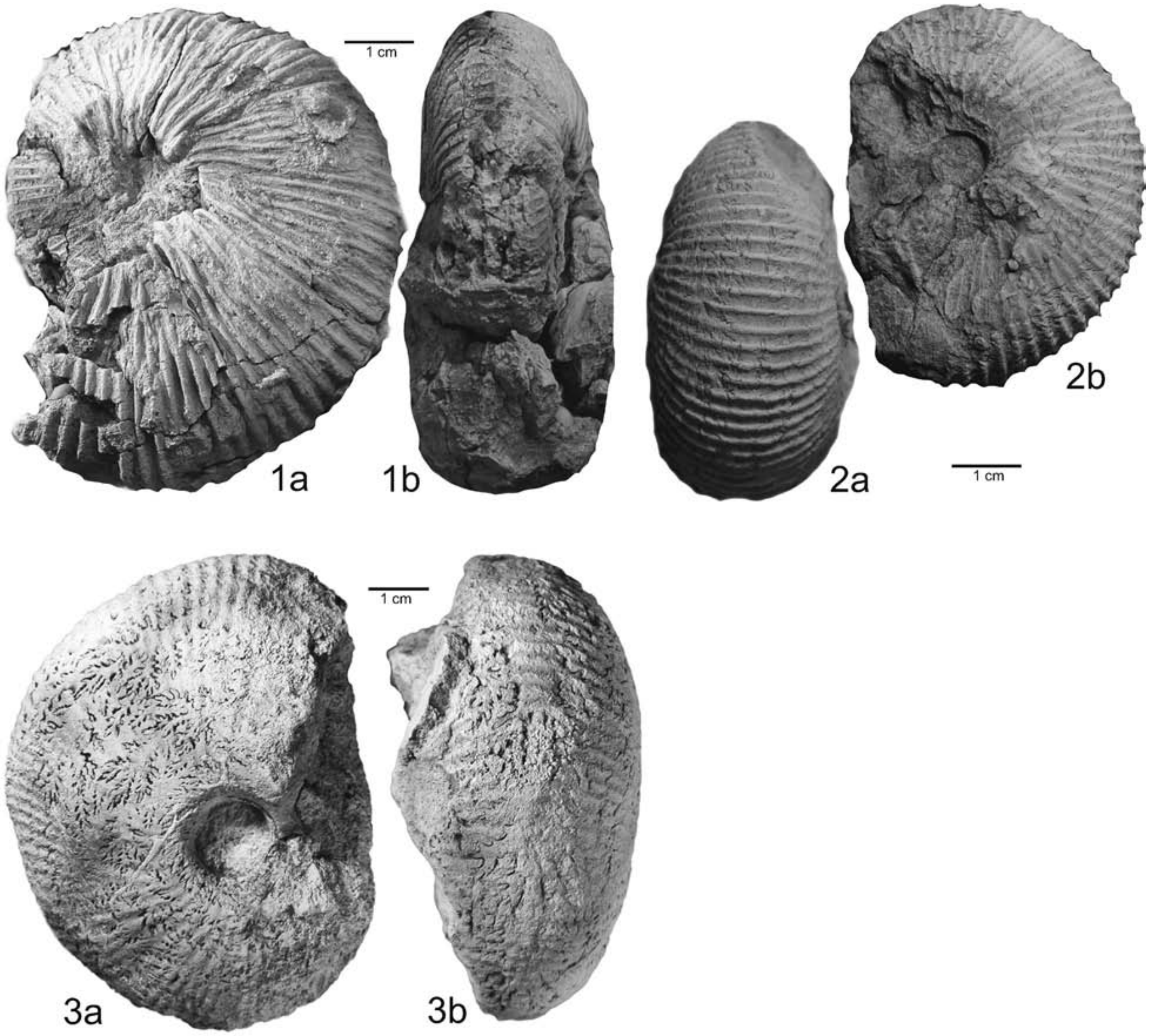

Fig. 6. 1a, b, 2a, b, 3a, b. *Macrocephalites* (*Tmetokephalites*) cf. *verus* Buckman [M]. **1a, b.** BSPG 2013 XXIV 16, from Tabas; **2a, b.** BSPG 2013 XXIV 24, from Talu; **3a, b.** BSPG 2013 XXIV 26, from Talu.

Macrocephalites (*Tmetokephalites*) *jacquoti* (H. Douvillé, 1878) [M]
Fig. 5.1

1846 *Ammonites macrocephalus compressus* Quenstedt, p. 182, pl. 15, fig. 1 [Holotype, figured by Thierry 1978: pl. 27, figs. 1a-b].
*1878 *Ammonites jaquoti* H. Douvillé, p. 570.
1994 *Macrocephalites* (*Macrocephalites*) *jacquoti* (H. Douv.) [M]. – Dietl, p. 13, pl. 2, fig. 4; pl. 3, fig. 1a-b; pl. 4, figs. 1-3; pl. 5, fig. 1.
1998 *Macrocephalites (Macrocephalites) jacquoti* (H. Douv.) [M]. – Dietl & Gygi, p. 250, pl. 3.

Material: More than 40 phragmocones from the Dalichai Fm of Ghoroneh and Chehar Borj (Binalud), from a bed c. 30 m below the first *Reineckeia*.

Dimensions:

	D	U	H	W
D4112	115	-	57	42

Description and Discussion: As the specimens are fragments and inner whorls, it is difficult to recognize the difference between *M. jacquoti* and *M. verus*, but most of the specimens are relatively compressed, indicating a level at the Bathonian-Callovian boundary. One specimen from Dahaneh

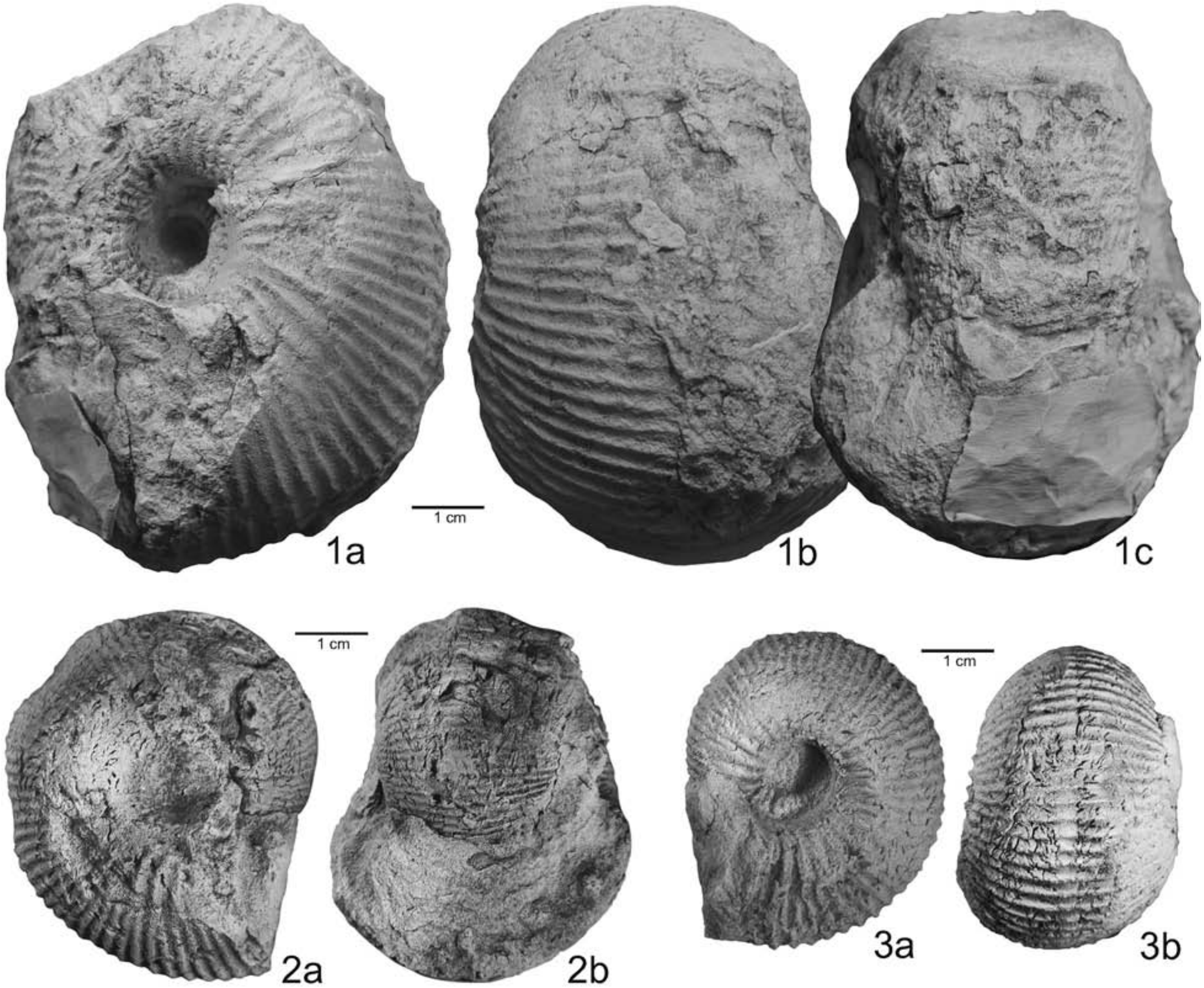

Fig. 7. *Macrocephalites* (*Platystomaceras*) *pila* Nikitin [M], from Talu: **1a-c.** BSPG 2013 XXIV 23; **2a, b.** BSPG 2013 XXIV 27; **3a-c.** BSPG 2013 XXIV 29.

Ojagh section (D 4112; personal number of Raoufian) is a nearly complete macroconch with a diameter of 115 mm. It is very close to *Macrocephalites keeuwensis* α Boehm, 1912 (figured in Thierry 1978, pl. 2 fig. 4a, b).

Age: The type of *M. jacquoti* (H. Douvillé) (= *Am. macrocephalus compressus* Qu.) comes from the Lochenpass in SW-Germany, probably *quenstedti* horizon (Keppleri Subzone). So it is a bit younger than the type of *M. verus* Buckman, which comes from the *keppleri* horizon below. But morphotypes of *M. jaquoti* are more frequent already earlier in the upper Discus Zone of Southern and Northern Germany and Poland (Dietl 1994; Mönnig 2014). It occurs also in the Keppleri Subzone of Switzerland and England and the lower Bullatus Zone of the entire Submediterranean Province (Mangold 1990). Very close, but probably not the same is *M. triangularis* Spath from the Indo-East-African Province with the same age (Krishna & Cariou 1993). The specimen D4112 from Dahaneh Ojagh resembling *Macrocephalites keeuwensis* [M] also could be an indication for Upper Bathonian.

Macrocephalites (*Tmetokephalites*) *verus* Buckman, 1920 [M]

Figs. 5.2, 6.1, 6.2, 6.3

1884 *Macrocephalites macrocephalus* (Schlotheim). – Zittel, p. 470, fig. 655 (neotype).

*1922 *Macrocephalites verus* Buckman, pl. 334A, B.

1971 *Macrocephalites macrocephalus* Zittel 1884 (non Schlotheim). – Callomon, p. 125, text-fig. 3, pl. 17, pl. 18, fig. 1 (neotype).

1995 *Macrocephalites* (*Macrocephalites*) *verus* Buckman. – Mönnig, p. 29, pl. 1, figs. 1-2, pl. 2, figs. 1-2.

2003 *Macrocephalites* cf. *subtrapezinus* (Waagen). – Majidifard, p. 103, pl. 5, fig. 6

Material: 1 specimen with test from the Baghamshah Formation (Tabas area, eastern Central Iran): BSPG 2013 XXIV 16. 3 badly preserved specimens from Talu (Col. Behfar): BSPG 2013 XXIV 24, BSPG 2013 XXIV 26, BSPG 2013 XXIV 28 and 10 small and strongly distorted specimens (unnumbered) from Talu. Two clearly identified macroconchs come from a similar stratigraphic level from the locality Dahane Ojagh (Binalud Range).

Dimensions:

	D	U	H	W
BSPG 2013 XXIV 26	65	15	54	-

Description: The specimen in Fig. 5.2 is an incomplete phragmocone with a diameter over 100 mm. It is slender, involute with high oval to sub-triangular whorl section. The maximum thickness is shortly above the umbilicus. The ribbing is fine, dense, and slightly flexuous and prorsiradiate and bifurcating obscurely within the lower half of the flank. Fig. 6.1 is a fragmentary specimen with much of its test. It is among a collection of ammonites from the Baghamshah Formation north of Tabas (eastern Central Iran), being described by Seyed-Emami et al. (1997) as *M.* cf. *macrocephalus*. It is rather slender with oval whorl cross section and rounded venter. The ribbing is moderately fine, sharp, and rather dense. The primary ribs mostly bifurcate below the mid-flank, with occasional intercalatory ribs. The specimen in Fig. 6.3 is a one-side preserved, inflated phragmocone with D = 65 mm. The ribbing is rather fine and dense. The primary ribs bifurcate about the mid-flank. The umbilicus is moderately wide with rounded shoulder and wall nearly vertical.

Age: The holotype comes from the base of the Callovian, the *keppleri* horizon of Eningen (Swabia). The main distribution of the species is in the lower half of the Herveyi Zone and the Bullatus Zone, but single morphotypes can be found even in higher stratigraphic positions.

M. (*Tmetokephalites*) cf. *madagascariensis* Lemoine, 1910 [M]

cf. 1910 *Macrocephalites macrocephalus* (Schlotheim) *var. noetlingi* Lemoine, p. 31, pl. 3, fig. 3a, b.

*cf. 1910 *Macrocephalites madagascariensis* Lemoine, p. 51.

cf. 1978 *Macrocephalites macrocephalus* (Schlothheim), sous-espèce *subcompressus* (Waagen): dimorphe macroconche [= *Macrocephalites madagascariensis* Lemoine]. – Thierry, p. 253, pl. 18, fig. 1a, b (holotype), pl. 19, figs. 1-4.

1997 *Macrocephalites* cf. *macrocephalus* (Schlotheim, 1813). – Seyed-Emami et al., pl. 3, fig. 1.

Material: 10 more or less complete specimens from Kuh-e-Echelon (Seyed-Emami et al. 1997).

Remarks: This species is very similar to *M. verus*, but much larger (Thierry 1978: 254; Krishna & Cariou 1993: 220). Some complete and full-grown specimens of Kuh-e-Echelon have a diameter of up to 300 mm, while *M. verus* usually is not larger than 200 mm. In the upper part of the Bullatus Zone of Deux-Sèvres occur also large *Macrocephalites* resembling those of Kuh-e-Echelon.

Macrocephalites (*Platystomaceras*) *pila* Nikitin, 1885 [M]
Fig. 7.1-7.3

* 1885 *Macrocephalites pila* Nikitin, p. 50, pl. (8)10, figs. 45, 46.

1988 *Macrocephalites folliformis* (Buckman, 1922). – Westermann & Callomon, p. 73, pl. 15, fig. 1a, b.

1995 *Macrocephalites* (*Platystomaceras*) *folliformis* (Buckman, 1922) [M]. – Mönnig, p. 40, pl. 6, fig. 2a, b, text-fig. 15 a, b, e.

2000 *Macrocephalites pila* Nikitin. – Mitta, pl. 2, fig. 3a, b (= holotype)

2003 *Macrocephalites* (*Dolikephalites*) cf. *perseverans* (Kuhn). – Majidifard, p. 105, pl. 6, fig. 1.

Material: 3 distorted internal moulds from Talu: BSPG 2013 XXIV 23, BSPG 2013 XXIV 27, BSPG 2013 XXIV 29, and ten small and strongly distorted specimens (unnumbered) from Talu; two specimens from the Navia section (Binalud): Q 4112, Q4113.

Dimensions:

	D	U	H	W
BSPG 2013 XXIV 29	43	23	43	~70
BSPG 2013 XXIV 23	66	20	44	80

Description: The specimen in Fig. 7.1 is a strongly depressed and relatively evolute *Macrocephalites* with broad trapezoid (cadicone) whorl cross section. About a third of the last whorl belongs to the body chamber, which begins at a diameter of 65 mm. The umbilicus is wide, deep and crater-like. The umbilical shoulder is rounded and the umbilical wall vertical. The ribbing is moderately coarse, the inner ribs begin somewhere on the umbilical wall and bifurcate around the mid-flank. On the body chamber the ribs become coarser. The specimen in Fig. 7.3 is also a phragmocone with more open umbilicus and slightly coarser ribbing.

Discussion: Regarding the strong depressed whorls, the relatively coarse, bifurcated ribs, our specimens can be closest compared with the holotype of Nikitin (see Mitta 2000, pl. 2, fig. 3a, b). *M. folliformis* Buckman sensu Mönnig (1995, pl. 7, fig. 2) may belong to the same species. Very similar taxa are *M. caucasicus* Djanelidze and *M. rionensis* Djanelidze, all coming from a slightly higher stratigraphic level.

Macrocephalites (*Platystomaceras*) cf. *caucasicus* Djanelidze, 1929 [M]

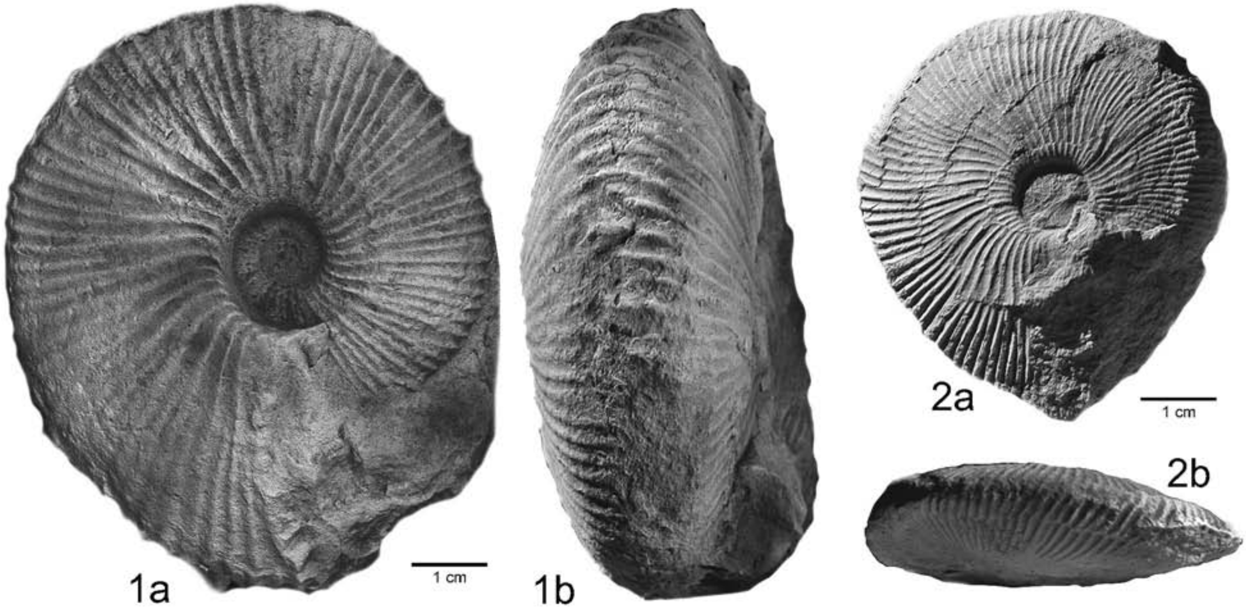

Fig. 8. 1a, b, 2a, b. *Macrocephalites* (*Dolikephalites*) cf. *subcompressus* Waagen [m], from Chaman Bid Fm., Sarakhs road to Mayamey east of Mashhad: **1a, b.** BSPG 2013 XXIV 30. **2a, b.** BSPG 2013 XXIV 31.

* 1929 *Macrocephalites caucasicus* Djanelidze, p. 138.
cf. 1933 *Macrocephalites caucasicus* Djanelidze, p. 26, pl. 7, fig. 3.
1957 *Macrocephalites caucasicus* Djan. – Khimshiashvili, p. 67, pl. 11, figs. 1-2.
1967 *Indocephalites caucasicus* (Djan.). – Lominadze, p. 125, pl. 2, fig. 1.
1997 *Macrocephalites* (*Macrocephalites*) cf. *caucasicus* Djanelidze, 1929. – Seyed-Emami et al., p. 33, pl. 2, fig. 2 (re-figured here), pl. 3, fig. 2.

Material: 13 specimens from Kuhe-Echelon.

Remarks: The holotype of *M. caucasicus* comes from Tsesi, Georgia. The accompanying fauna of the type, including *M. (Pleurocephalites) colchicus* Djanelidze and *Kepplerites rionensis* Djanelidze, indicates upper Herveyi Zone. Thus the fauna of Kuh-e-Echelon should have the same age.

Macrocephalites (*Dolikephalites*) cf. *subcompressus* (Waagen, 1875) [m]
Fig. 8.1, 8.2

* 1875 *Stephanoceras subcompressum* Waagen, pl. 34, fig. 1a, b.
1994 *Macrocephalites* (*Dolikephalites*) sp. nov. [m]. – Dietl, pl. 5, fig. 3a, b.
1997 *Macrocephalites* cf. *subtrapezinus* (Waagen, 1875). – Seyed-Emami et al., p. 33, pl. 2, fig. 2.
1998 *Macrocephalites* (*Dolikephalites*) sp. [m]. – Dietl & Gygi, fig. 3a, b, pl. 4, figs. a, b.
1998 *Macrocephalites* (*Kamptokephalites*) sp. [m]. – Dietl & Gygi, fig. 4a, b.
2012 *Macrocephalites* cf. *compressus* (Quenstedt, 1846). – Seyed-Emami et al. 2013, p. 53, fig. 6e-f.

Material: 2 internal moulds, from the Chaman Bid Formation at Mayamey, on the Sarakhs road, east Mashhad: BSPG 2013 XXIV 30 (Fig. 8.1) and BSPG 2013 XXIV 31 (Fig. 8.2); 2 specimens from Ghoroneh section, (Q5129; personal number of Raoufian) and Chehar Borj section, CB5118 (both Binalud).

Dimensions:

	D	U	H	W
BSPG 2013 XXIV 30	78	20	48	39

Description: The specimen in Fig. 8.1 is a fairly involute *Macrocephalites* with high oval whorl section. The umbilical shoulder is sharp, with subvertical umbilical wall. The beginning of the body chamber is indicated by a slight unco-

Fig. 9. 1a, b, 2a, b, 3a, b. *Macrocephalites* (*Dolikephalites*) *hoyeri* Mönnig [m], from Talu: **1a, b.** BSPG 2013 XXIV 25. **2a, b.** BSPG 2013 XXIV 14. **3a, b.** BSPG 2013 XXIV 17.

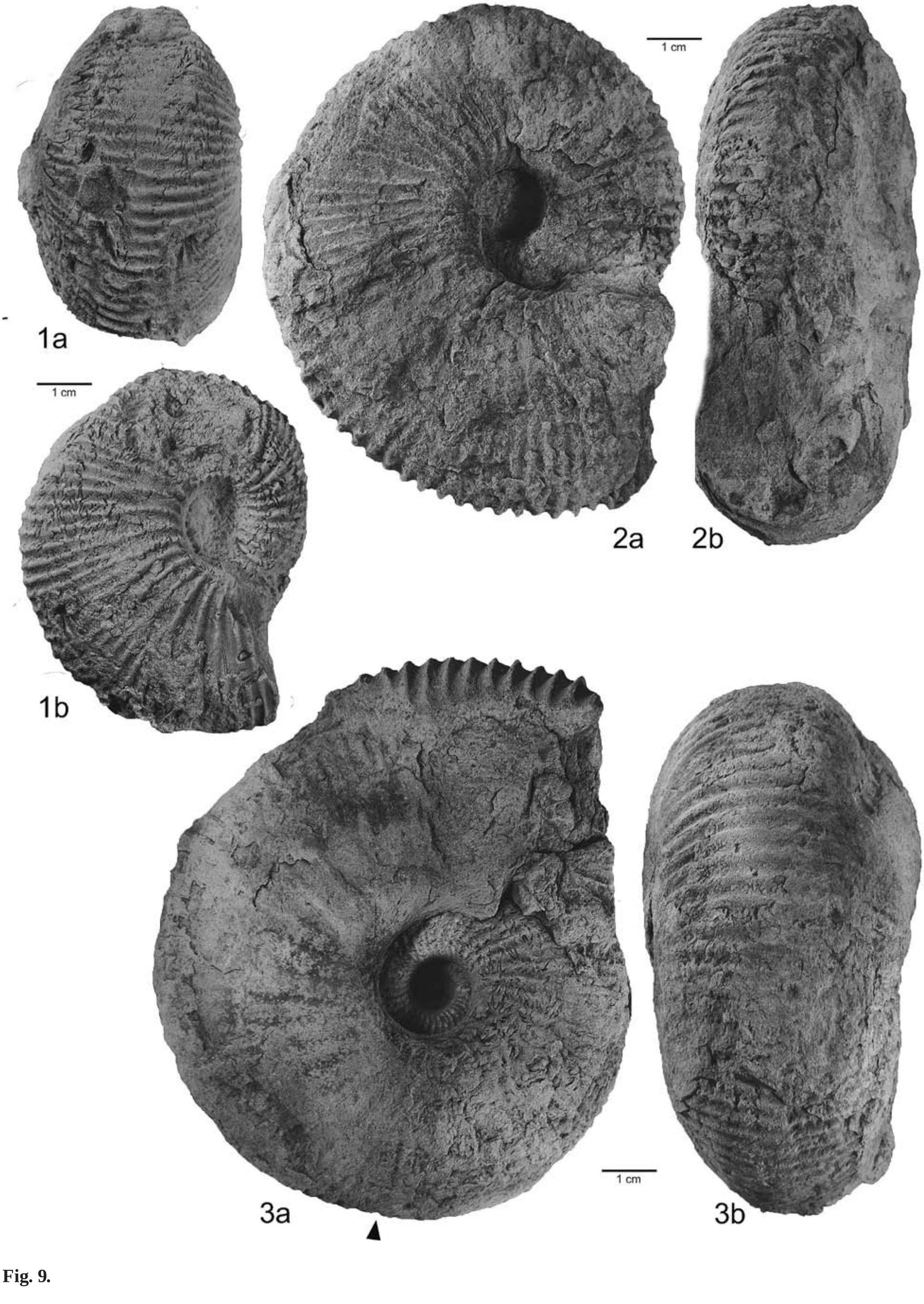

Fig. 9.

iling. The ribbing is prorsiradiate, fairly dense and fine. The slightly coarser primary ribs bifurcate mostly within the inner third of the flank. Additional intercalatory ribs, beginning at the height of the furcation point, are usually present. On the phragmocone at D = 78 mm there are about 33 primary and about 74 secondary ribs per whorl. The specimen in fig. 8.2 is a distorted *Macrocephalites* with a diameter of ca 45 mm. The ribbing is slightly flexuous, very fine and dense. The little prorsiradiate primary ribs bifurcate mostly into slightly rursiradiate secondary ribs.

Remarks: In the Bullatus and Herveyi zones of France and Southern Germany microconchs of *Macrocephalites* are rare, particularly in the Keppleri Subzone. Therefore it lacks in the literature for available names. That is why we compare our specimens with already described species from the Indo-East-African Province.

Macrocephalites (*Dolikephalites*) *hoyeri* Mönnig [m]
Figs. 9.1, 9.2, 9.3, 10.1

*1995 *Macrocephalites* (*Dolikephalites*) *hoyeri* Mönnig, p. 34, pl. 3, fig. 1, pl. 4, fig. 1 (= holotype), figs. 2-3, pl. 5, figs. 1-2.

Material: 7 specimens from Talu: 4 numbered specimens BSPG 2013 XXIV 14, 15, 17 and 25 and 3 unnumbered specimens from Talu.

Dimensions:

	D	U	H	W
BSPG 2013 XXIV 14	72	17	51	-
BSPG 2013 XXIV 17	80	19	50	-
BSPG 2013 XXIV 25	60	18	47	63

Description: The specimen Fig. 9.3 is a moderately depressed, rather involute *Macrocephalites* with D = 97 mm. About the 1/3 of the last whorl belongs to the body chamber, which begins at D ~ 70 mm. A distinct uncoiling indicates the specimen is adult. The umbilical shoulder is rounded the umbilical wall steep to vertical. The ribbing on the phragmocone is moderately fine and mostly biplicate, seldom triplicate or with intercalatory ribs. On the body chamber the ribbing becomes coarser. At the umbilical shoulder the ribs are slightly rursiradiate but become slightly prorsiradiate on the flank. The specimen in Fig. 9.2 has a diameter of ca 88 mm and includes seemingly a portion of the body chamber, which begins at 72 mm, being indicated by a clear uncoiling. The ornamentation is similar to the former specimen, but a little coarser. The specimen in Fig. 10.1 is a phragmocone with a diameter over 110 mm. It is semi-compressed, little involute with oval whorl cross section and fairly rounded venter. The ribbing is rather fine, dense and sharp. The primary ribs are slightly concave and prorsiradiate and mostly bifurcate near the mid-flank.

Discussion: *Macrocephalites* (*Dolikephalites*) *hoyeri* Mönnig is less compressed (W/H = 1.12) than *M. subcompressus* Waagen (W/H = 1). Thick specimens are very close to *M. (Dolikephalites) lamellosus* (Sowerby).

Age: After Mönnig (1995) upper Keppleri Subzone to Lower Terebratus Subzone of the Lower Callovian, what is equivalent to about the middle part of Bullatus Zone.

Ma*crocephalites* (*Dolikephalites*) *lamellosus* (J. de C. Sowerby, 1844) [m]
Fig. 10.3

*1840 *Ammonites lamellosus* J. de C. Sowerby, pl. 23, fig. 8.

1987 *Macrocephalites lamellosus* (Sowerby) □. – Krishna & Westermann, pl. 2, fig. 1 (cast of the holotype).

Material: 1 distorted internal mould from Golbini, north Jajarm: BSPG 2013 XXIV 32.

Dimensions:

	D	U	H	W
BSPG 2013 XXIV 32	ca 108	ca 22	ca 45	ca 42

Description: Rather evolute *Macrocephalites*, with an oval, slightly higher than wide whorl section. The ribbing is rather coarse and slightly flexuous. The slightly concave primary ribs bifurcate around the mid-flank.

Discussion: The holotype of *Macrocephalites lamellosus* (J. de C. Sowerby) comes from the "Upper Golden Oolite" of Kachchh (Lower Chari Formation, Kera Dome), but the exact level is unknown. Jeannet (1955) and Thierry (1978) attribute this species to the Lower-/Middle Callovian boundary. Krishna & Westermann (1987) consider *M. lamellosus* as the microconch of *M. madagascariensis* and put it in the higher Bullatus Zone, which is probably more likely.

Macrocephalites (*Pleurocephalites*) sp. [m]
Figs. 10.2, 10.4, 11.1, 11.2, 11.3

2003 *Macrocephalites* (*Kamptokephalites*) cf. *kamptus* (Buckman). – Majidifard, p. 102, pl. 5, fig. 5.

Fig. 10. 1a, b. *Macrocephalites* (*Dolikephalites*) cf. *hoyeri* Mönnig [m], BSPG 2013 XXIV 15 from Talu. **2a, b.** *M.* (*Pleurocephalites*) sp. [m], BSPG 2013 XXIV 19, from Talu. **3a, b.** *M.* (*Dolikephalites*) *lamellosus* Sowerby [m], BSPG 2013 XXIV 32, from Golbini, north of Jajarm. **4a, b.** *M.* (*Pleurocephalites*) sp. [m], BSPG 2013 XXIV 18, from Talu.

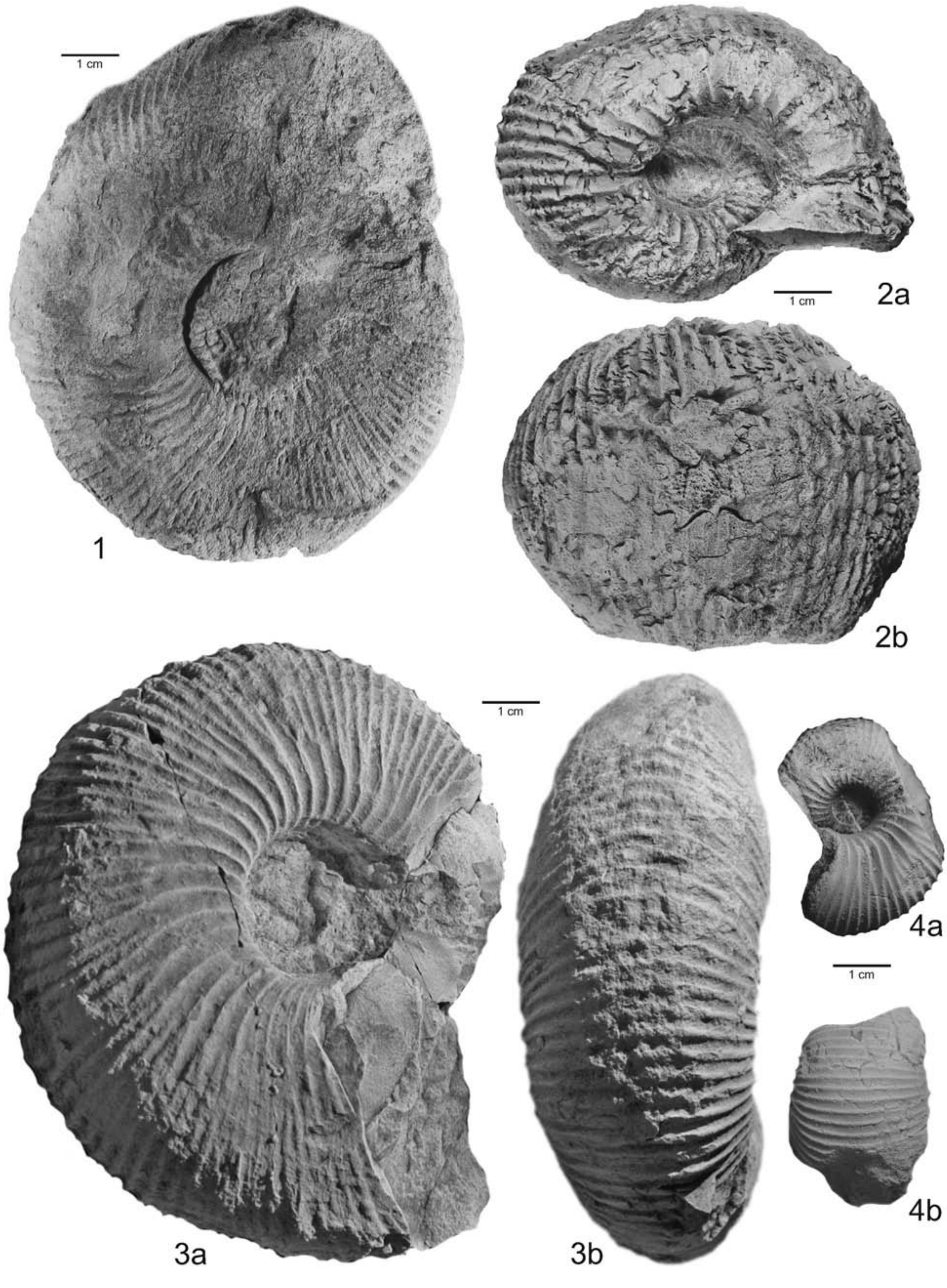

Fig. 10.

Material: 5 specimens: 2 specimens from Talu: BSPG 2013 XXIV 18 and BSPG 2013 XXIV 19; 3 specimens from Kuh-e-Echelon: BSPG 2013 XXIV 20 (E-14), BSPG 2013 XXIV 21 (E-15) and BSPG 2013 XXIV 22 (E-16/1).

Dimensions:

	D	U	H	W
BSPG 2013 XXIV 18	19	46	ca 73	-

Description: The specimen in Fig. 10.4 is a nucleus with *D* = 45 mm. It is depressed with broad oval whorls and a broad, rounded venter. The ribbing is up to *D* = 30 mm rather fine, becoming coarser towards the outermost whorl. The concave, prorsiradiate primary ribs faintly rise on the umbilical wall and bifurcate in the lower half of the flank. Umbilicus is deep with rounded shoulder and vertical wall. The specimen Fig. 11.3 is a crushed phagmocone, evolute and inflated (*W/H* >2). At a diameter of 50 mm there are 29 primary ribs per whorl.

Specimens from the Baghamshah Formation at Kuh-e-Echelon (Tabas): The Macrocephalitinae from Kuh-e-Echelon have already been partly studied by Seyed-Emami et al. (1997). Some specimens from that collection are described in following. The specimen in Fig. 11.2 is a distorted phragmocone with test, *D* = 60 mm. It is depressed and rather evolute with broad-oval, cadicone whorl section and steep umbilical wall. The slightly concave and prorsiradiate primary ribs begin at the seam. Shortly above the umbilical shoulder they furcate in two or three secondary ribs, crossing the rounded venter. The ribbing of the inner whorls is rather dense and fine, becoming coarser towards the outer whorl. The specimen in Fig. 11.1 is a phragmocone with test. It is depressed with broad cadicone whorl section. Contrary to the other specimens from Kuh-e-Echelon the coarsening of the ribs takes place much earlier. The specimen in Fig. 11.3 is a rather depressed and fairly evolute nucleus with broad-oval whorl section. The ribbing is relatively fine and dense, and bifurcates often within the inner flank near the umbilicus. The umbilical shoulder is rounded and the umbilical wall nearly vertical.

Age: Evolute and compressed microconchs of *Pleurocephalites* occur from the Upper Bathonian, but become frequent in the upper Bullatus or Herveyi zones and mainly in the Prahequense Subzone of the Submediterranean Province. *Pleurocephalites* is also a typical component of the macrocephalitid faunas of the Elephantinus, Chrysoolithicus and Diadematus zones of the Indo-East-African Province. The macrocephalitids of the lower half of the Herveyi/Bullatus zones have usually been assigned to *M. lophopleurus* Buckman or "*Kamptokephalites*" (Mönnig 1995; Callomon et al. 1989; Majidifard 2003).

Macrocephalites (*Pleurocephalites*) *cossmanni* Petitclerc, 1915
Fig. 11.4, 11.5

cf. 1840 *Ammonites elephantinus* Sowerby, p. 329, pl. 23, fig. 6.
* 1915 *Macrocephalites cossmanni* Petitclerc, p. 43, pl. 2, fig. 6.
cf. 1922 *Pleurocephalites lophopleurus* Buckman, pl. 284.
cf. 1929 *Macrocephalites colchicus* Djanelidze, p. 64, pl. 10, figs. 1-2.
cf. 1958 *Kamptokephalites amboromihantensis* Collignon, pl. 19, fig. 82.
2014 *Macrocephalites* cf. *tumidus* (Reinecke, 1818). – Parent et al., p. 18, pl. 3, fig. 6.

Material: 4 specimens: 1 internal mould from Fraizi, west of Mashhad (BSPG 2013 XXIV 33), 1 poorly preserved specimen from Talu, 1 specimen from Baghi, Binalud Range (Q5-26) and 1 specimen from Golbini, north of Jajarm (BSPG 2013 XXIV 33).

Dimensions:

	D	U	H	W
BSPG 2013 XXIV 33	108	31	41	63
Q5-26	76	30	43	72

Description: Strongly depressed *Macrocephalites* with a broad, whorl section and a deeply steepening umbilical wall. The ribbing is coarse, slightly prorsiradiate and flexuous. The primary ribs bifurcate, almost regularly, within the inner flank, without additional intercalate ribs.

Discussion: Microconchs of *Pleurocephalites* are highly variable, as can be seen in the fauna of Chippenham, UK (see Buckman 1922; Page 1988, from the *metorchus* horizon, base of Koenigi Zone). Isolated specimens like that of Fraizi or Bahgi can be merely compared with similar morphotypes, but with no implications for time-correlation. Due to its dense ribbing resembles *M. cossmanni* Petitclerc or *M. lophopleurus* Buckman. *M. colchicus* Djanelidze has fewer primary ribs, *M. elephantinus* Sowerby has a coarser ribbing.

Age: All species in the above synonymy list are typical of a level corresponding to the Prahecquense Subzone of the Submediterranean Province. The specimens from Talu and Bahgi come from a layer between the beds with rich *Macrocephalites* fauna and the first Reineckeids, which just indicates a level of this Subzone.

Fig. 11. 1a, b, 2a, b, 3a, b. *Macrocephalites* (*Pleurocephalites*) sp. [m], all from Kuh-e-Echelon, Tabas: **1a, b.** BSPG 2013 XXIV 20. **2a-c.** BSPG 2013 XXIV 21. **3a-c.** *M.* (*Pleurocephalites*) sp. [m], BSPG 2013 XXIV 22. **4a, b.** *M.* (*Pleurocephalites*) *cossmanni* Petitclerc [m] from Baghi, Binalud Range, 1 m above the main bed with *Macrocephalites*. **5a, b.** *M.* (*Pleurocephalites*) *cossmanni* Petitclerc [m], BSPG 2013 XXIV 33, from Fraizi, west of Mashhad.

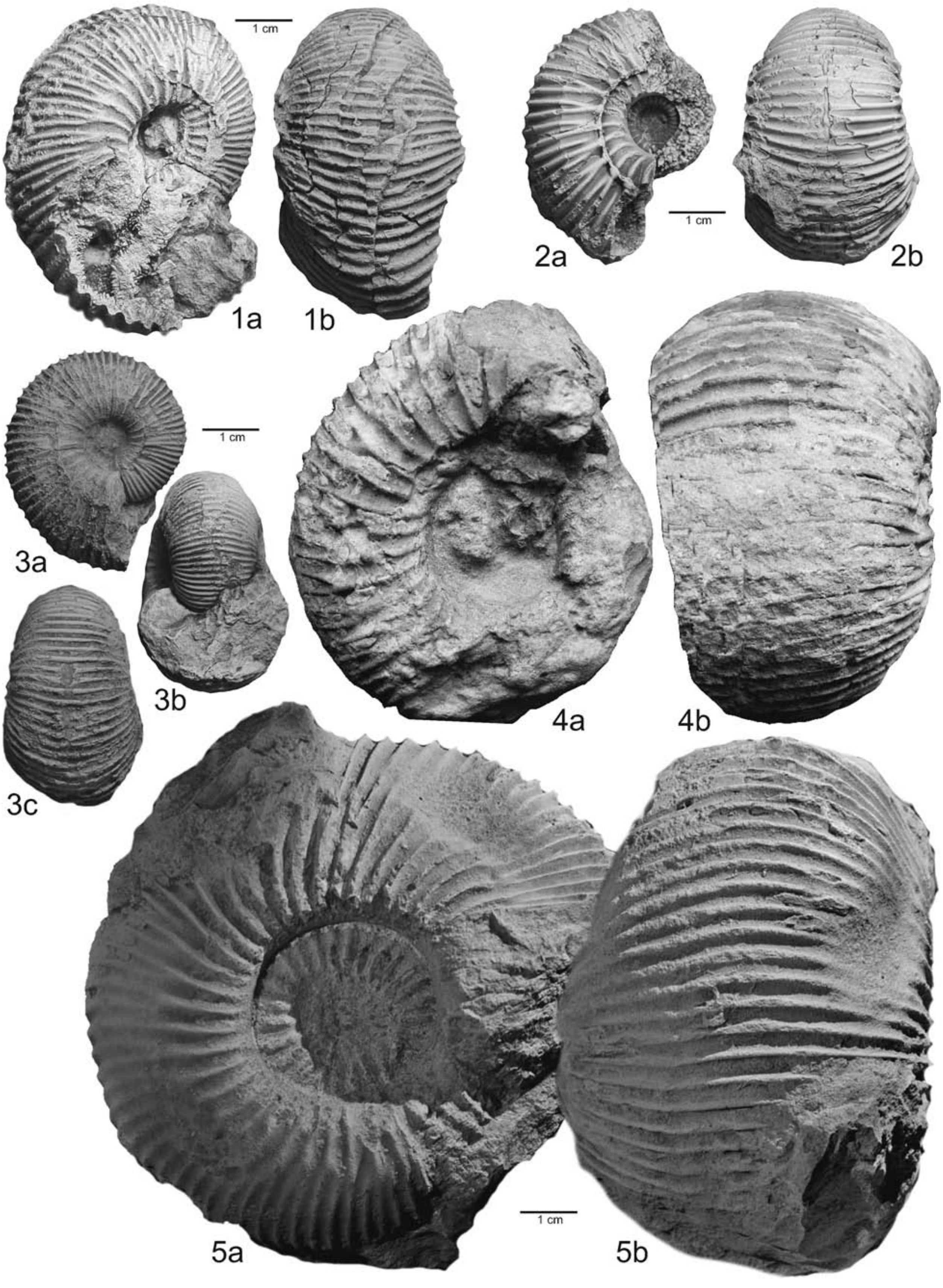

Fig. 11.

4. Ages and correlations

Before correlating the *Macrocephalites* assemblages of Iran with the standard zones and subzones of the Bathonian and Callovian stages, it is essential to clarify the palaeobiogeographic setting. Ammonites as many other organisms may be limited geographically to certain areas, and faunas may be clearly different from those in other faunal provinces.

In the upper part of the Middle Jurassic, we can distinguish the following areas and provinces (modified after Thierry 1988; Westermann & Callomon 1988; Krishna & Cariou 1990, 1993; Page 2008):

Boreal Province: Honshu, Canada, Alaska, Greenland, Svalbard, Siberia, Russian Platform.

Subboreal Province: England, NE France, Germany, Poland, Caucasus, Turkmenistan.

Submediterranean Province: Portugal, Spain, S France, the Balkans, Iran.

Mediterranean Province: Algarve, Betic Range, Algeria, Sicily, Western Pontides.

Indo-East-African Province: Ethiopia, Madagascar, India.

Eastern Tethys areas: Maorian/SW Pacific, E-Pacific.

The assignment of Iran to the Submediterranean Province needs some explanation. Concerning the ammonite faunas, the differences between the Submediterranean and the Subboreal provinces are very small in the Middle and Late Bathonian. Therefore, it has been proposed to combine the corresponding standard zones (Page & Melendez 2000). Moreover, it is not clear which ammonites are typical Subboreal or typical Submediterranean. Oppeliids and Pseudoperisphinctids are common on both sides and there are only differences in the accompanying fauna. At least *Prohectioceras* seems to be typical of the Submediterranean Province. This genus also occurs in the Upper Bathonian of Iran, however, it is rare (Seyed-Emami et al. 1991, 2001).

The above-cited authors emphasize the evident European affinity of the Bathonian Iranian faunas, but made no commitment on the two standard zonations. Nevertheless because of the few phylloceratids we can rule out an assignment to the Mediterranean Province. At the beginning of the Callovian the conditions are still very similar to those of the Late Bathonian, though the Mediterranean phylloceratids penetrated further into the Submediterranean area, including Iran (Seyed-Emami et al. 2013).

To the end of the Bathonian and the beginning of the Callovian, *Macrocephalites* and *Homoeoplanulites* became the most common ammonites in the Subboreal and the Submediterranean provinces. In some areas, or horizons, *Bullatimorphites*, *Kepplerites* and *Cadoceras* can be frequent. During the Herveyi (or Bullatus) Zone there are signs of provincialism, which reached its peak in the Koenigi Zone (~ lower half of the Gracilis Zone). This leads to a clear separation of the Subboreal and the Submediterranean faunal provinces. Thus we have in the Gracilis Zone for the first time predominantly reineckeiids, while in Subboreal Province beside of *Homoeoplanulites* and *Macrocephalites*, being still frequent, *Proplanulites* and *Kepplerites* become common. Thus, we can clearly assign Iran to the Submediterranean Province during the Early Callovian.

Below, we have composed a sequence of ammonite assemblages from the Alborz, Binalud Mountains (North Iran), and Tabas area (east Central Iran). The faunal assemblages from bottom to top are:

Bremeri and Retrocostatum zones (upper Middle to lower Upper Bathonian)

Assemblage of Tabas-Nayband (east Central Iran) (Fig. 2): The Retrocostatum Zone is documented by rich ammonite collections from Tabas-Nayband area (Seyed-Emami et al. 1991; 1998a, b). As in Central Europe the fauna mainly consists of *Oxycerites*, *Paroecotraustes*, *Procerites*, *Homoeoplanulites* and *Bullatimorphites*. In Kamar-e-Mehdi area (Fig. 2.12) particularly the upper Retrocostatum Zone (Hannoveranus/Histricoides Subzone) is well documented, but there is no evidence of the presence of *Macrocephalites*. Not quite clear are the conditions in India. After Pandey &Westermann (1988) and Krishna & Cariou (1993) *Macrocephalites* does not occur at a level of the Submediterranean Bremeri Zone, but in recent times Roy et al. (2007) and Jain (2014) described a *Macrocephalites* fauna from Jumara (Kachchh), which is associated with *Procerites* and which is consequently younger as the *triangularis* fauna of the Upper Bathonian. In Europe, the first *Macrocephalites* occurs in Southern Germany at the top of the Orbis-Zone (Dietl 1981; Dietl & Callomon 1988).

Discus Zone (topmost Bathonian)

Assemblage of Khorow-Pain (Central Iran) (Fig. 2.11): The Discus Zone is indicated by a collection from the Parvadeh Formation of Khorow-Pain in the Shotori Mountains, east of Tabas. Beside *Clydoniceras* (3 specimens), there are *Homoeoplanulites (Parachoffatia)* sp. (5), *H.* (*Homoeoplanulites*) sp. (2), *Bullatimorphites* (M & m) and *Phylloceras* (2). But *Macrocephalites* seems to be absent, as well as in other parts of the Submediterranean Province (Cariou et al. 1988). However, this classification is not quite sure, because in the Submediterrenean Province *Clydoniceras* already occurs in the higher Retrocostatum Zone (Mangold & Rioult 1997), and in India even deeper (Singh et al. 1983).

Bullatus Zone (Lower Callovian)

Assemblage of Ghoroneh (Binalud Mountains, NE Iran) (Fig. 1.6): From the lower Dalichai Formation of Ghoroneh come 46 undescribed specimens of *Macrocephalites*. Unfortunately these are either fragments or not studied material. Moreover most of the fossils are inner whorls coming from a level about 70 m below the first Reineckeiids. In addition there are fragments of *Phylloceras*, *Homoeoplanulites* and *Alcidellus* cf. *subdiscus*. One of the macrocephalitid microconchs of Ghoroneh is well preserved and more or less complete with the phragmocone. Noticeable features are the sharp edge of the umbilicus and the dense ribbing with nearly 50 primary ribs per whorl at a diameter of 60 mm. A similar specimen comes from Chehar Borj (Fig. 1.4), but there are also others with only 35 primary ribs per whorl. At the locality Dahaneh Ojagh (Fig. 1.5) come from a similar stratigraphic level two relatively compressed macroconchs (Fig. 5.1), which are very close to *Macrocephalites keeuwensis* α Boehm, 1912 (figured in Thierry 1978, pl. 2 fig. 4a, b). These data indicate some level around the Bathonian-Callovian boundary. Similar *Macrocephalites* assemblages are known from the Discus and Keppleri Subzones of Southern Germany (Callomon et al. 1989; Dietl 1994) and the lower Bullatus Zone of Western France and Portugal (Cariou 1984; Cariou et al. 1988). Here most of the macroconchs resemble the type of *M. jaquoti* Douvillé (= *Am. macrocephalus compressus* Qu.). The *triangularis* fauna sensu Krishna & Cariou (1993) of the Indo-East-African Province also shows some of these features. But the material from the Binalud Mountains is poorly preserved and the important Genera *Kepplerites* and *Cadoceras* are absent. So our stratigraphical classification remains uncertain.

Assemblage of Mayamey (Fig. 1.9), E of Mashhad: The two figured microconch macrocephalitids (Fig. 8.1, 8.2) from the Chaman Bid Formation are very compressed and have a dense ribbing that is typical of the representatives of the lower Bullatus Zone. The accompanying fauna consists of *Homoeoplanulites*.

Solitary specimen from Tazareh coal mine, NE of Dāmghān: This specimen was already described and figured by Seyed-Emami et al. (2013, fig. 6e, f) as *Macrocephalites* cf. *compressus* (Quenstedt, 1846). It is a very large ($D > 130$ mm) compressed and densely ribbed microconch (about 55 primaries on the last preserved whorl). The specimen fits to *Macrocephalites subcompressus* (Waagen) sensu Thierry (1978). This author interpreted such morphotype as microconch of *M. madagascariensis* and assigned it to the Rehmanni-/Laugieri zones. Neverthless according to Krishna & Westermann (1987) the stratigraphic position of *M. subcompressus* is in the lower Bullatus Zone.

Assemblage of Talu (Dāmghān, E Alborz; Fig. 1): This fauna consists almost entirely of *Macrocephalites*. Most of the specimens are much thicker than those from the Binalud Mountains. According to Krishna & Cariou (1993), the representatives of *Macrocephalites* become more and more inflated from Late Bathonian to the Prahecquense Subzone. The same is also applicable to the Subboreal Province (Callomon et al. 1989; Mönnig 1995). At a rough estimate on the macrocephalitinae from Iran, the fauna of Talu would be younger than that of Ghoroneh, but older than that of Kuh-e-Echelon, which will be described further below. Three microconchs (Fig. 9) are well preserved and can be compared with morphotypes from other areas. At half whorl of the body chamber the specimens are about 100 to 110 mm in diameter, the number of primary ribs per whorl is 35-40. In the Subboreal Province such microconchs are typical of the middle part of the Herveyi-Zone. Mönnig (1995) described similar species from Northern Germany as *M.* (*Dolikephalites*) *hoyeri*. For this level also must be considered a densely ribbed macroconch. The corresponding macroconch is *M. verus* (Fig. 5.2). The compressed specimens seem to be more frequent than in the horizons below and are determined as *M.* (*Platystomaceras*) *pila* Nikitin. Another specimen from this locality (Fig. 10.2) is very inflated and evolute, and could be assigned to the subgenus *Pleurocephalites*. Most likely the subgenus *Platystomaceras* Corroy includes the corresponding macroconchs. It should be mentioned that in the Subboreal Province *Macrocephalites* also provides over 80 % of the fauna of the upper part of the Herveyi Zone (Mönnig 1995). The accompanying fauna is not very significant. *Bullatimorphites* (*Bomburites*) *microstoma* is ubiquitous, ranging from the lower Retrocostatum Zone to the upper Bullatus Zone. In addition there are a few *Parachoffatia* and *Lytoceras*.

Possibly the specimens figured by Majidifard (2003, pl. 5, figs. 3a, b, 5, 6, pl. 6, fig. 1) also belong to the middle Bullatus Zone. They come from the locality Tooy (ca 30 km E of Jajarm) and occur here together with *Bullatimorphites* and *Subgrossouvria*, just below the first reineckeiids (Majidifard 2003, Table 2.3.).

Difficult to interpret are some inflate specimens from an outcrop near Navia (Binalud) (Fig. 1.3). These specimens have usually been determined as "*M.* (cf. or aff.) *folliformis*" and virtually occur in all horizons with *Macrocephalites*.

Assemblage of Kuh-e-Echelon (Fig. 2.8, NW Tabas, Central Iran): This collection comes from the Baghamshah Formation of Kuh-e-Echelon and has already been described by Seyed-Emami et al. (1997). It mostly consists of inner whorls of *Macrocephalites* and *Homoeoplanulites*. Within the accompanying fauna besides *Alcidellus subdiscus* also few specimens of *Subgrossouvria*, *Cadomites*, *Bullatimorphites* and a single *Phylloceras* was recorded. There are about ten very large specimens of *Macrocephalites* cf./aff. *verus* with a diameter up to 300 mm. The neotype of *M. verus* comes from the *keppleri* horizon of Eningen unter Achalm near Reutlingen (SW-Germany), at the base of the Callovian. But the species can be found throughout the entire Bullatus Zone, and single specimens even higher. However, large specimens resembling *Macrocephalites verus* are only common in the upper Bullatus Zone of the Submediterranean Province, like *M. madagascariensis* in the Indo-East-African Province. This is an indication that the fauna of Kuh-e- Echelon belongs to a high part of the Bullatus Zone. Another indication are thicker specimens of *Macrocephalites*, determined as *M.* cf. *caucasicus* Djanelidze by Seyed-Emani et al. (1997, pl. 3, fig. 2). The holotype of *M. caucasicus* comes from the upper Herveyi Zone of Tsesi (Caucasus). At this level *Bullatimorphites* is still relatively large, as in the Kuh-e-Echelon assemblage. The *Choffatia* (subgenus *Subgrossouvria*) described by Seyed-Emami et al. (1997, pl. 2, Fig. 3) also comes from this level. Final clarity gives the undescribed *Cadomites* in the collection. The three specimens of *Cadomites* are much

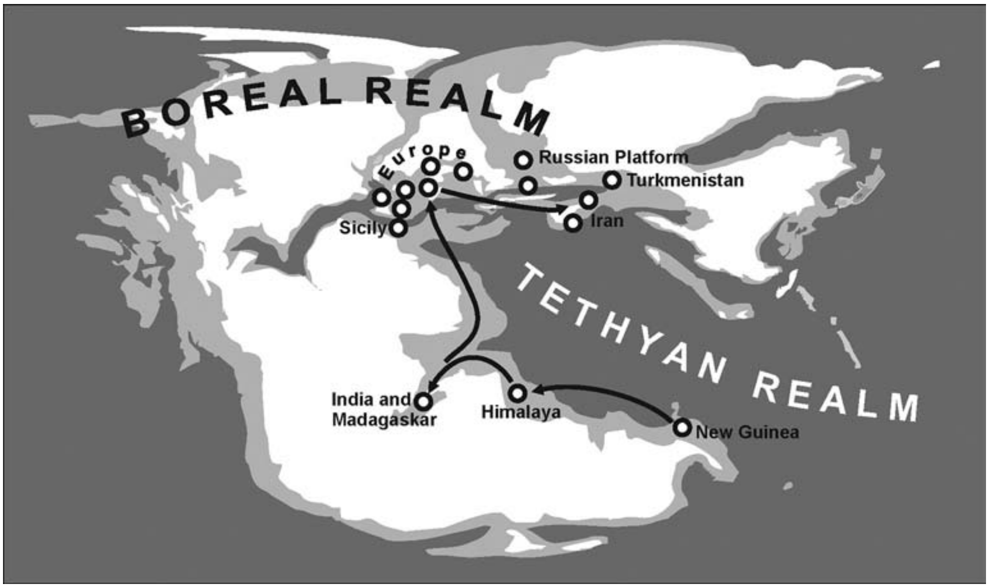

Fig. 12. Late Bathonian and Early Callovian palaeogeography and distribution of *Macrocephalites.* This ammonite genus reached Southern Germany in the Orbis Zone (Upper Bathonian). From here, it spread over the northern edge of the Tethys Ocean (map modified after Thierry 2000 and Wilmsen et al. 2010).

smaller than those of the Keppleri Subzone of Southern Germany and Switzerland, and have a much denser ribbing. So they resemble *Cadomites westfalicus* Mönnig & Beginski, a species of the Koenigi Zone of Northern Germany. In summary there are a lot of evidences that the assemblage of Kuh-e-Echelon belongs to a level in the upper Bullatus Zone, or lower Prahecquense Subzone. In the Subboreal Province this level could be correlated with the upper Herveyi Zone (Kamptus Subzone).

Probably the single *M. lamellosus* from Golbini, north of Jajarm (Fig. 10.3) also belongs to this level.

Gracilis Zone, Prahecquense Subzone (lowest Lower Callovan)

Stray finds from Golbini north of Jajarm, Fraizi (west of Mashhad), Talu (N of Dāmghān, East Alborz) und Baghi (Binalud Mountains):

In the upper part of the Dalichai Formation of Golbini (Kuh-e-Ozom, N of Jajarm), there is a package of three limestone benches. From the top bank comes a single *Macrocephalites*. It is an inflated microconch of the subgenus *Pleurocephalites*. The specimen has, at a diameter of 76 mm, more than 40 primary ribs per whorl, thus resembling *Macrocephalites cossmanni* Petitclerc. In the Submediterranean Province the species is typical of the Prahecquense Subzone (Cariou 1984). This would fit well, because immediately above the bench with *Macrocephalites* follow marls and limestones with reineckeiids and hecticoceratiids that already belong to the higher Gracilis Zone. The presence of the Prahecquense Zone in Golbini is also indicated by the find of *B. (Kheraiceras) prahecquense* from the same level (Majidifard 2003: pl. 5, fig. 2a, b, Golbini section, at 214 m).

Another typical *Pleurocephalites* comes from Fraizi, W of Mashhad (Fig. 11.5). The specimen has a diameter of 110 mm and a wide section, almost twice the height. In the Subboreal Province such morphotypes are typical of the lower Koenigi Zone, which correlates with the Prahecquense Subzone. The corresponding taxon in the Indo-East-African Province would be *M. elephantinus* Spath. Another specimen of *M. (Pleurocephalites) cossmanni* (morphotype *elephantinus* Spath) comes from Baghi (Binalud Mountains) (Fig. 11.4). A fragmentary specimen from Talu (not figured) probably also belongs to this species.

Gracilis Zone, Grossouvrei, Pictava and Laugieri subzones (middle Lower Callovian)

The fauna of the middle part of the Gracilis Zone of Iran mainly consists of reineckeiids. Besides *Hecticoceras* the first indosphinctids appear. In Iran *Macrocephalites* has not been recorded yet from these subzones.

Gracilis Zone, Michalskii Subzone (upper Lower Callovian)

Stray find of Kelariz: In Iran, the ammonite fauna of the upper Gracilis Zone mainly consists of hecticoceratids. *Choffa-*

tia and *Indosphinctes* also occur, but are not as frequent as in SW Europe. Seemingly *Macrocephalites gracilis* is missing in Iran. Typical taxa of this zone would be *Macrocephalites dicosmum* (Gemmellaro), *M. gracilis* (Spath) and *M. cannizaroi* (Gemmelaro) – all of them synonyms of *M. compressus* (Quenstedt) sensu Thierry (1978). These species are typical of the Michalskii Subzone. In Iran, the only *Macrocephalites* from this level comes from Kelariz (north Dāmghān). It is a single small nucleus, found together with numerous hectioceratiids.

Patina Subzone und lower Anceps Zone (Lower to Middle Callovian boundary)

There is no evidence of *Macrocephalites* in this stratigraphic level in Iran.

5. Conclusions

This study provides for the first time a number of new data concerning the occurrence of the genus *Macrocephalites* in Iran. The new material seems to fit the biostratigraphy and palaeogeography of *Macrocephalites* in Late Bathonian and Early Callovian of Europe and India in general (Fig. 12).

The main occurrence of *Macrocephalites* in Iran seems to be restricted to the Bullatus Zone and the Prahecquense Subzone of the Gracilis Zone. There is no clear evidence of *Macrocephalites* in the higher Discus Zone (uppermost Bathonian). This level is not clearly identifiable, because of the absence of *Cadoceras* and *Kepplerites* in the Submediterranean Province. In the Subboreal Province *Macrocephalites* reaches up to the Medea Subzone (Middle Callovian), but in Iran it disappears in the lower Gracilis Zone, where reineckeiids and oppeliids prevail. So we have similar conditions as in the southern Submediterranean Province.

In Iran the known successions of the Upper Bathonian and Lower Callovian show rather few ammonite horizons. The sequence of ammonite assemblages shown in Table 1 is only a tentative preview. It will be improved in the next future. For this purpose more fossils have to be collected bed-by-bed.

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