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The lower and middle Berriasian in Central Tunisia: Integrated ammonite and calpionellid biostratigraphy of the Sidi Kralif Formation

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ABSTRACT :

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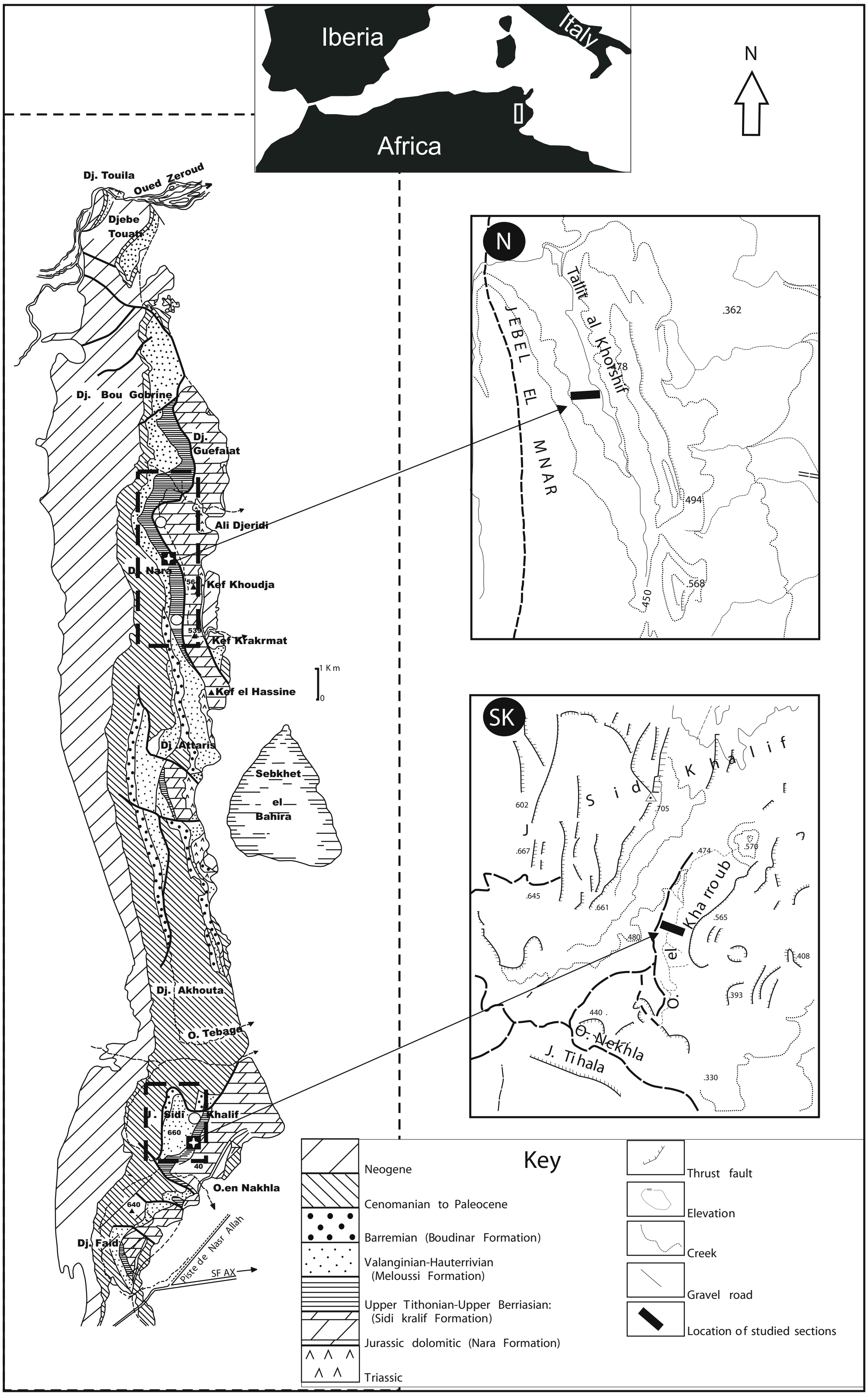
The lower and middle Berriasian sedimentary succession of the Sidi Kralif Formation has been a subject of biostratigraphic study in two key sections in Central Tunisia. Our contribution is an attempt to better define the basal Berriasian interval, between the *Berriasella jacobi* Zone and the *Subthurmannia occitanica* Zone. Zonal schemes are established using ammonites and calpionellids, and these permit correlation with other regions of Mediterranean Tethys and beyond. The use of biomarkers afforded by microfossil groups has allowed characterization and direct correlation with four widely accepted calpionellid sub-zones, namely *Calpionella alpina, Remaniella, Calpionella elliptica* and *Tintinopsella longa*. The two ammonite zones of *Berriasella jacobi* and of *Subthurmannia occitanica* are recognised on the basis of their index species. The parallel ammonite and calpionellid zonations are useful as a tool for correlation and calibration in time and space, thus allowing a better definition of a J/K boundary. The presence of four Berriasian calpionellid bioevents is recognised: (1) the 'explosion' of *Calpionella alpina*, (2) the first occurrence of *Remaniella,* (3) the first occurrence of *Calpionella elliptica* and (4) the first occurrence of *Tintinopsella longa*. The last is here documented as coeval with the presence of *Subthurmannia occitanica,* which marks the lower/middle Berriasian boundary.

Key words: Ammonite; Calpionellids; Berriasian; Bioevents; Biostratigraphy; Tunisia.

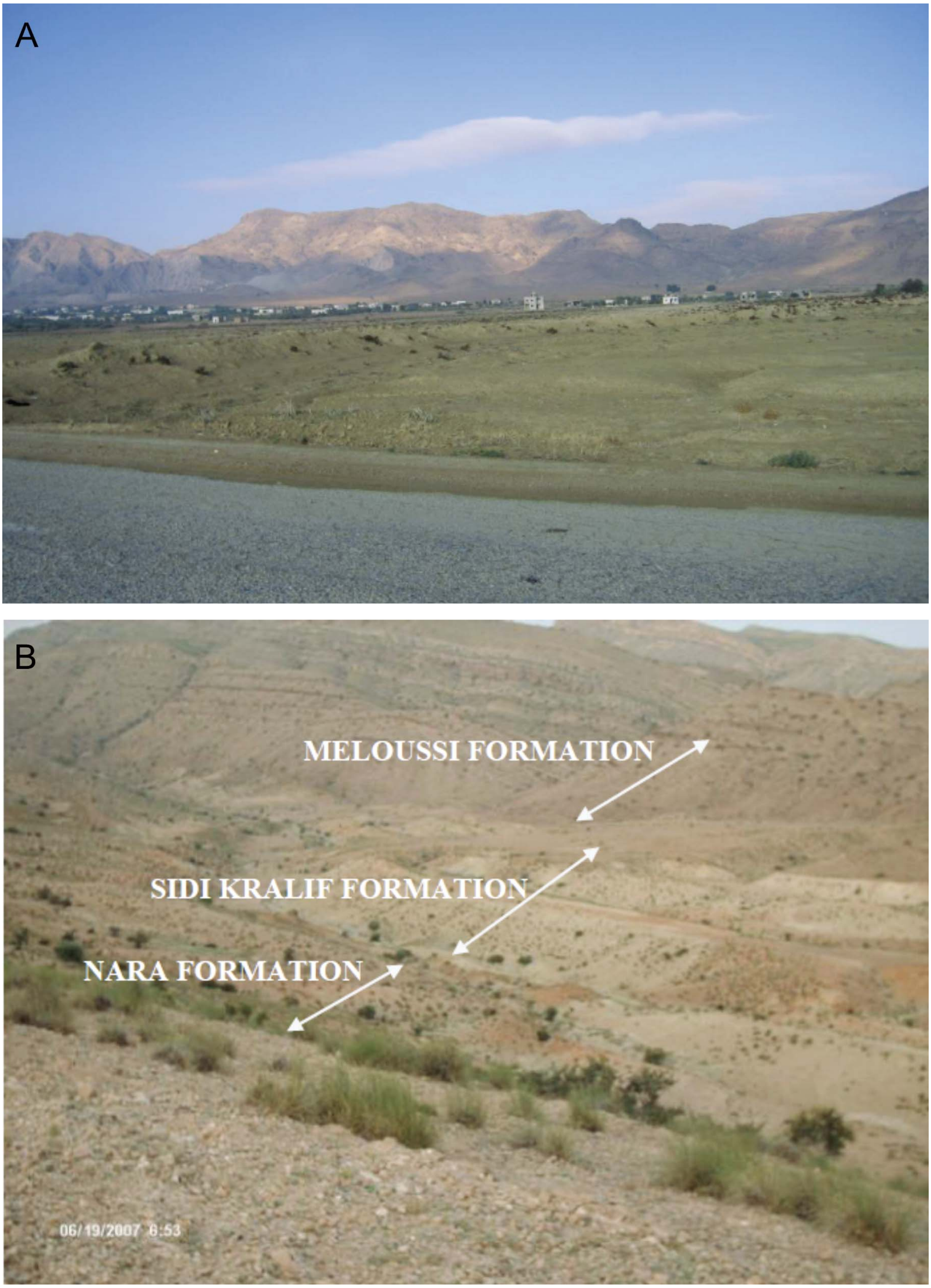
INTRODUCTION

In spite of intensive studies during recent decades, the formal definition of the Jurassic/Cretaceous boundary is still a problem, and it is the only Phanerozoic system boundary for which a GSSP has not been fixed (e.g., Remane 1991; Zakharov *et al.* 1996; Wimbledon 2008; Pessagno *et al.* 2009; Wimbledon *et al*. 2011; Wimbledon *et al*. 2014). There is a number of biological markers which may potentially be used as a marker for this boundary (Wimbledon *et al*. 2011), in an interval straddling the traditional base of the Berriasian Stage, the lower boundary of the Cretaceous. Successions across this critical interval, spanning the upper Tithonian and lower Berriasian, are known in Tunisia, in south-western Mediterranean Tethys. Many good sections are well-exposed in the central part of the country.

The present paper provides a biostratigraphic report on the lower and middle Berriasian (Lower Cretaceous) succession of central Tunisia. Two sections, represen-



Text-fig. 1. Geological map of Central Tunisia (after Guiraud 1968, simplified) and location of the measured sections: SK - Sidi Kralif Section; N - Nara Section



Text-fig. 2. A – Panoramic view of the Jebel Sidi Khalif; B – The Nara section tative for the Sidi Khalif and Nara Hill ranges (Text-figs 1, 2) were selected. The Berriasian of these ranges is represented by marls, marly limestones and micritic limestones of the Sidi Kralif Formation (Burollet 1956). The formation is underlain by dolostones of the Nara Formation and overlain by the massive dolostone-sandstone of the Meloussi Formation.

There is extensive bibliography on the geology of central Tunisia (e.g. Breistroffer 1937; Castany 1951; Arnould-Saget 1951; Burollet 1956; Bonnefous 1972; Guirand 1968; M'Rabet 1987). The biostratigraphy of the Sidi Kralif Formation was studied by Bismuth *et al.* (1967), Memmi (1967) and Busnardo *et al.* (1976, 1981). Bismuth *et al.* (1967) recognised four calpionellids zones in the Sidi Kralif Formation, although did not calibrate them to the ammonite zonation. Memmi (1967) recorded a succession of upper Tithonian and Berriasian ammonites in the Sidi Kralif Formation in the northern part of Jebel Nara and at Chaabet Attaris.

Both calpionellid and ammonite assemblages were analysed by Busnardo *et al.* (1976, 1981). These authors characterized the *Beriasella jacobi* Zone; the *Pseudosubplanites grandis* Zone was difficult to define, but seemingly ammonites were seen as different compared to the *B. jacobi* Zone assemblage. In the Nara Range, they recognised a *P. grandis* Zone interval with calpionellids. The *Subthurmannia occitanica* Zone of the middle Berriasian was also characterized by calpionellids. The middle/upper Berriasian boundary could not be accurately determined because the fauna was found to be very rare.

Both calpionellids and ammonites are critical in attempts to define the Jurassic–Cretaceous boundary (Wimbledon *et al.* 2011). Ammonites and calpionellids are treated in both sections studied herein, with the aim of calibration and correlation with other key sections in the Tethyan Realm: e.g., Msila area in the internal Prerif of Morocco (Benzaggagh *et al*. 2010); Le Chouet in SE France (Wimbledon *et al*. 2013); Puerto Escano in Spain (Pruner *et al.* 2010); Fiume Bosso in central Italy (Housa *et al.* 2004); Brodno in Western Carpathians, Slovakia (Housa *et al.*1999); Nutzhof in Austria (Lukeneder et *al.* 2010). All these sections have been discussed recently by Michalik and Rehakova (2011).

MATERIAL AND METHODS

Our detailed biostratigraphic survey has been on two sections: at Sidi Khalif (the type section of the Sidi Kralif Formation), and at Nara (Memmi 1967), localities which are c. 18 km apart. Both sections were collected for ammonites, and limestone beds were sampled for calpionellids. The calpionellids were studied in thin sections (25 in total) studied under an OLYMPUS BH-2 transmitted light microscope, and photographed with Nikon COOLPIX L310 camera. All fossils described are stored in the collections of the Geological Survey of the National Office of Mines of Tunisia.

GEOLOGICAL SETTING

The study area is a part of the foreland of the Tunisian Maghrebide Chain, in the northernmost part of the structure known as the N-S Axis (Text-fig. 1), which limits the western part of the Sahel plains (Castany 1951; Burollet 1956). The axis is a N-S anticline that interferes locally with NE-SW folds (Castany 1951; Burollet 1956; Richert 1971; Ouali 2007). It is a major palaeogeographical limit that has been interpreted as having been a shoal at different times during the Mesozoic (Burollet 1956; M'Rabet 1987; Soussi *et al*. 2000). During late Jurassic to early Cretaceous times, Central Tunisia experienced continuous and regular sedimentation with a relatively slow subsidence in an infra-neritic depositional environment (Burollet, 1956). The evolution of the sedimentation of the Sidi Kralif Formation reflects the geological history of central Tunisia during J/K boundary times. Its lower part was deposited in relatively deep water with a marly-limestone sedimentation, whereas its upper part shows essentially clay sediments and indicates shallower waters. The decrease in depth is related to an increase in clastic sediments not compensated by subsidence, which explains the diachronism of this formation (Busnardo *et al*. 1981). In fact, central Tunisia was an external carbonate platform during the early Tithonian, except for the Chotts region (the salt-lake area) that corresponds to a littoral platform (Bonnefous 1972). During the late Tithonian, the first clay deposits arrived on this platform in a prodeltaic situation. In late Tithonian to mid Berriasian times the deposits prograded towards Jebel Meloussi and Jebel Bouhedma. Jebel Sidi Khalif and areas further north were still on an external carbonate platform with marly limestone sedimentation (Busnardo *et al*. 1981; M'Rabet 1987).

AMMONITE AND CALPIONELLID RECORD IN THE STUDIED SECTIONS

The Sidi Kralif Formation (Text-fig. 2) consists of clays and dark grey or black marls with a green or bluish patina, often fissile, with a number of limestone or sandstone beds (M'Rabet 1987). It has two informal members (see Busnardo *et al.* 1976); (1) the lower composed of calcareous marls, with pyritic ammonites, belemnites, calpionellids, rare bivalves and brachiopods, and (2) the upper, composed of clays and marls, with numerous limestone beds, rich in bivalves, gastropods, brachiopods, echinoids, and ammonites, and rare calpionellids, limited to the lower beds. The lowest limestone beds are dolomitized, similarly as in the underlying Nara Formation.

Nara section (Text-fig. 2B, 3A) (35°15'52.50"N, 9°41'47.07"E)

The total thickness of the studied succession in the Nara section is 246 m. Both members of Busnardo *et al.* (1976) are recognised; the lower, beds N1–N18, and the upper, beds N19–N29.

Ammonites (Text-fig. 3): The ammonite preservation is good except for the pyritized fossils. In beds N1–N18, ammonite taxa identified are dominated by adult forms of the genera *Pseudosubplanites*, *Berriasella*, *Dalmasiceras*, *Fauriella*, *Jabronella* and *Subalpinites* (Text-fig. 5). Higher up in the succession the ammonites occur mostly in beds N19, N21, and in the two uppermost beds, N27 and N29.

Calpionellids (Text-figs 3, 4). Calpionellids are represented up to bed N25. Four successive stratigraphically assemblages were recognized. Assemblage 1, in beds N3–N8, consists of *Calpionella alpina,* (Text-fig. 4.1–4.3) *Tintinnopsella carpathica* (Text-fig. 4.8, 4.9) and *Crassicollaria parvula* (Text-fig. 4.7). This assemblage is dominated by *C. alpina* (47%), variable morphologically, but with small sphaerical forms predominating. Assemblage 2, in beds N9–N12, is still dominated by *C. alpina*, but is characterised by first appearances of various species of the genus *Remaniella.* Assemblage 3, in beds N13–N18, is characterised by the appearance and continuous occurrence of *Calpionella elliptica* (12%) (Text-fig. 4.4–4.6), *Lorenziella hungarica* (4%) (Text-fig. 4.17), and *Remaniella colomi* (1%) (Text-fig. 4.12), accompanied by species ranging up from below, *C. alpina* (57%), *Cr. parvula* (12%), *T. carpathica* (10%), *Remaniella catalanoi* (1%) (Text-fig. 4.16), *Remaniella duranddelgai* (2%) (Text-fig. 4.15) and *Remaniella ferasini* (1%) (Text-fig. 4.10, 4.11). Assemblage 4, in beds N19–N25, is characterised by the first appearance of *Tintinnopsella longa* (N19) (Text-fig. 4.19, 4.20) as well as an increased abundance of *C. elliptica* and a mass occurrence of a large variety *T. carpathica*.

Sidi Khalif section (Text-fig. 3B) (35° 6'42.72"N, 9°40'36.70"E)

The Berriasian of the Sidi Khalif section is c. 368 m thick. The succession is divided into two members; the lower, spanning beds SK2–SK42, and the upper, beds SK43–SK47. The lowermost part of the succession consists of alternating beds of marls and limestones of very irregular thickness.

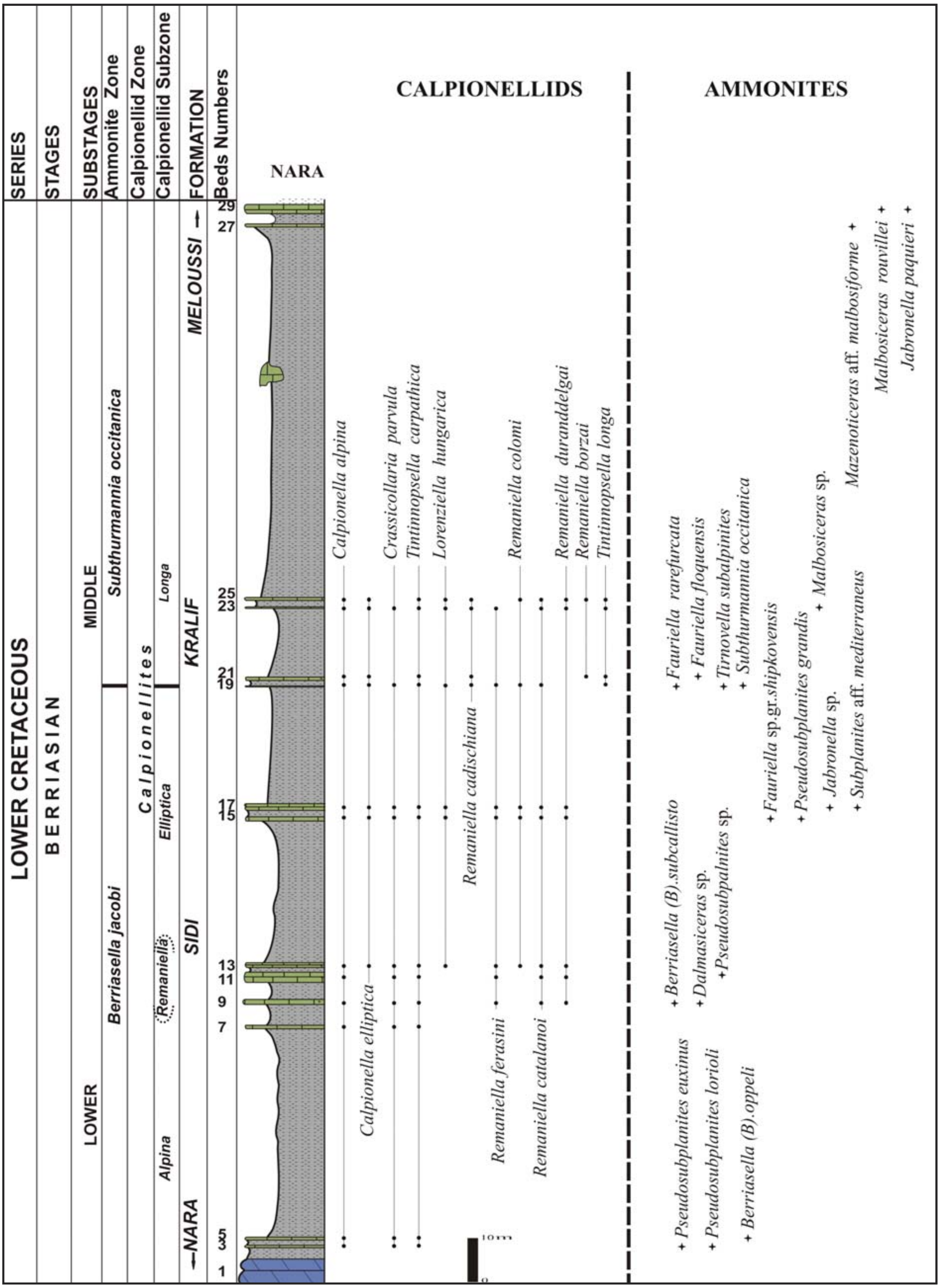
Ammonites (Text-figs 3, 6): In the lower beds, fossils are represented mainly by fragmentarily preserved, moderately small species of the genera *Dalmasiceras*, *Jabronella*, *Berriasella* and *Pseudosubplanites*. Higher in the succession (bed SK43), well-preserved representatives of the genera *Subthurmannia* and *Mazenoticeras* are common (Text-fig. 3).

Calpionellids: Similarly as in Nara section, four successive calpionellid assemblages are recognised (Text-fig. 4). Assemblage 1 (beds SK2–SK18) is dominated by *C. alpina* (58%) and *Cr. parvula* (36%); also noted was *T. carpathica* (6%). Calpionellid-rich Assemblage 2 (beds SK19–SK24) is characterised by the appearance of various species of the genus *Remaniella* (bed SK19) and the dominance of sphaerical forms of *C. alpina* (66%). Also noted were *Cr. parvula* (20%) and *T. carpathica* (7%). Assemblage 3 (beds SK25–SK42) is characterised by the appearance of *C. elliptica* (bed SK 25), which is accompanied by *C. alpina* (48%), *C. parvula* (10%), *T. carpathica* (6%), *R. colomi* (8%), *R. catalanoi* (2%), *R. ferasini* (1.5%), and *R. duranddelgai* (2.5%). In the upper part of the interval with Assemblage 3 there is an increase in abundance of small forms of *C. Elliptica*. Some of the *Remaniella* species are discontinuous through their range. Assemblage 4 (beds SK43–SK47) is characterised by the appearance of *T. longa* (2%), although it is clearly dominated by *C. elliptica* (37%) and *C. alpina* (19%). Also noted were: *Cr. parvula* (8%), *T. carpathica* (16%), *L. hungarica* (6%), *Remaniella cadischiana* (6%) (Text-fig. 4.13, 4.14), *R. catalanoi* (3%) and *Remaniella borzai* (3%) (Text-fig. 4.18).

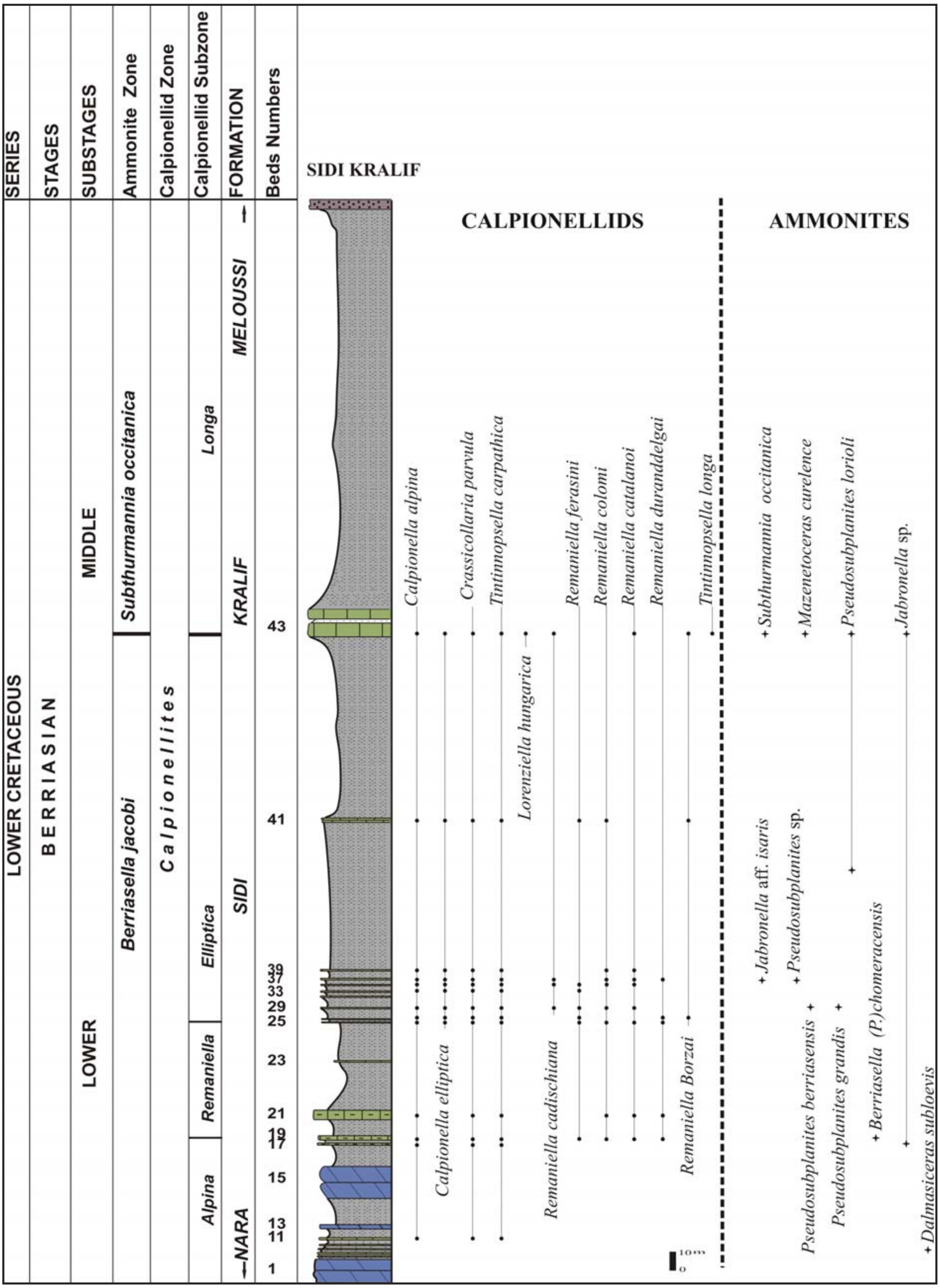
BIOSTRATIGRAPHIC RESULTS

Calpionellid biostratigraphy

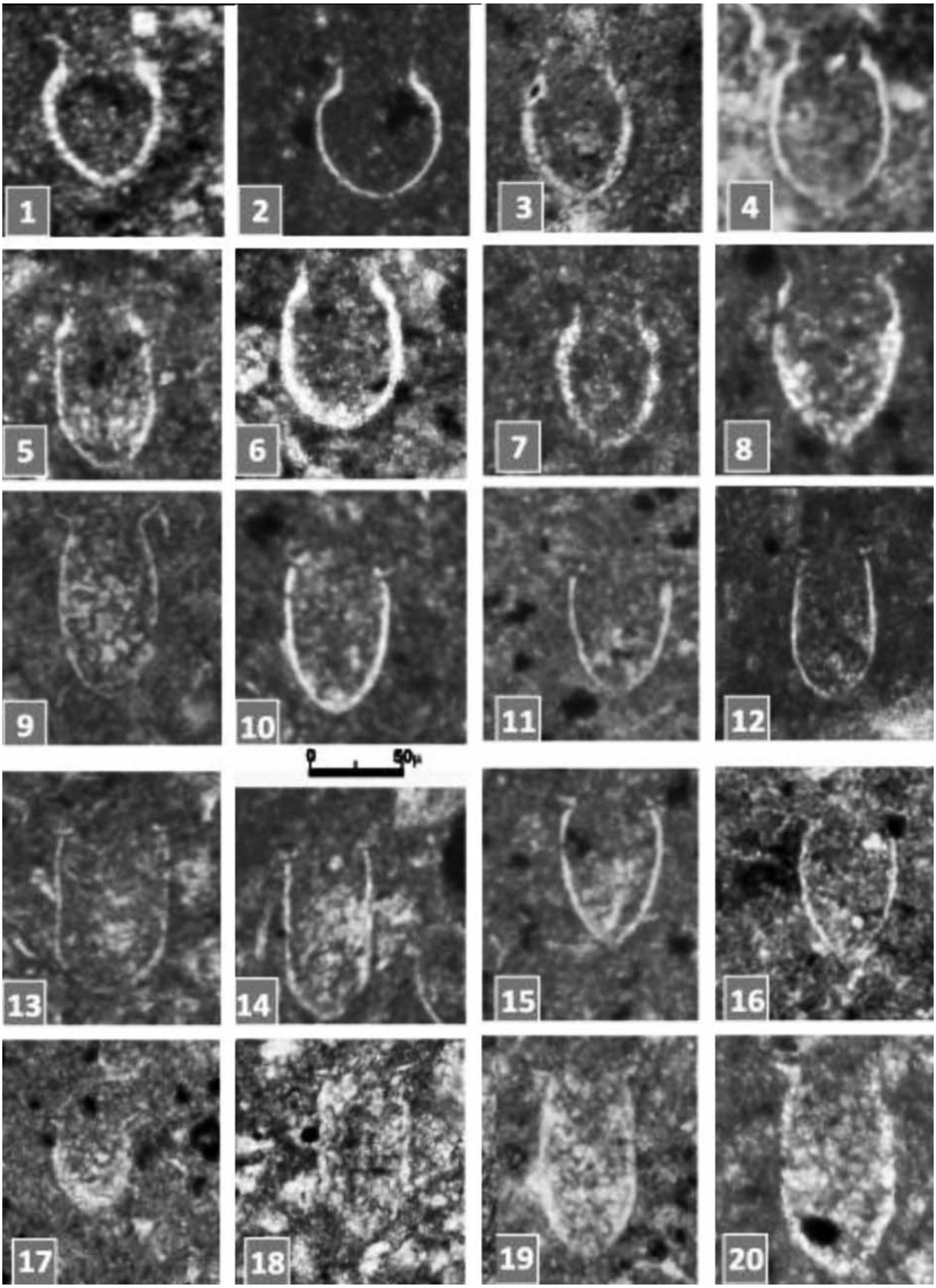
The *Calpionella* Zone, first defined by Allemann *et al.* (1971), was divided subsequently into the *C. alpina* and *C. elliptica* intervals by Catalano and Liguori (1971). Pop (1994) defined these two intervals as the Alpina and Elliptica Subzones, divided by a Remaniella Subzone (*Remaniella ferasini* Subzone of Pop 1994). The lower boundary of the *C. alpina* Subzone, taken as



Text-fig. 3a. Geological log, biostratigraphy, and vertical ranges of ammonite and calpionellid species in the Nara section



Text-fig. 3b. Geological log, biostratigraphy, and vertical ranges of ammonite and calpionellid species in the Sidi Kralif section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the Tithonian / Berriasian boundary by Remane *et al.* (1986), is characterized by a change in the morphology of *C. alpina,* with an 'explosion' of small spherical forms. The *C. elliptica* Subzone is marked by the first occurrence of the subzonal species. Pop (1994) distinguished a new Longa Subzone, named after *Tintinnopsella longa* Colom (1939), corresponding to the upper part of the *Calpionella* Zone.

The calpionellid zonation used in this work is that established by Rehakova and Michalik (1997); Remane *et al.* (1986); Pop (1994, 1997) and Lakova and Petrova (2013) (Text-fig. 7).

In this study, the preservation of calpionellid material from Nara and Sidi Khalif has been found to be generally good, and the fine and minute apertures of the loricas are well preserved, which facilitates their determination. In both the Nara section and the Sidi Khalif section the same calpionellid bioevents have been determined, The "acme" of small spherical forms of *C. alpina,* first appearance of the genus *Remaniella*, first occurrence of *C. elliptica,* and the last bioevent, the first appearance of index species *T. longa.* The events thus define and limit, respectively, the *C. alpina*, *Remaniella*, *C. elliptica* and *T. longa* subzones.

Calpionella alpina Subzone

The early Berriasian calpionellid association, i.e. Assemblage 1, is characterized by the species *C. alpina, Cr. parvula,* and *T. carpathica*. This composition is indicative of the *C. alpina* Subzone of the standard *Calpionella* Zone of the lower Berriasian, e.g., Remane *et al.* (1986) and Rehakova and Michalik (1997). This subzone has been recognized in North Africa by Boughdiri *et al.* (2006), and as sub-zone B1 of Ben Abdesselam-Mahdaoui *et al.* (2011) and Benzaggagh *et al.* (1995, 2012).

Remaniella Subzone

The Assemblage 2 association is typified by the first appearance of *Remaniella* with variable percentages of *C. alpina* and *Cr. parvula*. This association characterizes the *Remaniella* Subzone and corresponds to the upper part of B zone of Remane (1963, 1971). According to Oloriz *et al.* (1995), Pop (1994, 1996), Andreini *et al.* (2007) and Lakova and Petrova (2013), it correlates to the *Remaniella ferasini* Subzone (see Rehakova and Michalik 1997).

Calpionella elliptica Subzone

This subzone was created by Catalano and Liguori (1971) and redefined by Pop (1974). Its base is marked by the first occurrence of *C. elliptica* associated with *C. alpina, Cr. parvula, T. carpathica, L. hungarica, R. ferasini, R. colomi*, and *R. duranddelgai*. The subzone was recognised elsewhere by Pop (1994–1997) and Grun and Blau (1997).

Tintinnopsella longa Subzone

The *T. longa* Subzone was originally defined by Pop (1974), the first occurrence of the eponymous species marking its base. The calpionellids of our assemblage 4 are *T. longa, C. alpina, C. elliptica, R. borzai, R. duranddelgai, R. catalanoi, R. ferasini* and *T. carpathica*, which is similar to the association found by Pop (1974). A palaeobiogeographical study on this bioevent (Pop 1994) showed its distribution in western Tethys in the Southern Carpathians (Pop 1974, 1986), Western Carpathians (Vasicek *et al.* 1994; Borza and Michalik 1986), SE France (Le Hégarat and Remane 1968; Charollais *et al.* 1981), Southern Alps (Channell and Grandesso 1987), Sicily (Catalano and Liguori 1971), Subbetic area (Alleman *et al.* 1975), and westwards to Cuba (Pop 1976).

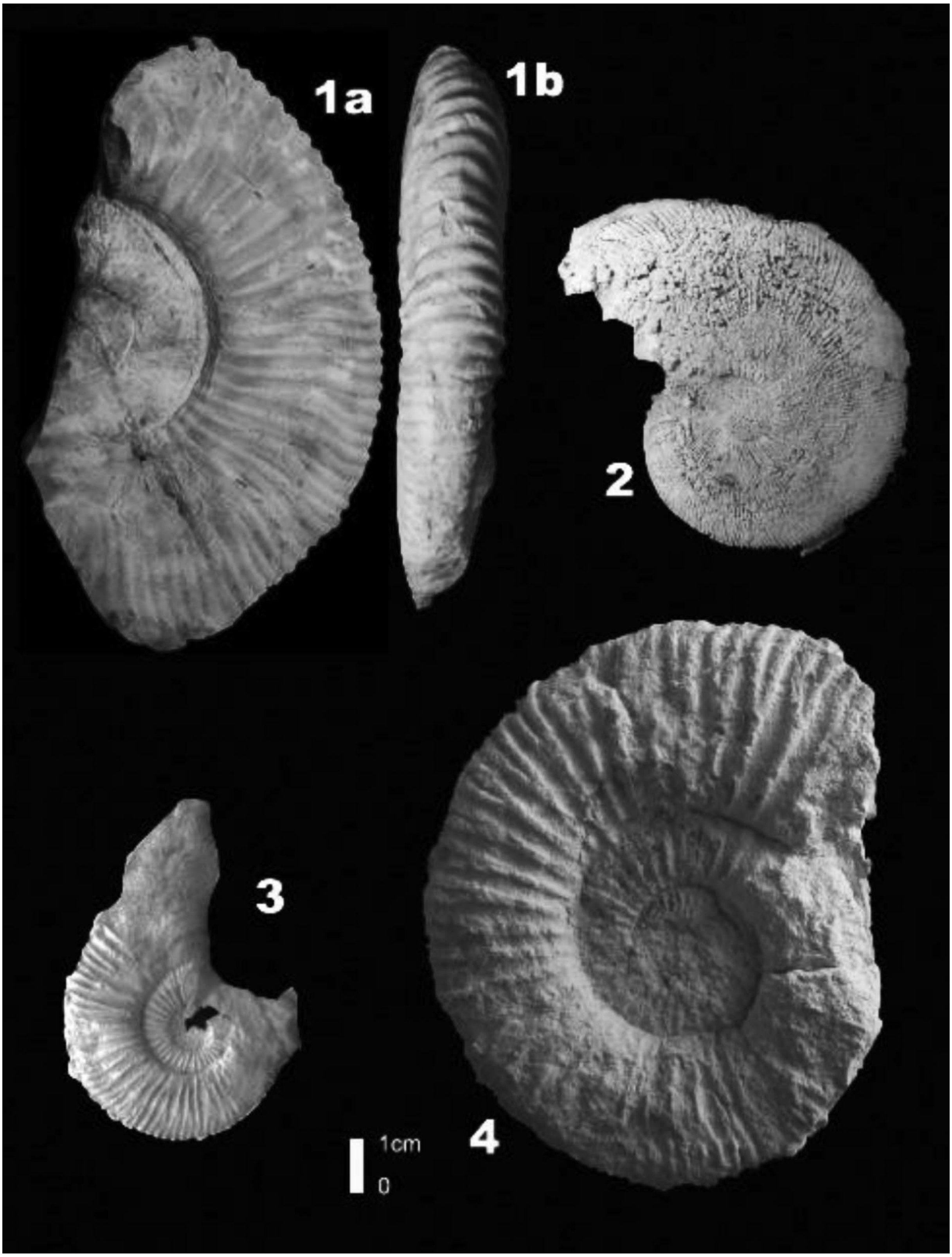
Ammonite biostratigraphy

The reference ammonite biostratigraphic scale used here is the Tethyan ammonite zonation of the Berriasian following Tavera (1985) and Hoedemaeker *et al*. (1990) (Text-fig. 7).

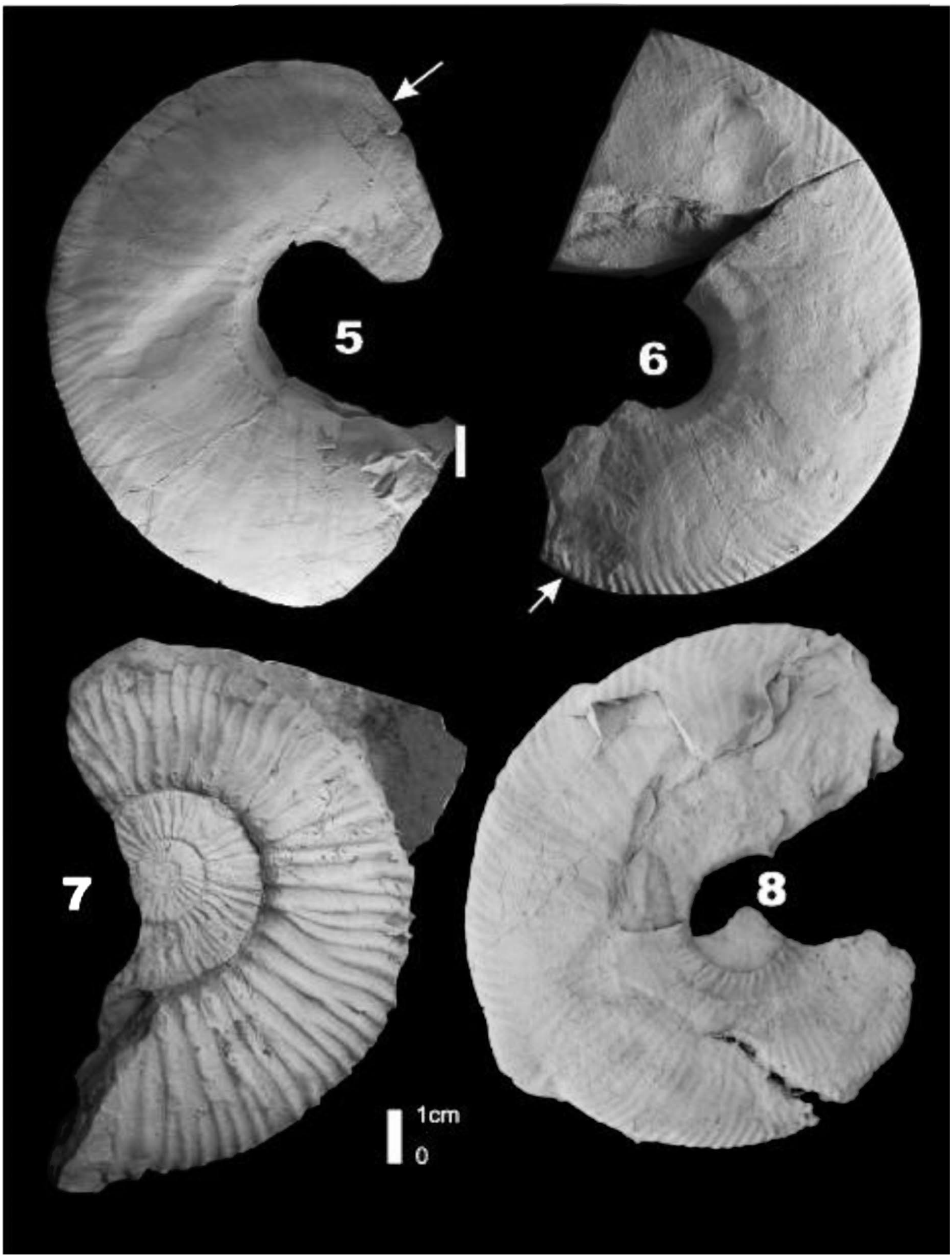
Berriasella jacobi Zone

The ammonite species from the lower part of the two studied sections (Nara, beds N1–N18; Sidi Khalif, beds SK2-SK42) are from the *Berriasella jacobi* and *Pseu-*

Text-fig. 4. Photomicrographs of calpionellids in thin sections from the Nara and Sidi Kralif sections. **1-3** – *Calpionella alpina* Lorenz, Lower Berriasian, Calpionella Zone, Alpina Subzone, sample SK17. **4-6** – *Calpionella elliptica* Cadisch, Middle Berriasian, Calpionella Zone, Longa Subzone, sample N21. **7** – *Crassicollaria parvula* Remane, Lower Berriasian, Calpionella zone, Remaniella Subzone, sample SK21. **8, 9** – *Tintinnopsella carpathica* Murgeanui & Filipescu, Middle Berriasian, Calpionella Zone, Alpina Subzone, sample N19. **10, 11** – *Remaniella ferasini* Catalano, Lower Berriasian Calpionella Zone, Elliptica Subzone, sample N17, **12** – *Remaniella colomi* Pop, Lower Berriasian, *Calpionella* Zone, *Remaniella* Subzone, sample SK21. **13, 14** – *Remaniella cadischiana* Colm, Middle Berriasian, *Calpionella* Zone, *Remaniella* Subzone, sample N21. **15** – *Remaniella duranddelgai* Pop, Lower Berriasian, *Calpionella* Zone, *Remaniella* Subzone, sample N9. **16** – *Remaniella catalnoi* Pop, Middle Berriasian, Calpionella Zone, Remaniella Subzone, sample N23**.** **17** – *Lorenziella hungarica* Knauer and Nagy, Middle Berriasian, *Calpionella* Zone, *Longa* Subzone, sample SK43. **18** – *Remaniella borzai* Pop, Lower Berriasian, Calpionella Zone, Remaniella Subzone, sample SK25. **19, 20** – *Tintinnopsella longa* Colom, Middle Berriasian, *Calpionella* Zone, *Longa* Subzone sample SK 43, N25



Text-fig. 5. Selected ammonites from the studied sections: **1a, b** – *Pseudosubplanites grandis* Mazenot; sample SK29: *Pseudosubplanites grandis* Subzone, *Pseudosubplanites euxinus* Zone, Lower Berriasian. **2** – *Fauriella* sp.gr. *shipkovensis* Nikolov and Mandov; sample N15: *Grandis* Subzone, *Euxinus* Zone, Lower Berriasian. **3** – *Mazenetoceras curelence* Kilian; sample SK43; *Subthurmannia occitanica* Zone, Middle Berriasian. **4** – *Jabronella* sp.; sample SK43 : *Subthurmannia occitanica* Zone, Middle Berriasian



Text-fig. 6. Selected ammonites from the studied sections. **5** – *Subthurmannia occitanica* Pictet; 5 – sample N2; **6** – sample SK43; *Subthurmannia occitanica* Zone, Middle Berriasian. **7** – *Pseudosubplanites grandis* Mazenot; sample N15, *Pseudosubplanites grandis* Subzone, *Pseudosubplanites euxinus* Zone, Lower Berriasian. **8** – *Malbosiceras* sp., sample N23; *Subthurmannia occitanica* Zone, Middle Berriasian *dosubplanites grandis* zones *sensu* Le Hégarat (1973). Hoedemaeker (1982) included them as subzones in a *Pseudosubplanites euxinus* Zone. Tavera (1985) proposed expanding the *B. jacobi* Subzone to be equivalent to the *Pseudosubplanites euxinus* Zone, This proposal which was accepted by the Working Group on Lower Cretaceous Cephalopods (1992; Hoedemaeker and Company 1993, and others e.g., Reboulet and Klein 2009; Reboulet *et al.* 2014). In the present paper, we follow the ammonite biozonation of Hoedemaeker *et al*. (1990) in discussing zonal calibration between ammonites and calpionellids.

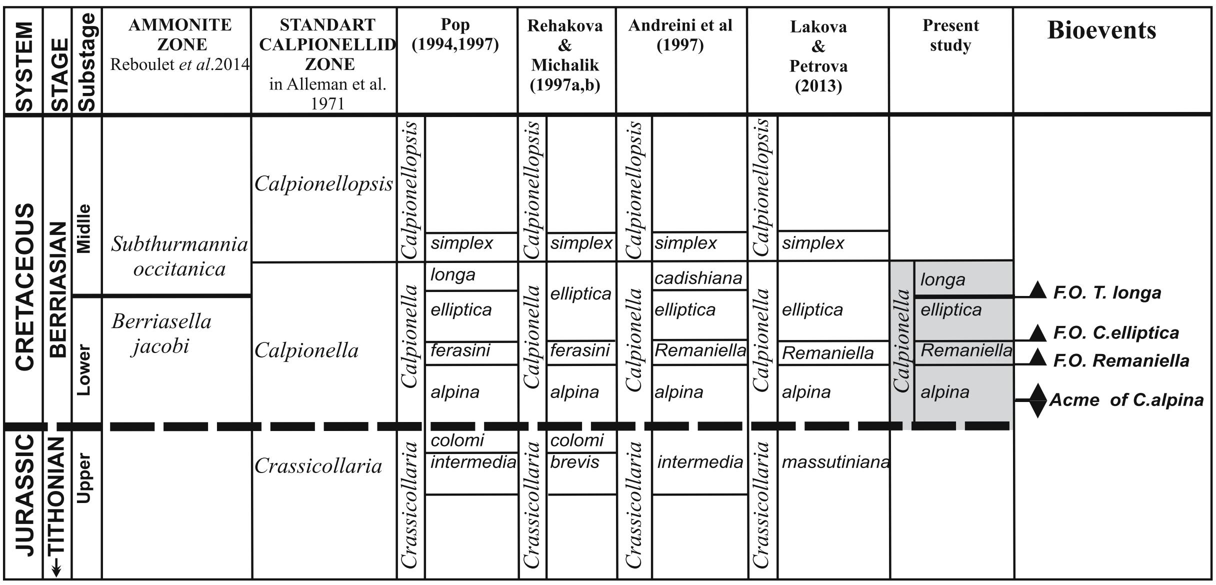
The *B. jacobi* Zone is characterized in the Nara section by the following ammonite association: *Pseudosubplanites euxinus, P. lorioli* (bed N3), *B.* (*B.*) *oppeli* (N5), *Dalmasiceras* sp. and *Berriasella* (*B.*) *subcallisto* (N7), and *Pseudosubplanites* sp. (N13). The assemblage at Sidi Khalif section includes *Dalmasiceras subloevis, Jabronella* sp. (Text-fig. 5.4) and *B.* (*Picteticeras*) *chomeracensis*. This association could be indicative of the *B. jacobi* Zone *sensu* Le Hégarat (1973) considering the association of the genera *Delphinella, Dalmasiceras* and *Berriasella* low in this zone in other regions (Wimbledon *et al.* 2013; Donze *et al.* 1975 in northern Tunisia, Memmi 1967, Busnardo *et al.* 1976 in Central of Tunisia, Memmi 1989). In the succeeding Nara beds we have been able to identify *Ps. grandis* (Text-fig. 5.1a, b) and *Fauriella* sp. ex gr. *shipkovensis* (bed N 15) (Text-fig. 5.2), *Jabronella* sp. and *Subalpinites* aff. *mediterraneus* (N17), and at Sidi Khalif *Ps. grandis* and *Pseudosubplanites berriasensis* (bed SK 29), whereas bed SK 37 contains *Pseudosubplanites* sp. and *Jabronella* aff. *isaris*. In this association the Grandis Zone *sensu* Le Hégarat (1973) is well represented by the index species *Ps. grandis* (Mazenot), as in the associations recorded by Memmi (1967) and Busnardo *et al.* (1976) in Central Tunisia.

Subthurmannia occitanica Zone

In the Nara section, we find an assemblage containing *Tirnovella subalpinites* (bed N19), *Fauriella rarefurcata* (bed N19), *Fauriella floquinensis* (bed 21), *Subthurmannia occitanica* (Bed N23) and *Malbosiceras* sp. (bed N25) (Text-fig. 6.8), *Mazenoticeras* aff. *malbosiforme* (Bed N27), *Malbosiceras rouvillei* and *Jabronella paquieri* (Bed N29). In the Sidi Khalif section, we collected *Pseudosubplanites lorioli*, *S. occitanica* (Text-fig. 6.5, 6.6) (bed Sk43), *Mazenoticeras curelence* (SK 43) (Text-fig. 5.3), and *Jabronella* sp. This association could be the equivalent of the Occitanica Zone (*sensu* Le Hégarat), correlated with the association of Memmi (1967); Enay and Geyssant (1975); Cecca *et al.* (1989); Wimbledon *et al.* (2011, 2013).

DISCUSSION

This work proposes a revised stratigraphy for the Lower to Middle Berriasian in Central Tunisia based on ammonites and calpionellids. The boundaries of the biostratigraphic units in this scheme fit well with those of the subdivisions of many other key Tethyan sections. The bases of our sections (Bed N1 in the Nara section and Beds SK1–SK5 at Sidi Khalif) do not allow us (because of unsuitable dolomitic lithologies) to rec-



Text-fig. 7. Correlation of ammonite and calpionellid zonations for the upper Tithonian and lower-middle Berriasian, and major calpionellid bio-events (after Lakova and Petrova 2013) ognize the top of *Crassicollaria* Zone (calpionellids) or the top of *Durangites* Zone (ammonites). However, comparing our *C. alpina* Subzone or *C. jacobi* Subzone (*sensu* Le Hégarat 1973) assemblages with those in other sections, one can conclude that the J/K boundary, i.e. the base of Berriasian approximately coincides with this lithological change from dolostones to micritic limestones, or is rather lower, within the dolomites of Nara Formation, since indications of lower laying *Crassicollaria* Zone and *Durangites* Zone are absent.

The quantitative analysis of calpionellids shows major variations in their abundance and composition, and the well-marked first occurrences of species allow the delimitation of the *C. alpina* and *Remaniella* subzones, represented by the first appearance of the genus *Remaniella* in bed N9 (Nara) and in bed SK 17 (Sidi Khalif). It is worth noting that the ammonite fauna crosses this level with no change. In bed N13 and bed SK 25, we see the same phenomena, with variations detectable in the calpionellids species (first appearance of *C. elliptica*). In fact, none of the ammonite zonal boundaries corresponds to any calpionellid boundary. The only exception is the first appearance of *T. longa* coinciding in the studied sections (bed N19 and bed SK43) with the presence of the ammonite *Subthurmannia occitanica.* These two coeval events mark clearly the lower/middle Berriasian boundary.

CONCLUSIONS

The detailed study of two key Tunisian localities has produced new biostratigraphical data which places those sequences close to the J/K boundary, and gives a early to middle Berriasian age for the Sidi Kralif Formation.

Main results from the Sidi Kralif Formation can be summarized in a few relevant points.

1. Two ammonite zones and four calpionellid subzones from the lower to middle Berriasian are defined, and we have discussed their comparison with equivalents, locally and more generally in Tethys.
2. The *Pseudosubplanites grandis* Subzone *sensu* Le Hegarat (1973) is identified in the studied sections.
3. The *T. longa* Subzone is reported for the first time from central Tunisia.
4. None of the ammonite zonal boundaries correspond to any calpionellids boundary (with one exception)
5. The base of the *Subthurmannia occitanica* Zone coincides with the base of the *Tintinopsella longa* Subzone.
6. Calibration between the base of *Berriasella jacobi* Zone and the base of the *C. alpina* Subzone is difficult because of the unfavourable lithological nature of the base of both studied sections.

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APPENDIX

The list of calpionellid and ammonite species.

Calpionellid species

Calpionella alpina (Lorenz, 1902)
Calpionella elliptica (Cadisch, 1932)
Crassicollaria parvula (Remane, 1962)
Remaniella borzai (Pop, 1994)
Remaniella cadischiana (Colom, 1948)
Remaniella catalanoi (Pop, 1996)
Remaniella colomi (Pop, 1996)
Remaniella duranddelgai (Pop, 1996)
Remaniella ferasini (Catalano, 1965)
Lorenziella hungarica (Knauer and Nagy, 1964)
Tintinnopsella carpathica (Murgeanui and Filipescu, 1933)
Tintinnopsella longa (Colom, 1939)

Ammonite species

Berriasella (*Picteticeras*) *chomeracensis* (Toucas, 1890)
Berriasella (*B.*) *oppeli* (Kilian, 1889)
Berriasella (*B.*) *subcallisto* (Toucas, 1890)
Dalmasiceras subloevis (Mazenot, 1939)
Dalmasiceras sp.
Fauriella floquinensis (Le Hégarat, 1973)
Fauriella rarefurcata (Pictet, 1867)
Fauriella ex gr. *shipkovensis* (Nikolov and Mandov, 1967)
Jabronella paquieri (Simionescu, 1889)
Jabronella aff. *isaris* (Pomel, 1889)
Jabronella sp**.**
Malbosiceras sp.
Mazenoticeras curelence (Kilian, 1889)
Malbosiceras rouvillei (Matheron, 1880)
Mazenoticeras aff. *malbosiforme* (Le Hegarat, 1973)
Pseudosubplanites berriasensis (Le Hegarat, 1973)
Pseudosubplanites euxinus, (Retowski, 1893)
Pseudosubplanites grandis (Mazenot, 1939)
Pseudosubplanites lorioli (Zittel, 1868)
Pseudosubplanites sp.
Subthurmannia occitanica (Pictet, 1867)
Tirnovella subalpinites (Mazenot, 1939)