Acta Geologica Polonica, Vol. 76 (2026), No. 2, e81
DOI: 10.24425/agp.2026.158195

The Albian of Central Tunisia in the Kalaat Senan-Jérissa area: planktonic foraminifera and ammonite faunas in an expanded section

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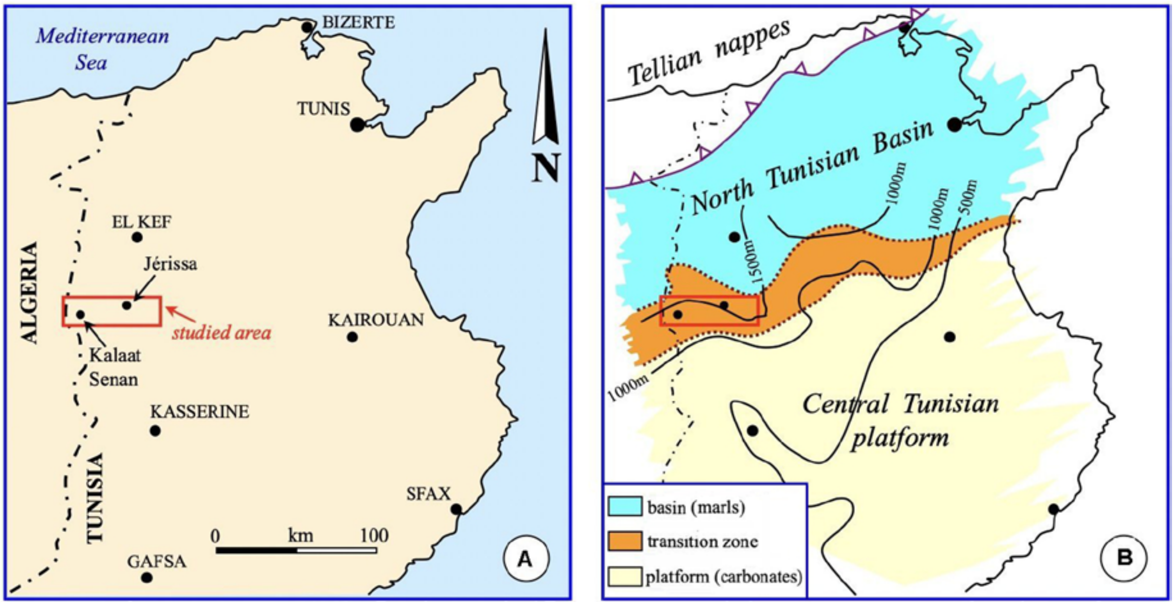
ABSTRACT:

Amédro F., Gale, A.S., Kennedy, W.J., Petrizzo, M.R., Robaszynski, F., Matrion, B. and Caron, M. 2026. The Albian of Central Tunisia in the Kalaat Senan-Jérissa area: planktonic foraminifera and ammonite faunas in an expanded section. *Acta Geologica Polonica*, **76** (2), e81.

An investigation of expanded sections spanning the upper Aptian to lower Cenomanian interval in the Kalaat Senan-Jérissa area of eastern central Tunisia demonstrates that the base of the Albian, defined by the first occurrence of the planktonic foraminiferan *Microhedbergella renilaevis* Huber and Leckie, 2011, lies above the successive ammonite zones of *Mellegueiceras chiaouiae*, ‘*Hypacanthoplites*’ *paucicostatus*, *Mellegueiceras ouenzaensis*, and part or all of the ‘*Hypacanthoplites*’ *buloti* Zone of previous authors, which are thus Aptian in age. A major hiatus, of approximately 1 myr duration, is present between the uppermost Aptian and lowermost Albian, which encompasses the lower Albian *Microhedbergella renilaevis*, *Ticinella rischi* and *Ticinella madecassiana* planktonic foraminiferan zones. Absence of an ammonite record extending from the lower (but not lowest) middle Albian to the lower (but not lowest) upper Albian indicates the presence of a further hiatus, including most of the middle Albian and the lower part of the upper Albian (*Dipoloceras cristatum* Zone). Recorded by previous authors, the extent of this hiatus is now precisely dated. The upper Albian *Pervinquieria* (*Pervinquieria*) *inflata*, *Pervinquieria* (*Pervinquieria*) *fallax* and *Pervinquieria* (*Subschloenbachia*) *rostrata* ammonite zones are also absent, as a result of either non-preservation, hiatus or condensation. This is the first precise dating of the major intra-Cretaceous hiatuses which extend across North Africa.

Key words: Ammonites; Planktonic Foraminifera; Cretaceous; Albian; Central Tunisia.



Text-fig. 1. Geographic framework and geological setting of the study area. A – Map of northern Tunisia, to show the study area. B – Palaeogeography of Tunisia in the Albian to show the positions of platforms and basins. Isopachs represent thickness of the Upper Cretaceous.

INTRODUCTION

During much of the Cretaceous, and particularly during the Albian, the region between Kalaat Senan and Jérissa in central Tunisia lay between a basin to the north, and a platform to the south (Text-fig. 1). The successions here, between two very different areas of sedimentation, yield both planktonic foraminifera (which define the boundaries of the Albian Stage) and ammonites. In contrast, ammonites are rare in the basinal facies, and benthic, rather than planktonic foraminifera dominate in the carbonate facies of the platform.

The Albian successions and faunas in the environment of Kalaat Senan and Jebel Jérissa were described by Léon Pervinquière in his masterly thesis *Études géologiques de la Tunisie centrale* (1903), followed by his *Études de Paléontologie tunisiennes* (1907, 1912). The lithostratigraphic divisions of the Aptian to Paleocene that remain in use today were introduced and described by Burollet *et al.* (1954) and Burollet (1956), and are shown in Text-fig. 2. According to the recent studies of Chihaoui *et al.* (2010) and Latil (2011), the Albian is represented by two units. The lowest of the two is the Hameima Formation, around 200 m of black pelites and sandy clays with numerous thick sandstone and/or carbonate intercalations. The second, of which only the lower two-thirds is Albian, is the Fadhène Formation, around 1500 m thick in the study area. It is made up predominantly of marls with some intervals with limestones [the Allam Limestones in the lower part, Mouelha Limestones in the middle part, and the Azreg Limestones (Robaszynski *et al.* 1994) in the upper part, at the base of the Cenomanian].

Several sections have been described by Chihaoui (2009) and Chihaoui *et al.* (2010) in the lower and middle Albian of Central Tunisia. Some are in the present study area (Jbel Jérissa); others are 15 km to the north (Jbel Hameima and Jbel Slata) or 10 km to the south (Jbel Bou el Hanneche) (Text-fig. 3). The correlation of sections and the stratigraphic dating based on ammonites (Jaillard *et al.* 2005, 2012; Latil 2011) led these authors to recognise several phases of tectonic activity, the first located near what they identified as the Aptian/Albian boundary, with a major event in the middle Albian, producing a pause in sedimentation and/or erosion, resulting in the absence of most or all of the middle Albian succession.

In this contribution, we build on previous work, linking the ammonite record to that of the planktonic foraminifera, the group that define the base of the Albian and Cenomanian stages in their global boundary stratotype sections (GSSPs; Cenomanian – Kennedy *et al.* 2004; Albian – Kennedy *et al.* 2017). This work (carried out in four periods of field work between June 1988 and May 1991) is thus a follow-up to the work on the Albian/Cenomanian boundary and the other Upper Cretaceous stages (Cenomanian to Maastrichtian) in the Kalaat Senan region of Central Tunisia (Robaszynski *et al*. 1990, 1993, 1994, 2000, 2008, 2012; Amédro *et al*. 2005). All the ammonites, originally in the collection of F. Amédro, are now housed in the collections of the Université de Bourgogne, Dijon, France (UBGD FAR). The illustrated planktonic foraminifera specimens are deposited with the code Micro-Unimi n. 2078 in the Micropalaeontological Collection of the Università degli Studi di Milano, Dipartimento di Scienze della Terra "A. Desio", Italy.

THE SUCESSION IN JBEL JÉRISSA

Jbel Jérissa lies immediately south of the town of that name (Text-fig. 3) and has a maximum elevation of 895 m; its origin lies in a subjacent Triassic diapir. The core of the massif is a 200 m thick limestone sequence that corresponds to the Serdj Formation of Burollet (1956). The outcrops studied (Text-fig. 4) are on the south and east of the massif, with four sections measured: JS, JL, JM, and JD, providing the composite section shown in Text-figs 5 and 6. Representative specimens of ammonites and foraminifera from the Jbel Jérissa composite section have been illustrated in Text-figs 7–15 and 16–22, respectively.

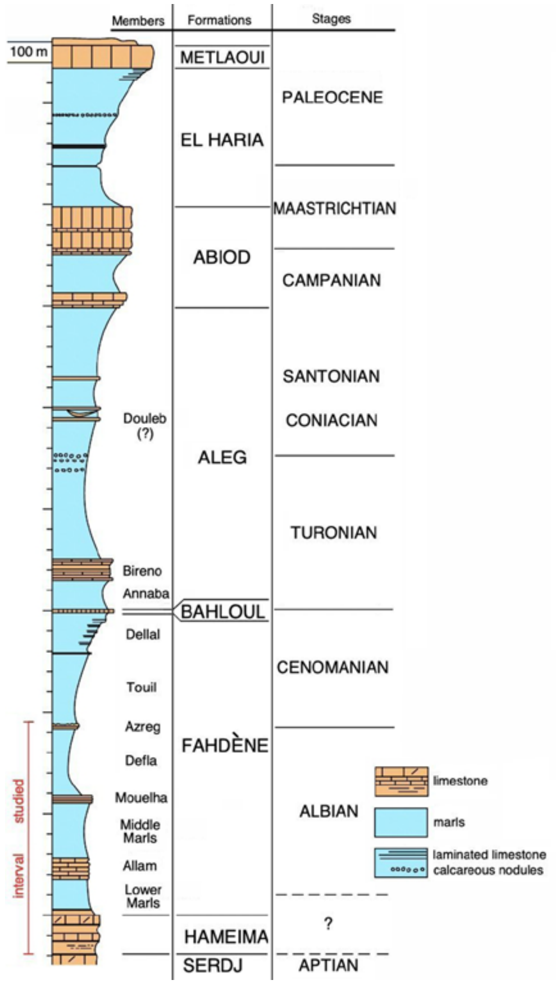
Hameima Formation

The Hameima Formation (Burollet 1956) was described as consisting of black or dark green clays with numerous thick intercalations of sandstone, dolomite, or limestone; horizons with orbitolinid foraminifera are frequent. According to Vila *et al*. (1995), Chihaoui (2009), and Chihaoui *et al.* (2010), a sandstone interval ('Clansayes Sandstones') in the middle part of the Formation defines a three-fold subdivision.

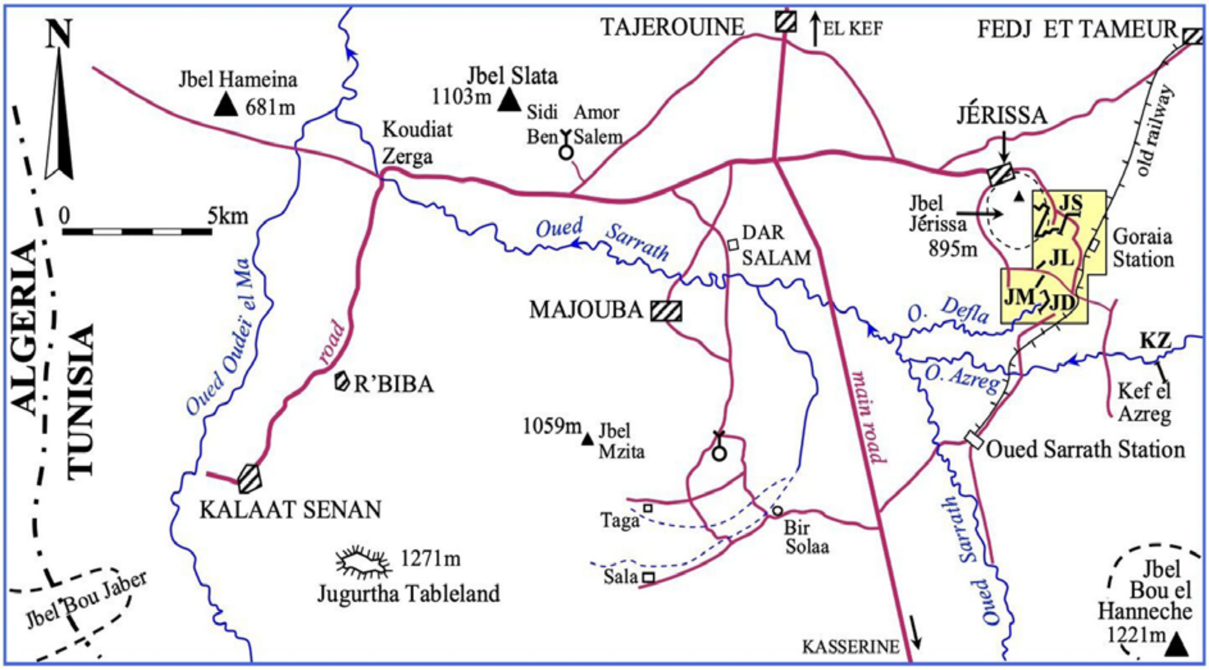
In contrast, observations by the present authors suggest the Hameima Formation, in Jbel Jérissa at least, consists of five cycles of quartzose to carbonate detrital deposits, the lower four terminated by a hardground, the fifth terminated by a karstification surface. These five cycles are made up of shallow-water deposits, with orbitolinid foraminifera, oysters, trigoniid bivalves and echinoids, also yielding ammonites and belemnites. The first two cycles correspond to the Lower Member of Chihaoui *et al.* (2010), the third to their Middle Member, the fourth and fifth to their Upper Member.

When considered in more detail, the five cycles begin with pelites with numerous intercalated tempestites, together with beds of fine sandstone and limestone, tens of centimetres to half a metre in thickness, rich in orbitolinid foraminifera, bioclasts, and small oysters. All of the cycles end in a series of massive orbitoline-rich black limestones up to several metres in thickness. The limestones at the top of cycle 3 have a sandstone component, those at the top of cycles 4 and 5 are dolomitic. Perforated surfaces covered with a ferruginous crust occur at several levels in the lower cycle. The fillings of these burrows consist of ferruginous detritus, rich in litho- and bioclasts. The upper surface of these omission surfaces is commonly rich in oysters, serpulids and orbitolines. The burrows at the JS 45 m level extend to a depth of 80 cm and mark the top of cycle 1.

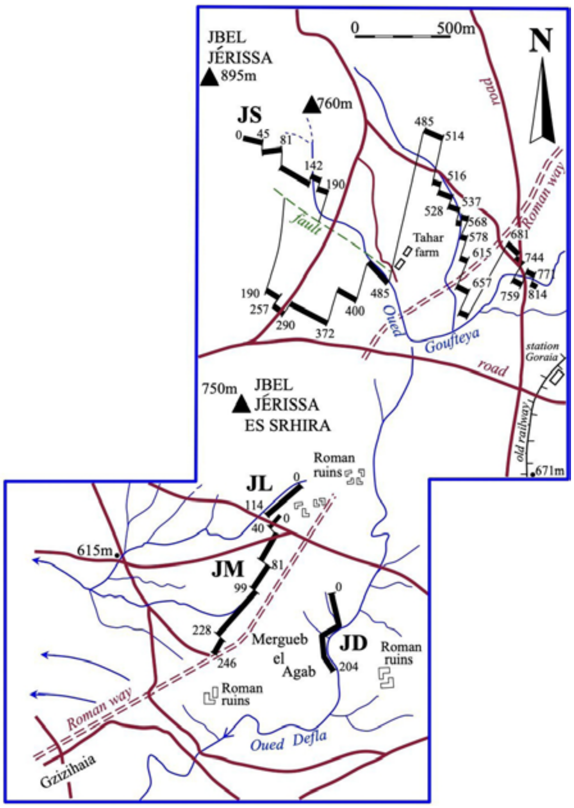
Cycles 2–4 (JS 45–108 m; 108–142 m; 142–169 m) are terminated by a hardground covered



Text-fig. 2. Post-Aptian Cretaceous formations and their ages in the transition zone (see Text-fig. 1B).



Text-fig. 3. The study area of east central Tunisia, to show the location of the Jbel Jérissa composite section (cf. Text-fig. 4).



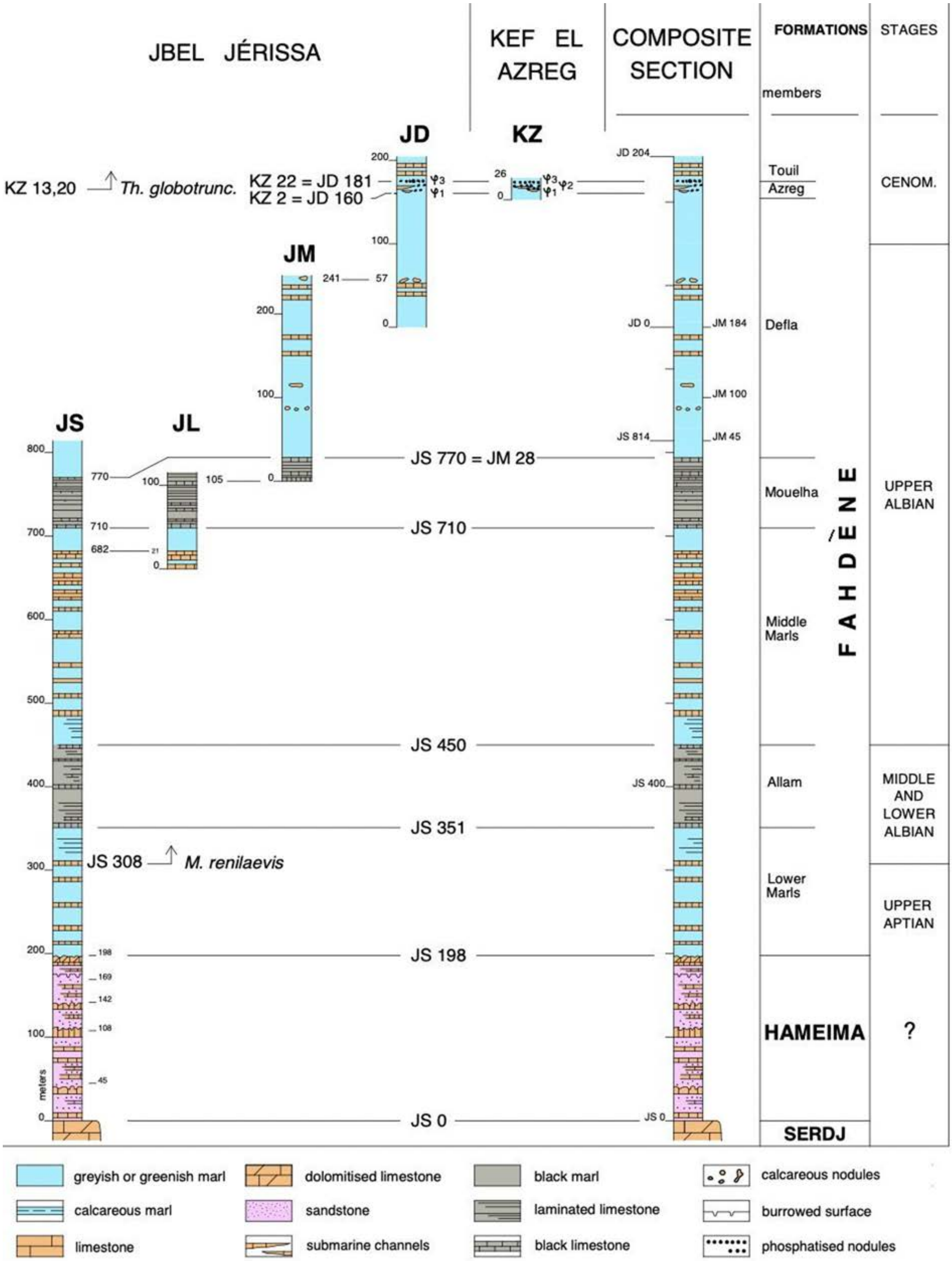
Text-fig. 4. Location of sections studied around Jbel Jérissa (cf. Text-fig. 5).

by a decimetric ferruginous sandstone crust rich in bioclasts, oysters and orbitolinid foraminifera, the burrows in the hardground extending to a depth of up to 60 cm. The surface of the hardgrounds is very fossiliferous, with numerous ammonites, oysters, trigoniid and pectinid bivalves, solitary corals, regular and irregular echinoids.

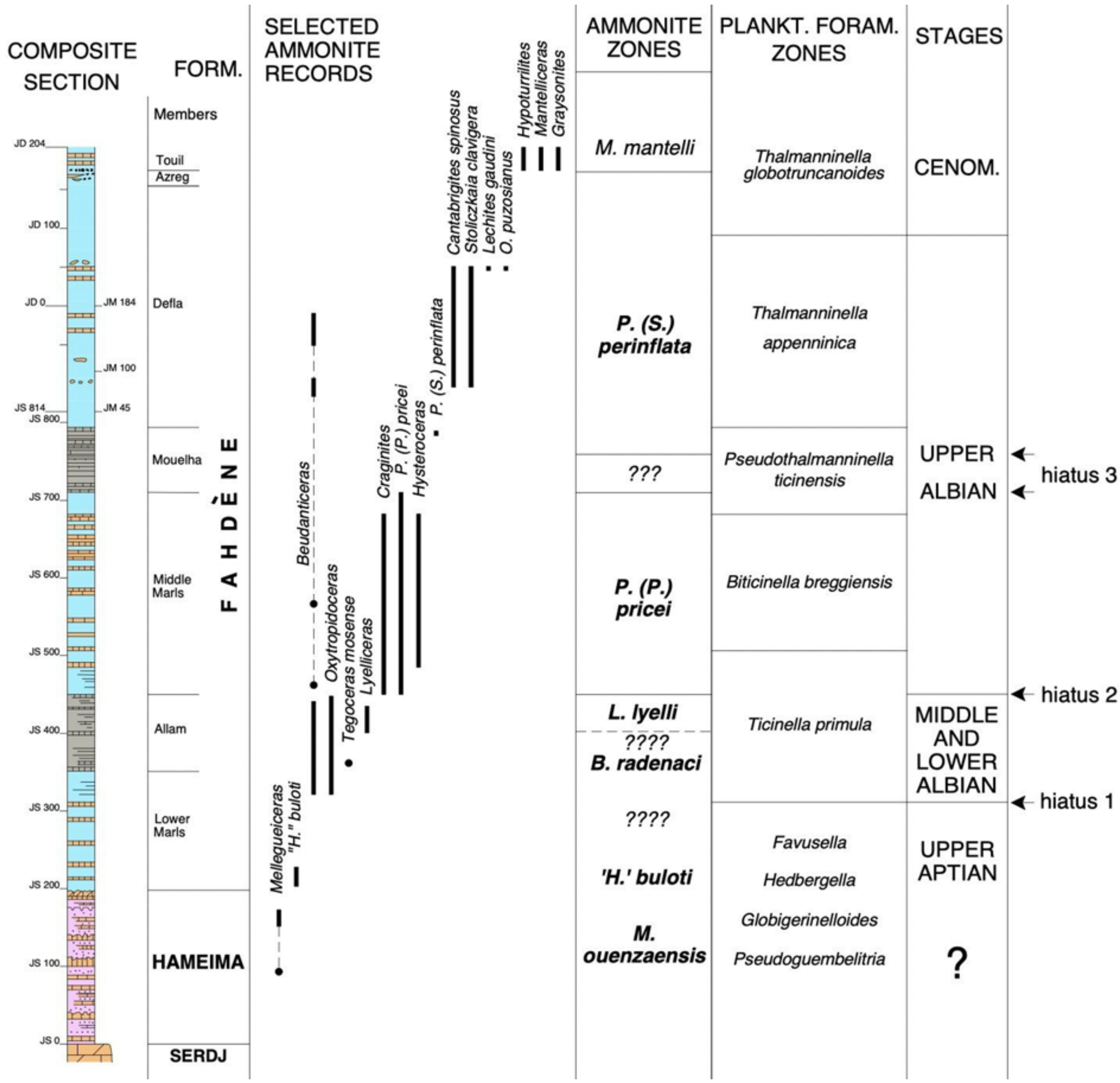
The fifth and final sedimentary cycle differs from cycles 1–4 in that the massive limestones at the summit are highly dolomitised, with karstification surfaces with pockets of ferruginous infill developed in the upper five metres at the JS 193 m, 195 m, 195.5 m, and 198 m levels, above which orbitoline foraminifera disappear and there is a transition to the marls of the Fahdène Formation.

Fahdène Formation

The lower boundary of the formation is at the 198 m level in the Jbel Jérissa (JS) composite section. The total thickness in the JS sections is 918 m up to the level of the lowest occurrence (LO) of the planktonic foraminiferan *Thalmanninella globotruncanoides* (Sigal, 1948), which marks the base of the Cenomanian Stage, as in the Global Stratotype Section and Point (Kennedy *et al*. 2004).The presence of several intervals with limestones (Allam and Mouelha limestones



Text-fig. 5. Jbel Jérissa, relative positions of individual sections shown in Text-fig. 4, and composite succession.



Text-fig. 6. Distribution and zonation of ammonites and planktonic foraminiferans in the Jbel Jérissa composite section. The lowermost Albian, including the planktonic foraminiferan zones of *Microhedbergella renilaevis*, *Ticinella rischi* and *Ticinella madecassiana* are not represented and are missing on hiatus 1 which has a duration of approximately 1 myr. Hiatus 2 represents a gap in the ammonite record, encompassing an interval from above part or all the lowest middle Albian *Lyelliceras lyelli* Zone to the base, or lower part of the *Pervinquieria* (*P.*) *pricei* Zone. There is no evidence of the *Pervinquieria* (*P.*) *inflata* and *P.* (*P.*) *fallax* zones, and only slight evidence for the *P.* (*S.*) *rostrata* Zone in the JS section, probably as a result of condensation or hiatus (hiatus 3).

in the Albian part of the sequence; Azreg Limestone at the base of the Cenomanian part of the sequence) provides the basis for the recognition of a series of members within the Fahdène Formation.

Lower Marls Member. This extends from level 198 m to level 351 m in the JS section (Text-fig. 5), a total thickness of 153 m. The member was described by Burollet (1956) as comprising black or dark grey clays and marls with thin beds of marly limestone. Chihaoui *et al.* (2010) distinguished five lithological units: (1) basal shale unit; (2) first carbonate interval, which corresponds to the ammonite-rich horizon of Burollet (1956); (3) intermediate shale unit; (4) second carbonate interval; and (5) upper shale unit.

Our observations are as follows:

– JS 198–224 m: blue-grey to greenish-grey marls, with a series of intercalated limestones up to 50 cm in thickness; characteristic of this interval is the presence of numerous ammonites in both marls and limestones; it corresponds to the "ammonite-rich horizon" of Burollet (1956);

– JS 224–257.5 m: greenish marls with only a few thin limestones, and few ammonites;

– JS 257.5–303 m: greenish marls, with a single metre of thick black limestone with numerous intraclasts in the lower part at level 290 m;

– JS 303–324.5 m: greenish-grey marls with numerous more calcareous units a few tens of centimetres in thickness.

Allam Member. This member extends within JS 351–450 m, is 99 m thick, and was described by Burollet (1956, p. 73) as follows: "*Ce sont des calcaires durs, parfois sublithographiques, noirs, prenant une couleur blanche ou grise très claire a l'alteration superficielle; ils alternant avec des marnes grises et quelques marno-calcaires*" ["These are hard black limestones, sometimes sublithographic, taking on a bright grey or white colour from superficial weathering; they alternate with grey marls and marly limestones"]. The boundaries of the Allam Member are not clear. If the main criterion is the black colour of the sequence, then the base lies at level JS 324.5 m, but the 324.5–351 m interval is predominantly argillaceous and it is only at level JS 351 m that the presence of limestones produces a positive topographic feature; accordingly, it is at this level that we place the base of the member. The member, so delineated, consists of hard marls with intercalations of dark grey to black laminated marls and courses of calcareous nodules.

Middle Marls Member. This extends from level JS 450–710 m and is 260 m thick. It differs from the Allam Member in that the marls and limestones are grey, rather than black. We have observed that:

– within JS 450–482 m the sequence is composed of alternations of grey-blue marls a few tens of centimetres in thickness and thin intercalated marly limestones;

– within JS 482–710 m the sequence is of dark grey marl units several metres in thickness and dark grey limestones up to a metre thickness.

Mouelha Member. This extends within JS 710–770 m and is 60 m thick. Burrolet (1956, p. 73) defined it as "*calcaires finement lités et même feuilletés*" ["thinly bedded and laminated limestones"]. We have observed that the sequence consists of alternating hard, black laminated marls and thin, finely laminated limestones.

Defla Member. This extends from level JS 770 m = JM 28 m to level JM 241 m = JD 57 m, then between JD 57–160.5 m (Text-fig. 4); the section is thus based on several outcrops, with a total thickness of 316.5 m. The term Defla Member was introduced by Robaszynski *et al.* (1994), but not defined, as it now is. The member takes its name from Wadi Defla, 4 km south of Jbel Jérissa (Text-fig. 3). The succession is made up of grey marls with calcareous marls and marly limestones a few tens of centimetres in thickness. We have observed that:

– within JM 28–147 m the sequence contains grey marls with some beds of calcareous marls a few tens of centimetres in thickness;

– from JM 147 m to 241 m = JD 57 m occur grey marls with several limestones a few tens of centimetres in thickness, separated by a few, up to 10 m thick marls;

– within JD 57–160 m occur grey marls with a limestone at levels JD 87 m and JD 123 m.

Azreg Member. This unit was defined by Robaszynski *et al.* (1994) in the Kef el Azreg section, 5 km south-east of the JS composite section. It extends from level JD 160.5 m to the 179 m level along the Oued Delfa section and is approximately 20 m thick in the Kef el Azreg type section. The sequence is of alternations of marly limestones and grey marls, sometimes channelled, with levels of calcareous nodules and calcareous concretions. At the top of the member there are three (sometimes four) beds of phosphatic nodules, mostly internal moulds of fossils including lower Cenomanian ammonites. In the type section of the member, the base of the Cenomanian Stage, defined by the first occurrence of the planktonic foraminiferan *Thalmanninella globotruncanoides*, is at level KZ 13.2 m (Text-fig. 6).

THE LIMITS AND DIVISIONS OF THE ALBIAN STAGE

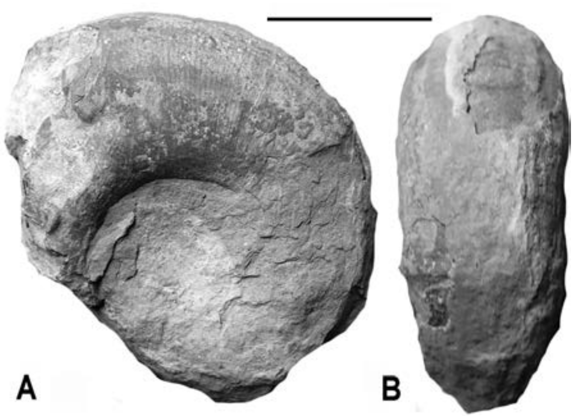
The Global Stratotype Section and Point for the base of the Albian Stage is the lowest occurrence of the planktonic foraminiferan *Microhedbergella renilaevis* Huber and Leckie, 2011 within the thin organic-rich Kilian level, at Pré-Guittard, Arnayon, Drôme, France (Kennedy *et al.* 2017; see also Kennedy *et al.* 2000, 2004; Petrizzo *et al.* 2012, 2013). This marks a major turnover in planktonic foraminiferans, with the extinction of larger species of *Hedbergella* Bronnimann and Brown, 1958 and *Paraticinella* Premoli Silva, Caron, Leckie, Petrizzo, Soldan and Verga, 2009, and their replacement by small, smooth species of

Microhedbergella Huber and Leckie, 2011. This same turnover has been recorded in the Atlantic and Indian Oceans (Huber and Leckie 2011). The GSSP falls some metres above the first occurrence of circular representatives of the nannofossil *Praediscosphaera columnata* (Stover, 1966) and coincides with a small negative excursion in $\delta^{13}C$. The boundary falls within the *Hypacanthoplites plesiotypicus* ammonite zone.

In the Jbel Jérissa composite section, *Microhedbergella renilaevis* first occurs at level JS 308 m in the lower marls of the Fahdène Formation and is absent in a sample from level JS 294 m (see Appendix). The boundary thus lies above level 294 m, within the 294–308 m interval.

The traditional base of the middle Albian is placed at the lowest occurrence of the ammonite *Lyelliceras lyelli* (d'Orbigny, 1841) (Birkelund *et al.* 1984; Hart *et al.* 1996; Reboulet *et al*. 2018).

The base of the upper Albian is drawn at the lowest occurrence of the ammonite *Dipoloceras cristatum* (Brongniart, 1822) (Birkelund *et al.* 1984; Hart *et al*. 1996; Gale *et al*. 2011; Szives *et al.* 2024).



Text-fig. 7. *Ammonoceratites* (*Argonauticeras*) sp. from the Jbel Jérissa composite section in lateral (A) and ventral (B) views, UBGD FAR 1, level JS 202 m. Scale bar equals 50 mm.

Text-fig. 8. *Oxytropidoceras* (*Oxytropidoceras*) sp. from the Jbel Jérissa composite section in lateral view, UBGD FAR 2, level JS 366 m. Scale bar equals 10 mm.

ALBIAN AMMONITE ZONES IN CENTRAL TUNISIA

The lower and middle Albian zonation for Central Tunisia proposed by Latil (2011) is as follows:

(youngest)
MIDDLE ALBIAN
Lyelliceras lyelli Zone
LOWER ALBIAN
Lyelliceras pseudolyelli Zone
Tegoceras camatteanum Zone
Buloticeras radenaci Zone
Prolyelliceras gevreyi Zone
'*Hypacanthoplites*' *buloti* Zone
Mellegueiceras ouenzaensis Zone
'*Hypacanthoplites*' *paucicostatus* Zone
(gap)
Mellegueiceras chihaouiae Zone
(oldest)

Latil (2011) placed the base of the Albian at the base of his *Mellegueiceras chihaouiae* Zone, but the records from the JS section (Text-fig. 6) suggest a different interpretation. Thus, *Mellegueiceras ouenzaensis* (Breistroffer, 1953) occurs at level JS 161–167 m, and '*Hypacanthoplites*' *buloti* Latil, 2011 (Text-fig. 10C, D) extends from level JS 198 m to level JS 213 m. The *buloti* Zone as well as the underlying *ouenzaensis*, *paucicostatus* and *chihaouiae* zones are thus upper Aptian.

The interval above the highest specimen of '*H.*' *buloti* at level JS 213 m and the first occurrence of *Microhedbergella renilaevis*, no lower than level JS 294 m, is difficult to date in terms of ammonite zones, and as with many of the sections studied, the zonal attribution of ammonites is possible, but their discontinuous record means that it is generally not possible to place zonal boundaries with any confidence. The presence of *Tegoceras mosense* (d'Orbigny, 1841) (Text-fig. 11A) at level JS 353 m indicates upper lower Albian (Kennedy and Klinger 2008).

The presence of *Lyelliceras* cf. *lyelli* (Text-fig. 11D) at level JS 428 m indicates the eponymous basal middle Albian Zone, but not necessarily the position of the base of the substage.

There is no ammonite evidence for the remainder of the middle Albian.

The upper Albian zonation used herein is as follows:

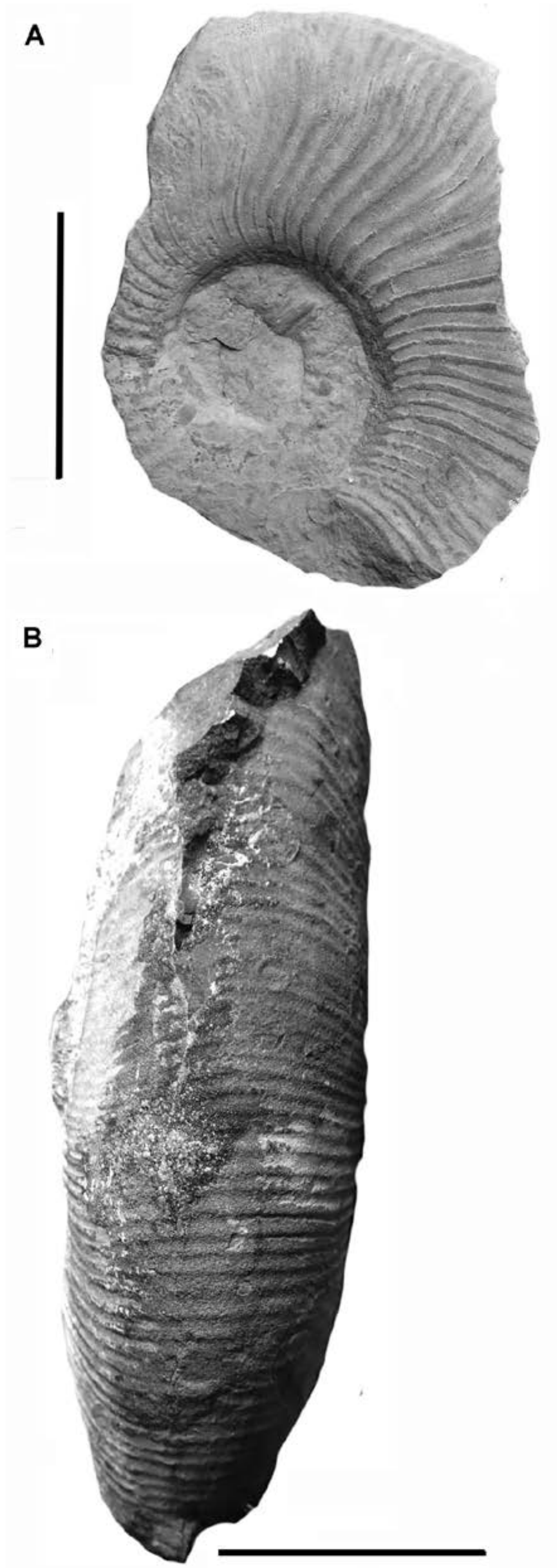
(youngest)
Pervinquieria (*Subschloenbachia*) *perinflata* Zone
Pervinquieria (*Subschloenbachia*) *rostrata* Zone
Pervinquieria (*Pervinquieria*) *fallax* Zone
Pervinquieria (*Pervinquieria*) *inflata* Zone
Pervinquieria (*Pervinquieria*) *pricei* Zone
Dipoloceras cristatum Zone
(oldest)

There is no ammonite evidence for the *Dipoloceras cristatum* Zone.

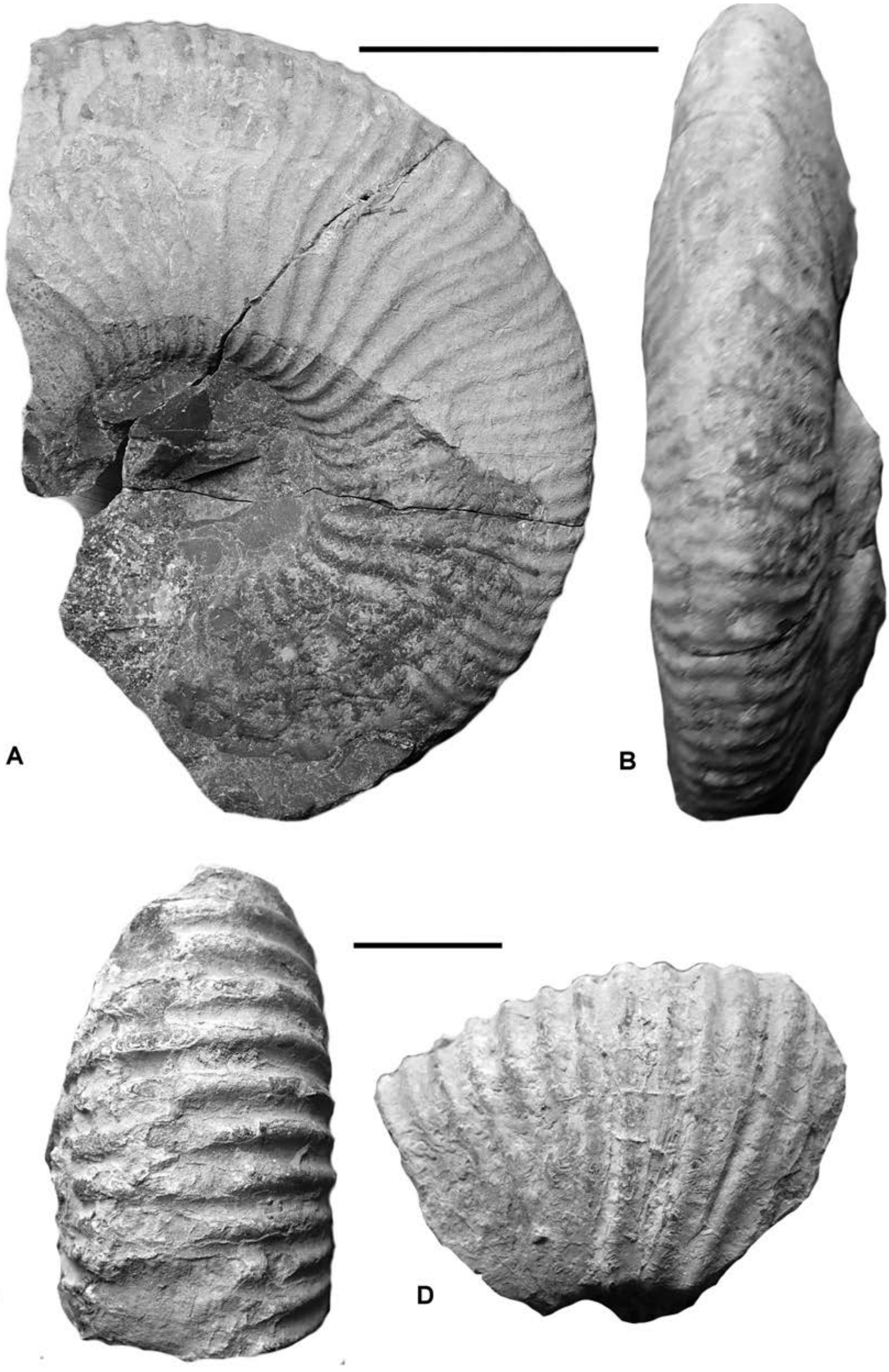
The intermittent occurrence of ammonites in the higher parts of the Albian means that although the presence of marker fossils can be demonstrated, it is not possible to place zonal boundaries.

The Jebel Jérissa composite section has yielded *Lyelliceras* cf. *lyelli* of the basal middle Albian at the 71 m level. The lower upper Albian zonal index *Pervinquieria* (*P.*) cf. *pricei* (Spath, 1922) (Text-fig. 13B) occurs at the 157 m level, whilst specimens of *Elobiceras* (*Craginites*) *serratescens* (Cragin, 1893) (Text-fig. 13A, C, D) occur at the 135 m level and at level JS 516–681.5 m, associated with *Hysteroceras* sp. (Text-fig. 13B, E). Gale and Kennedy (2020, p. 90) recognised a *serratescens* Zone in north-east Texas (the type area of the species), and suggested that the presence of *Hysteroceras* species in the lower part of the zone there indicated a correlation with the *pricei* Zone. Above this level, there is no evidence of the *P.* (*P.*) *inflata, P.* (*P.*) *fallax* and *P.* (*S.*) *rostrata* zones, with the exception of a single *Pervinquieria* (*Pervinquieria*)? cf. *rostrata* (J. Sowerby, 1817) at level JS 764.1 m. In contrast, the *perinflata* Zone is represented by diverse ammonite faunas, preserved, predominantly, as limonitic nuclei (Text-fig. 14A–L), corresponding to those described by Kennedy (2020).

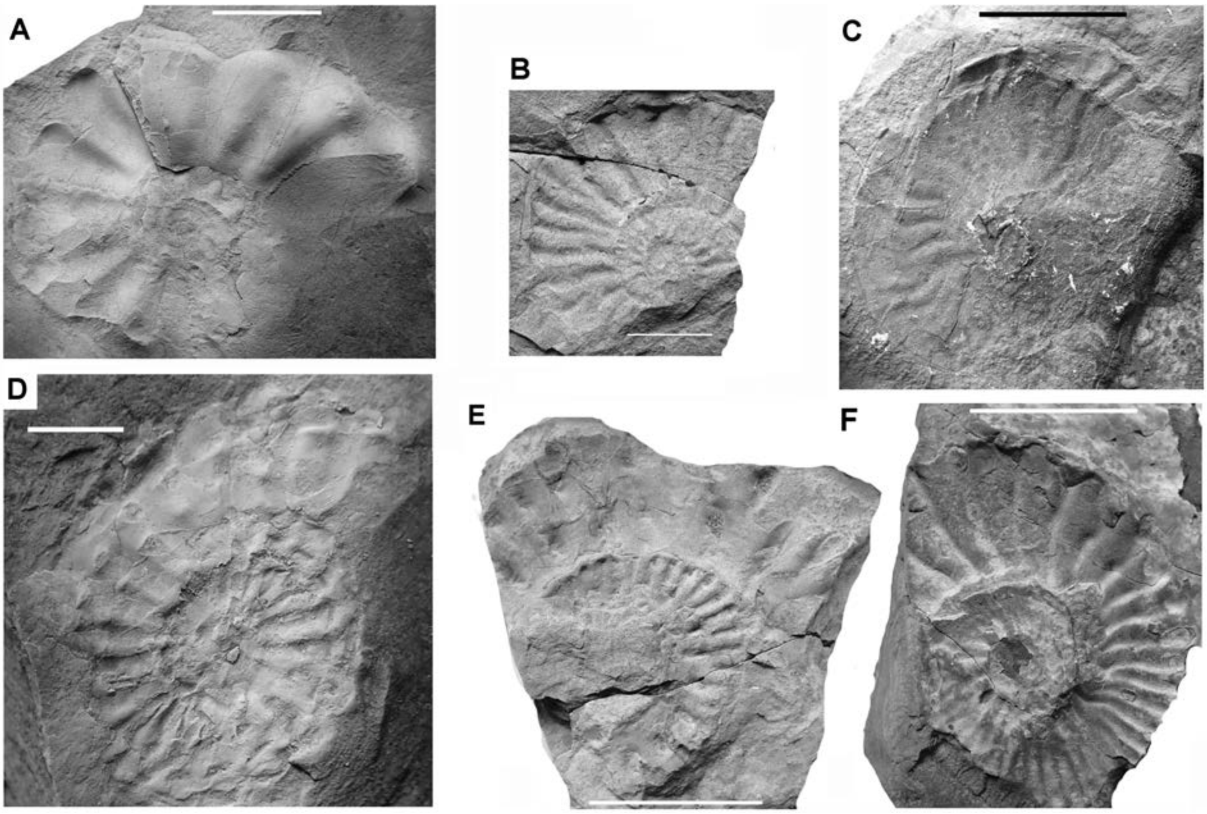
The phosphatic horizons of the Azreg Formation and the succeeding marls yield complex lower Cenomanian faunas, documented in detail by Amédro in Robaszynski *et al.* (1994), and referred to the *Graysonites azregensis* and *G. cobbani* zones. Unphosphatised faunas include *Graysonites wacoense* (Böse, 1928) (Text-fig. 15A, B, F, G) and *Mantelliceras mantelli* (J. Sowerby, 1814) (Text-fig. 15D, E).



Text-fig. 9. *Mellegueiceras jaillardi* Latil, 2011 from the Jbel Jérissa composite section in lateral (A) and ventral (B) views, UBGD FAR 3 and 4, respectively, level JS 161–167 m. Scale bars equal 50 mm.



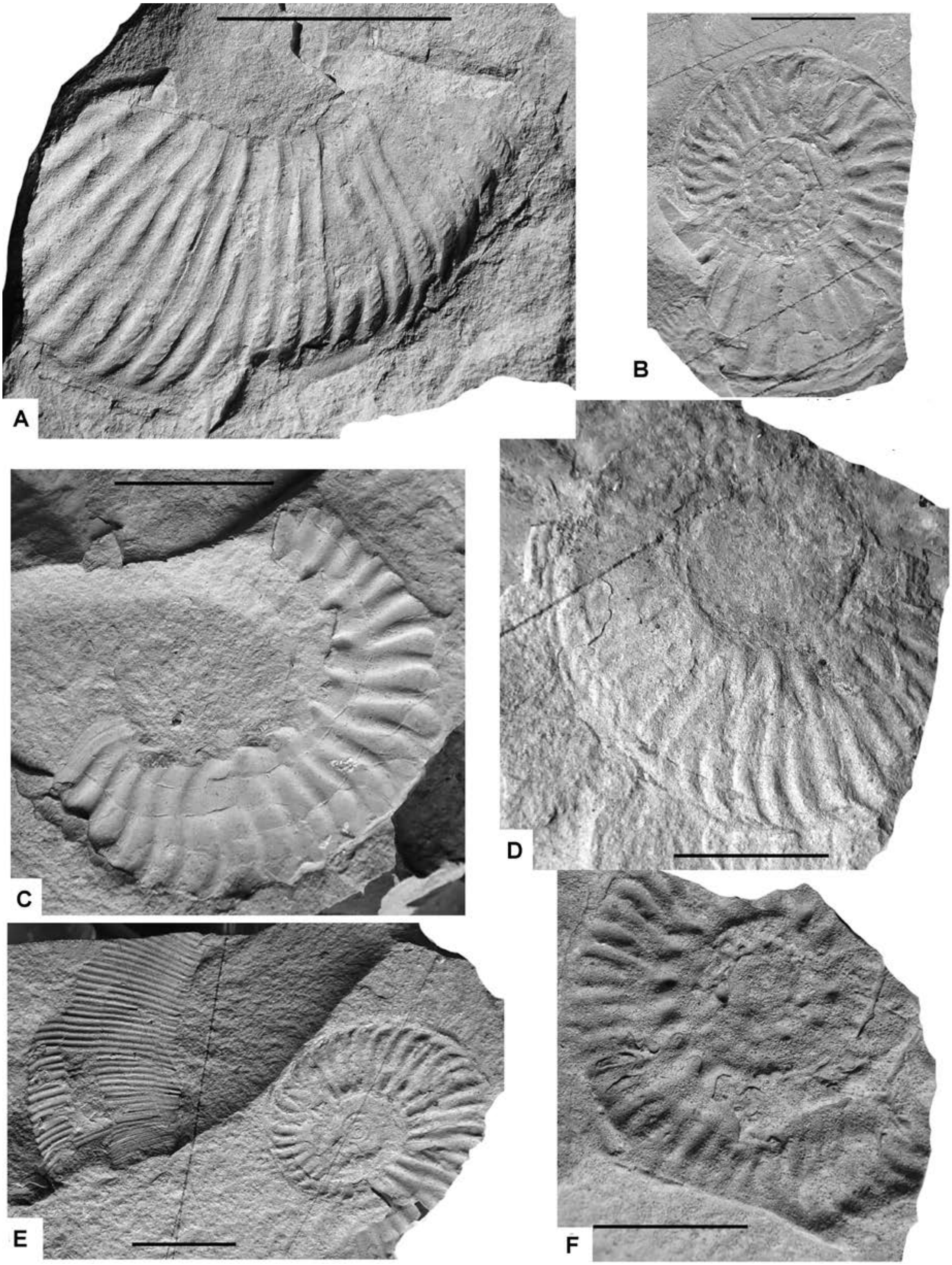
Text-fig. 10. Ammonites from the Jbel Jérissa composite section. A, B – *Mellegueiceras jaillardi* Latil, 2011 in lateral (A) and ventral (B) views, UBGD FAR 5, level JS 161 m. C, D – '*Hypacanthoplites*' *buloti* Latil, 2011 in ventral (C) and lateral (D) views, UBGD FAR 6, level JS 206 m. Scale bars equal 50 mm.



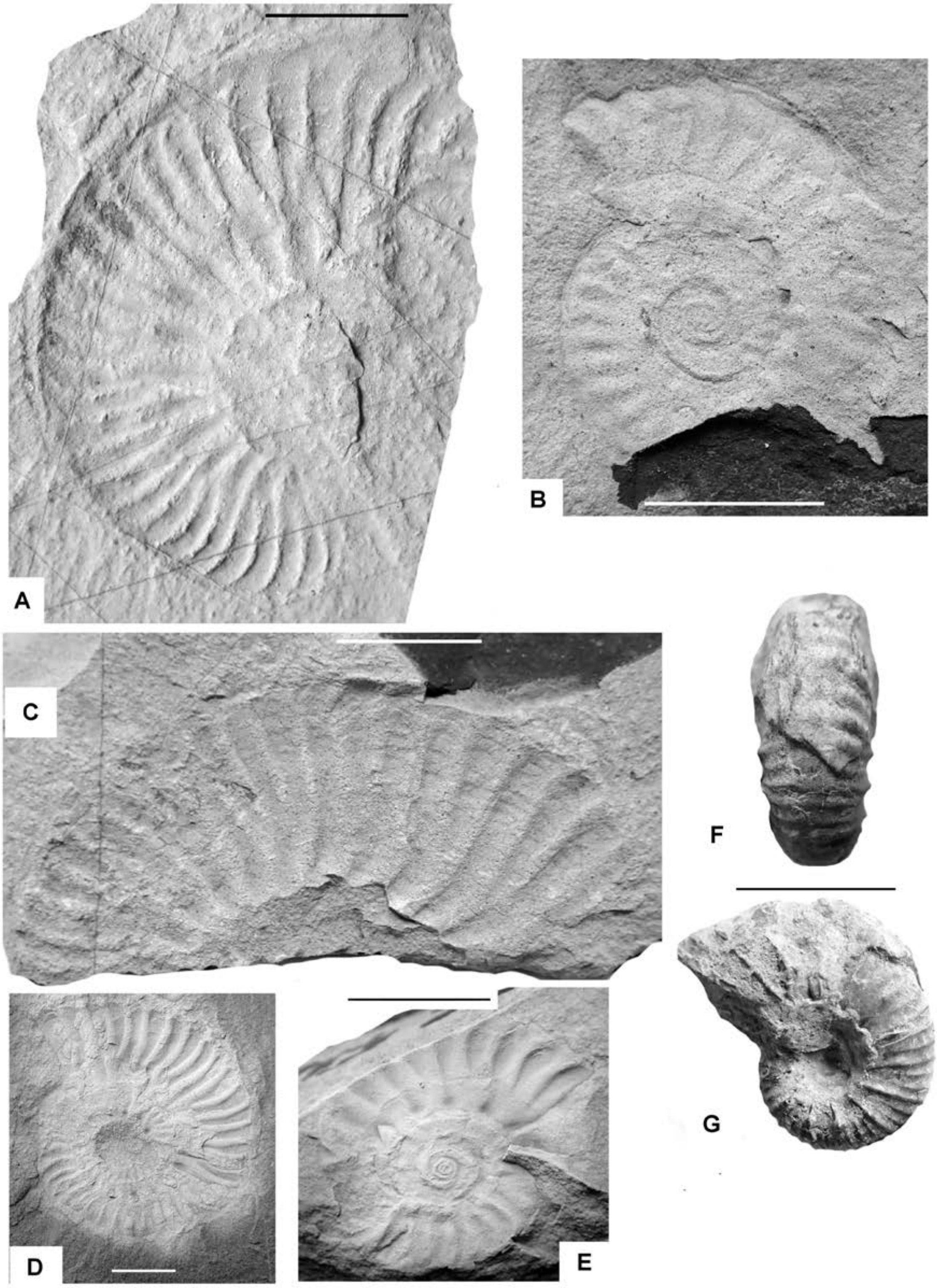
Text-fig. 11. Ammonites from the Jbel Jérissa composite section. A – *Tegoceras mosense* (d'Orbigny, 1841), UBGD FAR 17, level JS 353 m. B – *Pervinquieria* (*Pervinquieria*) sp. juv., cf. *pricei* (Spath, 1922), UBGD FAR 18, level JS 489 m. C – *Oxytropidoceras* (*Oxytropidoceras*) sp. juv., UBGD FAR 19, level JS 329 m. D – *Lyelliceras* cf. *lyelli* (d'Orbigny, 1841), UBGD FAR 20, level JS 428 m. E – *Elobiceras* (*Craiginites*) cf. *serratescens* (Cragin, 1893), UBGD FAR 21, level JS 578 m. F – *Pervinquieria* (*Pervinquieria*)? cf. *rostrata* (J. Sowerby, 1817), UBGD FAR 22, level JS 764.1 m. All specimens in lateral view. Scale bars equal 10 mm.

PLANKTONIC FORAMINIFERA

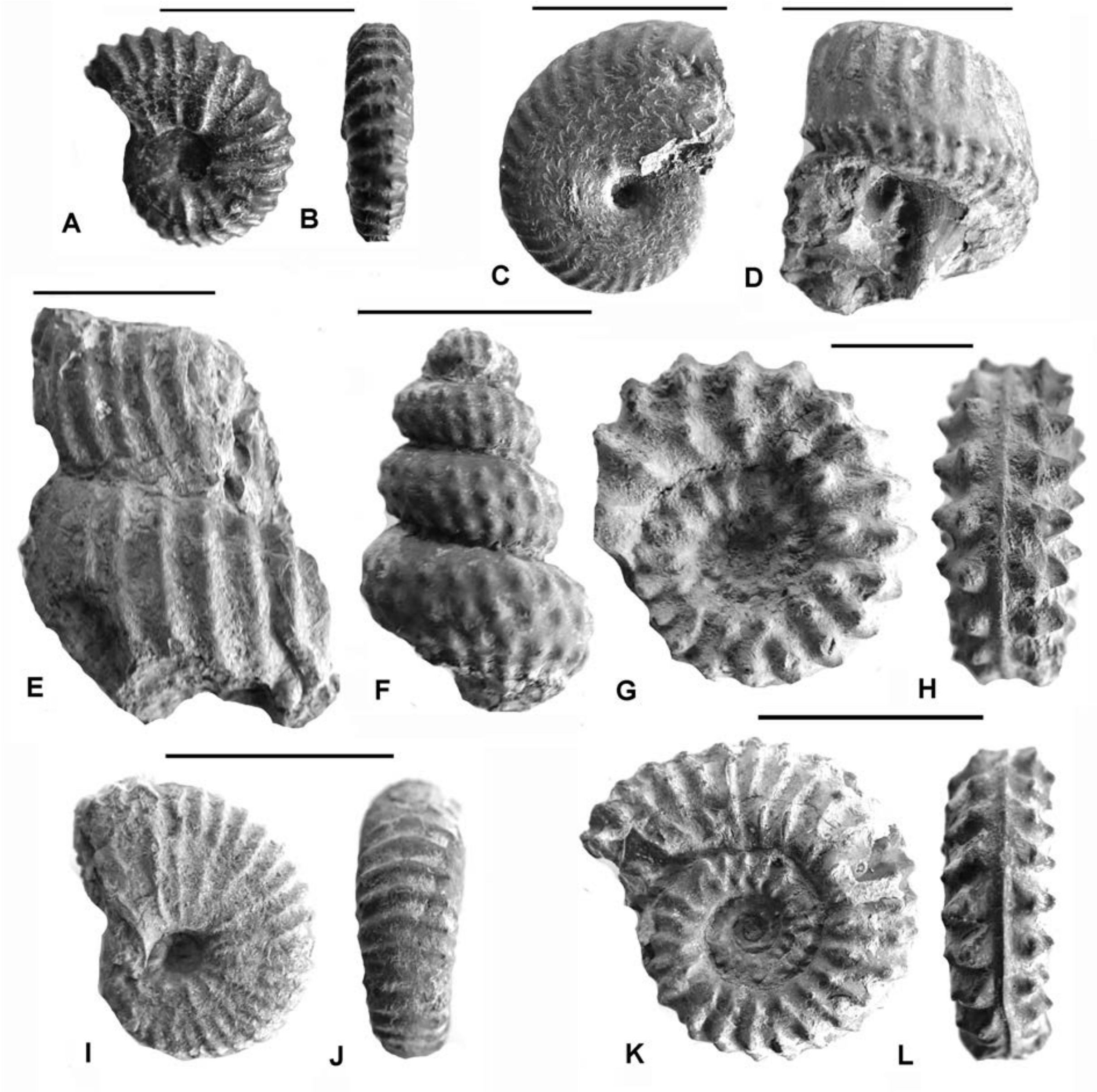
Samples from the 111–814 m interval in the Jbel Jérissa composite section were studied for planktonic foraminifera (see Appendix). Samples from 111 to 294 m are characterised by a low diversity assemblage dominated by *Favusella* spp., *Hedbergella* spp. and *Globigerinelloides* spp.; some of them are illustrated in Text-figs 16–22. The genus *Favusella* Michael, 1973 is the most common and shows a high morphologic variability that allowed identification of several species described in the literature in the 1970s (*F. nitida* Michael, 1973; *F. stiftia* Rosler, Lutze and Pflaumann, 1979; *F. quadrata* Michael, 1973; *F. wenoensis* Michael, 1973; *F. hedbergellaeformis* Longoria and Gamper, 1977; *F. confusa* Longoria and Gamper, 1977; *F. papagayosensis* Longoria and Gamper, 1977; see Appendix and Text-figs 18, 19F–H, 21J–N, R, 22D–G, J–W) and later synonymized under *Favusella washitensis* (Carsey, 1926) because they share the same faveolate wall texture (Text-fig. 22F, G, K–N). Representatives of *Favusella* spp., *Hedbergella* spp. and *Globigerinelloides* spp. are documented occurring throughout the Aptian, however marker zonal species are absent, hampering the assignment of the stratigraphic interval to precise biozones. Nevertheless, the concomitant presence of *Globigerinelloides blowi* (Bolli, 1959), *G. aptiensis* Longoria, 1974, *Hedbergella ruka* (Banner, Copestake and White, 1993), *H. compacta* (Banner, Copestake and White, 1993), *H. sigali* Moullade, 1966, and *H. gorbachikae* Longoria, 1974 (Text-fig. 21S–V) in the lower part of the JS section (from 111 to 142.9 m) could indicate the middle Aptian (see Appendix). Samples from levels JS 153.2 to 294 m do not yield marker species and only an increase in species of *Hedbergella* spp. is observed (see Appendix), however, the stratigraphic interval could be reasonably assigned to the lower part of the upper Aptian according to the composition of the as-



Text-fig. 12. Ammonites from the Jbel Jérissa composite section. A – *Elobiceras* (*Craginites*) *neuparthi* (Choffat, 1905), UBGD FAR 12, level JS 681.5 m. B, D – *Elobiceras* (*Craginites*) sp., UBGD FAR 13, level JS 516.8 m. C – *Hysteroceras* sp., UBGD FAR 14, level JS 681.5 m. E – *Pervinquieria* (*Pervinquieria*) sp. juv. and *Hamites* sp. nov., UBGD FAR 15, level JS 515 m. F – *Pervinquieria* (*Pervinquieria*) sp. juv., UBGD FAR 16, level JS 679.5 m. All specimens in lateral view. Scale bars equal 10 mm.



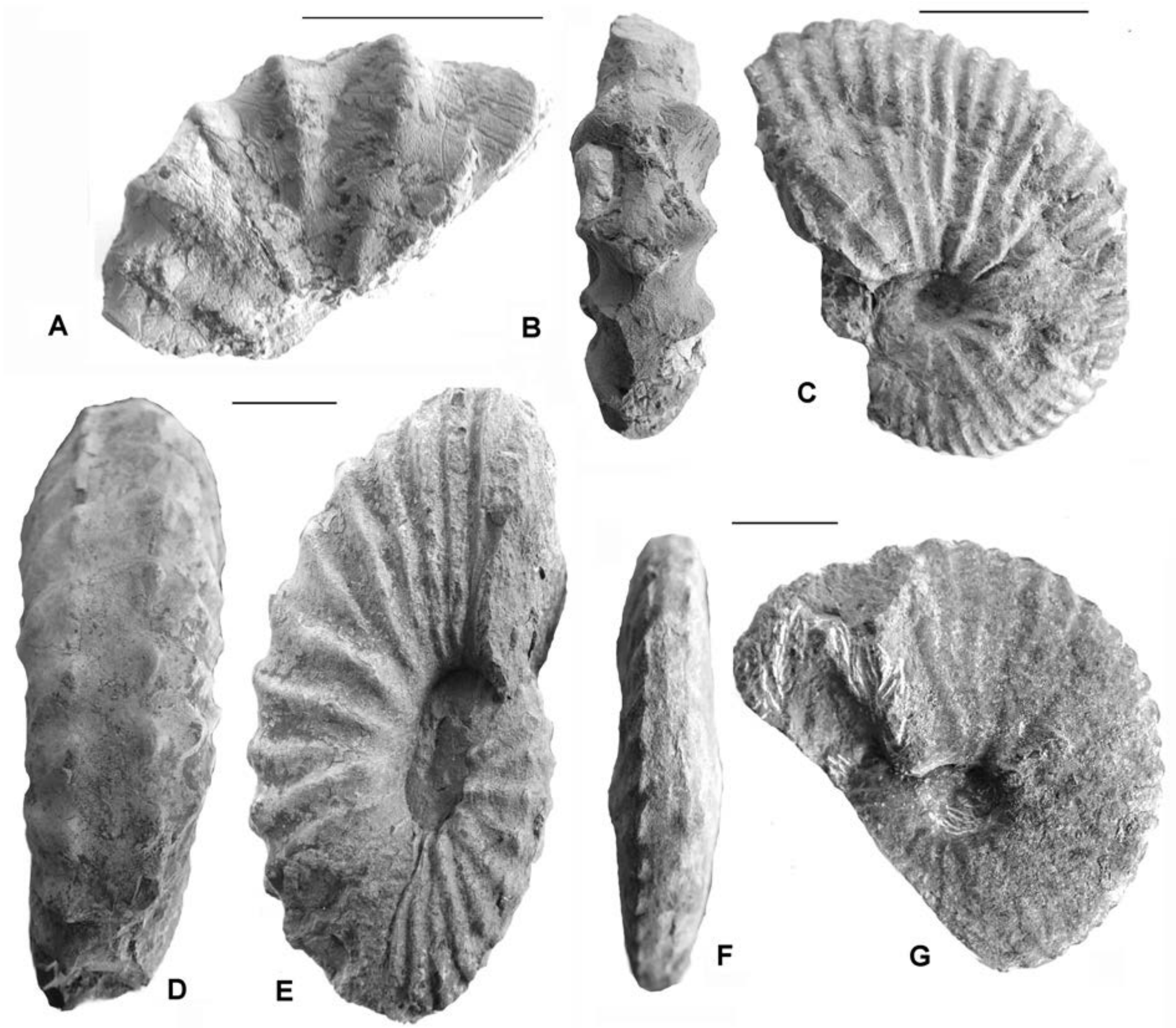
Text-fig. 13. Ammonites from the Jbel Jérissa composite section. A, C – *Elobiceras* (*Craginites*) *serratescens* (Cragin, 1893) in lateral view, UBGD FAR 7, level JS 516.8 m. B – *Hysteroceras* sp. in lateral view, UBGD FAR 8, level JS 506.5 m. D – *Elobiceras* (*Craginites*) sp. juv., cf. *serratescens* (Cragin, 1893) in lateral view, UBGD FAR 9, level JS 544.5 m. E – *Hysteroceras* sp. juv., cf. *orbignyi* (Spath, 1922) in lateral view, UBGD FAR 10, level JS 544.5 m. F, G – *Hypacanthoplites* cf. *clavatus* (Fritel, 1906) in ventral (F) and lateral (G) views, UBGD FAR 11, level JS 214 m. Scale bars equal 10 mm.



Text-fig. 14. Ammonites from the Jbel Jérissa composite section. A, B – *Stoliczkaia* (*Stoliczkaia*) *djerissaensis* Kennedy, 2020 in lateral (A) and ventral (B) views, UBGD FAR 23. C – *Stoliczkaia* (*Stoliczkaia*) *subboulei* (Sornay, 1955) in lateral view, UBGD FAR 24. D, E – *Ostlingoceras* (*Ostlingoceras*) *puzosianum* (d'Orbigny, 1842) in lateral views, UBGD FAR 25. F – *Mariella* (*Mariella*) *bergeri* (Brongniart, 1822) in lateral view, UBGD FAR 26. G, H, K, L – *Cantabrigites spinosum* (Pervinquière, 1907) in lateral (G, K) and ventral (H, L) views, UBGD FAR 28 (G, H) and UBGD FAR 29 (K, L). I, J – *Stoliczkaia* (*Stoliczkaia*) *clavigera* (Neumayr, 1875) in lateral (I) and ventral (J) views, UBGD FAR 30. All specimens are from the limonitic fauna of level JD 126.5 m (Text-figs 4 and 5). Scale bars equal 10 mm.

semblages and in the absence of *Paraticinella* spp. which usually show a continuous record in the upper Aptian.

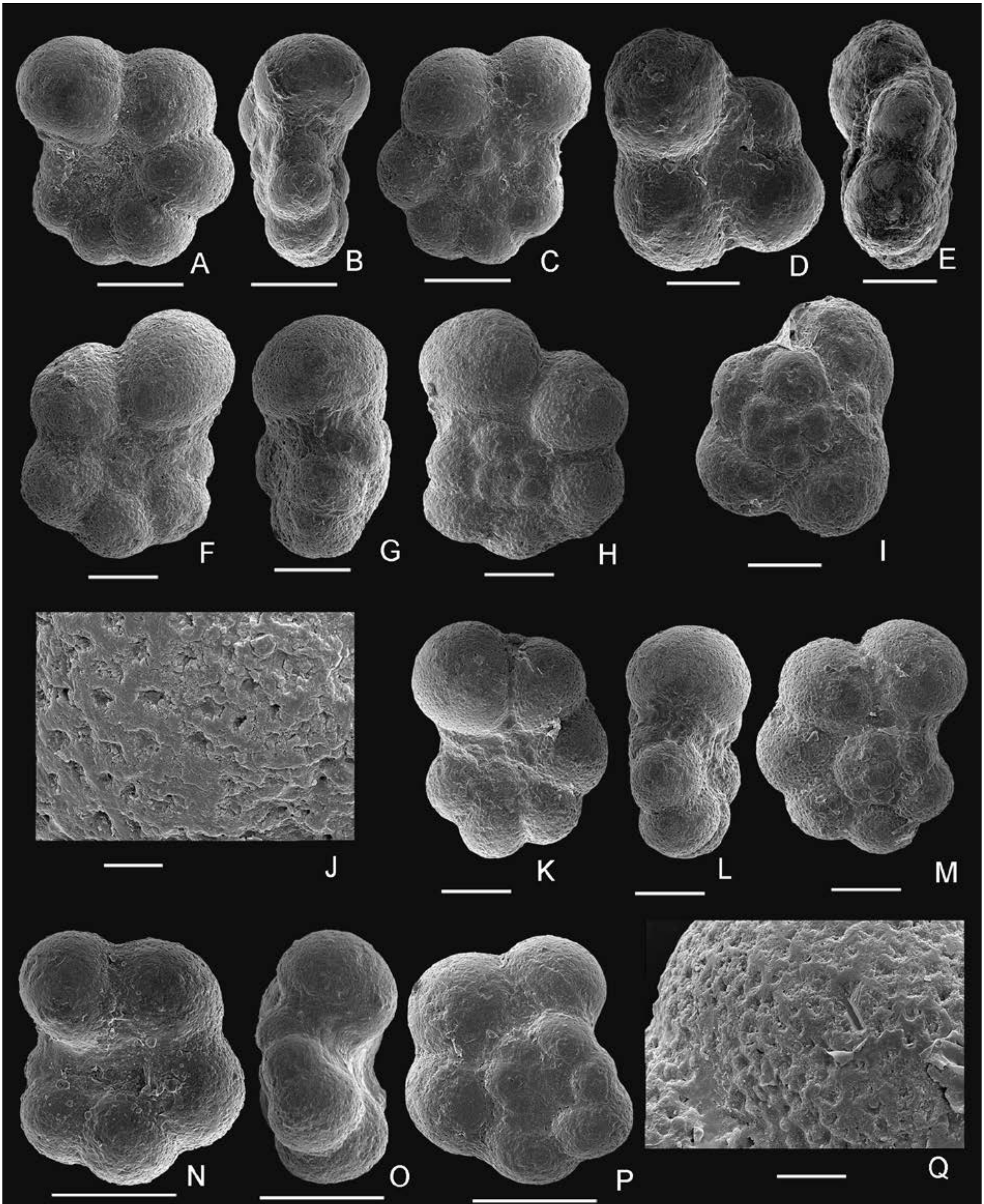
The next upwards investigated sample at level JS 308 m contains a typical Albian assemblage with *Microhedbergella renilaevis* (Text-figs 16D, E, I, 20D, E, J) and *Ticinella* spp. (Text-figs 16F–H, J, K–M, Q, 19O–R, T, U). Specifically, the presence of *T. primula* Luterbacher in Renz *et al*., 1963 (Text-fig. 16K–M, Q) allows the identification of the *Ticinella primula* Zone and indicate that the lowermost Albian, spanning the *Microhedbergella renilaevis*, *Ticinella rischi* and *Ticinella madecassiana* zones (e.g., Petrizzo *et al*. 2026), is missing. Therefore, the



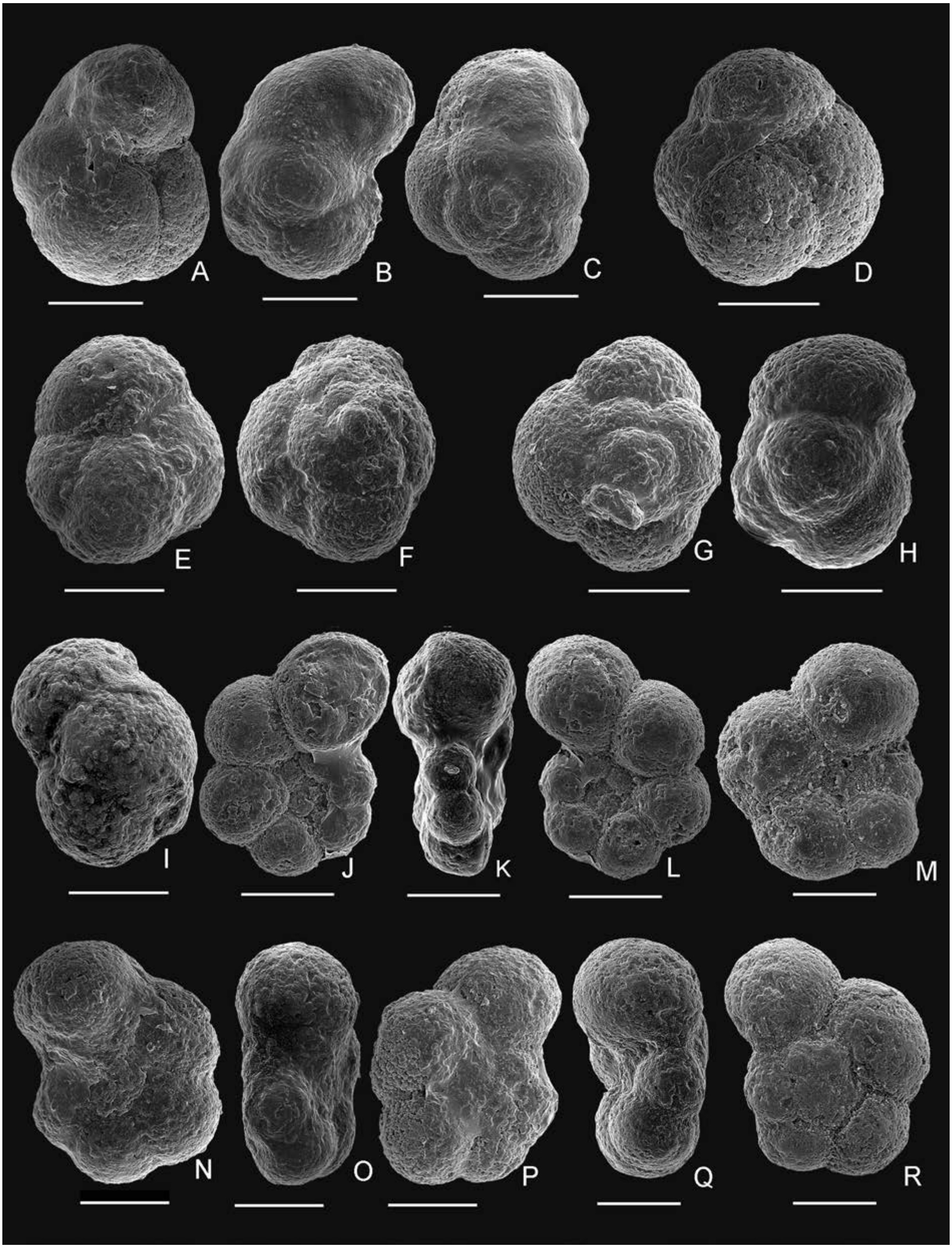
Text-fig. 15. Ammonites from the Jbel Jérissa composite section. A, B, F, G – *Graysonites wacoense* (Böse, 1928) in lateral (A, G) and ventral (B, F) views, UBGD FAR 31 (A, B) and UBGD FAR 32 (F, G), level KZ 10-12 m (Text-figs 4 and 5), from the unphosphatised fauna at the level of the lowest phosphate bed of the Oued Delfa section. C – *Stoliczkaia* (*Stoliczkaia*) *clavigera* (Neumayr, 1975) in lateral view, UBGD FAR 33, level JD 126.5 m (Text-figs 4 and 5). D, E – *Mantelliceras mantelli* (J. Sowerby, 1814) in ventral (D) and lateral (F) views, UBGD FAR 34, from the unphosphatised Lower Cenomanian fauna of the JD section (Text-figs 4 and 5). Scale bars equal 5 mm.

Aptian/Albian boundary is located between samples JS 294 m and JS 308 m and, considering the composition of the recorded Aptian and Albian planktonic foraminiferal assemblages (see Appendix), there is a hiatus of at least 1 myr, spanning the top of the Aptian and basal Albian (Gale *et al.* 2020).

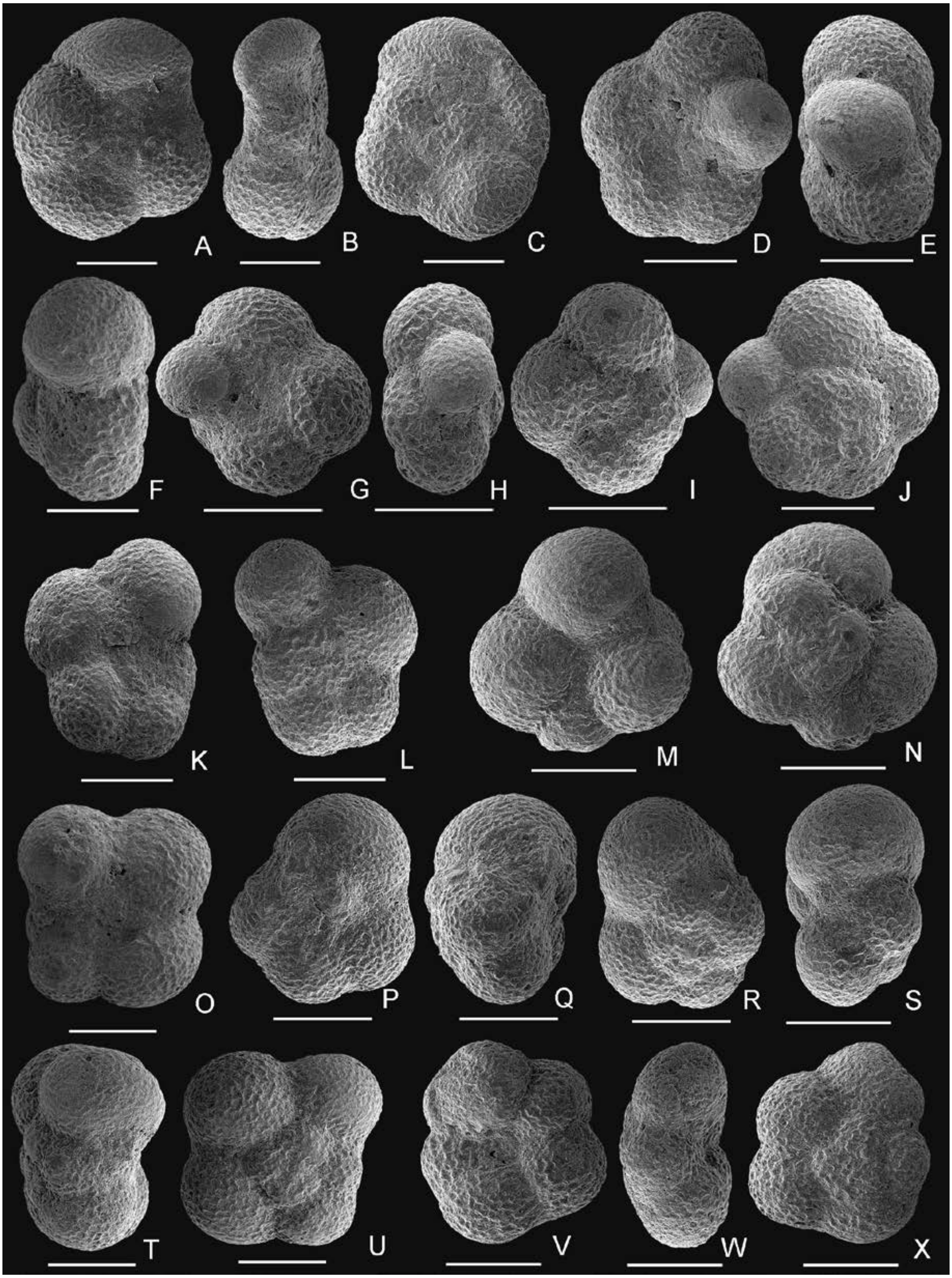
The stratigraphic interval from level JS 308 m to 456 m is assigned to the *Ticinella primula* Zone and the lowest occurrence (LO) of *Biticinella breggiensis* (Gandolfi, 1942) in sample JS 503 m allows the identification of the *Biticinella breggiensis* Zone (see Appendix). The planktonic foraminiferal assemblages in the *T. primula* and *B. breggiensis* zones are dominated by species of *Ticinella* and in minor abundance by *Muricohedbergella* species. Remarkable events in the *Ticinella primula* Zone are the LO of the planispiral *Laeviella primuloides* Huber, Petrizzo and Falzoni, 2022, *L. bentonensis* Morrow, 1934, and *Planohedbergella ultramicra* Subbotina, 1849, that are known to reappear in the evolutionary history of planktonic foraminifera after the planispiral gap observed worldwide across the Aptian/Albian



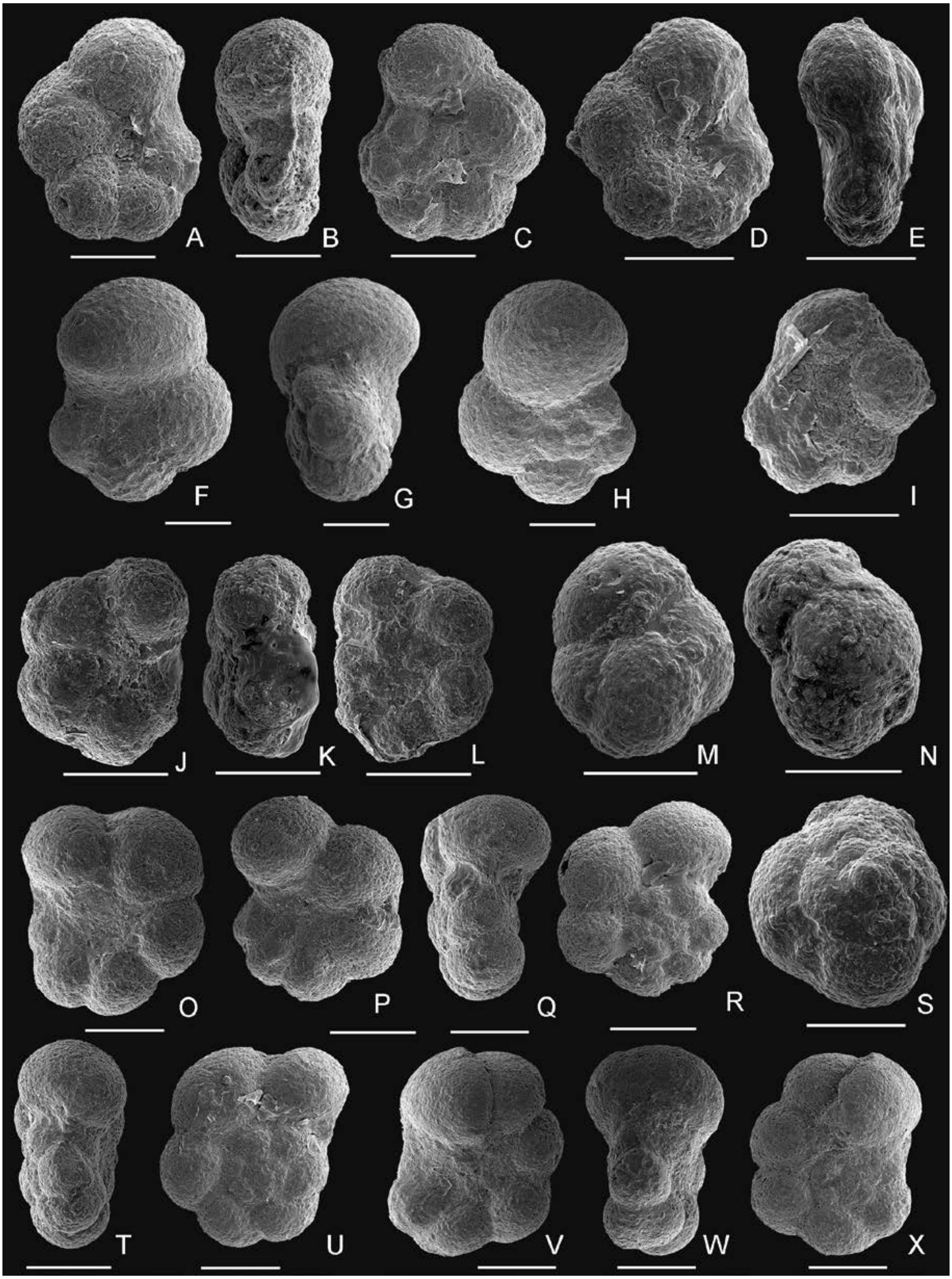
Text-fig. 16. Foraminifera from the Jbel Jérissa composite section. A–C – *Microhedbergella praeplanispira* Huber and Leckie, 2011, sample JS 315 m. D, E, I – *Microhedbergella renilaevis* Huber and Leckie, 2011, sample JS 308 m. F–H, J – *Ticinella madecassiana* Sigal, 1966, sample JS 308 m; supplementary apertures not visible on the umbilical side; the specimen, however, showing a typical ticinellid wall texture. K–M, Q – *Ticinella primula* Luterbacher in Renz *et al*., 1963, sample JS 308 m, supplementary apertures on the umbilical side not visible; the specimen, however, showing a typical ticinellid wall texture. N–P – *Ticinella rischi* (Moullade, 1974), sample JS 315 m. Scale bars equal 100 µm (A–C, F–H, K–M), 50 µm (D, E, I), and 20 µm (J, Q).



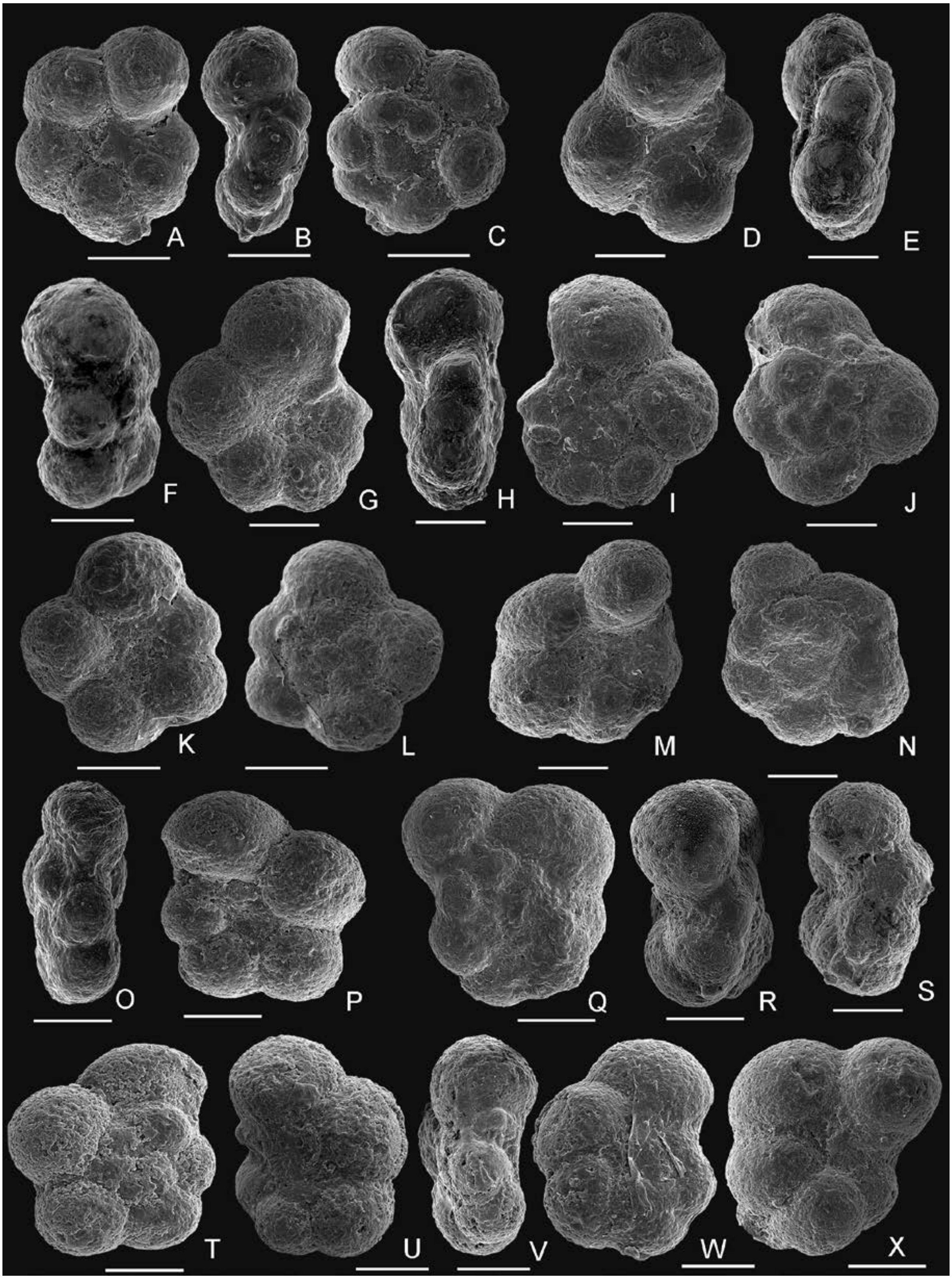
Text-fig. 17. Foraminifera from the Jbel Jérissa composite section. A–I – *Gubkinella graysonensis* (Tappan, 1940), sample JS 237 m (A–C and D, G, H) and sample JS 328 m (E, F, I). J–L – *Globigerinelloides aptiensis* Longoria 1974, sample JS 142.9 m. M, Q, R – *Hedbergella infracretacea* (Glaessner, 1937), sample JS 237 m. N–P – *Hedbergella aptiana* Bartenstein, 1965, sample JS 237. Scale bars equal 50 µm.



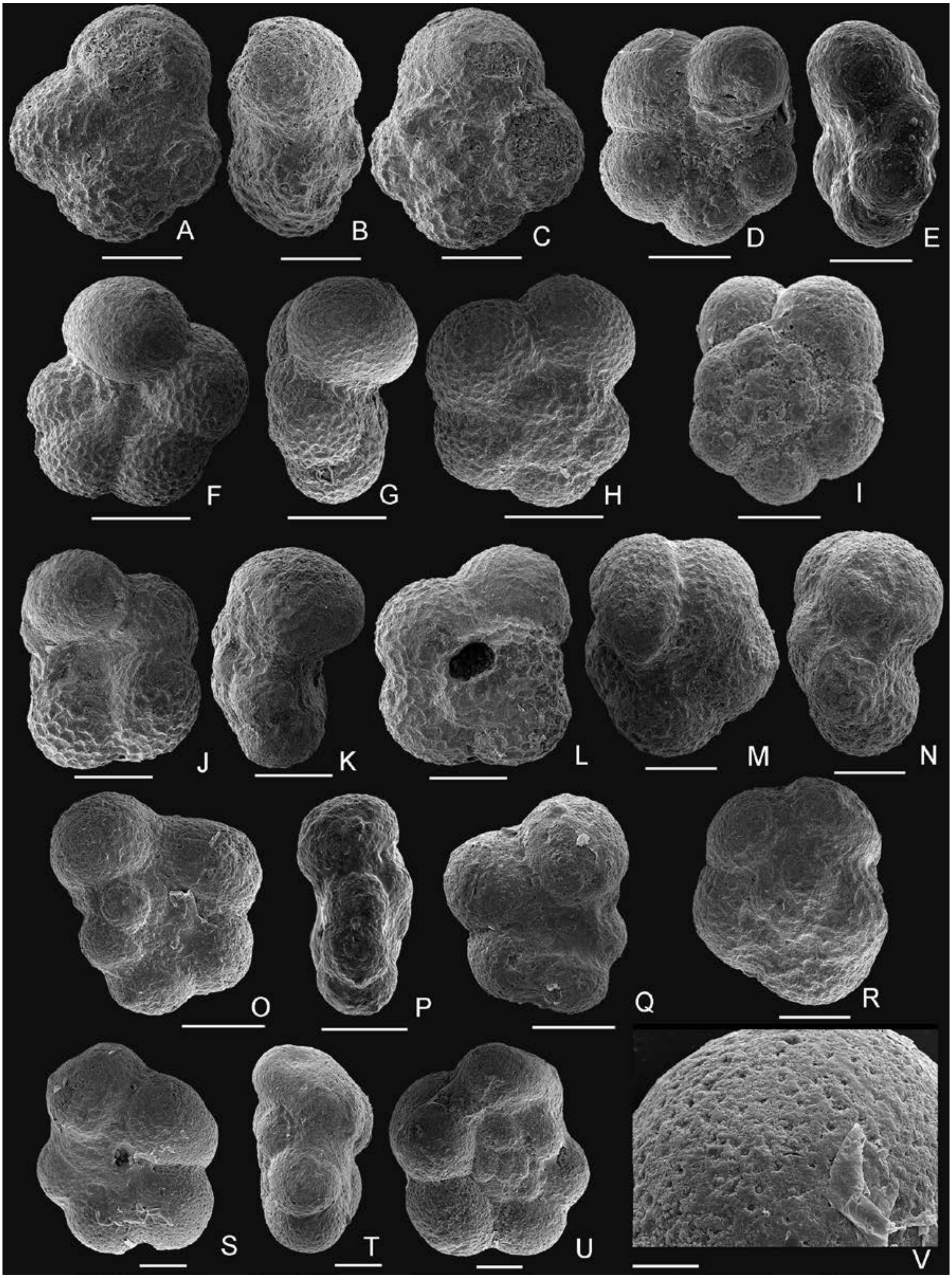
Text-fig. 18. Foraminifera from the Jbel Jérissa composite section. A–C, M, N, S – *Favusella* sp., sample JS 228.5 m (A–C) and sample JS 264 m (M, N, S). D–F, J–L, V–X – *Favusella nitida* Michael, 1973, samples JS 228.5 m (D, E, J), JS 142.9 m (F, K, L), and JS 252 m (V–X). G, H, I – *Favusella stiftia* Rosler, Lutze and Pflaumann, 1979, sample JS 228.5 m. O, T, U – *Favusella quadrata* Michael, 1973, sample JS 256 m. P–R – *Favusella papagayosensis* Longoria and Gamper, 1977, sample JS 264 m. Scale bars equal 200 µm.



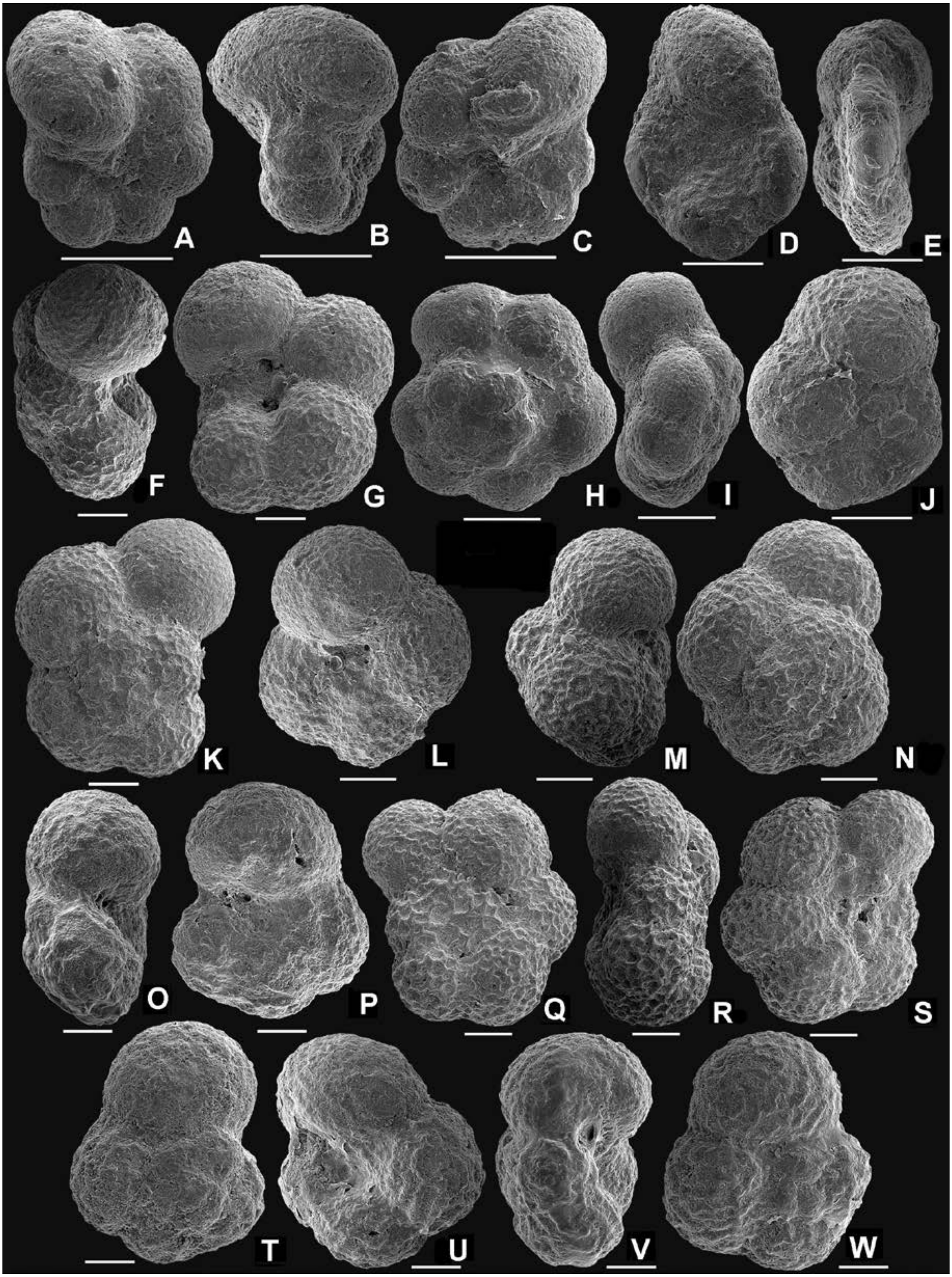
Text-fig. 19. Foraminifera from the Jbel Jérissa composite section. A–C, D, E, I and J–L – *Microhedbergella praeplanispira* Huber and Leckie, 2011, sample JS 328 m. F–H – *Favusella confusa* Longoria and Gamper, 1977, sample JS 318 m. M, N, S – *Gublikinella graysonensis* (Tappan, 1940), sample JS 328 m. O, T, U and P–R – *Ticinella madecassiana* Sigal, 1966, sample JS 308 m. V–X – *Biticinella subbreggiensis* Sigal, 1966, sample JS 318 m. Scale bars equal 100 µm (F–H, O–R, T–X) and 50 µm (A–E, I–N, S)



Text-fig. 20. Foraminifera from the Jbel Jérissa composite section. A–C, G–I – *Microhedbergella praeplanispira* Huber and Leckie, 2011, sample JS 308 m. D, E, J – *Microhedbergella renilaevis* Huber and Leckie, 2011, sample JS 308 m. M, N, S – *Ticinella* sp., sample JS 308 m. F, K, L – *Microhedbergella pseudodelrioensis* Huber and Leckie, 2011, sample JS 308 m. Q, R, X – *Hedbergella infracretacea* (Glaessner, 1937), sample JS 264 m. O, P, T and U–W – *Hedbergella aptiana* Bartenstein, 1965, sample JS 237 m. Scale bars equal 50 µm.



Text-fig. 21. Foraminifera from the Jbel Jérissa composite section. A–C and M, N, R – *Favusella* sp., samples JS 264 m (A–C) and JS 252 m (M, N, R). D, E, I – *Hedbergella praetrocoidea* Kretchmar and Gorbachik in Gorbachik, 1986, sample JS 237 m. F–H – *Favusella hedbergelliformis* Longoria and Gamper, 1977, sample JS 252 m. J–L – *Favusella quadrata* Michael, 1973, sample JS 264 m. O–Q – *Microhedbergella pseudodelrioensis* Huber and Leckie, 2011, sample JS 308 m. S–V – *Hedbergella gorbachikae* Longoria, 1974, sample JS 252 m. Scale bars equal 100 µm (A–C, F–H, J–N, R), 50 µm (D, E, I, O–Q, S–U), and 20 µm (V).



Text-fig. 22. Foraminifera from the Jbel Jérissa composite section. A–C – *Biticinella subbreggiensis* Sigal, 1966, sample JS 318 m. D, E, J, O, P, T and U–W – *Favusella wenoensis* Michael, 1973, sample JS 237 m (D, E, J) and JS 142.9 m (O, P, T and U–W). F, G, K and L–N – *Favusella washitensis* (Carsey, 1926), sample JS 142.9. H, I – *Ticinella roberti* Gandolfi, 1942, sample JS 308 m. Q–S – *Favusella* sp., sample JS 142.9 m. Scale bars equal 50 µm (O, P, T, U–W) and 100 µm for all others.

boundary (e.g., Huber *et al.* 2022). The appearance of *Pseudothalmanninella ticinensis* (Gandolfi, 1942) in sample JS 680.5 m and of *Thalmanninella appenninica* (Renz, 1936) in sample JS 756.5 m allow identification of the nominal zones, respectively (see Appendix). The assemblages in the two biozones are quite diverse and the most significant bioevents are observed, such as the LOs of *Planomalina pulchella* Todd and Low, 1964 (JS 683 m), *Planomalina buxtorfi* (Gandolfi, 1942) (JS 766.5 m), and *Paracostellagerina libyca* (Barr, 1972) (JM 194 m), among many others. The base of the Cenomanian is identified according to the LO of *Thalmanninella globotruncanoides* in sample JD 95 m, following the GSSP definition (Kennedy *et al.* 2004).

CONCLUSIONS

This contribution builds on previous work in Central Tunisia, noted in the introduction. There are three important conclusions:

1. The base of the Albian Stage, based on the first occurrence of the planktonic foraminiferan *Microhedbergella renilaevis* at level JS 308 m in the Jbel Jérissa composite section lies above part or all of the '*Hypacanthoplites*' *buloti* Zone (youngest), the *Mellegueiceras ouenzaensis* Zone, '*Hypacanthoplites*' *paucicostatus* Zone, and *Mellegueiceras chihaouiae* Zone of Latil (2011), which he referred to the lower Albian; they are actually late Aptian in age (Text-fig. 6). The lowermost Albian, including the *Microhedbergella renilaevis*, *Ticinella rischi* and *Ticinella madecassiana* planktonic foraminiferan zones are not represented and are missing in hiatus 1 which has a duration of approximately 1 myr. This hiatus (between JS 294 m and JS 308 m) probably includes the upper part of the *Hypacanthoplites*' *buloti* ammonite zone, all of the *Prolyelliceras gevreyi* Zone and part of the *Buloticeras radenaci* Zone (Text-fig. 6 – hiatus 1). This hiatus has been recorded extensively in Libya and central Tunisia as the 'Austrian unconformity', where it has been dated to the late Aptian (Bodin *et al.* 2010, fig. 8).
2. There is a gap in the ammonite record encompassing an interval from above part or all the lowest middle Albian *Lyelliceras lyelli* Zone to the base, or lower part of the *Pervinquieria* (*P.*) *pricei* Zone (Text-fig. 6 – hiatus 2); this gap includes most of the middle Albian and the lowermost upper Albian *Dipoloceras cristatum* Zone. The gap (between JS 428 m and JS 450 m) had been noted elsewhere in the area and is the result of a regional major hiatus within the Fahdène Formation (hiatus 2) with a duration of 2.5–3 myr. This hiatus has also been identified in Libya and central Tunisia as the middle Albian unconformity (Bodin *et al.* 2010, fig. 8).
3. There is no evidence of the *Pervinquieria* (*P.*) *inflata* and *P.* (*P.*) *fallax* zones, and only slight evidence for the *P.* (*S.*) *rostrata* Zone in the composite section. In the absence of evidence, it is unclear whether this can be attributed to condensation, hiatus or non-preservation (Text-fig. 6 – hiatus 3). However, the interval in which these zones would be expected to occur (within the *Pseudothalmanninella ticinensis* foraminiferan zone) is only (approximately) 50 m thick but evidently represents a long time interval of several myr (compare Gale *et al*. 2011, fig. 60).

Acknowledgements

Monsieur Christian Dupuis (Faculté Polytechnique de Mons) assisted us in the field. Monsieur Gérard Delanoy (Université de Nice-Sophia-Antipolis) assisted with the drafting of illustrations. We are grateful to the reviewers, Brian Huber and Markus Wilmsen, for their helpful and constructive reviews and to editor Anna Żylińska for her work on the text.

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Manuscript submitted: 12th January 2026
Revised version accepted: 28th March 2026

Appendix. Distribution of planktonic foraminifera in the Jbel Jérissa composite section.

COMPOSITE SECTION (JS, JM, JD) JBEL JERISSA	Thickness	*Gubkinella graysonensis*	*Favusella washitensis*	*Favusella wenoensis*	*Favusella* sp.	*Favusella nitida*	*Favusella stiftia*	*Favusella confusa*	*Favusella quadrata*	*Hedbergella aptiana*	*Pseuoguembelitria blakenosensis*	*Hedbergella gorbachikae*	*Globigerinelloides aptiensis*	*Globigerinelloides blowi*	*Hedbergella ruka*	*Hedbergella sigali*	*Hedbergella compacta*	*Hedbereglla occulta*	*Hedbergella praetrocoidea*	*Loeblichella convexa*	*Favusella papagayosensis*	*Favusella hedbergelliformis*	*Hedbergella* sp.	*Hedbergella infracretacea*	*Hedbergella excelsa*	*Hedbergella hispaniae*	*Hedbergella occulta*	*Microhedbegella renilaevis*	*Micohedbergella* sp.	*Micorhedbergella praeplanispira*	*Microhedbergella pseudodelrioensis*	***Ticinella primula***	*Ticinella madecassiana*	*Ticinella roberti*	*Tiicnella raynaudi*	*Ticinella rischi*	*Clavihedbergella simplicissima*	*Biticinella subbreggiensis*	*Leaviella bentonensis*	*Laeviella primuloides*	*Muricohedbergella planispira*	*Muricohedbergella angolae*	*Muricohedbergella delrioensis*	*Planohedbergella ultramicra*	*Ticinella praeticinensis*	***Biticinella breggiensis***	*Pseudothalmanninella subticinensis*	***Pseudothalmanninella ticinensis***	*Planomalina pulchella*	*Praeglobotruncana delrioensis*	*Thalmanninella balernaensis*	***Thalmanninella appenninica***	*Planomalina buxtorfi*	*Planomalina praebuxtorfi*	*Murixcohedbergella astrepta*	*Muricohedbergella blakensis*	*Laeviella tururrensis*	*Costellagerina praelybica*	*Guenbelitria cenomana*	*Costellagerina libyca*	*Thalmanninella gandolfii*	*Praeglobotruncana stephani*	*Thalmanninella brotzeni*	***Thalmanninella globotruncanoides***	ZONE
JD	95		X				X												X	X										X	X				X		X		X		X	X				X		X	X	X			X	X		X		X	X	X	X	X	*Thalman. globotrun.*
JD	83		X						X																						X	X	X			X		X		X		X	X				X			X	X			X	X	X			X	X	X			*Thamanninella appenninica*
JD	75						X		X												X	X										X		X					X		X		X	X				X		X	X		X		X	X		X		X	X			
JD	29		X																		X												X	X						X		X		X	X						X	X	X	X		X					X	X				
JD	4																					X												X	X				X		X		X		X									X	X	X	X	X	X	X		X					
JM	194		X				X		X												X											X	X				X		X		X		X	X				X			X	X			X	X	X		X					
JM	85								X																									X						X		X		X					X		X				X	X			X	X								
JM	82,5						X																											X	X		X		X		X		X		X			X								X			X								
JM	77						X				X																						X	X		X				X		X		X	X													X		X	X	X						
JM	74																															X	X		X		X		X		X		X	X		X		X					X	X	X	X										
JS	814						X																												X					X	X								X				X	X		X										
JS	809								X												X											X	X		X				X						X		X			X	X	X												
JS	798						X		X												X																				X		X			X		X		X	X	X	X												
JS	767																															X	X	X				X	X						X		X			X	X	X	X												
JS	757																															X	X	X	X		X	X	X					x	X	X	X		X	X												
JS	735																															X	X	X	X			X	X			X	X	X	X		X																	*Parathalman. ticinensis*
JS	714																															X			X			X	X		X			X				X	X																
JS	708																															X							X		X		X			X	X	X	X																
JS	699																																						X				X			X		X	X																
JS	683																															X	X		X				X					X			X	X	X	X															
JS	681																															X	X		X				X	X				X	X	X	X	X																	
JS	676																															X	X	X	X		X	X	X	X	X		X	X	X	X																		*Biticinella breggiensis*
JS	664																																X	X	X		X			X	X		X			X	X																	
JS	648																															X	X	X					X					X		X	X																	
JS	625																															X	X	X	X		X	X	X	X	X		X	X	X	x	X																	
JS	620																															X	X	X	X		X		X	X	X		X	X	X	X																		
JS	575																															X	X	X	X				X	X	X		X			X																		
JS	566																															X	X	X	X				X	X	X	X	X	X		X																		
JS	561																															X	X	X					X	X	X		X	X																				
JS	557																															X	X	X	X				X		X	X	X																						
JS	551																																	X	X				X	X	X	X		X		X																		
JS	538																															X	X	X	X				X	X		X		X	X	X																		
JS	532																																	X				X			X		X		X	X																		
JS	527																															X	X	X	X	X		X	X	X	X	X	X	X	X	X																		
JS	520																															X	X	X				X	X	X	X		X			X																		
JS	510																															X	X	X	X	X		X		X	X			X	X	X																		
JS	505																															X	X	X	X	X		X		X					X																		
JS	503																																X	X		X		X	X	X	X	X	X	X	X	X																		
JS	457																															X	X	X	X	X		X	X	X				X																				*Ticinella primula*
JS	422		X																																		X				X	X																								
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