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Cretaceous-Paleocene Biostratigraphy of Jardas Al Abid Area, Al Jabal Al Akhdar, NE Libya

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ABSTRACT

This study focuses on the biostratigraphy of the Cretaceous (Albian–Maastrichtian) and Paleocene (Danian) sequences exposed in both surface and subsurface sections of the Jardas al'Abid area, Al Jabal Al Akhdar, northeastern Libya. The investigation is based on systematically collected samples from four outcrop sections and one subsurface borehole (Water well). A total of thirty foraminiferal and five molluscan species were identified. Based on the vertical distribution of planktic foraminifera, nine biozones have been established in descending order: Parvularugoglobigerina Eugubine (Danian), Dicarinella concavata (Coniacian), Whiteinella brittonensis (Early Turonian), Hedbergella spp.–Pithonella spp. (Late Cenomanian), Rotalipora cushmani (Late Cenomanian), Thalmanninella brotzeni (Early Cenomanian), Biticinella breggiensis, Pseudothalmanninella ticinensis (Late Albian), and Ticinella primula (Middle Albian). Additionally, three molluscan biozones have been identified: Mecaster batnensis, Costagyra olisiponensis (both Late Cenomanian), and Inoceramus (Endocostea) balticus (Campanian), along with one ammonite biozone, Kitchinites emscheris (Early Santonian). This work represents the most detailed foraminiferal biostratigraphic framework for the region to date, with several of the proposed biozones being reported from Al Jabal Al Akhdar for the first time. The established biozones show a strong correlation with those of neighboring countries as well as with Mediterranean coastal regions of Europe, reinforcing the regional biostratigraphic continuity across the southern Tethyan margin. A new discovery of existing Paleocene (Danian) strata has been confirmed at the Jardas al'Abid area.

Keywords: Biostratigraphy, Cretaceous, Paleocene, Jardas al'Abid, Al Jabal Al Akhdar.

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1.INTRODUCTION

The Cretaceous (Albian-Maastrichtian) and Paleocene (Danian) surface and subsurface sequences in the Jardas al'Abid inlier area are predominantly rich in marine invertebrates. These sequences are lithostratigraphically divided into five-rock units: Daryanah (Middle to Late Albian), Qasr al'Abid (Cenomanian), Al Baniyah (Late Cenomanian-Coniacian), Al Majahir (Campanian), and Al Uwayliah (Danian). These rock units, exposed at Jardas al'Abid inlier, consist of limestones, marly limestones, chalky limestones, and claystones, which contain moderately preserved microfossils and macrofossils.

The microfossils identified include both planktic and benthic foraminifera, while the predominant macrofossils are pelecypods, the most abundant group. Cephalopod ammonites, though of secondary occurrence, are found in the Al Majahir and Al Baniyah formations.

Previous studies in the region have predominantly focused on macrofossil mollusks and echinoids, with limited attention given to foraminiferal biostratigraphy. Few biostratigraphic studies have been conducted on the Cretaceous micro- and macrofossils of Al Jabal Al Akhdar. Notable studies include the following: [1] an investigation of the pre-Campanian unconformity in the Ghwth Sas area, which confirmed the angular unconformity between the Al Baniyah and Al Majahir formations using microfossils (foraminifera and ostracods) and macrofossils (inoceramid bivalves). [2] A study of Late Cenomanian fossils from the Jardas al'Abid area, which identified two oyster biozones (Exogyra (Costagyra) olisiponensis and Pycnodonte (Phygraea) vesiculosum) and two ammonite biozones (Metoicoceras geslinianum and Pseudaspidoceras pseudonodosoides); [3] gives a detailed description of 49 species of Upper Cretaceous macrofossils from Jardas al'Abid. [4] A study of Cenomanian-Turonian mollusks and echinoids recognized three ammonite biozones and eight other macrofossil biozones; [5] Upper Cretaceous and Lower Tertiary foraminiferal biozones were recognized from five locations in Al Jabal al Akhdar, NE Libya, and eight foraminiferal biozones were established.

The study area is located in the western part of the Cyrenaica inverted basin, also known as the Al Jabal Al Akhdar Uplift,

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and is located at 32°18'34"N latitude and 20°59'97"E longitude (Fig. 1). Five stratigraphic sections were selected: (J1) behind the Jardas al'Abid School, (J2) approximately 1.3 km southeast of the school, (J3) the Water well section about 1.5 km to the north of the school, (J4) behind the Ghwth Sas School, and (J5) approximately 800 m northwest of the Ghwth Sas School. This study aims to identify biozones to date the lithological units and establish biostratigraphic correlations.

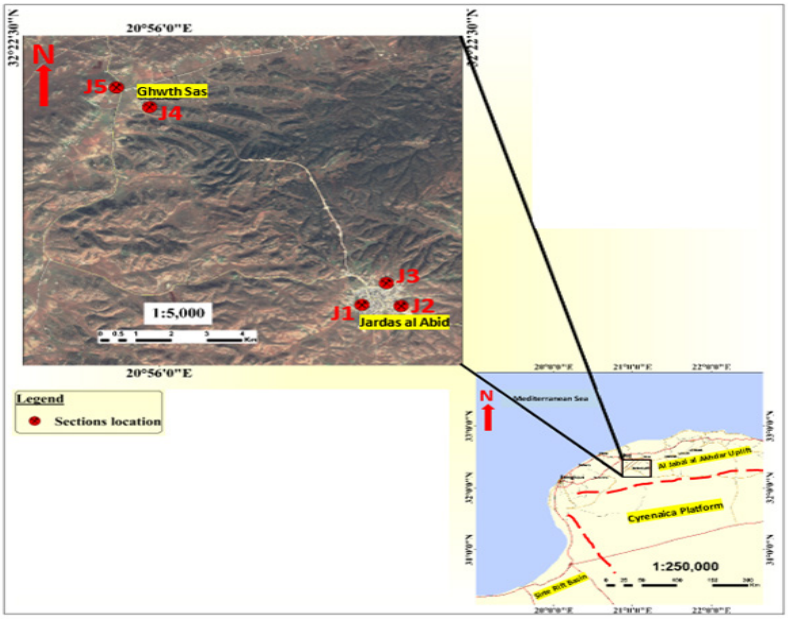

Figure. (1): Key map and satellite image of the Jardas al'Abid inlier, showing the locations of the five measured stratigraphic sections (J1–J5) along the upper escarpment of the study area.

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2.MATERIALS AND METHODS

Four field trips were conducted in the study area to systematically collect samples. Sampling was performed at regular intervals of 1–3 meters, depending on changes in lithology and fossil content, to capture both lateral and vertical facies variations. A total of 64 samples—comprising primarily limestone, claystone, marl, and chalky limestone—were collected from five stratigraphic sections. Of these, 42 hand specimens were obtained from four exposed outcrops, while 22 subsurface samples were collected from a water well in the Jardas al'Abid area.

All samples were processed for micropaleontological analysis using standard international preparation techniques. Approximately 50 g of each sample was crushed, disaggregated, wet-sieved through a 63-µm mesh, dried, and subsequently picked and mounted onto paleontological slides. However, many of the recovered foraminiferal specimens were poorly preserved or too small for accurate identification, limiting their utility for photomicrograph documentation. The poor preservation and overall scarcity of foraminifera posed a significant challenge during the study.

Recovered specimens were examined under a stereoscopic microscope, and identifications were made based on gross morphology. Taxonomic classification followed the planktic foraminiferal systematics outlined in [6]. Selected index species and other representative taxa were photographed using an AmScope ultra-compact 5MP USB digital microscope eyepiece camera (model MD500) mounted on a stereomicroscope.

All laboratory work was conducted at the Micropaleontological Laboratory, Department of Earth Sciences, University of Benghazi. The examined material will be permanently archived in the Geological Museum of the University. In total, 30 species were identified, representing 23 genera, 13 families, and 8 suborders.

3.RESULTS AND DISCUSSION

Field investigations resulted in the identification of five distinct lithostratigraphic units arranged in stratigraphic succession from the oldest to the youngest as follows: the Daryanah Formation (Middle to Late Albian), Qasr al'Abid Formation (Cenomanian), Al Baniyah Formation (Late Cenomanian to Coniacian), Al Majahir Formation (Early Santonian to Campanian), and Al Uwayliah

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Formation (Danian). These formations are well-exposed within the Jardas al'Abid inlier and are predominantly composed of limestone, marl, chalk, and claystone lithologies.

3.1.1. Stratigraphy

Based on the detailed field observations and a review of previous stratigraphic studies, the exposed rock succession in the study area is described below in ascending order, beginning with the oldest formation.

Daryanah Formation (Middle to Late Albian)

The Daryanah Formation, previously studied by [7] in wells Al-NC 120, Al-NC 128, and at the type section, displays a gradual shallowing-upward trend, transitioning from deeper marine shales and marls to shallower siltstones and limestones [9]. In the present study, this formation is identified in the Jardas al'Abid School section (J1) and the Water Well section (J3). At J1, it is represented by a 0.25 m thick interval of yellow, soft marly limestone containing fossil fragments. In contrast, at J3, the formation reaches a thickness of 76 m, comprising two main facies: silty claystone and interbedded limestone.

3.1.2.Qasr al'Abid Formation (Cenomanian)

Cenomanian-aged rocks are exposed in small inliers at the core of the Jardas al'Abid dome, close to the site of Libya's first wildcat well (Al-18), where deeply eroded anticlines have revealed these units [8]. Initially referred to as the "Gaser al'Abid Marl Member" of the Jardas Formation by [9], the unit was later elevated to formational rank and formally named the Qasr al'Abid Formation by [10,11]. It conformably overlies the Daryanah Formation and is, in turn, overlain by the Al Baniyah Formation. In the present study, the formation is observed in sections J1 and J3. At J1, it reaches a thickness of 2 m, consisting of greenish-brown clay facies at the base, grading upward into yellow marl. At J3, the unit is 70 m thick and dominated by claystone interbedded with limestone. Fossil content includes echinoid fragments, shell debris, and evidence of bioturbation.

3.1.3.Al Baniyah Formation (Late Cenomanian–Coniacian)

First described as the "Benia Limestone Member" by [9] and later elevated to formational status by [10,11], the Al Baniyah

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Formation is characterized by a lithological transition from marl to chalky limestone, with an unconformable contact at its upper boundary with the Al Majahir Formation. The formation is exposed in four sections: J1, J2, J3, and J4. At J1, it is 2 m thick, represented by white chalky limestone devoid of macrofossils. At J2, it reaches 9 m and is composed of white to brown chalky limestone interbedded with a thin phosphate layer at the base and a 1 m-thick deformed green claystone in the middle. Large calcite geodes are also present. At J3, it measures 10 m and comprises white chalky limestone. At J4 (Ghwth Sas School), it is also 10 m thick and consists of slightly chalky, white to brown marly limestone with three thin oyster beds. Fossils include internal molds of pelecypods and external molds of ammonites.

3.1.4.Al Majahir Formation (Early Santonian–Campanian)

Named by [11] after the Qasr al Majahir near Qandulah village, the Al Majahir Formation is equivalent to the Al Feitah Limestone and parts of the Ghwth Sas Marl Members [12]. It is composed of marly limestone, microcrystalline, and dolomitic limestones, with interbedded marls and calcareous claystones. This formation is reported only at J5 (Ghwth Sas quarry), where it reaches 10 m in thickness and consists of white marl interbedded with limestone beds. Fossils include molds of ammonites and Inoceramus. The lower part represents a pre-Campanian sedimentation cycle that gradually thins upwards.

3.1.5.Al Uwayliah Formation (Danian, Paleocene)

The formation was deposited during a marine transgression that began in the Danian; it reflects varied outcrop patterns influenced by regional tectonics and erosion [13]. The holostratotype, described by [12], is located in the Al Uwayliah area and comprises whitish chalk and greenish marl.

In this study, Paleocene (Danian) strata within the Al Uwayliah Formation have been confirmed for the first time at the upper part of section J2 in the Jardas al ‘Abid area. Previously, the Al Uwayliah Formation was only known from the northern part of Al Jabal al Akhdar, specifically in the Uwayliah area, where it was considered Landenian in age, as well as from remnant exposures to the south and in Jardas al Jarari [14]. This new occurrence significantly expands the known distribution and stratigraphic range of the

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Al Uwayliah Formation within northeastern Libya.

3.2. Biostratigraphy

3.2.1. Planktic Foraminiferal Biozones

Nine planktic foraminiferal biozones have been identified in this study, following the zonal marker scheme of [15,16], and are presented below in descending stratigraphic order:

1.Ticinella primula Interval Biozone (Middle Albian)

This biozone is defined as the interval from the first occurrence of Ticinella primula to the first appearance of Biticinella breggiensis. It is recognized in the Water Well section (J3). The upper boundary and the lower boundary of this biozone are defined by the occurrence of Ticinella primula and Pseudothalmanninella ticinensis at a depth of 122m; the associated marker species is Hedbergella gorbachikae (Fig. 2).

2.Biticinella breggiensis Interval Biozone (Late Albian)

This biozone is defined as the interval from the first occurrence of Ticinella primula to the first appearance of Biticinella breggiensis. It is recognized in the Water Well section (J3). This biozone was defined based on the last occurrence of the zonal marker Biticinella breggiensis and the lack of the earlier zonal marker species Ticinella primula (Fig. 2).

3.Pseudothalmanninella ticinensis Interval Biozone (Late Albian)

This biozone is defined as the interval from the first occurrence of Pseudothalmanninella ticinensis to the first occurrence of Thalmanninella appenninica, Late Albian. It is recognized in the Water Well section (J3). The upper boundary of this biozone is defined by the last occurrence of Pseudothalmanninella ticinensis and the first occurrence of Thalmanninella brotzeni at a depth of 72m, and the lower boundary is defined by the last occurrence of Ticinella primula at a depth of 104m. The associated marker species include Biticinella breggiensis and the benthic large foraminifera Orbitulina discoidea (Fig. 4).

4.Thalmanninella brotzeni Interval Biozone (Early Cenomanian)

As an interval from the first occurrence of Thalmanninella brotzeni to the first occurrence of Thalmanninella reicheli. It is recognized in the Water Well section (J3). The lower boundary of this biozone is defined at a depth of 72m by the extinction of all Late

Albian foraminifera such as Ticinella and Biticinella spp., while the upper boundary is defined at a depth of 52m by the absence of R. reicheli and the presence of the primary zonal marker Rotalipora cushmani. The associated planktic taxa, such as Praeglobotruncana stephani and Cyclamina (Figure. 4).

5.Rotalipora cushmani Total Range Biozone (Middle to Late Cenomanian)

It is defined by the total range of Rotalipora cushmani. This biozone is documented in the Water Well section (J3). The top of this biozone is picked at a depth of 12m by the lack of all rotaliporid members, especially the secondary marker species Thalmanninella greenhornesis, in addition to diagnostic agglutinated larger benthic foraminifera, Thomasinella punica. The lower boundary is defined by the last occurrence of Thalmanninella brotzeni. The associated planktic taxa in this biozone include Muricohedbergella delrioensis, Rotalipora montsalvensis, Praeglobotruncana carinata, Whiteinella baltica, and Praeglobotruncana stephani (Figure. 4). The biozone is also recognized in Jardas Al'Abid school section J1, where it is defined by the occurrence of the primary zonal marker Rotalipora cushmani. The associated planktic taxa in this biozone include Thalmanninella greenhornsis, Muricohedbergella planispira, and Muricohedbergella delrioensis (Figure. 2).

6.Hedbergella -Pithonella Assemblage Biozone (Late Cenomanian)

It is recognized as the Jardas al'Abid quarry section (J2). This biozone is defined by the occurrence of pithonella spp., and Hedbergella spp. in addition to the diagnostic secondary zonal marker Rotalipora greenhornensis (Figure. 3).

7.Whiteinella brittonensis Total Range Biozone one (Early Turonian)

Proposed herein based on the findings in the uppermost part of the Water Well section (J3), this biozone spans from the last occurrence of Rotalipora cushmani to the disappearance of Helvetoglobotruncana helvetica at 2 m depth. The associated taxa include Praeglobotruncana sp. (Figure. 4).

8.Dicarinella concavata Assemblage Biozone of (Late Coniacian to Early Santonian).

An interval from the first occurrence of Dicarinella concavata to the first occurrence of Dicarinella asymetrica is identified in the Ghwth Sas School section (J4).

It is defined based on the absence of Dicarinella asymetrica and the presence of Dicarinella concavata, Marginotruncana marginata, Marginotruncana sinuosa, Marginotruncana paraconcavata, and Marginotruncana schneegansi. The associated taxa are Whiteinella archaeocretacea and Planoheterohelix reussi (Figure. 5).

9.Paruvlarugoglobigerina eugubina Total Range Biozone (Early Paleocene).

This biozone represents the total range of Parvularugoglobigerina eugubina and is identified in the Jardas al'Abid Quarry section. Both the lower and upper boundaries are defined by the range of the zonal marker itself. Associated species include Globoconusa daubjergensis and Parvularugoglobigerina extensa (Figure. 3).

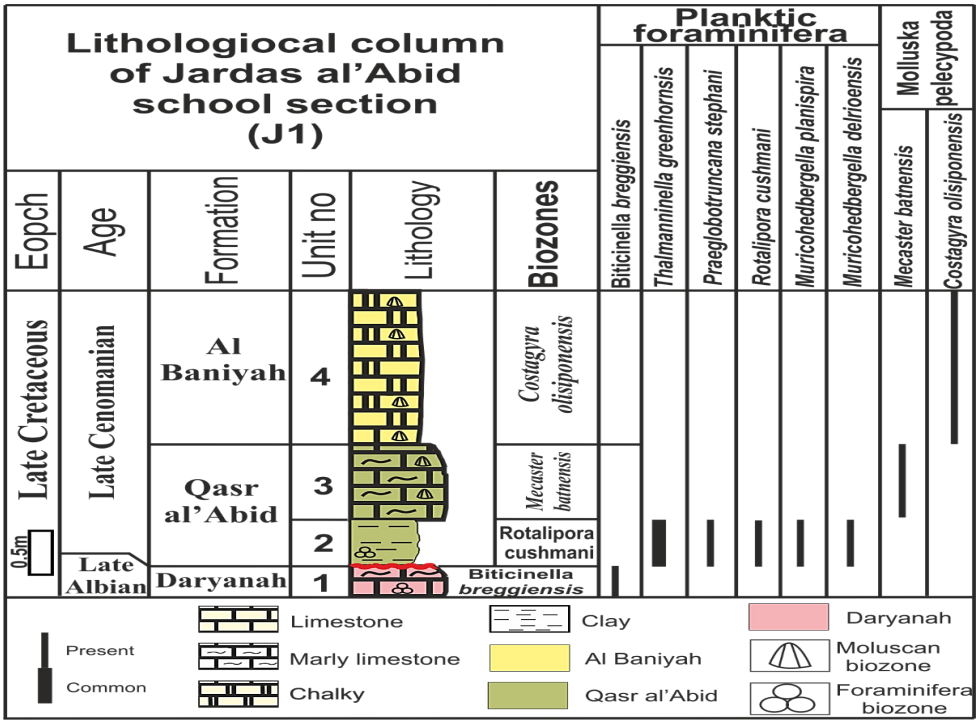

Figure. (2): Distribution chart of the identified foraminiferal taxa from the Jardas al'Abid School section. Note: Molluscan biozones are referenced from a previous study by (5).

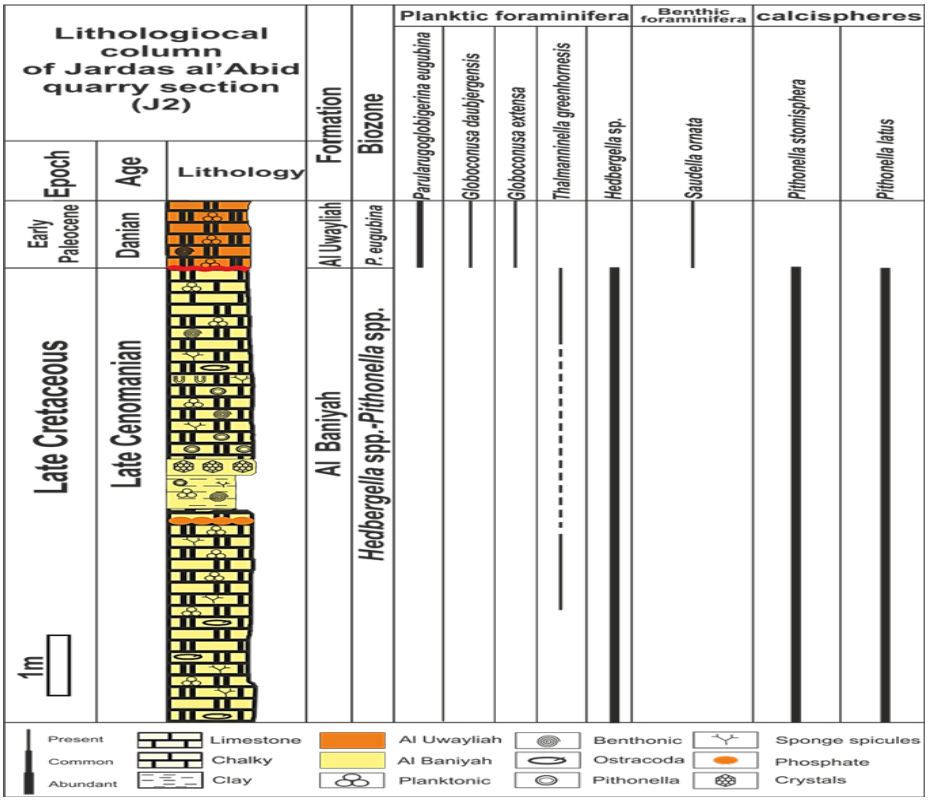

Figure. (3): Stratigraphic chart illustrating the lithological profile of the Jardas al'Abid Quarry section (J2) and the vertical distribution of the identified taxa.

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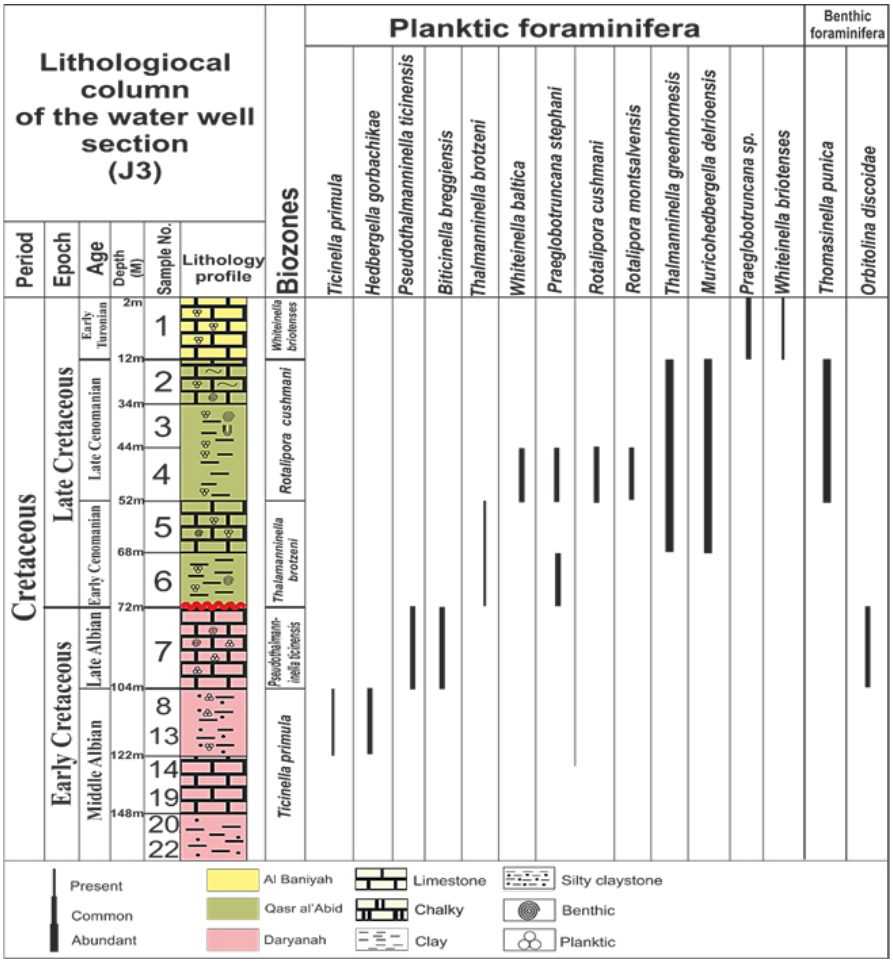

Figure. (4): Stratigraphic chart illustrates the lithological profile of the Water Well section (J3), the vertical distribution of the identified foraminiferal and molluscan taxa.

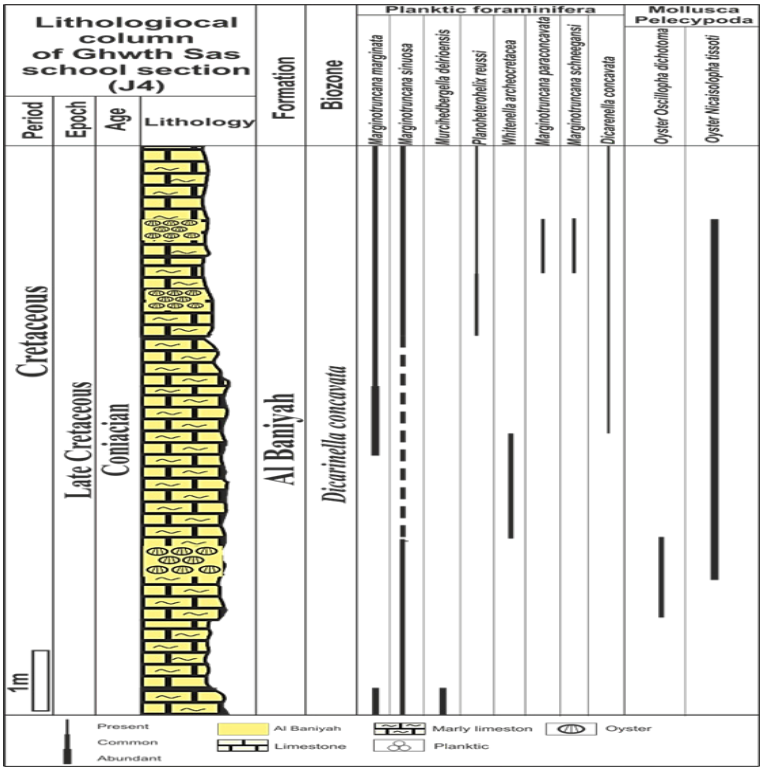

Figure. (5): Stratigraphic chart illustrating the lithological profile of the Ghwth Sas section (J4), along with the vertical distribution of the identified foraminiferal and molluscan taxa.

3.2.2. Molluscan Biozones

The molluscan biozones, identified in this study, include several pelecypod and ammonite assemblages. Among the pelecypod biozones, the Inoceramus balticus (Endocostea) biozone, attributed to the Campanian, is recognized within the Al Majahir Formation at the Ghwth Sas Quarried section (J5) (Figure. 6). Additionally, two Late Cenomanian pelecypod biozones—Mecaster batnensis within the Qasr al'Abid Formation and Costagyra olisiponensis within the Al Baniyah Formation—have been previously reported by [5] from the Jardas al'Abid School section (Figure. 2).

Furthermore, one ammonite biozone was identified in this study: the Kitchinites emscheris biozone of the Early Santo-

nian age, observed in the Ghwth Sas Quarried section (J5); this biozone was recorded for the first time in the Al Jabal Al Akhdar region (Figure. 6).

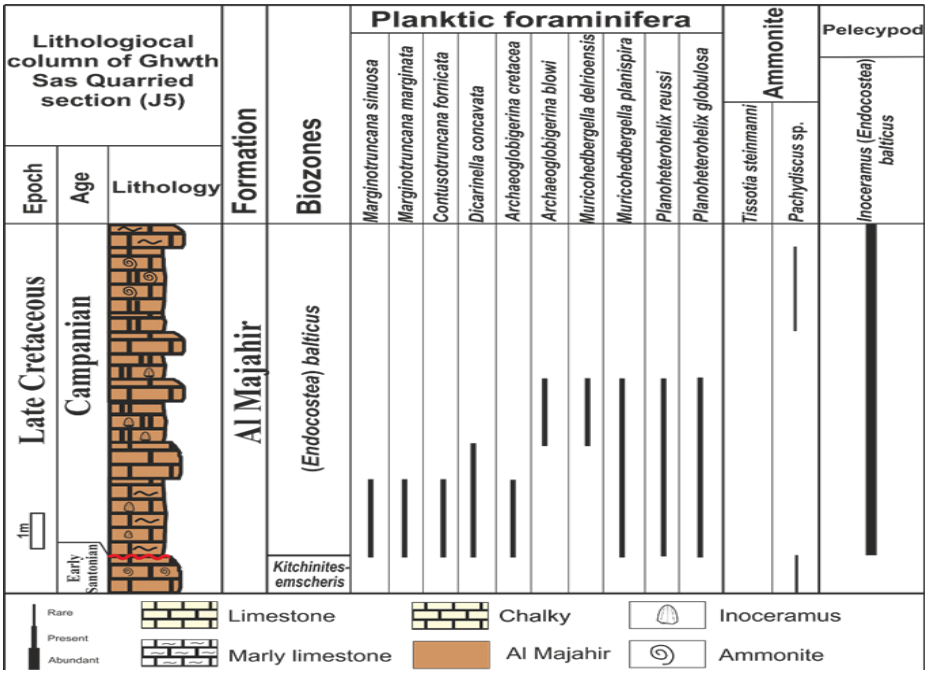

Figure. (6): Stratigraphic chart showing the lithological profile of the Ghwth Sas School section (J5), along with the stratigraphic distribution of the identified fossil taxa.

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3.3. Correlation

The measured sections, extending from southeast to northwest, include the following: Jardas al'Abid School (J1), Jardas al'Abid Quarry (J2), Water Well (J3), Ghwth Sas School (J4), and Ghwth Sas Quarry (J5). These sections have been correlated lithologically and biostratigraphically. The biozones established in this study are based on both planktic foraminifera and mollusks (Inoceramus and ammonite species).

The youngest unit, the Al Uwayliah Formation (Danian), is exposed only in the J2 section, where it is defined by the presence of the Parvularugoglobigerina eugubina biozone. The Water Well section (J3) is considered a reference hole, where three formations are present: Daryanah (Middle to Late Albian), Qasr al'Abid (Cenomanian), and Al Baniyah (Early Turonian). Five biozones have been identified in J3, listed from the oldest to the youngest: Ticinella primula (Middle Albian), Pseudothalmanninella ticinensis (Late Albian), Thalmanninella brotzeni (Early Cenomanian), Rotalipora cushmani (Late Cenomanian), and Whiteinella brittonensis (Early Turonian).

To the northwest, in section J4, where only the Al Baniyah Formation is exposed, the Dicarinella concavata assemblage biozone correlates laterally with the Whiteinella brittonensis biozone. To the southeast of J3, the lateral equivalent of the Whiteinella brittonensis biozone is the Hedbergella-Pithonella assemblage biozone, while at J1, the molluscan Mecaster batnensis biozone is equivalent. The Al Baniyah Formation exhibits variations in age, thickness, and faunal content from northwest to southeast, reflecting tectonic influences in the study area, particularly the dome (inlier) structure.

In the far northwest at site J5, the Al Majahir Formation (Campanian) is exposed and contains only molluscan biozones. The lower biozone, Kitchinites emscheris, is defined by the presence of Tissotia steinmanni, while the upper biozone is defined by the presence of the Inoceramus balticus (Endocostea) biozones.

The pre-Coniacian biozones show a good correlation between sections J1 and J3, particularly in the upper part of the Rotalipora cushmani biozone. However, the lower biozones are less well correlated, with only the Biticinella breggiensis, Pseudothalmanninel-

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la ticinensis, and Ticinella primula biozones being preserved (Figure. 7, 8, 9).

Worldwide, the reported foraminiferal biozones have been extensively correlated, particularly in North Africa. The Ticinella primula biozone is correlated with the Early Albian Fahdene Formation in Northern Tunisia [17]. Biticinella breggiensis biozone is correlated with the Hauterivian to Barremian–Aptian stages of Tunisia [18]. Thalmanninella brotzeni biozone is also correlated with the Late Albian deposits of northern Tunisia, within the southern Tethyan realm [19]. Dicarinella concavata biozone is correlated with the upper part of the pelagic limestones in the Kurdistan region, northeastern Iraq [20]. Additionally, the Parvularugoglobigerina eugubina biozone, marking the base of the Paleocene, is correlated with Gubbio, Italy [21]. Regarding macrofossils, the molluscan ammonite Kitchinites emscheris biozone, which was previously only known from Ecuador and Peru [22], is now reported for the first time in North Africa to represent from Libya.

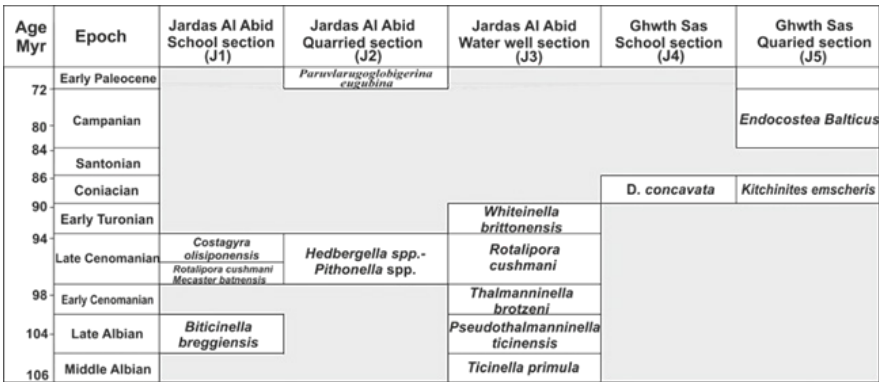

Figure. (7): Vertical distribution of the recognized biozones and a horizontal comparison between the studied sections on the bases of micro-macrofossils, in Jardas al'Abid inlier, of al Jabal al Akhdar, NE Libya.

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The foraminiferal biozones were established from the coastal and offshore areas by [23,24]. and later refined by [5], are correlated with the lateral equivalents recognized in the southern Al Jabal al Akhdar region. These include biozonations proposed by [3,4,5]. The correlation between these regional frameworks is illustrated in (Fig. 8), providing a comprehensive biostratigraphic comparison across northern Libya and contributing to the refinement of the regional chronostratigraphy. Additionally, the biozones established in the present study are also correlated with previous biozonation schemes (Fig. 8), although the earlier frameworks were based on a combination of foraminiferal and molluscan assemblages, particularly pelecypods and ammonites. This integrated approach enhances the resolution and reliability of the regional stratigraphic correlations.

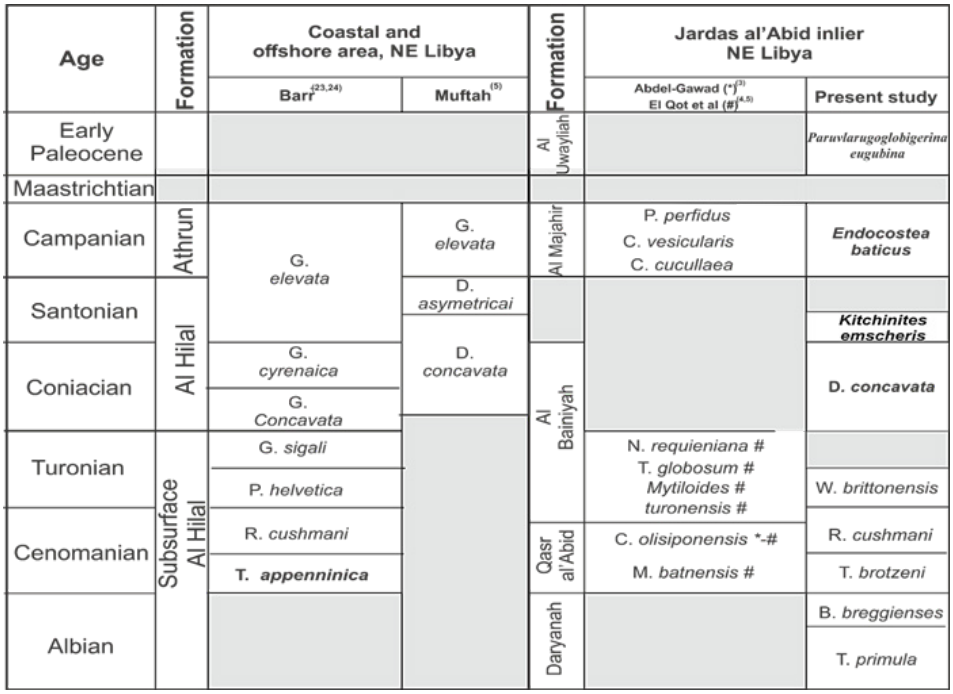

Figure. (8): Stratigraphic correlation chart comparing the previously published foraminiferal biozones with those established in the present study. Asterisks (*) and hash symbols (#) indicate molluscan biozones, specifically those based on

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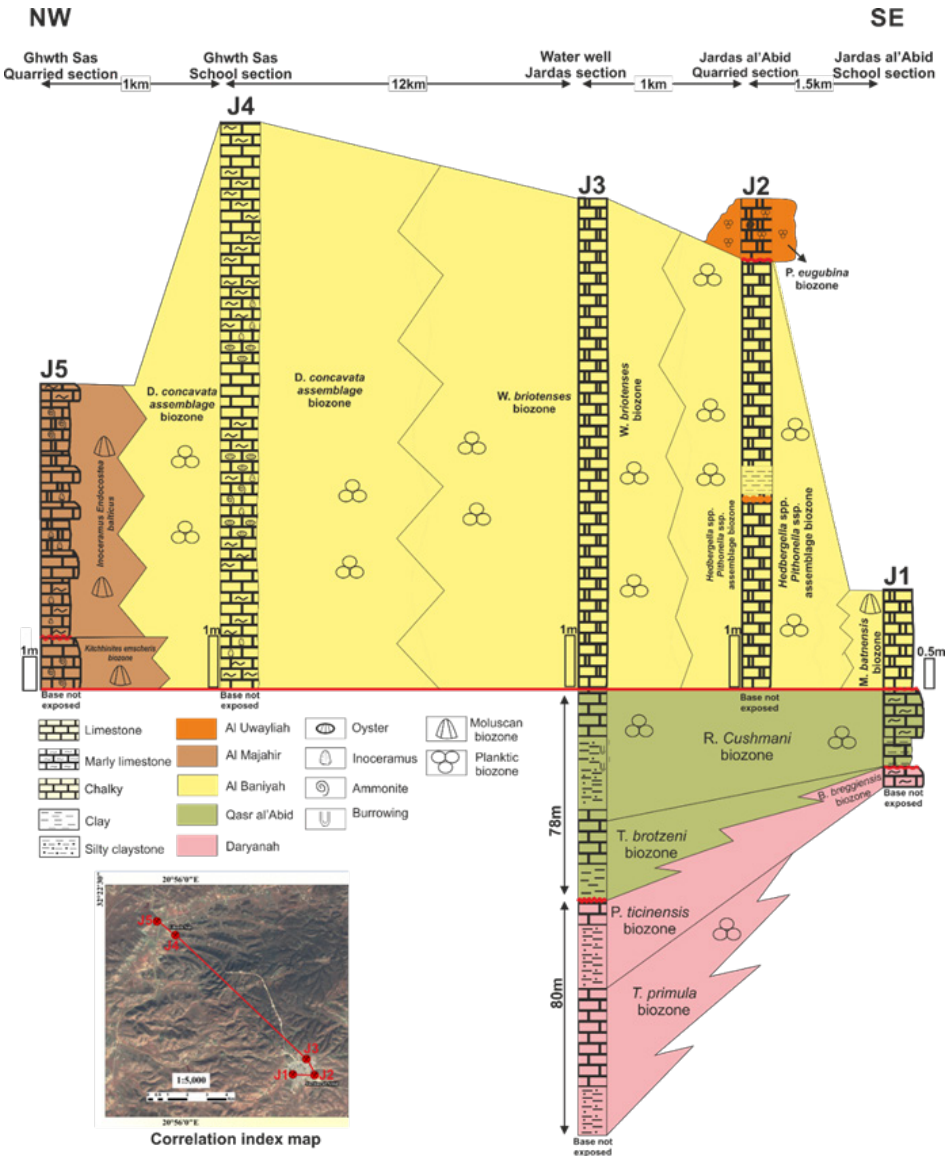

Figure. (9): Biostratigraphic correlation of the measured sections (J1–J5), illustrating the distribution of lithologic units and biostratigraphic zones across the study area. The correlation is referenced to the base of the Al Baniyah Formation (datum line). Note: the lower part of section J3 is presented at a different vertical scale.

4.CONCLUSION

The Cretaceous (Albian-Maastrichtian) and Paleocene (Danian) surface and subsurface successions from the measured and sampled sections of the Jardas al'Abid Inlier, including Jardas al'Abid School (J1), Jardas al'Abid Quarry (J2), Water Well (J3), Ghwth Sas School (J4), and Ghwth Sas Quarry (J5), have been analyzed for their foraminiferal and molluscan content. A total of 30 species were identified, belonging to 23 genera, 13 families, and 8 suborders, all of which have been systematically described and illustrated. Nine planktic foraminiferal biozones were identified in descending stratigraphic order:

1.Parvularugoglobigerina eugubina Total Range Biozone (Danian) – recognized in the Al Uwayliah Formation at the Ghwth Sas Quarried section (J2).

2.Dicarinella concavata Interval Biozone (Coniacian) – found in the Al Baniyah Formation at the Ghwth Sas Quarried section (J5).

3.Whiteinella brittonensis Total Range Biozone (Early Turonian) – identified in the Water Well section (J3), Al Baniyah Formation.

4.Hedbergella spp.-Pithonella spp. Assemblage Biozone (Late Cenomanian) – observed in the Al Baniyah Formation at the Jardas al'Abid Quarried section (J2).

5.Rotalipora cushmani Total Range Biozone (Late Cenomanian) – present in the Qasr al'Abid Formation at both the Jardas al'Abid School (J1) and Water Well (J3) sections.

6.Thalmanninella brotzeni Interval Biozone (Early Cenomanian) – identified in the Qasr al'Abid Formation at the Water Well section (J3).

7.Pseudothalmanninella ticinensis Interval Biozone (Late Albian) – observed in the Daryanah Formation at the Water Well section (J3).

8.Biticinella breggiensis Interval Biozone (Late Albian) – found in the Qasr al'Abid Formation at the Jardas al'Abid School section (J1).

9.Ticinella primula Interval Biozone (Middle Albian) – recognized in the Daryanah Formation at the Water Well section (J3).

An ammonite biozone, Kitchinites emscheris Biozone, was established in the Ghwth Sas Quarried section (J5), within the Al Majahir Formation, representing the total range biozone (Early Santonian).

Three molluscan biozones were identified: 1) Inoceramus balticus (Endo-

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costea) of Campanian age, found in the Al Majahir Formation at the Ghwth Sas Quarried section (J5); 2) Mecaster batnensis in the Qasr al'Abid Formation (Late Cenomanian) at Jardas al'Abid School section (J1); 3) Costagyra olisiponensis in the Al Baniyah Formation (Late Cenomanian) at Jardas al'Abid School section (J1).

The discovery of existing Paleocene (Danian) strata has been confirmed at the upper part of section J2 in the Jardas al'Abid area. This unit, approximately 1 meter thick, was identified based on its microfossil assemblages, notably the presence of early Paleocene planktic foraminifera, as well as its stratigraphic position, as it overlies the Al Baniyah Formation. This represents significant evidence for post-Cretaceous sedimentation in the region and provides biostratigraphic correlation with other Danian successions across North Africa.

Based on the micro-macrofossils distribution and lithological nature of the Cretaceous-Paleocene sequence in the Jardas al'Abid Inlier, the marine environments range from shallow marine facies (inner ramp) to deep marine facies (outer ramp).

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6.REFERENCES

1.Rohlich P, Salaj J. Palaeontological dating of the pre-Campanian unconformity in the Ghwth Sas area. In: First Symposium on the Sedimentary Basins of Libya, Geology of the Sirt Basin. 1996;1:265-286.

2.Abdel-Gawad GI. Late Cenomanian ammonites from NE Libya and the western desert of Egypt. Geology of East Libya. 2008;3:201-218.

 ISSN: Online 2790-1637, Print 2790-1629
National Library of Libya, Legal number: 154/2018

3.El Qot GM, Abdulsamad EO, Aly MF. Upper Cretaceous macrofossils from the Jardas Al'Abid area, Al Jabal Al Akhdar, northeast Libya: systematic paleontology. Egyptian Journal of Paleontology. 2013;13:185-254.

4.El Qot GM, Abdulsamad EO. Cenomanian-Turonian biostratigraphy of the Jardas Al'Abid area, Al Jabal Al Akhdar, northeast Libya. Journal of African Earth Sciences. 2016 Sep;121:84-99.

5.Muftah AM. Upper Cretaceous-Lower Tertiary foraminiferal biozones of Al Jabal al Akhdar, NE Libya. In: Proceedings of the Third Annual International Conference on Geological & Earth Sciences (GEOS 2014); 2014. p. 34–39.

6.Young JR, Wade BS, Huber BT. pforams@ mikrotax website. Available from: http://www.mikrotax.org/pforams. 2017.

7.Duronio P, Dakshe A, Bellini E. Stratigraphy of the offshore Cyrenaica (Libya). In: Symposium on the geology of Libya. 1991;1589-1620.

8.Hallett D. Petroleum Geology of Libya. Amsterdam: Elsevier; 2002. 503 p.

9.Kleinsmiede WF, Van Den Berg NJ. Surface geology of the Jabal al Akhdar, northern Cyrenaica, Libya. In: Barr FT, editor. Geology and Archaeology of North Cyrenaica, Libya: The Petroleum Exploration Society of Libya, 10th Annual Field Conference. Tripoli; 1968. p. 115-123.

10.Klen I. Geological map of Libya 1:250,000. Sheet. NI 34-14, Benghazi Explanatory Booklet. Industrial Research Centre, Tripoli; 1974. 49 p.

11.Rhölich P. Geological map of Libya 1:250,000. Sheet: Al Bayda NI 34-15. Explanatory Booklet. Industrial Research Centre, Tripoli; 1974. 70 p.

12.Barr FT. Upper Cretaceous stratigraphy of the Jabal al Akhdar, northern Cyrenaica. In: Barr FT, editor. Geology and Archaeology of Northern Cyrenaica, Libya: The Petroleum Exploration Society of Libya, 10th Annual Field Conference. 1968. p. 131-147.

13.El Hawat AS, Shelmani MA. Short notes and guidebook on the geology of Al Jabal al Akhdar, Cyrenaica, NE Libya. Earth Science Society of Libya; 1993.

14.Röhlich P. Tectonic development of Al Jabal al Akhdar. In: Salem MJ, Buserwil MT, editors. The geology of Libya. Vol. III. London: Academic Press; 1980. p. 923–931.

15.Caron M. Cretaceous Planktonic Foraminifera. In: Bolli HM, Saunders JB, Perch-Niel-

sen K, editors. Plankton Stratigraphy. New York: Cambridge University Press; 1985. p. 17-18.

16.Olsson RK, Berggren WA, Hemleben C, Huber BT. Atlas of Paleocene planktonic foraminifera. Smithsonian Contributions to Paleobiology. 1999;85:1-252.

17.Ben Fadhel M, Gallala N. Revised planktic foraminiferal biostratigraphy of the early late Albian of northern Tunisia (southern Tethys). Revista Soletras. 2021;42.

18.BouDagher-Fadel M, Banner FT, Bown PR, Simmons MD, Gorbachik TN. Gorbachikella from the Hauterivian, Barremian-Aptian of Tunisia. Rev Micropaleontol. 1995;38(3):179–93.

19.Ben Fadhel M, Gallala N. Revised planktic foraminiferal biostratigraphy of the early late Albian of northern Tunisia (southern Tethys). Stratigraphy. 2022 Sep 15;19(3):157–78.

20.Jaff RB. A designed model for identifications of Dicarinella concavata (Brotzen, 1934) and Dicarinella asymetrica (Sigal, 1952) planktic foraminifer species under thin sections: an example from the Kurdistan region, NE Iraq. Jordan J Earth Environ Sci. 2021;12(2):154–62.

21.Arenillas I, Gilabert V, Arz JA. An updated suprageneric classification of planktic foraminifera after growing evidence of multiple benthic-planktic transitions. 2022.

22.Jaillard E, Bengtson P, Dhondt AV. Late Cretaceous marine transgressions in Ecuador and northern Peru: a refined stratigraphic framework. J South Am Earth Sci. 2005;19(3):307–23.

23.Barr FT, Hammuda OS. Biostratigraphy and planktonic zonation of the Upper Cretaceous Atrun Limestone and Hilal Shale, northeastern Libya. In: Farinacci A, editor. Proceedings of the 2nd International Conference on Planktonic Microfossils (1970). Rome; 1971. p. 27–40.

24.Barr FT. Cretaceous biostratigraphy and planktonic foraminifera of Libya. Micropaleontology. 1972;18:1–46.

7.DESCRIPTION OF PLATES 1-6

PLATE 1

1.Ticinella primula (Middle Albian): a) Spiral view (X45), b) Umbilical view (X45), Daryanah Formation, Sample No. 8, Depth 104m, Water well section (J3).

2.Biticinella breggiensis (Late Albian): a) Spiral view (X45), b) Umbilical view (X45), Daryanah Formation, Sample No. 7, Depth 72m, Jardas al'Abid School section (J1).

3.Rotalipora montsalvensis (Late Cenomanian): a) Spiral view (X45), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 4, Depth 44m, Water well section (J3).

4.Pseudothalmanninella ticinensis (Late Albian): a) Spiral view (X45), b) Umbilical view (X45), Daryanah Formation, Sample No. 5, Depth 56m, Water well section (J3).

5.Rotalipora cushmani (Late Cenomanian): a) Spiral view (X45), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 7, Depth 72m, Water well section (J3).

6.Thalmanninella greenhornsis (Late Cenomanian): a) Spiral view (X45), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 2, Depth 12m, Water well section (J3).

PLATE 2

1.Archaeoglobigerina blowi (Campanian): a) Spiral view (X45), b) Umbilical view (X45), Al Majahir Formation, Sample No. 3, Ghwth Sas Quarried section (J5).

2.Whiteinella baltica (Late Cenomanian): a) Spiral view (X35), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 4, Depth 44m, Water well section (J3).

3.Praeglobotruncana stephani (Late Cenomanian): a) Spiral view (X45), b) Umbilical view (X25), Qasr al'Abid Formation, Sample No. 4, Depth 44m, Water well section (J3).

4.Muricohedbergella delrioensis (Late Cenomanian): a) Spiral view (X45), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 2, Depth 12m, Water well section (J3).

5.Hedbergella gorbachikae (Late Albian): a) Spiral view (X45), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 8, Depth 104m, Water well section (J3).

6.Archaeoglobigerina cretacea (Coniacian): a) Spiral view (X40), b) Umbilical view (X40), Al Majahir Formation, Sample No. 1, Ghwth Sas Quarried section (J4).

7.Muricohedbergella planispira (Late Cenomanian): a) Spiral view (X45), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 4, Jardas al'Abid School section (J1).

8.Whiteinella brittonensis (Early Turonian): a) Spiral view (X45), b) Umbilical view (X45), Qasr al'Abid Formation, Sample No. 1, Depth 2m, Water well section (J3).

PLATE 3

1.Marginotruncana marginata (Coniacian): a) Spiral view (X45), b) Umbilical view (X45), Al Baniyah Formation, Sample No. 8, Ghwth Sas School section (J4).

2.Contusotruncana fornicate (Campanian): a) Spiral view (X30), b) Umbilical view (X30),

Al Majahir Formation, Sample No. 2, Ghwth Sas Quarried section (J5).

3.Marginotruncana Sinuosa (Campanian): a) Spiral view (X45), b) Umbilical view (X45), Al Majahir Formation, Sample No. 2, Ghwth Sas Quarried section (J5).

4.Marginotruncana schneegansi (Coniacian): a) Spiral view (X45), b) Umbilical view (X45), Al Baniyah Formation, Sample No. 8, Ghwth Sas School section (J4).

5.Dicarinella concavata (Coniacian): a) Spiral view (X45), b) Umbilical view (X45), Al Baniyah Formation, Sample No. 8, Ghwth Sas School section (J4).

6.Dicarinella concavata cf. (Campanian): a) Spiral view (X30), b) Umbilical view (X30), Al Majahir Formation, Sample No. 2, Ghwth Sas Quarried section (J5).

PLATE 4

1.Parvularugoglobigerina eugubina (Early Paleocene): a) Spiral view (X45), b) Umbilical view (X45), Al Uwayliah Formation, Sample No. 10, Jardas al'Abid Quarried section (J2).

2.Globoconusa daubjergensis (Early Paleocene): a) Spiral view (X45), b) Umbilical view (X45), Al Uwayliah Formation, Sample No. 10, Jardas al'Abid Quarried section (J2).

3.Parvularugoglobigerina extensa (Early Paleocene): a) Spiral view (X45), b) Umbilical view (X45), Al Uwayliah Formation, Sample No. 10, Jardas al'Abid Quarried section (J2).

4.Marginotruncana paraconcavata (Coniacian): a) Spiral view (X45), b) Umbilical view (X45), Section (J4), Sample No. 8.

5.Planoheterohelix reussi (Campanian): Spiral view (X45), Section (J5), Sample No. 2.

6.Planoheterohelix globulosa (Late Cenomanian): a) Spiral view (X45), b) Umbilical view (X45), Section (J5), Sample No. 3.

7.Thalmanninella brotzeni (Early Cenomanian): a) Spiral view (X25), b) Umbilical view (X25), Section (J3), Sample No. 6, Depth 68m, Water well section.

8.Gaudryina serrata (Campanian): Spiral view (X45), Section (J5), Sample No. 3.

9.Orbitolina discoidea (Late Cenomanian): Dorsal view (X20), Qasr al'Abid Formation, Sample No. 7, Depth 72m, Water well section (J3).

10.Saudella ornate (Early Santonian): Side view (X45), Al Baniyah Formation, Sample No. 9, Jardas al'Abid Quarried section (J2).

PLATE 5

1.Inoceramus (Endocosta) balticus (Campanian): Al Majahir Formation, Sample No. 2,

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Ghwth Sas Quarried section (J5), bar scale = 3cm.

2.Oscillopha dichotoma (Coniacian): Articulated oyster valves, a) Right valve, b) Left valve, bar scale = 3cm, Al Baniyah Formation, Sample No. 4, Ghwth Sas School section (J4).

3.Nicaisolopha tissoti (Coniacian): Disarticulated oyster valves, a) Right valve, b) Left valve, bar scale = 3cm, Al Baniyah Formation, Sample No. 7, Ghwth Sas School section (J4).

PLATE 6

1.Pachydiscus neubergicus (Late Campanian): Side view, bar scale = 10cm, Al Majahir Formation, Sample No. 6, Ghwth Sas Quarried section (J5).

2.Tissotia steinmanni (Coniacian): Side view, bar scale = 4cm, Al Majahir Formation, Sample No. 1, Ghwth Sas Quarried section (J5).

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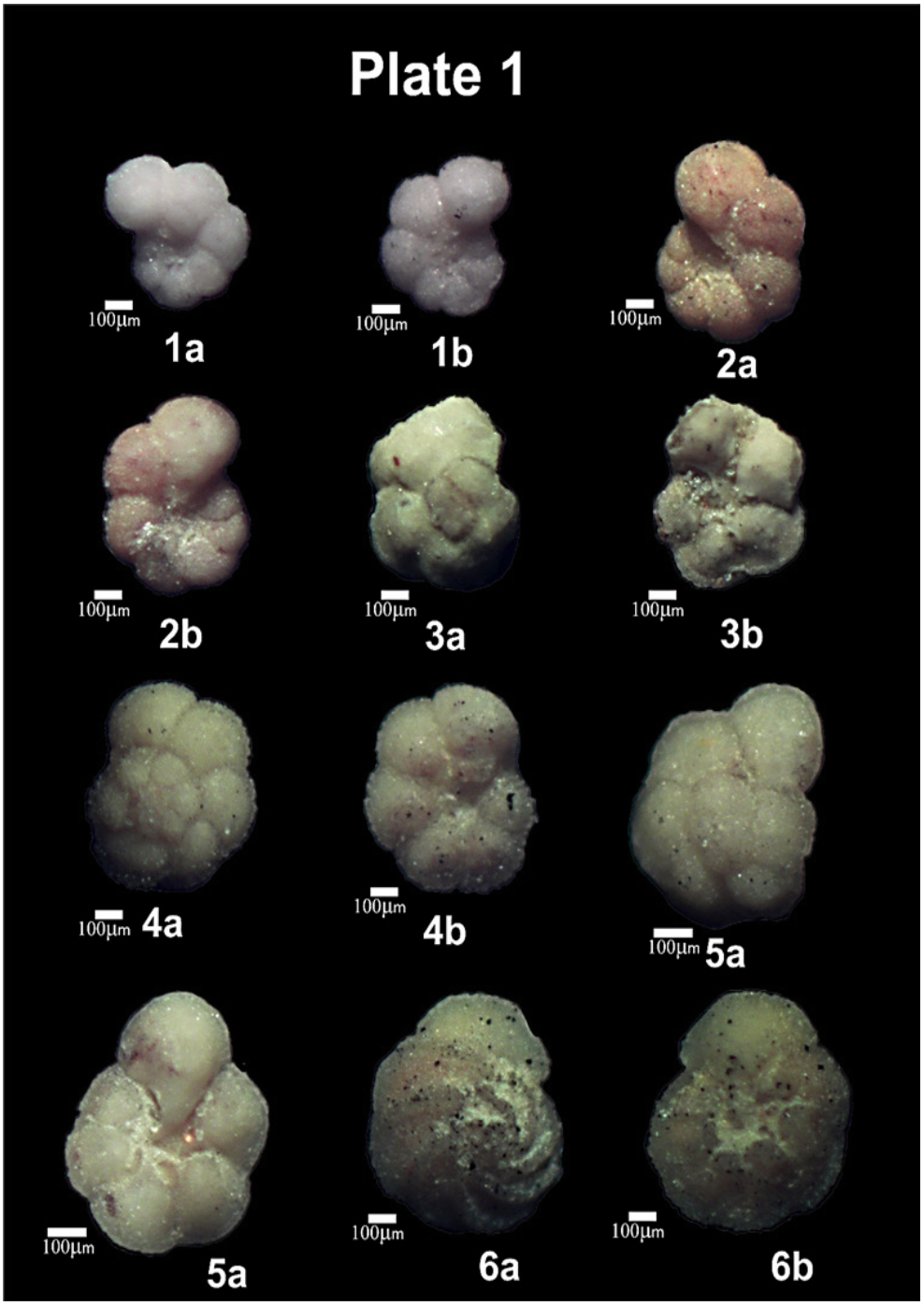

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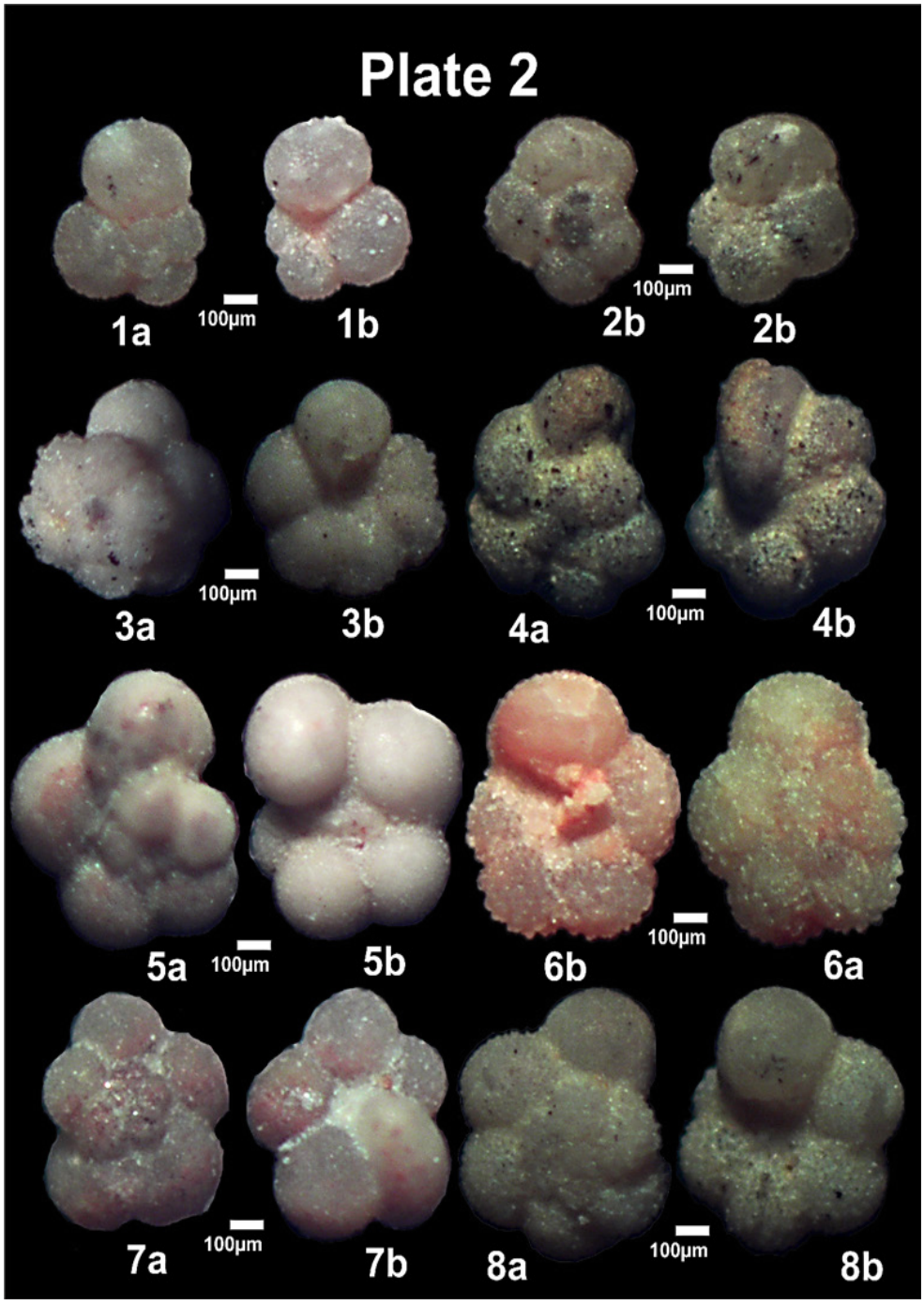

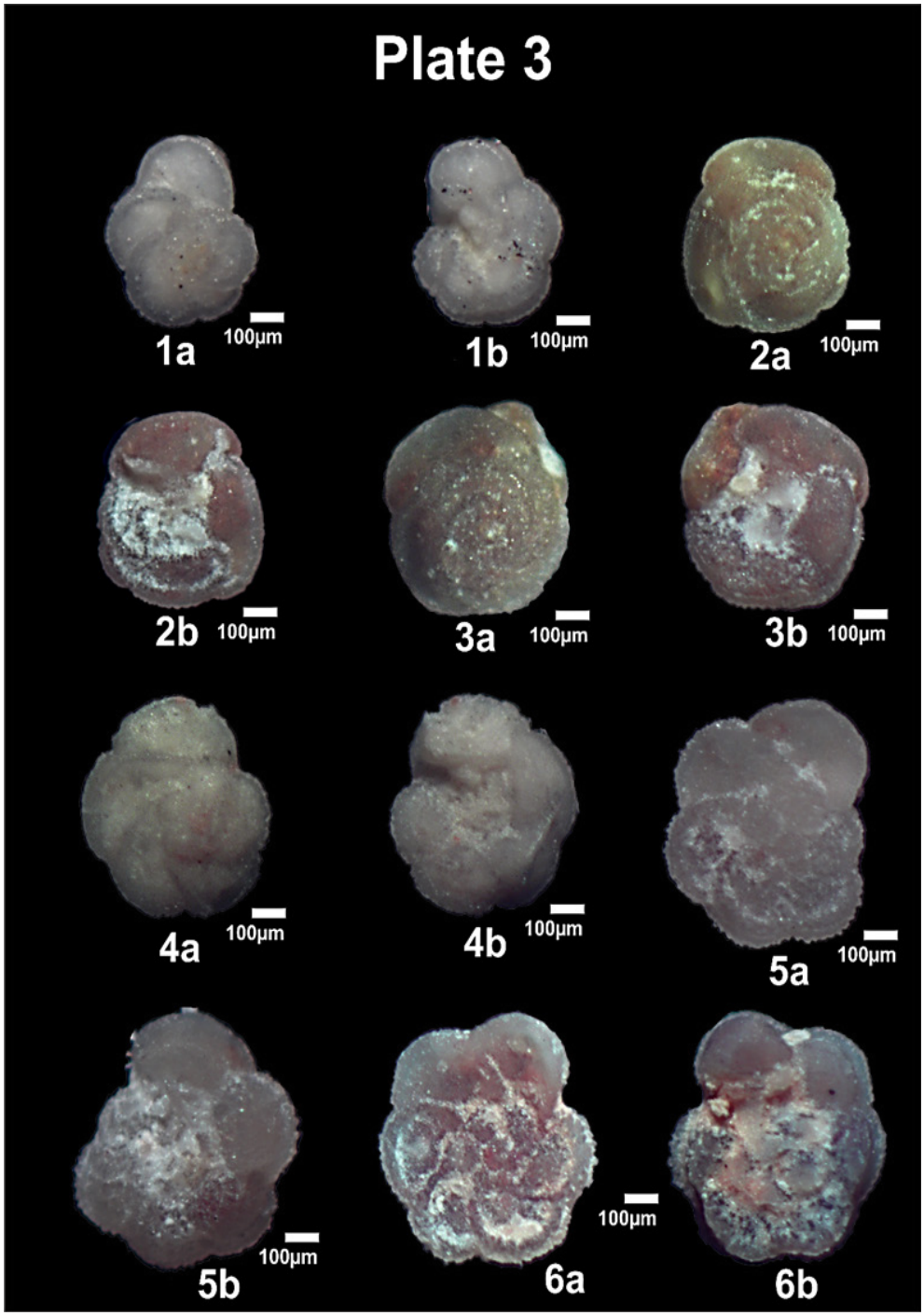

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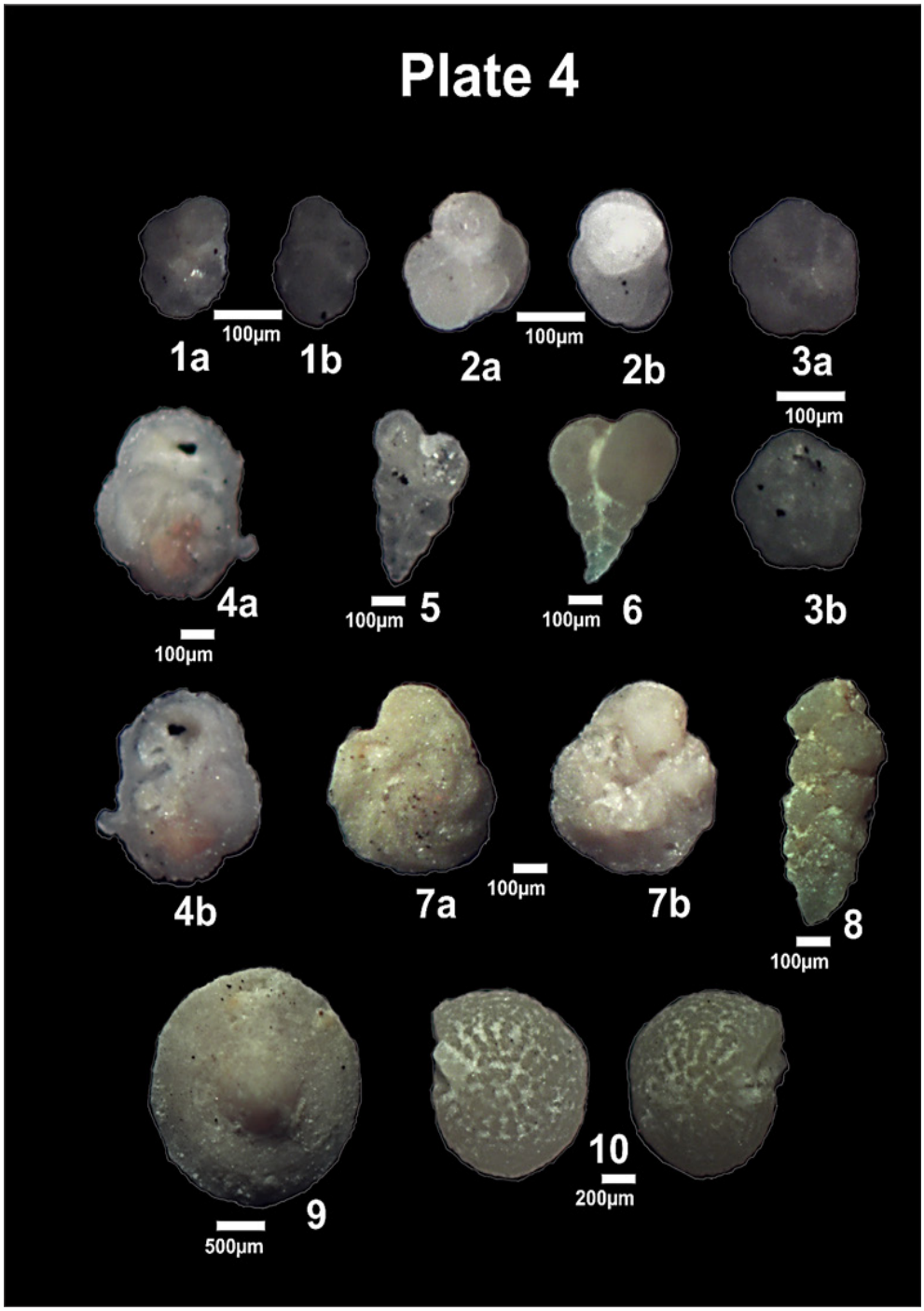

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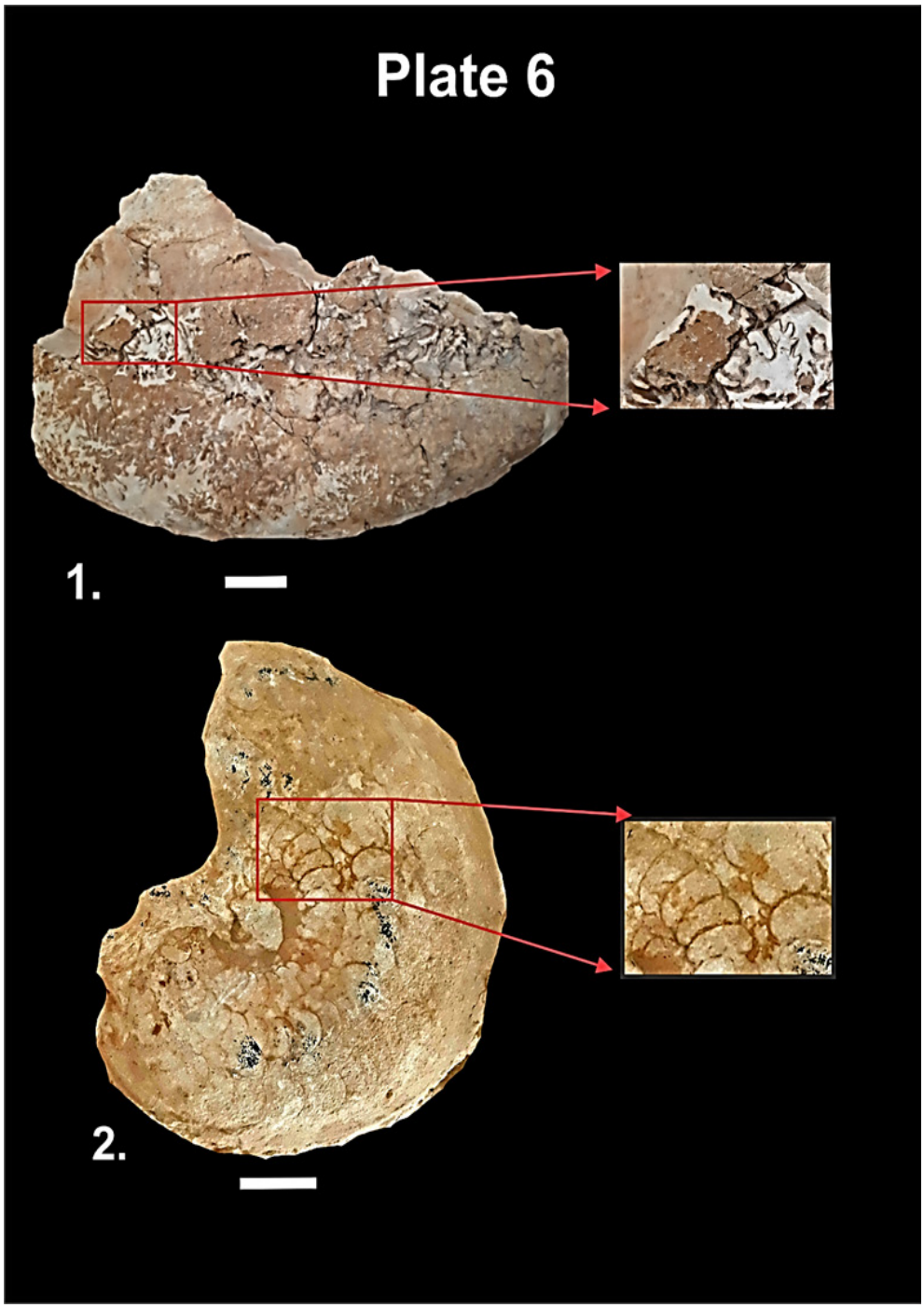

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