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A new early Barremian fossiliferous amber outcrop from North Lebanon and its palaeoenvironment

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Abstract

A new fossiliferous amber outcrop in Akkar El-Atiqa (Akkar District, Northern Lebanon) discovered during recent geological prospection, is described. This discovery constitutes the 31st amber outcrop with biological inclusions in Lebanon and hitherto the most septentrional one among those. It enriches and improves our knowledge about the palaeobiodiversity and the depositional palaeoenvironment of the North-Eastern coast of Gondwana during the early Barremian. An infrared spectrum of amber from Akkar El-Atiqa is given and discussed.

Key words: Akkar El-Atiqa, Lebanese amber, fossil insects, biological inclusions, Lower Cretaceous, FT-IR, Mesozoic

Introduction

Lebanon has many Kimmeridgian (Azar *et al*., 2010b; Nohra *et al*., 2013; Maksoud & Azar, 2020) and hundreds of lower Barremian amber outcrops (Granier *et al*., 2016; Maksoud *et al*., 2017). This latter number is continuously growing, with 30 described outcrops (Fig. 1) to date, all of which yield biological inclusions (Maksoud & Azar, 2023; Maksoud *et al*., 2019, 2020, 2021a, b, 2022, 2024). Lebanese amber is one of the most important, as it documents the initial diversification of many lineages of the extant entomofauna and the disappearance of some archaic insect groups (Azar, 1997, 2007, 2012; Azar & Nel, 1998; Poinar & Milki, 2001; Azar *et al*., 2010a; Maksoud & Azar, 2020).

Here we record the discovery of a new amber outcrop yielding biological inclusions found from the village of Akkar El-Atiqa, Caza (= District) Akkar, in Mouhafazet (= Governorate) North Lebanon (Figs 2, 3). We (DA and SB) discovered this site on 25th June 2024, during a geological survey of Akkar area in northern Lebanon.

This outcrop provided centimetric-sized amber pieces. It constitutes the 31st amber locality with biological inclusions and the most septentrional one in Lebanon (Fig. 1). This discovery sheds light on the palaeobiodiversity and palaeoenvironment of the North-Eastern coast of Gondwana during the early Barremian and adds to our knowledge on the richness of Lebanon in amber outcrops.

The amber from this outcrop is chemically analysed using Fourier Transform Infrared (FT-IR) spectroscopy.

Geological setting

The new amber-yielding locality is in an urban area of Al-Sayyah in the village Akkar El-Atiqa [Figs 2, 3 (34°31'09.8"N, 36°14'34.6"E, elev. 891 m)], Caza (= District) Akkar, Mouhafazet (= Governorate) North Lebanon, northern Lebanon. The outcrop includes ochre deltaic-estuarine and margino-littoral sandstone layers comprising lens of dark blackish silty shale and clay stone. Amber (centimetric in size, with variant transparency, with white, cream, yellow, dark yellow, orange and red colours) (Figs 2E, 4A–D), lignite and small plant fragments could be found in the dark layers of this site.

Geologically this outcrop (Figs 2, 3) is in the early Barremian sandstone of the "Grès du Liban" Alloformation (known also as Shouf Sandstones and "Grès de base") (Granier *et al*., 2015, 2016; Maksoud *et al*., 2017); in lower Barremian silicoclastic-dominated strata (Granier

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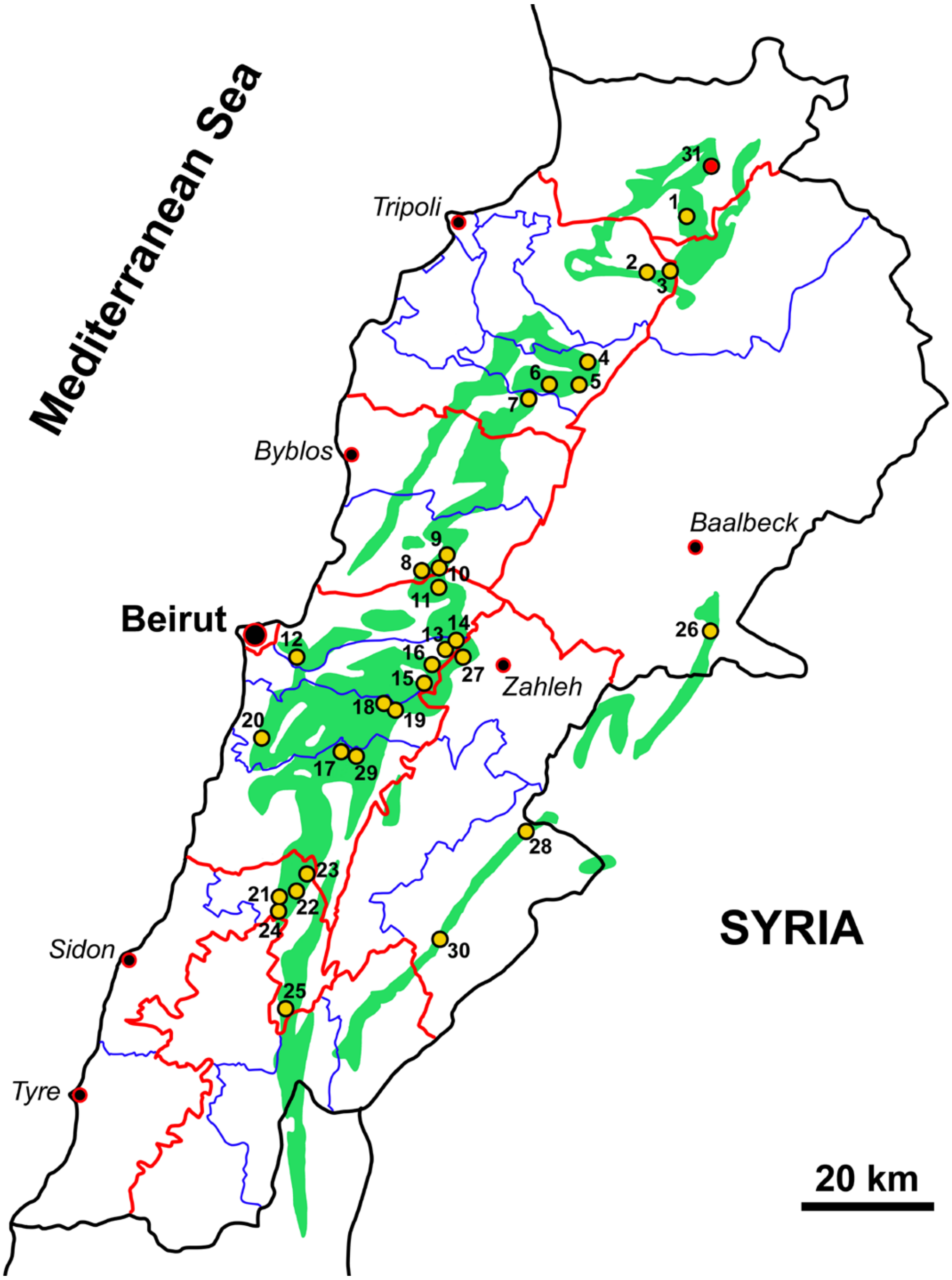

FIGURE 1. Map of Lebanon with Lower Cretaceous amber and fossil insect outcrops. Green areas indicate the distribution of the amber localities. Yellow circular spots indicate the emplacements of Lower Cretaceous amber outcrops with insect inclusions. Red circular spots indicate the herein described emplacement of Akkar El-Atiqa outcrop. 1, Mechmech (Ain El-Khyar); 2, Nimrin (El-Dabsheh); 3, Brissa; 4, near Bcharreh; 5, Beqaa Kafra; 6, Hadath El-Joubbeh; 7, Tannourine; 8, Mazraat Kfardibiane; 9, Ouata El-Jaouz; 10, Bqaatouta (El-Shqif); 11, Baskinta (Qanat Bakish); 12, Daychouniyyeh; 13, Kfar Selouan; 14, Kfar Selouan (Khallet Douaiq); 15, Mdeyrij-Hammana; 16, Falougha; 17, Ain Zhalta; 18 and 19, Ain Dara (two localities); 20, Sarhmoul; 21, Roum-Aazour-Homsiyeh; 22, Bkassine (Jouar Es-Souss); 23, Wadi Jezzine; 24, Maknouniyeh; 25, Rihane; 26, Esh-Sheaybeh; 27, Bouarij; 28, Aita El-Foukhar; 29, Ain Zhalta (Ain Azimeh); 30, Tannoura and 31, Akkar El-Atiqa. Red curves indicate the boundaries of Governorates; blue ones the boundaries of districts.

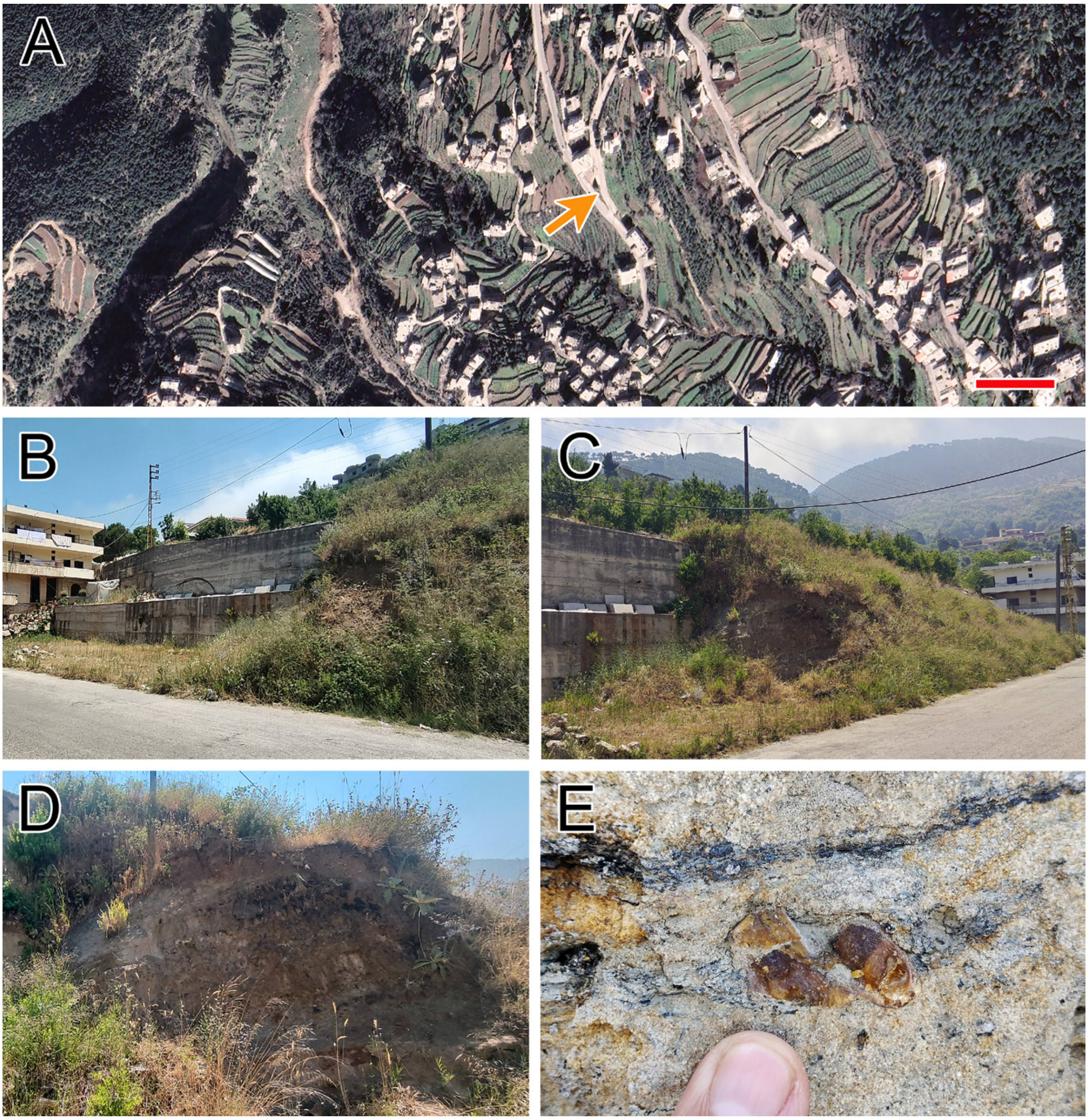

FIGURE 2. Akkar El-Atiqa amber outcrop. **A**, Aerial view of the Akkar El-Atiqa outcrop. **B**–**D**, Different views of the Akkar El-Atiqa outcrop. **E**, Amber as found on the outcrop.

et al., 2016) and deposited in fluvial margino-littoral palaeoenvironment.

Material and methods

The material was collected from Akkar El-Atiqa, North Lebanon. The amber piece containing inclusion was manually cut using denticulate shaving blades and then polished with increasing grade sandpapers and diatomite. Then for better visibility, the specimen was imbedded between two microscopic coverslips with Canada balsam medium as described in Azar *et al*. (2003). The amber inclusion and extracted palynomorphs were examined and photographed with an Olympus BX53. The amber samples were observed and photographed with a Zeiss AxioZoom V16 stereomicroscope. The figures and illustrations were processed with Helicon Focus 8 and Adobe Photoshop CC 2019 software. For the infrared analysis, the amber was crushed and mixed with potassium bromide (KBr) and pellets were prepared using a hydraulic manual press, the spectra were acquired between 4000 and 400 cm^{-1} (general) and 1600 and 400 cm^{-1} (including fingerprint zone) with 40 scans collected at 4 cm^{-1} resolution. Transmission FT-

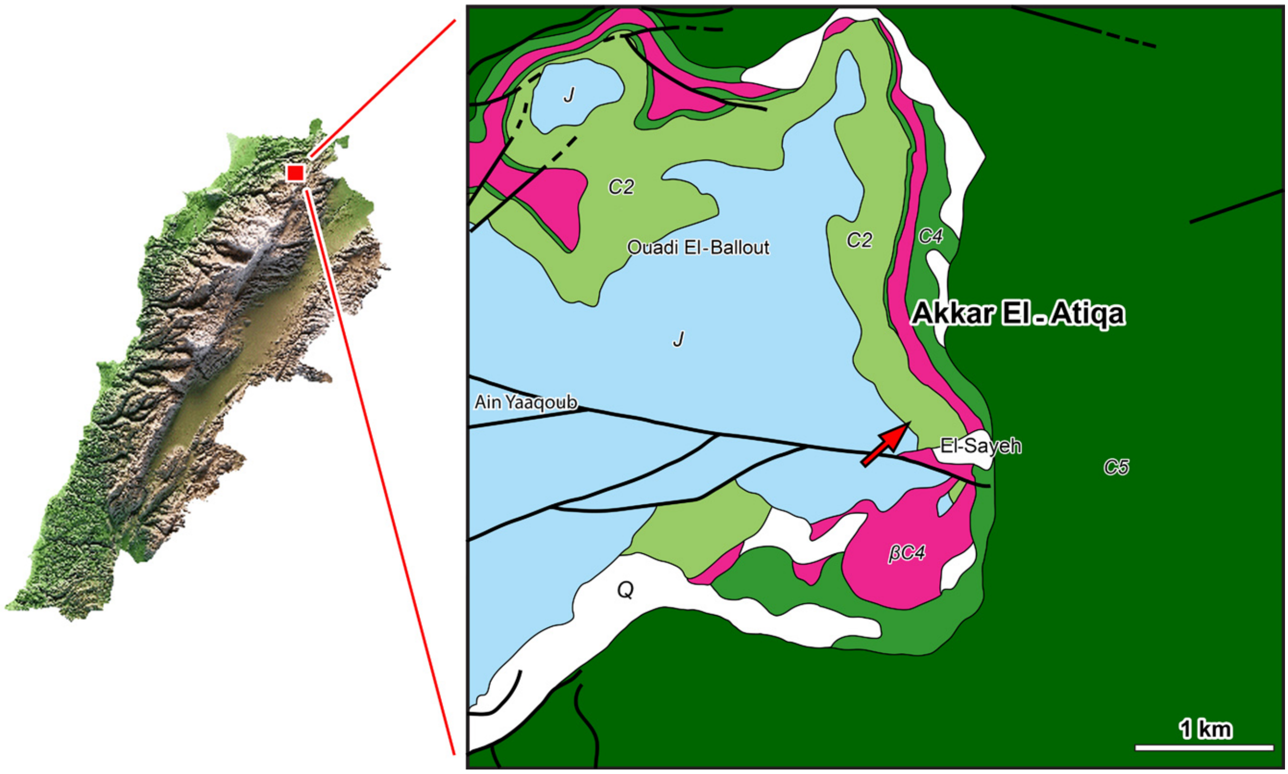

FIGURE 3. Geological map of Akkar El-Atiqa outcrop (red arrow). J = Jurassic; C2 = lower Barremian "Grès du Liban" sandstone; C4 = Albian; C5 = Cenomanian; Q = Quaternary scree; βC4 = Albian volcanic deposition. Thick lines represent faults.

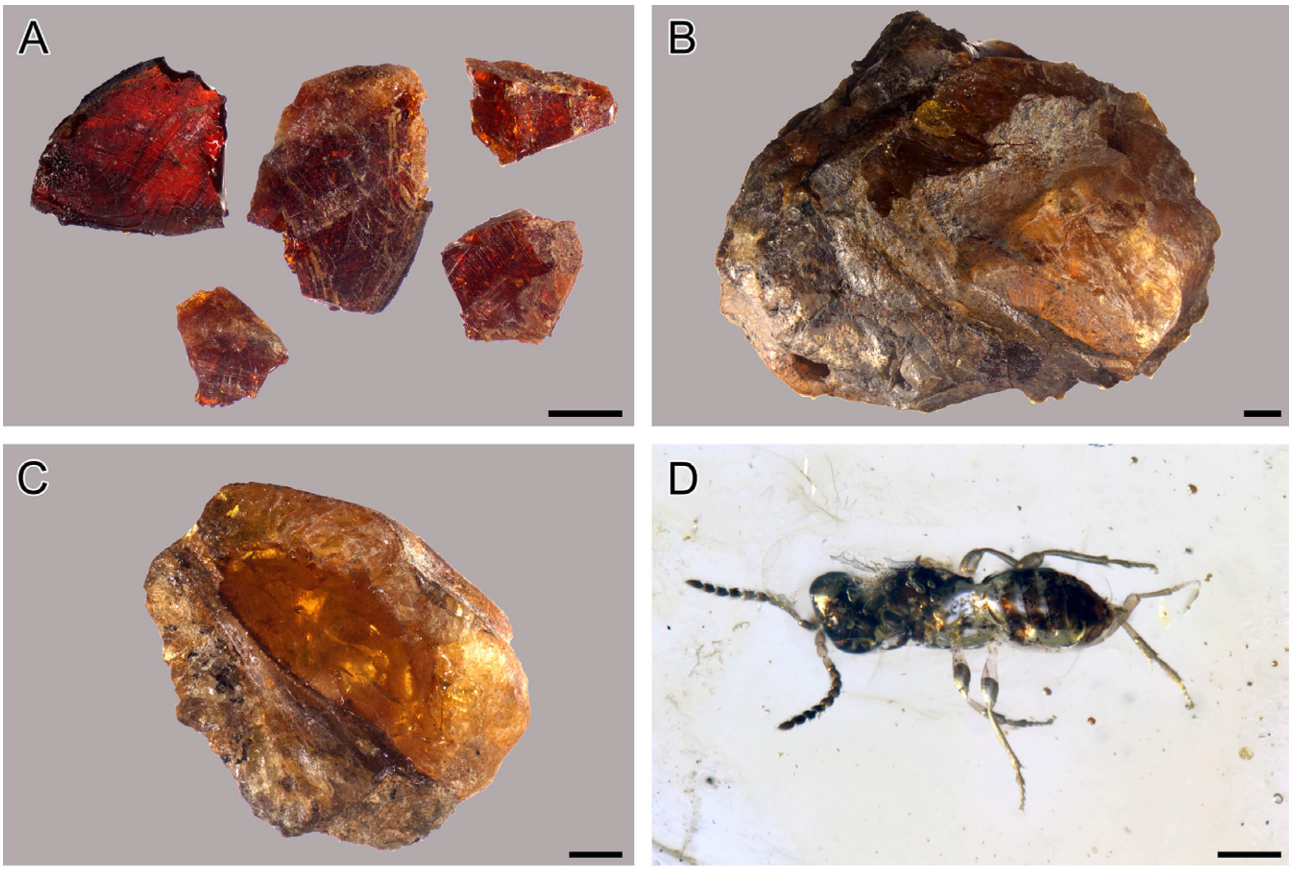

FIGURE 4. Ambers from the new outcrop. **A**–**C**, Different amber pieces found in Akkar El-Atiqa. **D**, Scelionid wasp. Scale bares = 2000 microns in **A**–**C** and 200 microns in **D**.

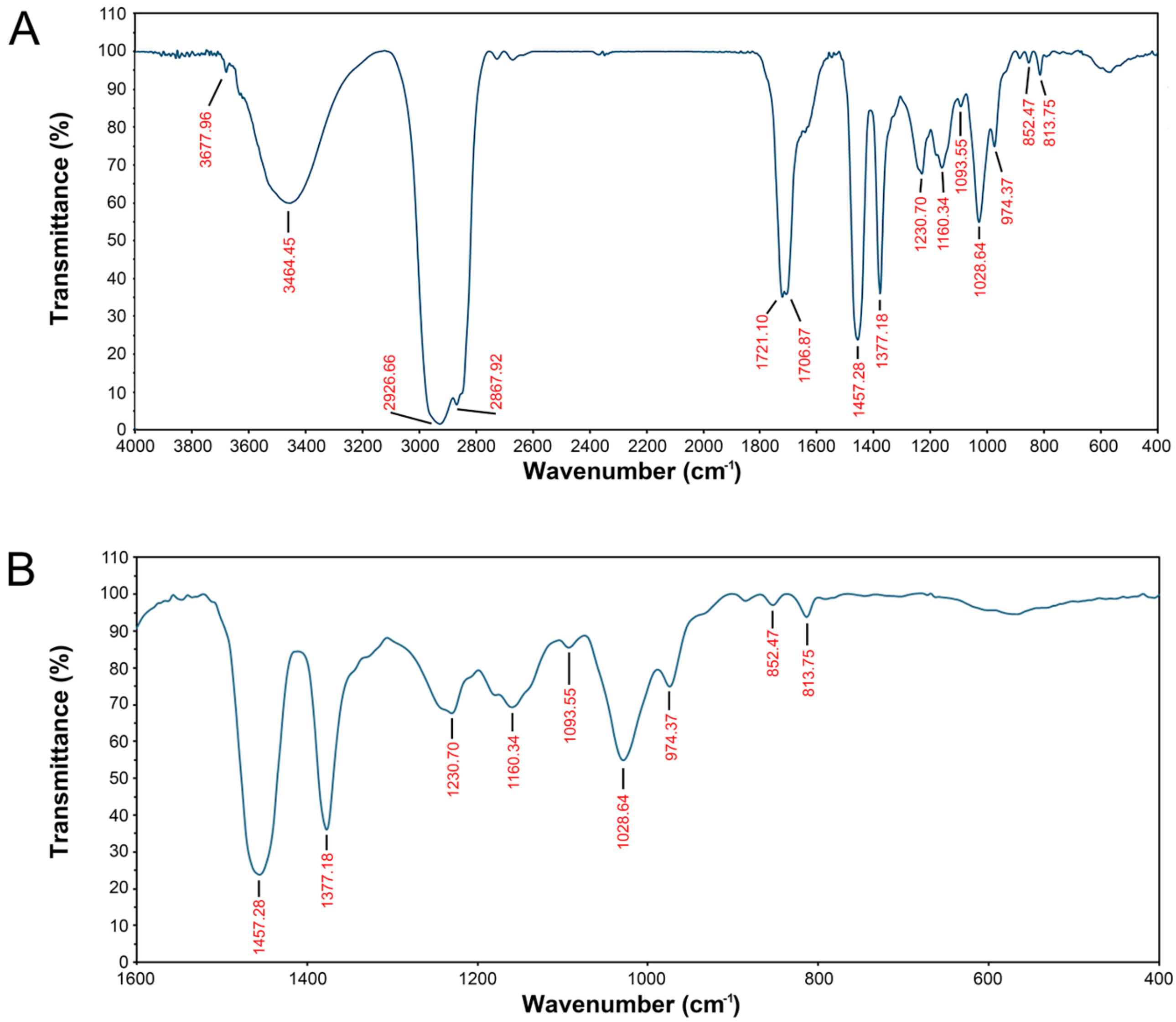

FIGURE 5. FT-IR spectrum of the amber of Akkar El-Atiqa. **A**, Spectrum for wavelengths between 4000 and 400 cm^{-1}. **B**, Spectrum for wavelengths between 1600 and 400 cm^{-1}.

IR spectroscopy was performed with a Bruker VERTEX spectrophotometer. Sediments containing the amber were collected in order to carry out a palynological study of the site and deduce the palaeoenvironment. These samples were prepared following the standard method of extracting palynomorphs from the sediment matrix based on acid attack in a fume hood [hydrochloric acid (HCl), hydrofluoric acid (HF) over several days, nitric acid (HNO_3)]. Afterwards, the attacked sediment was filtered at 8 µm.

Results

FT-IR analysis

FT-IR analysis Fourier Transform Infrared spectroscopy spectra were obtained from the new amber material in order to retain its chemical signature and to compare its chemical structure profile with other ambers profiles collected from Lebanon. We prefer to undertake such analyses even though it is known today that they are of very limited importance since most amber FT-IR spectra are more or less similar without providing accurate data for resolving the botanical origin of the fossil resin (Azar *et al*., 2010a). The spectra were acquired between 4000 and 400 cm^{-1} (for general aspect) and 1600 and 400 cm^{-1} (including fingerprint area) with 40 scans collected at 4 cm^{-1} resolution. The obtained spectra of the amber in Fig. 5 demonstrates clearly that this amber is characterised by similar features as most of the remaining Early Cretaceous ambers collected in Lebanon. The obtained spectrum acquired between 4000 and 400 cm^{-1}, could be divided into two areas: transmittance bands between 3700–1350 cm^{-1} are shared by almost all types of amber; transmittance bands between 1350 and 400 cm^{-1} are generally considered to be the fingerprint area. The weak

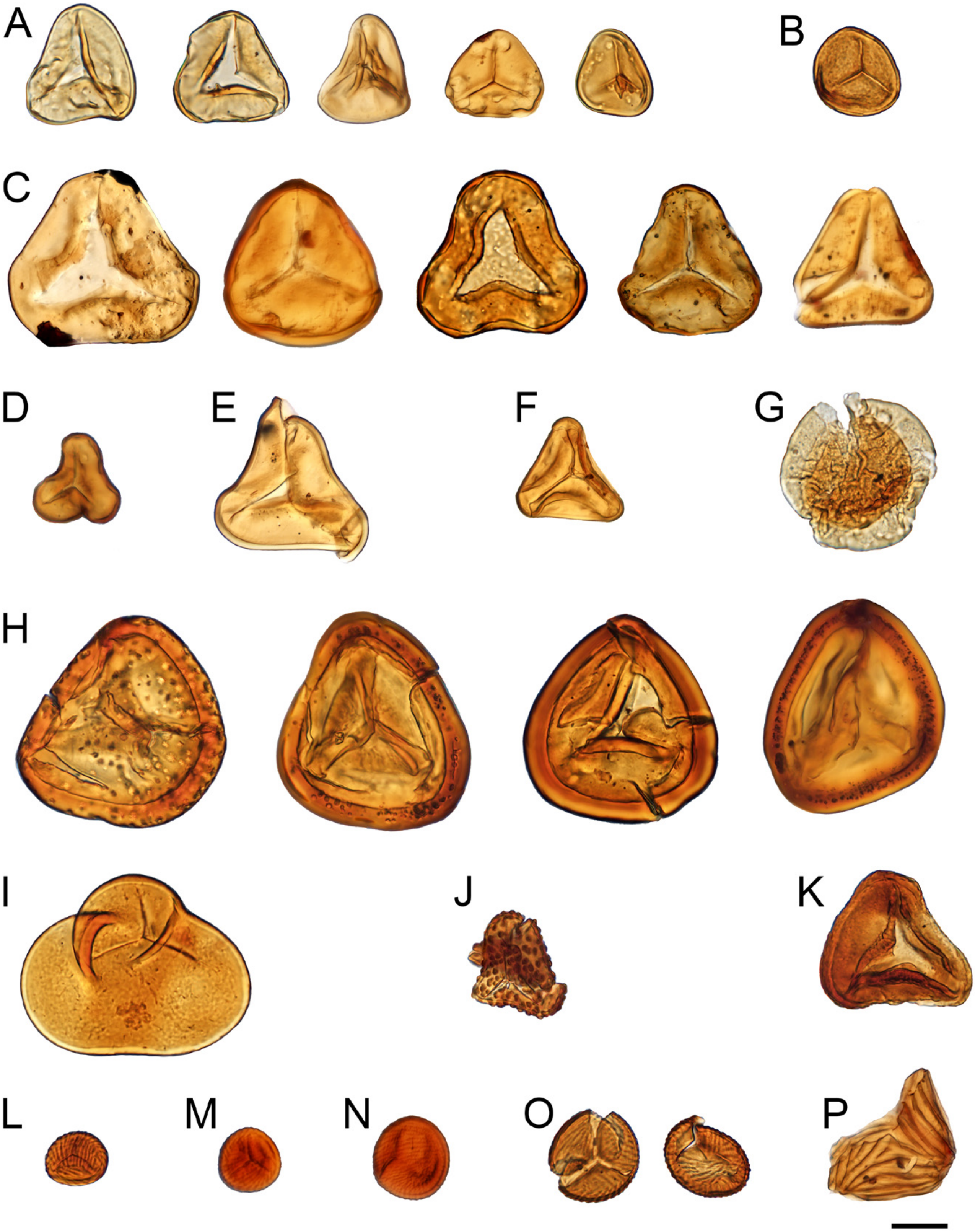

FIGURE 6. Microphotographs of selected palynomorphs. **A**–**P**, Light photomicrographs of selected spores (**A**–**F, H**–**P**) and pollen grains (**G**). **A**, *Cyathidites minor*. **B**, *Punctatisporites* sp. **C**, *Cyathidites australis*. **D**, **E**, *Deltoidospora* sp. **F**, *Dictyophyllidites* cf. *harrisii*. **G**, *Callialasporites trilobatus*. **H**, *Cingutriletes* sp. **I**, *Concavissimisporites punctatus*. **J**, *Concavissimisporites* cf. *verrucatus*. K, *Concavissimisporites*? sp. **L**–**P**, Several species of *Cicatricosisporites*. Scale bar = 20 microns.

transmittance peak at the wavelength 3677 cm^{-1} correspond to low concentration of O–H stretching in alcohol or phenol. The strong and broad transmittance peak at the wavelength 3464 cm^{-1} correspond to O–H stretching in alcohol and/or carboxylic acid. Transmittance peaks at the wavelengths 2926 and 2867 cm^{-1} correspond to C–H stretching in CH, CH_2 and CH_3. The transmittance peak at the wavelength 1721 cm^{-1} corresponds to C–H bending in aromatic compound. Transmittance peak at the wavelength 1706 cm^{-1} corresponds to C=O stretching in carboxylic acids. Transmittance peak at the wavelength 1457 cm^{-1} corresponds to C–H bending in CH_2 and CH_3 of alkyl groupings. Transmittance peak at the wavelengths 1377 cm^{-1} corresponds to C–H bending in CH_3 of alkyl groupings. Transmittance peaks at the wavelengths 1230 and 1160 cm^{-1} correspond to C–O stretching in carboxylic acids and esters. Transmittance peak at the wavelength 1093 cm^{-1} corresponds to C=O stretching in conjugated acid halide. Transmittance peak at the wavelength 1028 cm^{-1} corresponds to S=O stretching in sulfoxide. The transmittance peak at the wavelength 974 cm^{-1} corresponds to C–H bending in CH_2 of cycloalkane. The transmittance peaks at the wavelengths 852 and 813 cm^{-1} correspond to C–H bending. All these detected functional groups indicate the large dominance of the aliphatic chains in the chemical constitution of the studied amber. The large similarity of the obtained spectra compared to those of the other ambers from other Lebanese outcrops can be explained probably by the possible same botanical origin of the resin at that time (early Barremian). It is noteworthy that the infrared analyses have long been used in amber characterisation; however, used alone, they cannot be necessarily precise in correctly ascertaining the botanical origin of the amber.

Biological inclusions

A Scelionidae wasp was found (Fig. 4D) in a single piece of amber. It is however noteworthy to state that the outcrop was visited once for less than 20 minutes, so more sampling would certainly yield more biological inclusions.

Preliminar palynology of the site

The assemblages show a mixture of marine, mainly represented by dinoflagellate cysts, and terrestrial palynomorphs. The studied levels show almost equal

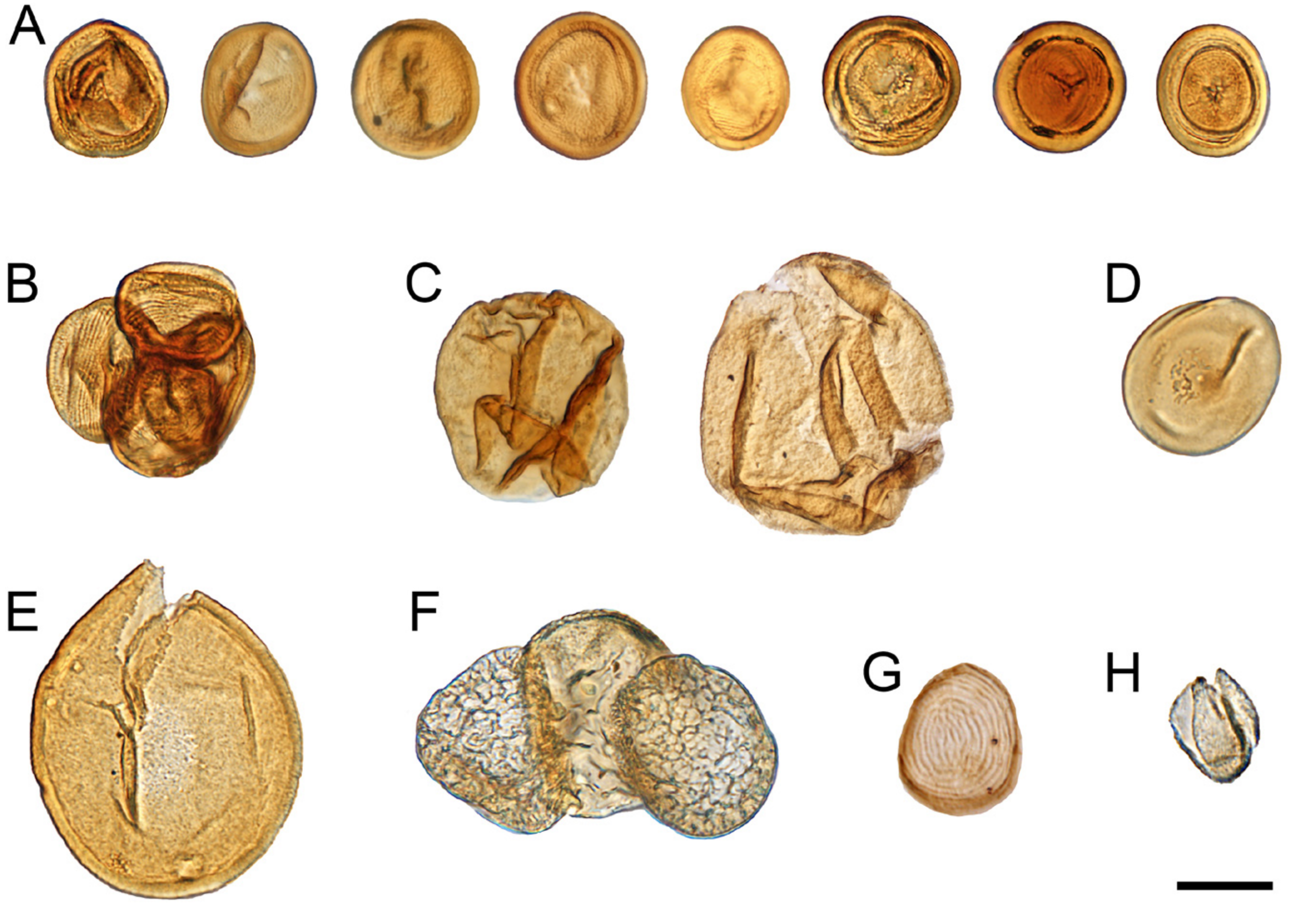

FIGURE 7. Light photomicrographs of selected pollen grains (**A**–**F**, **H**) and algae cysts (**G**). **A**, *Classopollis* sp. **B**, Tetrad of *Classopollis*. **C**, *Araucariacites* sp. **D**, *Spheripollenites psilatus*. **E**, *Balmeiopsis limbata*. **F**, *Pinuspollenites* sp. **G**, *Chomotriletes minor*. **H**, Tricolpate pollen grain. Scale bar = 20 microns.

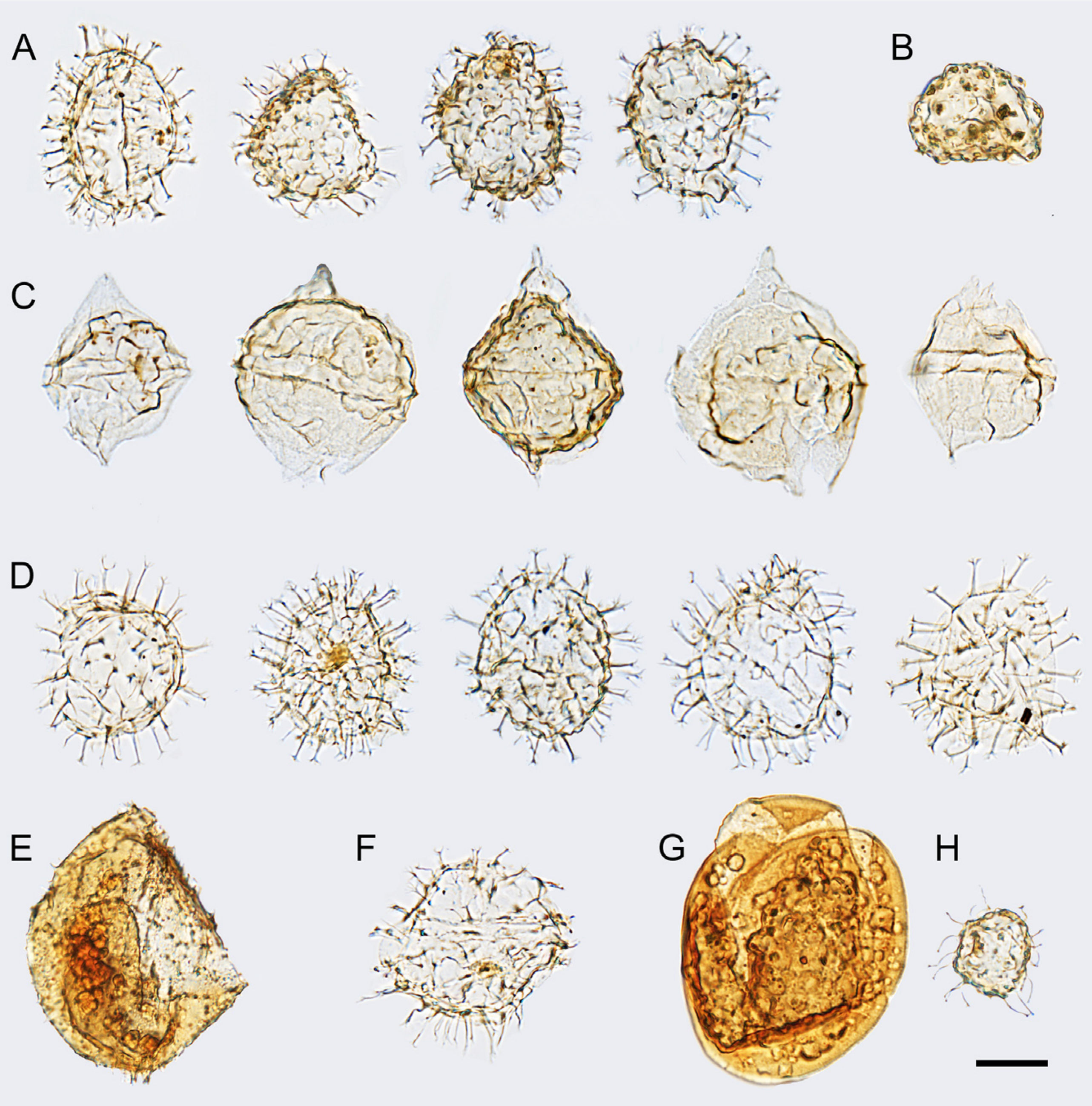

FIGURE 8. Light photomicrographs of selected aquatic palynomorphs. **A**, *Kiokansium* cf. *unituberculatum*. **B**, *Conosphaeridium* sp. **C**, *Subtilisphaera* sp. **D**, *Kiokansium* cf. *unituberculatum* sp. **E**, *Trichodinium castanea*. **F**, cf. *Achomosphaera* sp. **G**, *Ovoidinium* sp. **H**, *Michrystridium* sp.

rate of marine and continental specimens indicating that the depositional environment was clearly marine (or at least margino-littoral strongly influenced by tidal effect) as indicated by the usual occurrence of dinocysts. The abundance of *Classopollis* pollen (Fig. 7A, B), which was produced by Cheirolepidiacean conifers, traditionally indicates arid and/or salty coastal environments (Watson, 1988). Among fern spores, some species such as *Cyathidites minor* (Fig. 6A) and *C. australis* (Fig. 6C) exhibit conspicuous representation. In addition, *Punctatisporites* sp. (Fig. 6B), *Deltoidospora* sp. (Fig. 6D, E), *Dictyophyllidites* cf. *harrisii* (Fig. 6F),) *Concavissimisporites punctatus* (Fig. 6K), *Concavissimisporites* cf. *verrucatus* (Fig. 6J), *Concavissimisporites*? sp., several species of *Cicatricosisporites* (Fig. 6L–P) among others could be identified. The appearance of *Cingutriletes* sp. (Fig. 6H) points out the presence of bryophytes in the plant communities of the region.

As mentioned previously, *Classopollis* predominates in the studied assemblages (Fig. 7A, B). Other pollen grains related to gymnosperms that have been identified in the studied samples are *Araucariacites* sp. (Fig. 7C), *Callialasporites trilobatus* (Fig. 6G), *Spheripollenites psilatus* (Fig. 7E), *Balmeiopsis limbata* (Fig. 7E) and *Pinuspollenites* sp. (Fig. 7F). The occurrence of triaperturate pollen of possible angiosperms in the studied levels (Fig. 7) is remarkable since its presence is recorded in the late Barremian of North Gondwana (Boukhamsin *et al.*, 2022).

Among marine palynomorphs, the occurrence of *Kiokansium* cf. *unituberculatum* (Fig. 8A, D) and *Subtilisphaera* sp. (Fig. 8C) is dominant among dinocysts. *Conosphaeridium* sp. (Fig. 8B), *Trichodinium castanea* (Fig. 8E), cf. *Achomosphaera* sp. (Fig. 8F) and *Ovoidinium* sp. (Fig. 8G) are also present in the assemblage. We also noticed the presence of acanthomorph acritarchs of the genus *Michrystridium* (Fig. 8H) and *Chomotriletres minor* (Fig. 7G), a freshwater algae cysts of the family Zygnemataceae.

Conclusion

The discovery of additional lower Barremian amber outcrops with biological inclusions in Akkar El-Atiqa (Northern Lebanon) increases our knowledge about the palaeobiodiversity and the palaeoenvironment of the large Lebanese amber forest during the Early Cretaceous period. It is obvious that more intensive investigations (palaeontological, taxonomic, etc.) must be conducted on this very important and promising outcrop and efforts must be taken in order to preserve it.

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