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Tannoura: A new early Barremian fossiliferous amber outcrop from South Lebanon

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Abstract

A fossiliferous amber outcrop in Tannoura (Rashayya District, Southern Lebanon) is described. This new discovery constitutes the 30th amber outcrop with biological inclusions in Lebanon and enriches and improves our knowledge about the palaeobiodiversity and palaeoenvironment of the North-Eastern coast of Gondwana during the early Barremian. Also, an infrared spectrum of the amber from Tannoura is given and discussed.

Keywords: 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 several hundred lower Barremian amber outcrops (Granier *et al*., 2016; Maksoud *et al*., 2017). The latter count continues to increase steadily, with 29 outcrops to date (Fig. 1) yielding biological inclusions (Maksoud *et al*., 2019, 2020, 2021a, b, 2022). Lebanese amber is one of the most important ambers, 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 Tannoura, Caza (= District) Rashayya, in Mouhafazet (= Governorate) South Lebanon (Figs 2, 3A–D). We (DA and SM) discovered this site on 17th April 2023, during a geological survey of Rashayya and Mount Hermon area in the southwest of Lebanon.

This outcrop provided centimetric- to decimetric-sized amber pieces. This outcrop constitutes the 30th amber locality with biological inclusions in Lebanon (Fig. 1; Maksoud & Azar, 2023), and shed lights on our knowledge of the palaeobiodiversity and palaeoenvironment of the North-Eastern coast of Gondwana during the early Barremian. The amber from this outcrop is chemically analysed using Fourier Transform Infrared (FT-IR) spectroscopy.

Material and methods

The material was collected from Tannoura (Rashayya district, Southern Lebanon), (Figs 2, 3A–D). The amber pieces containing bioinclusions were manually cut using denticulate shaving blades, and then polished with increasing grade emery papers and diatomite. Then for better visibility, the specimens were imbedded between two microscopic coverslips with Canada balsam medium as described in Azar *et al.*, 2003. The amber inclusions were examined and photographed with a Leitz Laborlux-12 compound microscope, and Olympus SZX10 and Nikon SZ10 stereomicroscopes. Photographs were captured with an AmScope MU9000 digital camera. The palynomorphs were observed and photographed respectively with an Olympus compound microscope BX53 and Olympus digital camera DP74. The figures and illustrations were processed with Helicon Focus 8, Adobe Photoshop CS6 and Adobe Illustrator CS6 software packages. For the infrared analysis, the amber was crushed and mixed with potassium bromide (KBr) and pellets were prepared using a hydraulic manual press. The spectrum was acquired between 4000 and 400 cm^{-1} with 40 scans collected at 4

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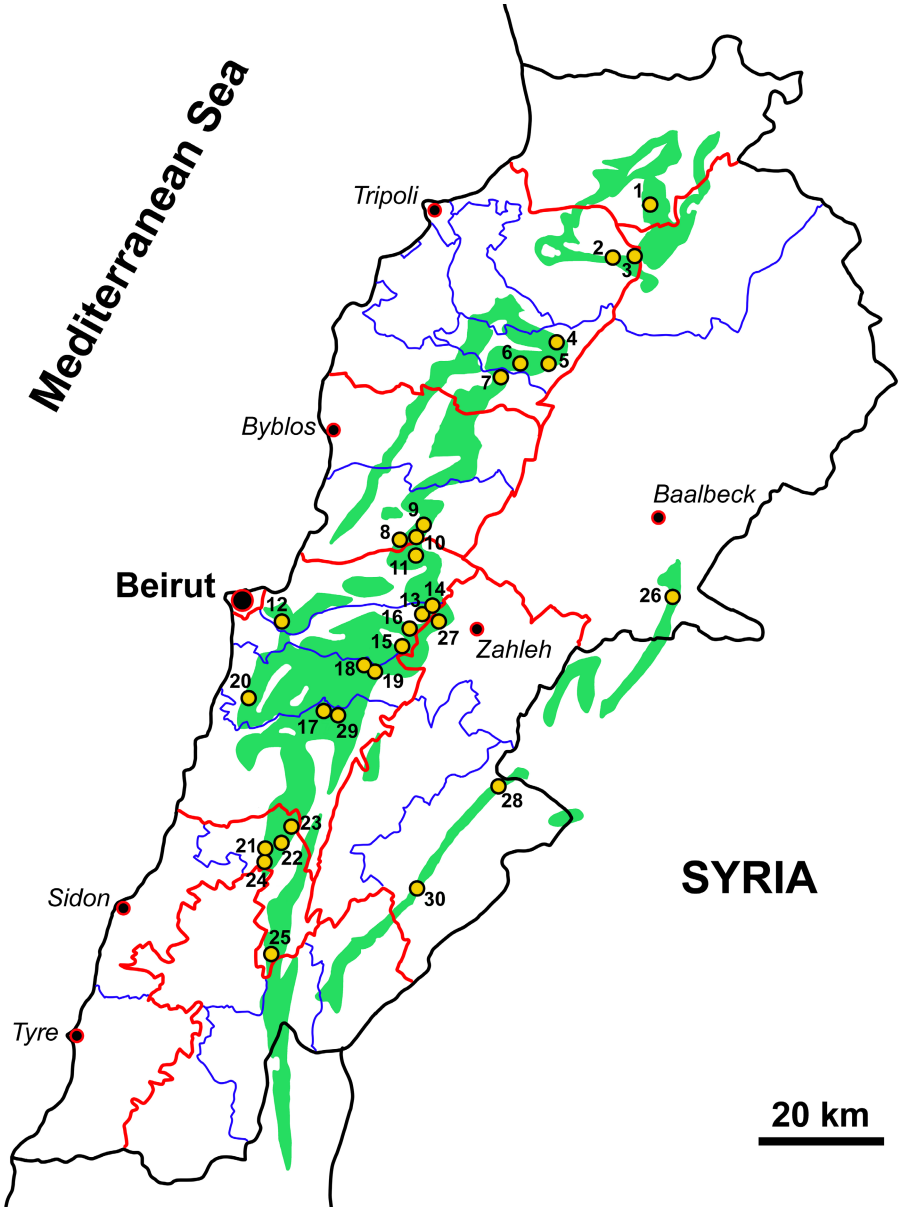

FIGURE 1. Map of Lebanon with Lower Cretaceous amber and fossil insect outcrops. Green areas indicate the distribution of the amber localities. Yellow circular spots indicate the emplacements of Lower Cretaceous amber outcrops with insect inclusions. Red circular spots indicate the emplacements of Baskinta and Bqaatouta outcrops herein described. 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); and 30, Tannoura. Red curves indicate the boundaries of Governorates; blue ones the boundaries of districts.

cm^{-1} resolution. Transmission FT-IR spectroscopy was performed with Bruker VERTEX and HYPERION 2000 spectrophotometers. 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 traditional 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. Observation and illustrations were made with a TESCAN MAIA3 GMU Field emission scanning microscope. The slabs with palynomorphs were gold coated using LEICA EM ACE 200 vacuum evaporation equipment.

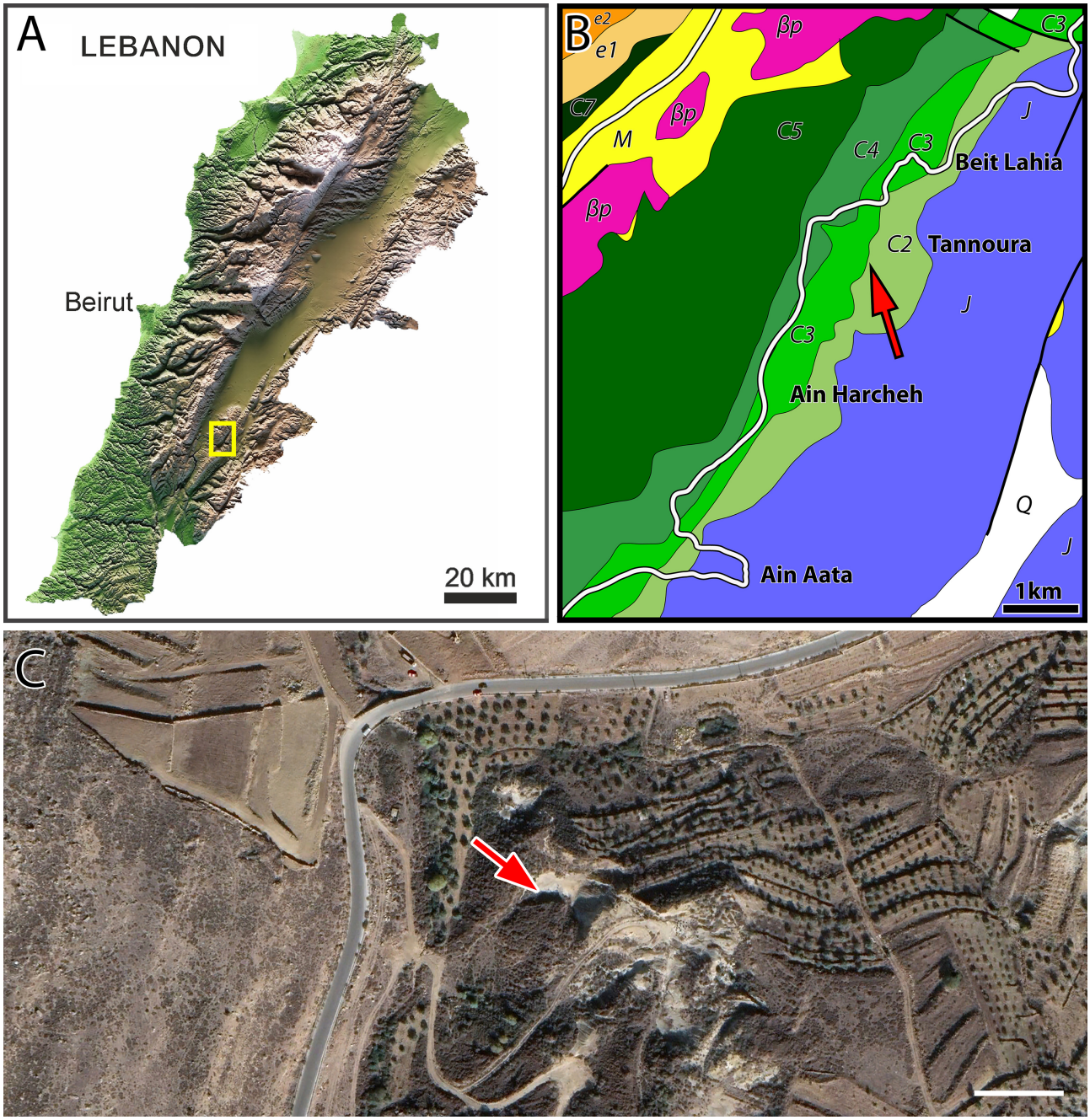

FIGURE 2. Tannoura amber outcrop. **A**, Natural map of Lebanon indicating the emplacement of the outcrop of Tannoura in the yellow frame. **B**, Geological map of Tannoura outcrop (red arrow), (modified from Dubertret, 1960). J = Jurassic; C2 = lower Barremian "Grès du Liban" sandstone; C3 = micritic part of the Jezzinian (uppermost Barremian-lowermost Aptian); C4 = Albian; C5 = Cenomanian; C7 = Senonian; M = mid-Miocene Q = Quaternary scree; e1 = lower Eocene; e2 = mid Eocene; βp = Pliocene volcanic deposition. Thick lines represent faults. Scale bar = 1 km. C, Aerial photography of the site. Scale bar = 50 m.

Geological setting

The Tannoura amber-yielding locality is situated within a sand quarry in the village Tannoura [Figs 2, 3 (33º 28' 33.64" N, 35º 47' 15.39" E, elev. 850 m)], Caza (= District) Rashayya, Mouhafazet (= Governorate) South of Lebanon, Southern Lebanon. The outcrop includes ochre deltaic-estuarine and margino-littoral sand stone layers comprising lens of dark blackish silty shale and clay stone. Fern leaves of *Weichselia reticulata* (Stokes and Webb) Fontaine *in* Ward *emend*. Alvin (Fig. 3E) and two pychnodontid fish teeth were found from the outcrop (Fig. 3F) supporting the coastal margino-littoral deposition place proposition. Amber (centimetric in size, with variant transparency, with white, cream, yellow, dark yellow, orange and red colours) (Fig. 4A–D), lignite and

FIGURE 3. Tannoura amber outcrop. **A**–**D**, Different views of the Tannoura outcrop. **E**, Fern leaves of *Weichselia reticulata*. **F**, Two pychnodontid fish teeth found from the Tannoura outcrop.

small plant fragments were found in the dark layers of this site.

This outcrop (Figs 2, 3A–D) is located in the early Barremian sandstone of the "Grès du Liban" [Sandstone of Lebanon (also known as Shouf Sandstones and "Grès de base")] (Granier *et al.*, 2015, 2016; Maksoud *et al.*, 2017) in the lower Barremian silicoclastic-dominated strata (Granier *et al.*, 2016). It was deposited in a fluvial margino-littoral palaeoenvironment.

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

FIGURE 4. Amber from Tannoura outcrop. **A**–**D**, Amber found from the Tannoura outcrop. **E**, Fossil insect inclusion, possibly a female nematoceran Diptera. **F**, Spider silk found in amber. Scale bares = 500 microns in **E** and 100 microns in **F**.

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} with 40 scans collected at 4 cm^{-1} resolution. The obtained spectrum of the amber in Fig. 5 demonstrates clearly that this amber is characterised by similar features as 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 considered to be the fingerprint area. The

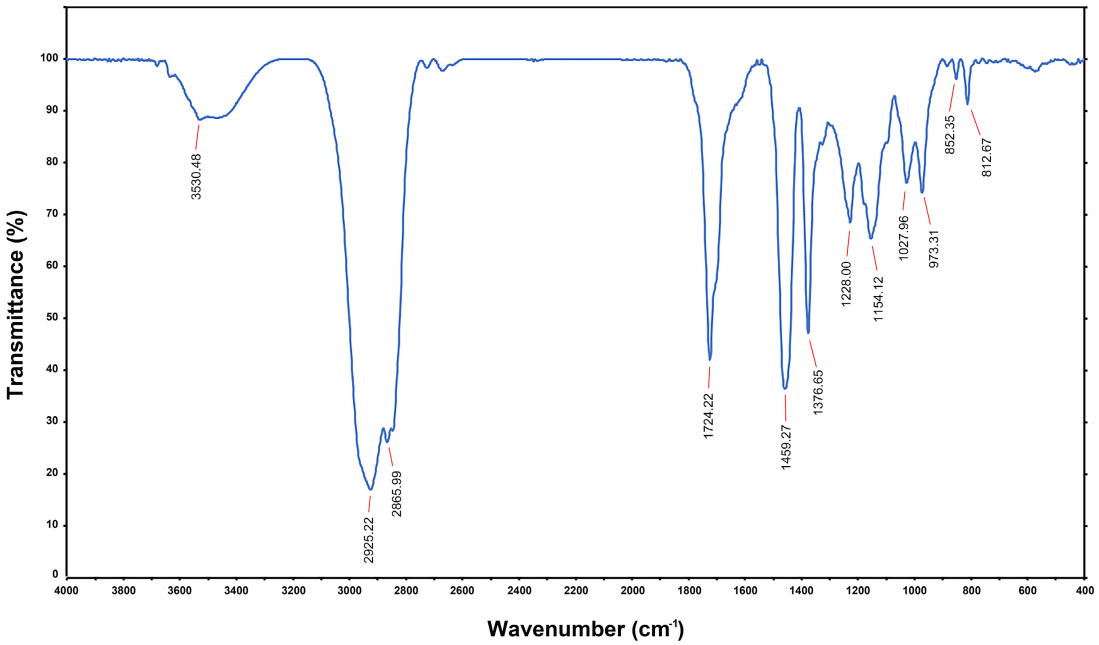

FIGURE 5. FT-IR spectrum of the amber of Tannoura for wavelengths between 4000 and 400 cm^{-1}.

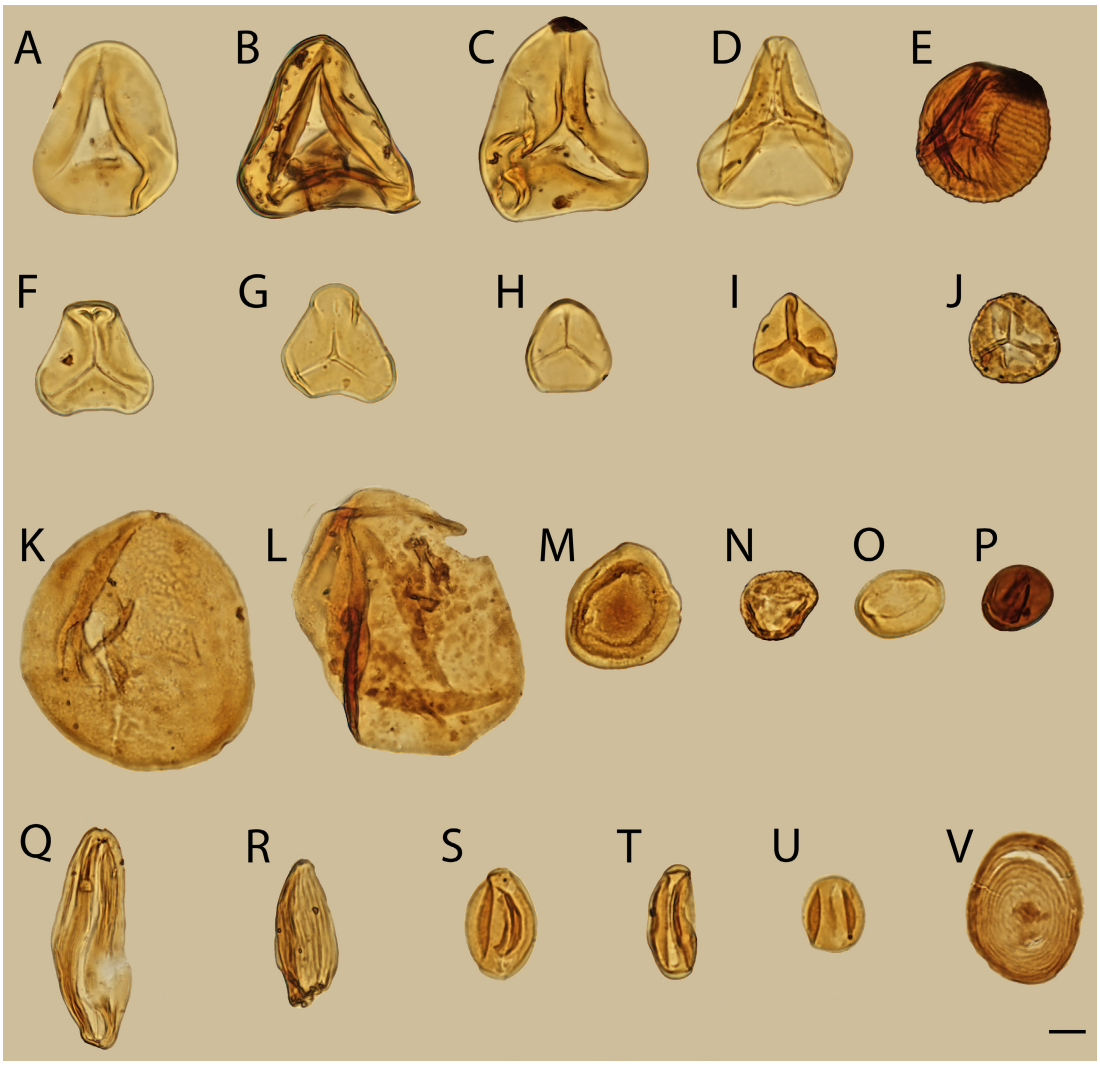

FIGURE 6. Palynomorphs from Tannoura amber outcrop. **A**–**J**, Pteridophyta spores. **E**, *Cicatricosporites australiensis*. **K**–**U**, Gymnosperm pollen grains. **K**, **L**, *Araucariacites australis*. **Q**, **R**, *Ephedra* sp. **S**–**U**, *Eucommiidites* sp. **V**, *Chomotriletes* sp. Scale bar = 10 microns.

strong and broad transmittance peak at the wavelength 3530 cm^{-1} corresponds to O–H stretching in alcohol and/or carboxylic acid. Transmittance peaks at the wavelengths 2925 and 2865 cm^{-1} correspond to C–H stretching in CH, CH_2 and CH_3. The transmittance peak at the wavelength 1724 cm^{-1} corresponds to C–H bending in aromatic compound. Transmittance peak at the wavelengths 1459 cm^{-1} corresponds to C–H bending in CH_2 and CH_3 of alkyl groupings. Transmittance peaks at the wavelength 1376 cm^{-1} corresponds to C–H bending in CH_3 of alkyl groupings. Transmittance peaks at the wavelengths 1228 and 1154 cm^{-1} correspond to C–O stretching in carboxylic acids and esters. The transmittance peak at the wavelength 1027 cm^{-1} corresponds to S=O stretching in sulfoxide. The transmittance peak at the wavelength 973 cm^{-1} corresponds to C–H bending in CH_2 of cycloalkane. Transmittance peaks at the wavelengths 852 and 812 cm^{-1} correspond to C–H bending. All these detected functional

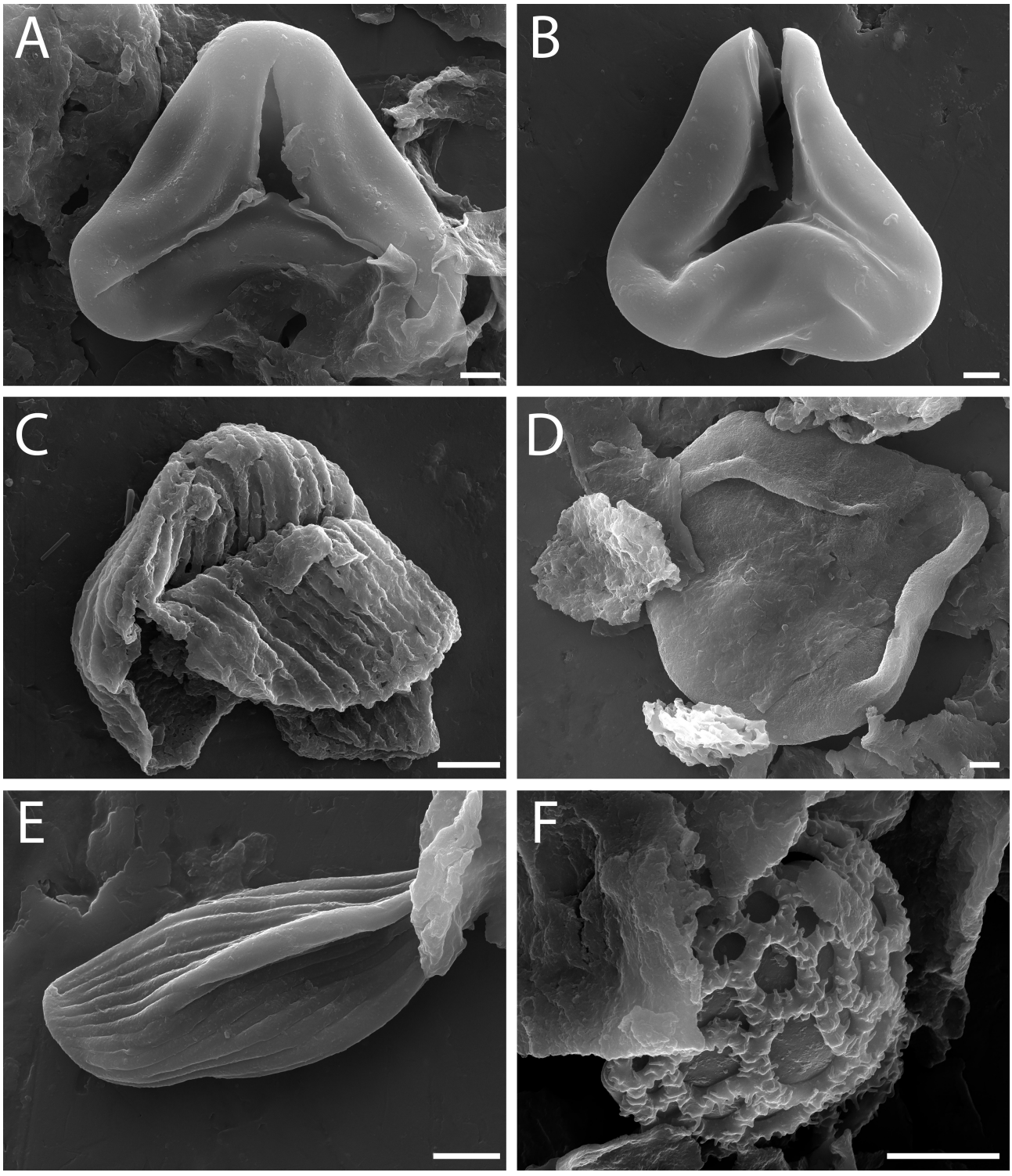

FIGURE 7. Palynomorphs from Tannoura amber outcrop observed with SEM. **A**–**C**, Pteridophyta spores. **C**, *Cicatricosporites australiensis*. **D**, *Araucariacites australis*. **E**, *Ephedra* sp. **F**, Palynomorph with angiospermian affinity. Scale bars = 5 microns.

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 perhaps be explained by the same possible botanical origin of the resin at that time (early Barremian). It is noteworthy that infrared analyses have long been used in amber characterisation; however, used alone, they are not necessarily precise in ascertaining the botanical origin of the amber.

Biological inclusions

An unidentified badly preserved insect (Fig. 4E; probably nematoceran Diptera) and a strand of spider silk (Fig. 4F) were found in a single piece of amber.

Palynology of the site

The palynofacies shows a mixture of marine (represented mainly by fragments of chitinous foraminiferal linings) and terrestrial contents. Analysed slides and SEM stubs show dominance of diversified continental contents. Pteridophyta spores (Figs 6A–J, 7A–C) are dominant (mainly dominated by *Dictyophyllidites* and *Deltoidospora)*; *Dictyophyllidites harrisii*, *Deltoidospora australis*, *Deltoidospora minor*, *Leiotrilites* sp., *Cicatricosporites australiensis* (Fig. 6E, 7C), *Cicatricosporites spinulosus*, *Verrucosisporites* sp. among others were identified. Gymnosperm pollen are present and dominated by *Araucariacites australis* (Figs 6K–L, 7D) and *Classopollis* sp. among others. Rare palynomorphs of angiospermian affinities are present (Fig. 7F). A complete palynological analysis of the outcrop will be subject of an elsewhere separate study.

Conclusion

The discovery of additional lower Barremian amber outcrops with biological inclusions in Tannoura (Southern Lebanon) increases our knowledge as to 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 official efforts must be undertaken in order to preserve it.

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References

Azar, D. (1997) A new method for extracting vegetal and insect fossils from the Lebanese amber. *Palaeontology*, 40, 1027–1029.

Azar, D. (2007) Preservation and accumulation of biological inclusions in Lebanese amber and their significance. *Comptes Rendus Palevol*, 6, 151–156. https://doi.org/10.1016/j.crpv.2006.10.004

Azar, D. (2012) Lebanese amber: a "Guinness Book of Records". *Annales Universitatis Paedagogicae Cracoviensis*, 111, 44–60.

Azar, D., Gèze, R. & Acra, F. (2010a) Chapter 14: Lebanese amber. *In*: Penney, D. (Ed.), *Biodiversity of fossils in amber from the major World deposits*. Siri Scientific Press, Manchester, pp. 271–298.

Azar, D., Gèze, R., El-Samrani, A., Maalouly, J. & Nel, A. (2010b) Jurassic amber in Lebanon. *Acta Geologica Sinica—English Edition*, 84, 977–983. https://doi.org/10.1111/j.1755-6724.2010.00228.x

Azar, D. & Nel, A. (1998) Lebanese Lower Cretaceous amber. *Meganeura*, 2, 18–20.

Azar, D. Perrichot, V., Néraudeau, D. & Nel, A. (2003) New psychodid flies from the Cretaceous ambers of Lebanon and France, with a discussion about *Eophlebotomus connectens* Cockerell, 1920 (Diptera, Psychodidae). *Annals of the American Society of America*, 96 (2), 117–127. https://doi.org/10.1603/0013-8746(2003)096[0117:NPFTCA]2.0.CO;2

Dubertret, L. (1960) *Carte géologique au 1:50 000; Feuille de Hermon*. République Libanaise, Ministère des Travaux Publics, Beyrouth, 1 coloured map + notice 46 p.

Granier, B., Azar, D., Maksoud, S., Gèze, R. & Habchi, R. (2015) New fossiliferous sites with Barremian Charophyta in the «Grès du Liban» auct. (Lebanon), with a critical perspective regarding the nature of *Munieria* Deecke, 1883. *Carnets de Géologie*, 15 (15), 199–229. https://doi.org/10.4267/2042/57947

Granier, B., Toland, C., Gèze, R., Azar, D. & Maksoud, S. (2016) Some steps toward a new story for the Jurassic—Cretaceous transition in Mount Lebanon. *Carnets de Géologie*, 16 (8), 247–269. https://doi.org/10.4267/2042/59924

Maksoud, S. & Azar, D. (2020) Lebanese amber: latest updates. *Palaeoentomology*, 3 (2), 125–155. https://doi.org/10.11646/palaeoentomology.3.2.2

Maksoud, S. & Azar, D. (2023) Lebanese amber: A fantastic journey

into the time of dinosaurs. *Journal of Gems & Gemmology*, 25 (4), 136–145.
https://doi.org/10.15964/j.cnki.027jgg.2023.04.012

Maksoud, S., Azar, D., Granier, B. & Gèze, R. (2017) New data on the age of the Lower Cretaceous amber outcrops of Lebanon. *Palaeoworld*, 26 (2), 331–338.
https://doi.org/10.1016/j.palwor.2016.03.003

Maksoud, S., Granier, B.R.C. & Azar, D. (2022) Palaeoentomological (fossil insects) outcrops in Lebanon. *Carnets de Géologie*, 22 (16), 699–743.
https://doi.org/10.2110/carnets.2022.2216

Maksoud, S., Taleb, K. & Azar, D. (2019) Four new Lower Barremian amber outcrops from Northern Lebanon. *Palaeoentomology*, 2 (4), 333–339.
https://doi.org/10.11646/palaeoentomology.2.4.6

Maksoud, S., Taleb, K. & Azar, D. (2021a) New early Barremian fossiliferous amber outcrop from North Lebanon. *Palaeoentomology*, 4 (1), 23–26.
https://doi.org/10.11646/palaeoentomology.4.1.4

Maksoud, S., Zaidan, O.T. & Azar, D. (2021b) Kfar Selouan: A new early Barremian fossiliferous amber outcrop from Lebanon. *Palaeoentomology*, 4 (3), 257–265.
https://doi.org/10.11646/palaeoentomology.4.3.13

Maksoud, S., Ziadé, K., Gèze, R. & Azar, D. (2020) New early Barremian amber outcrops from Central Lebanon. *Palaeoentomology*, 3 (4), 415–422.
https://doi.org/10.11646/palaeoentomology.3.4.14

Nohra, Y., Azar, D., Gèze, R., Maksoud, S., El-Samrani, A. & Perrichot, V. (2013) New Jurassic outcrops from Lebanon. *Terrestrial Arthropod Reviews*, 6, 27–51.
https://doi.org/10.1163/18749836-06021056

Poinar, G.O. & Milki, R. (2001) *Lebanese amber: the oldest insect ecosystem in fossilized resin*. Oregon State University Press, Corvallis, Oregon, 96 pp.