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Use of Lebanese amber inclusions in paleoenvironmental reconstruction, dating and paleobiogeography

Dany AZAR, André NEL and Raymond GÈZE

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Abstract. Fossil insects trapped in Lower Cretaceous Lebanese amber can be used for relative dating of its deposits. The detailed study of very large variety of the fossil insects and the consecutive establishment of faunistic profiles allows the paleoclimatic and paleoenvironmental reconstruction of the north-east region of Gondwana, 130 Million years ago.

Key words: Lebanese amber, fossil insects, dating, paleoenvironment, paleobiogeography.

Dany AZAR, André NEL, Laboratoire d'Entomologie,Muséum National d'Histoire Naturelle,45, rue Buffon, F-75005 Paris, France.
E-mail: azar@mnhn.fr; anel@mnhn.fr
Raymond GÈZE, Lebanese University, Faculty of Sciences II, Fanar, B.P. 90656, Lebanon.

I. INTRODUCTION

Precise chronologies and dating are necessary to reconstitute the history of the Earth, an area or a deposit. The traces of the past events are preserved in the geological formations. Thus, there are mainly two methods for dating. First one, known as absolute dating, is based on the study of the radioactive traces or "radioactive isotopes" of some precise chemical elements present in the holding layers. The second method (relative dating) is based on use of the "traces of living forms" or "fossils". If the relative dating of marine sediments is rather easy, the lack of reliable fossil indicators makes definitely more difficult the dating of the sediments of continental origin. We demonstrate that it is possible to obtain relative dating of outcrops of continental origin by using fossil insects trapped in amber. Moreover, the establishment of entomological profile and the systematic study of the insects will hopefully allow precise reconstitution of the paleoclimate and paleoenvironment.

Amber is a fossil plant resin that has the property to preserve animal or vegetable inclusions with details . In Lebanon, we have discovered more than 100 outcrops providing amber (Fig. 1). The age of these outcrops varies from the late Jurassic to the Albian (145-95 Million years). The majority of the sites are Neocomian (Valanginian-Barremian) or late Neocomian-early Aptian. Lebanese amber is, for almost all sites, in its primary deposit associated to vegetable remains and lignites. Some of these sites correspond to continental deposits. In these cases, rich paleofaunas and paleofloras in-

cluded in amber seem to be excellent potential tools for dating. The amber of Lebanon is the oldest fossiliferous one (POINAR 1992; CANO et al. 1993; AZAR 1998a, b), and corresponds to a crucial period for coevolution between flower plants and insects. This period witnesses the radiation of angiosperms; an event accompanied by rapid diversification of insects and massive extinctions of old groups (JARZEMBOWSKI & ROSS 1993). We focus our study on the outcrops of Jezzine (Southern Lebanon), Hammana (Central Lebanon) and Bcharreh (Northern Lebanon) (Fig. 1).

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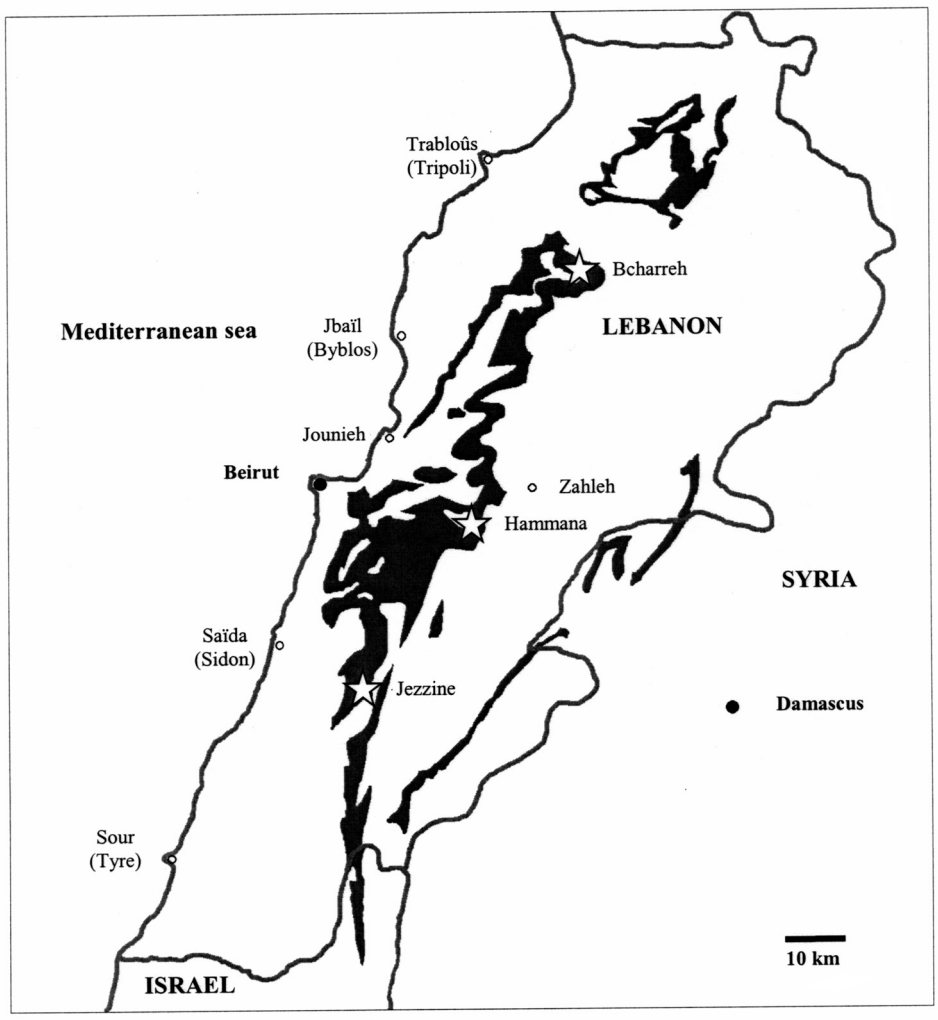

Fig. 1 Map of Lebanon (adapted from DUBERTRET 1941-3) presenting the distribution of amber outcrops (black area), the stars indicate three major fossiliferous outcrops of amber compared in this study.

II. COMPARED DATING OF THREE LEBANESE AMBER DEPOSITS

The dating of Hammana amber deposit has been obtained by palynological study (DEJAX et al. 1996; 1997) that confirms the Neocomian-lower Aptian age suggested by DUBERTRET (1951). The palynology showed that the sedimentation for Hammana amber deposit corresponds to that of a margino-littoral platform, probably related to an estuary, a lagoon or to a deltaic area. Recent discoveries of several other amber outcrops of nearly the same age, extending from the North of Lebanon to Jordan (BANDEL et al. 1979) and Israel (POINAR 1992) contradict the possibility of a sedimentation related to a lagoon or an estuary and support that of a delta for this area at the end of Neocomian -Lower Aptian. Palynology also provided information on the paleoclimate: it was probably moderate to hot and very wet (of tropical or subtropical type).

The exact age of Lebanese amber deposits is rather difficult to define, which is also true for all sedimentary rocks of continental origin because of the lack of reliable marker fossils. TILL 1994, the only available Lebanese amber material with biological inclusions was from the Jezzine outcrop. From that date more than 100 new amber outcrops (Fig. 1) were found in Lebanon, by the authors (D. A.), (R. G.) and Kamil ZIADÉ. Among them, inclusions were found in only six outcrops: Hammana (Caza Baabda, Central Lebanon), Bcharreh (Caza Bcharreh, North of Lebanon), Tannourine – Laklouq (Caza El-Batroun, North of Lebanon), Kfar Selouan (Caza Baabda, Central Lebanon), Ain Dara (Caza Aaley, Central Lebanon) and Ouata-El-Jaouz (Caza Kesserouan, Central Lebanon). The four latter gave less than 25 inclusions each, whereas the two remaining plus the one of Jezzine gave each a large amount of fossil organisms (more than 700). Therefore we base our study only on Jezzine, Hammana and Bcharreh outcrops (Fig. 1). In Jezzine and Hammana, amber occurs in different geological levels, in 250 m thick sandstone and clay layers, and with an age extending from the lower Neocomian to the upper Aptian. In this way, and regarding the geological age, one could consider that the amber occurs in several outcrops with several ages for both Jezzine and Hammana areas. Some sites in both areas may be less than 100 meters distant. More than six amber outcrops were found in Jezzine area, but also in Hammana. Curiously, only one of them in both areas gives amber with biological inclusions. The same situation is in Bcharreh: there are two levels where amber occurs, but only one level gives amber with inclusions (ESTEPHAN, pers. comm.). In this study we only consider the outcrops with amber containing inclusions.

The fossiliferous amber of Jezzine occurs in a locality named "Jouar Es-Souss" along the road of Saïda – Jezzine, just before the village of Jezzine and near a bifurcation leading to the village Bkassine, in grey clay-sandstone of Neocomian age (Valanginian-Hauterivian after DIETRICH 1976).

The fossiliferous outcrop of Hammana occurs in a locality named Hammana - Mdeyrij on the top of the road bifurcating from Damascus road and leading to the village Hammana, in grey clay and clay-sandstone, in layers belonging to a geological facies considered to be lowermost Aptian by DUBERTRET (1950; 1951). However, the outcrop of Hammana belongs to the boundary of the top of the Chouf Sandstone Formation – base of Abeih Formation *sensu* the stratigraphic nomenclature of WALLEY (1996). After WALLEY (1996), the Chouf Sandstone Formation is the "Grès de Base" or "C1" of older usage and is the most distinctive unit in Lebanon. The age range of the Chouf Sandstone is problematic: in theory it could extend from terminal Thitonian to early Aptian, but SHIMRON & LANG (1989) have dated the end of deposition of the equivalent Kurnub Group to possibly Barremian. The lower part of the Abeih Formation may be as old as Barremian, but in general the unit is early Aptian in age (WALLEY 1996).

Bcharreh amber deposit occurs around Hasroun village (ESTEPHAN, pers. comm.) in Neocomian clay-sandstone.

Recent taxonomic studies of fossil insects from Bcharreh, Hammana and Jezzine outcrops yield to the discovery of several shared taxa in these three outcrops. In Table I we present all the studied species of fossil insects shared by these outcrops. Further detailed studies of the faunas of Lebanese amber will surely yield to much more shared species in the different amber bearing localities, as for

example the ceratopogonids of Jezzine and Bcharreh outcrops (Table I) are probably also present in Hammana, but the ceratopogonid flies of this last outcrop are still not studied.

All these species shared by the three major Lebanese amber bearing deposits with biological inclusions, let us suppose that these outcrops are of very close ages.

Table I

Taxa shared by the three outcrops of Lebanese amber. H: Hammana outcrop; J: Jezzine outcrop; B: Bcharreh outcrop

Order	Family	Taxa	H	J	B
Hemiptera	Enicocephalidae	*Enicocephalinus acragrimaldii* AZAR et al. 1999 a	+	+	+
Diptera	Phlebotomidae	*Libanophlebotomus lutfallahi* AZAR et al. 1999 b	+	+	+
	Psychodidae	*Paleopsychoda jacquelinea* AZAR et al. 1999 b	+	+	?
	Empididae	*Phaetempis lebanensis* GRIMALDI & CUMMING 1999	?	+	+
	Incertae cedis	*Chimeromyia intriguea* GRIMALDI & CUMMING 1999	?	+	+
	Ceratopogonidae	*Archiaustroconops ceratoformis* SZADZIEWSKI 1996	?	+	+
		Archiaustroconops szadziewskii BORKENT 2000	?	+	+
		Archiaustroconops hamus BORKENT 2000	?	+	+
		Austroconops gondwanius SZADZIEWSKI 1996	?	+	+
		Austroconops fossilis SZADZIEWSKI 1996	?	+	+

III. IMPORTANCE OF FOSSIL INSECTS TO PALEOECOLOGY

The faunistic inventory of inclusions seems to be biased by several taphonomic factors (dimensions of insects trapped in amber, proximity of the resin producing tree, behavioural and seasonal factors, and repulsive property of the resin). Nevertheless, various types of fossil insects confirm the results of the palynology. Almost 60% of the entomofauna trapped in the amber of Hammana deposit are Diptera Nematocera, mainly of the families Chironomidae, Ceratopogonidae, Psychodidae and Phlebotomidae. Especially these latter flies are characteristic of wet and hot climate. Psychodidae and Phlebotomidae fear the light and do not leave their area of reproduction. It comes out from their study that these families were already very diversified at the end of Neocomian-Lower Aptian (three new Phlebotomidae and eight new Psychodidae species) (AZAR et al. 1999b). The great abundance and diversity of these flies shows that the amber forest was probably dense, under hot and wet climate.

Furthermore, *Enicocephalinus acragrimaldii* (Heteroptera: Enicocephalidae) is a good indicator of paleoenvironment (AZAR et al. 1999a). It was a predator bug of small size, which probably lived in died leaves, the plant remains and wet mosses in the forests, as modern Enicocephalidae do. These biota correspond to the paleoenvironment already established after the palynology. These bugs are definitely more rare in the amber deposit of Jezzine (South of Lebanon) than in Hammana. Only two specimens are known from Jezzine in the very large Acra collection, while in the Hammana outcrop we found more than one hundred of these bugs. As a result of the study (made by the first author) of the Lebanese amber collection in the American Museum of Natural History, only three specimens of this species were found in the area of Bcharreh (North of Lebanon). The origin of differences in the frequency of these insects could be related to paleoenvironment. It is possible that

the amber forests of Jezzine and of Bcharreh were less dense or even of different floristic composition than that from Hammana. It is always possible, but not very probable because of the large number of inclusions in the collections, that these differences are related to sampling artefacts. Only more researches undertaken in parallel in these various sites will help to solve this problem.

IV. IMPORTANCE OF FOSSIL INSECTS TO PALEOBIOGEOGRAPHY

The paleobiogeographic analysis of the site of Hammana was established after examination of the relationship between palynologic association of this site and those of the two microfloristic provinces of the peri-Tethys (south Laurasia and north Gondwana) of BRENNER (1976). The palynologic association of Hammana shares some characters with the two microfloristic provinces of peri-Tethys, but is not really integrated into any of them, but has a proper individuality (DEJAX et al. 1996; 1997). The flora was probably subjected to the "influences" of these two rather remote provinces. The study of Lepidoptera: Micropterigidae from the outcrop of Hammana (KRISTENSEN pers. comm.), Jezzine (WHALLEY 1976; 1986) and Bcharreh (BENDIB pers. comm.), enables us to propose a hypothesis of a north-eastern position in the Gondwanian continent for the future Lebanon during the Lower Cretaceous. These fossil butterflies have a constriction on the semi-length of the broad antennal scape, which is an apomorphic character proper to the Recent Micropterigidae of the southern hemisphere that corresponds to the Lower Cretaceous continent of Gondwana.

V. CONCLUSION

After these examples, it seems possible to use insects fossilised in amber to reconstruct the paleoenvironment, to compare the ages of continental deposits for which no other stratigraphic marker fossils exist and to bring information to define the paleobiogeography. Obviously, these first results will have to be supported by further analyses. The abundance and the great diversity of the insects in amber will render possible these studies in stratigraphic perspectives.

REFERENCES

AZAR D. 1998a. Lebanese amber. *Meganeura*, **1** : 26-27.

AZAR D. 1998b. L'ambre du Crétacé Inférieur du Liban: "une fenętre exceptionnelle sur le passé". Ecole Doctorale, la Logique du Vivant. Journées Boris Ephrussi- 20 et 21 Avril 1998. Pp: 20-21.

AZAR D., FLECK G., NEL A., SOLIGNAC M. 1999a. A new enicocephalid bug, *Enicocephalinus acragrimaldii* gen. nov., sp. nov., from the Lower Cretaceous amber of Lebanon. (Insecta, Heteroptera, Enicocephalidae). *Estudios del Museo de Ciencias Naturales de Alava*, **14** (Núm. Espec. 2): 217-230.

AZAR D., NEL A., SOLIGNAC M., PAICHELER J.-C., BOUCHET F. 1999b. New Genera and Species of phlebotomid and psychodid flies from the Lower Cretaceous amber of Lebanon. *Palaeontology*, **42**(6): 1101-1136.

BANDEL K., HADDADIN A., MAFRAQ A. 1979. The depositional environment of amber-bearing rocks in Jordan. *Dirasat*, **6**(8): 39-62.

BORKENT A. 2000. Biting midges (Ceratopogonidae: Diptera) from Lower Cretaceous Lebanese amber with a discussion of the diversity patterns found in other ambers. [In:] D. GRIMALDI (ed.) – Studies on fossils in amber, with a particular reference to the Cretaceous of New Jersey. Backhuys Publ., Leiden Nederlands. Pp: 355-451.

BRENNER G. J. 1976. Middle Cretaceous floral provinces and early migrations of Angiosperms. [In:] C. B BECK (ed.) – Origin and early evolution of Angiosperms. Columbia University Press, New York. Pp: 23-47.

CANO R., POINAR H., PIENIAZEK N., ACRA A., POINAR G. 1993. Amplification and sequencing of DNA from a 120-135 millions-year-old weevil. *Nature*, **363**: 536-538.

DEJAX J., MASURE E., AZAR D. 1996. Analyse palynologique d'un échantillon de sédiment du Crétacé inférieur du Liban. *Strata*, **1**(8): 66-67.

DEJAX J., MASURE E., AZAR D. 1997. Analyse palynologique de deux échantillons de sédiment du Crétacé inférieur du Liban. XVème Symposium de l'Association des Palynologues de Langue Française. Lyon 1-3 Septembre 1997. Pp: 20-21.

DIETRICH H.-G. 1976. Zur Entstehung und Erhaltung von Bernstein-Lagerstätten 2: Bernstein-Lagerstätten im Libanon. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **152**: 222-279.

DUBERTRET L. 1941-43 Carte géologique de la Syrie et du Liban au millionič me (2ème édition) Beyrouth. 67 pp., 1 map.

DUBERTRET L. 1950. Carte géologique au 50 000e, feuille de Djezzine. Ministère des Travaux Publics, République Libanaise. 80 pp., XII plates, 1 map.

DUBERTRET L. 1951. Carte géologique au 50 000e, feuille de Beyrouth. Ministère des Travaux Publics, République Libanaise. 66 pp., XII plates, 1 map.

GRIMALDI D., CUMMING J. 1999. Brachyceran Diptera in Cretaceous ambers and Mesozoic diversification of the Eremoneura. *Bulletin of the American Museum of Natural History*, **239**: 1-124.

JARZEMBOWSKI E. A., ROSS A. 1993. Time flies: the geological record of insects. *Geology Today*, **XI-XII**: 218-223.

POINAR G. O. 1992. Life in amber. Stanford University Press, Stanford. 350 pp.

SZADZIEWSKI R. 1996. Biting midges from Lower Cretaceous amber of Lebanon and Upper Cretaceous amber of Taimyr (Diptera, Ceratopogonidae). *Studia Dipterologica*, **3**: 23-86.

SHIMRON A. E., LANG B. 1989. Cretaceous magmatism along the southeastern flanc of Mont Hermon. *Israel Journal of Earth Sciences*, **38**: 125-142.

WALLEY C. D. 1996. The stratigraphy and geological history of Lebanon: an outline. American University of Beirut, Beirut, Lebanon.

WHALLEY P. 1976. Lower Cretaceous Lepidoptera. *Nature*, **266**: 526.

WHALLEY P. 1986. A review of the current fossil evidence of Lepidoptera in the Mesozoic. *Biological Journal of the Linnean Society*, **28**: 253-271.