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PALAEOENVIRONMENTAL AND BIOSTRATIGRAPHIC DATA FROM THE RESSON TUFA (AUBE, FRANCE): REASSESSMENT OF AN EEMIAN RECORD



Julie DABKOWSKI¹, Nicole LIMONDIN-LOZOUET¹ & Marie-Claude JOLLY-SAAD²

ABSTRACT

Since the mid-19th century, the large tufa deposit of Resson (Aube, northern France) was of great interest to geologists and palaeontologists because of its rich content in macroflora and large mammal fossils, while some archaeological artefacts were also described. A geomorphological and sedimentological study in the mid-xxth century assigned this deposit to the Last Interglacial. Despite its great potential for palaeoenvironmental investigation, the Resson tufa had not been studied since. We have recently retrieved the collection of plant imprints from Resson allowing new taxa determination, prospected the tufa location and made new malacological analyses. This paper thus combines new records and reassessed historical data to confirm the assignment of Resson tufa to the Eemian and discuss a first reconstruction of palaeoenvironmental dynamics in the Seine basin for this interglacial period, demonstrating the potential of this tufa deposit as a reference site for the Last Interglacial in northern France.

Keywords: calcareous tufa, Eemian, imprint macroflora, malacofauna, palaeoenvironments, Paris basin, France.

RÉSUMÉ

DONNÉES PALÉOENVIRONNEMENTALES ET BIOSTRATIGRAPHIQUES DU TUF DE RESSON (AUBE, FRANCE) : RÉVISION D'UN ENREGISTREMENT EEMIEN

Depuis le milieu du xix^e siècle, l'important dépôt de tuf de Resson (Aube) a suscité l'intérêt des géologues et paléontologues par sa richesse en macrorestes végétaux et ossements de grands mammifères, par ailleurs associés à des vestiges archéologiques. Une étude géomorphologique et sédimentologique menée au milieu du xx^e siècle attribua ce dépôt au Dernier Interglaciaire, mais malgré son potentiel important pour la recherche paléontologique et paléoenvironnementale, le tuf de Resson n'a pas été étudié depuis. Récemment, la redécouverte de la collection d'empreintes foliaires de Resson a permis la détermination de nouveaux taxons et de nouvelles analyses malacologiques. Parallèlement, des prospections sur le site et des analyses malacologiques préliminaires ont été réalisées. Cet article présente la combinaison des données historiques et celles acquises plus récemment afin de discuter l'attribution du site à l'Eemien et de proposer une première reconstitution des dynamiques paléoenvironnementales en amont du bassin de la Seine à cette période. Le tuf de Resson pourrait ainsi devenir à terme un site de référence pour le Dernier Interglaciaire dans le nord de la France.

Mots-clés : tuf calcaire, Eemien, empreintes foliaires, malacofaunes, paléoenvironnements, bassin de Paris, France.

1 - INTRODUCTION

Calcareous tufas are continental carbonate rocks precipitating in open-air conditions, in streams and rivers (Capezzuoli *et al.*, 2014), widely observed in fluvial areas with calcareous bedrock (Pentecost, 1995). They result from the dissolution of the carbonate content of the bedrock in the aquifer, favoured by soil and forest development and the resulting groundwater acidification (Pentecost, 2005). Those characteristics induce that, at mid-latitudes, tufas mainly deposit during warm and wet climatic periods, i.e. interglacials (Pentecost, 2005). Tufas usually contain abundant remains of fauna and flora fossilized in situ (Capezzuoli *et al.*, 2014; Dabkowski, 2014).

The tufa deposit at Resson was first studied by Leymerie (1846) who mentioned the presence of numerous aquatic and terrestrial plant imprints, abundant mollusc shells and some remains of elephant and beaver. The site thus came into focus for geologists and palaeontologists (Belgrand, 1869; de Mortillet, 1883) but the most detailed investigations were provided by Fliche (1883). The author gave a synthesis of early research and a full inventory of palaeontological remains from Resson, especially a list of 35 plant taxa preserved as imprints in the tufa calcite, eight species of molluscs and six vertebrates (including a bird and mammals). He also mentioned, after Belgrand (1869), remains of a human skull and bones, and described cut marks and intentional breaking of cervid bones and a 'Moustier type'

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flint tool. Those oldest studies position Resson into a warm period of the Quaternary. In the 20th century, the geomorphological context and the sedimentology of Resson were further discussed and the tufa was assigned to the last interglacial (Tricart, 1949; Michel, 1967).

According to Fliche (1883), most of the palaeontological and archaeological remains he described at Resson were stored at the *Musée de Troyes*. However, only part of the plant imprints and few mollusc shells have been recently retrieved thanks to Ghislain Grégoire, an assistant at the now called *Muséum d'histoire naturelle* in Troyes (Aube, France); and the plant macrofossil collection has been re-examined to specify the taxa determination and its palaeoenvironmental significance (Jolly-Saad & Dabkowski, unpublished).

In parallel, new field prospection in 2014 allowed to re-evaluate the potential of the Resson site. Together with preliminary geomorphological and stratigraphic observations, malacological samples were collected to test the abundance and preservation of the shells and species diversity. They provide a new list of taxa complementing the overview of past environmental conditions recorded in this tufa. This paper thus combines new records to reassess historical data,

comparing them with those from similar sites in northern France, to discuss the attribution of the Resson tufa to the last interglacial and evaluate the development of further studies at the site.

2 - STUDY SITE AND GEOMORPHOLOGICAL OBSERVATIONS

The site is located in the hamlet of Resson, north to La Saulotte (Aube, France), in the small valley of the same name (fig. 1A-B). The Resson River (earlier called La Doué), a tributary of the Seine, has incised the carbonated bedrock (Leymerie, 1846; Michel, 1967), which mainly comprises Palaeogene (mainly Eocene) limestone, clay and sandstone, and the Cretaceous chalk at the bottom (1:50000 Geological Map: Provins section; Lacot, 1967; fig. 1C). The tufa deposit has an ellipse shape of about 1 km-long and 200-300 m-large, oriented NW-SE along the Resson Valley (48°32'59" N, 3°29'24" E, 82 m asl), as shown on the local geological map (Lacot, 1967; Michel, 1967). The top of the tufa mount has a maximal altitude of about 98 m asl while the modern Resson River, which re-incised the tufa and

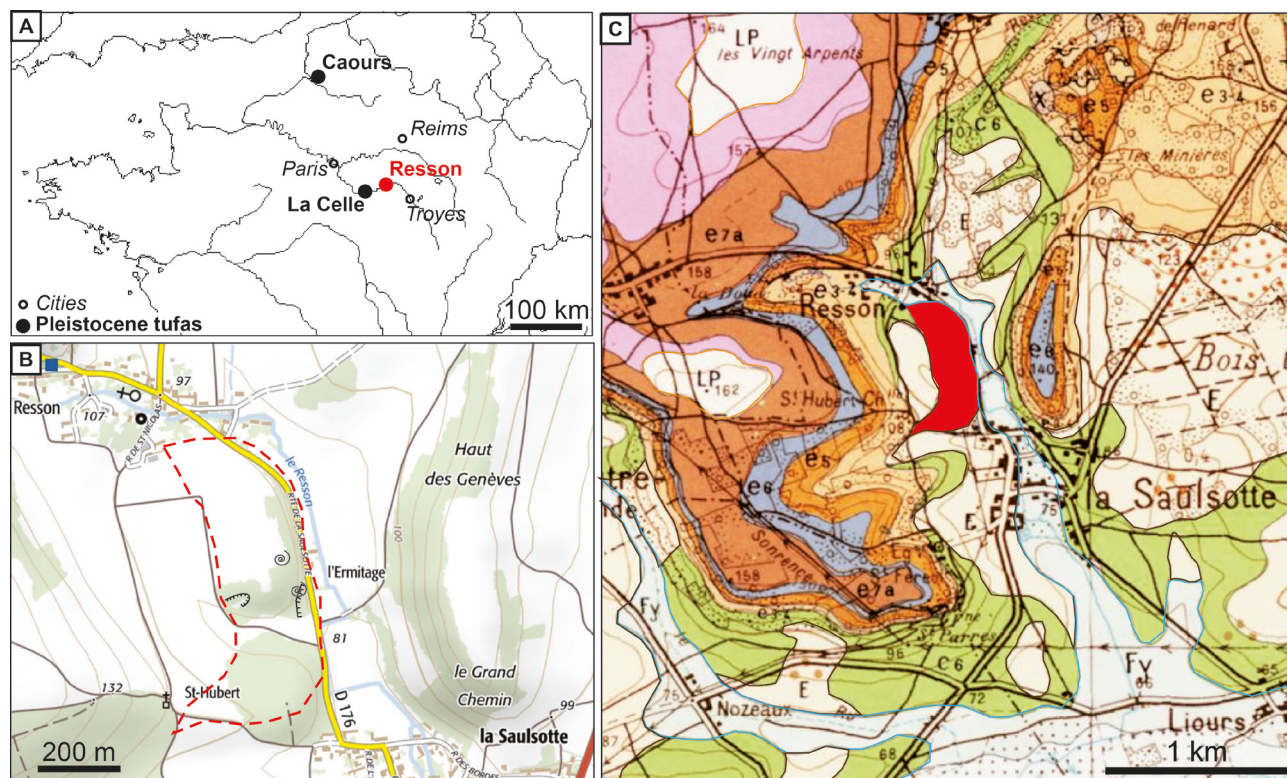
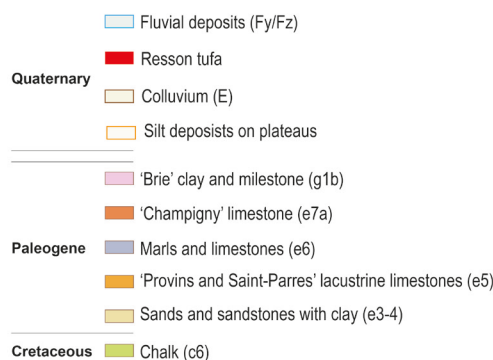


Fig. 1: Location maps of the Resson tufa.

(A) Location of Pleistocene tufa sites cited in the text (Resson, Caours - Somme - and La Celle - Seine-et-Marne). (B) topographic map of the Resson area showing the extension of the tufa deposit (according to the geological map - fig. 1C) and location of profiles and malacological test samples. (C) Geological map of the Resson area with indication of the tufa deposit (modified after Lacot, 1967).

Fig. 1 : Carte de localisation du tuf de Resson. (A) Localisation des sites pléistocènes cités dans le texte (Resson, Caours - Somme - et La Celle - Seine-et-Marne). (B) Carte topographique du secteur de Resson montrant l'extension du dépôt de tuf (d'après la carte géologique - fig. 1C) et localisation des coupes et des échantillons malacologiques test. (C) Carte géologique du secteur de Resson indiquant le dépôt de tuf (modifié d'après Lacot, 1967).



colluvial deposits, flows at 81 m asl at the locality called “*l’Ermitage*” (fig. 1B-C).

The water feeding the river comes from the Champigny limestone aquifer and emerges at the contact with clayish (impermeable) Lower Eocene sands and sandstone (e3-4; fig. 1C) at the Resson and the Reveillon springs. The Champigny aquifer is one of the largest in the Eastern Paris Basin and comprises the Champigny formation (e7a) and underlying Eocene limestones (e6 and e5, fig. 1C; Verjus *et al.*, 2008). This calcareous bedrock is likely to have provided the dissolved carbonate which has fed the tufa deposit at Resson.

Due to the exploitation of the Resson tufa as a local building stone since at least the Middle Ages (Leymerie, 1846; Koeniguer, 1996; Gérard *et al.*, 1997), several profiles were excavated, which present, according to former studies, an 8-10 m-high deposit with two main phases of tufa deposition: the lower part, comprising fine to sandy material, is indurated while the upper deposit is described as mostly crumbly and porous, with phytoclasts and detrital sands and gravels (Leymerie, 1846; Michel, 1967).

Recent field prospection has confirmed previous observations regarding the extension and height of the Resson tufa. Several profiles were identified, but only one, near ‘*l’Ermitage*’ (fig. 1B), can be ascribed to the former extraction wall described by Michel (1967). At the bottom of this 8 to 10 m high and 20 m long profile, the fractured Cretaceous chalk described by Michel is not visible. The lowermost deposits are composed of centimetric to decimetric angular blocks of sandstone and limestone (corresponding to unit 2 described by Michel; fig. 2). They are likely to correspond to the colluvial deposits shown on the geological map and must have been fed by the erosion of the surrounding bedrock, especially the Lower Eocene Sandstones (e3-4; fig. 1C).

The following deposits, 50-60 cm thick, comprise gravels and granules of carbonated material, mainly fragments of chinks, roughly laminated, that may correspond to the units 3 to 5 described by Michel (1967) as ancient fluvial deposits from the Resson River. The bottom of those deposits in the ‘*l’Ermitage*’ profile is at about 85 m a.s.l.

Above the colluvial and fluvial deposits, major features of the profile present tufa with a sub-horizontal lithology as reported by Michel (1967), although some lateral variations were not shown in the former publication. The general stratigraphy of the Resson tufa as described by previous authors (Leymerie, 1846; Fliche, 1883; Tricart, 1949; Michel, 1967) has been recognized in the field, especially in the central, best-preserved part of the profile (fig. 2). First, an indurated lower part comprises units of whitish silty to sandy homogeneous tufa (lime mud facies called ‘white marl’ by Michel, 1967: units 6, 8, 10 and 12), alternating with light-brown coarse tufa units, which display plant imprints (mostly stems and fragments; Michel’s units 7, 9 and 11; fig. 2). According to the previous authors, these units, especially the uppermost are likely to have also locally provided part of the leaf, *Chara* and moss imprints composing the collection described by Fliche (1883) (fig. 2). The upper tufa has been difficult to observe in detail during field prospection due to its elevation and the vegetation covering it. However, a brown to beige level of coarse porous tufa, which progressively becomes sandier then silty can be seen from about 2 m from the top of the ‘*l’Ermitage*’ profile. These observations are consistent with facies described by Michel (1967) in units 13 to 15. The porous level, comprising indurated beds is likely to have provided part of the leaf and *Chara* imprint collection (fig. 2).

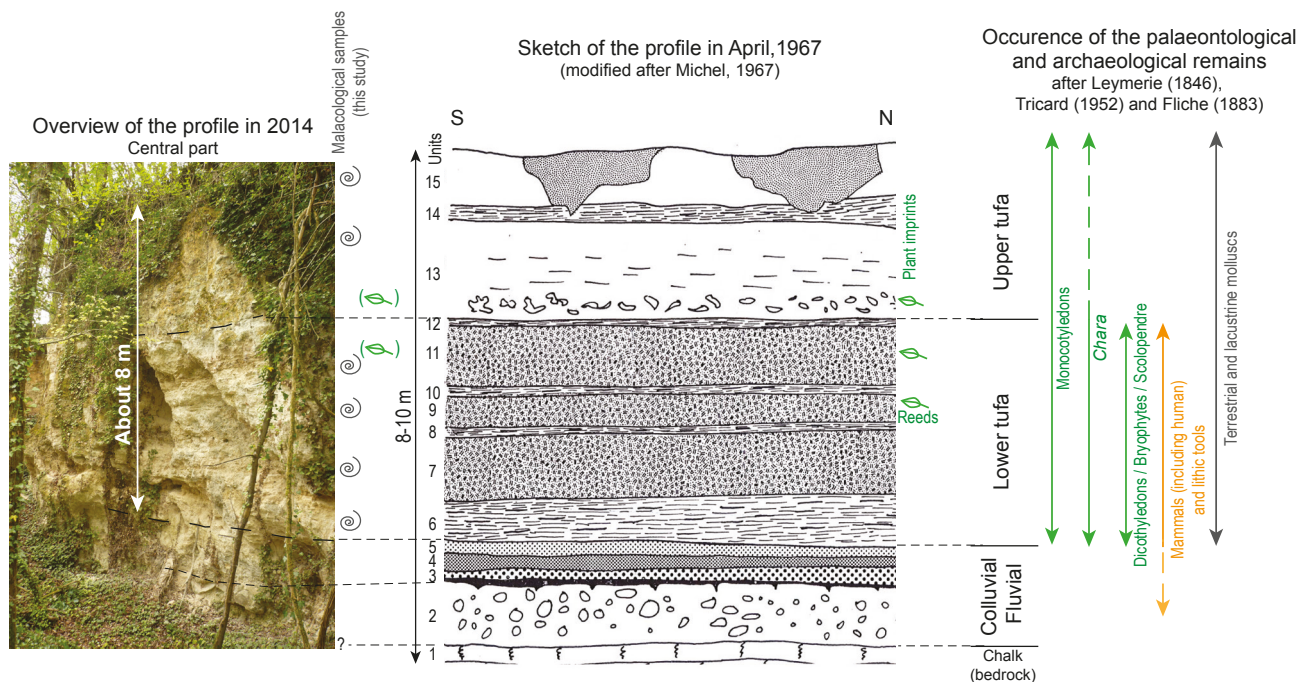


Fig. 2: Summary of stratigraphic, palaeontological and archaeological data from the Resson tufa at “*l’Ermitage*” profile.

From previous publications and new observations, see text for details.

Fig. 2 : Synthèse des données stratigraphiques, paléontologiques et archéologiques de la coupe de « l’Ermitage » dans le tuf de Resson. D’après les données anciennes et les nouvelles observations, détails dans le texte.

3 - FORMER PALAEOLOGICAL AND ARCHAEOLOGICAL DATA AND COLLECTIONS

3.1 - PLANT MACROFOSSILS

According to Leymerie (1846) and Fliche (1883), both the indurated lower and the upper parts of the tufa have provided palaeontological remains at Resson but most of them are preserved in a single unit of the lower phase, which, according to stratigraphic observations, is likely to correspond to Michel (1967)'s unit 9 or 11 (fig. 2). All aquatic plant remains (especially *Chara*), and most of dicotyledon, fern and moss imprints, come from the indurated lower part (Leymerie, 1846; Fliche, 1883). Only monocotyledons are common in both parts. Fliche (1883) inventoried 35 taxa including algae, bryophytes, pteridophytes, monocotyledons and dicotyledons. The full list of species described by this author is given in table 1.

The collection retrieved at the *Muséum d'histoire naturelle* in Troyes comprises 52 fragments of indurated tufa, from 5 to 15 cm in size, with numerous plant imprints on each (pl. 1). The full revision of these specimens provide a new list of taxa (Jolly-Saad & Dabkowski, unpublished), the majority of them being angiosperms (tab. 1). Identified botanical groups are monocotyledonous angiosperms (n = 3) and dicotyle-donous angiosperms (n = 22), Characeae (n = 1), bryophytes (n = 1), pteridophytes (n = 1). New families, new species and new genera are identified such as *Fraxinus* cf. *excelsior*, *Taxus baccata*, *Equisetum* cf. *fluviatile* and probably the group Potamogetonaceae/Alismataceae. However, several taxa in the list of Fliche (1883) were not found in the museum collection (tab. 1). It is likely that part of the collection remained private or was destroyed and is thus lacking at the *Muséum d'histoire naturelle* in Troyes.

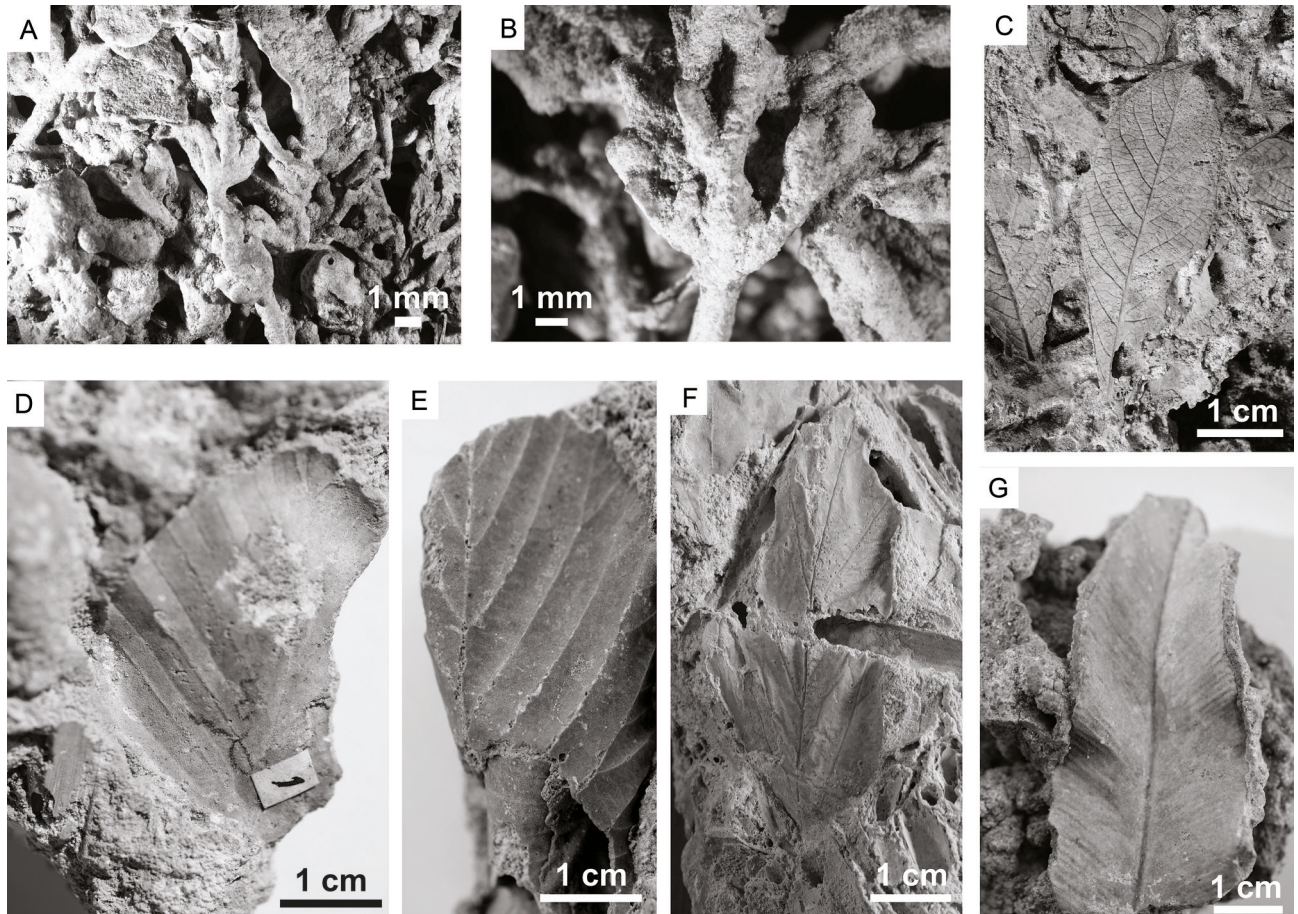
Three plant assemblages can be differentiated (Jolly-Saad & Dabkowski, unpublished). The first reflects an

		Fliche (1883)	Revised list (Jolly-Saad and Dabkowski, unpublished)
ALGAE	Characeae	<i>Chara foetida</i> <i>Chara hispida</i> var. <i>Brachyphyla</i>	<i>Chara</i> cf. <i>vulgaris</i>
BRYOPHYTES	Bryaceae	<i>Bryum bimum</i>	<i>Bryum pseudotriquetum</i>
PTERIDOPHYTES	Aspleniaceae	<i>Scolopendrium vulgare</i>	<i>Asplenium scolopendrium</i>
MONOCOTYLEDONS	Poaceae	<i>Phragmites communis</i>	<i>Phragmites</i> sp. Uncertain
	Cyperaceae	<i>Scirpus</i> sp.	
		<i>Carex glauca</i>	
		<i>Carex maxima</i>	
		<i>Carex flava</i>	
Typhaceae	<i>Typha latifolia</i>	<i>Typha</i> sp.	
Potamogetonaceae or Alismataceae		Uncertain	
DICOTYLEDONS	Betulaceae	<i>Betula alba</i>	<i>Betula</i> sp.
		<i>Betula alba</i> , var. <i>papyrifera</i>	
		<i>Alnus glutinosa</i>	<i>Alnus glutinosa</i>
		<i>Alnus incana</i>	
		<i>Corylus avellana</i>	<i>Corylus avellana</i>
	Salicaceae	<i>Populus canescens</i>	
		<i>Populus tremula</i>	<i>Populus</i> cf. <i>tremula</i>
		<i>Salix purpurea</i>	<i>Salix</i> cf. <i>alba/purpurea/fragilis</i>
		<i>Salix cinerea</i>	<i>Salix</i> cf. <i>caprea/cinerea</i>
		<i>Salix grandifolia</i>	
		<i>Salix nigricans</i>	
	Corylaceae	<i>Corylus avellana</i>	
	Fagaceae	<i>Fagus sylvatica</i>	<i>Fagus sylvatica</i>
	Juglandaceae	<i>Juglans regia</i>	
	Buxaceae	<i>Buxus sempervirens</i>	<i>Buxus sempervirens</i>
	Oleaceae	<i>Ligustrum vulgare</i>	<i>Ligustrum vulgare</i> <i>Fraxinus</i> cf. <i>excelsior</i>
	Cornaceae	<i>Cornus sanguinea</i>	
	Araliaceae	<i>Hedera helix</i>	<i>Hedera helix</i>
	Apiaceae	<i>Heracleum spondylium</i>	Uncertain
	Rosaceae	<i>Rubus fruticosus</i>	
<i>Cerasus padus</i>		<i>Sorbus aria</i>	
Rhamnaceae	<i>Rhamnus frangula</i>		
Tiliaceae	<i>Tilia platyphylla</i>		
		<i>Tilia</i> cf. <i>cordata</i>	
Sapindaceae	<i>Acer campestre</i>	<i>Acer</i> cf. <i>campestre</i>	
	<i>Acer platanoides</i>	<i>Acer</i> cf. <i>pseudoplatanus</i>	
	<i>Acer opulifolium</i>		
Renonculaceae	<i>Clematis vitalba</i>	<i>Clematis</i> cf. <i>vitalba</i>	
Celastraceae		<i>Euonymus europaeus</i>	
PINOPHYTES	Taxaceae		<i>Taxus baccata</i>
SPHENOPHYTES	Equisetaceae		<i>Equisetum</i> cf. <i>fluviatile</i>

Tab. 1: Plant taxa identified in the Resson tufa.

After Fliche (1883) and after revision by Jolly-Saad (Jolly-Saad & Dabkowski, unpublished).

Tab. 1 : Taxons végétaux identifiés dans le tuf de Resson. D'après Fliche (1883) et après révision par Jolly-Saad (Jolly-Saad & Dabkowski, unpublished).



Pl. 1: Plant imprints from Fliche's collection at the Muséum d'histoire naturelle in Troyes.

(A-B) *Chara* type *C. vulgaris* (Characeae). (C) *Salix* type *cinerea/caprea* (Salicaceae). (D) *Fagus sylvatica* L. (Fagaceae). (E) *Sorbus aria* L. (Rosaceae). (F) *Hedera helix* L. (Araliaceae). (G) *Asplenium scolopendrium* L. (Aspleniaceae).

Pl. 1 : Empreintes foliaires de la collection Fliche conservée au Muséum d'histoire naturelle de Troyes. (A-B) *Chara* type *C. vulgaris* (Characeae). (C) *Salix* type *cinerea/caprea* (Salicaceae). (D) *Fagus sylvatica* L. (Fagaceae). (E) *Sorbus aria* L. (Rosaceae). (F) *Hedera helix* L. (Araliaceae). (G) *Asplenium scolopendrium* L. (Aspleniaceae).

aquatic habitat characterized by a mass accumulation of Charophytes remains (pl. 1, cls. A-B). These algae prefer undisturbed, clear, oxygenated water and alkaline environments. If charophytes meadows are usually composed of a single *Chara* species, the possible presence of species of the group Potamogetonaceae/Alismataceae is recorded at Resson. Open conditions are also supported by some moss species, which may have lived on damp soils along the stream and played an important role in the deposition and consolidation of tufa.

The second plant association is characterized by hygrophytes and heliophytes, which permanently occupy waterlogged substrate of the riverside, comprising grasses and reeds (Poaceae, Cyperaceae and Typhaceae) and an abundant fern, *Asplenium scolopendrium* (pl. 1G). Moreover, some woodland taxa indicate a temperate riparian forest, especially *Alnus*, *Acer*, *Fraxinus*, *Betula* and *Populus*, which generally occupied humid environment even if they do not tolerate waterlogged soils too much.

Finally, the third plant association corresponds to a temperate deciduous forest, mainly composed of *Fagus* (pl. 1D), *Corylus*, *Tilia* and *Taxus*, that developed in a drained area away from the immediate vicinity of the stream. Arboreal species are accompanied by diversified shrubs (*Ligustrum*, *Sorbus*-pl. 1E, *Euvonymus*) and one liana (*Clematis*); all are mesophile, light demanding, trees or shrubs.

In 1883, Fliche concluded to similar ecological conditions with different habitats ranging from aquatic environments to a dense forest in some distance of the palaeo-Resson River. He noticed the strong similarities between the vegetation recorded at Resson and the one present nowadays in the area but emphasized the presence of thermophile taxa, which are not part of the extant local flora, such as *Buxus* and *Juglans* (the latter one has not been seen in the collection preserved at the *Musée de Troyes*; tab. 1). Fliche thus concluded that Resson tufa has formed during an interglacial period under temperature slightly warmer, at least during winter, than at present time.

3.2 - VERTEBRATES: BIRDS AND MAMMALS

According to Michel (1967), the few vertebrate remains collected in the 19th century was already missing at the *Muséum d'histoire naturelle* in Troyes in the late 1960s and our recent reinvestigation was not successful in finding new remains. According to Leymerie (1846) and Fliche (1883), they were all sourced from the indurated lower tufa (fig. 2). Fliche (1883) inventoried six species plus human remains (tab. 2). This assemblage appears heterogeneous as some species are clearly characteristic of temperate conditions (*Anas bochas*, *Castor fiber*, *Cervus elaphus*) but others are typical of steppe and cold environments (*Elephas primigenius* - now assigned to

Vertebrate taxa in Fliche (1883)		Anatomical element	Possible confusion with	Archaeological record
Bird	<i>Anas boschas</i>	cubitus and metacarpal (+ tibia ?)		
Mammals	<i>Canis familiaris</i>	1 first molar	<i>Canis lupus</i>	
	<i>Castor fiber</i>	Maxillar bone with incisor and 3 molars		
	<i>Elephas primigenius</i>	1 molar	<i>Palaeoloxodon antiquus</i>	
	<i>Rhinoceros tichorhinus</i> (= <i>Coelodonta antiquitatis</i>)	1 tooth (not seen by Fliche)	<i>Stephanorhinus kirchbergensis</i> <i>Stephanorhinus hemitoechus</i>	
	<i>Cervus elaphus</i>	Several fragments of antlers, fragments of a skull, 2 molars, 2 vertebrae	other Cervideae	2 pointed antlers, potential cut marks and breakages
	<i>Homo</i>	Fragments of skull and jaw		

Tab. 2: Vertebrate remains found at Resson.

According to Fliche (1883) and possible misidentification.

Tab. 2 : Restes de vertébrés découverts à Resson. D'après Fliche (1883) et possibles erreurs de détermination.

the *Mammuthus* genus, *Coelodonta antiquitatis*). Two hypotheses can explain this inconsistency: either some species were formerly misidentified or not all specimens did originate from the tufa; these assumptions are non-exclusive.

The 19th-century literature provides insufficient description to discuss in detail any misidentification (first hypothesis). The second hypothesis is based on the fact that, at mid-latitude in Europe, tufa deposits are characteristic of interglacial periods as they require warm and wet conditions to precipitate (Pentecost, 2005; Capezzuoli *et al.*, 2014). Therefore, the presence in the tufa itself of large mammals associated to cold and dry environments is unlikely. Additionally, it would be inconsistent with the thermophiles plant macrofossils preserved in these tufa units. However, the colluvial deposits, and possibly the fluvial sediments, observed at the bottom of the 'l'Ermitage' profile (fig. 2) can be contemporaneous of glacial conditions and may have reworked faunal material, which would also explain that *M. primigenius* and *C. antiquitatis* are only represented by single molars in the Resson collection (tab. 2).

3.3 - ARCHAEOLOGICAL RECORDS

In his description of mammal fauna, Fliche (1883) indicated 'indisputable evidence' of the human presence at Resson, especially two large Cervidae antlers that have been pointed plus cut marks and intentional breakages. Only cervid remains show signs of human activities; they are also the more numerous in Resson (tab. 2). Those observations may be consistent with an archaeological accumulation regarding this taxon. Additionally, Fliche mentioned a flint tool that he described as 'Moustier type' and human remains (skull and jaw), which were already inventoried by Belgrand (1869); all associated to the cervid remains. Those elements suggest that archaeological level(s) might be preserved at Resson. Unfortunately, as the collection is apparently lost, no recent confirmation has been made so far.

3.4 - MOLLUSCS

While eight molluscan taxa were described at Resson in former inventories (De Mortillet, 1883; Fliche, 1883), only two specimens were retrieved in the collection of the *Muséum d'histoire naturelle* in Troyes (tab. 3), corresponding to two thermophile species: *Cepaea nemoralis* and *Fruticicola fruticum* (pl. 2). The total absence of minute species that are observable only after sediment sieving (< 4 mm) is noticeable and suggests that only large shells visible in the section (> 1 cm) were then collected in the field. Despite this incomplete data compared to modern requirements in malacological studies, Fliche (1883) emphasized the similarity between malacofaunas found within the tufa and those known nowadays in the area. He concluded that analogous climatic conditions (i.e. interglacial) might have prevailed during the Resson tufa deposition.

4 - NEW MALACOLOGICAL DATA

During field prospection in 2014, five malacological samples (R2 to R6) were collected within various facies, at different depths along the northern (accessible) part of the profile and one (R1) at the very top of the tufa about 40 m north-westward of the profile (fig. 1B). Stratigraphic position and facies descriptions of these samples allow correlation them with units described by Michel (1967): malacological samples R6 to R1, from bottom to top, are likely to come respectively from units 6 and 7, units 9 and 10, the bottom of unit 14, and finally from unit 15 (tab. 4). All six sediment samples were sieved at 500 µm, complete shells and fragments were picked from the remaining fraction for species identification under binoculars. Shell preservation is good, except for samples at profile mid-height: R3 and R4, which are also the smallest (≤ 100 g; tab. 3). The diversity is high with 30 terrestrial taxa, including eight forest snails, and 13 aquatic species (tab. 3). Such a diversity and

	Sample ID	Musée	Fliche	R1	R2	R3	R4	R5	R6
	Sample weight (kg)	Troyes	(1884)	2	3	0,05	0,1	3	3
Forest	<i>Acanthinula aculeata</i>				1				
	<i>Aegopinella pura</i>				6				
	<i>Aegopinella nitidula</i>				2				
	<i>Discus rotundatus</i>				35				
	Clausiliidae				7				
	<i>Helicodonta obvolvata</i>				1				
	<i>Arianta arbustorum</i>				1				
	<i>Cepaea</i> sp.				3				
	<i>Cepaea nemoralis</i>	x	x						
	<i>Fruticicola fruticum</i>	x	x						
Mesophilous	<i>Punctum pygmaeum</i>				1			1	
	Vitrinidae				1				
	<i>Vitrea contracta</i>				11		1		1
	<i>Nesovitrea hammonis</i>				1			2	1
	<i>Oxychilus</i> sp.				4				
	<i>Trochulus hispidus</i>				2		1	2	
	<i>Helicigona lapicida</i>				1				
	<i>Euconulus</i> sp.			1	1			1	
	Limaces				31		1	2	7
Openland	<i>Vallonia costata</i>			4	19			2	2
	<i>Vallonia pulchella</i>							1	
	<i>Pupilla muscorum</i>			16					
	<i>Truncatellina cylindrica</i>			1					
	<i>Helicella itala</i>		x	1					
	<i>Cecilioides acicula</i>				1				
Hygrophilous	<i>Carychium minimum</i>			1	39			4	
	<i>Oxyloma elegans</i>			1	4			2	
	<i>Vertigo antivertigo</i>				7			5	2
	<i>Vertigo angustior</i>				1				
	<i>Zonitoides nitidus</i>				2		1		1
Aquatiques	<i>Valvata piscinalis</i>			130	35				
	<i>Valvata cristata</i>				120			8	
	<i>Bithynia tentaculata</i>			2	23				1
	<i>Lymnaea stagnalis</i>				2				
	<i>Stagnicola palustris</i>		x						
	<i>Galba truncatula</i>		x	2	6		1	4	
	<i>Radix</i> sp.		x	70	6		1	1	3
	<i>Acroloxus lacustris</i>				8				
	<i>Belgrandia marginata</i>			120	50		4		
	<i>Armiger crista</i>						1	4	
	<i>Planorbis planorbis</i>			54				17	
	<i>Gyraulus albus</i>		x						
	<i>Hippeutis complanatus</i>		x						
	<i>Anisus</i> sp.				2				
	<i>Pisidium amnicum</i>				10	1			
	<i>Pisidium</i> sp.				14	50			3
NISP				417	494	1	11	58	46
Number of taxa	2	8	14	35	1	8	16	9	

Tab. 3: Mollusc species retrieved in the collection of the Muséum d'histoire naturelle in Troyes and listed by Fliche (1883) and comparison with taxa collected in 2014 test samples at Resson.

NISP: Number of identified specimens.

Tab. 3 : Espèces de mollusques retrouvées en collection au Muséum d'histoire naturelle de Troyes et listées par Fliche (1883) comparées à la liste des taxons collectés à Resson dans les échantillons-test de 2014. NISP: Nombre d'individus.

the abundance of thermophiles are characteristic of an interglacial context (Limondin-Lozouet & Preece, 2014).

Preliminary results allow identifying the following environmental dynamic: the earliest tufa deposits occurred during a humid phase, marked by the predominance of aquatic taxa while terrestrial taxa include only hygrophilous and ubiquitous taxa

(samples R6 and R5, tab. 3), which are typical of pioneer faunas at the beginning of an interglacial (Limondin-Lozouet, 2011). Malacofaunas are badly preserved in samples R4 and R3, in the middle of the sequence (units 9 and 10), with extremely corroded shells. However, the presence of *Belgrandia marginata* is noteworthy: this freshwater thermophile species is living at present in



Pl. 2: Sample PI 1581 from Resson as it was preserved at the *Muséum d'histoire naturelle* in Troyes.

(1-3): *Cepaea nemoralis* (Linné, 1758). (4 & 5): *Fruticicola fruticum* (Müller, 1774), scale bars = 1 cm.

Pl. 2 : Echantillon PI 1581 provenant de Resson, tel que conservé au *Muséum d'histoire naturelle* de Troyes. (1-3) *Cepaea nemoralis* (Linné, 1758). (4 & 5) *Fruticicola fruticum* (Müller, 1774), échelle = 1 cm.

Sample ID	Depth from top of the profile (m)	Sample weight (g)	Facies description	Correspondence with Michel (1967)'s stratigraphical units
R1	0.2	2000	Yellowish calcareous sand	15
R2	2	3000	Greyish fine silty tufa	14
R3	4	50	Fine white tufa (lime mud)	10
R4	4.2	100	Whitish, coarse, granular to sandy, tufa	9
R5	7.7	3000	Yellowish, sandy to granular, tufa	7
R6	8	3000	Whitish to beige, fine sandy tufa	6

Tab. 4: Malacological test samples collected in 2014 at Resson and their stratigraphic position.

Tab. 4 : Description et position stratigraphique des échantillons malacologiques test collectés en 2014 à Resson.

the Mediterranean area (Germain, 1930) and is also an important biostratigraphic indicator of Middle to Late Pleistocene interglacial periods. In the last third of the sequence, sample R2 is the richest, both in number of shells and diversity (tab. 3), with several species indicating a well-developed forest environment. This mollusc assemblage thus demonstrates well-established interglacial conditions. Finally, the uppermost sample R1, at the top of the tufa body, also shows a high number of shells, close to R2 (tab. 3), but its malacological assemblage is less diversified and dominated by aquatic taxa. The few terrestrial ones observed are mostly open-land taxa. This may characterize the phase of forest decline often observed at the end of interglacials (Limondin-Lozouet & Preece, 2014).

Noticeably, the two thermophiles species retrieved in the collection of the *Muséum d'histoire naturelle* in Troyes and mentioned in former inventories (de Mortillet, 1883; Fliche, 1883) were not found in the new samples (*Cepaea nemoralis* and *Fruticicola fruticum*; tab 3, pl. 2). According to the authors' description of their stratigraphic position and their thermophile ecological requirements, they might be associated with malacofauna from sample R2, which has also provided fragments allocated to the *Cepaea* genus (tabs. 3 & 4).

5 - DISCUSSION

The general stratigraphic framework observed on “*l'Ermitage profile*” shows at least three main phases of deposition: 1) colluvial and fluvial deposits at the bottom, comprising gravels and granules of chalk and sandstone, may be assigned to a cold phase as already suggested by Michel (1967); 2) the first phase of tufa deposition is indurated and characterized by the alternation of silty to sandy-lime mud facies with coarse tufa; 3) the upper part of the tufa comprise crumbly coarse to sandy tufa (fig. 2). According to the climatic and environmental conditions required for its precipitation (Pentecost, 2005; Capezzuoli *et al.*, 2014), the tufa sequence must have deposited under temperate wet conditions (i.e. in this part of Europe, interglacial conditions).

Additionally, the colluvial and fluvial formations (phase 1) are accumulated ca. 5 m higher than the modern Resson River (fig. 1A) which is the usual relative altitude gap from valley bottom of the first fluvial terrace in the rivers of the Paris basin (Antoine *et al.*, 2007). In large north-western European valleys, fluvial terrace systems are mainly driven by the glacial/interglacial cycles, the lowest terrace being assigned to the last climatic cycle, and tufas appear to be the specific and only records of full interglacial conditions (Antoine & Limondin-Lozouet, 2004; Antoine *et al.*, 2007, 2010). The geomorphological position of Resson tufa thus strongly indicates a Pleistocene attribution, most probably to the last interglacial (Eemian).

It is noteworthy that malacological assemblages provided by the test samples at Resson show a high richness especially in the number of both land snails ($n = 30$) and forest species ($n = 10$; tab. 3). This strong biodiversity already reaches more than a half of that observed during full interglacial periods in detailed malacological records from 32 tufas in north-western Europe (Limondin-Lozouet & Preece, 2014) while only six rather small, discontinuous, samples were analysed (tab. 4). The presence of *Belgrandia marginata* in these test samples supports an attribution to a Middle to Late Pleistocene Interglacial.

The various palaeoenvironmental information available at Resson, combining new malacological data, recent reinvestigation on the plant macrofossil collection and data published by ancient authors, have various time resolution, time distribution and reliability. Recent malacological data, even if they are test results from a non-continuous sampling, provide the first reconstruction of the palaeoenvironmental dynamic at Resson, while plant imprints and vertebrate fauna give more localized information with some uncertainty concerning their precise stratigraphic position (fig. 2, tab. 5).

From bottom to top, mollusc assemblages document the development of an interglacial period from its beginning, shown by pioneer taxa. Well-established interglacial conditions are then demonstrated by the extreme richness of malacological fauna both in number of shells and

Stratigraphical units (according to Michel, 1967)	Lithology	Malacology	Palaeobotany	Vertebrates	Interpretation
15	Tufa (Upper part)	R1 forest decline			Interglacial
14		R2 well-developed forest environment			
13					
12	Tufa (Lower part)	R3 and R4 thermophilous <i>B. marginata</i>	Deciduous temperate forest with thermophilous taxa (<i>Buxus</i> , <i>Taxus</i> , <i>Juglans</i>)	Temperate adapted fauna (cervids, beaver, Mallard duck)	
11					
10					
9					
8					
7	Colluvial and fluvial deposits	R5 and R6 pioneer taxa typical of early IG		<i>Cold adapted fauna (Mammoth and wooly rhino ?)</i>	
6					
5					
4					Glacial
3					
2					
1	Chalk				Tertiary

Tab. 5: Compilation of Resson palaeoenvironmental data from plant, malacological, and vertebrate records correlated with stratigraphic units.
 Tab. 5 : Compilation des données paléoenvironnementales de Resson en fonction de leur position stratigraphique: empreintes foliaires, mollusques et vertébrés.

diversity, by the presence of thermophiles taxa and by the record of a well-developed forest environment (tab. 5). This is consistent with the contemporaneous temperate deciduous forest revealed by leaf prints of *Fagus*, *Corylus*, *Tilia* and *Taxus*. The presence of thermophiles plant taxa as *Taxus bacata*, *Buxus sempervirens*, and possibly *Juglans regia*, demonstrates warm conditions (tab. 5). Most faunal remains may be contemporaneous of these early to full interglacial conditions which is coherent with the presence of cervids (especially *Cervus elaphus*), beaver (*Castor fiber*) and Mallard duck (*Anas boschas*). The attribution of other large vertebrate remains is more suspicious. If *Mammuthus primigenius* (mammoth) and *Coelodonta antiquitatis* (wooly rhinoceros) have been found at Resson we can suppose that they come from colluvial and fluvial deposits as the presence of such steppe environment taxa is not consistent with tufa deposition conditions as well as with other palaeoenvironmental data. However, misidentification cannot be excluded either. Finally, at the top of the tufa sequence, open-land molluscs are recorded while the assemblage is still rich, which may characterize the forest decline at the end of an interglacial period.

In northern France, long sedimentary sequences of Middle and Late Pleistocene temperate periods remain scarce. The longest are La Celle (Seine valley) and Caours (Somme Basin; fig. 1), which are both thick tufa deposits (Antoine *et al.*, 2006; Limondin-Lozouet *et al.*, 2006, 2010). They provide macroplant imprints, mammal remains, and especially ones of the richest and most detailed malacological interglacial assemblages in north-western Europe: mollusc data from both sites

record the almost complete development of MIS 11 and MIS 5e interglacials respectively, from the onset of temperate environment to the full development of forest environments and finally, the premises of a cooler and opening conditions (Limondin-Lozouet *et al.*, 2006; Dabkowski *et al.*, 2011, 2016; Dabkowski, 2012), while most other tufa deposits from the area register only snapshots of the interglacial optimum (Limondin-Lozouet & Antoine, 2006; Antoine *et al.*, 2007, 2015; Limondin-Lozouet & Preece, 2014).

The La Celle tufa also provides the largest collection of plant imprints (166 specimens) from northern France, including leaves and fruits (Jolly-Saad *et al.*, 2007). A total of 24 taxa (dicotyledons only) were described at La Celle with only six not present at Resson, specifically the thermophiles *Celtis australis* and *Ficus carica*, while *Buxus sempervirens* is preserved at both sites. Few mammal remains were discovered at La Celle; they mainly comprise *Cervus* sp. and *Equus* sp. and, more noticeably, a tooth of *Macaca sylvanus* and a metatarsus of *Hippopotamus incognitus*. Compared to Resson, only ca. 20 km east, La Celle MIS 11 tufa thus provides evidence of warmer conditions with several thermophiles floral and faunal taxa that are absent at Resson.

Caours tufa has provided a few imprints of riverine and rocky soil plants especially *Fraxinus* cf. *excelsior*, *Salix* and *Asplenium scoparium* (Antoine *et al.*, 2006), which are all present at Resson (tab. 1). Conversely, a very large collection of vertebrates, especially large mammals has been found at Caours as the site comprise several archaeological levels, which have been excavated since 2005 (Antoine *et al.*, 2006; Loch *et al.*, 2009, 2017).

Thousands of remains have been collected so far, widely dominated by cervids (*Cervus elaphus* and *Dama dama*) and aurochs (*Bos primigenius*). The rhinoceros *Dicerorhinus hemitoechus* is also well represented, while *Equus* sp., *Capreolus capreolus*, *Castor fiber*, *Sus scrofa*, *Ursus arctos*, and *Aonyx antiqua* are sparser.

Resson palaeontological data thus show more similarities with the Eemian site of Caours than with the La Celle MIS 11 deposit. These preliminary observations are consistent with an attribution of Resson tufa to the Last Interglacial.

6 - CONCLUSION

The geomorphological position of Resson tufa and the strong similarities between its palaeontological assemblages and others from the same periods demonstrate its attribution to a Pleistocene Interglacial and most probably to the Eemian (MIS 5e). Malacological preliminary results, combined with the reassessed plant macrofossil collection and former palaeontological descriptions already provide rich palaeoenvironmental information, which demonstrate that Resson tufa covers a long portion of the development of an interglacial period, from the onset to full interglacial conditions followed by the decline of a temperate forest. This overview strongly demonstrates the high potential of the Resson deposit for palaeoenvironmental and palaeoclimatic research.

New field investigations are now required to allow a promising and complete malacological study and in parallel, geochemical analyses on tufa calcite that may provide independent reconstruction of palaeoclimatic variations. Additionally, suspicions remain about the presence of archaeological levels at Resson; while investigations are still ongoing to retrieve the old collection missing at the *Muséum de Troyes*, special attention will be paid in finding *in situ* artefacts during new field investigations. Altogether, the Resson tufa could become one of the major records of Pleistocene Interglacials in the Paris Basin together with Caours and La Celle.

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