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## **Fuliginochronology: a new way of studying fire events chronicles in archaeological sites. Example of the Grotte Mandrin during glacial period**

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# Fuliginochronology: a new way of studying fire events chronicles in archaeological sites.

## Example of the Grotte Mandrin during glacial period

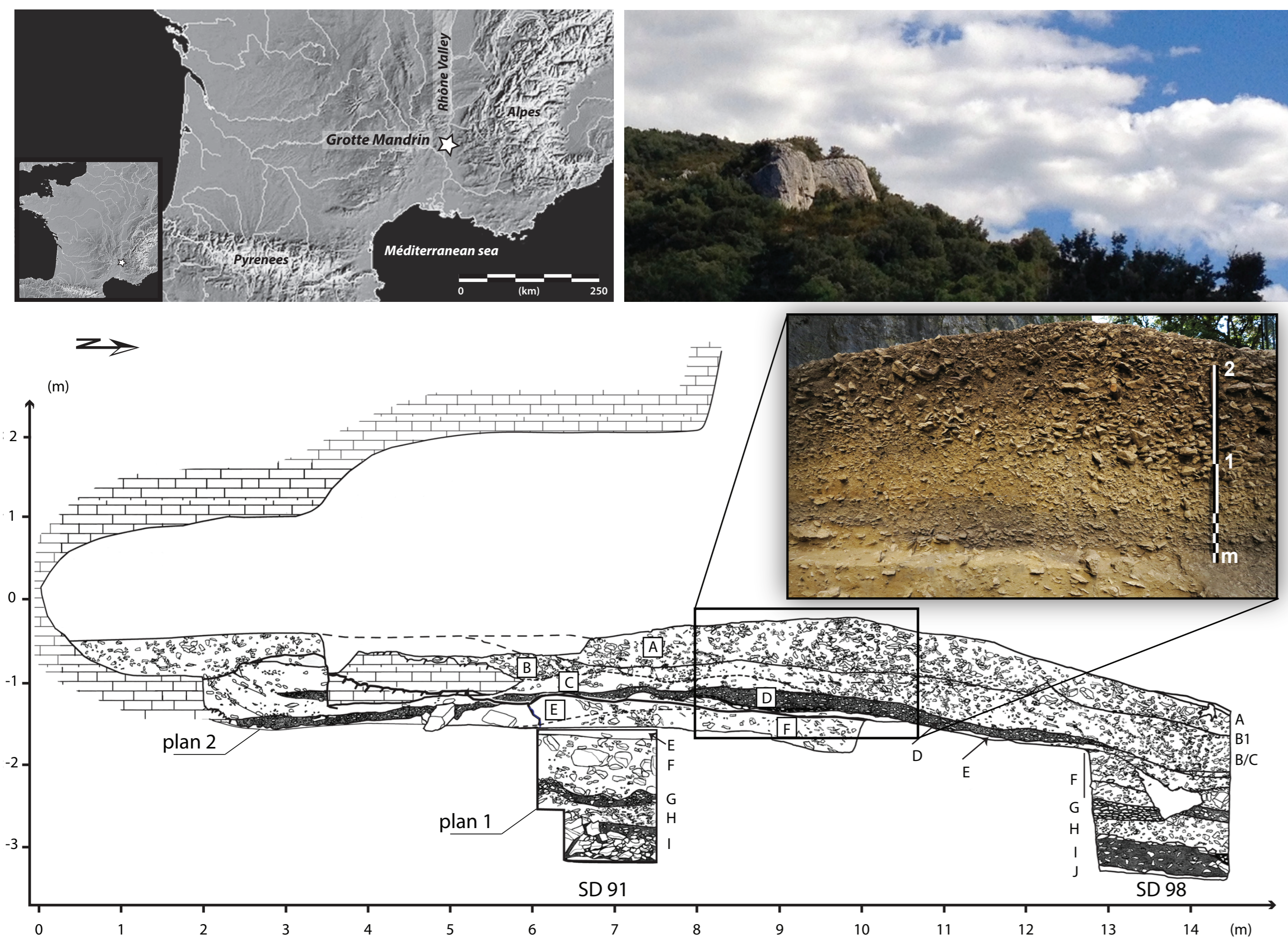


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### CONTEXT

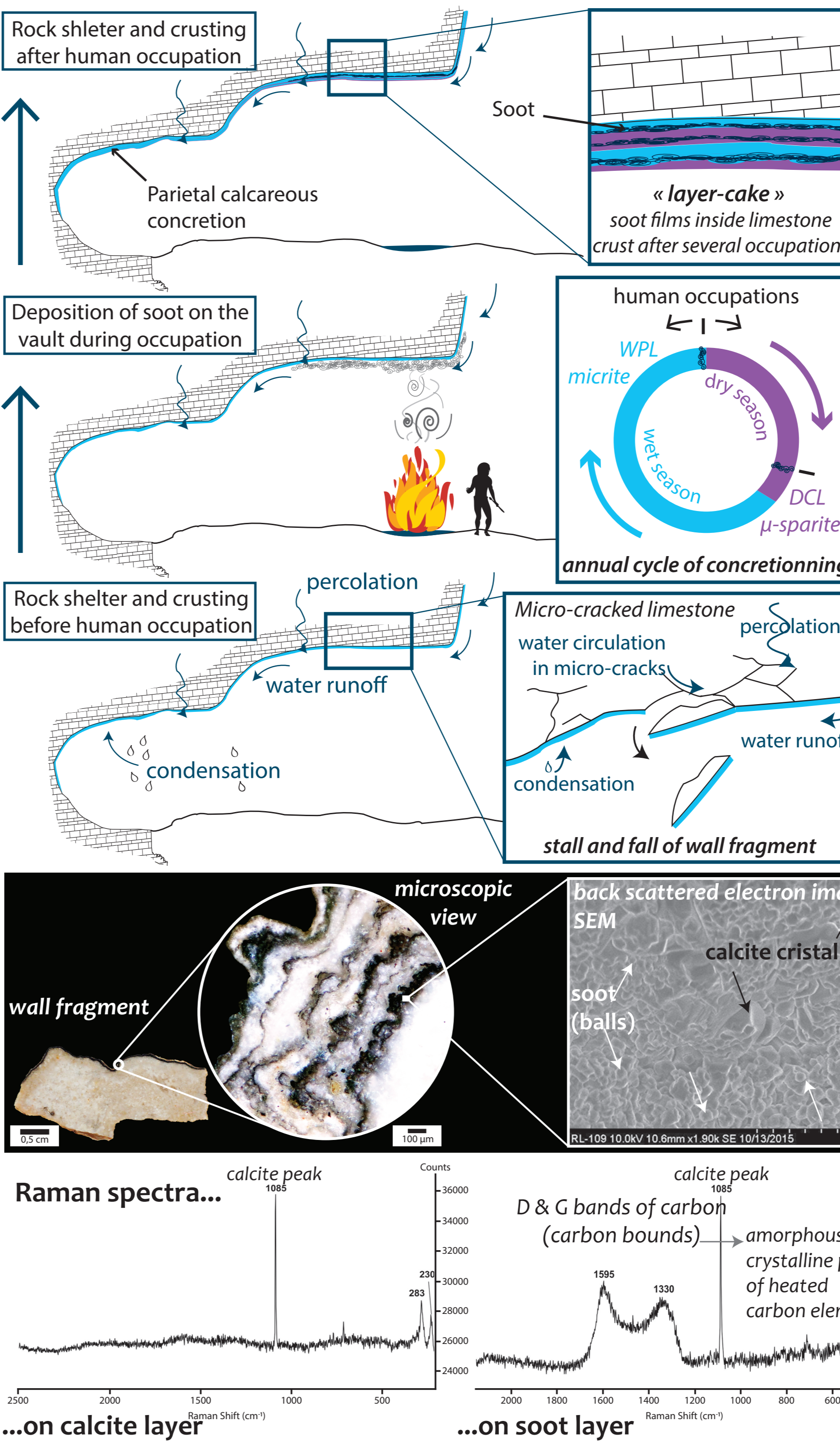


The **Grotte Mandrin** (France) is a rock shelter located in the middle Rhône Valley, on the left bank of the River. Explored since 1990, its filling is divided into 10 stratigraphic units splittable into 13 archaeological levels. The lower part of the sequence (layers J to C) is attributed to classic Mousterian occupations, while the upper part of the stratigraphy documents late Middle Palaeolithic occupations (levels F to B2) and early Upper Palaeolithic occupations (level B1). At the very top lays a Neolithic level (layer A), recording multiple human cremation events.

Soot traces, testifying of control of fire by our ancestors, are witnesses of past human activities. They can sometimes be noticed on the walls and/or vaults of caves and rock shelters and also within calcareous concretions (ex: stalagmites). They prove to be a particularly suitable material for very high temporal resolution archaeology.

At Grotte Mandrin site, wall fragments discovered in the archaeological levels of the shelter are covered with thin (infra-centimetric) black-bluish deposits. These traces result from combustions in the rock shelter during prehistoric times. This soot deposited on the vault is covered and preserved by thin calcareous crusts. Microscopic observation of these concretions shows a kind of "layer cake" in which carbonates blackened by soot and "clean" carbonates are intermingled.

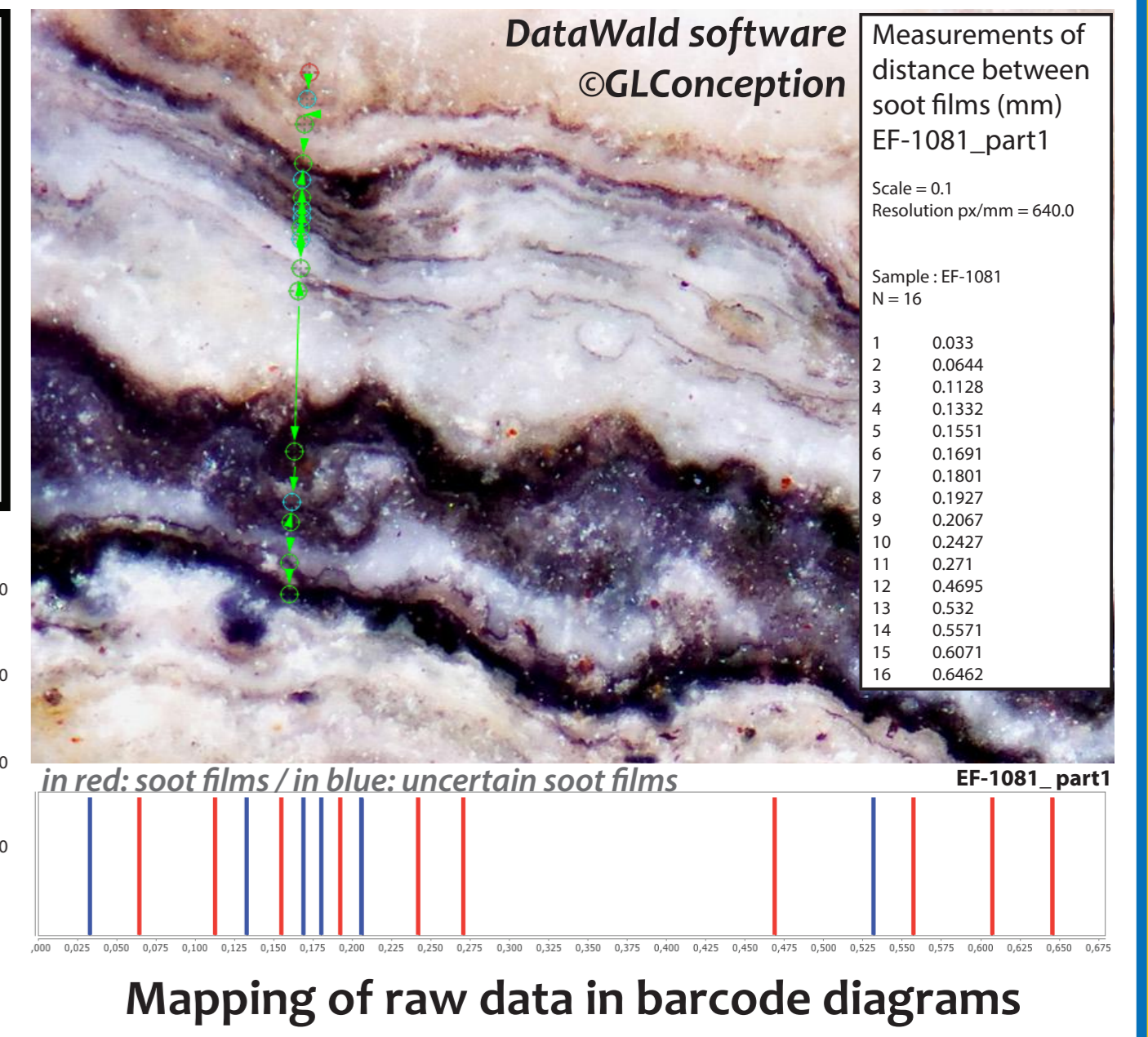
### MATERIAL & METHOD



For analysis, the blackened wall fragments are either polished or thin sections are prepared. They are then observed under microscope in order to reveal the succession of multiple very thin soot films appearing as a single deposit to the naked eye. Position of each film is then recorded from photographs by using DataWald software, usually employed in dendrochronology (study of tree rings). Collection of these data allows the representation of the succession of soot films in the form of "barcodes". To each sample corresponds its own barcode.

Multiple samples with their unique barcodes are then matched in order to build the entire soot films sequence for each archaeological unit. This graphical representation traces the human occupations' chronicle in the shelter (each soot deposit on the photograph = 1 line on the barcode = 1 occupation at least: two too close occupations will only leave a single black deposit). Occupations can then be counted and their succession rhythm can be studied.

This pioneer method is called **Fuliginochronology**, from Latin fuliginosus, fuligo: soot, fuliginous. In the particular case of an archaeological site like a rock shelter or a cave, these fuliginous calcite deposits are a record of past human occupations, which can be enumerated (Vandavelde et al. 2017; 2018; Vandavelde et Dupuis 2017): **Minimum Number of Occupations (MNO)** per layer can be defined.



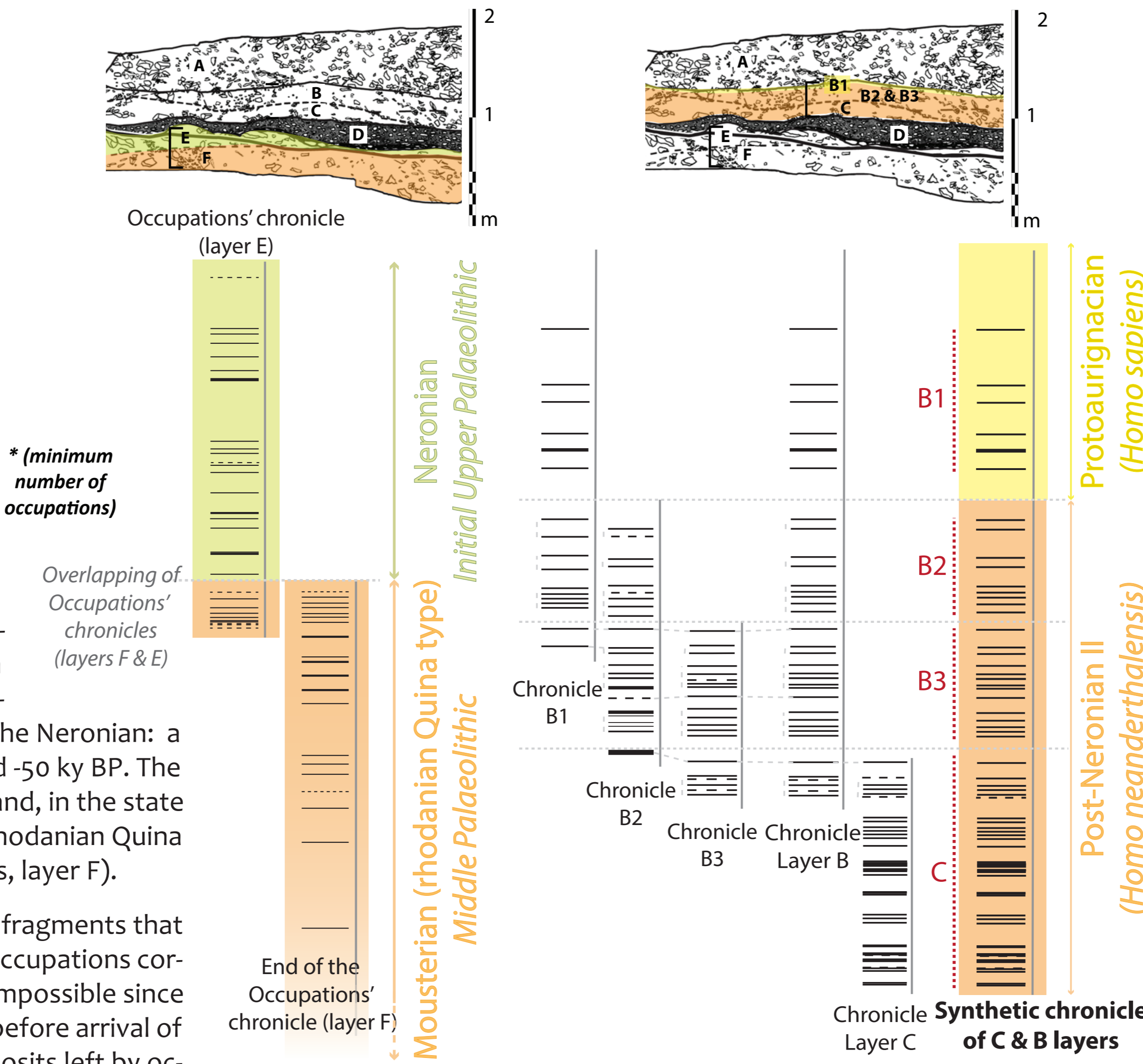
### RESULTS

Layer	Level	Chrono-cultural phase	MNO *
A		Neolithic	29
B1		Protoaurignacian	6
B2			9
B3			14
C1		Post-Neronian II	38
C2			
D		Post-Neronian I	30
E		Neronian	18
F		Mousterian (rhodanian Quina type)	21
G		Mousterian (Ferrassie)	12
H		Mousterian	8
I		Mousterian	70
J		Mousterian	18
TOTAL	A to J		273

At the Grotte Mandrin, occupations chronicles from archaeological levels F (underlying) and E (overlying) were traced from the wall fragments covered with fuliginous speleothems collected in the filling. Occupations of layer E are attributed to the Neronian: a Middle to Upper Palaeolithic transitional group dated around -50 ky BP. The lithic industries of the Neronian show a very high technicity and, in the state of knowledge, seem to share no technical feature with the rhodanian Quina type Mousterian that precedes it (attributed to Neanderthals, layer F).

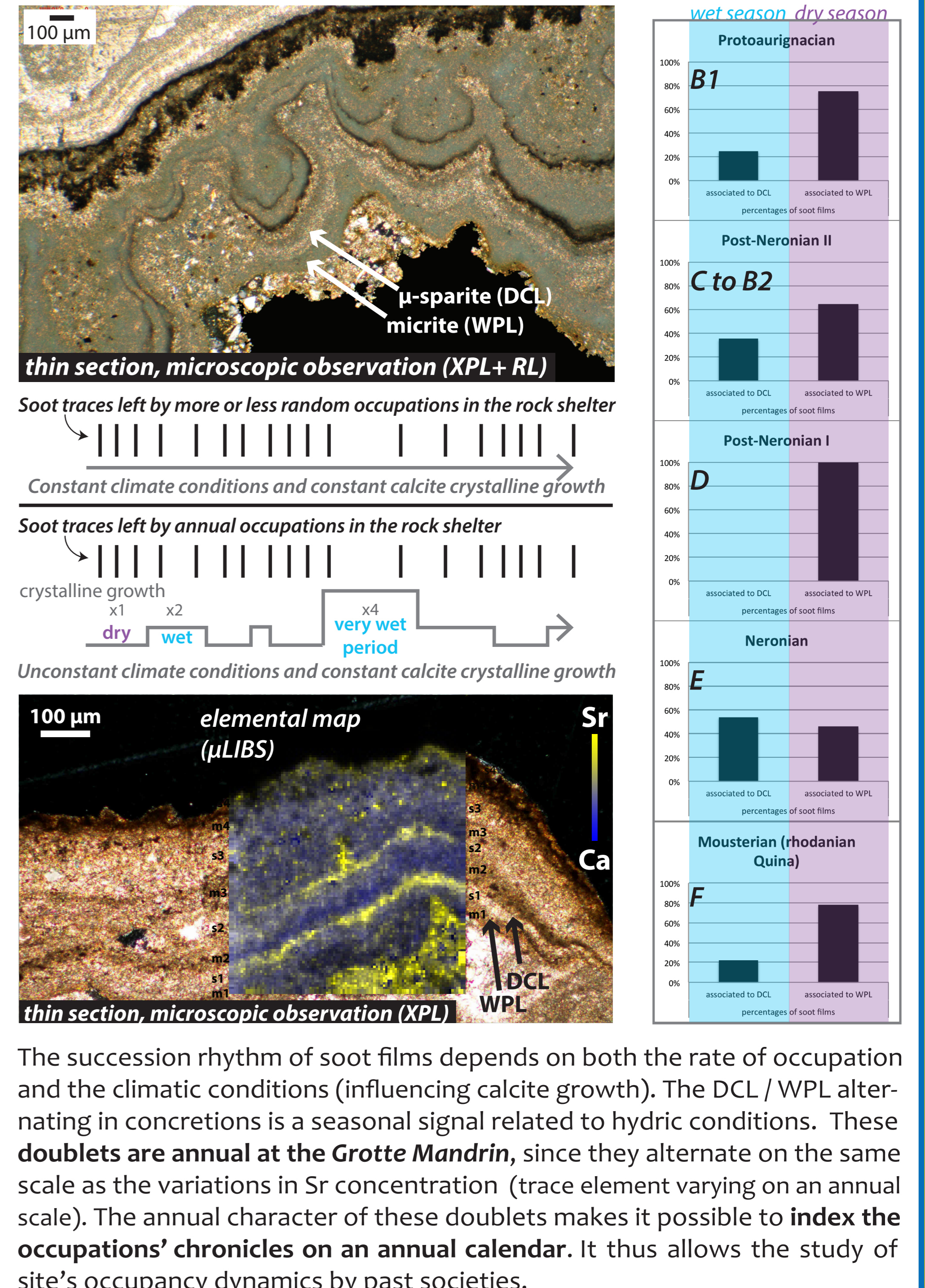
Due to the progressive crumble of the walls and vault, some fragments that have fallen in the E archaeological layer may have recorded occupations corresponding to human installations in layer F. The reverse is impossible since wall fragments found in F have already fallen to the ground before arrival of the next group. They can no longer record the new soot deposits left by occupations of layer E. This explains the **partial overlap between the occupations' chronicles** of layers F and E presented here.

The same situation is observed for layers C&B: occupations' chronicles overlap. Layer B is a sedimentary unit that records three archaeological levels: B1, located at the top of the sedimentary layer, is attributed to Protoaurignacian (generally associated with *H. sapiens*) and is dated around 42 ky cal. BP. B2 lies directly under level B1 and is separated from B3 by a thin sterile



layer. These two assemblages (+layer C) are assigned to the Post-Neronian II (late group of Mousterian tradition). One again, synthetic sequences overlap.

It is here noteworthy that **Neronian and Protoaurignacian groups succeed very quickly to local Mousterian groups** that preceded them. This short time can be evaluated to few years or seasons and must be in any case inferior to a human life generation, meaning that **these different cultures are contemporary, at a human scale, on a same territory.**



The succession rhythm of soot films depends on both the rate of occupation and the climatic conditions (influencing calcite growth). The DCL / WPL alternating in concretions is a seasonal signal related to hydric conditions. These **doublets are annual at the Grotte Mandrin**, since they alternate on the same scale as the variations in Sr concentration (trace element varying on an annual scale). The annual character of these doublets makes it possible to **index the occupations' chronicles on an annual calendar**. It thus allows the study of site's occupancy dynamics by past societies.

### CONCLUSION

**Fuliginochronology** allows definition of **Minimum Number of Occupations (MNO)** per archaeological layer. It also gives an idea of **time**:

- 1/ The resolution and precision of the method has made possible the demonstration of **rapid succession** (few seasons or years) of **two different cultural groups** in the Grotte Mandrin territory: around 50 ky BP (between Neanderthal's Quina Mousterian and the Neronian) and around 42 ky cal. BP (between the last regional Neanderthals of Post-Neronian II and the Protoaurignacian, Early Upper Palaeolithic group). We can therefore **rethink the Middle to Upper Palaeolithic transition** thanks to the **unmatched temporal resolution** obtained here.
- 2/ **Rhythms of human occupations in a site can also be recorded, at annual scale.** In this case, different dynamics of occupation are seen when looking at the position of soot films in DCL/WPL doublets: occupancy dynamics are differing between the different archaeological levels (and cultural groups).

Moreover, **during glacial period, fire use by Neanderthal is common on this site.** It is not scarcer during colder periods (layer F or C) or more common during more temperate times (layer D). These elements confirm that Neanderthals were able to make fire (unlike Dibble et al. (2018)'s statement).

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