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Chapter 9 1

The Bronze Age Decorated Cave of Les 2

Fraux: Ritual Uses of an Atypical French 3

Heritage Site 4

Albane Burens, Laurent Carozza, Raphaëlle Bourrillon, Stéphane Petrogani, Pierre Grussenmeyer, Samuel Guillemin, François Lévêque, Vivien Mathé, Yves Billaud, Aurélie Brodard, Pierre Guibert, Stéphane Jaillet, Olivier Jest, and Mathieu Koehl 5

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9.1 Introduction 9

This chapter details the study of an exceptional and atypical Bronze Age French site of Les Fraux (Dordogne, France), which combines cave art and testimonies of domestic and symbolic activities (Fig. 9.1). The interdisciplinary research conducted on the site since 2007 attempts to untangle the ‘interwoven uses’ of this cave for later prehistoric communities, during short but regular visitation. 10

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A. Burens (✉) · L. Carozza

Environmental Geography Laboratory, CNRS, UMR 5602 GEODE, Toulouse, France
e-mail: albane.burens@univ-tlse2.fr; laurent.carozza@univ-tlse2.fr

R. Bourrillon

TRACES-UMR 5608, CREAP, Toulouse, France

S. Petrogani

UMR 7041 ArScAn, Ethnologie Préhistorique, MAE René Ginouvès, Nanterre, France

P. Grussenmeyer · S. Guillemin · O. Jest · M. Koehl

ICube Laboratory, CNRS, UMR 7357, Photogrammetry and Geomatics Group, INSA
Strasbourg, Strasbourg, France

e-mail: pierre.grussenmeyer@insa-strasbourg.fr; samuel.guillemin@insa-strasbourg.fr;
olivier.jest@insa-strasbourg.fr; mathieu.koehl@insa-strasbourg.fr

F. Lévêque · V. Mathé

UMR 7266 LIENSs, CNRS, Université de La Rochelle, La Rochelle, France

e-mail: fleveque@univ-lr.fr; vmathe@univ-lr.fr

Y. Billaud · S. Jaillet

UMR 5204 EDYTEM, CNRS, Le Bourget du Lac, France

e-mail: yves.billaud@culture.gouv.fr; stephane.jaillet@univ-savoie.fr

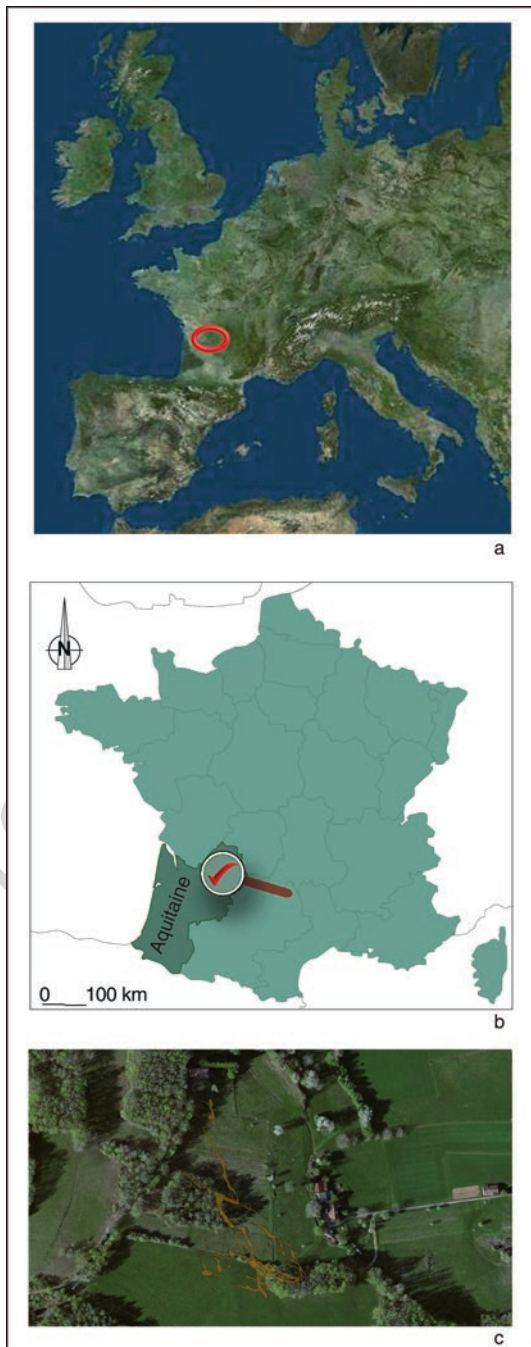
A. Brodard · P. Guibert

UMR 5060 IRAMAT CRPAA, CNRS, Pessac, France

e-mail: guibert@u-bordeaux3.fr

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Fig. 9.1 The Bronze Age cave of Les Fraux (Saint-Martin-de-Fressengeas, Dordogne, France): **(a, b)** Location of Saint-Martin-de-Fressengeas, Aquitaine (© Google Maps; A. Burens), **(c)** Location of the underground network on aerial photograph (orange) (© Google Map; M. Koehl)



The opportunity to study a cave which temporarily hosted small Bronze Age communities over nearly three centuries allows us to gain a detailed understanding of the nature of activity in relation to the long duration of Palaeolithic occupation that characterises most of the major French painted caves. Indeed, there is no evidence of human activity inside the cave of Les Fraux before the Middle Bronze Age, and none after the Late Bronze Age, when a roof collapse sealed the cave and preserved intact the archaeological remains until 1989: the date of the site's rediscovery. Thus, Bronze Age activity in the cave corresponds to a single period around 1450–950 BC (the maximum duration of human activity inside the cave).

The extraordinary conditions of preservation of the site (due to the collapse of its entrance), and the plurality of human activity of different kinds over a short period of time, force us to take advantage of new technologies, in order to elucidate information unattainable in most French prehistoric painted caves.

By combining chronology, interactions between people and their environment and emerging technologies, our broader objective was to gain a better understanding of the complexity of perceptions of the cave of Les Fraux by local or exogenous prehistoric communities.

One aim was the interpretation of archaeological data within a framework which combined space and time (in which all stages of the research are integrated), from data acquisition, implementation of site monitoring (temperature, CO₂ levels, etc.), experimentation and simulation to reconstruction. We employed an integrative and interdisciplinary research approach, based on new technologies able to acquire full 3D documentation of the entire site (even in inaccessible and non-visible parts) and to process interdisciplinary data according to accurate 3D models of the cave that constituted the common framework for the various studies and partners involved. The 3D geographic information system of the cave aggregates all types of data produced since 2008, within the same system, including overall 3D recording of structural elements, maps, pictures, analyses, databases, drawings and reports. It allows, for example, for spatial analyses between scientific data and archaeological and geomorphological contexts. By using non-invasive techniques such as laser scanning and photogrammetry, we aimed to preserve the archaeological remains and the integrity of the site, in which all of the material survives in situ, over 9 years of study.

9.2 The Contribution of the Cave of Les Fraux to Existing Palaeolithic Sites

The cave of Les Fraux is located in south-west France, in the Périgord-Limousin Regional Natural Park, within the township of Saint-Martin-de-Fressengeas (Fig. 9.1). It consists of a wide underground network (Fig. 9.2), difficult to access, and comprising narrow, damp and sinuous galleries of more than 1 km, formed in a Middle Jurassic geology. Its development is nearly horizontal, following two

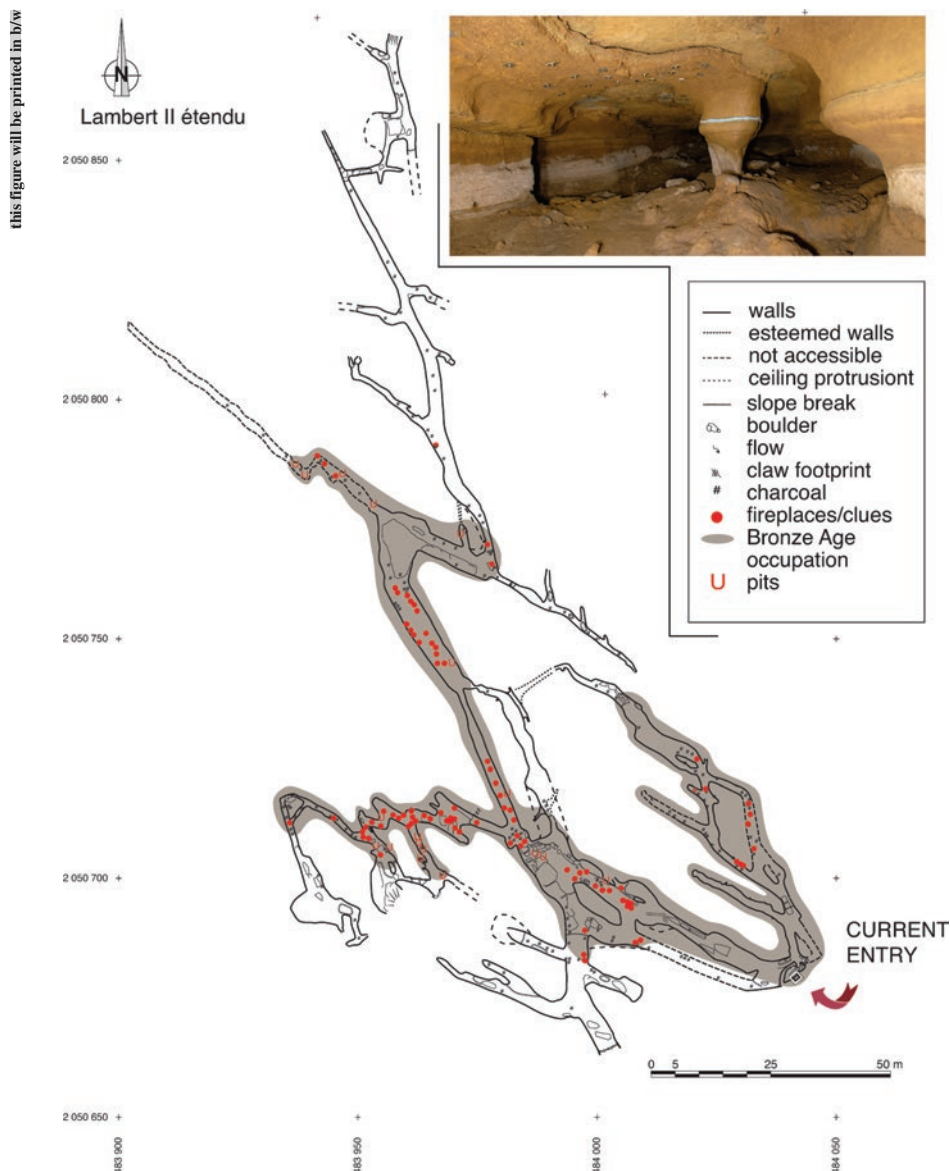


Fig. 9.2 Map of the underground network (Y. Billaud and A. Burens) and view of gallery no. 13. (Photograph: A. Burens)

55 preferential directions (Burens et al. 2014). The cave comprises two independent
 56 parts, simultaneously occupied during the Bronze Age. It is poorly ventilated and
 57 does not benefit from natural light: Les Fraux is an entirely dark-zone cave (Faulkner
 58 1988). It might have been chosen for its discrete entrance, which is hardly visible on

the surface of the landscape. Geomorphological studies indicate that several entrances could have been used since the network's formation, though our reconstruction suggests that the Bronze Age point of entry could have existed near the current one.

The cave is characterised by a succession of phases in which it was alternately accessible and inaccessible. The presence of cave bears demonstrates that the cave was open for a time during the Pleistocene, before its first (undated) obstruction, probably at some point before the Holocene. After a long period of inaccessibility, the cave became accessible once again in the Middle to Late Bronze Age; radiocarbon dating and archaeological investigations suggest that the cave was used from 1450 to 950 BC. At the end of the Bronze Age, the collapse of the cave entrance sealed the cave and preserved intact the archaeological remains until 1989. In short, there is no evidence of human activity in the cave before the Middle Bronze Age, and none after the Late Bronze Age. As a result, the site displays very little evidence of multi-layered deposits (except in one gallery characterised by two different palaeosols); neither does it show evidence for human activity beyond the Middle to Late Bronze Age.

This peculiarity establishes a considerable advantage in our ability to study the relatively short-term perception of the site by ancient communities, in comparison, for example, to Upper Palaeolithic sites, which were generally occupied for longer. For instance, the study of 259 radiocarbon dates from the exceptional Chauvet-Pont d'Arc Cave in Ardèche, France (mainly related to the rock art and human activity), recently highlighted two periods of human activity: one from 37 to 33,500 years ago and the other from 31 to 28,000 years ago (Quiles et al. 2016). This outstanding and unparalleled work has had allowed for a global overview of the site's occupation history and argues in favour of creation of the parietal art before 28,000 years ago. But the temporal sequence of human occupation remains too large to allow for a detailed understanding of the tempo of activity at the cave, in contrast to Les Fraux where the short-term activity helps us to remove any ambiguity in the nature of the various visitations.

The site was discovered in 1989; it was immediately nicknamed the 'Lascaux of the Bronze Age' by French media, owing to its extraordinary archaeological and heritage significance, and was registered with the French Historical Monuments in 1995. According to the French Office of Geological and Mining Research (BRGM), the cave's geology is highly unstable, and it may unfortunately collapse in the coming years. The cave has, therefore, been sealed off to the public, and access is now severely restricted.

The cave of Les Fraux is thought to contain rare examples of Bronze Age cave art in Europe and forms the only protohistorical cave site with evidence for domestic, symbolic and/or votive activities and cave art. When comparing the site with other French Bronze Age caves, there are several similarities. Mostly, however, there are distinct differences, such as the absence of cave art and/or the presence of funerary activity in association with deposits (as is the case, for instance, in Charente, where multiple graves have been found in Bronze Age caves; Gomez 1980). The Bronze Age activity at Les Fraux, which occupies nearly 70% of the cave (Fig. 9.2),

104 left the remains of very well-preserved archaeological deposits, domestic features
105 (such as stairs dug into the clay), torches and postholes, together with no less than
106 66 hearths and a further 24 traces of hearths. The same galleries included 32 depos-
107 its of ceramics and metalwork. The cave contains also many perfectly preserved
108 carvings on the walls and ceiling. Most of the wall art comprises finger-strokes or is
109 otherwise engraved in the clay and comprises linear, schematic and geometric
110 designs (Carozza et al. 2009). All available evidence (typology, radiocarbon dating,
111 etc.) suggests that the cave art and some material deposits should be assigned to the
112 Middle Bronze Age, whilst other deposits date to the Late Bronze Age.

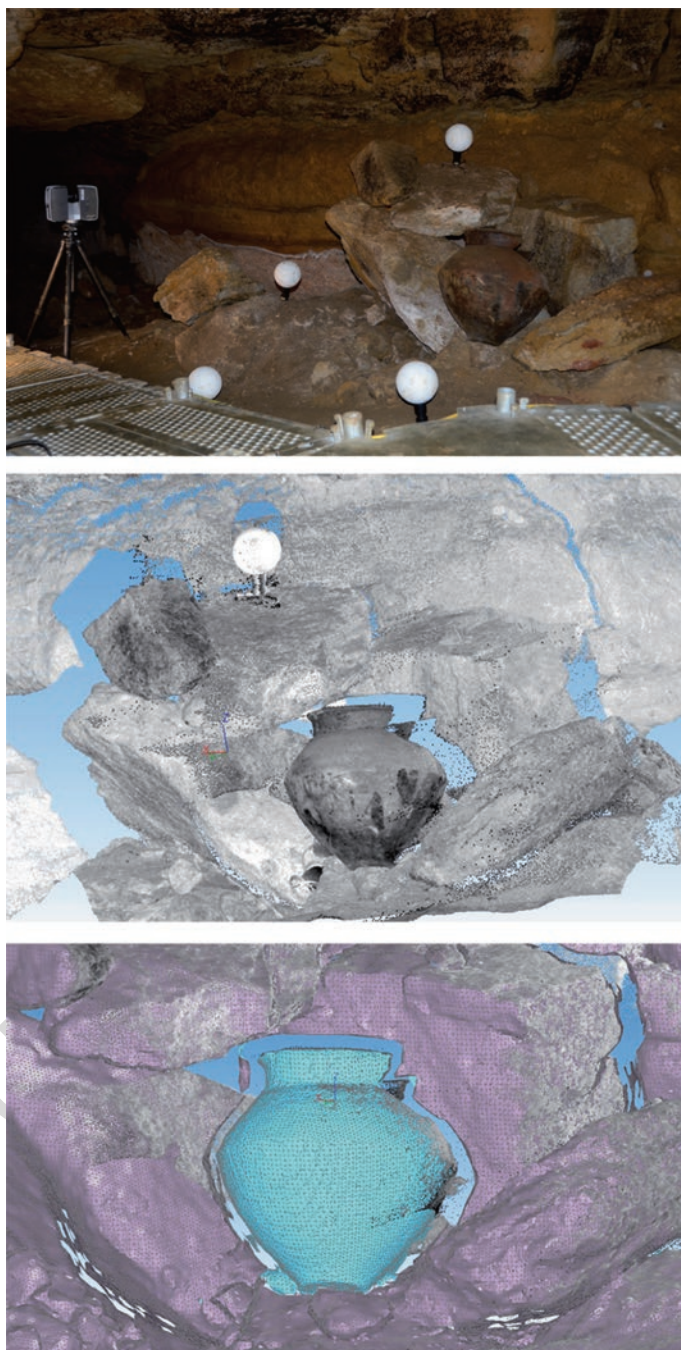
113 The cave of Les Fraux represents an extraordinary opportunity for study, in all its
114 complexity, of prehistoric cave use (practical versus symbolic) and the significance
115 of this place for prehistoric communities. The short duration of human activity wit-
116 nessed has also allowed us to create fine-grained chronologies of the various activi-
117 ties taking place.

118 **9.3 Benefits of New Technologies in Understanding** 119 **the Complexity of Sites and Their Interwoven Uses**

120 It was decided that, in pursuit of understanding the complex uses of decorated cave
121 sites, archaeological deposits at the site of Les Fraux would not be destroyed by exca-
122 vation; their integrity would be maintained for potential future studies. In the course
123 of the study, almost no archaeological material were handled or removed from the
124 site; it was, instead, studied, registered, measured and drawn in situ, without physical
125 contact, or was studied virtually through the use of 3D models (Fig. 9.3). This meth-
126 odology had a significant impact on how the site was studied and on the conditions
127 under which data were obtained. Working with non-invasive techniques, such as
128 contact-free measurement of ceramic deposits and wall art, was challenging.

129 The analyses were performed using equipment designed to record the maximum
130 amount of information possible, even in inaccessible or non-visible parts of the cave
131 (narrow galleries, cracks, areas underneath roof collapse, etc.). This 3D protocol
132 corresponded to an attempt from the team to georeference each archaeological and
133 geological dataset from the site and to enforce large-scale spatial analysis, allowing
134 for the full integration of interdisciplinary and multi-scalar data. Furthermore, we
135 aimed to produce 3D models in order to test our archaeological hypotheses and
136 generate accurate visualisation documentation.

137 We integrated different techniques of data recording based on terrestrial laser
138 scanning, digital photogrammetry and spatial imaging systems (Fig. 9.4), in order
139 to generate geometric and photorealistic 3D models of all structural elements of the
140 cave and of the main archaeological artefacts, from a combination of point clouds
141 and photogrammetric images. Furthermore, our approach integrated different data-
142 sets generated at different scales using the various types of 3D recording, including
143 the overall volume of the cave (Fig. 9.5a, b), wall art representations (Fig. 9.5d) and



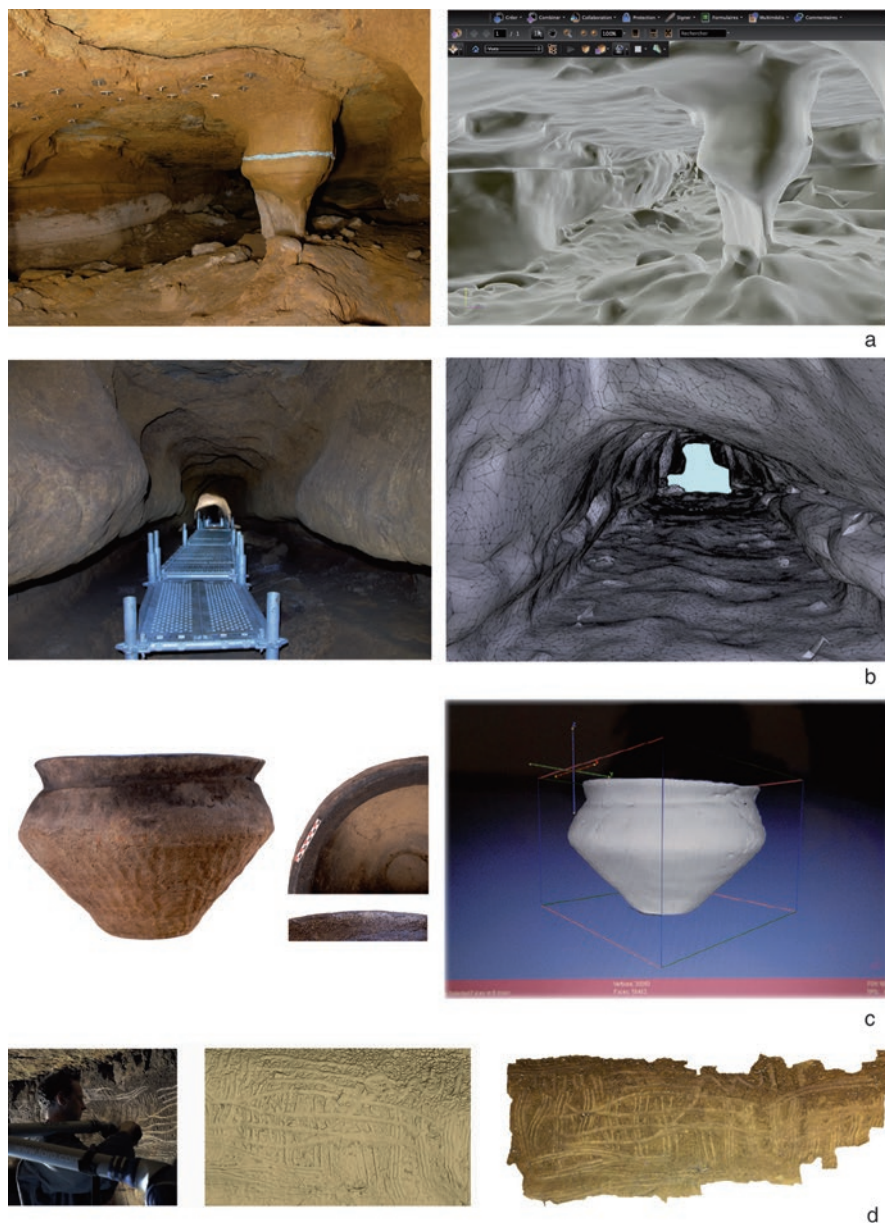
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Fig. 9.3 3D recording of a Bronze Age ceramic deposit inside gallery no. 13 (using *FARO Focus 3D*): top view of the deposit and of the 3D recording system, middle and bottom visualisation of the deposit as a point cloud (A. Burens, S. Guillemain and P. Grussenmeyer)

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Fig. 9.4 Recording of the total network of galleries by surveying techniques and terrestrial laser scanning (TLS). The cave is linked to the above terrain thanks to surveying techniques (total station underground and GPS measurements in the field): (a) GPS measurements, (b) Surveying techniques by total station, (c, d) TLS, (e) TLS combined with photogrammetry, (f) Photogrammetry. (Photographs: A. Burens)



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Fig. 9.5 3D recording of archaeological and geological information from the site based on terrestrial laser scanning, digital photogrammetry and spatial imaging system: (a) Image of gallery no. 13 of the cave (left) and its 3D model in PDF 3D format for visualisation in Adobe Reader (right), (b) Image of gallery no. 18 (left) and its 3D model in PDF 3D format (right), (c) 3D recording of a Bronze Age vessel from the cave, coated with the charred remains of animal fat, (d) 3D recording of the main decorated panel from gallery no. 13 (S. Guillemain, P. Grussenmeyer and A. Burens)

144 archaeological deposits (Fig. 9.5c), and demonstrating that it was in fact possible to
145 combine, in the same depiction system, several different sources of information.

146 These data not only included drawings (such as sections and elevations) but also
147 photorealistic perspectives from different viewpoints and visual 3D models. We also
148 implemented various other interdisciplinary studies, including different modelling
149 approaches, magnetic field mapping, palaeoenvironmental reconstructions and a
150 simulation of the cave's thermal dynamics. In addition, we tested innovative and
151 experimental approaches which combined photogrammetry and terrestrial laser
152 scanning, including photorealistic rendering of the cave art. The documentation and
153 recording work contributed to accurate indexing and georeferencing of the entire set
154 of surveys, images, structural models and relief drawings acquired in the different
155 parts of the cave.

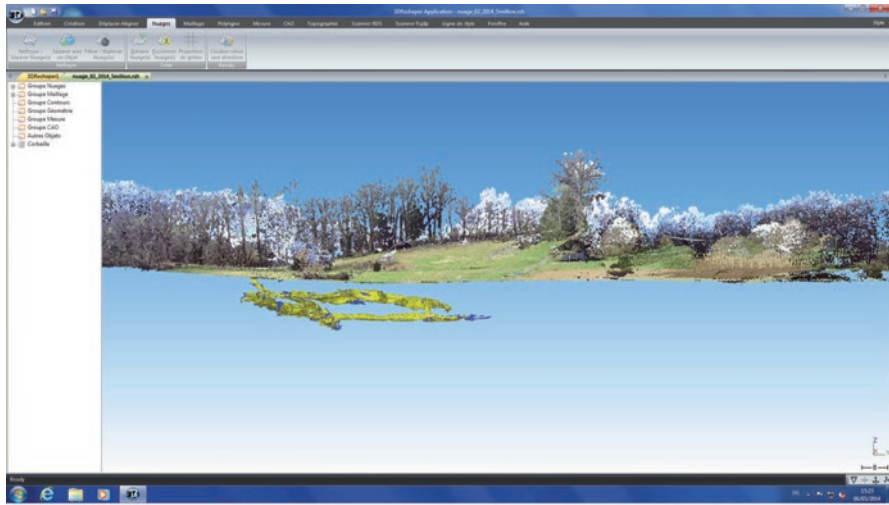
156 The following sections provides a technical overview of some of the basic meth-
157 ods used in the study, in order to reconstruct and model the cave and to help us
158 understand the character of the various human activities which took place within it.

159 **9.3.1 Overall 3D Recording of Structural Elements**

160 Overall recording of the cave by terrestrial laser scanning (TLS) was our first goal,
161 since it allowed for georeferencing of any type of object, image or measurement and
162 accurate indexing of the data between the various researchers involved in the project.
163 The study began with consolidation of the topography and the creation of a polygonal
164 network inside the cave with a total station. This network was connected to the land-
165 scape outside the cave by several geodetic points, measured using differential Global
166 Navigation Satellite System techniques. The first TLS campaigns were undertaken
167 using a *FARO Photon 120 Scanner*, which was well-adapted for the central under-
168 ground passage. Since 2012, data acquisition has been undertaken using a *FARO Focus*
169 *3D Scanner*. The expected accuracy of both scanners is about 2–5 mm at 25 m. The
170 scanner was moved along the galleries, and an overlapping area between two stations
171 was routinely provided. More than 600 m of galleries have been recorded so far
172 (Fig. 9.6), requiring more than 130 stations and 30 days in the cave.

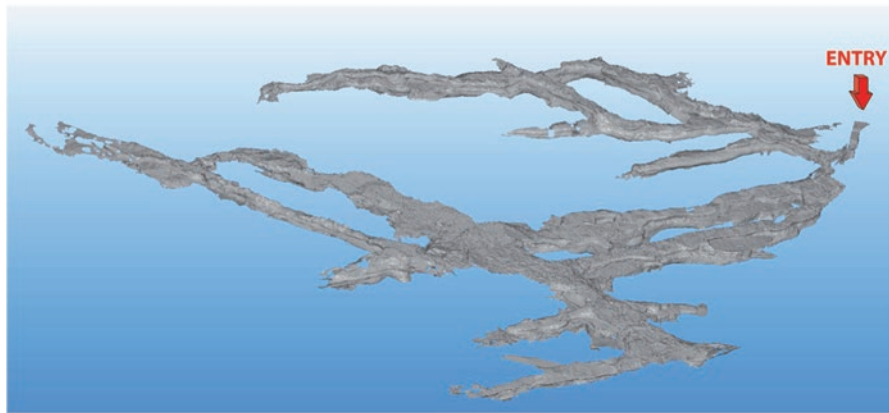
173 Handling data from multiple stations required resampling of the individual point
174 clouds, which were then imported and merged into a single point cloud. The need to
175 facilitate the exchange and dissemination of data within the team led us to export the
176 global 3D model of the cave, resampled at 1 point/cm, in 3D PDF format. This format
177 allowed for the retention of measuring functions and toolkits (distances, sections, etc.),
178 as well as visualisation options (such as wireframe, shaded, solid, vertices).

179 We also recorded ceramic and metalwork deposits within the galleries (Figs. 9.3
180 and 9.5c). When the 3D model was transformed into 3D PDF, it was then possible
181 to draw, measure and define the section and typology of every ceramic artefact,
182 without the need for any contact with the deposit (though this approach was not
183 possible for completely inaccessible deposits, such as pottery almost entirely hid-
184 den within and between rocks).



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a



b

Fig. 9.6 Global 3D models of the underground network of the cave; data recorded in the French Geodetic Reference System (Lambert 2) (P. Grussenmeyer, S. Guillemain and A. Burens)

9.3.2 Photorealistic Rendering

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In archaeological caves, studies of wall art require the processing of high-definition images with greater accuracy than is usually necessary for the total volume of the underground network. A common solution is the correlation of high-resolution digital photographs of specific panels with 3D volumetric models of the cave (Grussenmeyer et al. 2012). The aim of the experimental work developed in Les Fraux since 2008 was to find an interface between the 3D imaging methods and the photographic and manual illustrations of cave art specialists, an interface which

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193 reconciled the subtleties of traditional drawing with the rigorous precision and
 194 swiftness of 3D survey (Fig. 9.7). We managed to negotiate, for the first time in an
 195 archaeological cave, access to the latest generation of a *FARO ScanArm V3* (19,200
 196 points/s and 0.035 mm accuracy). The exceptional quality of the resulting point
 197 cloud is due to the accuracy of the *FARO* fusion arm and ensuring that the laser V3
 198 head remained only a few centimetres from the object during the time-consuming
 199 recording process. This new equipment, providing submillimetre resolution, has
 200 enabled the team to succeed in mapping high-definition images onto a very accurate
 201 3D model, in order to obtain photorealistic rendering of the decorated panels by
 202 combining photogrammetry and TLS. Orthophotos from the 3D models were used
 203 (after digital image enhancement processing) to support vectorisation of the deco-
 204 rated panels and produce an alternative to traditional and time-consuming drawings
 205 by creating an accurate, georeferenced image. This technique provided better
 206 recording of superimposed archaeological depictions, in order to gain a better
 207 understanding of their relative chronology. The recording of cave art using ortho-
 208 photos, based on 3D models, will prove very useful for archaeologists.

209 We were also able to carry out experimental work on identifying the various
 210 techniques and tools used to create the decorated panels, by comparing 3D models
 211 of several in situ panels with their experimental counterparts (Fig. 9.8). The latter
 212 were made in soft clay materials placed in vertical frames. Finger-strokes were
 213 hand-made, whilst engravings were made using a wide range of tools on the surface

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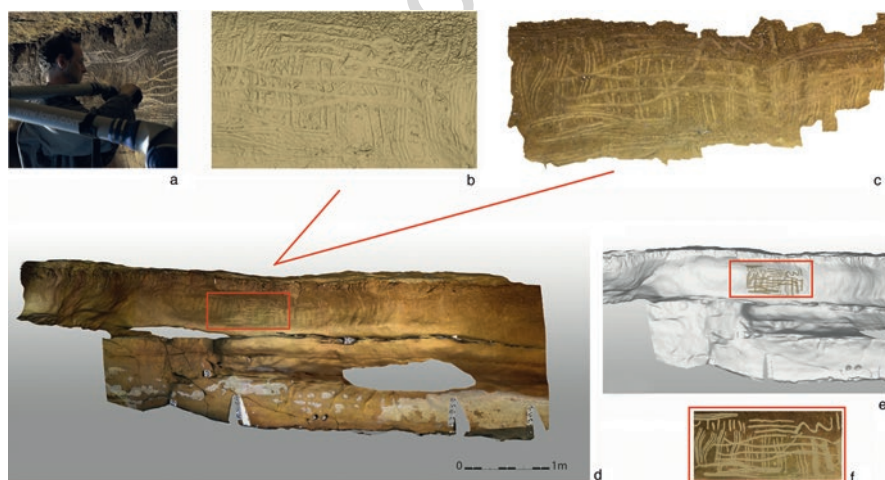


Fig. 9.7 3D recording of Bronze Age finger-strokes in the clay wall of the main panel from gallery no. 13 of the cave: (a) Recording test with the *FARO ScanArm*, (b) View of the high-density point cloud recording using the *FARO ScanArm*, (c) Digital surface of a selected piece of the panel, (d) Textured 3D model, (e) Projection of drawn finger-strokes on the 3D model, (f) Detail of the digital drawing from the orthophoto extracted from the 3D model (S. Guillemain, P. Grussenmeyer and A. Burens)



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Fig. 9.8 3D recording of a decorated panel from gallery no. 10 and its experimental duplicate with the *FARO ScanArm*: (a) View of the decorated panel, (b) 3D recording of the decorated panel by TLS with the *FARO ScanArm*, (c) Preparation of experimental duplicates with different tools, (d) Scanning the experimental duplicate used as reference, (e) View of the section of the finest carvings from the decorated panel (A. Burens, S. Guillemin and P. Grussenmeyer)

of the clay: flint, bone, bronze and copper spikes, dry wood, freshly cut branches, 214
 fingertips, etc. Drawings were created in conditions close to those observed on site 215
 (e.g. moisture content of clay, position of drawing inside the cave, etc.). The aim 216
 was to attempt to differentiate between the various techniques used to create the 217
 motifs, such as finger-strokes, engraving using tools or etching. The flexibility of 218
 the head of the *ScanArm* used for this work allowed for recording of the base of 219
 even the thinnest engravings, including oblique ones, both on the in situ panels and 220
 their experimental counterparts. Indeed, the laser can be oriented effortlessly in all 221
 directions. After, we compared sections through the 3D archaeological motifs with 222
 the 3D experimental duplicates in order to assess the morphology and types of tools 223
 used. By using this approach, we were able to propose the probable use of wooden 224
 and metal tools for the execution of engravings. 225

226 9.3.3 The Les Fraux 3D Geographic Information System

227 The Les Fraux 3D GIS was designed to store, manipulate, manage, present and
 228 share the huge amount of 2D and 3D spatial and geographical data produced and
 229 georeferenced by the total station and laser scanning (Fig. 9.9). This system allowed
 230 us to create interactive queries, interrogate spatial information and edit data in maps
 231 whilst also taking into account the location and nature of archaeological artefacts
 232 and geomorphological contexts. A 3D approach is crucial in the context of under-
 233 ground networks. Thus, chose a system able to manage 3D point clouds (*ArcMap*
 234 *10.2*) and temporalities. Unlike traditional relational databases, this GIS processes
 235 the spatial dimension of multi-scalar and heterogeneous data of various different
 236 disciplines. The conceptual data model thus expresses relationships between multi-
 237 disciplinary information. Very large datasets, including images, maps, analyses,
 238 reports in JPEG and PDF formats and associated objects and features, have been
 239 integrated within this GIS.

240 According to this system, we are able to produce 2.5D thematic maps—in which
 241 the coordinates of a point $[x, y]$ are associated with only one altitude $[z]$ —to simu-
 242 late 3D movement within the galleries, to manage archives (images, analysis, etc.)
 243 and to create automated dynamic mapping of atmospheric measurements. Some
 244 tools deal with the spatial analysis of artefacts, hearths, deposits and decorated pan-
 245 els, in relation to other entities (e.g. the close association between the location of
 246 decorated panels and symbolic deposits). Overall 3D recording of the cave struc-
 247 tural elements constitutes the basic element of the GIS. 3D data were resampled
 248 before being integrated in the GIS. The georeferenced point clouds allowed for the
 249 3D visualisation of the cave and of the semantic data linked to artefacts and geologi-
 250 cal objects recorded on the site. Data were either quantitative or qualitative. Semantic
 251 data were located according to the point clouds (i.e. the structural elements of

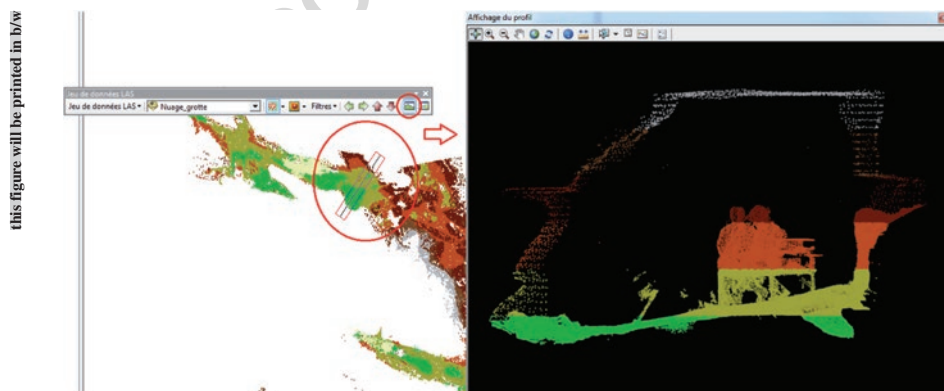


Fig. 9.9 Left screenshot from the cave of Les Fraux 3D geographic information system (gallery no. 28), right handling of 3D point clouds in *ArcMap 10.2* viewing window and the creation of sections (O. Jest, M. Koehl, A. Burens)

the cave). They were processed in a table before being integrated into the GIS. Vector data (2D maps) were exported in DWG format for georeferencing and integration into the GIS. Raster data were used as the background of the GIS and also required coordinates.

The GIS included, for example, all information related to the hearths (morphology, location, spatial context, presumed function, analysis, radiocarbon date, etc.). Preliminary analyses suggest that spatial correlations exist between hearths and other elements which structured space, such as votive deposits, cave art or domestic debris. Thus, the GIS constitutes an important tool for analysing the location of the hearths within their immediate environment.

Now that the georeferenced data gathering period is complete, our goal is to create a reconstruction and simulation of the various past activities which took place in the cave, using the 3D models of the cave and the GIS. The integration of temporality in 3D numerical simulation is an important challenge for our understanding of the development of the underground network, from the modern day to various hypothetical past states, particularly in terms of palaeoclimate. Furthermore, this tool already provides a way for us to compare 3D models of different archaeological cave systems using spatial analysis, in order to deepen our knowledge of human interaction with these environments.

In this regard, archaeologists and surveyors from the team have committed themselves to a new project based on archaeological and ethnographic analogy: studying a historical underground network, temporarily occupied by a small population and documented by direct testimony (living witnesses, pictures, written accounts, historical archives, etc.), akin to Cyril Marcigny's study of the Norman quarries of Caen (Carpentier et al. 2016). Our collective goal is to study, under the same conditions as those implemented at Les Fraux, the quarry of 'Saingt', Fleury, Normandy. The latter was occupied by the local population in June and July 1944 (through the allied troops' bombing raids during the so-called Normandy landings). It has been digitised in 3D according to the same techniques to those implemented at Les Fraux, in order to produce 3D models of the site and a 3D GIS. Preliminary results allow us to observe a wide range of similarities in the spatial distribution of artefacts (the remains of meals) and living spaces between these two underground networks. The comparison of characteristics between one site and the other encourages us to reconsider some of our interpretations of Les Fraux, notably that some activity in the cave is more domestic in character than might otherwise have been expected. It is important to note, however, that ethnographic and ethnohistorical evidence cannot always be used as a *direct* parallel for archaeological interpretations. As Tolan-Smith and Bonsall (1997, p. 217–218) warn us, 'the dimension of human behavior... is notoriously difficult to appreciate in periods before the emergence of documented history and recorded ethnographic observation', and 'the distinction between economic and ritual behaviour may be partly false as it arises from the application of a twentieth century rationalist perspective which may not be entirely appropriate in other contexts'.

295 9.4 The Visible and the Unseen: The Issue of Hearths

296 Hearths, which are widely considered as structuring elements, especially in caves,
297 provide important information about the nature of space occupation. Sixty-six
298 domestic hearths (Figs. 9.2 and 9.10) have been recorded in the cave of Les Fraux,
299 together with a large amount of combustion products, across the entirety of the area
300 which saw activity during the Bronze Age (this is to say, nearly 70% of the net-
301 work). Some structures are partially washed away or buried by sand from the decay
302 of sandstone blocks or flood events.

303 We have recorded 41 fireplaces built directly on the ground surface, 10 hearths
304 not attributable to a specific type because of their poor state of preservation, 7 fire
305 pits (both in natural and anthropogenic features), 5 instances of the indirect evi-
306 dence of hearths (such as traces of reddening on the cave ceiling or walls and iso-
307 lated heat-affected sandstone blocks) and 3 hearths made from clay extracted from
308 inside the cave. One of these latter features is represented by a semi-elliptical shape,
309 a ridge of clay and a pattern made with a thumb; the only one protohistorical parallel
310 for this is in Ouessant, Finistère (Le Bihan and Villard 2010).

311 The exceptional preservation of most of these structures has allowed us to collect
312 quantitative and qualitative data relating to their function. We have established a clas-
313 sification based on morphology, location in relation to their immediate surroundings,
314 dimension, typology (see Beeching and Gasco 1989; Gasco 2003) and the materials
315 used in their construction. Most of the hearths are characterised by their small dimen-
316 sions (<0.35 m in length) and quadrangular shape; they are located on slopes, in pas-
317 sageways, near to walls or atop ridges. In some cases, delimitation devices have been
318 observed (e.g. sandstone blocks or imprints left by stones). Three hearths were built on
319 top of large blocks. They seem to have been used for lighting and heating. Larger
320 hearths and fire pits (0.35–0.65 m in length), characterised by higher fire intensity
321 (>300 °C), are located in narrow galleries (with low ceilings) and more open spaces
322 (rooms). Some of them are close to material deposits and domestic debris; their uses
323 seem more variable. Flat hearths might have been used for baking.

324 All of the information related to fires has been registered in the 3D database
325 (including morphology, typology, location, archaeozoological remains, photo-
326 graphs, description of geological alterations and combustion remains, taphonomy,
327 radiocarbon date, charcoal analysis, fire intensity, etc.). A novel approach to under-
328 standing the intensity of these fires has already been published, based on a combina-
329 tion of archaeological observation and analyses of hearth sediments (i.e.
330 thermoluminescent properties of the sedimentary quartz; see Brodard et al. 2012)
331 and relevant proxies obtained from experimental structures (Brodard et al. 2016).
332 This study is thought to allow for the evaluation of fire intensity of hearths (tem-
333 perature/time/energy) and to contribute to our understanding of their role and their
334 impact on the ground, walls and atmosphere of the cave.

335 In addition, we wanted to find a way to map potential hidden, displaced or ruined
336 structures. This was another innovative approach, managed by two of the team
337 (F. L. and V. M.), and was particularly interesting in terms of 3D modelling, in



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Fig. 9.10 Overview of some hearths in the cave: (a) Gallery no. 13, (b) Gallery no. 18, (c, d) Gallery no. 29, (e) Bronze Age palaeosol from the gallery no. 13 and its five hearths (F3, F5, F7, F9 and F17) (photographs: A. Burens)

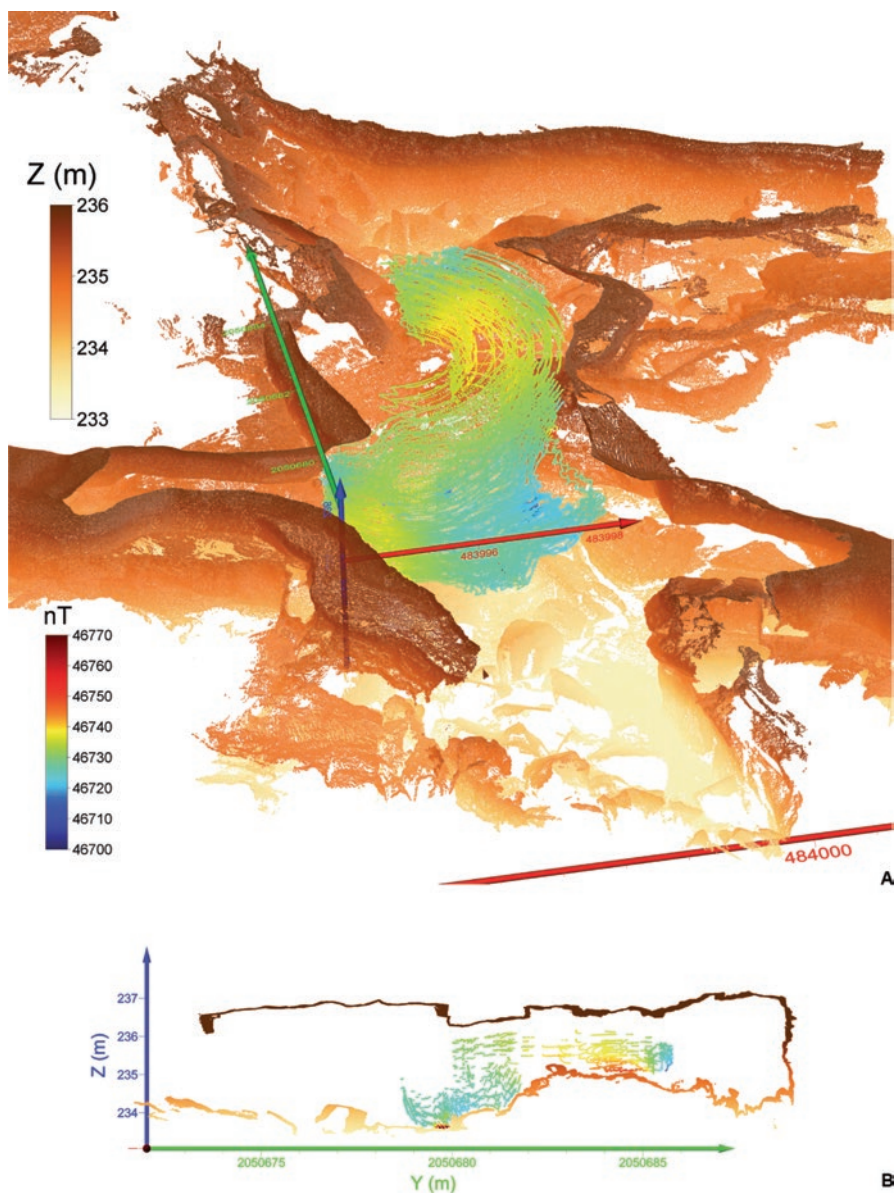
338 establishing significant progress in our methodological framework. On outdoor
339 archaeological sites, cartography of local distortions of the earth's magnetic field
340 (e.g. generated by the thermal impact on soil or sediment) allows researchers to
341 locate ancient hearths (visible, or not) or other structures. For the first time, François
342 Lévêque and colleagues successfully adapted this technique of magnetic survey to
343 the underground network at Les Fraux. The complex topographic configuration of
344 the underground galleries required full 3D data acquisition (instead of the usual 2D
345 acquisition), together with higher resolution data capture. All rocks interact more or
346 less with the earth's magnetic field, depending on their nature and their thermal history.
347 The interpretation of local variation in the magnetic field required us to clearly
348 identify the source of an anomaly (i.e. the highest and lowest values of intensity of
349 the local magnetic field). In order to distinguish topographic effects from the impacts
350 of fire, both magnetic and topographic information were combined in the same 3D
351 model of the cave.

352 The 3D cartography of local distortions of the earth's magnetic field in relation to
353 Les Fraux was useful in helping to complete the inventory of ancient hearths, both visible
354 and invisible. Measurements of the magnetic field were recorded in the cave using
355 a dual-sensor magnetometer coupled to a 360° prism reflector (Fig. 9.11). Geolocation
356 of measurements was ensured by tracking the 360° prism with a total station. This
357 magnetic field mapping project succeeded in combining, in the same depiction system,
358 several sources of magnetic, topographic and archaeological information (Fig. 9.12).
359 Due to this innovative 3D approach, we were able to map unseen hearths within the
360 cave and to differentiate in situ structures from displaced hearths (Burens et al. 2014).
361 This new method is now applied to other French painted caves, for example, the caves
362 of Cussac, Dordogne and Chauvet Vallon-Pont-d'Arc, Ardèche.

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Fig. 9.11 View of the 3D magnetic prospecting device inside gallery no. 40. (Photograph: A. Burens)



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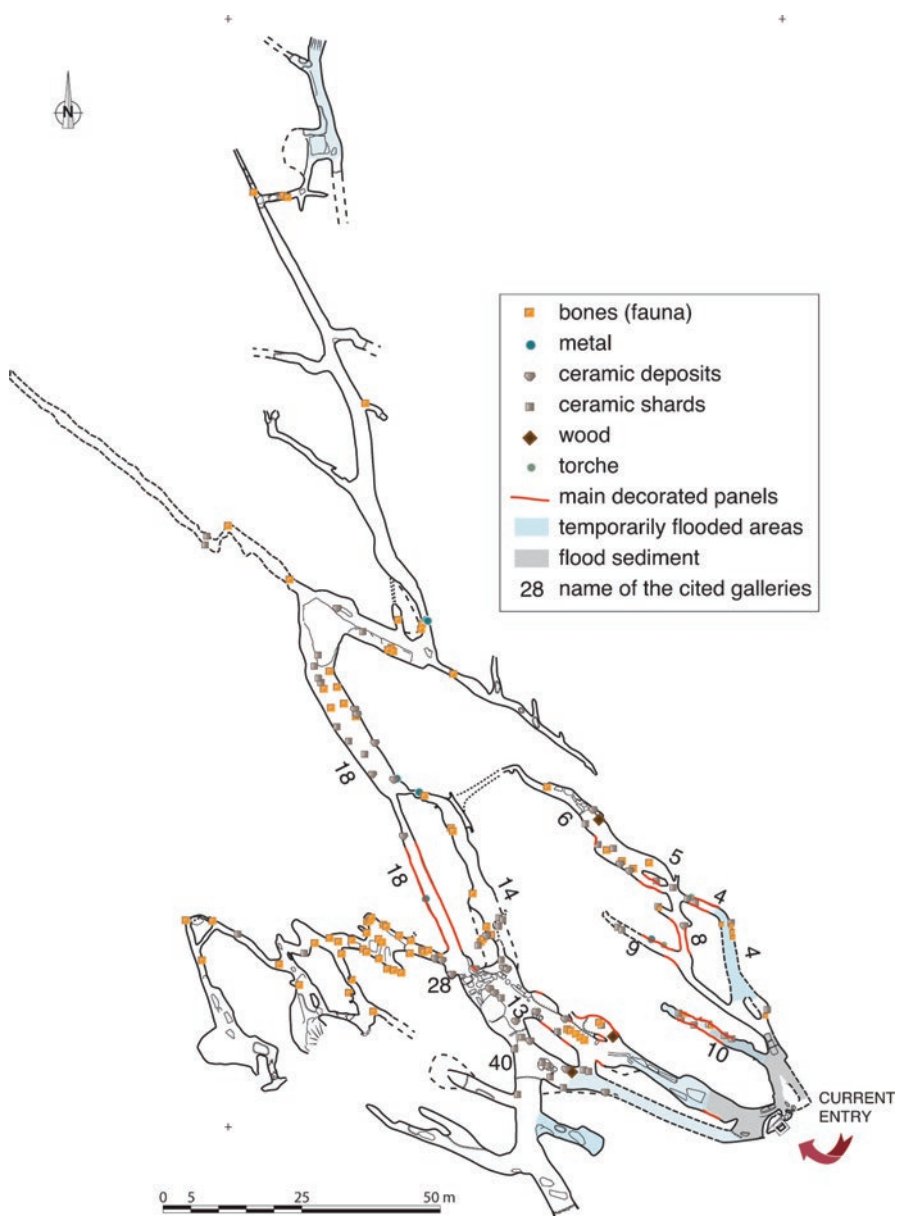
Fig. 9.12 Protocol of 3D magnetic prospection in the cave of Les Fraux: (a) Device comprising a telescopic pole fixed on a tripod allows for good control of the space covered by the sensors (white cylinders); geolocalisation of the measurements is obtained by a tracking method thanks to a total station, (b) Gallery no. 40: 3D mapping of the magnetic field (georeferenced in Lambert 2). The magnetic survey is created with a telescopic boom pole fixed on a tripod. Both sensors are superimposed and hanging at the end of the pole. The point clouds of both intensity of the magnetic field and wall surface are shown on image (a) (the top of the cave is truncated). Thanks to a second magnetometer, the diurnal variation of the local earth magnetic field is corrected. Image (b) displays a vertical section, 20 cm in thickness (F. Lévêque)

363 9.5 Types of Space Use and the Meaning of Cave Art

364 As mentioned above, nearly 70% of the cave of Les Fraux displays significant evi-
365 dence for Bronze Age human activity (Fig. 9.2). That said, we have also found
366 traces of lesser activity throughout the whole cave (isolated charcoal, imprints on
367 the walls, etc.), which probably indicates a willingness to recognise and utilise the
368 entire underground network. Our results show that a whole range of evidence for
369 different types of activities (such as hearths, fire pits, faunal remains and wood,
370 ceramic sherds, postholes, votive deposits, stairs dug into the clay, toolmarks on the
371 walls, torches, etc.) were present in a wide range of galleries, even those which were
372 narrow, had low ceilings or were located a long way from the entrance. It must be
373 understood that no remains have been recovered from around the cave entrance,
374 owing to the burial of archaeological deposits by sediment that have flooded in from
375 outside (Fig. 9.13). Nevertheless, it appears that people occupied all parts of the
376 cave, from the entrance to remote parts of the interior, with the exception of inacces-
377 sible or inhospitable galleries (which were too damp, too poorly ventilated, rich in
378 carbon dioxide, difficult to access, temporarily flooded or affected by subsidence,
379 etc.). Multiple lines of evidence indicate that at least some of the archaeological
380 deposits are associated with domestic activities (Carozza et al. 2009); conceivably,
381 the cave may have been used as a temporary shelter during a period of climatic
382 change (e.g. the 3.2ky BP event). But regarding the spatial location of the cave art,
383 spread over 75 cumulative linear metres (the network extends over more than 1 km),
384 our understanding of the cave's use over time needs to be reconsidered.

385 The cave contains a vast amount of cave art (Figs. 9.13, 9.14, 9.15 and 9.16),
386 featuring a wide range of schematic and geometric drawings widely dominated by
387 parallel traces and finger-strokes (>80%) (Petrognani et al. 2014). This preponder-
388 ance gives the impression of a low variability of patterns, made in a repetitive way,
389 using predominantly one technique (fingers: >75%).

390 The drawings have preserved their integrity (Figs. 9.14, 9.15 and 9.16), whilst
391 blocking of the cave and the effective sealing of this archaeological context suggest
392 a high degree of authenticity. The spatial distribution of art does not represent con-
393 tinuous development, even if some small sections present an almost uninterrupted
394 continuous sequence of patterns; it is random in its composition (Fig. 9.14).
395 Drawings have been recorded in 13 different galleries; only 4 display hundreds or
396 thousands of marks. Around 1500 graphical entities and 73 panels contain non-
397 figurative motifs. The right network of passages (looking in from the entrance) has
398 delivered a remarkable concentration of 39 decorated panels and 90 groups of
399 motifs. The left network is characterised by a less dense concentration of drawings,
400 with 26 decorated panels and 54 groups of motifs, but it contains the largest and
401 most elaborate panel of cave art (in gallery no. 13). Motifs have been formed using
402 four different techniques (Fig. 9.17). By far the most common is finger-strokes, with
403 more than 70% rendered using this technique. Two, three or four fingers were
404 deliberately pressed several times onto the moist clay of the wall and were moved
405 vertically, horizontally or obliquely, forming sequential unexplained patterns. The



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Fig. 9.13 Map of the underground network displaying the location of cave art and other material (Y. Billaud and A. Burens)

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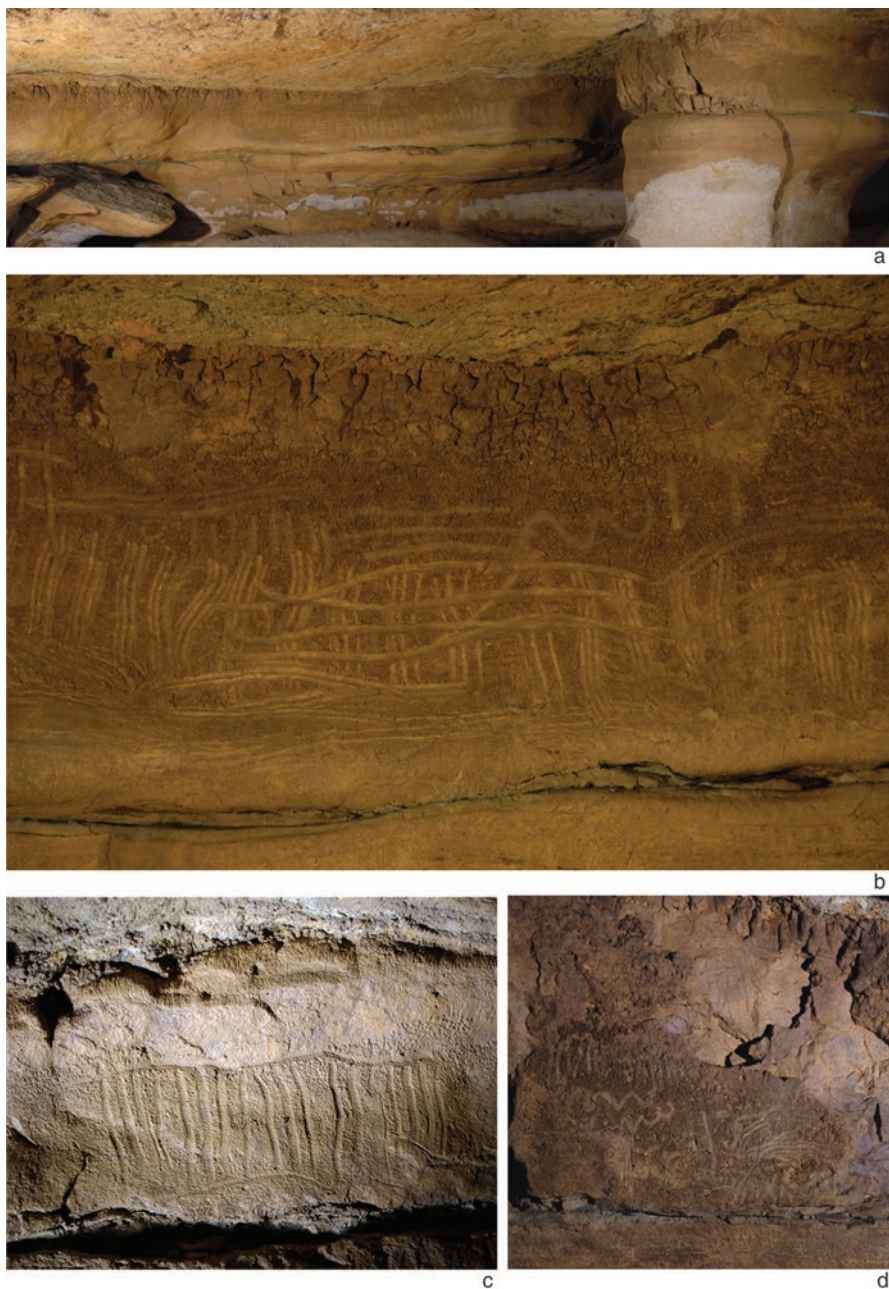


Fig. 9.14 A select range of decorated panels from gallery no. 13. (Photographs: A. Burens and R. Bourrillon)



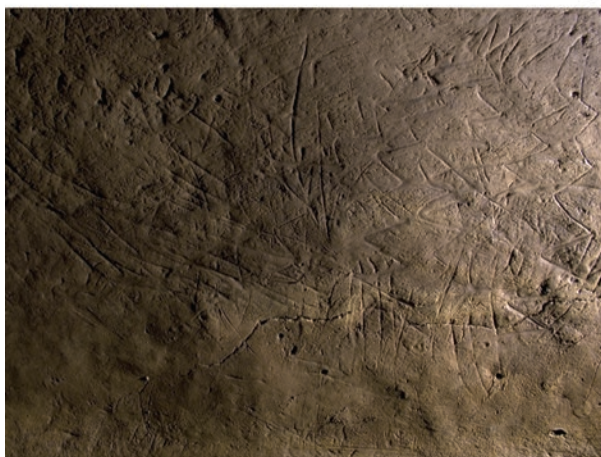
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Fig. 9.15 A select range of decorated panels from the cave: (a, c) Gallery no. 13, (b) Gallery no. 28. (Photographs: A. Burens and R. Bourrillon)

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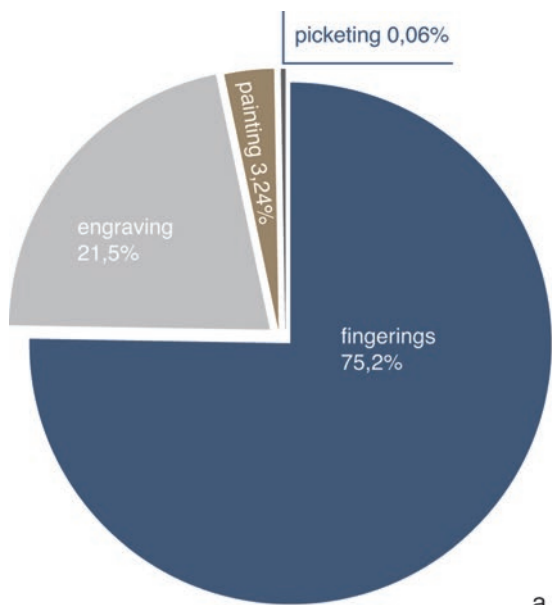
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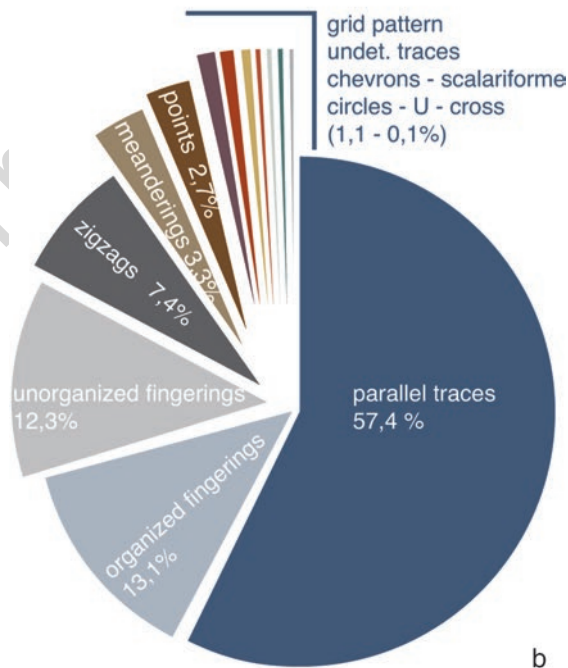
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Fig. 9.16 A select range of decorated panels from the cave: (a) Gallery no. 6, (b) Gallery no. 10, (c) Gallery no. 9. (Photographs: A. Burens and R. Bourrillon)

Fig. 9.17 Les Fraux cave art: (a) Technical characteristics, (b) Presentation of the main patterns (A. Burens, R. Bourrillon and S. Petrognani)



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406 second most common technique is engraving (with more than 20% of motifs rendered in this way): patterns were engraved by using metal and wooden tools pressed
407 into the soft clay surface of the rock (Burens-Carozza et al. 2011). Finally are painting and pecking techniques. Only two techniques have been discovered in the left
408 part of the cave network, which contains the densest concentration of motifs rendered
409 by finger-strokes, together with some engravings. In contrast, all four techniques
410 have been used in the right part of the cave network. Two are exclusively
411 represented in this area: the painting and picking technique. Engraving is also pre-
412 dominant in this part of the cave, but finger-strokes are less common. Motifs are
413 organised into 13 different patterns, reflecting a rich symbolic system (Fig. 9.17).
414 They comprise a relative wide repertoire, including parallel lines (which predomi-
415 nate), organised and unorganised finger-strokes, zig-zags, meanders, points, grid
416 patterns, undetermined motifs, chevrons, scalariforms, circles, U shapes, crosses
417 and so on.
418

420 For Marcel Otte, the Mediterranean Bronze Age is characterised by an extreme
421 degree of symbolism, but often excluding human representations (except in the
422 south-east of France and in the mountains; Otte et al. 2002, p. 193). Variations can
423 of course be explained by various cultural influences, such as those from the Atlantic
424 associated with the 'Tumulus Culture' in Aquitaine and the north of France, or the
425 emergence of the Duffaits Group in Middle Bronze Age in Perigord (Carozza et al.
426 2009; Gomez de Soto 1995; Otte et al. 2002). In karstic regions, however, caves are
427 rarely decorated; the cave of Les Fraux constitutes an exception.

428 Even though direct dating of the cave art of Les Fraux remains somewhat specu-
429 lative and is based on the maximum duration of the human activity on the site (from
430 1450 to 950 BC according to relative chronology and radiocarbon dates), it seems
431 that we should assign at least some of the wall art to the Middle Bronze Age. Indeed,
432 radiocarbon dating has been undertaken on a charcoal sample from inside one of the
433 motifs on a large decorated panel in gallery no. 18 and returned a date of 1410–
434 1190 BC (at 98%) and 1380–1210 BC (at 68%) (Lyon SacA 15,773: 3035 ± 35 BP).

435 The cave art only features in a small part of the underground cave network. Its
436 spatial distribution, however, shows a good correlation between art, hearths, the
437 remains of domestic activities and votive deposits. In seven galleries, cave art is
438 closely associated with votive deposits, whilst in the same areas decorated panels
439 have been found near to pot sherds and other archaeological remains (animal bone,
440 metalwork, etc.). In the four most decorated galleries (nos. 8, 13, 18, 28), panels are
441 closely associated with contemporaneous hearths, perhaps in order to provide light.
442 On the contrary, however, in six other galleries (nos. 4, 5, 6, 9, 10, 14), no visible
443 hearths have been found in close proximity to cave art. Here we observe a clear
444 disconnect that cannot be explained purely to problems of taphonomy.

445 Residential and ritual activity is rarely witnessed simultaneously in the same
446 cave. Work in progress, especially in gaining additional radiocarbon dates and refin-
447 ing our relative chronology, could eventually create a more detailed understanding
448 of these patterns of activity and whether they were indeed contemporary or
449 sequential.

From a different perspective, research on reverberation sounds in caves suggests links between prehistoric paintings and the acoustic properties of the places in which they were created (e.g. Bahn 1997, p. 37; Clottes 2003, p. 21; Lewis-Williams 2002, p. 225; Reznikoff and Dauvois 1988; Sieveking 1997, p. 29). In France, studies conducted in Palaeolithic caves (e.g. Grotte du Portel, Niaux, Fontanet) have shown—by measuring the intensity and duration of sounds and changing resonances in relation to the point of emission—a correlation between the location of paintings and the acoustic properties of that peculiar location within the cave. Reznikoff and colleagues (1988) have found that major points of resonance within caves tend to correspond to the location of paintings. Furthermore, the location of some paintings seems to be exclusively explained by the acoustic properties of that specific place. It might be suggested that prehistoric communities developed close associations between the ritual uses of the voice (or other sound sources, such as musical instruments) and cave paintings. In the cave of Les Fraux, work in progress has revealed that the main decorated panel of the cave is located in the most important room within the network (gallery no. 13), in that it offers the best resonance of any part of the cave. Furthermore, some unusual resonances have been observed between two different galleries, not in direct contact with one another, and in two different branches of the cave system. At these peculiar locations, deposits of pottery and metalwork have been found, in some cases associated with engraved motifs and finger-strokes. Of course, more concrete evidence is needed, and this preliminary work is based on qualitative observations, but it seems that, in the cave of Les Fraux, the acoustic properties of the cave might also have been important in the Bronze Age for artistic or ritual expression.

It is worth at this stage remembering that we have no idea of the meaning of the cave depictions. The significance of geometric patterns remains unknown. In Spain, some figures (e.g. zig-zags, meanders) which are associated with figures, such as deer, could depict water or thunderstorms (Hameau 2009). The grid patterns and scalariforms are, however, dissimilar from Alpine rock art, such as those discovered in the Val Camonica (Anati 2009). At the cave of Les Fraux, interpretations remain largely speculative and range from utilitarian functions, artistic expression and space appropriation to a counting or measuring system. Alternatively, do the signs represent the property or the presence of a group, or were they made consciously or under altered states of consciousness, induced by a sensory deprivation linked to silent, isolation and a totally dark environment (Barnatt and Edmonds 2002, p. 125; Lewis-Williams 2002, p. 214)? We have explored different and alternative avenues of research, including modern fetishist practices, such as those performed in Burkina Faso and Mali, and which involve heaps of pot sherds and finger-strokes in ground surface, in order to ward off evil (Pataux 2010), evidence very similar to that observed at Les Fraux. The motifs might also be associated with story-telling, in a similar way to the mnemonic Rongorongongo tablets used by people who recite oral traditions on Pascua Island. The difficulty arises when the culture and its traditions are of great antiquity. The originality of the iconography of the Les Fraux cave art sets it apart from traditional European protohistorical rock art. There are few parallels for this non-figurative art, and often the archaeological contexts in which it is

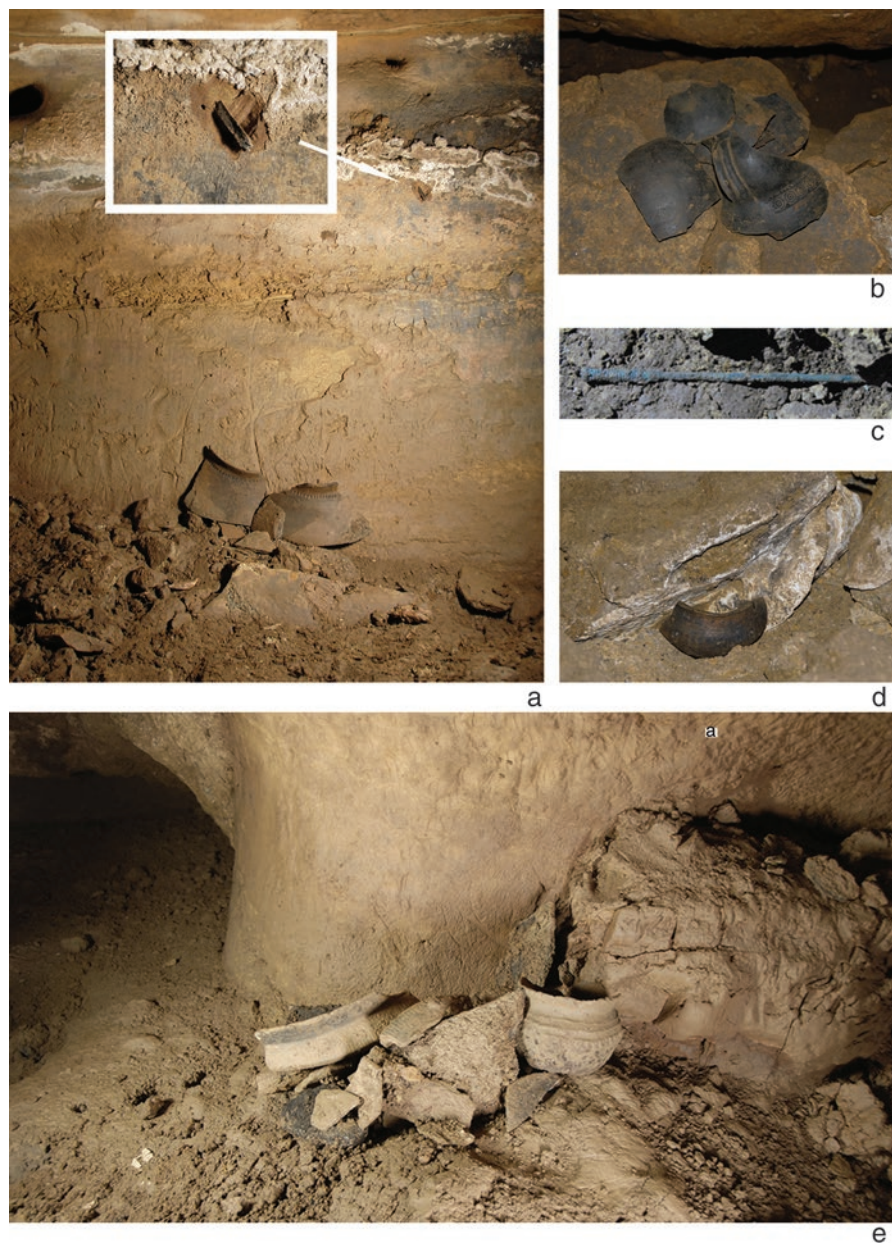
495 found are undated. Locally, Rouffignac Cave displays some finger-rendered motifs
496 that could possibly be assigned to the Bronze Age (Barrière 1974, 1975). Some
497 parallels can also be found in Spain, but the activity represented there is much older
498 (e.g. Ojo Guareña Cave, tune de la Varaime; Gómez-Barrera 1999) or the parallels
499 are less obvious (e.g. Cueva Mayor). Furthermore, Bronze Age rock art, megalithic
500 art and cave art shares a wide range of geometric designs with other protohistorical
501 periods, whilst the indiscriminate comparison of artefacts across time and space
502 leads to inappropriate analogies (Wylie 1985).

503 9.6 From Domestic Use to Votive Practice

504 Through the course of this chapter, we have discussed the rich archaeological char-
505 acter of the cave of Les Fraux. Some of the activities represented seem to relate to
506 the domestic sphere, whilst others relate to ritual practices. In relation to Neolithic
507 caves in Ireland, Marion Dowd (2008, p. 305) notes that ‘Understanding the use of
508 caves... has to begin with a careful evaluation of the material available and its con-
509 text’. For William Walker (1995), objects used during rituals are made sacred and
510 must be disposed of in respectful ways. ‘Many of us report finding broken objects
511 in caves that may be the result of ritual activities occurring at the site, so broken
512 votive offerings may be an imperative of ritual practice’ (Moyes 2012, p. 8). If this
513 is the case, how do we set ritual remains apart from domestic objects? Despite
514 renewed interest in this issue, it remains difficult to objectively define the notion of
515 ‘deposit’.

516 Inside the cave of Les Fraux, the galleries include 32 deposits, the majority of
517 which comprise ceramics and more rarely metalwork (3), faunal remains (5) or
518 speleothems (1) (not to mention pebbles deliberately deposited on raised areas of
519 calcite) (Figs. 9.18 and 9.19). Unlike other protohistorical caves in France charac-
520 terised by rich deposits—especially those excavated in Charente-Maritime by José
521 Gomez de Soto (1980)—the cave of Les Fraux has not yielded any human remains,
522 and thus no association with the funeral sphere can be objectively confirmed. Half
523 of the deposits are located in eight galleries which also include cave art, where they
524 are located under or close to decorated panels. But in seven galleries, deposits are
525 located some distance away from wall art panels.

526 Some of the deposits are organised in a highly visible way (at the junction of
527 galleries, on the top of stone blocks, etc.); others are intentionally hidden (under
528 boulders, inside crevices, etc.). Meanwhile, metal artefacts (necklaces, small bronze
529 rings, pins, etc.) and faunal deposits are often spatially distinct from ceramic depos-
530 its (which include a large range of storage, cooking and fine ceramic vessels).
531 Deposits sometimes comprise complete vessels, but most often they are broken;
532 most bear traces of use, with some coated with the charred remains of animal fat
533 (ongoing work by Arnaud Mazuy and Martine Regert, UMR7264). The requirement
534 to leave all archaeological material in situ, and working with non-invasive tech-
535 niques, forced the team to study the ceramic deposits using contact-free



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Fig. 9.18 A select range of deposits in the cave: (a) Gallery no. 6, (b, d) Gallery no. 18, (c) Gallery no. 12, (e) Gallery no. 8. (Photographs: A. Burens)

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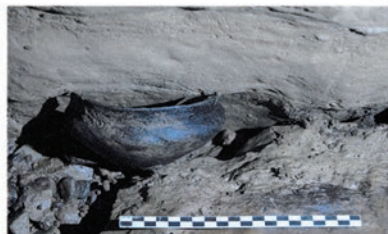
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Fig. 9.19 A select range of deposits in the cave: (a, b) Gallery no. 13, (c) Gallery no. 27, (d, e) Gallery no. 18. (Photographs: A. Burens)

measurements only. As a result, we were unable to undertake any petrographic study or technological analysis which might provide information about the origin of the pots. However, typological analysis suggests that some of the vessels belong to the 'Duffaits Group', dating from the Middle to the beginning of the Late Bronze Age. This corresponds with the outlying 'Tumulus Culture' and the Atlantic Complex (Gomez de Soto 1995, p. 201). Both radiocarbon dating and typological study of the artefacts suggest that votive practices were performed within the cave, together with and disconnected from cave art and domestic activity. In each phase of activity, however, previous deposits and decorated panels were respected and left intact.

9.7 Conclusion: Residential Activity Versus Cave Art: Towards Overlapping Uses?

According to Tolan-Smith and Bonsall (1997, p. 217–218):

'Most researchers concerned with the human use of caves find it convenient to summarize their data in terms of economic or ritual behavior... [and]...When people decide to adopt a sedentary mode of existence they usually come out of their caves and the use of these natural shelters is given over to ritual'. Furthermore, 'the use of cave as theatre for ritual... [is]... usually evidenced by cave art and/or the presence of votive deposits and the use of caves as burial vaults'.

The atypical decorated Bronze Age cave of Les Fraux combines cave art with evidence for domestic and symbolic activities, simultaneously but temporarily within two distinct branches of one large underground network, over nearly four centuries. Even if both residential and ritual uses are rarely evidenced simultaneously in the same cave, the diversity of archaeological remains here suggests a plurality of uses, perhaps shifting in time between Middle and Late Bronze Age.

The interpretation of the site is closely linked to the control of time within the cave and is the reason why we developed a contextual approach, taking into account the economic, cultural, topographic and ecological factors of this environment. Difficulties have included a lack of stratigraphy and the absence of direct links between deposits, archaeological sediments and decorated wall panels; at this stage, we have only 14 radiocarbon dates from 5 galleries of the cave. Nevertheless, according to archaeological investigation, the cave appears to have witnessed activity from 1450 to 950 BC. Work in progress suggests three periods of activity within this broader date range: a period between the Middle and the Late Bronze Age (from 1450–1250 BC), based on dates from hearth nos. 3, 12 and 14, archaeological deposits and 'torch holes'; a period at the beginning of the Late Bronze Age (around 1250–1125 BC), associated with hearth nos. 8 and 18 and one decorated panel from the gallery no. 18; and finally, a period between about 1200 and 950 BC, based on dates from hearth nos. 4 and 19. It comes as no surprise that activity within the cave is more complex than previously thought. One must bear in mind that the cave of

576 Les Fraux is unique in Europe. When comparing the site with other French Bronze
577 Age caves, there are several similarities but mainly distinct differences (such as the
578 absence of cave art and the almost systematic presence of funeral activity).

579 Whilst not conclusive, several possibilities emerge. Evidence for interruptions in
580 the archaeological record between the Middle and Late Bronze Age, combined with
581 the low density of features and other remains within the cave over such a long
582 period of use and the minimal disturbance of older deposits, suggests that activity at
583 the site took the form of numerous short but regular visits over this broader time
584 period. It is worthwhile at this stage to consider that the nature of the various activi-
585 ties may have been very different. The cave may first have been utilised for sym-
586 bolic activities (cave art, votive deposits, etc.), becoming increasingly used for more
587 domestic activities, with the occasional continuation of some symbolic practices,
588 but with respect for the ancient wall art panels. In order to take these interpretations
589 further, more radiocarbon dates from a wider range of galleries is required, in order
590 to complement the chronological framework based on ceramic typology.

591 The difficulty lies in the definition and meaning of ritual or symbolic gesture, as
592 practised in a cave context. Our contribution to the study of Norman quarries (Cyril
593 Marcigny pers. comm.) will allow us to compare these two sites, recorded according
594 to the same 3D technology, and will improve our understanding of underground
595 networks by combining the results of archaeological investigations (as 3D simula-
596 tion) with the benefits of 2.5D spatial analysis.

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603 cave. We would also like to express our sincerest gratitude to Delphine Cross.

604 References

- 605 Anati, E. (2009). L'art rupestre du Valcamonica: évolution et signification. Une vision panoramique
606 d'après l'état actuel de la recherche. *L'Anthropologie*, 113, 930–968.
- 607 Bahn, P. G. (1997). Dancing in the dark: probing the phenomenon of Pleistocene cave art. In
608 C. Bonsall & C. Tolan-Smith (Eds.), *The human use of caves. British archaeological reports*
609 *(international series) 667* (pp. 35–37). Oxford: Archaeopress.
- 610 Barnatt, J., & Edmonds, M. (2002). Places apart? Caves and monuments in Neolithic and earlier
611 Bronze Age Britain. *Cambridge Archaeological Journal*, 12(1), 113–129.
- 612 Barrière, C. (1974). Rouffignac: l'archéologie. *Travaux de l'Institut d'Art Préhistorique de*
613 *Toulouse*, 16, 3–210.
- 614 Barrière, C. (1975). Rouffignac: l'archéologie. *Travaux de l'Institut d'Art Préhistorique de*
615 *Toulouse*, 17, 3–83.
- 616 Beeching, A., & Gasco, J. (1989). Les foyers de la préhistoire récente du sud de la France (descrip-
617 tions, analyses, et essais d'interprétation). In M. Olive & Y. Taborin (Eds.), *Nature et fonction*

- des foyers préhistoriques. Actes du colloque international de Nemours (12–13–14 ai 1987). Mémoire du Musée de Préhistoire d'Île de France* (pp. 275–292). Nemours: APRAIF. 618
- Brodard, A., Guibert, P., Lévêque, F., Mathé, V., Carozza, L., & Burens, A. (2012). Thermal characterization of ancient hearths from the cave of Les Fraux (Dordogne, France) by thermoluminescence and magnetic susceptibility measurements. *Quaternary Geochronology*, 10, 353–358. 620
- Brodard, A., Lacanette-Puyo, D., Guibert, P., Lévêque, F., Burens, A., & Carozza, L. (2016). A new process of reconstructing archaeological fires from their impact on sediment: a coupled experimental and numerical approach based on the case study of hearths from the cave of Les Fraux (Dordogne, France). *Archaeological and Anthropological Sciences*, 8(4), 673–687. 622
- Burens, A., Grussenmeyer, P., Carozza, L., Lévêque, F., Guillemin, S., & Mathé, V. (2014). Benefits of an accurate 3D documentation in understanding the status of the Bronze Age heritage cave “Les Fraux” (France). *International Journal of Heritage in the Digital Era*, 3(1), 179–195. 623
- Burens-Carozza, A., Grussenmeyer, P., Guillemin, S., Carozza, L., Bourrillon, R., & Petrognani, S. (2011). Numérisation 3D de la grotte ornée des Fraux, Saint-Martin-de-Fressengeas, Dordogne, France: approche multiscalaire. Images et modèles 3D en milieux naturels. *Collection EDYTEM*, 12, 183–189. 624
- Carozza, L., Burens, A., Billaud, Y., Ferrulo, O., Bourrillon, R., Petrognani, S., Fritz, C., Tosello, G., Goineaud, E., & Goineaud, M. (2009). L'horizontal et le vertical: l'âge du Bronze de la grotte des Fraux (Saint-Martin-de-Fressengeas, Dordogne). In D. Fabre (Ed.), *De Méditerranée et d'ailleurs... mélanges offerts à Jean Guilaine* (pp. 159–172). Toulouse: Archives d'Écologie Préhistorique. 625
- Carpentier, V., Dujardin, L., Marcigny, C., avec Burens, A., Carozza, L., Grussenmeyer, P., Guillemin, S., Mazet, S., & Vipard, L. (2016). ‘Archéologie du refuge’ ou de ‘l’enfermement-volontaire’: la carrière-refuge de la brasserie Saingt à Fleury-sur-Orne (Calvados). *Les Nouvelles de l'Archéologie*, 143, 59–63. 626
- Clottes, J. (2003). Caves as landscapes. In K. Sognnes (Ed.), *Rock art in landscapes: landscapes in rock art (volume 4)* (pp. 11–30). Trondheim: Tapir Akademisk. 627
- Dowd, M. A. (2008). The use of caves for funerary and ritual practices in Neolithic Ireland. *Antiquity*, 82(316), 305–317. 628
- Faulkner, C. H. (1988). Painters of the “dark zone”. *Archaeology*, 41(2), 30–38. 629
- Gasco, J. (2003). Contribution pour une proposition de vocabulaire des structures de combustion. In M.-C. Frère-Sautot (Ed.), *Le feu domestique et ses structures au Néolithique et aux Âges des métaux. Actes du colloque de Bourg-en-Bresse et Beaune (7–8 Octobre 2000)* (pp. 109–112). Montagnac: Éditions Monique Mergoil. 630
- Gomez de Soto, J. (Ed.). (1980). *Les cultures de l'âge du Bronze dans le bassin de la Charente*. Périgueux: Fanlac. 631
- Gomez de Soto, J. (1995). *Le Bronze Moyen en occident: la culture des duffaits et la civilisation des tumulus. L'âge du Bronze en France tome 5*. Paris: Picard. 632
- Gómez-Barrera, J. A. (1999). *Approche de l'étude des gravures rupestres post-paléolithiques de la péninsule Iberique Préhistoire Ariégeoise, LIV* (pp. 265–292). 633
- Grussenmeyer, P., Alby, E., Landes, T., Koehl, M., Guillemin, S., Hullo, J.-F., Assali, P., & Smigiel, E. (2012). Recording approach of heritage sites based on merging point clouds from high resolution photogrammetry and terrestrial laser scanning. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXIX-B5*, 553–558. 634
- Hameau, P. (2009). Site, support et signe: une cohérence de sens. L'expression graphique picturale au Néolithique. *L'Anthropologie*, 113, 861–881. 635
- Le Bihan, J.-P., & Villard, J.-F. (2010). *Archéologie d'une île à la pointe de l'Europe: Ouessant. Tome 2: l'habitat de Mez-Notariou des origines à L'âge du Bronze*. Saint-Thonan: Centre de recherche archéologique du Finistère. 636
- Lewis-Williams, D. (2002). *The mind in the cave*. London: Thames & Hudson. 637
- Moyes, H. (2012). Introduction. In H. Moyes (Ed.), *Sacred darkness: A global perspective on the ritual uses of caves* (pp. 1–14). Boulder: University Press of Colorado. 638

- 670 Otte, M., David-Elbiali, M., Eluère, C., & Mohen, J.-P. (2002). *La protohistoire*. Bruxelles: De
671 Boeck Université.
- 672 Pataux, A. (2010). *Cœur blanc, ventre blanc: fétiches et féticheurs*. Montreuil: Gourcuff Gradenigo.
- 673 Petrognani, S., Bourrillon, R., Burens, A., & Carozza, L. (2014). À la poursuite du temps court:
674 les expressions pariétales de l'âge du Bronze de la grotte des Fraux (Dordogne). In P. Paillet
675 (Ed.), *Les arts de la Préhistoire: micro-analyses, mises en contextes et conservation. Actes du*
676 *colloque 'micro-analyses et datations de l'art préhistorique dans son contexte archéologique'*,
677 *MADAPCA, Paris, 16–18 Novembre 2011. PALEO*, numéro special (pp. 163–169).
- 678 Quiles, A., Valladas, H., Bocherens, H., Delque-Kolickoli kolic, E., Kaltnecker, E., van der
679 Plichtf, J., Delannoy, J.-J., Feruglio, V., Fritz, C., Monney, J., Philippe, M., Tosello, G.,
680 Clottes, J., & Geneste, J.-M. (2016). A high-precision chronological model for the decorated
681 Upper Paleolithic cave of Chauvet-Pont d'Arc, Ardèche, France. *Proceedings of the National*
682 *Academy of Sciences*, 113(17), 4670–4675.
- 683 Reznikoff, I., & Dauvois, M. (1988). La dimension sonore des grottes ornées. *Bulletin de la Société*
684 *Préhistorique Française*, 85(8), 238–246.
- 685 Sieveking, A. (1997). Cave as context in Palaeolithic art. In C. Bonsall & C. Tolan-Smith (Eds.),
686 *The human use of caves. British archaeological reports (international series) 667* (pp. 25–34).
687 Oxford: Archaeopress.
- 688 Tolan-Smith, C., & Bonsall, C. (1997). The human use of caves. In C. Bonsall & C. Tolan-Smith
689 (Eds.), *The human use of caves. British archaeological reports (international series) 667*
690 (pp. 217–218). Oxford: Archaeopress.
- 691 Walker, W. H. (1995). Ceremonial trash? In J. M. Skibo, W. H. Walker, & A. E. Nielsen (Eds.),
692 *Expanding archaeology* (pp. 67–79). Salt Lake City: University of Utah Press.
- 693 Wylie, A. (1985). The reaction against analogy. In *Advances in Archaeological Method and Theory*
694 (Vol. 8, pp. 63–111).