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# Sedimentation, re-sedimentation and chronologies in archaeologically-important caves: problems and prospects

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20 # Sedimentation, re-sedimentation and chronologies in archaeologically-
21 # important caves: problems and prospects

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23 **Abstract**

24 Excavations in the photic zones of caves have provided cornerstone archaeological sequences in
25 many parts of the world.  Before the appearance of modern dating techniques, cave deposits
26 provided clear evidence for the antiquity, relative ages and co-occurrence of ancient human
27 remains, material culture and fauna.  Earlier generations of archaeologists had generally rather
28 limited understanding of taphonomic and depositional processes, but the twentieth century saw
29 considerable improvement in excavation and analytical techniques.  The advent of modern dating
30 and chronological methodologies offers very powerful tools for the analysis of cave fill deposits and
31 this has resulted in the recognition of chronological incoherence in parts of some sites, with
32 consequent re-evaluation of previous archaeological disputes.  Obtaining multiple dates per context
33 provides a means to assess the integrity and coherence of the archaeological and environmental
34 records from cave fills.  In the case of the Haua Fteah (Libya), this technique allowed the recognition
35 of chronological coherence in low-energy depositional environments and limited recycling in high-
36 energy contexts.  We provide a conceptual model of the relationship between recycling,
37 sedimentation rate and process energy.  High-resolution investigation enables recognition of the
38 complexity of the formation of cave sequences, thus an increasingly sophisticated understanding of
39 human behaviour and environmental relationships in the past, and potentially gives a new life to old
40 data.

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45 ## Introduction

46 This paper deals with issues arising from the mobility and re-deposition of predominantly-clastic
47 sediments in the photic zones (areas reached by at least diffuse daylight), of archaeologically-
48 important caves, particularly from the perspective of chronology and chronological integrity.  It
49 therefore complements the paper by Canti and Huisman (this volume) which deals with site
50 formation and diagenesis in anthropogenic and biological sediments in cave fills.  The majority of
51 archaeologically-important caves are karst (dissolution) features in limestone or dolomite and the
52 following discussion mostly addresses caves in these lithologies, although caves also form in gypsum,
53 rock salt, sandstone, quartzite and granite, among others.  Further, virtually all rock types - other
54 than the very weakest mechanically - can give rise to rock shelters, and these share many properties
55 and issues with caves.

56 In the early days of Archaeology, caves provided some of the most important evidence for human
57 antiquity, such as the demonstration by Pengelly et al. (1873) of the association of humanly-shaped
58 artefacts with the bones of extinct animals.  Caves were the source of the first Neanderthal skeletal
59 material (e.g. Schaffhausen 1861; Fraipont and Lohest 1887), indicating for the first time that other
60 human species had existed in the past, thus being seen to validate early evolutionary theory (e.g.
61 Huxley 1863).  The recognition of changing material culture through time, although partly realised
62 from open-air sites, was also further demonstrated and refined from cave excavations.  Some of the

63  most important early expositions of regional Palaeolithic and later sequences came from caves in
64  France (Lartet and Christie 1875; de Mortillet 1886; Laville et al. 1980) and the UK (Pengelly et al.
65  1873; Dawkins 1874).  Examples among many influential later expositions of key cave sequences are
66  those for La Ferassie, France (Peyrony 1934; Delporte 1984), Taforalt, Morocco (Roche 1953),
67  Shanidar Cave, Iraq (Solecki 1955, 1963), the Haua Fteah, Libya (McBurney 1967), Niah Cave, Borneo
68  (Harrisson 1964, 1970) and  Franchthi  Cave, Greece (Jacobsen and Farrand 1987).

69  The three-dimensional complexities of past processes, sedimentation and chronology reflected by
70  cave fills were not suspected by many early researchers - and indeed many had little idea of, or
71  interest in, the processes which gave rise to the sediment accumulations that they excavated.
72  While, for instance, the excavations at Creswell Crags by Dawkins (1874) were truly ground-breaking
73  at the time, their execution reflected the contemporary limitations of knowledge, with skilled coal
74  miners employed  to cut and work back a vertical face in the cave sediments, while the excavator sat
75  in a chair at the cave mouth and selected items visible in the barrows as sediments were cast from
76  the cave, with minimal attention to the details revealed by the shifting exposure and the provenance
77  of the 'finds'. Not all early work was this crude: Pengelly et al. (1873) used what they termed 'prisms'
78  (arbitrary excavation units) to demonstrate the close proximity of lithics and bones of extinct
79  animals in the Brixham Cave, Devon (MacFarlane and Lundberg 2005). Again, no detailed attention
80  was paid to stratification, other than to demonstrate that all finds were stratified beneath a
81  flowstone floor.  This is hardly surprisingly given the lack of adequate and safe lighting and the
82  extremely difficult conditions under which the excavators worked.

83  Later researchers such as Leslie Armstrong, who dug at Creswell Crags from the early 1920s, typically
84  controlled their excavation by measured units.   Armstrong controlled his excavation in Pinhole Cave
85  by 1 foot 'boxes' with distances measured in from a datum at the cave mouth and down from a
86  prominent flowstone floor which capped the deposits, enabling recognition of distinct cultural and
87  faunal horizons in the cave fill (Jenkinson 1984; Hunt 1989; Jacobi et al. 1998).

88  The advent of radiometric dating methods has completely changed approaches to the chronology of
89  cave fills and their archaeology.  The first radiocarbon dates required the collection of several
90  hundred grams of charcoal and were extremely expensive, but they revolutionised understanding of
91  the antiquity of modern humans in many parts of the world (Wood, this volume). Thus, for example,
92  the dating of charcoal associated with the 'Deep Skull' of Niah to ~42,000 (radiocarbon) years ago
93  (Harrisson 1959) made this for many years the oldest human remains known anywhere on the
94  planet (Barker et al. 2007a).

95  Lack of attention to sediments, stratification and stratigraphy is evident in some publications up to
96  the middle of the last century, and even as late as McBurney (1967) and Harrisson (1964, 1970).
97  Thus, McBurney (1967) recognised natural layering in his trench sides in the Haua Fteah (Libya) but
98  his arbitrary excavation units cut across this.  Similarly, at Niah, Harrisson (1964, 1970) rejected the
99  complex stratigraphy visible in the baulks of his excavations. In both cases, linear extrapolation of a
100  handful of dates resulted in very simple vertical-accretion models which did not recognise the
101  complexity and discontinuity of sedimentation in these caves (Hunt et al. 2010; Gilbertson et al.
102  2005, 2013).  Their chronological systems relied on observations of a 'continuous drizzle' of material
103  falling from cave roofs and this was extrapolated as a continuing process operating at broadly steady
104  rates for millennia. This type of uniformitarian approach and the assumptions behind it were not
105  uncommon in analyses of cave sedimentation at this time (Anderson 1997).  Work of significantly
106  higher quality was done, however, by some mid-Century archaeologists and their geoarchaeologist
107  colleagues (e.g. Movius 1963, 1975, 1977; Farrand 1975).

108  More recently, excavation by sedimentary context has become widespread, although by no means
109  universal.   This important innovation enabled sampling at the level of the depositional event in
110  geomorphologically-active caves, enabling the sophisticated analysis of archaeological site formation

111    and thus a fine-resolution dissection of human behaviour (for instance Movius 1977; Butzer 1984,
112    1986; Farrand 2001).

113    In recent years, as the general quality of excavation, stratigraphic work and recording has risen, the
114    capabilities and resolution of dating techniques have also improved.  The average number of dates
115    per project has sharply increased because dating laboratories have increased capacities and
116    relatively reduced costs for dates.  Innovations including the now almost-universal Accelerator Mass
117    Spectrometry, the ABOX stepped-combustion technique for charcoal (Bird et al. 1999), the
118    ultrafiltration technique for bone (Higham et al. 2006) and dating the bone-specific amino acid
119    hydroxyproline  (Marom et al. 2013) have decreased sample sizes, considerably increased the
120    accuracy of radiocarbon dating and the range of reliably datable materials.  The INTCAL project has
121    enabled radiocarbon dates to be calibrated to calendar years back to 50,000 years ago (Reimer et al.
122    2013; Hogg et al. 2013; Wood, this volume).

123    Many other dating methodologies have also been refined, for instance the single grain technique
124    (Olley et al. 1999; Murray and Wintle 2000) has dramatically improved the accuracy of optically-
125    stimulated luminescence.  Careful application of individual dosimetry for flints, together with
126    investigation of their localised mineralogical context has improved the reliability and precision of the
127    Thermoluminescence technique, (Mercier et al. 2007), while application of a variation on the SAR
128    protocol has enabled use of smaller and older samples, fewer dose points and less machine time for
129    dates (Richter and Krbetschek (2006). The use of laser ablation has enabled microsampling and
130    refined dating of bone, teeth and flowstone using the Uranium-series technique (e.g. Pike et al.
131    2005; Grün et al. 2005), while Diffusion-Adsorption Modelling (Millard and Hedges 1996; Pike et al.
132    2002) has enabled the post-depositional uptake of uranium in bone to be allowed for (Grün et al.
133    2014).  The U-Pb method has extended the range of Uranium-series dating well beyone the first
134    hominins (Pickering and Hellstrom this volume). Electron Spin Resonance (Grün 1989; Schwartz and
135    Grün 1992) has provided dates beyond the range of the Uranium/Thorium technique and is often
136    used in conjunction with Uranium-series dating (e.g. Grün et al. 2005), Amino-acid racemisation,
137    which has had a chequered history, is now providing reliable relative dates on bird eggshell,
138    mammalian tooth dentine and mollusc shell (e.g. Clarke et al. 2007; Penkman et al. 2008; Torres et
139    al. 2014).

140    Developments of modelling and statistical techniques have also resulted in advances in dating
141    resolution and chronology construction.  The outstanding example is the widely-used Oxcal Bayesian
142    program (Ramsey 1995) which enables modelling of dates and construction of chronologies, but
143    alternative Bayesian and non-Bayesian modelling approaches are also  available (e.g. Blaauw 2010;
144    Blaauw and Christen 2011; Shao et al. 2014).

145

**Chronological patterns in cave fills – indications of complex taphonomies**

147    It is becoming increasingly apparent that the chronological pattern in some archaeologically-
148    important caves is not straightforward (e.g. Jacobi et al. 1998; Barker et al. 2007a; David et al. 2007;
149    Mallol et al. 2009; Kourampas et al. 2009; Higham et al. 2010; Bar-Yosef and Bordes 2010; Bordes
150    and Teyssandier 2012; Russell and Armitage 2012; Hunt and Barker 2014; Yravedra and Gómez-
151    Castanedo 2014).  Similar conclusions may be drawn from some high-resolution analyses and
152    refitting studies of archaeological artefacts (e.g. Jacobi et al. 1998; Bordes 2003; Bernatchez et al.
153    2010; Staurset and Coulson 2014) and from detailed sediment and micromorphological analysis (e.g.
154    Bar-Yosef et al. 1996; Albert et al. 1999; Karkanas et al. 2000; Goldberg 2000; Weiner et al. 2002;
155    Karkanas and Goldberg 2010;  Berna et al. 2012; Inglis 2012).

156 Recognition of complex chronological patterns may have major implications for archaeological
157 understanding.  For instance, the recognition of mixing of younger and older materials in the
158 Chatelperronian layers at Grotte de Renne by Higham et al. (2010) removes the security of the
159 association of Neanderthal fossils from artefactual evidence for behavioural complexity that had
160 been claimed previously at this site.  At the Abri Pataud, high-precision dating provides compelling
161 evidence for the shortness of the occupation phases (Higham et al. 2011).  Dating can also explore
162 evidence of contemporaneity.  Thus, the Deep Skull of Niah was dated to ~35 ka BP but dates on
163 adjoining contexts were dated to ~42 ka BP.  The dating complements geochemical, mineralogical
164 and palynological evidence that this important fossil is an early burial (Hunt and Barker 2014).

165 Fundamentally, any assessment of the archaeology of a cave relies on the detailed understanding of
166 the chronology of sedimentation (and re-sedimentation).  The next section outlines new evidence
167 for chronological incoherence caused by erosion and re-deposition at the Haua Fteah.  This type of
168 chronological incoherence is widely seen as problematical, but it is, in fact, highly informative in
169 terms of site formation processes and taphonomy.

170

171 **New high-resolution work at the Haua Fteah**

172 The Haua Fteah (NE Libya), originally excavated by McBurney (1967) has been the subject of recent
173 reinvestigation using carefully-controlled single-context excavation augmented by a large-scale
174 scientific program (Barker et al. 2007b, 2008, 2009, 2010, 2012; Simpson and Hunt 2009; Hunt et al.
175 2010, 2011; Inglis 2012; Russell and Armitage 2012; Rabett et al. 2013; Douka et al. 2014; Hill 2014;
176 Simpson 2014).  Re-analysis of the sedimentary sequence shows the prevalence of wash and small-
177 scale mudflow in the accumulation of the Haua sequence (Hunt et al. 2010, Inglis 2012).

178 As part of the work on the cave, previously-unpublished high-resolution dating of the Holocene and
179 Late Pleistocene sequence was carried out by Evan Hill.  Exploratory dates on charred seeds showed
180 a considerable spread suggestive of recycling (Hunt et al. 2010; J. Morales pers. comm 2011). Land
181 snails were therefore selected for this exercise because they were judged to be significantly less
182 durable and thus less likely to survive recycling than charred plant macrofossils.  Multiple samples,
183 each consisting of a single land snail (*Helix melanostoma* Drap.) were AMS radiocarbon dated from
184 each sedimentary context.  The samples were calibrated using Calib 7.1 and dates were adjusted for
185 metabolic fractionation using a method based on assessment of fractionation in modern specimens.
186 Details are given in Hill (2014).

187 An OxCal plot (Fig. 1) shows that most contexts studied show a considerable range of dates.  Some
188 layers, most notably contexts 11001-11011, contained spreads of dates of as much as 6000 years.
189 Other contexts contained very tight clusters of dates.  There is a distinct tendency for those contexts
190 which accumulated through high-energy processes such as debris-flows – the origin for contexts
191 11001-11010 – to contain comparatively large spreads of dates.  Those contexts which accumulated
192 in quieter conditions, such as the silts of context 11018, in contrast, contain very tight clusters of
193 dates.

194

195 Fig. 1. Oxcal plot of radiocarbon dates on *Helix melanostoma* showing recycling and redeposition in
196 the upper part of Trench M in the Haua Fteah (data from Hill 2014).

197

198 Where there is a spread of dates, the youngest date in each context most probably provides a point
199 in time shortly before the context accumulated in its present location.  Older specimens in the

200 context likely accumulated on the cave floor or were present in previously-deposited sediments and
201 were then incorporated in their present context by erosion and deposition by high-energy processes.

202 This data thus most probably indicates episodes of erosion and relocation of stored sediment in the
203 Haua Fteah.  Erosion went no deeper than sediments accumulated over the 6000 years prior to the
204 terminal deposition event for a context.  Alternatively there were stillstands of up to 6000 years
205 between depositional events, where land snails and other material accumulated as a palimpsest on
206 the cave floor, as suggested by Farrand (2001).  In either case, it is likely that recycling of sediments
207 and molluscs was accompanied by localised recycling of other materials including artefacts, faunal
208 and floral remains.

209 As an example of other material involved in recycling, we provide an excerpt of the previously-
210 unpublished palynological work by David Simpson (Fig. 2).  This covers approximately the same
211 stratigraphic interval as shown in Fig. 1.  Low-impact preparation methods were used to minimise
212 damage to poorly-preserved palynomorphs (details in Simpson 2014). Sampling in this work followed
213 sedimentary contexts but used a 5 cm sample interval in contexts thicker than this distance.

214

215 Fig. 2. Summary pollen diagram of the upper part of the Middle Trench in the Haua Fteah.  The
216 diagram covers approximately the same stratigraphic interval as that in Fig. 1. Data from Simpson
217 2014).

218

219 The pollen assemblages from this sequence are dominated either by *Pinus* or Asteraceae or a
220 combination of these taxa.  Also present are pollen of grasses, a wide variety of herbs, some maquis
221 species and some desertic taxa (Fig. 2). These assemblages are highly unusual and unlike soil pollen
222 and pollen-trap assemblages in the region around the Haua (Simpson 2014), so present difficulties
223 for interpretation.  *Pinus* is a prolific generator of wind-dispersed pollen. Stunted (usually less than 2
224 m high) *Pinus halepensis* is today very sparse in dry coastal steppe between el Atroun and Derna, to
225 the east of the Haua Fteah, so it is conceivable that high percentages of *Pinus,* with Poaceae and
226 other herbs, might be consistent with some sort of arid pine-scrub steppe, if the pine-dominated
227 assemblages are taken at face value.   Asteraceae, on the other hand, are often relatively
228 concentrated in cave sediments because of the activities of ground-nesting bees (Bottema 1975), so
229 it is by no means clear that the peaks of Asteraceae reflect anything more than periods where
230 insects colonised the cave floor.  *Pinus* and Asteraceae are, however, extremely resistant to
231 degradation in soils compared with most pollen types (e.g. Havinga 1984). It is therefore argued that
232 elements resistant to corrosion and bacterial degradation such as *Pinus* and Asteraceae would tend
233 to survive burial, exhumation and recycling during erosion episodes better than less resistant taxa.
234 These recycled grains would then have become re-incorporated into the sequence together with
235 pollen relating to the environment at the time of final deposition, thus leading to the extremely high
236 percentages for *Pinus* and Asteraceae (Fig. 2).  Fluorescence microscopy (Hunt et al. 2007) was used
237 to attempt a test of this hypothesis, but pollen from assemblages from the Haua did not fluoresce in
238 visible wavelengths, probably because of its general degradation in the cave sediments. Issues
239 relating to the archaeopalynology of caves are further explored in Edwards et al. (this volume).

240

241 **Processes of cave-mouth sediment deposition and re-deposition and their implications for**
242 **chronologies**

243 All caves are unstable and complex environments, not least because in geological terms they are
244 ephemeral features that go through a lifecycle of inception, formation, continued modification,

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245 unroofing and finally complete erosional removal.  Sediment generation, transport and deposition
246 are mediated by the cave morphology, parent rock lithology, bedding and joint patterns, by climate,
247 and by the activities of, and materials produced by plants, animals and people.  The predominant
248 sediment sources, transport and depositional media in cave photic zones are:

249 1.      From the cave walls and roof, from which material may be detached by dissolution, granular
250 disintegration, running water, action of ice and/or mineral salts, rockfall and stoping  (detachment of
251 rock or indurated sediment slabs from the cave roof)

252 2.      From external sources, by wind, rivers, the sea, glacial ice and/or mass-movement

253 3.      From solutes in groundwaters and meteoric waters through chemically and biochemically-
254 mediated deposition

255 4.      From the actions of animals, plants and humans in introducing and sometimes processing
256 inorganic and organic materials including lithics, nesting materials, bedding, food items, droppings,
257 scats, dung, firewood etc. and in introducing sediments on their feet.

258 The combined actions of these media and processes result in a considerable variety of sediments,
259 with deposition of particular facies resulting from the actions of particular groups of processes
260 operating in spatially-restricted areas (e.g. Goldberg and Sherwood 2006; Hunt et al. 2010; Canti and
261 Huisman this volume).

262 Cave sediments are inherently unstable and often prone to post-depositional movement and erosion
263 including by running water, the sea, mass movement, slumping, excavation by animals and people,
264 partial dissolution and subsurface erosion by running water, cavern collapse and, in tectonically
265 active zones, by faulting (Glover 1979; Gilbertson 1989; 1996; Bar-Yosef et al. 1996; Goldberg 2000;
266 Gilbertson et al. 2005, 2013; Dykes 2007; Soficaru et al. 2007; Burney et al. 2008; Yravedra and
267 Gómez-Castanedo 2014). Erosive processes often truncate sequences.  The solubility of ash,
268 carbonate and phosphatic minerals and prevalence of mineral-rich groundwater in karst landscapes
269 is of considerable importance for our understanding of cave sediment stratigraphies (Canti and
270 Huismann, this volume).  Minerals may dissolve and reprecipitate as a result of changes in carbon
271 dioxide partial pressure, dilution in pore and surface waters, concentration by evaporation and as a
272 response to acidity and redox gradients caused by the presence of decaying organic matter
273 (Karkanas et al. 2000, Goldberg 2000; Weiner et al. 2002; Shahack-Gross et al. 2004; Stephens et al.
274 2005; Canti and Huisman, this volume).  Mineral dissolution and organic decay may cause major
275 changes to sediment volume (Glover 1979; Karkanas et al. 2000; Goldberg 2000) and consequent
276 slumping.   A further key issue associated with the circulation of chemically-active fluids within cave
277 sediments is the often-deleterious impact of these fluids on the preservation of organic remains,
278 through dissolution, disruption by crystal growth and so forth (e.g. Shahack-Gross et al. 2004;
279 Stephens et al. 2005; Canti and Huisman this volume).

280 Conversely, precipitation of minerals may armour surfaces against erosion and provide complete or
281 patchy stability to what otherwise would be structurally-weak sediments.  Dissolution or erosional
282 removal of unconsolidated sediments may leave 'bridges' of indurated material behind: later infill of
283 the voids under these 'bridges' may lead to stratigraphic inversions (Coles 1989; Rowe et al. 1989).

284 Modern geoarchaeological techniques provide ways to identify evidence of past instability and
285 sediment movement, solution and reprecipitation (Canti and Huisman, this volume).  Various
286 taphonomic indicators may also provide indications: these include

287 • ecologically-incoherent faunas and floras,
288 • the presence only of chemically-resistant body parts such as teeth,

- the presence of indicators of transport such as abrasion, rounding and disarticulation of elements,
- winnowed assemblages, where, for instance there are concentrations of dense, large elements at the bottom of layers laid down by high-energy processes, or concentrations of light, easily-transported elements, typically in fine-grained deposits resulting from ponding.

Close-interval dating provides another tool in the cave geoarchaeologist's toolkit, since it will provide evidence of dating reversals and of chronological incoherence, as discussed above (Fig. 1). In this case the archaeologist must consider the degree to which the archaeology from layers with evidence of chronological incoherence may be *in-situ*, and the chronological resolution possible, when assessing evidence for human behaviour.

There is a general relationship between the energy of processes of deposition, the sedimentation rate and the degree of chronological resolution (caricatured in Fig. 3). At very low sedimentation rates, poor chronological resolution is likely. In many sites, most of the time encompassed by depositional sequences is not recorded in the sedimentary record except as hiatuses between layers. For instance Hunt et al. (2010) recognised no more than 22 depositional episodes, most lasting for not more than a few minutes, during the Holocene in the Haua Fteah. This leads to the possibility that several phases of human activity may be condensed into a palimpsest (Farrand 2001). With low sedimentation rates and high process energy, particularly with water flows, there is a good chance that lighter artefacts will be removed (winnowed) from the deposition site, leaving only a lag of large artefacts and the heavier skeletal elements. As sedimentation rate rises, if process energy remains low, then chronologically-defined horizons will become more widely separated. With increasing process energy, however, there is an increasing probability that erosion of previously – deposited sediment will occur, and that the resulting contexts will contain recycled as well as *in-situ* material.

Fig. 3. Conceptual model of the relationship between sedimentation rate, process energy and the probability of chronologically-resolved in-situ archaeology.

**Conclusion**

It is quite probable that the days of heroic-scale cave excavations are limited, simply because in the current climate of financial austerity the level of resources necessary for a major cave excavation will be only very infrequently available. Further, most of the early cave excavations took place with almost total disregard for health and safety, something that we could not contemplate today.

Cave sediments are often staggeringly rich in a very wide variety of material and are likely to be complex chronologically and in three dimensions. The quantities of material preserved in cave fills can be enormous: it is estimated that over half a million finds were generated during McBurney's (1967) excavation of the Haua Fteah (G. Barker, pers. comm. to COH, 2006). It is essential that new excavations are embarked upon with the expectation of recovering this range and abundance of material and to take account of the sheer richness and unpredictability of the cave record, with detailed plotting in three dimensions of sedimentary facies, fossils and artefacts and high-resolution dating and geoarchaeological sampling. It follows that archaeological materials should be analysed in conjunction with the chronological, environmental and taphonomic datasets from excavations, rather than becoming detached from them. This approach will enable us to focus our attention on the human behaviours in the context of environmental change and the physical, chemical and biotic processes which together led to the formation of the cave archaeological record.

333 We suggest that reappraisal of many previously-excavated cave fills and the assessment of new
334 excavations using the sophisticated dating and modelling methods now available will result in the
335 increasing recognition of chronological complexity.   Quantifying this complexity in any depositional
336 unit will become important in assessing the degree of interpretation which may be applied to the
337 archaeology from that context.

338 At present, innovation in dating and chronology-building techniques applicable to cave sediment
339 sequences appears to be in a healthy state.   The new methodologies mentioned in this short review
340 offer enormous possibilities for archaeological research, particularly when applied in conjunction
341 with the geoarchaeological methodologies described by Canti and Huisman (this volume) and the
342 multitude of other archaeological science techniques recorded in the pages of this journal.

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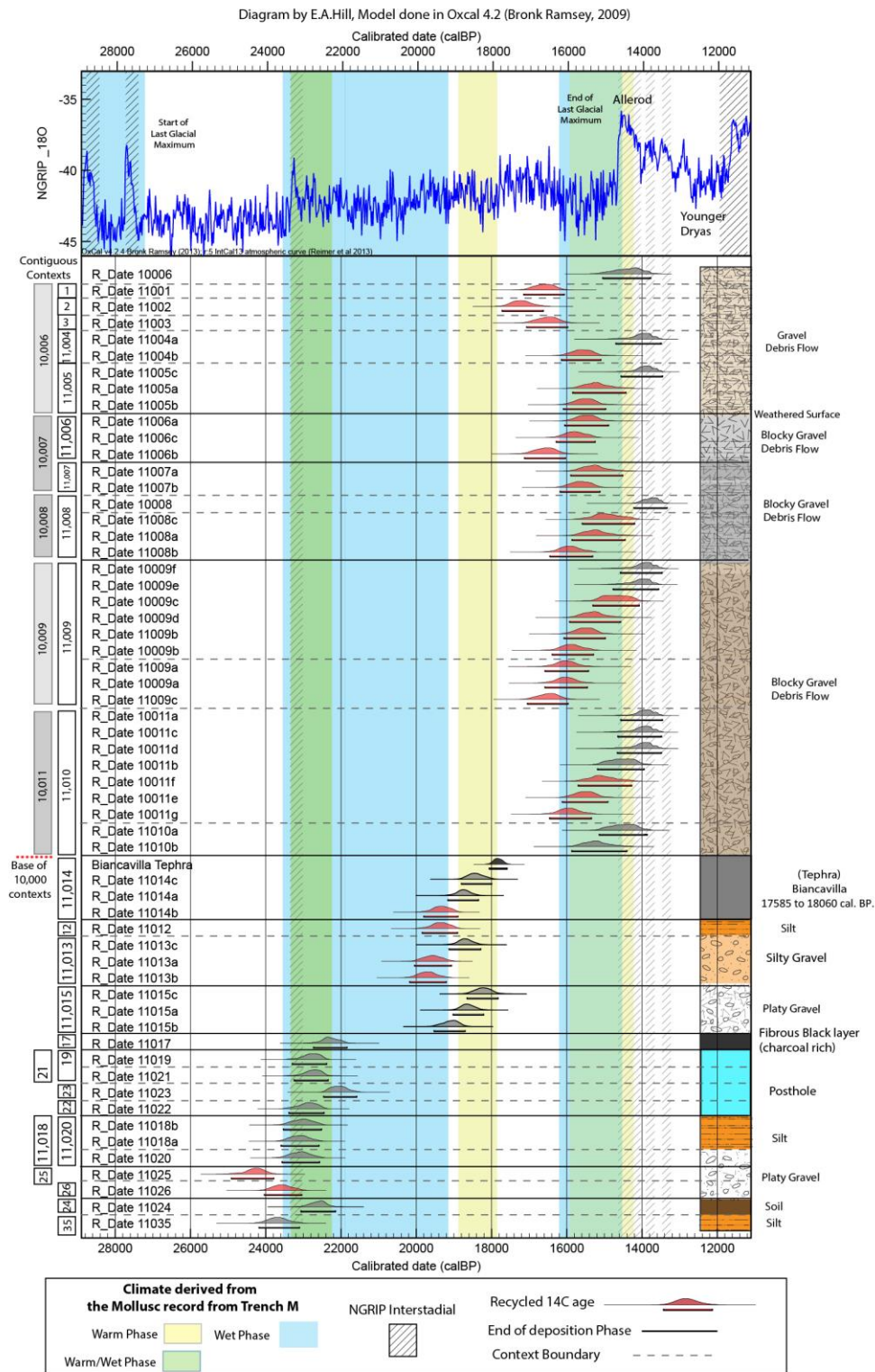629    dating

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Fig. 2. Summary pollen diagram of the upper part of the Middle Trench in the Haua Fteah. The diagram covers approximately the same stratigraphic interval as that in Fig. 2.
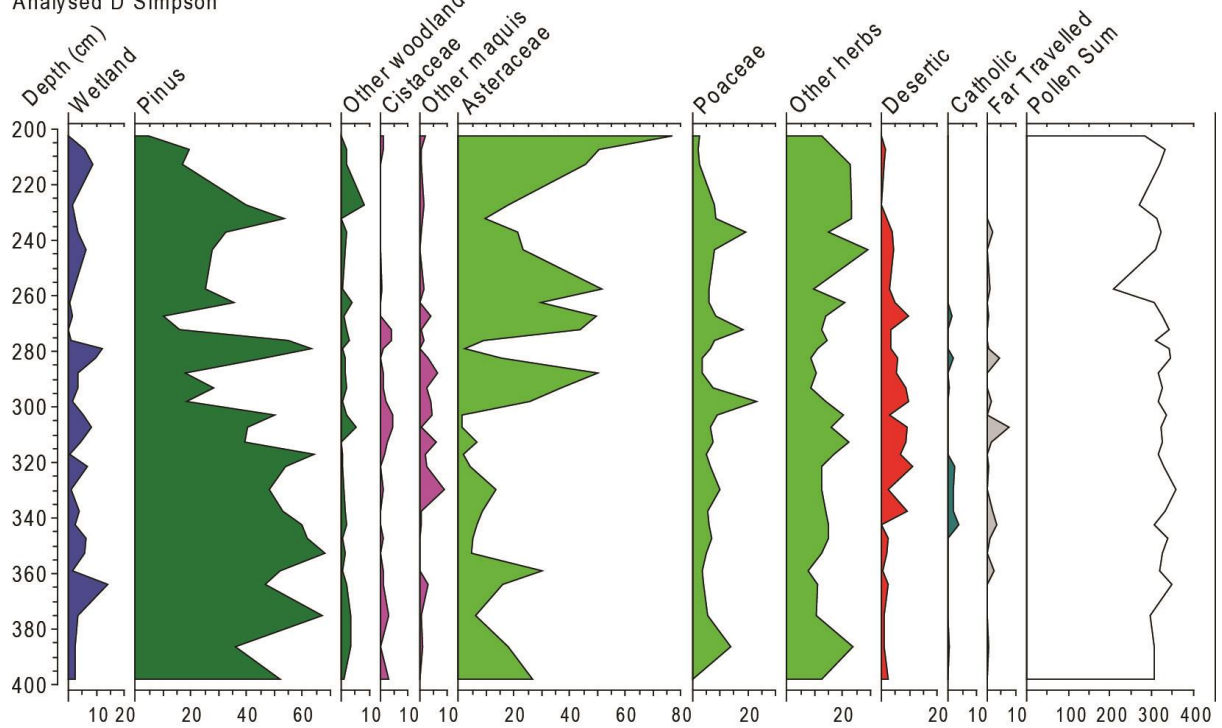


Haua Fteah Main Section (part)

Analysed D Simpson

657 Fig. 3. Conceptual sketch of the relationship between sedimentation rate, process energy and the
658 probability of chronologically-resolved *in-situ* archaeology.



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