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

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ABSTRACT

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

1. Introduction

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

In the early days of Archaeology, caves provided some of the most important evidence for human antiquity, such as the demonstration by Pengelly et al. (1873) of the association of humanly-shaped artefacts with the bones of extinct animals. Caves were the source of the first Neanderthal skeletal material (e.g. Schaafhausen, 1861; Fraipont and Lohest, 1887), indicating for the first time that other human species had existed in the past, thus being seen to validate early evolutionary theory (e.g. Huxley, 1863). The recognition of changing material culture through time, although partly realised from open-air sites, was also further demonstrated and refined from cave excavations. Some of the most important early expositions of regional Palaeolithic and later sequences came from caves in France (Lartet and Christie, 1875; de Mortillet 1885; Laville et al., 1980) and the UK (Pengelly et al., 1873; Dawkins, 1874). Examples among many influential later expositions of key cave sequences are those for La Ferassie, France (Peyrony, 1934; Delporte, 1984), Taforalt, Morocco (Roche, 1953),

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Shanidar Cave, Iraq (Solecki, 1955, 1963), the Haua Fteah, Libya (McBurney 1967), Niah Cave, Borneo (Harrisson, 1964, 1970) and Franchthi Cave, Greece (Jacobsen and Farrand, 1987).

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

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

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

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

More recently, excavation by sedimentary context has become widespread, although by no means universal. This important innovation enabled sampling at the level of the depositional event in geomorphologically-active caves, enabling the sophisticated analysis of archaeological site formation and thus a fine-resolution dissection of human behaviour (for instance Movius, 1977; Butzer, 1984, 1986; Farrand, 2001).

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

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

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

2. Chronological patterns in cave fills – indications of complex taphonomies

It is becoming increasingly apparent that the chronological pattern in some archaeologically-important caves is not straightforward (e.g. Jacobi et al., 1998; Barker et al., 2007a; David et al., 2007; Mallol et al., 2009; Kourampas et al., 2009; Higham et al., 2010; Bar-Yosef and Bordes, 2010; Bordes and Teyssandier, 2012; Russell and Armitage, 2012; Hunt and Barker, 2014; Yravedra and Gómez-Castanedo, 2014). Similar conclusions may be drawn from some high-resolution analyses and refitting studies of archaeological artefacts (e.g. Jacobi et al., 1998; Bordes, 2003; Bernatchez et al., 2010; Staurset and Coulson, 2014) and from detailed sediment and micromorphological analysis (e.g. Bar-Yosef et al.,