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Pollen taphonomy of cave sediments: What does the pollen record in caves tell us about external environments and how do we assess its reliability?

Chris O. Hunt*, Marta Fiacconi

School of Natural Sciences & Psychology, Liverpool John Moores University, Liverpool, L3 3AF, UK

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ABSTRACT

Cave sediments may contain important long-term records of past environments and human activity. Pollen provides key evidence, since it disperses widely and is relatively durable. We still know relatively little about the dispersal of pollen into caves, and its preservation within cave sediments, compared with our relatively detailed knowledge of pollen taphonomy in other sedimentary environments. Pollen taphonomy in caves is dependent on a variety of transport pathways and seems to be very contingent on local circumstance. The airfall component of cave pollen assemblages often seems comparable with airfall spectra in the landscape outside the cave, but bees, birds and bats may transport considerable quantities of pollen into caves, and the entrance-flora may also be significant. Cave sediments are rarely waterlogged and pollen within them can be subject tomicrobial and chemical degradation. Sedimentation in caves is often episodic, with episodes of storage and deposition, sometimes redeposition of sediment, which means that biostratinomic, preservational, factors become very significant. Comparison with sequences outside caves is difficult because few caves are found in landscapes where there are comparable pollen records from lakes and bogs. Here we review the factors affecting cave pollen taphonomy and hence the reliability of palynological analysis of sediments from caves, with suggestions for future investigation.

1. Introduction

Cave sediment sequences often accumulated over hundreds of thousands of years (e.g. Bouzouggar et al., 2007; Douka et al., 2014; McFarlane and Lundberg, 2005). They contain important sedimentary evidence for environmental change plus archaeological and palaeobiological materials indicating cultural practises and environmental change — including lithics, animal bones, mollusc shell, eggshell, pollen, plant macro-remains such as seeds and charcoal (e.g. McBurney, 1967; Bailey 1997; Barker et al., 2007; Barker, 2012; Bouzouggar et al., 2007). With multidisciplinary study of cave sequences, we can piece together a relatively rounded understanding of the sequence of human activity and its changing environmental context.

Pollen assemblages are, *in potentia*, a key line of evidence in the study of cave sequences. Pollen assemblages from non-cave depositional environments such as bogs and lakes are used widely to infer past environments (Faegri and Iversen, 1975; Faegri et al., 1989; Moore et al., 1991). Pollen thus provides a potential link between the cave and its wider landscape context, because pollen grains and spores, which are produced by plants living in the landscape outside the cave, are known to disperse widely by both wind, insect and vertebrate vectors (Englund, 1993; Nason et al., 1996; Hunt and Rushworth, 2005; Jha et al., 2010; Šikoparija et al., 2013). This dispersal may take pollen into caves where they may be preserved by being buried in accreting sediments. Although pollen has been used in an increasing number of cave investigations (e.g. Schutrumpf, 1939; Derville and Firtion, 1951; Welten, 1954, 1956; Van Campo and Leroi-Gourhan, 1956; Anderson, 1955; Donner and Kurten, 1958; Martin et al., 1961; Solecki and Leroi-Gourhan, 1961; Bryant, 1974; Leroi-Gourhan, 1975; Gale and Hunt, 1985; Gale et al., 1993; Carrión et al., 2001; Caseldine et al., 2008; Djamali et al., 2011; Festi et al., 2016; Gatta et al., 2016; Hunt et al., 2016; Linstädter et al., 2016), our knowledge of the how representative of outside environments cave pollen assemblages might be is still fairly insubstantial, relative to our understanding of

* Corresponding author.
E-mail address: Hunt@ljmu.ac.uk (C.O. Hunt).

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taphonomic processes in bogs and lakes, which are often the preferred environments for pollen research in regions where they exist. This matters because without a robust understanding of taphonomy it is not completely clear how much of the pollen signal reflects environmental events in the world outside the cave, and how much reflects taphonomic processes, in any given case. This paper therefore reviews the state of the art in cave pollen taphonomy, identifies wide-scale trends and patterns and suggests research directions for the future.

2. The concept(s) of taphonomy

The term ‘taphonomy’ was coined by Efremov (1940). It is the science of the route by which living organisms become fossilised (Behrensmeyer and Kidwell, 1985). Pollen taphonomy can be conceptualised as the processes of necrolysis (by which organic materials such as pollen grains are generated and dispersed), biostratinomy (in which they are transported, deposited and buried) and diagenesis (in which buried materials come into equilibrium with the burial environment after deposition). Thus, pollen taphonomy includes a sequence of necrolytic processes through which pollen grains are generated in the male organs of plants, and dispersed by vectors such as insects, birds, mammals, wind and water. Then follow biostratinomic processes, firstly of transport in the environment by these and other vectors, then deposition, burial and preservation resulting from a variety of sedimentary and diagenetic processes (Fig. 1).

3. Necrolysis: pollen dispersal

In nature, plants produce pollen and disperse it to other plants (in most cases: there are a few self-pollinators) as part of their reproductive cycle. Dispersal is generally either by wind (anemophilous pollen such as pine, oak and grass) or by animal vectors such as bees, flies or beetles (entomophilous pollen such as that of the daisy family [Asteraceae]) bats and birds (zoophilous pollen such as the mangrove *Sonneratia*), although a few taxa, such as the marine eel-grasses, have pollen grains without preservable exines that disperse in water.

4. Biostratinomy

Pollen can be dispersed into caves by the vectors utilised by the plants (wind, insects, bats and birds in particular), but it may also enter caves by indirect means, carried by secondary vectors or processes after original deposition in the landscape. A variety of transport pathways, very contingent on local circumstance, are known from studies of pollen taphonomy in caves (e.g. Van Campo and Leroi-Gourhan, 1956; Dimbleby, 1985; Coles, 1988; Burney and Piggott Burney, 1993; Coles and Gilbertson, 1994; Prieto and Carrión, 1999; Navarro Camacho et al., 2000; Navarro et al., 2001, 2002; Hunt and Rushworth, 2005; Simpson and Hunt, 2009; de Porras et al., 2011). These biostratinomic processes are usually regarded as a linear sequence, but pollen grains are durable enough and some cave environments sufficiently dynamic geomorphologically that recycling can occur. This means that sediments and their contained pollen can be eroded and redeposited (Hunt et al., 2015) on more than one occasion in the history of a pollen grain.

Biostratinomic processes include:

4.1. Direct fallout from the cave entrance flora

At Creswell Crags, in caves such as C7 and Dog Hole Cave, spores derived from the cave-entrance fern flora comprised between a 25 and 40% of the annual palynological fallout (Coles and Gilbertson, 1994). This phenomenon seems to be most marked in small humid caves subject to little human activity, with luxuriant cave-mouth vegetation. It is less marked in larger caves, and in caves where the cave-mouth flora is restricted at Creswell (Coles and Gilbertson, 1994). In the wet tropical forest zone, fern spores, derived mostly from the entrance flora are between 20 and 40% of the total annual fallout in the very large cave-mouth of the Great Cave of Niah (Hunt et al. in press). The contribution of the entrance

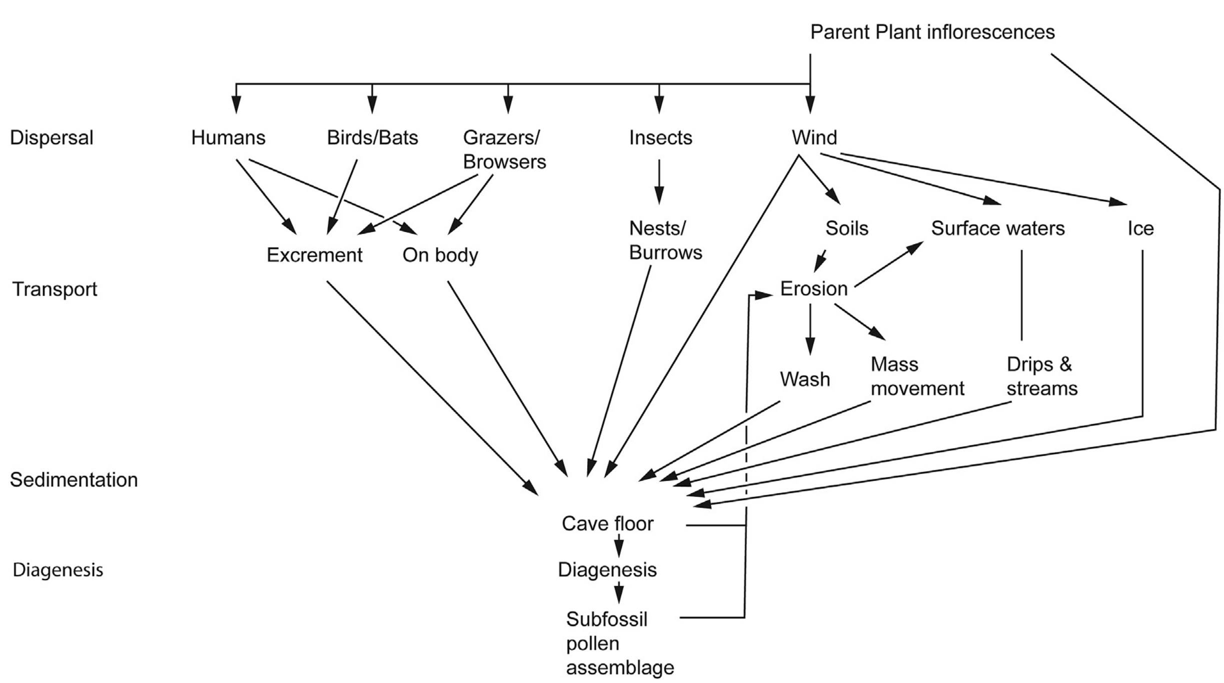

Fig. 1. Sketch of taphonomic pathway from vegetation outside caves to the subfossil pollen assemblages in cave deposits.

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