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Charcoal recognition, taphonomy and uses in palaeoenvironmental analysis

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ABSTRACT

Charcoal, predominantly the product of wildfires, is abundant in many sedimentary rocks deposited in a wide range of environments, from terrestrial to marine. It also occurs in some volcanic rocks. This paper outlines aspects of charcoal formation (both natural and experimental) and briefly considers the taphonomic processes leading to a final assemblage. This is done using examples from recent fires and through experimentation. The ways in which charcoal assemblages are recognized in the field and extraction in the laboratory are also considered. Methods of charcoal identification are presented. The range of charcoalified plant organs that can be found is discussed and a wide range of study methods outlined (including light microscopy, dark field light microscopy, reflectance microscopy, scanning electron microscopy and synchrotron radiation X-ray tomographic microscopy). Emphasis in this paper is on the study of macro- and meso-charcoal (above180 µm). Finally there is a consideration of the broad use of charcoal from plant evolution studies, fire history studies, vegetation studies, anatomical studies, climate and atmospheric studies and the wider importance of charcoal for the Earth and Biological Sciences. Charcoal is information rich but yet is an under-utilized resource.

1. Introduction

Charcoal occurs predominantly as a product of wildfire (Kuhlbusch and Crutzen, 1996; Bird, 1997; Schmidt and Noack, 2000). It has two fundamental characteristics: the anatomy of the plant is preserved in pieces over a few microns in size (Fig. 1d, Scott, 2001) allowing taxonomic identification; is relatively inert (Scott and Glasspool, 2007) and easily preserved (Scott and Jones, 1991b) in the fossil record (Scott, 2000). Charred materials are the product of the incomplete combustion of vegetation, resulting from the processes or pyrolysis (Goldberg, 1985). The continuum of combustion products such as char, ash and charcoal are commonly referred to as black carbon (BC) (Forbes et al., 2006). Charcoal typically has a high carbon content (60–90%), a proportion of which has a highly condensed aromatic molecular configuration (Eckmeier et al., 2007a,b). Macroscopic and mesoscopic charcoals typically preserve anatomical information (Scott, 2001). Charcoal also floats for a considerable time (hours, days or weeks) before becoming waterlogged (Nichols et al., 2000) and hence can be transported long distances before being deposited and incorporated into sedimentary sequences, not only in terrestrial and non-marine sequences but also in to near-shore shallow marine and even in to deeper marine shelf sediments (Masiello and Druffel, 1998; Forbes et al., 2006). Microscopic charcoal, although not taxonomically identifiable, may be windblown and is found from terrestrial to deep oceanic deposits where they provide a record of wildfire (Smith et al., 1973; Griffin and Goldberg, 1979; Goldberg, 1985; Herring, 1985; Peters and Higuera, 2007; Power et al., 2008; Marlon et al., 2008, 2009 — see Power et al., 2010-this issue).

The charring process has some, but quantifiable, effect upon the stable isotopic value of the plants (Poole et al., 2002; McParland et al., 2007) so that the distinction of, for example, C3 and C4 plants can even be made from microscopic charcoal (Pessenda et al., 1996; Beuning and Scott, 2002; Gouveia et al., 2002; Czimczik et al., 2002).

Despite the common occurrence of macroscopic charcoal in sedimentary rocks (Scott, 2003), it is often overlooked by geologists, sedimentologists and palaeontologists. This is partly because of a lack of recognition — there is not an understanding of how charcoal might be recognized in the field (Fig. 2). However, as important is the possibility that neither the ways in which charcoal may be studied, nor the potential use of such studies, are appreciated (Fig. 3). This is surprising, given the high profile of some charcoal discoveries. A good example is the widespread occurrence of early angiosperm flowers in the Cretaceous and their role in unraveling early angiosperm evolution (Schönenberger, 2005; Friis et al., 2006). Despite the high profile of such work, there are relatively few broad studies of Cretaceous charcoal assemblages, given their abundance (Herendeen et al., 1999; Eklund et al., 2004).

In more recent geological studies the use of macroscopic charcoal has been predominantly for radiocarbon dating (Bird, 2006).

It may be that the study of charcoalified plants is seen as a specialism. However, such an approach does not prevent exceptionally

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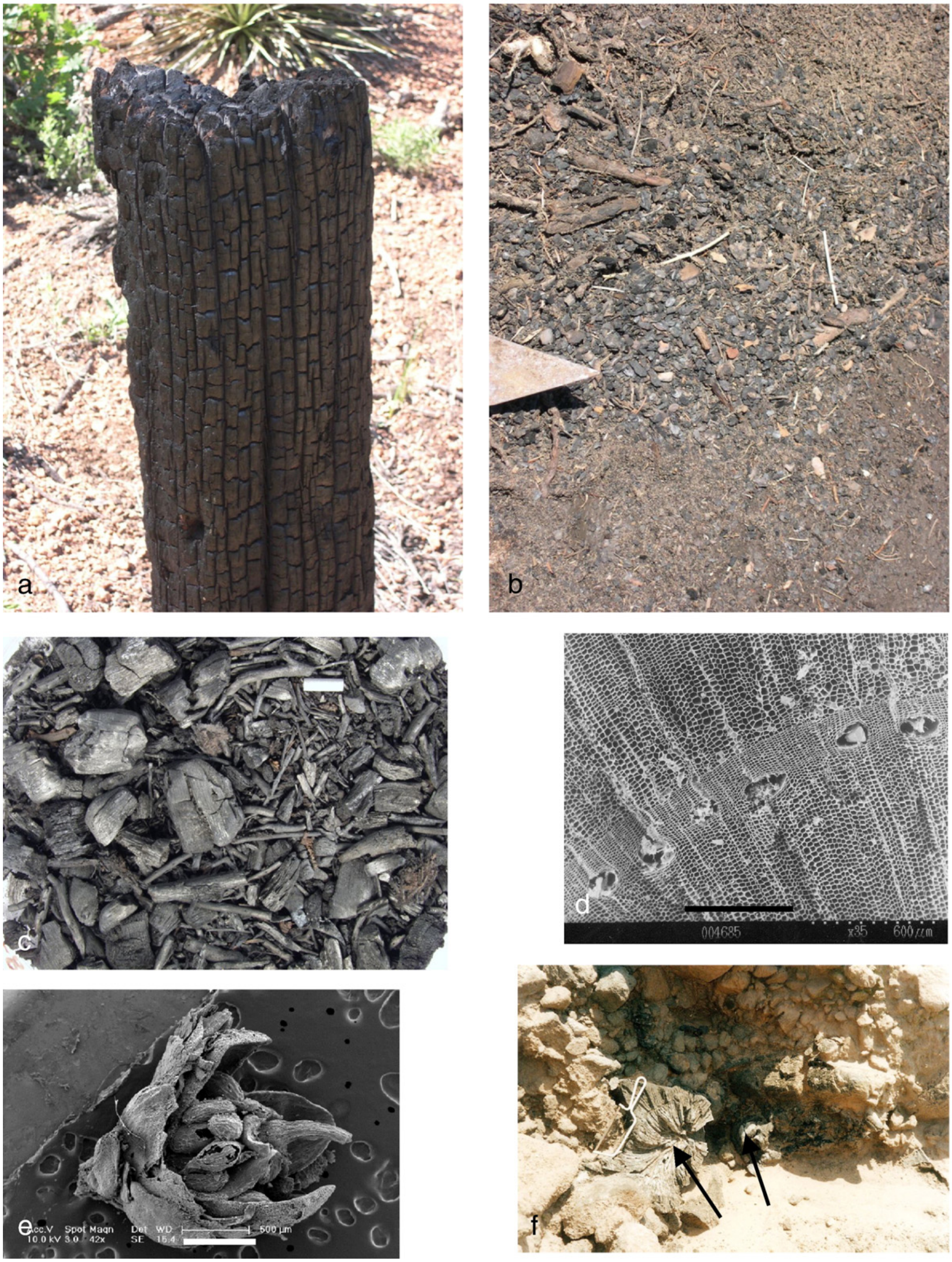

Fig. 1. The occurrence of charcoal in recent environments. a) Charred dead tree stump, Buffalo Creek Fire (1996, see Moody and Martin, 2009), Colorado showing typical cracking pattern. b) Charcoal in trap after single rainstorm, Hayman Fire (2002, See Graham, 2003), Colorado. c) Charcoal from charred litter layer from the Frensham Fire (1995, see Scott et al., 2000), Surrey England showing cubic pieces of pine (*Pinus*) wood charcoal and charred stems of *Calluna*. d) Scanning electron micrograph of pine charcoal illustrated in c. Scale bar 500 µm. e) Scanning electron micrograph of charred flower from the Thursley (2006) fire, Surrey, England. Scale bar 500 µm. f) Charcoalified trunk and logs (arrowed) from the 1996 block and ash flow, near Plymouth, Montserrat, British West Indies (see Scott and Glasspool, 2005).

preserved animals being widely collected and studied (Briggs, 2001). Charcoal assemblages have been considered fossil lagerstätten themselves (Glasspool et al., 2006). It is possible that palaeobotanical accounts of charcoalified plants that are published are in specialist journals and are not read by a non-palaeobotanical audience.