Available online at www.sciencedirect.com
ScienceDirect
International Journal of Coal Geology 70 (2007) 53–66
International Journal of COAL GEOLOGY
www.elsevier.com/locate/ijcoalgeo

Observations and experiments on the origin and formation of inertinite group macerals

Andrew C. Scott [a,*], Ian J. Glasspool [b,1]

[a] Geology Department, Royal Holloway University of London, Egham, Surrey, TW20 0EX, UK
[b] Geology Department, Field Museum of Natural History, 1400 S. Lake Shore Drive, Chicago, IL, 60605, USA

Received 30 December 2004; accepted 21 February 2006
Available online 30 June 2006

Abstract

The inertinite group macerals include fusinite, semifusinite, inertodetrinite, macrinite, micrinite and, funginite and secretinite, which together replace sclerotinite. The macrolithotype fusain comprises fusinite and semifusinite, and is now widely accepted as charcoal formed by wildfire activity. However, alternative origins for fusinite and semifusinite are still claimed. This paper considers the use of the terms pyrofusinite, degradofusinite, rank fusinite and primary fusinite misleading, while the definitions of the terms funginite and secretinite are also considered problematic. Observations made on modern, wildfire derived and volcanogenic, charcoal assemblages using reflectance and scanning electron microscopy, together with experimental charcoalification studies, demonstrate that most, if not all, inertinite macerals have acquired their optical and physical characteristics through the action of elevated temperatures. The criteria for the identification of charcoals produced by wildfire and volcanic activity are outlined and the role of the petrographic nomenclature system is discussed.

Keywords: Coal petrography; Inertinite; Macerals; Charcoal; Wildfire

1. Introduction

The ICCP define inertinite as "Inertinite is a maceral group that comprises macerals whose reflectance in low- and medium rank coals and in sedimentary rocks of corresponding rank is higher in comparison to the macerals of the vitrinite and liptinite groups" (ICCP, 2001). Inertinite comprises a range of macerals that includes fusinite, semifusinite, inertodetrinite, macrinite, micrinite, funginite and secretinite. Of these macerals, fusinite and semifusinite that comprise the macrolithotype fusain (Stopes, 1919, 1935) have had, perhaps, the most hotly debated origin (for a summary see Scott, 1989a, 2002). However, fossil fusain, and its constituent macerals are now generally accepted to be the products of charcoalification (incomplete combustion either as a result of wildfire or volcanogenic activity) (e.g. Cope, 1980, 1981; Scott, 1989a; Jones and Chaloner, 1991; Jones et al., 1991, 1996; Jones, 1991, 1993; Guo and Bustin, 1998; Bustin and Guo, 1999; Falcon-Lang, 2000; Glasspool, 2000; Scott, 2000, 2001, 2002; Uhl and Kerp, 2003), though alternative mechanisms of formation have been suggested for these macerals (e.g. Varma, 1996; Taylor et al., 1989, 1998), which have high reflectance

* Corresponding author. Fax: +1 44 1784 471780.
E-mail addresses: a.scott@gl.rhul.ac.uk (A.C. Scott), iglasspool@fieldmuseum.org (I.J. Glasspool).
[1] Fax: +1 312 665 7641.

0166-5162/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.coal.2006.02.009

when studied in polished blocks using reflected light (Teichmüller, 1989; Taylor et al., 1998). The origins of other inertinite group macerals have also been discussed over the past 25 years, most especially the nature and origin of sclerotinite (e.g. Lyons et al., 1982).

The publication of the new inertinite classification (ICCP, 2001) offers an opportunity to further consider the origin of the inertinite group macerals in the light of new observations and experiments. This paper presents observations on modern charcoal deposits formed by wildfire and provides additional experimental charcoalification data that supplements the work of previous authors (e.g. Scott, 1989a, 2000; Jones et al., 1991; Scott and Jones, 1991; Guo and Bustin, 1998; Bustin and Guo, 1999). The charcoalification of woods by volcanic processes (e.g. Correia et al., 1974) is also illustrated and discussed. The definition of the new maceral term funginite (ICCP, 2001) is reassessed in light of experimental charcoalification studies on the bracket fungus *Gandoderma*. These new data lead to broad considerations of the definition and use of inertinite macerals as a whole.

2. Observations on modern wildfire charcoals

The homology of the physical and chemical characteristics of fossil fusain and recent wood charcoal has led to the conclusion that the two terms are synonymous (Cope, 1980, 1981; Scott and Jones, 1991; Jones et al., 1993; Scott, 2000, 2001, 2002, 2003). Of particular note is the increase in reflectance observed in recent wildfire produced charcoals (Scott et al., 2000). Through this character alone, and using the ICCP definition (ICCP, 2001), modern charcoal can be equated with the inertinite group macerals. However, petrographically charcoals from modern wildfires show a much broader range of morphology than is encompassed by the macerals fusinite and semifusinite as defined.

2.1. Formation of charcoal

Pyne et al. (1996) have shown that for a fire to start and spread there needs to be three phases of combustion: pre-ignition, ignition, and combustion. These phases are discussed, more appropriately, elsewhere (e.g. Pyne et al., 1996; Scott, 2000) and are not detailed here. However, it is important to note that in the pre-ignition phase the temperature is raised by endothermic reactions so that water evaporates and volatiles are released (Pyne et al., 1996). The pyrolysis of the volatile gases generates tars and other liquid products that will burn in the presence of oxygen. Carbonaceous char (charcoal) and ash are preserved where combustion is incomplete. Therefore, charcoal forms in the absence of oxygen and is essentially a pyrolysis (heated in the absence of air) residue. It is important to note that charcoal is not formed by an 'oxidation' process. The temperatures reached during the charring process are also important. Low temperatures produce higher yields of flammable volatiles (Pyne et al., 1996). Cellulose, which is a fundamental building block of all plant cells and accounts for 70% of the cell wall in woody tissues, is relatively stable up to 250 °C. At 325 °C it begins to break down, generating flammable gases (Pyne et al., 1996). In contrast, lignin, which makes up the remaining 30% of the cell wall in woody tissues, is more stable and resistant to thermal degradation, and will tend to survive as a char product (Pyne et al., 1996).

It is important to note that a single fire can afford a great range of temperature; common flame temperatures may be 700–980 °C, while within the litter layer temperatures are often around 300 °C, elsewhere temperatures may reach 600 °C and remain high for several hours (Pyne et al., 1996). Our observations on modern wildfires indicate that crown fires do not produce significant quantities of macroscopic charcoal. Wind transported microscopic charcoal and other combustion products are the dominant material produced (Clark et al., 1998). In contrast, surface fires, where there is a fuel of either extensive litter (e.g. Hayman fire in Colorado, Graham, 2003) or shrubby vegetation (e.g. Frensham fire in the UK, Scott et al., 2000) may produce large quantities of charcoal (Fig. 1a).

2.2. Charcoal transport

Much microscopic charcoal is wind blown (Clark et al., 1998) and may be deposited away from the area of the fire (Clark and Royall, 1995). In contrast, most macroscopic charcoal incorporated into the fossil record is not wind blown (Ohlson and Tryerud, 2000) but water transported (Scott et al., 2000). Experiments indicate that the sedimentary behaviour of charcoal is governed by its size, organ type and temperature of formation in combination with more traditional sedimentological processes (Vaughan and Nichols, 1995; Nichols et al., 2000). In general, larger pieces of charcoal will float for longer than small pieces and may be transported further (Nichols et al., 2000).