

Dating recent peat profiles using spheroidal carbonaceous particles (SCPs)

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SUMMARY

This article provides a brief overview of spheroidal carbonaceous particles (SCPs) as age-equivalent stratigraphic markers in recent peat profiles. A detailed method for the extraction and analysis of SCPs is provided and specific limitations of the technique are discussed.

KEY WORDS: fly-ash, geochronology, Holocene.

1. INTRODUCTION

Spheroidal Carbonaceous Particles (SCPs) are a component of fly-ash formed by the incomplete high-temperature combustion of fossil fuels, and are therefore unambiguous indicators of atmospheric deposition from industrial sources including power generation (Griffin & Goldberg 1983, Wik & Renberg 1991, Rose 1995, Rose *et al.* 1995, Rose & Appleby 2005, Rose & Monteith 2005, Figures 1 and 2). SCPs are composed mainly of elemental carbon, unlike the smaller inorganic ash spheres (IASs), which are formed through the fusion of mineral inclusions within the fuel (Rose 1996, 2008). SCPs are well preserved in sediments (Rose *et al.* 1999a, 1999b) and have proved useful for reconstructing atmospheric pollution histories from lakes and peatlands (cf. Clymo *et al.* 1990, Rose *et al.* 2003), and as age-equivalent markers for dating stratigraphic sequences spanning the last ~150 years (Renberg & Wik 1984, 1985; Rose *et al.* 1995, Rose 2001, Yang *et al.* 2001a, 2001b; Hendon & Charman 2004, Swindles & Roe 2006). SCPs have proved particularly useful as chronological indicators in studies where researchers have compared recent peat-derived records with instrumental climate data (e.g. Charman *et al.* 2004, Hendon & Charman 2004, Schoning *et al.* 2005, Lamentowicz *et al.* in press).

The spatial distribution of SCPs in north-west and central Europe is now well understood (Rose *et al.* 1995, Rose 2001, Kamenik *et al.* 2009) and there are data from other regions, including those remote from sources (Rose 1995, Rose *et al.* 2003, 2004;

Korhola *et al.* 2002, Muir & Rose 2005, Nagafuchi *et al.* 2009, Martins *et al.* 2010). The regional chronology of SCP concentration changes is best established for the UK and Ireland using lake profiles dated by radiometric methods (Rose *et al.* 1995, Rose & Appleby 2005). The UK data are freely available on the Carbydat online database (Rose 2010).

Although the specific dates are subject to geographical variation (Figure 3), three marked features of SCP profiles have been used for dating sediments, namely:

- the start of the record (mid-nineteenth century);
- the start of the rapid increase in concentration following the Second World War (mid-twentieth century); and
- the peak in SCP concentration (late-twentieth century).

2. METHODOLOGY

SCPs should be extracted from a sub-sampled peat profile following a modified version of the method proposed by Rose (1990), using HNO₃ rather than H₂O₂ (Rose 1994, Rose *et al.* 1995, Yang *et al.* 2001a). This method is suitable for ombrogenous peat deposits, where little siliceous material is present. For other sediments containing siliceous material, HF and/or HCl treatments may also be needed (cf. Rose 1990).

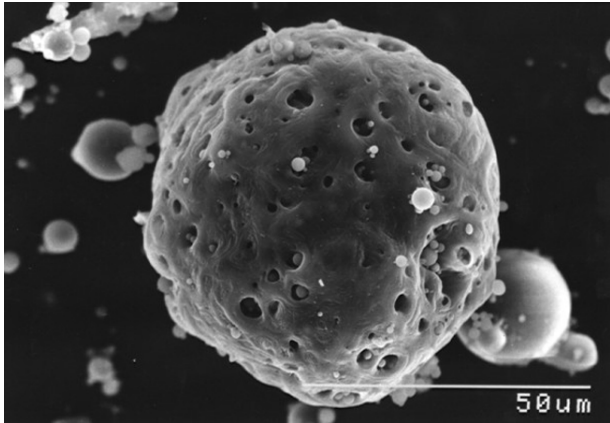


Figure 1. Scanning electron microscope image of a typical spheroidal carbonaceous particle (Neil Rose, University College London).

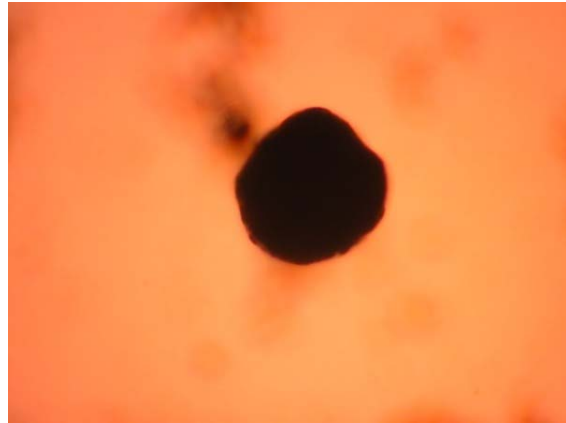


Figure 2. Light microscope image of a typical spheroidal carbonaceous particle (Neil Rose, University College London).

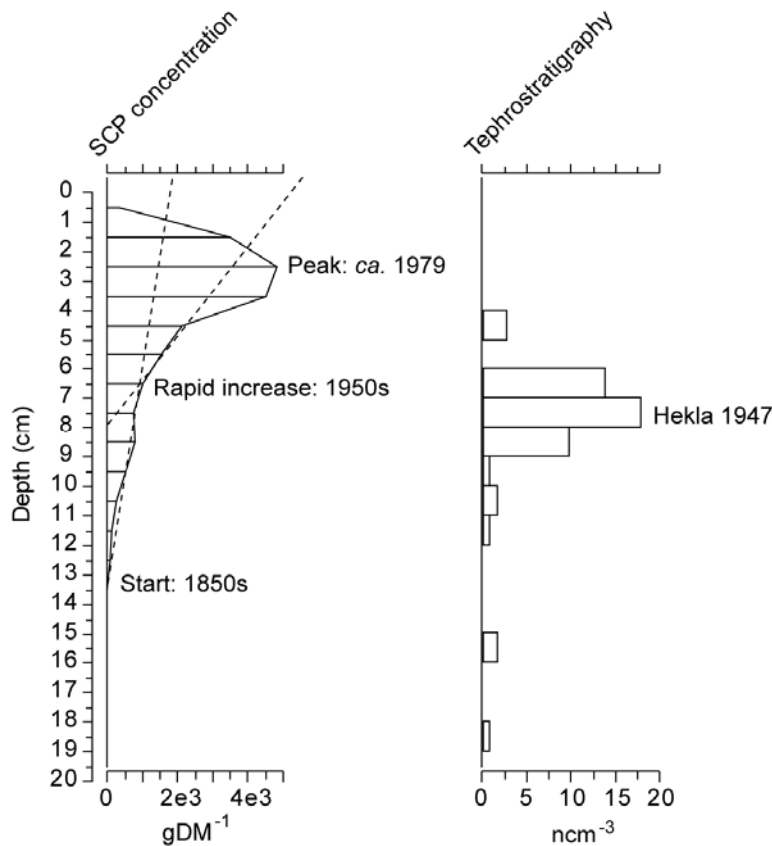


Figure 3. Typical UK SCP concentration diagram showing the start of the record in the 1850s, the rapid increase in the 1950s and the peak in SCP concentrations at *ca.* 1979. These data are from Dead Island Bog, Northern Ireland. The Hekla 1947 tephra occurs just beneath the rapid increase in SCPs (Swindles & Roe 2006). However, spatial variation in the timing of these features is apparent. In Denmark, for example, SCP deposition was low until the 1920s, increased slowly after World War II, peaked around 1970 and decreased thereafter (Odgaard 1993). Variation in the timing of these features is also apparent at a regional scale (Rose 2010).

1. Dry 1–2 cm³ of peat overnight in a drying oven at 40–50°C.
2. Place 0.1 g of dry peat in a 50ml Teflon® beaker, add 6 ml of concentrated HNO₃ and leave for 24 hours.
3. Place the beaker on a hotplate and heat at 100°C until the solution is reduced to approximately 1 ml and all organic material has dissolved. Rock the beaker to avoid the digestion sticking to the sides.
4. Remove the beaker from the hotplate and add 10 ml of distilled water. Transfer the suspension to a 15 ml polypropylene centrifuge tube.
5. Centrifuge at 1500 r.p.m. for five minutes and decant the supernatant into a sink with running water. Wash the residue twice with distilled water, centrifuge and decant.
6. Weigh a small (~15 ml or less) centrifuge tube (V_E) then decant the residue into it. Re-weigh. Centrifuge, then remove as much water as possible using a Pasteur pipette. Weigh the tube containing the residue (V_S).
7. Remove a quantity of the residue and evaporate it on a coverslip on a hotplate. Heat gently to remove water. Re-weigh the centrifuge tube (V_{SUB}). Mount the coverslip on a standard microscope slide using a low refractive index mountant such as 'Naphrax'.
8. Count SCPs using light microscopy at 400x magnification and express the data as gDM⁻¹ (number of particles per gram of dry mass of peat). SCPs are easily identified on the basis of their spheroidal three-dimensional morphology (easily determined by focusing in and out on the particle using a light microscope) and distinctive black colour (Figure 2). The particles are usually between 10 and 70 µm in diameter and may have a pitted or lacy surface texture. Variability in the sizes and characteristics of SCPs within stratigraphical records and between sites is commonly due to changes in prevailing winds, changes in source fuel type (e.g. the dominance of oil over coal) and the distance from source.

The concentration of SCPs in the peat sample (C) is thus:

$$C = 100 N/E \div M \quad (1)$$

where N is the total number of SCPs counted on the coverslip, M is the mass of dry peat used, and E is the percentage of the final suspension evaporated on the coverslip:

$$E = 100 \times (V_S - V_{SUB}) / (V_S - V_E) \quad (2)$$

where V_E is the mass of the empty centrifuge tube, V_S is the mass of the tube and sample and V_{SUB} is the mass of the tube after the coverslip has been loaded.

Notes:

1. Make sure that particles have settled out properly before pipetting off the supernatant liquid.
2. All containers must be kept covered when not in a fume cupboard to avoid contamination from airborne SCPs.
3. Care should be taken to ensure that the entire slide is analysed for SCPs, by viewing a sufficient number of transects.
4. Standard laboratory safety procedures should be followed. The above procedure should always be conducted in a fume cupboard and the analyst should wear appropriate eye protection, laboratory gloves and protective clothing. Protocols for the correct use and disposal of HNO₃ should be followed.

3. POTENTIAL AND LIMITATIONS

SCP-derived chronologies are particularly important to peat-based studies because radiometric methods (most commonly ²¹⁰Pb, ²⁴¹Am, ¹³⁷Cs) can be problematic due to downwash and displacement effects (Oldfield *et al.* 1995). Furthermore, dating the full post-industrial period using ²¹⁰Pb will become increasingly problematic as it has a short half life of 22.26 years. Thus, SCPs will provide a reliable and independent peat chronology for future researchers (Rose & Appleby 2005). A sediment reference material for SCP analysis has now been developed for quality control purposes; and standardised criteria to assist identification have also been proposed, based on particle morphology (spheroidal but not spherical), colour (black only), depth (three-dimensional rather than disc like) and porosity (characteristic when present) (Rose 2008).

Despite the value of SCPs for dating recent peat profiles, a number of problems and limitations are apparent. It is assumed that the movement of SCPs within peat profiles is very limited and, like the

movement of pollen and other small particles, may only slightly reduce the sharpness of boundaries (cf. Clymo 1987). SCP profiles occasionally show odd characteristics such as double peaks or indistinct rapid increases in concentration, which may suggest displacement of the particles affecting their integrity as chronological markers. In addition, regional differences in the timing of the main features used for age determination need to be taken into account before they are used in peat chronology (Rose & Appleby 2005). Although the start of the SCP record and the rapid increase in concentration have been established as reliable dating features in peat, the SCP concentration peak may be problematic as it could be a by-product of decomposition in the acrotelm (Clymo 1984, Yang *et al.* 2001a). Another potential problem for SCP concentration profiles arises when a rapidly accumulating matrix dilutes the SCPs to below the limit of detection of the technique. In this case the lower end of the profile may be truncated, commencing where the rapid increase feature takes SCP concentrations above the detection limit for the first time, so that the record appears to begin anomalously late. Researchers planning to use SCPs to date recent peat profiles should be aware of these potential problems before carrying out the analysis.

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