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The procedure used to develop a coal char classification—Commission III Combustion Working Group of the International Committee for Coal and Organic Petrology

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ABSTRACT

This paper describes an assessment of char classification system by the Combustion Working Group in Commission III of the International Committee for Coal and Organic Petrology (ICCP). The work of the group culminated in the production of a char atlas after a final round robin exercise. This round robin involved 21 analysts and was an electronic exercise using digitally captured images of individual char particles, rather than actual char blocks. A software program featuring 170 char images was specifically designed to allow operators to identify each char based on a classification system with 9 individual char types; tenuisphere, crassisphere, tenuinetwork, crassinetwork, mixed porous, mixed dense, fusinoid, solid and mineroid.

The program electronically recorded all decisions as well as the time taken for each decision to be made. From 170 chars, 128 chars were identified by a majority (>70%) and these chars were then compiled in a char atlas that is now available for download (www.nottingham.ac.uk/~eczehl/charatlas).

As would be expected all analysts appeared to become more confident in identifying chars during the exercise, taking less time per image, but with no clear evidence of improvement. Without exception, analysts took longer to make an incorrect decision.

1. Introduction

Pulverized coal combustion has played (and will continue to play) an important role in energy generation for the foreseeable future. The IEA has forecast that 38% of the world's electricity will still be generated from coal by 2030 (International Energy Agency, 2005), so it is imperative that higher energy efficiencies are achieved as part of the drive towards worldwide sustainability. Understanding how powdered coal burns out during the combustion process is therefore an important area of study for scientists and engineers across the globe. During pulverized fuel combustion, coal particles are rapidly pyrolysed (Pyatenko et al., 1992) to yield char particles which then burnout (Bend et al, 1989). The ability to describe chars in a meaningful way, not least to other researchers working on char combustion behavior, is therefore very important (Jones et al., 1999; Wells and Smoot, 1991). Oil immersion microscopy is a useful way of studying char morphology by observing sectioned char particles (Alvarez et al., 1997; Lester et al., 1996; Wu et al., 2006). Scanning electron microscopy is another method of imaging char particles, but is generally used to image the external surfaces of whole char particles (Rosenberg et al, 1996).

Whilst there are many papers that use customized char classes for describing different observed structures (Alvarez et al., 1997; Bailey et al., 1990, Barranco et al., 2003), there are still essentially three common characteristics that are used to differentiate between them; wall thickness, fused and unfused structures, porosity and voidage.

1.1. Char wall thickness

There has always been a distinction made between thin walled (classically known as *tenui-*) and thick-walled (known as *crassi-*) chars. Differences in classification systems (Buhre et al., 2001; Jones et al., 1999; Alonso et al., 1999; Baltrus et al., 2001) normally originate from the thresholding (e.g. 3, 5, 8 µm thickness). This distinction is based on an assessment of the majority of the walls being above or below a specific wall thickness. The threshold used in this system is based on the experience of members within the ICCP Combustion Working Group and has been above or below 3 µm. Secondary pores are generally ignored when making an assessment of the thickness of char walls i.e. they are counted as char material which, again, reflects the group's emphasis on a classification system that is relevant to combustion processes.

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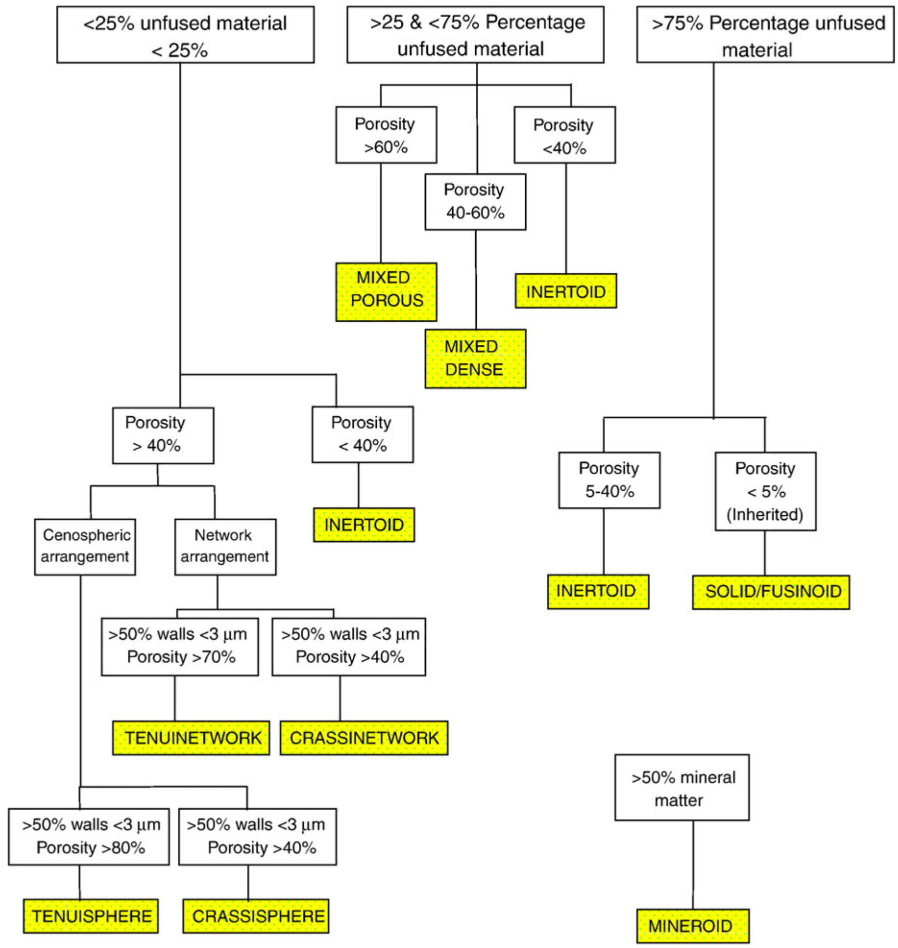

Fig. 1. The logic tree for the classification system as used in the exercise (http://www.iccop.org/index.php?id=49).

1.2. Fused and unfused structures

The formation of char structures during pyrolysis and combustion will depend on the petrographic components in the original coal particle (Bend et al., 1989; Alvarez et al., 1997; Alonso et al., 1999; Cloke and Lester, 1994). Some components will plasticise, vesiculate or swell and form new, potentially anisotropic structures (Ulloa et al., 2005; Alonso et al., 2001), higher reflectance materials, particularly fusinite and macrinite structures will tend to remain unchanged during heating and present a relatively isotropic solid material, with little sign of plasticization or swelling (Alonso et al., 1999), even after extended high temperature histories.

Table 1
The classification system for chars as used in round robin exercises by the Combustion Working Group of the ICCP Commission III.

Char type	Description
Tenuisphere	Spherical to angular, porosity >80%, >50% of wall area <3 µm.
Crassisphere	Spherical to angular, porosity >60%, >50% of wall area >3 µm.
Tenuinetwork	Internal network structure, porosity >70%, >50% of wall area <3 µm.
Crassinetwork	Char with internal network structure, porosity >40%, >50% of wall area >3 µm.
Mixed Porous	Char with fused and unfused parts, porosity >60%. More than 25% unfused (otherwise it would be Ceno- or Net-) but less than 75% (if more than 75% unfused, it would be Inertoid or Solid/Fusinoid).
Mixed Dense	Char with fused and unfused parts, porosity 40–60%. More than 25% unfused (otherwise it would be Ceno or Net) but less than 75% (if so, it would be Inertoid or Solid/Fusinoid).
Inertoid	Dense, porosity 5–40%, can be either fused or unfused.
Fusinoid/Solid	Inherited cellular fusinite structure or solid particle with <5% porosity.
Mineroid	Particle with >50% inorganic matter.

Table 2
A table showing the timing information from the participants (excluding operator 19 who completed the round robin as a paper exercise).

Analyst	Total time (min)	Average response time (s)	Minimum response time (s)	Maximum response time (s)	Standard deviation of response time
1	20	7	3	25	3.9
2	20	7	2	31	5.4
3	28	10	2	80	11.3
4	30	11	2	80	11.2
5	42	15	3	134	16.9
6	42	15	2	83	12.8
7	106	37	4	182	37.3
8	19	7	2	27	4.5
9	68	24	3	194	27.0
10	18	6	3	27	3.3
11	56	20	3	99	16.1
12	26	10	3	111	12
13	43	15	4	86	12.6
14	25	9	2	100	10.0
15	26	9	3	49	7.0
16	20	7	3	59	7.6
17	67	24	3	210	34.1
18	48	17	4	74	10.7
20	16	6	2	31	4.5
21	52	18	4	117	13.4