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Coal/biomass Combustion Prediction using Image Analysis Methods

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History of Image Analysis



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- *Manual Methods* - based on modal analysis, first applied to coal in 1934 by Glagolev, but originated by Delesse in the late 19th century.
- *Photomultiplier systems* - the flying spot microscope and photomultiplier system (Roberts and Young, 1952) was the beginning of automated systems.
- *Image Analysis Systems* - a progression in technology led to the replacement of the photomultiplier with a video camera. The image under the microscope is then fed to the image analysis system for analysis.



- **Point Counting** An automatic point counter keeps a running total of the number of points out of 500 labelled for each maceral type. The movement of the stage is automated, and the distance moved each time is constant.
- **Lineal analysis** uses an automated stage which moves the block under the eyepiece using a series of micrometer spindles (Krevelen, 1961, Galehouse, 1971). Each maceral type has its own spindle which is used to pass the cross hairs over the particle.

Advantages of photomultiplier systems



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- Early systems could analyse 106 points in 20 minutes (Denton 1967).
- The system from the Nippon Steel company was developed ten years later and compromised speed for increased accuracy (Kojima., 1976). 20,000 points required 30 minutes and so it is still preferable to manual methods.

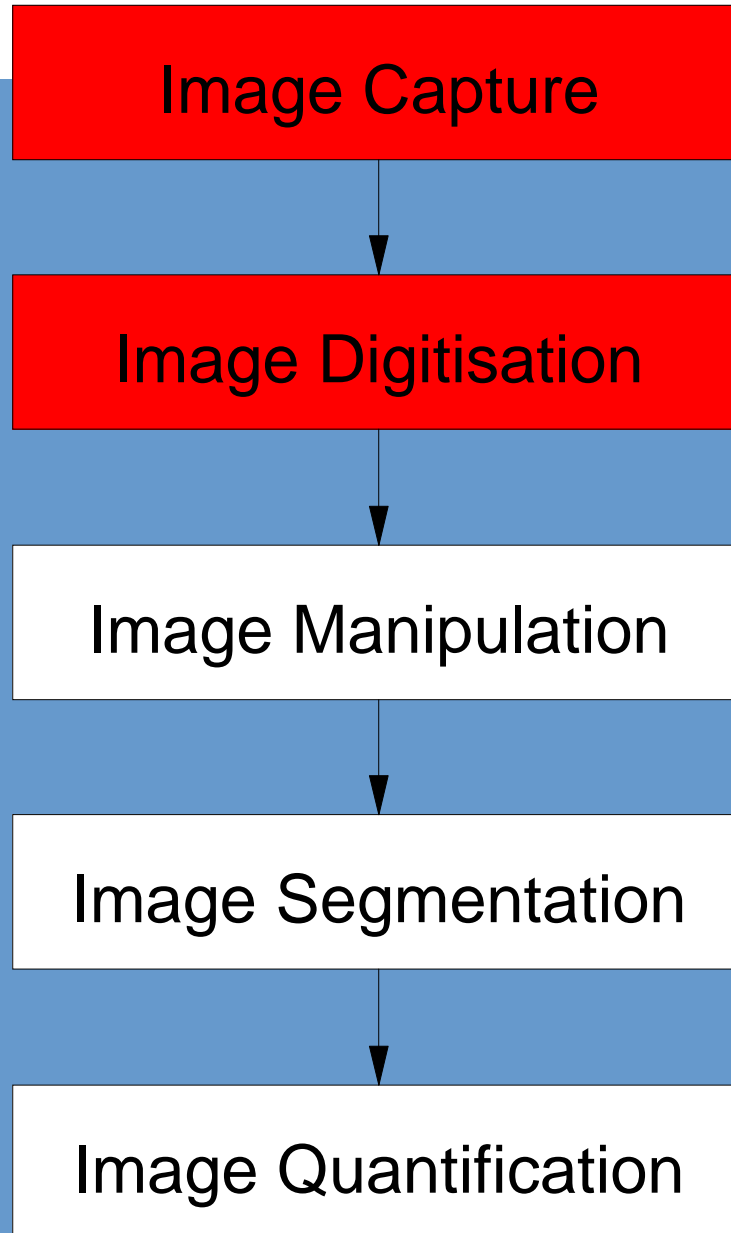


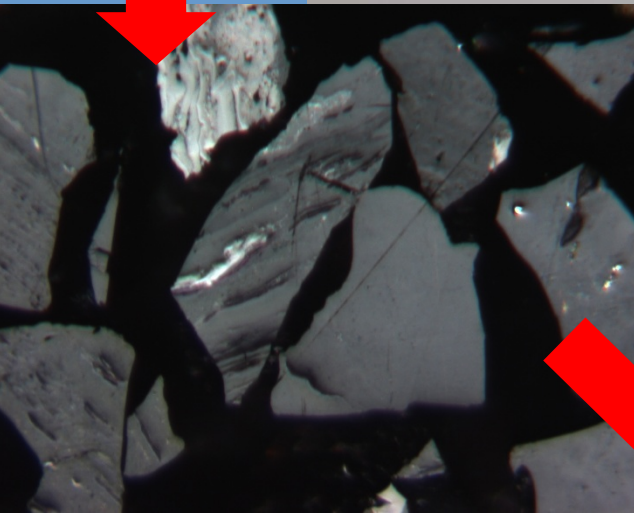
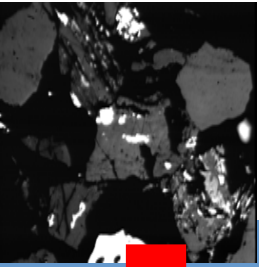
Advent of IA

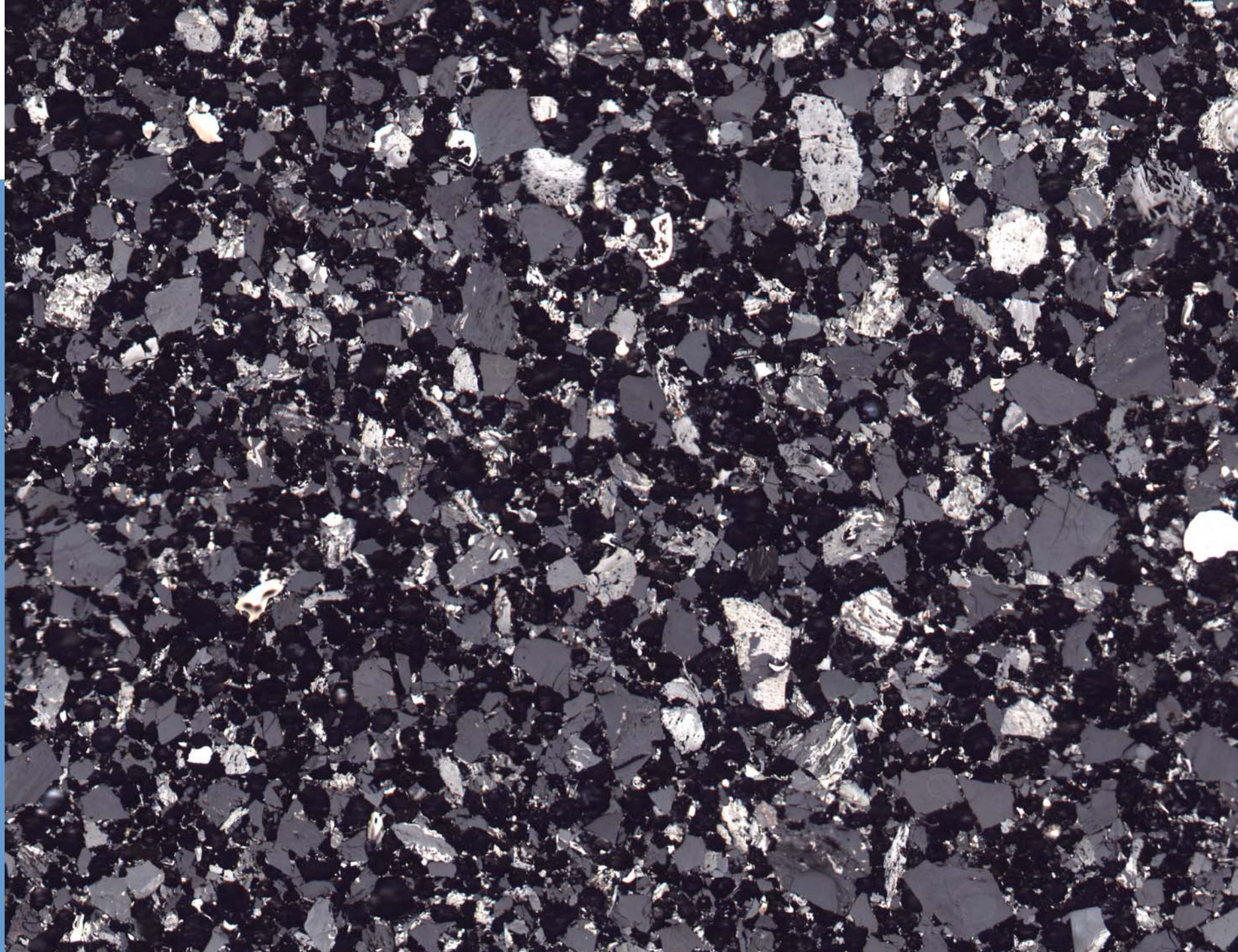
- Image analysis systems are fast reliable and do not require a skilled operator to run on a day to day basis. Each captured image can be manipulated to correct 'halo effects' and uneven illumination.
- Image analysis systems can perform the same functions as a photomultiplier, as well as being able to attempt microlithotype analysis (Chao et al., 1982a, Crelling, 1982) liberation analysis (Finch & Gomez, 1989) and association analysis (Vleeskens et al., 1984).



IA processing

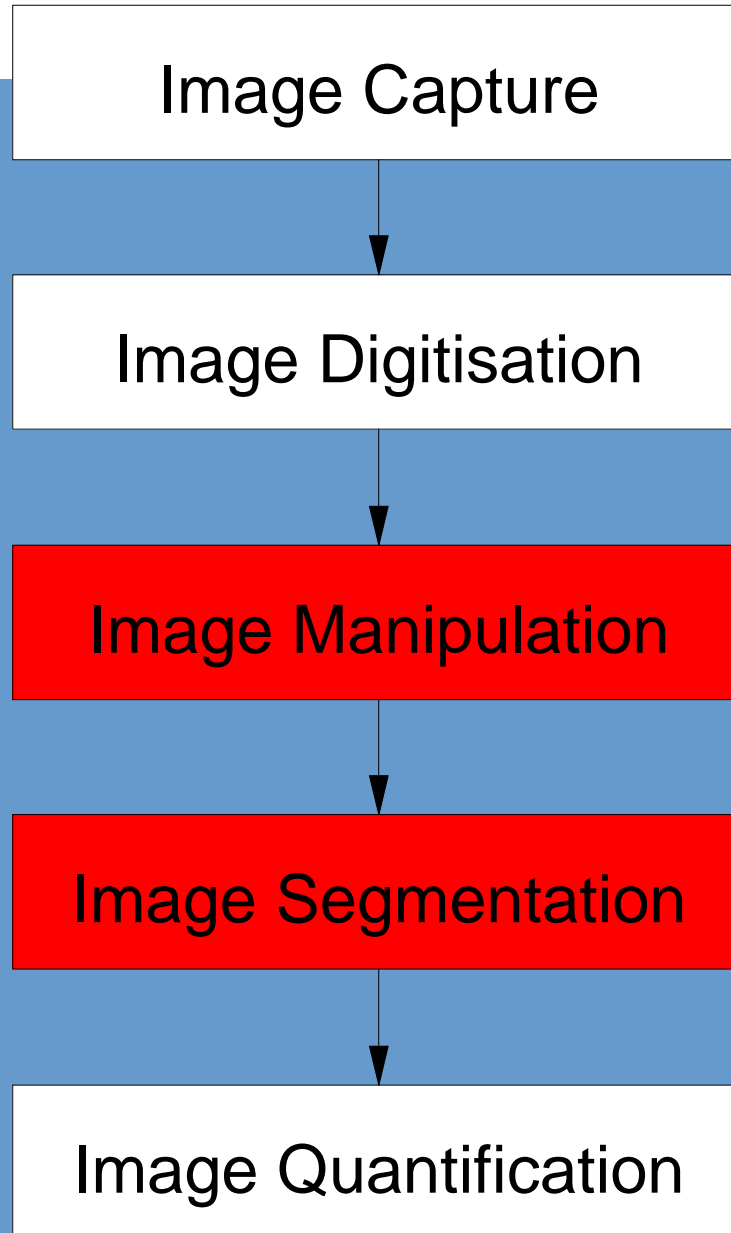








IA processing

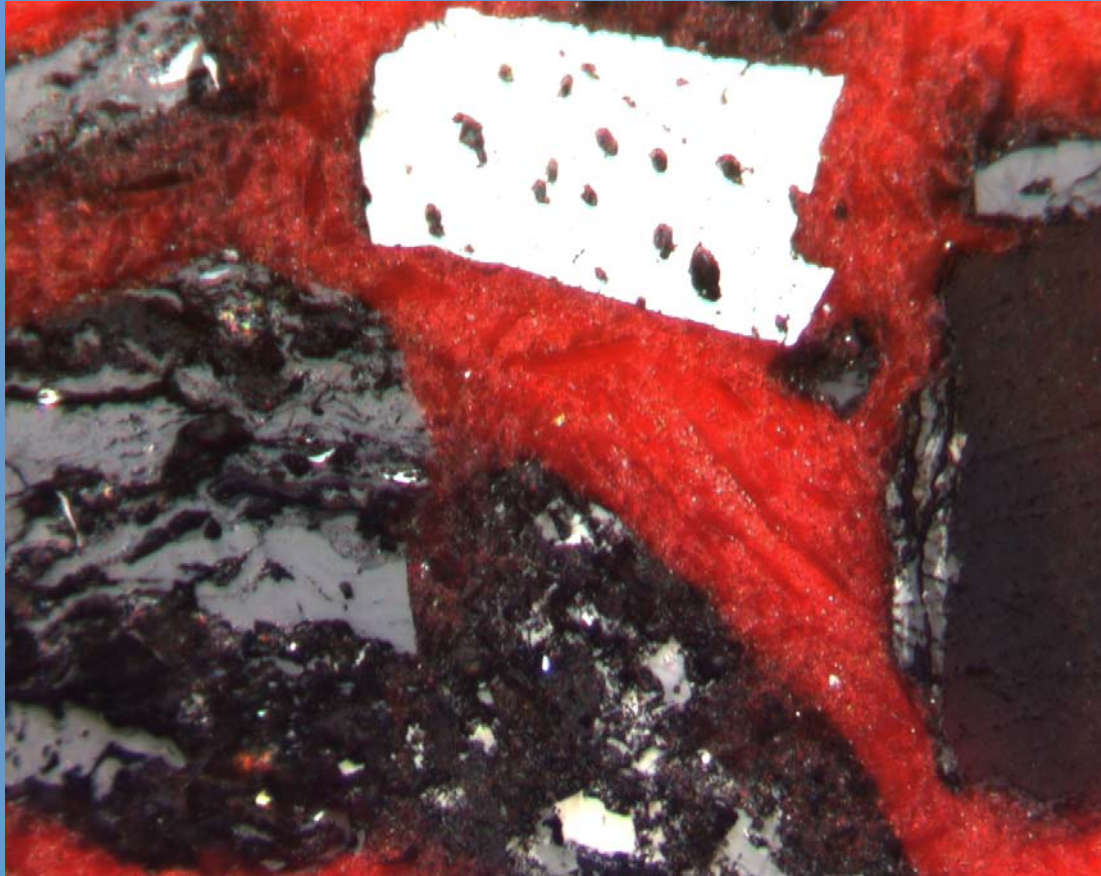


Finding particles

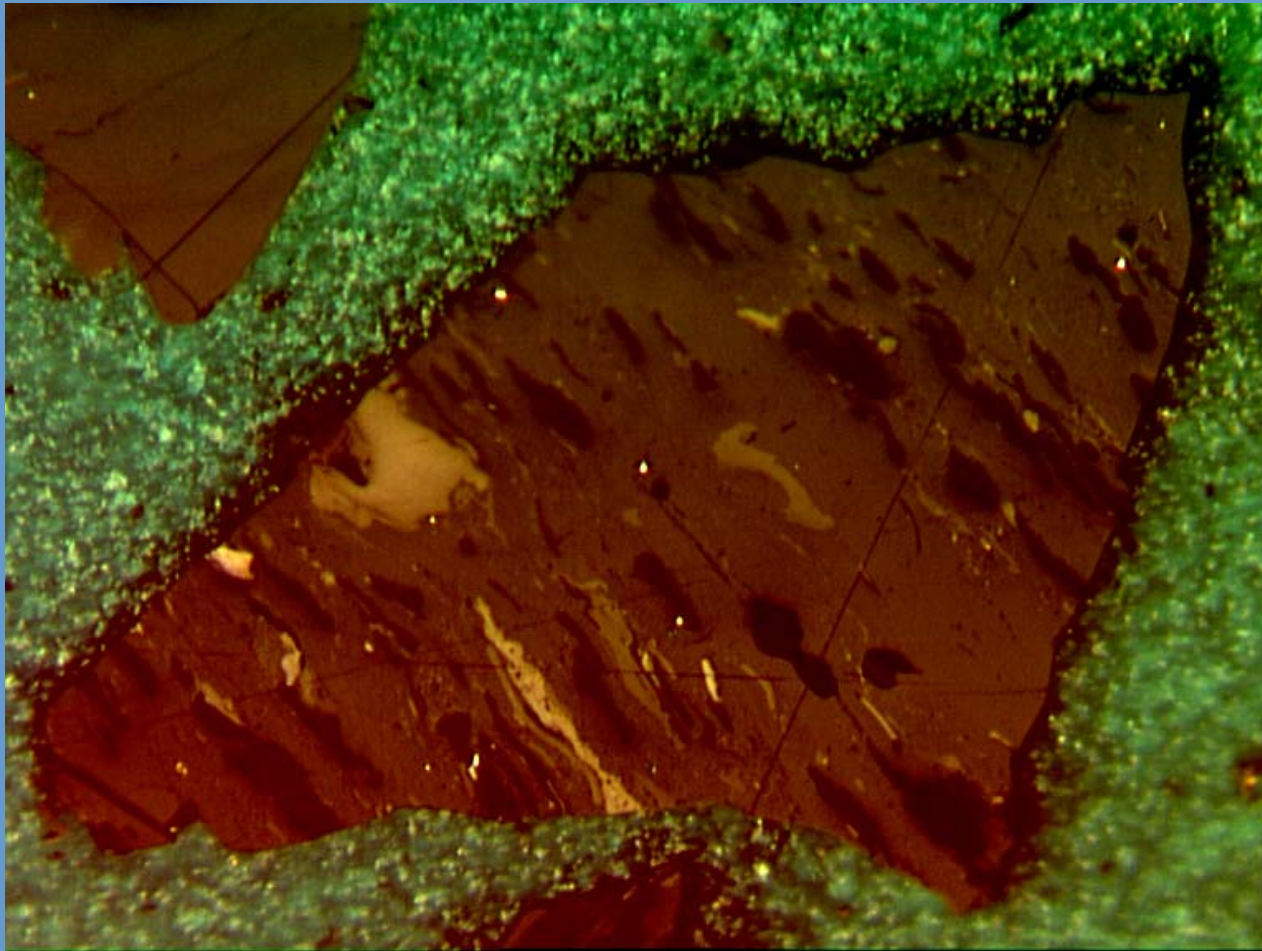
- Problem with finding liptinite
 - Morphological associations
 - Fluorescence
 - Colour Image analysis on coloured resins
 - Other methods



Red resin



Green resin



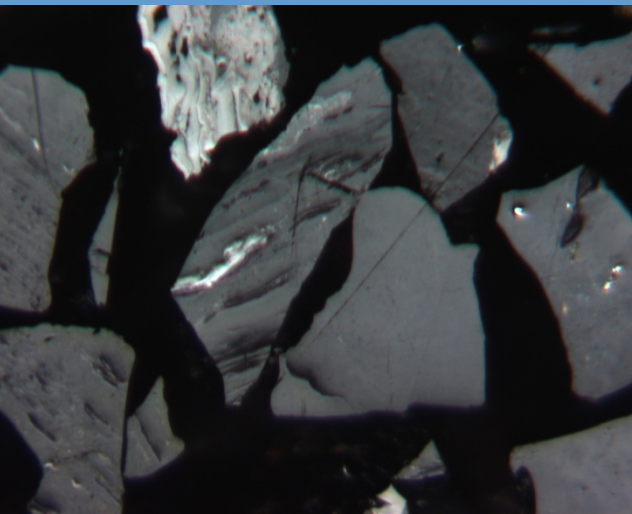


Image at 320ms

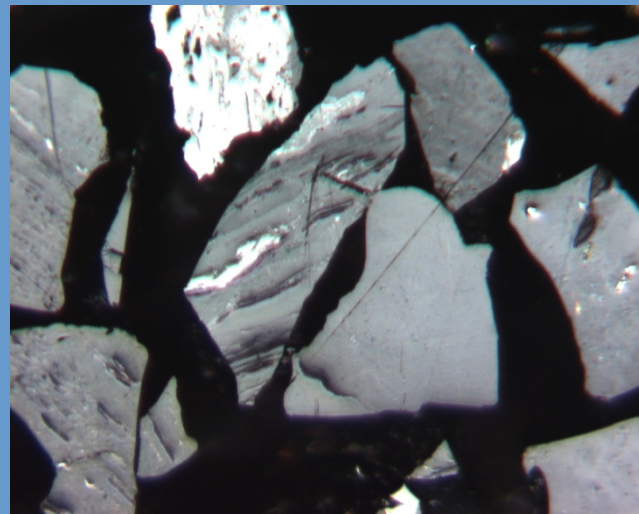
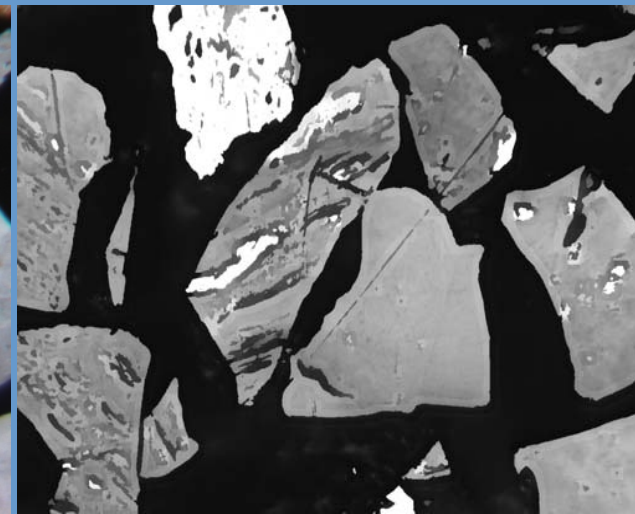


Image at 750 ms



Sharpened image



Particle Mask



'Clean'
particle
mask



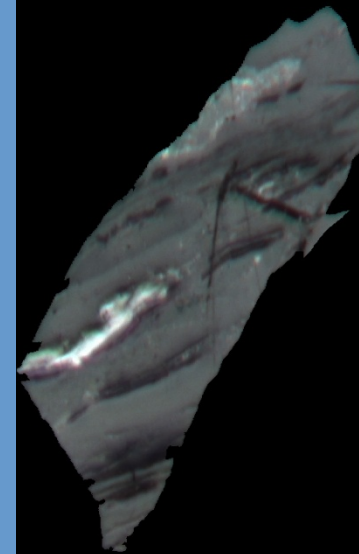
'Clean'
non touching
particle
mask



Separated
particles
mask



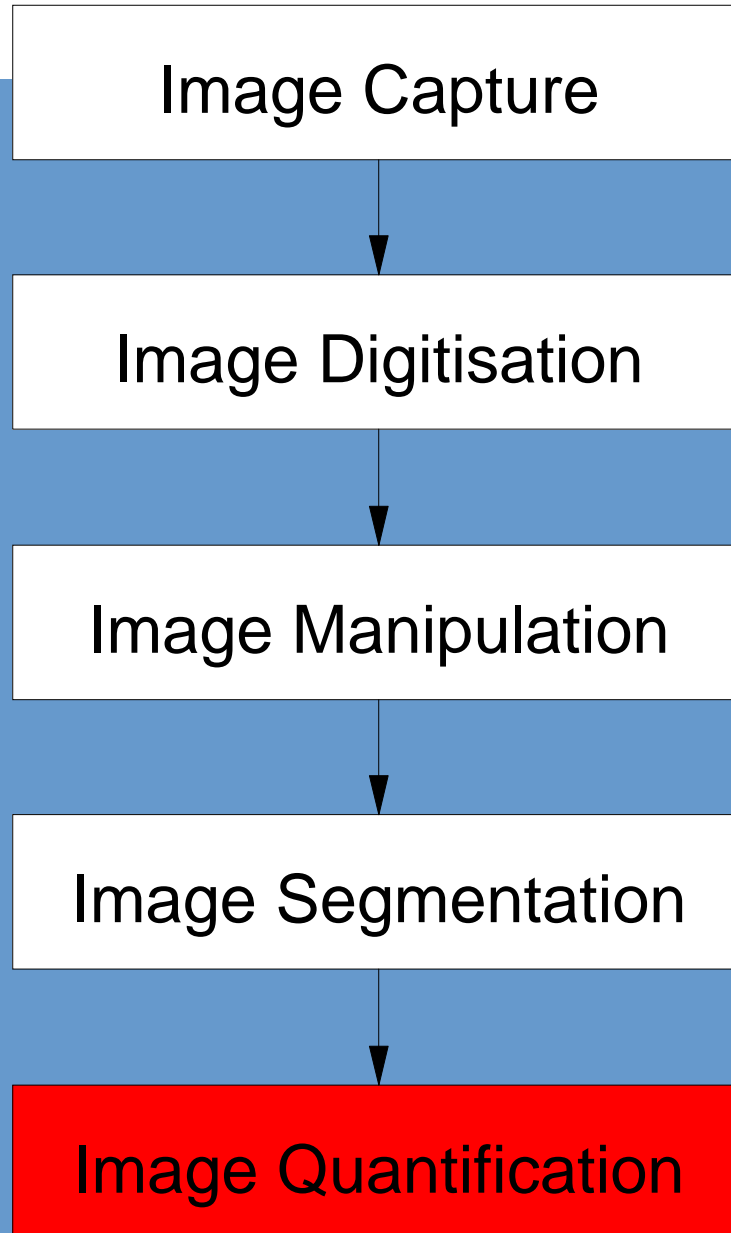
individual
Particle
mask

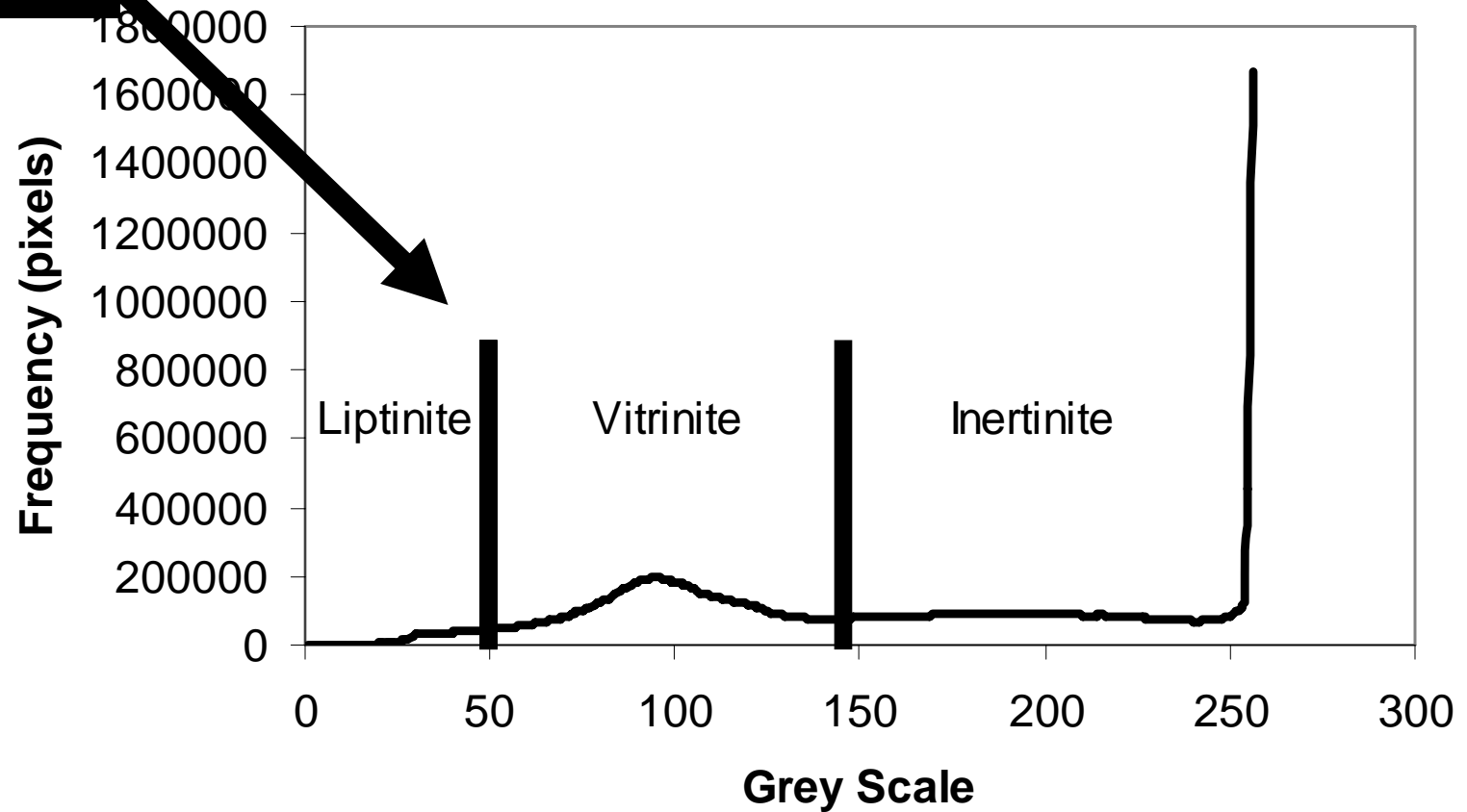
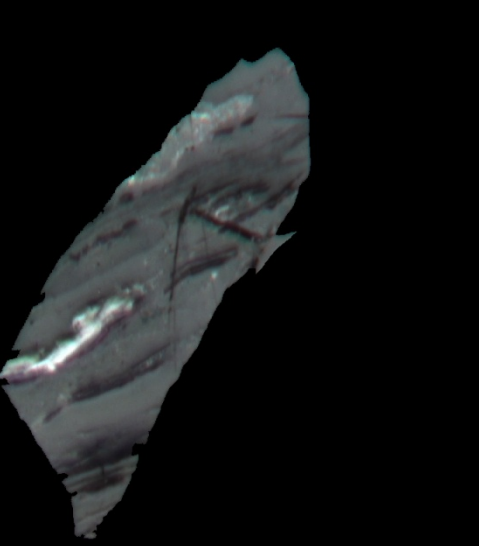


Separated
particle



IA processing





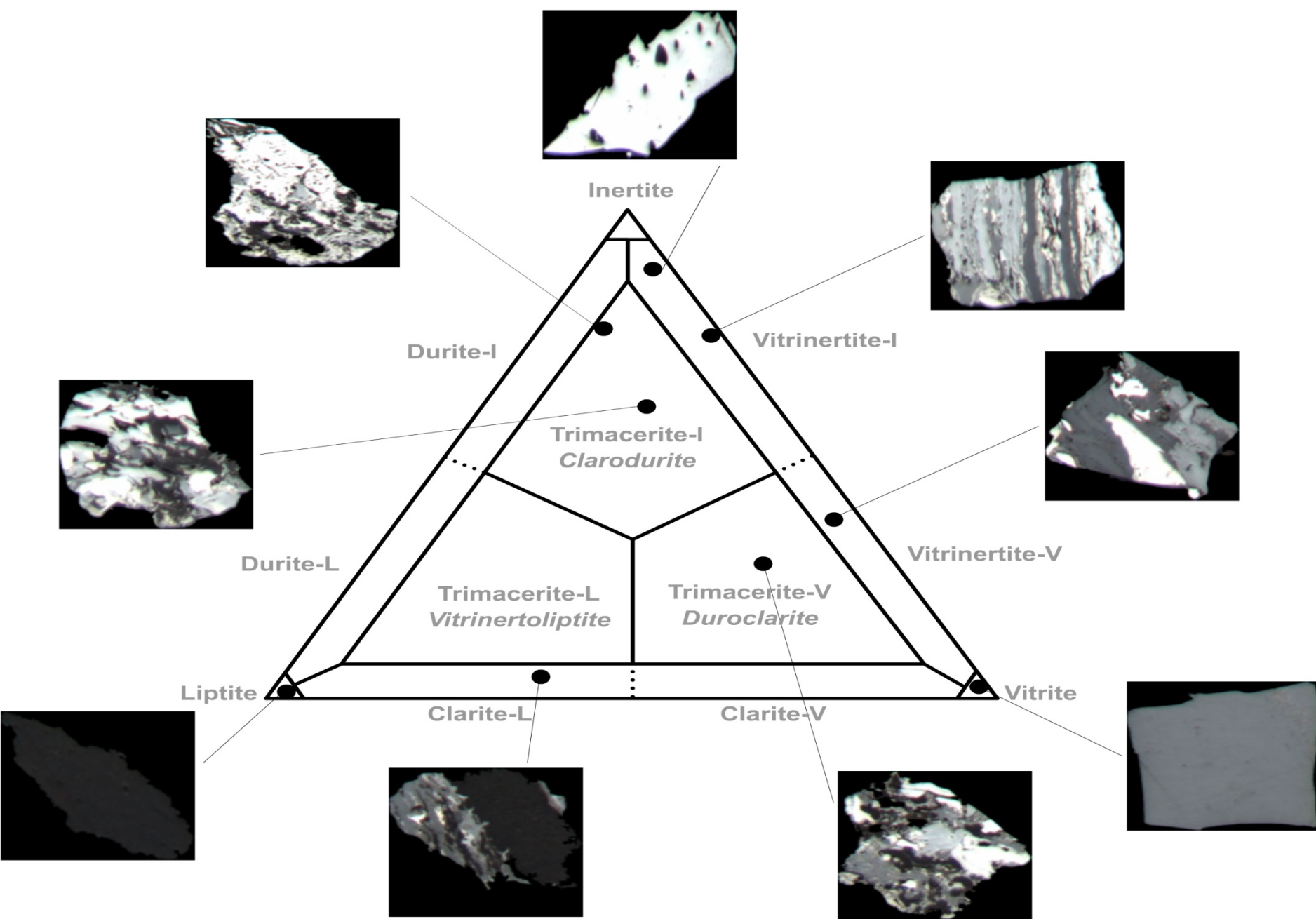
Particulate analysis

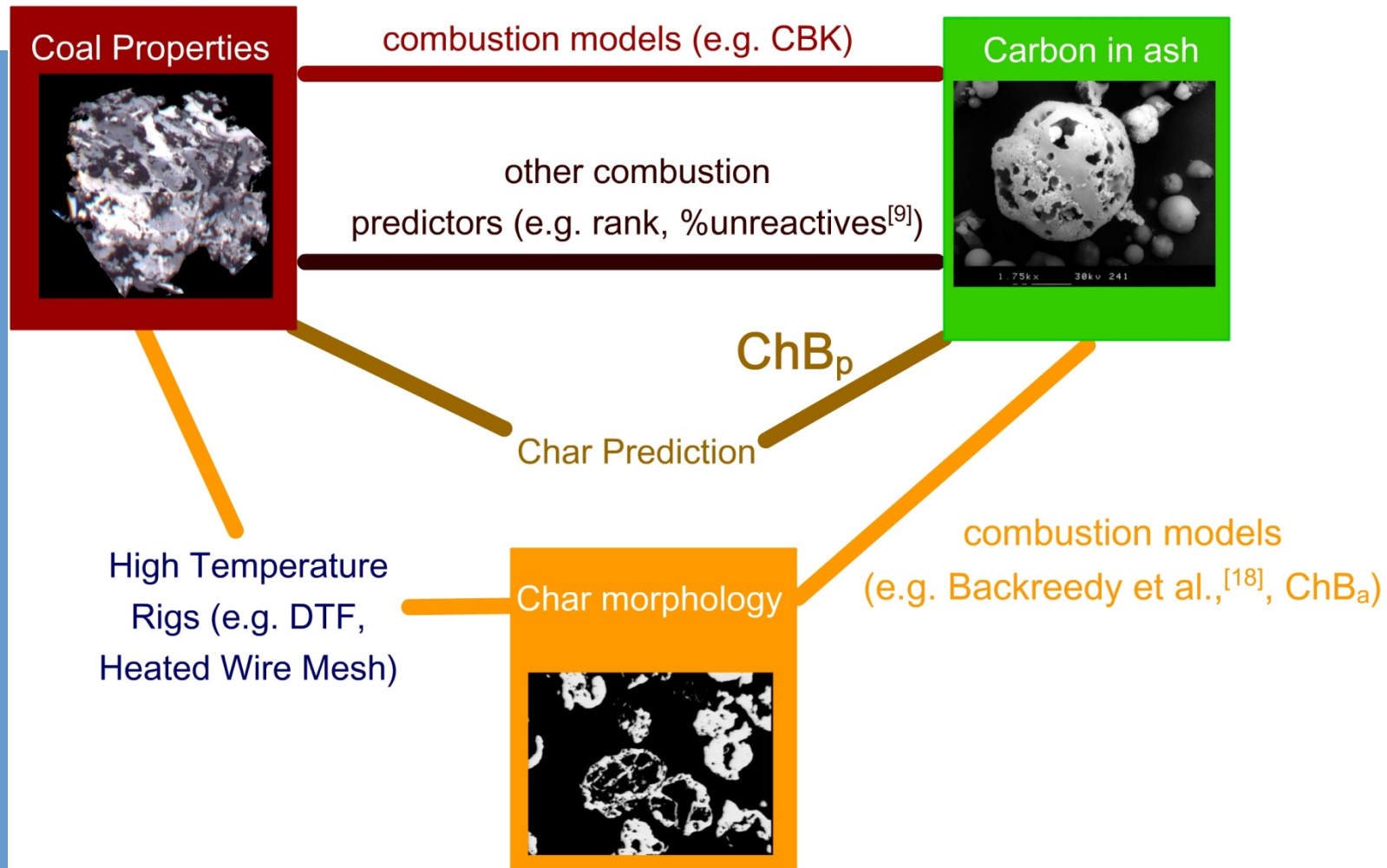


- Isn't this established already?
- What's the difference between particulate analysis and bulk analysis?

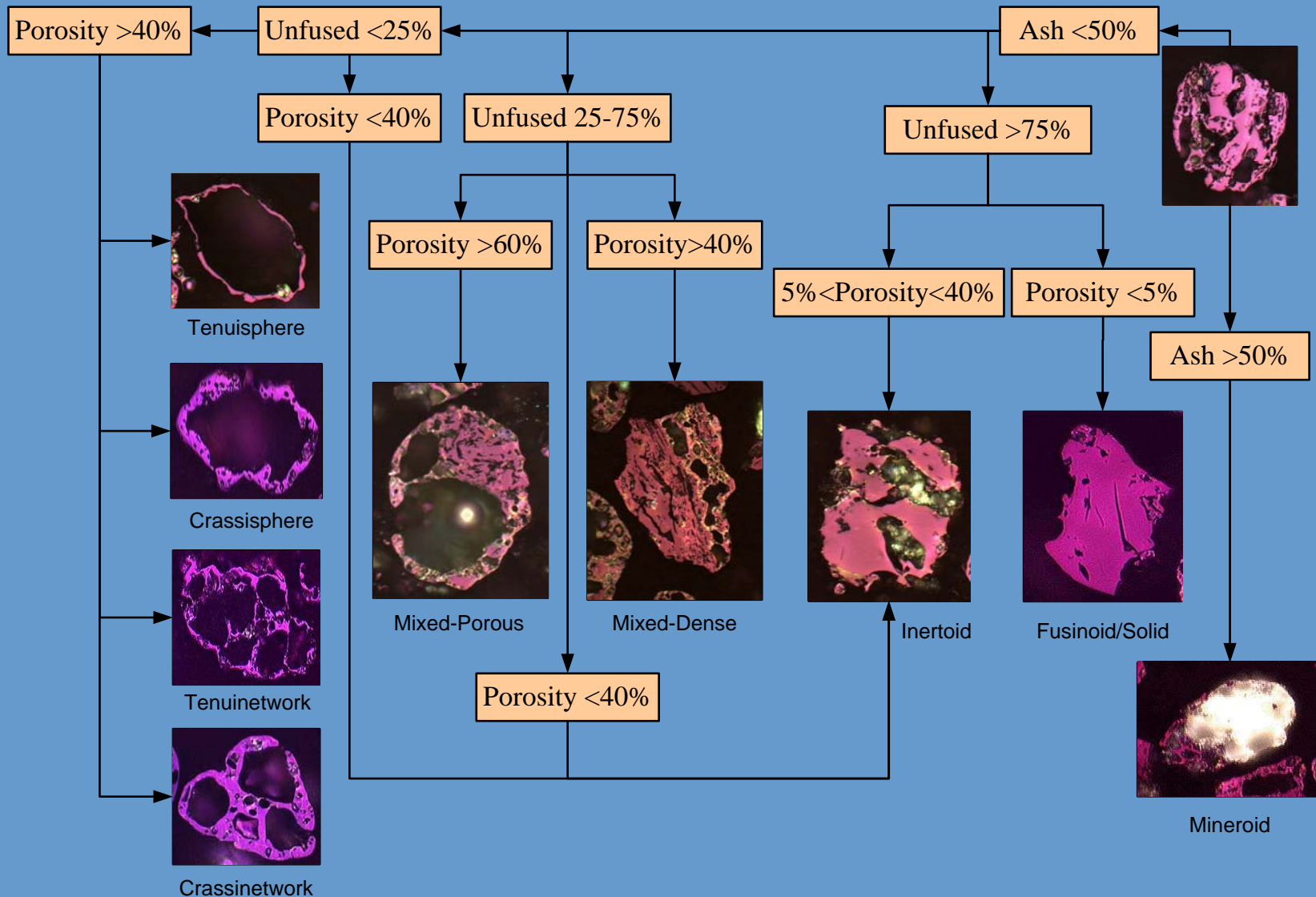


Figure 7 - The position of each particle on the trigonal microlithotype diagram using the image analysis technique. *This figure is discussed in the "Manual and Automated Microlithotype results" section*



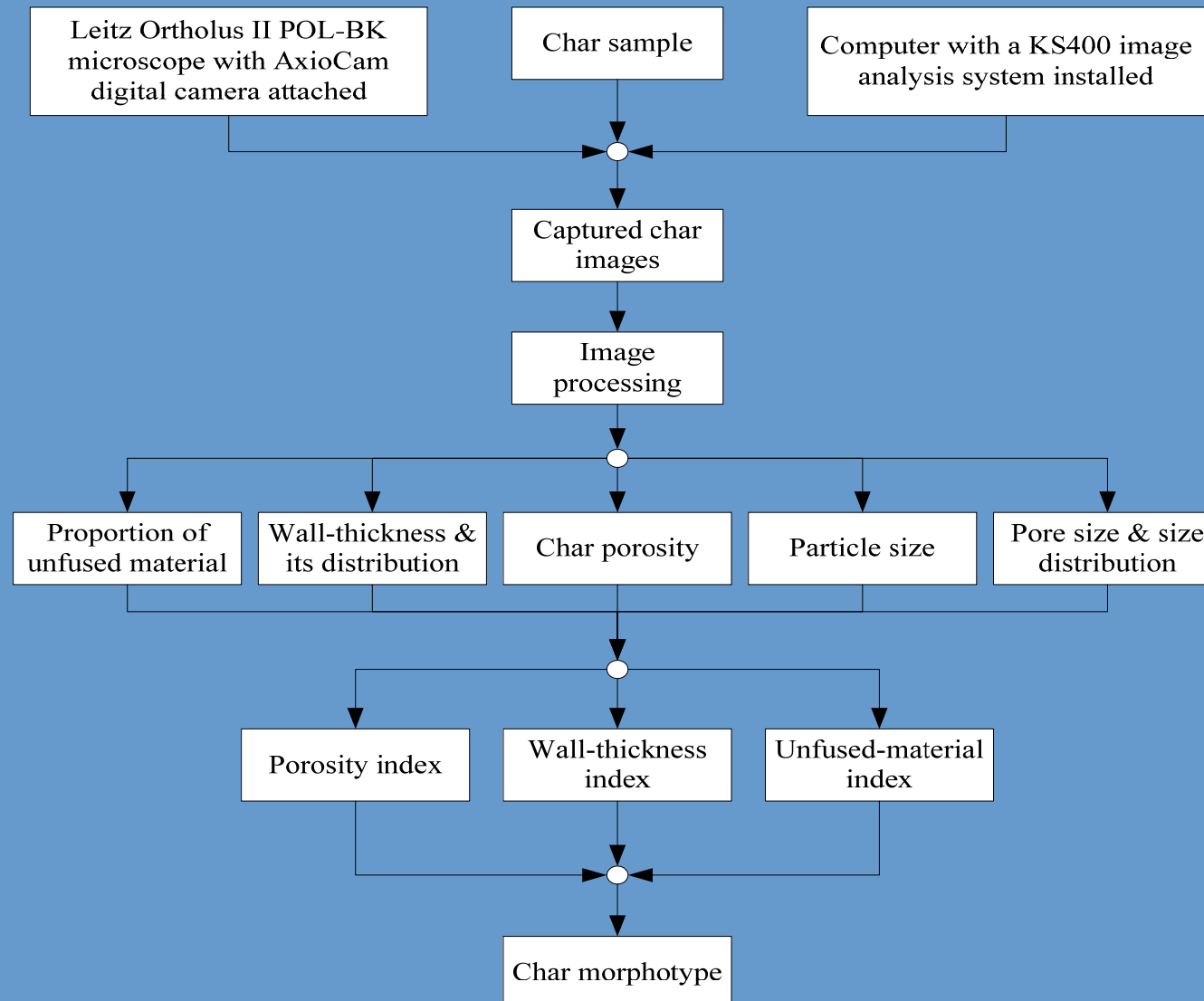


Char morphology & Classification

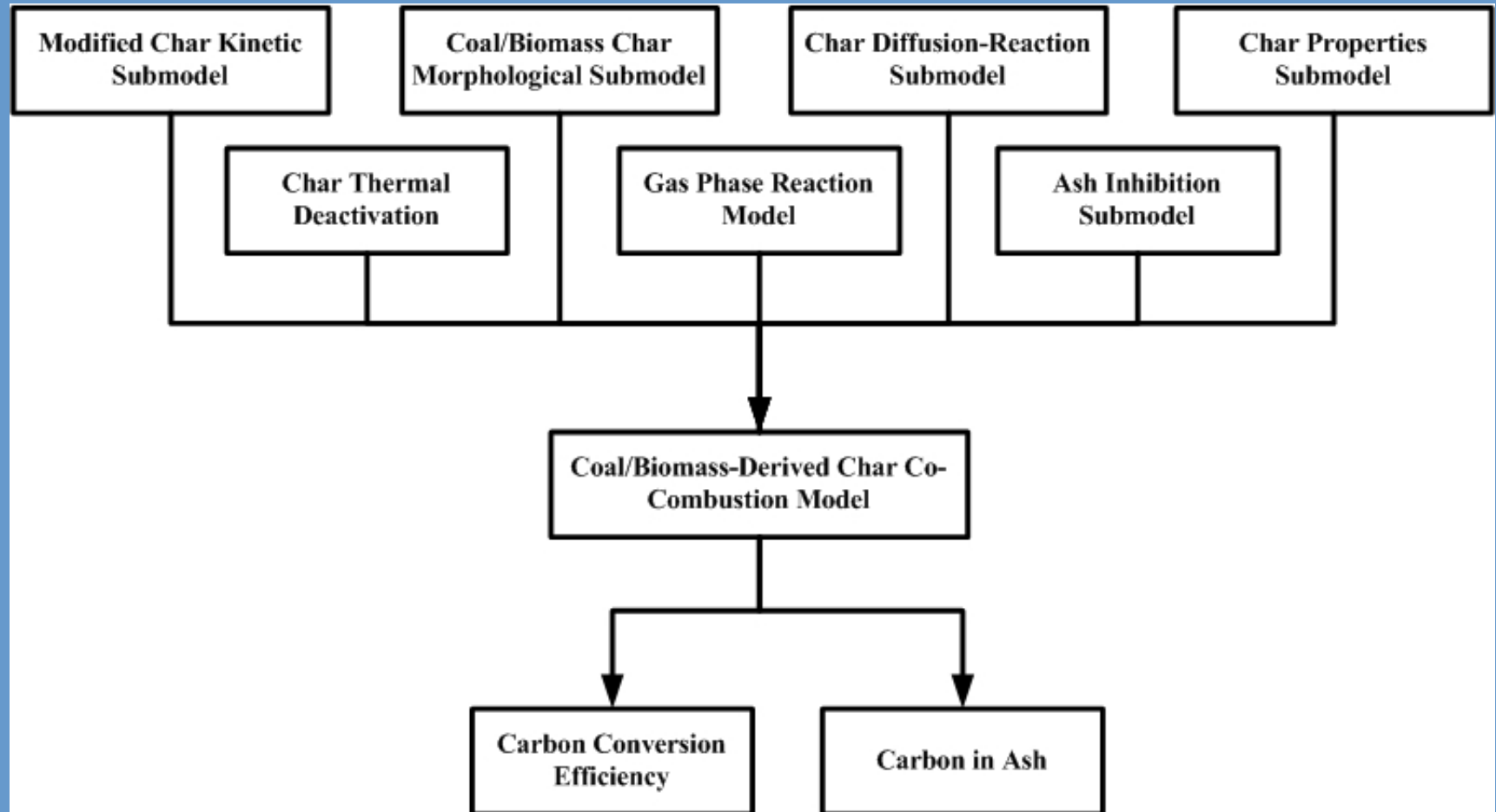




Char image analysis procedure



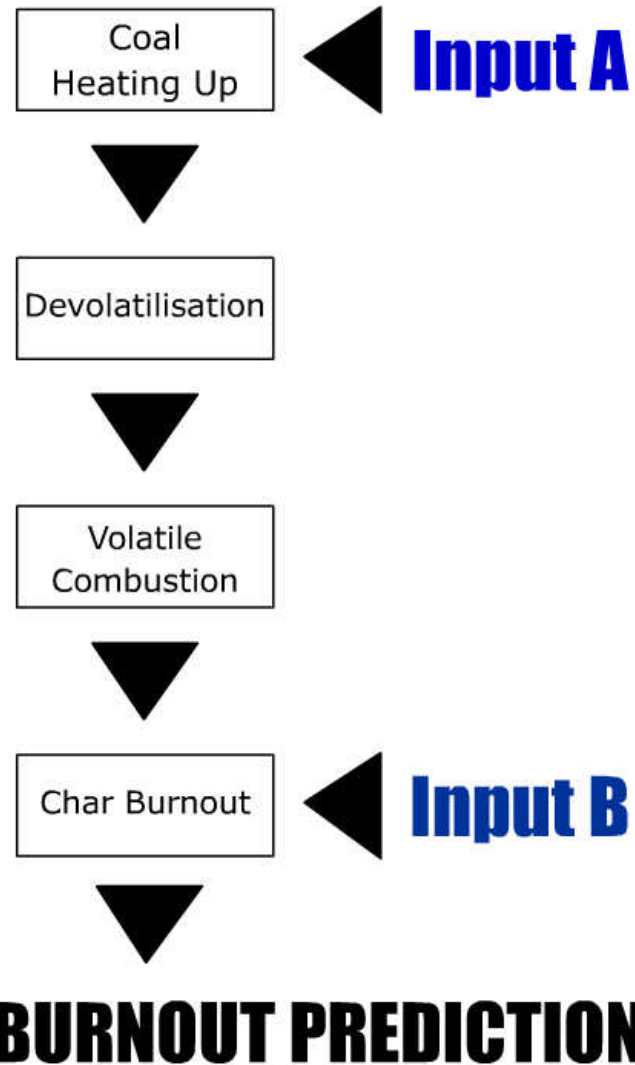
Burnout Modelling of Biomass/Coal Blends



ChB Model

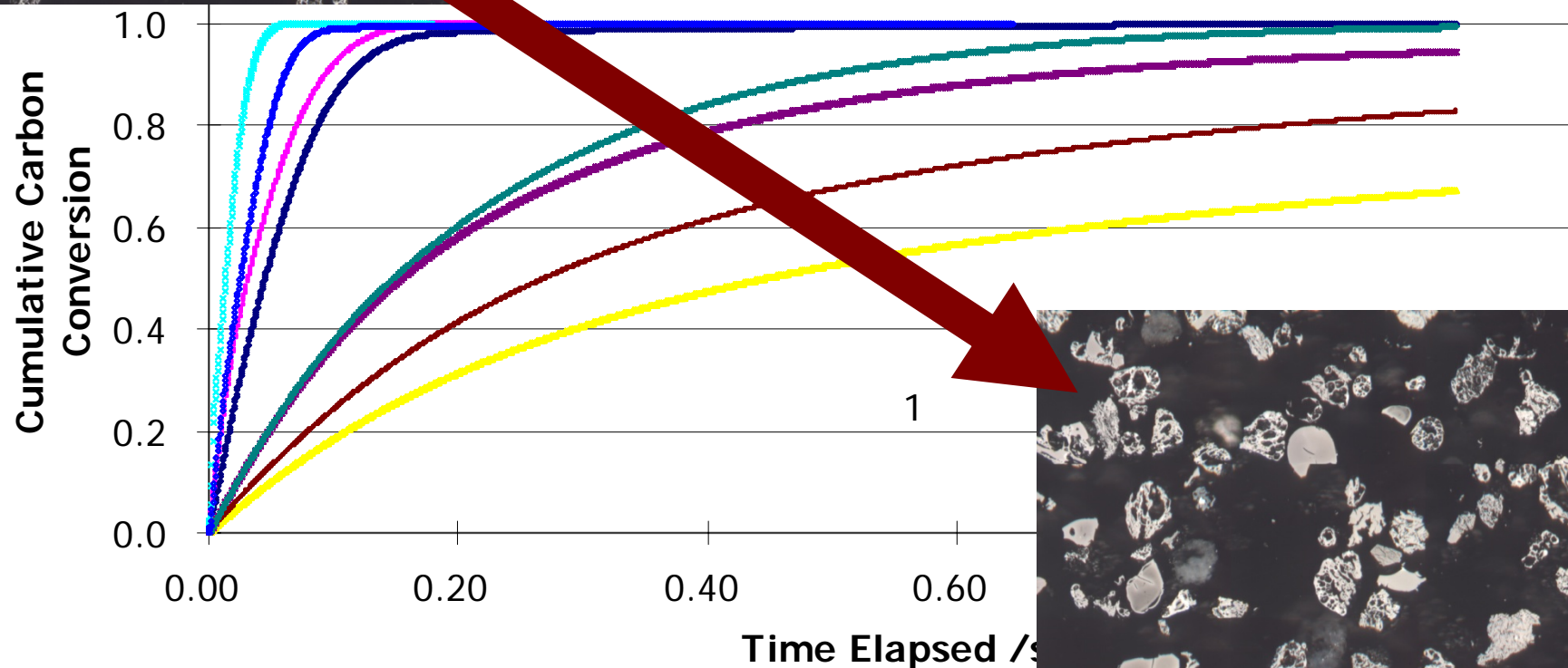


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Burnout History ChBa



- Kotinskaya
- Kyrgaiskaya
- Proko
- Erunakovsky
- Taldinsky
- Skolovskaya
- 7thNovember

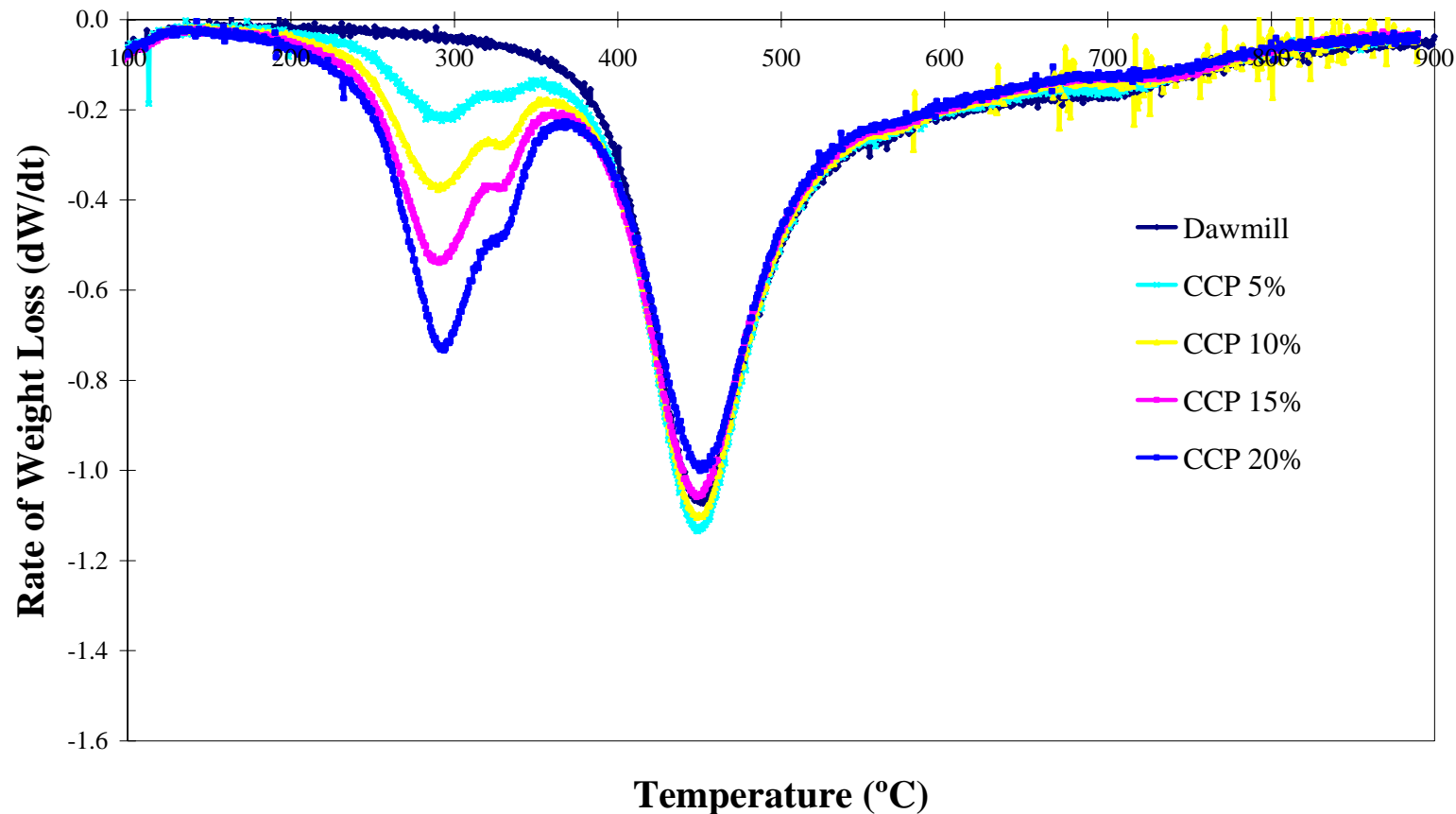


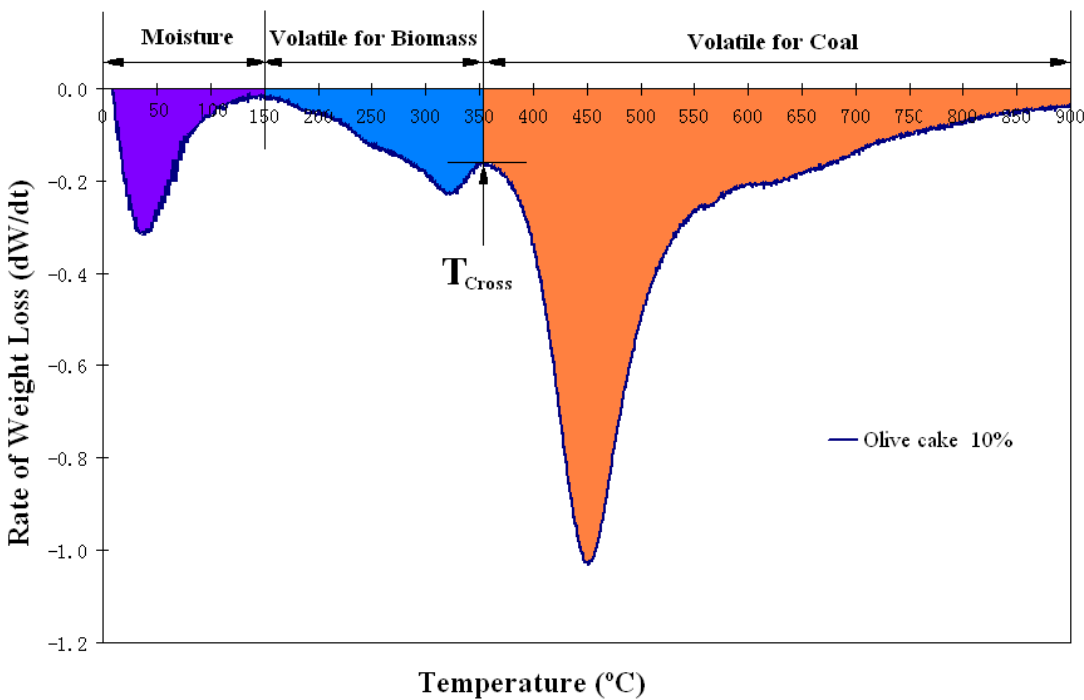
COAL with BIOMASS

Different Proportions of biomass



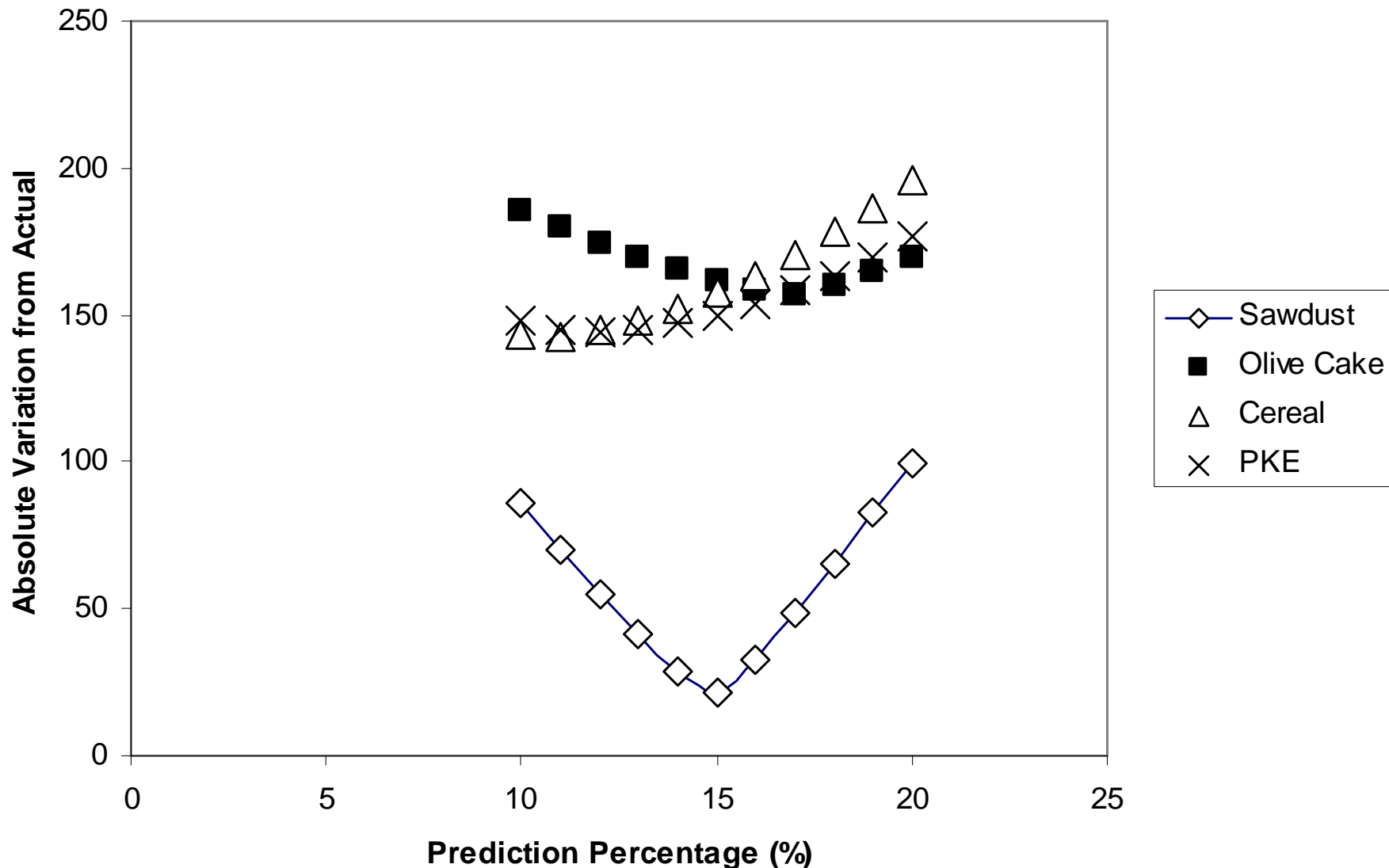
CCP/Daw Mill coal 106-150





Proportion	Proportion predicted and difference, %			
	PKE	Sawdust	Olive cake	CCP
5%	6 (+1)	7 (+2)	6 (+1)	7 (+2)
10%	10 (0)	11 (+1)	8 (-2)	11 (+1)
15%	13 (-2)	16 (+1)	12 (-3)	14 (-1)
20%	16 (-4)	20 (0)	15 (-5)	16 (-4)

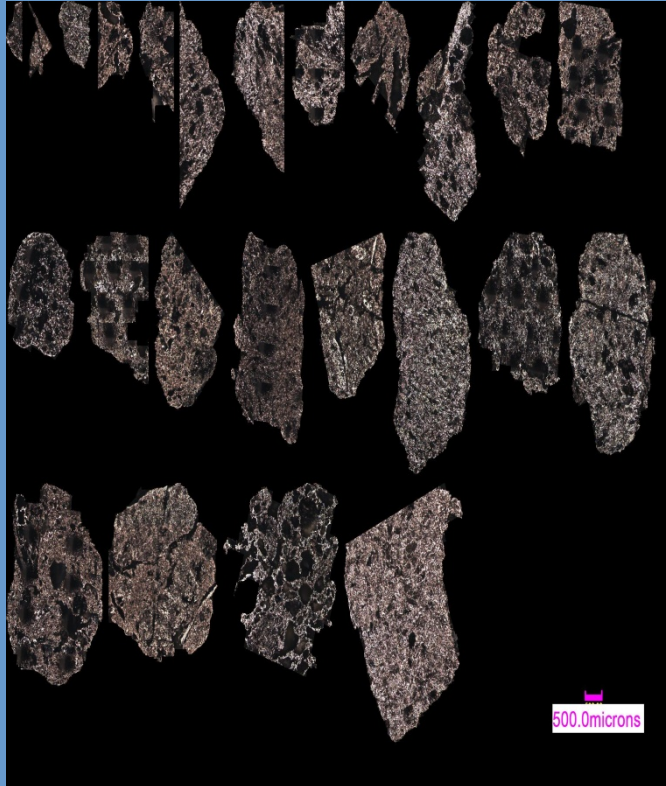
Cumulative Wrongness Index for finding the best fit



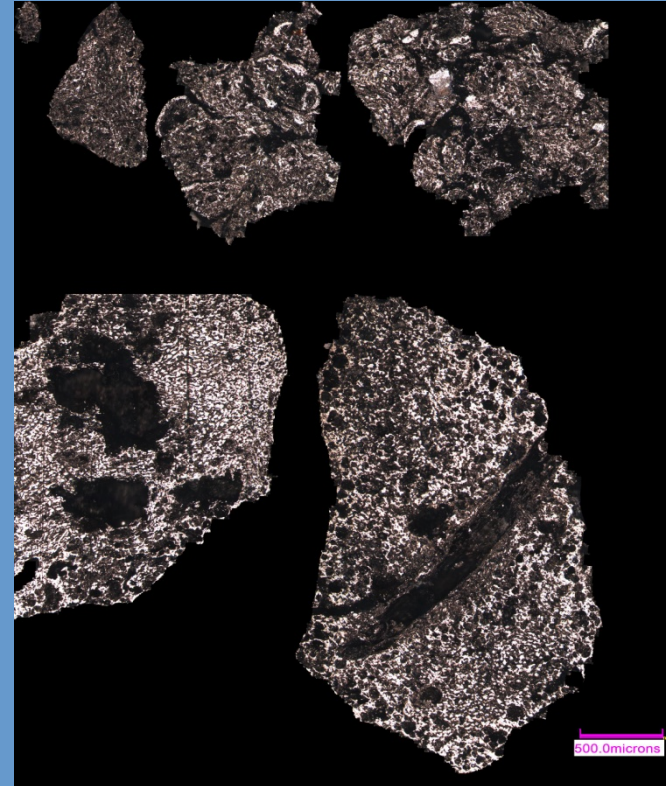
Typical images of coal and biomass chars



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Olive cake char 2-3mm



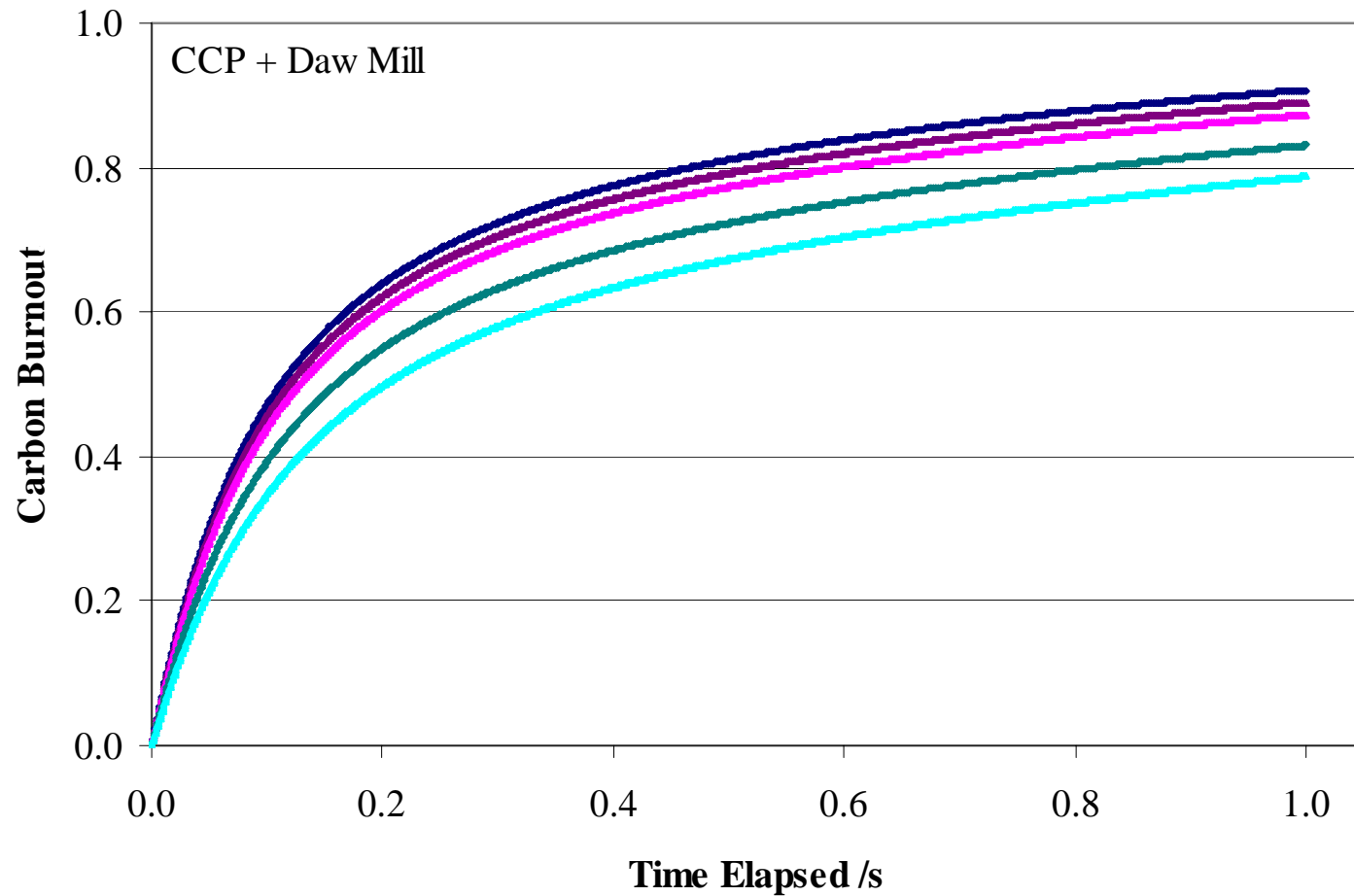
PKE char 2-3mm

Characterisation of Char Morphology



Average porosity of pure biomass and coal samples

Size fractions (mm)	Average porosity (%)			
	CCP	OC	PKE	Daw Mill
0.5-1.0	74	60	85	62
1.0-2.0	72	53	86	59
2.0-3.0	79	52	70	66



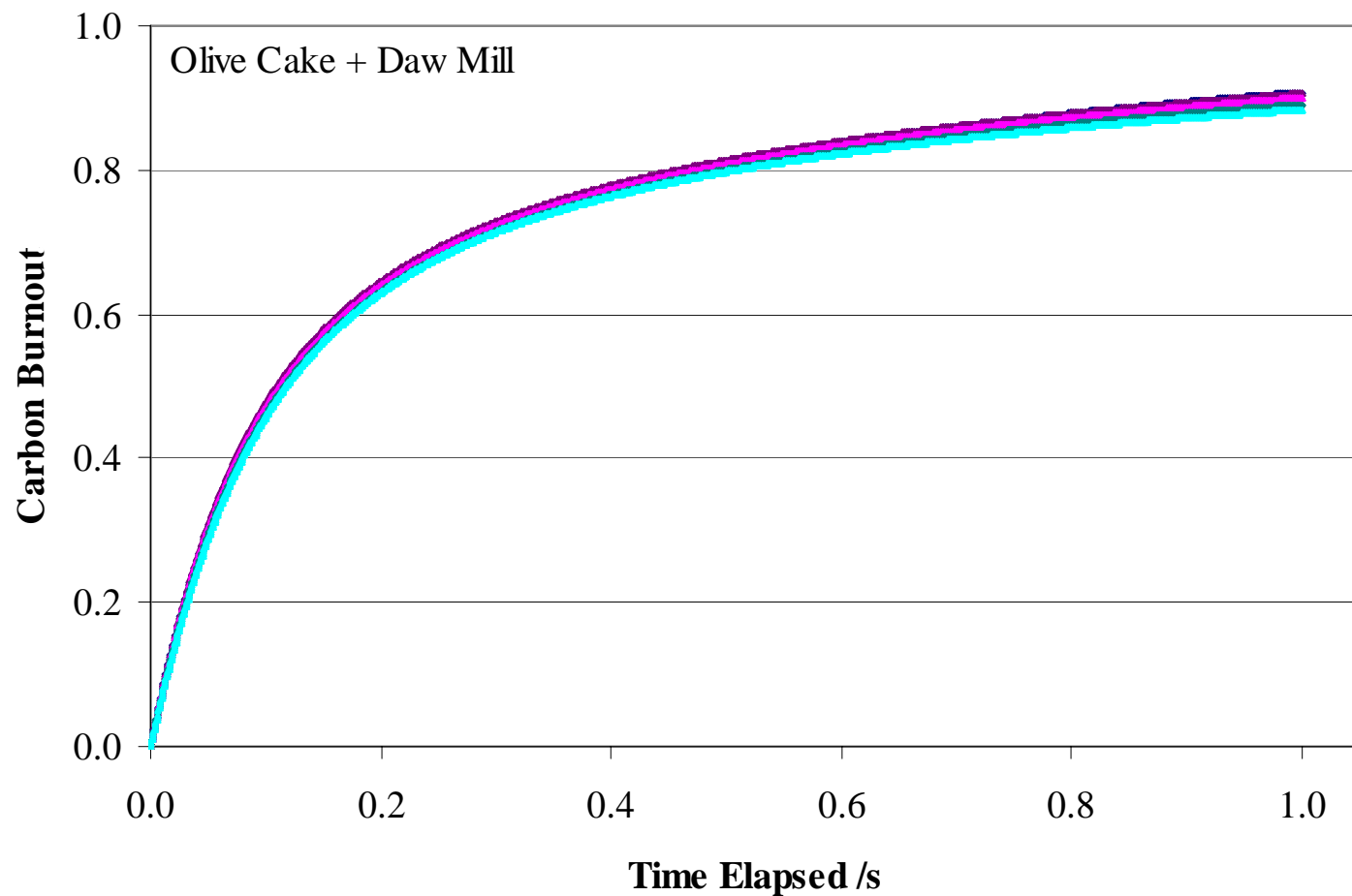
0% Daw Mill

5% CCP

10% CCP

20% CCP

30% CCP



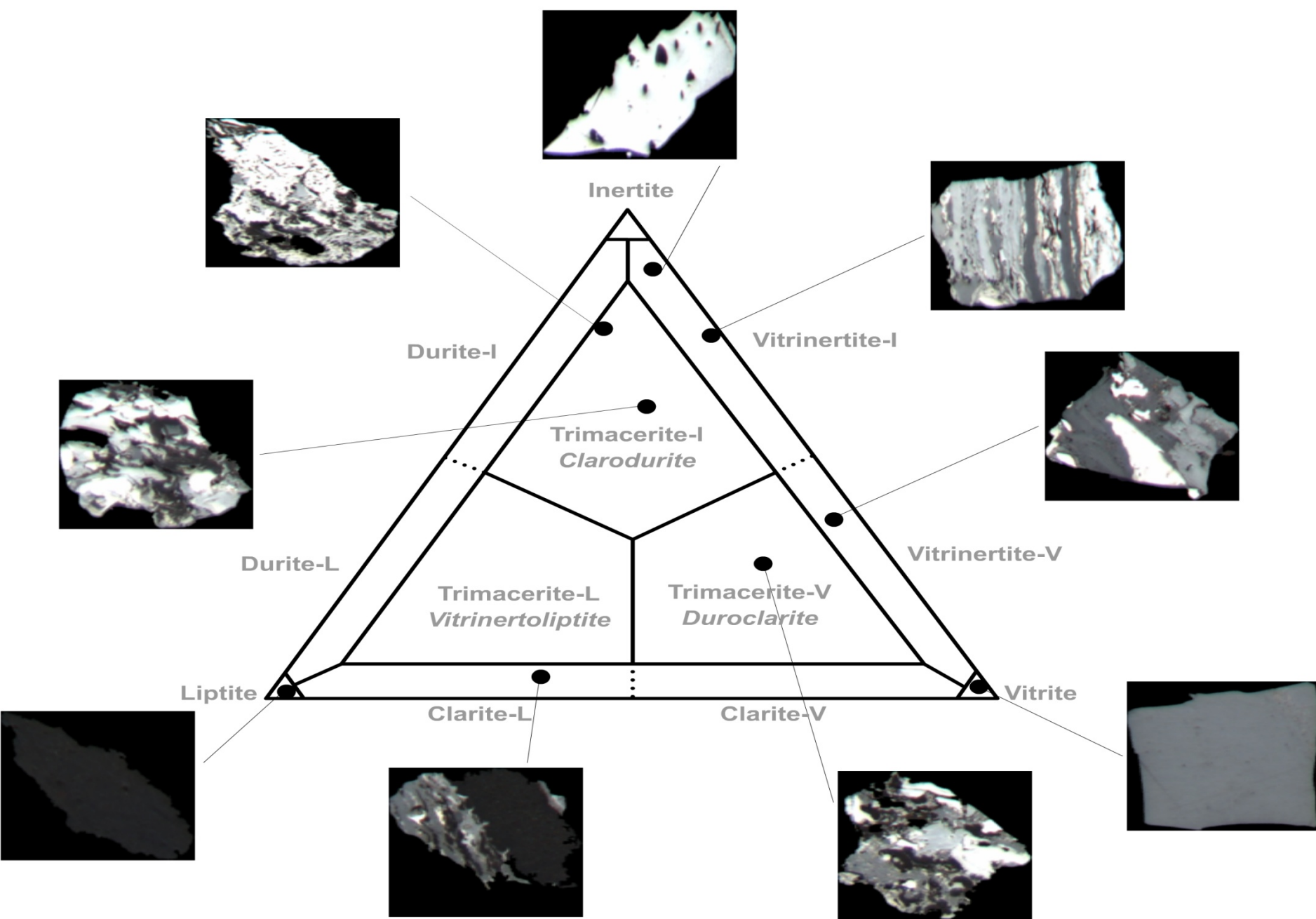
0% Daw Mill 5% Olive Cake 10% Olive Cake 20% Olive Cake 30% Olive Cake



ADVANCED COMBUSTION MODELLING

Virtually modelling free!

Figure 7 - The position of each particle on the trigonal microlithotype diagram using the image analysis technique. *This figure is discussed in the "Manual and Automated Microlithotype results" section*



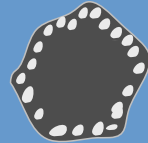
Formation of Different Chars



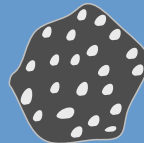
Coal Particles



Vitrinite + <5%Inertinite



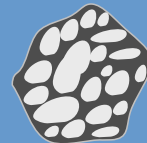
Vitrinite +
<50%Inertinite



Vitrinite +
<50%Inertinite



Vitrinite +
<50%Inertinite



Vitrinite +
>75%Inertinite

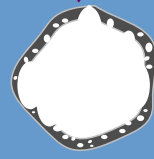
Char Types



Tenuisphere



Crassinetwork



Crassisphere



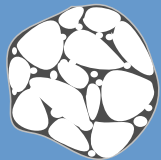
Crassinetwork



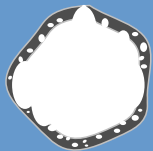
Mixed-Dense



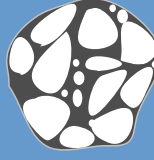
Inertoid



Tenuinetwork



Crassisphere



Mixed-Porous



Mixed-Porous

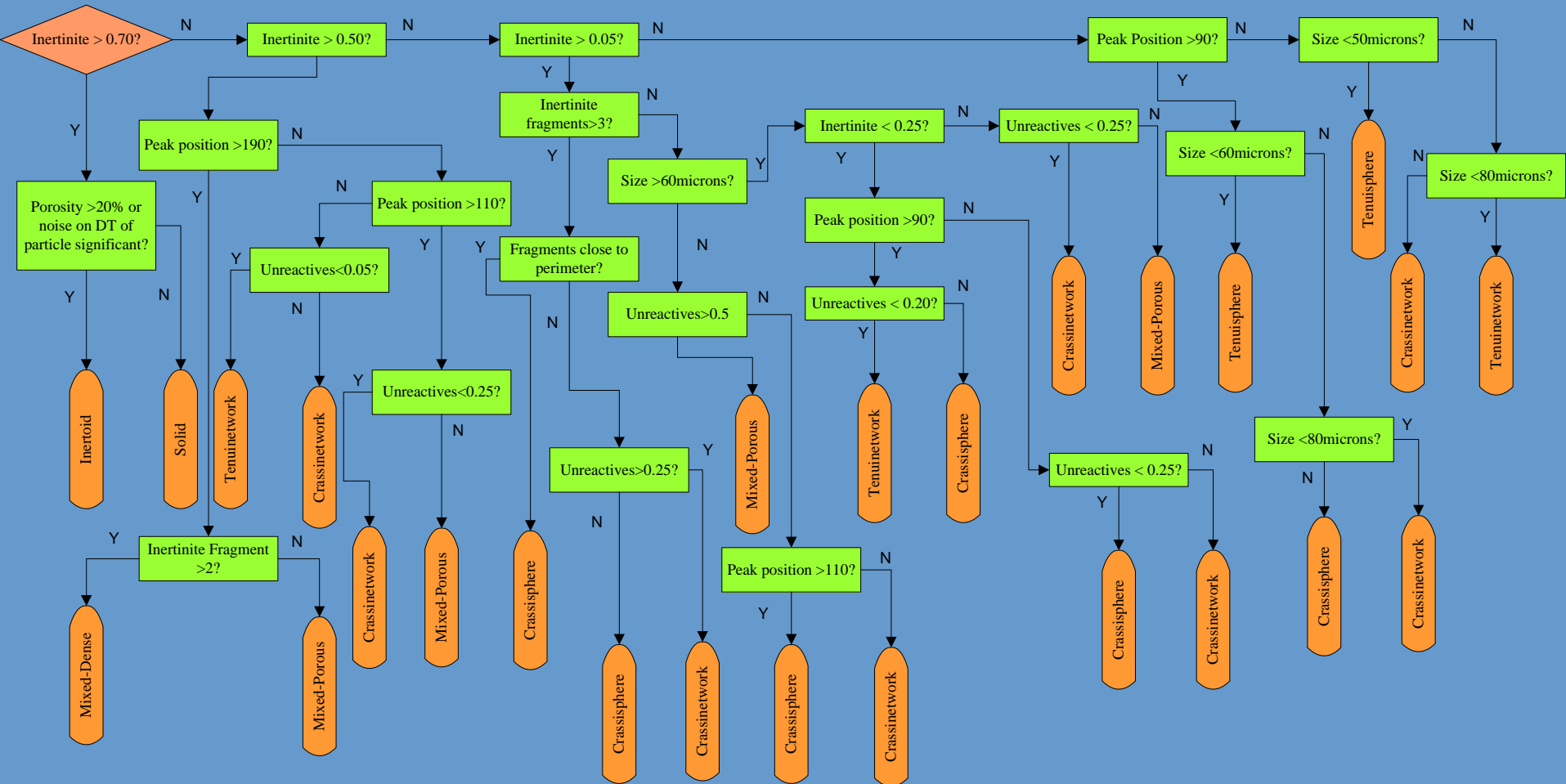


Solid

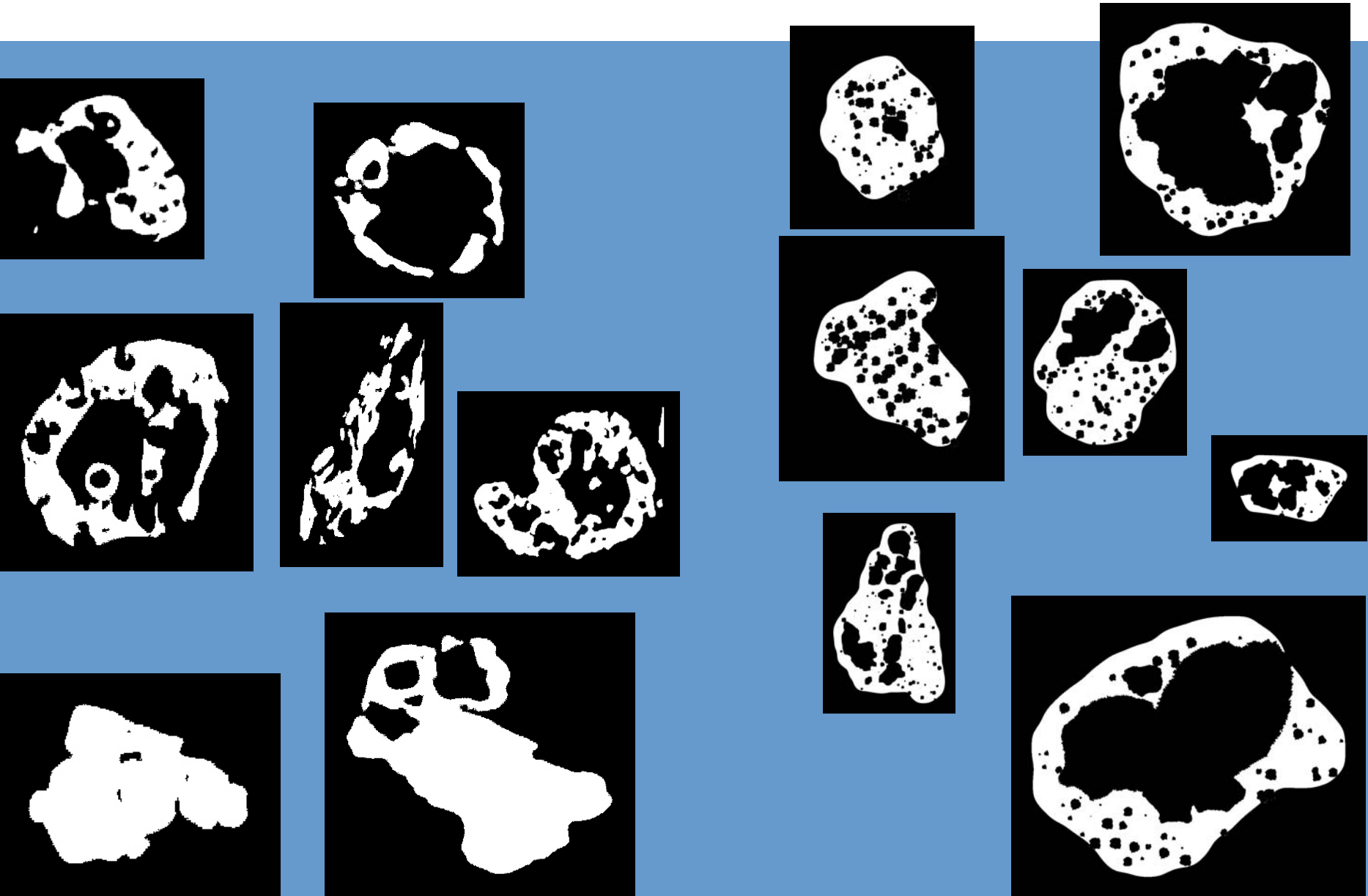


Mixed-Dense

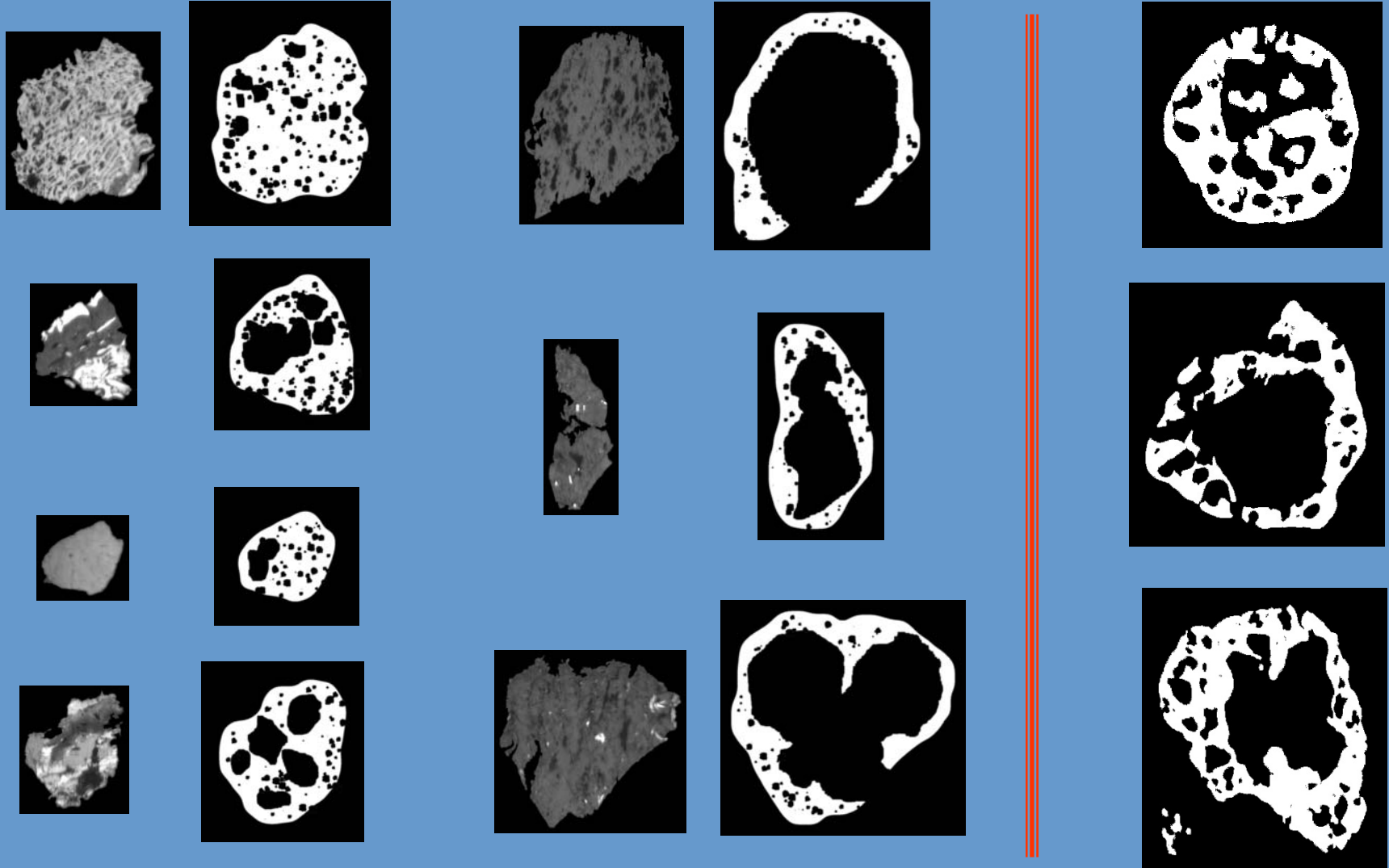
How to Predict Char Morphology?



REAL AND FAKE?



Predicted Char Morphology



Predicted Char Burnout History



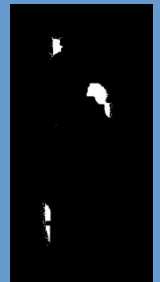
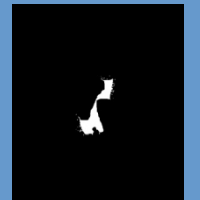
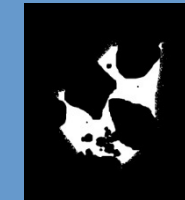
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25%

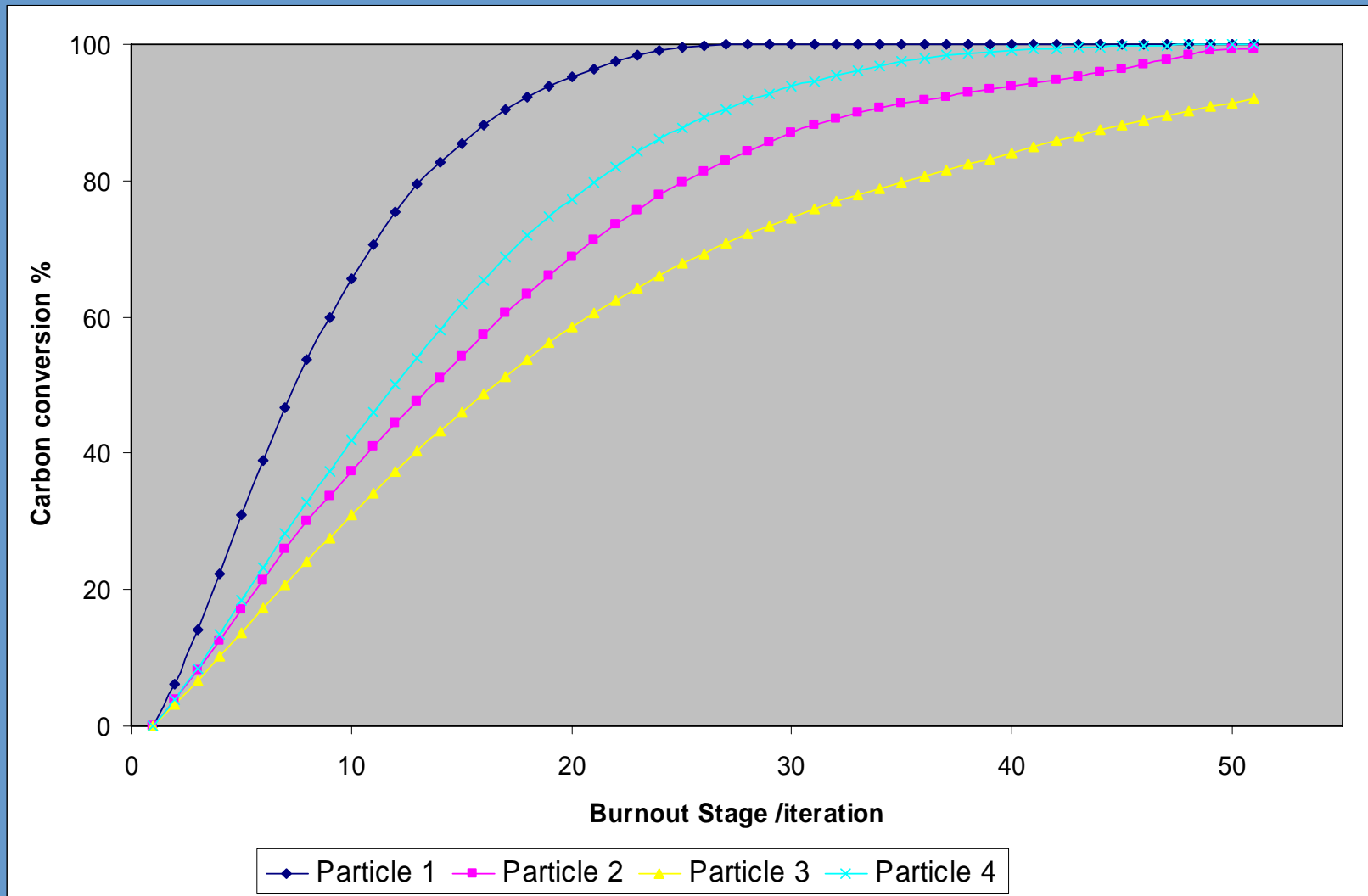
50%

75%

95%



Char Burnout History





Conclusions

- Image analysis plays a key role in
 - Coal characterisation
 - Char Characterisation
 - Combustion Modelling
- IA essentially is quantitative rather than qualitative
- IA is not perfect but can be based around rules from operators (expert systems)
- IA is more consistent than manual operators

acknowledgements



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- BCURA B77