Tracing the maceral origin in combustion chars.
The inertinite in Combustion WG of ICCP

Report of the Activities in the Inertinite and Combustion WG of ICCP in the period 1995-2001

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Inertinite in Combustion W.G.
Tracing back the origin of char material

Introduction, objectives
and activities 1995-2001

Participants of the Inertinite in Combustion W.G.

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Thanks!!

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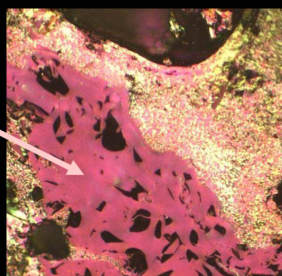
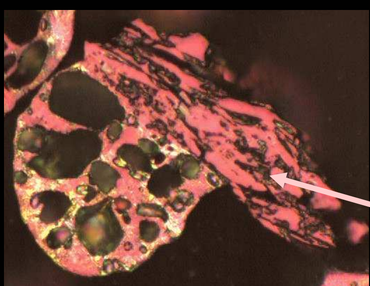
The inertinite in combustion W.G. was established in 1995 at the Krakow Meeting as the natural evolution of the former **reactive inertinite W.G.**, which mainly dealt with the behaviour of inertinite under the conditions prevailing in coke ovens.

Unreacted inertinite in coke



Once the reactive inertinite W.G. accomplished the objectives pursued [1], it was decided to redirect it to the study of the transformations undergone by inertinite in conditions similar to those occurring in pulverised fuel (p.f.) boilers, taking advantage of the expertise acquired, but also bearing in mind that the conditions at which both processes operate strongly differ from each other in heating rates, atmosphere, particle size, etc.



Unreacted inertinite in char

[1] Kruszewska K., Fuel 1989, 68, 753-757

The combustion reactivity of inertinite has been the subject of a number of studies [1-14], many of which made use to a variable extent of the experience achieved from the coking industry. These studies coincide in that the plasticity of inertinite when submitted to p.f. conditions is enhanced compared with carbonisation, and that most of the inertinite undergoes changes which are identifiable with the aid of an optical microscope. Experience has also shown that the inertinite-rich coals may burn as efficiently as vitrinite-rich ones and therefore the concept of reactivity is not necessarily linked to that of fusibility [10-12].

[1] Nandi B.N., Brown T.D., Lee G.K. Fuel **1977**, 56, 125-130.
[2] Gray R. Goscinsky J. Schoenberger R. Proc J. Conf. Iron Steel Soc. Soc Min. Eng. AIME **1978**, 3
[3] Diessel C.F.K. Fuel **1983**, 62, 883-892
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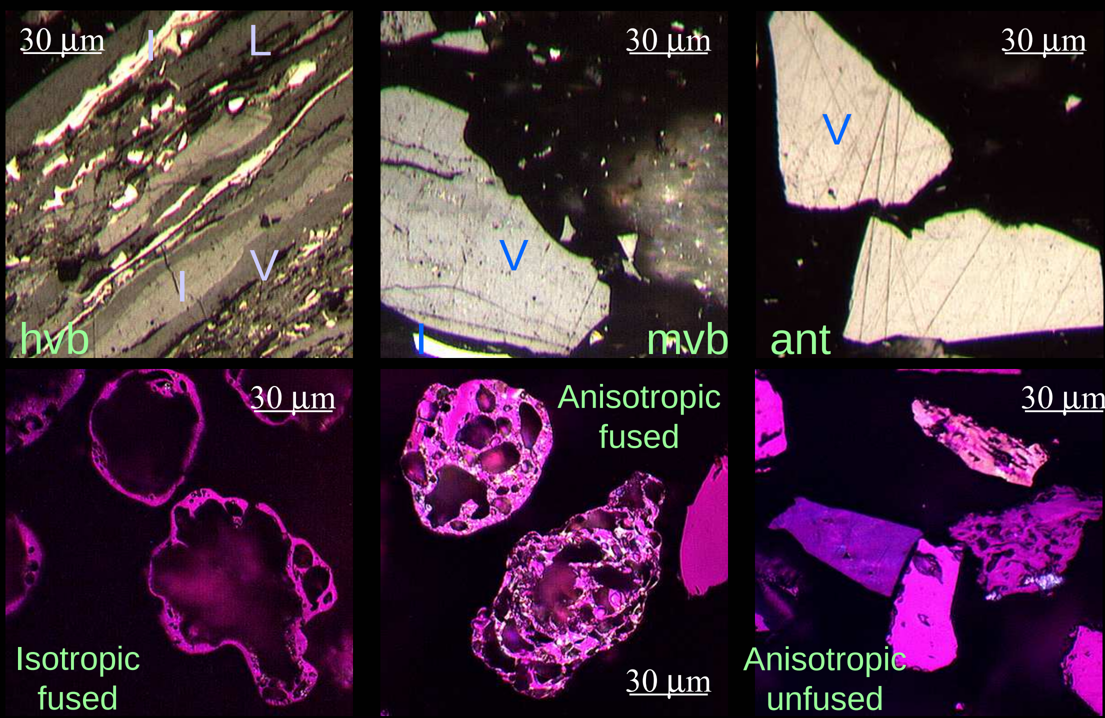
[5] Falcon R.M.S., Snyman C.P. **1986**. The Geological Society of South Africa, Review 2
[6] Diessel C.F.K. & Wolff-Fischer E.M. Int J. Coal Geol. **1987**, 9, 87-108
[7] Skorupska N.M., Sanyal A., Hesselman G.J., Crelling J.C., Edwards I.A.S., Marsh H. Proc. Int. Conf. Coal Science 1987, 827-831
[8] Bailey J., Tate A., Diessel C.F.K. & Wall T., Fuel 1990, 4, 225-239.
[9] Furimsky E., Palmer A.D., Kalkreuth W.D., Cameron A.R., Kovacik G. Fuel Proc. Technol. 1990, 25, 135-191
[10] Thomas C., Shibaoka M., Gawronski E., Gosnell M.E., Phong-anant D. Fuel 1993, 72, 913-919
[11] Vleeskens J.M, Menéndez R.M., Roos C.M. & Thomas C.G. Fuel Proc. Technol. 1993, 36, 91-99
[12]Thomas C., Gosnell M.E., Gawronski E., Phong-anant D. Shibaoka M. Org. Geochem. 1993, 20, 779-788
[13] Borrego A.G., Alvarez D. & Menéndez R. Energy Fuels 1997, 11, 702-708
[14]Alonso M.J.G., Borrego A.G., Alvarez D. & Menéndez R. Fuel 1999, 78

Vitrinite follows rather defined trends depending on the rank of the coal under p.f. combustion conditions [8,14].



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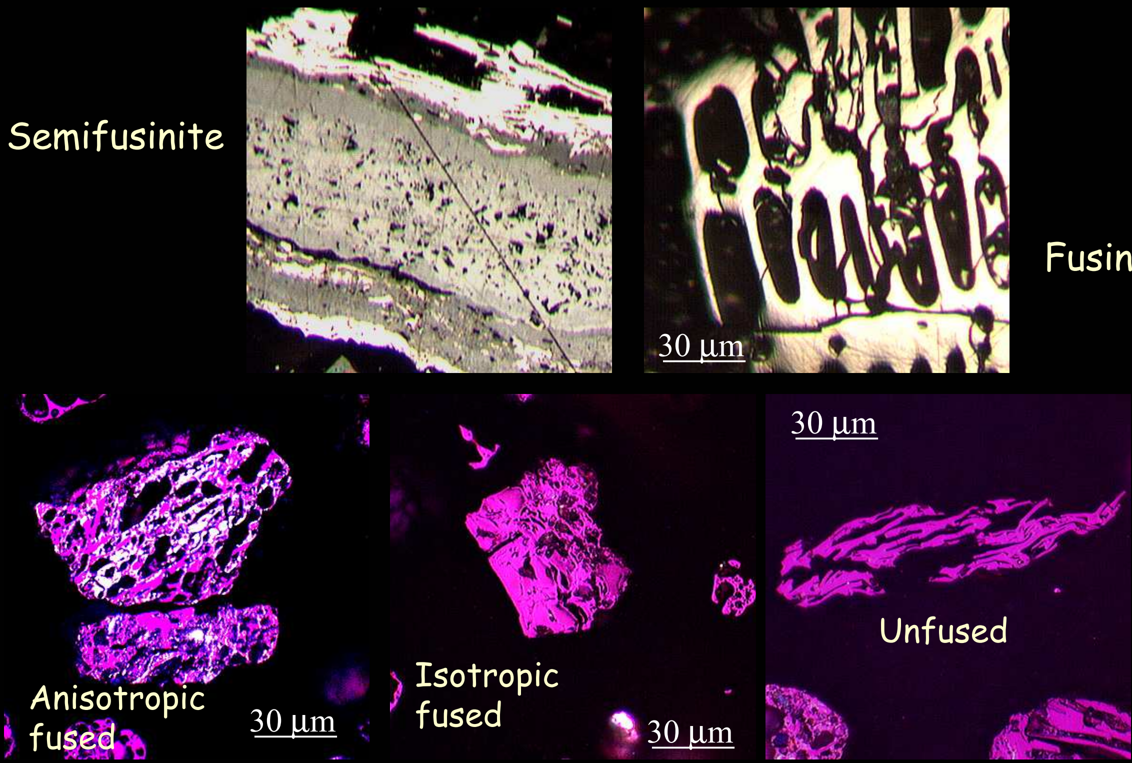
Inertinite behaves (under p.f. combustion conditions) in a way, that is difficult to systematise, due to its inherent heterogeneity.



Objectives

Although the subject "reactivity of inertinite" may be well beyond the scope of an ICCP W.G., there are a number of points where petrology may make a contribution to the understanding of inertinite behaviour in the boilers, provided that we are able to establish the relevant features to be considered.

- Description of the optical appearance of the inertinite in chars
- Establishment of petrographic criteria able to group those materials which are likely to behave in a similar manner during combustion
- Determination of the relationships between the optical properties of inertinite in coals and chars

Classification scheme

A rather simple classification scheme was established in the Meeting held in Heerlen (1996), in which the criteria to distinguish between classes consider both the optical texture (isotropic/anisotropic) and the porosity development. The system has 7 different classes that cover all the possible char occurrences.

Origin	Behaviour	Optical texture	Porosity	Group
Vitrinite				G1
		Anisotropic	Porous	G2
	Fused		Dense	G3
		Isotropic	Porous	G4
Inertinite			Dense	G5
			Massive	G6
	Unfused		Fusinoid	G7

The counting procedure is similar to the one used for **maceral** analysis and considers **the material under the crosswire**, which has a homogeneous optical appearance and **not the whole particle**.

Classes description

- **G1** would include all kind of domains which could derive from vitrinite, and these can be isotropic or anisotropic, depending on the rank of the coal.
- **G2** would include the char materials which have been presumably formed from inertinites, but have been highly altered during pyrolysis, showing both anisotropic texture and an important porosity development ($\rho > 50\%$).
- **G3** would include those domains formed from inertinites which have developed an appreciable anisotropy without further porosity development ($\rho < 50\%$).
- **G4** would be those isotropic inertinites, which have passed though a plastic stage and generated a porous structure ($\rho > 50\%$).
- **G5** would include the isotropic dense domains with evidence of having fused (i.e.: small spherical degassing pores) ($\rho < 50\%$).
- **G6** would include all the least altered inertinites not showing cellular structure. They will be mainly massive isotropic material without any sign of having passed through a plastic stage.
- **G7** would only include the unchanged fusinites. They will be typically isotropic but might also exhibit wavy-like anisotropy.

Round Robin exercises:

- In 1997, the char obtained at 1300 ºC from the inertinite-rich (68%) Middelburg hvb coal was microscopically analysed
- In 1998, the char obtained under similar conditions from a hand picked inertite of a hvb coal was microscopically analysed.
- In 1999, the round robin was carried out on CD images with marked fields. Participants were also asked to run manually the sample from last year round robin and the char from Collinsville (mvb coal 46% inertinite)
- In 2000, the CD contained images taken with and without retarder plate in order to study the influence of observation conditions in the results

The assignements agreed on the images by the W.G. participants are the basis of the atlas included in this CD

Summary of results; microscopy analysis

- Briefly, the results of the manual analysis were rather poor. Some of the difficulties were related to imprecision in the definition of the groups (porosity limits, size of the field) or to variable observation conditions (magnification, retarder plate) and some other were linked to characteristics of the coal itself.
  - The definitions were improved and some porosity limits were established (ρ ~ 50%).
  - The size of the field to be classified was defined as the material having similar appearance to that under the crosswire.
  - Magnification of 40x-60x were selected as compromise among the participants.
  - The main discrepancies were related to the distinction between isotropic and anisotropic material.
  - Establishment of the origin of porous material (vitrinite-derived vs. inertinite-derived).
  - Distinction of small degassing bubbles and establishment of the origin of unfused material completed the summary of uncertainties.

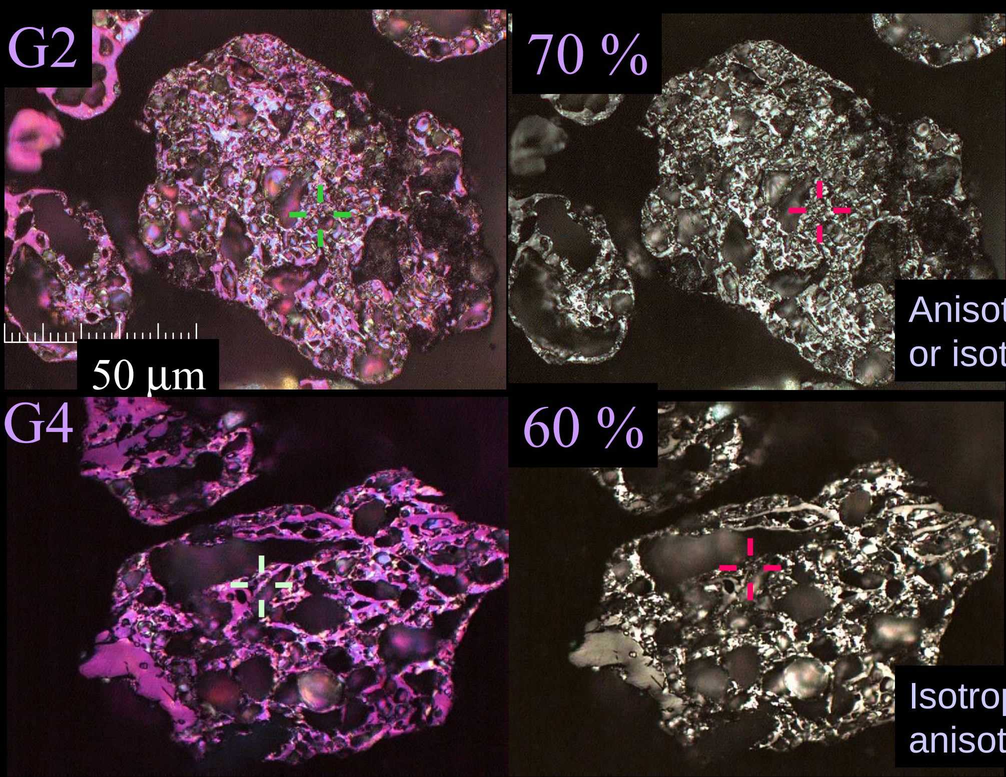
Summary of results; CD analysis

Images were taken with 50x oil immersion objective, crossed polars and retarder plate. Complete information on chemical and petrographic analysis of the parent coals was provided.

- Briefly, the results of the CD analysis were very good. Uncertainties related to observation conditions were eliminated and only some difficulties related to the size of the field to be identified and characteristics of the coal itself remained.
  - The main discrepancies were still related to the distinction between isotropic and anisotropic material.
  - Estimation of porosity (under/over 50%)
  - Establishment of the origin of porous material (vitrinite-derived vs. inertinite-derived).
  - Did fusinite fuse to certain extent?
  - Establishment of the origin of unfused material completed the summary of uncertainties.

Examples of these discrepancies are given in the following slides

Distinction between isotropic and anisotropic material is difficult in chars due to the small size of the domains.



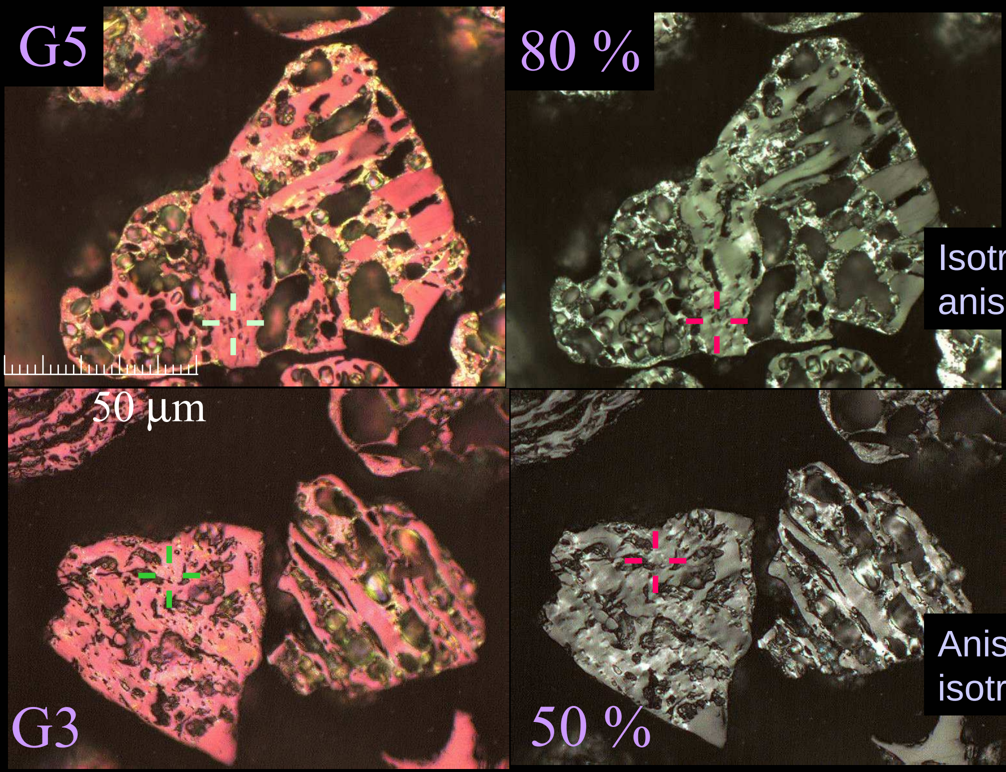
Mvb coal

Anisotropic porous or isotropic porous ?

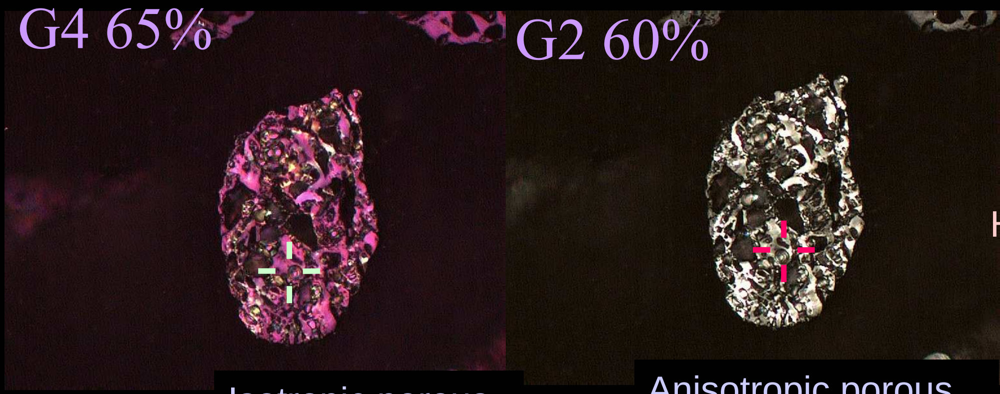
Hvb coal

Isotropic porous or anisotropic porous ?

Distinction between isotropic and anisotropic material is difficult in chars due to the small size of the domains.

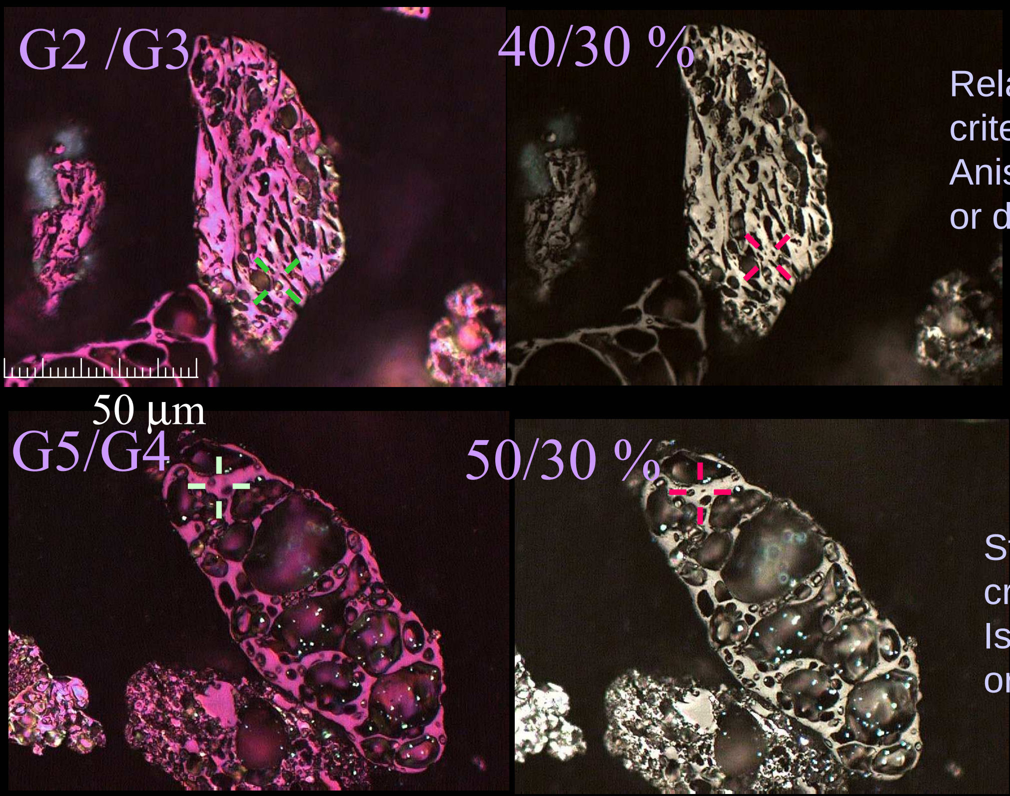


Distinction between isotropic and anisotropic materials might be more difficult in the images than under the microscope since the microscope allow the stage rotation. The use of retarder plate decreases the effect of both polishing relief and internal reflections in the pores that might produce the impression of anisotropy in materials otherwise isotropic.



This effect was observed in few cases, but it cannot be regarded as the main source of discrepancies.

Difficulties in the estimation of porosity (under/over 50%) are mainly related to the size of the field having an homogeneous optical texture

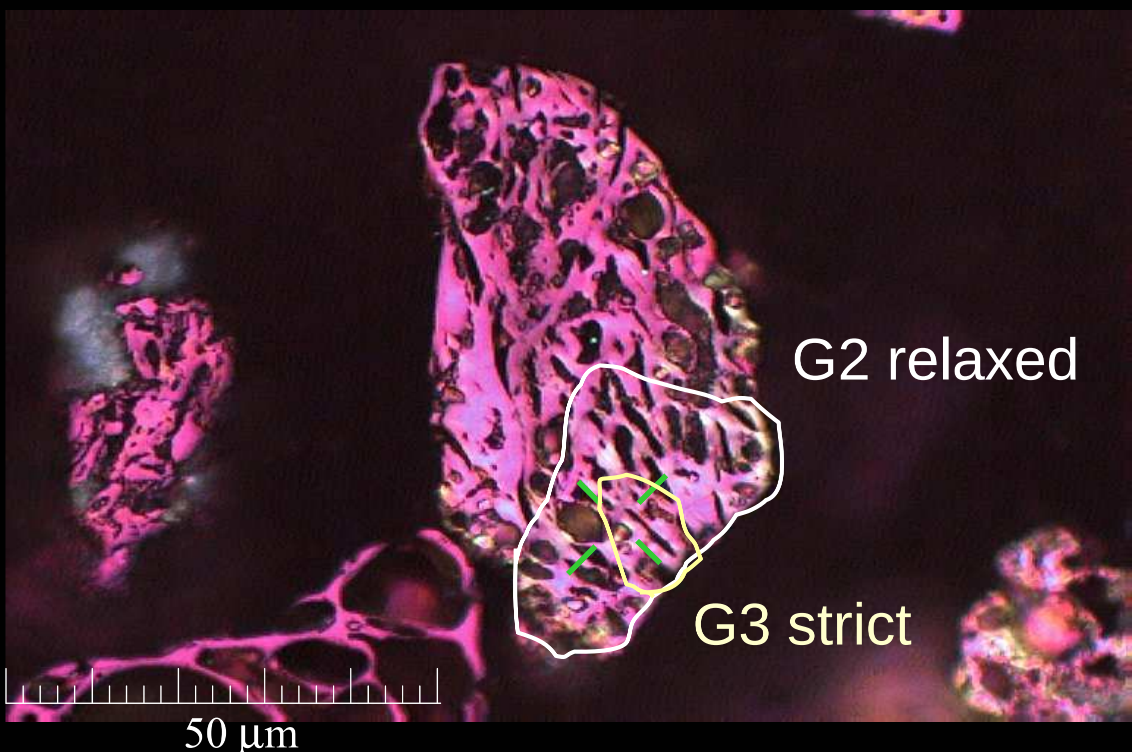


Relaxed or strict criterion?
Anisotropic porous or dense?

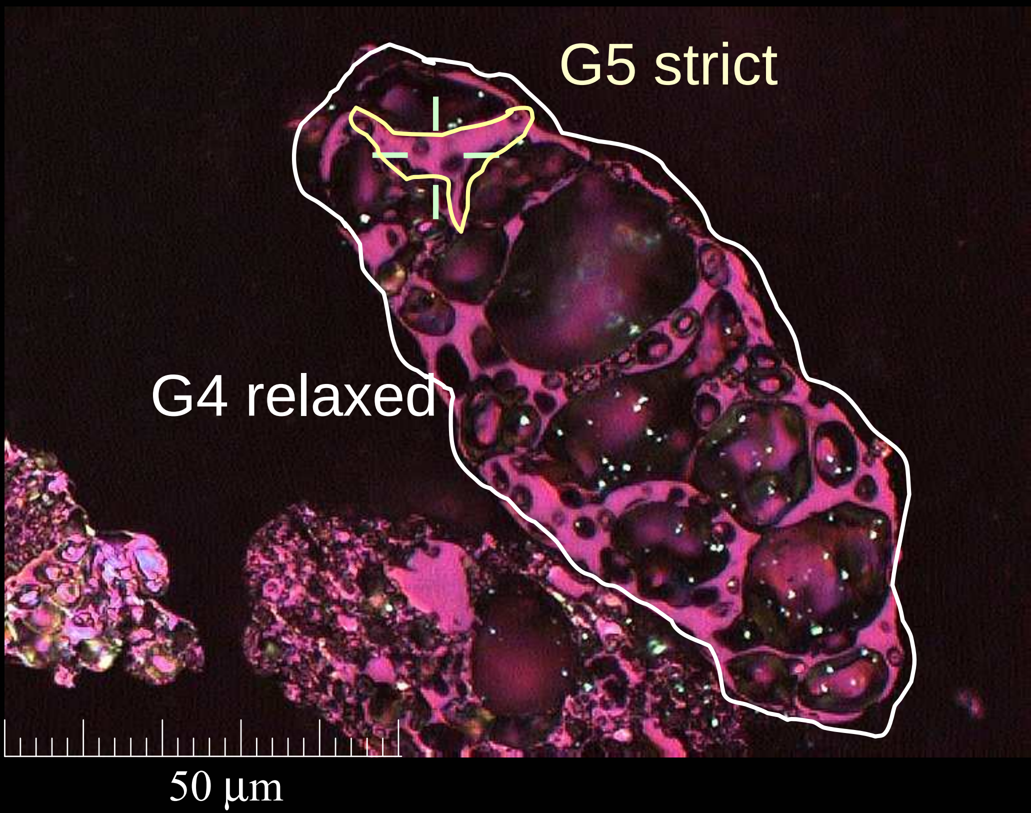
Hvb coal

Strict or relaxed criterion?
Isotropic dense or porous?

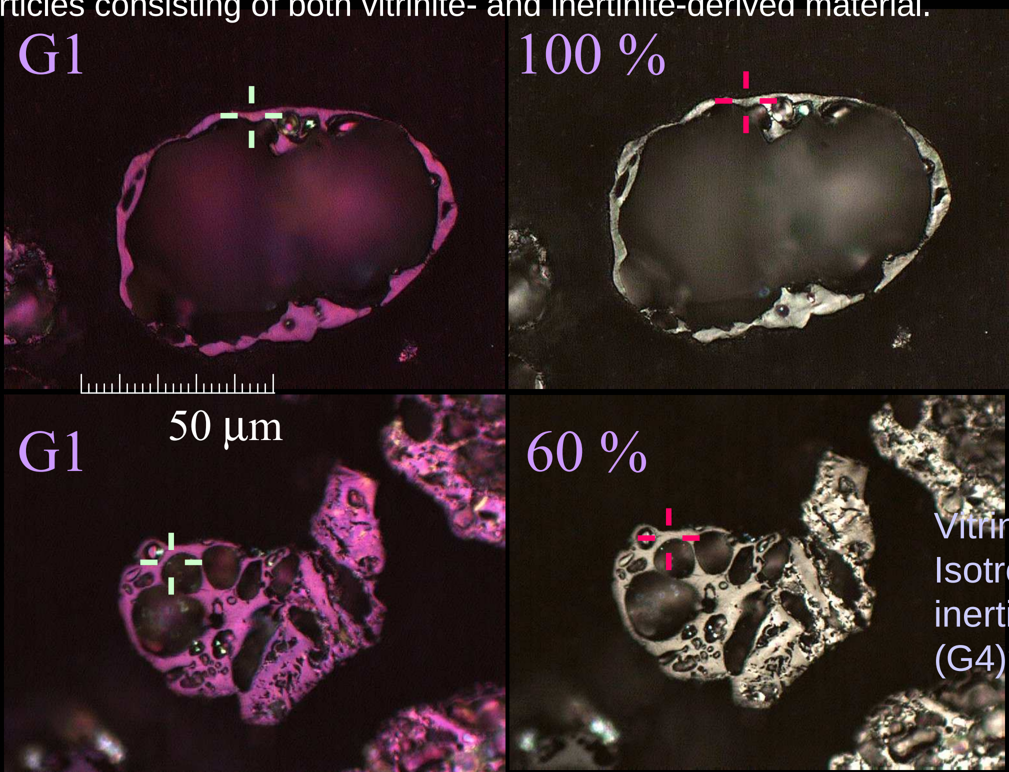
Relaxed or strict criterion?



strict or relaxed criterion?



Establishment of the origin of porous material (vitrinite-derived vs. inertinite-derived). The level of agreement was very high in cenospheric-like particles, but lower in particles consisting of both vitrinite- and inertinite-derived material.

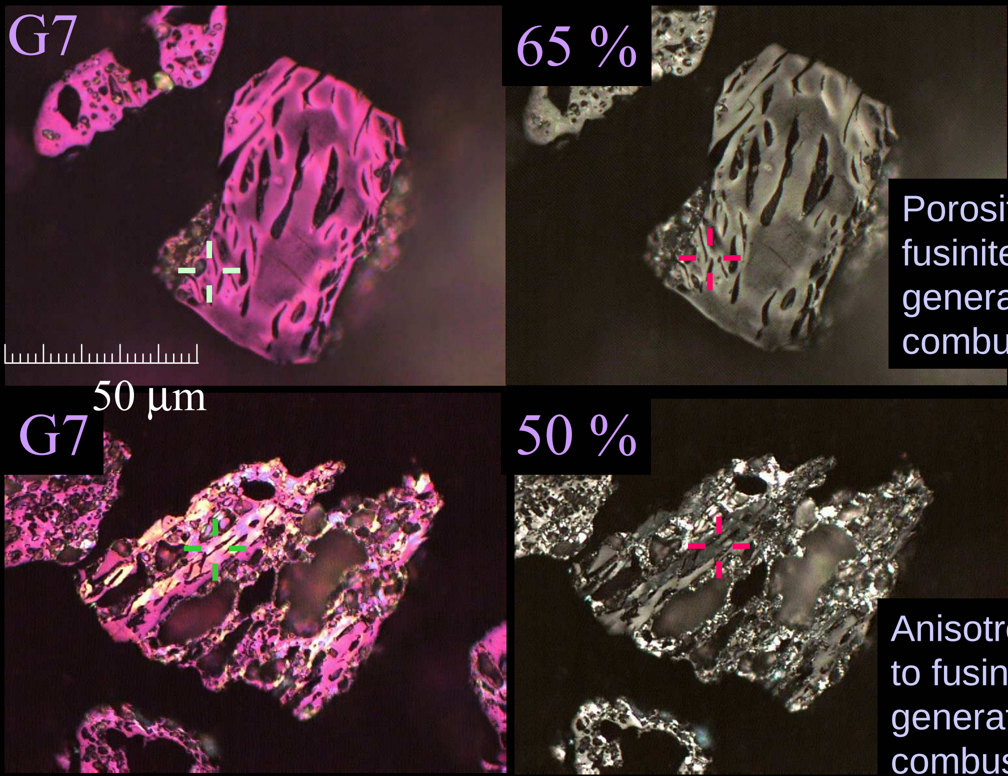


Vitrinite-derived

Hvb coal

Vitrinite-derived or Isotropic porous inertinite-derived (G4)?

Was fusinite transformed to certain extent?

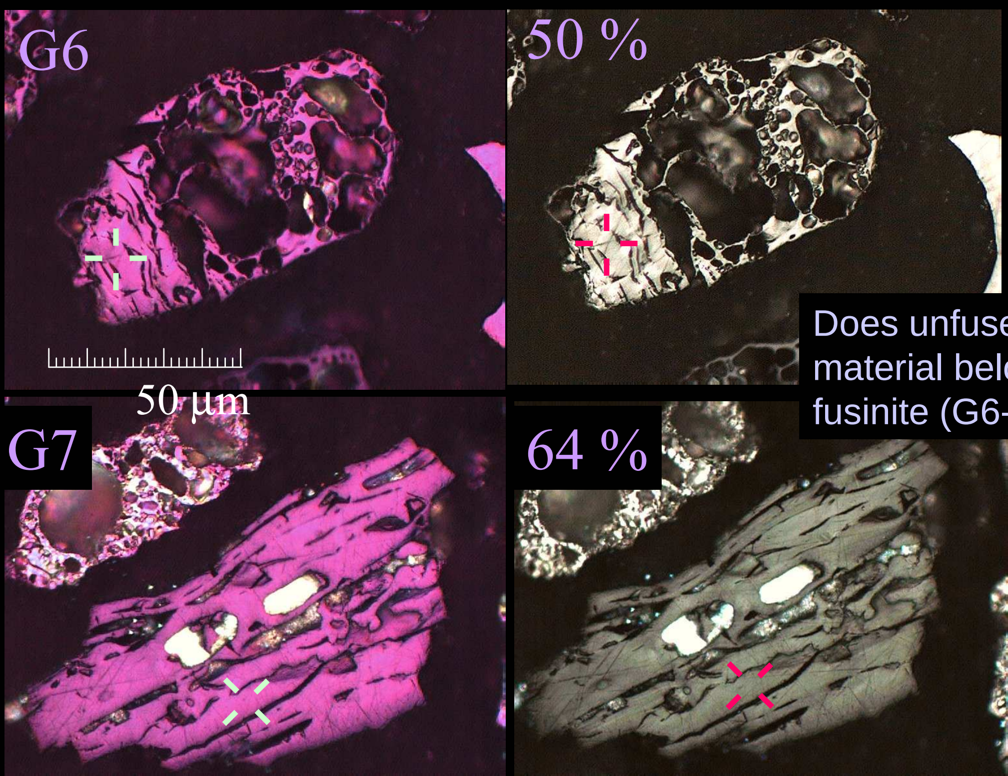


Porosity belongs to fusinite or it was generated during combustion (G5)?

Hvb coal

Anisotropy belongs to fusinite or it was generated during combustion (G3)?

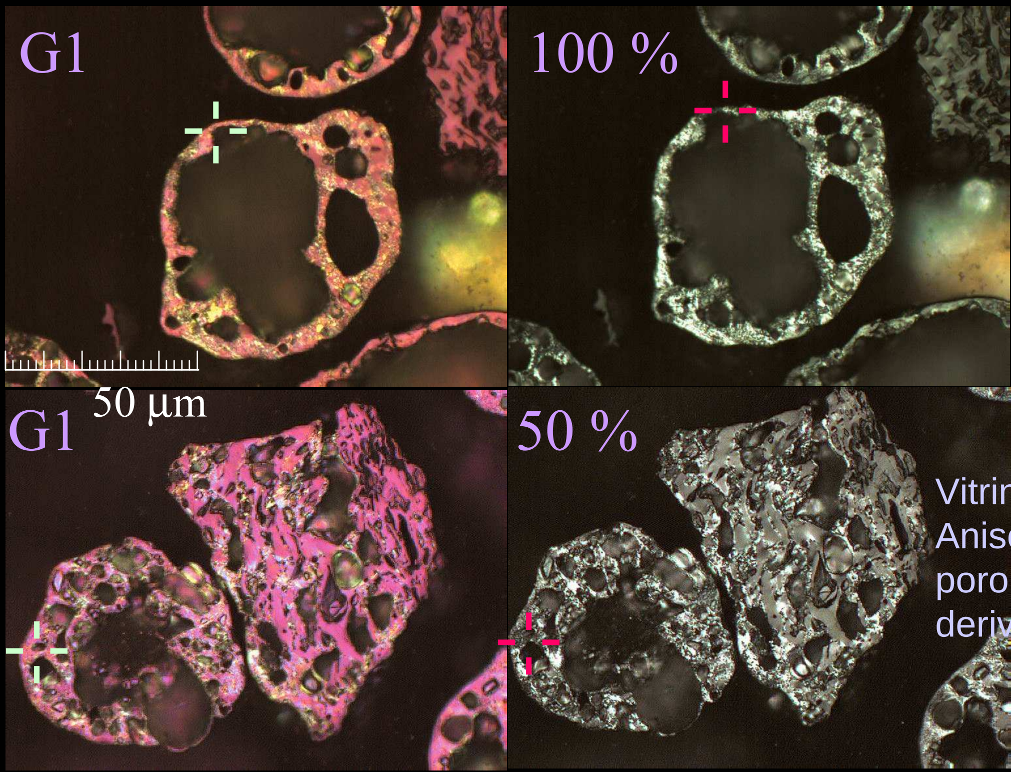
Establishment of the origin of unfused material



Hvb coal

Does unfused material belong to fusinite (G6-G7)?

Establishment of the origin of porous material (vitrinite-derived vs. inertinite-derived). The level of agreement was very high in cenospheric-like particles, but lower in thick-walled particles with porosity within the walls.



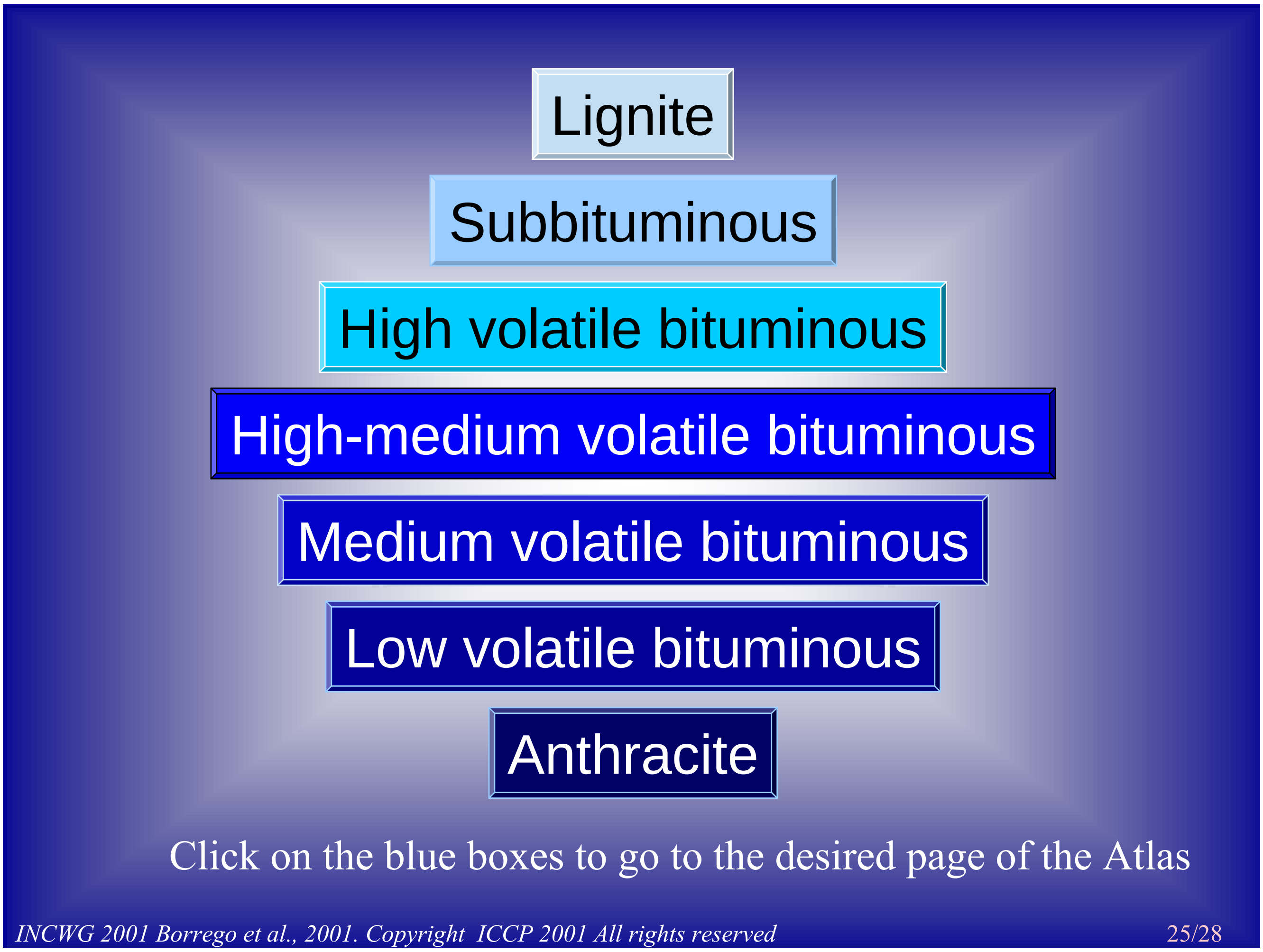
Vitrinite-derived

Mvb coal

Vitrinite-derived or Anisotropic porous inertinite-derived (G2)?

Coals used for the preparation of the chars

	T	I	D	A	N	C	J	K	S	M-B	L	T	V	W
Vitrinite	79.0	92.0	68.8	81.8	1.6	30.6	84.2	27.4	74-30	55	54.2	71.6	75.2	61.8
Inertinite	20.0	4.0	28.6	17.0	97.2	66.0	10.4	67.6	24-64	45	45.8	28.4	24.8	38.2
Liptinite	1.0	4.0	2.6	1.2	1.2	6.4	5.4	5.0	3-8					
Rr (%)	0.46	0.55	0.56	0.61	0.66	0.68	0.68	0.73	0.81	1.05	1.28	1.77	2.06	3.23


Lignite
Subbituminous
High volatile bituminous
High-medium volatile bituminous
Medium volatile bituminous
Low volatile bituminous
Anthracite
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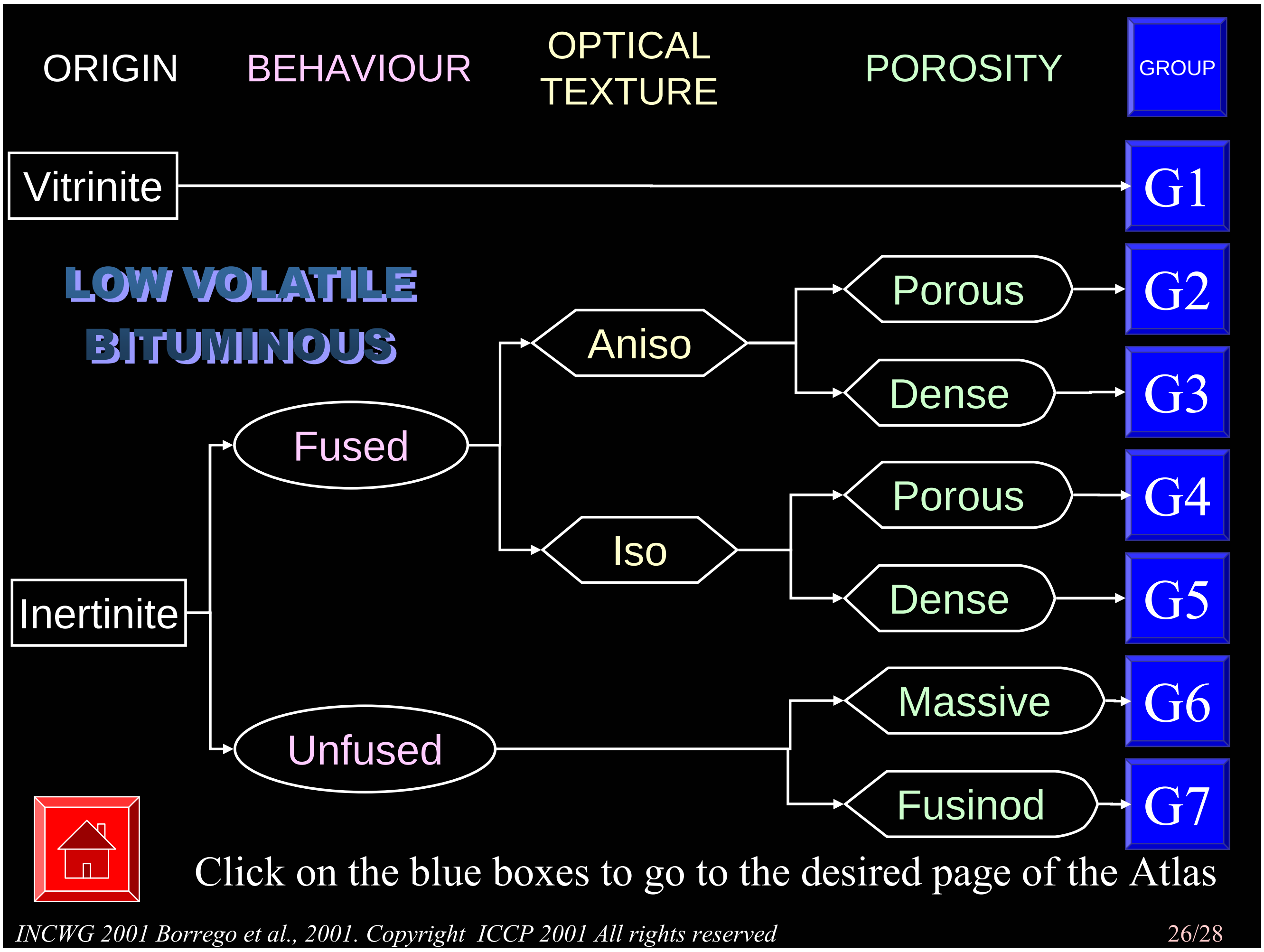
ORIGIN
BEHAVIOUR
OPTICAL TEXTURE
POROSITY
GROUP
Vitrinite
G1
LOW VOLATILE BITUMINOUS
Porous
G2
Aniso
Dense
G3
Fused
Porous
G4
Iso
Dense
G5
Inertinite
Massive
G6
Unfused
Fusinod
G7
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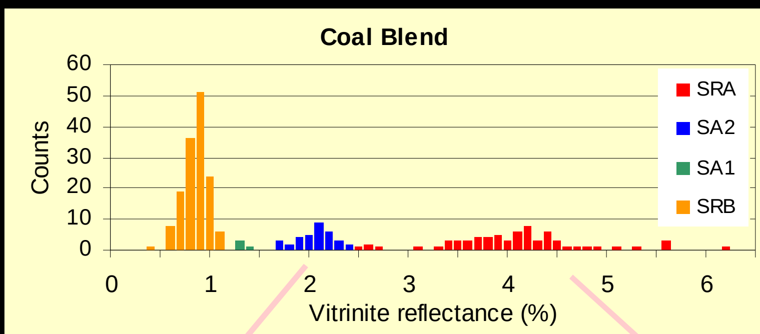
CD

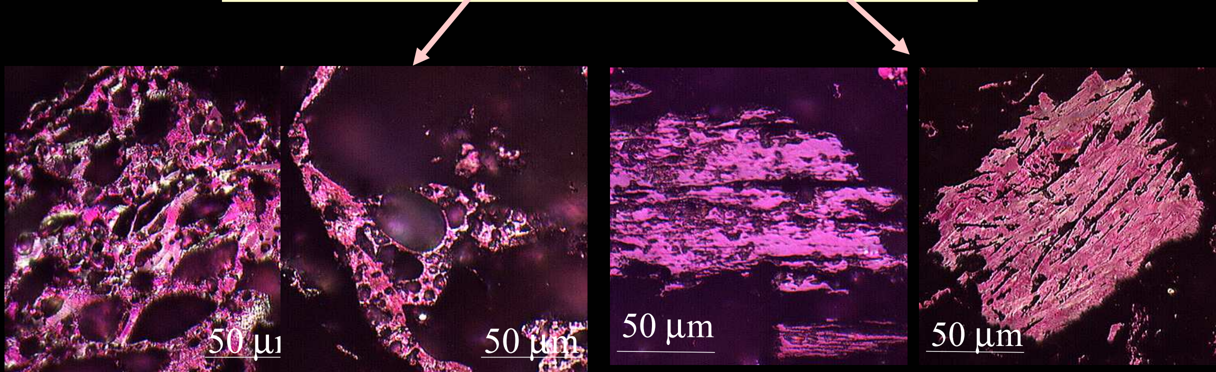
- The CD illustrates the variation in appearance of inertinite- and vitrinite-derived materials in chars from coals of increasing rank

- It is an aid for the identification of the origin of the char material.

- It will be equally useful to identify the origin of unburned material in flyashes

Unburnt carbon in fly-ashes from a commercial blend





Full scale combustion residues from a lvb coal

Full scale combustion residues from high rank anthracite