



Distribution of Pyrite and Mineral Matter in Coal Seams from Samarinda Area, Lower Kutai Basin, Indonesia

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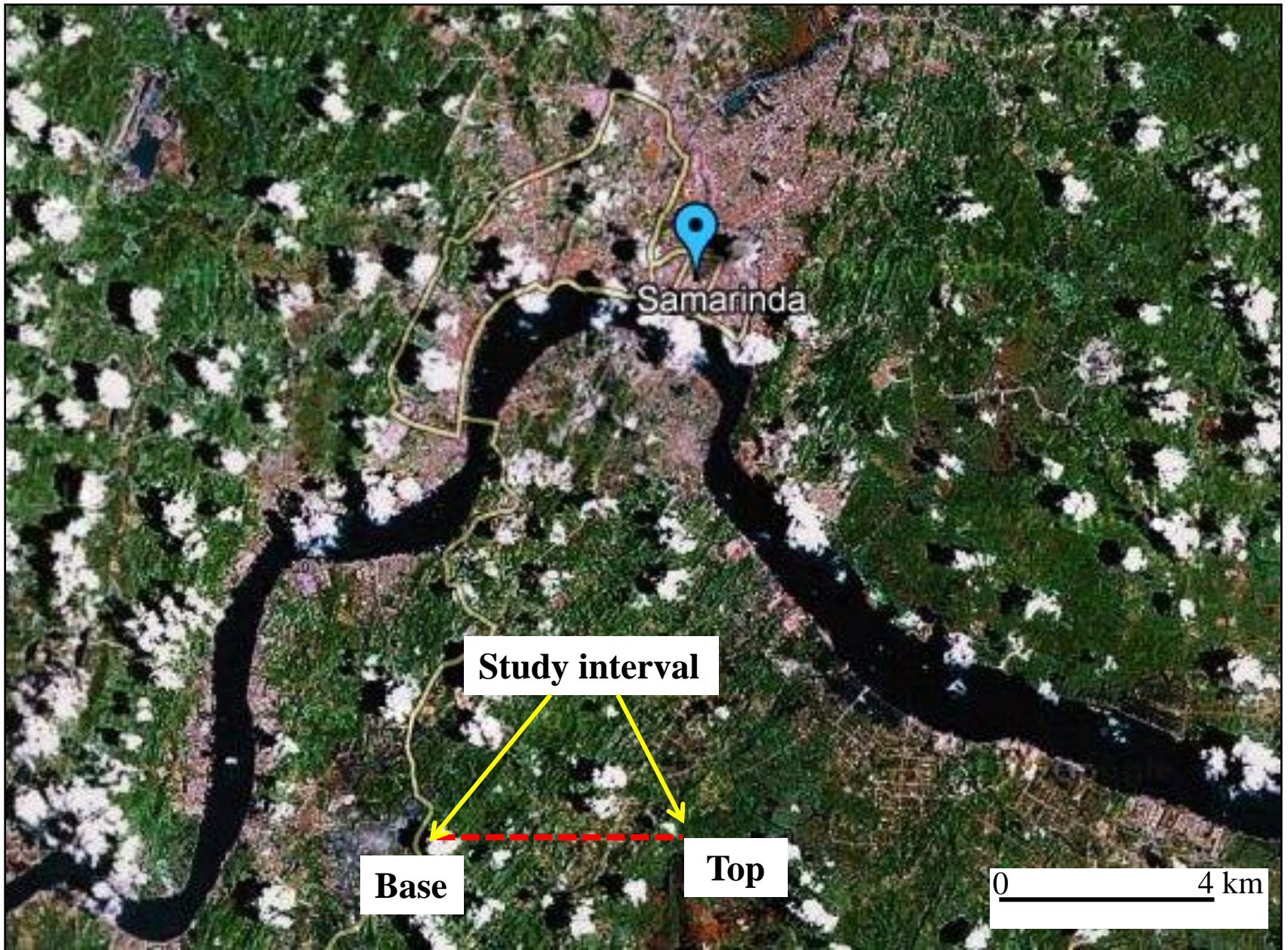
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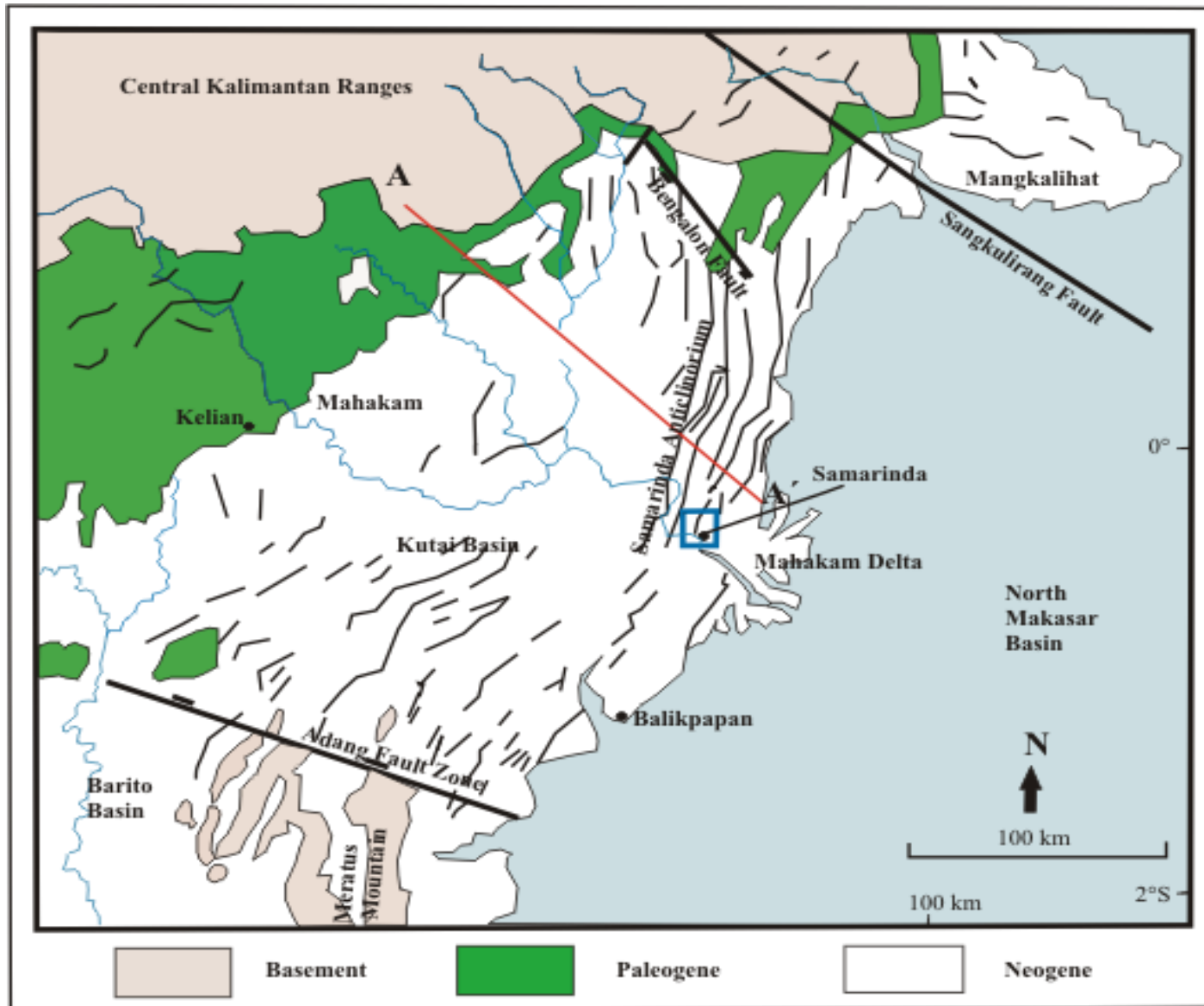
Seminar Program

- **Introduction**
- **Materials and methods**
- **Results and discussions**
- **Conclusion**

Introduction

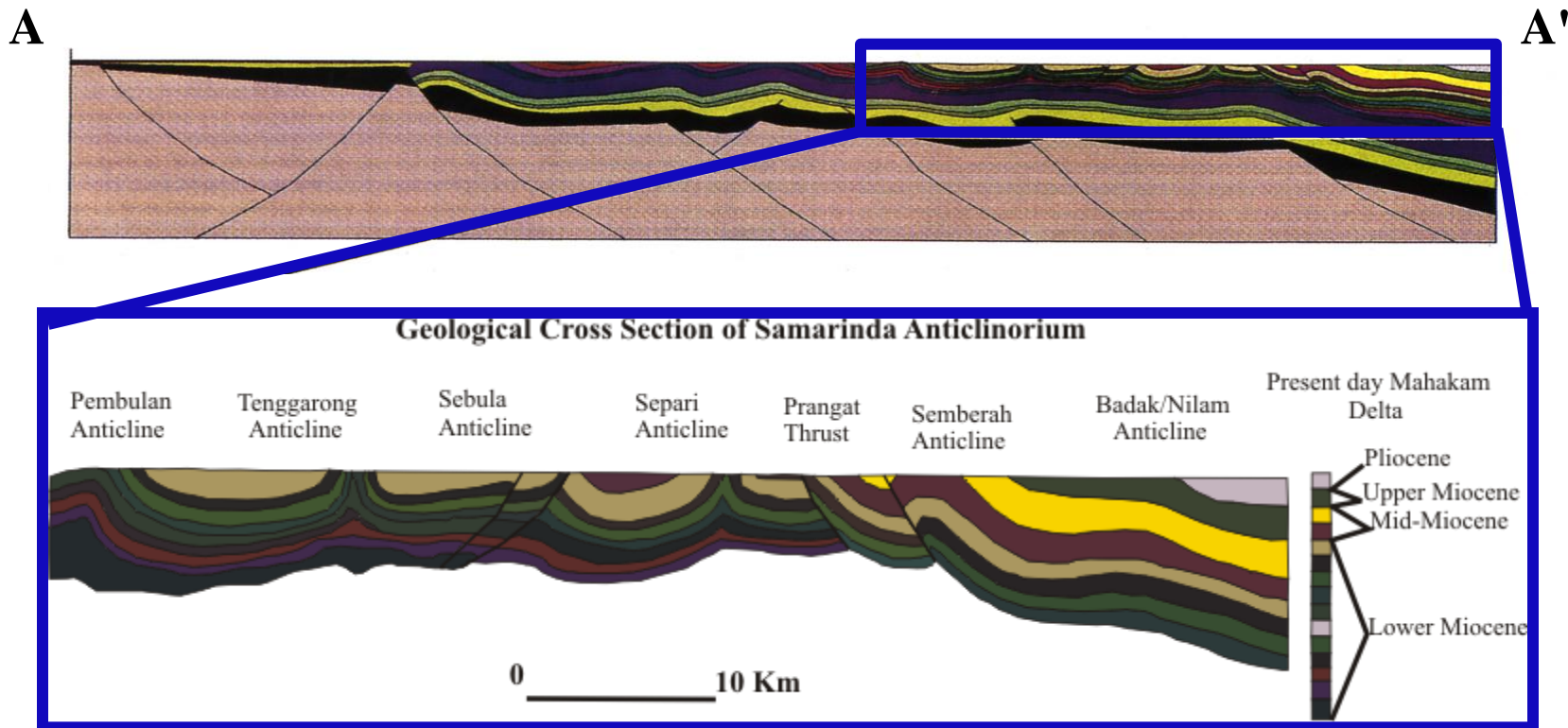


Regional Geology of the Kutai Basin

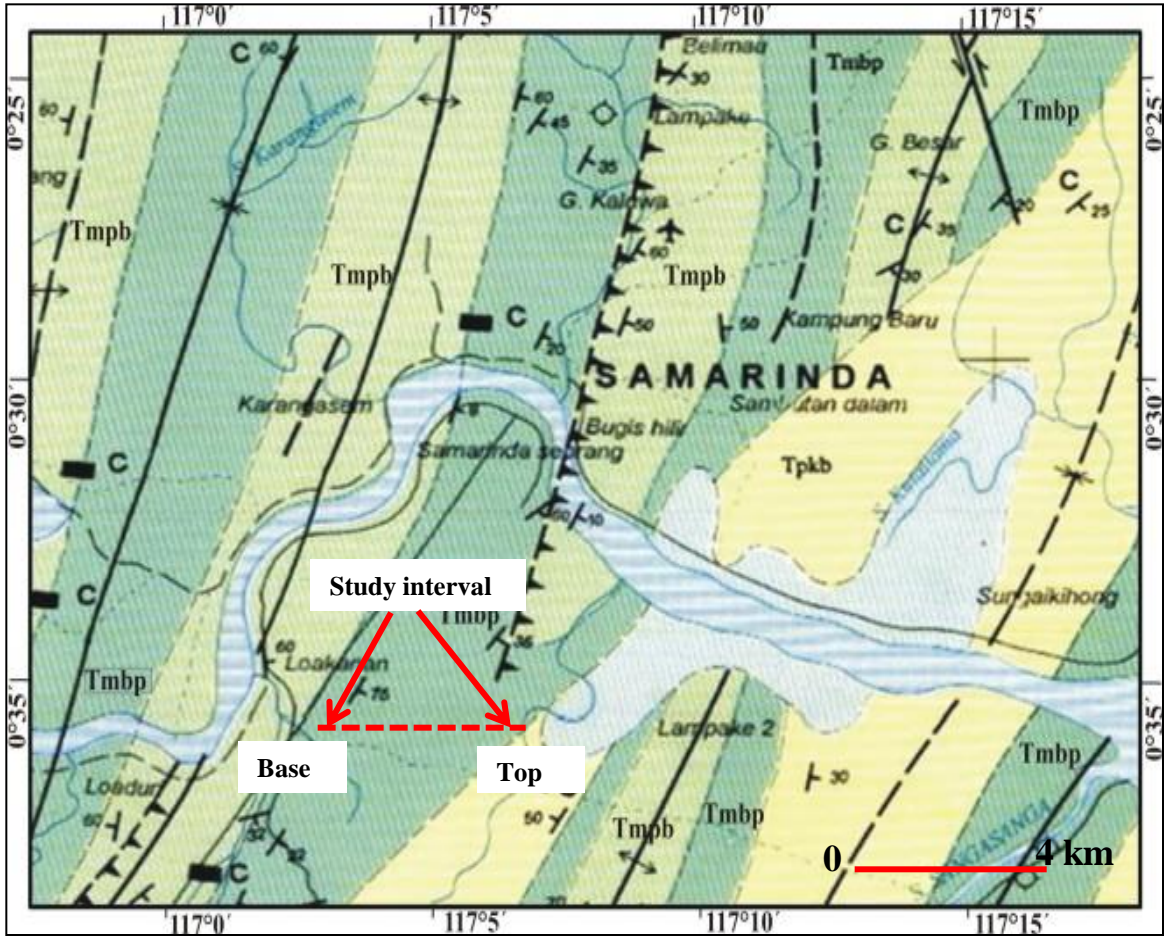


(George *et al.*, 1998).

Regional Cross Section of Samarinda Anticlinorium and Mahakan Delta Areas



(George *et al.*, 1998).



EXPLANATION

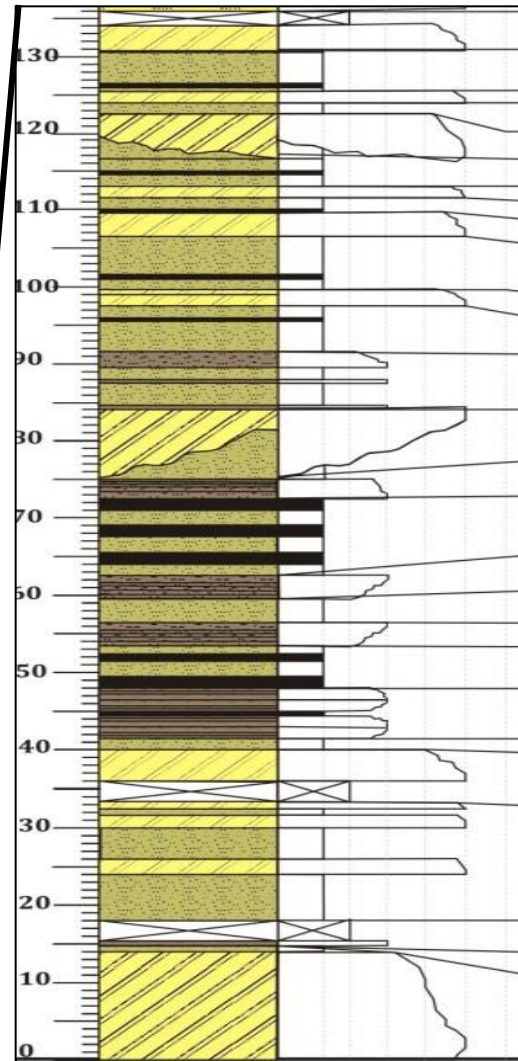
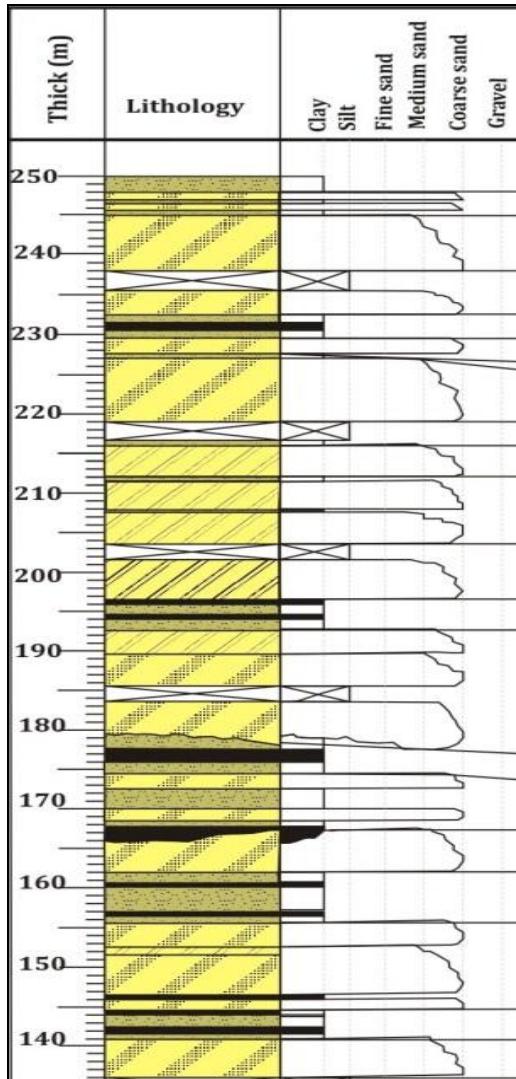
- Qa Alluvium
- Tpkb Kampungbaru Formation
- Tmbp Balikpapan Formation
- Tmbp Pulau Balang Formation
- Geological boundary
- Anticline and syncline
- Fault
- Thrust fault
- Strike slip fault
- Coal
- River

(Supriatna *et.al*, 1995)

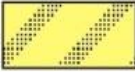




Coal of the Kutai Basin

- Early Miocene Pulau Balang Formation, Late Miocene **Balikpapan Formation** and Pliocene Kampungbaru Formation
- **low to moderate**, ranging from **lignite to high-volatile bituminous**
- Vitrinite reflectance is **0.45 to 0.63%**, higher than other Indonesian coal basins
- Ash content is **low** and **high in volatile matter** : these factors usually promote **good cleating** and may enhance **permeability** (Situmorang *et.al*, 2006)
- In Samarinda, **high-volatile bituminous and sub bituminous** (Land and Jones, 1987)

Material and Methods



Legend

-  Conglomerate and sandston
-  Coarse to medium-grained sandstone with trough cross-bedding
-  Fine-grained sandstone
-  Claystone
-  Coal

Summary Outcrop log and coal bearing interval of the studied stratigraphic section

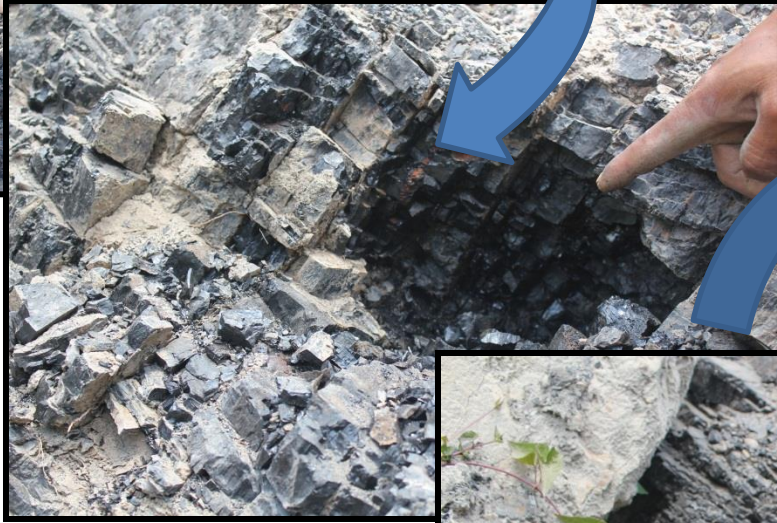
Procedure for measure section



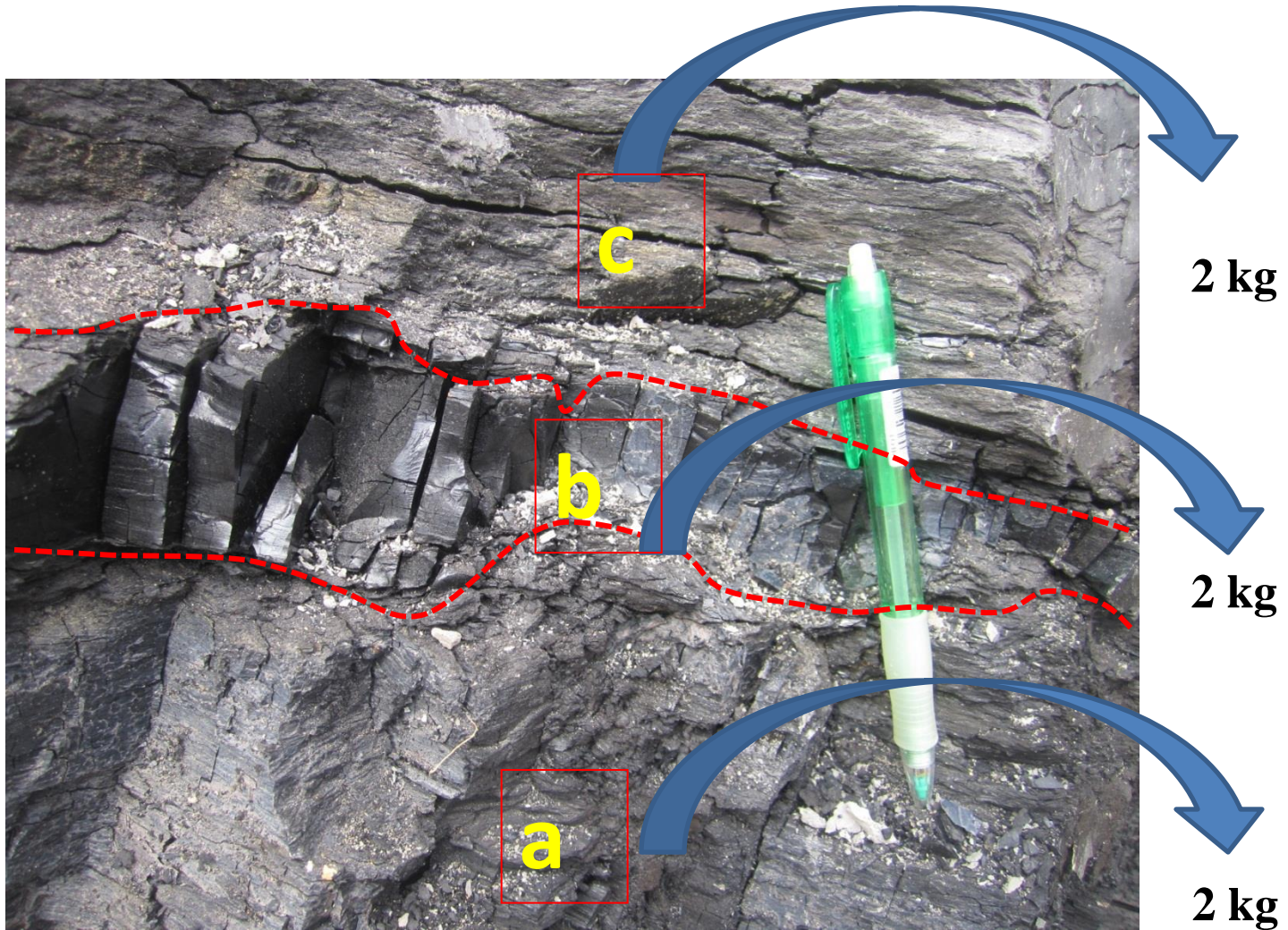
Procedure of coal sampling



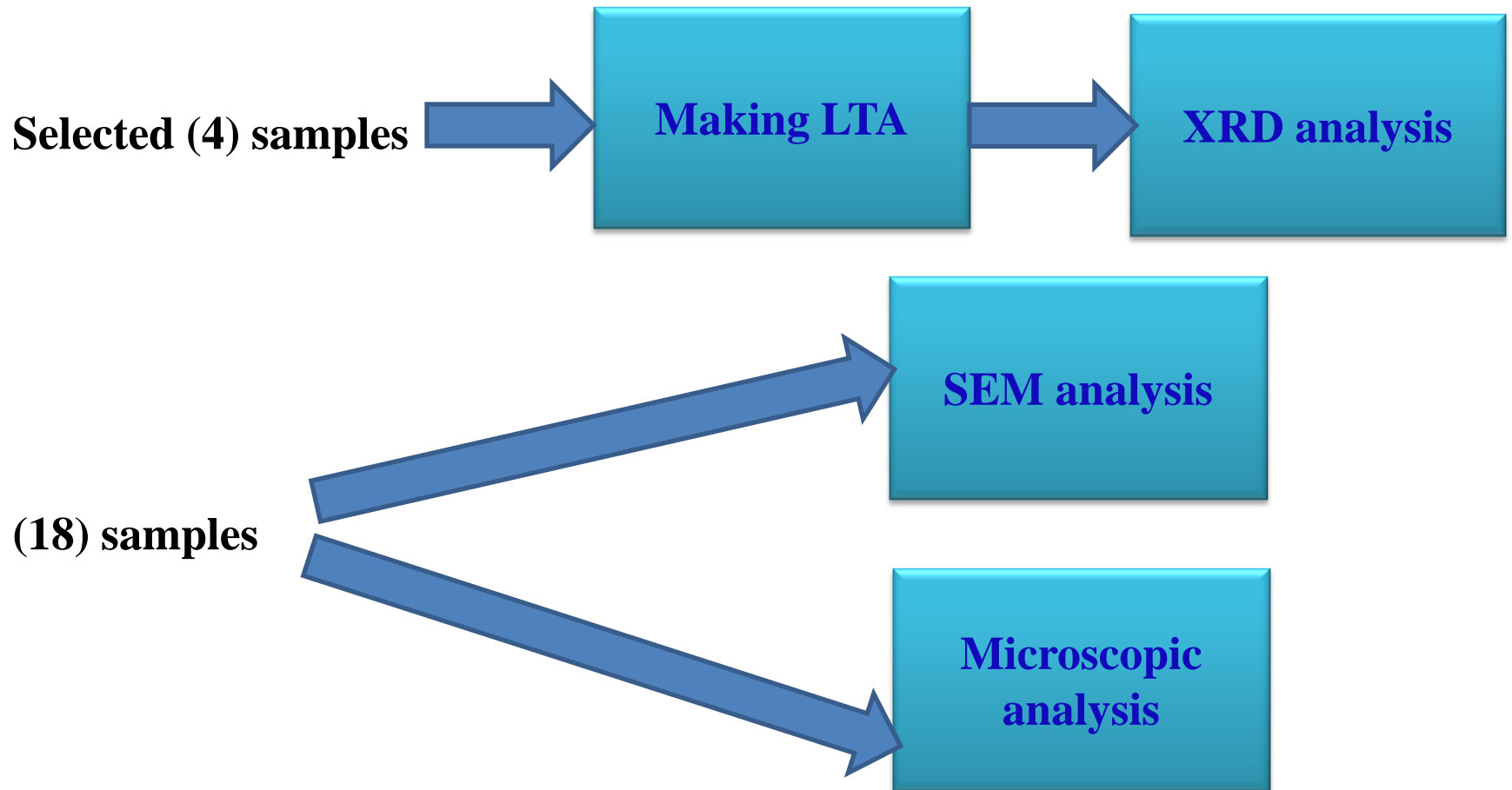
Procedure of coal sampling



In the case in changing Lithotypes



Sample preparation and analysis



For XRD analysis

Oxygen Plasma Ashing

- Particle size < 80 mesh
- A sample layer density 30 mg/cm³
- Oxygen flow rate 100 cm³/min
- Chamber pressure 50-W net radio frequency power
- Total time required 36 to 72 hours



SEM analysis



For Microscopic analysis

•18 Coal samples (represent **all seams**) for petrography.

•The sample preparation and microscopic examination generally followed the procedures described by Taylor et al., 1998.

Coal
sample

Wash with
water and
clean in the
ultrasonic
cleaner

Dry about
one hour

Crushing
by hand

Sieving
with 20
mesh size



embedded
in epoxy
resin,
ground and
flat

polished
with
Alumina 0.3
micron

clean in the
ultrasonic
cleaner



- Petrographic analysis was carried out on polished pellets **under incident light**
- Line to line, point to point spacing was maintained **1 mm**
- More than **200 counts** for each sample

Results and discussions

Pyrite and Mineral Matter in coal

- **Mineral Matter- Syngeneic (with coal formation)**
 - **Epigenetic (initial stages of colification)**
- **Mineral Types- (1) Aluminosilicates (clay minerals)**
 - **(2) Carbonate minerals**
 - **(3) Silicate minerals**
 - **(4) Sulfate minerals**
 - **(5) Sulfide minerals**
 - **(6) Other minerals**

XRD analysis result

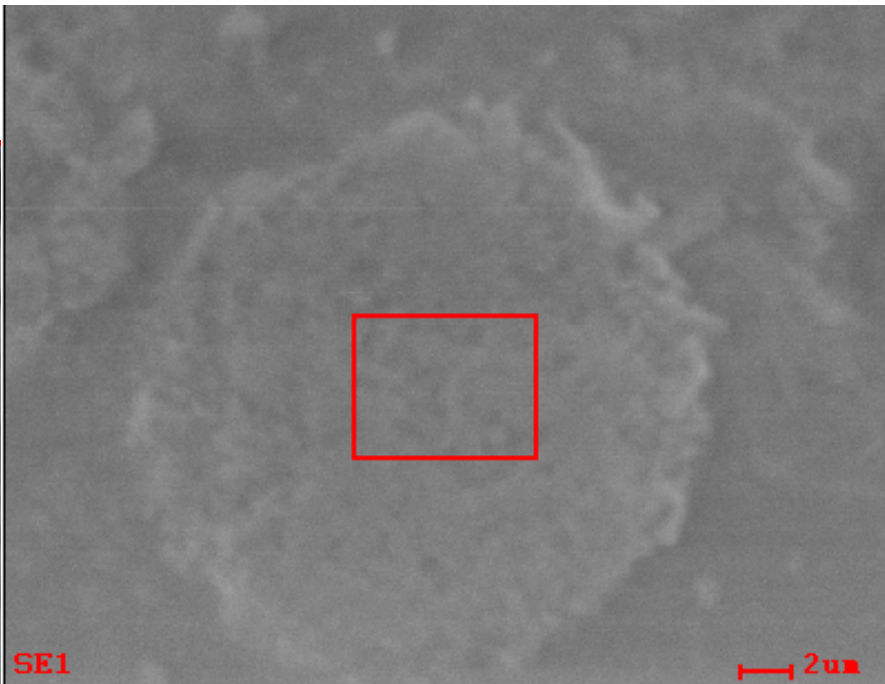
- **Owing to the difficulty of identifying minerals in raw coal due to the matrix effect, LTA was produced from selected four seams for XRD analysis.**
- **quartz, clay group minerals (kaolinite, Hydrargillite, Illite), calcite, pyrite, feldspar and gypsum.**

SEM- EDX analysis result

- **Aluminosilicates (clay minerals), Carbonate minerals, Silicate minerals and Sulfide minerals**

Framboidal pyrite

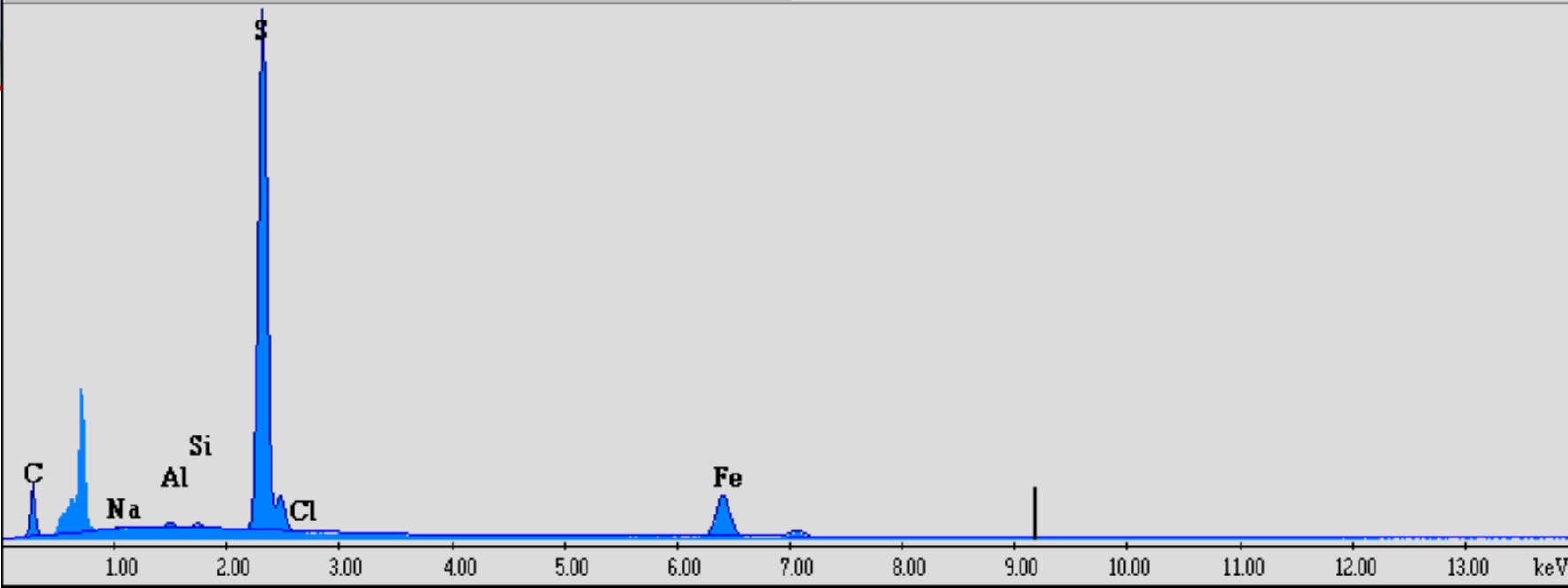
- Syngenetic (*Dai et al., 2007*).
- originates from pyritization of sulfur bacteria (*Casagrande et al., 1977; Casagrande et al., 1980; Kortenski and Kostova, 1996; López-Buendía et al., 2007; Querol et al., 1989; Renton and Cecil, 1979*).
- Generated from mineral solutions in inorganic material (*Dai et al., 2002, 2003; Kortenski and Kostova, 1996*).
- in the first step of the activity of biogenic processes i.e., pyritic fossilization of bacterial colonies, and in a second step further growing of framboidal pyrite by organic processes (*Wilkin and Barnes, 1997*)
- Bacterial framboidal pyrite preserves the independence of the separate globules even when they form aggregates



Standardless Quantitative Data

Matrix Correction: ZAF

Element	Wt%	At%	Net Inte	Bgnd
CK	35.24	62.20	178.10	11.06
NaK	0.25	0.23	8.10	56.14
AlK	0.40	0.31	23.06	72.16
SiK	0.30	0.23	20.30	77.34
SK	45.50	30.08	3066.30	61.96
ClK	0.00	0.00	0.00	59.10
FeK	18.31	6.95	371.56	23.24

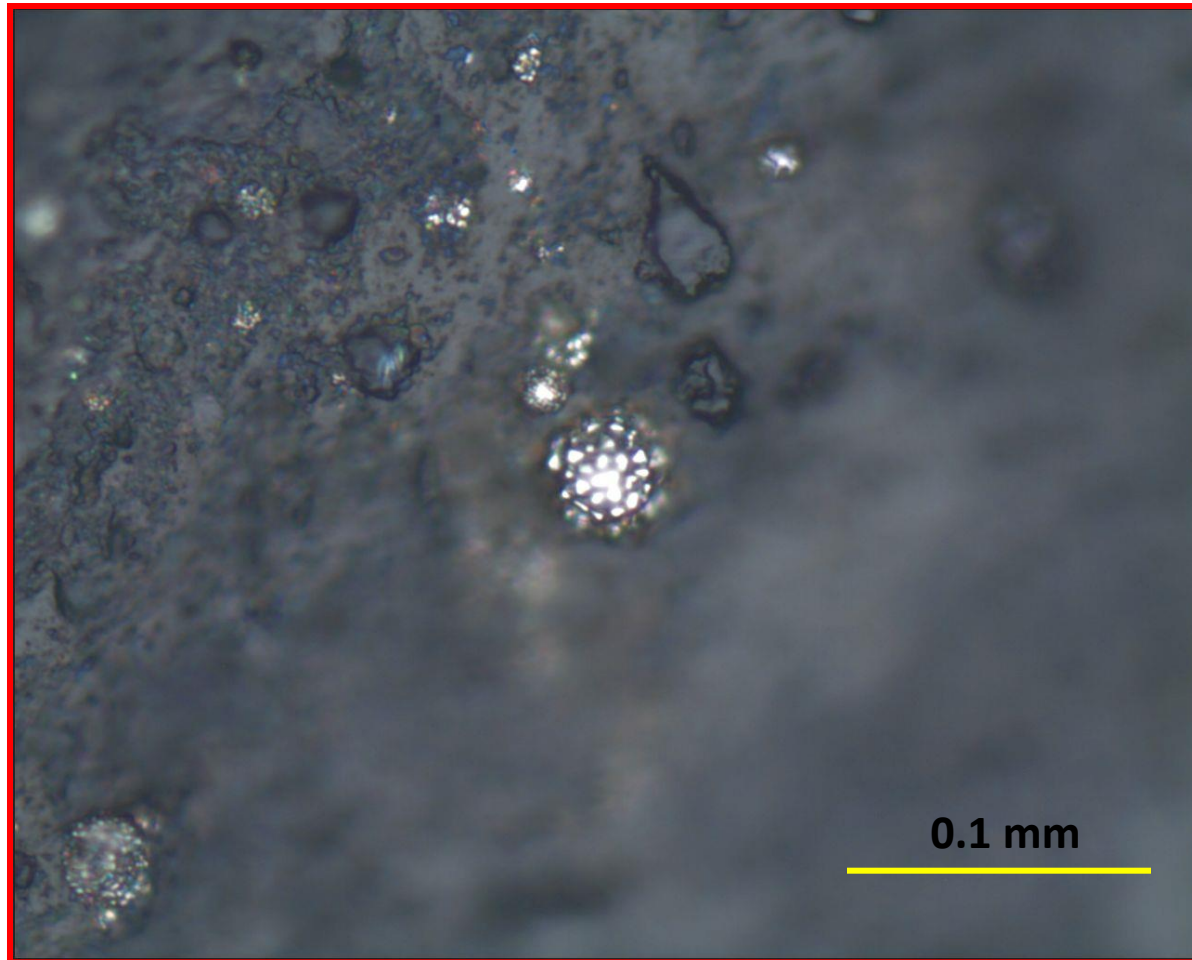


in
of

Euhedral pyrite

- **Well shaped pyrite crystals (Kortenski and Kostova, 1996)**
- **Most of the euhedral pyrite is syngenetic and is generated during deposition of peat and/or during early humification**
- **In general, the crystals of euhedral pyrite are small in size and intimately dispersed throughout the coal**
- **Isolated euhedral pyrite was found only in small amounts in sample from Seam 1, Seam 2 and Seam 6**

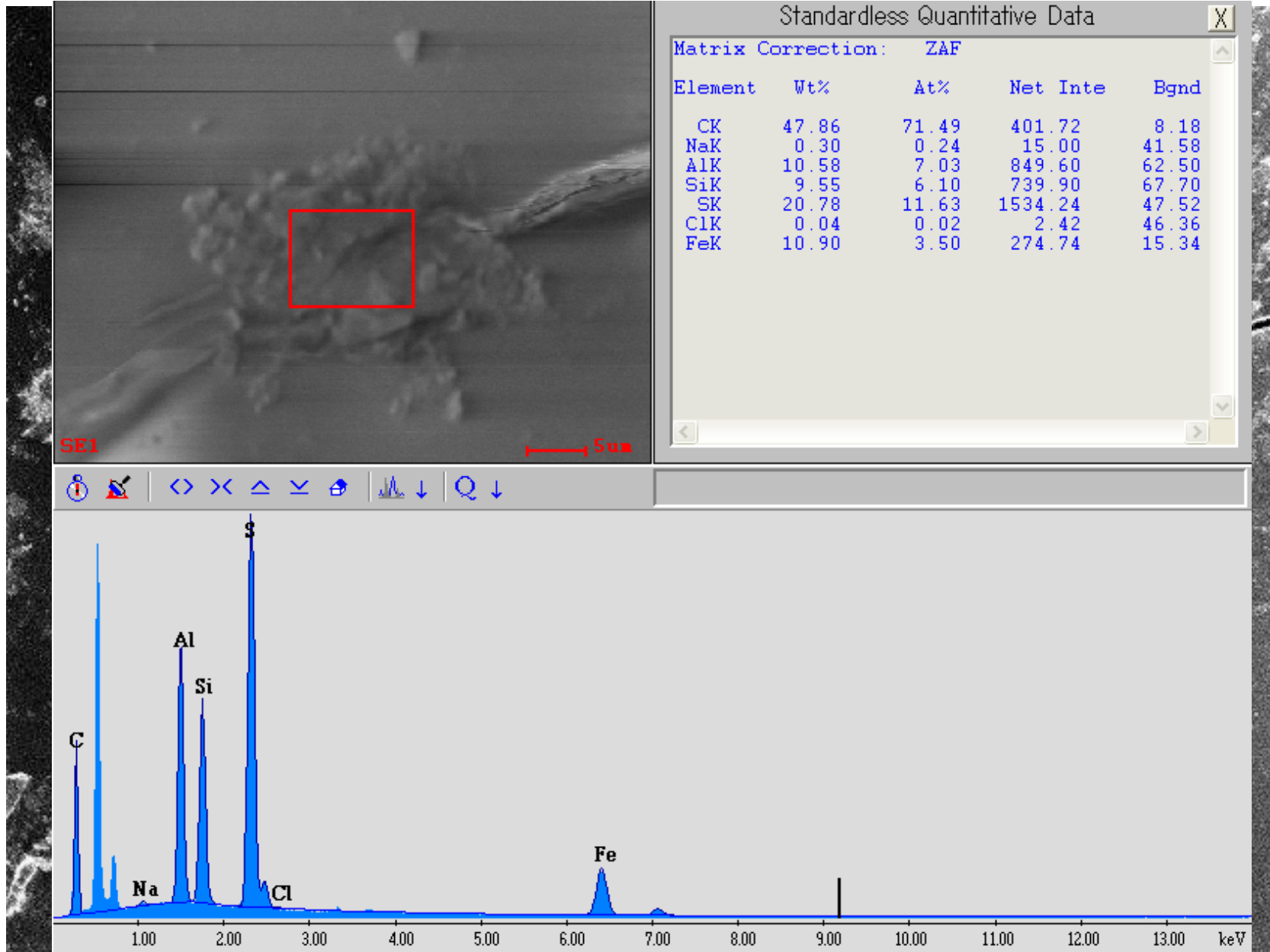
Euhedral pyrite



Massive pyrite

- **Pyrite grains with irregular shapes and different sizes**
- **Found as cleat-/cell-fillings, cementing or coating framboids, euhedral or detrital minerals**
- **Found as a replacement of organic matter in different macerals**
- **found in most coal samples from Seam 1 to Seam 10**
- **The homogeneous massive pyrite was generally porous and not compact, which is due to the inclusion of relict organic matter and clay minerals during the crystallization processes**
- **Homogeneous massive pyrite was present in irregular form**

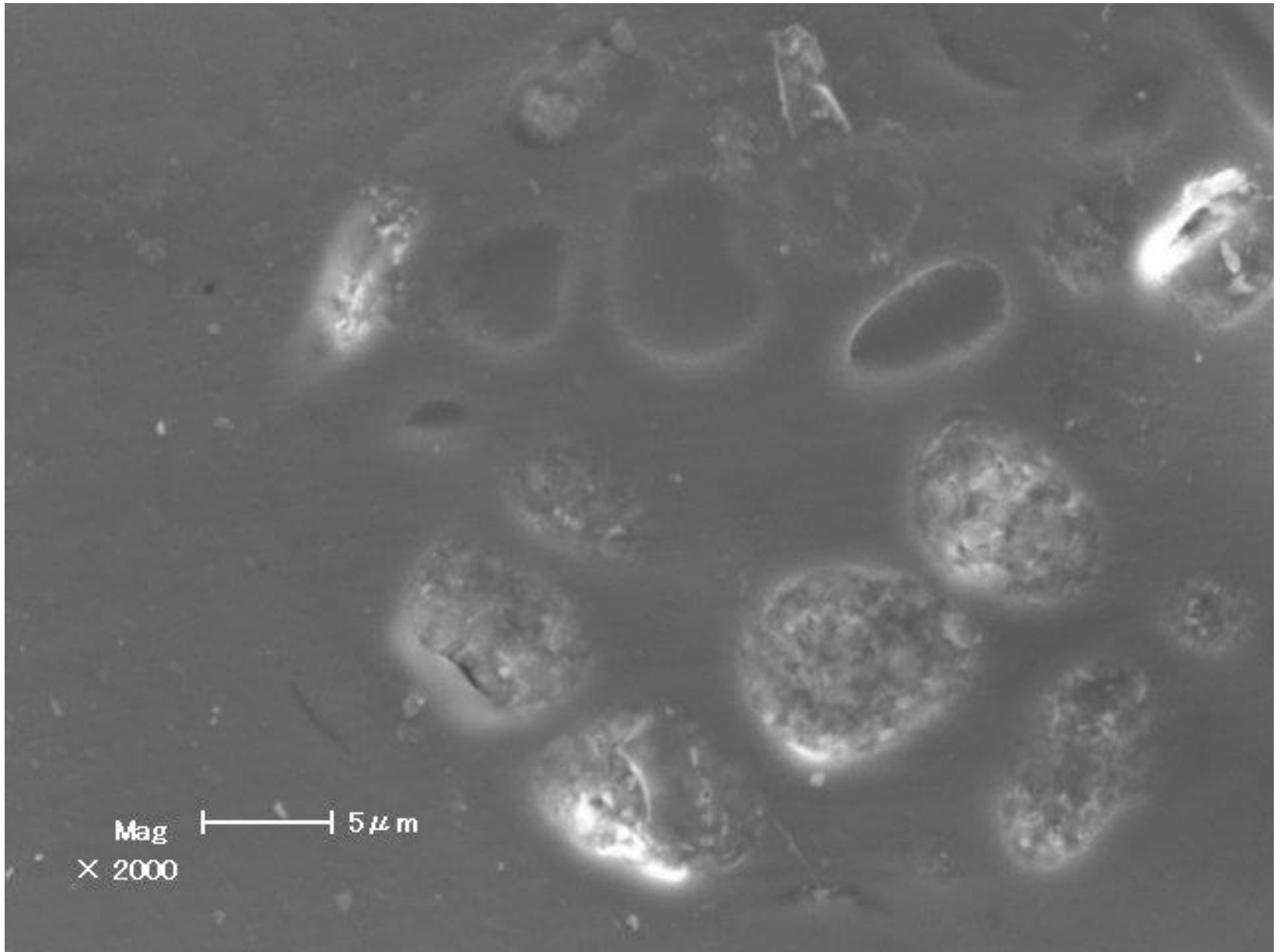
Massive pyrite



Anhedral pyrite

- **The replacement anhedral pyrite was a result of mineralization of cell wall and described to originate from replacement of plant material or massive pyrite replacement of organic matter (Kortenski and Kostova, 1996; Querol et al., 1989; Wiese and Fyfe, 1986).**
- **Shape depends on the shape of the plant debris in which they were deposited**
- **Late syngenetic and epigenetic origin**
- **Found in small amounts**
- **Replacement anhedral pyrite was deposited in the lumens of funginite maceral**

Anhedral pyrite



CONCLUSION

- **The predominance of mineral matter in the coals of Samarinda area is quartz, clay group minerals (kaolinite, hydrargillite, illite), calcite, pyrite, feldspar and gypsum.**
- **Both epigenetic and syngenetic pyrite occurred in the Samarinda coals and their types can be classified as syngenetic bacterial framboidal pyrite, syngenetic euhedral pyrite, epigenetic massive pyrite and epigenetic pyrite in cleats and fractures.**
- **Syngenetic pyrite in this coal formed during accumulation of the peat or during early humification processes and sulphide minerals are precipitated by interaction of dissolved iron with H₂S.**

CONCLUSION

- **Since the coal seams from lower portion of the studied stratigraphic section contains higher proportion of syngenetic pyrite than the upper part, it can be said that sulphide precipitation and influence of marine conditions is more favored in the lower portion than the upper portion of the studied stratigraphic section.**
- **Epigenetic pyrite might be deposited by the aeolian and fluvial import of iron-rich mineral and percolating water into fractures, cavities and pores within the coal seam long after initial accumulation of the peat.**
- **In case of the epigenetic pyrite and mineral content of Samarinda coals, they might originate from the erosion of Early Tertiary marine sediments of the Central Kalimantan Ridge, delivering sufficient iron and sulphate for pyrite formation under subaquatic conditions.**

*Thank you very much
for your kind attention*



REFERENCES

- Land, D.H., Jones, C.M., 1987. Coal geology and exploration of part of the Tertiary Kutei Basin in East Kalimantan, Indonesia. *Coal and Coal-bearing Strata: Recent Advances, Geological Society Special Publication No. 32*, pp. 235-255.
- Longley, I.M., 1997. The tectonostratigraphic evolution of SE Asia. In: Fraser, A., Matthews, S., Murphy, R.W. (Eds.), *Petroleum geology of southeast Asia: Geological Society of London: Special Publication*, 126, pp. 311–340.
- Marchioni, D.L., 1980. Petrography and depositional environments of the Liddel seam, Upper Hunter Valley, New South Wales. *International Journal of Coal Geology* 1, 35–61.
- Satyana, A.H., Biantom, E., 1995. Seismic Stratigraphy of Eocene Beri Sands of West Bungalon, East Kalimantan, Indonesia. A Contribution to the Paleogene Stratigraphical Knowledge of the Kutai Basin. *Proceedings of the International Symposium on Sequence Stratigraphy in SE Asia*, May 1995.
- Singh, P.K., Singh, M.P., Singh, A.K., Arora, M., 2010. Petrographic characteristics of coal from the Lati Formation, Tarakan basin, East Kalimantan, Indonesia. *International Journal of Coal Geology* 81 (2010) 109–116.
- Situmorang, B., Dwiyoga, C.D., Kustamsi, A., 2006. The untapped “Unconventional” Gas: CBM Resources of Kutai Basin with reference to the North Kutai Lama Field, Sangasanga area, East Kalimantan. *Proceedings of International Geosciences conference and exhibition*. Jakarta, August 14-16, 2006. Jakarta 06-OT-07.
- Stach, E., 1982. *Stachs Textbook of Coal Petrology 3rd Edn* (Eds E. Stach, M.-Th. Mackowsky, M. Teichmüller, G. H. Taylor, D. Chandra and R. Teichmüller), *Gebriüder Borntraeger, Berlin*. 1982, 87 pp.
- Weimer, R J., 1975. Impressions of the Geology of the Mahakam Delta Complex and Petroleum Exploration *Geology Indonesia*. v2, no 2. pp 45-47.

REFERENCES

- Amijaya, H., Littke, R., 2005. Microfacies and depositional environment of Tertiary Tanjung Enim low rank coal, South Sumatra basin, *Indonesia*. *International Journal of Coal Geology* 61, 197–221.
- Cibaj, I., 2010. Fluvial channel complexes in the Middle Miocene of Lower Kutai Basin, East Kalimantan: the stacking pattern of sediments. *Proceedings of Indonesian Petroleum Association Thirty-Fourth Annual Convention & Exhibition*, May 2010 (IPA10-G-053).
- Cibaj, I., Syarifuddin, N., Ashari, U., Wiweko, A., Maryunani, K., 2007. Stratigraphic interpretation of Middle Miocene Mahakam delta deposits: Implications for reservoir distribution and quality. *Proceedings of Indonesian Petroleum Association 31st Annual Convention & Exhibition*, May 2007 (IPA07-G-116).
- Cole, J.M., Crittenden, S., 1997. Early Tertiary basin formation and the development of lacustrine and quasi-lacustrine/marine source rocks on the Sunda Shelf of SE Asia. In: Fraser, A.J., Matthews, S.J., Murphy, R.W. (Eds.), *Petroleum Geology of Southeast Asia: Geological Society London Special Publication*. 126, pp. 147–183.
- Davis, R.C., Noon, S.W., Harrington, J., 2007. The petroleum potential of Tertiary coals from Western Indonesia: Relationship to mire type and sequence stratigraphic setting. *International Journal of Coal Geology* 70, 35–52.
- Diessel, C.F.K., 1992. Coal-bearing Depositional Systems. *Springer, Berlin*, 721 pp.
- Friederich, M.C., Langford, R.P., Moore, T.A., 1999. The geological setting of Indonesian coal deposits. *The Aus IMM Proceedings* 304 (no. 2), 23–29.
- Hacquebard, P.A., Donaldson, J.R., 1969. Carboniferous coal deposition associated with flood plain and limnic environments in Nova Scotia. In: Dapples, E.C., Hopkins, M.E. (Eds.), *Environment of Coal Deposition. Geological Society of America, Special Paper*, 114, pp. 143–191.
- Kusnama, Mangga, S.A., Sukarna, D., 1993. Tertiary stratigraphy and tectonic evolution of southern Sumatra. *Proceedings Symposium on Tectonic framework and energy resources of the western margin of the Pacific Basin: Bulletin Geological Society Malaysia, Special Publication no. 33*, pp. 143–152.

Macroscopic appearance of Samarinda coal (Lithotypes)

Sample No	Measure Section Location	Basic Features of coal sample	Structural Features
Seam 1	From S 0° 35' 9.74"	Exposed thickness is 1.5 m, banded bright coal	Dip in 46° due SE and strikes in NE – SW direction
Seam 2	to	1 m, dull coal	
Seam 3	S 0° 35' 48.04"	1.5 m, banded bright coal	
Seam 4	E 117° 5' 50.94"	1.5 m, banded dull coal	
Seam 5		1.5 m, banded dull coal	
Seam 6	From S 0° 35' 48.04"	0.5 m, bright coal	Dip in 42° due SE and strikes in NE – SW direction
Seam 7	E 117° 5' 50.94"	1.5 m, bright coal	
Seam 8	to	0.5 m, bright coal	
Seam 9	S 0° 35' 8.37"	0.4 m, bright coal	
Seam 10	E 117° 7' 16.62"	0.5 m, bright coal	
Seam 11		0.3 m, dull coal	
Seam 12	From S 0° 35' 8.37"	0.5 m, bright coal	Dip in 36° due East direction and strikes in NNE – SSW direction
Seam 13	E 117° 7' 16.62"	0.5 m, banded bright coal	
Seam 14	to	0.5 m, bright coal	
Seam 15	S 0° 34' 59.09"	0.5 m, bright coal	
Seam 16	E 117° 7' 32.21"	0.5 m, bright coal	
Seam 17		1 m, banded bright coal	
Seam 18		1.5 m, bright coal	
Seam 19	S 0° 34' 53.97" E 117° 7' 42.73"	1.5 m banded bright coal	Dip in 74° East direction and strikes in NNE – SSW direction

Petrographic data: (microlithotype group) analysis of Samarinda coal

Seam No	Group A	Group B	Group C	Group D
Seam 1	6.15	44.13	49.16	0.6
Seam 2	18.1	48.4	23.93	9.5
Seam 3	0.5	3.96	95.5	0.4
Seam 4	0	18.2	59.73	22.15
Seam 5	25.29	30.46	43.97	0.29
Seam 6	17.9	24.1	57.65	0.3
Seam 7	15.56	20.37	64	0
Seam 8	18.1	23.68	58.22	0
Seam 9	16.4	19.86	63.01	0.68
Seam 10	15.97	31.93	47.9	4.2
Seam 12	13.51	51.35	33.98	1.16
Seam 13	13.47	27.35	58.37	0.8
Seam 14	6.6	36.32	57.08	0
Seam 15	0	1.5	98.5	0
Seam 16	15.72	35.81	42.79	5.68
Seam 17	19.16	25.78	54.36	0.7
Seam 18	2.7	60.33	35.87	1.1
Seam 19	27.14	27.39	49.97	0.5

A- Sporoclarite + Duroclarite + Vitrinertoliptite

B- Fusito-clarite + Vitrinertite I

C- Clarite V + Vitrite + Cutico-clarite

D- Clarodurite + Durite + Macroite + Carbominerite

Petrographic (microlithotype) analysis of Samarinda coal

	Vitrite	Liptite	Inertite	Vitrinertite	Clarite	Durite	Duoclarite	Viteroliptite	Clarodurite
Seam 1	39	0	0	34.5	5	0	20.5	0.5	0.5
Seam 2	7.5	0	0	30.5	15	0	36	2	9
Seam 3	96	0	0	3.5	0.5	0	0	0	0
Seam 4	44.5	0	2.5	13.5	0	0	23	0	16.5
Seam 5	32.5	0	0	9	44	0	14	0	0.5
Seam 6	61	0	0	9.5	27.5	0.5	1.5	0	0
Seam 7	65.5	0	0	6.5	21	0	7	0	0
Seam 8	61	0	0	8.5	27.5	0	3	0	0
Seam 9	68	0	0	5	24	0.5	2	0	0.5
Seam 10	19	0	0	9.5	9.5	0	59.5	0	2.5
Seam 12	26.5	0	0	49	17.5	0	5.5	0	1.5
Seam 13	55	0	0	17	16.5	0	10.5	0	1
Seam 14	53.5	0	0	31.5	7	0	8	0	0
Seam 15	98.5	0	0	1.5	0	0	0	0	0
Seam 16	31	0	1.5	23	18	0	20	0	6.5
Seam 17	51	0	0	10	27	0.5	10.5	0.5	0.5
Seam 18	30.5	0	1	53	2.5	0	12	0	1
Seam 19	35.5	0	0	0.5	54	0	9	0	1

Maceral Group

Maceral group	Maceral	Characteristics
Vitrinite	telinite	cell wall
	collinite (telo-/detro-)	amorphous (gel or gelified tissue/detritus)
	corpocollinite	cell fillings
	vitrodetrinite	detritus
Liptinite (exinite)	sporinite	spores, pollen
	cutinite	cuticles
	suberinite	suberitized cell walls (cork)
	fluorinite	plant oils
	resinite	resins, waxes, latex
	alginate	algae
	bituminite	amorphous (bacterial, algal, faunal)
	chlorophyllinite	chlorophyll
	liptodetrinite	detritus
	exsudatinite	secondary exudates
Inertinite	fusinite	cell walls (charred, oxidized)
	semifusinite	cell walls (partly charred, oxidized)
	sclerotinite	fungal cell walls
	macrinite	amorphous gel (oxidized, metabolic)
	inertodetrinite	detrinite
	micrinite	secondary relics of oil generation (mainly)