The role of coal "cleat system" in Coalbed Methane Prospecting/Exploring: A new approach

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Notice

Part of the research team of the “Organic Petrology and Geochemistry Unit”, Faculty of Sciences, University of Porto, has moved to a new entity entitled “Research Unit for Environment Systems Modelling and Analysis” at University Fernando Pessoa, Porto, Portugal. Researchers who moved to University Fernando Pessoa are those specialized in Coalbed Methane (CBM) and CO2 sequestration in coal seams.

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- **Main objectives:**
  - **To develop R & D projects related with Modelling and Analysis of Environment Systems (5 + 2 current R & D projects)**
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  - **17 Ph D**
  - **2 M Sc**
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Research Team Practice in CBM studies

- **Lorraine Basin (France) – Conoco, Dupont**
- **Waterberg Basin (South Africa) – Anglo Coal**

- **Spain**
- **Brazil**
- **Chile**

Publications: 19 papers, abstracts and posters

Research Team main Publications

see:

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Contents

Key words

Cleat system, Coal, Coalbed Methane (CBM), Natural gas, Exploration, Prospection

Abstract

The Coalbed Methane (CBM) generated by coal is located in coal pores and the drainage of the coalbed gas to the production well is made through the so-called "cleat system", i.e., the natural fracture network of coal. This justifies the classic method of CBM production by providing fracture-stimulation with fluids under pressure to open coal natural fractures.

However, natural fracturing system of any coal is very complex, depending on coalification process and local and regional tectonics. Additionally, the cleat network cannot be inferred using conventional regional micro-tectonics studies.

Abstract (Continuation 1)

Therefore, what really matters is to know, in each case, the spatial orientation of the different classes of fracturing, ordered by connectivity frequencies, to make possible an orientated injection of fluids to open the cleat permitting higher amounts of gas release/drainage. In fact, the cleat family of highest connectivity frequency is the one that define the gas circulation network to the producing well, and consequently the most favorable one to be opened by fluids injected in the correct direction.

The current investigation refers to a new and innovative proposal to develop a method for determining cleat family orientation in the space, ordered by cleat connectivity frequency. This new semi-automatic method is based in the study of "cleat characteristics" by image analysis in orientated core samples of boreholes for CBM prospection/exploration. The information from image analysis is studied by statistical CCT ("coal-core tectonics") methodology and subsequently combined with Geographic Information System, thus referring to location of the real case under study.

1. Introduction

WHY to study the “cleat system”?

Define the gas flow network

↓

Producing well stage

Main goal of any CBM prospecting/exploring Programme

WHAT is the main problem?

To answer the following unresolved questions:

Spatial distribution ...

Orientation ...

Frequency of connectivity ...

... of the different classes of cleat?

WHERE is applicable?

In any Coal Basin all over the World

WHEN is applicable?

When "prerequisites" are full filled

See: Lemos de Sousa, M.J.; Pinheiro, H.J. and Rodrigues, C., 2003. Prerequisites, general criteria and primary studies required in the Coalbed Methane prospecting and exploring: A review. In: **AAPG International Conference, Barcelona. (Abstract published in the Conference Abstracts book and in the corresponding CD-ROM; Full presentation in digital library, Universidade Fernando Pessoa, Porto, Portugal at https://bdigital.ufp.pt/dspace)**

WHO is interested?

Companies interested in CBM programmes

Entities concerned with environmental issues:

- Reducing gas emissions
- Quality control of water produced with CBM
- CO_2 injection/sequestration

HOW much?

Fluids under pressure should be injected in the correct direction

In fact, drilling more and more holes do not solve *per se* the problem of gas production from coal seams!

2. The Duality

Cleat

↕

Macroporosity

Definition

Coal porosity: conceptually is the volume fraction of coal occupied by empty spaces”, however, this is not strictly measurable. Operationally, porosity is the volume fraction of coal that may be occupied by a particular fluid. This varies from fluid to fluid.

(Levine, 1993)

Microporosity is defined by the micropore structure of the coal matrix; the micropore space accounting for as much as 85 % of coal total porosity.

Macroporosity represents the openings of coal that are too large to be considered part of the molecular structure such as cracks, cleat, fissures, which are not isotropic and tend to be parallel to the cleavage plane of the coal seam.

(Rojey et al 1997)

Methods of coal porosimetry

(after Levine 1993, modified)

Major category	Scattering methods	Microscopic methods	Fluid probe methods
Method	Low angle x-ray sattering	Optical microscopy	Volumetric fluid displacement
			Vapor sorption studies
	Electron scattering	Scanning electron microscopy	Heats of wetting
			NMR spectroscopy
	Neutron scattering	Transmission electron microscopy	ESR spin label probe

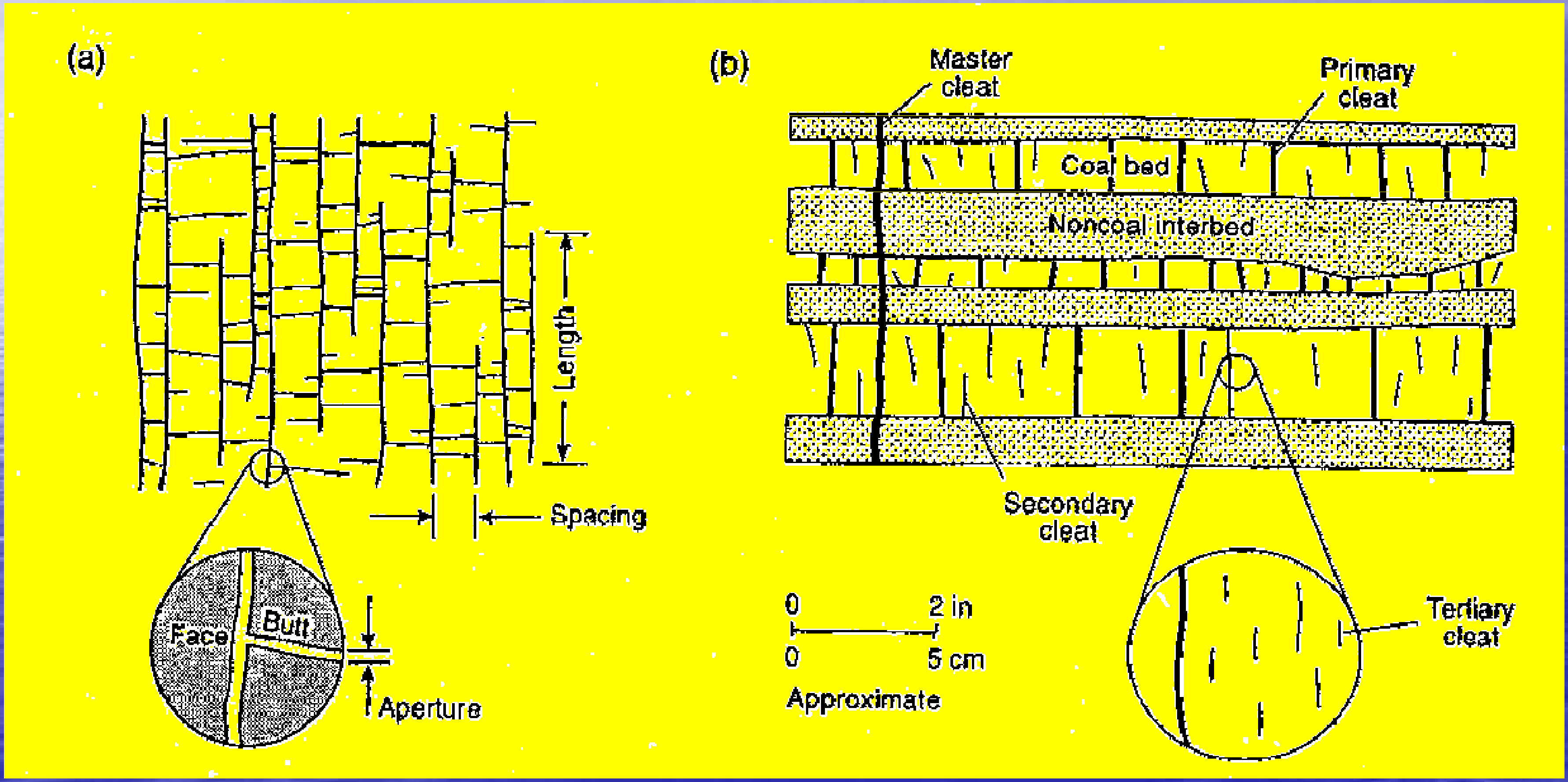
Volumetric fluid displacement

- **He and Hg density** (Levine, 1993)
- **Sorption isotherms**
  (Rodrigues and Lemos de Sousa, 2002)

3. Creating
a new
METHODOLOGY

Schematic illustration of coal cleat (Laubach et al 1998):

(a) cleat characteristics in plan view;
(b) cleat hierarchies in cross- section view



Coal cleat characteristics

(Laubach et al 1998)

- **Cleat directions relative to a reference;**
- **Cleat frequency;**
- **Cleat height;**
- **Cleat length;**
- **Cleat spacing;**
- **Number of cleat connectivity/intersections;**
- **Cleat aperture;**
- **Number of cleats filled by minerals.**

Methods used

- **Manual**
  (take photos, stick them to each other, mark the cleat on a transparency)

- **"Coal-core tectonics" (CCT) – Rodrigues 2002**
  (Semi-automated computerized: GIS combined with a set of different softwares, such as "Georient", "Rockworks")

4. The "Coal-core tectonics" (CCT) method

Save time

"time is money!"

Save money

Direct link between field and computerized data

High accuracy

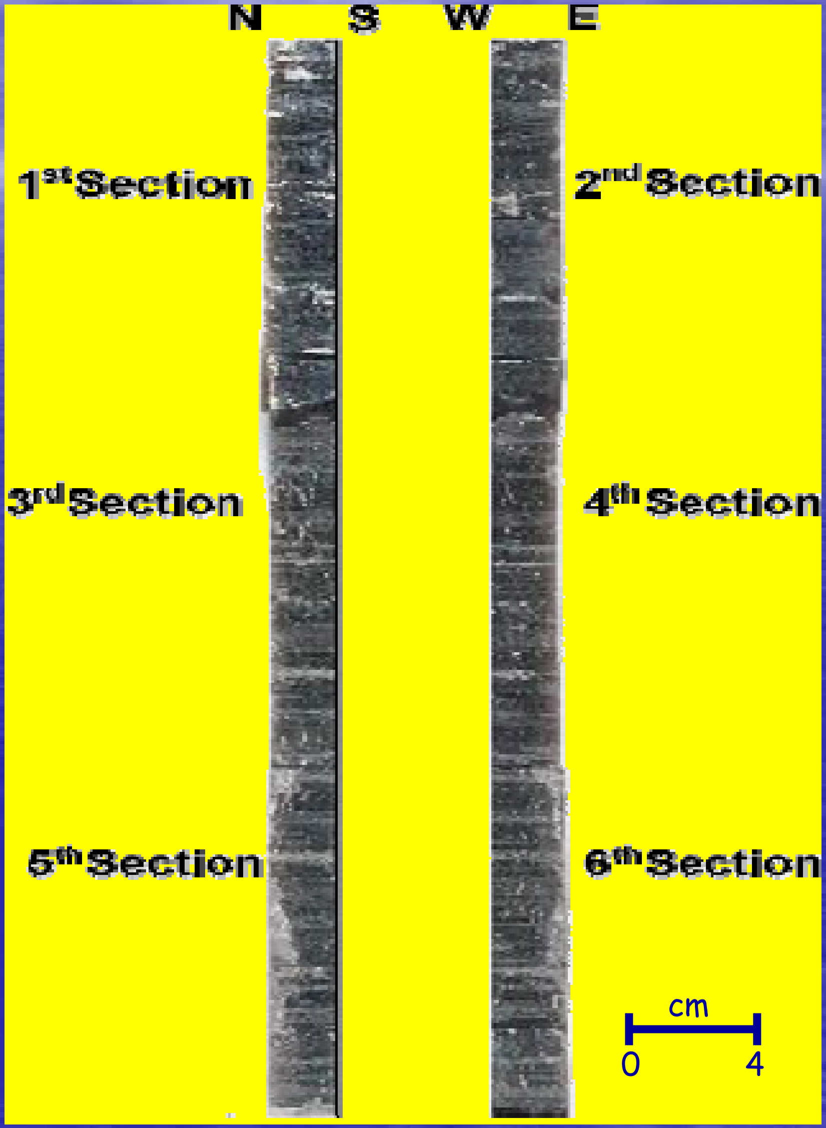
Representative statistical data

Methodology

- Borehole geographic localization;
- Sample orientation;
- Scanning of core samples;
- Presenting the adopted model;
- Georeferentiation of core sample images, cleat digitalization and cleat characterization;
- Statistical analyses from georeferentiated data;
- Connectivity frequency;

Borehole geographic localization

Sample orientation



⇨ Scanning of core samples

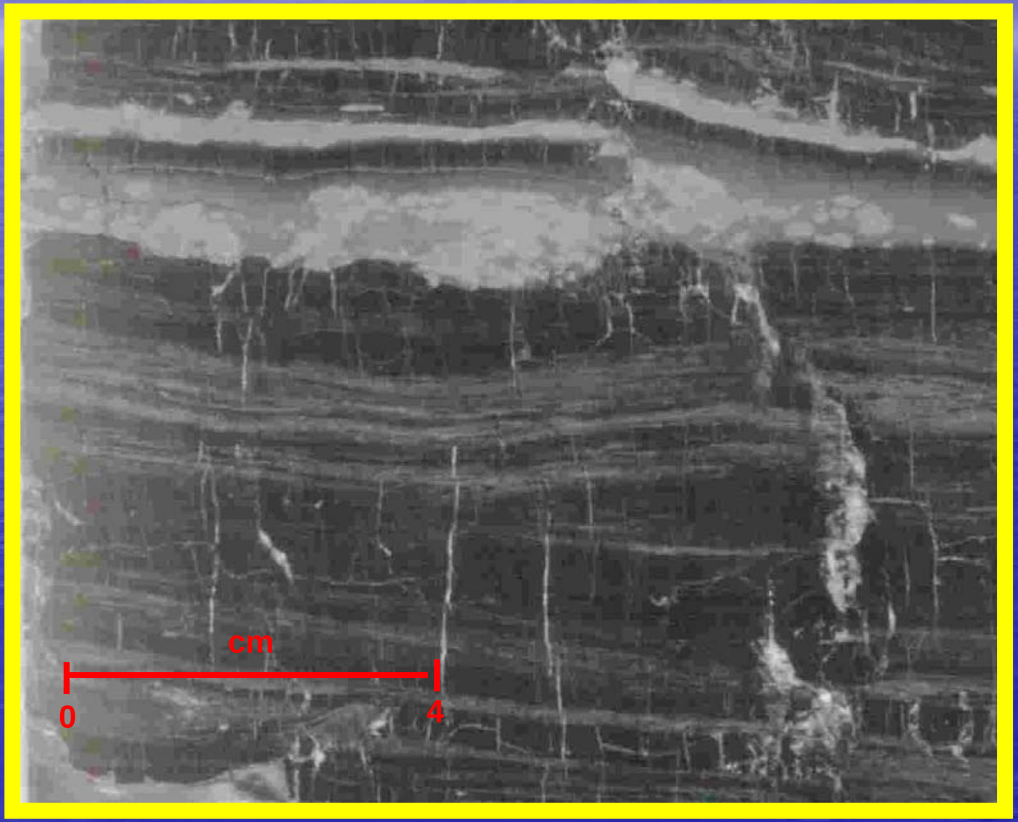


Image obtained from high resolution scanning

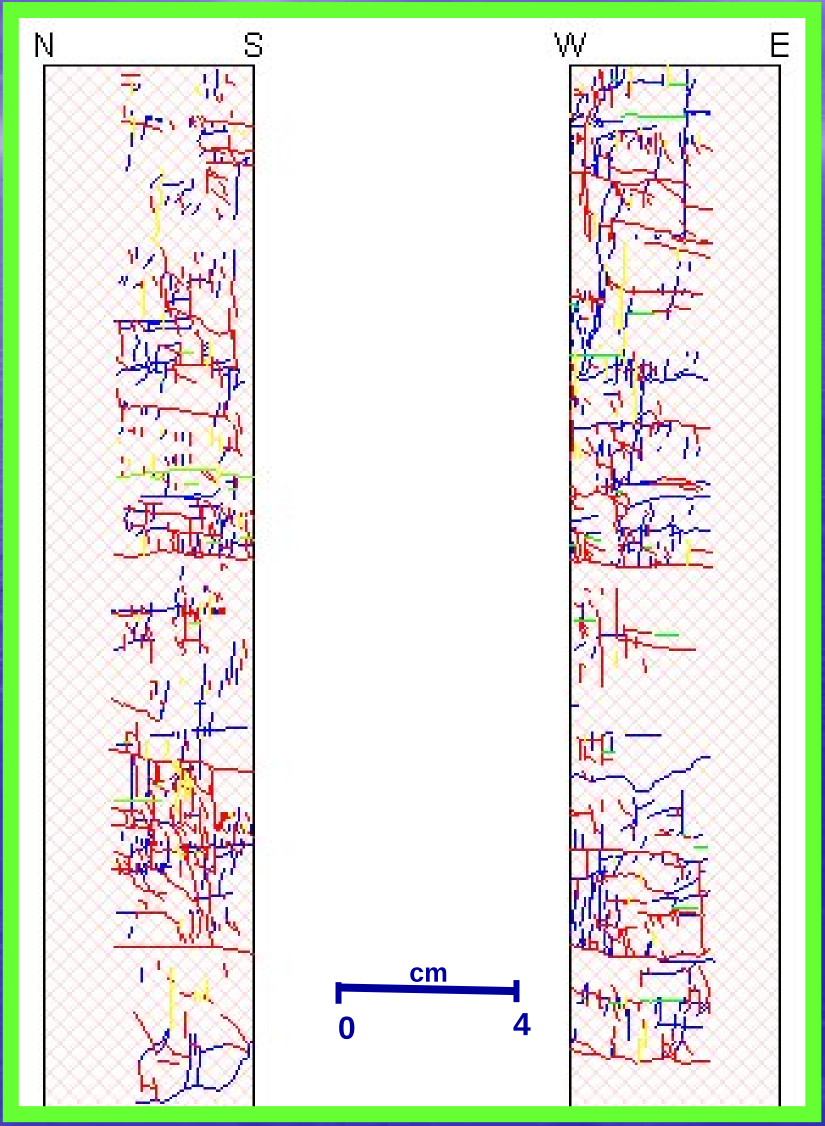
Presenting the adopted model

- to mention the plane where the data were collected
- to measure the azimuth of the cleat, expressed by cleat dip direction
- to calculate cleat direction
- to measure cleat length
- to observe if the cleat is opened or closed
- to see if cleat is fulfilled by minerals
- to consider additional information

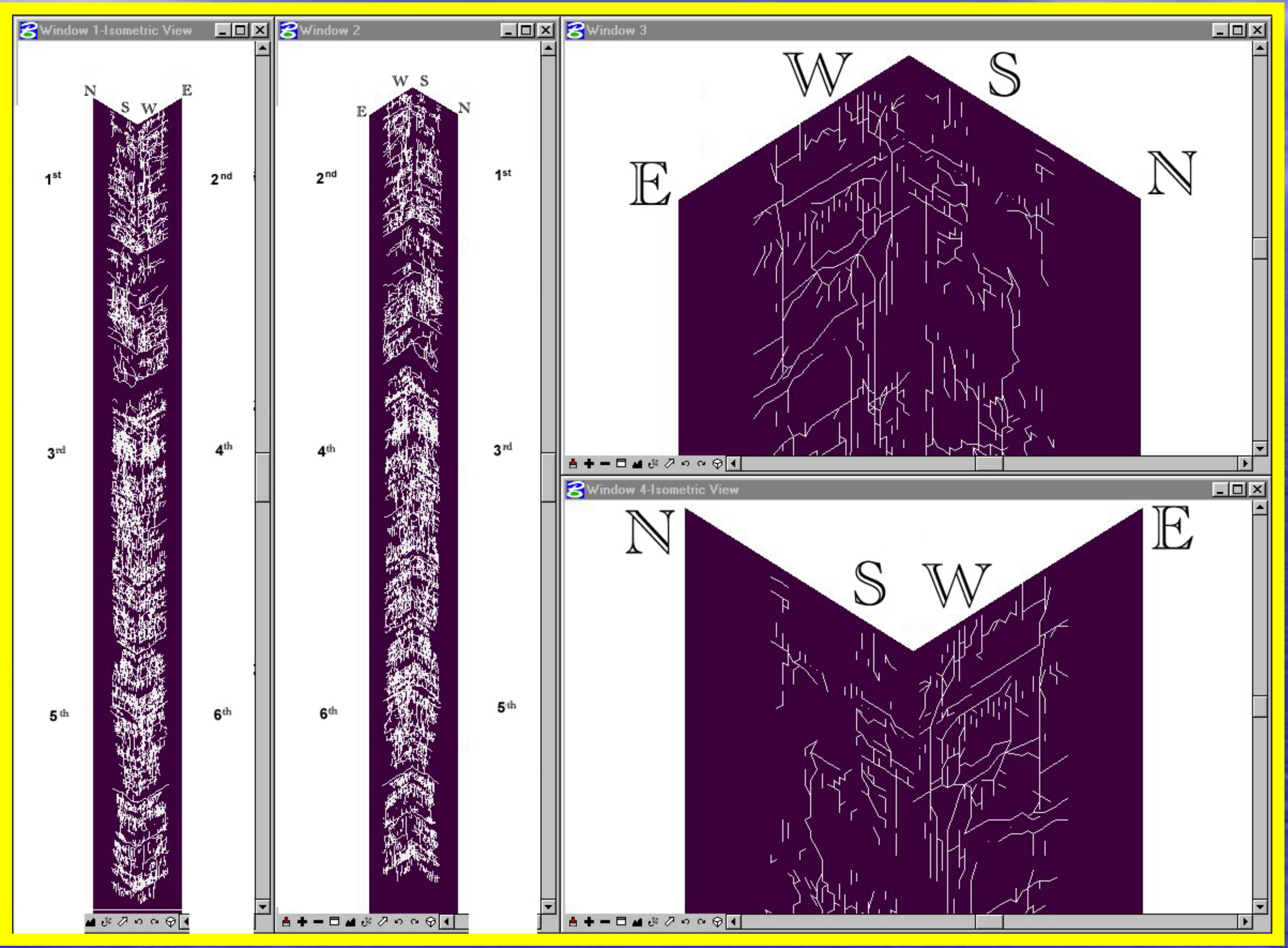
Coal cleat characteristics

- Cleat directions relative to a reference;
- Cleat frequency;
- Cleat height;
- Cleat length;
- Cleat spacing;
- Number of cleat connectivity/intersections;
- Cleat aperture;
- Number of cleats filled by minerals.

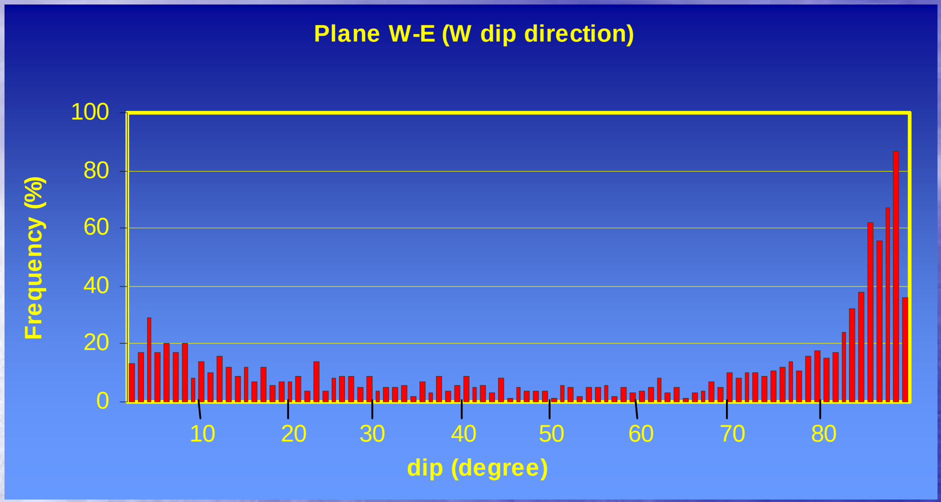
Georeferentiation of core sample images, cleat digitalization and cleat characterization



Cleat elements three-dimensionally represented in core sample

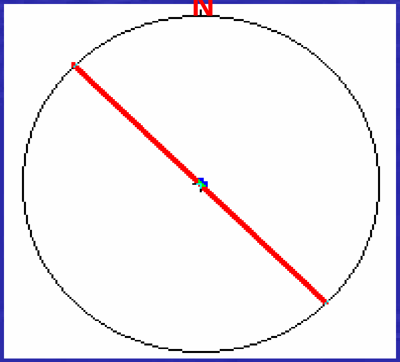


Statistical analysis from georeferentiated data



Cleat frequency (decrease order)	Cleat lines measured in N-S plane (N dip direction)	Cleat lines measured in W-E plane (E dip direction)
1	88º → 0º	88º → 90º
2	89º → 0º	87º → 90º
3	87º → 0º	85º → 90º
4	85º → 0º	86º →90º
5	86º → 0º	84º → 90º
6	80º → 0º	89º → 90º
7	3º → 0º; 83º → 0º and 84º → 0º	83º → 90º
8	2º → 0º	3º → 90º
9	5º → 0º	82º → 90º
10	82º → 0º	7º → 90º and 5º → 90º

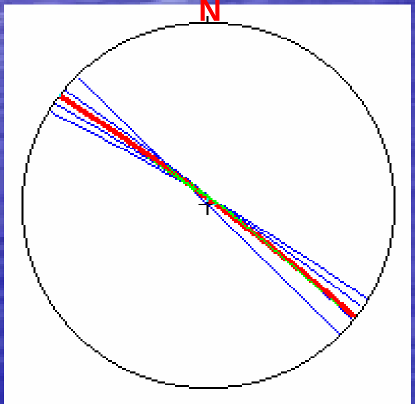
Cleat frequency 1



Mean Direction = 89-045
Mean Resultant dir'n = 89/045
Mean Resultant length = 1,00
(Variance = 0,00)
Calculated. girdle: 89/045

Plane: N 135º, 89ºE

Dip direction interval 120º - 150º

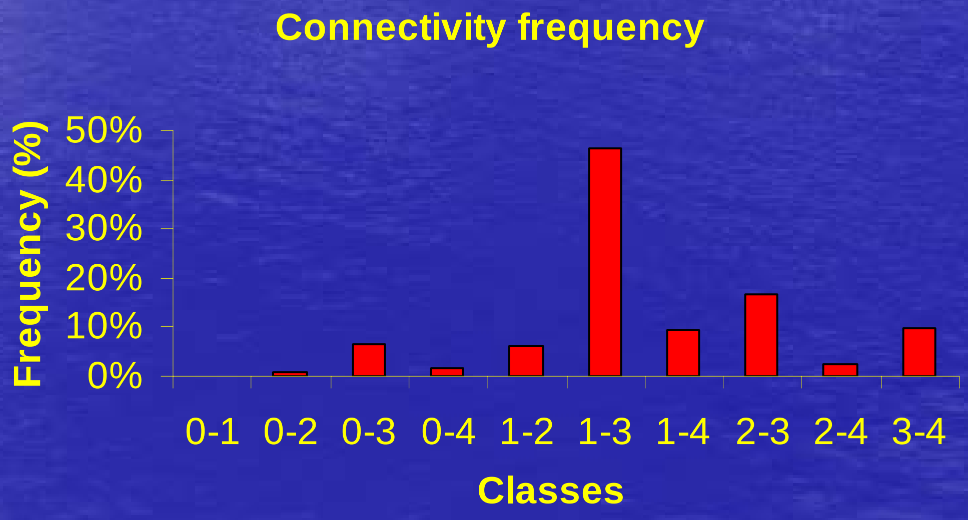


Mean Orientation = 87/037
Mean Resultant dir'n = 87-037
Mean Resultant length = 1,00
(Variance = 0,00)
Calculated. girdle: 8/145
Calculated beta axis: 82-325

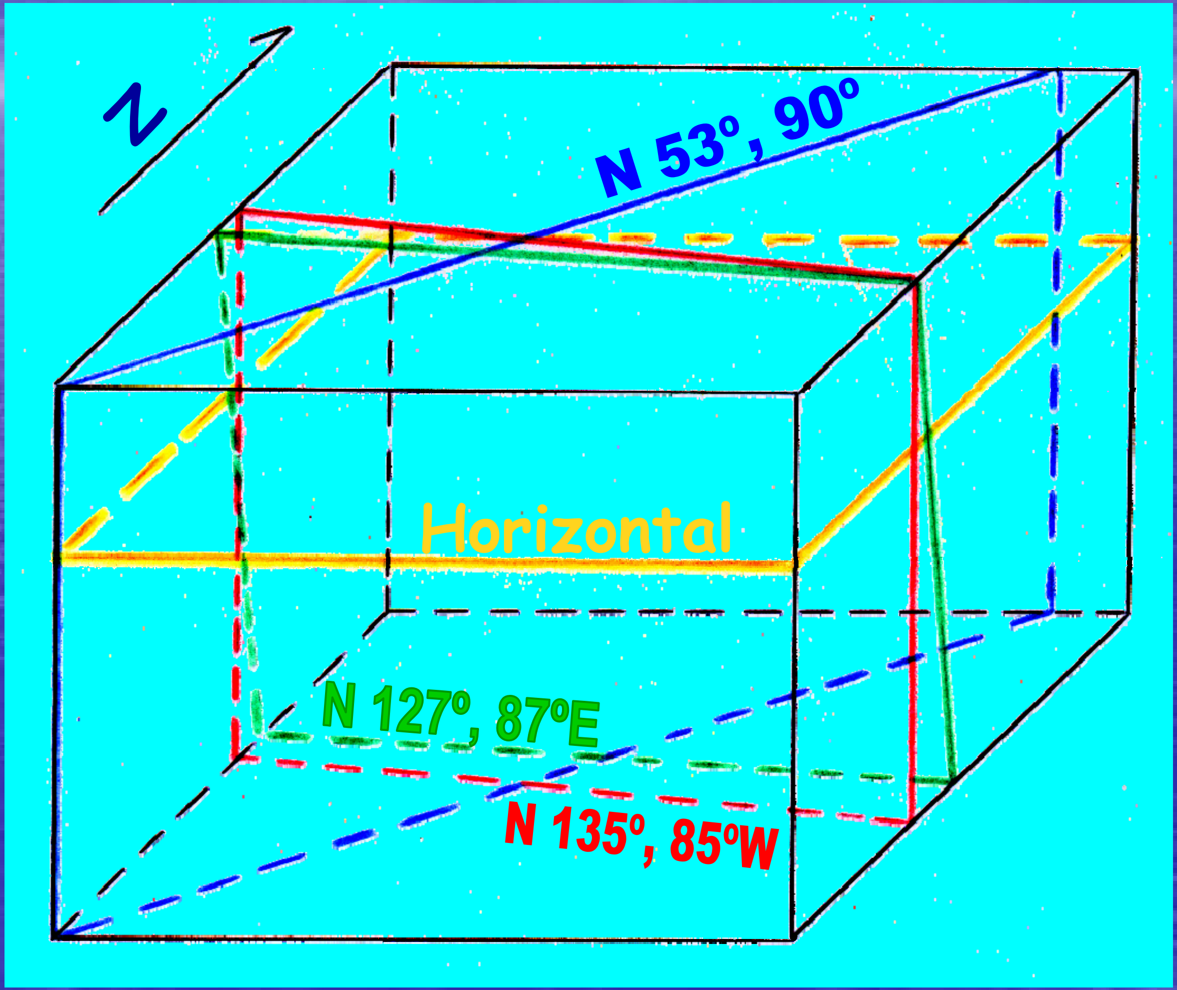
Mean Plane: N 127º, 87ºE

Connectivity frequency

Class designation	Dip interval
Class 0	0º
Class 1	> 0º and ≤ 30º
Class 2	> 30º and ≤ 60º
Class 3	> 60º and ≤ 90º
Class 4	90



Schematic representation of the preferential planes



5. Summarizing and Concluding:

In a classical approach:

- Drainage of CBM to the production well is made through the so-called “cleat system”, i.e. the natural network of fractures present in the coal.
- Only in very “favourable” conditions it is possible to obtain good (economic) levels of production.

Natural fracturing (cleat) of any coal depends of both genetic conditions and regional tectonics

However:

- The cleat network cannot be inferred using conventional regional micro-tectonic studies.

- In terms of mechanical properties, coal have a very particular rheological behaviour, different of the other local rocks, particularly at seam roofs and floors.

Therefore:

- To make possible, in each case, an orientated injection of fluids to open fracturing (cleat) system, permitting the highest amount of gas release, one dramatically need to know the spatial orientation of the different classes of fracturing (cleat), ordered by connectivity frequencies. This is also applicable to CO2 injection/sequestration by coal seams.

- The CCT methodology herein presented is a new fast and precise approach in response to the above addressed critical issue.

Yet, new developments are needed:

A further major goal will be to correlate CCT methodology data (core analysis) with both logdata whilst drilling and geophysical logged data.

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