LOW PERMEABILITY COALS

Tahmoor Colliery

1. Tahmoor.
2. Tahmoor North and Bargo.
3. Background geology.
4. History of gas and outburst management.

Low permeability coals

i. history of occurrence and impact on mining

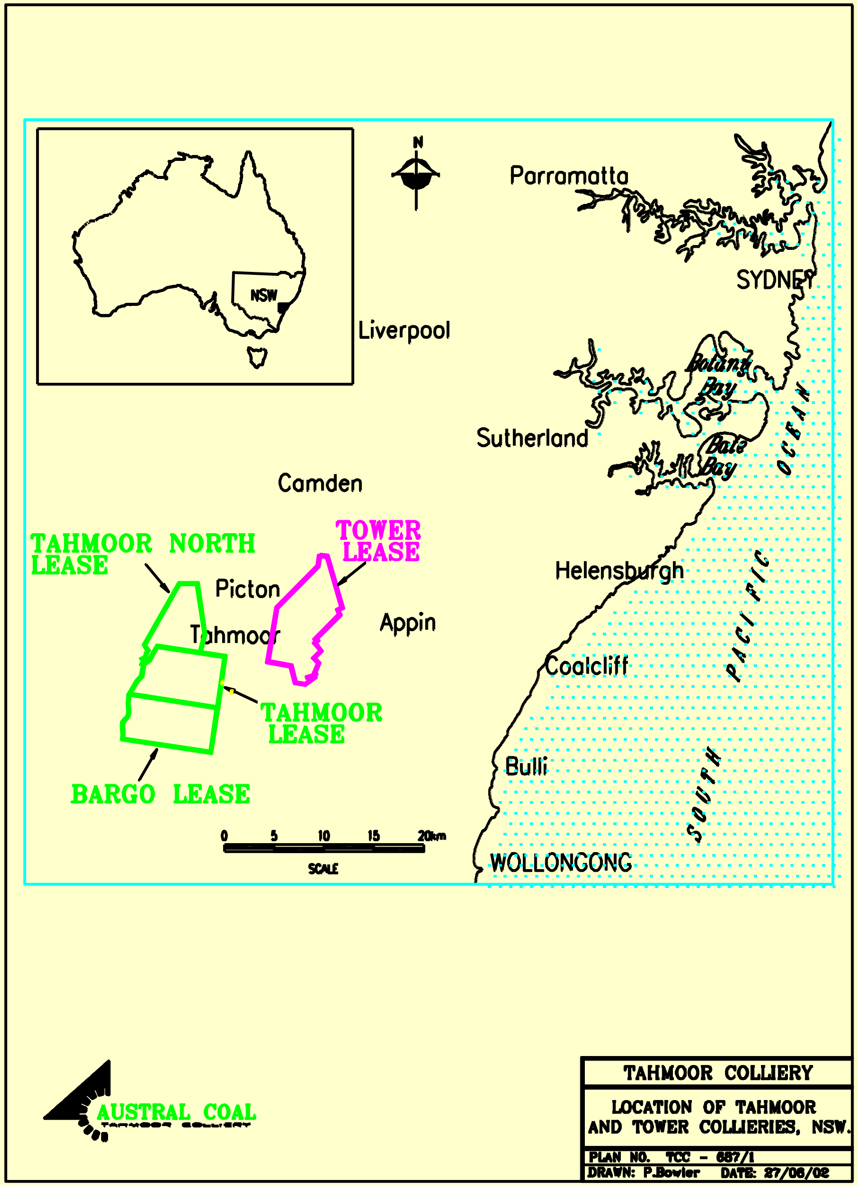
ii. description

iii. probable causes/controls (carbonate mineralisation, high stress in coal)

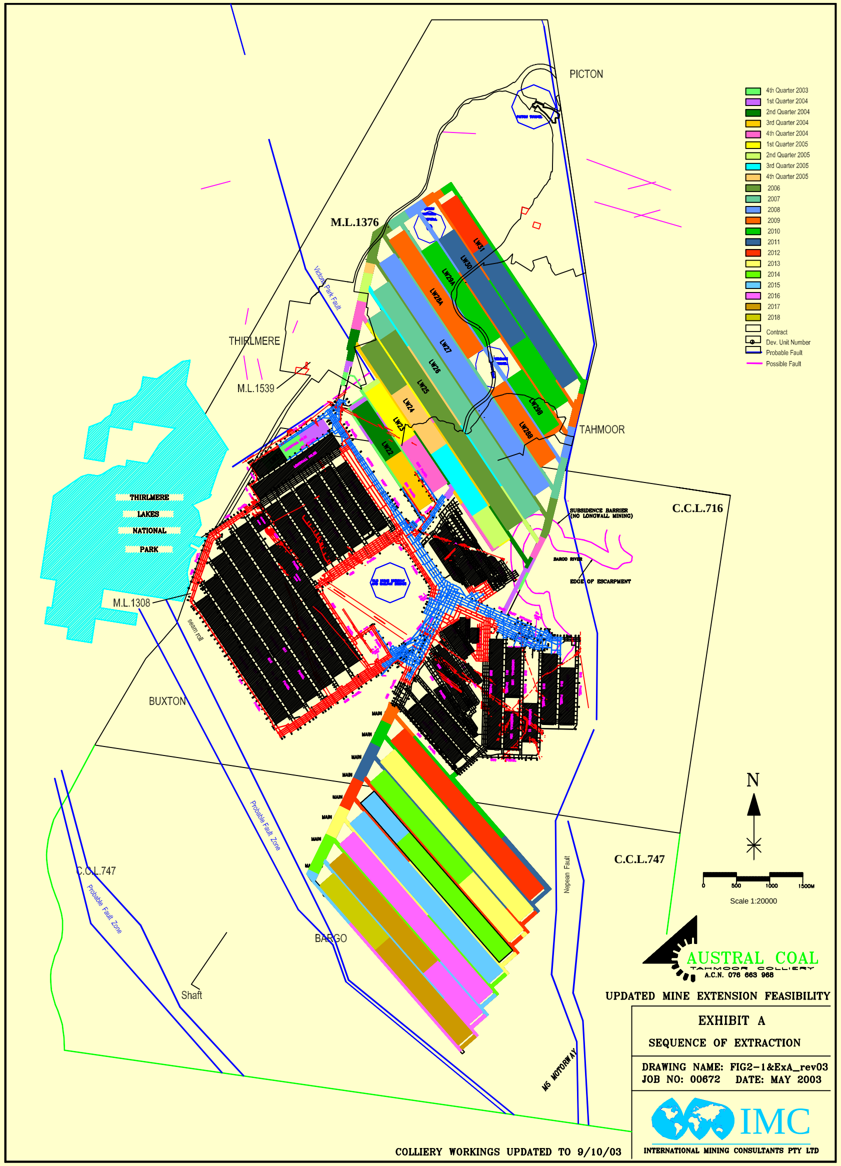
iii) Prediction / detection

iv) management.

Location

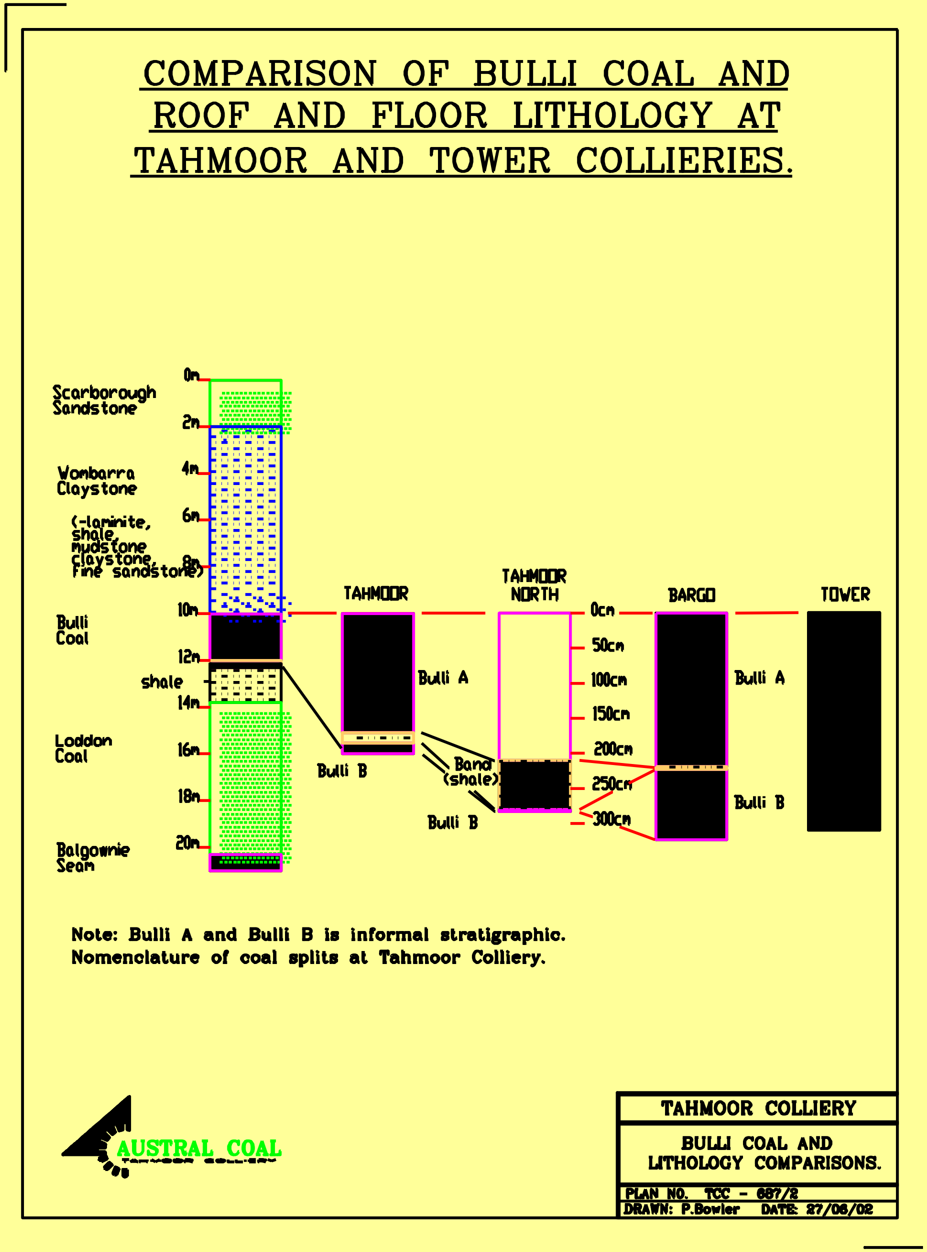

NSW
N
Parramatta
SYDNEY
Liverpool
Botany Bay
Sutherland
Bate Bay
Camden
TOWER LEASE
TAHMOOR NORTH LEASE
Picton
Tahmoor
Appin
Helensburgh
Coalcliff
TAHMOOR LEASE
BARGO LEASE
Bulli
SOUTH PACIFIC OCEAN
0 5 10 15 20km
SCALE
WOLLONGONG
AUSTRAL COAL
TAHMOOR COLLIERY
LOCATION OF TAHMOOR AND TOWER COLLIERIES, NSW.
PLAN NO. TCC - 687/1
DRAWN: P.Bowler DATE: 27/06/02

Leases, major structures



- **Low permeability coals potentially a major factor in achieving the mining goals of Tahmoor North and Bargo.**

GEOLOGY : Stratigraphy



GEOLOGY contd.

Cleat: (major) face cleat consistent (~315)

- (major) butt cleat consistent (~230)
-

Permability: (Lama, 1996)

- field 1.5 - 2.5mD
-
- samples 0.7mD (no stress)
- 0.1mD (high stress)

- Newlands (3-10mD); North Goonyella (9mD)
- Central (3-10mD); South Bulga (30mD)
-

GEOLOGY contd.

Horizontal (virgin) stress (roof overcore).

Uniaxial	$\sigma_1 : \sigma_2 : \sigma_3$	**21 : 13 : 11 (MPa)**	**(11GPa)**
	to		
Isotropic	$\sigma_1 : \sigma_2 : \sigma_3$	**11 : 9 : 6 (MPa)**	**(12GPa)**

Depth of cover - 380-430

Orientation σ_1 variable. 180 to 128
σ_1 seldom parallel to face (or butt) cleat.

GEOLOGY contd.

Gas

- Virgin gas content (Tahmoor) about 13cu.m/t.
- CO_2 (variable)
  - LW14-19 35 - 90%
  - LW's 20-21 75 - 85%
  - Tahmoor North 85% (south) - 10%(north)
  - Bargo high CO_2

Drainage times (normal coal)

- 120 days, spacing of 20-25 metres.

Are the <u>zones</u> of carbonate mineralisation and low permeability (N-S to NNE-SSW) related to the regional or lease scale dyke/strike slip structures ?

OUTLINE OF OUTBURST AND GAS DRAINAGE HISTORY

History of outbursts and relationship to geology.

Drainage and Outburst Management.

Low permeablity coals and grunching

(extraction by shot firing).

History of outbursts, relationship to geology.

- **90 outbursts between 1981 and 1992**

- **Largest outburst**
  - **400 liberated tonnes**
  - **violent**
  - **4500m^3 CO2 (fatality)**
  - **proximity to dyke**

- **all outbursts**
  - **related to structures and high gas content (un-drained)**
  - **and occurred whilst cutting**
  - **mostly in the immediate vicinity of dykes and associated faults**

Response to managing outbursts

- **mid- to late 80's to early 90's (personnel protection)**
  - **encapsulated continuous miner**
  - **remote miner (video/ radio control)**

- **early to late 90's (outburst prevention)**
  - **development and refinement of an outburst management plan**
    - **locate structures**
    - **lower gas content to below threshold**
    - **flow monitoring and gas sampling prior to mining**
  - **improvement in in-seam drilling (survey and steering).**

Outcome of OMP and improvements in gas drainage.

- no outbursts since 1992
- major increase in safety
- Tahmoor went from a development lag to a comfortable development lead
- 1998 beginning of problem with low permeability coals that lead to grunching (3m /shift)

ZONES OF COAL WITH LOW PERMEABILITY

History of Occurrence and Impact on Mining.

I. LW's 14-19 (Panels 508-514)

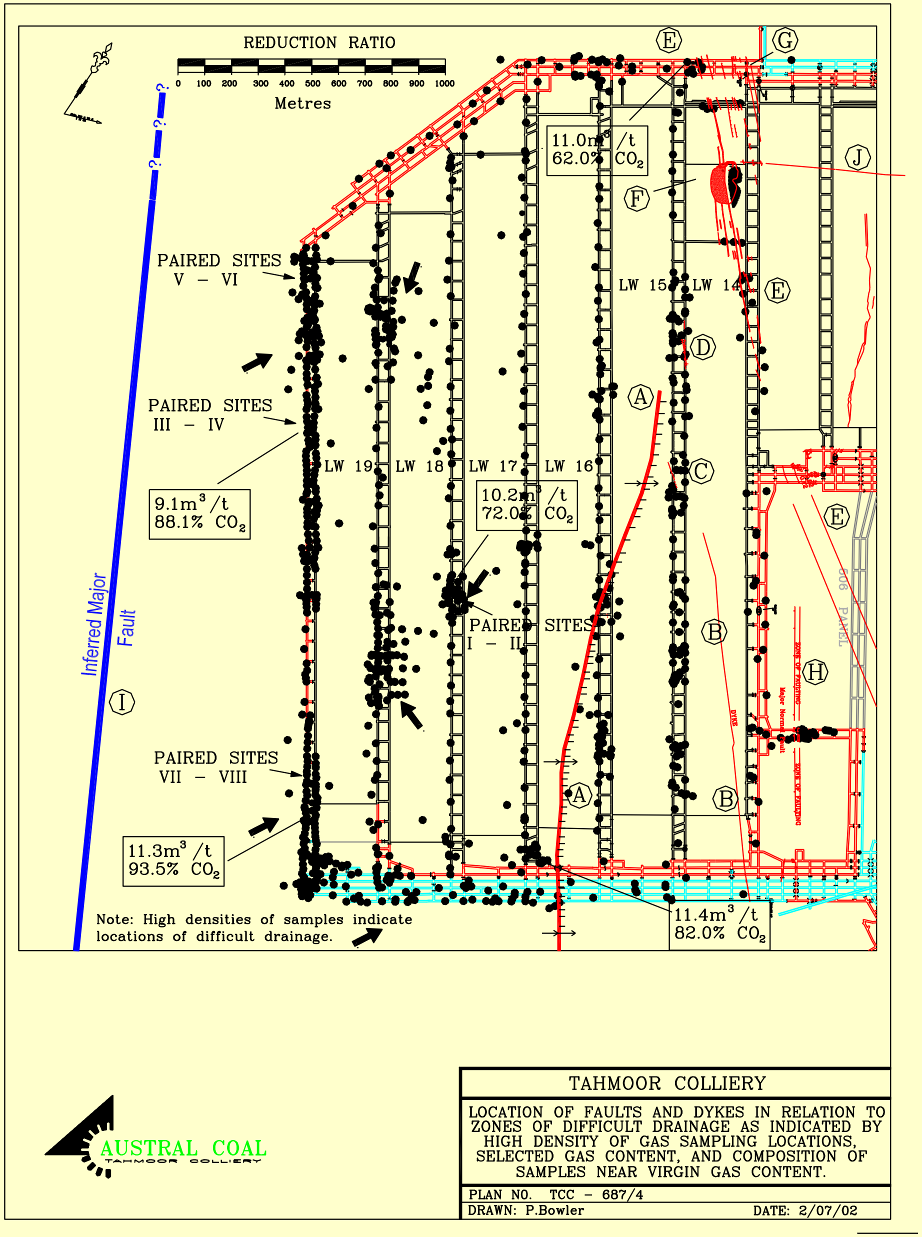
II LW 20

III LW21 and 900 panel

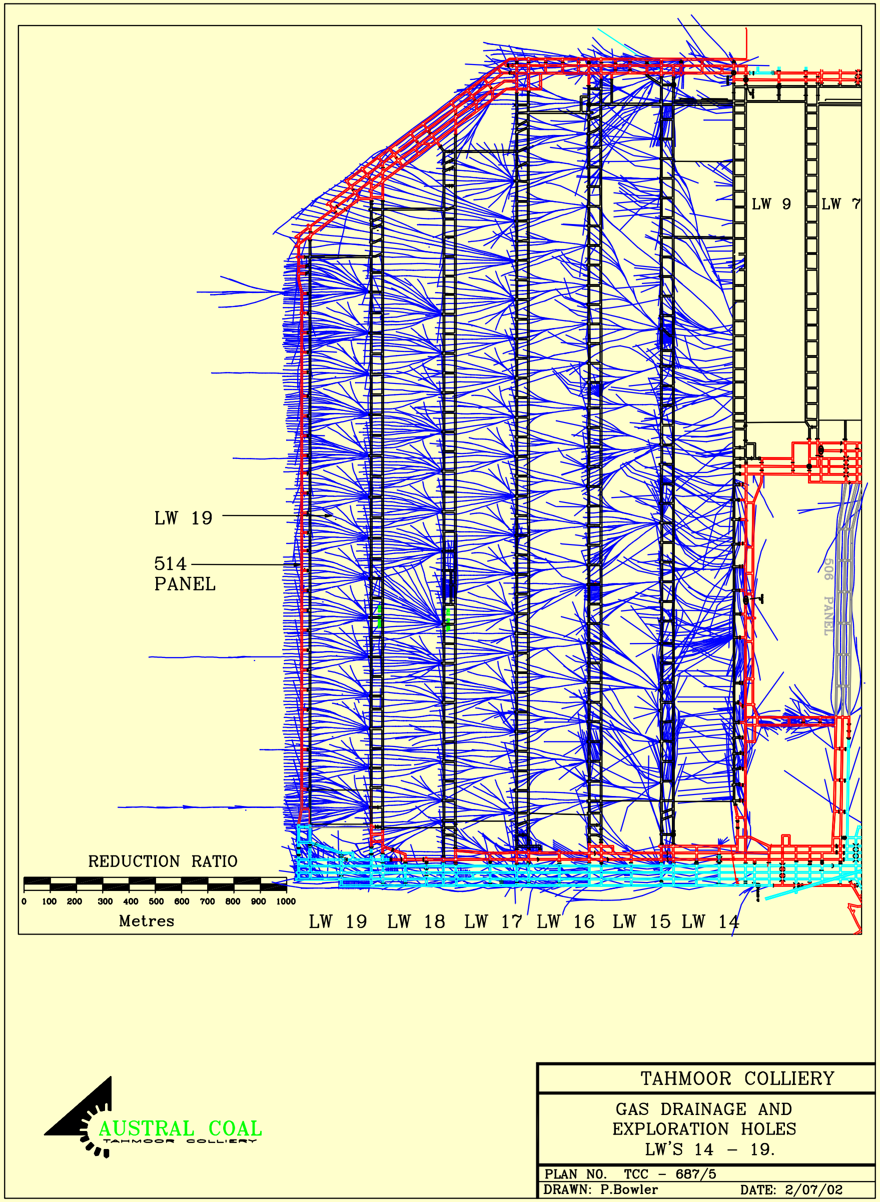
LW's 14-19 (Panels 508-514)

Panel	No of sites	Metres affected	Geology/ drilling	Response	Causes
509	3	~80	2 sites close to small fault/roll	Remedial drilling	?
510	3	~130	1site close to small fault/roll	Remedial drilling	?
511	3	~60	-	Remedial drilling	?
512	1	~100	**6 months to drain 55m.**	Drilling and split pillar	carbonate
513	1 (S)	~250	-	Remedial drilling	carbonate
513	1 (N)	~250	-	grunching	carbonate
514	many	1600	-	grunching	carbonate

Location of zones of difficult drainage LW14-19



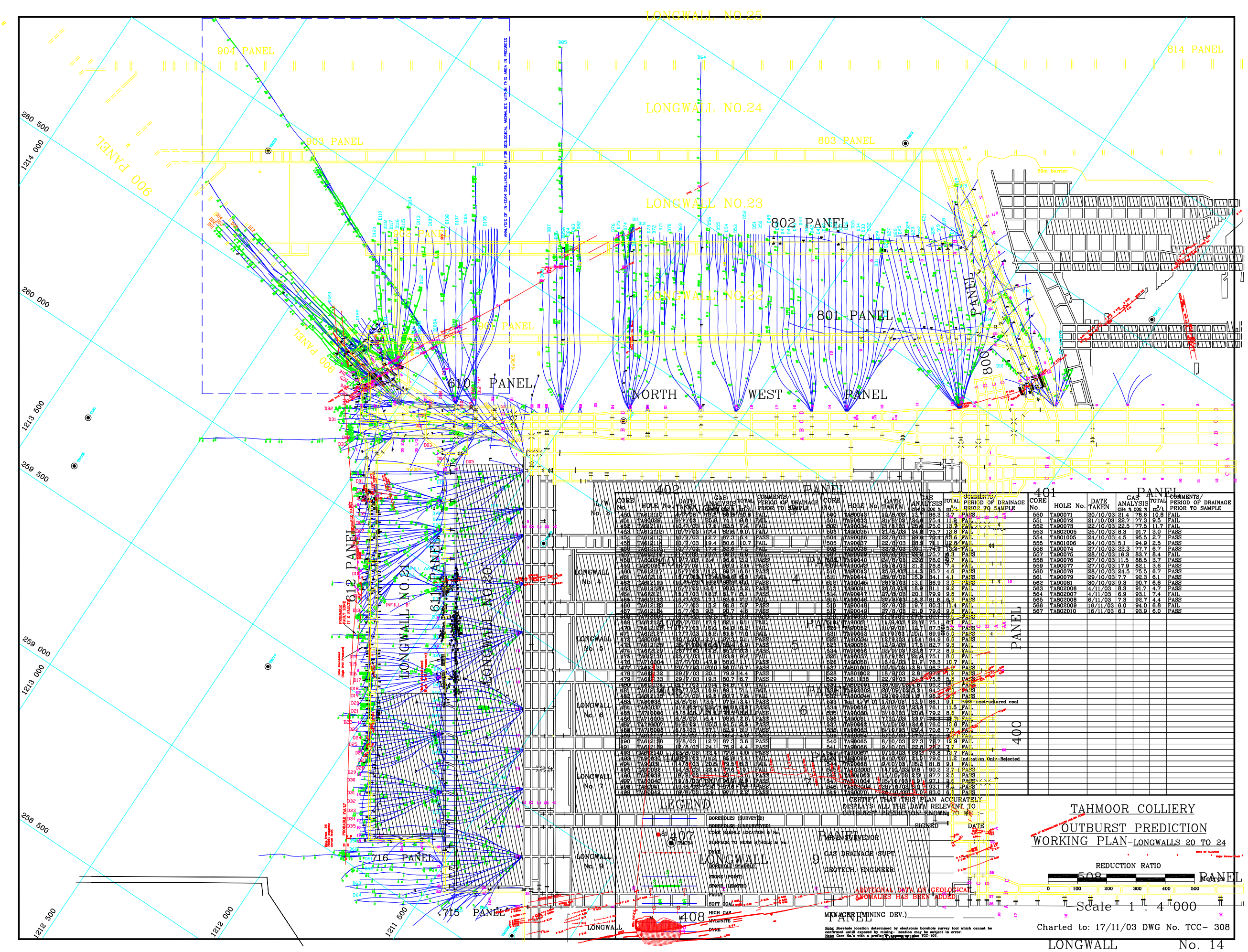
Drilling LW14-19



LW's 20-21 (611 and 612 panels) and 900 panel main headings.

Panel	Metres affected	Geology
700	Mined 15 years ago. No drainage. No outbursts.	1 minor strike slip fault. Calcite in coal 14-8ct. Consistent with trend of 611,612 panel.
611	1000	1 minor strike slip fault
612	1600 pass/fail	**Close to major thrust fault. Numerous small scale thrusts.**
900	Still being mined by grunching	Zone of abundant carbonate in coal. Separate from 611/612 zone. **Crosses thrust fault zone. Soft coal. Difficult to drill.**

LW20, 21 (611 and612 panels) and 900 panel.



PROBABLE CAUSES/CONTROLS

ACARP Project C10011.

Microscopy of low permeability coals at Tahmoor and Tower Colliery.

Commenced during extraction of 514 panel

Major findings.

i) Low permeability associated with mineralisation of:
- **μ-cleat**
- **μ -breccias - cement**

ii) Major mineral infills:
- **calcite (Tahmoor)**
- **calcite and dolomite (Tower)**

•

PROBABLE CAUSES/CONTROLS contd

.

CURRENT AND PLANNED ENDEAVOURS.

i) Characterise **vertical** and **lateral variation**

in

normal and **low permeability** coals

- macroscopic features
- microscopic features
- reservoir parameters/coal properties (eg. permeability, shrinkage, strength)

CURRENT AND PLANNED ENDEAVOURS contd.

ii) Investigate context of zones of mineralisation

- **history** of mineralisation (2 calcite phases ?, siderite, kaolinite) in relation to burial/ faulting / intrusion

  field relationships,isotope, cathodoluminescence,

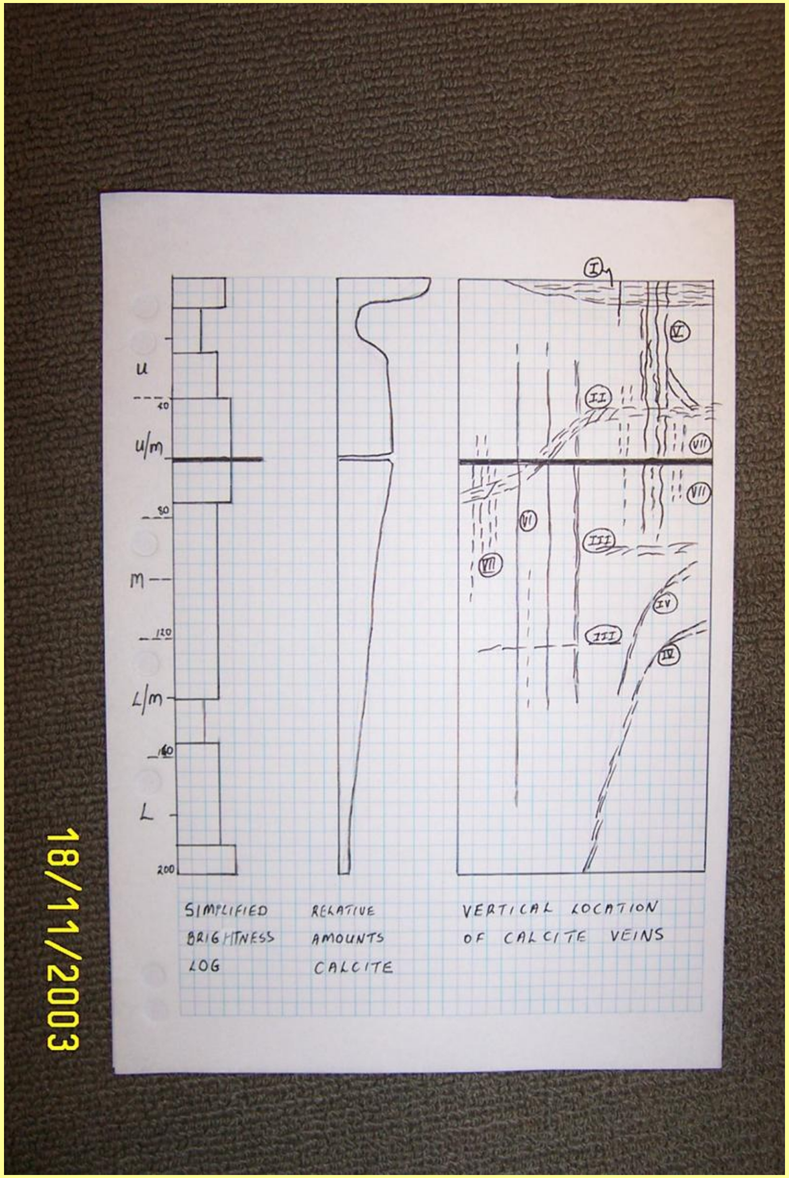
- **origin of fluids** associated with mineralisation and **mechanism of fracture formation / cleat infilling**

- develop a **model for predicting** the occurrence of zones of low permeability

Classification of calcite veins (tentative)

		Dip of veins	**Fracture type**	**FZ density**	**Location in seam**
A	I	H-SH	WFZ	VH	U
A	II	H-SH-I	WFZ	H-M	U/M - M
A	II	H-SH-I	WFZ-D	M-L-D	U/M – L/M
B	IV	SV-I	NFZ*	H	M-L
B	V	V	WFZ**	L	U – U/M
B	VI	V	MC/NFZ*		U – L/M
B	VII	V	C*		U/M - M
B	VIII	V	Mc*		U/M - M

* associated with μ breccia. ** associated with μ fauilts (1-2 cm)



18/11/2003
U
40
U/M
80
M
120
L/M
160
L
200
SIMPLIFIED BRIGHTNESS LOG
RELATIVE AMOUNTS CALCITE
VERTICAL LOCATION OF CALCITE VEINS

VEIN DESCRIPTIONS

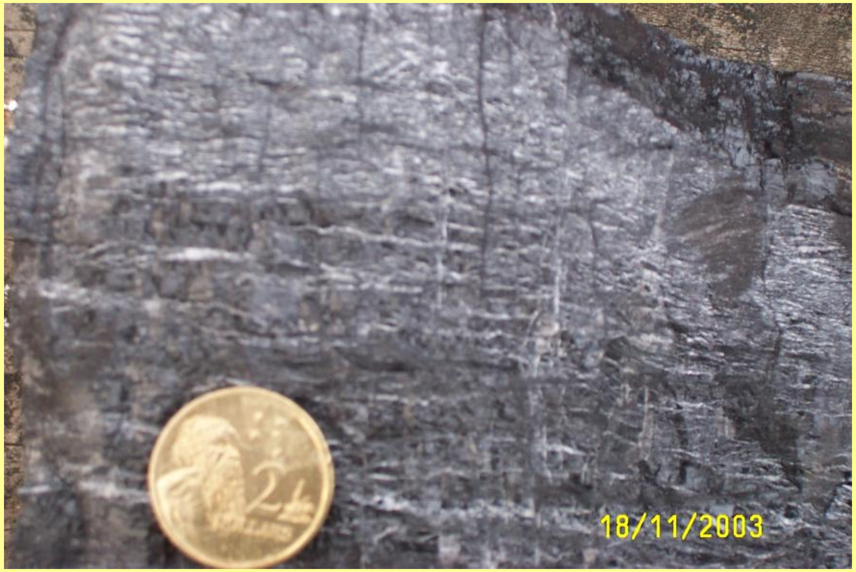
I Very dense concentration of horizontal veins near roof.

- **mostly calcite (coal is remnant)**
- **? replacement of coal by calcite (white)**
- **cut by dark veins parallel to cleat (calcite) and Type V**
  - **dark veins in Type I have kaolinite centres**
- **little impact**

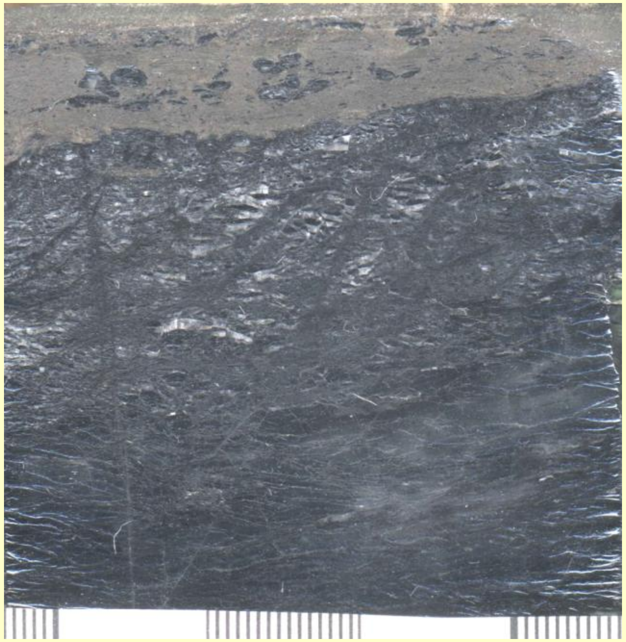
kaolinite on cleat to about 15cm below roof throughout lease regardless of whether Type I is present or not

? kaolinite present on fractures in proximity of dykes

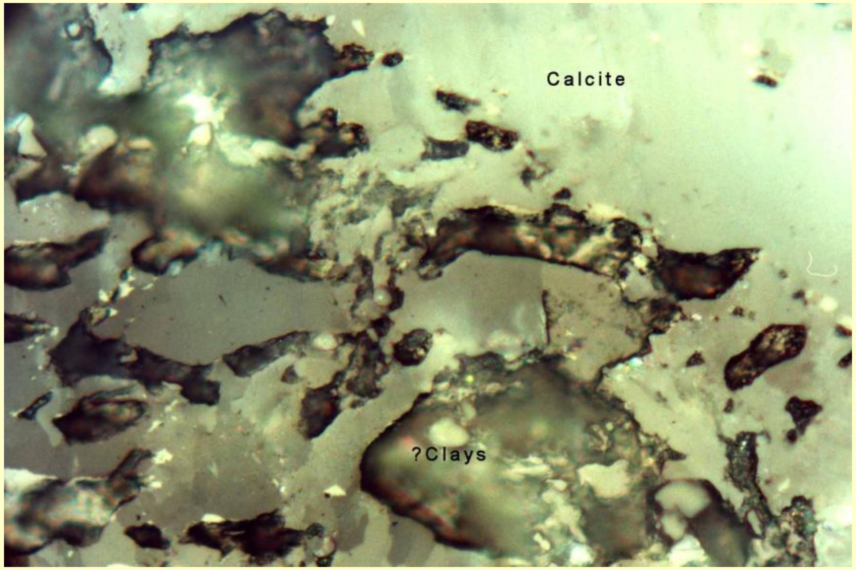
Type I

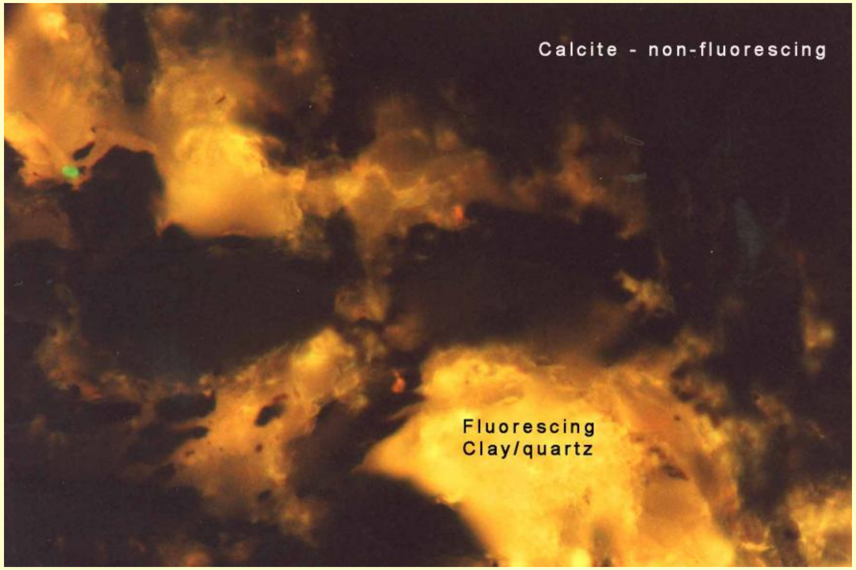


Dark veins in type I



Dark veins in type I





VEIN DESCRIPTIONS contd

II Very dense concentration of horizontal veins below roof.

- **laterally extensive 10's -100's of metres**
- **cut by dark veins (if dense concentration of fractures)**
- **can "migrate" below sideritic mudstone**
- **if so calcite on cleat (and m-cleat) in U/M to M part of seam more abundant**

Type II

VEIN DESCRIPTIONS contd

V Fracture zones near roof.

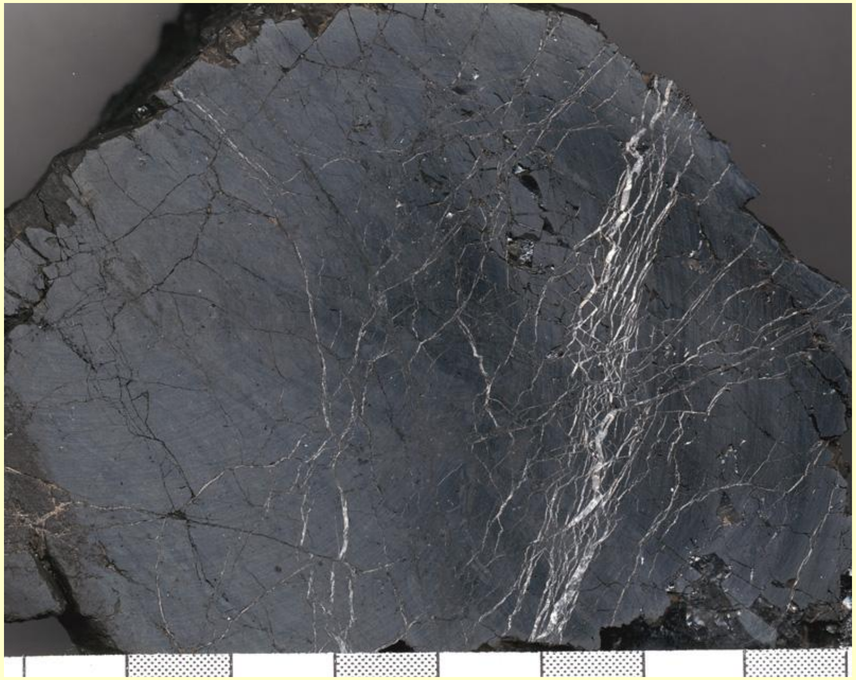
- same orientation as cleat (face and butt)
- preference if any not known
- associated with small faults to 1-2cm
- curved veins connect with Type II
- less frequent below sidertic mudstone band
- higher density of calcite on cleat (and micro cleat) in proximity to Type V

Type V, and curved fractures/veins

Type IV polished block

LHS – bedding plane section field of view ~10cm

RHS – perpendicular to bedding, field of view ~10cm



- <u>Relative ages.</u>

Types V + II + cleat fill (VI, VII, VIII) same "age" (event)

- All of these after Type I

- Calcite (2) → kaolinite (?) siderite ?

VEIN DESCRIPTIONS contd

Fractures, nature of calcite veins.

- **calcite habit is fibrous (cf blocky)**
- **small (mm) veins (and microcleats)**
  - **1 centre line with coal slivers separating fibrous crystals**
-
- **large veins(1cm+)**
  - **several lines with coal slivers sseparating fibrous calcite**
  - **“fibres” slight kink**

Comparison of fibrous and blocky crystals

	Fibrous	Blocky
Crystal habit	Long relative to width; perpendicular or near perpendicular to opening	equant
Origins	1. Crack and seal. 2. Diffusion	1. Open cavity. 2. Re-crystallisation

- * Crack origins: 1. fluid pressure 2. tension 3.shear 4. tectonic + fluid pressure

Fibrous vein minerals.

	Syntaxial	**Antitaxial**
Wall rock/ mineral	Same mineralogy	**Different mineralogy (eg calcite in coal)**
Growth direction from crack	inwards	**outwards**
Site of subsequent cracking*	Median line (initial crack)	**Host rock/ filling wall contact; remnants of host rock at median line**

- *where molecular bonding is weakest

Origin of horizontal to sub-horizontal fractures and veins.

- shear at roof; lineations
- fibrous (anti-taxial) calcite
- sometimes low angle veins
- slightly sigmoidal veins
- slight departure of “fibres” from perpendicular
- horizontal fibrous veins in roof in proximity to thrust fault

→ bedding plane shear in the presence of mneralising fluids

Vertical to sub-vertical fractures and veins

- **cemented μ - breccias (V,VI, VII, VIII)**

  → shear prior to entry of mineralising fluids.

- **μ Cleat - angular slivers of coal parallel to cleat**

  → mineralising fluids opened incipient cleat; cleat width result of mineralisation ?

Summary of structural / sedimentary model

Type, location and abundance of veins dependent on:

- location in seam
- occurrence of bright coal, dull coal, sideritic mudstone
- fracture mechanisms
  - bedding plane shear, strike slip shear
  - presence of mineralising fluids during or after fracturing

HYDROFRAC

- Water only fracs in low permeability zones of 611and 612 panels (collared 700 and 611 panels).

- Pressure, water injection response suggest good fracs.
  - However no stimulation
  - Frac pressures 16MPa
  - Possibility of closure due to high stress

- Another Bulli Seam mine.
  - minimum stress in coal 8MPa; 16MPa to frac
  - complex multi-branched fracture mapped
  - if Tahmoor fractures planar/simple - high stress.

Has mineralisation contributed to effective stress ?

Source of carbonate mineralising fluids (field evidence)

1. Magmatic

- 2 known instances where no carbonate in coal adjacent to dyke.
- Also isotopic evidence.

2. Scarborough Sandstone

- Contains CO2
- Stalagmites in drill hole
- Calcite on exto hole dripping water
- Long wall take-off face coated in calcite
- Separated from Bulli Seam by 8-10m impermeable Wombarra Shale; access at time of mineralisation

Prediction/detection

Importance:

need to be able to plan management well in advance

Predicting location of low permeability zones

Zones of carbonate mineralisation and low permeability (N-S to NNE-SSW).

? Related to strike slip movement of:

Lease scale structures or regional features

- ***How to explain deformation features with respect to strike slip regime.***

Detection

Can a knowledge of mineralisaton in coal be applied to detection ?

Requires a detailed characterisation of vertical and lateral variability of macroscopic and microscopic features.

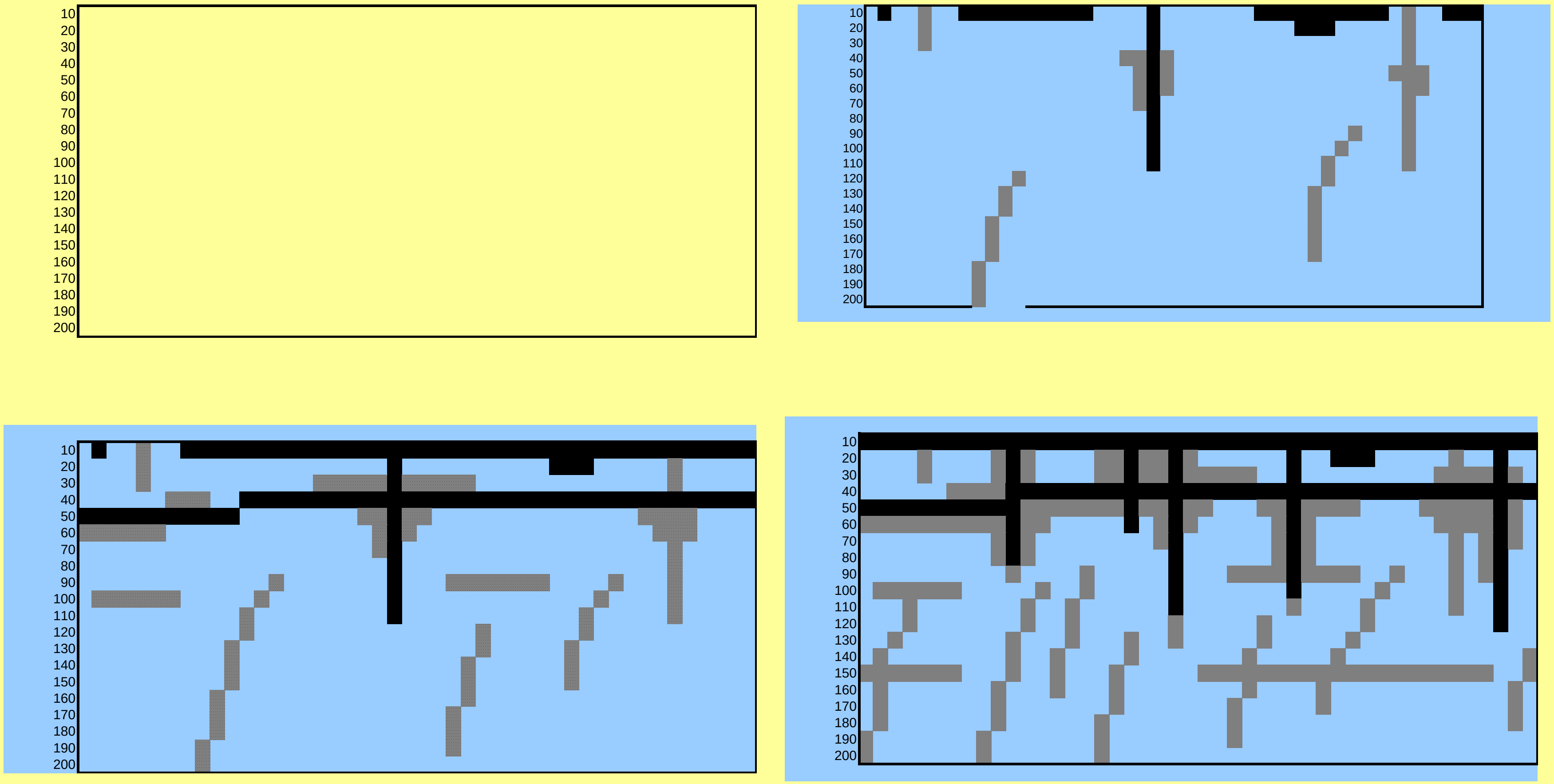
Sampling extremes.

i) Spot samples and random sampling.

ii) long lengths of core from known parts of the seam.

Hypothetical section of roof to floor calcite distribution

Importance: interpreting results of exploration samples



Variation in bright coal calcite over 1m

LHS – abundant calcite on cleat above mudstone
RHS – absence of calcite on cleat above mudstone

Detection: Gas flow measurements

- Entire hole
  - **Local low permeability can be masked**
  - **Has provided some indication of problem but other possibilities for low flow**

- Sectionalised down-hole flow measurements
  - **best means.**

Management: "Reactive"

- Grunch (slow)

- Large diameter auger
  - **Destress**
  - **Degas**
  - **Trigger outburst**
    - **Operator protection**
    - **Needs R & D**

Management: “Proactive”

Need to know well in advance (importance of detection/prediction).

1. Avoidance.
   - Depends on extent
   - Not always possible

2. Drill closer spaced holes
   - time dependent
     - some cases has worked , other cases not

Management: “Proactive” contd.

3. Hydrofrac

Tahmoor mineralisation and ? high stress in coal

- **Water treatment**
  - **Stress reduces effectiveness**

- **Proppant**
  - **? High Stress reduces effectiveness**

Even if proppant is not nullified by high stress, will good fracs stimulate coal with abundant mineralisation ?

Management: “Proactive” contd.

4. **Acid leaching**

- **chemically induced porosity/permeability**
- **Calcite easily dissolved in dilute HCl**
- **From the surface**
- **Underground**

Management: “Proactive” contd.

- **From the surface**
  - **Established technology for extraction/ precipitation and waste water treatment**
    - **Uranium**
    - **Copper**
    - **Acidification (HCl) commonly used where host rocks are limestone or dolomite**
  - **Easier to manage than from underground**
  - **In-seam holes needed for effectiveness**

Management: “Proactive” contd.

5. Acid leaching + hydrofrac of in-seam holes

- **Potentially most effective ?**
- **Need to connect surface plumbing for acid flushing with in-seam holes**
- **Proximity to urban areas**
- **How effective will acid leaching be with very fine calcite?**

Management: “Proactive” contd.

Acid leaching + hydrofrac of in-seam holes contd.

- **Most effective leaching and hydrofrac**
  - **In-seam holes near top of seam (Tahmoor; elsewhere ?)**
  - **Drilled perpendicular to preferred direction of mineralisation**

    (Cf. Best result for CBM and u/g drainage is across face cleat)

  - **Hence need for characterisation / predictive model !**

Summary

1. Low permeability coals can be a significant local mining impediment
2. Most likely cause at Tahmoor is calcite (and stress?).
3. Effective management requires prediction and detection.
4. Prediction requires understanding mechanism of fracturing and fluid migration in relation to local and regional geology.
5. Acid leaching involving in-seam holes and hydrofrac is probably most effective means of management.
6. Mitigation (via above) requires characterisation of lateral and vertical variabilty.
7. Best initial detection may be sectionalised gas flow monitoring.