



Geodynamics a view after Eurock 2018

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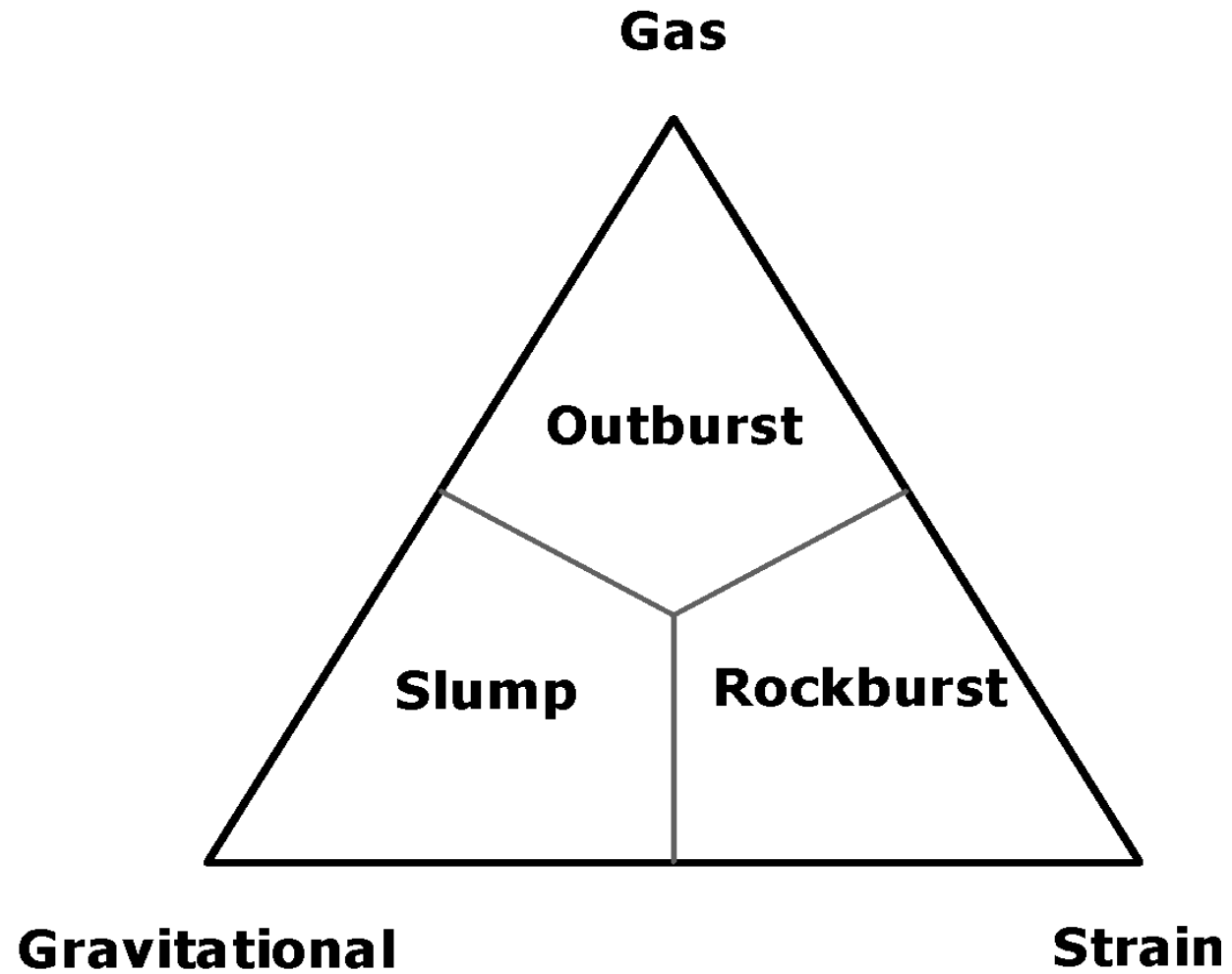
Catherine the Great's Palace



Catherine
the Great
set up
School of
Mines as
part of the
military in
1770



Energy
release
and event
names?



Failure and Energy Release

- Failure is really excessive deformation.
- It may also be defined by a loss of strength
- Excessive deformation frequently follows a loss of strength that precedes the major part of the deformation
- Total energy release is important but the consequences are much more serious if it happens quickly
- This is related to the power of the event
- For example a goaf collapse behind a longwall represents a huge energy release but it really only matters if it happens suddenly

TYPES OF DYNAMIC EVENTS

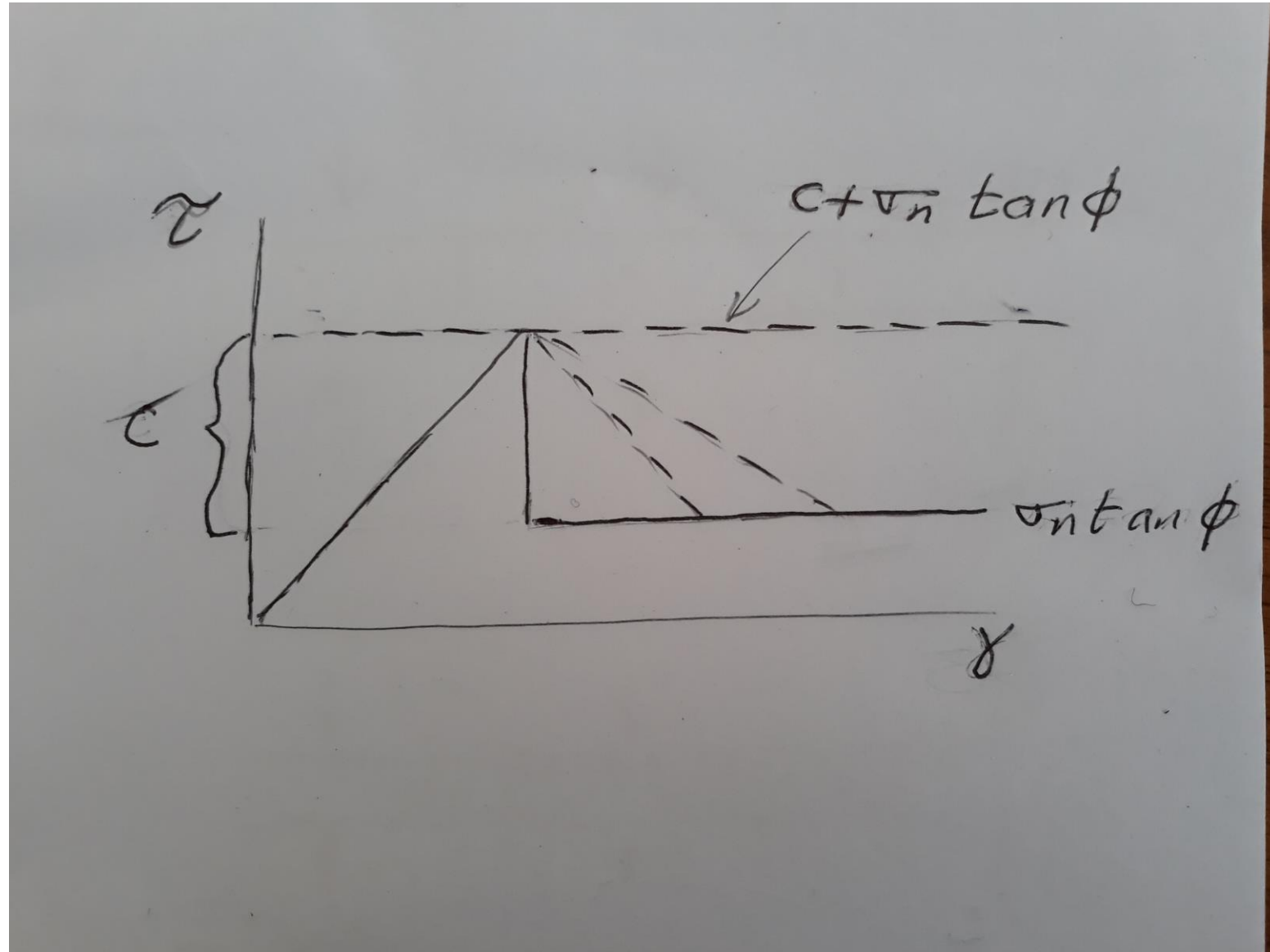
- STRAIN BURST
- BUCKLING EVENTS
- ROCKBURST AS A RESULT OF SEISMIC EVENT (CAUSED BY MINING)
- PILLAR FAILURES AND ASSOCIATED BUMPS
- STRUCTURALLY INFLUENCED ROCKBURSTS

STRAIN BURST -1

- Localised failure of drive/drift/roadway/shaft/adit/winze/raise
- Nearly always occurs in high strength rock which is under high stress
- Brittle failure leads to sudden drop in material resistance to deformation
- Drop in material resistance may be thought of as loss of cohesion term within the failure stress equation
- $$\tau = c + \sigma_n \tan \phi$$
- The question is how rapidly does cohesion disappear?
- This is a shear failure process

Strain burst - 2

- Does not occur with high confinement
- leads to ejection of fragments



Buckling Events

- Buckling is a structural term indicating collapse due to factors of geometric stability
- Simple example is the failure of a straight pin ended strut which has quite high enough strength to withstand axial load but by pure geometry and material stiffness character will fail at a certain load
- Deformation is initially elastic but then because of the associated change in geometry becomes permanent
- Buckling consumes very little energy allowing this to project fragments

Buckling in Rock

- Commonly occurs in schistose material with planes of weakness
- May form in cleated (natural or induced) coal
- Multiple hinges form as the material fails
- Each hinge consumes little energy
- Particles are ejected due to the release of strain energy of unbroken material

Buckling in rock - 2

- Buckling may be greatly assisted by asymmetry of loading
- Asymmetric loading can be due to geometry of fractures
- Asymmetric loading may be caused by fluid pressure. This will initiate failure at a much lower load than would otherwise be the case.

Buckling Failure

- Buckling failure does not occur in a continuum.
- It can exist in planes between cleats and joints which are pre-existing or induced.



Buckling is associated with many rockbursts in metalliferous mining

Shear loading

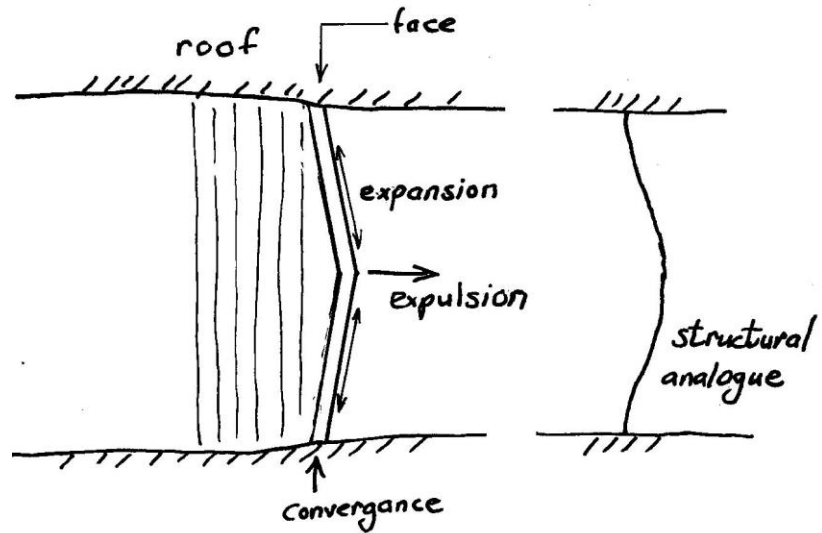
- Energy is consumed in part by frictional resistance

Buckling

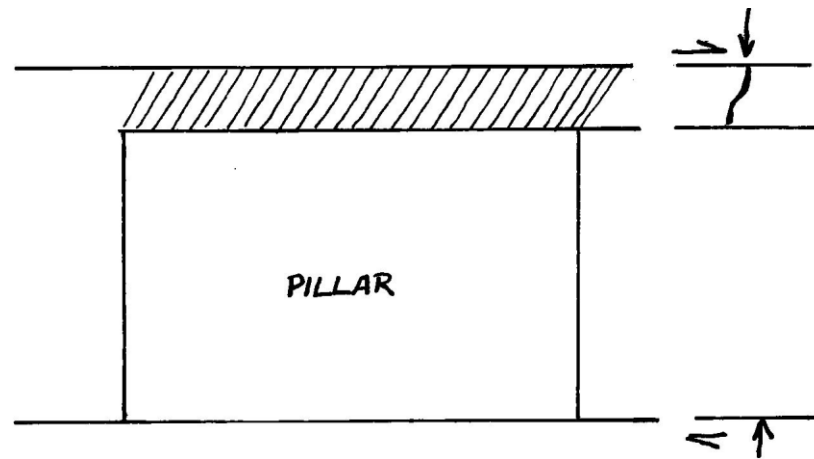
- Buckling forms hinges in which a require comparatively little energy to create
- This leaves the coal/rock free to expand and convert its strain energy into kinetic energy

Buckling behaviour

Face



Buckling of Pillar Top



Gas can cause failure to slab of coal 50 mm thick with joint behind to initiate failure

2.0 m high slab of coal

- Vertical stress required to buckle slab = 2.6 MPa
- Gas pressure to cause failure = 3.8 kPa
- -----
- State of restraint important = persistence of joints/cleats

0.5 m high slab of coal

- Vertical stress required to buckle slab = 42 MPa (shear failure first)
- Gas pressure to cause failure = 60 kPa
- -----
- Gas pressure is clearly very important – case of supply and leakage

Seismic event induced rockbursts

- These are a major problem in deep metalliferous mines
- They can also be a major problem in coal
- Caused by failure of the rock mass emitting substantial seismic energy
- Wave travels through rock and reaches an open face of a drive causes tensile or shear stress that leads to failure
- High stresses in the rock near the rock adjacent to the face combine with the seismic energy to produce violent failure
- In coal mines the main example of this seems to be the failure of massive hard rocks within the goaf

Seismic event induced rockbursts - 2

- These may lead to massive failures that may destroy long lengths of roadway – this includes coal mines in China
- The main metalliferous mining way of dealing with these is energy absorbing rock reinforcement

Seismic event induced rockbursts - 3

- Metalliferous mines put a large effort into seismic monitoring
- Listen for the sounds of failure and locate the source
- Estimate where a major failure might occur and be prepared to deal with the consequences on surrounding mine openings
- This may mean to abandon certain areas until the activity has quietened down or a major rockburst event has taken place.

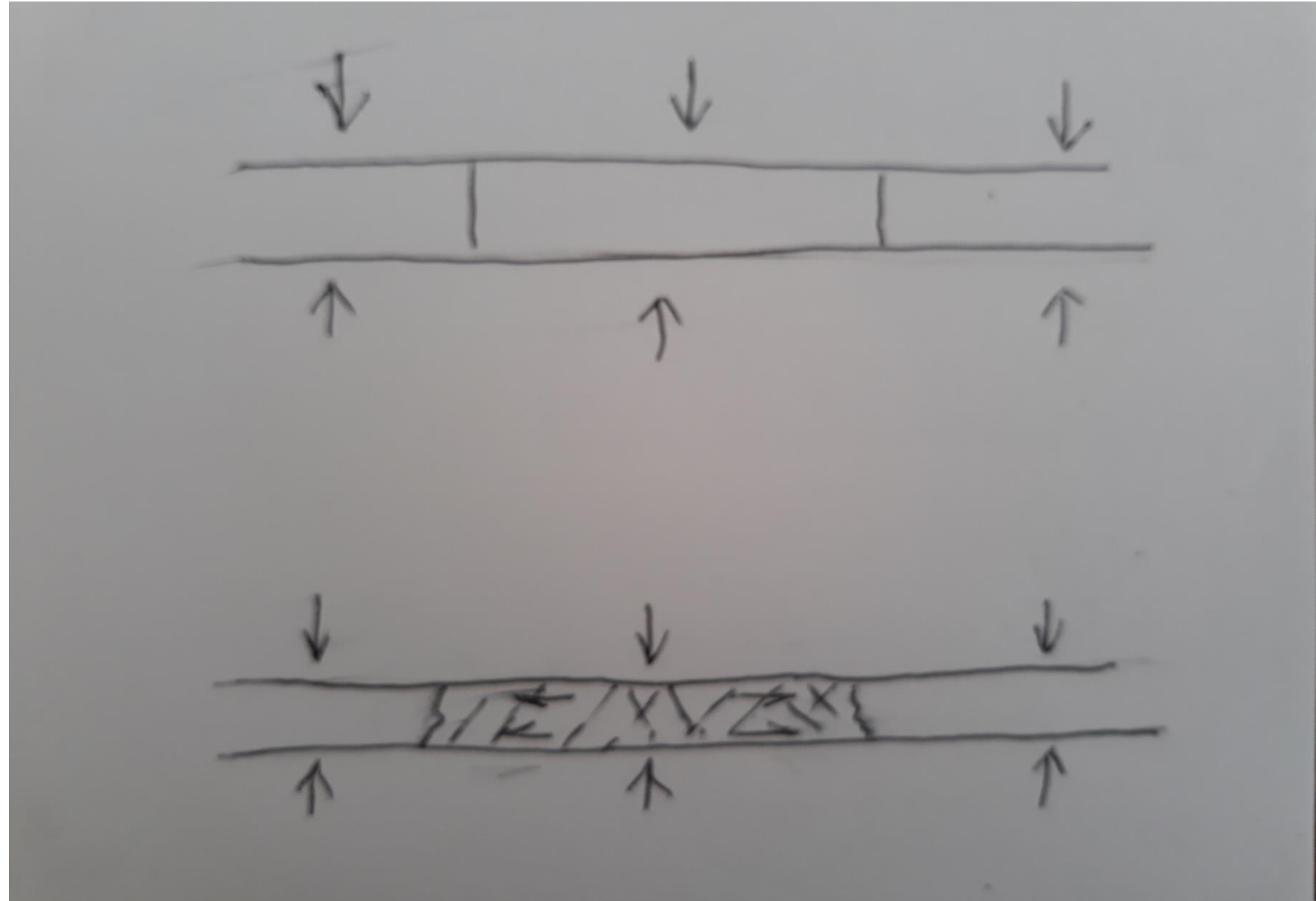
Pillar failure and associated bumps

- Pillar failure may occur as a yielding process or by some violent failure
- Whether pillar failure occurs is frequently a function of the confining stress within the pillar.
- Confinement comes from the initial stress within the pillar and how it is modified by mining or by gas drainage
- When strength based failure occurs does this lead to catastrophic pillar failure or simply convergence?
- This depends substantially on the pillar geometry
- Fat pillars build up internal confining pressure as they yield
- The shock associated with failure before this may be considerable

Important measurements for pillar behaviour

- Pillar geometry
- Initial lateral stress within the pillar – can be difficult to measure
- How pillar develops lateral stress with progressive deformation
- Rock/Coal stiffness
- Structure – controlling failure – essentially by removal of cohesion

Broad pillar
developing
lateral
stress
under
failure



Structurally induced rockbursts

- These are failures due to structure within the rock mass that are associated with significant high power, high energy release.
- Buckling is a subset of these
- Squeezing of a wedge bounded by joints or bedding planes
- The range of possibilities is infinite!

One of the
rooms at
the Winter
Palace



What do you do about rockbursts?

- Seismic monitoring to warn of problem locations
- Use energy absorbing reinforcing to deal with the consequences
- Get people out of harms way
- Determine the stored energy
- Remove energy from the face

Energy absorbing reinforcement – 1 bolts

- Bolts that permit extensive elongation between anchor points – ploughing type devices
- The performance of these is very dependent on the grout or chemical anchoring material
- The current favourite would appear to be a smooth bar with deformed sections - These are grouted in place.
- The Chinese have patents over what they call –ve Poisson's ratio bolts

Energy absorbing reinforcement - 2

- Shotcrete with fibre – gives the shotcrete yield capability
- External mesh held by bolts – high deformability – ‘the keepers glove’
- Reinforced concrete technology
Structural engineers have designed highly deformable beams, columns and junctions to absorb flexure. This is currently totally ignored by the mining industry. Shotcrete over rebar is extremely effective – note swimming pool construction.

Energy at the face -1

- Will failure occur? – if not then there is no concern
- If failure occurs then the energy within the rock mass near the face is very important
- The failure type will determine how much energy it absorbs. Buckling will absorb less energy than shearing
- The energy within the rock mass is a function of the stress / strain state. This tends to be a function of the rock stiffness and the local state of strain within the rock mass
- The state of strain is determined by regional factors, local geology & mining

Removing energy at the face

- Destroying cohesion ahead of the face

Blasting

Hydrofracture

Mining method that ensures that yield occurs at depth ahead of the face

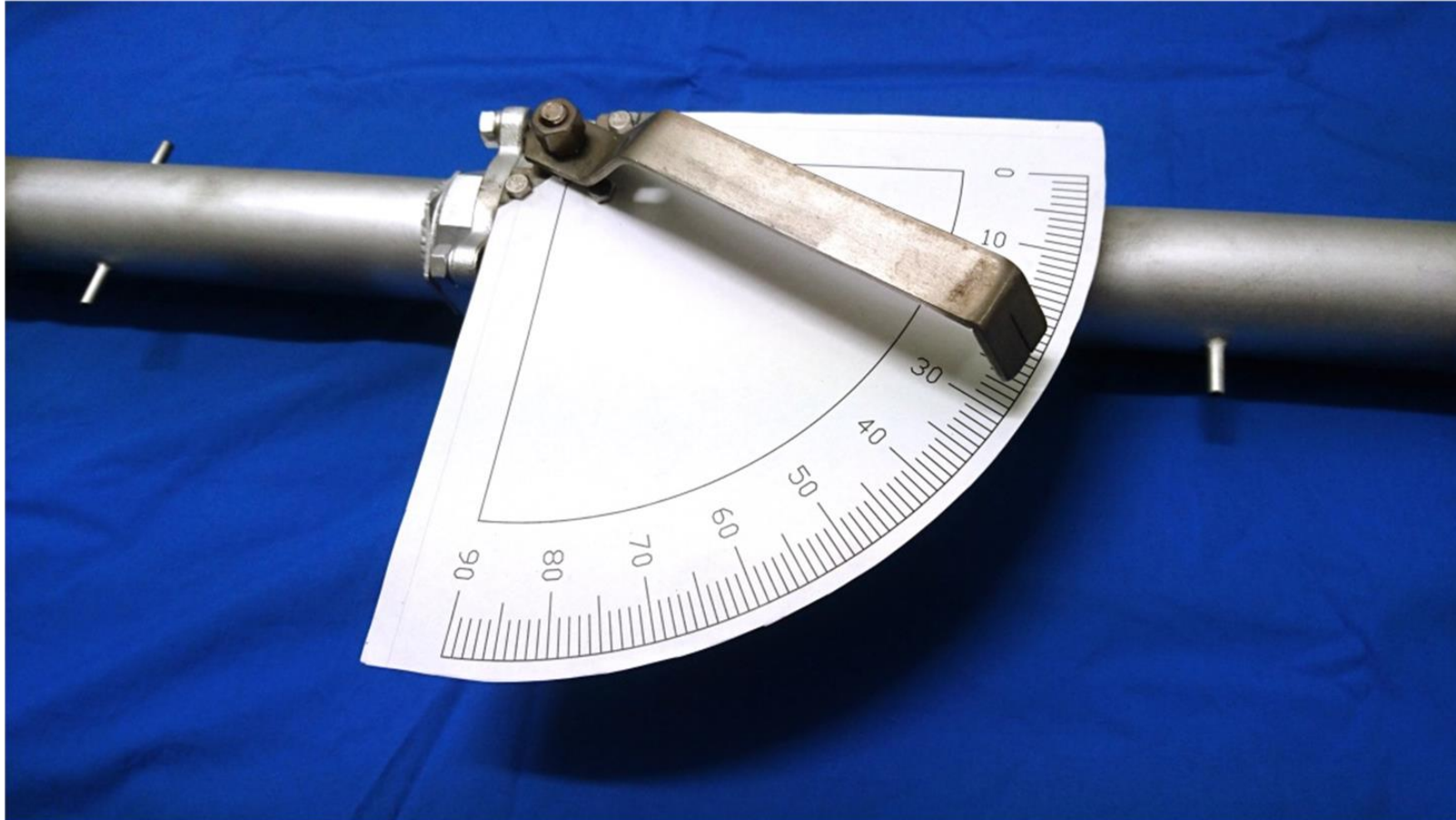
Major research needs

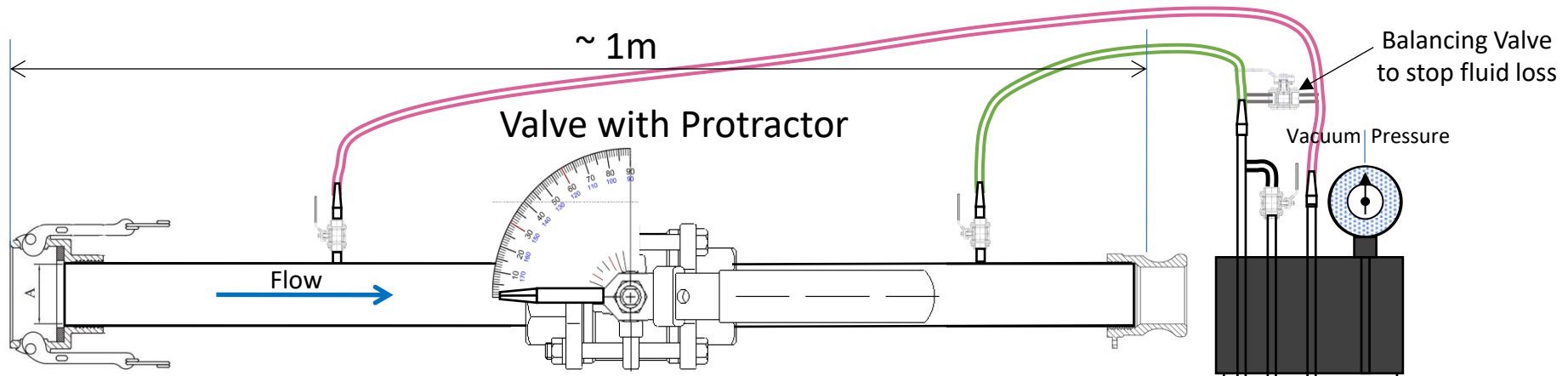
- Determination of depth of yielded zone ahead of the face
- Rapid determination of the stress state in coal
- How good is the hardness of the face as an indicator of problems?

School of Mines



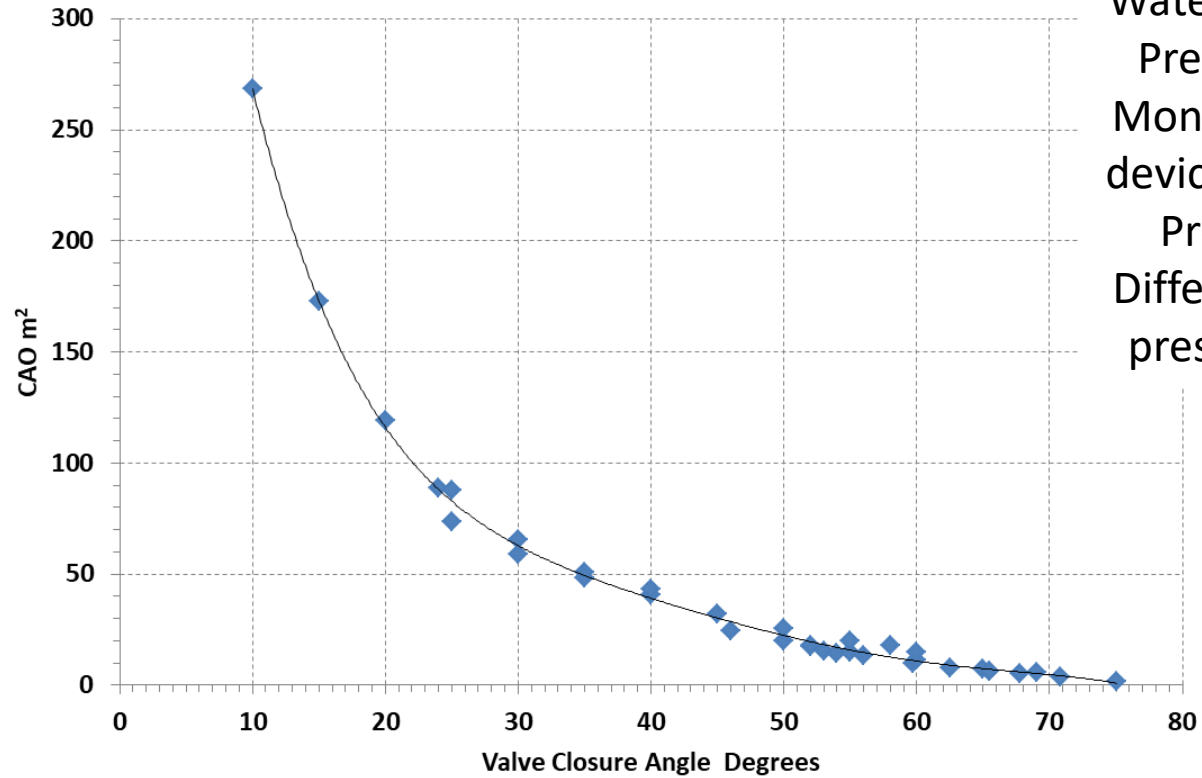
Permanently installed flow metering for gas drainage pipework



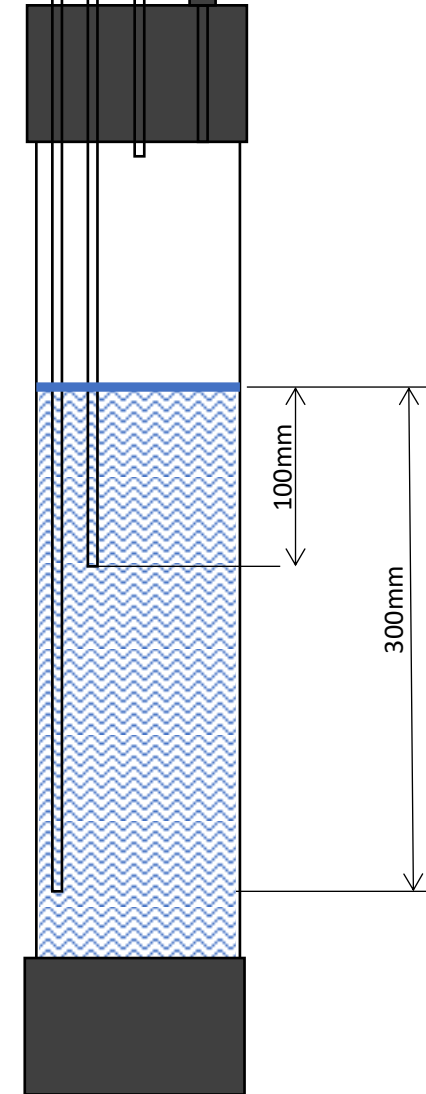


Flow Meter ~ Weight 12kg

CAO Vs Valve Closure Angle of Ball Valve



Water filled
Pressure
Monitoring
device With
Preset
Differential
pressures



Nominal Flow Range of Ball Valve Flow Meter (Methane at Atmospheric Pressure)

| Differential Pressure mm H2O | 50mm | 100mm | 300mm |
|------------------------------|-------------------|-------------------|----------------|
| Valve Closure Angle | 68° | 68° | 15° |
| Nominal Pipe velocity m/s | 1.5 | 2.2 | 125 |
| Valve Diameter | Min Flow l/min | Min Flow l/min | Max Flow l/min |
| 1" | 45 | 65 | 3,710 |
| 2" | 180 | 255 | 14,850 |
| 3" | 440 | 620 | 36,150 |
| 4" | 720 | 1020 | 59,420 |
| 6" | 1,620 | 2,290 | 133,690 |

Ball valve flowmeter - benefits

- Turndown ratio 80 x (Max flow/ Min flow)
- Permanent installation – saves time
- Minimal delay to read - saves time
- Runs full bore unless being used to read flow – no restriction
- Can be used as permanent isolating valve
- Economic