Rock Mechanics From a Broad View
Civil, Mining, Petroleum

Eurock 2018

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The purpose of this course is to share knowledge

-mine & yours

I want to learn too!

Today should not be a monologue

The need to understand the geology

- Nothing in the ground can be put into any sensible context without a knowledge of the geology.
- What rock type is it?
- What order did it arrive in?
- What has happened to it since it got there?
- What is happening to it now? strains, erosion, igneous activity, earthquakes.

Rock Types

- Sedimentary – depositional process

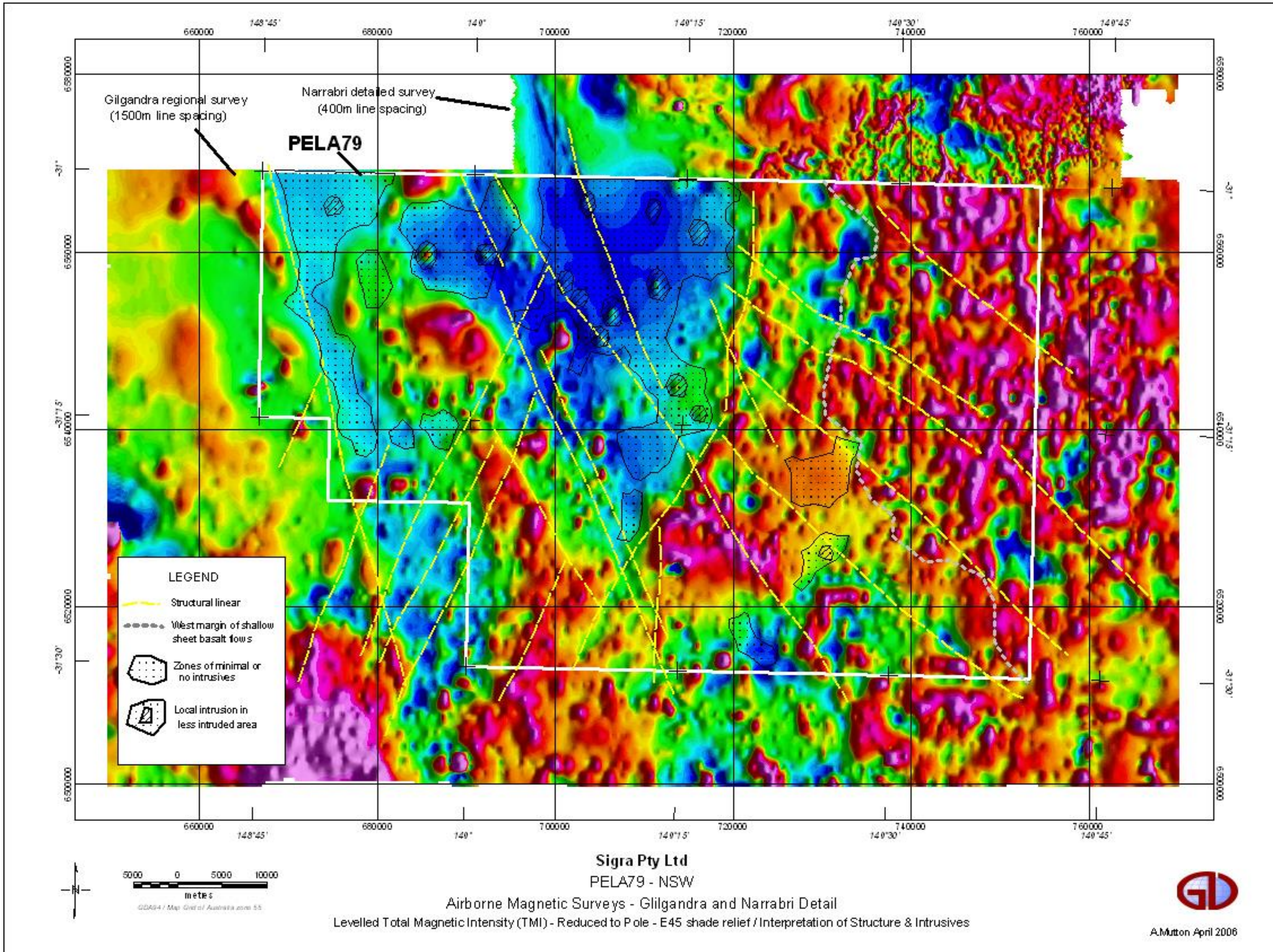
  Transition from soil to rock with lithification and diagenesis

  maturation of contained fluids, fluid loss and replacement
- Igneous – plutonic & extrusive
- Metamorphic - anything can be changed
- Weathering changes everything

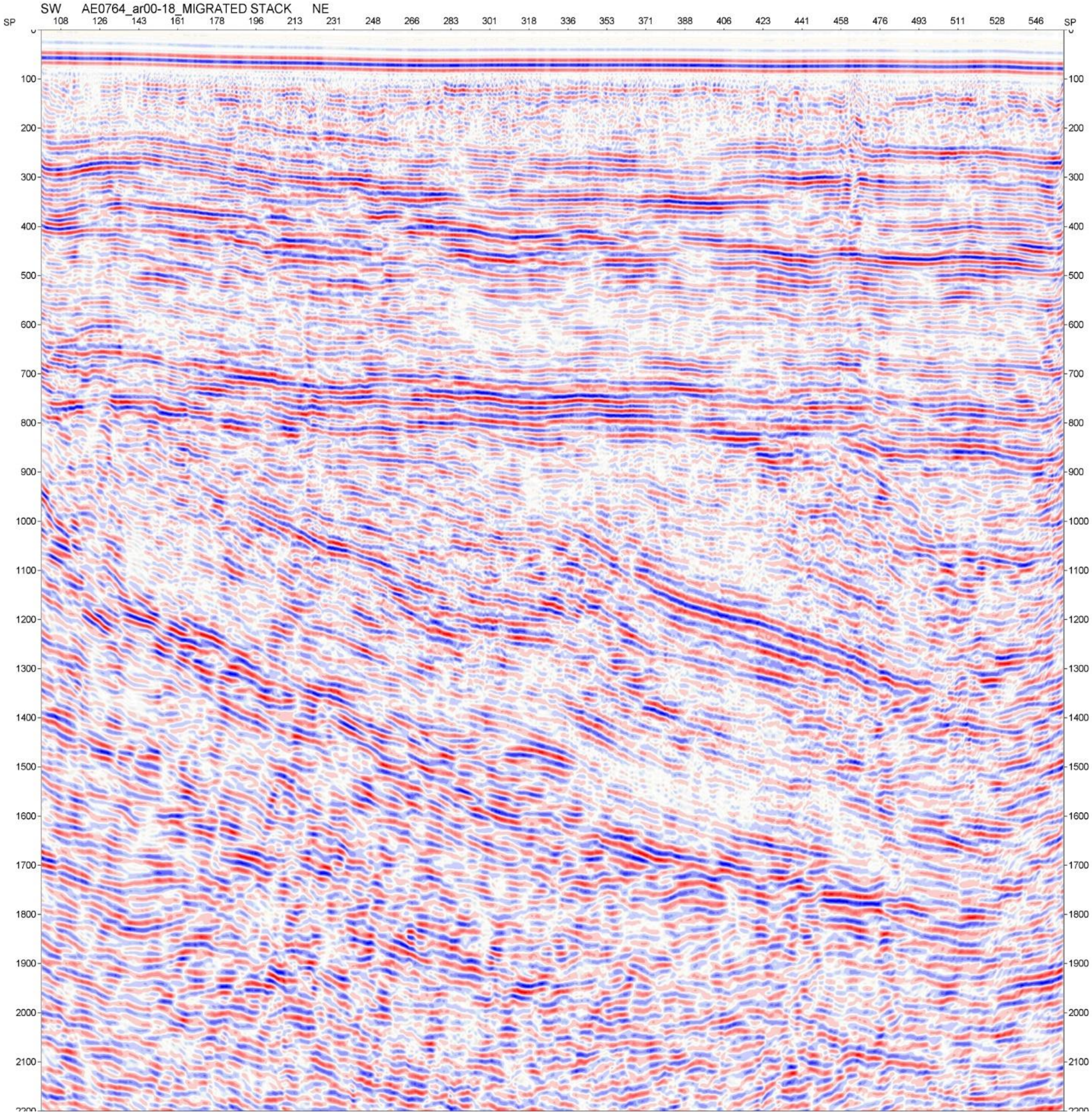
Investigation/Exploration

- Geological survey
- Aerial or satellite survey information
- Surface mapping – rock types and landform
- Broad geophysics - gravity, magnetic, seismic, resistivity, induced polarisation etc.
- Natural seismic event records – what is moving?
- Drilling – open hole -mud, air, reverse circulation
- Coring – (un)conventional or wireline
- Borehole geophysics – sonic, density, resistivity, natural gamma, neutron etc.
- Acoustic and optical scans, calliper logs

Magnetic Survey

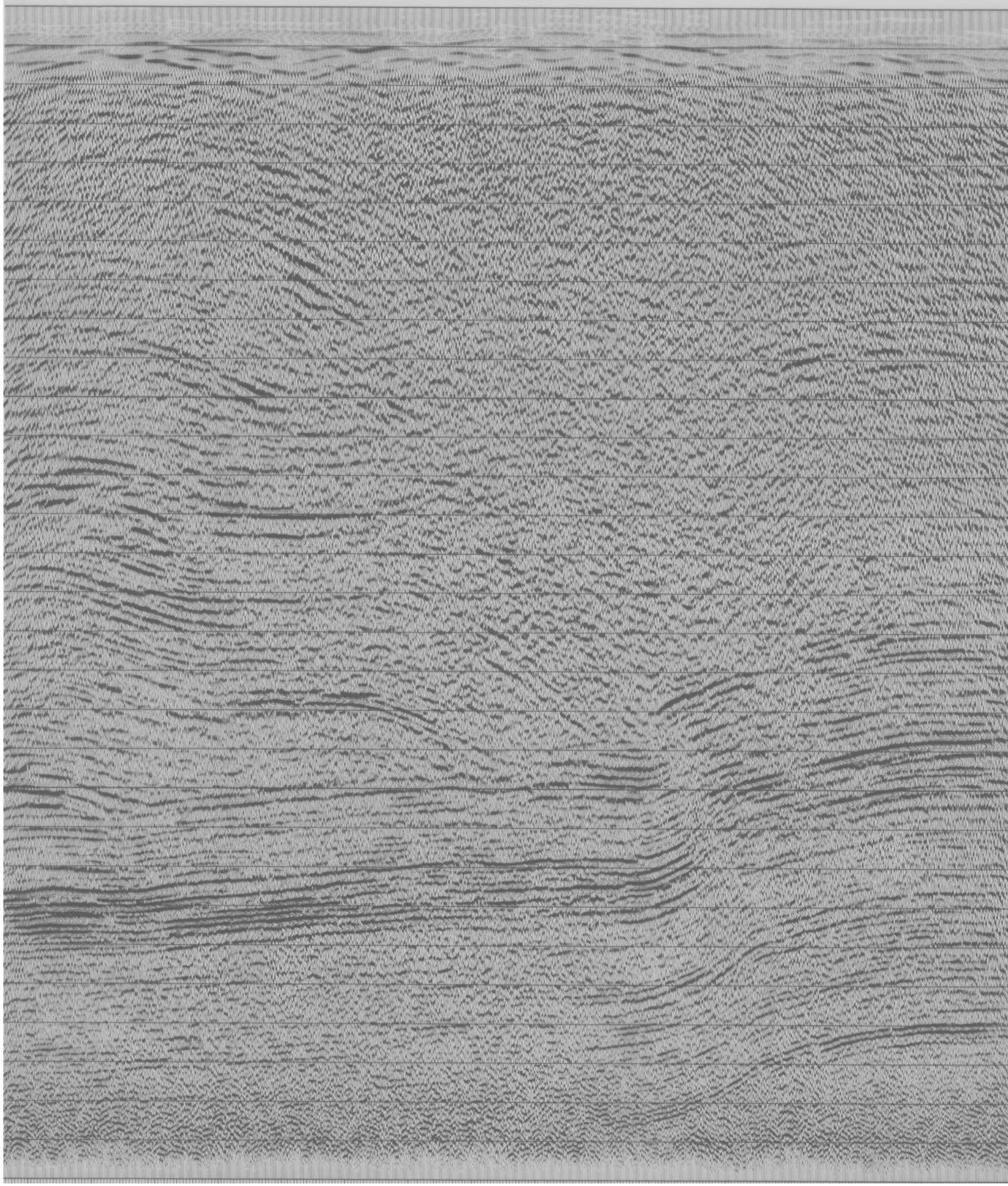


2 D Seismic Line showing unconfor -mity

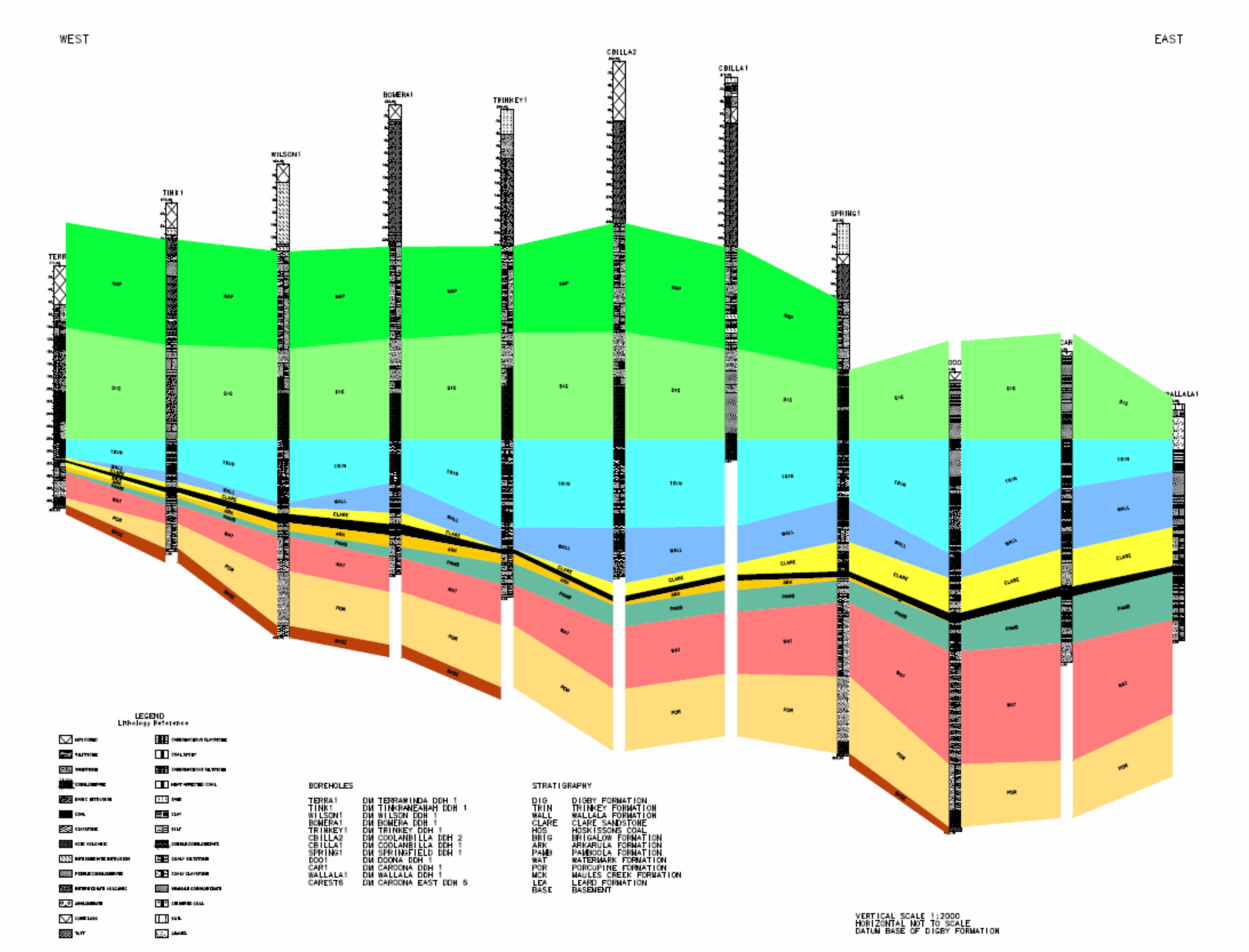


Seismic Survey

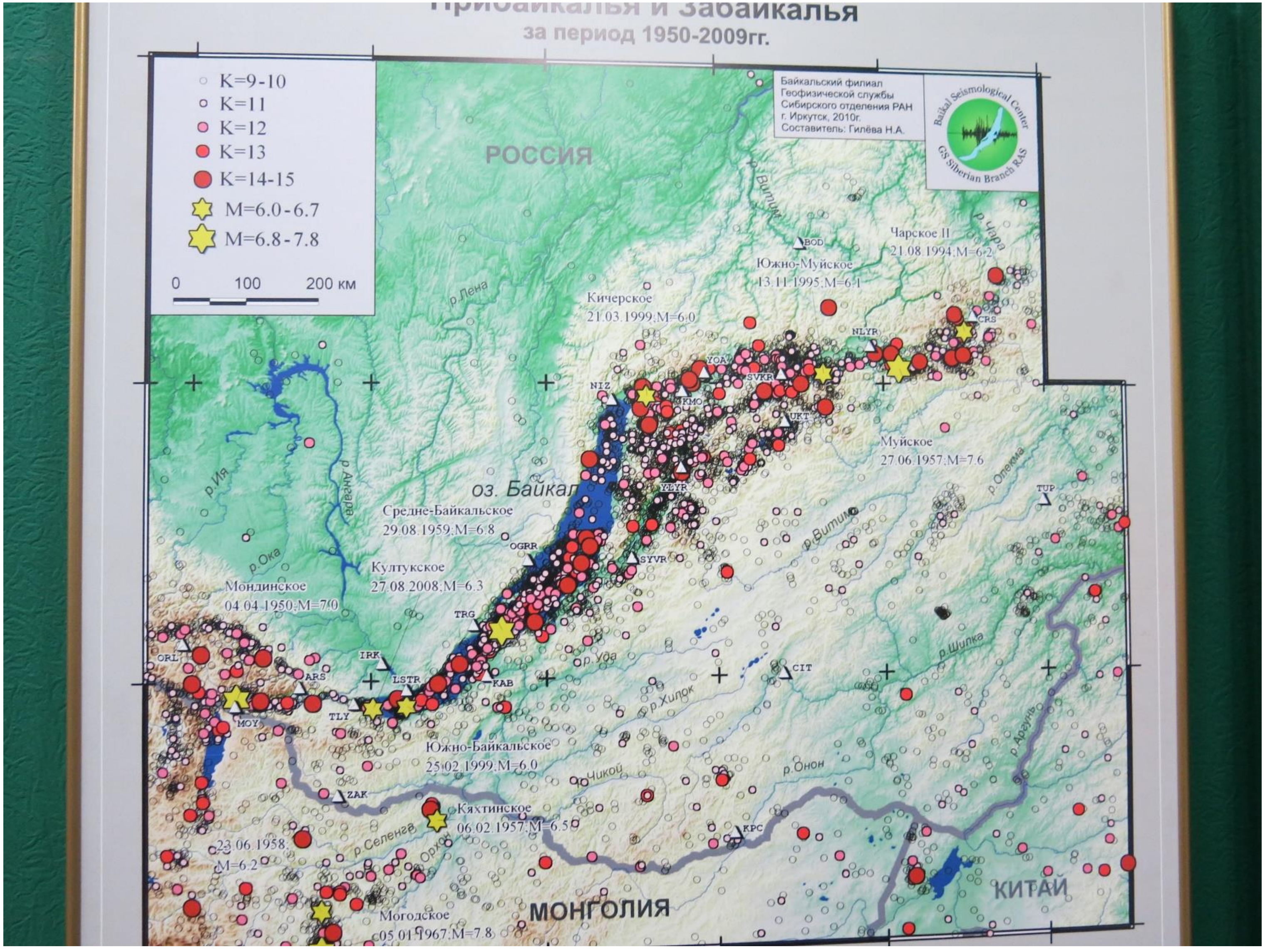
Reverse Fault



Fence Diagram



Natural Seismic Activity



Open Hole Drilling

Air Drilling

- Top Hammer – shallow tool
- Down the hole hammer – deep, usually limited by water
- Reverse circulation hammer – dual tube drill string sample from bit face

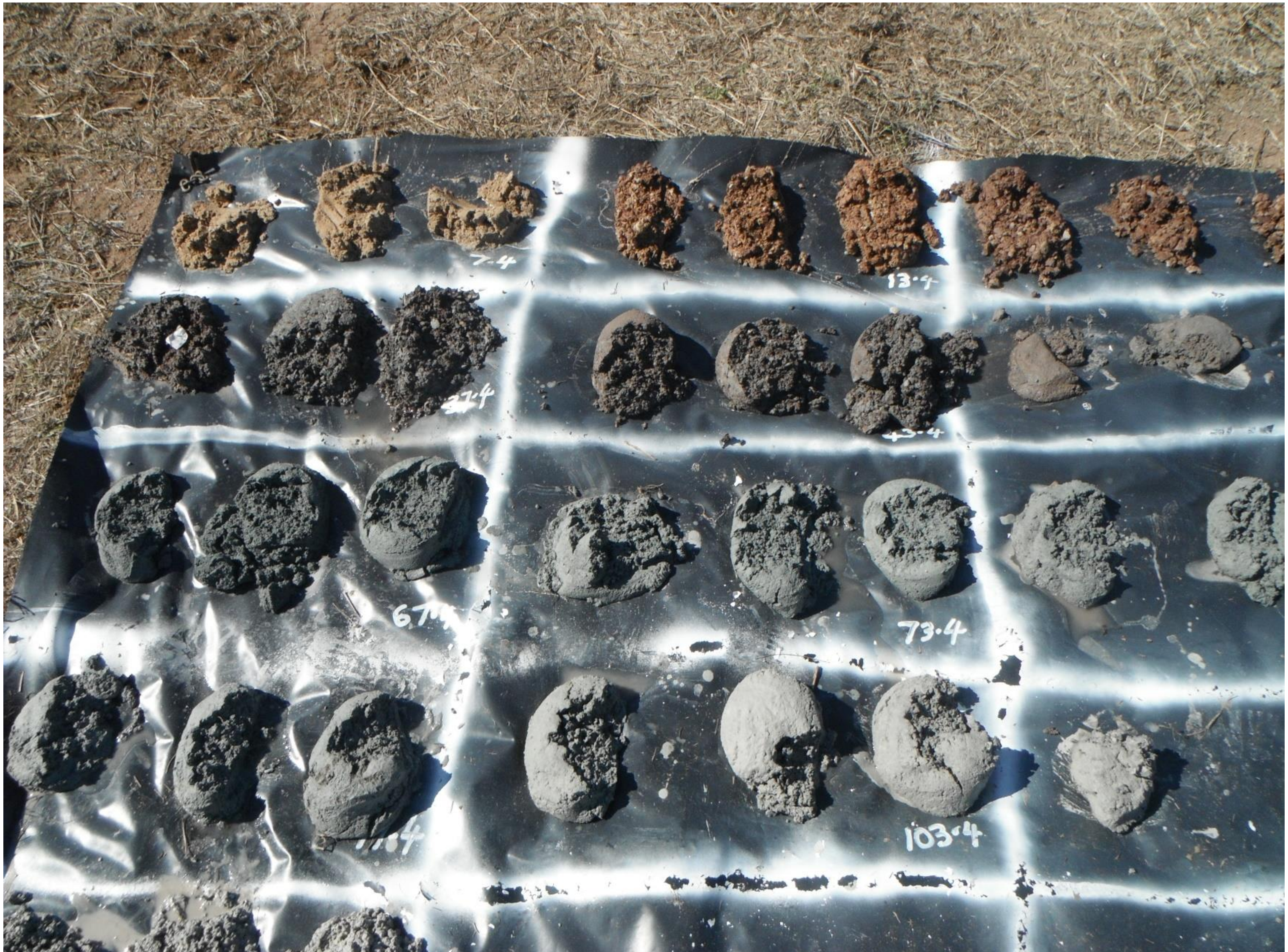
Mud Drilling

- Rotating drill string
- Downhole motor

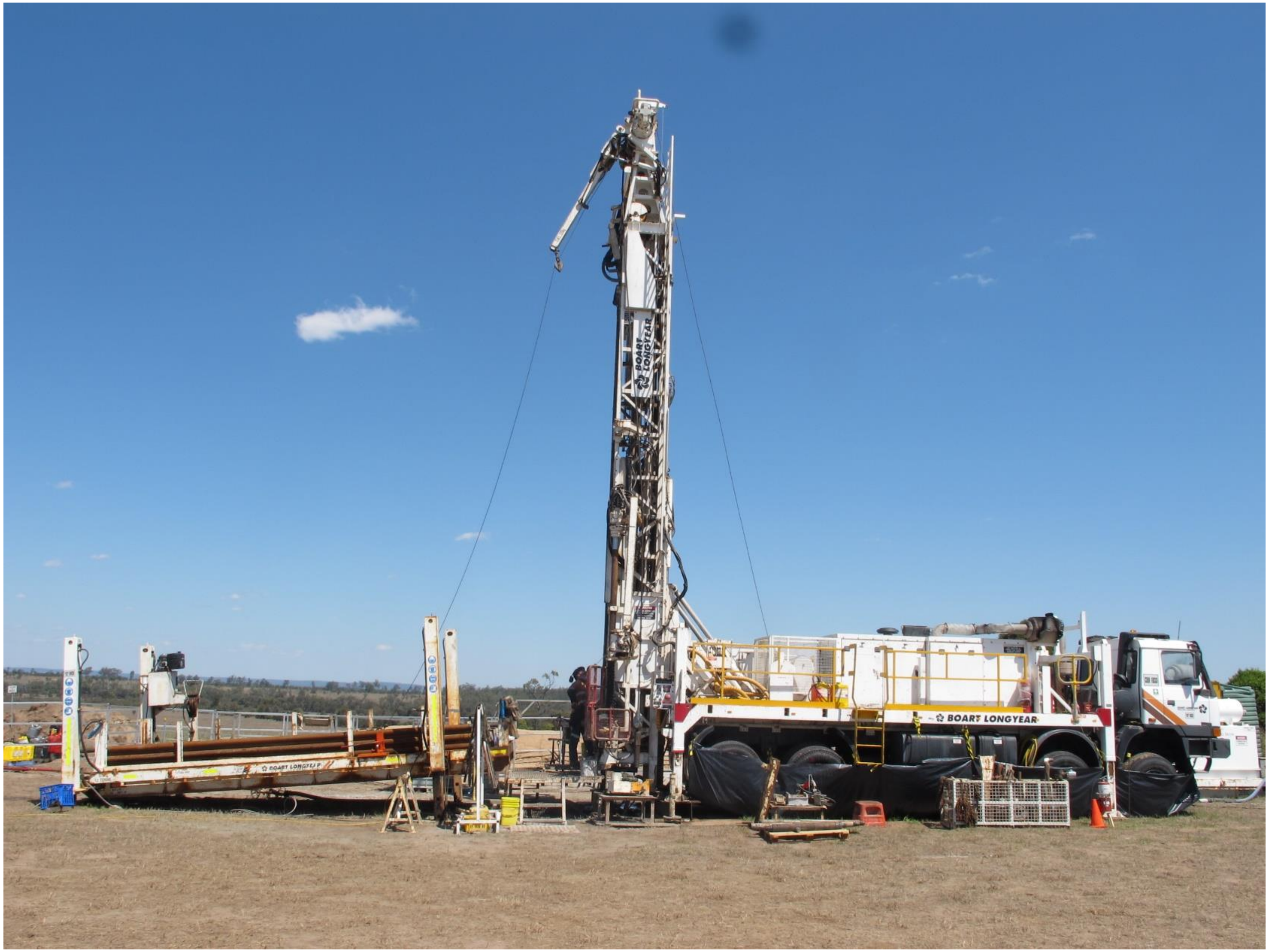
What you get >>

- Samples from cuttings
- Logging of penetration rate
- Hole for geophysics

Cuttings Taken From Drilling Mud



UDR1200 Drill Rig - General Purpose



Core Drilling

- Conventional coring needs pulling of the drill string to retrieve the core barrel. This is generally unacceptably slow.
- Wireline coring has become the norm. It is now conventional. Most operations that we deal with are drilled using the Boart Longyear wireline system. It has been in use since 1958 and is robust.
- The HQ-3 triple tube is most common and cuts a 60.9 mm core. This is a good size to work with.

Alpine Core Drilling in New Zealand

Core Pumped Out of Splits

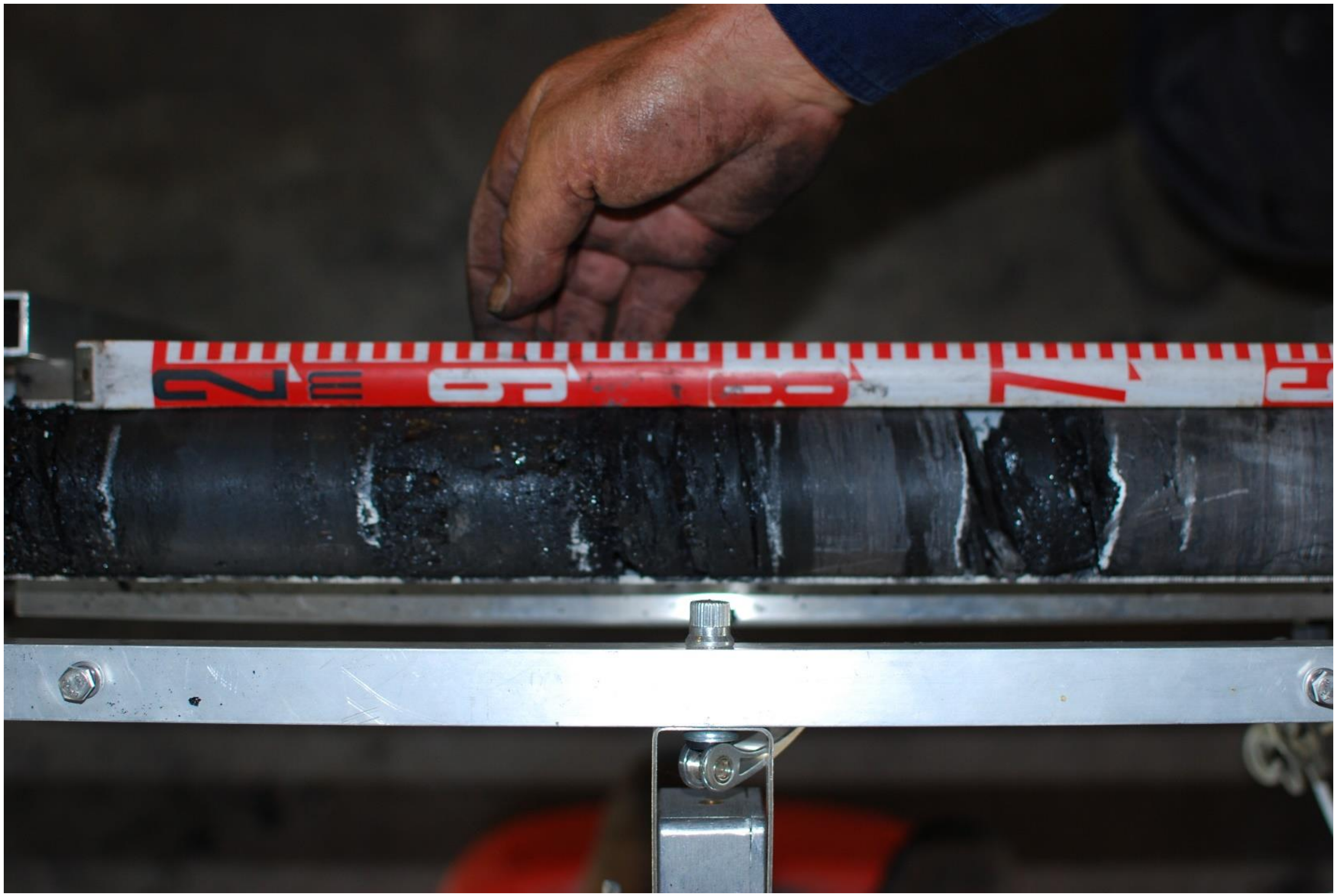
Core Photos


HOLE: BD_158
RUN: 11
SITE: YR-10-18
FROM: 546.2
GEOLOGIST: H. FRASER
TO: 552.2
DATE: 13/9/11
DRILLED: 6
RECOVERED: 6.03
OBS: D/S
LOSS/GAIN: +.03
547
550.5
550.5
MG
SS

Logging Table PC view

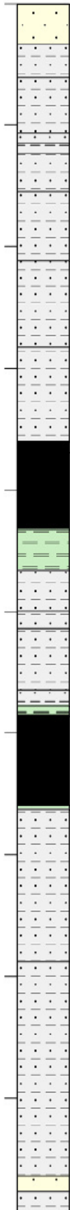
Logging Table

Photo of Core from Logging Table



Lithology Log

Lithology | **Fr** | **Gamma** | **SSD**



230.010-230.333m [0.323m] : SANDSTONE Light grey lithic abrupt lwr contact low angled strong BP Extremely Strong RM Very Strong - occasional bands of carb wisps

230.333-230.609m [0.276m] : SILTSTONE Mid grey erosionl lwr conct low angled medium strong BP Strong RM Strong - occasional bands of SANDSTONE Light grey 10%

230.609-231.063m [0.454m] : SILTSTONE Mid grey laminated abrupt lwr contact low angled medium strong BP Weak RM Strong - numerous bands of SANDSTONE Light grey 40%

231.063-231.150m [0.087m] : SILTSTONE Mid grey fissile dessication crack low angled broken in places weak BP Very Weak RM Weak - (band of 5mm expanding clay at 231.092m)

231.150-231.231m [0.081m] : SILTSTONE indurated Dark grey abrupt lwr contact strong BP Strong RM Very Strong

231.231-231.543m [0.312m] : SILTSTONE Mid grey grad lwr contact faulted broken in places BP Weak RM Strong (Section from 231264 to231.319m in broken broken pieces fused together.)

231.543-232.113m [0.570m] : SILTSTONE Mid grey laminated abrupt lwr contact faulted weak medium strong BP Weak RM Strong (Multiple high angle fractures in section.) - numerous bands of SANDSTONE Light grey 30%

232.113-232.827m [0.714m] : SILTSTONE Mid grey abrupt lwr contact faulted broken in places weak BP Weak RM Strong (Multiple high angle fractures along section.)

232.827-233.610m [0.783m] : SILTSTONE carbonaceous Mid to Dark grey abrupt lwr contact faulted broken in places weak BP Very Weak RM Weak (Section highly fractured.)

233.610-233.695m [0.085m] : COAL -dull mnr brts black weak BP Weak RM Strong - veins of CALCITE (occasional)

233.695-234.315m [0.620m] : COAL

234.315-234.667m [0.352m] : CARB CLAYSTONE coaly Dark grey to black coaly grad lwr contact faulted weak BP Weak RM Strong - streaks of COAL VEINS

234.667-234.996m [0.329m] : SILTSTONE carbonaceous Dark grey slump beds irregularly bedded grad lwr contact faulted weak BP Strong RM Strong - occasional bands of COAL VEINS

234.996-235.141m [0.145m] : SILTSTONE Mid grey erosionl lwr conct medium strong BP Strong RM Strong

235.141-235.644m [0.503m] : SILTSTONE Mid grey thinly laminated abrupt lwr contact low angled medium strong BP Strong RM Strong - numerous bands of SANDSTONE Light grey 40%

235.644-235.776m [0.132m] : SILTSTONE carbonaceous Mid grey abrupt lwr contact low angled weak BP Weak RM Strong - (8mm band of crumbled siltstone reconstructed together at depth 235.736m.)

235.776-235.855m [0.079m] : CARB CLAYSTONE coaly Dark grey to black abrupt lwr contact weak BP Weak RM Strong

235.855-236.595m [0.740m] : COAL

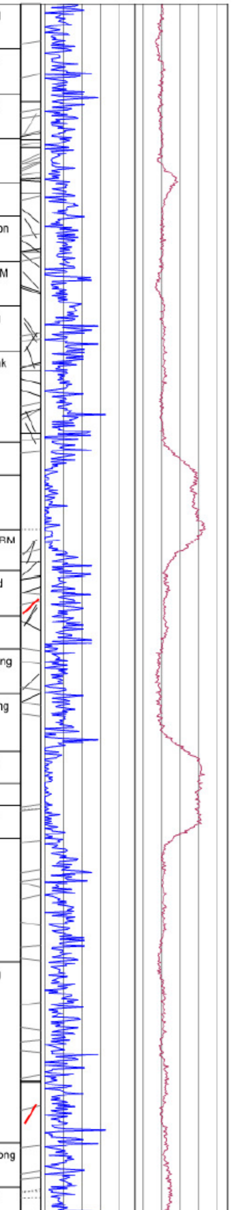
236.595-236.625m [0.030m] : CARB CLAYSTONE coaly Dark grey to black near horizontal weak BP Strong RM Strong - streaks of COAL VEINS

236.625-237.874m [1.249m] : SILTSTONE Mid grey grad lwr contact low angled medium strong BP Strong RM Strong - occasional bands of COAL VEINS

237.874-239.640m [1.766m] : SILTSTONE Mid grey thinly bedded abrupt lwr contact low angled medium strong BP Strong RM Strong - numerous bands of SANDSTONE Light grey 10%

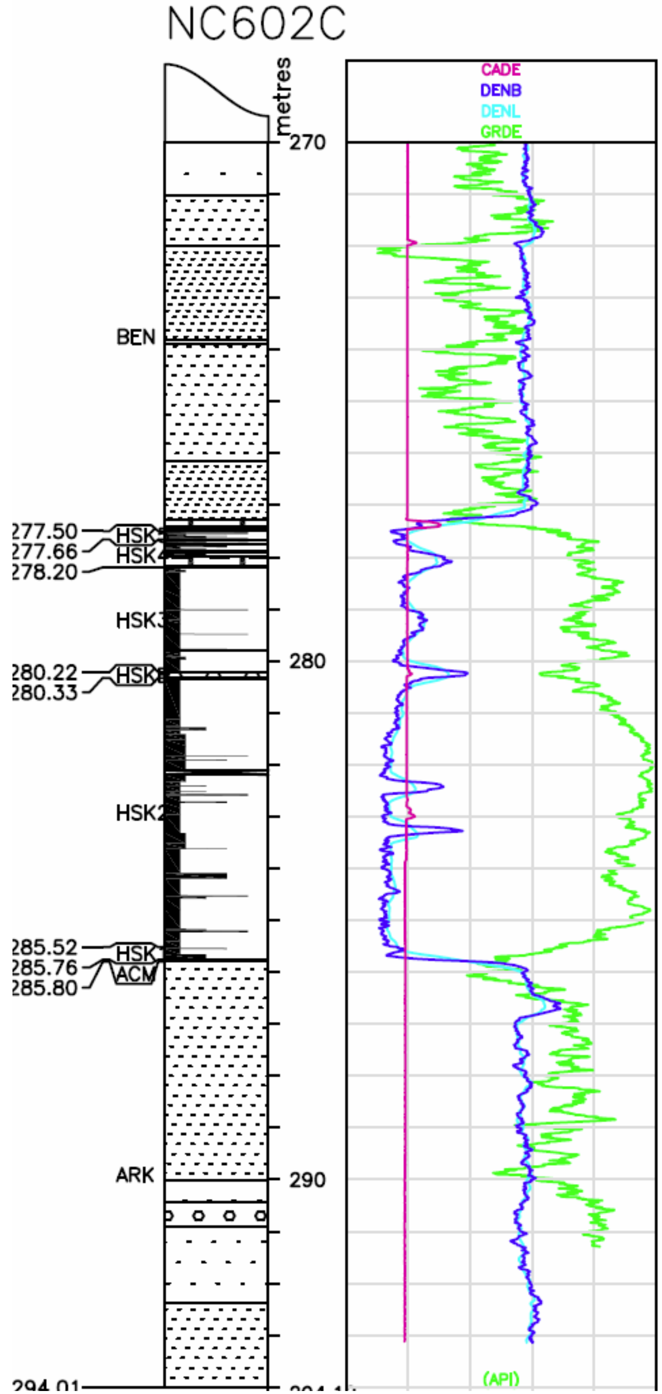
239.640-239.765m [0.125m] : SANDSTONE creamy grey cross beds low angled strong BP Extremely Strong RM Very Strong - streaks of carb wisps Dark grey (numerous)

239.765-240.004m [0.239m] : SILTSTONE Mid grey erosionl lwr conct low angled medium strong BP Strong - occasional bands of SANDSTONE Light grey 20%



Depth (m): 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240

Borehole
Geophysics
Natural
Gamma
Calliper
Density



Sonic Log

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A wealth of information

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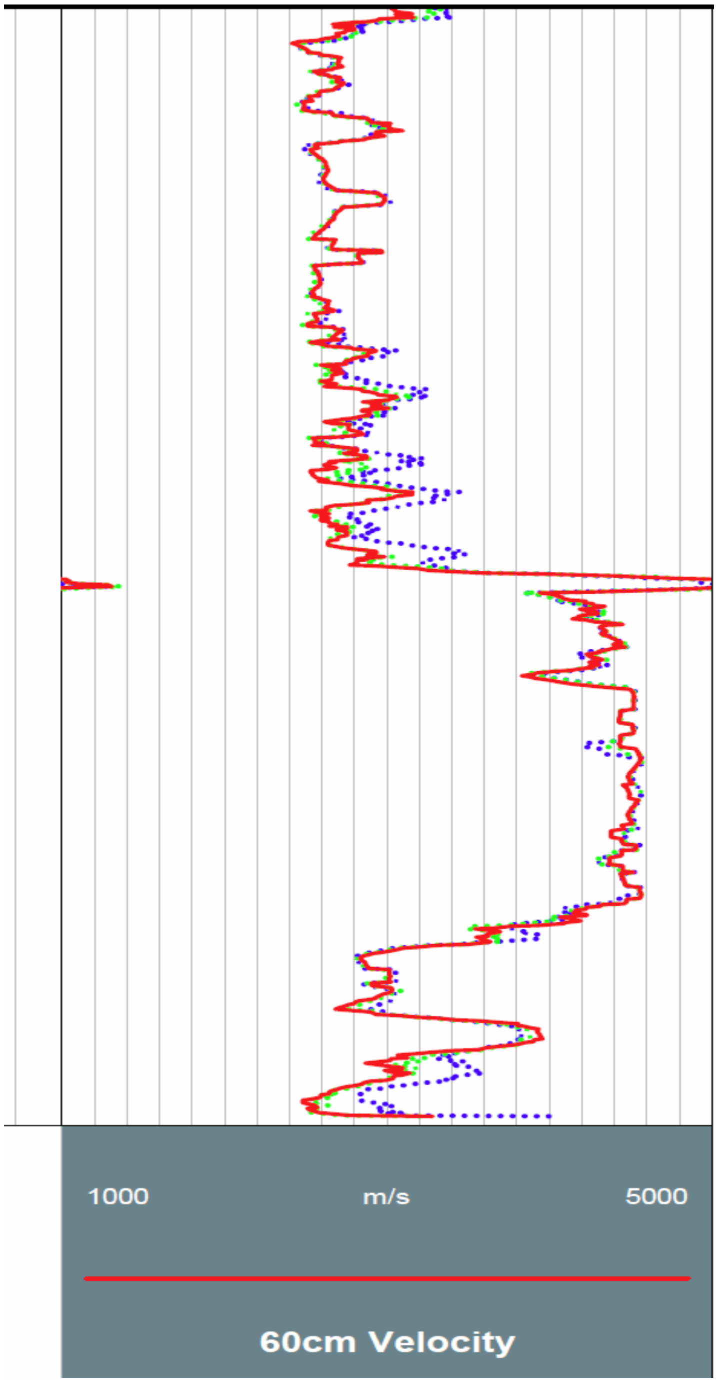
Should use P & S wave logs



Modulus relationships for sonic data

$$Poisson's\,Ratio = \frac{\frac{1}{2}\cdot\left(\frac{dts}{dtc}\right)^2 - 1}{\left(\frac{dts}{dtc}\right)^2 - 1}$$

$$Shear\,Modulus = \frac{Bulk\,Density}{dts^2}$$

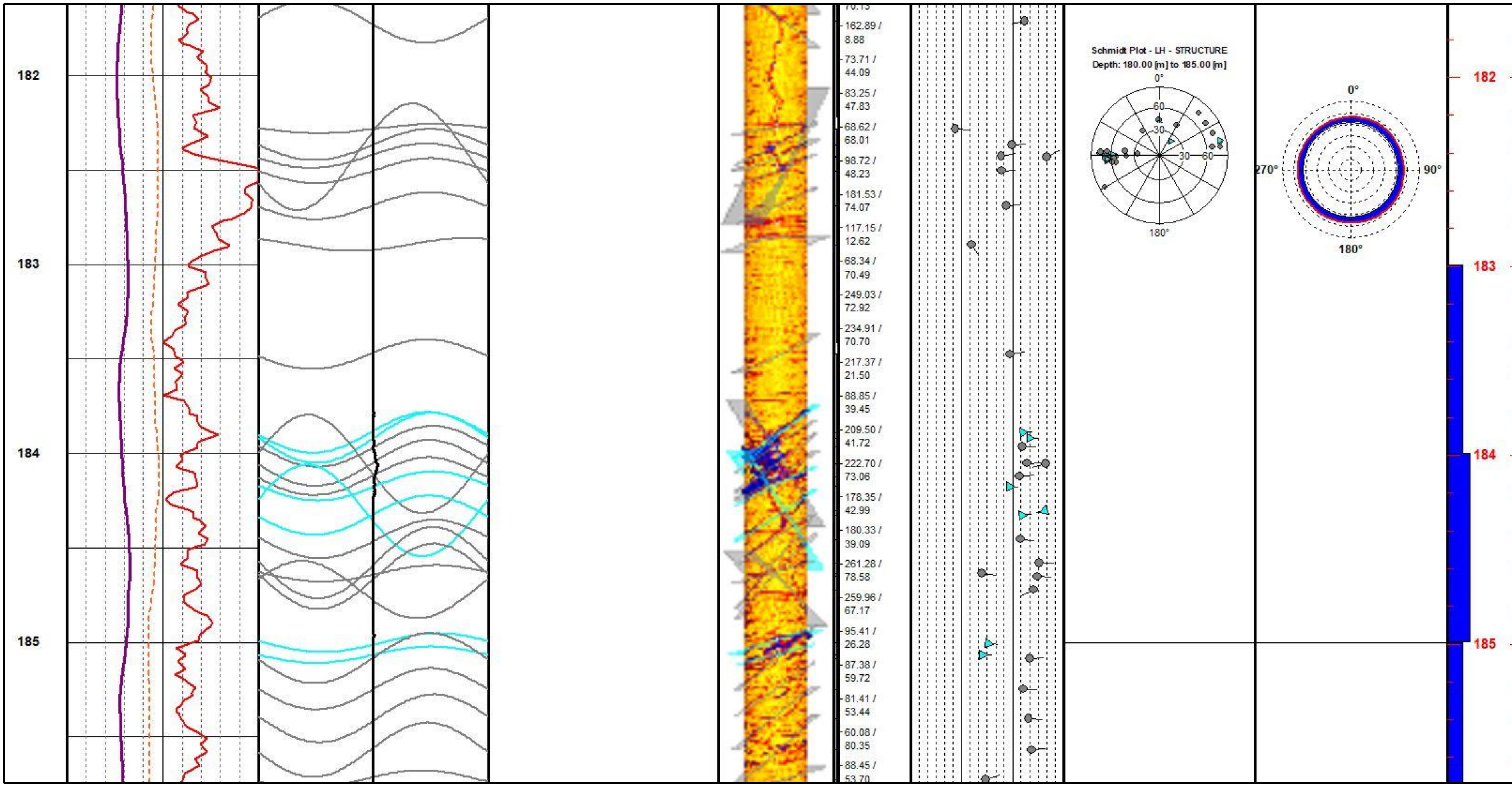
$$Young's\,Modulus = 2.\,Shear\,Modulus.(1 + Poisson's\,Ratio)$$

$$Bulk\,Modulus = Bulk\,Density.\left(\frac{1}{dtc^2} - \frac{4}{3.dts^2}\right)$$

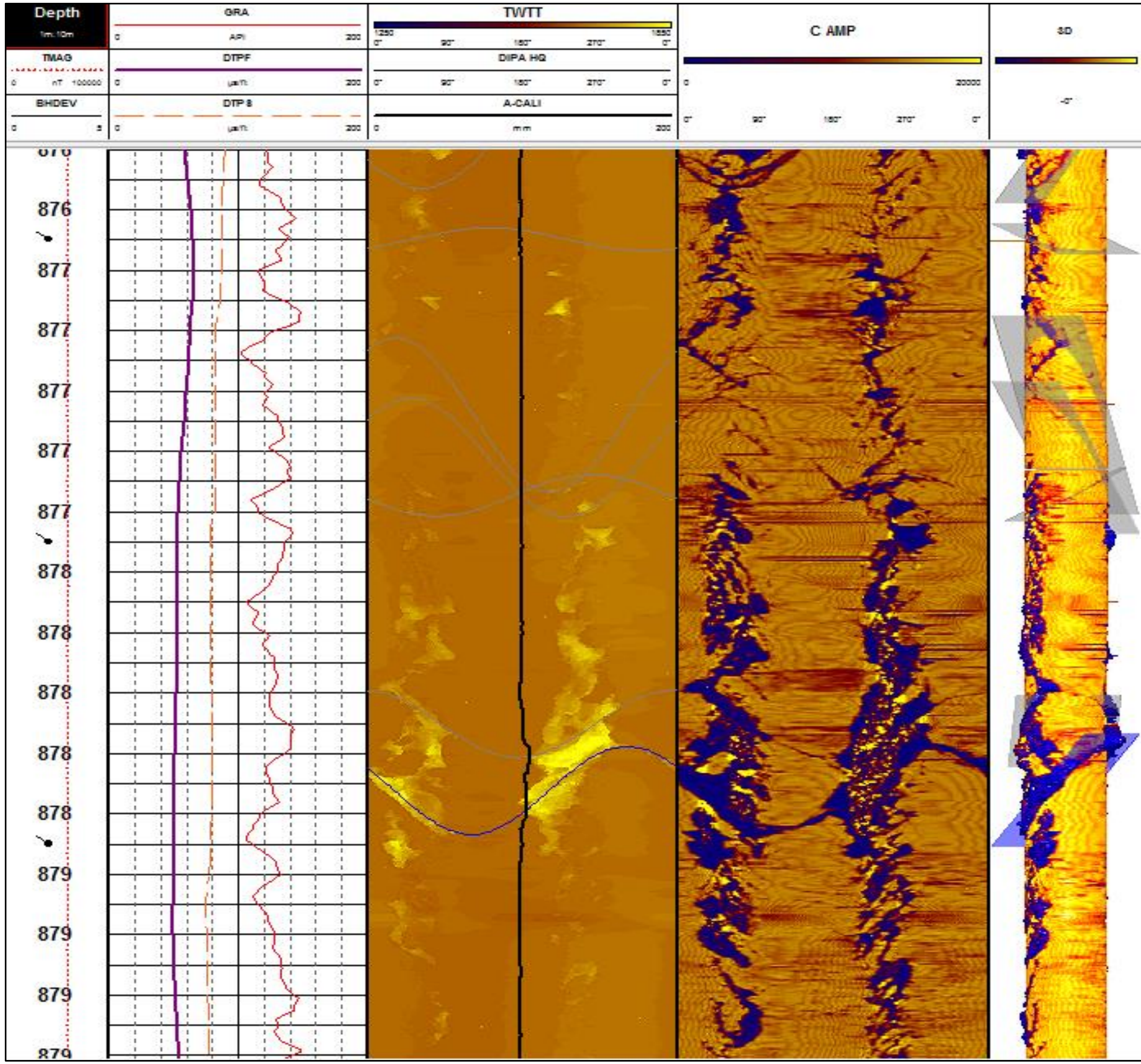
$$Bulk\,Compressibility = \frac{1}{Bulk\,Modulus}$$

- dtc
  compres
  -sional
  wave
  transit time
- dts
  shear wave
  transit time

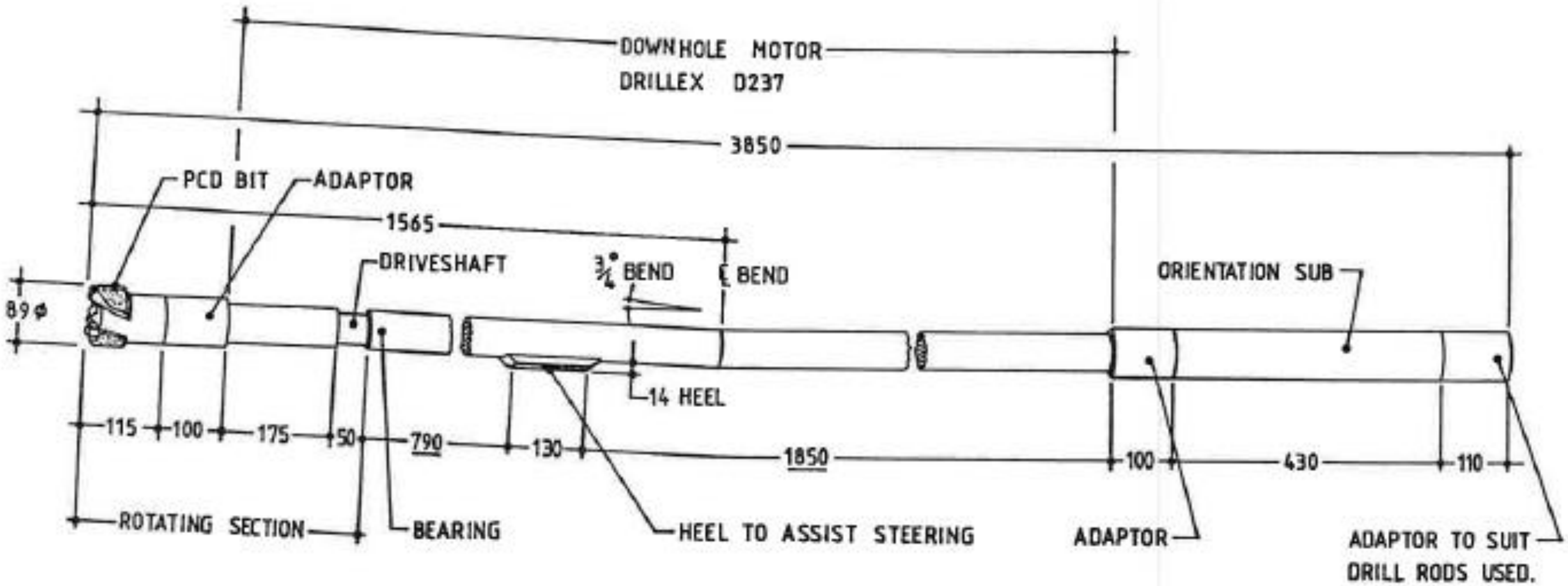
Acoustic Televiewer Data

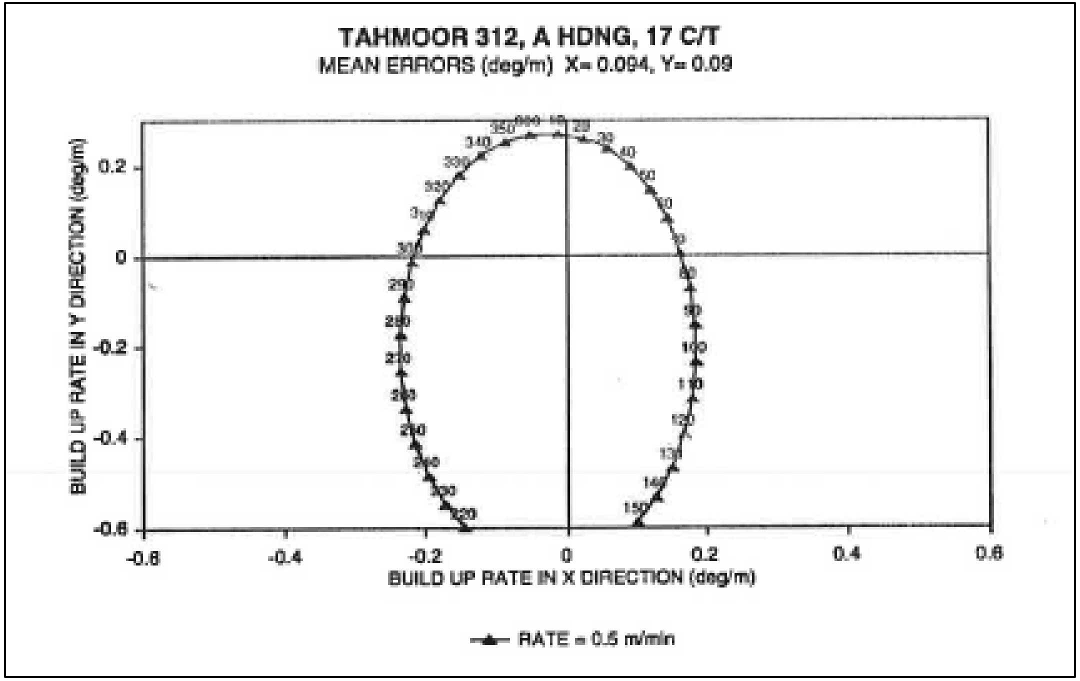


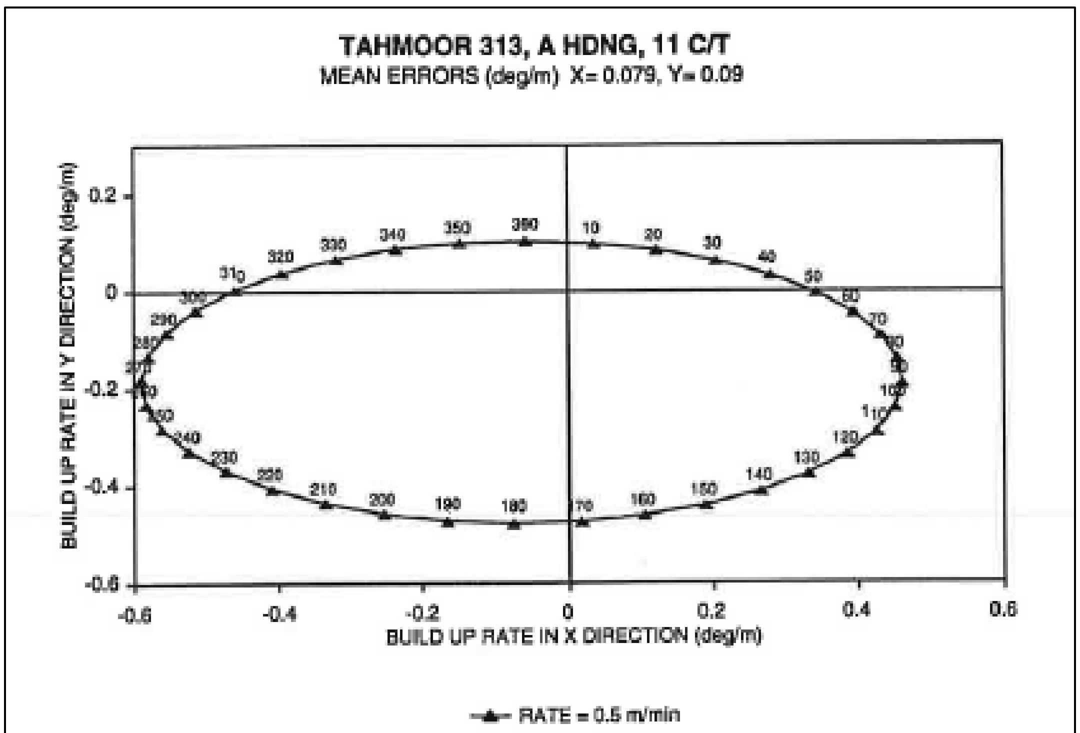
Borehole Breakout



Directional Drilling - Downhole Motor







Mud motor build up behaviour

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Very dependent on geological structure

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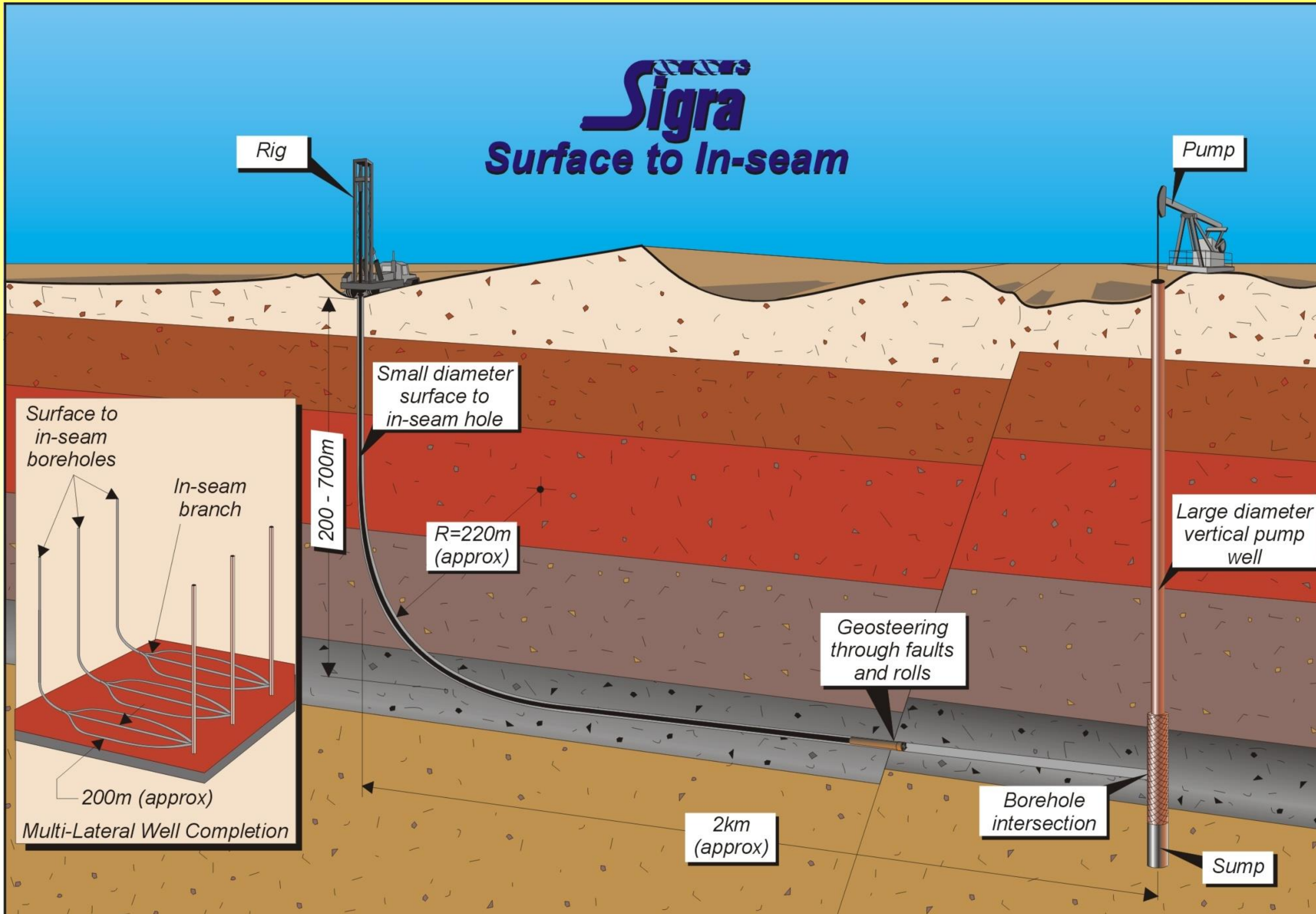
On average the tool drills down


Sigra
Surface to In-seam
Rig
Pump
Small diameter surface to in-seam hole
200 - 700m
R=220m (approx)
Geosteering through faults and rolls
Large diameter vertical pump well
Borehole intersection
2km (approx)
Sump
Surface to in-seam boreholes
In-seam branch
200m (approx)
Multi-Lateral Well Completion

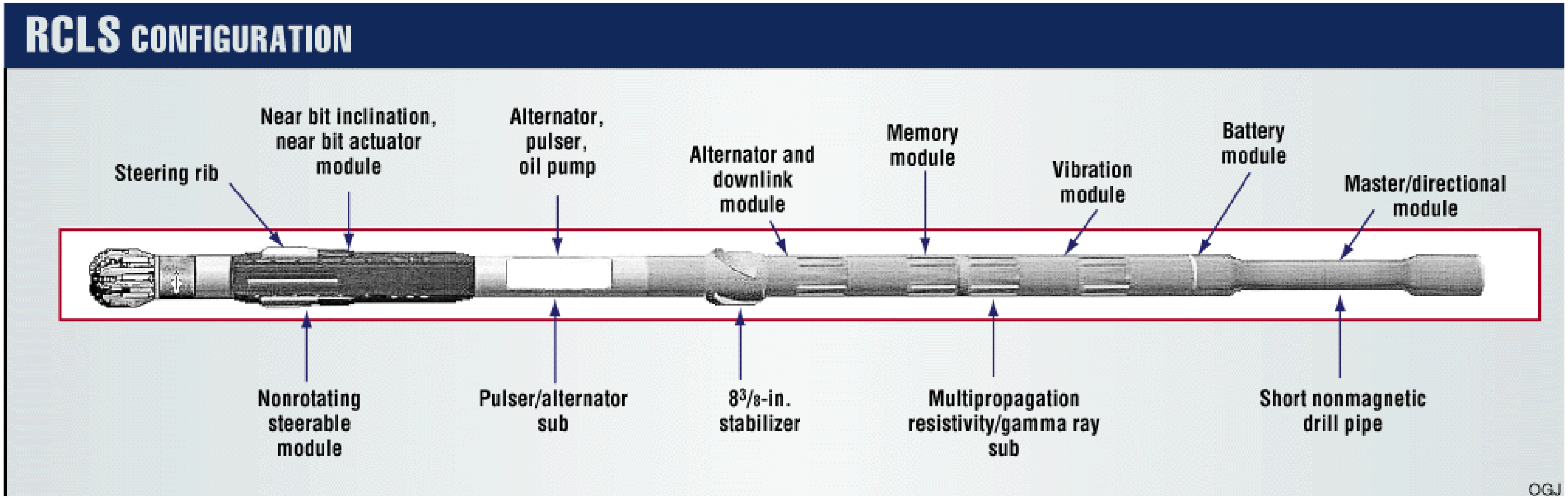
Limitations of Downhole Motors

- Slide drilling without rotation
- Cuttings build - up
- Frictional build up – stick slip drilling then helical buckling leading to lockup in the hole
- Practical limit of lateral well 1 to 2 km

Rotary steering systems

- Rotate the entire drill string
- Use pads to push or point the drill string
- Mostly have closed loop control to maintain trajectory
- Rotation stirs up the cuttings bed thus clearing the annulus of the hole
- Shell achieved 12 km lateral in 12 days off Kamchatka
- Rotary steering has huge potential for many investigations, it just needs to be lower cost. (Watch this space!)

A rotary steering system



Open directional holes

- Limitation is frequently not the drilling hardware but the ability to pump drilling fluid through the hole.
- To make full use of these need to have geophysical logging of the holes while drilling LWD or subsequent to drilling. The latter may be a tractor system or record on board geophysics conveyed by the rod string.