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Seismic, petrophysical and petrological constraints on the alteration of igneous rocks in the Northern Carnarvon Basin, Western Australia: Implications for petroleum exploration and drilling operations

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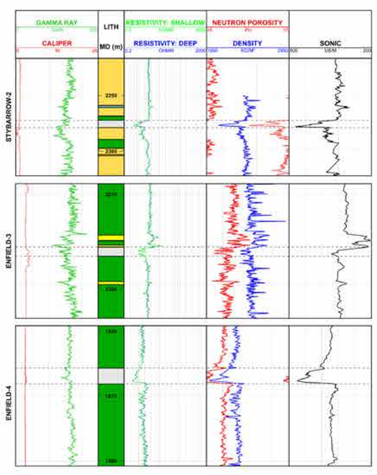
Altered igneous rocks in the Carnarvon Basin: Implications for exploration and drilling.

Stybarrow 2, Enfield 3 & 4 – Altered ashfall – Swelling clays.



Ash erupted from the Toro Volcanic Complex and Mt Aneto is present in Late Jurassic strata of the central Exmouth Sub-Basin. The mafic ash deposits are characterised by:

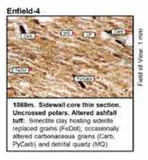
- Low resistivity.
- High neutron porosity.
- Low density.
- Low sonic velocities.

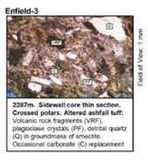
Inspection of cuttings shows that the ash has been **altered to smectite**.

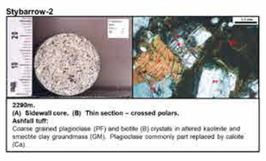
Smectite is a swelling clay, **expanding up to 15x** on contact with water. Hydrated smectite can cause:

- **Clogging of the drillbit**, leading to...
  ...slow drilling.
  ...pulling out of hole for cleaning.
- Expansion of clay into to wellbore, leading to:
  ...reservoir damage.
  ...loss of drilling assembly.
  ...well abandonment.

Oil-based or inhibited drilling muds must be used to avoid effects of clay expansion.





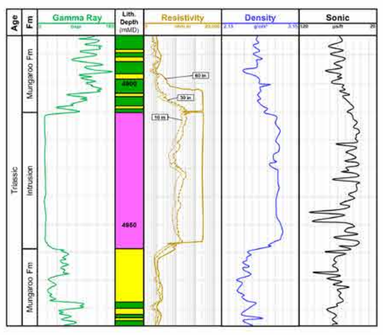


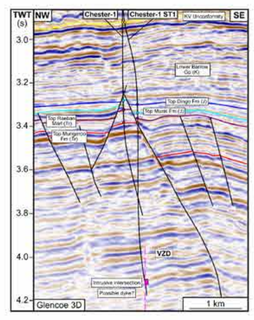
Chester 1 – Altered intrusion. Dyke swarm & compartmentalisation?

Chester 1 ST1 intersected 48 m of mafic intrusion from 4910 mMD, whilst the well path was oriented 18° from vertical.

The mafic igneous rock is characterised by:

- Blocky and low gamma ray.
- High resistivity.
- High density.
- Elevated sonic velocities.





Were the intrusion a horizontal sill:

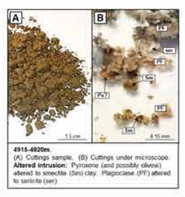
- Sill thickness would be ~45 m
- It would be visible on seismic data, given its increased density and sonic velocity.

There is no high amplitude response, so **not a sill.** The intrusion must be steeply oriented – i.e. **a dyke**:

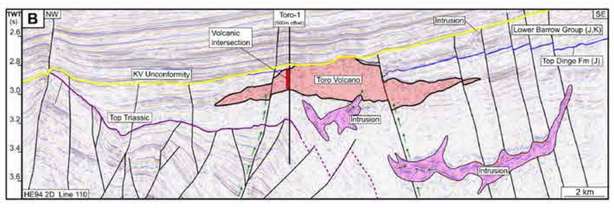
- Dyke thickness would be ~18 m if vertical.
- Would explain lack of seismic imaging, and coincidence with vertical seismic disruption (VZD).
- Coincident with Exmouth Dyke Swarm.

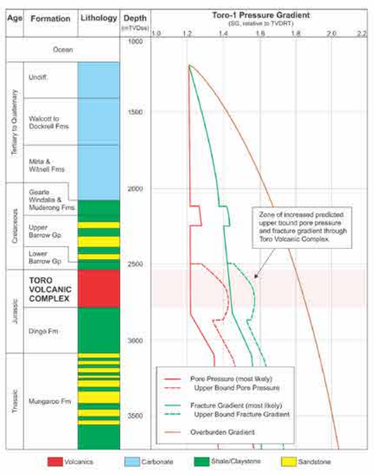
Dykes are vertically extensive, and could be compartmentalizing much of the Exmouth Plateau beneath the Early Cretaceous 'KV' Unconformity.

Despite elevated density and sonic response, cuttings from the dyke show alteration to smectite clay. **Unexpected intersection of swelling clays is therefore a potential drilling problem over large areas of the Exmouth Plateau.**



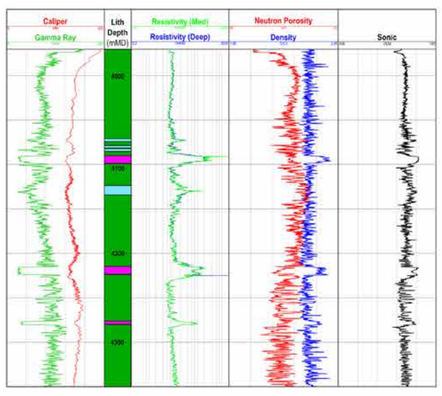
Toro 1 – Altered Volcano – Overpressure?





- Woodside's velocity model suggested low seismic velocities through the Toro Volcanic Complex (TVC) prior to drilling Toro 1.
- It was believed that the TVC may have been overpressured. Drilling was slowed, and appropriate safety mechanisms put in place. However, no elevated pressures were encountered.
- No crystalline or tuffaceous volcanic rocks were encountered in the interval. Cuttings were described as soft grey clays containing calcite and pyrite, supporting crystals of plagioclase feldspar.
- Subsequent analysis revealed that the clay was an alteration product of basaltic lavaflows. **This clay was the cause of low seismic velocities.**

Yardie East 1 – Altered intrusions – Localized maturation.

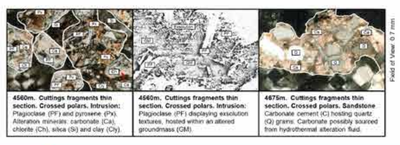


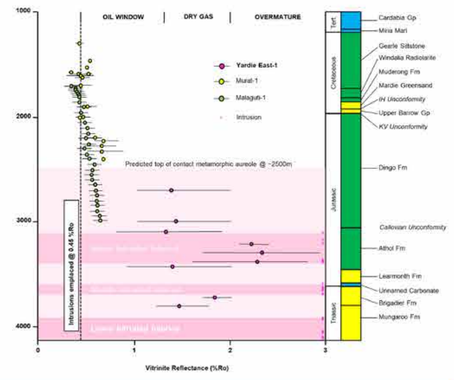
20 mafic igneous intrusions were intersected in Yardie East 1. These intrusions are characterised by:

- Low gamma ray, blocky response.
- Narrow caliper response.
- High resistivity, bell shaped response.
- Low neutron porosity.
- High density.
- High sonic speeds.

Heat generated by these intrusions has:

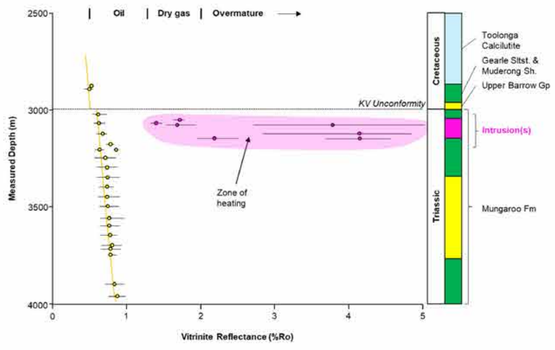
1. Driven hydrothermal fluids through the intrusions causing alteration of mafic igneous minerals to carbonate and clay.
2. Driven hydrothermal fluids through the host sedimentary rocks causing carbonate mineral cementation, and **reduction of porosity in potential reservoir**.
3. Caused localised maturation of host sedimentary rocks.
   - Background vitrinite reflectance in Yardie East 1 is higher than in nearby Murat 1 and Malaguti 1.
   - Vitrinite reflectance in intruded intervals shows host source rocks are now **overmature for gas generation**.

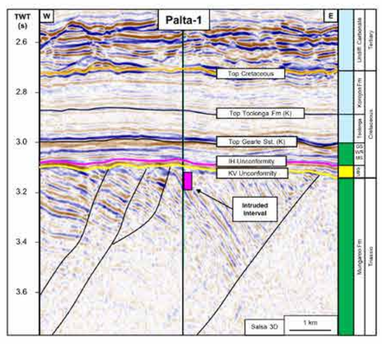




Palta 1 – Altered intrusion – Missed by mudloggers.

1. Post drill vitrinite reflectance analysis at Palta 1 showed a narrow zone of high heat flow in Triassic rocks beneath the Early Cretaceous 'KV' Unconformity.
2. A subsequent study of cuttings showed mafic igneous rocks altered to siderite (iron carbonate) and clay. Host sands were cemented with silica and siderite.
3. It was concluded that heating in the interval was caused by the emplacement of an igneous intrusion, which was altered by circulating hydrothermal fluids.





- The intrusion was not resolved on seismic data pre-drill.
- The intrusion was not recognised by mudloggers during drilling. Cuttings were described as sandstone and siltstone containing dolomite and clay.

Had the vitrinite reflectance study not been ordered the intrusion would not have been recognised.

- Lack of recognition of altered intrusions in a basin can lead to incorrect heatflow and basin modelling.

Possible solutions:
- Arm wellsite geologists with awareness of igneous rocks and their alteration products.
- Provide **portable XRF machines** to wellsite geologists for help with mineral identification.