

# Habanero-3 Well Control Review



# Important notice

**Any forward looking information in this presentation has been prepared on the basis of a number of assumptions which may prove to be incorrect and these statements speak only as of the date of this presentation.**

**This presentation should not be relied upon as a recommendation to buy or sell shares by Geodynamics Limited.**

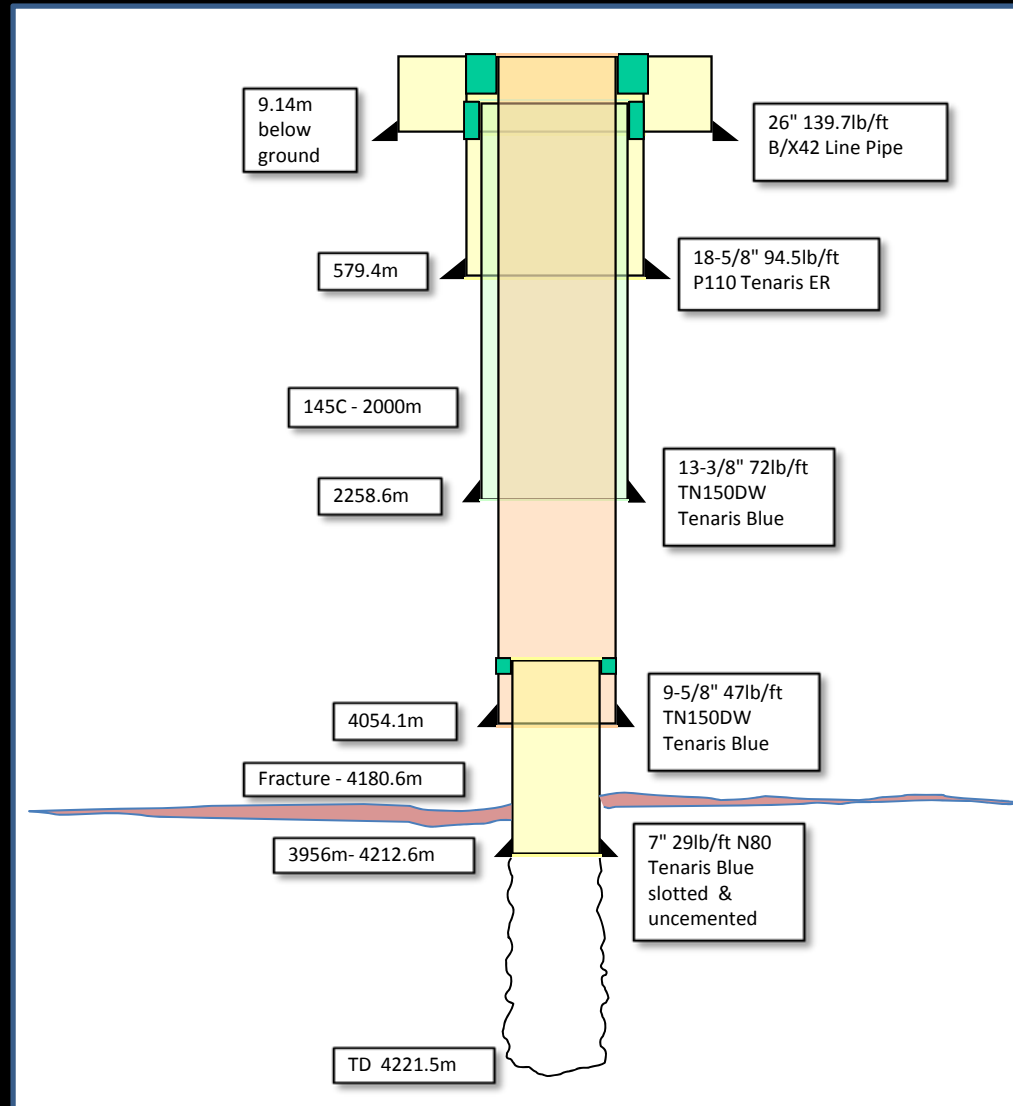
**Nothing in this presentation should be construed as either an offer to sell or a solicitation of an offer to buy or sell shares in Geodynamics Limited.**

## Basis of Design

- A stimulation and production well
- Maximum operating wellhead pressure 6000 psi
- Stimulation at 30°C with 10,000 psi surface pressure
- Fully cemented casing strings
- 3 year life and 125 l/s brine production
- H<sub>2</sub>S not present in the granite or geothermal brine
- CO<sub>2</sub> would not cause a problem
- Double barrier containment (9-5/8" & 13-3/8") for pressure

## Operating Conditions

- Completion rig released - 5 February 2008
- Production testing completed on - 24 March 2009
- Wellhead pressures ranged from 4300 – 5000 psi
- Wellhead temperatures ranged from 20°C (shut-in) to 220°C (during production)
- Initial bottom hole temperature 244°C at 4180.6 m



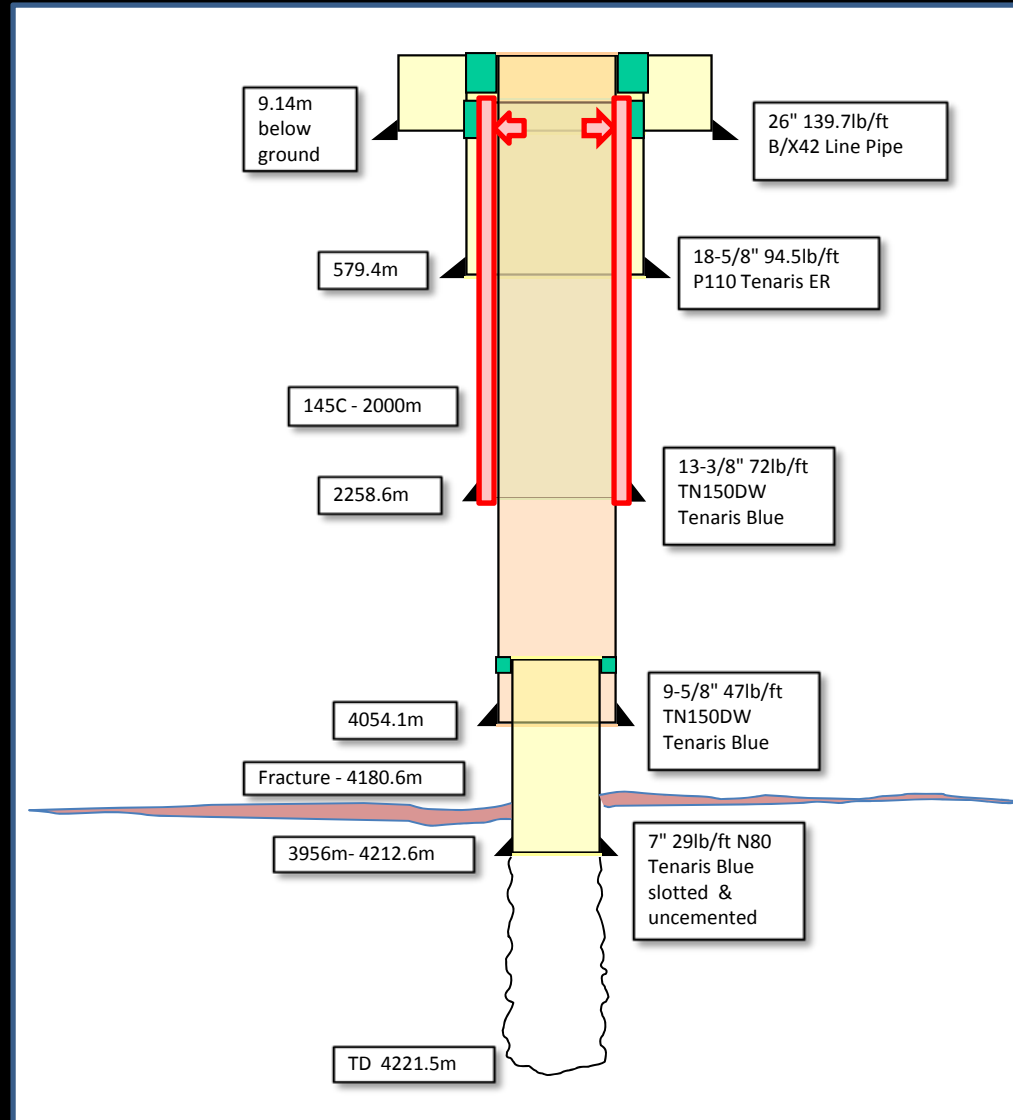
## Failure Summary

- At 8:19 pm on the 24<sup>th</sup> of April 2009 a rapid release of fluid occurred at Habanero-3



# Habanero-3

- The 9-5/8" casing failed from stress cracking due to hydrogen embrittlement in several locations
- Vertical stress cracks were found from 2.96 m – 8.4 m (below ground level)
- Some cracks were initiated from tong or slip marks
- When these stress corrosion cracks penetrated the 9-5/8" casing it allowed high pressure brine to pass into the 9-5/8" x 13-3/8" annular area



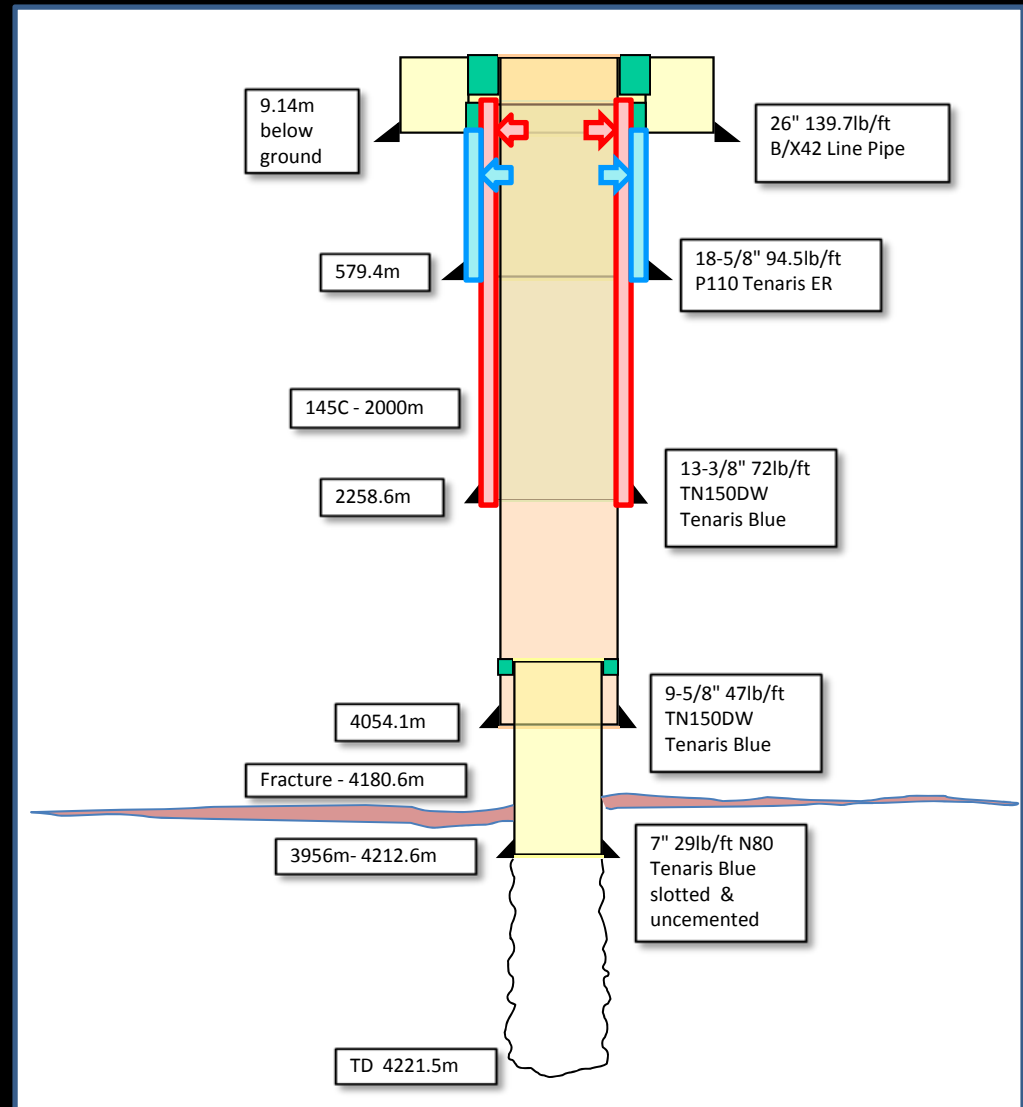
# Habanero-3

- Longitudinal cracks formed on the outside of the 9-5/8" casing indicating stress corrosion cracking resulting from hydrogen migrating to areas of high residual stress on the outer surface of the 9-5/8" casing.



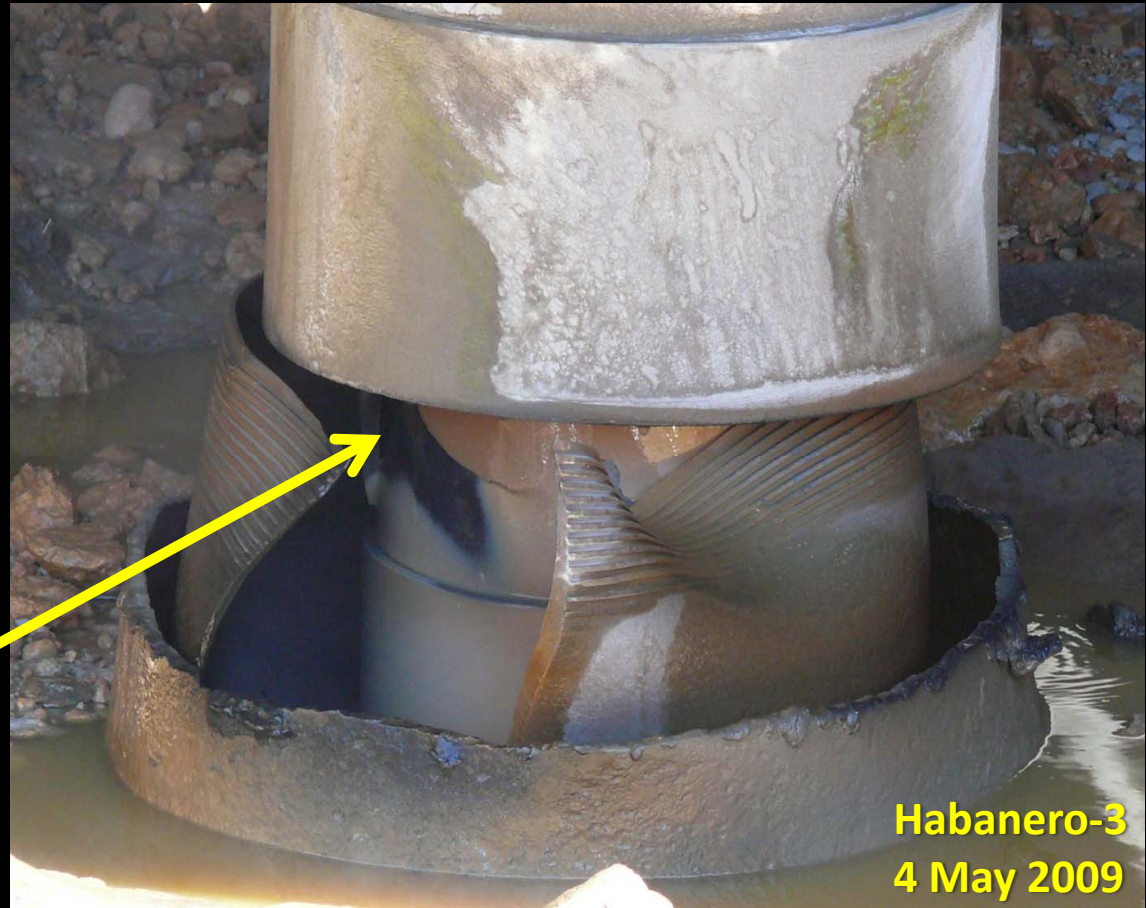
# Habanero-3

- After being exposed to hydrogen and high pressure fluids a crack formed in the 13-3/8" casing
- This allowed the brine to charge the annular area between 18-5/8" casing and the 13-3/8" casing



# Habanero-3

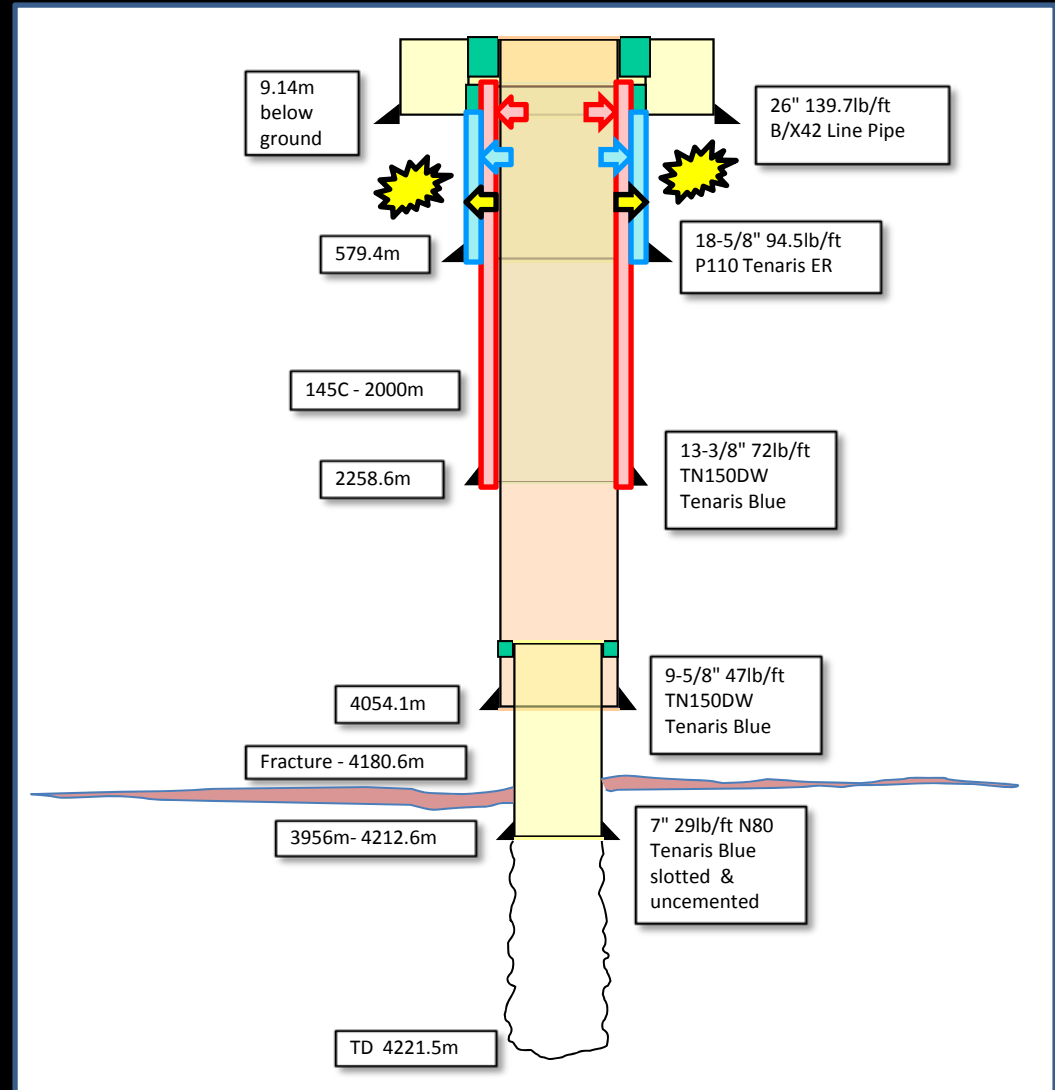
- The crack in the 13-3/8" casing was initiated from a tong mark in the hanger pup joint
- Repeat efforts to make up this connection may have caused deep tong marks
- Evidence of fluid scour



Habanero-3  
4 May 2009

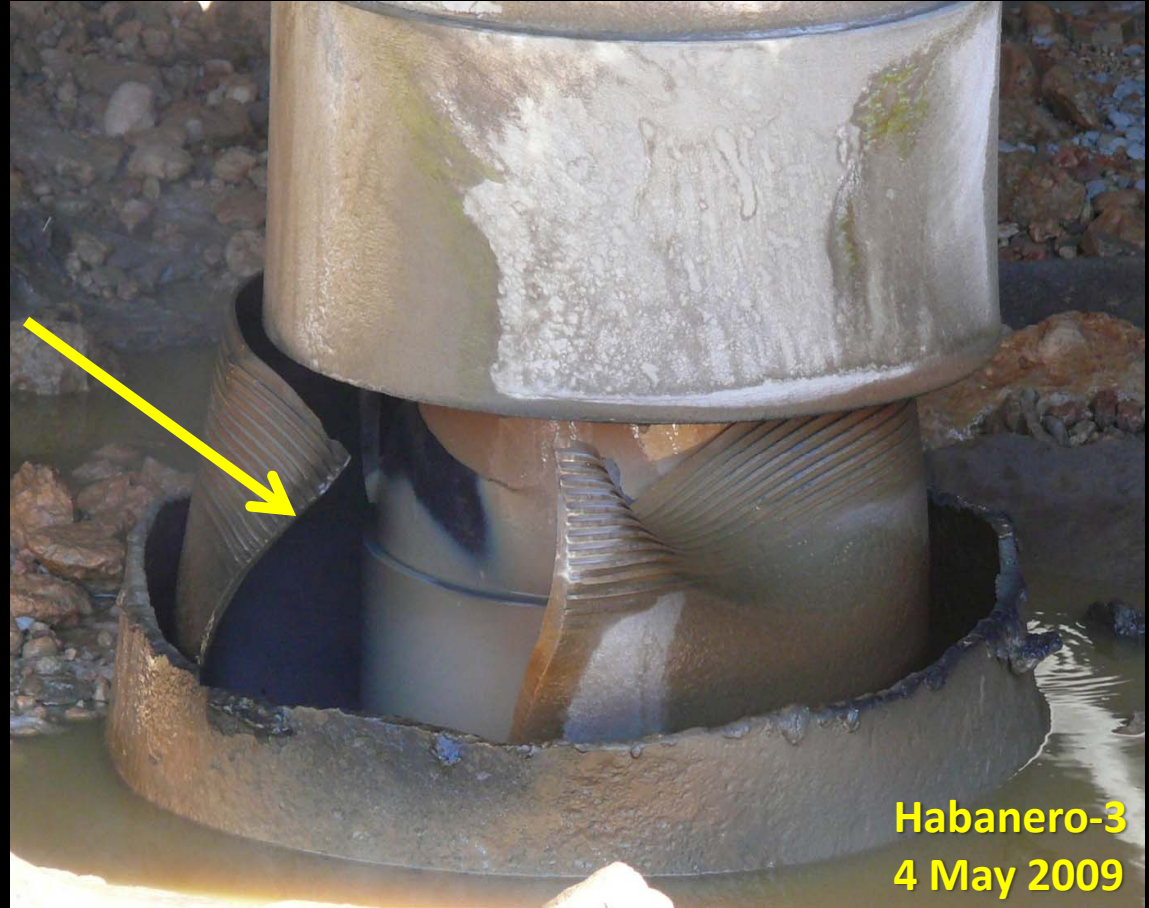
# Habanero-3

- No evidence of brittle failure or cracking in the 18-5/8" casing
- A release of pressure from 18-5/8" x 13-3/8" annulus resulted in the rapid fracture of the 13-3/8" casing and complete fracture of the 9-5/8" casing 1.7 m (below ground level)



# Habanero-3

- 18-5/8" not designed to contain reservoir pressure
- 18-5/8" casing rated to 4840 psi (internal yield pressure – Tenaris web site)



Habanero-3  
4 May 2009

## Findings

- Principal cause of the incident was the design and use of TN150DW steel for the two barrier strings
- Hydrogen embrittlement caused the cracks in the TN150DW casing
- H<sub>2</sub>S may not have been the primary source of the hydrogen. The lack of corrosion by-products (iron sulphide or pyrrhotite) indicate CO<sub>2</sub> may have produced the hydrogen required for hydrogen embrittlement
- Siderite or iron carbonate (FeCO<sub>3</sub>) was found on the surface of the 9-5/8" casing and 7" tubing.
- The corrosive reaction is:
  - $\text{Fe} + \text{CO}_2 + \text{H}_2\text{O} \Rightarrow \text{FeCO}_3 \text{ (Siderite)} + \text{H}_2$

- Anodic reaction
  - $\text{Fe} \Rightarrow \text{Fe}^{2+} + 2\text{e}^-$
- Cathodic reactions
  - $\text{H}_2\text{CO}_3_{\text{sol}} \Rightarrow \text{H}^+_{\text{sol}} + \text{HCO}_3^-_{\text{sol}}$  (by dissociation of  $\text{H}_2\text{CO}_3$ )
  - $\text{H}_2\text{CO}_3_{\text{ad}} + \text{e}^- \Rightarrow \text{H}_{\text{ad}} + \text{HCO}_3^-_{\text{ad}}$  (by direct reduction)

And

- $2\text{H}^+_{\text{sol}} + 2\text{e}^- \Rightarrow \text{H}_{2\text{gas}}$
- $2\text{H}^+_{\text{ad}} \Rightarrow \text{H}_{2\text{gas}}$
- The absorption of  $\text{H}_{\text{ad}}$  and  $\text{H}^+_{\text{sol}}$  is facilitated by one or more of the following:
  - High partial pressures of  $\text{CO}_2$
  - Presence of  $\text{H}_2\text{S}$
  - Acid conditions
  - Presence of arsenic

- Hydrogen embrittlement is more likely to occur in TN150DW casing when the temperature of the steel falls below 145°C.
- Prior to failure there were three shut in periods long enough to cool the well below 145°C and allow stress corrosion cracking due to hydrogen embrittlement. The well was shut in 30 days prior to the incident.
- The geothermal brine from Habanero-3 has a cold pH of 5-6 due to high dissolved CO<sub>2</sub> content.
- There was no indication that geothermal gas was present in the 9-5/8" x 13-3/8" annulus prior to the casing failure.

## Current Status

- The well was suspended on May 23<sup>rd</sup> with two downhole cement plugs and a steel cap welded on the 13 3/8" casing and 26" conductor.
- Quest Engineering has been contracted to further investigate the chemical reaction that caused the casing failure.



**Habanero-3**  
**8 June 2009**

# Power from the Earth



Visit us at [www.geodynamics.com.au](http://www.geodynamics.com.au)