Applying Experience from Geothermal Reservoirs to Oil Wells in the Asia Pacific Region*

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Abstract

This presentation will show how electrical borehole images, sometimes supported by Stoneley waveform data, have been used to identify lithological facies within igneous rock formations as well as to characterize fracture systems, which can act as reservoirs in both geothermal, and petroleum systems. Examples will be shown from Indonesia, Vietnam, Japan and the People's Republic of China. Two case studies will demonstrate how an analysis of the fracture type and knowledge of the orientation of fracture swarms was used to land wells and to optimize production. This content was previously published at IPA and SPE meetings, but seems very pertinent to the subject of this GTW and has therefore been offered for display.

Reference Cited

Newberry, B.M., L.M. Grace, and D.O. Stief, 1996, Analysis of Carbonate Dual Porosity Systems from Borehole Electrical Images: SPE 35158, Permian Basin Oil and Gas Recovery Conference, 27-29 March 1996, Midland, Texas, https://doi.org/10.2118/35158-MS

Applying experience from geothermal reservoirs to oil wells in the Asia Pacific Region

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Facies Recognition in Volcano-clastic Settings

Fracture Characterization in Igneous Rocks

A nice analog!

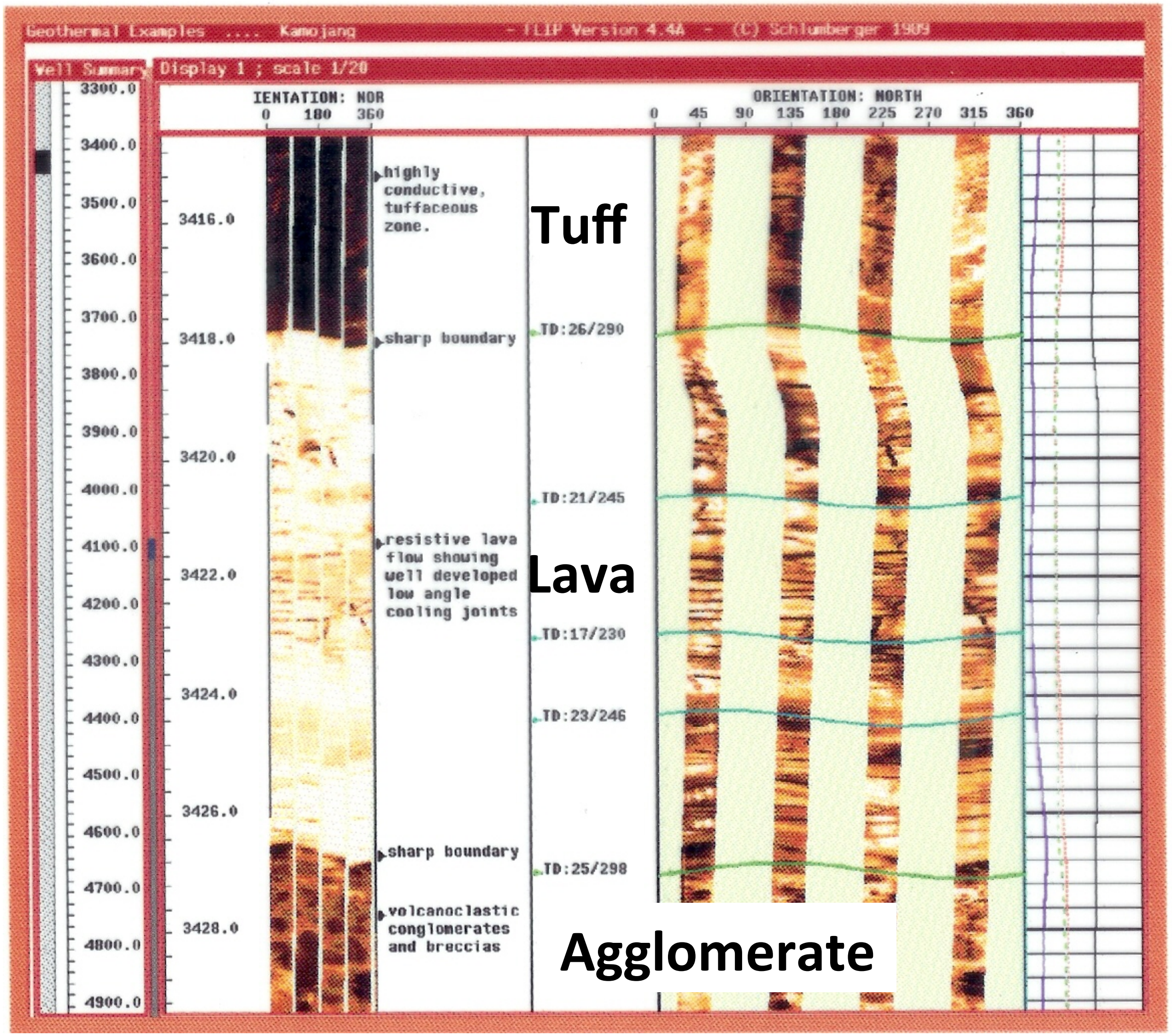
Agglomerates
& lithic tuffs

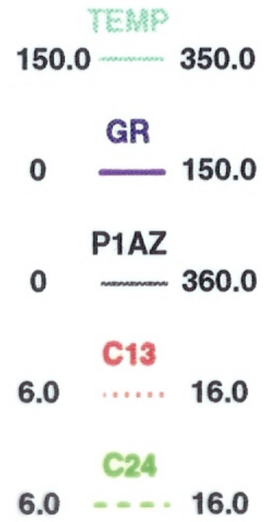
Lava flows

Facies variations
on Krakatoa

(core-image comparison work in Java area)

Gross lithology recognition

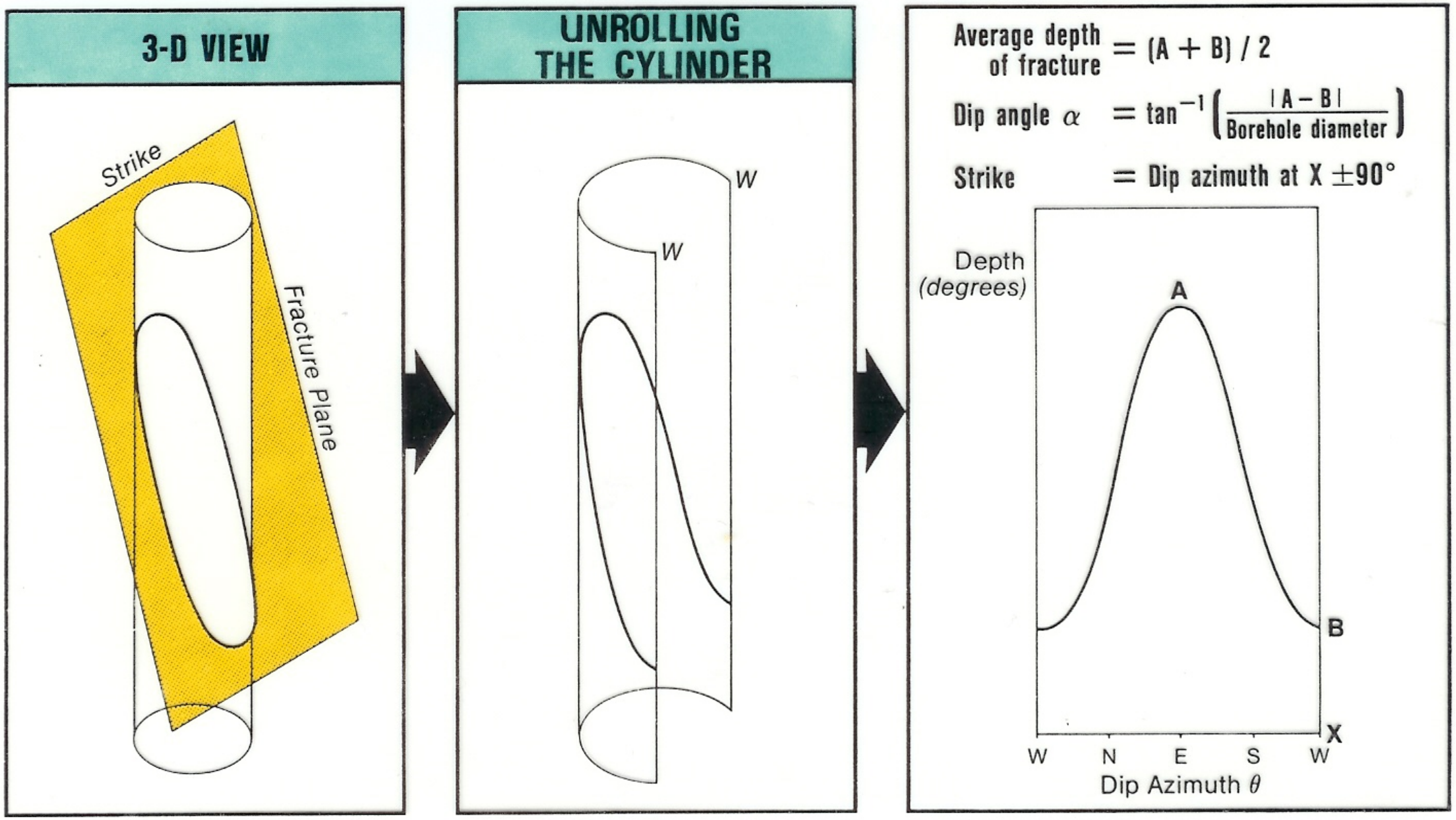




Initial interpretations backed up with core comparisons in Amoseas, Conoco and Pertamina wells in Central and West Java

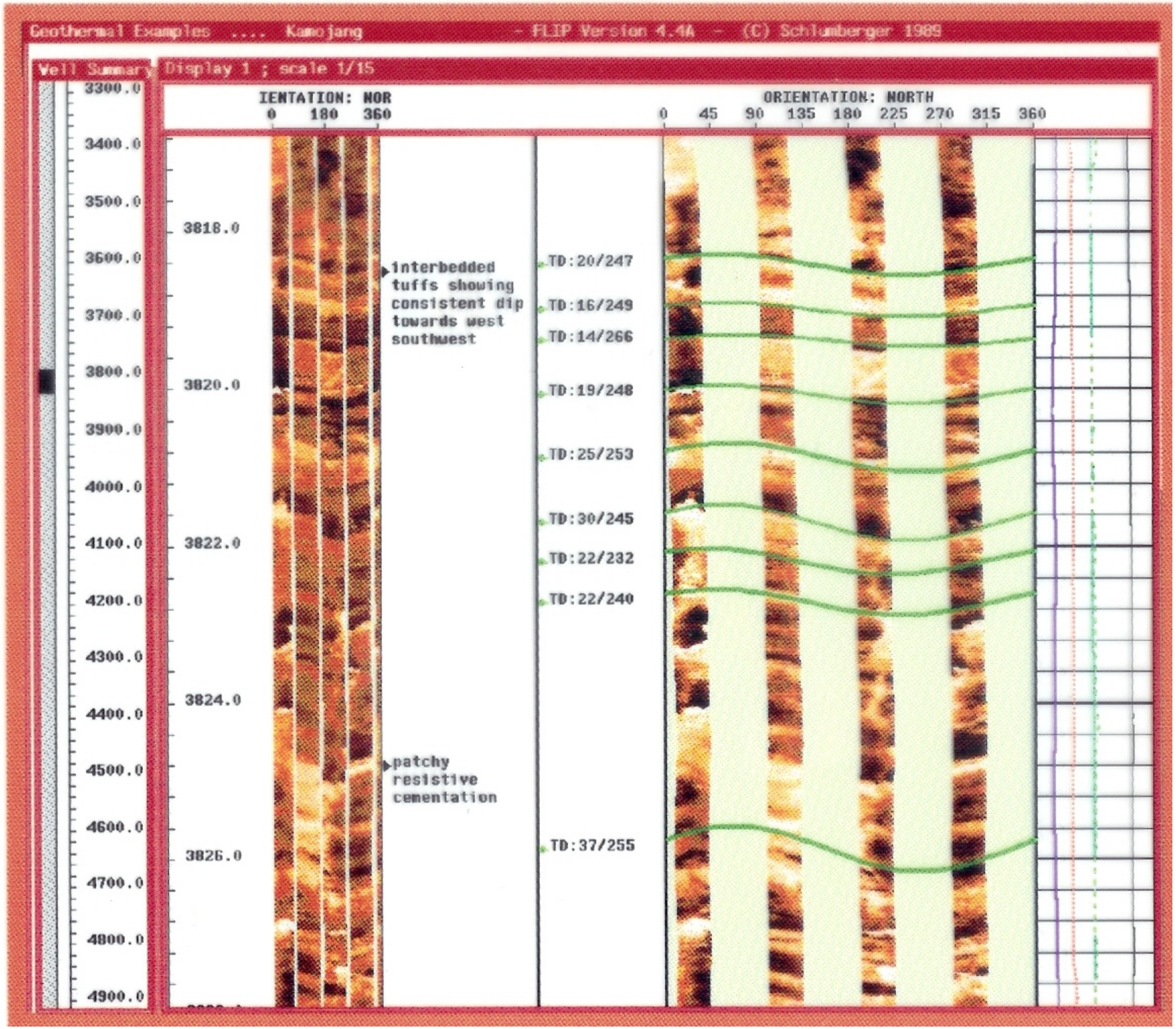
Rock type and textures can be interpreted from the resistivity images

Dip-Fracture strike & dip computation



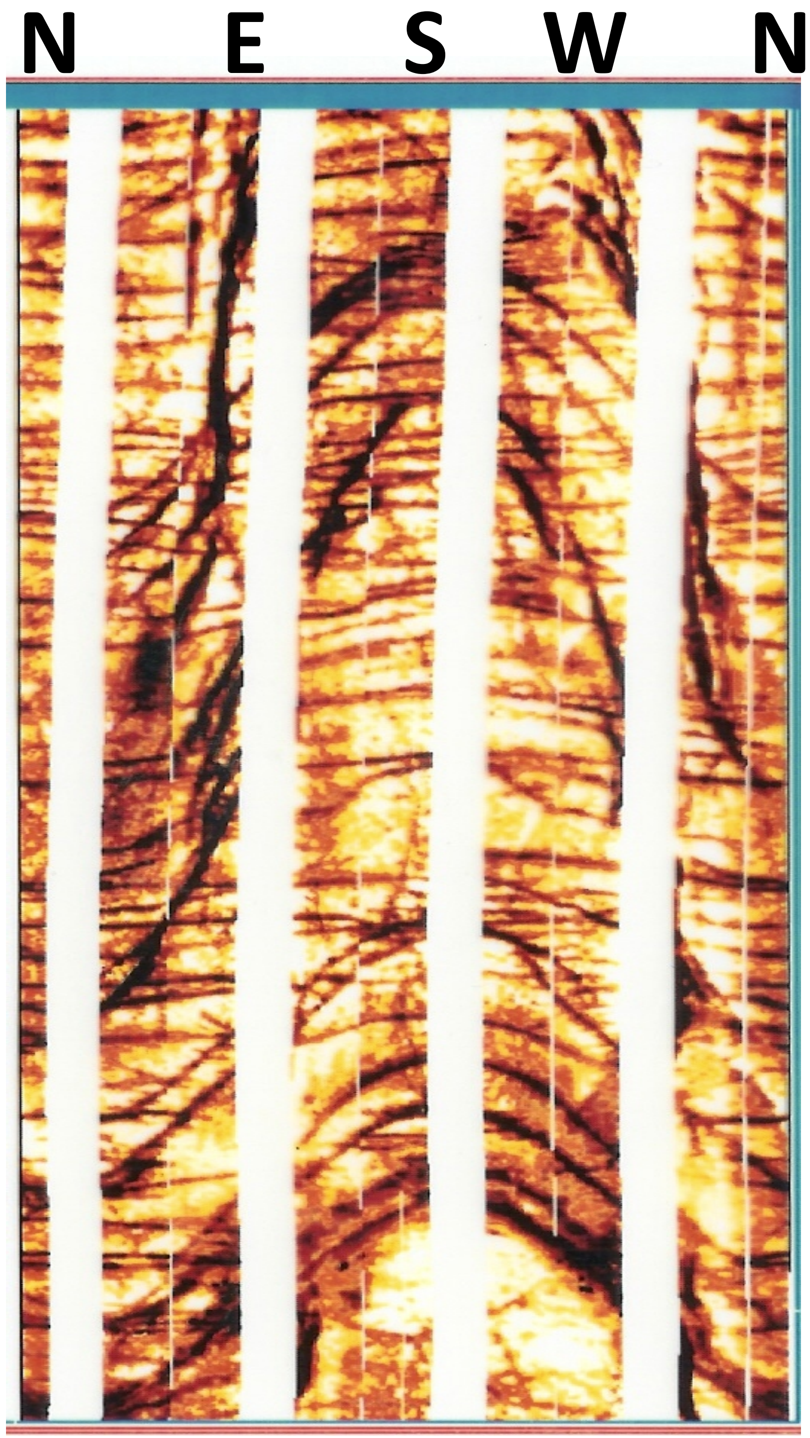
After computing relative dip, need correction for borehole deviation

Bedded tuffs: very fine grain - non reservoir



Lava flow

John Simmons, GSL photo library, www.geolsoc.org.uk



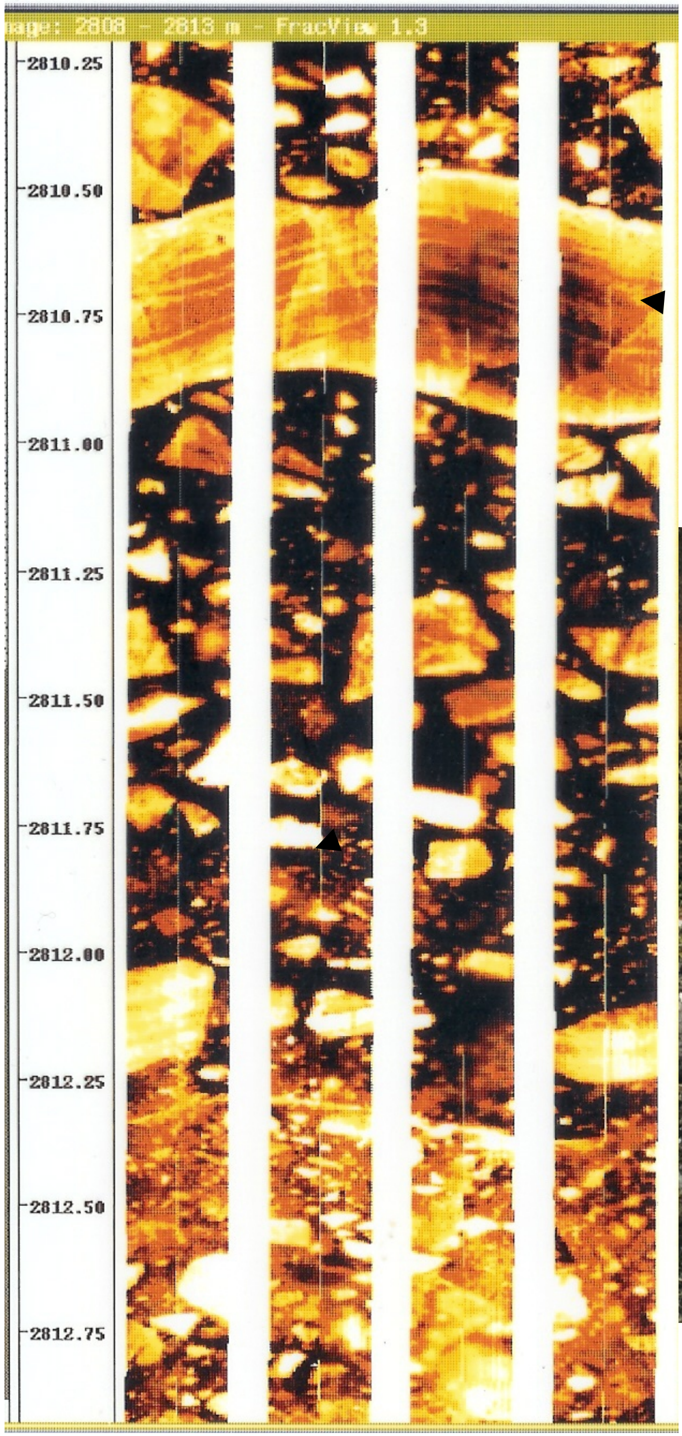
Lava with low angle joints & high angle open fractures

Conductivity along joints due to pyrite and does not indicate production potential.

The high angle open fractures produce oil

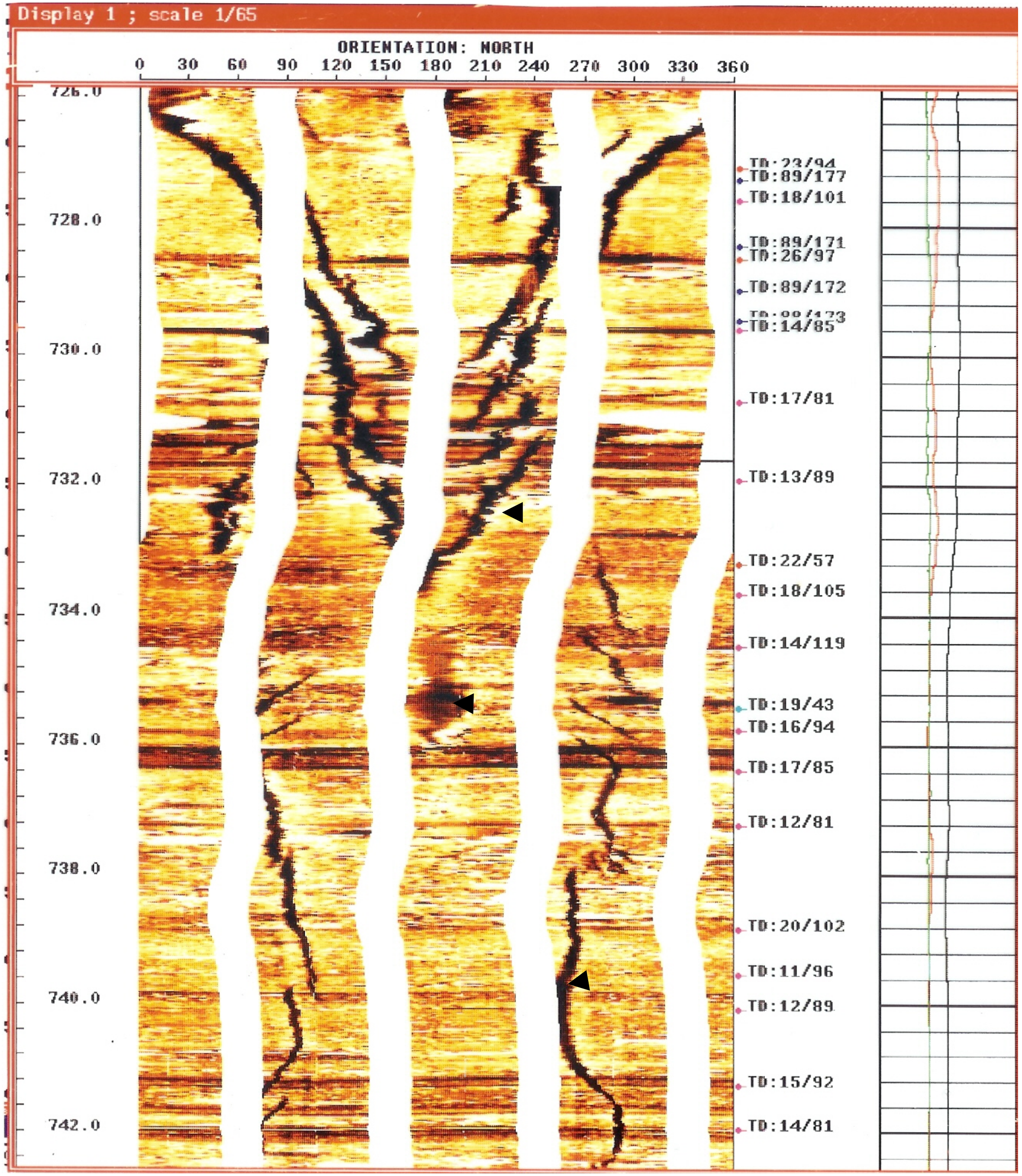
This image example from the Carboniferous in North West China

Agglomerate Facies



Thinly bedded tuffs (as big clast/ boulder) in brecciated interval

Agglomerate

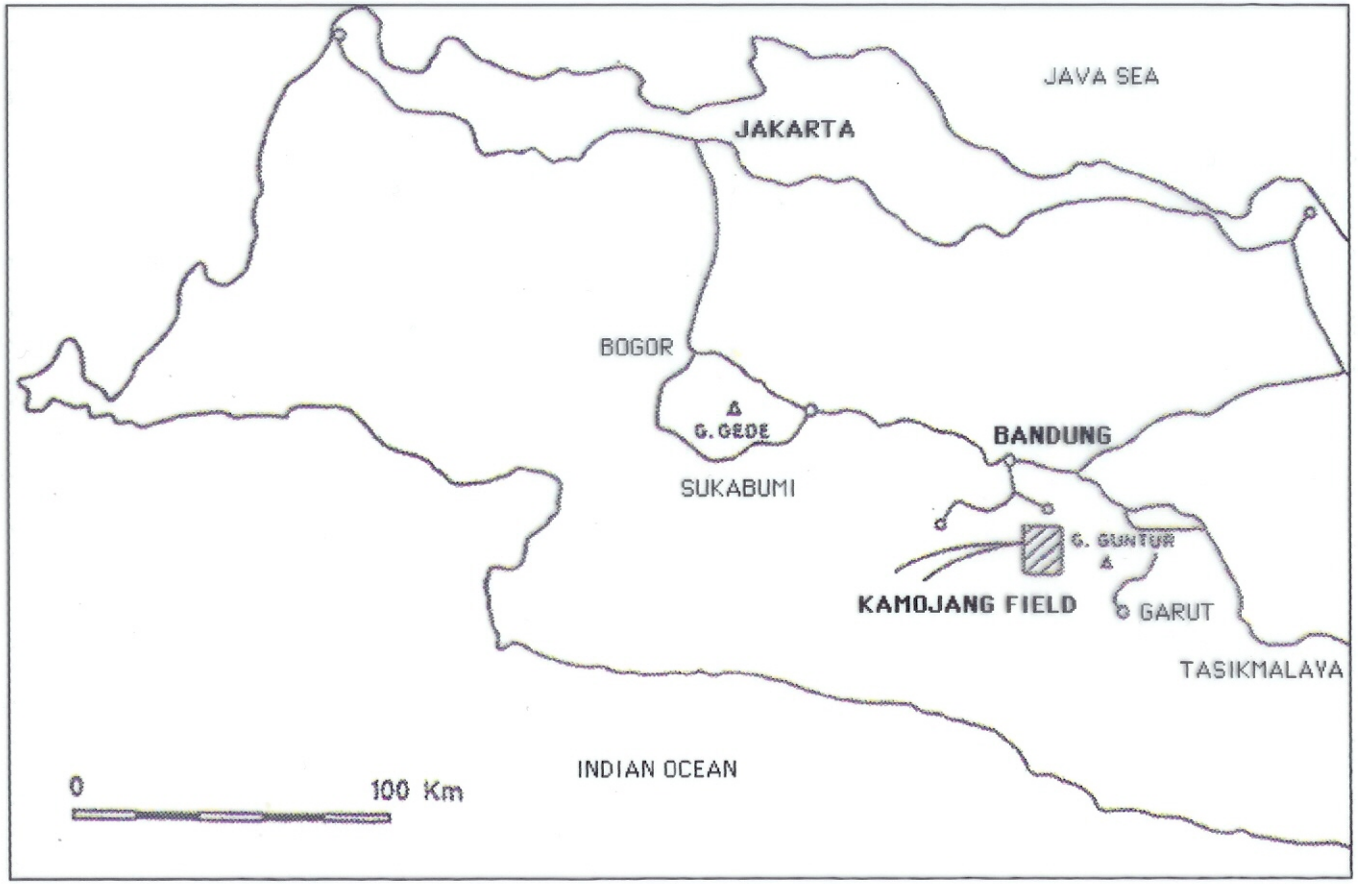


Oil producing fractures; volcanic agglomerate/ conglomerate, NW China

- Natural Fracture System
- Breakout
- Tensile - Induced

Maximum horizontal geostress E-W

Case study; using images to resolve reservoir delineation & development issues in West Java



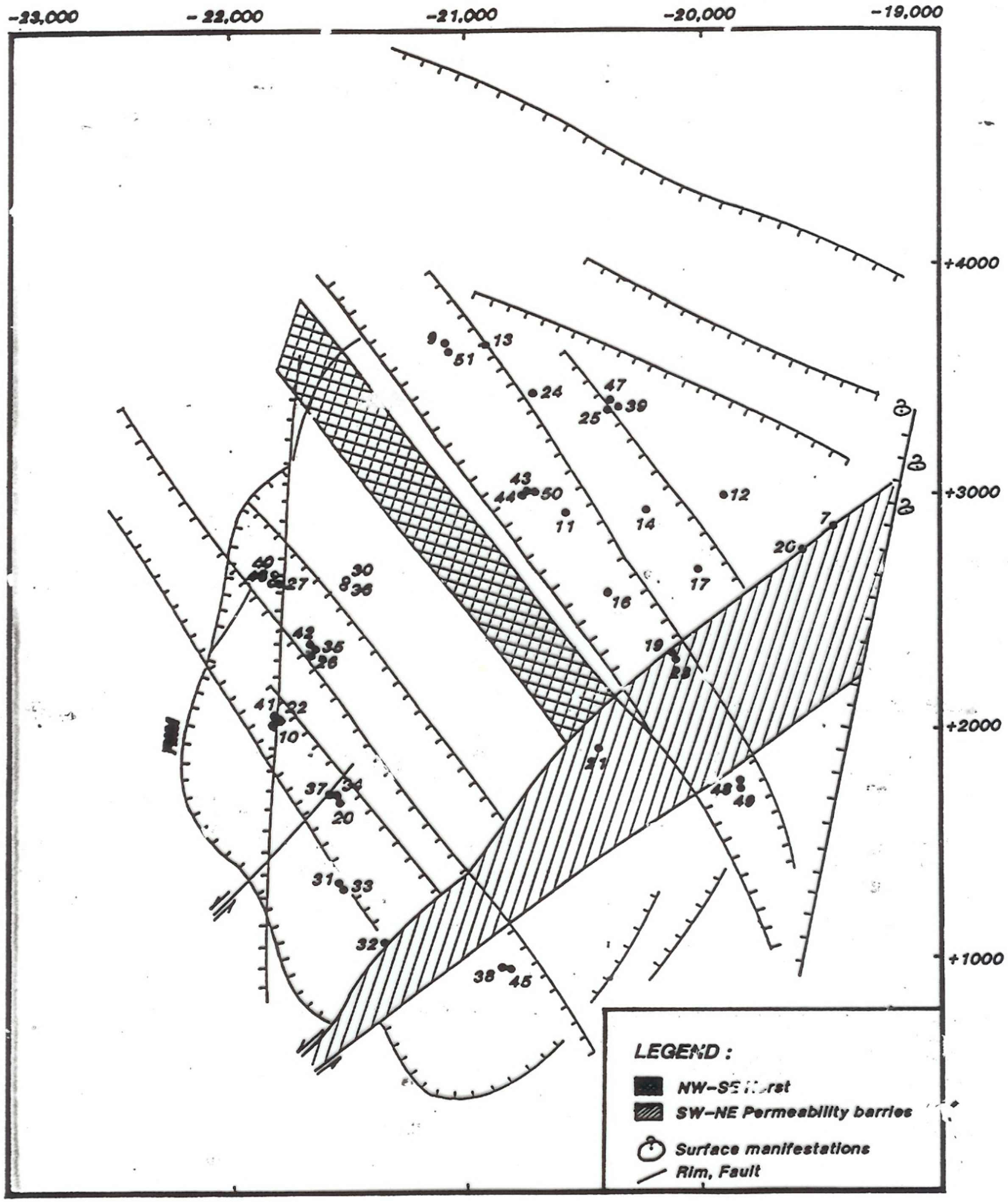
Acknowledging my co-authors:

T. Huntoro
R.R. Wathan
K. Hendrowibowo
H. Sumantri

& thanking Pertamina for permission to show this data

Kamojang Field

- First exploration well in Kamojang area in 1926
- Development started in 1964; 65 wells
- Field now produces 140MW, 3 power plants
- Bottom hole temperatures typically range from 230-255 degs C; depths to 5000'
- Pressure 29-35 bars
- Main production from faults and related fracture zones in volcanic sediments

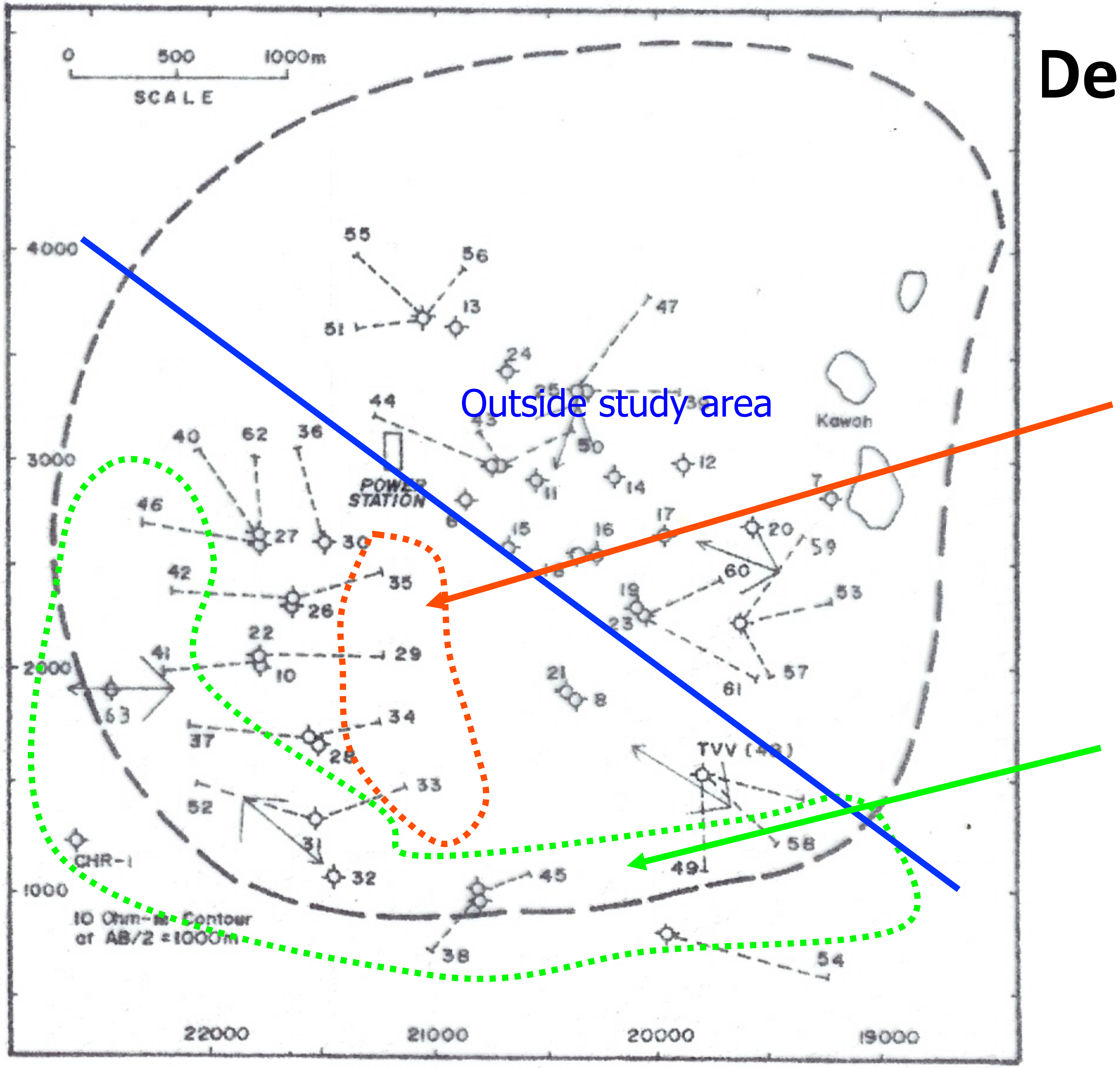


Main structural features

Based upon regional fault lines as well as local mapping and well control

Main fracture trend believed to be NW-SE (hence wells in central part of field drilled towards NE)

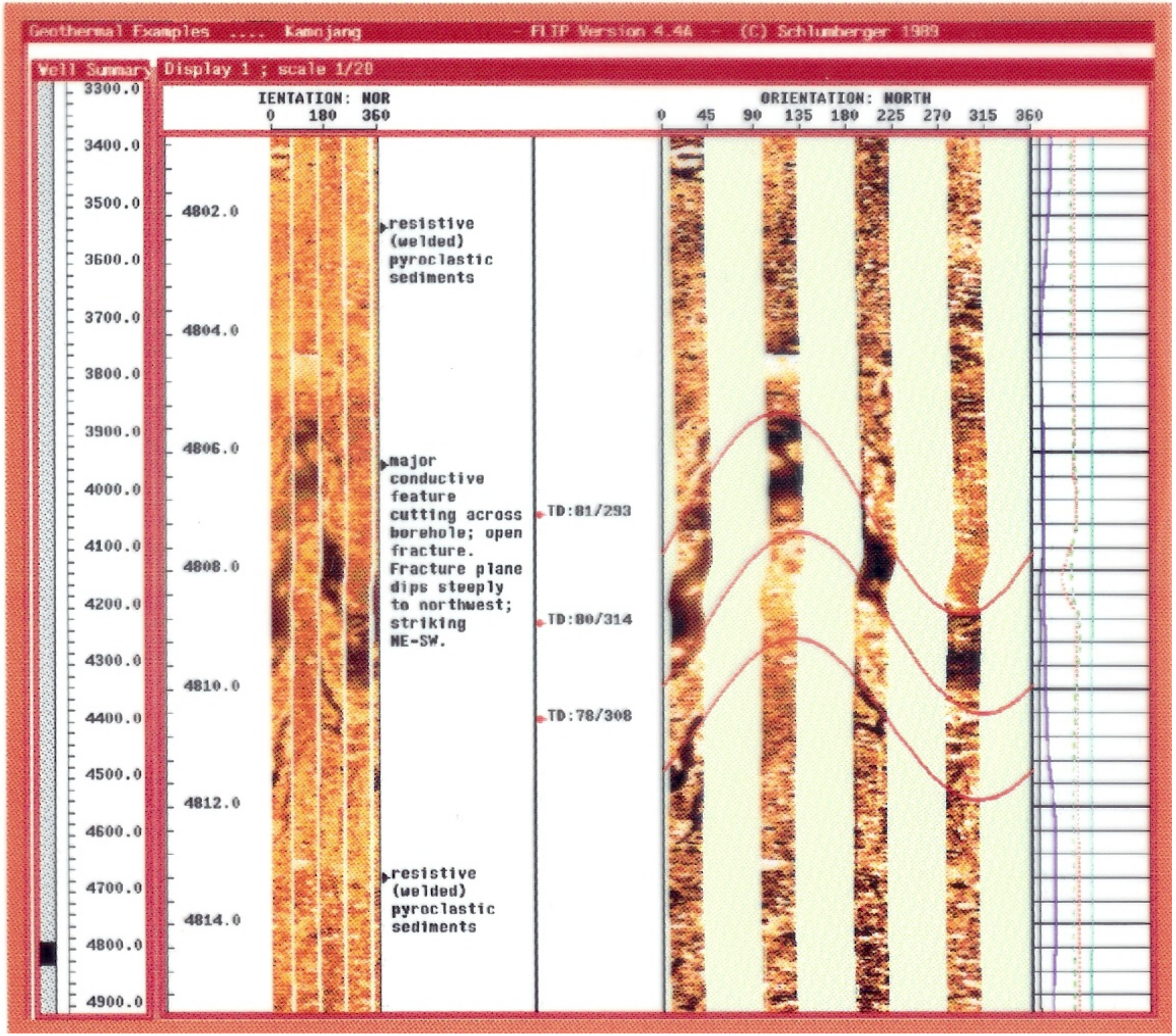
Development results



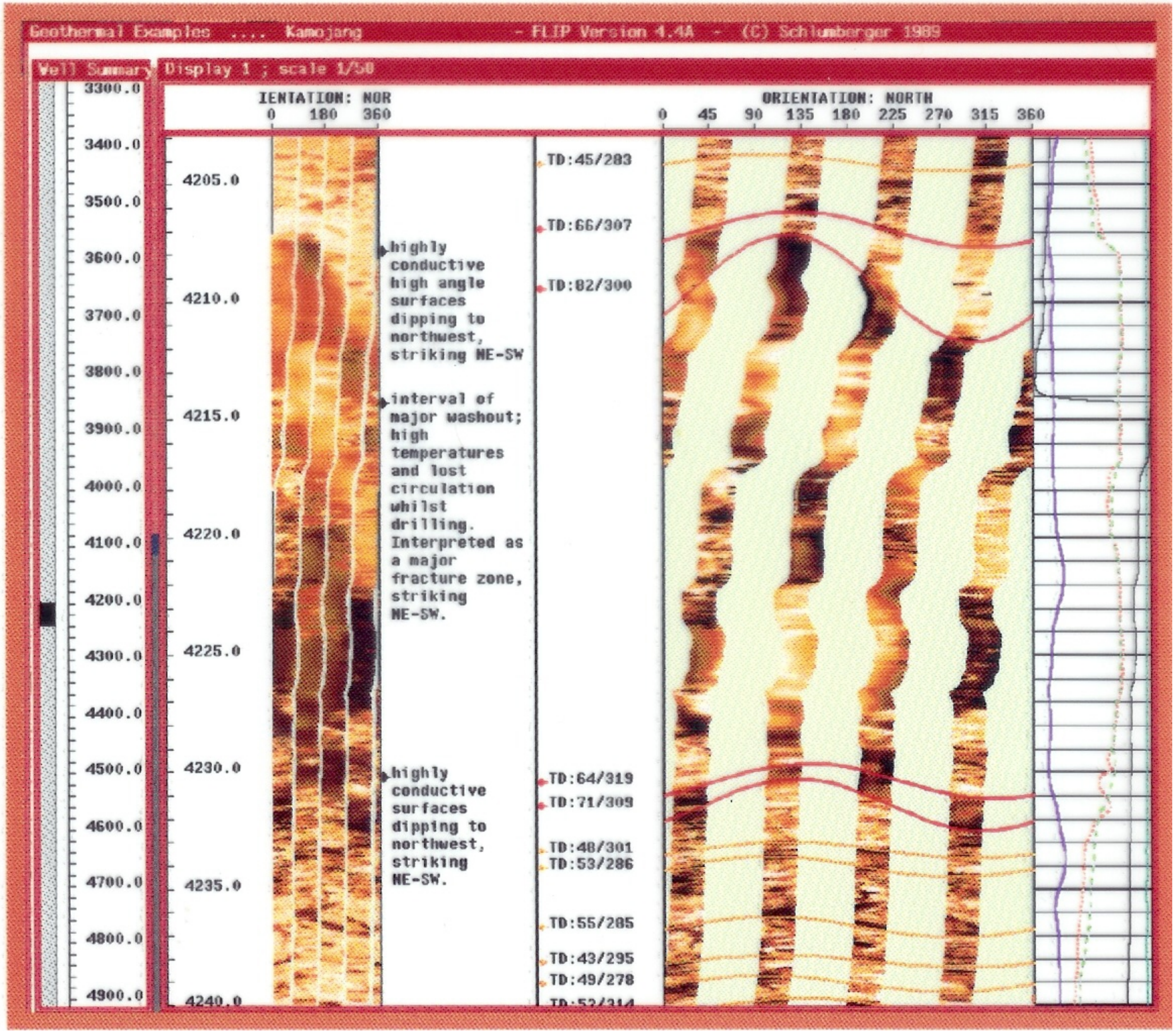
Poor production despite being drilled at right angles to main fracture trend

Good production in wells around collapse zone of central crater area

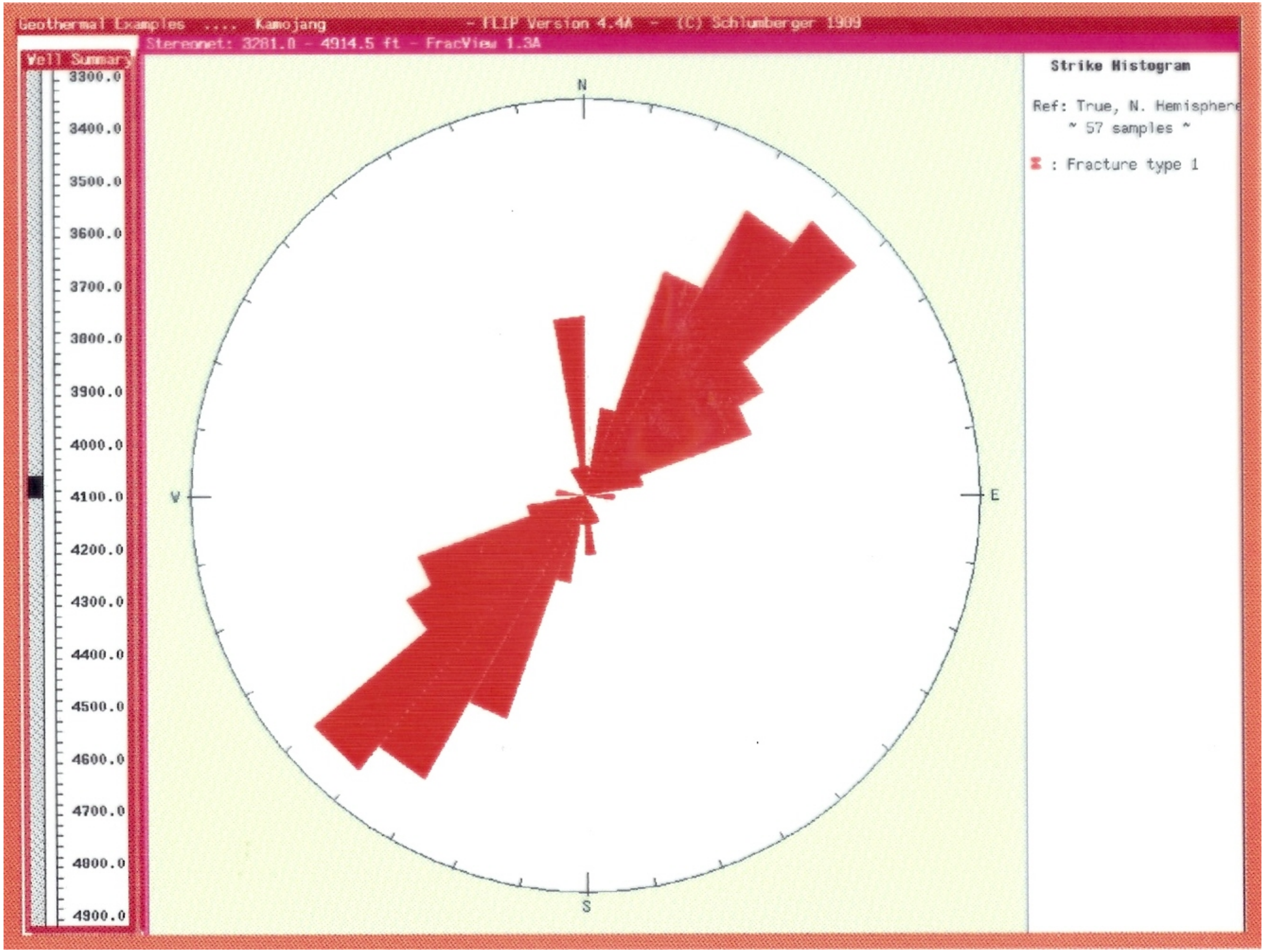
Natural fractures; some production



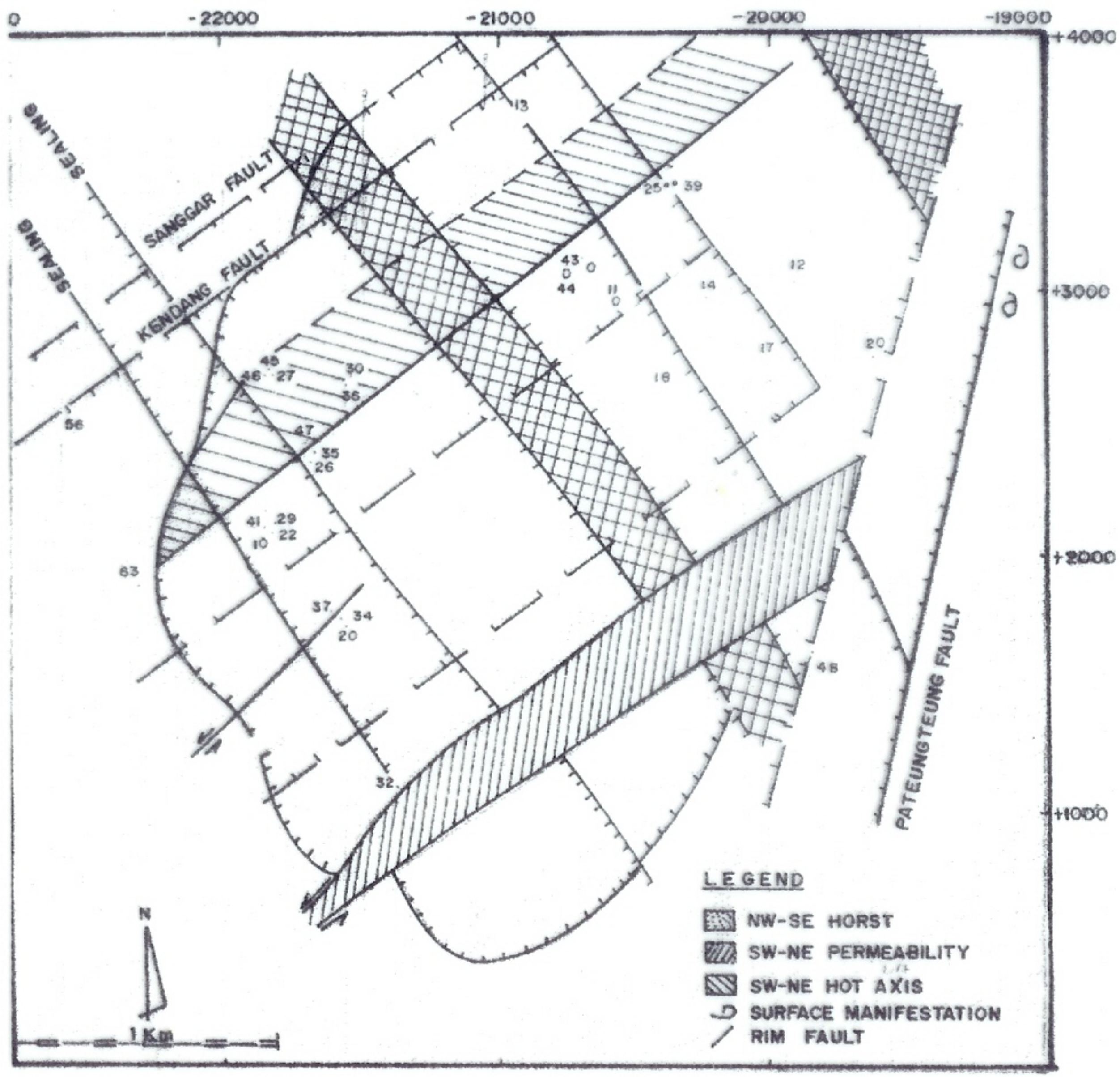
Mega fracture zone; main production

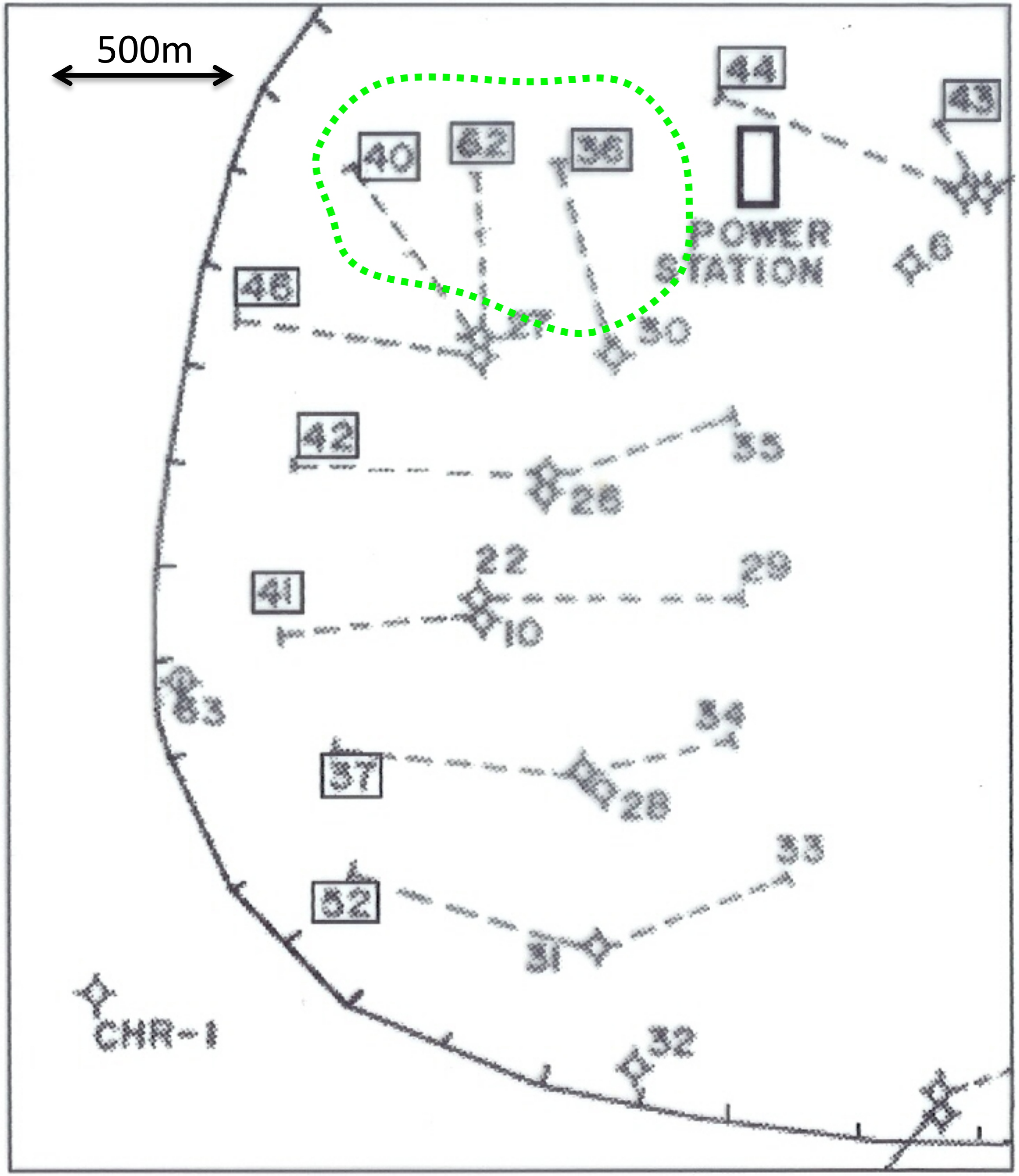


Fracture strike (not NW-SE as expected)



Revised structural interpretation





Recommended well locations

All three wells came in with good production; >12MW's per well

(compares with field average of <4MW's)

Quantifying fractures: width, porosity, fill

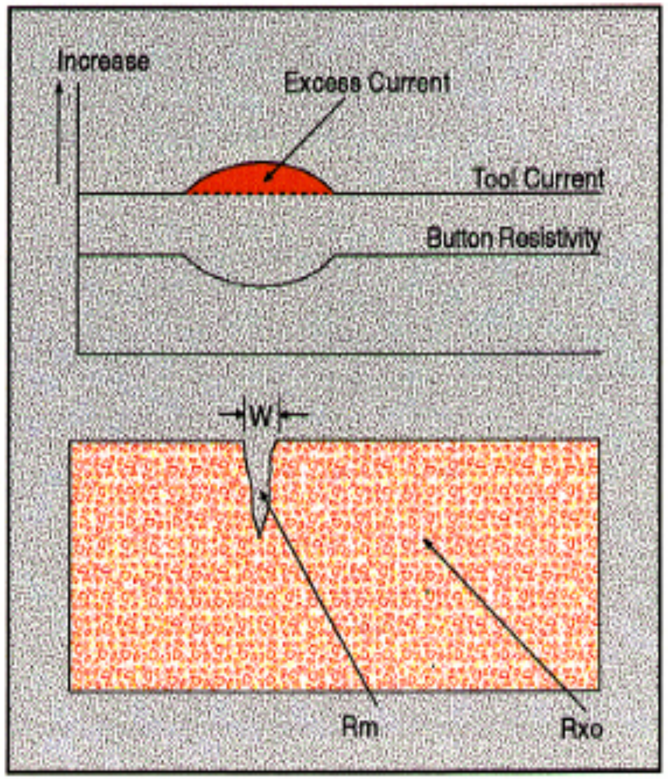
- The electrical images provide information on fracture type (natural/induced), density & direction
- Stoneley Response from Shear Imager and Current Leakage from electrical images combine for fracture width (Hornby)
- The Stoneley response is sensitive to deep(>3m) open fracture systems, meaning near borehole effects
- Stoneley insensitive to fractures filled with mineral alteration products
- Electrical Images can yield porosity distribution distinguishing primary, secondary & tertiary systems

Fracture Aperture Computation

$$W = c \cdot A \cdot Rm^{b} \cdot Rxo^{1-b}$$

Where **W** = fracture aperture
b,e = constant from tool modeling
A = excess current divided by voltage and integrated along a line perpendicular to the fracture trace
Rm = mud resistivity
Rxo = flushed zone resistivity

Fracture Aperture Calculation

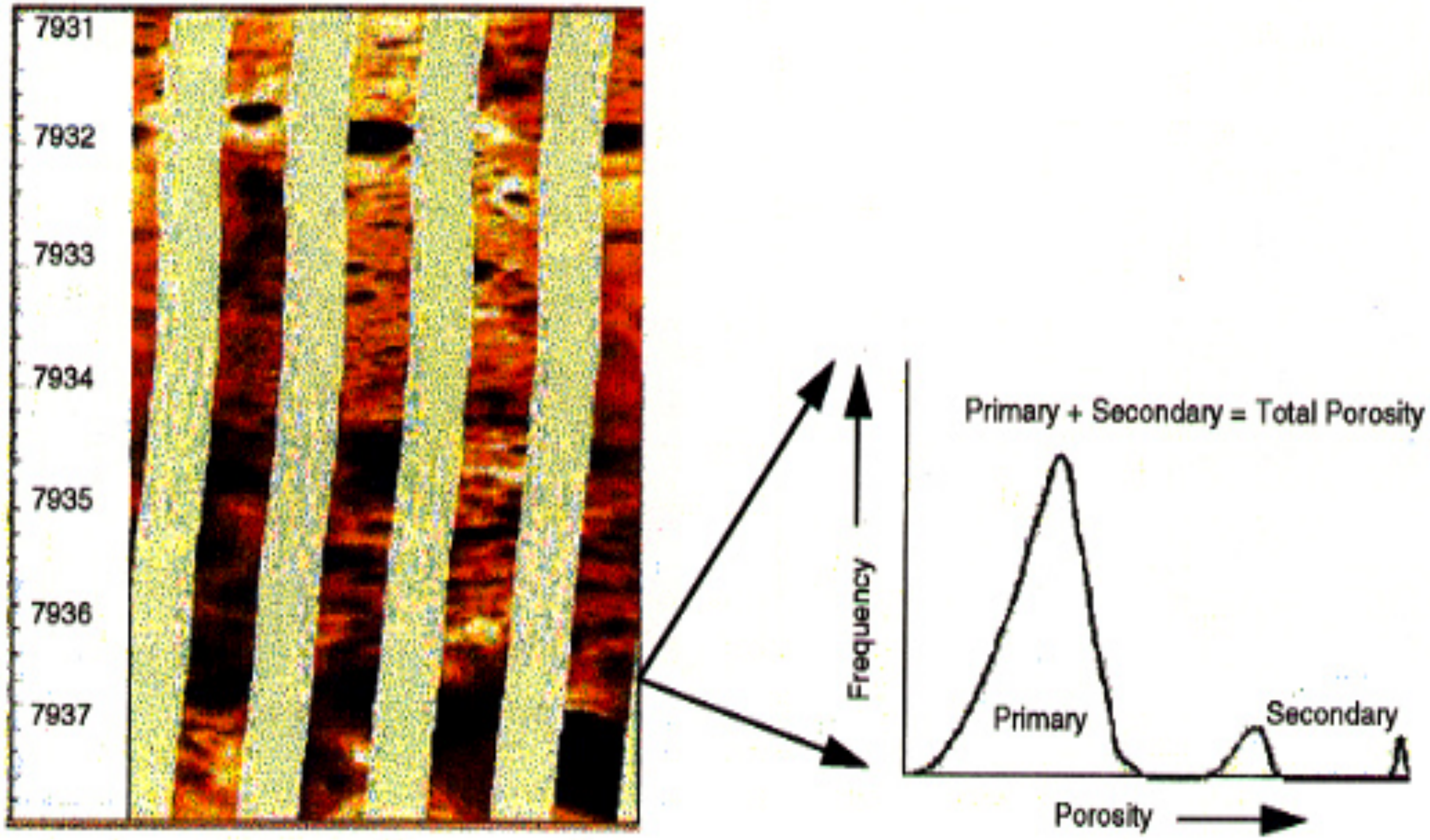


Current leakage into a fracture increases as the formation becomes more resistive and/or the fracture becomes wider

It is also a function of mud resistivity

Images need careful calibration

Archie: Resistivity is a map of the porosity



Local variations in porosity distribution produce distinct histograms.

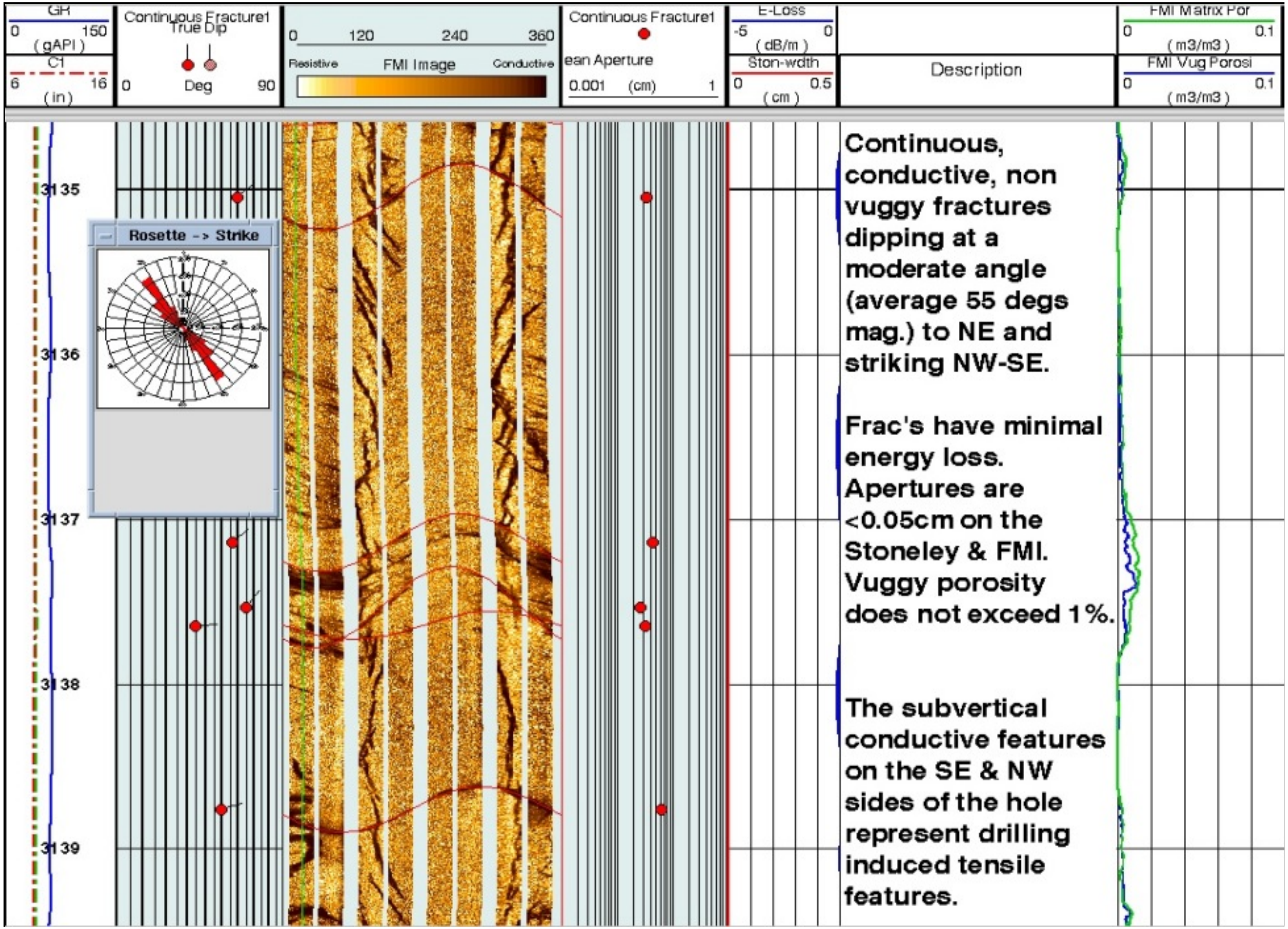
From Newberry et al, SPE 35158; Analysis of Dual Porosity Systems

A rare "open" fracture at a highly fractured outcrop

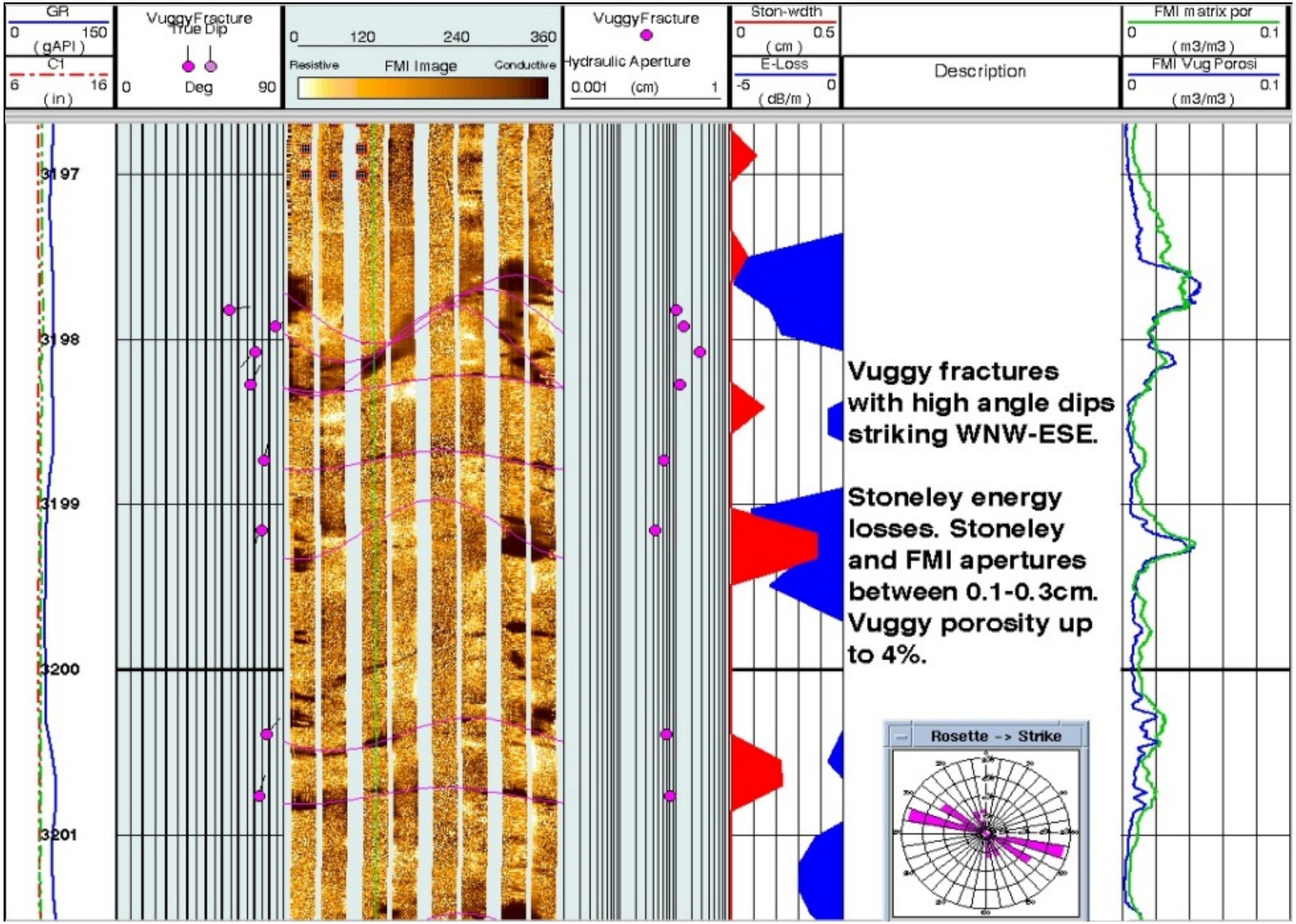
Jointed and fractured granites,
Vung Tau, Mekong Basin

Most granite outcrops show thousands of healed-tight joints

Tensile Shear & Natural Fractures: but how big?



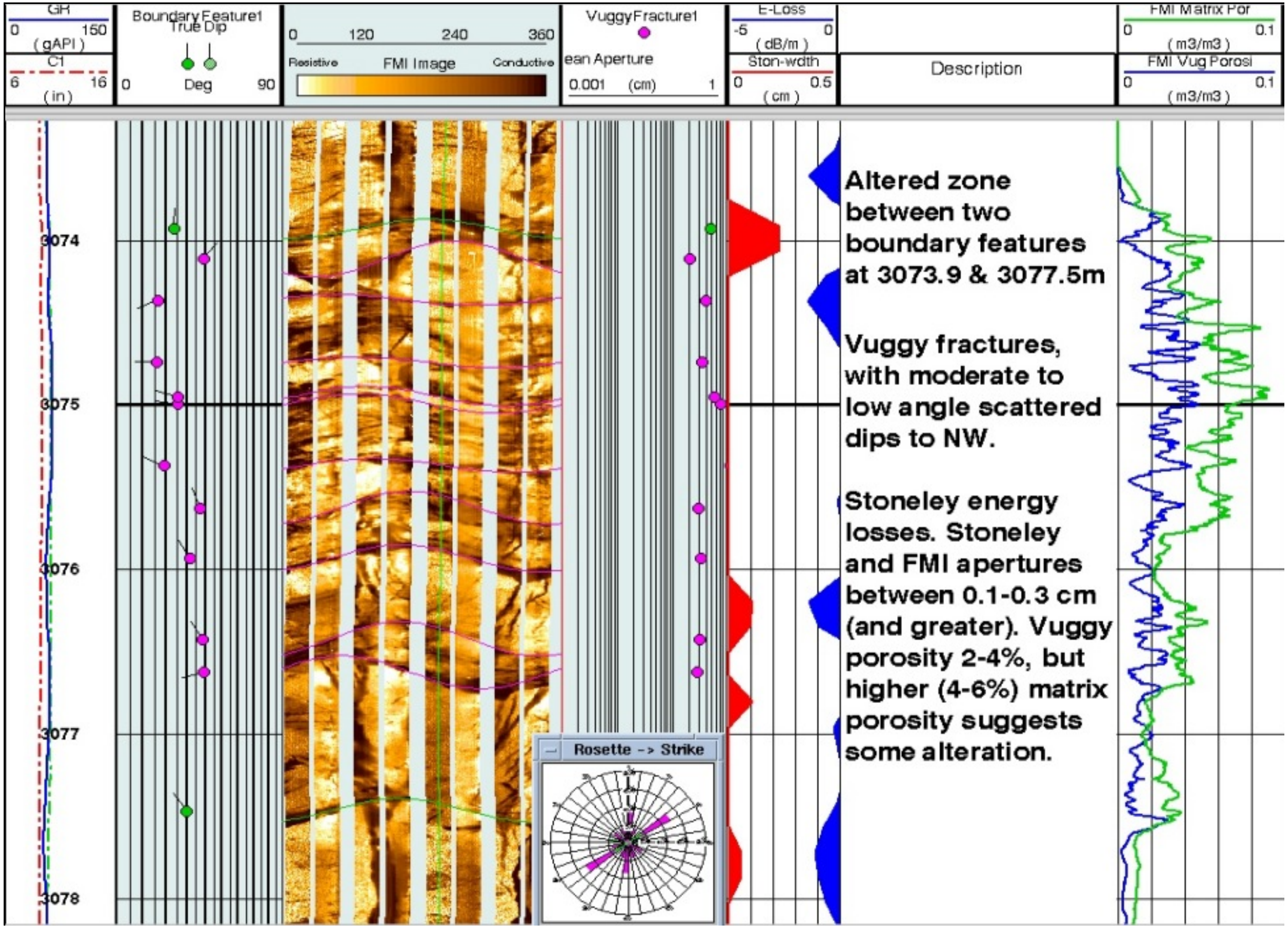
Vuggy fractures: candidate for production



Vuggy, permeable fractures at outcrop

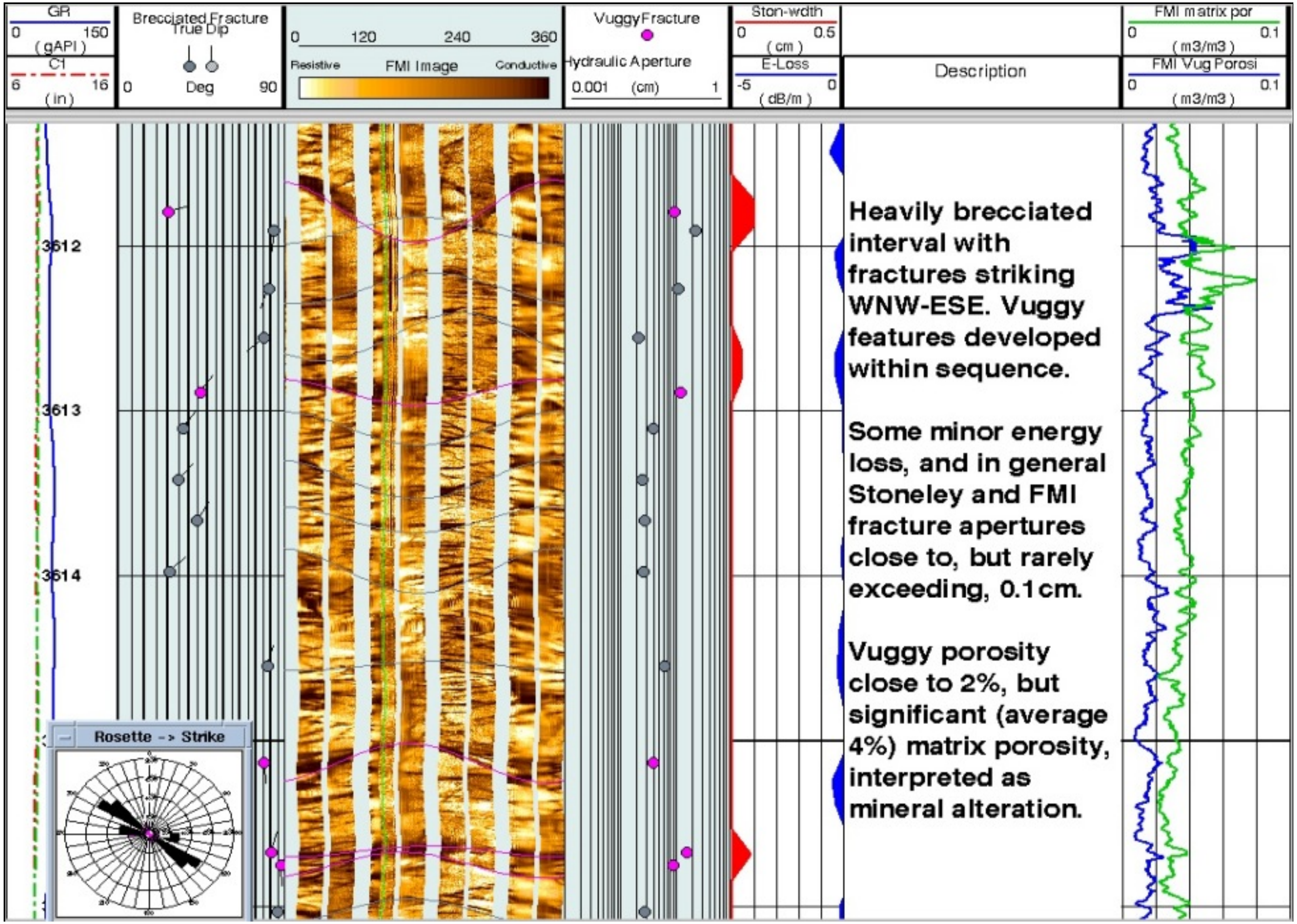
Note staining showing natural springs

Vuggy fractures, some clay mineral alteration, with boundary fractures



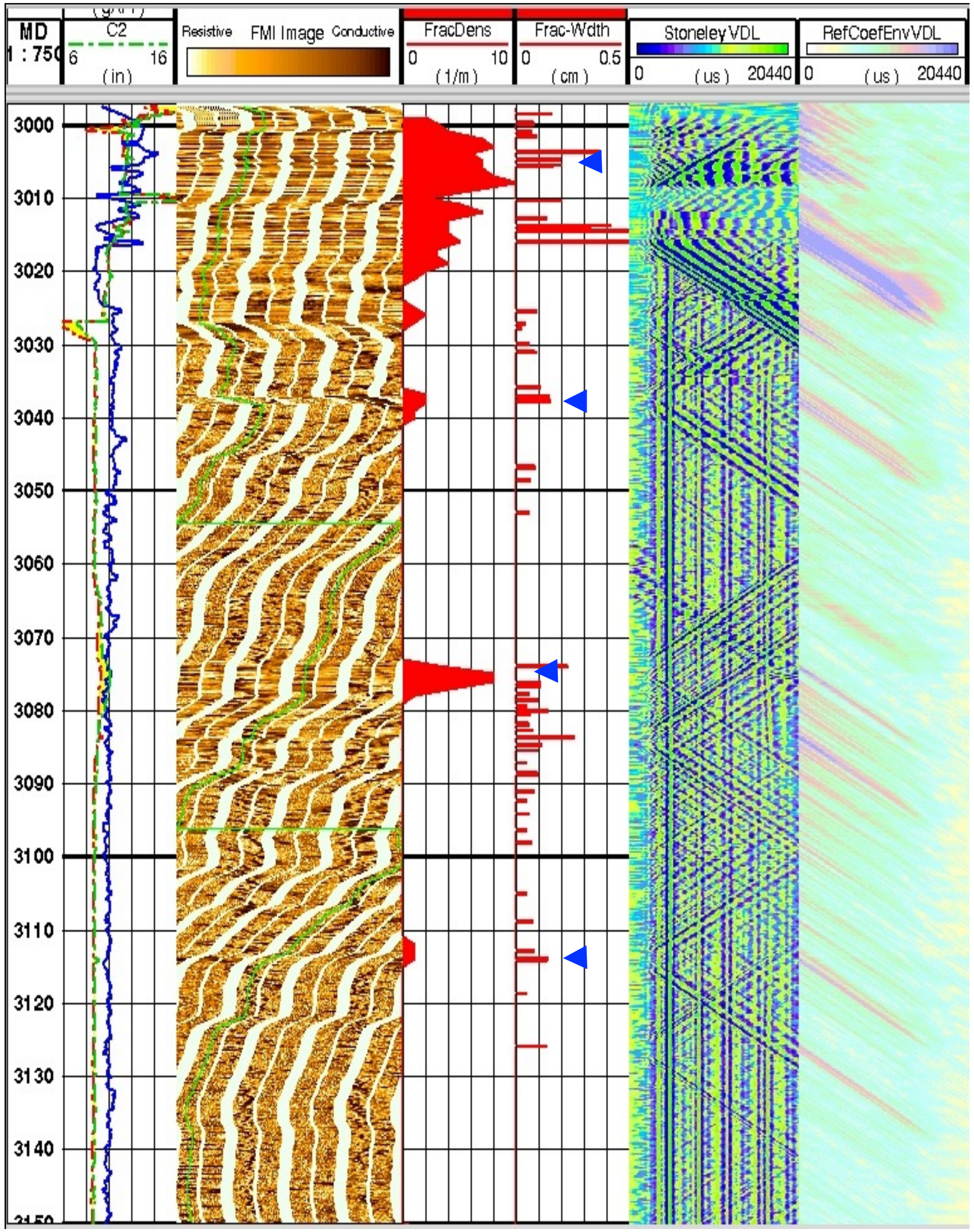
Vuggy fractures at outcrop; some clay mineral alteration

Brecciated fracture zone, heavily altered with clays



Brecciated fractures, heavily altered with clays

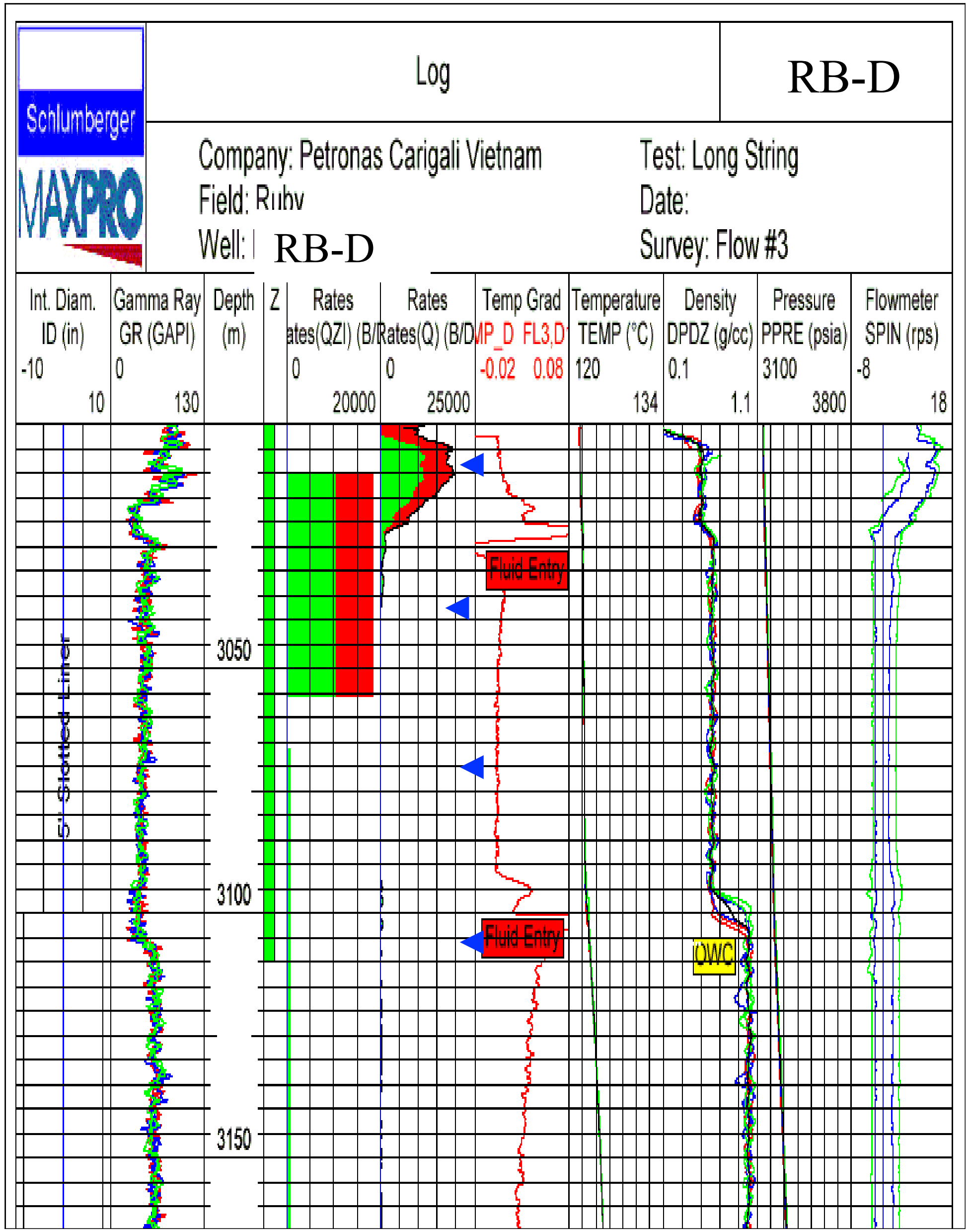
Integrated analysis



- A: High fracture density; apertures exceeding 1mm
- B: Apertures exceeding 1mm
- C: Apertures exceeding 1mm
- D: Apertures exceeding 1mm

85% of apertures in zone A, 5% in each of B, C & D

Production Testing



Production logs after well being on line for 10 weeks

- A: 85% of production
- B: 7% of production
- C: 1% of production
- D: 7% of production

Conclusions

- Images can help one distinguish igneous lithofacies
- Examples of oil production in extrusive lava's, coarser agglomerates and intrusive granites
- Igneous primary poro-perm characteristics poor, so need enhancement through fracturing & dissolution
- Images help determine natural vs. induced systems, geomechanics, dip & azimuth, fracture density
- Electrical Images & Shear Sonic Waveforms can be combined to identify fracture width & fill
- Primary porosity can be distinguished from Secondary & Tertiary porosity in vuggy & fractured systems

Applications

- Identify zones of production in geothermal and O&G wells
- Land wells at right angles to the strike of the fracture swarms in the reservoir to optimize production
- Average well production in the Kamojang Field substantially increased from 3MW to 12MW (T. Huntoro, H. Sumantri & P.M.Lloyd, IPA Transations, 1997)
- Well production increased to a sustained 4,000 BOPD in Vietnam Basement Granite well, Ruby Field, (P.M. Lloyd, P. Tandom & N. H. Ngoc, & Dr. H. D. Tjia, SPE paper 57324)
- Lowering drilling risk in the top sections by deviating trajectory parallel to the maximum horizontal

Improving Drilling Efficiency

- A well completed with borehole deviated to the NE or SW would optimize the chances of hitting open fractures

- Drilling the upper section with deviation to the NW or SE minimizes the chances of borehole collapse and stuck pipe