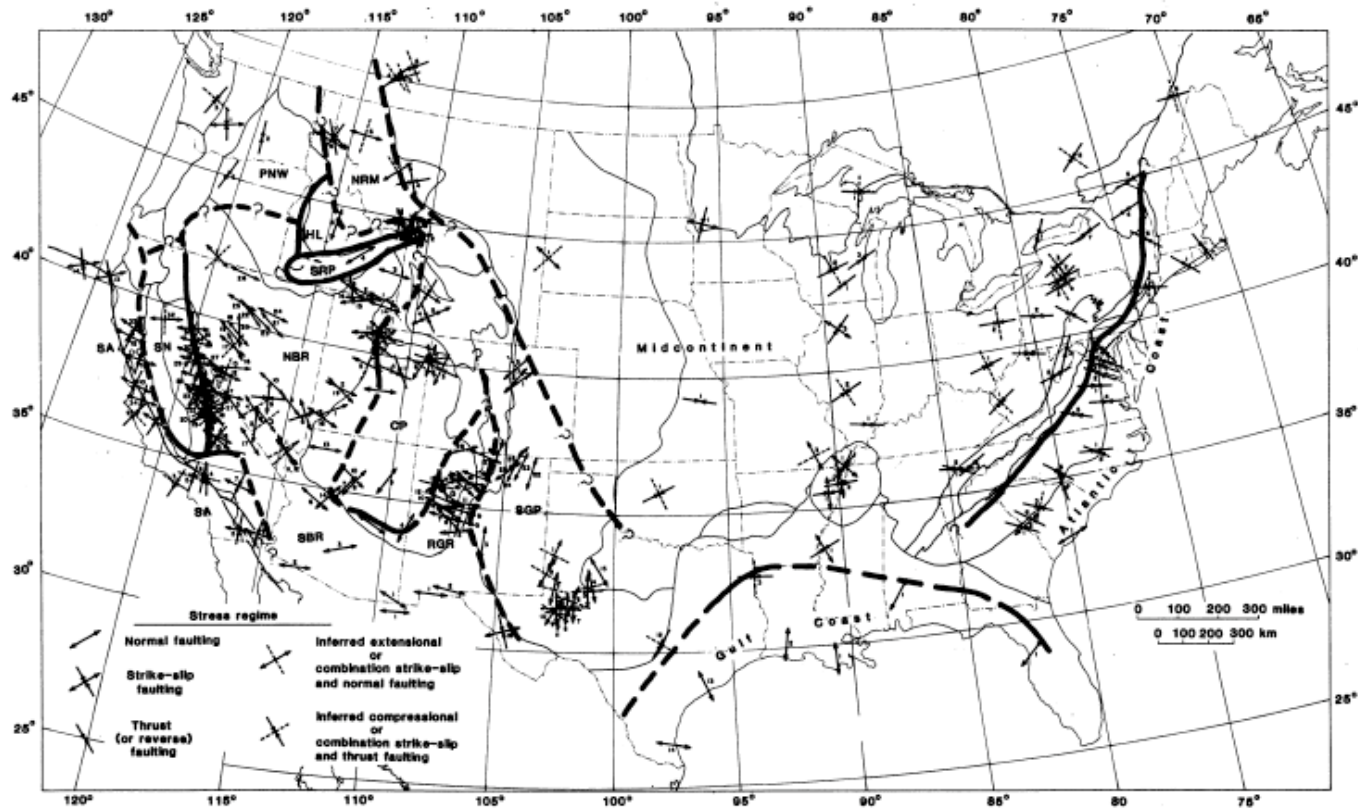


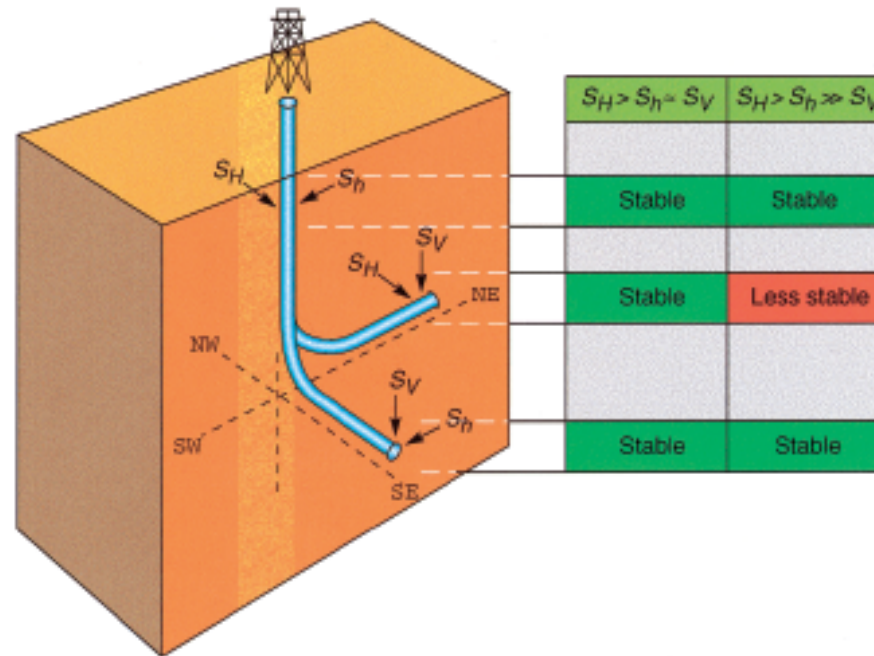
Well Logging Principles and Applications
G9947 - Seminar in Marine Geophysics
Spring 2008

In situ STRESS estimation

Why do we care about in situ stress?



Wellbore (& foundation) stability



S_H = max. Horizontal stress

S_h = min. horizontal stress

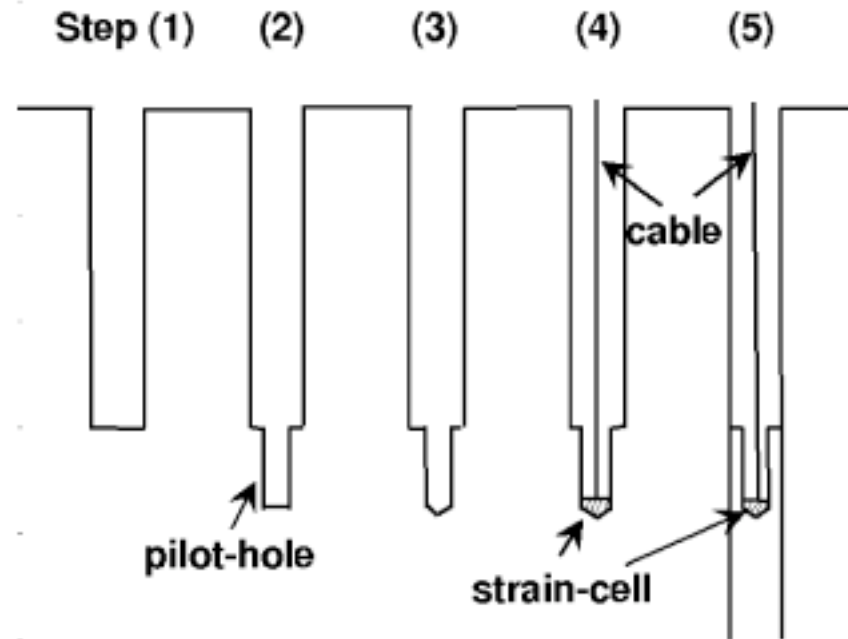
S_V = vertical stress

Sources of in situ stress information:

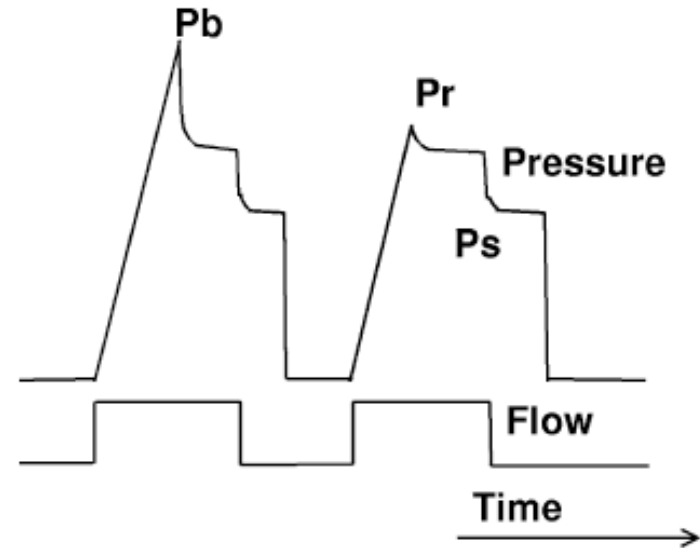
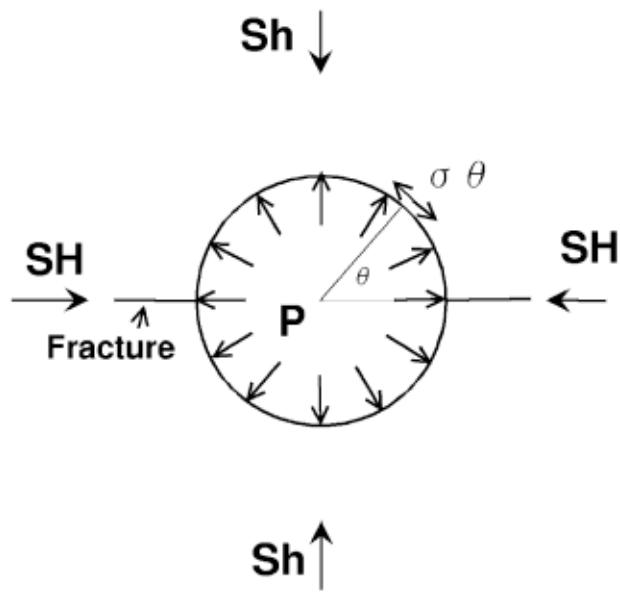
1. Earthquake focal mechanisms
2. Wellbore breakouts*
3. Hydrofracturing*
4. Elastic-wave anisotropy*
5. Overcoring* / doorstoppers
6. Quaternary fault slip
7. Alignment of volcanoes

*borehole methods

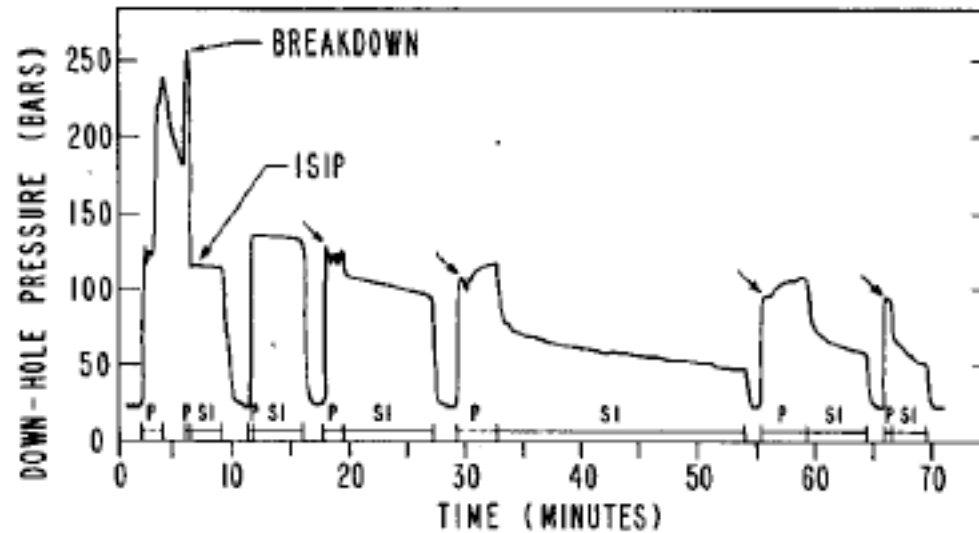
Overcoring - in situ stress relief



Hydrofracturing



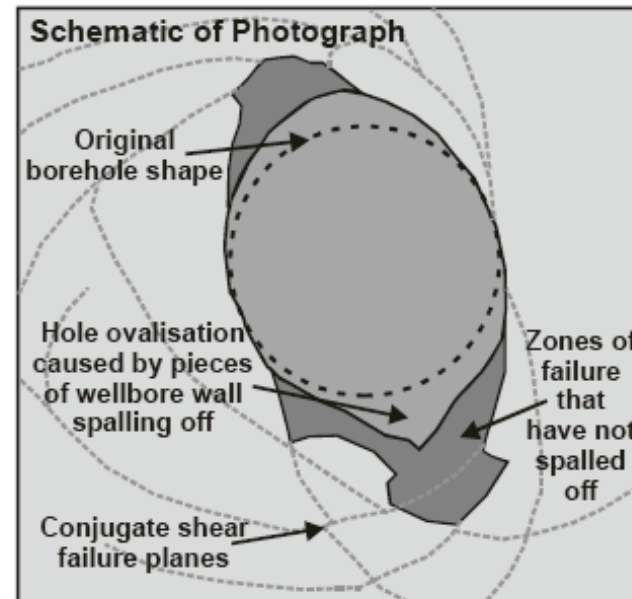
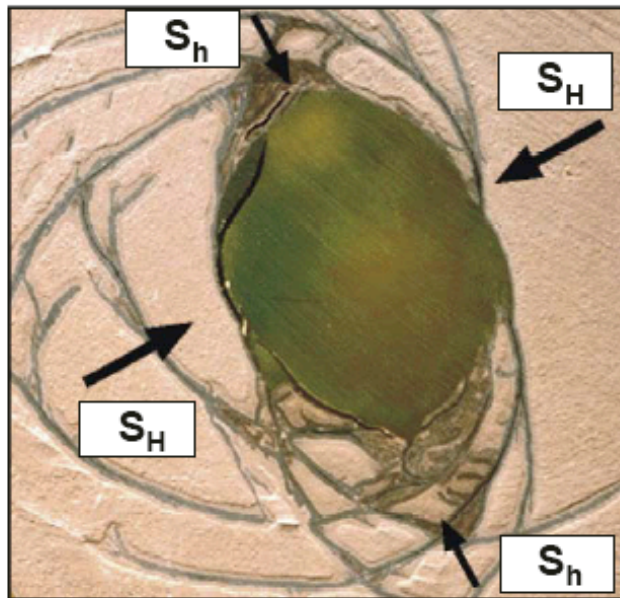
Hydrofracturing



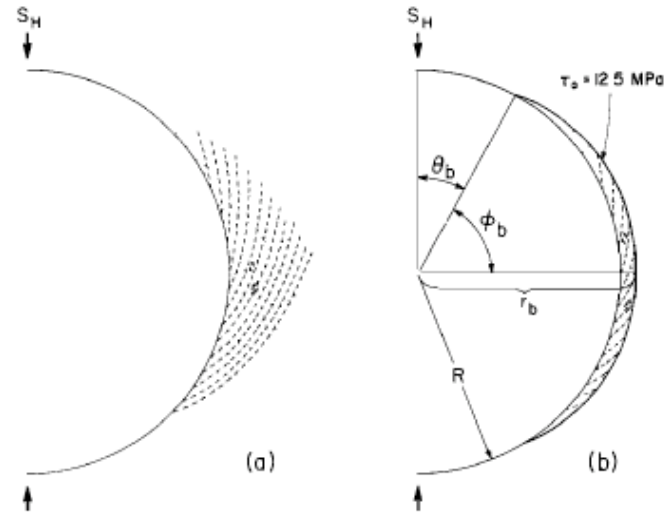
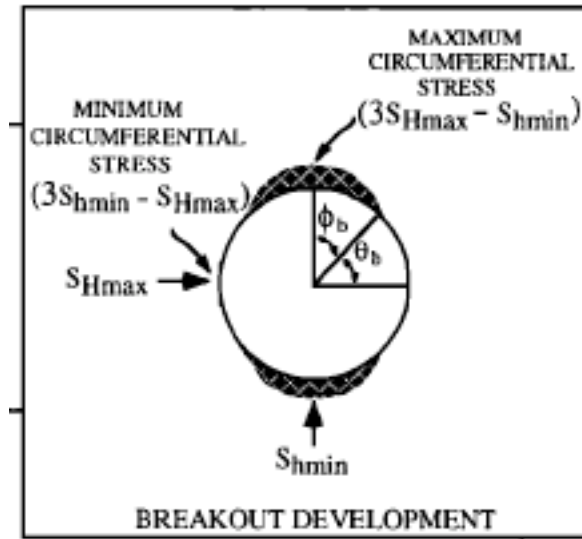
$$P_b = T + 3S_{Hmin} - S_{Hmax} - P,$$

where T is the tensile strength of the rock and P is the static pore pressure in the rock surrounding the borehole. As T and P can be determined independently, Equation (1) allows S_{Hmax} to be determined. Assuming that one of the principal stresses is oriented vertically, the third principal stress can be estimated from $S_v = \rho g H$, where ρ is the average density, g is gravity, and H is the depth to the interval that is isolated by packers.

Wellbore Breakouts



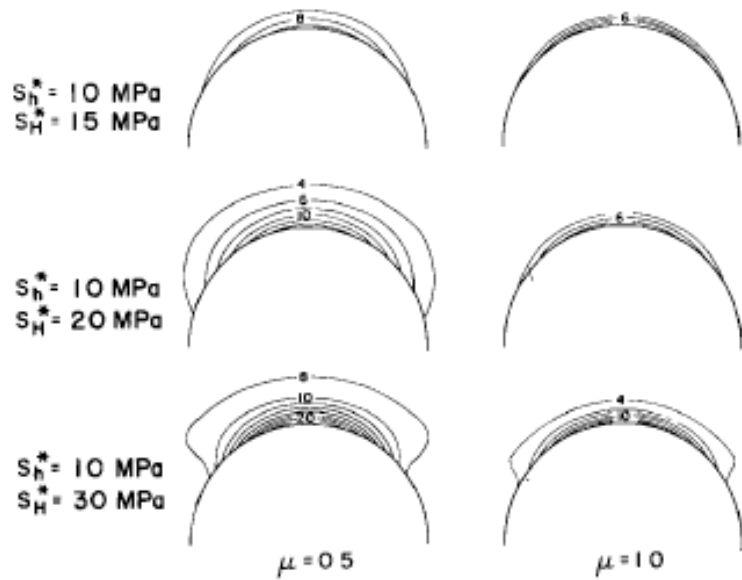
Wellbore Breakouts



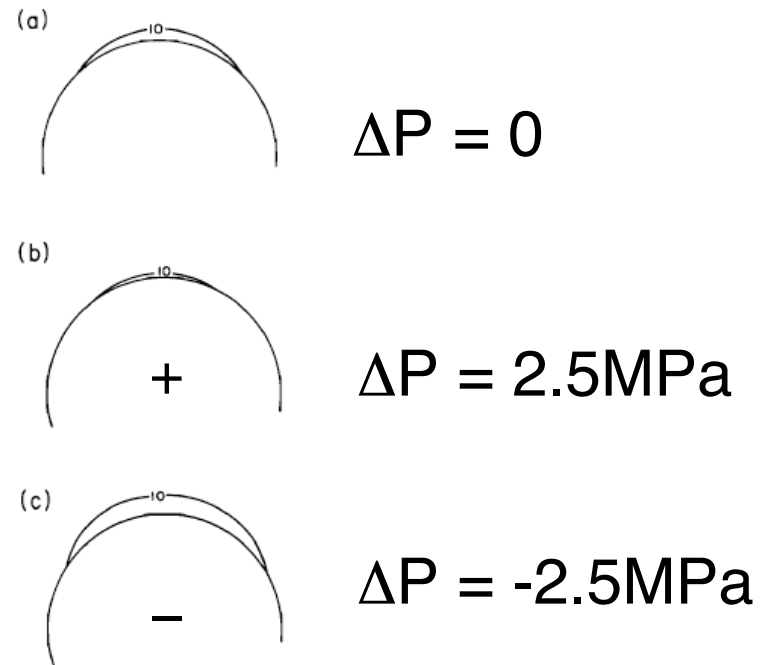
$$S_c = S_H + S_h - 2(S_H - S_h)\cos 2\Theta_b - \Delta P_b$$

$$\tau_o = S_c, \text{ at } \Theta_b = \Pi/2 - \Phi_b$$

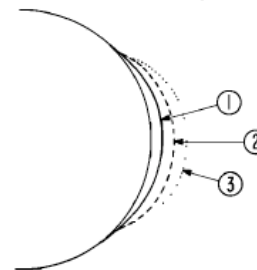
Effects of ΔS_H and friction



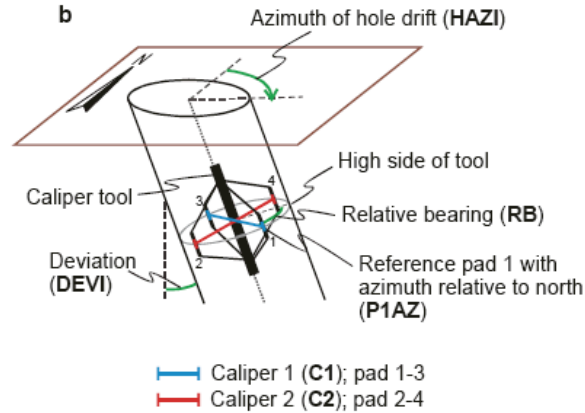
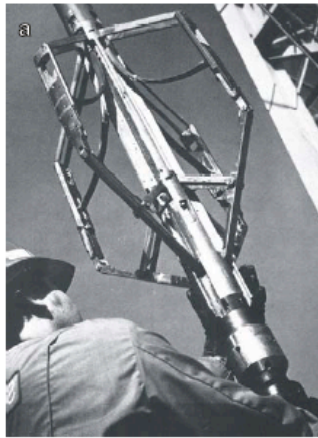
Effect of Borehole Pressure



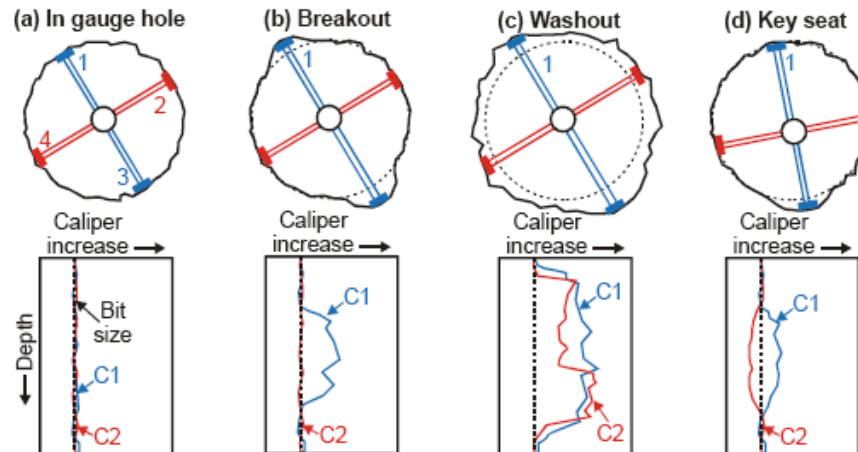
BREAKOUT SHAPES UNDER SUCCESSIVE EPISODES OF FAILURE



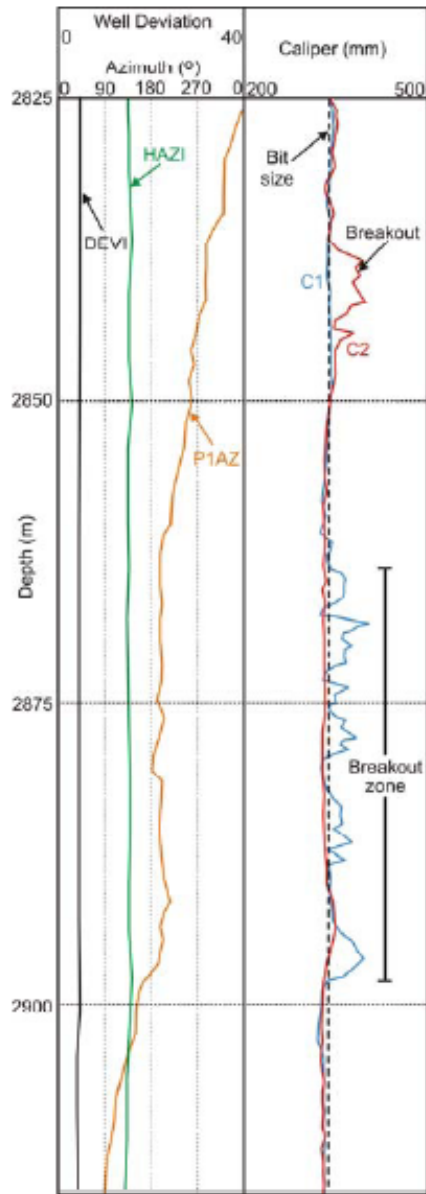
4-arm caliper tool



$$P1AZ = HAZI + \text{atan} \frac{\tan RB}{\cos DEVI}$$



4-arm caliper log



[6]

NORTHEAST-SOUTHWEST COMPRESSIVE STRESS IN ALBERTA EVIDENCE FROM OIL WELLS

J S BELL

BP Canada Ltd., 333 5th Ave S W, Calgary, Alta T2P 3B6 (Canada)

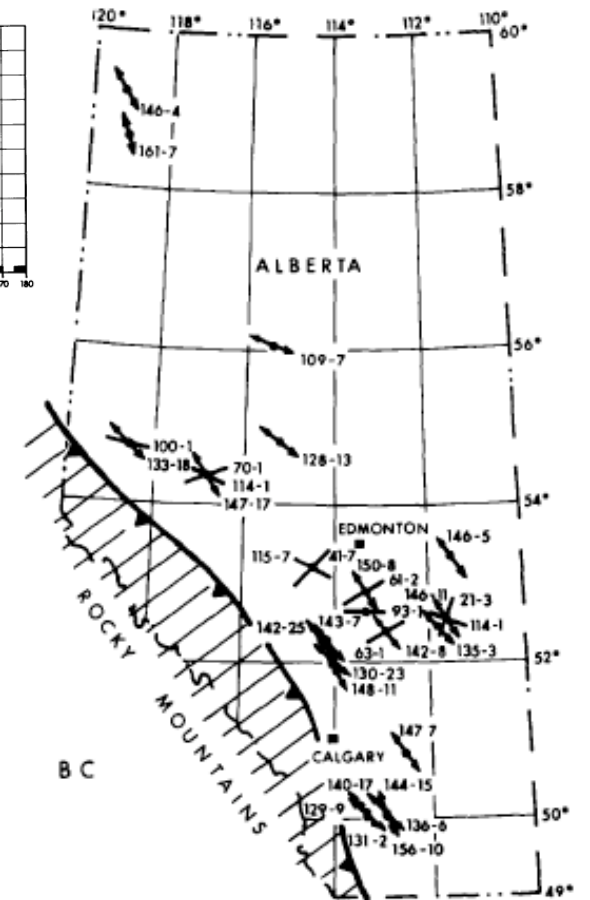
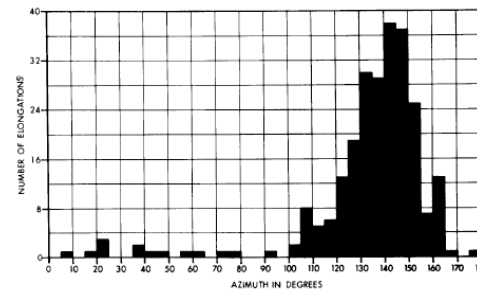
and

D I GOUGH

Institute of Earth and Planetary Physics, University of Alberta, Edmonton, Alta T6G 2J1 (Canada)

Received April 10, 1979

Revised version received June 18, 1979



Acoustic Televiewer (BHTV) tool

The Borehole Televiewer 255

are presented as a continuous record. Features are easily followed throughout any interval of the borehole.

TOOL DESCRIPTION

A schematic of the televiewer logging tool is shown in Figure 1. High frequency sound (about 2 megahertz) from an acoustic transducer, pulsed at a rate of about 2000 times a second, is used to survey the borehole walls. A flux-gate magnetometer senses the earth's magnetic field and provides orientation information in open hole. A motor

rotates the transducer and flux-gate magnetometer within the tool about three times a second. Although the transducer has a diameter of only a half-inch, the sound emitted is confined to a very narrow beam because of the high operating frequency. Pulses of sound are directed toward the borehole wall where a portion of each pulse is reflected back toward the transducer. The transducer converts the reflected sound pulses into electrical signals; these are utilized at the surface for producing the televiewer log. The combination of transducer rotation with a continuous

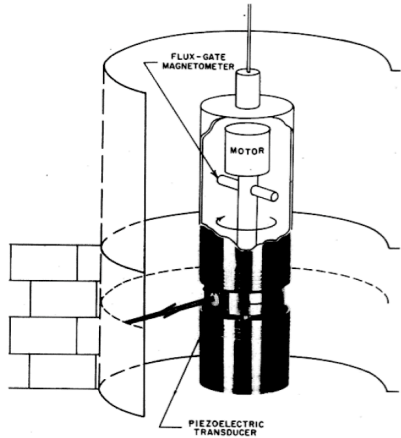
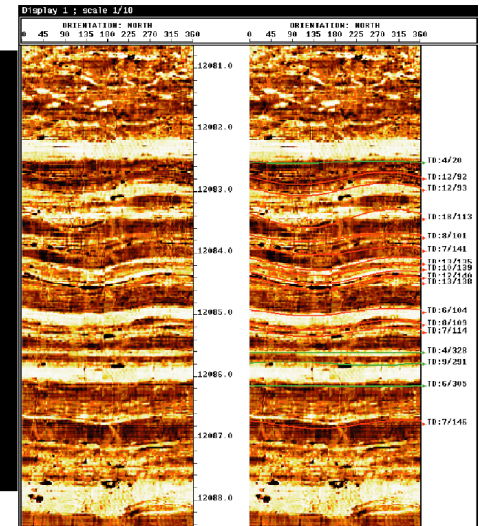
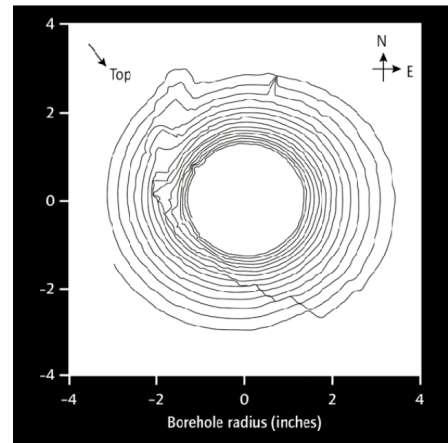
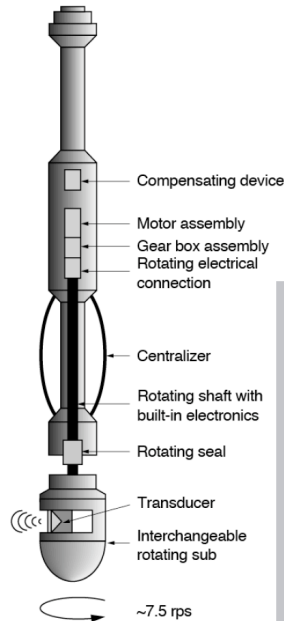
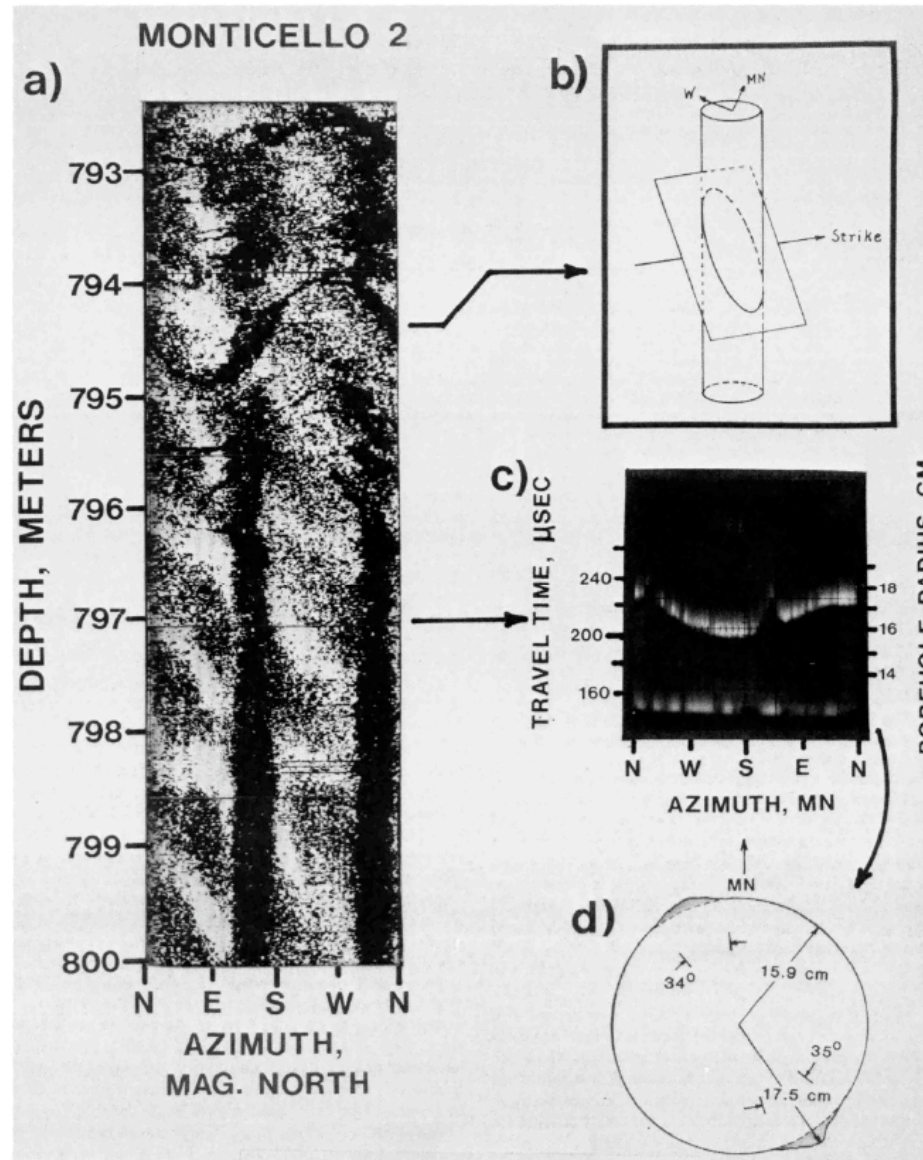


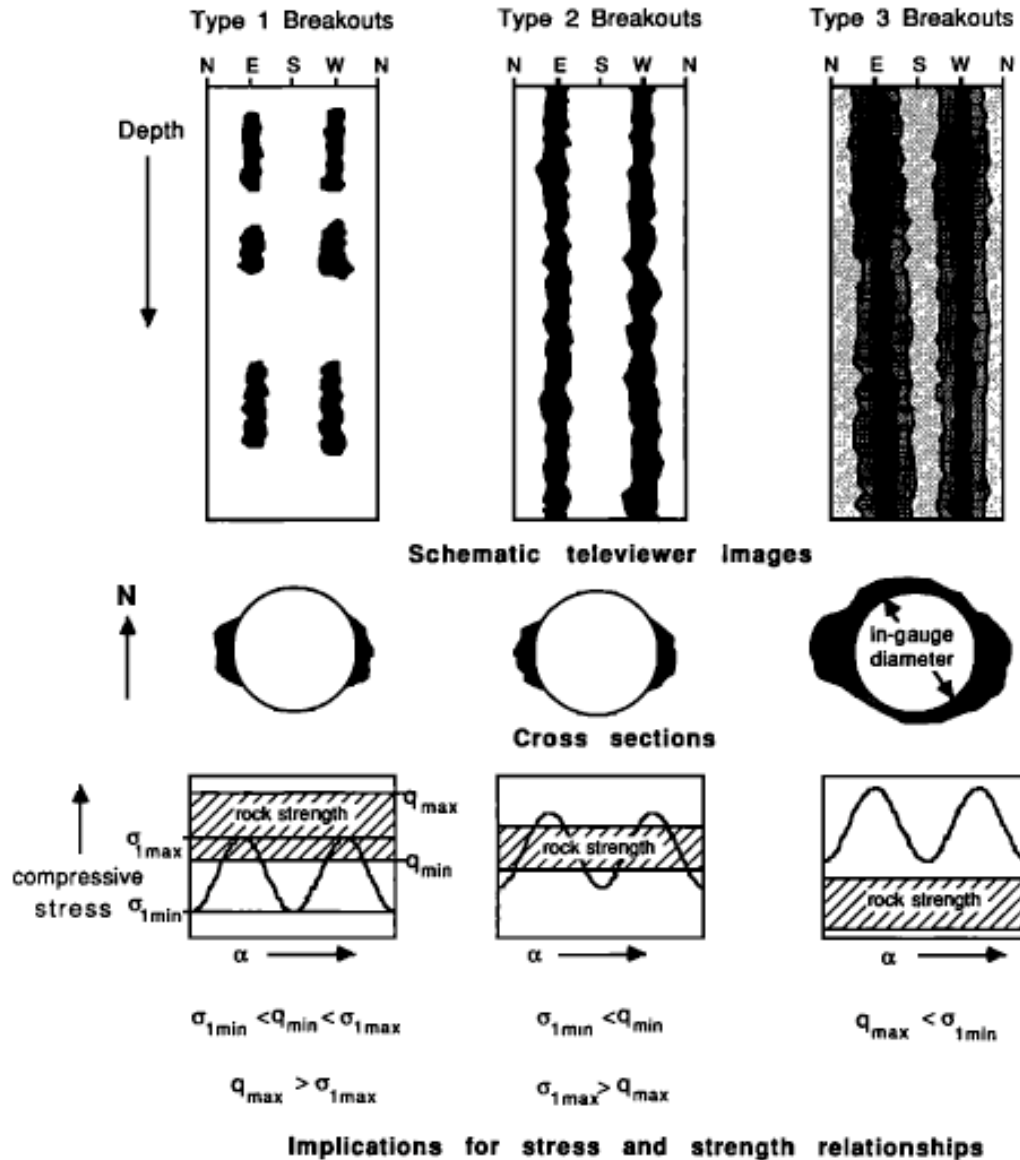
FIG. 1. Schematic layout of televiewer showing scanning acoustic transducer, magnetic north sensing magnetometer, and driving motor.



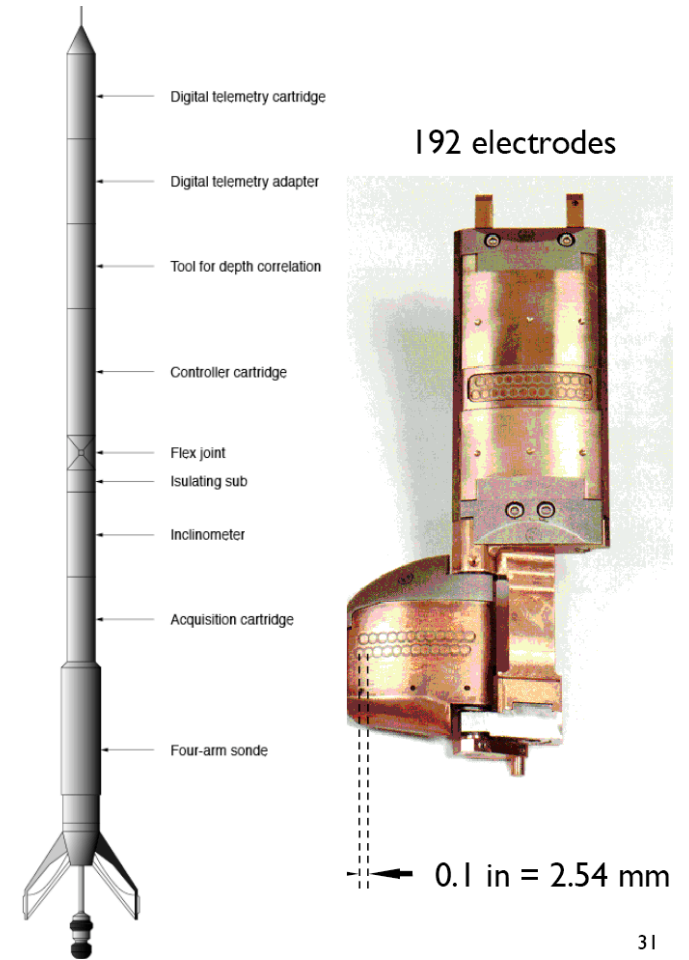
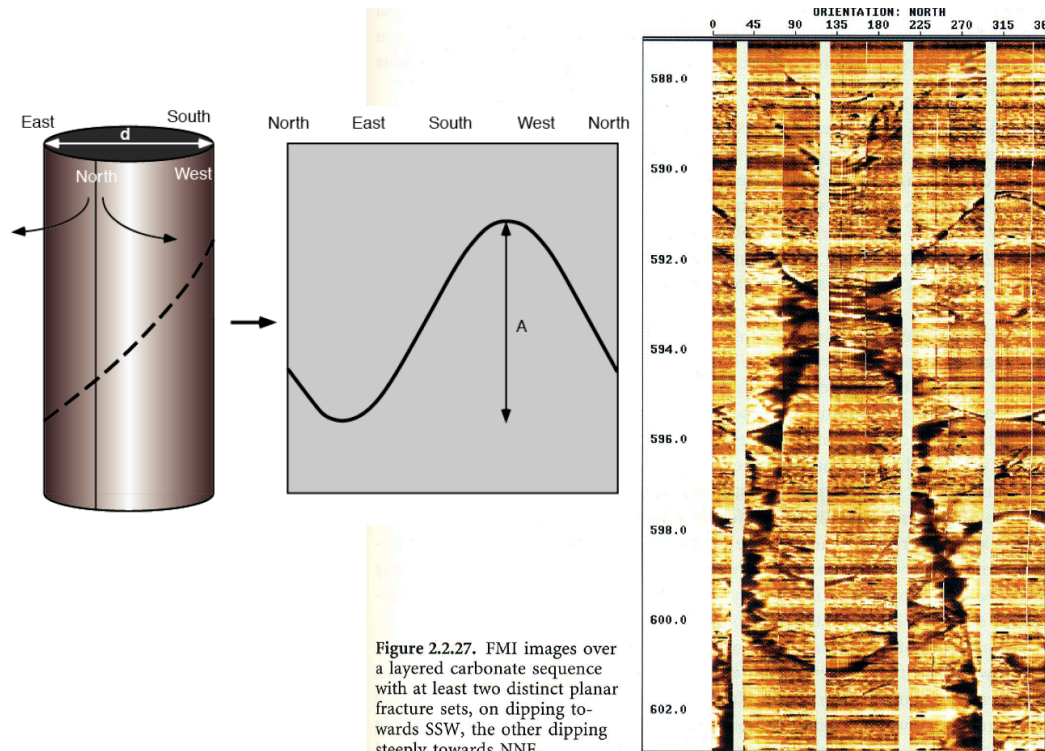
BHTV breakout image



BHTV breakout logs



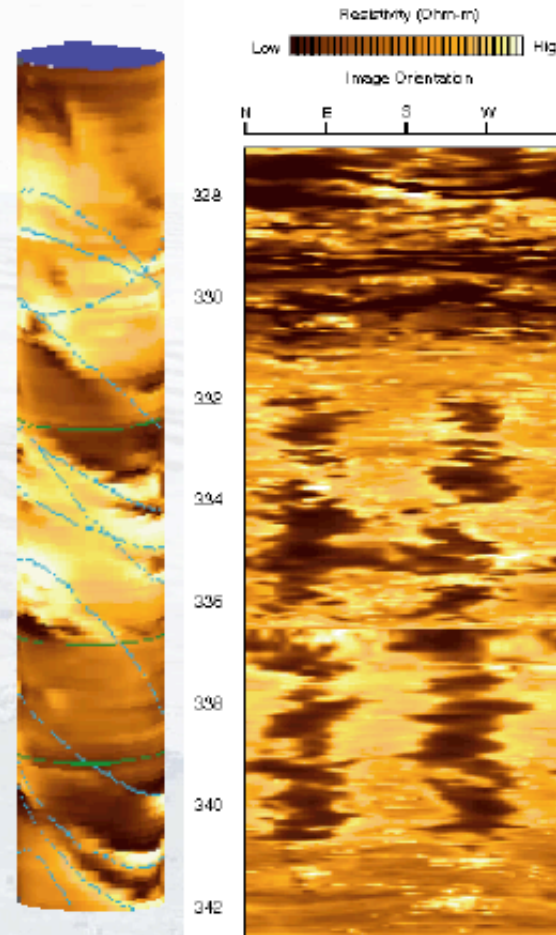
Resistivity (FMS/FMI) tools



Resistivity (LWD) tools

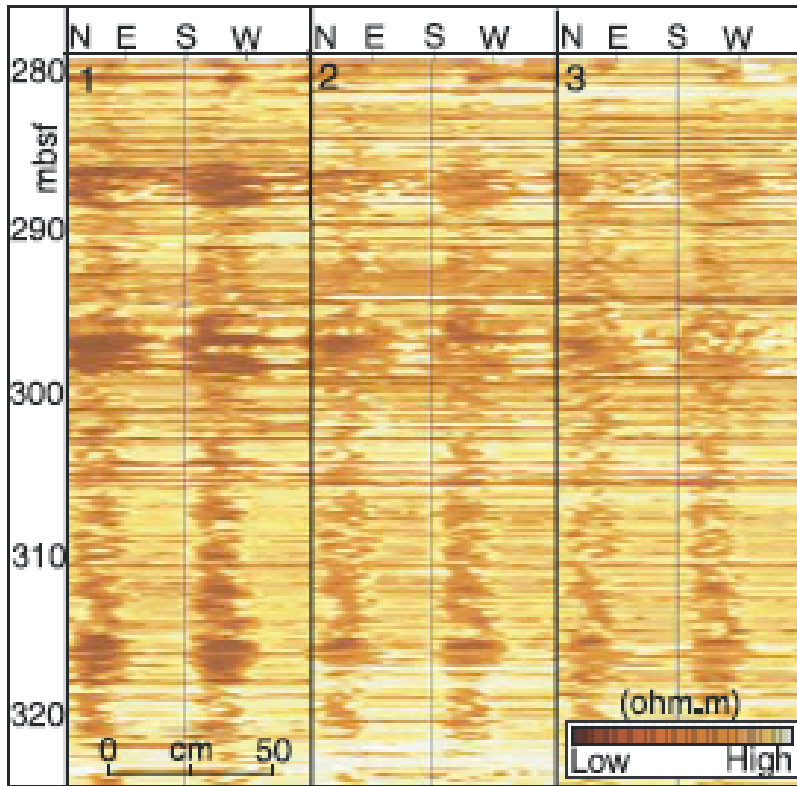
Resistivity Images

- geoVISION Resistivity (6-3/4)
- Resistivity-at-the-Bit (8-1/4)
- Laterolog, like FMS/FMI

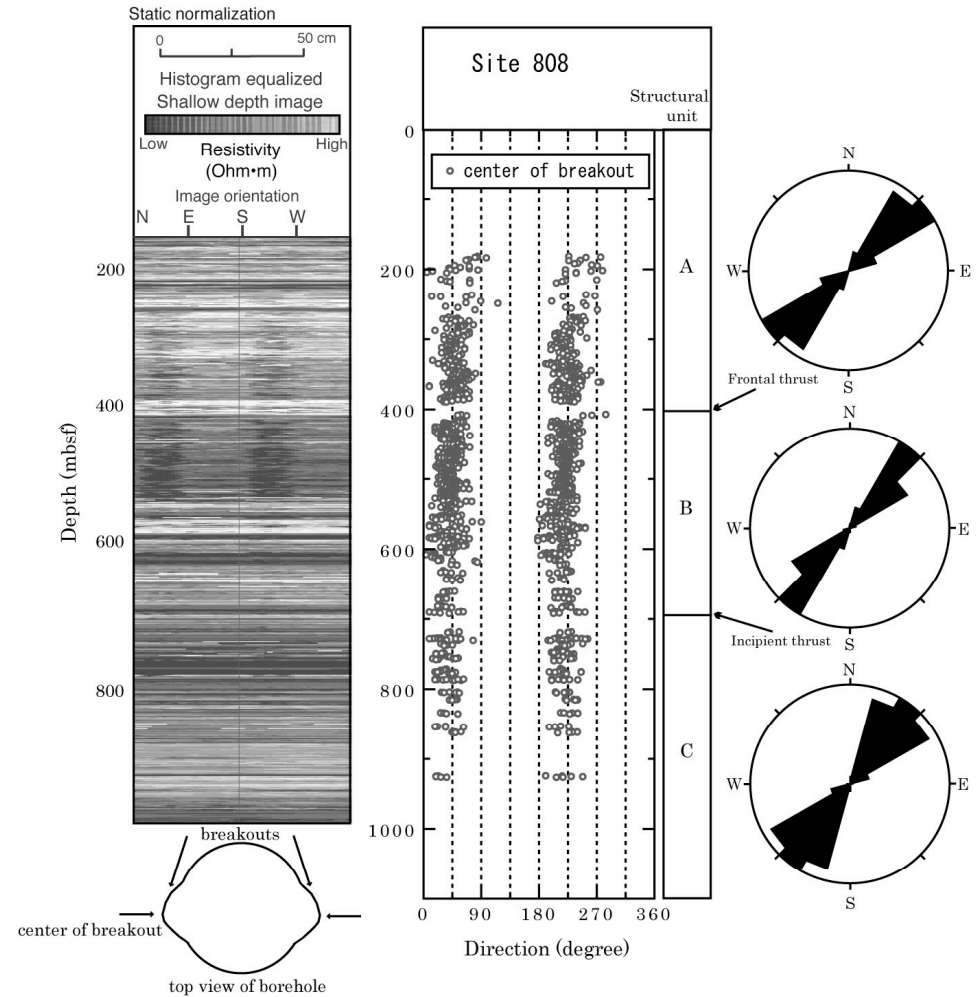


LWD Breakout images

e.g. Nankai trough

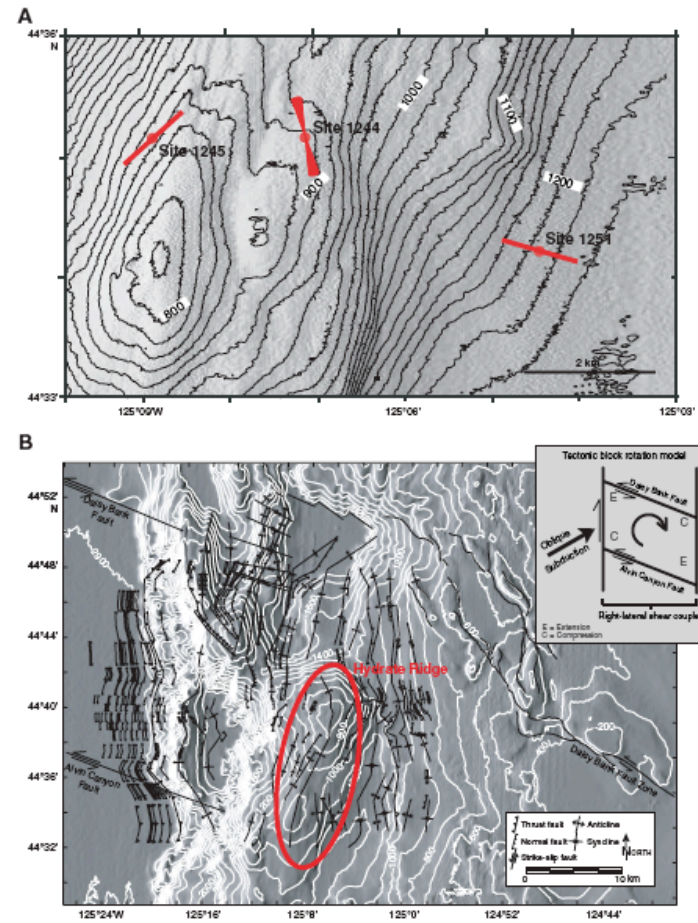
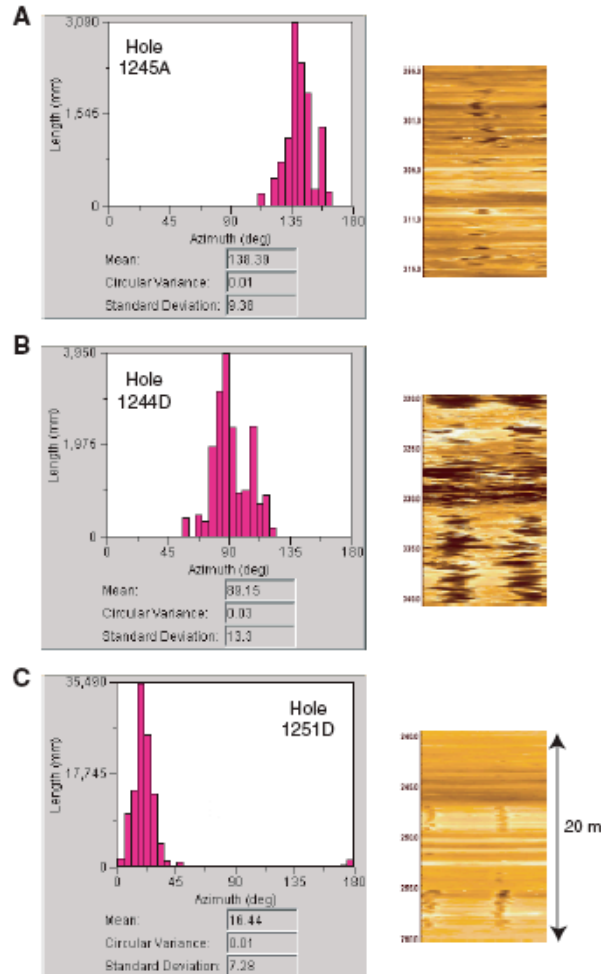


shallow medium deep



LWD Breakout orientation

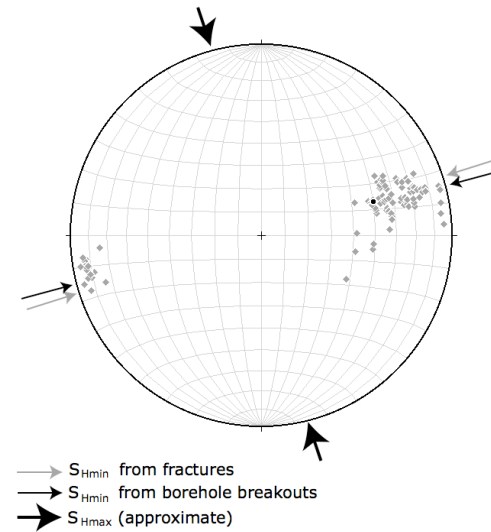
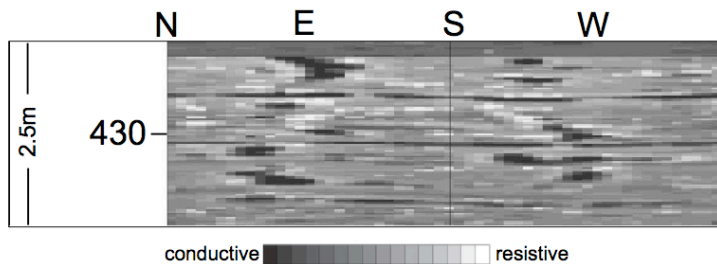
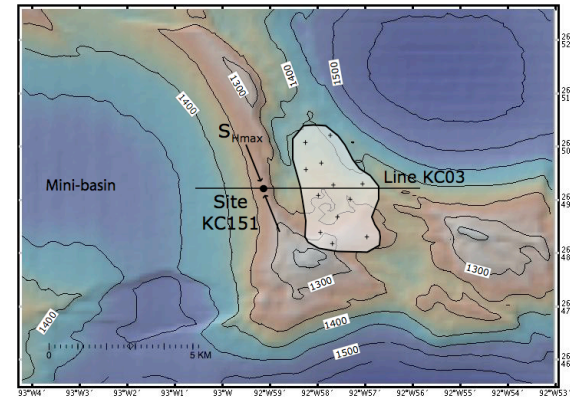
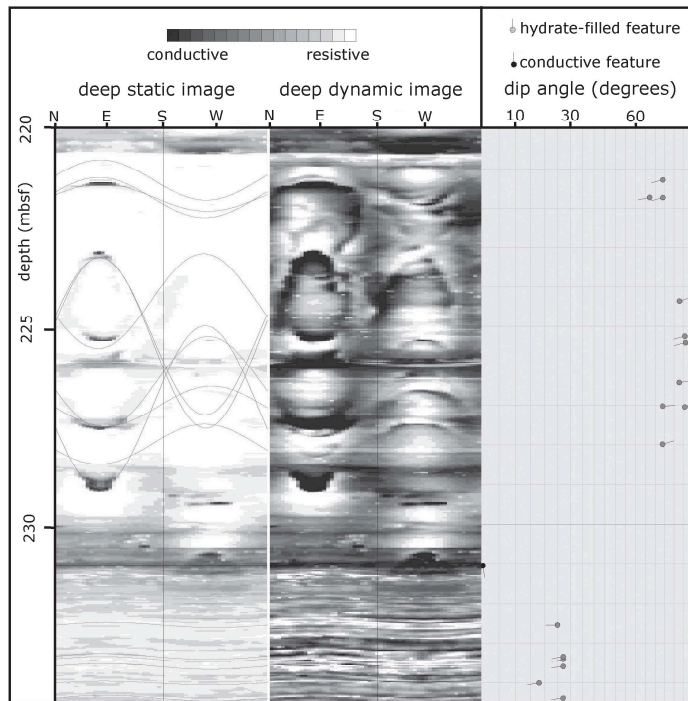
e.g. Oregon Margin



Breakouts and Fractures

(present-day stress) (paleo-stress)

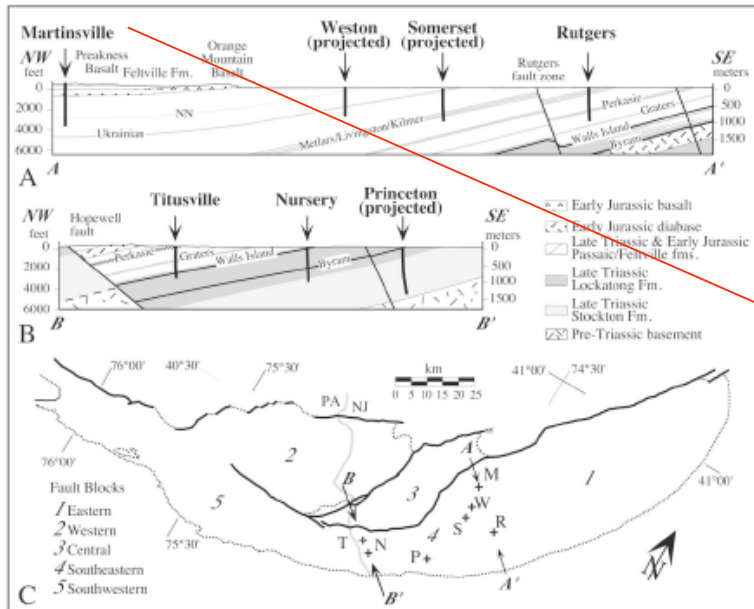
e.g. Gulf of Mexico



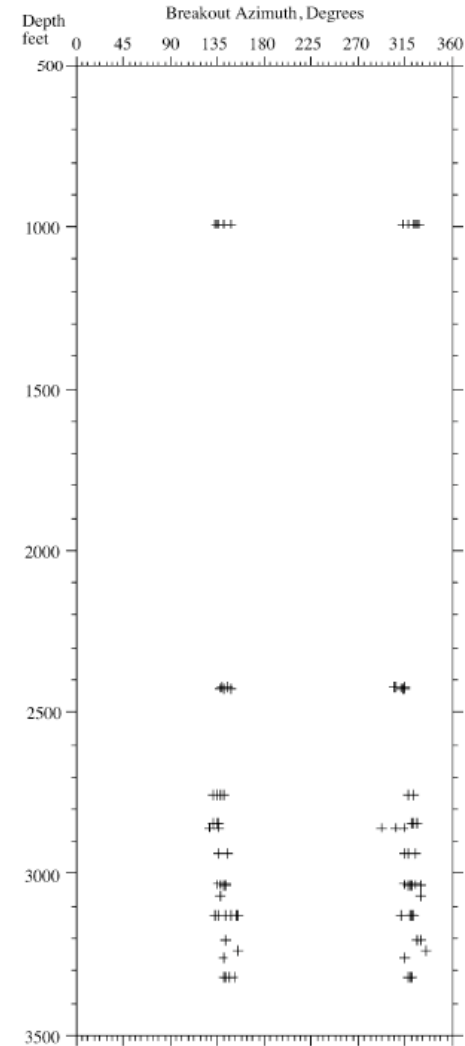
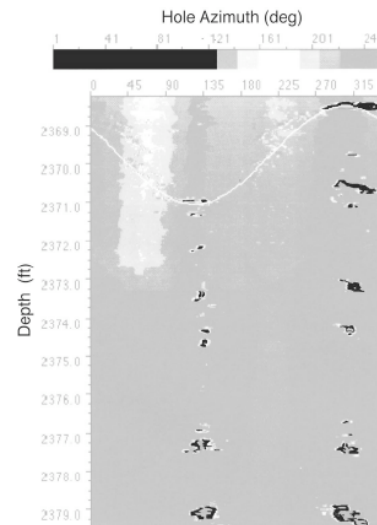
Breakouts and Fractures

(present-day stress) (paleo-stress)

e.g. Newark Basin



BHTV

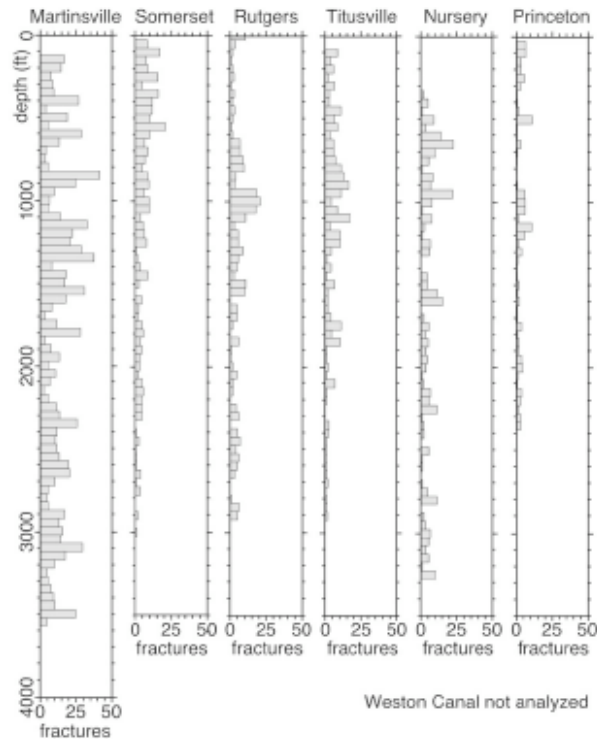
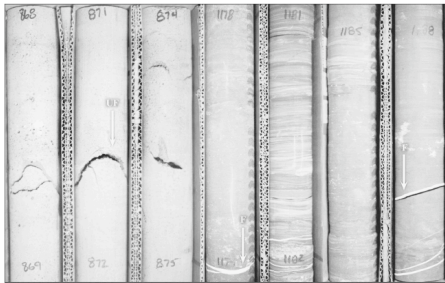


Breakouts and Fractures

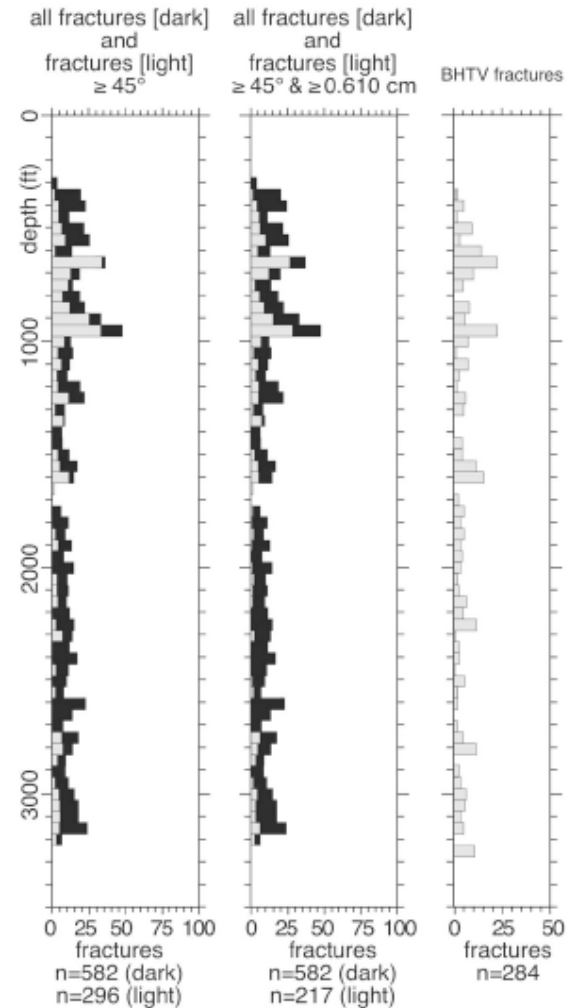
(present-day stress) (paleo-stress)

e.g. Newark Basin

Core fractures



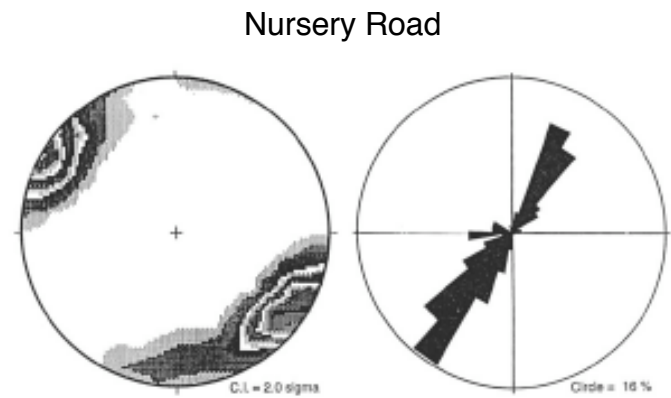
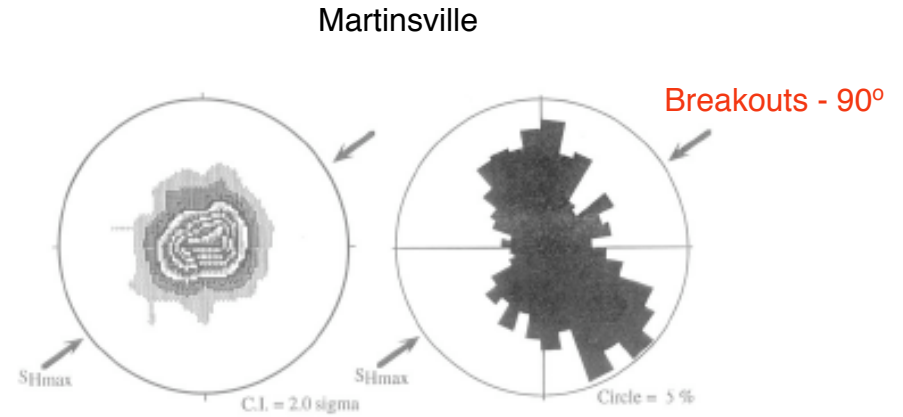
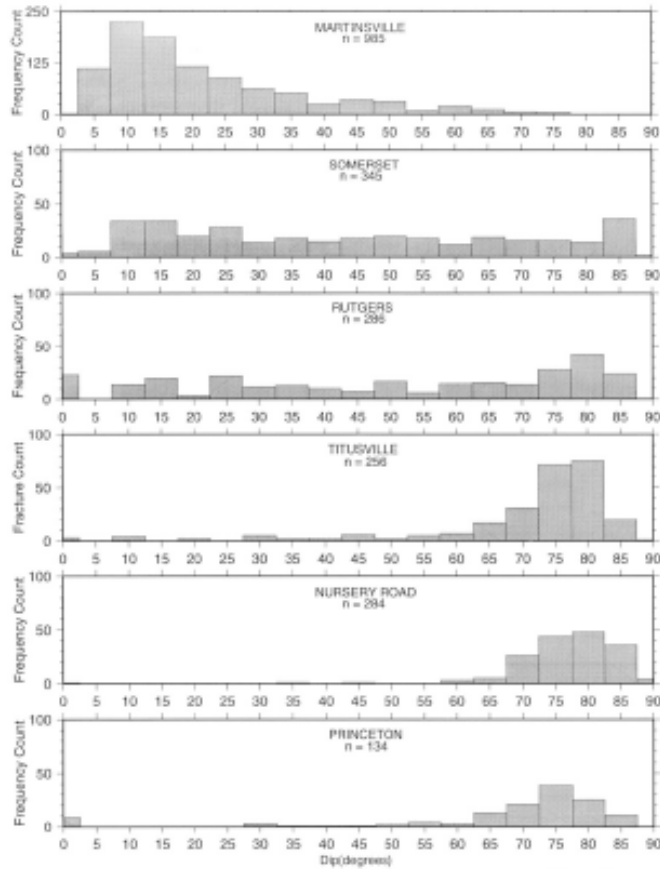
Core vs BHTV



Breakouts and Fractures

(present-day stress) (paleo-stress)

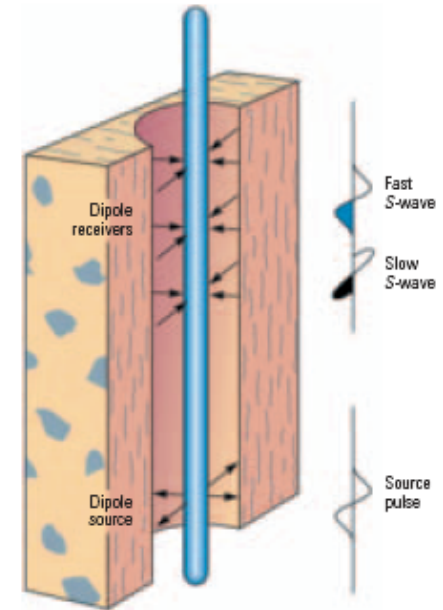
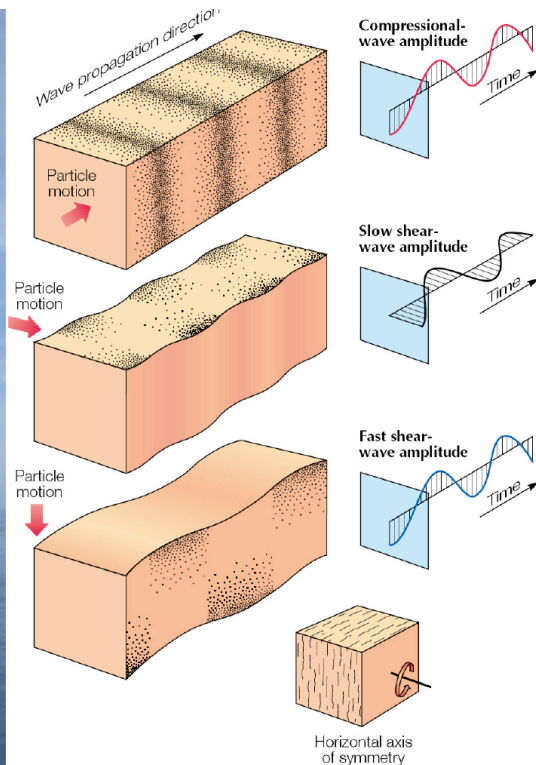
e.g. Newark Basin



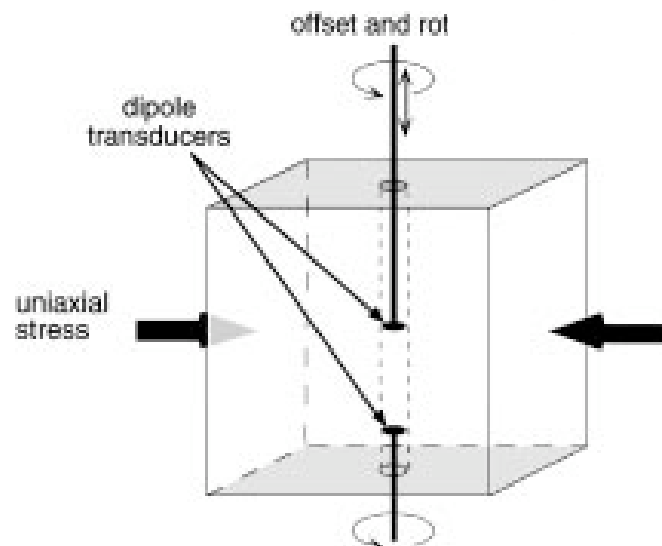
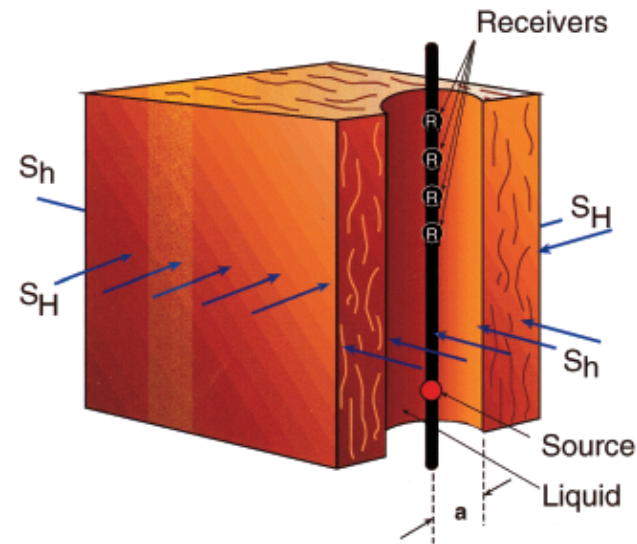
Elastic wave anisotropy

Shear waves splitting

- ▶ Wave propagate faster when the direction of particle motion is parallel to the direction of greatest stiffness
- ▶ The “fast” shear wave will travel in the direction of maximum horizontal stress

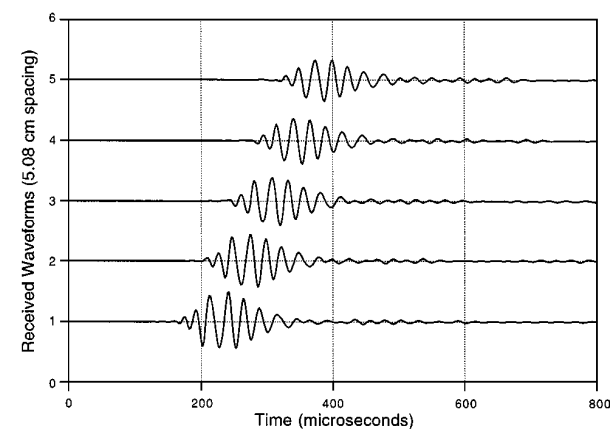


Stress-induced anisotropy - ?



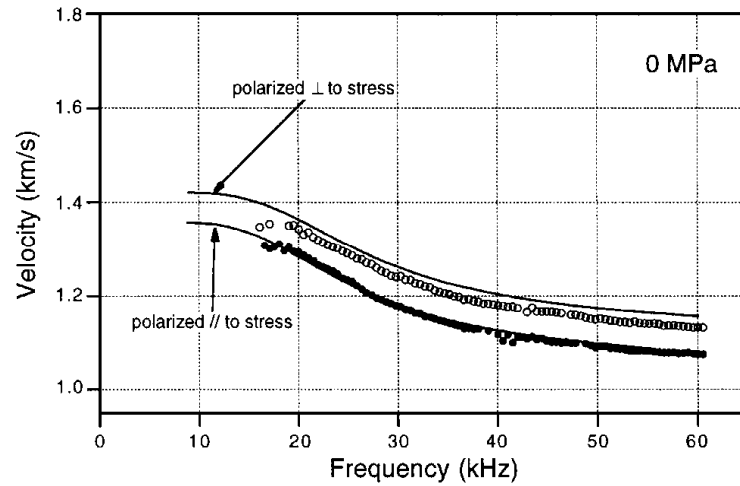
Winkler et al. (1998)

Dipole waveforms

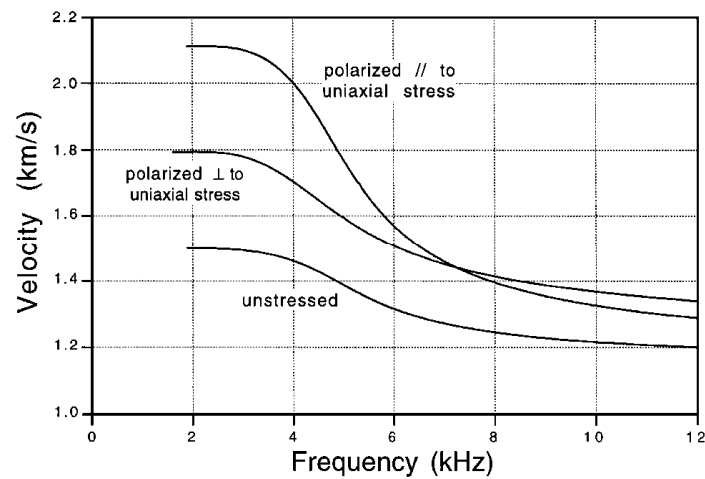
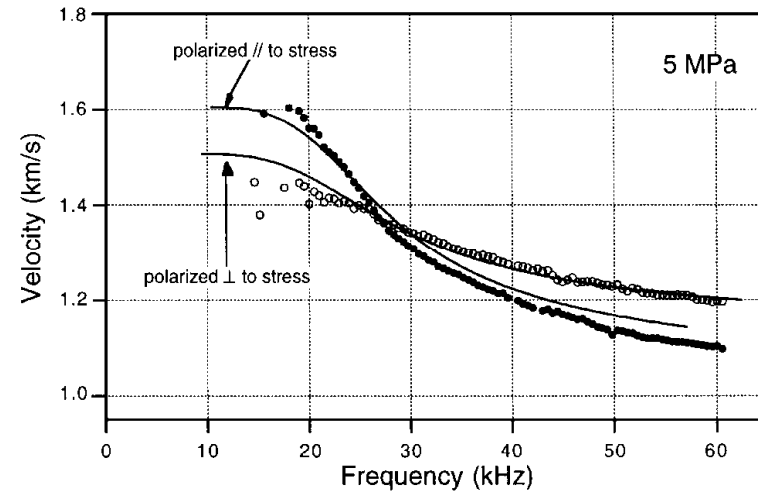


Stress-induced dispersion

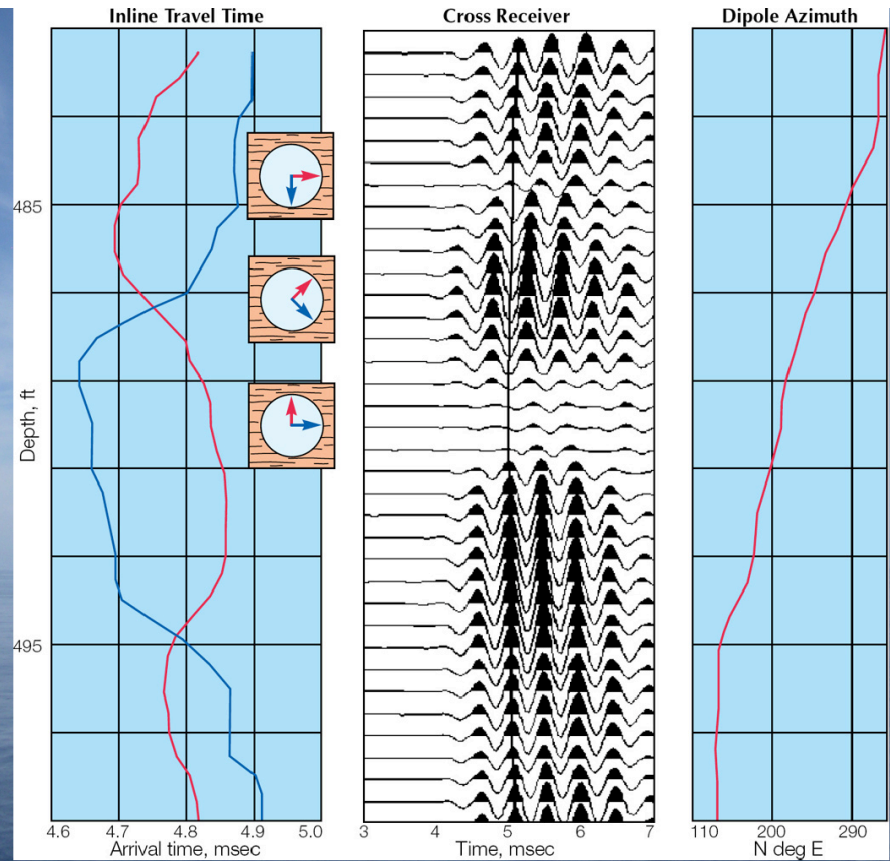
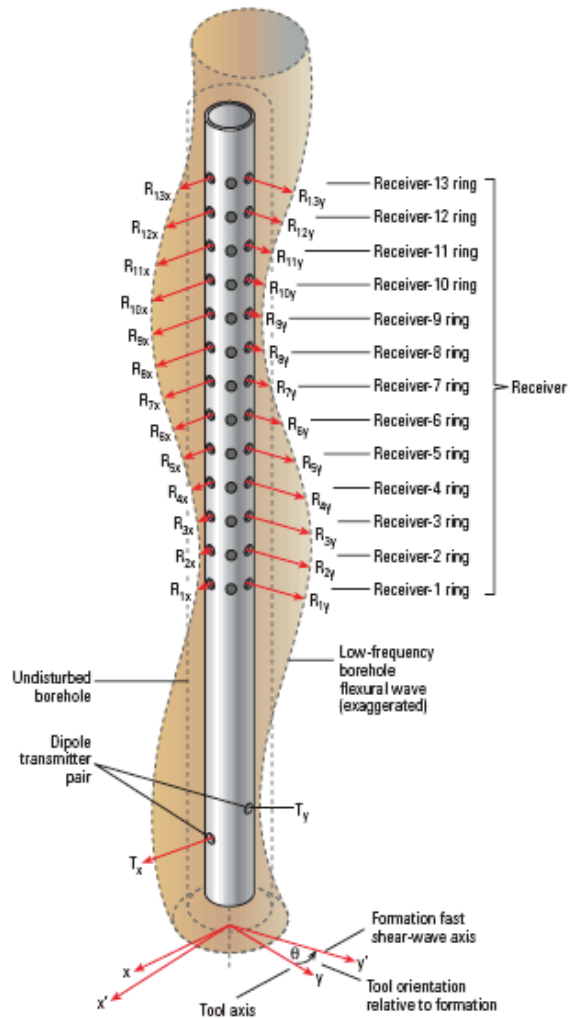
V_s dispersion



V_{fast} crossover

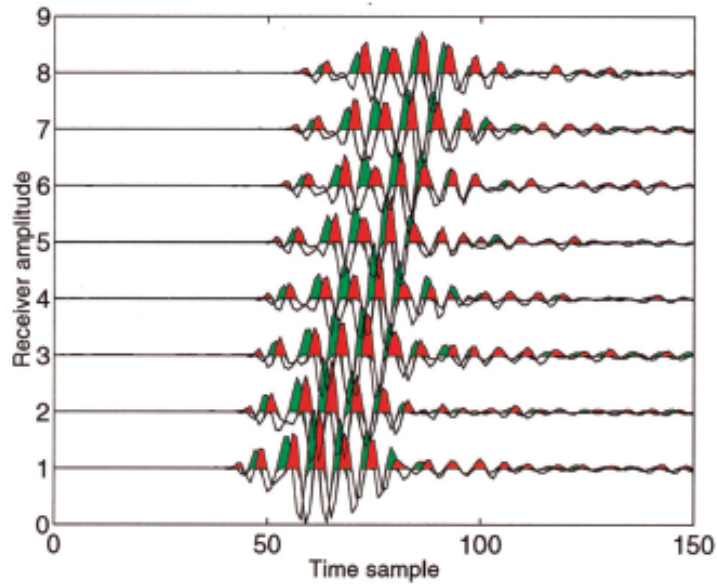


Cross-dipole Vs logging

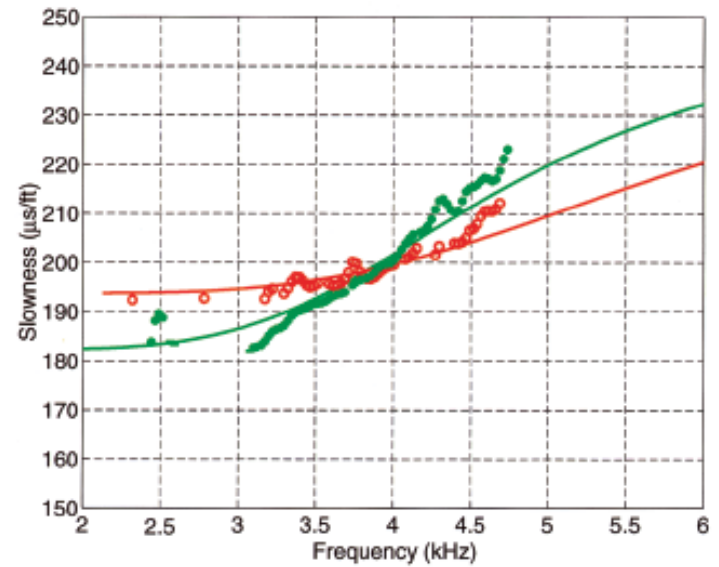


Stress-induced anisotropy

Rotated dipole waveforms

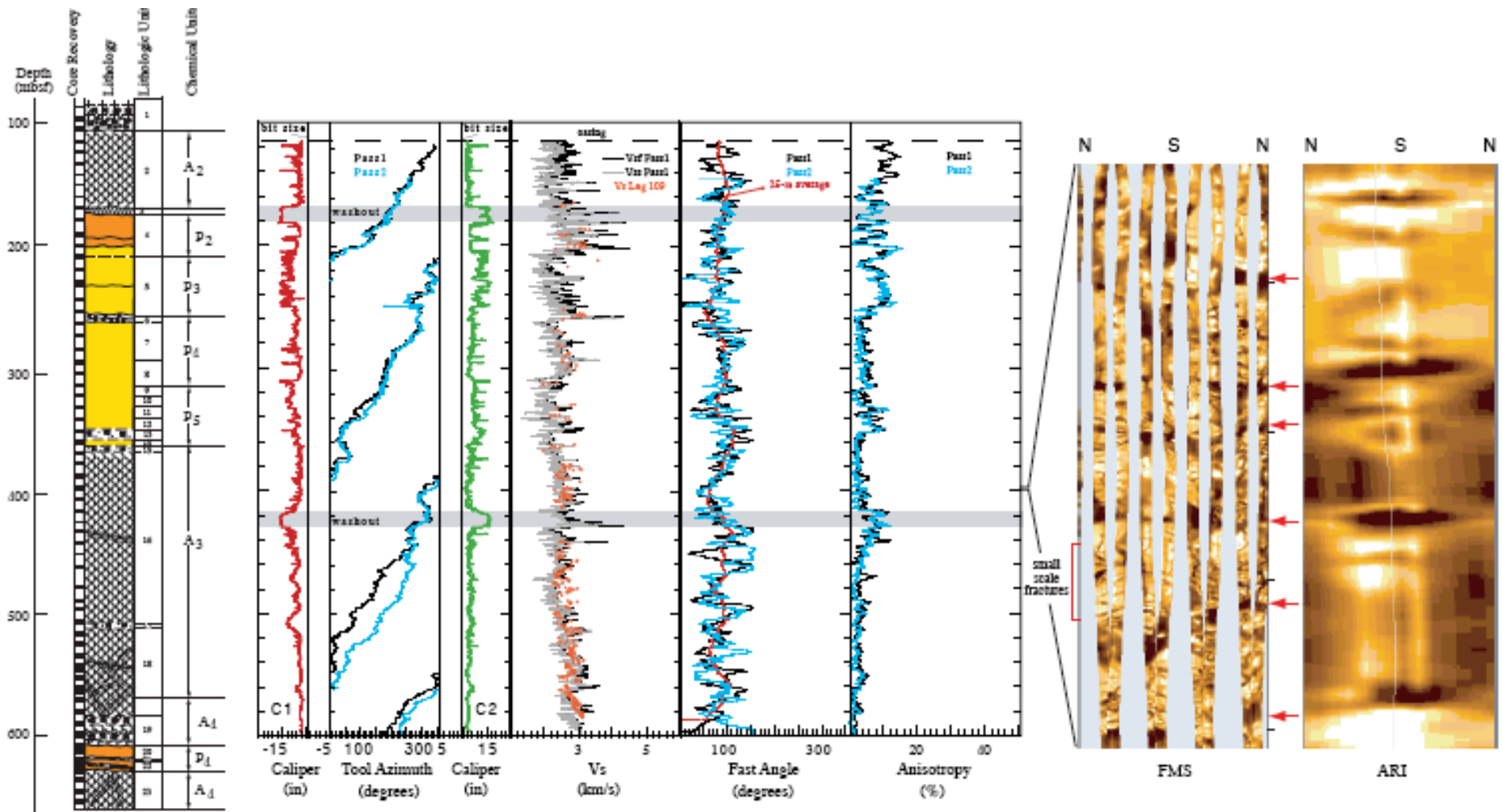


Dispersion crossovers



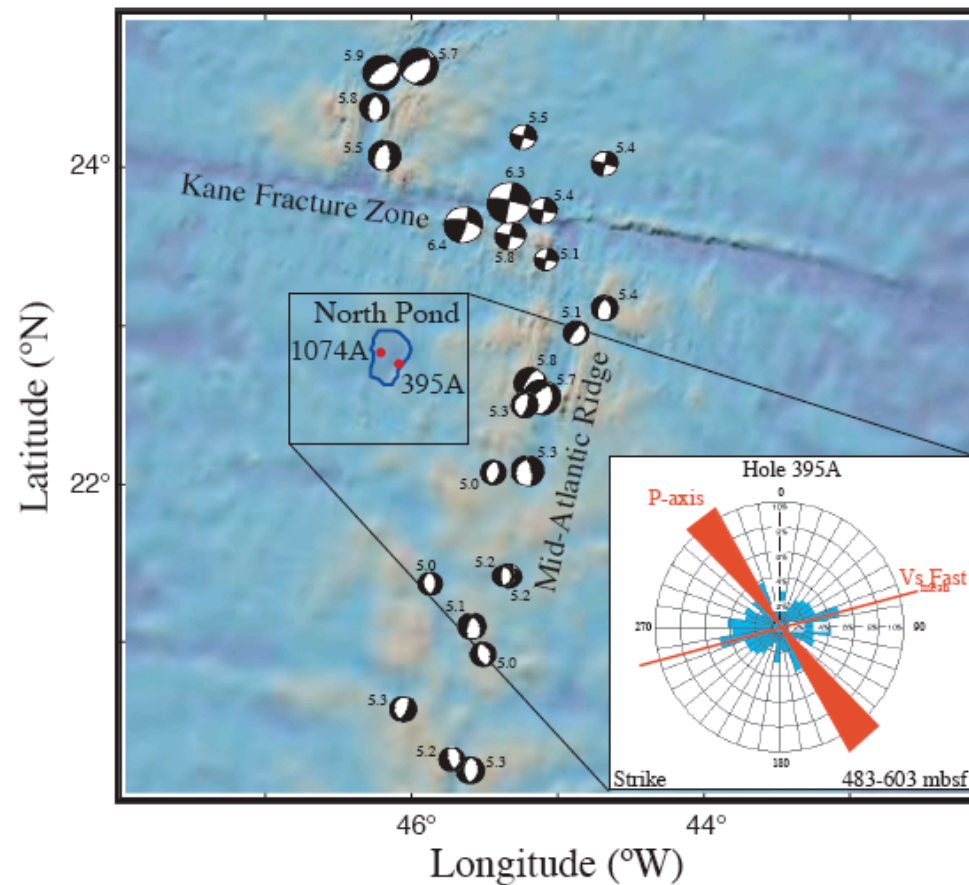
Stress-induced anisotropy

e.g. Kane Fracture Zone



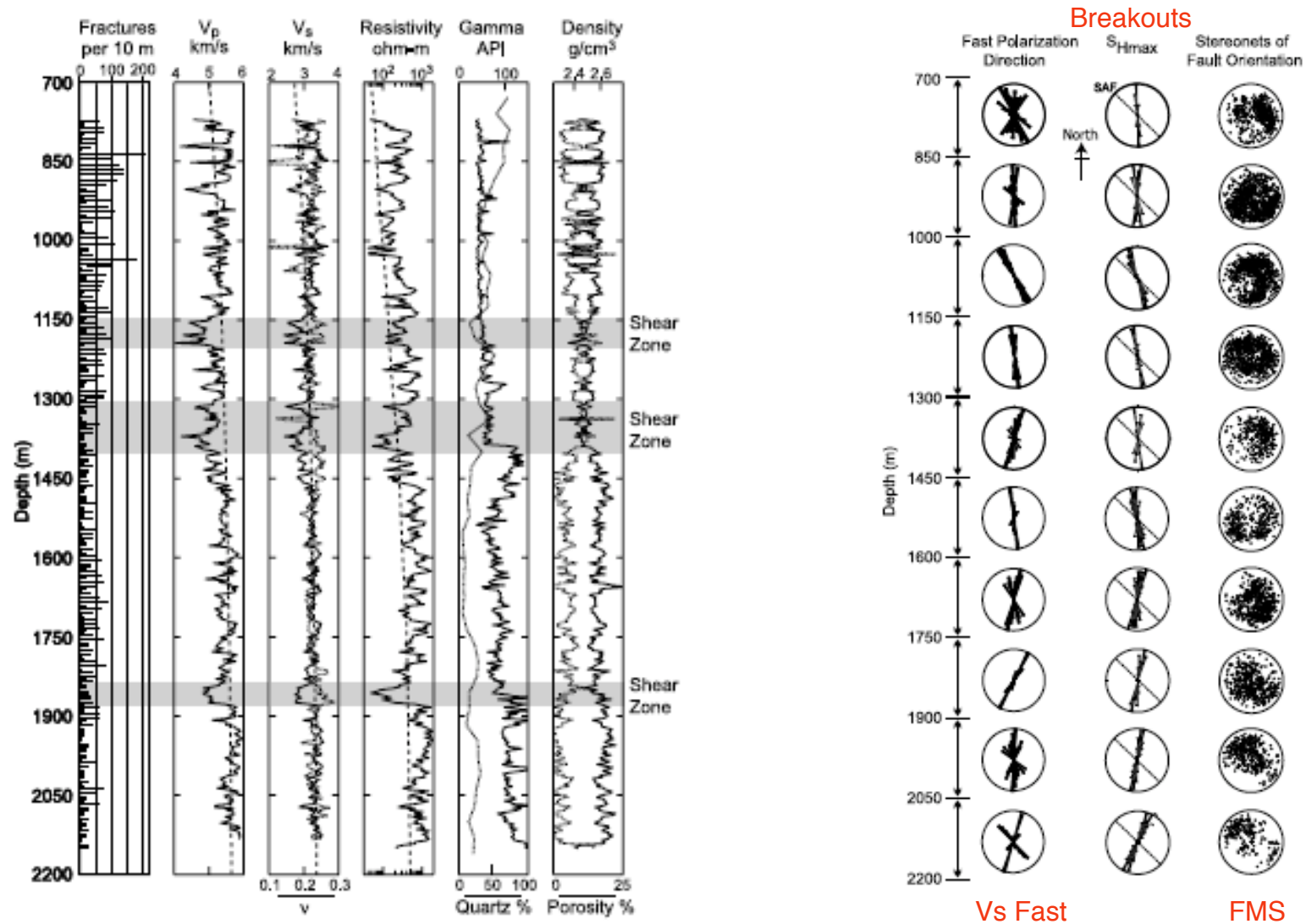
Stress-induced anisotropy

e.g. Kane Fracture Zone



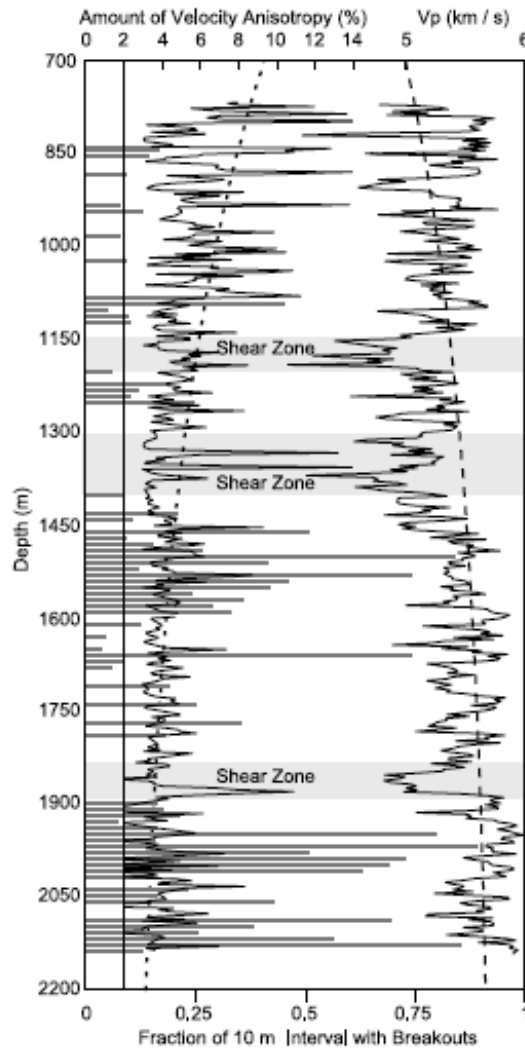
Stress-induced anisotropy

e.g. San Andreas Fault



Stress-induced anisotropy

e.g. San Andreas Fault



No Breakouts, high Anisotropy

=> Stress relief zones