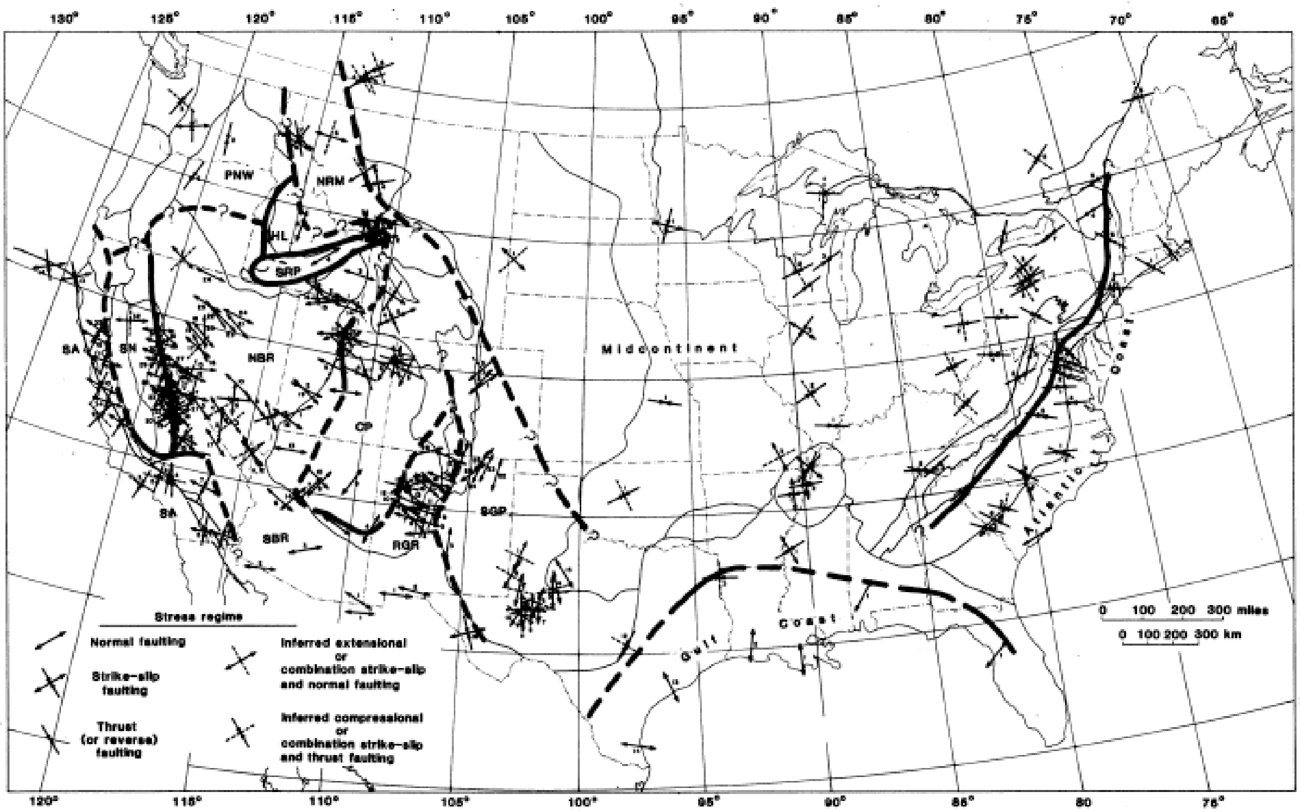
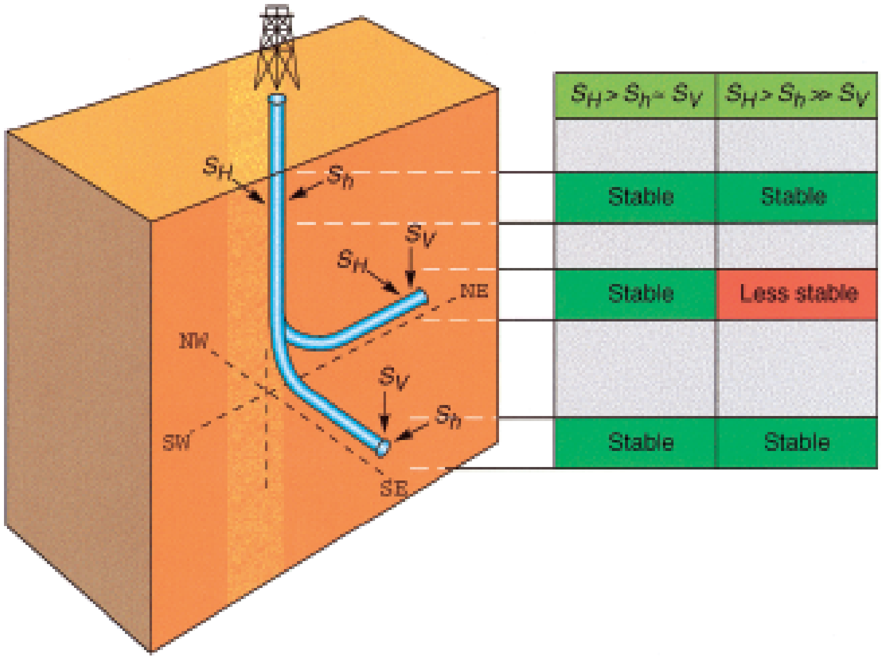
Well Logging Principles and Applications
G9947 - Seminar in Marine Geophysics
Spring 2008

In situ STRESS estimation

Why do we care about in situ stress?



Wellbore (& foundation) stability



$S_H > S_h \approx S_V$	$S_H > S_h \gg S_V$
Stable	Stable
Stable	Less stable
Stable	Stable

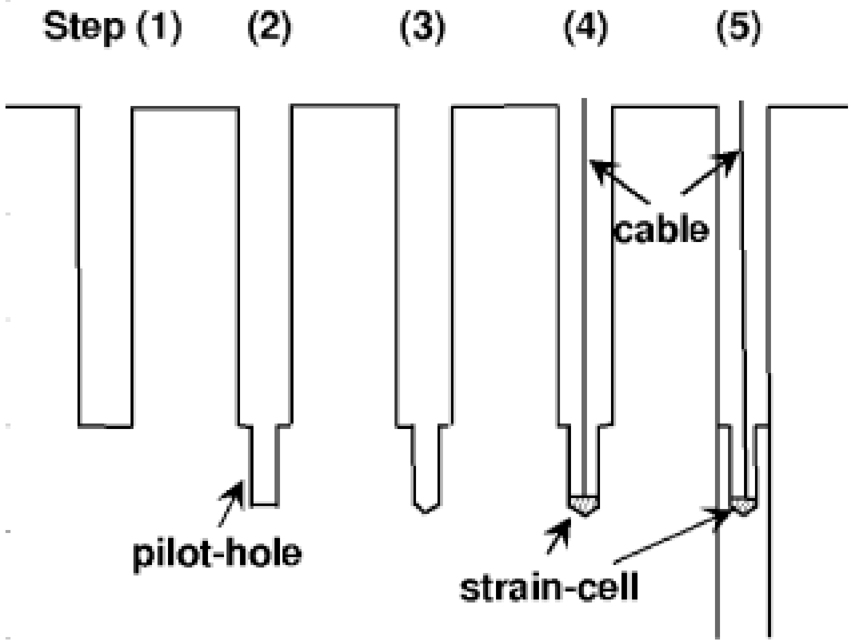
S_H = max. Horizonatal stress
S_h = min. horizonatal stress
S_v = vertical stress

Sources of in situ stress information:

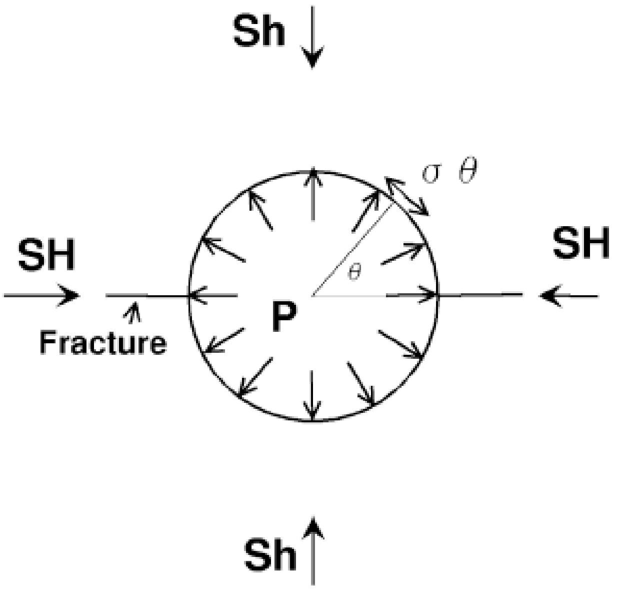
1. Earthquake focal mechanisms
2. Wellbore breakouts*
3. Hydrofracturing*
4. Elastic-wave anisotropy*
5. Overcoring* / doorstoppers
6. Quaternary fault slip
7. Alignment of volcanoes

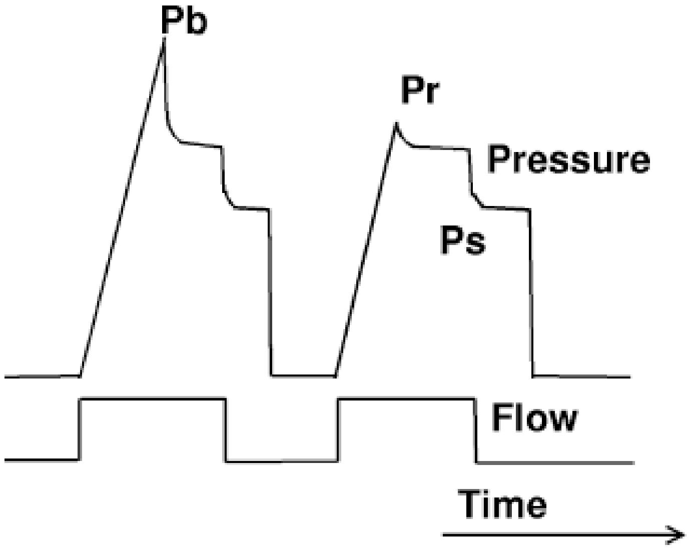
*borehole methods

Overcoring - in situ stress relief

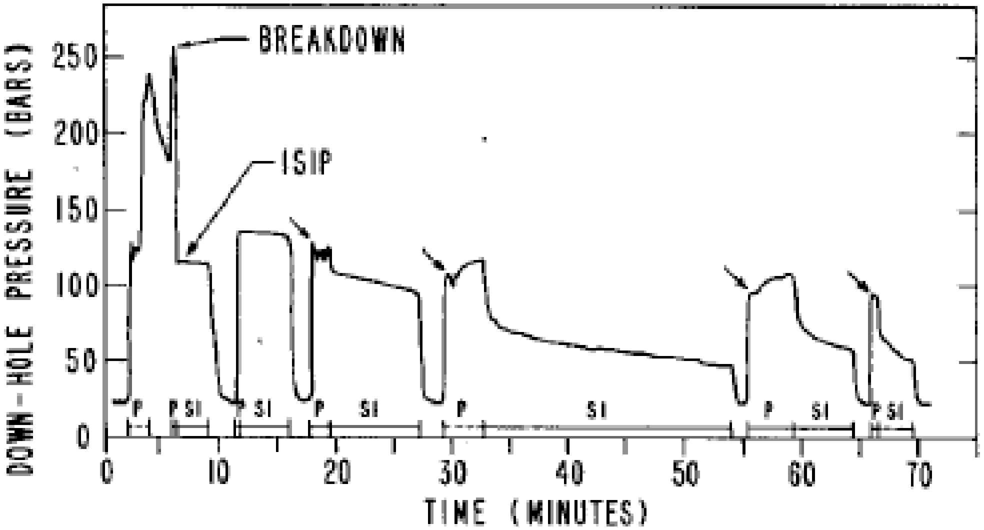


Hydrofracturing





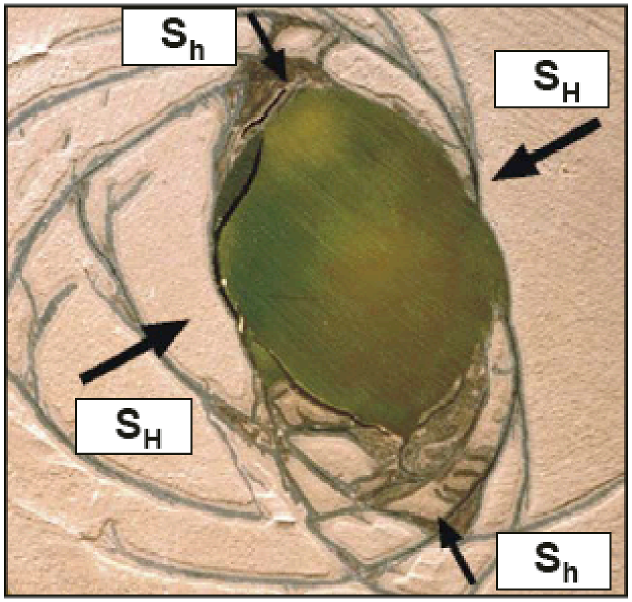
Hydrofracturing

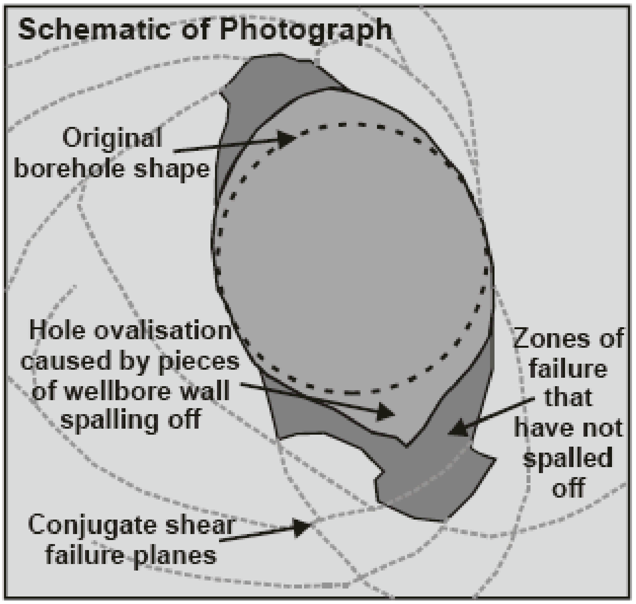


$$P_b = T + 3S_{H\min} - S_{H\max} - P,$$

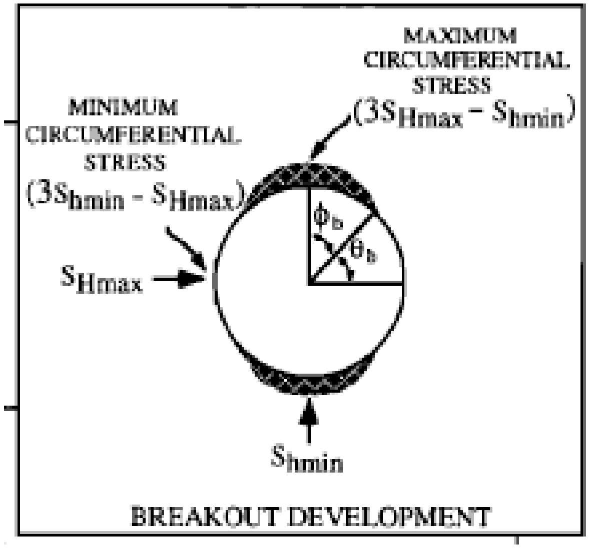
where T is the tensile strength of the rock and P is the static pore pressure in the rock surrounding the borehole. As T and P can be determined independently, Equation (1) allows $S_{H\max}$ to be determined. Assuming that one of the principal stresses is oriented vertically, the third principal stress 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.

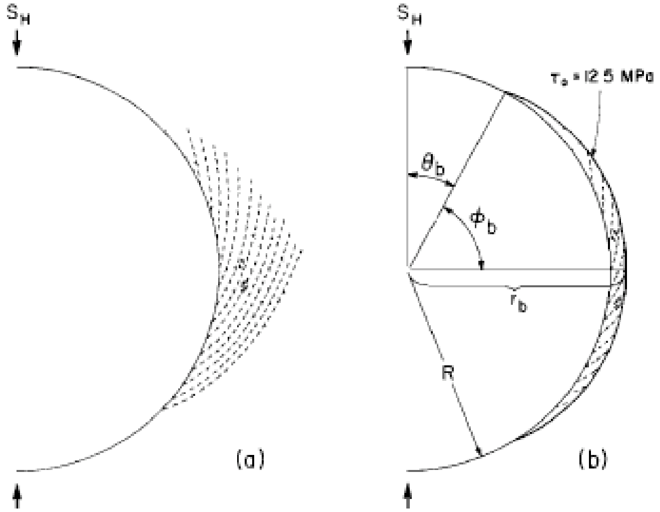
Wellbore Breakouts





Wellbore Breakouts

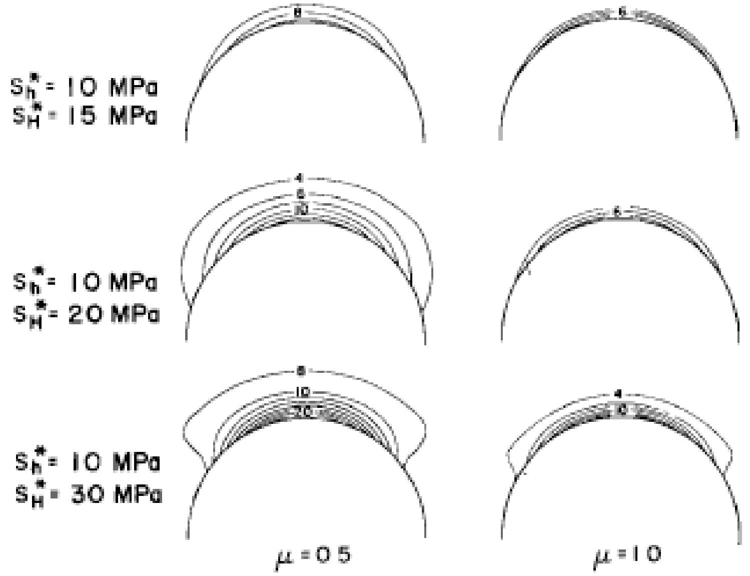




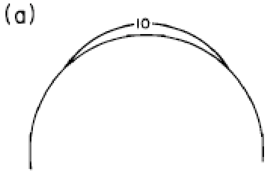
$$S_c = S_H + S_h - 2(S_H - S_h)\cos 2\Theta_b - \Delta P_b$$

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

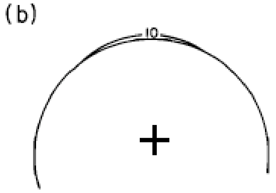
Effects of ΔS_H and friction



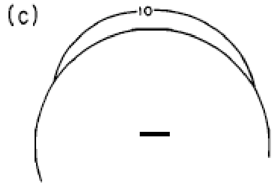
Effect of Borehole Pressure



$\Delta P = 0$

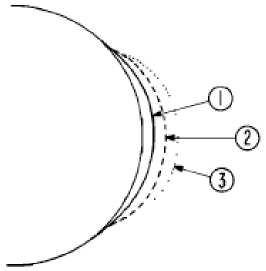


$\Delta P = 2.5$MPa

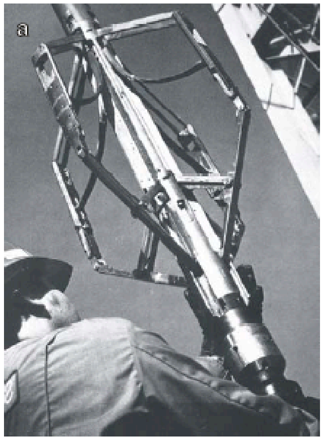


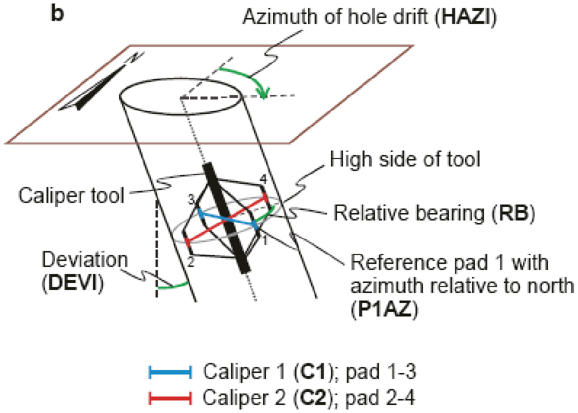
$\Delta P = -2.5$MPa

BREAKOUT SHAPES UNDER SUCCESSIVE
EPISODES OF FAILURE

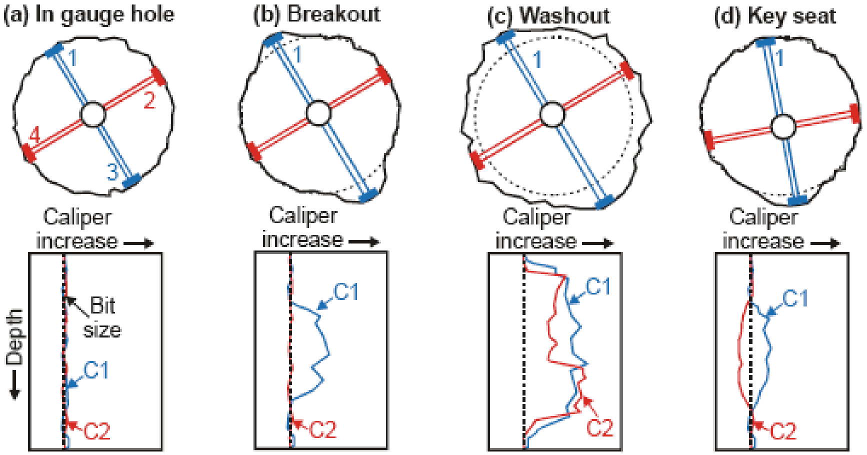


4-arm caliper tool

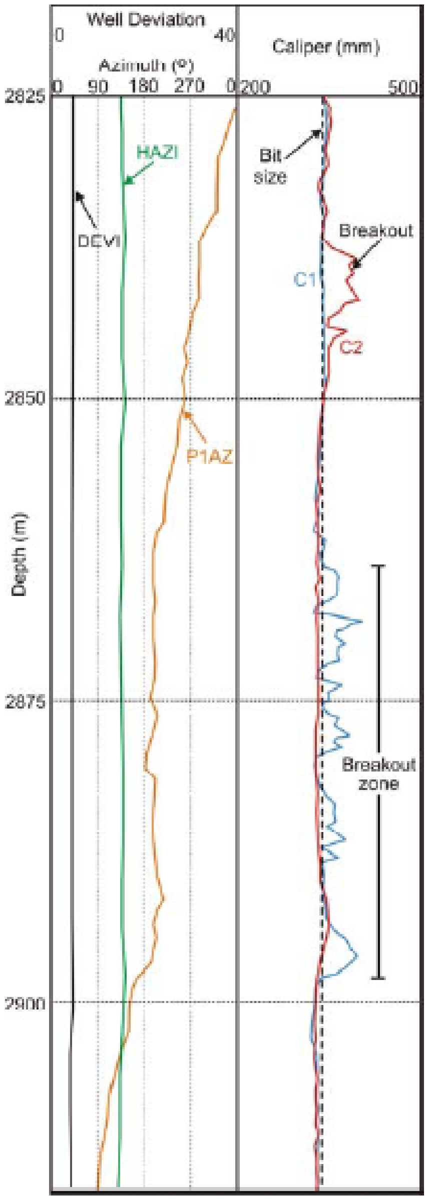


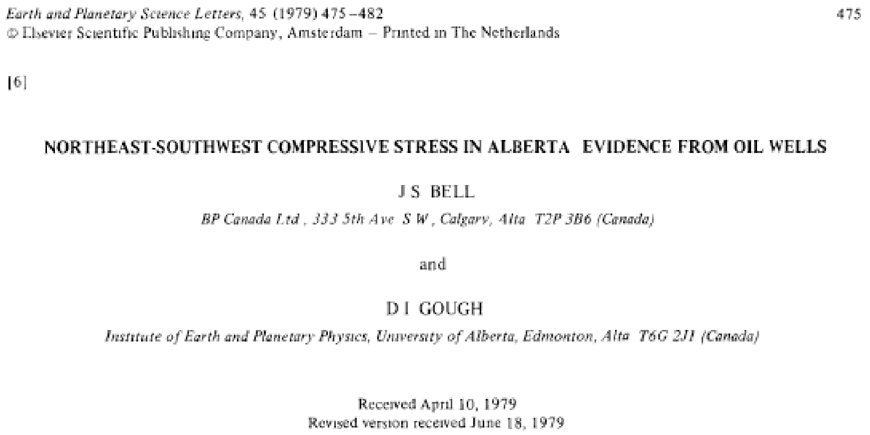


$$P1AZ = HAZI + \mathrm{atan}\frac{\tan RB}{\cos DEVI}$$



4-arm caliper log





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[6]

NORTHEAST-SOUTHWEST COMPRESSIVE STRESS IN ALBERTA EVIDENCE FROM OIL WELLS

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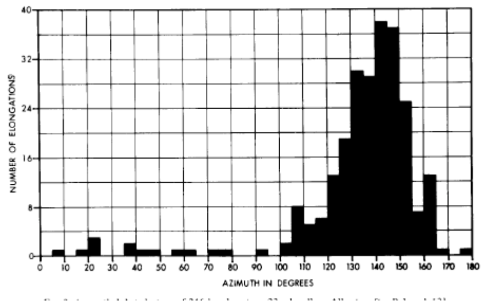
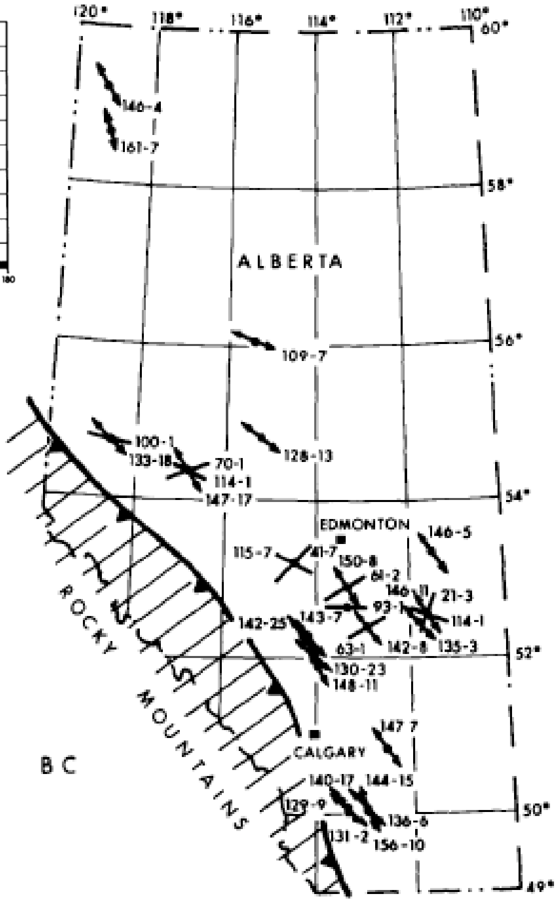
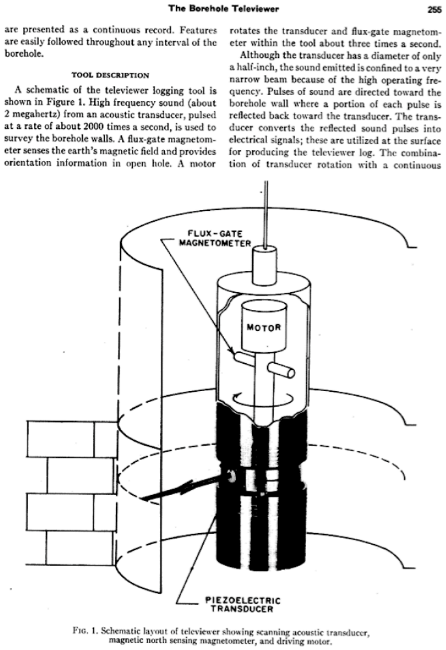




Acoustic Televiewer (BHTV) tool



The Borehole Televiewer 255

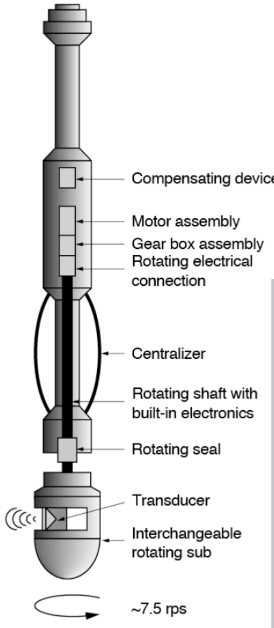
are presented as a continuous record. Features are easily followed throughout any interval of the borehole.

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.



Compensating device

Motor assembly

Gear box assembly

Rotating electrical connection

Centralizer

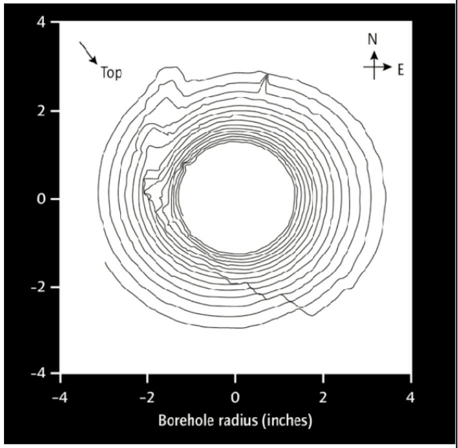
Rotating shaft with built-in electronics

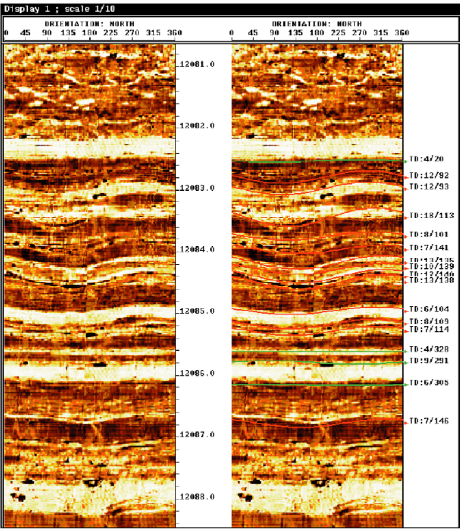
Rotating seal

Transducer

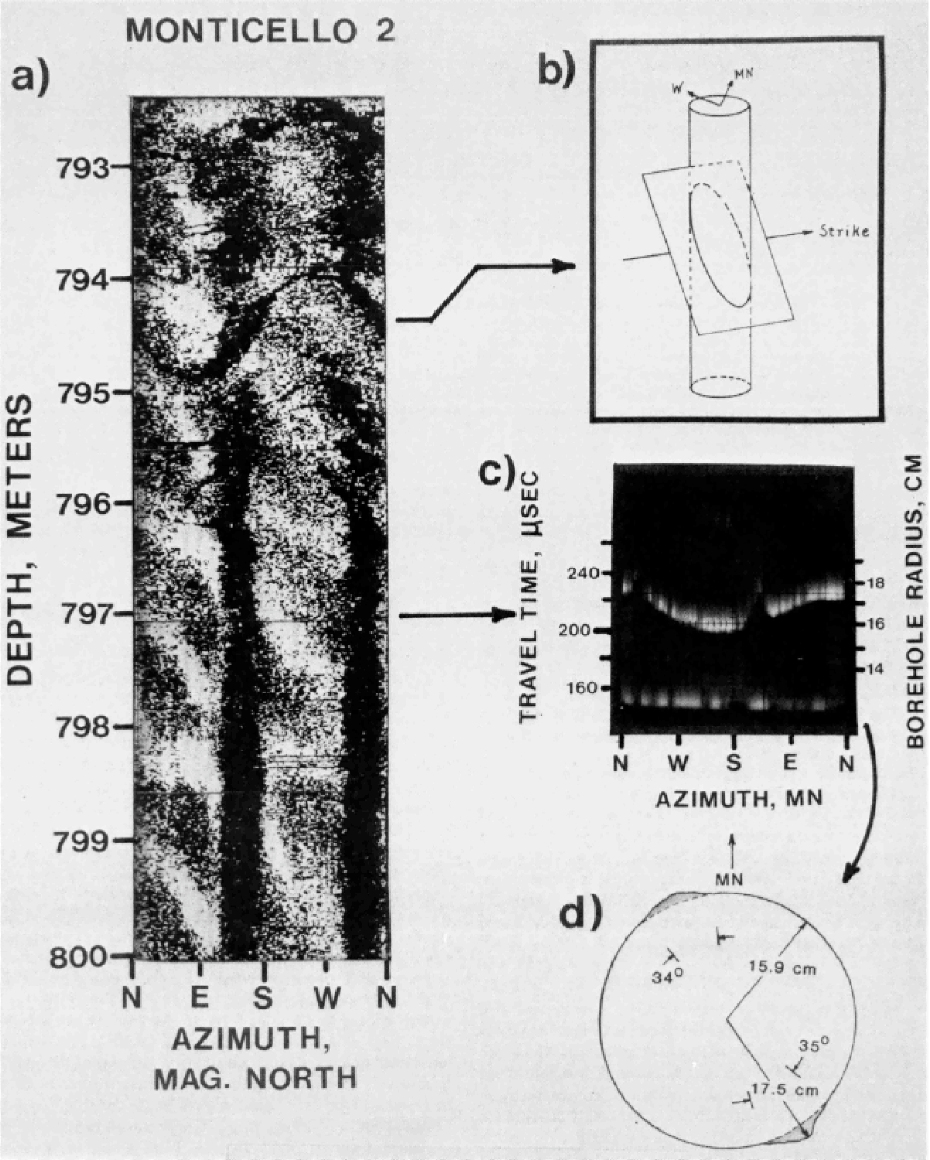
Interchangeable rotating sub

~7.5 rps

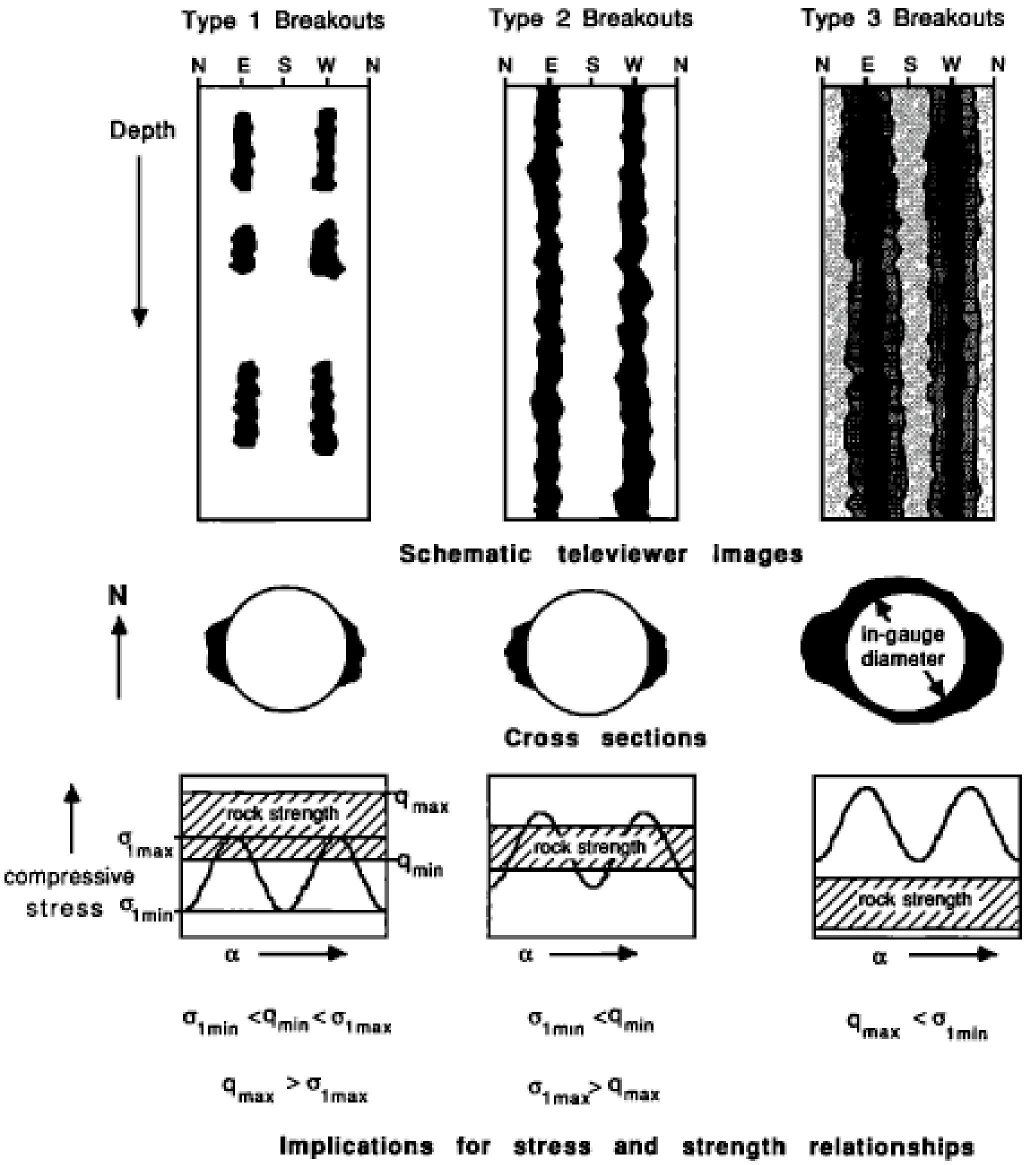




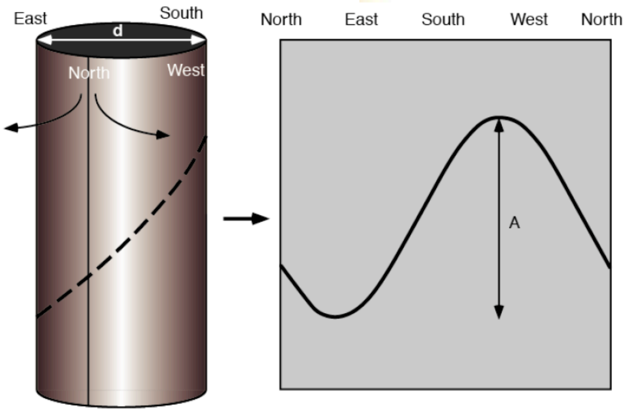
BHTV breakout image



BHTV breakout logs



Resistivity (FMS/FMI) tools



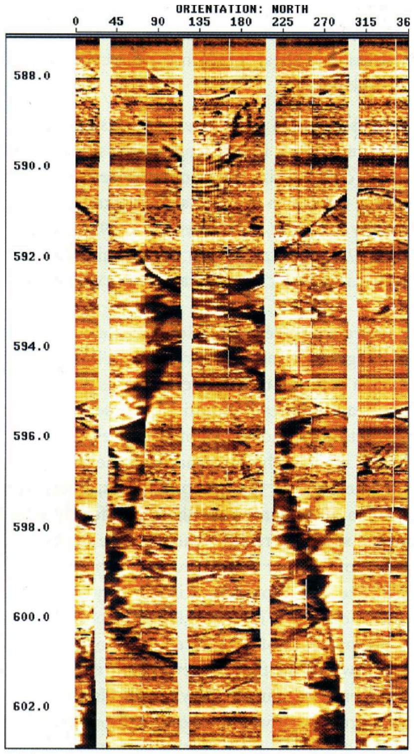
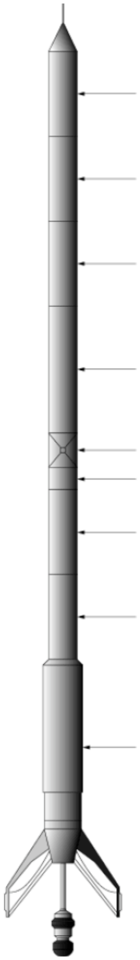
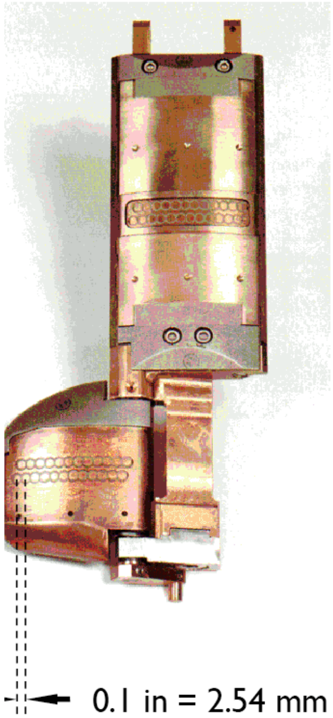


Figure 2.2.27. FMI images over a layered carbonate sequence with at least two distinct planar fracture sets, on dipping towards SSW, the other dipping steeply towards NNE.

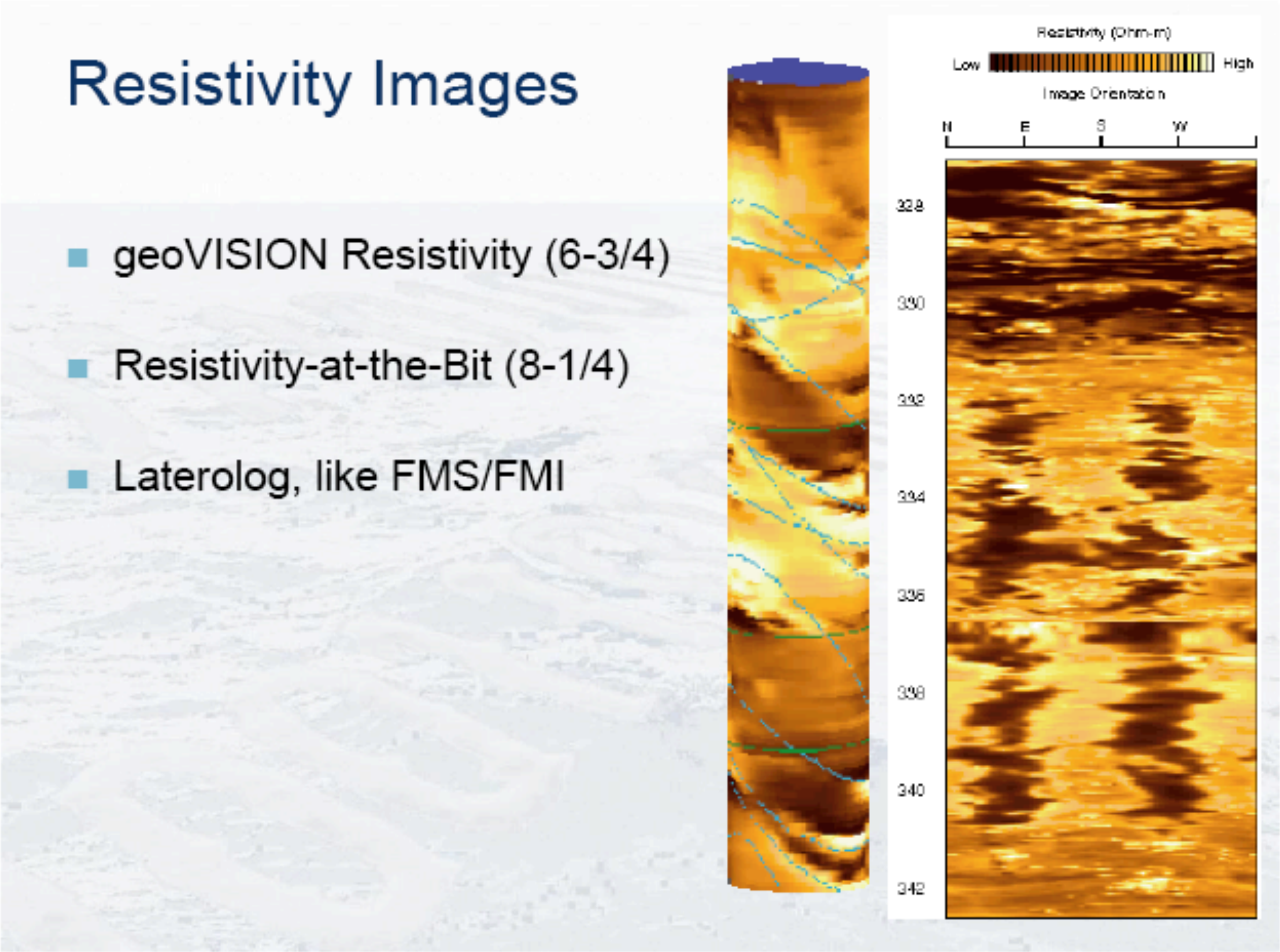


192 electrodes



0.1 in = 2.54 mm

Resistivity (LWD) tools

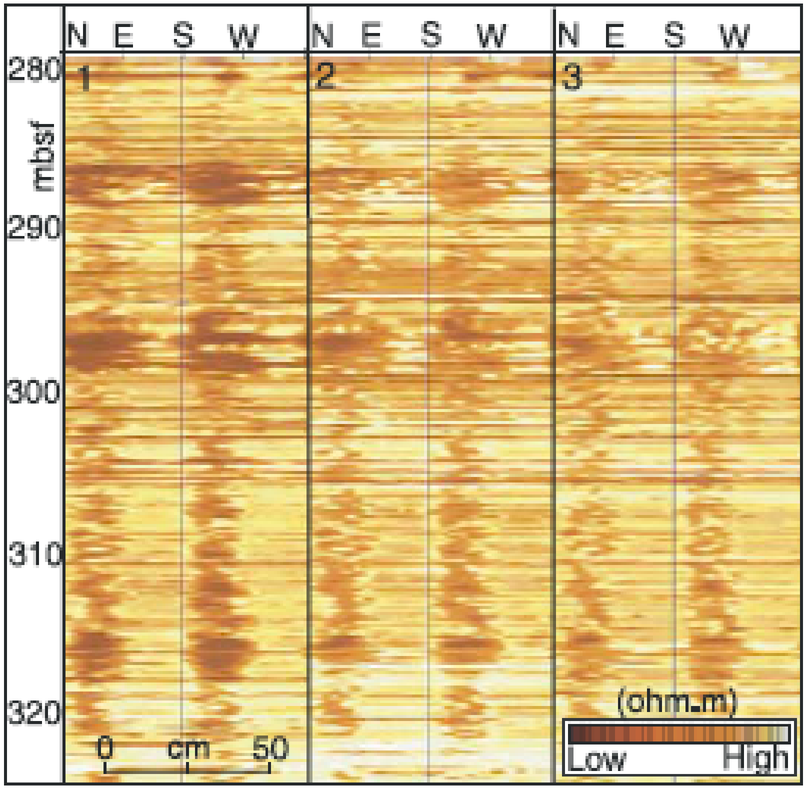


Resistivity Images

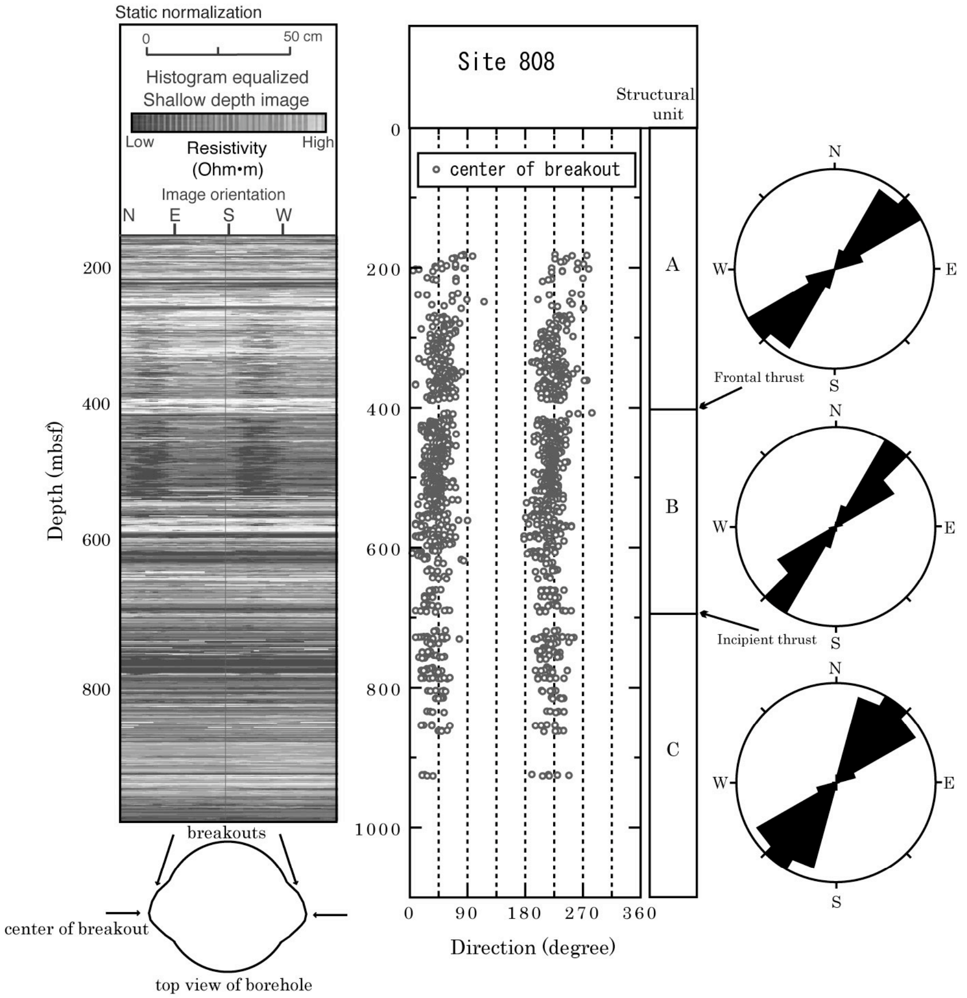
- geoVISION Resistivity (6-3/4)
- Resistivity-at-the-Bit (8-1/4)
- Laterolog, like FMS/FMI

LWD Breakout images

e.g. Nankai trough

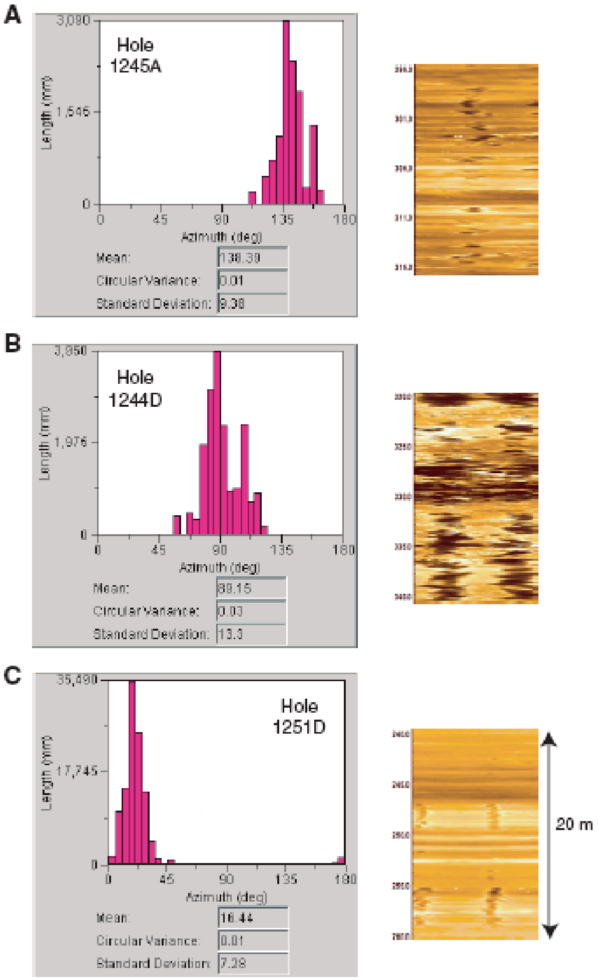


shallow medium deep



LWD Breakout orientation

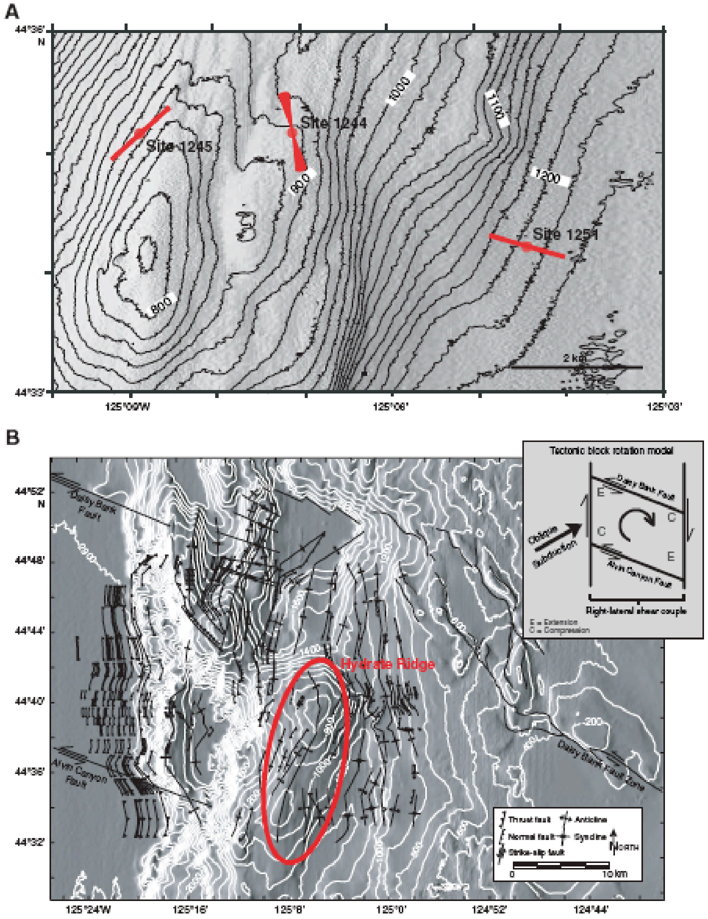
e.g. Oregon Margin



Mean: 138.39
Circular Variance: 0.01
Standard Deviation: 9.38

Mean: 89.15
Circular Variance: 0.03
Standard Deviation: 13.3

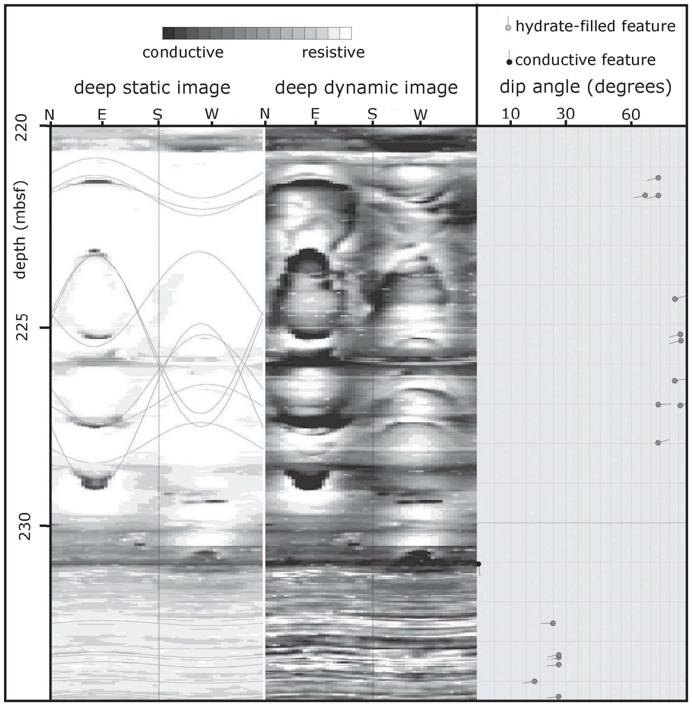
Mean: 16.44
Circular Variance: 0.01
Standard Deviation: 7.28

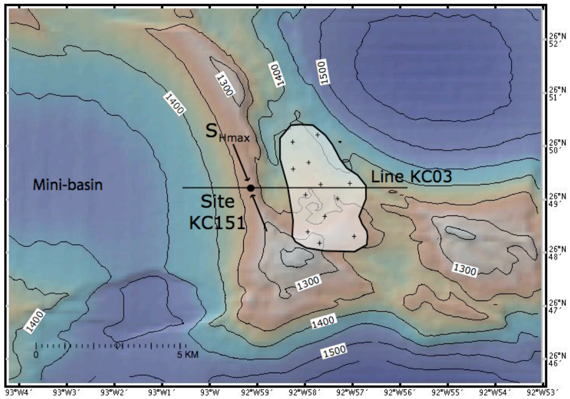


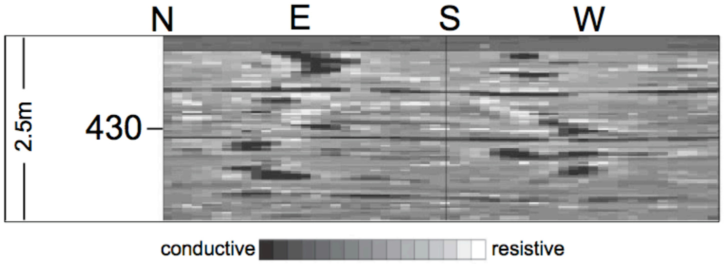
Breakouts and Fractures

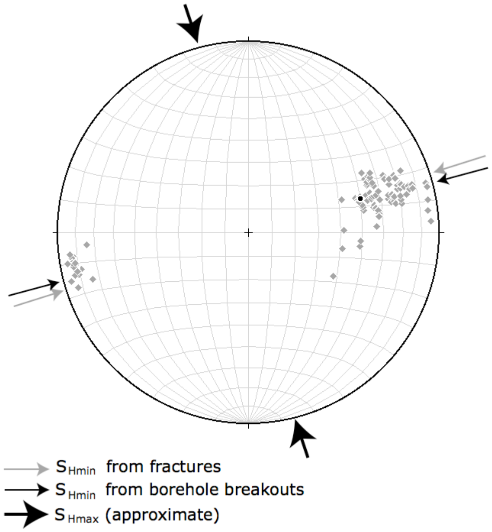
(present-day stress) (paleo-stress)

e.g. Gulf of Mexico





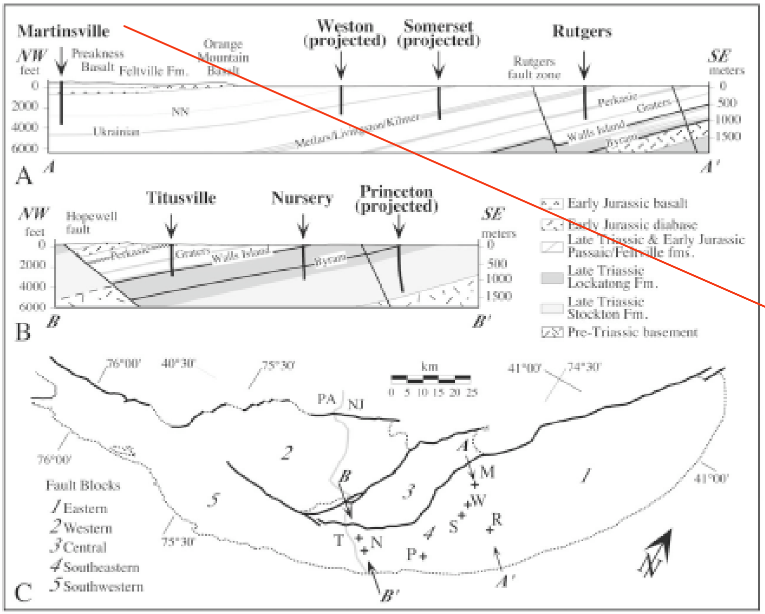




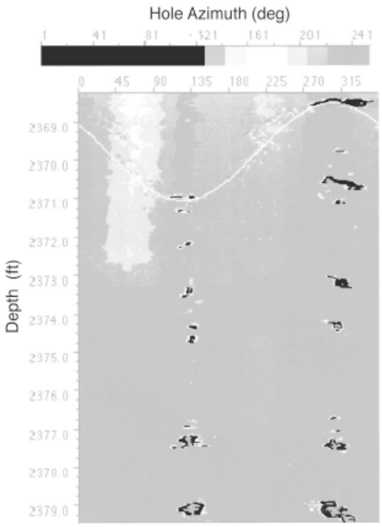
Breakouts and Fractures

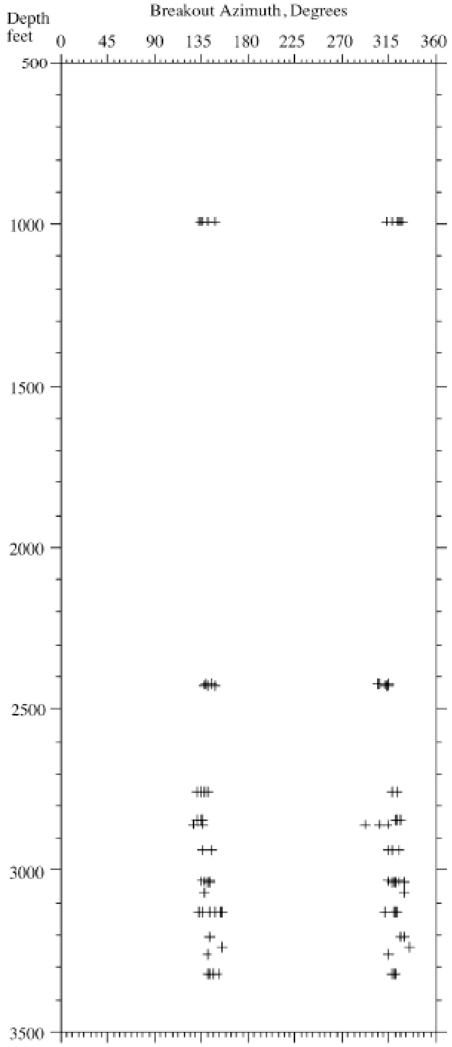
(present-day stress) (paleo-stress)

e.g. Newark Basin



BHTV



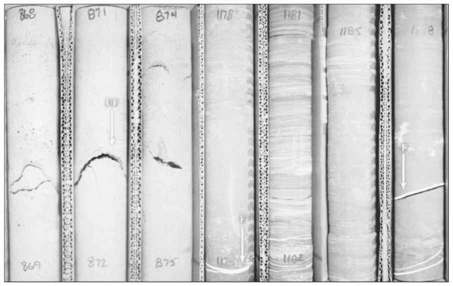


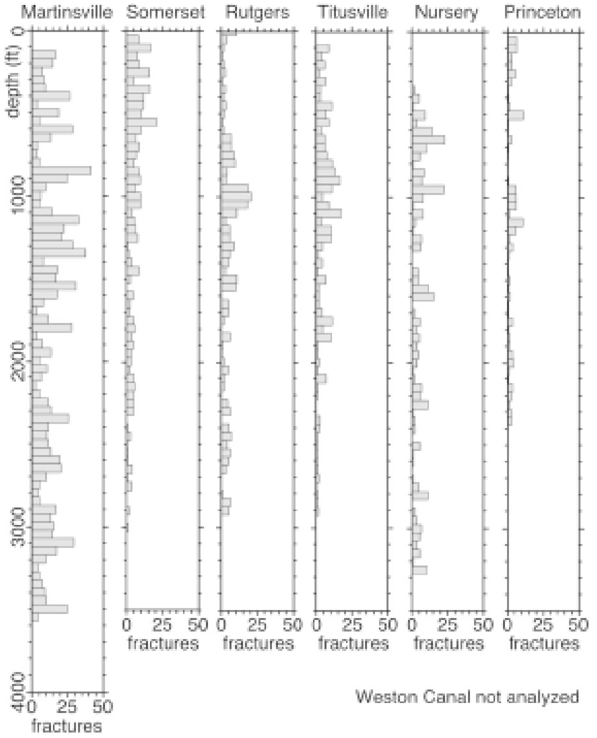
Breakouts and Fractures

(present-day stress) (paleo-stress)

e.g. Newark Basin

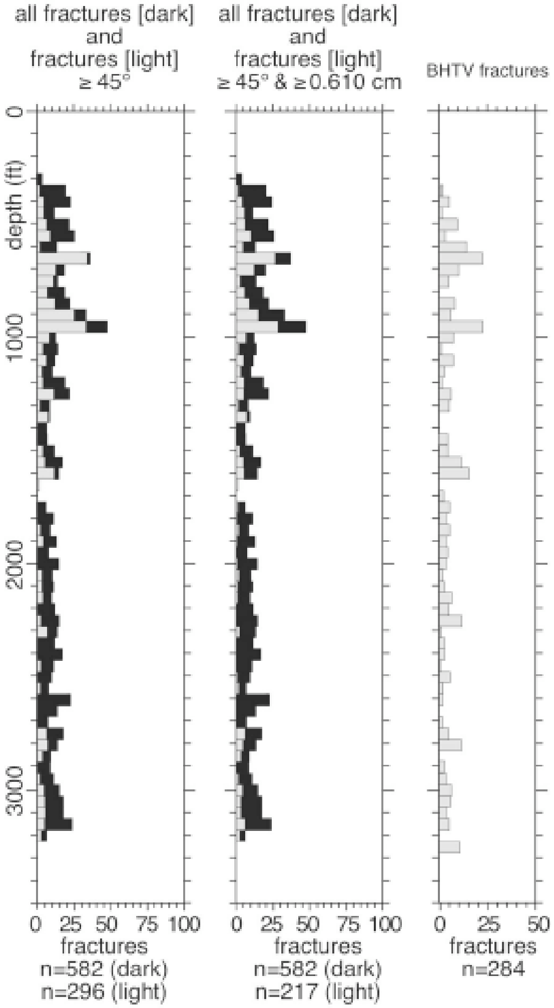
Core fractures





Weston Canal not analyzed

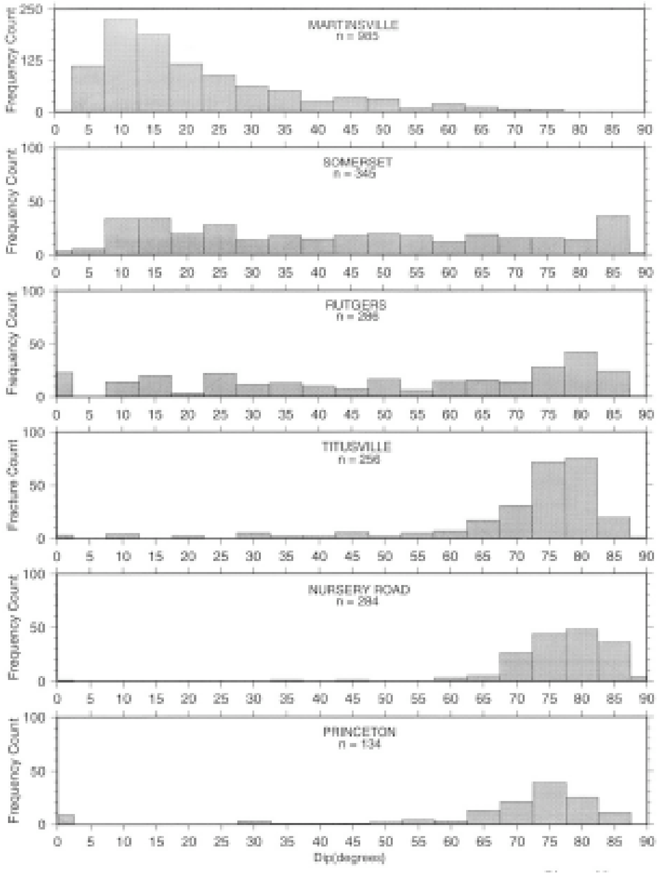
Core vs BHTV



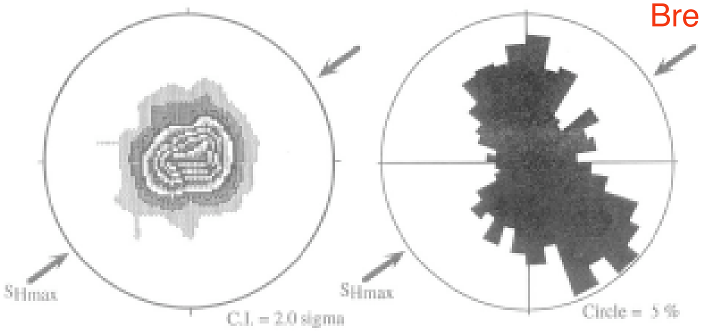
Breakouts and Fractures

(present-day stress) (paleo-stress)

e.g. Newark Basin

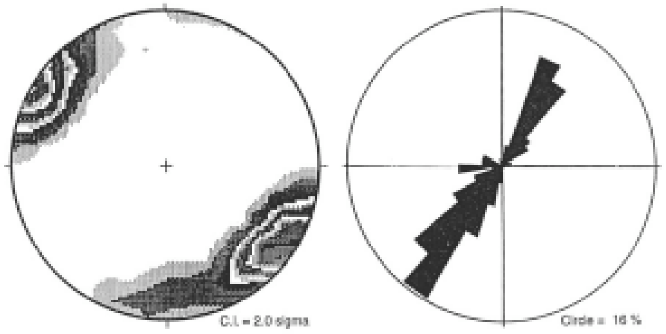


Martinsville



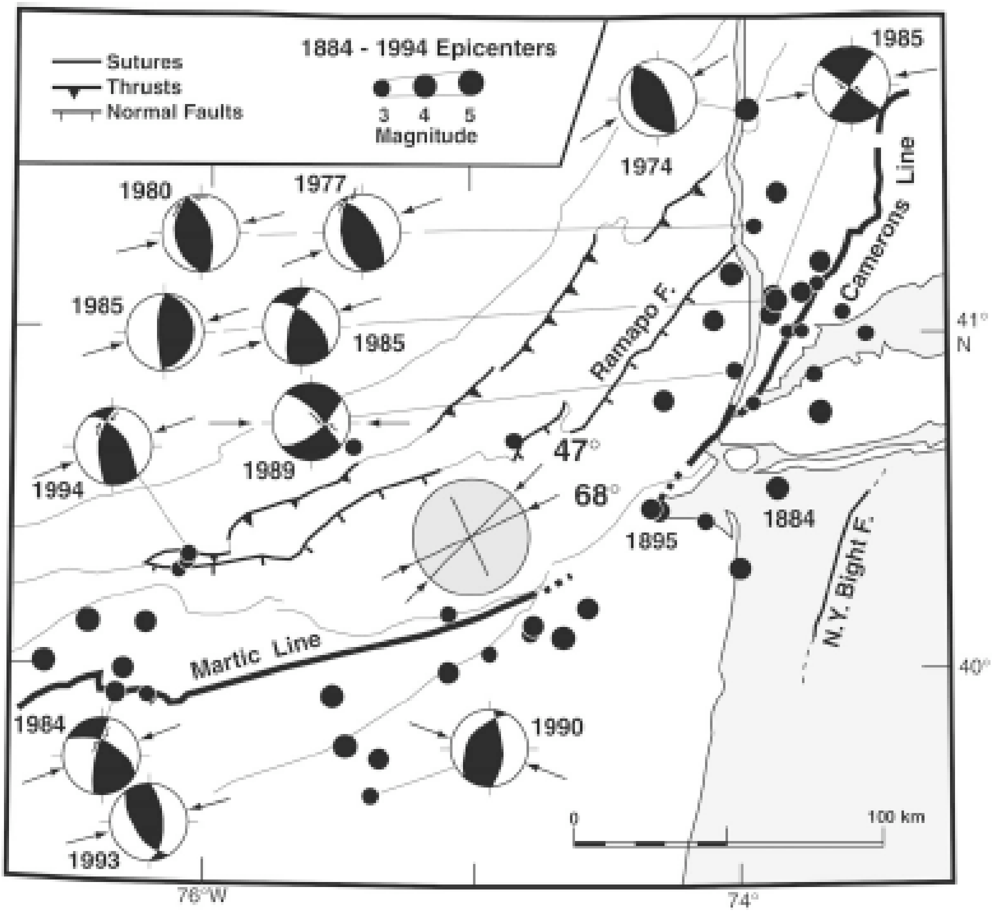
Breakouts - 90°

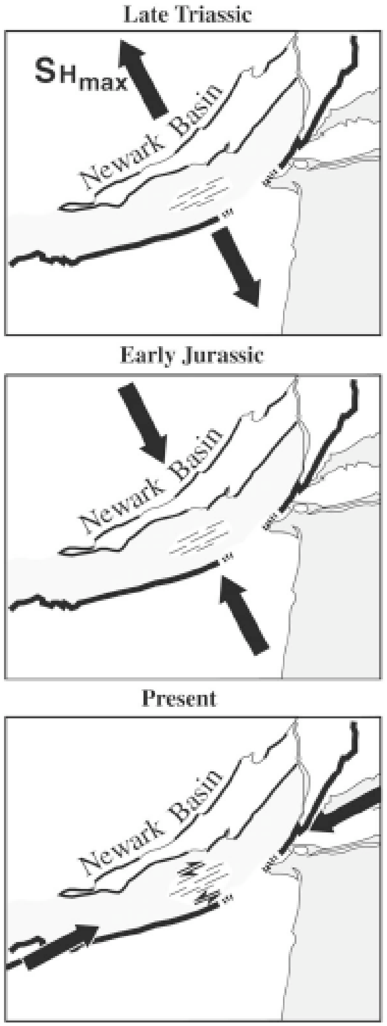
Nursery Road



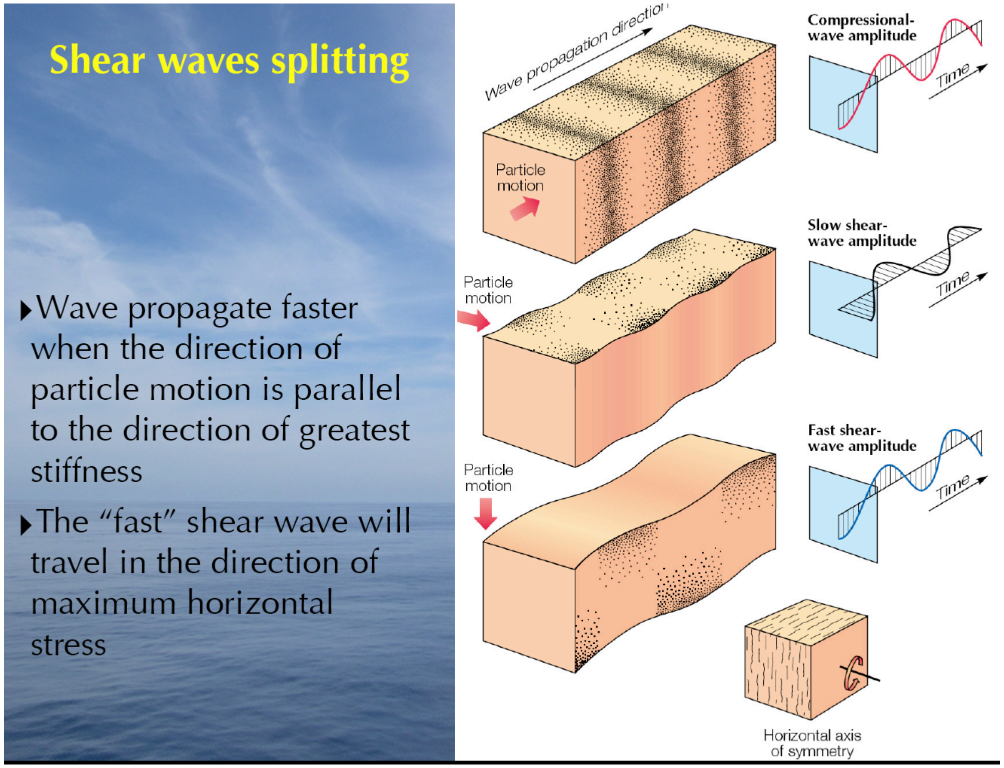
Breakouts, EQs, and Fractures

e.g. Newark Basin



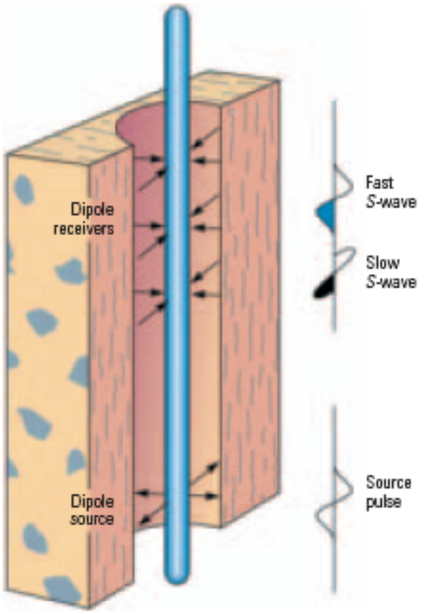


Elastic wave anisotropy

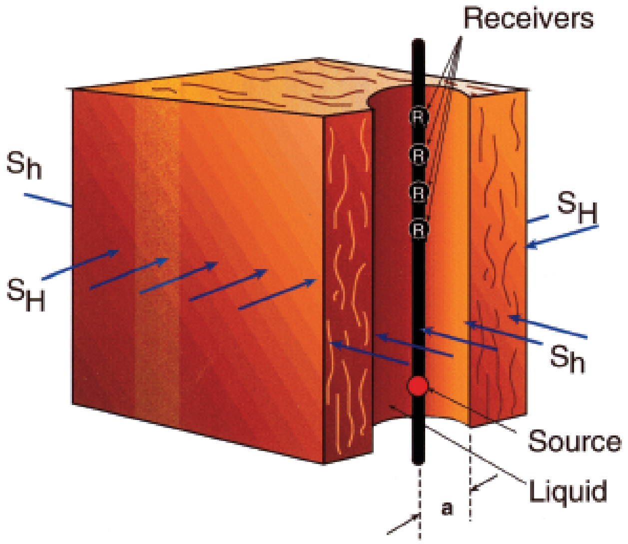


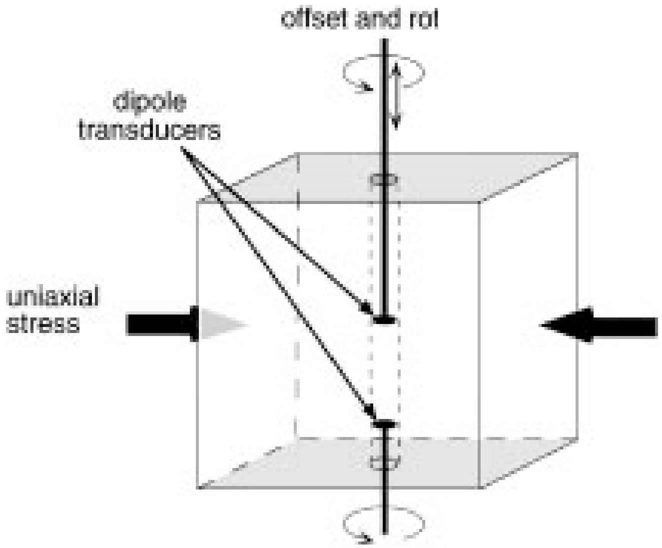
Shear waves splitting

- 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



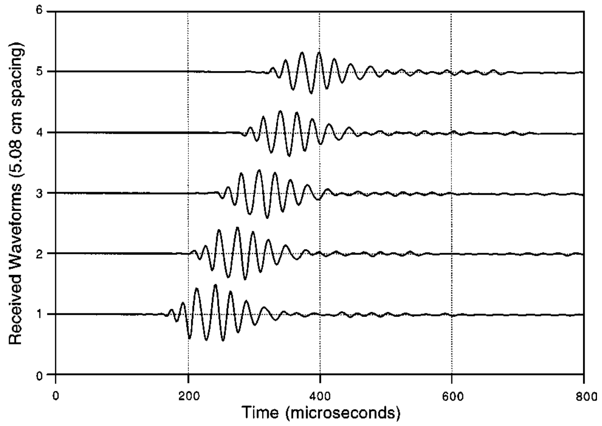
Stress-induced anisotropy - ?





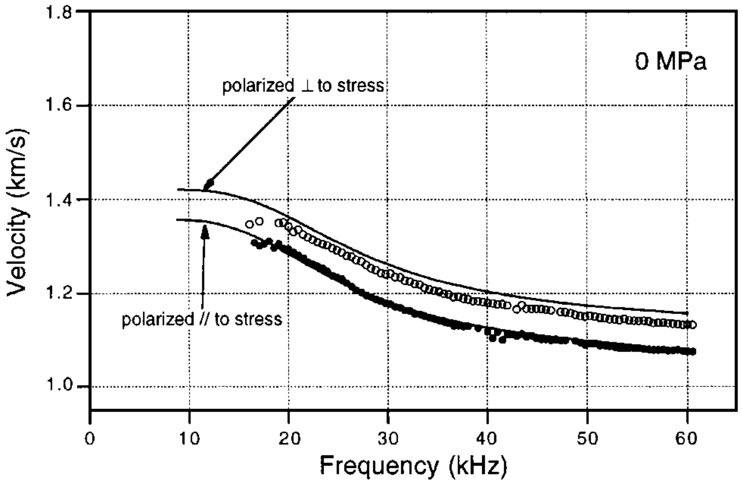
Winkler et al. (1998)

Dipole waveforms

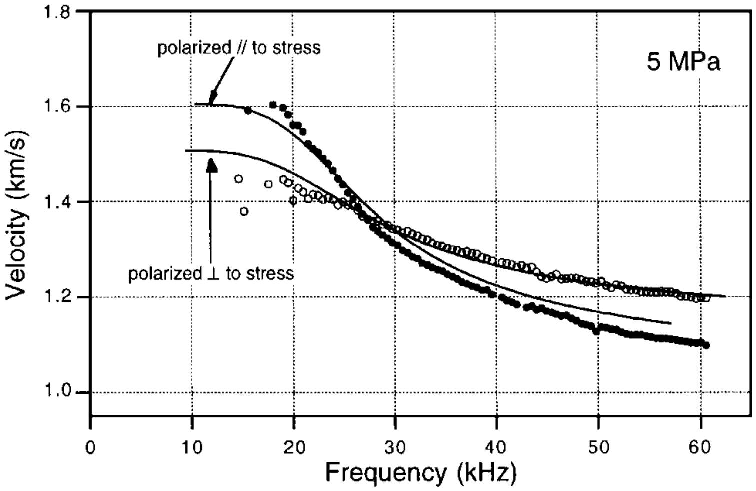


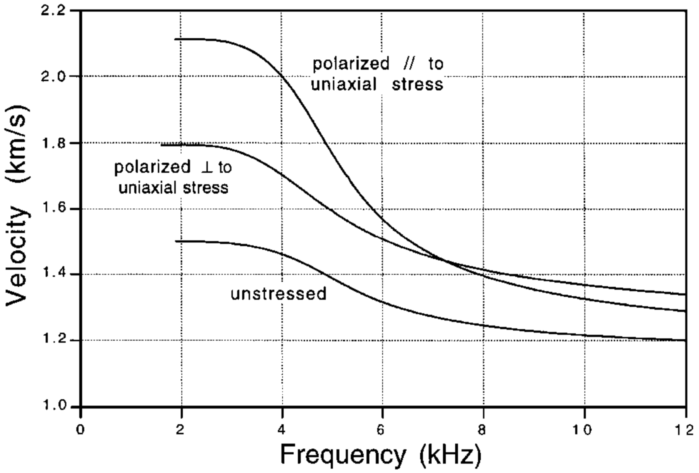
Stress-induced dispersion

Vs dispersion

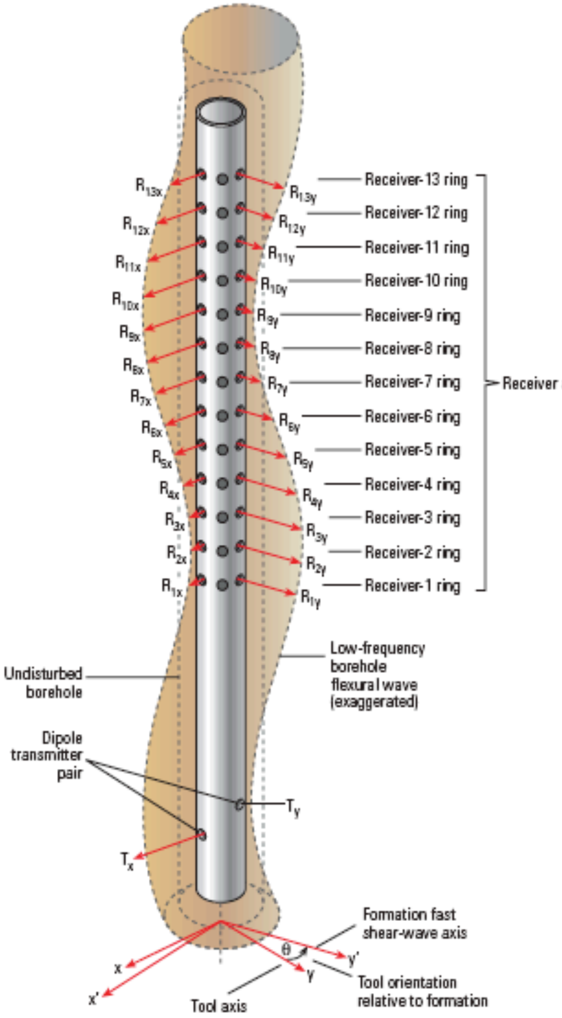


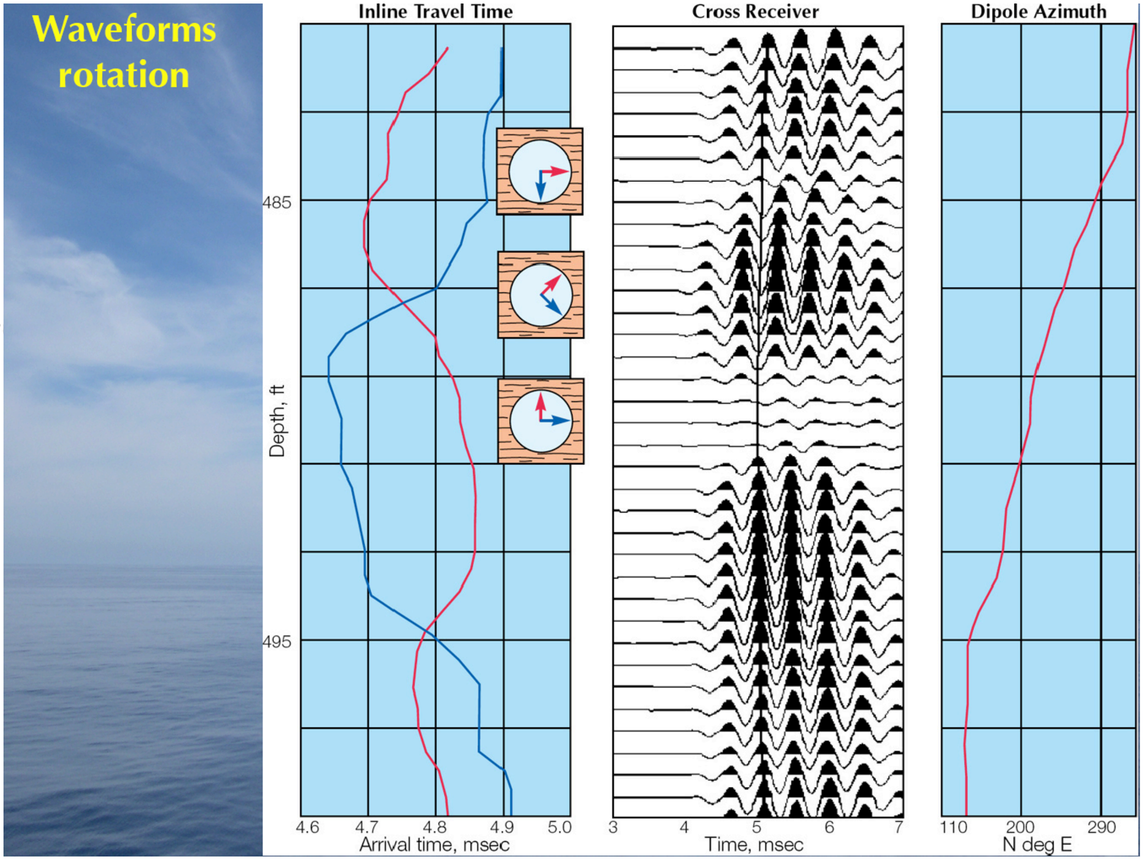
V_{fast} crossover





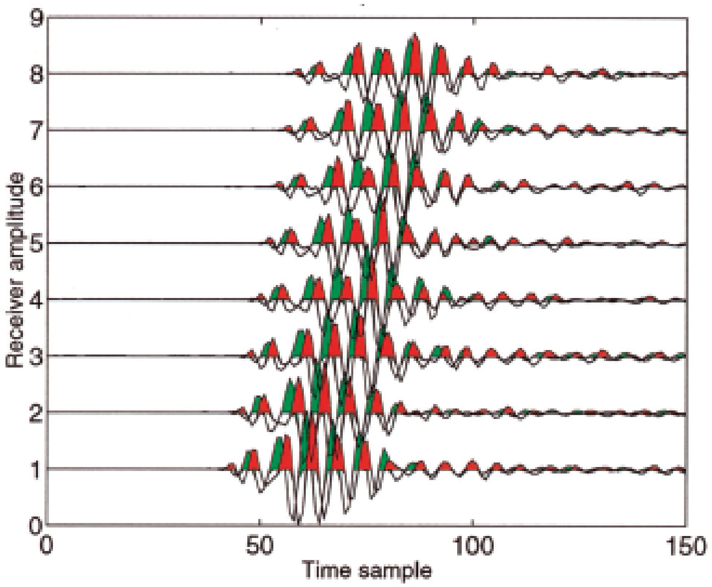
Cross-dipole Vs logging



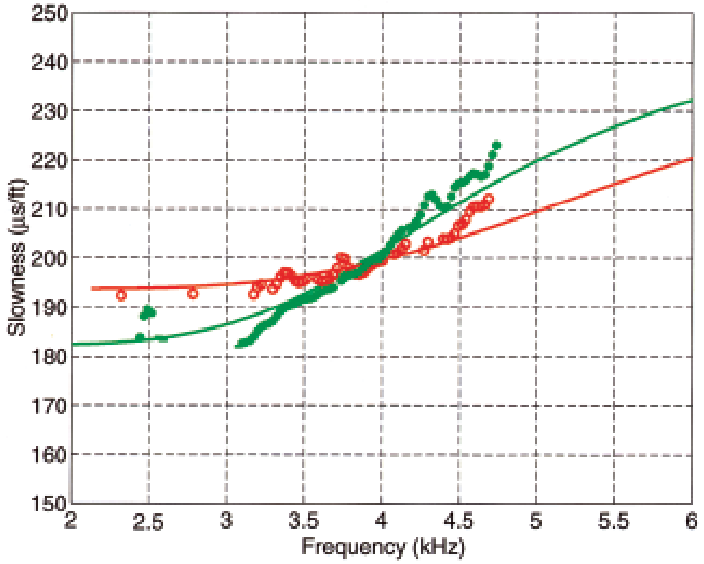


Stress-induced anisotropy

Rotated dipole waveforms

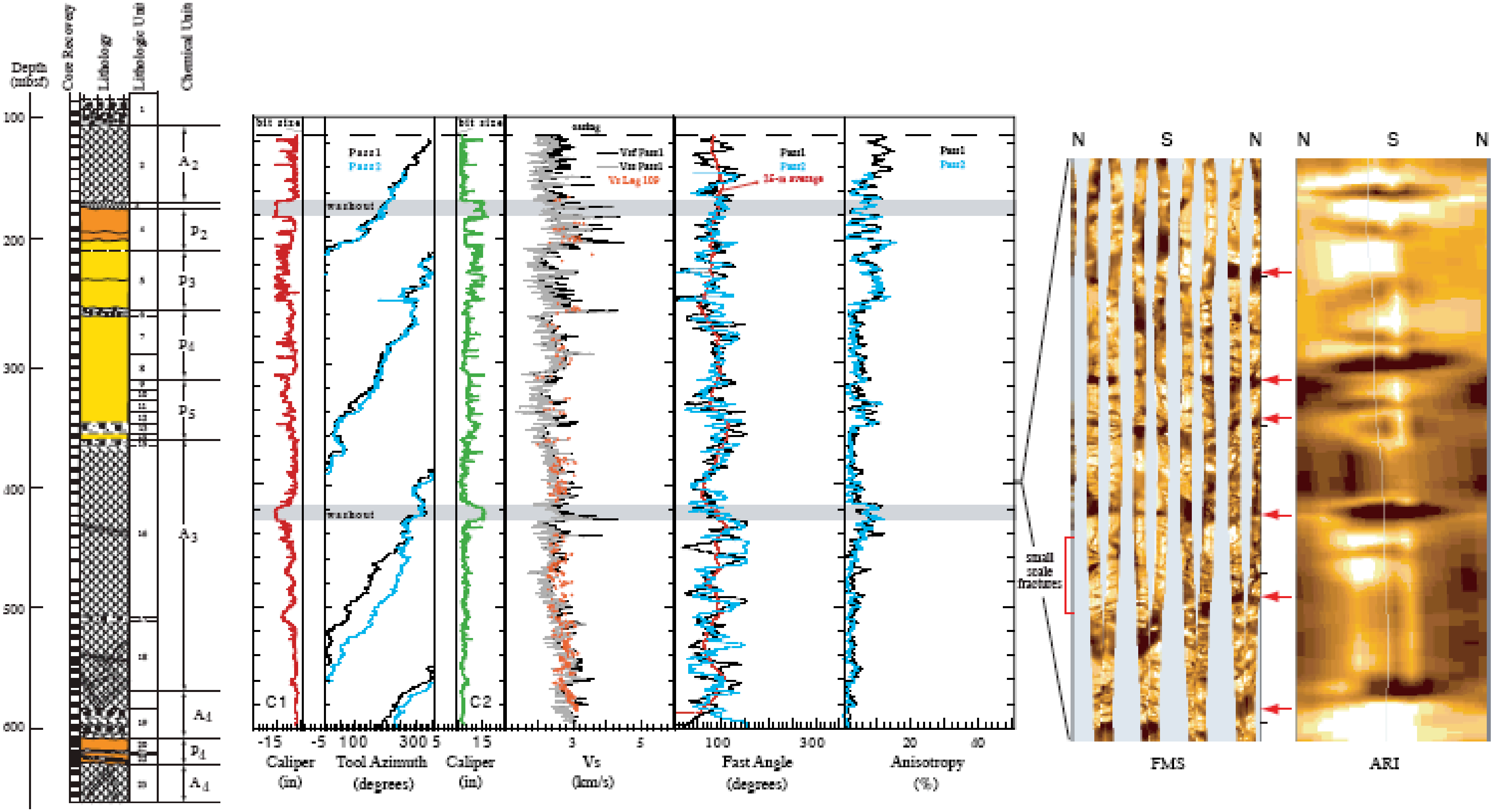


Dispersion crossovers



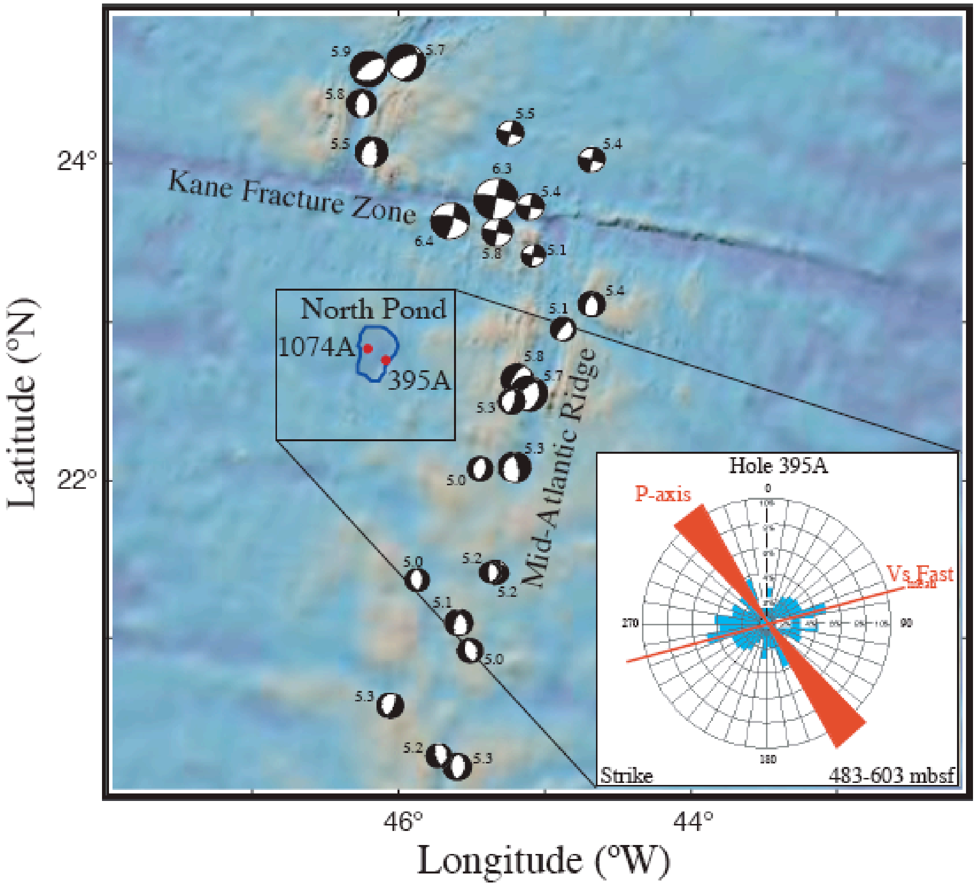
Stress-induced anisotropy

e.g. Kane Fracture Zone



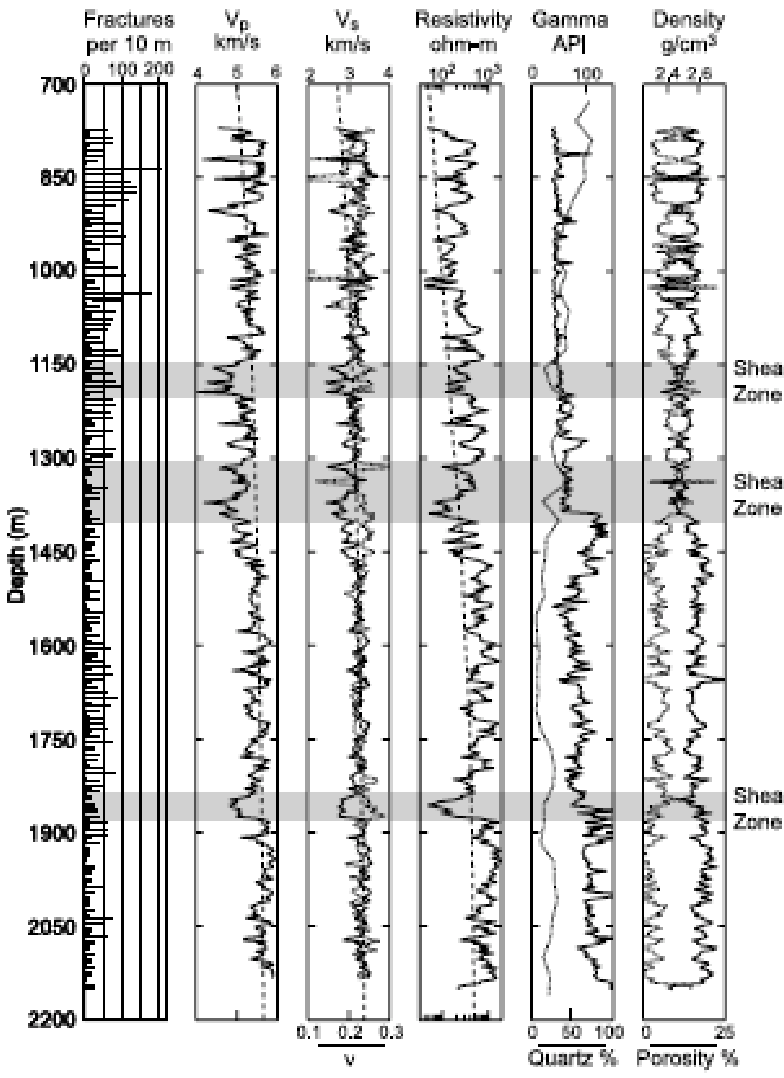
Stress-induced anisotropy

e.g. Kane Fracture Zone

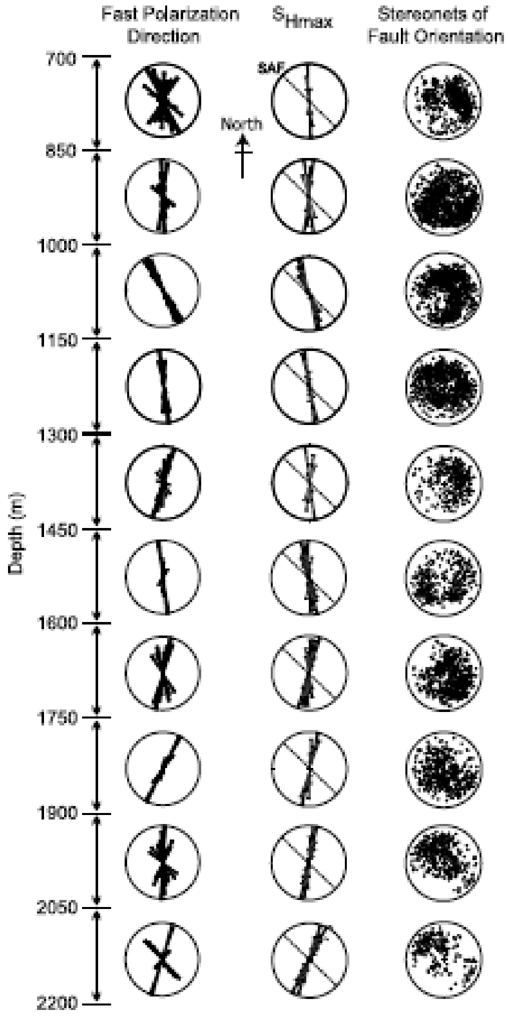


Stress-induced anisotropy

e.g. San Andreas Fault



Breakouts

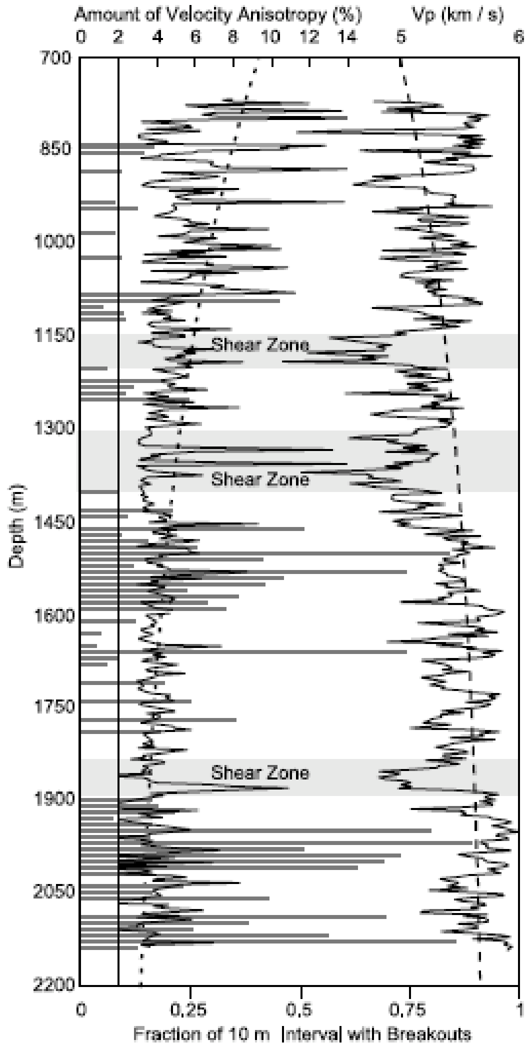


Vs Fast

FMS

Stress-induced anisotropy

e.g. San Andreas Fault



No Breakouts, high Anisotropy

=> Stress relief zones