Ice Deformation at the South Pole

Determining borehole shape and size using an acoustic televiewer

Emilie Sinkler, IceCube Polar Science Workshop, January 19, 2021

UAF
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FAIRBANKS

Acoustic Televiewer

- Sonic borehole logging tool

- Collects:

  - Travel time and amplitude of returned signal (up to 288 pts/revolution)

  - Borehole inclination

  - Temperature, Roll, etc.

Borehole Fluid

Oil

Motor

Mirror

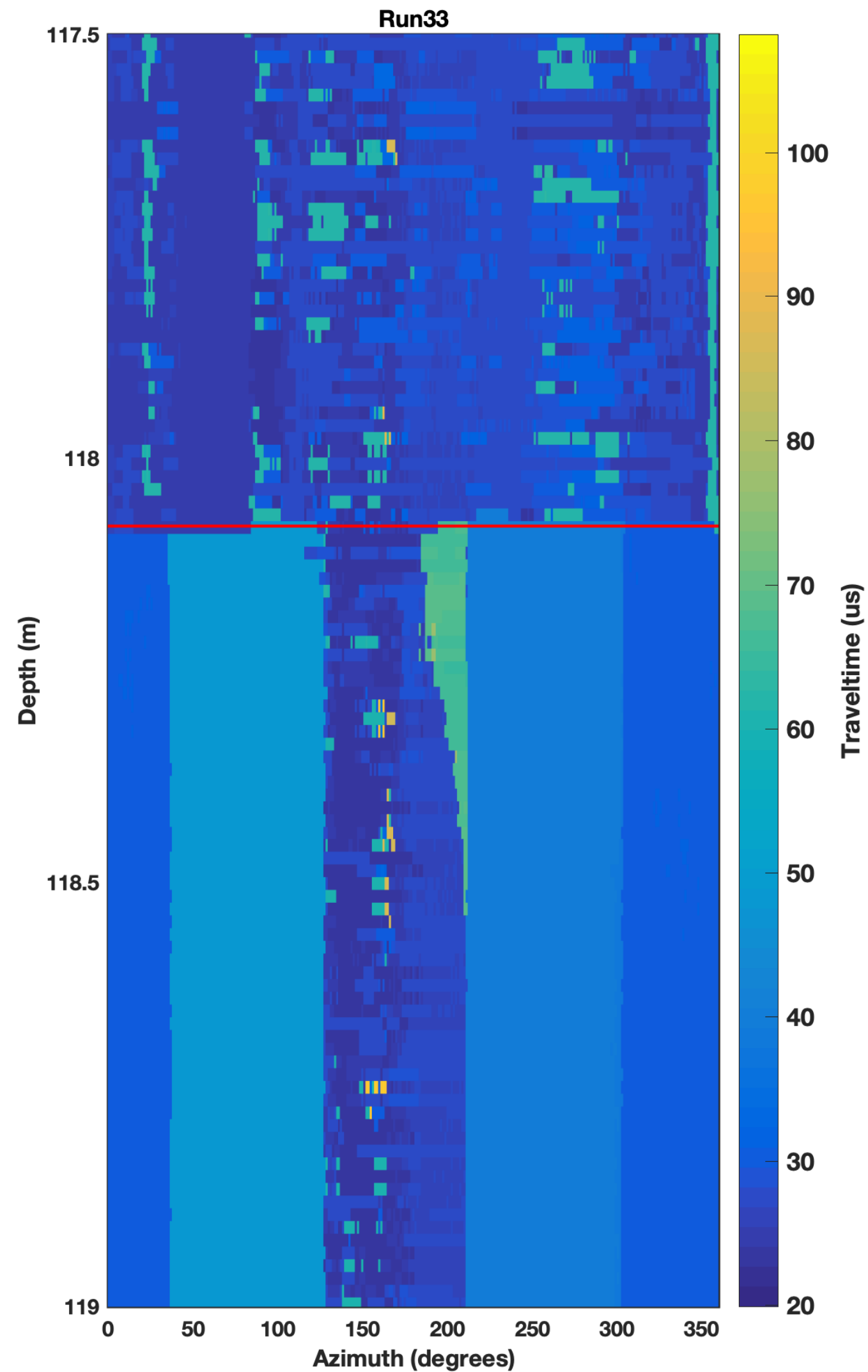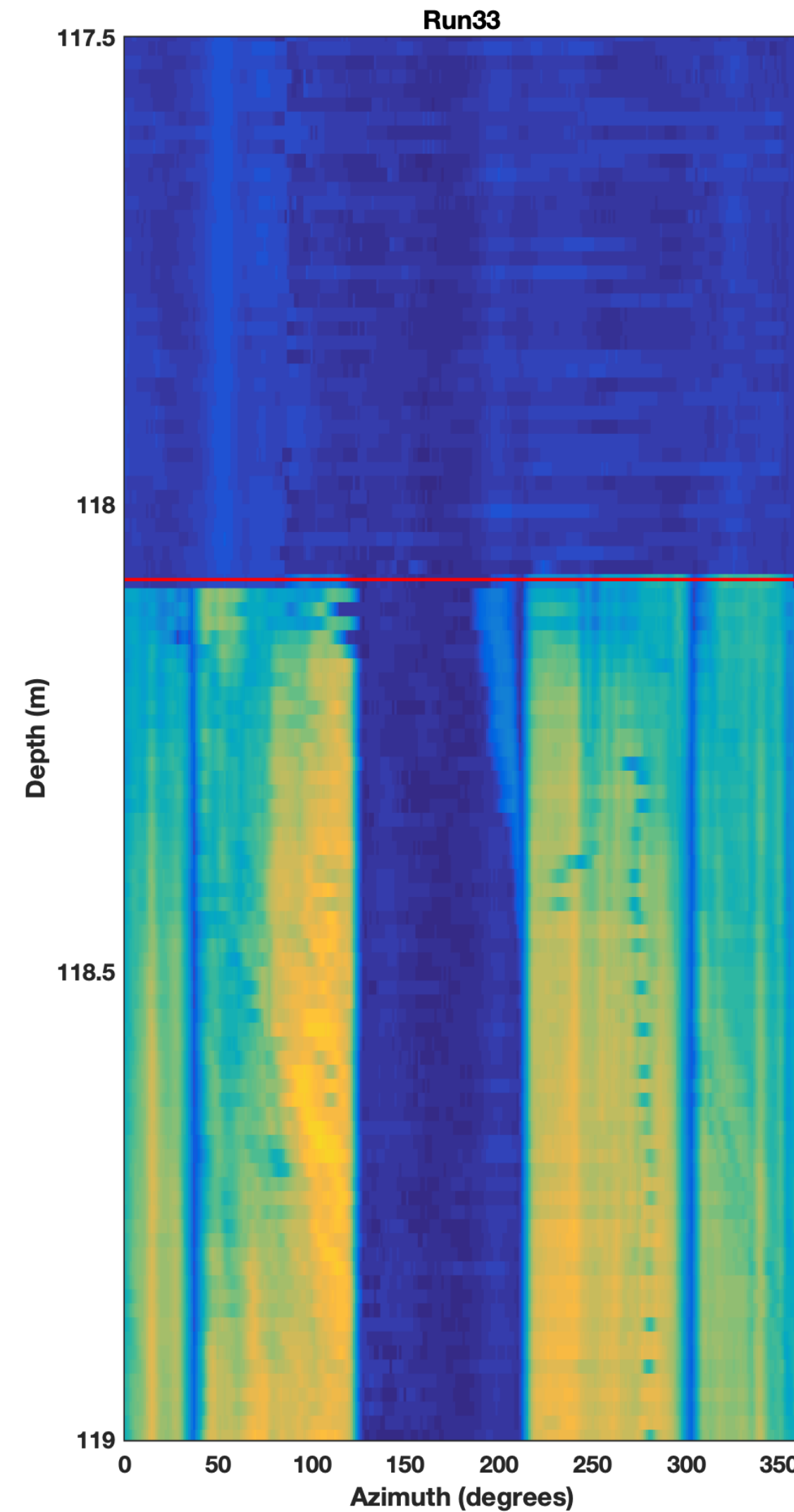Acoustic window

Transducer
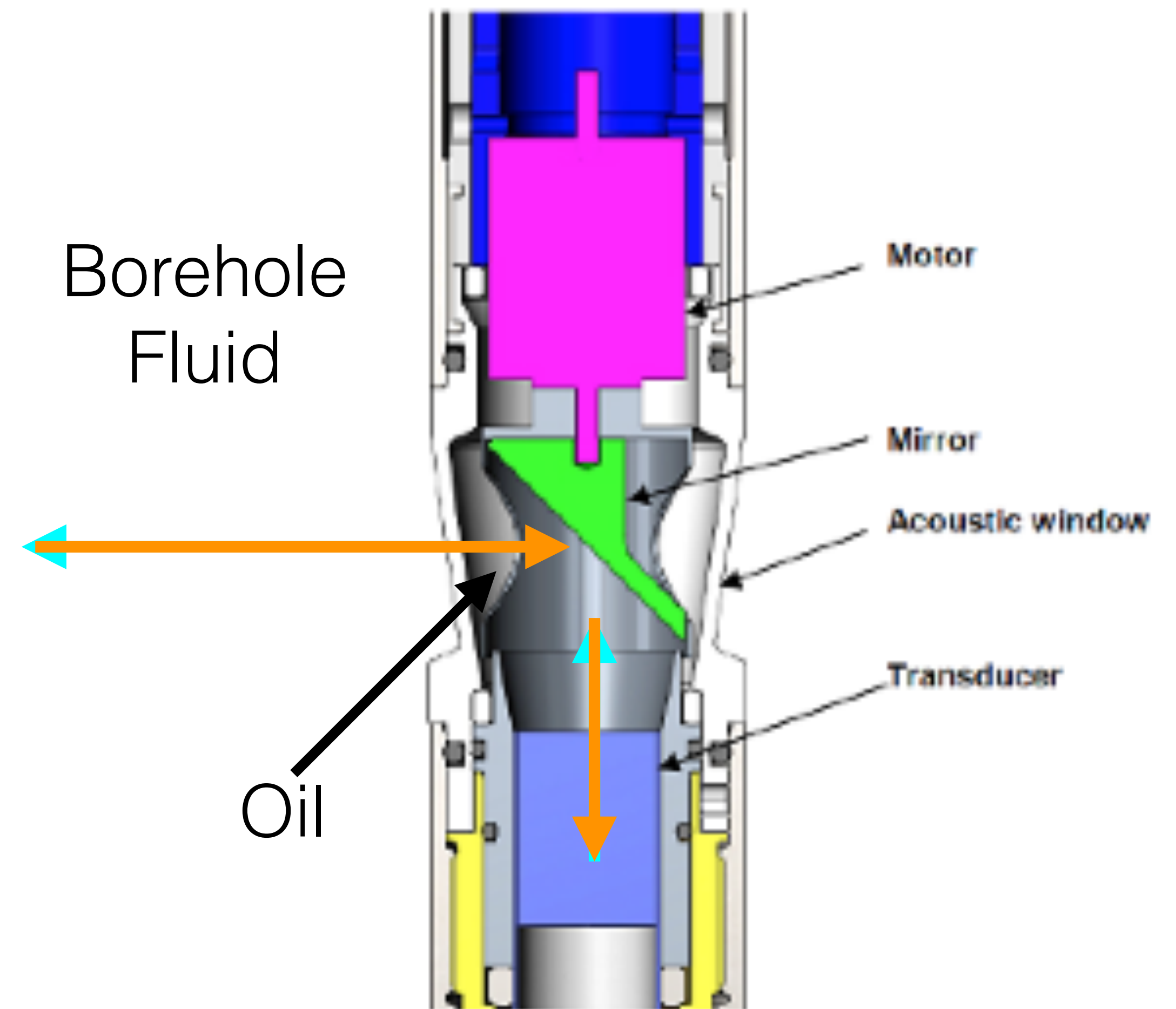
Borehole Trajectory

- Bottom of the borehole is ~16m at 157 degrees SW of surface hole

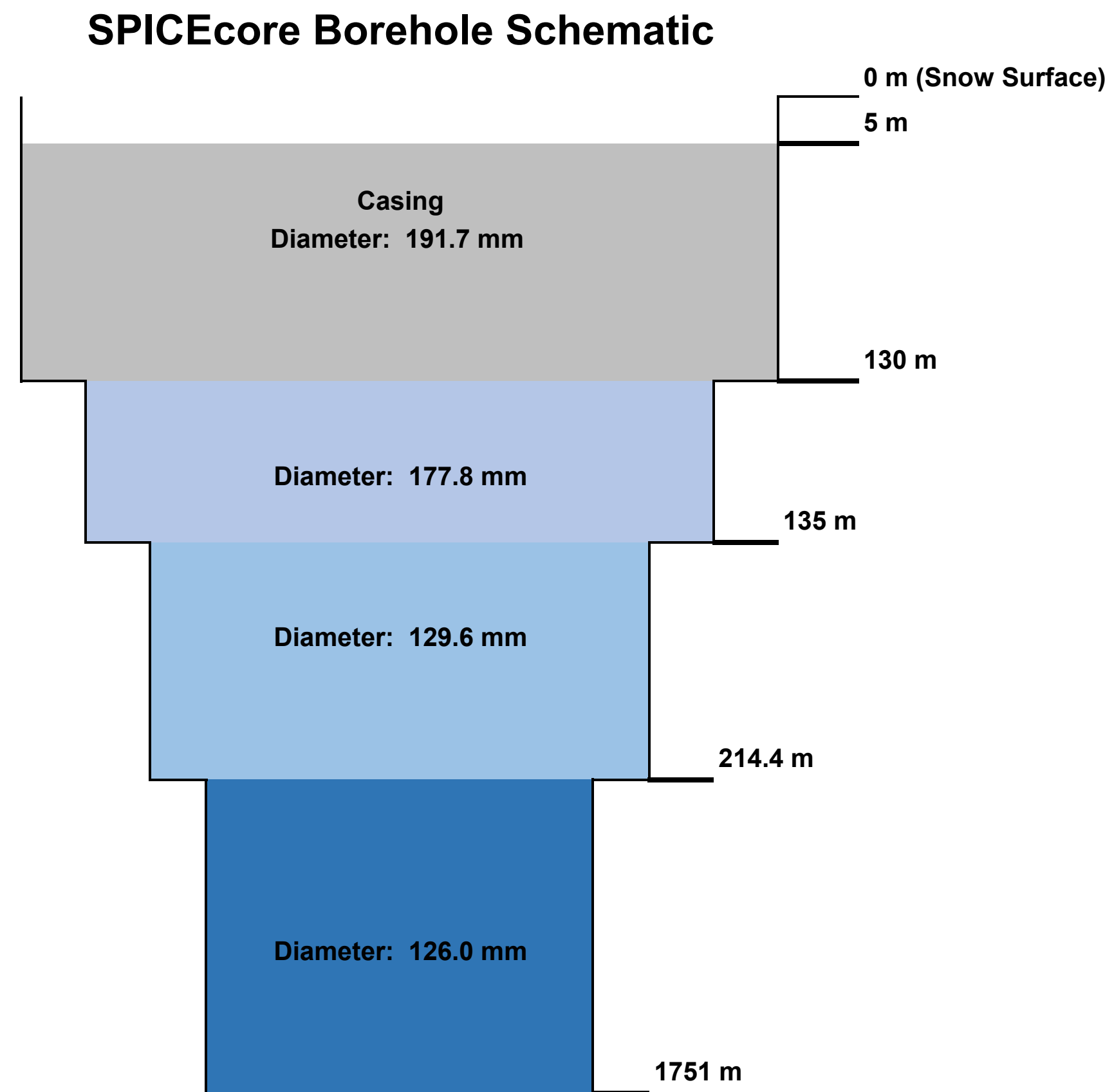- Shearing of the borehole is unlikely since it is not near the bed
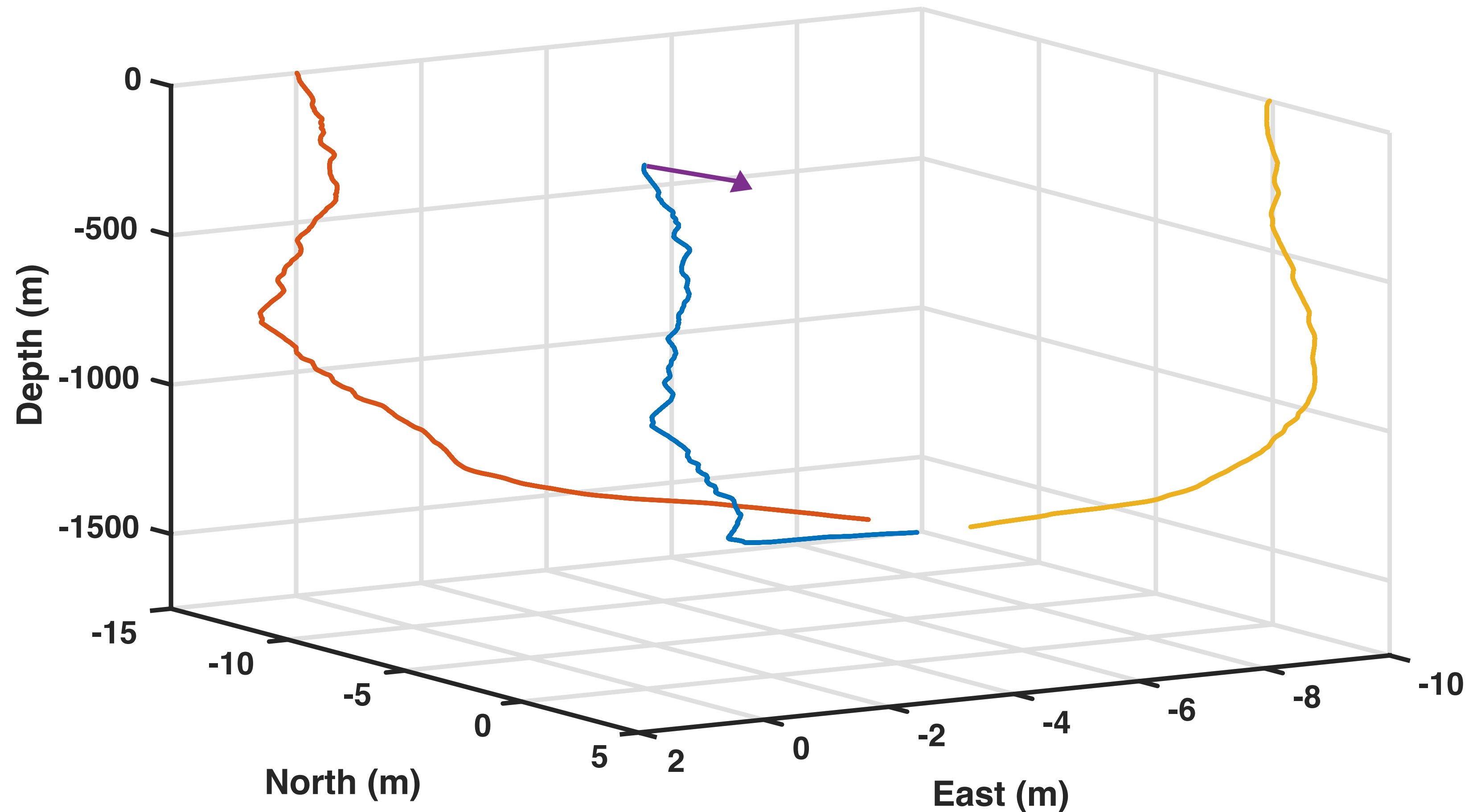
Borehole Fluid Depth

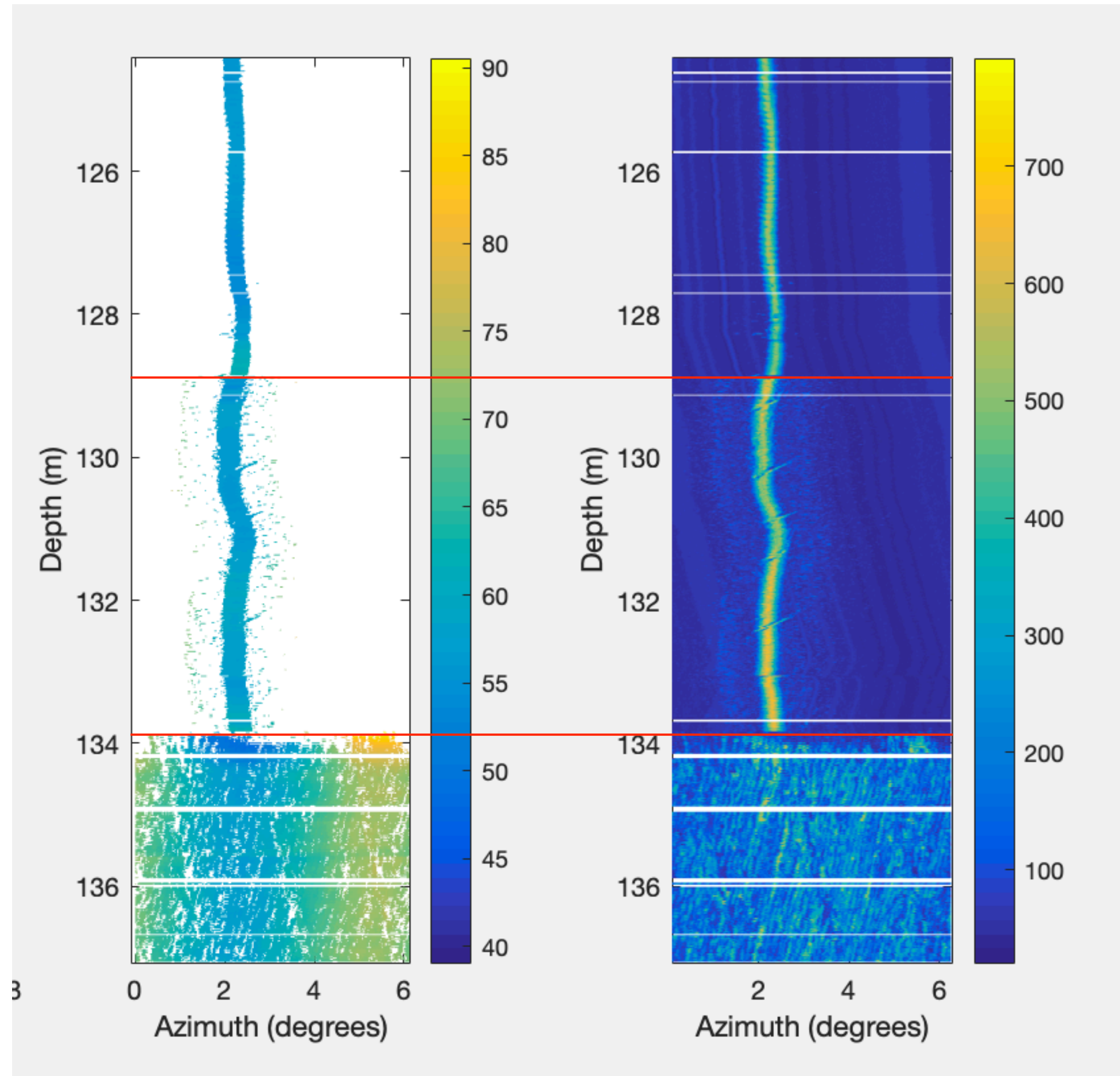- The first run down into the borehole shows a fluid level of 118.08m

Borehole Diameter

SPICEcore Borehole Schematic

0 m (Snow Surface)

5 m

Casing
Diameter: 191.7 mm

130 m

Diameter: 177.8 mm

135 m

Diameter: 129.6 mm

214.4 m

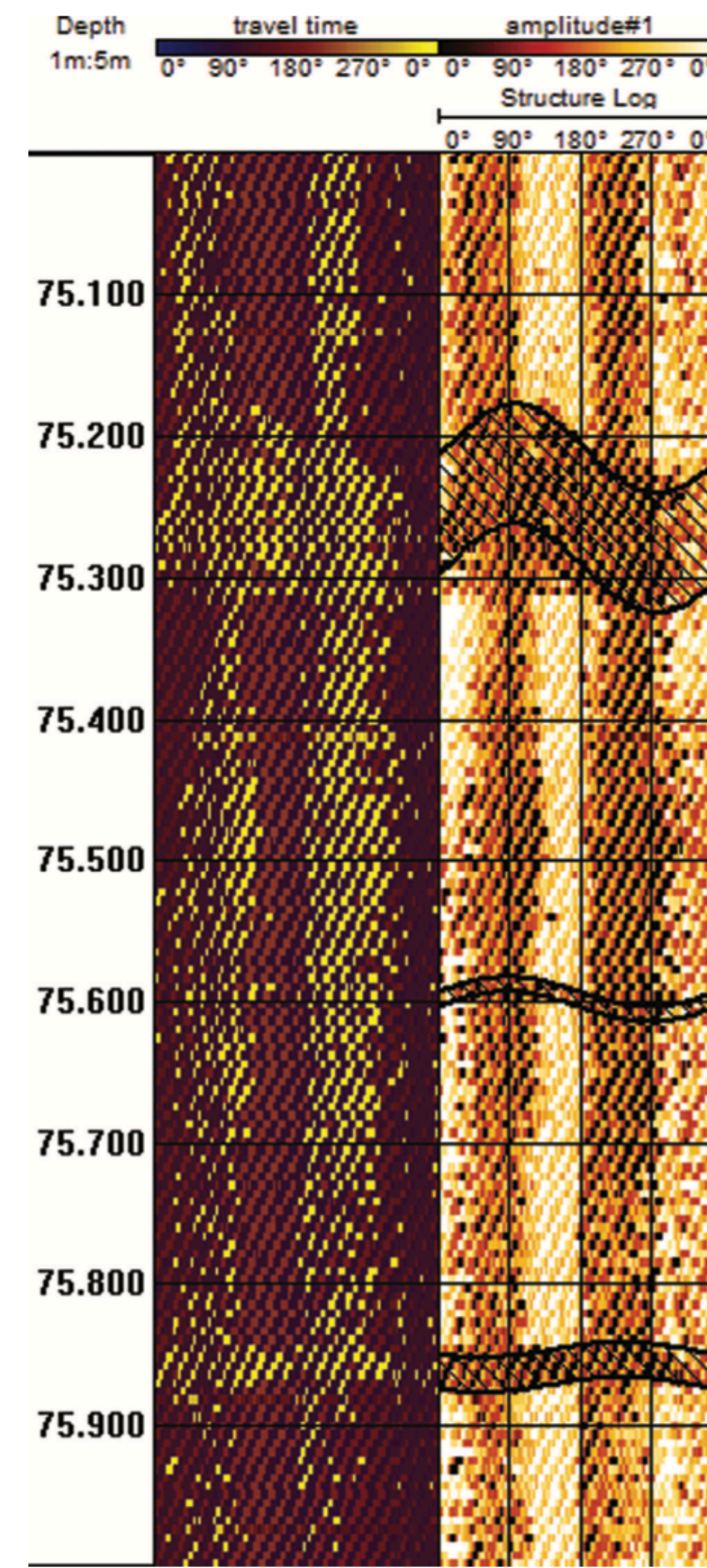Diameter: 126.0 mm

1751 m

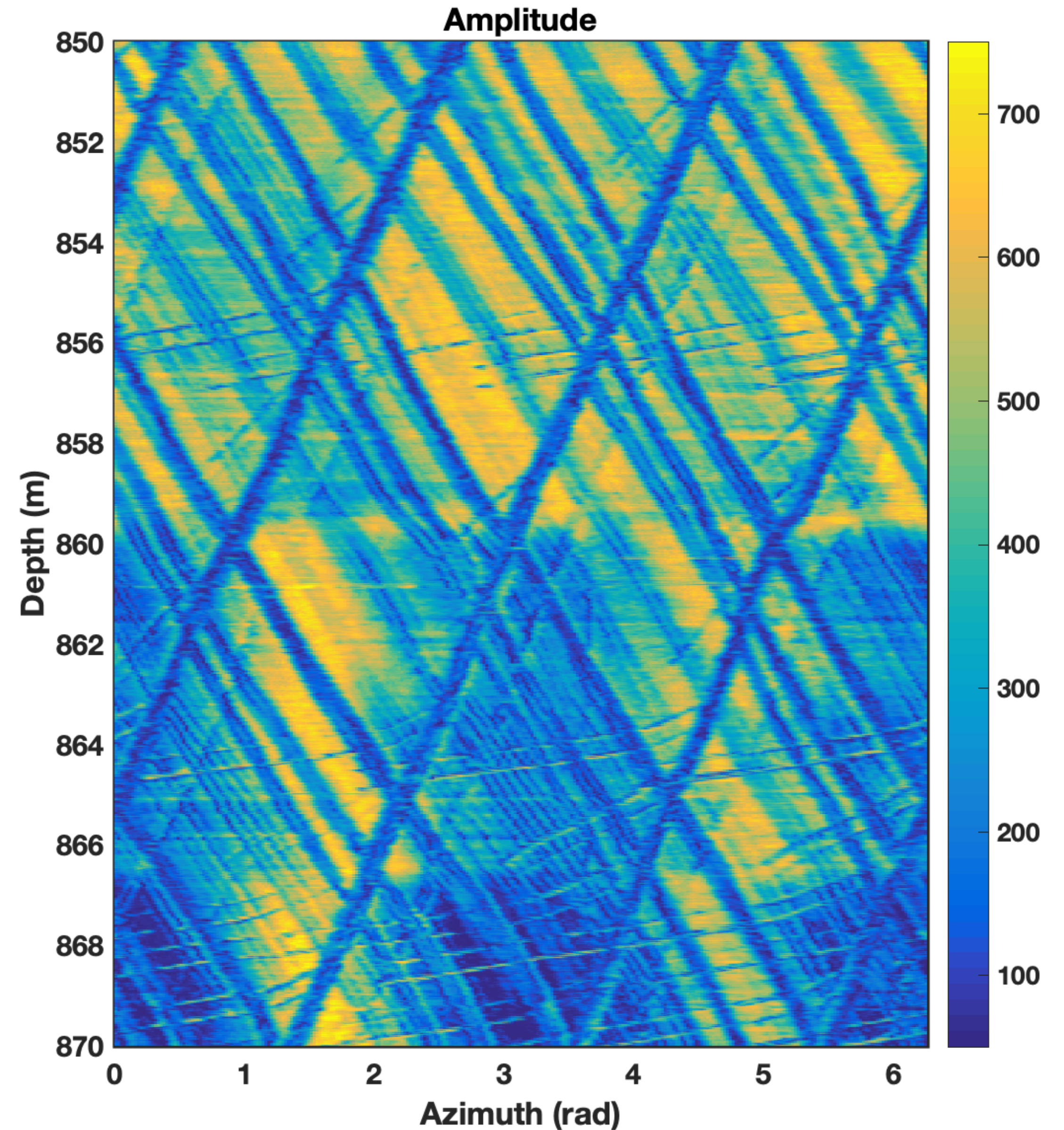**NOTE: Drawing is not to scale.**

4/28/2020, JAJ

Amplitudes

- See Drill Artifacts

- Good for aligning depths of different runs

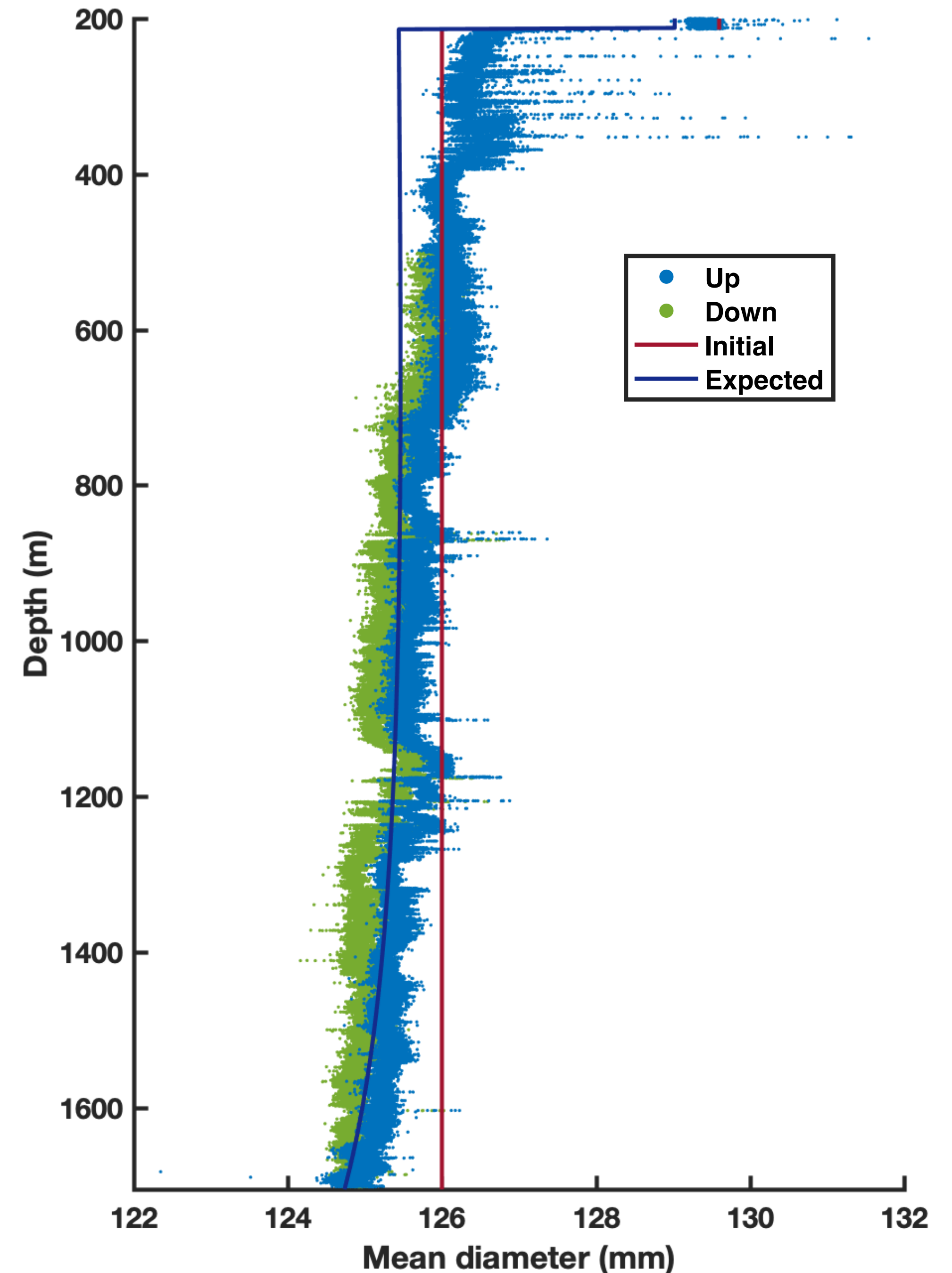- Can be used to reorient core where tilted layers are present
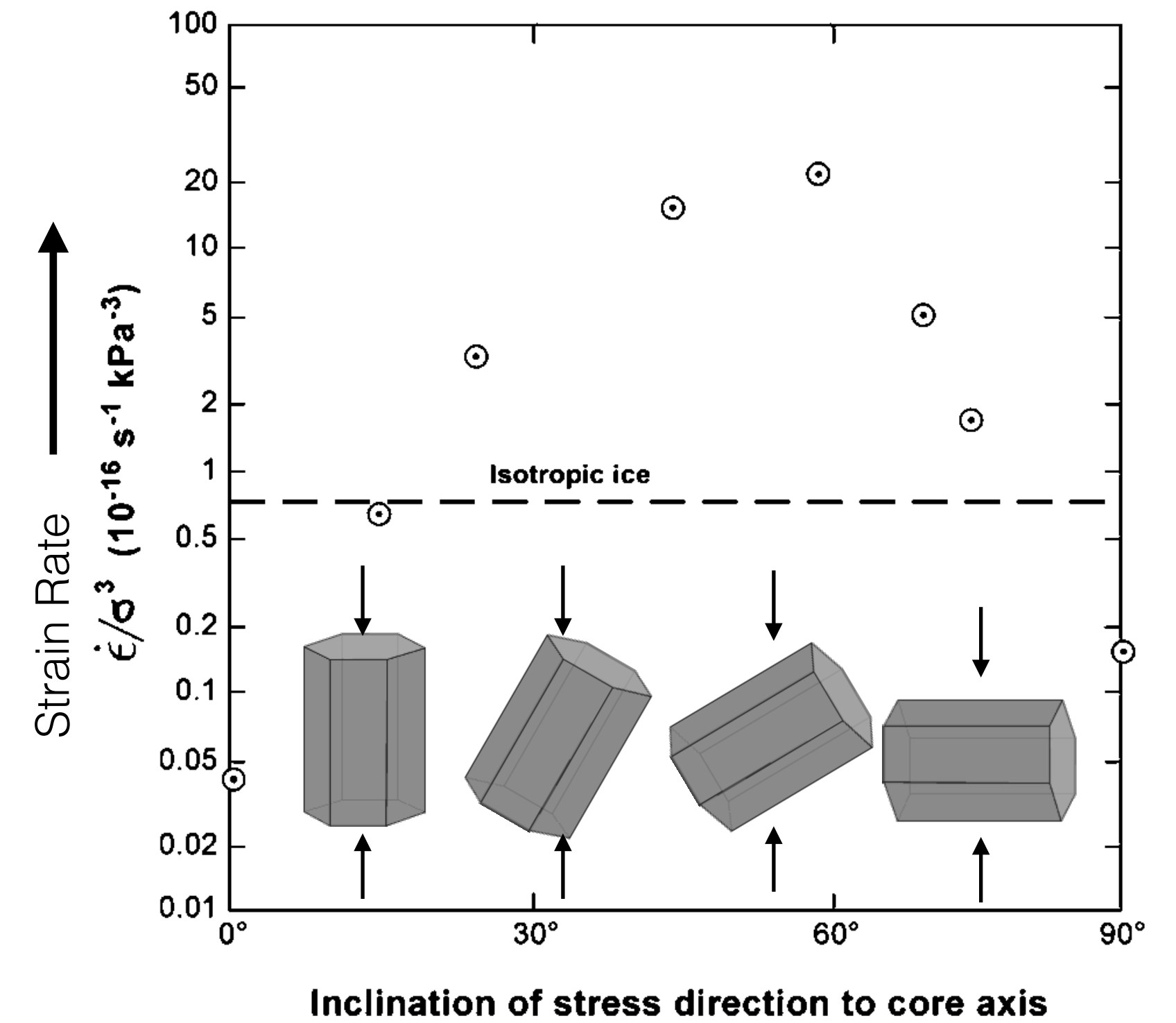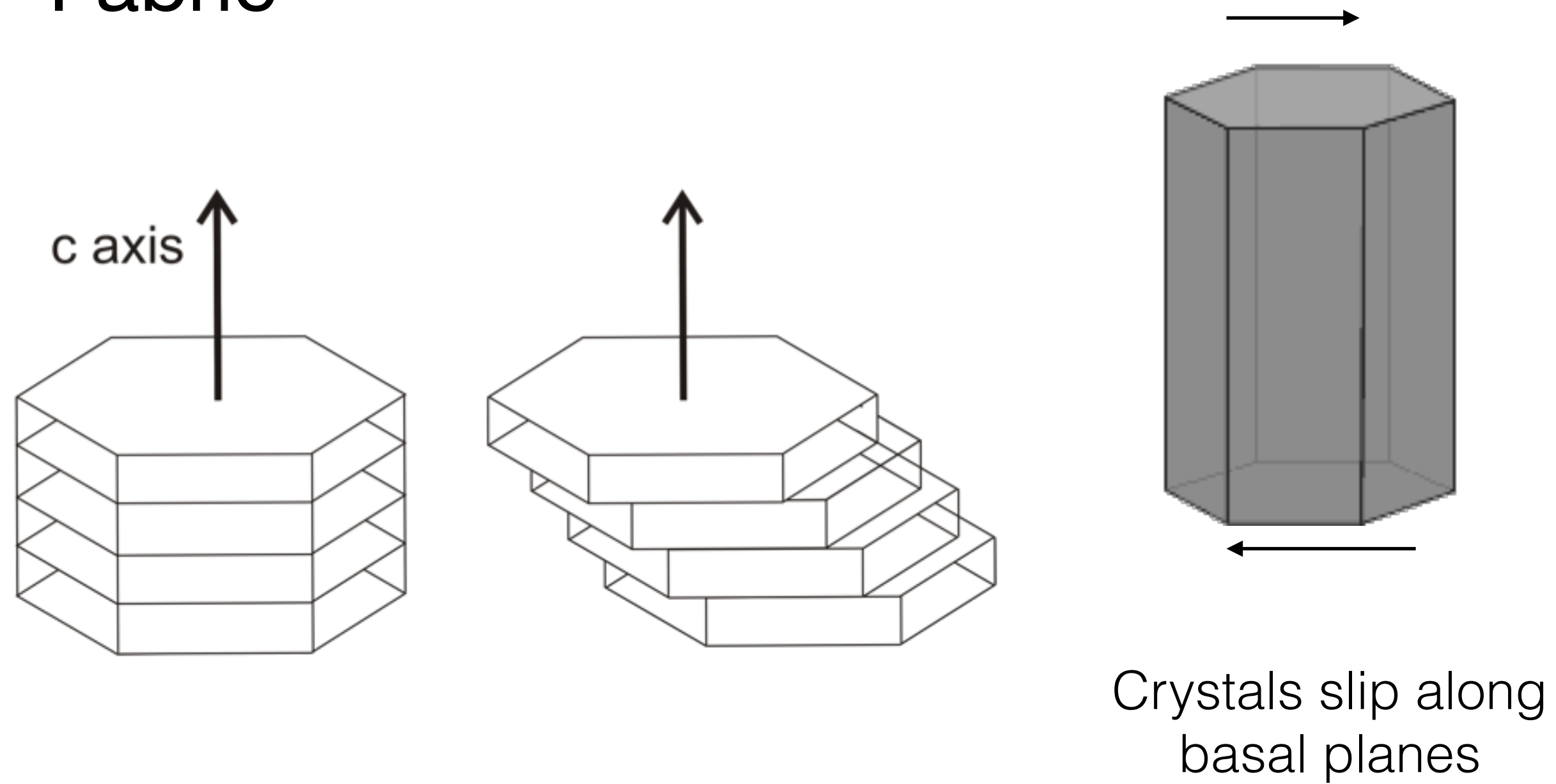

Obbard et al., 2011

Borehole Diameter

- Diameter shows differences between up/down runs, which is likely due to temperature differences within the tool oil

- Expected diameter follows Talalay et al., 2013

- Deviations from the expected diameter could be drilling-related and/or the influence of ice properties
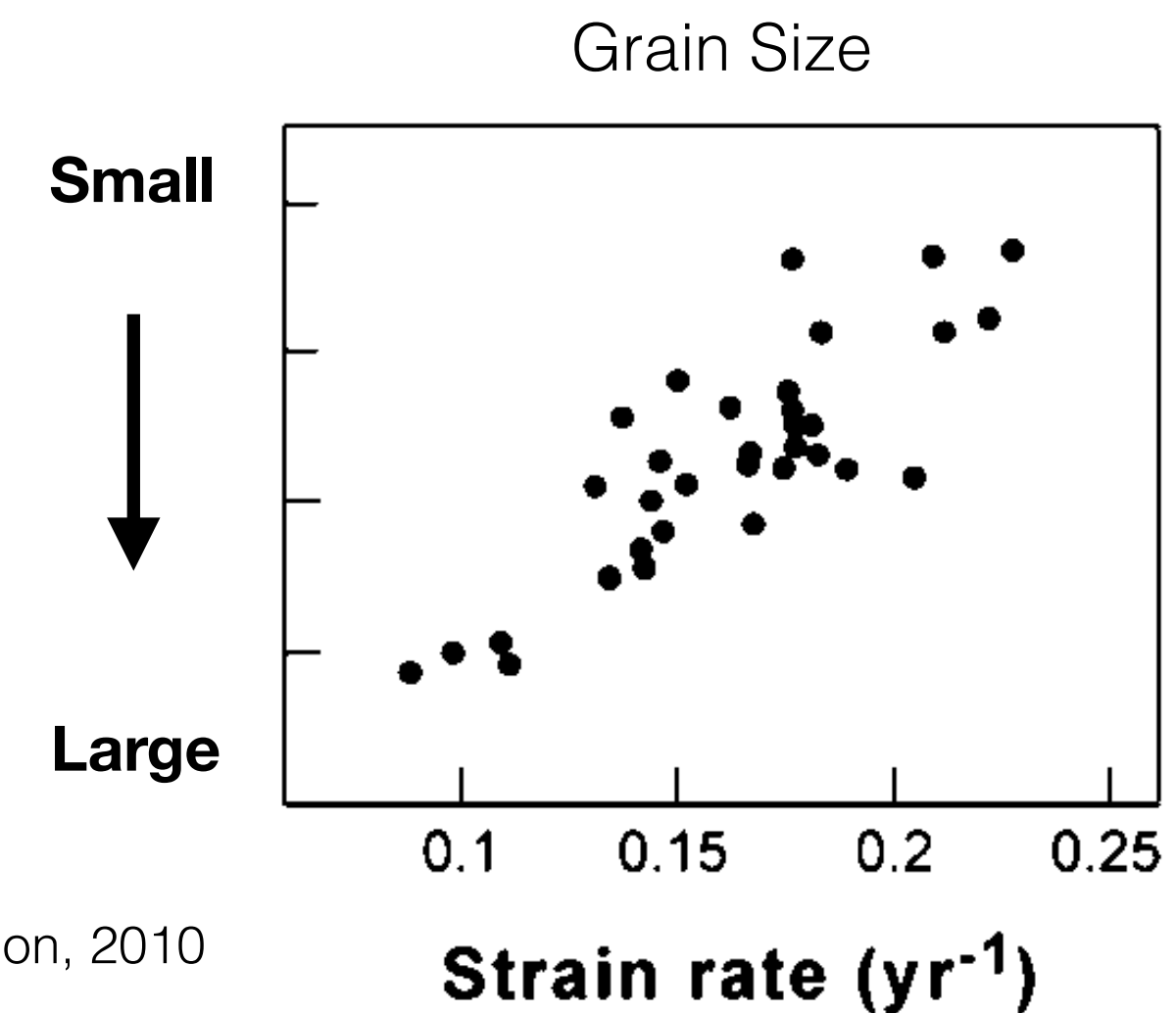
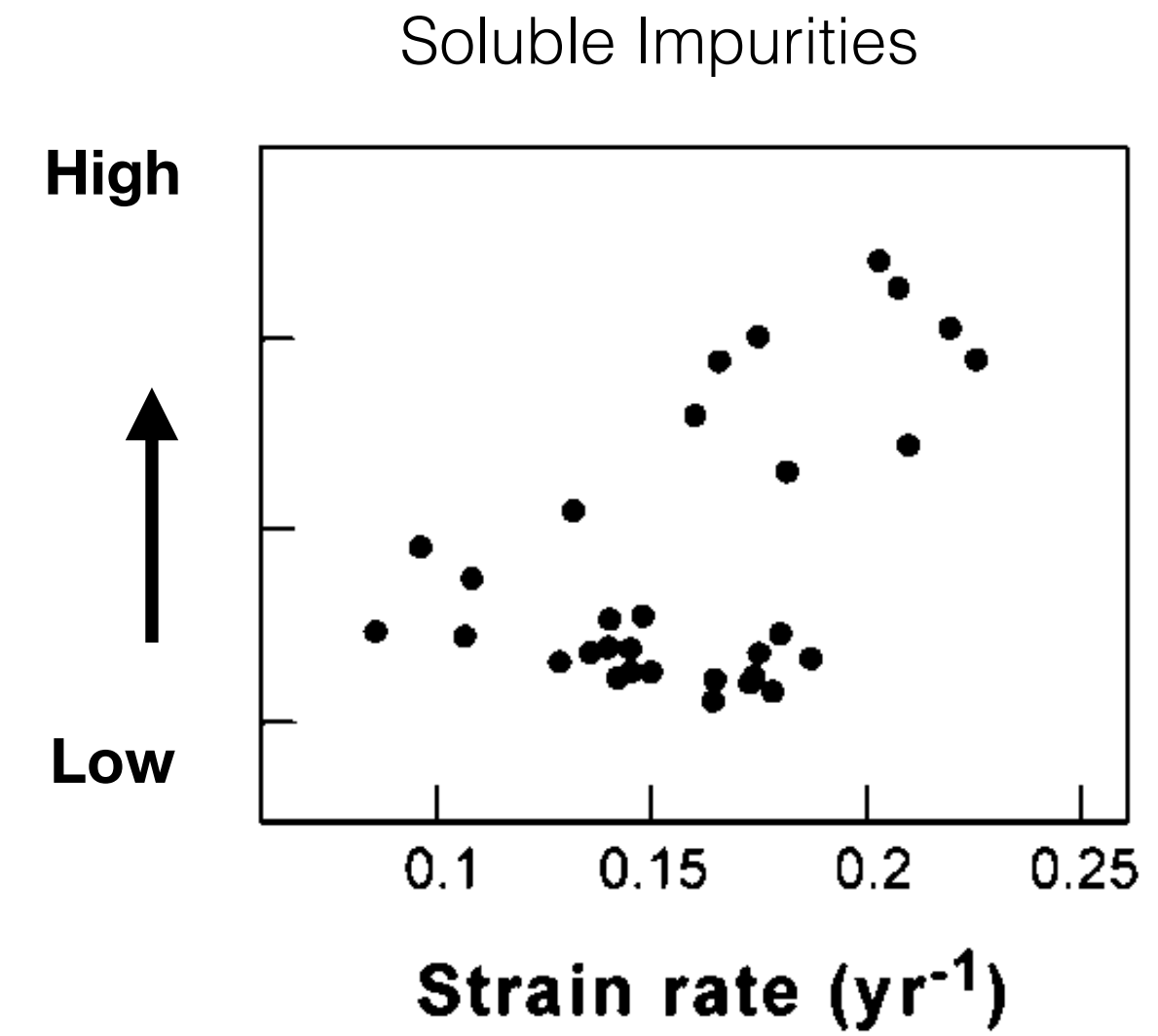# Influence of ice properties on flow

- Fabric

c axis

Crystals slip along basal planes

Isotropic ice

Strain Rate $\dot{\varepsilon}/\sigma^3$ (10^{-16} s^{-1} kPa^{-3})

Inclination of stress direction to core axis

Shoji and Langway, 1988

Influence of ice properties on flow

- Fabric

- Impurities

- Grain Size

Soluble Impurities

High

Low

0.1   0.15   0.2   0.25

Strain rate (yr^{-1})

Grain Size

Small

Large

0.1   0.15   0.2   0.25

Cuffey and Paterson, 2010

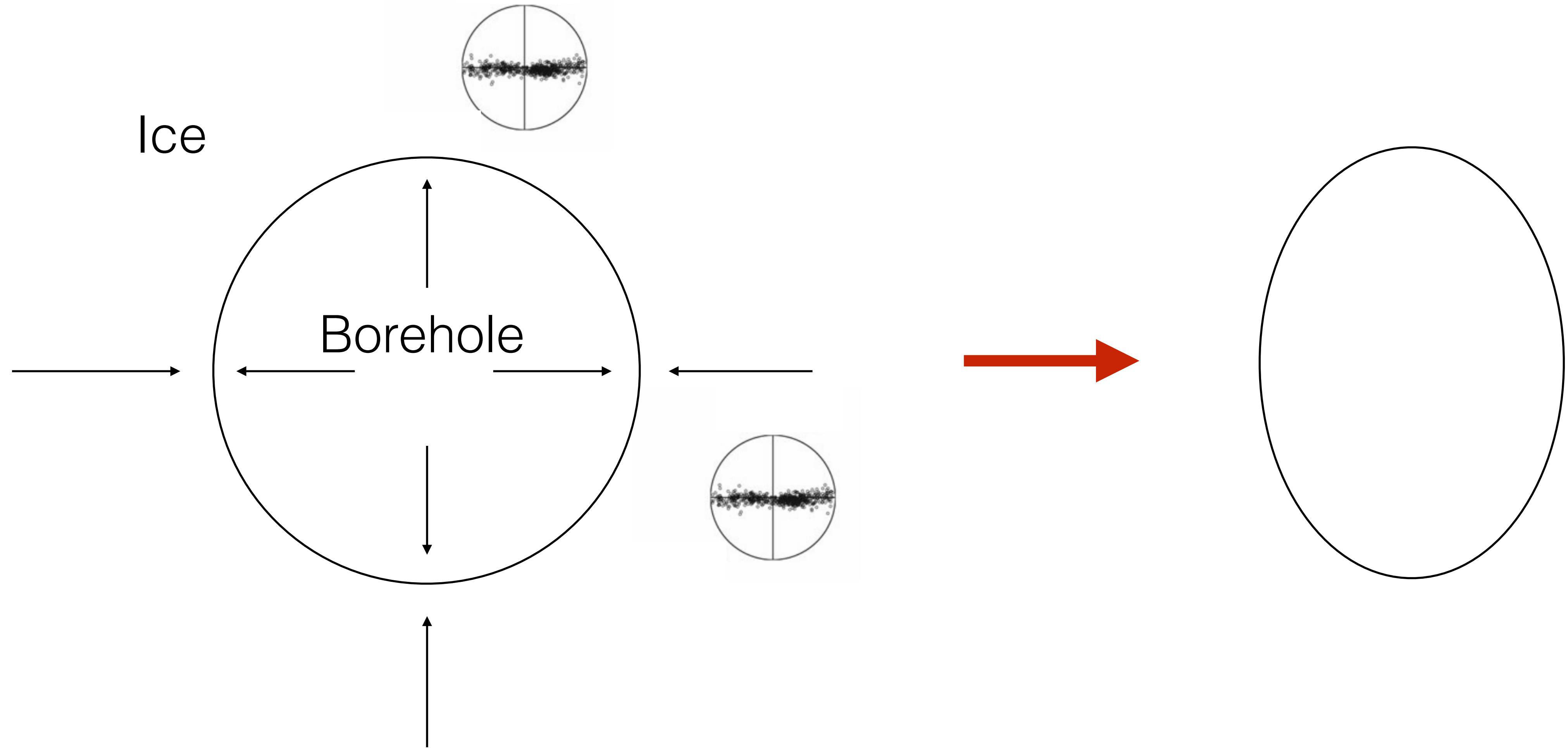**Strain rate (yr^{-1})**

Influence of ice properties on flow

- Fabric

- Impurities

- Grain Size

- Temperature

- Stress

$$\dot{\epsilon}_{jk} = A\tau_E^{n-1}\tau_{jk}$$
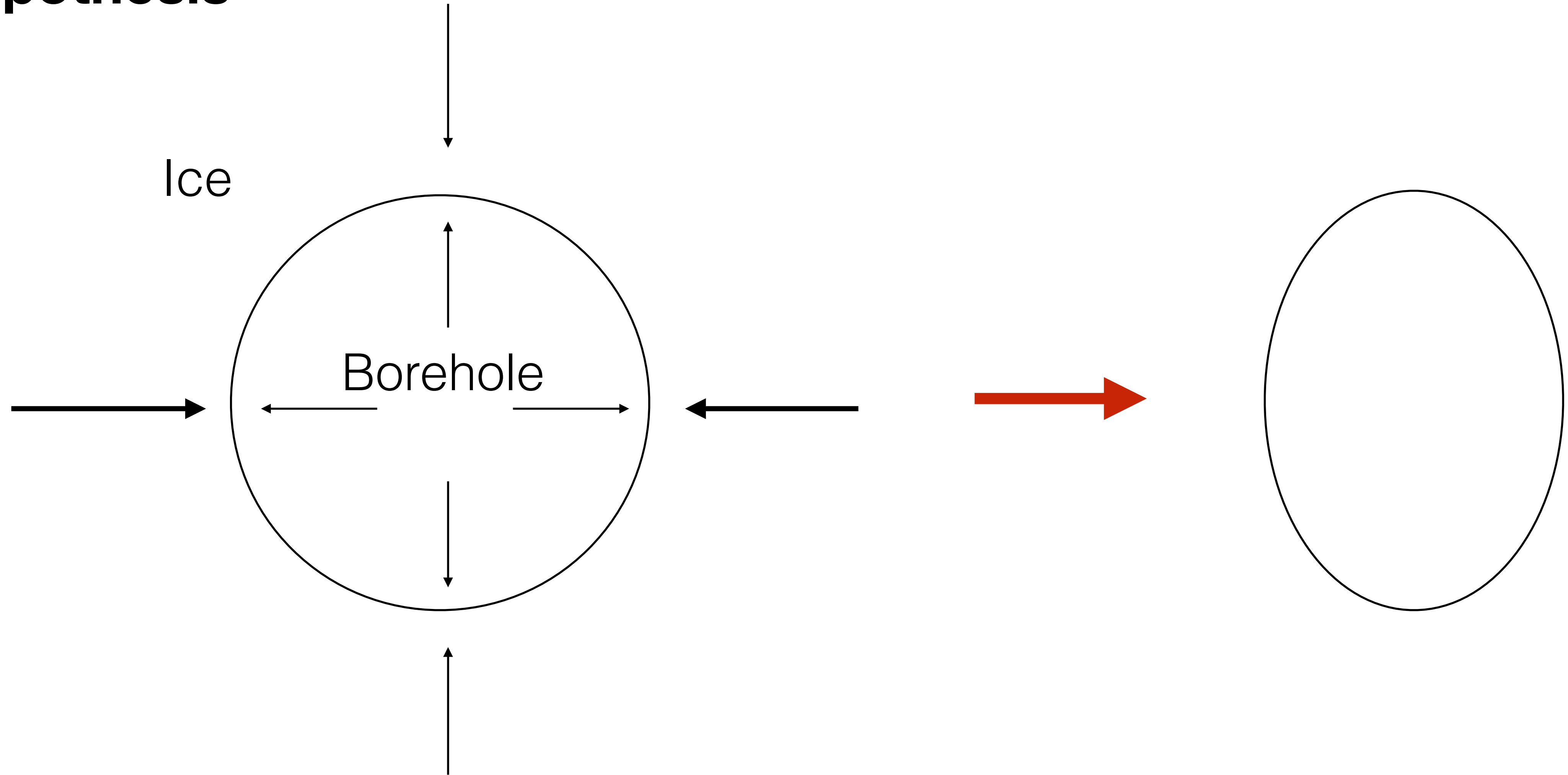
$$A = A_o \exp\left(-\frac{Q^-}{RT_h}\right)$$
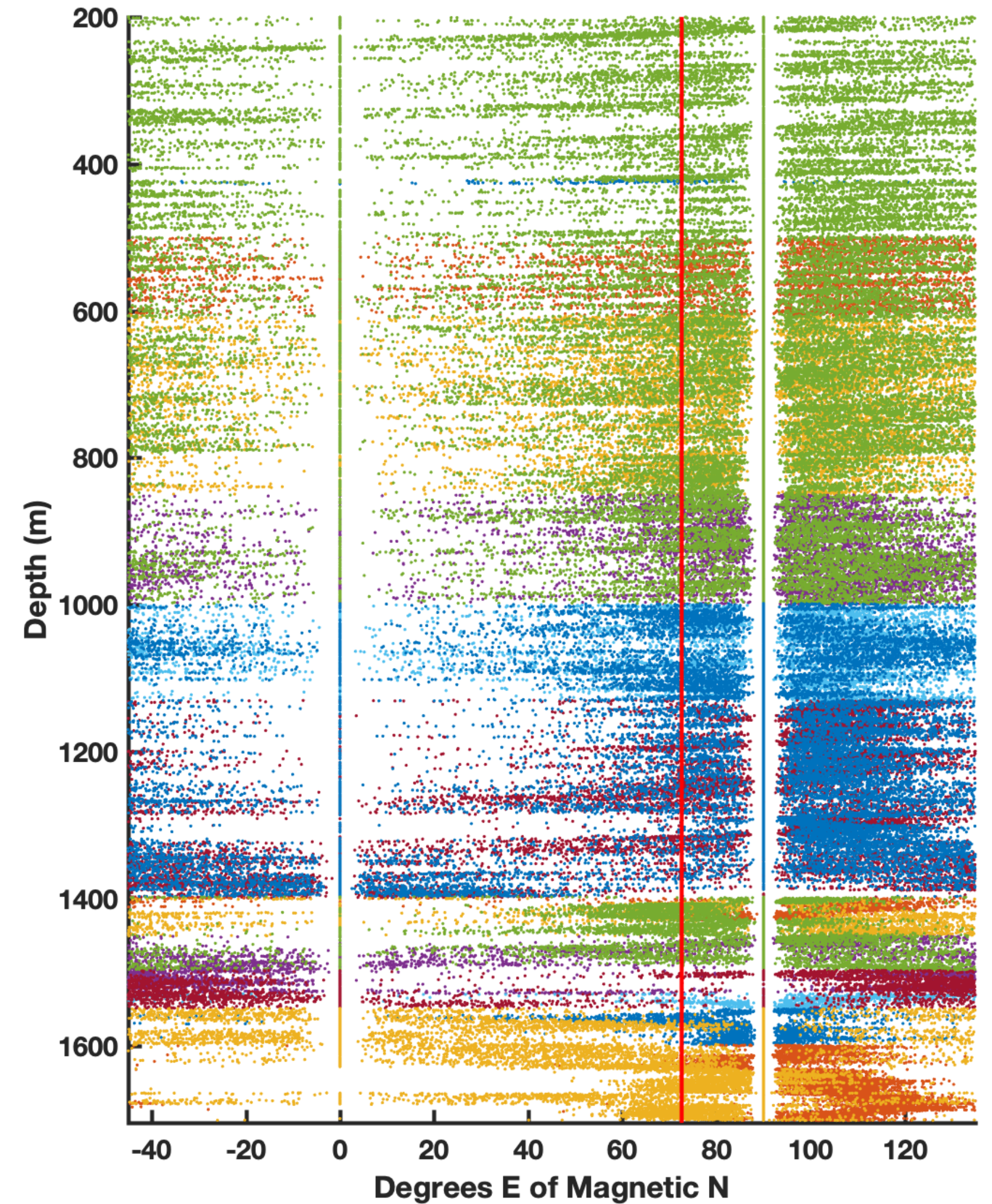
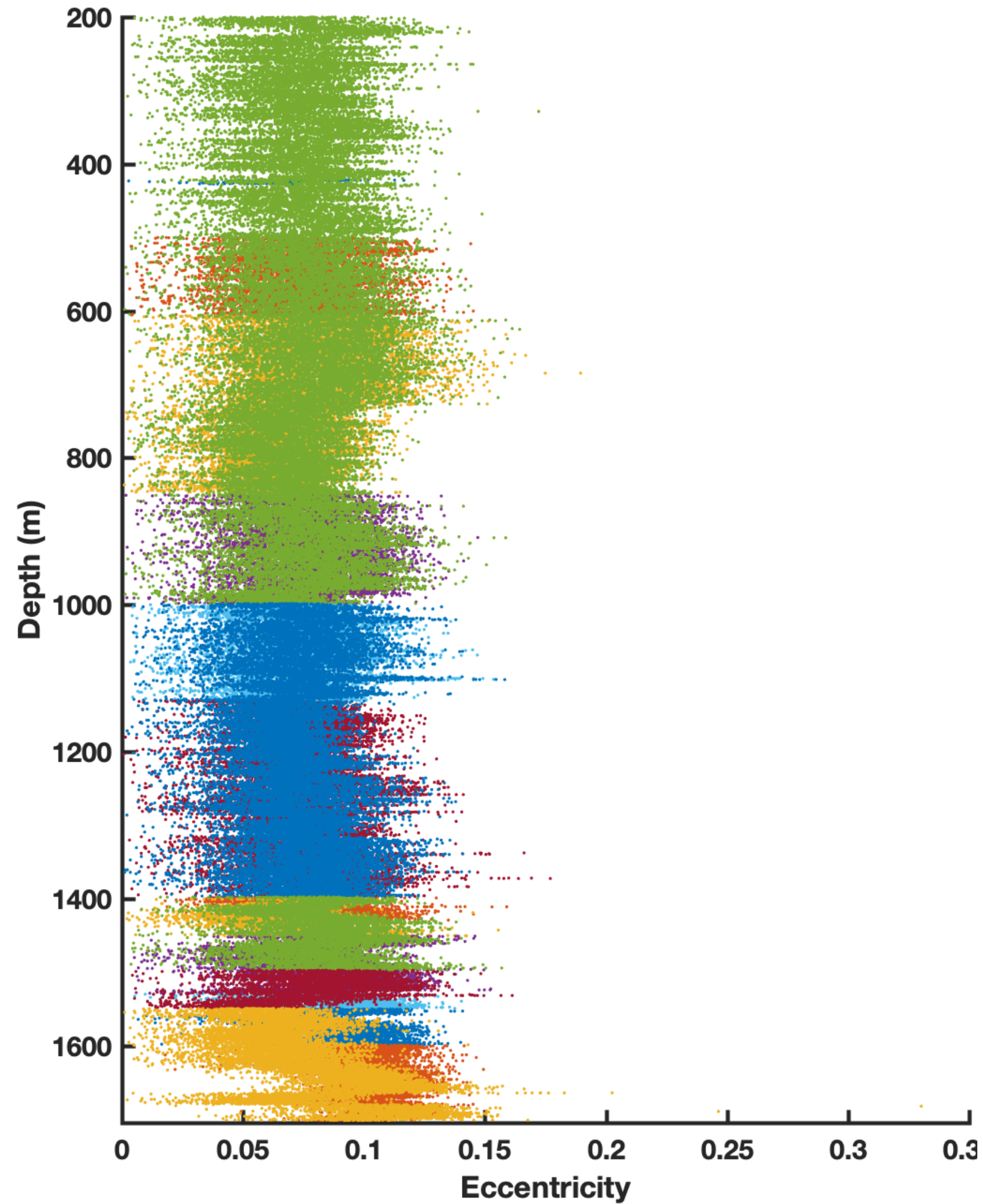# Borehole Eccentricity

A hypothesis

Ice

Borehole

Borehole Eccentricity

A hypothesis

Ice

Borehole

Borehole Eccentricity

A hypothesis

Next Steps

- Return to South Pole with the acoustic televiewer

- Gather ice properties data

- Run borehole deformation and ice properties data through our inverse flow model to determine best fit parameters

- Investigate eccentricity hypothesis

Thank you!

Thanks to the IceCube team, and especially to Delia, who took the acoustic televiewer to South Pole in 2019/2020!