Wireline Logging

Caliper Log

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What is well Logging

- Well log is a continuous record of measurement made in bore hole respond to variation in some physical properties of rocks through which the bore hole is drilled

Log acquisition – types of logs

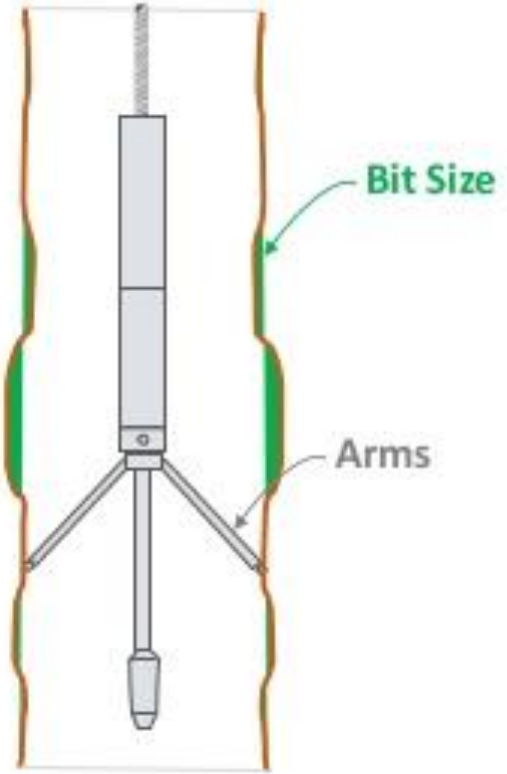
- Geophysical Logs
  - Gamma Ray
  - Resistivity
  - Sonic
  - Neutron
  - Density
  - Dip Meter
  - Borehole Imaging
- Production Logging
  - Pressure
  - Temperature
  - Spinner
  - Fluid Density
- Well Inspection
  - Caliper
  - Electro-magnetic
  - Ultrasonic
  - RA Tracer
  - Video

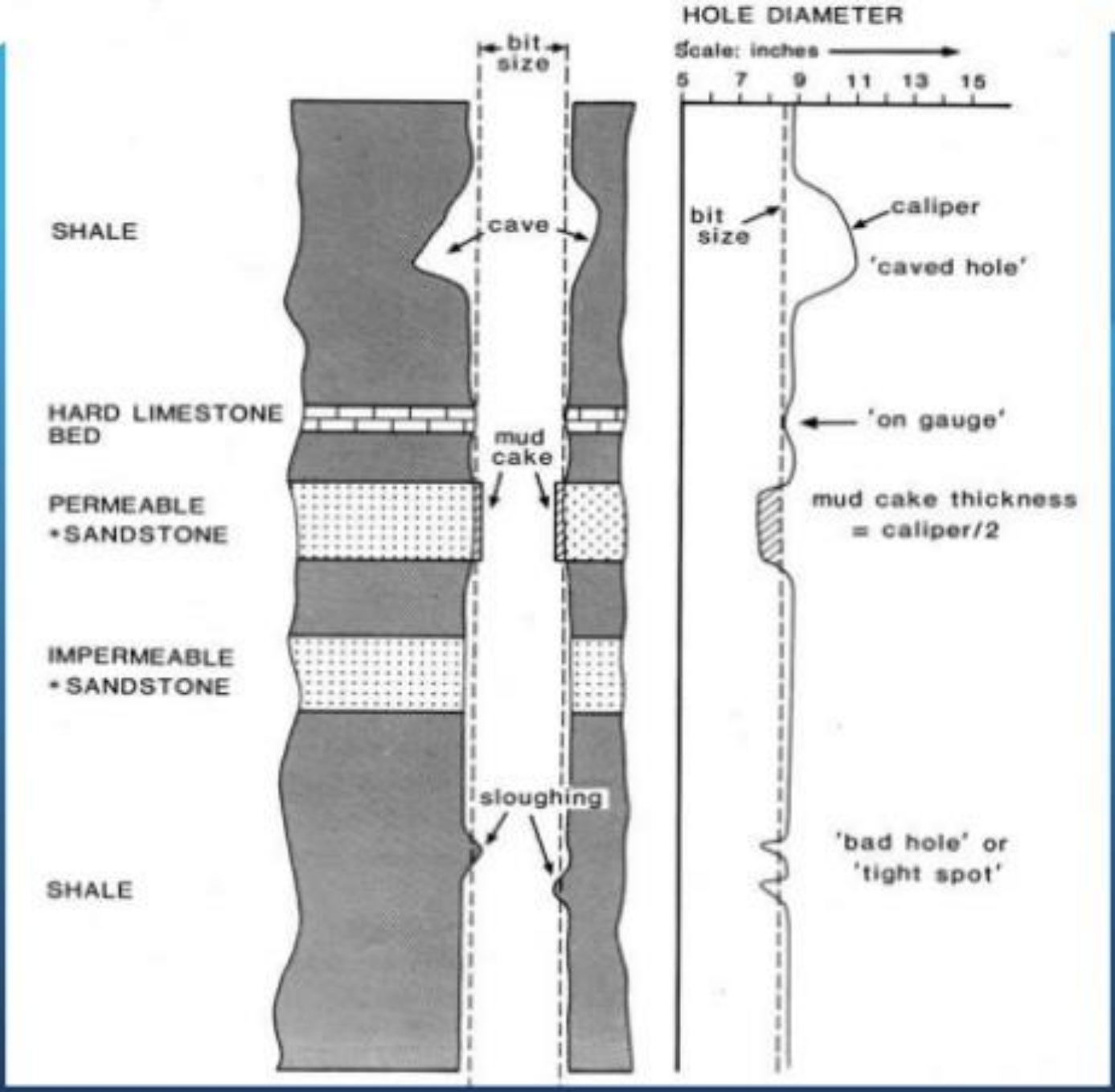
Caliper Log

Caliper Log

- Continuous measurement of the size and shape of a borehole along its depth.

- Measures the variation in borehole diameter as it is withdrawn from the bottom of the hole, using two or more articulated arms that push against the borehole wall





Caliper log showing hole Diameter and some Typical Responses

Various types of caliper

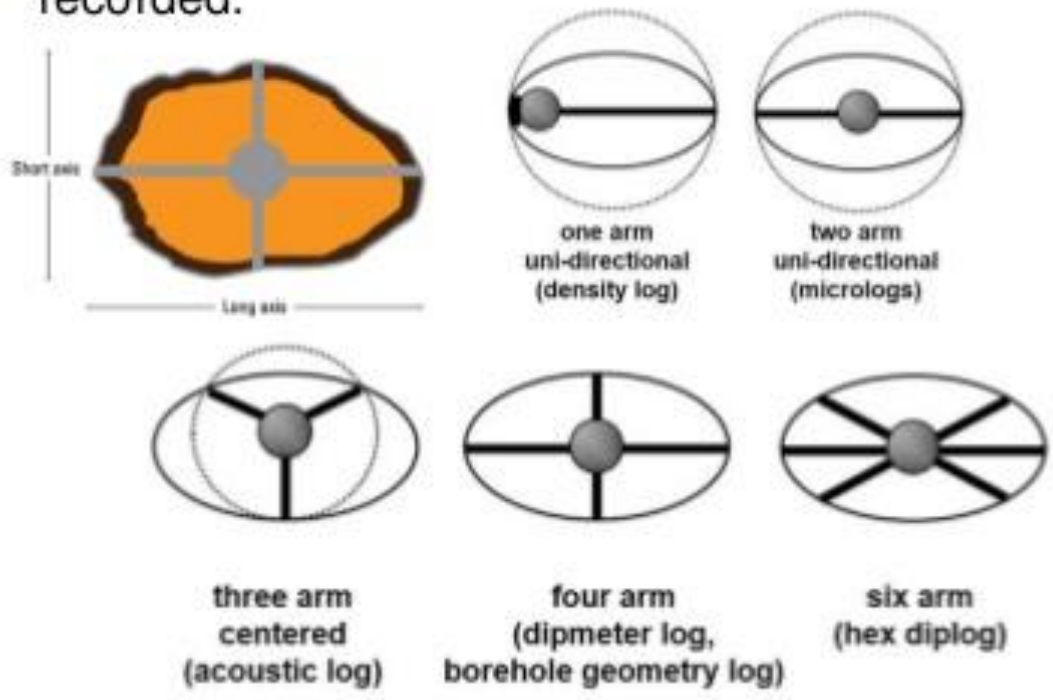
- Mechanical Caliper -arm averaging
- Ultrasonic Caliper -An Ultrasonic transducer scans around the borehole walls, and the reflected travel time is converted to the distance between the sonde and the wall.
- Acoustic caliper - calculated from acoustic transit time and velocity

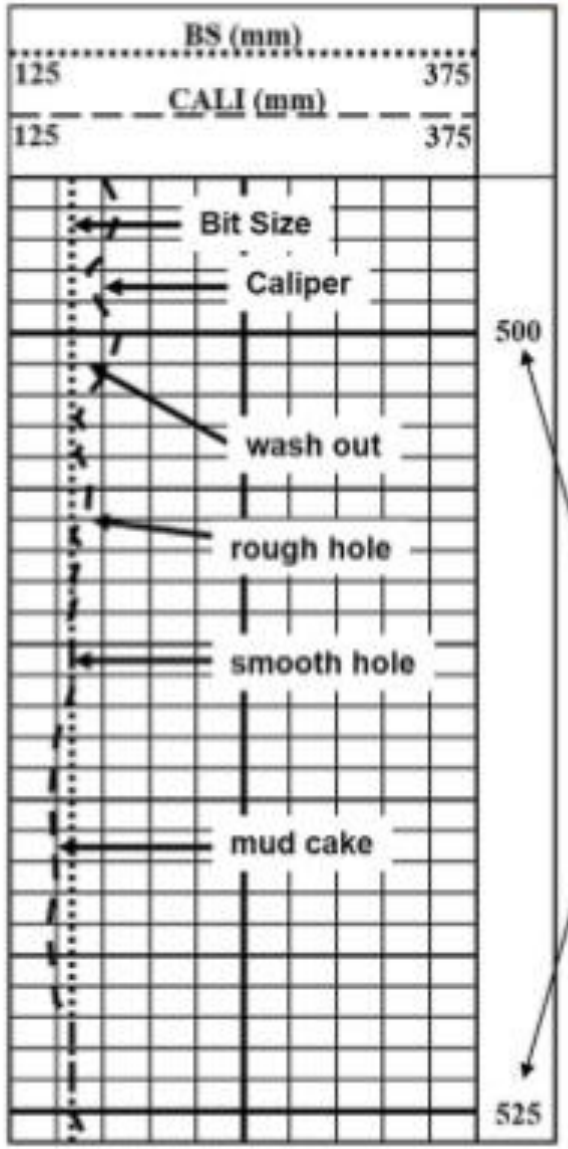
Why Caliper Log?

- Borehole Shape and volume
- Environmental correction
- Quantitative interpretation
- Cement Volume calculation
- Push a section of a probe against the side of the borehole
- Indicate build-up of mud cake.
- Selection of consolidated formations
- Borehole breakout analysis

Caliper configurations

- The more arms, the more accurate the measurement of the shape and cross-sectional area of the wellbore.
- Caliper logs are usually run simultaneously with an acoustic or a neutron-density log.
- An average hole diameter is calculated and recorded.





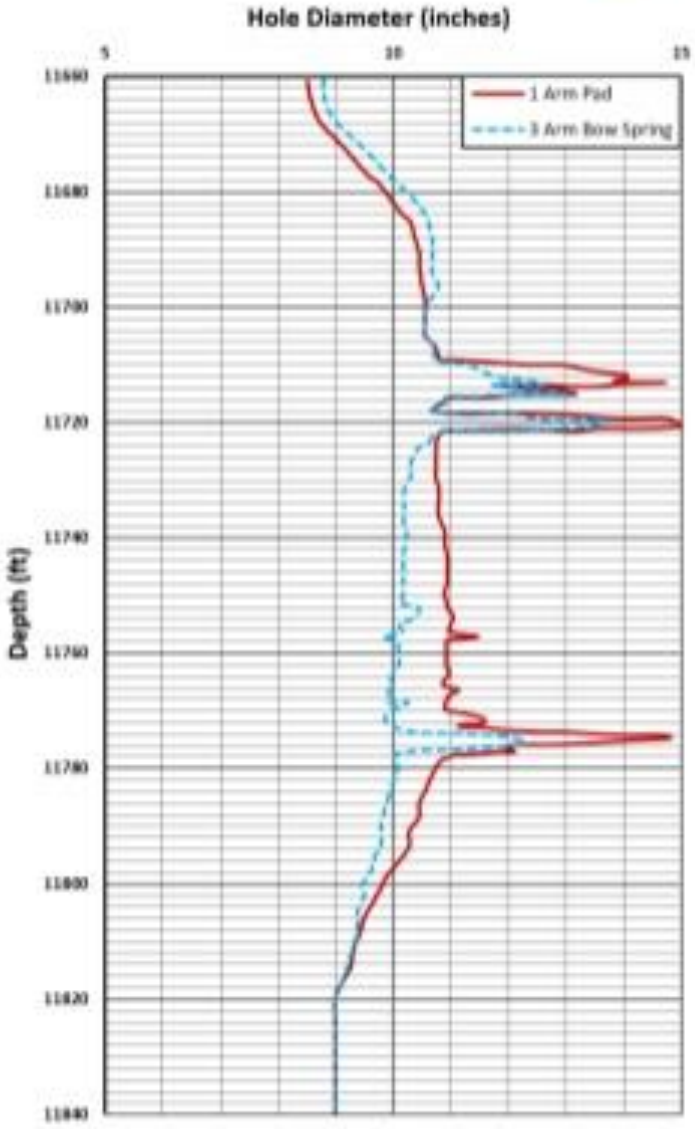
Caliper Interpretation

- **Hole volumes**
  - In general, more arms give better accuracy
  - Two arms < 100% error
  - Three arms < 20% error
- **Mud cake**
  - If $d_{caliper} < d_{bit}$
  - $h_{mc} = (d_{bit} - d_{caliper})/2$
- **Lithology**
  - Shales may indicate borehole enlargement
  - Spikey curve may indicate fractures

Caliper configurations

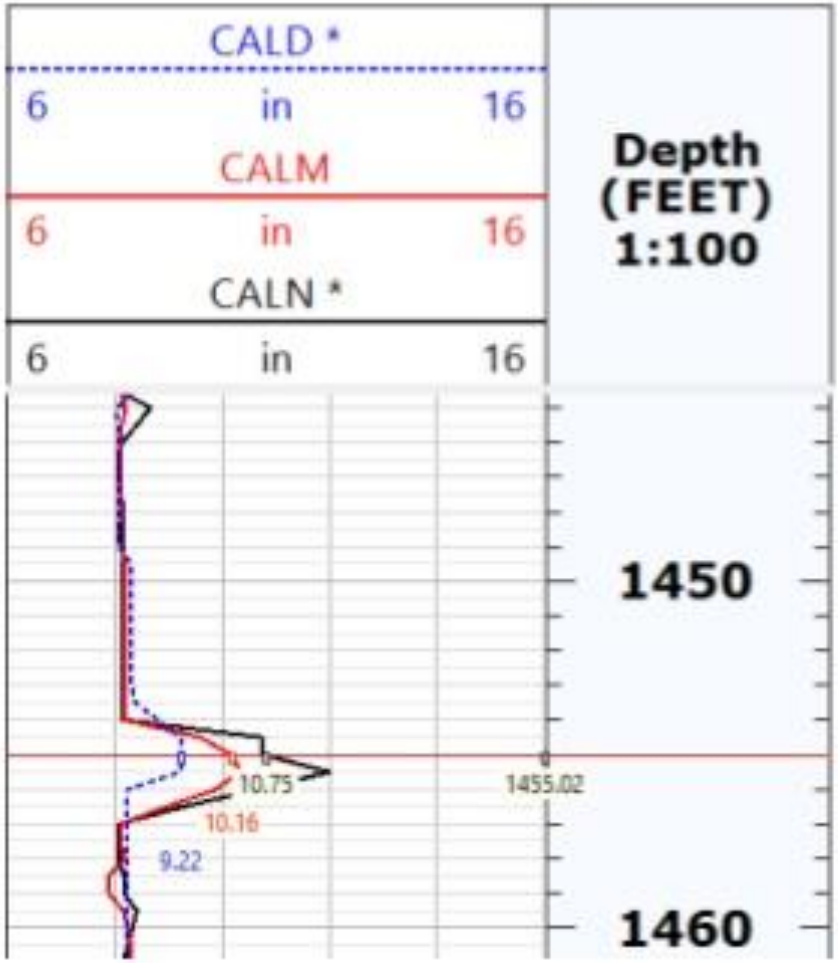
- A one-arm device caliper and three-arm bow-spring device caliper obtained in the same borehole interval.

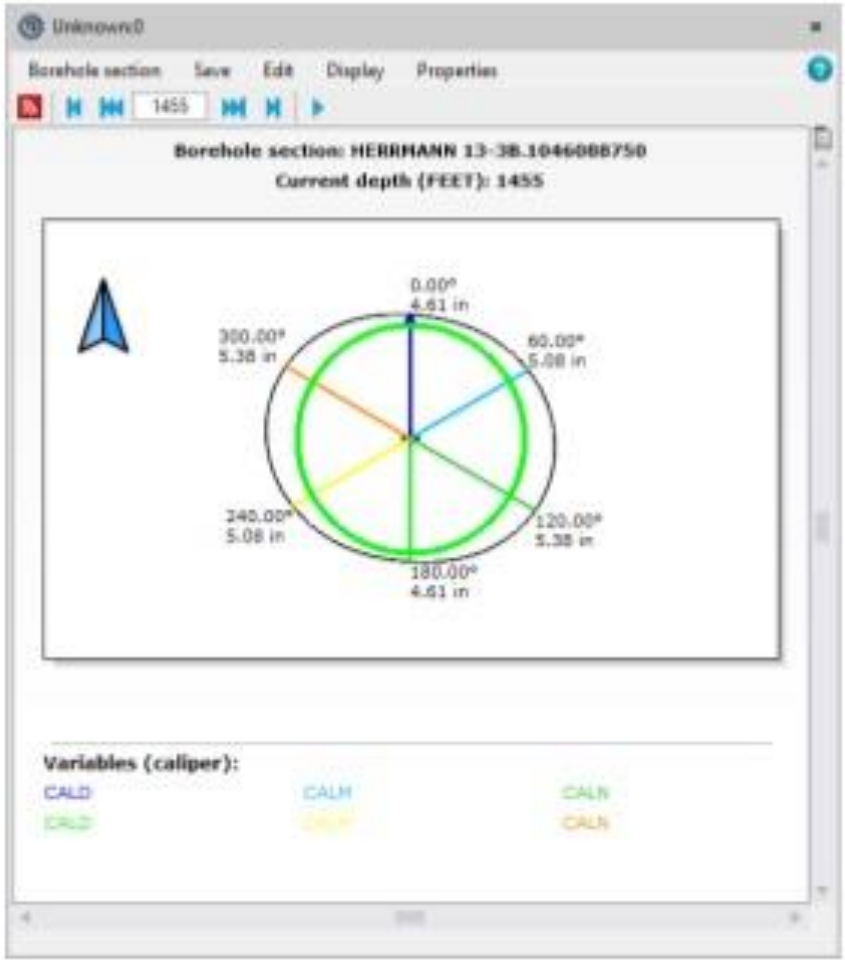
- How to explain the disagreement ?!



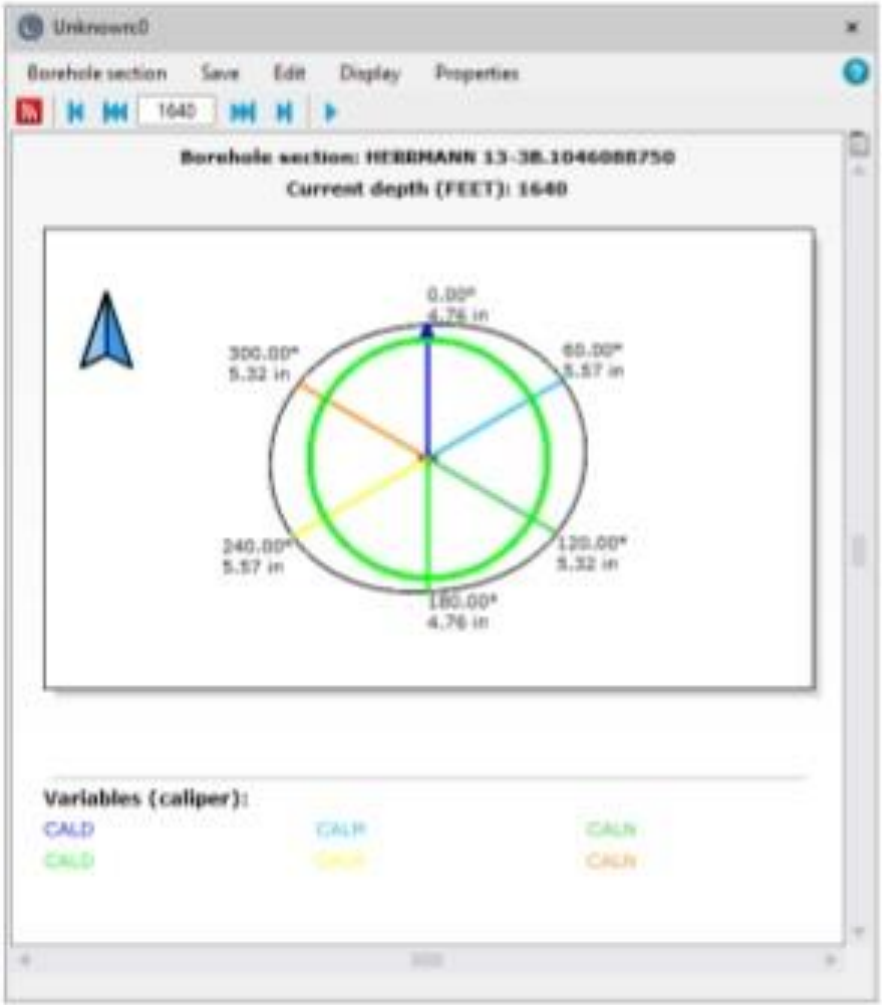
Different Caliper logs

CALN Compensated Neutron Caliper (Diameter)
CALD Litho Caliper (Diameter)
CALM Micro Spherically Focused Tool Caliper (Diameter)

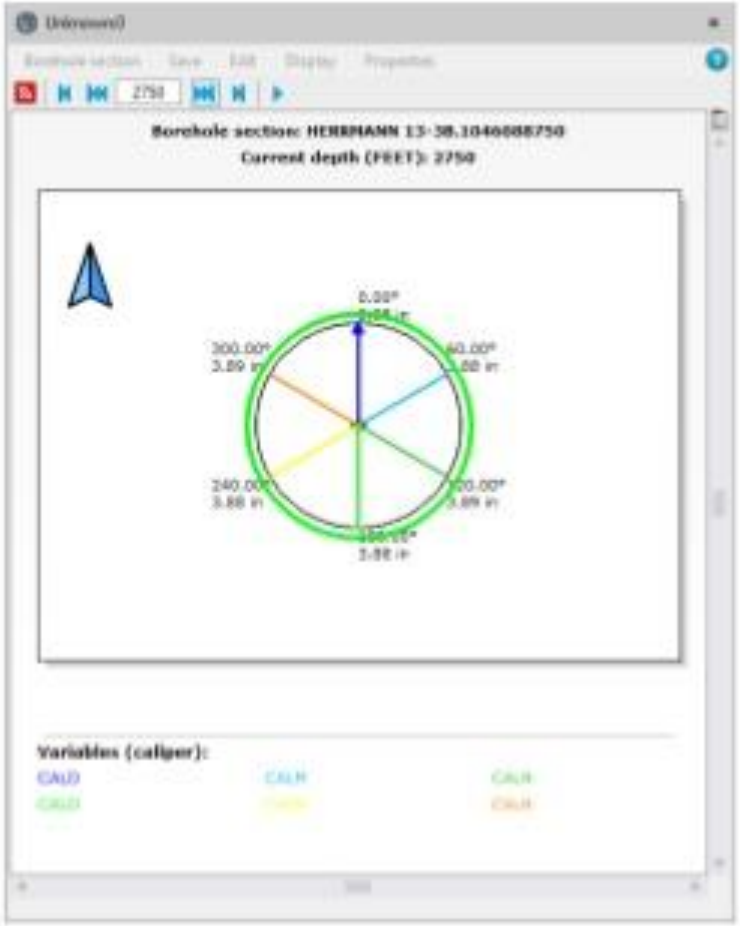




Different Caliper logs



Different Caliper logs



Caliper Log Interpretation

Hole Diameter	Cause	Possible Lithologies
On Gauge	Well consolidated formations. Non-permeable formations.	Massive sandstones Calcareous shales Igneous rocks Metamorphic rocks
Larger than Bit Size	1. Formation soluble in drilling mud. 2. Formations weak and cave in.	1. Salt formations drilled with fresh water. 2. Unconsolidated sands, gravels, brittle shales.
Smaller than Bit Size	1. Formations swell and flow into borehole. 2. Development of mudcake for porous and permeable formations.	1. Swelling shales. 2. Porous, permeable sandstones.

$h_{mc} =$

$V_h =$

$V_{cement} =$

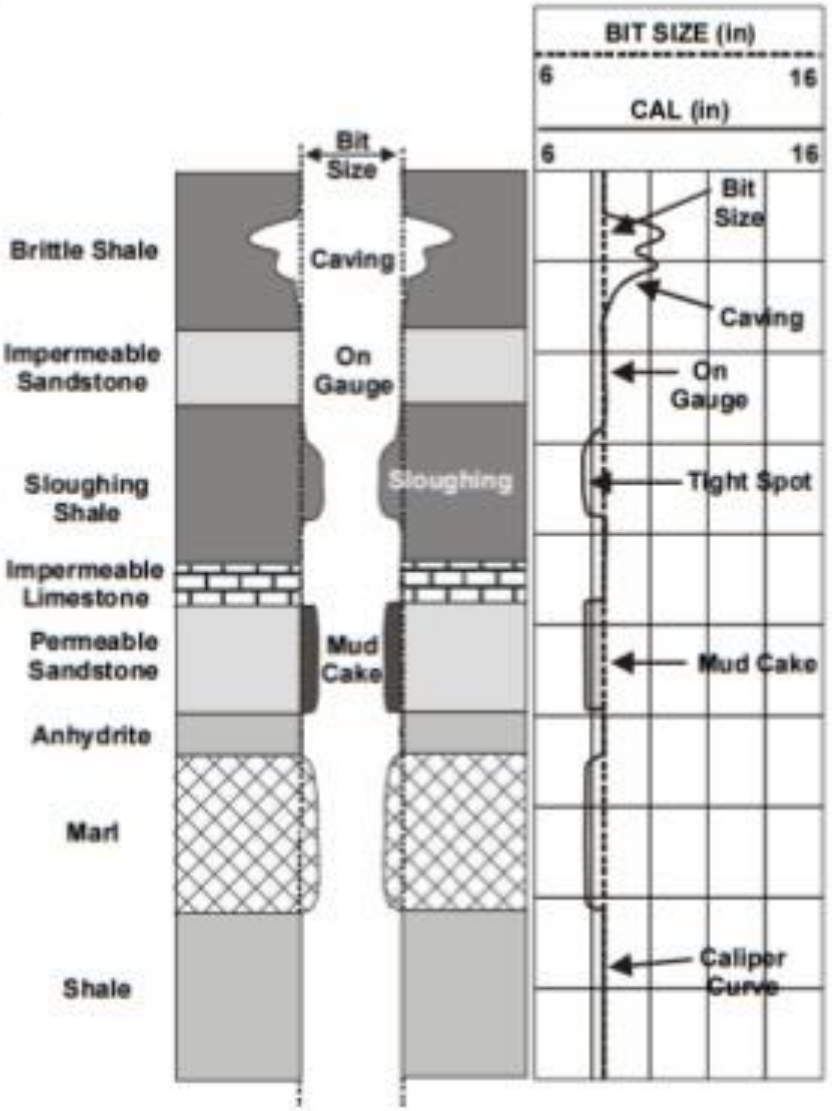


Table: Factors influencing caliper responses

Hole Diameter	Cause	Possible Lithologies
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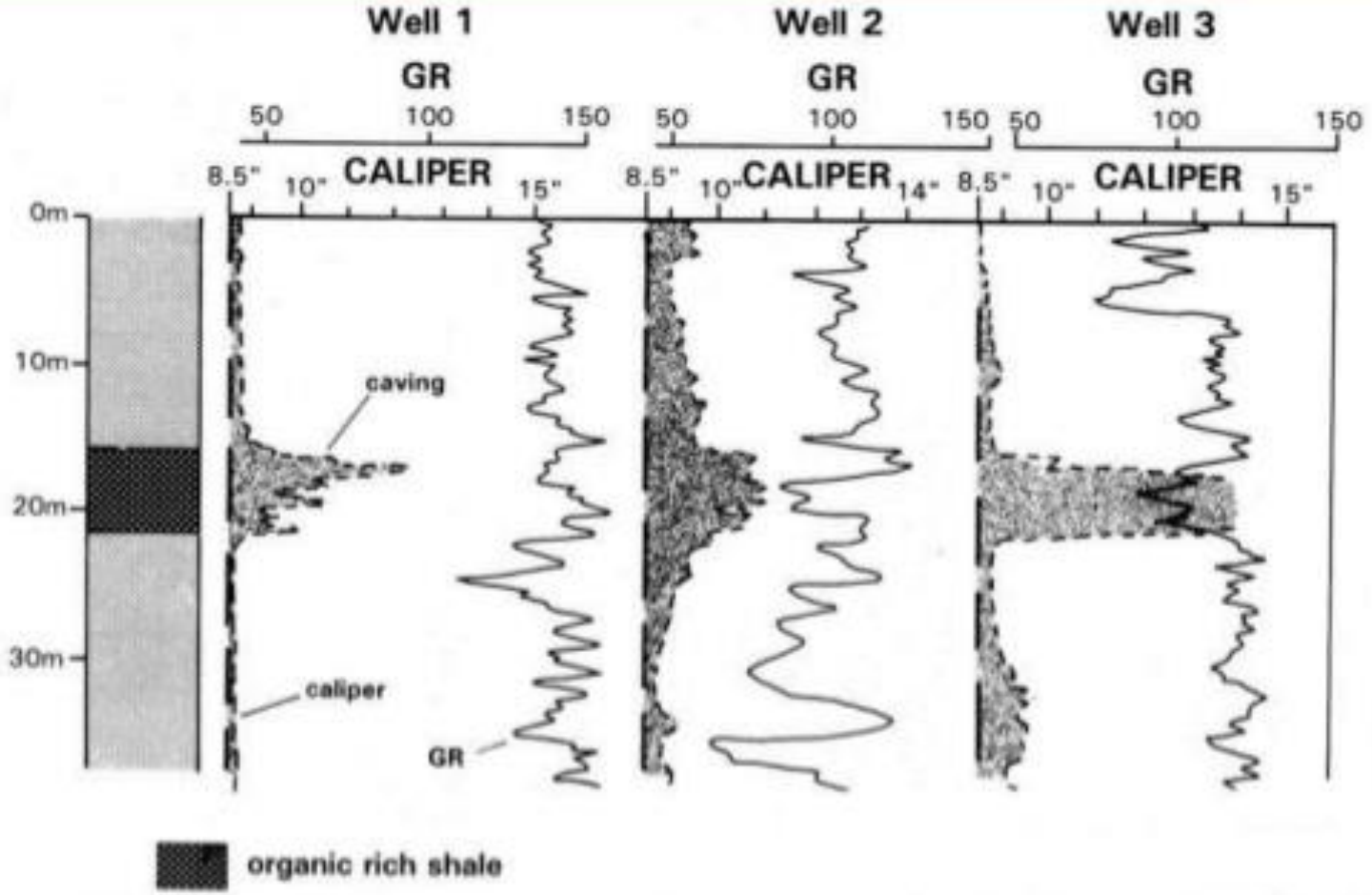


Figure 4.5 Consistent caving, indicated on the caliper log, over the same, organic rich, stratigraphic level in three different wells. Upper Carboniferous, East Midlands, U.K.

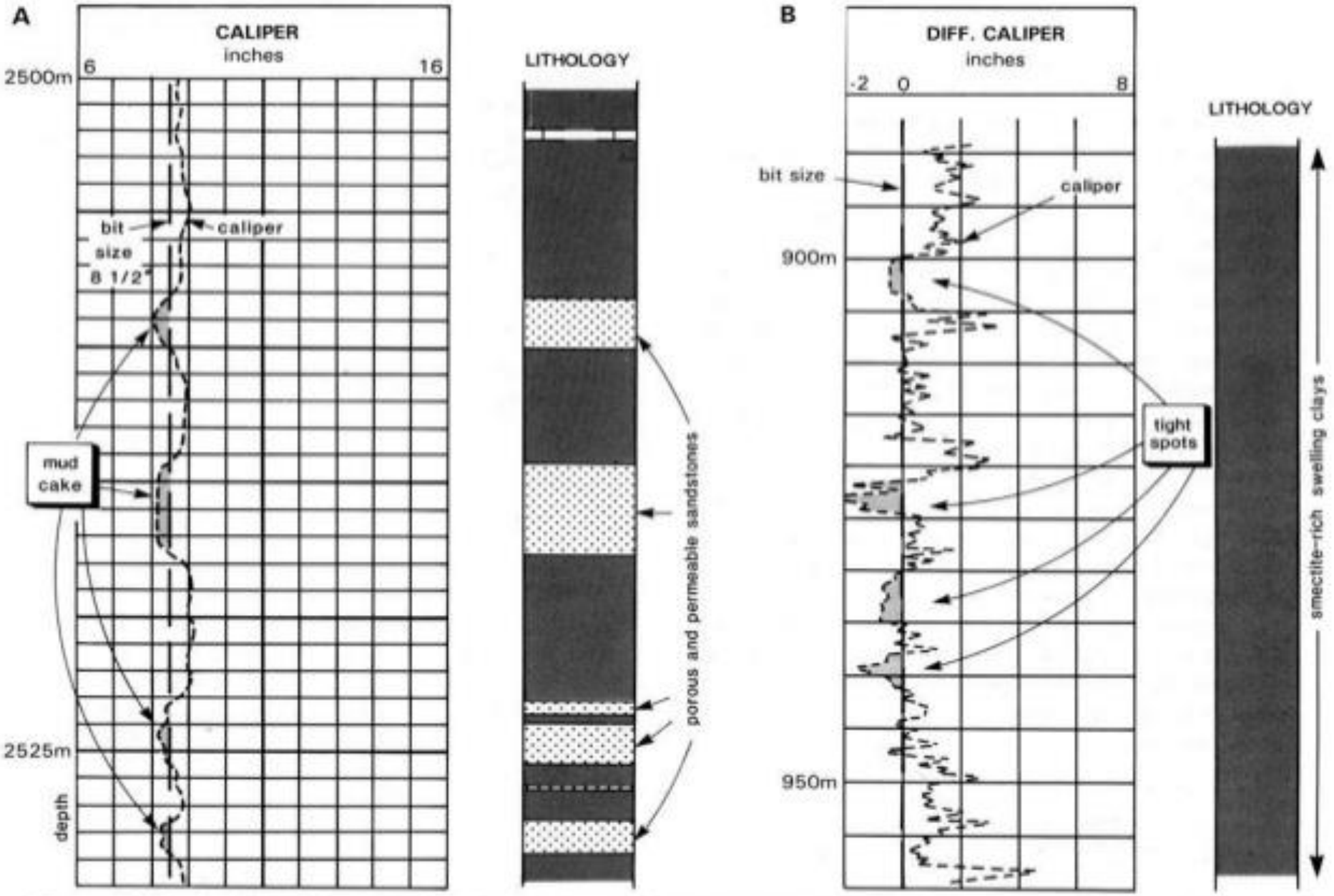


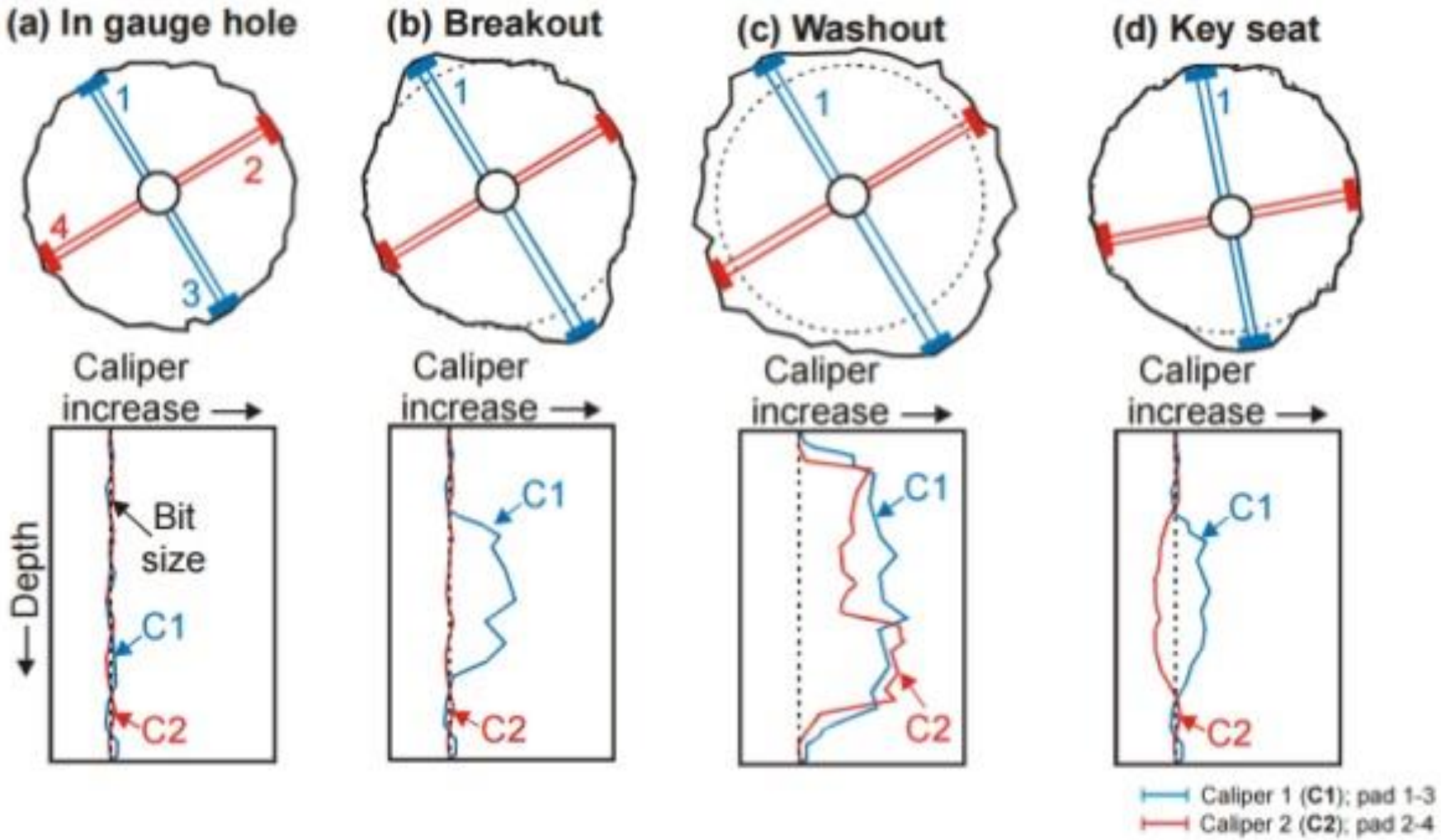
Figure 4.6 Hole size diminution seen on the simple caliper. (A) Mud-cake build-up opposite porous and permeable sandstones. (B) Tight spots in a shale sequence caused by hole sloughing due to swelling clays.

Four-arm caliper interpretation

- More information can be found by dual(4-arm) caliper than simple caliper tool.
- A hole can be seen to be “on gauge” and round, or “washed out” and oval, or enlarged by “key seat”. When oval, the direction of enlargement can be given.
- However, much more can be interpreted from borehole shape.

Caliper Log Interpretation

- Types of enlarged borehole and their caliper log response



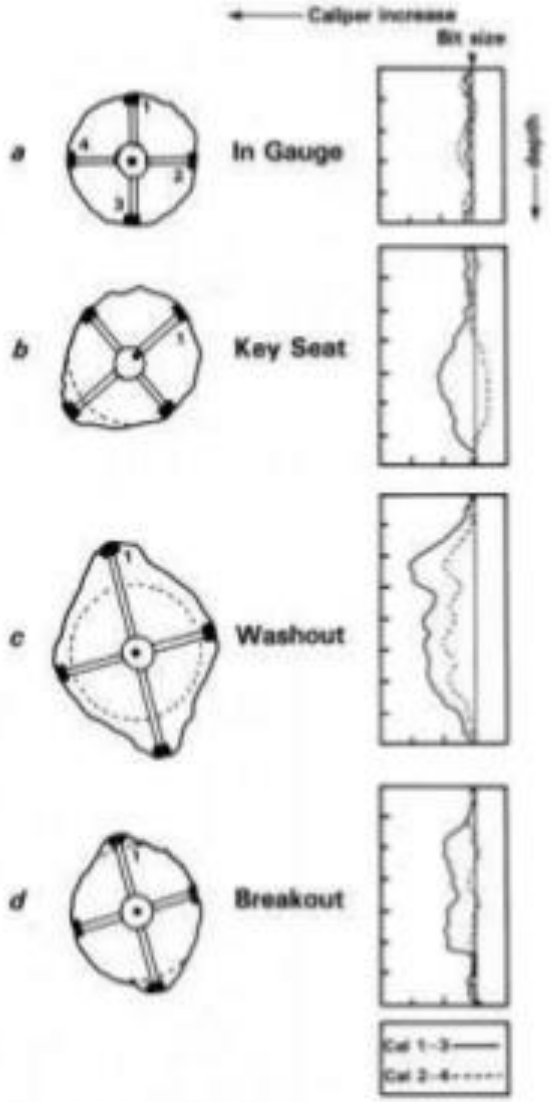


Figure 4.9 Diagrammatic representation of types of borehole shape and profile as identified on the two-arm caliper. *a*. Round, in-gauge hole. *b*. Key seat hole enlargement at a dogleg. *c*. Washout hole enlargement due to general drilling wear. *d*. Breakout, showing characteristic oval hole with abrupt vertical limits (re-drawn, modified from Plumb and Hickman, 1985).

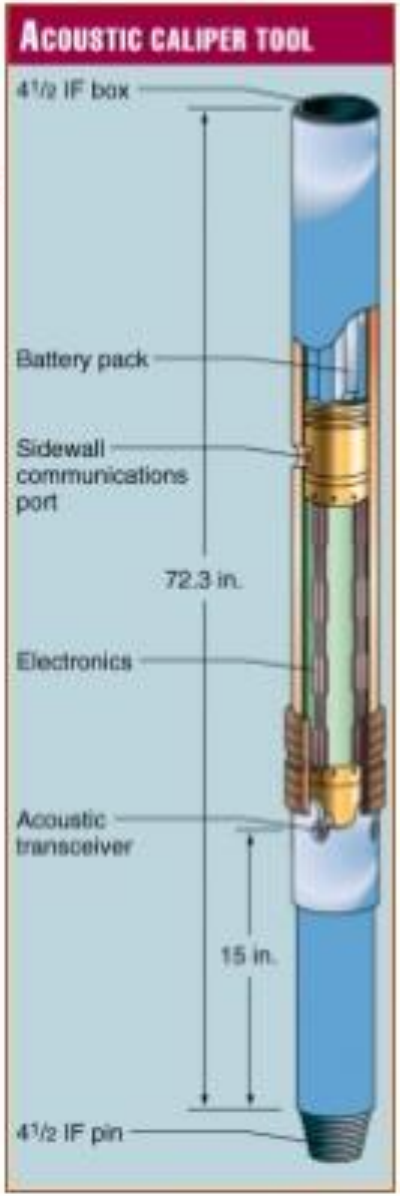
- Keyseats: asymmetrical oval hole, formed by wear against the drill string at points where the borehole inclination changes(doglegs).
- Washouts: develop from general drilling wear, especially in shaly zones and dipping beds. On the geometry logs, it has a considerable vertical extent and both calipers are larger than the drill bit size with one caliper being much larger than other.
- Both have general drilling phenomena, but breakouts have a specific cause.
- Breakouts: consider to form as a result of the interaction of stresses induced by drilling and the existing stress regime of the country rock.

Ultrasonic caliper

- Using high-frequency acoustic signals.
- A transducer emits a high-frequency pulse that is reflected by the pipe or borehole wall and received by the transducer.
- The diameter is determined from the time of flight of this echo and the fluid acoustic velocity.
- The transducer is rotated to produce a cross section of the borehole size and full-coverage images of the borehole wall.
- The measurement has high resolution and is used to detect deformations, the buildup of scale, or metal loss due to corrosion.

$$\text{Standoff } (d) = (v_m t)/2$$

$$D_h = D_t + 2d$$

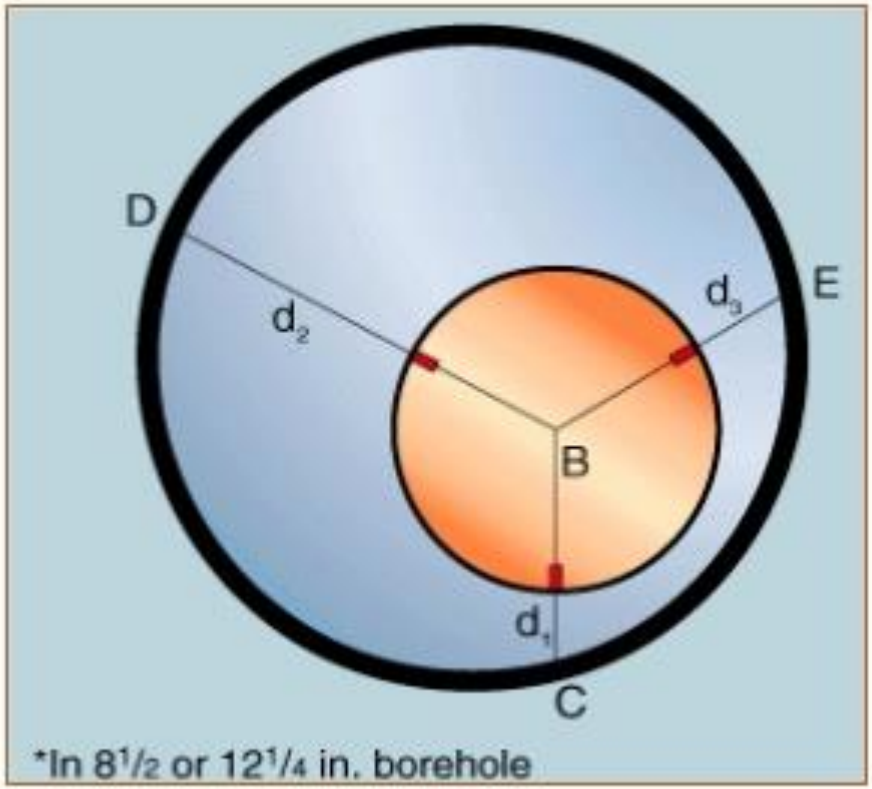


3-D internal diameter caliper image

Ultrasonic caliper

Standoff (d)=(v_m t)/2

$D_h = D_t + 2d$



Quality control using Caliper

- When caving is serious, the quality of log reading is impaired.
- It should be pointed out that simple caliper attached to the open hole tools (microlog, formation density) will be pessimistic in terms of hole condition, because in oval holes a simple caliper will naturally open to the maximum diameter of the borehole.
- So, the log measurements recorded will be made across the larger diameter, the hole condition is not as bad as may first appear.

- For this reason, many boreholes can attain an oval shape after drilling.
- This is due to the effect of the pressures in the crust being different in different directions as a result of tectonic forces.
- In oval holes, the two arm caliper will lock into the long axis of the oval cross section, giving larger values of borehole diameter than expected. In this case tools with more arms are required.

The common uses of the caliper log are as follows:

- In a logging context, the greatest application of caliper data is in environmental corrections to other logs that are sensitive to hole size such as Natural gamma ray , Density, Neutron logs.

- Contributory information for lithological assessment.

- Indicator of good permeability and porosity zones (reservoir rock) due to development of mudcake in association with gamma ray log.

- Calculation of mudcake thickness, h_{mc} = (dbit- dh)/2, where h stands for the hole, in inches.

The common uses of the caliper log are as follows:

- Selection of consolidated formations for wireline pressure tests, recovery of fluid samples, for packer seating for well testing purposes, and for determining casing setting depths.

- calipers can be used to center or eccenter logging-tool strings.

- Openhole caliper data are used to estimate the volumes of gravel and cement needed for well-completion planning.