9. CALIPER LOGS

9.1 Introduction

The *Caliper Log* is a tool for measuring the diameter and shape of a borehole. It uses a tool which has 2, 4, or more extendable arms. The arms can move in and out as the tool is withdrawn from the borehole, and the movement is converted into an electrical signal by a potentiometer.

In the two arm tool (Fig. 9.1), the borehole diameter is measured. This is shown in track 1 of the master log together with the bit size for reference. Borehole diameters larger and smaller than the bit size are possible. 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.

In the 4 arm (dual caliper) tool, the two opposite pairs work together to give the borehole diameter in two perpendicular directions. An example of a 4 arm tool is the Borehole Geometry Tool (BGT). This has 4 arms that can be opened to 30 inches (40 inches as a special modification), and give two independent perpendicular caliper readings. The tool also calculates and integrates the volume of the borehole and includes sensors that measure the direction (azimuth) and dip of the borehole, which is useful in plotting the trajectory of the borehole.

In the multi-arm tools, up to 30 arms are arranged around the tool allowing the detailed shape of the borehole to be measured.

Some of the other tools in this course have sensors attached to pads that are pressed against the borehole wall. The pressing device is also a form of caliper, and so caliper information can sometimes also be obtained from these tools.

Figure 9.1 The Reeves 2 arm caliper tool.

3.42 (11.20)

Caliper —0.31 (1.00)*

0 (0)
m (ft)

* Caliper depth offset calculated at 200 mm (7.9 ins) diameter

9.2   Log Presentation

The caliper logs are plotted in track 1 with the drilling bit size for comparison, or as a differential caliper reading, where the reading represents the caliper value minus the drill bit diameter (Fig. 9.2). The scale is generally given in inches, which is standard for measuring bit sizes.
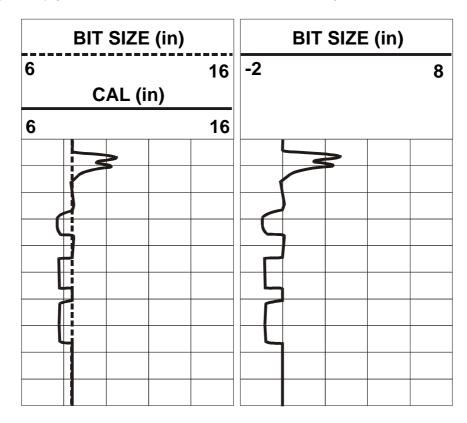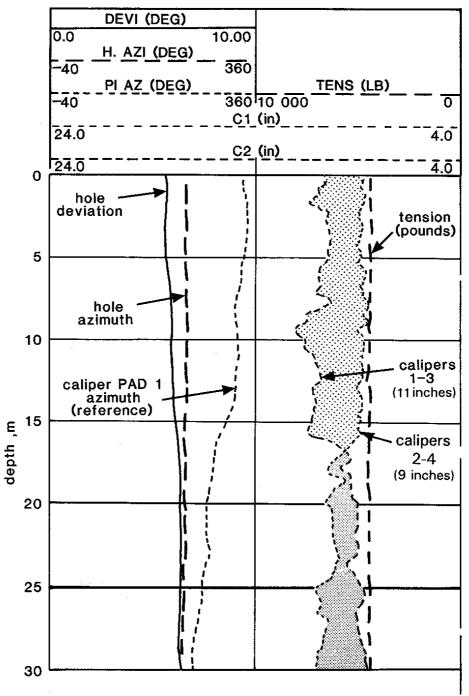

Figure 98.2 Presentation of 2 arm caliper log data.

The 4 arm (or dual caliper) tools are presented in a range of formats, an example of which is given in Fig. 9.3. Note that data from the caliper pairs are shown together, and that they are different indicating an oval hole. Also the tool rotates in the hole (the pad 1 azimuth P1AZI changes). The hole azimuth is reasonably constant at HAZI$\approx$180°, and the dip is almost vertical (DEVI is about 0°).

The ticks represent borehole volume. This information is useful to estimate the amount of drilling mud in the borehole, and to estimate the amount of cement required to case the hole. There are engineering approximation formulas to calculate both of these from caliper data.

Figure 9.3 Presentation of 4 arm caliper log data (After Rider, 1996).

9.3 Simple Caliper Interpretation

Figure 9.4 shows a schematic hole with caliper information, and Table 9.1 describes the main influences on caliper values. Note that when a hole is the same diameter as the bit-size it is called *on gauge*.

Table 9.1 Factors influencing caliper responses.

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.

9.4   Uses of the Caliper Log

The commoner uses of the caliper log are as follows:

- Contributory information for lithological assessment (see Table 9.1 and Fig. 9.4).

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

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

- Measurement of borehole volume, $V_h = (d_h^2/2)+1.2\%$, in litres per metre.

- Measurement of required cement volume, $V_{cement} = 0.5 \times (d_h^2 - d^2_{casing}) + 1\%$, in litres per metre.

- Indication of hole quality for the assessment of the likely quality of other logs whose data quality is degraded by holes that are out of gauge. Other log data can often be corrected for bad hole conditions using the caliper readings, but the larger the correction, the less reliable the final data will be. Centralized tools are designed to be about 4 inches in diameter for a standard 8.5 inch hole, and they are designed to work with 2.25 inches of drilling mud between them and the formation. If the hole caves to 14 inches, which is not uncommon, the distance to the formation becomes 5 inches and the tool responses are degraded. This can be corrected for to some extent if the caliper value is known. Tools that work by being pressed up against the side of the borehole wall have even greater problems because the irregularity of the borehole wall makes it impossible to obtain reliable readings. In both cases the recognition that a borehole has bad caving or thick mudcake can help us judge the reliability of other tool's readings.

- 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.
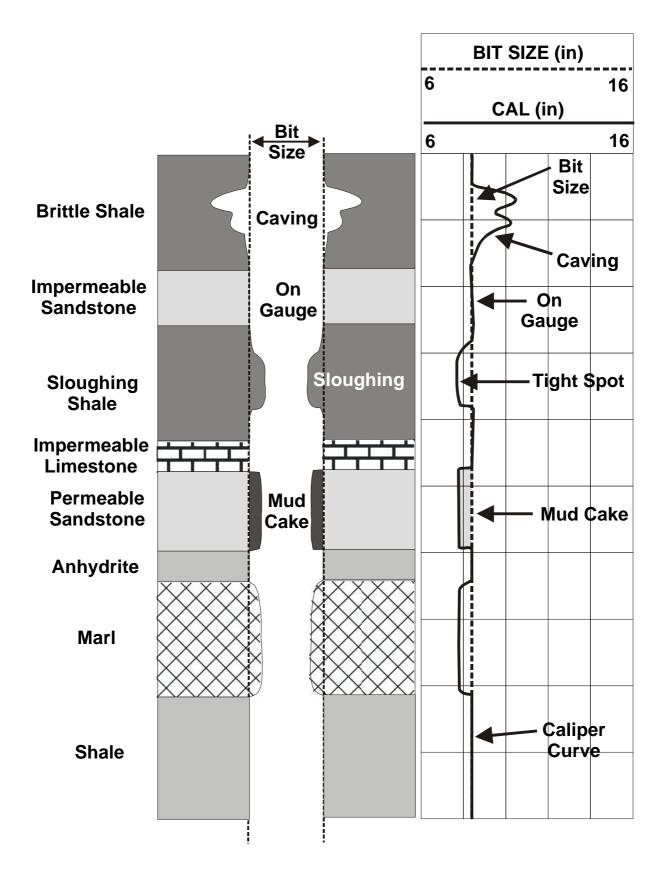
Figure 9.3 Typical caliper responses to various lithologies.