Well Logging: Principles, Applications and Uncertainties

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Chapter 16

Well Logging: Principles, Applications and Uncertainties

Nazmul Haque Mondol

16.1 Introduction

Well logging is a means of recording the physical, acoustic and electrical properties of the rocks penetrated by a well. It is carried out by service companies, which work under contract for the oil companies. Logging has the advantage that it measures *in situ* rock properties which cannot be measured in a laboratory from either core samples or cuttings.

Logging started with simple electric logs measuring the electrical conductivity of rocks, but it is now an advanced and sophisticated method used routinely in different phases of hydrocarbon exploration, field development and monitoring. It gives us a continuous downhole record that provides a detailed subsurface picture of both gradual and abrupt changes in physical properties from one bed to the next. By contrast, only selected parts of the reservoir rocks are cored, and samples of cuttings from the rest of the well give no more than a general idea of the lithology.

None of the logs actually measure the parameters that are of most interest to us, such as how much oil or gas is in the subsurface, or how much is being produced. Such important knowledge can only be derived, from the measured properties such as gamma radiation, density, velocity and resistivity, using a number of assumptions which, if true, will give reasonable estimates of hydrocarbons. To perform a logging operation on wireline, the measuring instrument is lowered into the borehole on the end of an insulated electrical cable after the drilling tool is pulled up (Fig. 16.1). The cable itself is used as the depth measuring device, so that properties measured by the tools can be related to particular depths in the borehole.

Well logs are usually recorded while the logging device is being winched upward through the well. The measurements from the instruments housed in the logging tool are recorded digitally at intervals of between 3 and 15 cm and the data is processed near the well on land, or on the platform in the case of offshore. Recording the well log involves a number of steps, beginning with sensing and pre-processing the measurement in the logging tool itself, transmission of this information to the surface over several kilometers of wireline, further processing in the logging truck computer, data storage on disc or magnetic tape, and finally display of the data on film or paper. A measured log shows many variations from top to bottom (log display in Fig. 16.1), and each wiggle has significance. Most logs are dependent on direct contact with the rock via the walls of the well, and have to be run after successive intervals of the drilling, before each stage of the steel casing is installed in the well.

16.2 Well Logs: The Necessity

Geological sampling during drilling (cuttings) provides a very imprecise record of the formations encountered. Entire formation samples can be brought to the surface by mechanical coring, but this is both slow and very expensive. In the narrowest sense, well logging supplements the analysis of cores, side-wall samples and cuttings. Logs are used for a variety of purposes depending on the nature of the data recorded. Correlation from well to well is one of the oldest and probably the most common use of

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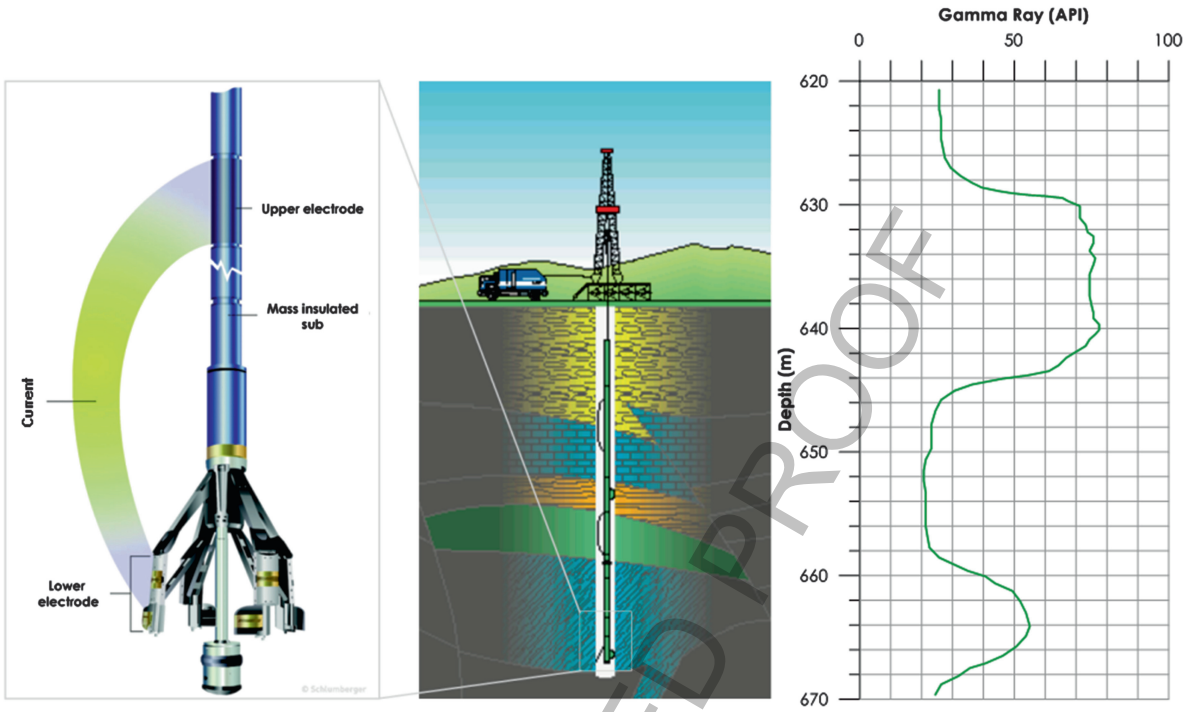

Fig. 16.1 Example of a logging tool (*left*, Courtesy of Schlumberger). The wireline logging operation showing logging truck, logging cable strung into the rig, then lowered into the borehole with logging tools at the end of the cable (*middle*). Example of a recorded gamma ray log display (*right*)

logs. Correlation is usually based on the shapes of the recorded curves versus depth. It allows the subsurface geologist to map formation depths, lateral distributions and thicknesses, and then to identify conditions that could trap hydrocarbons. Identification of the lithology of the rock sequence is another important use. After acquiring experience in an area it is possible for a log analyst to make an educated guess as to lithology by looking at the log from a new well. A set of logs run in a well will usually mean different things to different professionals (Table 16.1). Currently, over fifty different types of these logging tools exist in order to meet various information needs and functions. Some of them are passive measurement devices, others exert some influence on the formation being traversed.

Pickett (1963) indicated some of the applications for well logs in petroleum engineering (Table 16.2). The applications fall into three categories: identification, estimation and production. Identification concerns subsurface mapping or correlation.

Table 16.1 How is logging viewed by others? (Adapted from Ellis and Singer 2008)

The Geologist:
What depths are the formation tops?
Is the environment suitable for accumulation of hydrocarbon?
Is there evidence of hydrocarbons in this well?
What type of hydrocarbon?
Are hydrocarbons present in commercial quantities?
The Geophysicist:
Are the tops where you predicted?
Are the potential zones porous as you assumed from seismic data?
What does a synthetic seismic section show?
The Drilling Engineer:
What is the hole volume for cementing?
Where can you get a good packer seat for testing?
Where is the best place to set a Whipstock?
The Reservoir Engineer:
How thick is the pay zone?
How homogeneous is the formation?
What is the volume of hydrocarbon per cubic metre?
Will the well pay-out?
The Production Engineer:
Where should the production well be placed?
What kind of production rate can be expected?
Will there be any water production?
Is the potential pay zone hydraulically isolated?