# PART - I

# GENERALITIES

CHAPTER- I

# DIPMETER SURVEYS

## INTRODUCTION

Oil forms an important and easy source of energy and is one of the major elements for industrial growth of any country. However, its exploration and exploitation is a very costly affair and risky gamble. Even if 99% of the factors are favourable for oil accumulation but sometimes only one factor may be such that it may completely drain out the oil from that area. Hence, all possible efforts should be made to completely understand the geological set-up of any area which makes exploration and exploitation of oil easy and economical. There are various types of surveys like geological, geophysical, geochemical etc. which can be of use in understanding the geological set-up of the sub-surface. All these surveys fall into two categories- 1. Interpretative and 2. Direct observation. To begin with it should be geomorphological surveys (direct observation) followed by field checks if necessary. This can help in delimiting the area which are more promising and where more costlier interpretative seismic and other geophysical surveys may be undertaken to learn more about the subsurface geological structures along with its litho-stratigraphic set-up. However, the correctness of the interpretation will depend upon the various inputs that are chosen for such interpretations. Such interpretations if found promising are followed by actual drilling of the wells in that area. While drilling the hole various kinds of wire-line logs like S.P., Gamma Ray, Resistivity, Redioactive etc. are recorded and efforts are made to understand the litho-stratigraphy encountered in the well along with the contents of the promising horizons. Cuttings and cores (which are very expensive to obtain) obtained from the wells are further analysed in the laboratory to understand the sedimentological characters, their depositional environments etc. which govern the accumulation of hydro-carbons. These studies are quite costly and time consuming. Apart from this, they give details only about the vertical variation in the litho-stratigraphic units but fail to give any information about the lateral variations in litho-stratigraphic units in the adjoining areas surrounding the bore-hole. This variation which also controls the distribution of hydro-carbons will be known only after drilling of number of wells on the structure. In this process, so many dry wells may also get drilled, particularly where stratigraphic and /or combination type of traps exist. However, such an information about the lateral variation in litho-facies may be obtained quickly and easily by the study of dipmeter logs. From the information thus obtained it is possible to avoid drilling of dry wells. It is to be noted here that dipmeter log can not be interpreted in isolation but it has got to be interpreted in combination with other types of logs as mentioned above.

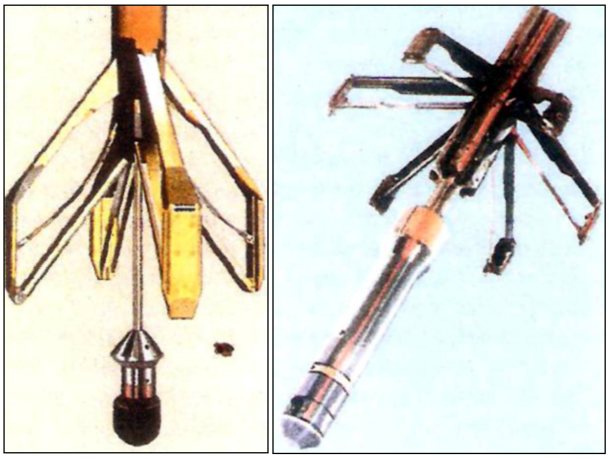

***Fig. 1.1 -*** *On the left : photograph of the SHDT tool (stratigraphic High resolution Dipmeter Tool) (courtesy of Schlumberger). On the right photograph of the six-arms tool (courtesy of Halliburton) (From Serra-2003)*

In the present day context it is to be noted that major structural traps in the potential oil bearing regoins of the world have been discovered and drilled. The increasing demand for oil has resulted in exploration of difficult to discover and explore, stratigraphic or combination type of traps. It is easy to explore and exploit structural traps, but costly and difficult in respect of stratigraphic or combination type of traps. No entrepreneur in the world would like to drill dry wells and sink his money for nothing unless dictated by the necessity of acquiring geo-technical data. Since the advent of dipmeter tool in 1930 and its progressive refinement with time, to the extent of high sampling density of 120 readings per foot of bore hole, its use has consdierably reduced the possibility of drilling dry wells. It is because of the indications obtained from it about the probable locales

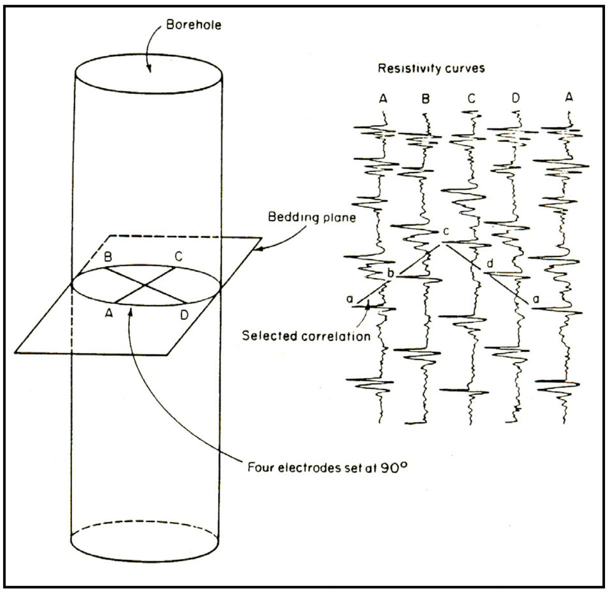


***Fig. 1.2 -** Mode of operation of the dipmeter log.* From Selly 1985

or trends in a sedimentary formation, where favourable litho-structural conditions exist for the accumulation of hydro-carbons. However, the interpretation of dipmeter log is not an easy task. It requires an imagination and skill, apart from the sound knowledge of the local geology of the area. It is to be noted here, that dipmeter tool is exclusively meant for geologists simply because, it is the geologist who can visualize the fine variations in natural geological set-up. Though many programmes like SYN-DIP, MS DIP, GEODIP, LOC DIP etc. have been developed by various companies to extract the best possible geological information, yet these can not conclusively depict or bring out the final geological set-up of the regime. It is only the geologist, who after dwelving deep into other available data obtained from drilling and other well-logs, can come to probable meaningful conclusions regarding geological set-up of the regime.

**THE DIPMETER TOOL**

The dipmeter tool does not measure the dip of the beds directly but it measures resistivity or conductivity changes as it is pulled-up the hole. The conventional 4 curve dipmeter tool which is still in vogue (fig. 1.1.) is a wire-line logging device consisting of micro-resistivity electrodes mounted on four pads equally spaced at $90^0$ from one another. It is gradually pulled up through the bore-hole and readings from each of the four pad-electrodes are recorded as resistivity curves. Alongwith this, a correlation log-generally SP (Self Potential), GR (Gamma ray) or deep resistivity log, caliper log and orientation of sonde is also recorded. It is but apparent, that the same bed without any facies variation will show the same resistivity in all the four pads (Fig 1.2.). The data so obtained is fed into the computer programme that correlates the recorded curves bringing out the bed boundaries clearly and computes appartent dips of the beds alongwith their azimuths on the basis of the vertical displacements between the recorded curves, created as a result of amount and direction of the dip of the bedding plane cutting across the bore-hole at some angle (fig 1.2.) Computed dips are later corrected for sonde tilt and the true dips are thus calculated.

It is to be noted here that to define a dipping plane completely, the details of minimum three points on the plane are required. Hence, it is necessary. that in four curve conventional tool the bedding plane is crossed at least by; three of the four pads and the resistivity curves recorded by them are correlatable (fig 1.2). This is possible only in case of well laminated formations, which are generally deposited in calm water conditions; but such conditions may not exist everywhere in the same formation even within the limits of borehole diameter, due to facies variation vertically as well as horizontally, thus depicting totally different environments of deposition. Some of the beds may be deposited in shallow agitated water conditions with different dIps in different directions having different azimuthus; and many a times these original depositional dips may be completely destroyed by burrowing animals or due to rooting of the zone itself by plants. In such cases pad to pad correlation of the four curve conventional tool may not be able to detect such heterogenities nicely. In order to overcome this difficulty and to have better curve likeness than that from pad to pad correlation, 6 and 8 curve dipmeter tools (fig. 1.1) have been devised. For the 8 curve tool, there are two measure electrodes on each of the four pads with a short spacing of 3 cm. It results in better curve likeness as compared to 4 curve dipmeter tool enabling larger number of high credibility correlations. Apart from this, shorter correlation intervals available from this tool helps in measuring displacements even between the side by sides curves (resulting from the same pad), while maintaning a sharp and unambiguous curve match.

This improved data collection capabilities of the eight curve tool helps in achieving a fine vertical resolution of the dips. With this tool it is possible to detect heterogeneties either radially out into the formation or circumferentially around the bore-hole. The very high resolution by this tool allows detection of objects as small as 1 cm. (the eight curve tool has a sampling rate of 0.1” as compared to 0.2” for the four curve tool), Further with more refinement of this tool, a new tool called formation imaging tool (FMI-formation micro-imager; FMS - formation micro-scanner)has been devised which analyses formation along twelve or even more sectors and the objects as small as 0.5 cm can also be detected. These image tools have the advantage to allow the seperation of sedimentary features from tectonic or other features (like stylolites fractures, etc.) which is not possible from the dip data provided by dip-meter tools processed by interval correlation techniques. However, because of the shallow depth of investigation, each dip measurement has an individual significance which can only be local if it corresponds to phenomenon of small lateral extent and minimal vertical effects (small scale sedimentary features). As against this, vertical persistence of nearly parallel dips with slowly varying amplitude or azimuth over a certain vertical thickness will indicate the presence of large structural features

In four curve tool the lower limit for meaningful interval correlation is of the order of one dip computation per foot but with 8 curve tool, this is incresed to four dips per foot. As stated earlier the resistivity measurements are sampled 60 times per foot or every 0.2". Such detail

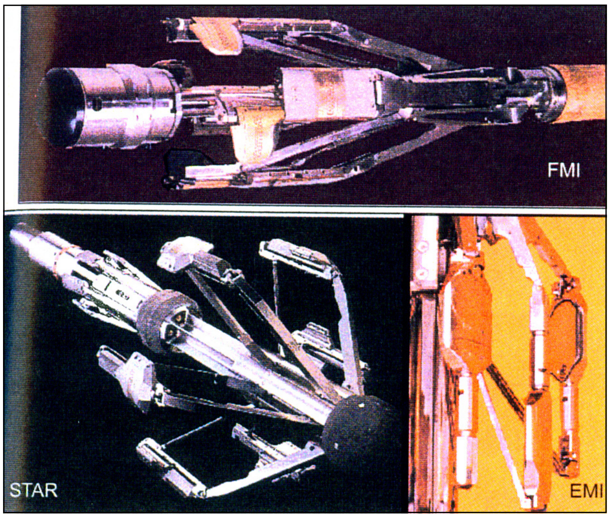


***Fig. 1.3 -*** *Photograph of imaging tools (After Serra, 2003)*

is essential because, even $1^0$ of structural dip may be significant in location of the hydrocarbon traps . A $1^0$ dip across an 8 inch bore hole causes a shift of 0.14 inch between the curves.

**TYPES OF TOOLS**

Various types of dipmeter tools are available in the market; each well logging company having its own version. Three arm tools which were in vogue in the beginning in thirtees and forties are now completely replaced by four arm tools which are still in vogue. Some of the companys like Halliburton have six arm tools (fig. 1.1). Schlumberger company has different kinds of dipmeter tools like HDT and SHDT useful for different kinds of geological investigations.However, all dipmeter tools currently in vogue have the following common characters :

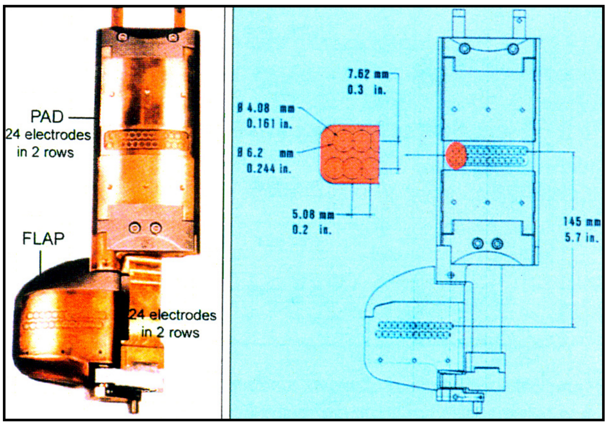


***Fig.1.4 -*** *Innovative pad and flap design of FMI tool (Courtsey Schlumberger)*

1. Deviation section which measures tool deviation from vertical and its azimuth.

2. Caliper section for measuring two or more hole diameters. Tthis is necessary because, all the pads of the tool carrying electrodes should touch the wall of the hole. Hence, it is necessary that the size of the bore-hole does not become larger than the limit to which the pads of the selected tool can open-up. In other words the hole condition should be ideal and healthy i.e. the hole should not contain large sized sections created as a result of caving, fishing etc. than orginally planned. When hole size becomes larger than the originally planned, the pads of dipmeter tool may not touch wall of the hole and consequently may not be able to record the resistivity of the formation, but may record resistivity of the mud only and dip-scattering may result. Same situation may arise during a fishing operation in the well.

3. Micro-electrode array for recording the resistivity of the formation in a very localized area where the pads of the tool contact the formation.

4. The section for recording GR, SP or resistivity curves for correation with other well logs.

5. The tool is so fabricated that it keeps itself in a centralized position in a circular bore-hole. For this, opposite arms are linked up. By this arrangement the tool remains centralized in holes, where the deviation is less than $70^0$. This centralization assures tangential contacts between the pads and the wall of the bore-hole, ensuring good contact of electrodes on the pads with the formation. However, in an oval hole, each pair of arms opens to a different diameter making electrodes on them non-coplanar. The non-coplanar geometry is accounted for in the computation process for dip calculations. The four curve tool design uses a more complex arm geometry to keep all electrodes coplaner.

As mentioned above, the FMI tool (fig. 1.3 ) which is an improved version of the eight curve dipmeter tool with special focussing circuitry system of array of button electrodes (24 in case of FMI tool of Schlumbeger) above two measuring electrodes ensures that the measuring currents are forced into the formation, where they are modulated in amplitude with the formation, conductivities to produce both low frequency signals rich with petrophysical and lithological information and a high resolution component that provides the micro-resistivity data used for imaging and dip interpretation. The depth of investigation is about 30 in, similar to that of shallow lateral resistivity devices. The image is normalized through calibration with low frequency, deeper resistivity measurements from the tool signal or from another resistivity measurement tool. The spacing of the button electrodes, innovative pad and flap design (fig. 1.4) and high frequency of data transmitted by the digital telemetry system results in vertical and azimuthal resolution of 0.2 in. This means that the dimension of any fracture that is 0.2 in or larger can be readily estimated from the image. The size of the features smaller than 0.2 in, can be estimated by quantifying the current flow to the electrode. Fine scale details such as 50 micron fractures filled with conductive fluids are visible on FMI logs.

Apart from formation images obtained from the FMI tools, dip data is also obtained. This dip data when interpreted in conjunction with the image data gives the best results.

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