New Insights in the Use of the Petro-Sonde

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Introduction

The Petro-Sonde has been used with mixed success by explorationists now for nearly a decade. This paper is being written specifically to assist those who have used the tool with less than the desired success. Dry holes are most commonly being blamed on the Petro-Sonde operator, which is not necessarily the case, and the most frequently requested improvement has been the development of a computer-prepared Petro-Sonde log. Geophysics International has made an effort to do just that, but it now appears that such a log may be some time in forthcoming. Dr. Michael Manry, an engineering professor at The University of Texas at Arlington, has been in charge of this research, and while there have been instances where the computer-prepared logs are very good, on many other occasions, the computer comes up with no usable log. Dr. Manry's work has provided me with some new insights as to how the tool really works. Understanding how the tool works should aid in the collection of a better data set even with the current audio system. Although a proper computer log will eventually be developed, most of us cannot afford to forgo the Petro-Sonde's use until that day arrives. At present, I do not believe we can supplant the human brain. It is still the most powerful computer available.

The Petro-Sonde

This passive electrotelluric surveying device, based on accepted principles of plasma physics, produces a signal that is being digitally recorded, and a correlatable conductivity log can be easily constructed by various Petro-Sonde operators using the same digital tape. Its reliability and accuracy can be verified by calibrating with as many existing logged boreholes as one so chooses. It has been established that the Petro-Sonde provides true vertical depth measurements with far greater accuracy than almost any other geophysical tool, and at a far lesser cost. The Petro-Sonde records formation tops with an error of 50' or less to depths below 25,000', and if the data is gathered properly, this tool can produce 3-D geological maps that in some respects are far better than those obtained by all but the newest 3-D seismic.' If these statements are true, what is causing most of the geologic failures? I believe that they arise from the fact that most users have not been properly trained in the use of the Petro-Sonde in the field. It appears that it should be a simple matter to convert the digitally-recorded data to an accurate computer prepared hard-copy log, but, Dr. Manry has found that the variable telluric current data are not easily assembled on a single log.

While Dr. Manry has produced very good computer logs on occasion, he has found that variations in the telluric signal over time are causing more problems than he had anticipated. However, I suspect that this comes as no surprise to the Petro-Sonde operators themselves. I have probably spent more time in the field working with various Petro-Sonde operators than most during the past eight years, and that experience provides me with some insights as to why the hard-copy log is difficult to come by. I might add, I have drilled more dry holes trying to determine how to use it than most geologists. The moment I fully realized that I could calibrate to logged boreholes nearly every time, I knew that it was imperative that I learn how to use the tool most effectively. I thought that I would probably encounter some difficulty in mastering the art, and I informed my investors that I would surely drill a number of dry holes before I learned how to master the tool. That proved to be a very accurate prognostication, but it didn't prevent me from losing some of my investors. However, this exercise proved to be very worthwhile. It helped me to explain many of the negative results geologists were having in using the Petro-Sonde. Most importantly, it paid off by assisting me in defining many of

the major undrilled and/or underexploited prospects within the Permian Basin in 3-D, and I came to realize that we geologists are only half way through our jobs. I write this paper in hopes that my insights will assist others in making better use of this most valuable tool, particularly while having to depend on the present audio format.

Dr. Manry's Research

For the past several years Geophysics International has retained the services of Dr. Mike Manry, who is attempting to convert the digitally recorded telluric signal to a hard-copy log with the use of a 486 computer. I previously had described the plasma physics involved in the Petro-Sonde in a layman's language, (Elam, 1986, 1990), and I will attempt to do the same thing to describe the difficulties encountered by Dr. Manry in attempting to develop a hard-copy Petro-Sonde log. It is not so much that these problems cannot be overcome in theory; it may be more of a matter of being able to obtain a good log in a cost-effective manner. Mind you, I make no claim to be an expert in either plasma physics or the computer; my Ph.D. is in geology. However, after working with the tool in the field all these years, I have a sense of how the tool really works. Note, though, that these conclusions are tentative and need to be further confirmed by Dr. Manry.

Using Dr. Manry's data, I have selected a 100' stratigraphic interval from a Catahoula gas well situated in Goliad County, Texas, which illustrates his problems. I constructed a jammed log section that includes the Petro-Sonde log at the well site, the electrical log, and three computer processed logs of that same stratigraphic interval recorded on the digital tapes.

The top and thickness of the gas sand is within a few feet of being the same on the Petro-Sonde and the electrical logs, but the three computer logs differ markedly. In Log A, the computer accurately records the top and the bottom of the gas pay, and that log looks even more impressive than the Petro-Sonde log. It must appear that Dr. Manry, has accomplished his objective. However, note that Log B has ended up as an inverse log. The conductivity breaks are located where they are in Log A but display the opposite polarity, and in Log C, there is no usable data. To obtain these logs, Dr. Manry has processed three different 10-second snips of the same digital tape. Where there is an existing logged borehole to calibrate with, one can see that Log A is the best, but if we were to merge the results of these three logs, we would end up with a less than satisfactory log. In choosing the "best" log, we don't want to introduce the same human element we are trying to overcome.

Keep in mind that the telluric current generated at the various conductivity interfaces in the subsurface is embedded in a background of white noise, and the intensity of both the white noise and the telluric current varies with time. Sometimes the telluric current admitted by the notch filter in the Petro-Sonde tool prevails, as it did in Log A, but in Log B, the white noise is apparently intense enough so that although the computer was able to sense the location of the conductivity breaks, the polarity was not clearly defined, and in Log C, the white noise completely prevailed, and no conductivity breaks could be identified. This is what the Petro-Sonde operator is faced with in logging an interval manually using his stereo earphones. To overcome these variations, the operator tunes his notch filter across the conductivity interface again and again, until eventually this repetitive action allows him to zero in on the specific depth of the telluric current break he is seeking. In this manner, he eventually will be able to determine the originating depths of the telluric currents emanating from the conductivity interfaces and also establish a sense of the polarity of those breaks. He may only hear the left break 30% of the time, a right break 20% of the time, and pick up nothing but white noise the remainder of the time, but his brain can handle that situation. Audio readings of the same interval on different days also sometimes show up these opposite breaks on the Petro-

Sonde logs. We generally ignore those inverse readings if all the other breaks correlate. It is most specifically the intervals between the breaks that aid in correlating the log.

Commonly, the telluric signal is weakest around noon (it is called the noon bucket!). In addition, there may be other periods during the day when the operator needs to completely shut down. Also, when cold fronts are moving through the area, or when thunderstorms are nearby, the tool also does not work satisfactorily. I learned the hard way not to press a Petro-Sonde operator to log when the data becomes marginal. (Geophysics International does not charge for this down time.)

What this shows is that an experienced Petro-Sonde operator has some very distinct advantages over the computer in gathering viable data. As pointed out earlier, in Goliad county, should Logs A, Band C be merged into a single printout, the resultant log would be poor. The human mind is better able to handle the occasional failures to pick up breaks, as is apparent in Log c. At present, I am not convinced that a hard-copy log is the only way to decrease Petro-Sonde errors. When the tool was first developed years ago, the inventors found the human ear superior to the best computer, and as of now that may still be true.

For my exploration work, I would be happy with a hard-copy log that just displayed the conductivity breaks alone. That log might appear to be quite crude, but identifying the breaks would be a great stress reliever for the Petro-Sonde operator. That using the Petro-Sonde need to appreciate that one of the primary problems in using a Petro-Sonde is audio burn-out. I make a point of trying to reduce that operator's stress whenever possible.

A far greater cause of dry holes is the gathering of the Petro-Sonde data incorrectly. The Petro-Sonde can be used as a glorified Brunton compass, and using it, anyone can obtain dips and strikes at any location on a map. It is the failure to fully substantiate the geological structure prior to drilling that causes most of the dry holes. I use the Petro-Sonde as a validating tool, not a wildcatting device. In a geologic setting where there are many significant stratigraphic variations, miscorrelations are easy to come by, and these cause many of the dry holes. The responsibility for the correct correlation falls upon the company geologist. If the interval being read by the operator does not happen to contain the pay objective, that is really the geologist's fault and will result in a dry hole almost every time!

Conclusion

When I first started using the Petro-Sonde log, I expected to get results in as little as a half day, and when I paid for a whole day, I tried to read as many stations as possible. I would often log 100' or less, and it was only after I had drilled several dry holes that I finally realized that the dry holes I was getting were the result of my faulty data gathering, not the Petro-Sonde operator's fault. Now, I don't attempt to survey much more than one square mile in a day, and I approach a proposed drillsite from every direction. I spend most of the first day in the field calibrating to existing wells so I can really acquaint the Petro-Sonde operator with the stratigraphic section. I almost always log at least 300-400' at a station, and if I am thinking about spending $1,000,000 or so to drill a multi-pay well, I log the second pay interval as well. I use isopachous maps as well as contour maps to help define the geologic history. That helps to reduce the correlation errors. I have spent as many as 40-50 days in the field when I am prospecting for a giant field. It is only when a geologist gathers that much data that he fully appreciates the vast amount of data that is easily available with the use of the Petro-Sonde. When I reach that point, I feel that I will just be doing development drilling on that prospect.