

Well logging— A successful journey to integration

R.N.Chakravorty

In E&P companies, well logs are used at different times and segments, for various reasons: ranging from— exploration, development, assessment, quality checking, ancillary services, exploitation, rehabilitation, affluent disposal and abandonment. To be able to address these array of dimensions amicably, a log-analyst has to be versatile in all domains of E&P business cycle, and poses full expertise in own line. e.g tool physics, design, its response in different environment, interfaces of various transforms, underlying assumptions in framing those transforms, and the end effect in the final analysis.

In addition to these, knowledge about background history of tool development and how these transformations have brought the technology to the present status is advantageous, because it adds excitement and a sense of gratification towards innovations, discoveries, and the experiences gained over the years by the seniors. It motivates Young engineers and analyst take up new challenges and move forward by indulging in intense R&D efforts for further value addition and creation to effectively contribute in the assessment of final realization.

Well logging technology has witnessed many improvements, these improvements, by and large, is evolutionary, and is the result of innovations and new discoveries taken place in hardware, software, and computing and transmission technology over the years. Among these, hardware miniaturization occupies the central place. This triggered improvements in tool design, computing, display, data compression and transmission.

Discovery of new materials, new opportunities in MWD / LWD technology, and the recent focus to bind multi disciplinary information to a common platform for integrated interpretation, is the other supplementary compulsions propelling improvements. Thanks to Mr. Archie for opening a new discipline in 1942. The relationship that he developed is inclusive of well logging and petrophysics. His was the only relationship which ruled petrophysics till about 1969. It is based on deductive approach.

This relationship was then substituted by modified Archie's equation in early 1970's when porosity devices came into existence and the industry saw a growth in interpretation techniques. We are all familiar with SIRIBAND, SARABAND, and CORIBAND techniques. We mastered these techniques and enjoyed using these techniques all around. We were so complacent with our achievements, as if, there is no tomorrow. These relations are relatively more inclusive, but continued to remain under deductive approach. 1980's saw a paradigm shift, when Mr. Allen Sibbit and his team brought out the concept of GLOBAL processing. This is based on inductive approach. This technique is much more inclusive and therefore could be used for integration and synergy. In analysis, multiple data input is a necessity now, because it gives rise to redundant solution, and opens up avenues for validation and reaffirmation.

Redundancy of data has encouraged— use model based inverse interpretation technique having capability to address complex reservoir situations, and display properties of reservoir rocks and volume of associated fluids of the well column comprehensively.

Interpretations are now through model based inversion technique, which has got the capacity to encompass more variables /components. They provide reliable quantitative values with a tag on quality

statement. The method is robust and withstood the test of time (25 years), irrespective of reservoirs/basins, and worldwide practicing log analysts.

Around that time, 3-D seismic surveys and seismic inversion also became a reality, which further encouraged the two disciplines come together for supplementary support towards better spatial realization and reservoir characterization.

Interpretations emanating from integration of data are reliable, adoptable and relatively free from ambiguities and uncertainties. The output results therefore act as benchmark for reserve estimation, seismic attribute calibration, and in preparing 3-D spatial model. This 3-D model is helpful in deciding well trajectories, especially in case of inclined and horizontal wells and in all kind of planning process.

E&P companies' world over has already tasted fruition of integrated interpretation. This has the potential for better comprehension, visualization and characterizing reservoirs in full details. Future is going to hold on integrated interpretation in a routine manner, because it is a progression from **data** to **knowledge management** stage having capability to reduce risks and uncertainties.

Our experience in integrated interpretation at JRC for L-II reservoirs has been very satisfying and also very rewarding to Mumbai asset. Improvements in sonic devices have opened a new dimension to effectively address rock physics related issues. These are regularly being used for break outs, shearing and borehole stability studies. Rock physics binds seismic and well logging discipline through mechanical properties and therefore is an important interface for integration.

In unconventional reservoirs, where evaluation through modified Archie's equation is questionable, rock physics offers a viable alternative. Industry has recognized Rock physics as an alternate viable option for identifying hydrocarbon bearing intervals, identify dominant lithology from the established lithology cluster, and confirm possibility of porosity development in the X-plots of derived mechanical properties.

Hydrocarbon identification in rock physics domain becomes easy if reservoir is gas prone. It has been noted and pointed out in the literature that variation in Porosity, fluid, clay volume, and degree of contact cement, influence elastic properties. From dynamic elastic properties therefore it becomes possible to detect hydrocarbon bearing layers. These are manifested in Acoustic impedance vs. Poisson's ratio plot, V_p^2 vs. V_s^2 plot and Poisson's ratio vs. P wave velocity plot.

Rock physics and petrophysics are now being considered complementary approaches for evaluation. A single theoretical rock model is used simultaneously derive both petrophysical and elastic properties of reservoirs and surrounding rocks. Rock physics construct a model consistent with physics principles, keeping petrophysics model in the background. The accuracy and consistency of petrophysics and rock physics models determine the quality and reliability of all subsequent evaluation. Rock physics properties are of critical importance to geophysicists, geologists, and drilling, production and reservoir engineers for wide range of applications in different phases of field life. It has made well logging discipline much more inclusive and useful.

Parameters emanating from formation evaluation (static parameters) are then linked to dynamic parameters through Leverett 'J' function, using permeability transform obtained through magnetic resonance surveys for inputs to Geocellular grids created from 3-D model segmentation, for end use to simulation studies. Simulation enables prediction of field behavior as scenario changes, giving opportunity to monitor the field, and initiate preparatory measures in advance, to control adverse field behavior that may emerge from time to time.

Conclusions

Improvements in well logging discipline have taken place in all dimensions. Introduction of digital technology was the most significant event. Hardware miniaturization is another important event, which facilitated in reducing tool length and place more number of transmitters/ receivers and probes for superior measurement capabilities emanating from different depth of investigation with finer vertical resolution. Many tools could be combined now in a single run, reducing acquisition time.

New materials and innovation of better variety of source, receivers and probes helped in improving signal statistics and increase in speed of recording, thereby making technologies more acceptable to industry. These improvements are of evolutionary nature and continue to grow with more research.

In the interpretation front, model based inversion technique, developed in the middle of 1980's is routine now. It has swayed the forward based interpretation technique in the back stage, restricted only for quick look gross assessment of well column.

Present day emphasis is on integrated interpretation for full visualization of reservoir column—encompassing structures (oil entrapment), reservoir properties (oil/ gas reserves), sequence stratigraphy (facies variation) and other allied interpretation having linkages to hydrocarbon habitats.

Many softwares are in vogue now and many more are emerging to capture the industry needs. These software packages are built on a common platform having capabilities to make inroads to seismic, petrophysics, reservoir engineering, geology and many other allied subjects just by click of mouse button, making cross talk between disciplines, integration and synergy an easier task. This has helped in displaying detail reservoir characteristics on a map view, which infuses a better understanding of the petroleum system, and enhances exploration manager capability in framing firm ideas for new plays and prospects. These softwares were made available to clients in late 1990's.

When the field has been characterized in detail, it is possible to predict logs in “application wells” using neural network training facilities of a “training well”. These gives the confidences to engineers check the quality of data during acquisition time and infuse confidence to customers. In the event, the predicted and the acquired data are in reasonable agreement it may eventually restrict costly services only in few key wells, especially when the field is in development stage.

Rock physics is another new dimension which has made the logging discipline more inclusive and useful.

Gentlemen, we are living in a changing world, where change is the only constant. We have seen changes happening in the past and in our own lifetime. The only difference is that now the world is changing fast. Experts say that 80% of the products you see today will not be there in 2020.

In today's changing world, every business has to produce fast and accurate information in order to stay ahead of competition. You have to organize your business with the latest developments in handling your business. This requirement is all the more valid to people working in the energy sector, because today, amongst the crucial issues Energy occupies the top most priority.

Today there is astronomical rise in expectations and unexpected competition around us, but there is technology, information flow and death of distance, and these have made our life much easier and have the potential to make it even prettier. We have to only align ourselves to the needs of changing value shifts. It's not enough to know what's to be done. A leader at any level of the organization must be able to mobilize others to action.

Petrophysicists have much bigger role to play and for that we don't require independent Petrophysicist but Petrophysicist of independent mind.

Always remember good time doesn't last for ever, we should not remain complacent with past glories and success made in our time, sooner you will realize that you became the victim of your own crime. Today's metaphor of success is "winners take all" and "success at all cost". Competition will stay for ever, and with time it will become more stringent. Today there is competition Act (2003) and about 106 countries have adopted competition law.

Competition has several advantages: it promotes allocative and productive efficiencies, innovation, and consumer welfare. It is integral to market based economy and is now essential condition for national competitiveness.

Competition has basic objectives of preventing exploitation by big capitalist and Govt. intervention.

You have to re-evaluate, re-envison, re-engage, re-invent, re-brand and reward communication, transparency and relevance. Today's market is global, so today's leaders must be able to communicate globally. Integration and inclusiveness makes you more proficient.

You can't compete if you are incomplete.

Thanks.