AADE-05-NTCE-12

Five Things Your Pore Pressure Analyst Won't Tell You

Roger A. Young and Taylor Lepley, eSeis, Inc.

Abstract

As the industry moves into more hostile environments and the cost of drilling continues to escalate, pore pressure analysis has become a key part of the asset team's planning process – whether it is the explorationist assessing the integrity of a trap or the engineer needing a pore pressure prediction for a proposed location. Although these teams bring together the expertise and experience necessary to address pore pressure analysis, it is incumbent upon the drilling engineer to have a working knowledge of the components that make up this aspect of the project. This knowledge can be the difference between a well drilled trouble-free and one that is plagued by NPT.

This paper focuses on five areas that are key to the preparation of a viable pore pressure analysis. First is a review of the quality and relevance of the offset well control. Second is a discussion of seismic calibration. The third area covers geologic issues. The fourth point deals with different pore pressure prediction methodologies. Last, this paper addresses the driller's confidence in the overall pore pressure prediction. Overall, it is designed to help the driller understand where the science leaves off and where the art begins so that the driller can determine the level of confidence to place in a pressure analysis.

Introduction

A pore pressure analysis is premised upon predicting the pressure in shale. However, shale pressures cannot be measured directly but are, at best, an educated guess made by correlations that use other information, such as well logs, mud weights and seismic data. Since the quality of any pore pressure analysis can be no better than the data available and the techniques applied, it is important to involve as many different members of the team as possible – geophysicist, geologist, petrophysicist, and engineer – during the preparation and evaluation stages. The data acquired and processed by each member can have a far-reaching effect on the analysis and the results of those predictions can have a significant influence on the decision-making process of the asset team. Without a sharing of this data, it is possible to inadvertently create a "knowledge gap". In order to prevent this gap the questions posed in this paper are meant to encourage a crossflow of information, to ensure open communication and to provide for some measure of oversight.

The paper is organized such that increasing levels of uncertainty are addressed as they are introduced into the analysis. First there is an assessment of the pressures in the analog wells. Then the geology and the seismic must be interpreted and calibrated. Finally, the pressures can be predicted at the remote location. It is incumbent on the engineer to recognize these concepts *"assess, calibrate and predict"* because the best prediction can only be as good as the data used in the preceding assessment and calibration.

Quality and Relevance of Offset Well Data

The confidence in a pore pressure analysis begins with selecting quality offset or analog well data for pressure assessment. Given this point from which error can be introduced into a pressure analysis, it is clear that the driller needs to be aware of exactly which wells are being used in the calibration, the relevance of the well to the proposed location and the potential sources of error.

Do the offset wells penetrate the same geological sequence as the proposed location? This is key to acquiring top quality analogs for calibration purposes. This does not mean that the nearest offset well is the most relevant but rather a well that has penetrated a similar stratigraphic sequence is more likely to provide data that is relevant to the proposed well[1]. The technique used to assess pressures in the analog well is presumed to be appropriate for a proposed well location. If different stratigraphic sequences are anticipated, then this assumption may be invalid and additional error may be introduced into the analysis.

What logs are used to assess the pressures in the analog well? The industry is running fewer wireline logs over shorter intervals. However, a much-improved suite of LWD tools minimizes this shortcoming. Still the driller should ascertain if the logs are from wireline suites, LWD runs or if they are forward modeled from a combination of other logs.

For overburden assessment, the density log is the best choice. However, density logs from mudline to TD are not common. Given this situation, a pseudo-density must be generated from a sonic or resistivity log or from a previously established correlation in the area. This pseudo-density can then be integrated to provide the overburden gradient.

For shale pressure assessments, the resistivity and sonic logs are typically used. Again, the key to establishing a level of confidence in the assessment is to determine the quality of the logs. Needless to say, the driller's confidence drops as shorter, less precise, forward modeled logs are used for the pressure assessment.

How are complicating lithology events handled? Complications may arise when the analog well penetrates different age formations. A common solution, when using an empirical method, is to use multiple NCTL's. Another complicating issue deals with high pressure environments where the shale/sand velocity relationship "flips." In the Gulf of Mexico, normal pressure and slightly overpressured shale/sand sequences will exhibit the conventional velocity relationship in which the shales are faster than the sands. However, as the overpressure increases, this relationship may become "flipped" and the sands exhibit a higher velocity than do the shales. If an empirical pressure model is used, then the deeper sands will appear to be associated with a pressure regression. These sand-influenced anomalies should be recognized as such and discounted in the assessment.

Is more than one NCTL used? It is not uncommon for wells to penetrate rocks of different geological age, such as drilling from the Tertiary into the Cretaceous. Then using two different NCTL's may be in order. However, using two NCTL's may provide a facile solution when an assessment based on a single NCTL cannot be achieved – even though the well did not drill through rocks of different age. Therefore, an assessment based on multiple trendlines should cause the driller to seek clarification before accepting the pore pressure analysis.

What techniques are used to prepare the pressure assessment? Whenever possible, multiple and germane independent methodologies should always be employed[2]. For example, when the overpressure is caused by compaction disequilibrium, then equivalent depth as well as empirical methods are useful for preparing the pressure assessment[3]. When unloading also influences overpressure, then an assessment – such as that proposed by Bowers[4] – would be in order.

In addition to selecting the appropriate method, the driller must ensure that the technique is employed correctly. For example, the NCTL should be fitted to the normally pressured velocity or resistivities extracted from only the shale intervals. Sand can have a negative influence on the NCTL and should not be included in the analysis. When presented with wells that penetrate long sandy sequences or a velocity profile prepared with large interval smoothing routines, then the driller should be suspicious of this analysis until such time as corroborating data can be obtained.

What well data are available to validate these pressure assessments? Validating a shale pore pressure assessment is next to impossible. Low permeability shales are not amenable to pressure testing by conventional methods. However, there are data sources available to help the analyst provide a qualitative level of confidence with respect to a pressure assessment. The sparse sand pressures acquired by formation testing are one source of data. Another source of data are derived from drilling operations, such as mud weights. However, all of these sources are subject to some error. In a geopressured environment, the sand pressures may be influenced by the "centroid effect"[5] and not be representative of the shale pressure in the immediate vicinity of the wellbore. Also the mud weights do not reflect shale pore pressure but rather the cumulative effect of a series of events that are related to the open hole section of the well. For example, "barite sag" can make it increasingly more difficult to narrow the error in the assessment. Also highly deviated and/or extended reach wells may require higher mud weights warranted for borehole stability issues not pore pressure issues.

Validating the fracture pressure assessment is also extremely difficult. It is complicated by the fact that there is no accepted industry-wide procedure in place for conducting, measuring and reporting LOT data[6]. The driller should be aware that the values used for fracture gradient calibration may be the results from FIT's, LOT's, ELOT's or squeeze tests. The driller must also be cognizant of the fact that the mud system in the hole while the test is run and the temperature of the formation can both have a significant impact on the reported results.

How confident is the team with the analog well pressure assessment? Do not be lulled into a false sense of security when presented with confidence intervals or error bars from a probabilistic analysis. A reliable statistical analysis must be supported by robust data. When science and art merge – as they do in a pressure assessment – it is important to identify the possible sources of error in an assessment and work to reduce or eliminate them. It is imperative that the team ensures that quality logs are evaluated, the techniques used to assess the pressures are appropriate and the sparse data (e.g. RFT's and LOT's) available to constrain the limits are honored. Only then can the team begin to feel a measure of confidence in the assessment.

Seismic Calibration

Seismic data – regardless of how it is processed – does not directly measure pressure. However, when a correlation between seismic velocity and porosity can be established, then methods exist that can be used to estimate shale pore pressures from the velocities. In the same context, it is also possible to establish a strong relationship between the frequency content of the seismic data and pore pressures.

The driller must also be aware that there are errors that can creep into the seismic data from different sources – geology, acquisition parameters and processing. From a geological perspective the problems can arise from salt, dipping beds, velocity anisotropy[7] or thick homogeneous intervals that display no reflectivity. Acquisition errors can include cable length and shooting direction – strike or dip. Processing errors could occur from sparsely picked velocities, the presence of multiples or the use of the wrong moveout function.

With respect to velocity-based pore pressure analysis, the driller needs to be aware that there are two aspects of seismic data that should be considered important. These two components are reflectivity, such as seen on a full offset stack, and kinematics, such as the RMS velocity model prepared by the processing geophysicist. While the reflectivity components are more widely recognized, the kinematics component is key to preparing a pore pressure prediction from velocities. The objective is to generate a velocity file that replicates as closely as possible the velocity profile from a well[8].

With respect to frequency-based pressure analysis, the reflectivity component of the seismic data is used. Studies show that the amount of frequency attenuation in the seismic signal is inversely proportional to the effective stress of the rock[9]. By quantifying this relationship an empirical technique – based on extracting the frequency from the stack – has been developed[10]. This technique tends to be more robust in the presence of salt and provides an alternative to the velocity-based methods.

Notwithstanding the errors that may be present, seismic data still provides a solid, well-established approach to pore pressure analysis. Once the driller recognizes these issues, the key questions remaining are designed to help the driller determine the quality of the seismic-based pore pressure calibration.

Why use seismic data in the first place? Seismic data has long been recognized as a means of addressing shale pore pressure concerns without actually having a well at that particular location. The industry has limited control in the form of well logs and cores; these data provide a detailed look at a very small area. Seismic data, and especially 3D data, gives a more general assessment of a larger area and, when calibrated with the existing well control, provides a method for increasing the driller's confidence in the pressure regime anticipated at a remote, untested location[11].

For what purpose was the seismic originally shot? A high-resolution data set designed to assess shallow events would be inappropriate for deeper investigation. On the other hand, conventionally acquired data focused on deeper targets can only be reprocessed so much to enhance the shallow signal.

How deep is the objective section? The quality of the seismic data is inversely related to the depth of the objective. The geologic sequence being penetrated by the sound waves acts as a natural filter that has a diminutive effect on the quality of the data.

What cable length was used to acquire the seismic? Industry experts feel that the depth of the objective should be less than or equal to the cable length used to acquire the seismic. In fact it is not uncommon to see recommendations for the depth of the objective to be significantly less than the cable length[7]. If this rule-of-thumb is ignored, then an increasing depth-to-cable-length ratio results in a decreasing angle of incidence and decreasing accuracy in the velocity determination.

How has the seismic been processed? For pore pressure prediction, the use of PSTM or PSDM gathers provides the two data sources from which the velocities are extracted. However, it is important to know the assumptions that went into the velocity field used to migrate/process the gathers. It is also important to know the difference in the two data sets. Imaging near or below salt is difficult at best. If the target formation lies below or close to the salt, then PSDM gathers typically provide a significantly better image and velocity field for pressure estimation. Also some industry experts recommend that the velocity analysis be done at every CDP[7] or bin while others do the analysis more sparsely. However, a denser sampling pattern – both spatially and temporally – will yield a velocity field that is more appropriate for pressure analysis work when compared to a velocity file that was picked on broad spatial or temporal intervals.

Has a velocity profile been inferred? It is not uncommon for the processing geophysicist to re-pick the seismic velocities, perform a tomographic velocity inversion and a residual velocity analysis. However, the coherent reflectivity may still be limited or non-existent. The processor then provides a "best guess" through that portion of the seismic data set. The lack of coherent reflectivity may be caused by complex imaging issues resulting from the geology, the stratigraphy or perhaps the presence of a very homogeneous lithologic sequence that will not exhibit any reflectivity. Regardless of the reason for limited reflectivity, the driller needs to know the velocity field has been "forced" by the processor and may or may not be relevant for pore pressure prediction in the interval. The driller can get a feel for this source of error simply by looking at the stack. If the seismic section exhibits strong bedding indications then the velocities are probably of higher quality than where there is limited or no coherent reflectivity.

Geological Issues

Understanding the source of the overpressure helps determine what methods should be used to assess the pressure in the analog wells[12]. It improves the probability that the proper analysis will be made. Therefore, it should give the driller more confidence in the pressure prediction for the proposed location.

The specific causes of geopressures are numerous but they fall into basically three categories – undercompaction, fluid expansion and tectonic activity. In the Gulf of Mexico undercompaction (or compaction disequilibrium) is prevalent. It occurs in young, clay-sand sequences that have experienced rapid sedimentary loading. Fluid expansion may be due to thermal effects, clay diagenesis (perhaps in the form of smectite-to-illite conversion) or hydrocarbon maturation. Tectonic events may include crossflow along faults, overthrust faulting or compressional loading.

Of the three categories, compaction disequilibrium is the only one that does not cause a reduction in the effective stress. Therefore, the operating window between pore pressure and fracture gradient should not decrease with depth. On the other hand, both fluid expansion and tectonic activity can reduce the effective stress and at depth cause the operating window to be significantly constrained[12].

What is known about the basin? A number of simplifying assumptions are made when pore pressure work is done. Basins that experienced high sedimentation rates are prone to overpressured shales and sands caused by compaction disequilibrium. However, the impact of this phenomenon may be overshadowed if clay diagenesis occurs in the deeper portions of the geologic sequence.

In addition, it is not uncommon to assume the rock is isotropic and homogeneous to simplify assumptions regarding the stresses in the basin[13]. In a relaxed, extensional environment such as the Gulf of Mexico, the minimum horizontal stress is normally estimated by using the leak off test. However, this is not always appropriate and when compressional stresses in a basin (or mini-basin) exceed the vertical stresses then pressure-related problems are apt to occur.

Are sands areally extensive? It is not enough for the driller to focus on just the portion of the reservoir that contains the hydrocarbons. The driller must be aware that the well may penetrate large hydraulically connected sands. When presented with a sequence of horizons, the driller needs to know not only about the limits of the hydrocarbon traps but also the areal extent of the reservoirs both downdip and updip. This will allow for a thorough investigation that could address anything from cross-fault fluid migration to the "centroid effect" in continuous sands.

Is the formation temperature expected to exceed 160^o F? In clay-rich deposits, diagenesis in the form of smectite-to-illite conversion can occur. This process is temperature sensitive and occurs in the range of 160^o – 220^o F[14]. As the diagenesis progresses, the extraneous water that is trapped causes unloading (or a reduction in effective stress). The driller should be cognizant of this lithologic change because the classic undercompaction pressure algorithms must be modified to address this additional layer of complexity.

Is the well being drilled through an erosional environment? Sediments that are subject to surface erosion will not experience full elastic rebound. This can impact not only the overburden gradient but also the fracture gradient. If not recognized when assessing the pressures in the analog well, the tendency would be to understate both the overburden and fracture gradients.

Are the objectives below or near salt? One concern deals with the viability of the velocity-based algorithms. Acquisition and processing issues in and around salt limit the usefulness of velocities. However, the frequency-based algorithm tends to be more robust and it is capable of identifying pressure ramps on top of salt as well as pressure increases below the salt.

Pore Pressure Analysis Techniques

Over the years the petroleum industry has developed a number of different techniques to assess the shale pore pressure encountered by a well. These techniques fall into several categories. There are techniques suited for geopressures associated with undercompaction. These methods include the equivalent depth and the empirical (Eaton[15]) methods. Additionally, for geopressured environments that result in the effective stress being reduced, there is the Bowers technique. Each method helps to reduce pore pressure uncertainty in post-drilling cases, but – by themselves – they are only marginally successful in reducing the uncertainty in the pre-drill environment. Today these methods may be used to calibrate the basin model, the seismic inversion (both velocity and frequency) and/or the neural network. Ultimately, these strategies can increase the level of confidence a driller has in a pore pressure prediction designed for well planning purposes.

For what purpose was the pore pressure prediction prepared? If the prediction was originally prepared for the explorationist, then the accuracy of the prediction for well planning purposes should be questioned[16]. Pore pressure predictions that focus on pressure changes across large areas are well suited for trap integrity and cost bracketing but do not provide the detail that is preferred for addressing the risks inherent with drilling operations.

Is the analysis based on "closeology"? Extrapolating pressure from an offset well to a proposed drill site has been done with some success for a number of years. However, when this approach is proposed, the driller should ensure that a complete risk analysis has been prepared for the project. Subtle differences in structure and stratigraphy coupled with the presence of extensive sand packages have the potential to create a pressure anomaly that is not identifiable from the analog well assessment.

Does the water depth change dramatically between wells? Water depth and overburden gradient are inversely related. Deeper water means a lower overburden gradient and, therefore, a lower fracture gradient. All pressure prediction algorithms should address this phenomenon not only with respect to the offset wells but also with respect to the pressure prediction at the proposed location.

What are the causes of overpressure in the area of the proposed location? There are two reasons for the driller to ask this question. First, it is possible that the causes of overpressure at the proposed location may be different than at the analog well site. This difference would warrant closer scrutiny of the pressure prediction. Secondly, the technique employed in the prediction algorithm should be influenced by the cause of the geopressure. For example, when undercompaction is anticipated, then either equivalent depth or an empirical method performs well. When unloading is encountered, then the Bowers' method or a basin model may be more viable.

What techniques are being employed? The driller wants to be sure that the technique employed is "fit for service." At the same time when multiple independent methods can be run in a cost-effective manner then a higher level of confidence in the pore pressure prediction can be achieved. A case in point would be that both the equivalent depth and empirical methods, while based on porosity-dependent parameters, are considered independent predictive techniques. Seismic inversion using both velocity and frequency-based algorithms can be used to extract pressure predictions thus providing a measure of confidence from one prediction to another. Last of all, velocity and frequency-based models are limited to generating a shale pore pressure prediction. When sand pressures and "centroid effects" are key concerns then an integrated approach using seismic petrophysics and pressure analysis would be appropriate. Another technique – basin modeling – may also be appropriate to address the pressures in each stratigraphic sequence.

Do assessed pressures from the analog well match the seismic-based predicted pressures? The quality of a prediction can be no better than the quality of the assessment and calibration that precedes it. If the pressure profile extracted from the seismic at the location of the offset well does not tie closely with the pressure assessment using the log data, then the driller should seek clarification as to the discrepancy. On the other hand, when the two profiles match, the driller must also confirm that the parameters used to generate the matching pressures are consistent.

What is the source of the time-depth or depth-depth profile? Drillers work in a depth-based environment while geophysicists may work in either a time or a depth domain. The depth to targets identified from PSTM seismic are converted for the driller's use by using a time-depth profile while a depth-depth profile must be used if the targets are acquired from PSDM seismic. When these targets can only be reached by means of a complicated well path trajectory, then it is paramount that everyone on the team uses the same conversion file.

Driller's Confidence

Knowing that careful study has gone into the pressure analysis can be the best boost for the driller's confidence. However, there are still questions to ask before the driller should accept a shale pore pressure analysis.

Have the pressure data been reviewed in three dimensions? The geoscience community uses 3-D visualization to reduce risk in exploration and development projects. The same visualization techniques can and should be used by the asset team when reviewing a pore pressure analysis. It is not simply a matter of viewing the pressure volumes in a 3-D format. It is important to consider all components that interact in a pressure analysis. Seismic velocities cannot differentiate between porosity, lithology or fluid changes[2], but these rock properties – when viewed together with the pressure volumes – are valuable tools for evaluating the level of risk to assign a pressure prediction.

Have any "what-if" scenarios been reviewed? When preparing a pore pressure analysis, data-fitting algorithms are employed in many instances. However, much of the work done by the team in preparing a pore pressure analysis is done using visual cues. In fact, the results of a pressure assessment on an analog well are driven more by art – than by science. As long as empirical relationships are employed, assessments prepared by individual interpreters will always be unique even though they may be similar. This uniqueness is not limited to analog well assessments, but also applies to seismic calibration and pressure prediction as well. The fact that individual interpretation is required justifies the time and effort required to prepare different "what-if" cases.

Has a probabilistic analysis be done? There are opportunities to apply a probabilistic assessment during the preparation of a pore pressure analysis. The quality of that assessment is predicated on the quantity and quality of the actual pressure data available. If the actual pressure data set is sufficiently robust, such as that in the Greater Mars-Ursa Area of the Gulf of Mexico[17] or the Campos Basin offshore Brazil[18] (over five hundred pressure data points in each set), then a probability analysis could have substantial meaning. However, this is a luxury not generally available to those focused on exploration. For that reason, a statistical analysis based on a limited data set must be viewed with caution.

Conclusions

The petroleum industry is constantly seeking ways to improve and to cut costs. Improving our ability to predict events ahead of the bit – whether it is lithologically or pressure related – is key to achieving this goal. However, the asset team must be able to recognize the sources of error in a shale pore pressure analysis in order to properly determine the quality of a prediction.

The selection of offset well data is key to preparing an analysis. It is vitally important that the stratigraphic sequence encountered in the analog wells be representative of the sequence anticipated at the proposed location. When this is possible in some wells but not in others then the viability of each well's pressure assessment should be weighted accordingly.

Seismic data is subject to any number of processing errors that can invalidate it as a tool for pressure analysis. Seismic velocities cannot identify effects related to changes in porosity, lithology or fluids. The coherent reflectivity can change from location to location in the data set. Pressure is not read directly but rather by means of relationships between porosity and velocity then by correlation to pressure or by correlation from frequency decay to pressure. Given all of these caveats, seismic data still provides a valuable means of reducing risk with respect to shale pore pressure prediction at a proposed location – when the uncertainties inherent in the data are recognized by the team and addressed.

Identifying the correct cause of overpressure is key to selecting the appropriate method to use when preparing an analog well assessment or a well planning prediction. When possible, the team should utilize as many independent techniques as are available. The use of multiple methods is a viable means of increasing confidence in a prediction.

Acknowledgments

The authors wish to thank all of those creative, forward-thinking individuals in the petroleum industry whose hard work and perseverance have given us this solid foundation in pore pressure analysis.

Nomenclature

CDP = *common depth point*
ELOT = *extended leak off test*
F = *Fahrenheit*
FIT = *formation integrity test*
LOT = *leak off test*
LWD = *logging-while-drilling*
NCTL = *normal compaction trend line*
NPT = *non-productive time*
PSDM = *prestack depth migrated*
PSTM = *prestack time migrated*
RFT = *repeat formation test*
RMS = *root mean square*
TD = *total depth*

References

1. Ostermeier, R. M., Pelletier, J. H., Winker, C. D., Nicholson, J. W., Rambow, F. H. and Cowan, K. M.: "Dealing with Shallow-water Flow in the Deepwater Gulf of Mexico", *The Leading Edge*, V. 21, No. 7, July 2002, pp. 660-664.
2. Scott, D. and Thomsen, L. A.: "A Global Algorithm for Pore Pressure Prediction", SPE 25674, SPE Middle East Oil Technical Conference and Exhibition, Bahrain, April 3-6, 1993.
3. Traugott, M.: "Pore Pressure and Fracture Pressure Determinations in Deepwater", *World Oil,* Deepwater Technology Supplement, August 1997.
4. Bowers, G. L.: "Pore Pressure Estimation From Velocity Data: Accounting for Overpressure Mechanisms Besides Undercompaction", *Pore Pressure and Fracture Gradients,* SPE Reprint Series No. 49, pp. 78-84.
5. Heppard, P. D. and Traugott, M. O.: "Use of Seal, Structural, and Centroid Information in Pore Pressure Prediction", <http://www.kingdomdrilling.co.uk/drillops/engineer/DWPP01.PDF>, (December 27, 2002).
6. Wang, H., Sweatman, R. and Deeg, W.: "The Difference between Fracture Gradient and Wellbore Pressure Containment and the Effect on Drilling Beyond Natural Pressure Limits", AADE-03-NTCE-26, AADE National Technology Conference, Houston, Texas, April 1-3, 2003.
7. Liaw, A. L., and Kan, T. K., "Pre-drill Pore Pressure Prediction – Geophysical Perspective", The Energy Forum, Pore Pressure Prediction – The GOM Challenge, March 23, 2004.
8. Dutta, N. C.: "Deepwater Geohazard Prediction Using Prestack Inversion of Large Offset P-wave Data and Rock Model", *The Leading Edge*, V. 21, No. 2, February 2002, pp. 193-198.
9. Wyllie, M. R. J., Gardner, G. H. F. and Gregory, A. R.: "Studies of Elastic Wave Attenuation in Porous Media", *Seismic Wave Attenuation,* Geophysics Reprint Series No. 2, pp. 21-41.
10. Young, R. A., Pankratov, A. B., Greve, J. F., U. S. Patent 6,681,185, <http://www.uspto.gov/patft/index.html>, January 20, 2004.
11. Hirsche, K., Porter-Hirsche, J., Mewhort, L. and Davis, R.: "The Use and Abuse of Geostatistics", *The Leading Edge*, V. 16, No. 3, March 1997, pp. 253-258.
12. Bowers, G. L.: "Detecting High Overpressure", *The Leading Edge*, V. 21, No. 2, February 2002, pp. 174-177.
13. Gray, K. E.: "Some Updates for Fracture, Lost Circulation, Leak-Off, and Pore Pressure Technology", AADE-01-NC-HO-45, AADE National Drilling Conference, Houston, Texas, March 27-29, 2001.
14. Alberty, M. W. and McLean, M. R.: "Emerging Trends in Pressure Prediction", OTC 15290, 2003 Offshore Technology Conference, Houston, Texas, May 5-8, 2003.
15. Eaton, B. A.: "The Equation for Geopressure Prediction from Well Logs", SPE 5544, Annual Fall Meeting of SPE of AIME, Dallas, Texas, Sept. 28 – Oct. 1, 1975.
16. Albertin, M. L., Petmecky, S., Jay, C. and Vinson, P: "Drillability Assessment in Deepwater Exploration", OTC 15295, 2003 Offshore Technology Conference, Houston, Texas, May 5-8, 2003.
17. Lopez, J. L., Rappold, P. M., Ugueto, G. A., Wieseneck, J. B., Vu, C. K.: "Integrated Shared Earth Model: 3D Pore-Pressure Prediction and Uncertainty Analysis", *The Leading Edge,* V. 23, No. 1, January 2004, pp. 52-59.
18. Falcao, J. L.: "Uncertainties in the Pore Pressure Evaluation in Deepwater: a Statistical Approach", SPE/ISRM 78247, SPE/ISRM Rock Mechanics Conference, Irving, Texas, October 20-23, 2002.