5º CONGRESSO BRASILEIRO DE PESQUISA E DESENVOLVIMENTO EM PETRÓLEO E GÁS

Technical Analysis of Main Problems in Salt Drilling

Nascimento A.[1], Horta L. A. [2], Prohaska M. [3]

[1] B.Eng., Computer Engineer - Federal University of Itajubá, Brazil;
[2] D.Sc., Mechanical Engineer - Federal University of Itajubá, Brazil;
[3] PhD., Petroleum Engineer – Mining University of Leoben, Austria.

Technical Analysis of Main Problems in Salt Drilling

Abstract

Over the next decade a significant amount of exploration and new field developments have been taken and will although take place in salt provinces around the world , such in the deepwater in the Gulf of Mexico, in Iraq Basin, in Brazilian's Santos and Campos Basin, in the offshore sea of Angola, North and West Africa, etc. These salt formations have a complex behaviours system, needing some special knowledge during its exploration, in special during drilling, where the motion of the salt has to be closely managed.

Thus, find a nowadays important subject to be studied at the Petroleum Engineering, this paper will be presenting a study of the behaviour of salt formation in response to different conditions, explaining important mechanism and drilling related solutions.

Methodology

As a methodology has been used many researches from the Gulf of Mexico and also North sea drilling database. Developing the meaning from the basic concepts, analysing the world wide salt dome distribution, the main problems related from this kind of formation to the petroleum industry and finally the main challenging that are happening nowadays in the petroleum industry, an interesting point of view could be converged to some discuss and related conclusions.

1. Introduction

The presences of evaporite formations are becoming common in the petroleum industry; formations that are formed through many phenomena in relating to salt depositions and to solution vaporization, it has a very interesting and complex mechanical behaviour to be study. The presence of these evaporite sequences in locations of oil exploration, in itself, is a factor that increases the probabilities of success in the area due to favourable conditions for the generation and trapping of hydrocarbons [4]. On the other hand, the presence of evaporites can cause major operational problems such as stuck drilling pipe and casing collapse due to the closure of the well in response to its creep behaviours.

As a world wide known problem in the oil and gas industry, a methodology for the special problem in drilling through salt layers is a very interesting and actual theme to be explored, since the petroleum exploration are being more and more in deeper water and through different kind of situation, in which different physically phenomena are influencing and playing a main important role in relation to the drill system [6].

2. Salt domes and the petroleum industry

Since salt domes have a frequently tendency for motions, many dips and secondary traps can start to be created, by which the migration of the fluids are strongly encouraged [10]. Because as well of these aspects mentioned above, salt domes provide an important indication of the possible occurrence of oil and gas in a district. During these deformations, an important happening is the possibility separation of gas, oil and water in distinguish traps. An common example of faults occurring in response to salt diaper can be seen by the Figure 1 below.

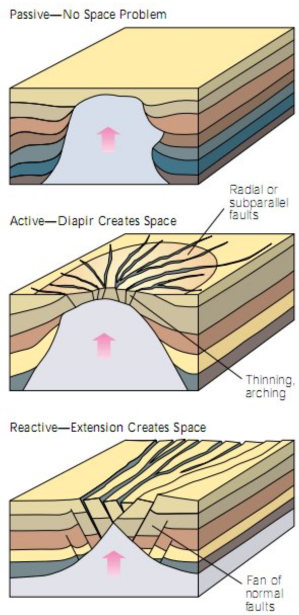

Figure 1. Salt diaper allowing fault and traps [10].

It are primarily found in rift basins and along passive margins. Most are formed during the early post-rift phase, such as the offshore Brazil and West African basins [16]. Some were formed during rifting or lulls between rifting episodes such as those of the northern Atlantic Ocean basins. A few may be older than the main rifting phases, for example the North Sea, where the Permian salt is older than the Triassic and Jurassic rifting. It can also form in any restricted intracratonic basin. Some examples include the Amazon Basin in Brazil and the foreland basins such as the Paradox in the western U.S. Other basins are characterized by narrow entrances that become closed off, such as the Red Sea, the Mediterranean Sea, and the Pre-Caspian Basin. Studies conducted by Martin Jackson, University of Texas at Austin, shows that many salt basins comprise some of the most productive and prospective oil and gas provinces. The Figure 2 above shows a world wired distribution of evaporite formations.

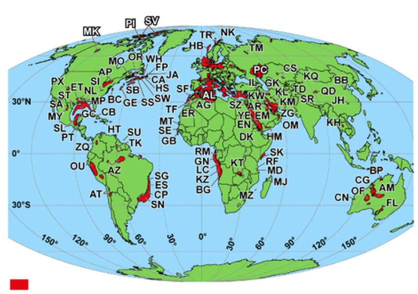

Figure 2. World wide evaporites occurrences, 2007 [16].

3. Salt behaviour and the petroleum industry

A common behaviour of salt rocks, is its nature to “walk” in relation to level of stress, being influenced sensibly by thickness of the layer of salt, formation temperature, mineralogical composition, water content, presence of impurities, and the extent to which differential stresses are applied to the salt body [5]. During trying to find any amount of a petroleum reservoir, after many analysis of geological and geophysical data, the necessity to drill well tests or, if the case is, drill the main well is known [10]. Since all these operations make very disturbs, passing probably through this type of formation, its behaviour is one of the most important to be studying, knowing its limits.

Many drilling problems are due to conditions or situations that occur after drilling begins and for which the drilling fluid was not designed. Some of these problems can be solved by adding materials to the drilling fluid to adjust its properties. Since salt formations have from its nature the motion to walk in response to applying stress, the right mud to be using during drilling is one of the most important specifications to be keeping attention [3]. While drilling, it may be necessary to replace the drilling fluid being used with another fluid system, changing the mud weight or density and, if is the case, add weighting material by high-pressure formations, by which knowing the right mud system to be used is extremely helpfully.

Lost circulation can occur in several types of formations, including high permeable formations, fractured formations, cavernous zones, and salt formations [18]. Against this lost circulation, materials can be added to the mud to bridge or deposit a mat where the drilling fluid being lost to the formation. These materials include as well cane and wood fibres. Stuck pipe can occur after drilling has been halted for a rig breakdown, while running a directional survey or when conducting other non-drilling operation [19]. The drill pipe may stick to the wall of the hole due to the formation of filter cake or a layer of wet mud solids on the wall of the hole in the formation. This occurs for example when shale enters the well bore after the section has been penetrated by the bit [19]. To solve this problem, drilling is suspended the hole is conditioned, by letting the mud in circulation for a period of time.

4. Problems related to salt drilling

Many different little things can influence, increasing the probability problems occurrence during salt drilling [2]. Some of them are related to specific happening, and some of them are directly related to a first one, which come to influence the secondary affected. But, in the most common case, the mud system plays the most important role through this challenging. By the Figure 3, a short example of the most common problems occurring can be seen.

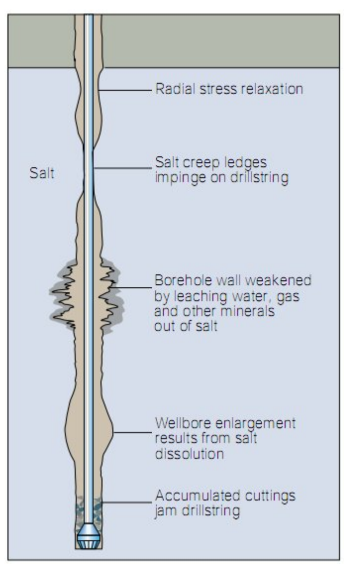

Figure 3. Most common problem in salt drilling [17].

Never less important, is the fact that an exactly knowing about the formation has to be reported, in order to increase the probability to use the most perfect mud for the situation. Throughout this point of view, is known how the seismic data plays an important role at the formations analysis, and since salt formations does not permit a good recording of data in a easy way, the salt formations seismic analysis will be presented as well by a short explanation of its challenging as well.

4.1. Salt bodies imaging

Due to characteristic of salt bodies to “absorb energy”, it show a really challenge by seismic analysis in itself. The most common problem encountered is a non true real imaging of the geological formation to be encountered during drilling, transmitting an uncertain information for the crude, who have always to find the best systematically choice for the real time situation.

4.2. Solubility and dispersion

The solubility of certain evaporites varies depending on the nature of the liquid phase (water or oil) of the drilling fluid used and of the rock encountered [11]. It is maximised in the case of a freshwater mud and salt formation, and can have a different configuration in respect to different systems, so that the solubility varies as well with temperature, making sometimes salt saturation of the drilling fluid at the formation impossible during circulation.

High delicate processes are required to control the viscosity and density of the mud and to maintain its essential characteristics on the presence of dispersions. It is thus seen that the phenomenon of dissolution can be added to the earlier mentioned difficulties of detection. By creating cavities, dissolution can cause collapse, particularly in salt sections with clay intercalations.

4.3. Salt Flow

Evidence acquired and test conduced around the world and experience acquired in the course of deep drilling of salt formations has increased the importance of salt flow in relation to pressures and temperatures [6]. This phenomenon, in association to the low density of salt and its plasticity, is accentuated by local tectonic stresses. This can result in the rise of voluminous salt, difficult operations, which can even include jamming of the drill collar, increased frequency of re-drilling and even breaking of the casing.

It has been shown experimentally that cavity formed in salt under certain temperature conditions, approximately above 150 Celsius degrees, and at differential pressure approximately 210 bars, can be closed up under the effect of flow. This effect ceases if adequate back-pressure is exercised on the walls of the cavity. In drilling, this back-pressure is obtained increasing the density of the mud [11].

4.4. Evaporites and its abnormal pressures

Evaporites constitute an impermeable cover, hindering the normal expulsion of interstitial waters contained in the underlying sediments [11]. They can thus give rise to abnormally high pressures in these sediments. It is almost impossible to detect the entry of water into such high-pressure zones due to the absence of transitional zone in an evaporite sequence. In fact, almost all existing special techniques used in borehole studies for this purpose are based on the existence of transitional zones.

Water entry can also take place while drilling even in the middle of an evaportie sequence. It seems to be more often associated with porous and permeable dolomitic horizons, which are occasionally lenticular, isolated and of small size, but sometimes attain considerable horizontal extension. Even with water inflows, drilling becomes inevitable in some cases. Drilling is generally possible since if the pressure is high, the inflow rate is generally low [16].

On the other hand, intercalation horizons can occasionally cause loss of water. The two phenomena can be found in conjunction in the same evaporite formation, thus seriously complicating the progress in drilling. Their presence remains impossible to predict except in local conditions that are well recognised during earlier drilling operations, one example of the importance of a real-time drilling data management and geological analysis.

5. Discussion

A new techniques used nowadays for drilling is the directional drilling, which leave the necessity to be enrolled in a vertical drilling, moving to a combined performance, which are done with a horizontal drilling possibility. Many wells are drilled as directional wells, since this can lower the costs and permit precisions during drilling operations.

In the meaning of salt drilling, to keep maintaining a directional control, higher weight-on-bit is required, compared to sediments. Consequently it can be observed, that the higher the weight-on-bit, the greater the tendency for the bottom hole assembly to build inclination. In an attempt to counter the build tendency, weight-on-bit may be reduced causing penetration rates to drop. In order to enhance the performance with a high-tech solution, a successful approach has been a rotary steerable assembly and a weight set under-reamer. This type of bottom hole assembly can maximize rate of penetration in the salt, minimize vibrations due to inter-bedded formations, control wellbore direction and maintain certainty of enlarged hole. It can also help maintain gauge hole, which is as important as high penetration rates.

6. Conclusion

Salt drilling has to be planned carefully and strategies for risk reduction need to be found case by case in order to minimise injuries and maximise the chance of a successful exploration.

The best way to prevent problems is to understand the geology and in the best case the magnitude of stresses in all directions across the salt formation and across close geological structures which may function as possible hydrocarbon traps.

The drilling mud system plays a major role in salt drilling. Only a proper selection will enable to overcome the discussed problems.

But not less important are the properties of the casing. Excessive high collapse forces have lead to special solutions like the application of a cemented liner in a cemented casing across the salt section.

Salt drilling requires quick reaction on sometimes unforeseen problems. Thus real time drilling data monitoring and interpretation plays a major role for safe drilling to the planned target.

7. Acknowledgements

The authors are thankful for the support from Brazilian's Institute of Petroleum, Mining University of Leoben and Federal University of Itajubá.

8. References

[1] IADC/SPE 112669, *Challenges of Directional Drilling Through Salt in Deepwater Gulf of Mexico*, by R.R. Israel, P. D'Ambrosio, and A.D. Leavitt, Schlumberger, J.M. Shaughnessey, BP America Inc., and J. Sanclemente, Chevron North America E & P Co., 2008;

[2] IADC/SPE 115208, *Deep Salt Formation Wells Successfully Drilled with Integrated Techniques in Tahe Oilfield*, by Zhong Liguo/Daqing Petro. Inst.; Cong Haiyang/ Shengli Oilfield,SINOPEC; Wang Shiping/ Huabei Petroleum Oilfield, CNPC; Zhao Defu/ Daqing Oilfield Co. Ltd. CNPC; Wang Zhifeng/ Shengli Oilfield,SINOPEC; Yang Guang/ Daqing Oilfield Co. Ltd. CNPC, 2008;

[3] IADC/SPE 112569, *Drilling Salt Formations Offshore With Seawater Can Significantly Reduce Well Costs*, by Stephen M. Willson and Peter M. Driscoll, BP America Inc.; Arnis Judzis, Alan D. Black, and esley Martin, TerraTek Inc.; and Brian L. Ehgartner and Tom E. Hinkebein, Sandia Natl. Laboratories, 2004;

[4] IADC/SPE 99161, *Well Design for Drilling Through Thick Evaporite Layers in Santos Basin—Brazil*, by E. Poiate Jr., A.M. Costa, and J.L. Falcao, Petrobras S.A., 2008;

[5] SPE 113216, *Analyzing Geomechanical Effects While Drilling Sub Salt Wells Through Numerical Modeling*, by F. Mackay, SPE, N. Inoue, S.A.B. da Fontoura, SPE, GTEP-PUC Rio and F. Botelho, Petrobras, 2008;

[6] SPE 95621, *Geomechanics Considerations for Through- and Near-Salt Well Design*, by S.M. Willson, SPE, BP America Inc., and J.T. Fredrich, SPE, Sandia Natl. Laboratories, 2005;

[7] OFFSHORE ENGINEER, *Brazilian's Pre Salt*, June 2008;

[8] E&P DAILY NEWS, *Conquering the Challenges of Directional Drilling Through Salt*, SPE Drilling Conference 2008;

[9] NEWSLETTER GTEP BRAZIL, *Workshop GTEP*, May 2008;

[10] RECENT ADVANCE IN GEOSCIENCE, *Salt Deformation and Trapping*, May 2008;

[11] BORCHERT H. and MUIR R., *The Origin, Metamorphism and Deformation of Evaporites*, 1964;

[12] DREYER W., *Geology of Petroleum – Underground Storage of Oil and Gas in Salt Deposits and Other Non-Hard Rocks*, 1982;

[13] POTTER C. and WIGGERT D., *Mechanics of Fluid*, 1997;

[14] MUNSON D. E. and SENSENY P. E., *Approach to First Principles Model Prediction of Measured WIPP (Waste Isolation Pilot Plant) In-Situ Room Closure in Salt. Tunneling and Underground Space Technology*, 1990;

[15] BARKER J. W. and TSAO Y. H., *Drilling Long Salt Sections Along the U.S. Gulf Coast*, 1992;

[16] SMITH T., Salt's *Effects on Petroleum Systems*, 2007;

[17] FARMER P., *Exploring the Subsalt*, 1996;

[18] *DRILLING THROUGH SALT: CONSTITUTIVE BEHAVIOR AND DRILLING STRATEGIES*, by Maurice B. Dusseault, Vincent Maury, Francesco Sanfilippo

and Frédéric J. Santarelli

[19] Hiliard V., *Drilling, The Manual of Methods, Applications and Management*, 1996;

[20] Clausthal University – Germany, *Laboratory Test for Casing in Salt Formations;*

[21] PARADIGM A. *Subsalt Imaging using 3D Pre-stack Depth Migration*, 2005;

[22] VOLKER D., *Subsalt velocity analysis by combining wave equation based redatuming and Kirchhoff based migration velocity analysis*, 2006.

[23] CHARLES M., *Iterative imaging for subsalt interpretation and model building,*