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Managing Wellbore Stress Data in the Niger Delta

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Abstract-Wellbore instability has continued to be a major source of cost overruns and drilling delays in different parts of the world. Knowledge of stress history and state of a given formation is important for maintaining well stability in drilling engineering. Professor Adewale Dosunmu, Shell Aret Adams Chair in Petroleum Engineering was commissioned to carry out a study of the wellbore stability management in the Niger Delta and develop a database to show the various subsurface stresses and other important parameters affecting the stability of the wellbore. Current literature on wellbore stability and field experiences worldwide were examined as well as current tools available for well bore stability prediction and the correlations upon which they were based. Past and current stress templates of different regions documented by the World Stress Map (WSM) Project team were examined.

It was observed that extensive work has been done on the subject by the WSM team on other continents. However there are no such records of stress data compiled for the African continent. Operators in this region have used various correlations however, which estimate the in situ state of stress but with a lot of flaws that has led to well stability problems.

The new software developed provides a general template for viewing and understanding the stress state of the Niger Delta, on a field by field basis for the various operators.

Keywords*- Database, Wellbore Stability, Niger Delta*

I. INTRODUCTION

To minimize wellbore failures in unstable environments, knowledge of complete stress tensor is crucial to designing optimally stable borehole trajectories, selecting suitable mud weights, and determining appropriate casing depths. Understanding how in situ stress field interacts with the drilling and production of a well enables one to design for maximum stability and to facilitate intersecting the greatest population of hydraulically-conductive fractures for efficient production. Knowledge of in situ stress field is also important to reduce uncertainties in sand production prediction to allow more aggressive completion designs and production schedules.

Stresses in the earth play a critical role in many geologic processes and engineering problems. For example, the migration path of hydrocarbons may be determined by stresses in the earth and wells may collapse as a result of the stresses they encounter as they are drilled.

II. THE WORLD STRESS MAP PROJECT

As part of the International Lithosphere Program a project to compile and update regional stress orientations, profiles, regimes and provinces in different parts of the world began in 1985. This research has developed into what is today called, the World Stress Map WSM, a global compilation of information on the present-day tectonic stress field in the Earth’s crust. These rock stresses cannot be measured directly and can only be inferred by disturbing the rock. Also, rock stress cannot be inferred accurately due to the complex nature of rocks and rock masses (Amadei and Stephansson, 1997). Under good conditions where the rock is linearly elastic, homogenous and continuous, it is generally possible to determine rock stresses with an error of 10-20% for their magnitude and an error of 10-20 percent for their orientation (Amadei and Stephansson, 1997). In poor quality rock (weathered, weak, soft or heavily fractured) the measurement of rock stresses is extremely difficult.

A number of methods have been applied able to determine the in situ stress field indirectly in the rock mass. These methods include earthquake focal mechanisms, hydraulic fracturing, overcoring, borehole breakouts, drilling induced tensile fractures (DITF) and geological indicators. Each stress measurement technique has advantages and limitations. The hydraulic fracturing technique is one of the most popular in situ stress determination techniques available, as it provides information on both the orientation and magnitude of the in situ stress field. However, hydraulic fracturing measurements are commonly undertaken at shallow depths in association with engineering work and hence, the information obtained may not be representative of the tectonic stress field at depth (Zoback and Zoback, 1980). Similar limitations also inhibit the overcoring technique. In contrast, earthquake focal mechanisms provide in situ stress information from a much greater depth range (many kilometers). They also provide important information on the relative stress magnitudes of the principal stresses. Nonetheless, earthquake focal mechanisms also have their limitations. The earthquake may have resulted from slip along a pre-existing plane of weakness (McKenzie, 1969a) or may represent deformation due to the complex interaction of active faults, and hence the information provided would not relate directly to the tectonic in situ stress field (Zoback, 1992).

The WSM project also includes a ranking system for the various stress indicators based on different levels of consistency. The stress information is recorded in a standardized format and quality-ranked in order to be comparable on a global scale (Sperner et al., 2003; Zoback and Zoback, 1991; Zoback, 1992; Zoback and Zoback, 1989).

Despite the extensive work done on the subject of insitu stress by the world stress map projeet, no such comprehensive data has been compiled for Africa, let alone the Niger Delta Province.

III. OBJECTIVES OF STUDY

The objectives of this study for the Niger Delta are to:

1. Examine various stress related data which are critical to defining the stress state of Niger Delta formation,
2. Collate these Data from operators through the Directorate of Petroleum Resources
3. Perform necessary sorting and processing on obtained data.
4. Develop and implement criteria for verifying data integrity- QAQC
5. Develop a robust database software to store all obtained data for display in the given format so that oil and gas companies can have ground knowledge of the sub-surface before carrying out drilling operations.

IV. PROJECT DELIVERABLES

The following will be the objectives of the study and represent the business value of the study

1. Develop a subsurface geomechanical profile for the field by correlating well data from available data base.
2. Using developed stress map generated from the seismic and log data define potential drilling hazards.
3. Define stress magnitudes and orientations on a field wide basis
4. Provide a risk based approach to wellbore instability in the node using quantitative risk analysis.
5. Design a Niger Delta database for stresses in order to have a concrete knowledge of stress profile.

V. MODEL DEVELOPMENT

The methodology of database for wellbore stability management will include: the model build – up which takes into consideration well log data, drilling reports and formation test made available. Also there will be model calibration. The model will be updated and extrapolated with the available wells based on the model approach for predicting the stability and instability of wells at any fault regime depending on the well placement for both vertical and deviated wells. In these report we are presenting a database to store the various subsurface rock properties which will give a concrete knowledge of the region where an exploration and exploitation is to take place.

VI. DESIGN SPECIFICATIONS FOR MODEL DEVELOPMENT

The database stress template will be documented on operator by operator basis so as to ensure that all the existing fields in the Niger delta region (both east and west) are accounted for. The design template for the wellbore stability management database would include the following below:

A. Input Data

The database input data for the wellbore stability management comprises of the following as shown below;

- The operator name
- Region of drilling operation is currently taking place or is to take place.
- The block name e.g. OML 14
- The names and number of fields under the various operators under consideration.
- Latest date of measurement of the various in situ stress related parameters.
- Names of fields in the regions considered.
- Names of wells within the fields mentioned above bearing in mind that the in situ stress indicators where observed in these wells.
- Measured wellbore stresses

The model database will be made to be flexible and robust enough to import the above data from an active excel sheet.

On completing the spaces for the above mentioned parameters, the interface would transfer the user to another bearing the following data;

- Measured/ vertical depth
- The vertical stresses at given depths as calculated from density logs or check shot velocity surveys
- The magnitudes of maximum and minimum horizontal stress, at given depths. Included alongside this will be;
    - Well azimuth
    - Azimuth of maximum horizontal stress
    - Type of stress indicator (DITF, overcoring, focal mechanisms, etc)

- Depth range within which the stress indicator was observed
  - The latitude and longitude of the stress site
  - The mean maximum horizontal stress orientation and the circular standard deviation (if available)
  - Stress regimes
  - The quality rankings, according to WSM ranking scheme
- The maximum stress orientation
- Pore pressures at given depth

B. Output Data:

The database output interface for the wellbore stability management comprises of the following as shown below;

- The vertical stresses with respect to depth
- The maximum and minimum horizontal stresses with respect to depth
- Other stress related properties fed at the input stage
- Other relevant rock properties - Poisson's ratio, Young's Modulus, cohesion, over-burden gradients, etc
- Mogi (3D) failure criteria
- Mohr (2D) failure criteria and possible comparison of the two
- Failure diagrams
- A plot of the stress trajectories of each field as well from the mean orientations

Microsoft excel sheets are best suited for displaying the output of the software. An illustration of the output is shown below.

Thus the software would also link the stress data base to their corresponding well sites, well names, operator, dates, etc which appeared on the first interface. With this, it will be easier to view as well as compare data from different regions of fields. Update to previously entered data should be possible as well in case of changes to existing ones.

VII. MODIFICATIONS TO THE MEASURED IN SITU STRESSES

In situ stresses measured at different locations in each well might require averaging in areas of cluster. This will help us record single results for each depth. In the case of stress orientations, the average orientation and standard deviation of the stress-induced features observed in each well are calculated using circular statistical analysis following Mardia (1972).

The average stress orientations measured from each well are quality-ranked to the updated World Stress Map criteria and available in the world Map 2008.

TABLE I. A DISPLAY OF MODEL DATA

OPERATOR	FIELDS	WELL	LAT	LON	TYPE
COMP 1	FIELD1	WELL-36	-24.520	150.05	HF
		WELL-38	-23.094	148.502	HF
		WELL-40	-22.920	148.61	HF
			-21.740	148.05	HF
			-21.592	148.173	HF
COMP 2	FIELD1	WELL 1	-23.590	150.7	FMS
		WELL 2	-21.602	147.957	HF
		WELL 3	-21.592	147.966	HF
		WELL 4	-21.833	148.058	HF

TABLE II. A DISPLAY OF MODEL OUTPUT SHOWING WELLBORE DATA AT DIFFERENT DEPTHS

LAT	LON	Depth	Ovb. Pr, (psi/ft)	Pp (psi/ft)
142, 128.32mN	320, 244.17mE	5598	0.874	0.434
		5858	0.878	0.434
		6214	0.883	0.434
		6323	0.885	0.434
		6614	0.889	0.434
		6951	0.893	0.434
		7362	0.898	0.437
		7515	0.9	0.431
		7589	0.901	0.429
		7728	0.903	0.429
		7827	0.904	0.429
		7832	0.904	0.426

TABLE III. A DISPLAY OF MODEL OUTPUT SHOWING WELLBORE STRESS AT DIFFERENT DEPTHS

S_{hmin} [psi/ft]	Young	Poisson	Friction Angle (deg)	Cohesion (Psi)
0.781	0.22	0.38	24.85	696.95
0.779	0.2	0.38	24.68	633.05
0.778	0.13	0.38	24.14	434.73
0.778	0.16	0.38	24.38	523.13
0.778	0.17	0.38	24.45	549.84
0.779	0.16	0.38	24.39	528.38
0.781	0.22	0.38	24.89	710.22
0.782	0.22	0.38	24.88	707.94
0.783	0.25	0.38	25.14	800.68
0.784	0.16	0.38	24.34	508.45
0.785	0.4	0.38	26.37	1231.92
0.785	0.32	0.38	25.72	1006.29

VIII. APPLICATIONS

A comprehensive knowledge of regional stress directions is not only important in scientific terms and earthquake hazard assessment but also gives important information for optimizing petroleum recovery and exploration of fracture related reservoirs [Fuchs and Müller, 2001]. The identification of global, regional and local patterns of stress distribution provides new insight into mountain building, evolution of sedimentary basins and characterization of active faults with earthquake potential [Zoback, 1992; Tingay et al., 2005]. The estimation of the principal horizontal stress directions using borehole breakouts is used by petroleum industry and drilling engineers to determine the stress regime for wellbore stability analyses and reservoir simulation

This database is used to store a wide variety of data used in geomechanics and provides a means by which a large amount of data can be stored and recovered in a logical and rapid manner. Data base provides a consistent and accesible repository for storing for the Stress Group.

IX. Conclusions

Software with inclusions of comparison between correlation and many other existing models.

Acknowledgments

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Nomenclature

σ hmin = minimum horizontal stress [Mpa]

σ Hmax = maximum horizontal stress [Mpa]

σ max. = orientation of max. horizontal stress

σ v = vertical stress [Mpa]

TF = thrust fault regime

SS = strike-slip fault regime

NF = Normal fault regime

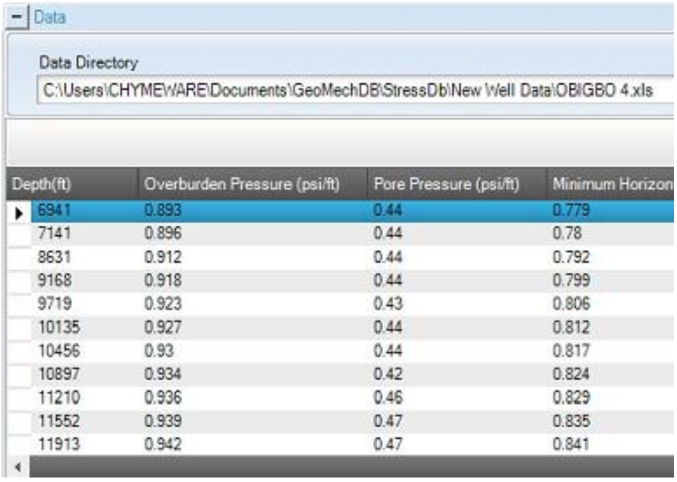
LAT = Latitunal location of stress indicator

LON = Longitudnal location of stress indicator

HF = Hydraulic Fracture

FMS = Focal Mechanism

APPENDIX



Data

Data Directory

C:\Users\CHYMEWARE\Documents\GeoMechDB\StressDb\New Well Data\OBIGBO 4.xls

Depth(ft)	Overburden Pressure (psi/ft)	Pore Pressure (psi/ft)	Minimum Horizon
6941	0.893	0.44	0.779
7141	0.896	0.44	0.78
8631	0.912	0.44	0.792
9168	0.918	0.44	0.799
9719	0.923	0.43	0.806
10135	0.927	0.44	0.812
10456	0.93	0.44	0.817
10897	0.934	0.42	0.824
11210	0.936	0.46	0.829
11552	0.939	0.47	0.835
11913	0.942	0.47	0.841

Figure 1. Database Pressure Data Display

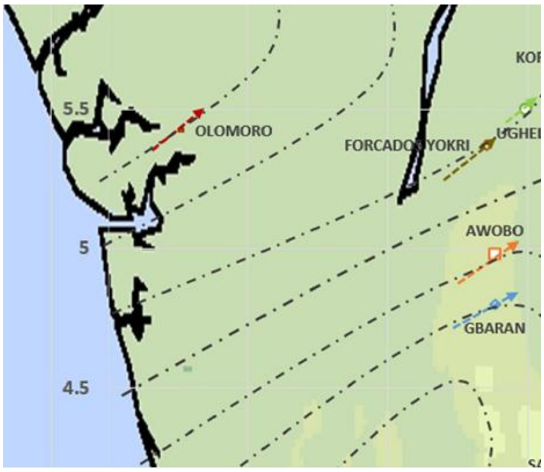


Figure 2. Stress Map

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