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Development of the Overburden Stress Relationship in Niger Delta Brown Fields

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ABSTRACT

Pore pressure, fracture pressure and geomechanical studies require accurately determined overburden stress magnitudes, which sum up the combined weight of overlying materials to the depth of interest. Ideally, overburden stress is determined from in-situ density data. Such data is not available for pre-drill studies where offset data or an overburden model must be used. Often, a quick-fix approach is to assume a simple constant gradient (usually 0.9 psi/ft or 1.0 psi/ft) for the overburden or any missing sections of the density log. A simple overburden function or trend is not appropriate in the Niger Delta region due to the unexpected changes with depth in lithology and sediment compaction state. In order to minimize this limitation, overburden stress models are developed based on some distinct, geologically driven, density trends that are seen in the Niger Delta brown/developed oil and gas fields.

Keywords *– Density Well Logs, Fracture pressure, Niger Delta brown fields, Overburden stress, Pore Pressure.*

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I. INTRODUCTION

The overburden stress, or sometimes referred to as vertical stress (Sv), is one of the principal stresses which direction is pointing directly to the center of the earth. The vertical stress, Sv, is the maximum principal stress (S1) in normal stress faulting regimes, the intermediate principal stress (S2) in strike slip stress regimes and the least principal stress (S3) in reverse stress faulting regimes (Zoback , 2007). The magnitude of vertical stress Sv is equivalent to the integration of rock densities at each incremental depth from surface to the depth of interest. Rock density data is most commonly acquired from wireline logging data or logging while drilling (LWD) data.

THEORY AND BACKGROUND

DENSITY MEASUREMENT:

Density tools provide measurement of formation density, formation photoelectric factor, and borehole diameter. The density data are used to calculate porosity, lithology analysis for identification of minerals, rock mechanical properties calculation, and determination of overburden stress (Schlumberger, 2012). There are many different types of density measurement tools in the industry today. Some have three detectors which use the third detector located close to the radiation source as a backscatter density measurement. The density tool with additional detector supersedes the predecessor of the density tool with only two detectors and provides higher resolution and quality of measurement. Density tools also come in sizes for different wellbore diameters and different temperature and pressure ratings for different environments.

The density tools are active gamma ray tools that use the Compton scattering of gamma rays to measure the electron density of the formation. A radioactive source is used and emits medium energy gamma rays into the formations. These gamma rays collide with the electrons in the formation. At each collision a gamma ray loses some energy and may also be captured by another electron. The scattered gamma rays reaching the detector, at a fixed distance from the source, are counted as indication of formation density (Buryakovsky, et al., 2012).

Using appropriate lithology corrections, the electron density is converted to mass density with reasonable accuracy (Fjaer, et al., 2008). Density measurement is performed with a skid pad which makes full contact with wellbore during measurement. A good wellbore without washout or mud cake, is more conducive to good pad contact between the tool and wellbore, and thus correctly measures the formation density. In poor borehole conditions, an "environmental" mud correction is applied to the density algorithm. The density tool gives an erroneous formation density value when run in borehole with high barite content in the drilling mud. This is because barite has electron density of 26728 barns/electron compared with values of less than 6 barns/electron for most common minerals (Schlumberger, 1985). Barite is such an efficient absorber of gamma rays that it reduces the level of gamma rays to levels too low to be measured accurately (Glover, 2000). The work of Wahl et al. (1964) indicated that a mudcake containing 60 percent barite by weight can have a bulk density of 2.5 g/cc, but its effect might be the same as that of a barite free mudcake with a density of 3.5 g/cc (Wahl, et al., 1964).

A study done by Nieto et al. in 2005 for high density and photoelectric factor reading in northern Alberta has confirmed some density correction requirement for western Canada formation with large anisotropy in the stress field that resulted in elliptical or rogues borehole. The study included the effect of borehole size, pad contact, temperature effect, barite mud and mudcake thickness to the quality of density and photoelectric value. Although some effects cancel each other, a certain amount of correction is needed for borehole rigidity and effect of heavy mud weight due to the amount of barite (Nieto, et al., 2005).

II. OVERBURDEN STRESS

Overburden stress, also called vertical stress or lithostatic pressure, is pressure or stress exerted on earth's formation from the weight of overlying rock and soil. The magnitude of overburden stress, Sv, is equivalent to integration of rock densities from the surface to the depth of interest, z.

$$\mathbf{Sv = \rho(z)\ x\ g\ x\ dz}$$

Where $\rho(z)$ is the density as a function of depth, g is gravitational acceleration. Note that the z-axis is pointing vertically downward, with z=0 corresponding to the Earth surface. The rock above any given depth will have various lithology and porosity, hence varying density. A more accurate determination of overburden pressure can be obtained by adding the pressure fraction of density from each incremental depth. Some of the practical problems associated with the computation of Sv using the above equation relate to the fact that density logs frequently measured anomalously low density when the well is rogues with high barite mud content. On top of that, density log is often not measured all the way up to the ground level or rig floor. Hence it is necessary to extrapolate densities to obtain the overburden stress as a function of depth.

III. METHODOLOGY (METHODS AND MATERIALS)

Integration of the formation bulk density data versus depth establishes the overburden stress relationship. There is formation bulk density data from multiple wells from various Niger Delta developed fields. In the offshores, with the water depth varying from one offshore fields to another offshore fields in Niger Delta, there's a significant amount of sediments without bulk density measurements above 3000ft.

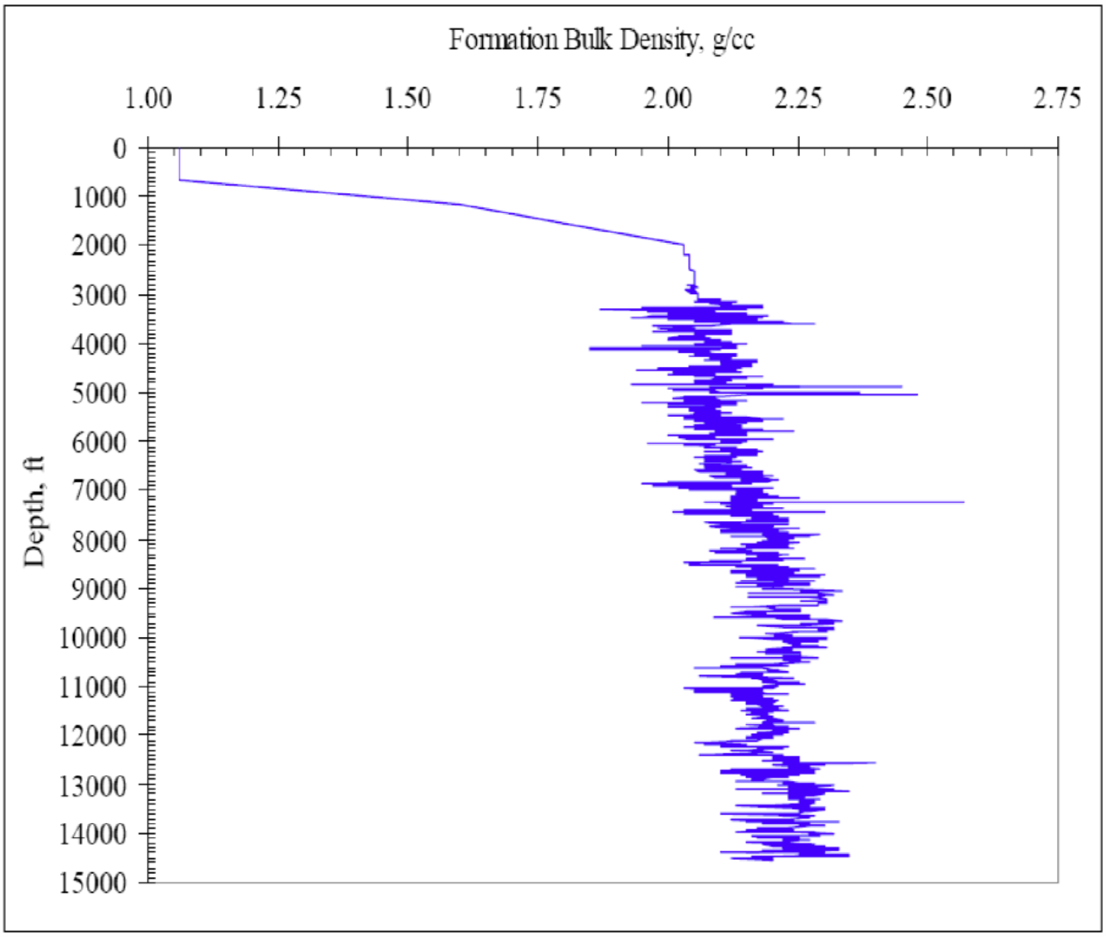
Gardener et al developed the following relationship between average interval velocity, V, and bulk density:

$$\rho_b = 0.23 * V^{0.25}$$

Where velocity is in ft/sec. This relationship was applied to the long spaced sonic data to estimate bulk density data for the interval in the various brown fields.

With the velocity relationship described above, the only interval requiring a bulk density estimate is from the surface to 2000ft. Eaton assigns a bulk density of 1.06 g/cc from the sea level to the mudline and 1.6 g/cc from the mudline to 2000ft below the mudline (BML).

A straight line from the bulk density value at 500ft BML to the bulk density value at 2000ft is assumed. This should provide a fairly accurate estimate of bulk density which can be integrated to determine the overburden stress relationship. Figure below is a plot of average formation bulk density versus depth Niger Delta area based on these assumptions and the available measured data. The data was obtained from various developed fields in the Niger Delta region.



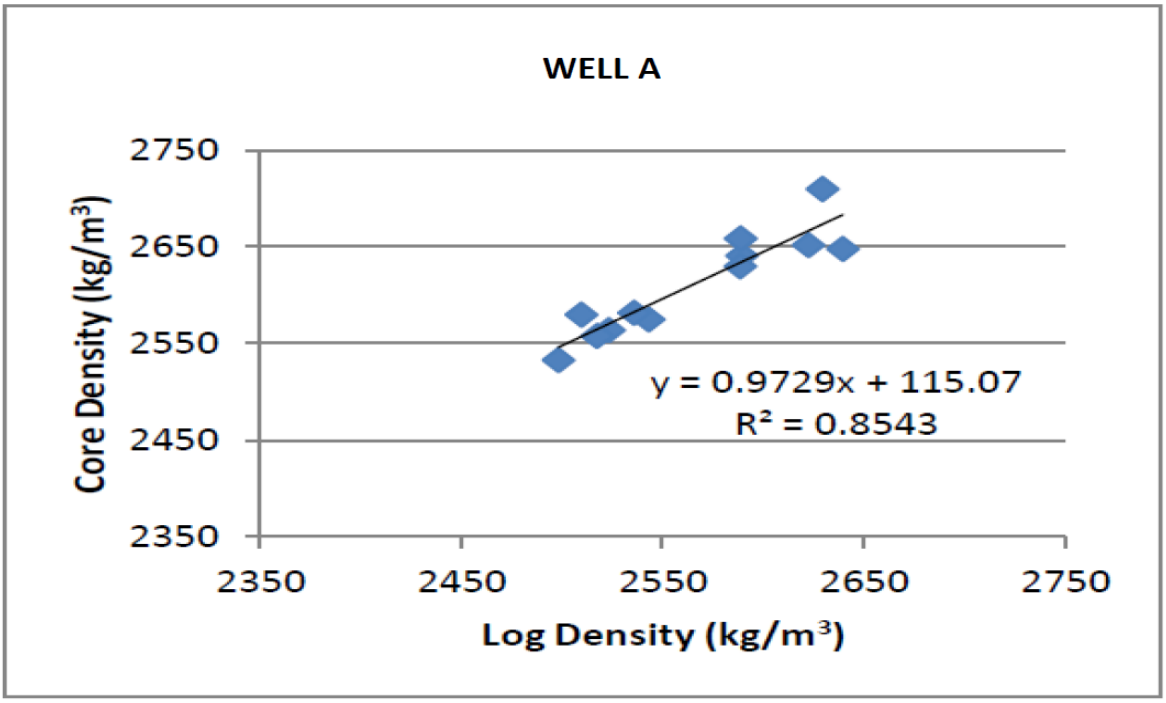
Formation bulk density of Niger Delta region

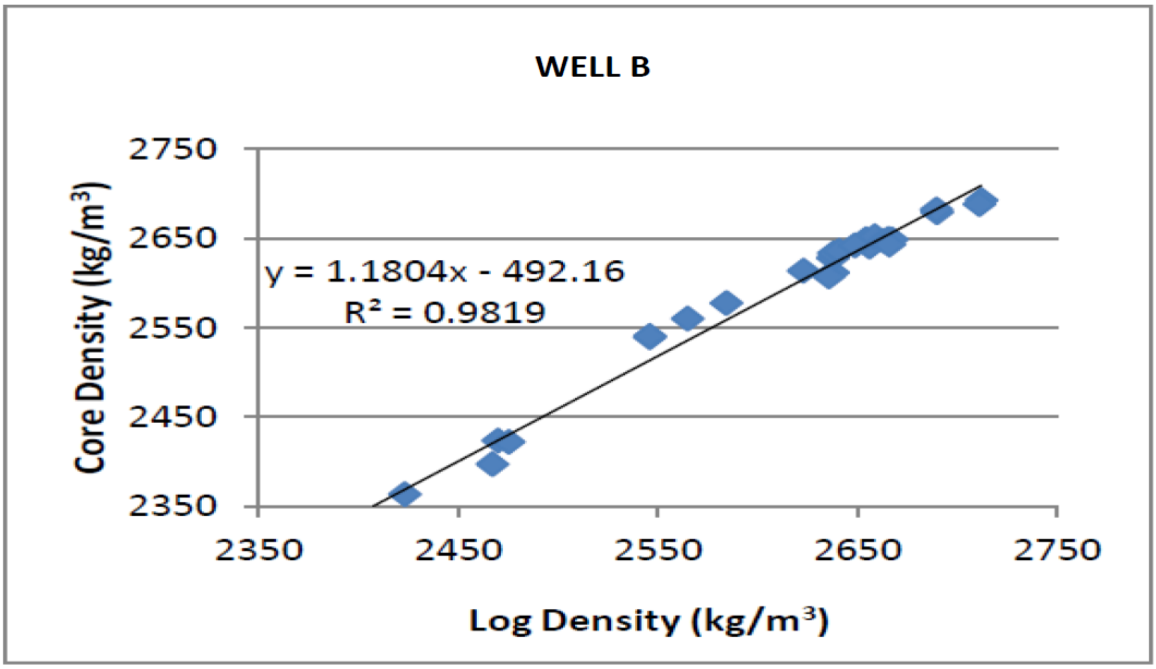
IV. ANALYSIS AND RESULTS (BULK DENSITY MEASUREMENTS COMPARISON IN NIGER DELTA BROWN FIELD)

Being only 6.7km apart, comparison between density log of wells A and B in Niger Delta brown field have shown different density value of averagely 90-210 kg/m^3. Well A has lower density value compare to B for the same formation. Both wells, A and B, have density data from total depth to surface at around 648 meter, just below surface casing. Further investigation from drilling reports revealed that both wells were drilled with high barite content mud. Barite, barium sulfate is a mineral frequently used to increase the weight or density of drilling mud (Drill-Tek MWD, 2001). Being gamma rays absorber, barite will cause less gamma ray returns to the detector and hence increase the density reading of the tool.

Logging companies have different barite mud algorithms for density correction. Well A was logged with drilling mud of 1789.5 kg/m3 and well B was logged with 1454.5 kg/m^3 mud weight. About 298% of extra barite was used in well A compared to well B. According to drilling reports, 6495 sacks of barite were added to the mud system in well A, compared to 2329 sacks for well B.

The density measurement is generally affected by hole rugosity as indicated by the caliper log. For the purpose of this study, the density data has been filtered to account for erroneous data caused by large washouts. For caliper readings 15% larger than bit size, the density data has been eliminated. Since the density tool cannot measure formation density inside a casing, proper care should be taken not to include density data above surface casing depth. Interpretation from caliper and resistivity data along with drilling reports, the surface casing was confirmed to end around 659 meter, and therefore density values above 651 meter are discarded from any calculation. Since both wells have some cores taken and analyzed, correction was made to logging density data for both wells by direct correlation between core density and logging data density as shown on figure below. Logging density data from well A was corrected to yield higher values, while logging density data from B were corrected to yield a lower value.





Comparison and Correction performed each on well A and Well B log density data from core density data in Niger Delta brown field. Well A corrected logging density value is increased and Well B corrected density value is decreased from the initial value.

V. OVERBURDEN STRESS CALCULATION

Both well A and well B wells were logged from surface casing until total depth. Density of formation behind surface casing from ground level to 650m was assumed to be equal to the density of rock just below surface casing depth. Overburden pressures for both wells were calculated with the equation below:

$$Sv_1 = \rho 1 \text{ x } g \text{ x } z1$$

$$Sv_n = \rho_n \text{ x } g \text{ x } (z_1 - z_{n-1}) + Sv_{n-1}$$

ρ1 is the bulk density at 651 meter and z1 is depth at 651 meter. After density is corrected to its true value, the overburden stress calculation is a straightforward integration of density at each incremental depth toward total depth for both wells.

V. CONCLUSION

The following are the conclusions reached in this research work:-
Overburden stress calculation is a straightforward integration from corrected density logging data. Proper quality control of density logging data is important for an accurate overburden stress computation.

High barite content in drilling mud will increase density readings. However, a standard barite correction algorithm may over correct the density value. A proper logging density correlation with core density data is the best approach to accurately correct the density value.

BIOGRAPHY:

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