THE EFFECTS OF CHANGES IN OVERBURDEN PRESSURE ON KLIKENBERG PERMEABILITY MEASUREMENTS FOR SIRT BASIN

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Abstract: Klinkenberg permeability (Kl) correction at different overburden pressures and air permeability (Ka) was carried out at the same overburden pressures for one hundred plug samples of 1" and 1.5" diameter from different formations from Sirt Basin of clastic and carbonate reservoirs. The samples were measured using Keyphi instrument, the measurements covered a permeability range of 0.03mD - 600mD. The results showed a strong correlation between the Klinkenberg and air permeabilities for the samples of high permeability values and the effect of slippage is more clear on the low permeability samples (less than 1mD), a composite curve has been established for all the samples in order to investigate the effect of variation in O.B.P on the permeability values.

Keywords: Air permeability, Klinkenberg permeability, Gas slippage, Overburden pressure.

INTRODUCTION

Permeability is a property of the porous medium and is a measure of the capacity of the medium to transmit fluids. Absolute permeability is a very important parameter necessary for any prediction of reservoir production performance. In the measurement of permeability certain precautions must be exercised in order to obtain accurate results when gas is used as a testing fluid. Correction must be made for gas slippage; this correction must also be applied to the change in permeability caused by the reduction in pore size due to the effect of the change in overburden pressure (Estes *et al*, 1956 and Amyx *et al*, 1960;).

Klinkenberg (1941) had reported variations in permeability as determined using gases as the flowing fluid from that obtained when using non reactive liquids at ambient conditions. These variations were attributed to slippage, a phenomenon well known with respect to gas flow in capillary tubes (Klinkenberg, 1941; Jones, 1972). In general, conventional measurement of porosity and permeability are conducted at ambient conditions. However, in the reservoir the rocks are subjected to both pressure and temperature. When cores are brought up from the well bottom, all the external forces acting on them are eliminated and the rock matrix is al-lowed to expand in all directions. The shape of the pores for storage of fluids and pore throats for fluid flow are therefore changed.

Expansion of the rock due to overburden pressure/ stress relief can produce an increase of 30% or higher in the permeability of the rock. Consequently, a large population of plug samples was subjected to porosity and permeability measurements at varying overburden pressures in order to develop an empirical correlation necessary for correcting the permea-bility of the rest of the rock samples for the effect of overburden pressure. Groups of samples with low, medium and high permeability were used (Jones, 1988; Abousrafa, 2004).

EXPERMINTAL WORK

Core data was gathered over a period of years from 18 wells representing all of the formations in Sirt Basin. One hundred plug samples of 1" and 1.5" diameter were used in this petrophysical analysis at LPI laboratories to establish a relationship between air permeability and Klinkenberg permeability at different overburden pressures.

The plug samples used for permeability testing were cleaned using toluene to extract the hy-drocarbons, then leached of salt using methanol and

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oven dried at 80 °C. The samples were then placed in the Keyphi instrument, which is a fully automated porosimeter and permea-meter which is used to determine porosity and permeability at different over burden pressures, Keyphi utilizes an unsteady state measurement technique. The measurements and the calculations of these petrophysical properties are based on the techniques described by API (Recommended practice 40, 1998).

The plug sample is mounted in a hydrostatic core holder, which is connected by pipe-work and valves to a chamber of known volume in conjunction with a pressure transducer (Fig. 1). The core holder is capable of applying confining pressure of up to 10,000psi. The chamber is charged with helium to a predetermined pressure. When the valve which separates the core holder and the chamber is opened, the gas flows through the sample and exits to atmosphere at the downstream end of the sample (Keyphi User Manual, 2001).

The draw down pressure is then recorded versus time. Analysis of the pressure transient pro-file makes it possible to calculate Klinkenberg corrected permeability and non-corrected permeability. The permeability of the plug samples were measured at confining pressure values of 800, 1500, 2500, 4000 and 6000psi with a permeability range of 0.03mD to 600mD.

RESULTS AND DISCUSSION

Klinkenberg (Kl) and air (Ka) permeabilities for a range of 0.03-600 mD were measured at different overburden pressures (OBP) and compared graphically. The lithologies of the rock samples included clastic and carbonate rocks are all from formations of the Sirt Basin. Air and Klinkenberg permeabilities at each OBP

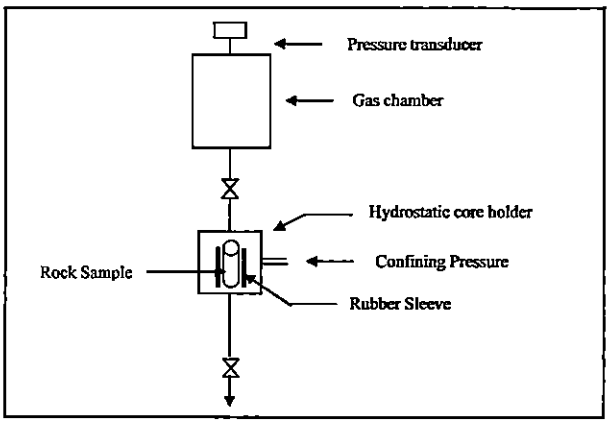

Fig. 1. Schematic of pressure-fall off gas permeameter.

are presented separately in log-log scale along with a composite plot for all the pressures. The two parameters show a strong relationship over the measured range. Klinkenberg Corrected permeabilities at O.B.P are slightly lower than the equivalent air permeabilities as would be expected, but also because of the changes in pore geometries due to the effects of the applied OBP.

Figures 2 through 6 show equivalent data for one hundred sets of specific air and Klinken-berg permeabilities measured at an increasing OBP for both clastic and carbonate formations. The graphs show good correlation between the measured permeabilities at each overburden pressure.

Figure 7 shows a composite plot of all of the overburden data and gives the equation derived from that data. This plot displays a strong correlation over the OBP range, where the correlation coefficient (R2) of this plot is 0.9939 and the standard error is 0.077. There is a tendency for the lower permeability samples (less than 0.1 mD) to deviate from the trend line; this may be due an increased gas slippage in these tight samples

CONCLUSIONS

1) The composite graph shows a strong correlation between Klinkenberg permeability and air permeability at varying OBP.
2) Based on the data presented, a general equation fits all the tested samples is established. This equation has the form:

$$Kl_{(OBP)} = 0.834 * K_{a\,(OBP)}^{\;1.025}$$

3) Corrected Klinkenberg permeability obtained from this correlation can be used as a good tool in reservoir characterization for the Sirt Basin.
4) The correlation is a cost-effective method for estimating Klinkenberg permeability instead of measuring Kl in the laboratory. This correlation can also be applied to previously measured air permeabilities at different OBP.

RECOMMENDATIONS

1) This study should be continued to include more samples and also cover a wider per-meability range.
2) Implementation of such a correlation tool could be extended to cover all the Libyan basins.

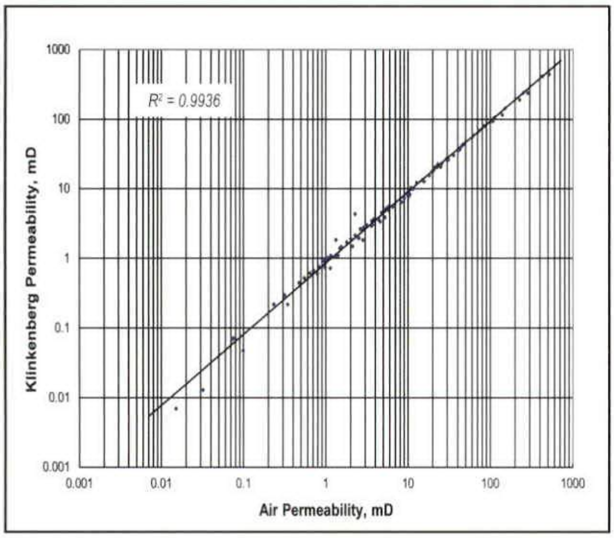

Fig. 2. Klinkenberg Permeability Vs Air Permeability at NOB of 800.

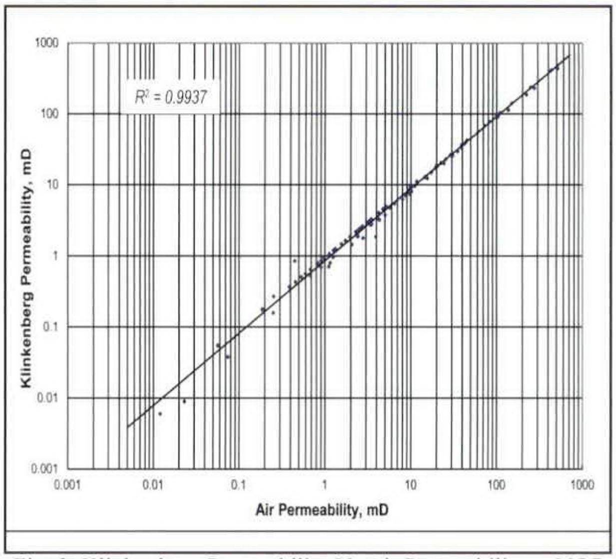

Fig. 3. Klinkenberg Permeability Vs Air Permeability at NOB of 1500.

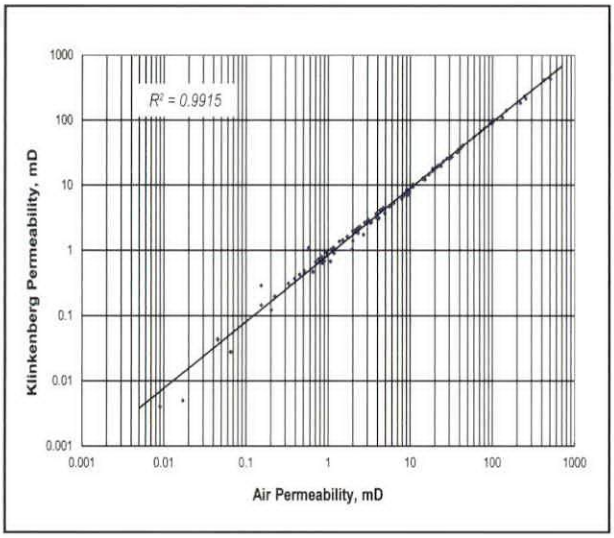

Fig. 4. Klinkenberg Permeability Vs Air Permeability at NOB of 2500.

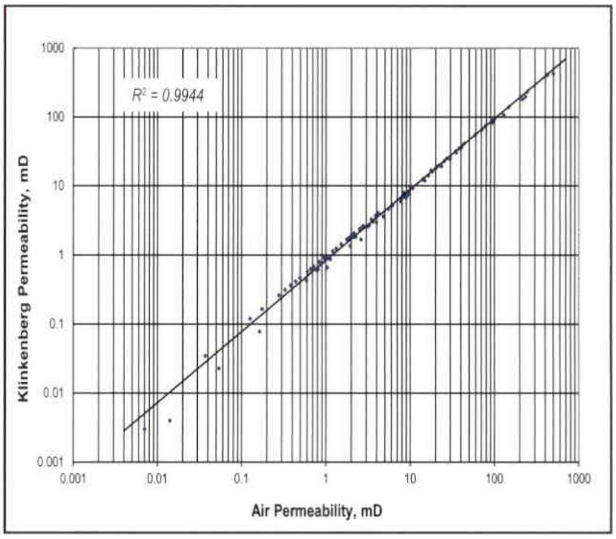

Fig. 5. Klinkenberg Permeability Vs Air Permeability at NOB of 4000.

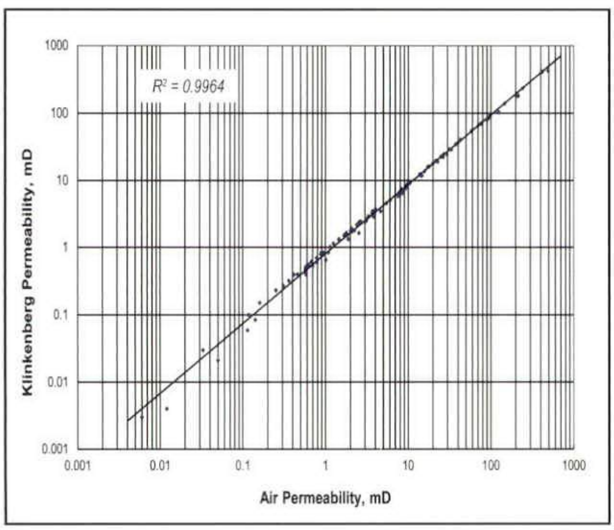

Fig. 6. Klinkenberg Permeability Vs Air Permeability at NOB of 6000.

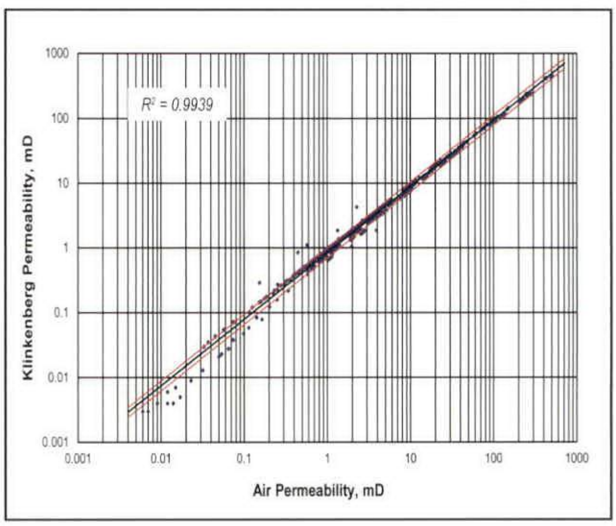

Fig. 7. Composite Graph.

NOMECLATURES

K_a = Air permeability, mD
K_l = Klinkenberg permeability, mD
$K_{a\,(OBP)}$ = Air permeability at overburden pressure, mD
$K_{l\,(OBP)}$ = Klinkenberg permeability at overburden pressure, mD
OBD = Overburden pressure, psi
mD = milli Darcy

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