[PS]Unconventional Reservoirs: Basic Petrophysical Approach for Shale Gas

Ahmed Rashed[1]

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[1]Gemsa Petroleum Company (Gempetco), Egypt (ahmedrashed999@gmail.com)

Abstract

Shale gas is as an unconventional natural gas resource that is the current focus of the oil and gas exploration and development industries worldwide. However, as the gas content of shale reservoirs is one of key factors justifying the economic development of these reservoirs, and an accurate estimation of the gas content is required in the assessment of shale gas resources. Shale Gas has intense activity taking place in regions like North America.

Organic matter deposited with shales containing kerogen that matured as a result of overburden pressure and temperature, giving rise to source rocks yielded and expulsed hydrocarbons. Produced gas comes from both adsorbed gas in the organic matter and free gas trapped in the pores of the organic matter and the inorganic portions of the matrix. i.e. quartz, calcite, and dolomite.

Gas volumes are estimated through a combination of geochemical analysis and log interpretation techniques. TOC, desorbed total gas content, adsorption isotherms, and kerogen maturity amongst other parameters can be measured in cores, and cutting in the laboratory. These data are used to estimate total desorbed gas content and adsorbed gas content which is a part of total gas. The ΔlogR Passey log method is used to detect potentially productive areas. Permeability is one of the most important parameters, but at the same time, one of the difficult to measure in a shale gas. core calibrated porosity, mineral composition, water saturation , and elastic modules can be obtained through electric and radioactive logs. It is possible to estimate different gas in-situ volumes using porosity-resistivity based total gas in-situ, and geochemical based adsorbed gas in-situ. The difference should be the free gas in-situ.

The study successfully identified the state of the art in petrophysical evaluation through logs and core, log response in presence of kerogen, log interpretation techniques, and petrophyical workflow is an index for volumetric estimation of gas in-situ in shale gas reservoirs. Horizontal drilling and Hydraulic frac are the most of the technologies that should use as lessons learned.

Unconventional Reservoirs: Basic Petrophysical Approach for Shale Gas

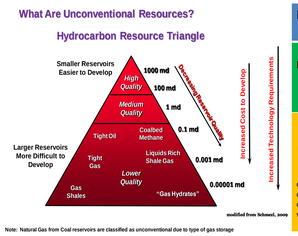
Ahmed Rashed
Petrophysics Section Head, Gemsa Petroleum Company (Gempetco), Egypt (ahmed_ismail_rashed@yahoo.com)

Motivation

The way of functioning of shale gas reservoirs has been re-analysed regarding storage capacity and most importantly, transport and fluid production. Historically, it has been recognized that these source rocks have expelled hydrocarbons which have been trapped in high quality reservoir rocks by means of seal rocks. Today, the remnants of hydrocarbon that has not been expelled, trapped gas and liquid and adsorbed gas in the rock are extracted in some areas by using well designs and stimulation techniques increase the production capacity of these reservoirs. However, as the gas content of shale reservoirs is one of key factors justifying the economic development of these reservoirs, and an accurate estimation of the gas content is required in the assessment of shale gas resources. Shale Gas has intense activity taking place in regions like North America.

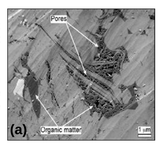
Introduction

Fine-grained, detrital rocks, composed of silts and clays. laminar and fissile structure present in certain rocks. Every clay is shale but Nor every shale is clay. Unconventional Resources refers to hydrocarbon resources that are found in difficult to produce reservoirs



Matrix	Fluids		Porosity (ϕ)
KEROGEN	Free (ϕkFF)	Gas	Kerogen porosity
	Adsorbed (ϕkad)		
INORGANIC MATRIX (Dry Clay + Non-clay Minerals) clay and carbonate or quartzitic silts, in which often the % of clay is very low.	Free (ϕFF)	Gas	Porosity of non-clay matrix + Fractures
	Pc bound (ϕCpBW)	Water	
	Clay bound (ϕCLBW)	Water	Clay porosity

Figure 1: Schematic Petrophysical model of the rock.



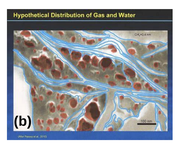


Figure 2: (a)SEM showing pores in organic matter. This can be considered secondary porosity as it results after kerogen maturity and the consequent expulsion of hydrocarbons (Reed, R, BEG2008). (b) Fluid distribution in the porous system according to Passey; free gas (dark red) in kerogen pores, adsorbed gas in the kerogen pore wall (light red) and water (light blue) in the inorganic matrix that looks microfractured (Passey, 2010).

Total Organic Carbon (TOC)

$$TOC = \frac{Vol_{Ker} \times \rho_{Ker}}{\rho_b \times k}$$

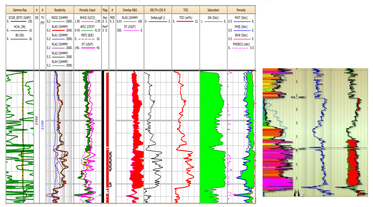
$$\mathrm{Ker(vol\%)} = \mathrm{TOC(wt\%)} \times \mathrm{f} \qquad \mathrm{f} \approx 2 - 2.5$$

$$\mathrm{Ker(vol\%)} = \left[\frac{(1-\varphi) * \rho_{ma}}{(\rho_{Ker} * C_{Ker})}\right] * TOC(wt\%)$$

$$\rho_{Ker} * C_{Ker} = 1$$

TOC	= total organic carbon (lbf/lbf)
Vol_{ker}	= kerogen volume (vol/vol)
$P_{ker} - P_b - P_m$	=kerogen – formation- matrix density (g/cc) res.
k	=conversion factor (~1.2)
C_{ker}	= w% of carbon in kerogen

TOC from Logs (Hot GR- Passey)



TOC from Geochemistry

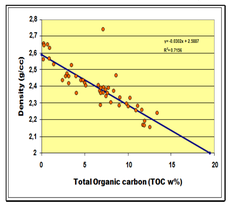
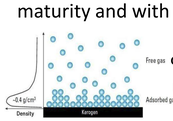


Figure 3: (a) Δ Log R Techniques For Unconventional Resource Sonic resistivity overlay showing crossover in Barnett Shale, Texas & Brown limestone, Egypt labeled "ΔlogR" and shaded red (Passey et al.,1990),, computed TOC values range from 4 and 9 %. (b) Correlation must be adjusted if the apparent laboratory density has been measured in a dry sample with density log (adapted from Jarvie, D. 2011)

Gas Content of Adsorbed Gas

Kerogen has a high adsorptive capacity because of its very large internal surface area. **Langmuir isotherm,** it is widely used to estimate adsorbed gas content. The variation of gas adsorbed capacity of a specific rock with pressure at a given temperature the form of methane gas adsorbed by the surface of kerogen. Adsorbed gas **decreases**, when pressure decreases as it released as free gas into the pore system, and with increasing temperature. Higher sorption capacity **increases** with increasing maturity and with increasing TOC.

$$gC_{ads} = \frac{V_1 \times P}{P + P_1}$$



CO2 has a much higher sorption affinity to kerogen than methane.

P= reservoir pressure (psia)
V_l= Langmuir volume (scf/ton)
P_l= Langmuir pressure (psia)
V_{lc}= Langmuir volume at TOC corrected reservoir temp (scf/ton)
TOC_{log}= TOC level as established by logging (w%)
TOC_{iso}= TOC level used to measure Langmuir isotherm (w%)

$$V_{lc} = V_l * \frac{TOC_{log}}{TOC_{iso}}$$

Porosity measurements

MICP measures gas filed Porosity. NMR magnetic resonance techniques are useful for measuring porosity independently from the matrix.

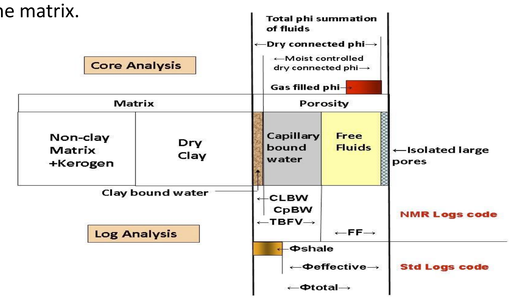


Figure 4: Types of porosity measures in laboratory and with logging; in a shale gas-type reservoir, clay bound water is proportional to the type of clay and its volume percentage. Non-scaled volumes in this picture.

$$\phi = \frac{\rho_{ma} - \rho_b}{\rho_{ma} - \rho_f}$$

ρ_{ma} = (vol Min1*ρmin1)+(vol Min2*ρmin2)+(vol MinN*ρminN)+(vol Ker*ρker)

Water Saturation Estimation

EPT measurement is affected primarily by the water-filled porosity. Since, moreover, the propagation time in water is constant for most salinities, saturation estimations can be made without prior knowledge of the resistivity of the formation water.

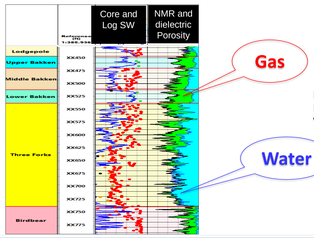


Figure 5: Bakken organic shale NMR & Dielectric Overlay Show Interval is Water Filled Porosity

GIIP-Reserve estimations

Decline curve analysis is rarely available during the initial stages of field development.

- Total gas in-place based on log interpretation and adsorbed gas in-place based on adsorbed gas content derived with Langmuir isotherms are estimated using the following equations:

GIIP Tot = 43560*A*h*ϕT *(1-SwT) *(1/Bg) *10^-9

- Adsorbed in-place gas, derived with Langmuir isotherm:

GIIP ad = gc*Den*A*h*C

GIIP free= GIIP Tot – GIIP ad

Technically recoverable volume (TRV)

Conclusion

1. For high reservoir pressure, the volume of free gas is greater than the adsorbed gas and, on the contrary, that the volume of adsorbed gas is more important at lower reservoir pressure.
2. Logs respond to kerogen and heavy minerals which must be accounted for in equations used to convert log measures to porosity.
3. Horizontal drilling and Hydraulic frac should use intensively.

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Natural gas is the cleanest of all fossil fuels, CO2 and water vapor are the main products of natural gas consumption, CO2 is less potent pollutant. Costs more to produce but low risk of shale gas wells.