DRILL CUTTINGS AS AN ECONOMIC TOOL TO UNDERSTAND THE PETROLEUM SYSTEM FOR EXPLORATORY AND DEVELOPMENT WELLS

[1]Rushdi Ali, [2]Ibrahim Ghiniwa
(1) Reservoir Geology Team Leader, Corex Services LTD., (Egypt Branch)
(2) Core Analysis Manager, Corex Services LTD., (Egypt Branch)

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ABSTRACT

The geological studies (petrographical analyses) can be applied on drill cuttings (old/new, dry/wet sets) recovered from un-cored intervals, in order to help the oil and gas companies to understand the characteristics of their source rock, reservoirs and seals, with special focus on the reservoir quality.

Drill cutting samples are as useful for geological studies as core or side wall core samples. These types of samples are recovered each 3-5m or 10-15 ft, from each well. Their availability, nature and sample volume would dictate the amount of geological and geophysical data resulted from various types of analyses as petrography, scanning-electron microscopy (SEM), X-ray diffraction analysis (XRD), grain size analysis (include sieving and laser particle “LSPA” analyses) and mercury injection capillary pressure analysis (MICP). Petrographical analyses include identification and description of the detected rock types by quantitative (point counted) or qualitative petrographic thin-section analysis; whereas MICP is considered a useful tool for improved understanding of porosity and matrix permeability distributions of petroleum systems (including source rock, reservoirs and seals). Thin section analysis performed on selected drill cutting pieces aims to identify rock types and to define their mineralogy, texture and composition, and the evaluation of mineralogical and diagenetic controls on porosity and permeability (reservoir quality). This type of study could focus on individual wells or multi wells (exploratory and/or development wells). Based on petrographical results a rock type scheme could be built and applied on a regional scale to better interpret the electric logs (Gamma-Ray) in terms of reservoir/seal intervals and their potentials. Each identified rock type could be further analysed by applying SEM and XRD analyses. Each special petrographical test provides more and more details with regard to the pore geometry, pore occluding minerals, clay minerals differentiation and quantification. In addition to that, MICP can provide data that are equally suitable for the calibration of porosity logs and has the added advantage that the analysis can be done on fresh or archived cuttings samples as well as core. Potentiality of sandy intervals and their characteristic grain size distribution is also possible to be determined by performing sieve and/or laser particle (LSPA) analyses.

INTRODUCTION

Drill cuttings are the broken bits of solid material removed from a borehole drilled by rotary or percussion methods. Boreholes drilled in this way include oil and/or gas wells for exploratory and/or development stages. The drill cuttings are commonly examined to make a record (a well/mud log) of the subsurface materials penetrated at various depths recovered each 3-5m or 10-15 ft. Drill cuttings are produced as the rock is broken by the drill bit advancing through the rock; the cuttings are usually carried to the surface by drilling fluid circulating up from the drill bit. Drill cuttings can be separated from liquid drilling fluid by shale shakers, by centrifuges, or by cyclone separators [1].

Objective of the Study

The main objective of this study is to provide the importance of applying and integrating the lithological description, with petrographical characteristics and the rock properties of the drill cutting samples and to interpret the gained information with regard to reservoir quality. Petrographical analyses were performed (special attention to thin section and scanning-electron microscope) of the selected drill cutting samples from different parts of petroleum systems, with the aim to identify and characterise their mineralogy, texture and composition, which further allows the petrographical classification of rock types and the evaluation of mineralogical controls on porosity and permeability, and could be supported with mercury injection capillary pressure (MICP) data.

ANALYTICAL PROCEDURES AND RESULTS

As a part of this study the lithological description and petrographical analyses (thin section “TS” and scanning-electron microscope “SEM”) were carried out on drill cuttings. A brief description of the analytical procedures is as follows:

Samples Preparation and Lithological Description

When received the cutting samples are cleaned first using water depending on the nature of the samples. If the samples contain swelling clays, we won’t wash them with water but we will crush them and try to blow the drilling mud that coats the grains. If the samples are sandstone or carbonate or normal clays, we will wash them gently with water. Figure 1A shows the samples laid out after washing and ready for petrophysical analysis and description. After cleaning the samples are studied macroscopically (naked eye) and microscopically (by using binocular microscope, Figure 1B).

The available material of each sample was inspected with regard to its overall condition (degree of recovery) and the nature and relative abundance of components. Rock types distinguished within the cutting samples have been lithologically classified according to their specific characteristics and were further described considering their colour, composition, textures and percentages; then facies schemes (lithologically) can be established by preparing a log description (e.g., by using canvas software) and integrated / interpreted with the electric logs (Gamma-Ray) in terms of reservoir/seal intervals and their potentiality (Figure 2).

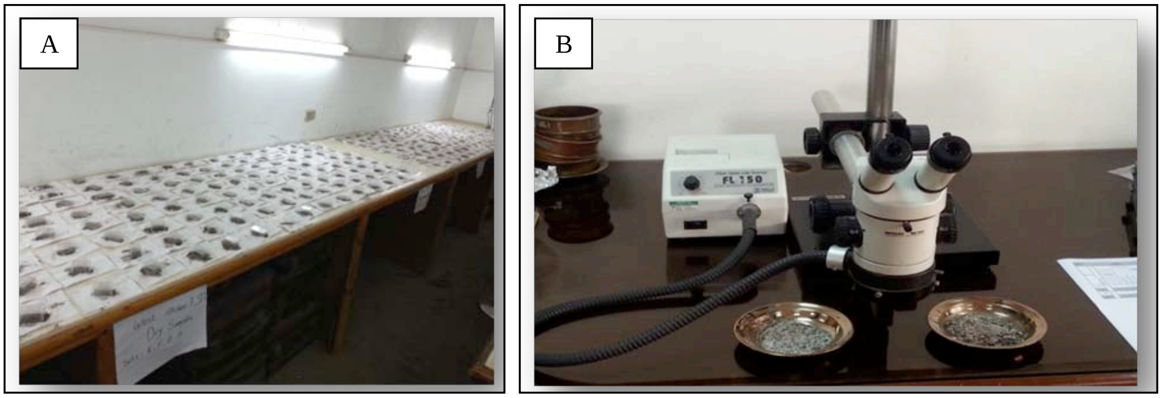


Figure 1. A) Showing the samples layout after washing and ready for description. B) Showing the Binocular microscope used in describing the samples.

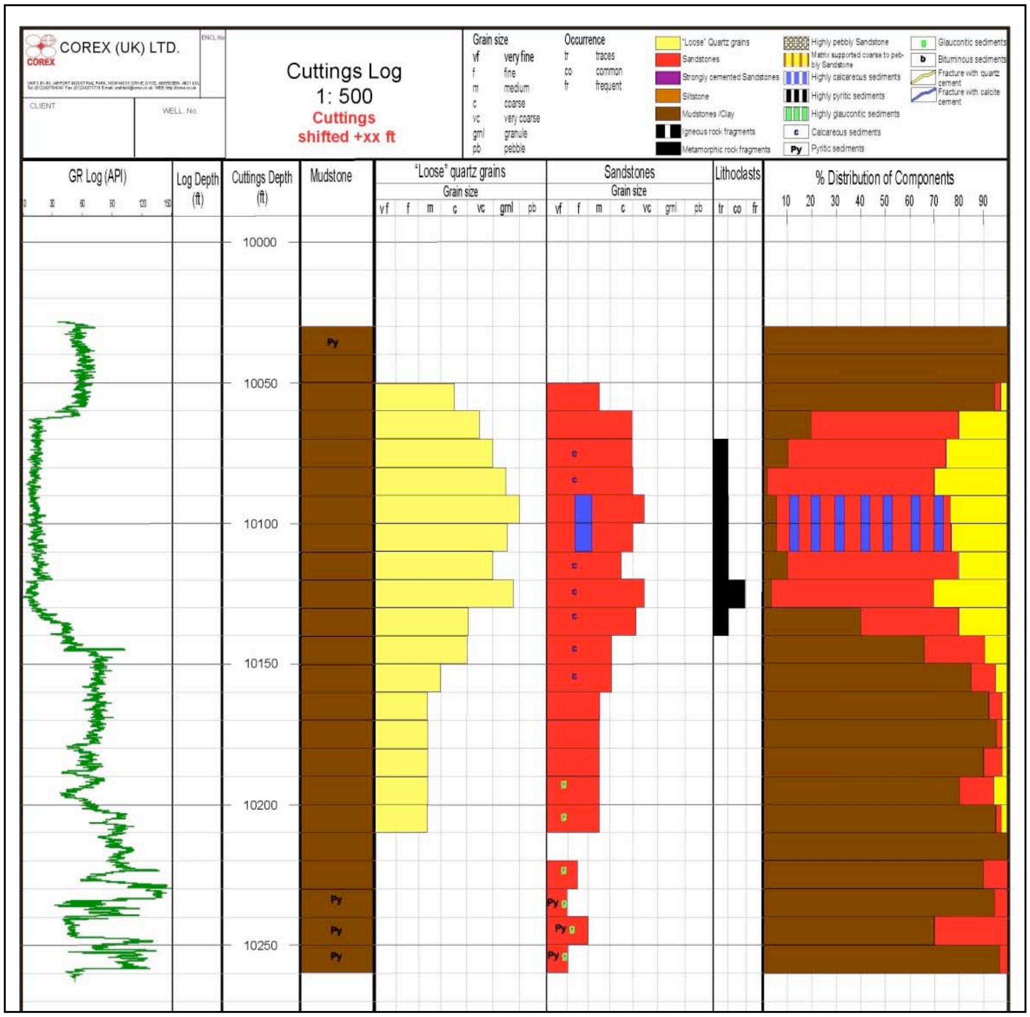


Figure 2. Example for cuttings log description integrated with Gamma-Ray (GR) log, by using Canvas software.

Petrographical Analyses (TS and SEM)

After lithological description we pick the cutting samples for petrographical analyses (thin section and SEM) to cover all the represented lithotypes, in order to built-up microfacies types integrated with lithofacies types. During the selection process we divide the material into three parts: 40% for thin section; 40% for SEM and 20% as a reference for quality control, and try to avoid additives (such as calcite pieces of drilling).

Thin Section (TS)

Thin section preparation involved vacuum impregnation with blue dyed resin to facilitate the recognition of porosity and staining with a mixed Alizarin Red-S and potassium ferricyanide solution to allow the identification of the carbonate minerals. In addition, samples were stained with a sodium cobaltinitrite solution to aid the recognition of alkali feldspars [2]. The thin sections were examined under plane- and cross-polarised light with a petrographic polarising microscope. Different lithologies (microfacies) were selected from each thin section and separately analysed. The texture, mineralogy and porosity of each lithology (microfacies) were described and the relative abundances (in % by volume) of detrital and authigenic components and pore spaces were determined by either point counting (quantitative descriptions: 50, 100, or 200 counts) in some pieces/samples or estimated (qualitative descriptions) in other parts depending on the quality of the cuttings. Due to the poor nature of some analysed samples, point counts couldn't be applied. Instead quantification of minerals and porosity was achieved through visual estimation. Rock types were petrographically classified according to an established rock classification scheme (such as sandstone classification scheme, after Dott [3]). The results of the thin section analyses are summarised on a petrographic data sheet (Figures 3 and 4). The specific characteristics of the samples are further illustrated by coloured photomicrographs for each sample depending on the number of microfacies distinguished in each individual sample (Figure 4).

DEPTH [ft]	SAMPLE TYPE	TEXTURAL DATA: Grain Size Min.	Av.	Max.	GRAIN SORTING	GRAIN ROUNDNESS	GRAIN CONTACTS	Pore System: AV. PORE SIZE (µm)	AV. PORE CONNECTIVITY	PORE TYPES	ROCK NAME (After Dott, 1964)
9900		vfL	fU mL	cU	MS WS	SA SR	P, L, F, C	10 50	Very Poor	SBP, FR	*Fe-Dolomitic Sublithic Arenite
9910		silt	fU mL	mU	WS	SA SR	P, L, F, C	_	_	_	***Fe-Calcitic Subfeldspathic Arenite
9910		vfL	mL mU	cL	MS WS	SA SR	P, L, F, C	10	Very Poor	FR	**Fe-Dolomitic Sublithic Arenite
9920		silt	fL fU	mL	WS	SA SR	P, F, L	_	_	_	Fe-Calcitic Subfeldspathic Arenite
9920		silt	fL fU	mL	WS	SA SR	P, L, F	_	_	_	Fe-Dolomitic Subfeldspathic Arenite
9920		silt	mL	cL	WS	SA SR	P, F, L	_	_	_	Lithic Wacke

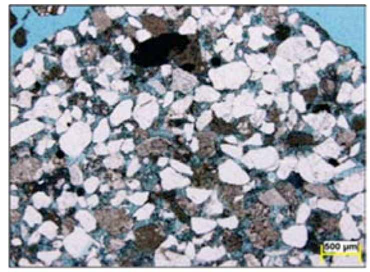
POINT COUNTED / ESTIMATED DATA [% BY VOLUME]

DEPTH [ft]	DETRITAL COMPONENTS: Quartz: POLYCRYSTALLINE	Quartz: MONOCRYSTALLINE	LITHIC FRAGMENTS	Feldspars: K-FELDSPARS	Feldspars: PLAGIOCLASE FELDSPARS	MICAS	Accessory Minerals: OPAQUES	Accessory Minerals: HEAVY MINERALS	GLAUCONY	BIOCLASTS	PHOSPHATIC FRAGMENTS	CARBONACEOUS DEBRIS	Matrix: DETRITAL CLAYS
9900	1.5	39	10	1	8	1	1	1	2	_	_	_	2.5
9910	1	38	6	_	10	2	1	1	2	4	_	_	_
9910	3	31	12	_	8	2	1	1	2	1	_	_	2
9920	2	37	8	5	6	1	0.5	1	1	0.5	_	_	_
9920	2	38	7	3	5	1	0.5	0.5	1	7	_	_	6
9920	3	20.0	10	1	5	_	_	_	1	4	_	_	51

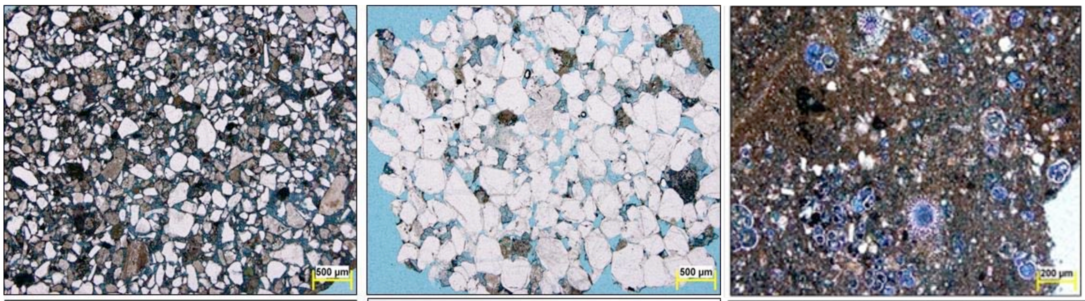
DEPTH [ft]	AUTHIGENIC COMPONENTS: QUARTZ OVERGROWTHS	FELDSPAR OVERGROWTHS	Carbonates: CALCITE	Carbonates: FERROAN CALCITE	Carbonates: DOLOMITE	Carbonates: FERROAN DOLOMITE	Carbonates: SIDERITE	Clay Minerals: KAOLINITE	Clay Minerals: ILLITE	Clay Minerals: CHLORITE	PYRITE	SPHALERITE	Evaporites: ANHYDRITE	Evaporites: GYPSUM	Evaporites: BARITE	SECONDARY SILICA	Organic Matter: RESIDUAL HYDROCARBONS	Organic Matter: HYDROCARBON STAINS	POROSITY	TS-PLATE NUMBERS
9900	2.5	_	_	1.5	_	22	_	_	TR	TR	4.5	_	_	_	_	_	1	TR	1.5	*13*
9910	2	_	_	26	_	1	_	_	TR	TR	6	_	_	_	_	_	_	_	_	*14a*
9910	2	_	_	2	_	27	_	_	TR	TR	4	_	_	_	_	_	_	_	2	*14b*
9920	1	_	_	33	_	2	_	_	TR	TR	2	_	_	_	_	_	TR	TR	_	*15a*
9920	1	_	_	4	_	20	_	_	_	_	4	_	_	_	_	_	TR	TR	_	*15b*
9920	1	_	_	_	_	3	_	_	TR	TR	1	_	_	_	_	_	TR	TR	_	*15c*

Figure 3. Example for petrographical data sheet (TS) of cutting samples (* 200 point counts; ** 100 point counts; *** 50 point counts; % by volume – whereas the rest of samples were visually estimated.

Distinguished Lithologies	%	*Distinguished Lithologies*	%
Fe-Dolomitic Sandstone	27	Loose Quartz Grains	3
Fe-Calcitic Sandstone	40	Loose Bioclasts	1
Argillaceous Sandstone	5	Porosity	3
Porous Sandstone	10	**Pore Type:** Secondary Inter- and Intraparticle.	
Mudstone	6	**Pore Size:** 10-100 μm	
Bioclastic Mudstone	4	**Pore Connectivity:** Poor-Moderate	
Calcitic/Limestone	1		
Total			**100%**



(Photo A; PPL): Fe-Dolomitic Sandstone.



(Photo B; PPL): Fe-Calcitic Sandstone. ***(Photo C; PPL):*** Porous Sandstone. ***(Photo D; PPL):*** Bioclastic Mudstone.

Figure 4. Another example for lithology definition in thin section by % by volume / sample (visual estimation) and examples for thin section photomicrographs representing different types of microfacies.

Scanning Electron Microscopy (SEM)

SEM examination can be carried out on selected lithofacies types from cutting samples, where the samples are mounted on standard aluminum SEM stubs and coated with gold using a sputter coater. SEM analysis involved detailed description of the cutting material with a special focus on the pore geometry, composition and morphology of the main pore-occluding clays / carbonate cement minerals. Figure 5 shows examples of the quality and resolution of SEM images for cutting pieces.

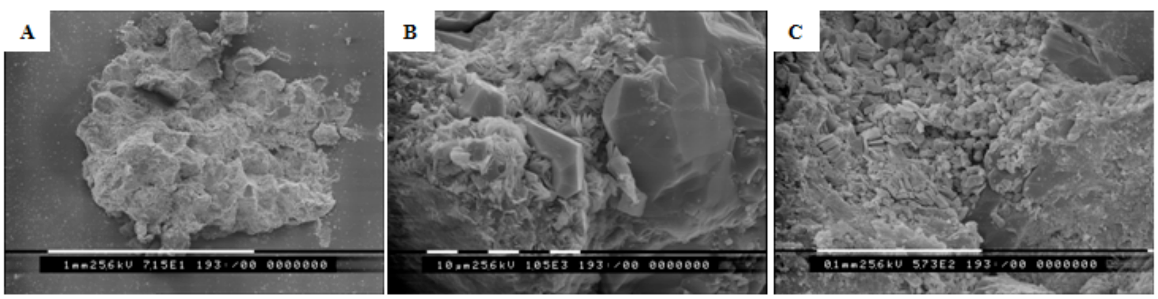


Figure 5. Examples for SEM images of cutting pieces: A) shows the quality of cutting sample in SEM. B) shows euhedral, smooth-faced and pyramidal quartz overgrowths, locally enclosed with moderately crystallised chlorite plates (card-house texture). C) shows moderately crystallised pore filling kaolinite booklets of partly corroded pseudohexagonal basal plates.

RESERVOIR QUALITY

Petrographical analyses (TS and SEM) on cutting samples can help clarify the reservoir quality from the mineralogical and textural composition of detected microfacies/lithofacies types from cutting samples, and their effects on porosity types and distributions. The importance of MICP on cutting samples is shown in Figure 6 for improved understanding of porosity and matrix permeability distributions of reservoirs [4], and integrated with the observations of the petrographical analyses.

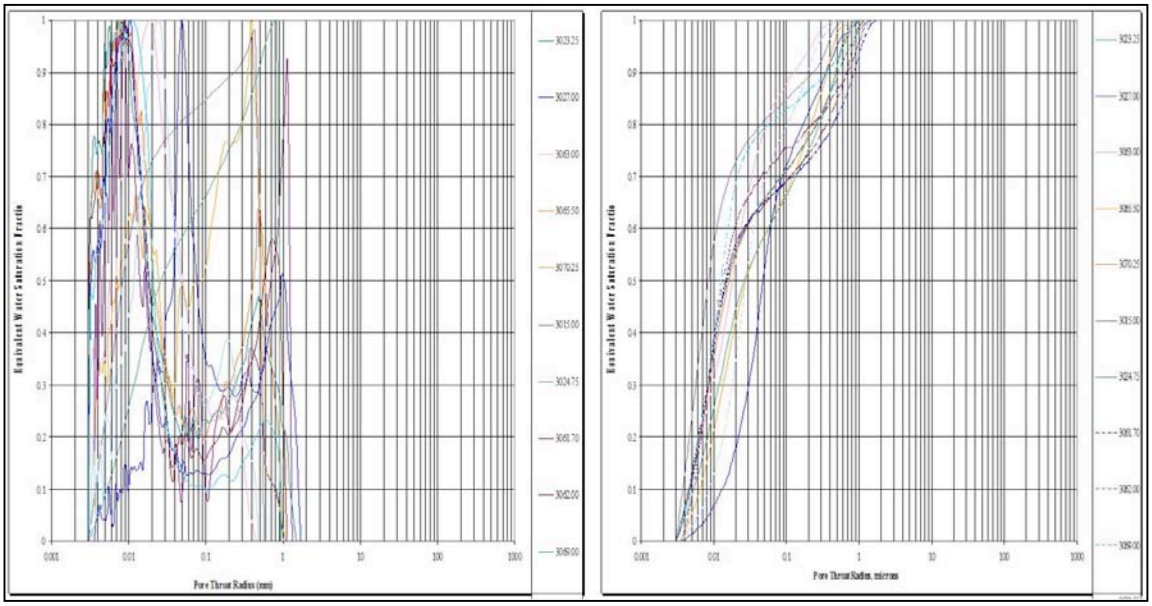


Figure 6. Example for MICP data for different samples that shows smaller pore throat radius and strong positive skewness, where GeoMean Permeability = 0.12mD and Average He Porosity = 10.7%.

CONCLUSION

Drill cutting samples are recovered as a minimum record of rock material from each well. Petrographical and petrophysical studies can be applied to them and offer a continuous record of lithologies over wide depth ranges where cores are not recovered. Comparison and correlation of wells over an entire field area can also be undertaken.

ACKNOWLEDGEMENTS

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