

Porous Media Characterization for Feasibility Study of Oil Well Water Production Control

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ABSTRACT: The Upper Assam Basin, the earliest explored petroliferous basin of India has been producing hydrocarbons since 1989. Currently, it is reported that a large numbers of wells in the basin are producing high volume of water alongwith crude oil. This present study aims to the characterization of the aquifer support porous media in a part of oil bearing horizon belonging to tipam sandstone formation at depths 2483-2487m, 2504-2506m, and 4504.50m of reservoir formation with temperature 72-76⁰C belonging to some high water cut wells of Upper Assam Basin. The objective is to find out the feasibility of polymer-gel system for conformance control. Based on petrography, scanning electron microscope study, reservoir temperature, initial and current pressure, driving mechanism and API gravity of crude oil it could be concluded that channelling is the main problem for high water cut from the reservoir of Upper Assam basin and polymer gel system could be a measure towards in-situ reduction of produced water (P.W).

KEYWORDS: Characterization, porous media, heterogeneity, clay minerals.

I. INTRODUCTION

The certain oil wells of Upper Assam Basin currently produce excessive water causing abandoning in some cases for the failure to extract with environmental compliance and economic efficiency. Water shut off to extract crude oil from the depleted reservoir with high water cut production would reduce the abandoning of such oil wells. The presence of heterogeneities and natural fractures put impact on crude oil production and accelerate water cut [1, 2]. The water channelling through high permeability layers is reported in heterogeneous reservoir. The matured porous media are a major concern for high water cut [3]. The injection of polymer gel i.e., chrome acetate polyacrylamide gelant treatment in Arbuckle reservoir that produced under natural water drive with high water cut resulted drop in water production [4]. The Iranian oil reservoir at temperature 90⁰C (194⁰F) was studied with PAM/chromium acetate polymer gel for water shut off as referred by Simjoo et al. 2007 [5]. The study of clay minerals viz., kaolinite [Al₂Si₂O₅(OH)₄], illite [KAl₃Si₃O₁₀(OH)₂], chlorite present as [NaClO₂ or Mg(ClO₂)₂], smectite, corrensite clay minerals, quartz (SiO₂), feldspar (KAlSi₃O₈ – NaAlSi₃O₈ – CaAl₂Si₂O₈) and mica [KAl₃Si₃O₁₀(OH)₂] in the porous media indicates the pore distribution pattern and permeability within the reservoir rock. The reservoir to be considered for polymeric gel treatment include parameters viz., temperature ($\leq 353.15K$), API degree (oil) ≥ 25 , permeability ≥ 100 mD, rock sandstone, with low heterogeneity and clay content [6]. In the present work, the impact of clay mineralogy on reservoir quality is evaluated with the help of thin section petrography and scanning electron microscopic (SEM) analyses of the reservoir formation (72-76⁰C) to find out the feasibility to be shut off with the polymer-gel system for enhanced oil recovery.

The main objective of present study is to find out the facts behind the high water cut in a part of the oil producing horizons of Upper Assam Basin. The present study is dealing with the characterisation of the porous media with respect to its mineralogical and textural characteristics and their role in controlling the petrophysical properties of the rock.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

II. RELATED WORK

Water shut off (WSO) treatments to reduce the production of water in oil producing wells started in late 19's with the injection of some polymer solutions into the porous media following which the potential of water soluble polymers to increase oil recovery was well acknowledged. Many significant research papers on laboratory studies, patents and proceedings have been published on WSO since then. The attempts toward the understanding of the polymer rheological behaviour or its suitability under reservoir conditions and the mechanisms that cause mobility control and improve oil recovery have appeared in the literatures. The interaction between the polymer and matrix, the solution rheology and viscoelastic behaviour of polymer solution causes mobility control inside porous media [7]. [8] in his research work observed the causes of water cut as the onset of water coning, the rise of regional oil water contact, the presence of high permeable water flow layer and fracture. [9] identified the cause of water cut as the casing, tubing or packer leaks, channel flow behind casing, moving oil water contact, watered-out layer without cross flow, presence of fracture or faults from a water layer, coning or cusping. The gel polymer system involved in WSO are HPAM, resorcinol, scleroglucan, lignosulfonate, polyvinyl alcohol (PVA) and polyvinylamide, two types of cross-linker, metal ions (Cr^{3+} , Al^{3+} , Zr^{4+} and Ti^{4+}), organic system (phenol-formaldehyde and polyethylene imine with HPAM and acrylamide or acrylate derivative polymers [10]. [11] observed that WSO in hydrocarbon reservoirs may be done with low or high molecular weight polyacrylamide solutions with varied cross-linkers i.e., hydroquinone (HQ) and hexamethylenetetramine (HMTA) as the acrylamide groups in it undergoes hydrolysis creating solid gel.

III. EXPERIMENTAL ANALYSIS

Core samples of Tipam sandstone porous media of depths (2483-2487)m, (2504-2506)m and 4504.50m were collected from a part of oil bearing horizons of Upper Assam basin that has been producing with high water cut. The sandstone reservoirs at temperature $(72-76)^{\circ}C$ with initial pressure 242-246 ksc started production under self flow mode, currently switched to SRP (Sucker Rod Pumping) and GL (Gas Lift) mode under current pressure of 210-230 ksc, delivers crude oil at $23-25^{\circ}$ API gravity and pour point of $29-30^{\circ}C$. Thin sections of porous media were studied under petrological microscope for evaluation of detail framework mineralogy and textural characteristics. Scanning Electron Microscope analysis was carried out to identify the clay minerals with their morphological characteristics and other properties of porous media that could not be identified under petrological microscope.

IV. EXPERIMENTAL RESULTS ROCK PETROGRAPHY

Rock thin section analysis of selected core samples of the candidate porous media under Leica Polarizing microscopic examination shows the presence of framework minerals like quartz, feldspar (Figure 1 a), rock fragments (Figure 1b), alongwith different types of cements and matrix (Figure 1c). The quartz grains are mainly angular to sub-angular in shape indicating short distance of transportation. However certain grains show sub rounded to well round shape indicating reworked sediment derivation. Inclusion of micrograins within quartz is also reported. Certain quartz grains show intra-granular fracture as well as overgrowths (Figures 1d and 1e). Feldspar ($KAlSi_3O_8$ - $NaAlSi_3O_8$ - $CaAl_2Si_2O_8$) concentration is comparatively less in the sandstones (Figure 1a). The sandstones with fewer amounts of feldspars, their absence indicate prolonged transportation of source sediments or a high rate of chemical weathering in the provenance. The rock fragments are mainly of sedimentary and low grade metamorphic origin and are squeezed to transform to pseudo-matrix (Figure 1b) under late stage of diagenesis in certain cases. Certain rock-fragments are reported from igneous varieties, but their concentration is very less. The matrix consists of both detrital as well as authigenic grains of siliceous and argillaceous materials (Figure 1c). Silica cement in the form of quartz overgrowth, secondary precipitation of argillaceous materials within the framework grains has significantly reduced the reservoir quality of the sandstone.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

SEM ANALYSIS

Scanning electron photomicrographs of sandstones recovered from some wells of Upper Assam oil field showed the presence of different types of clay minerals with their typical morphological characteristics. The results of the SEM microscopic images show the presence of kaolinite, illite, chlorite, smectite and corrensite clay minerals in the porous media is shown in Figure 2, i.e., a to e. The SEM images show the presence of kaolinite (Figure 2a), chlorite (Figure 2b), smectite (Figures 2c, 2d) clay minerals in the porous media. The kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$) is recorded as stacking of books pattern. Flaky illite bridges the intergranular pore spaces offering resistance to fluid flow through the sandstone and thereby reduces permeability. The SEM images of certain samples showed that many of the feldspar grains have undergone partial dissolution (Figure 2e) resulting in the formation of secondary pores, thereby enhancing the porosity and permeability of the sandstone reservoir. The SEM analysis of some other samples show chlorite crystals along with the framework grains coated with pore-filling smectite clay (Figure 2b) which is identified by typical honeycomb structure. However, the SEM images showing development of intra-matrix porosity (Figure 2d), presence of fine detrital minor grains inhibiting overgrowth (Figure 2b), intra-particle microfractures, good porosity (secondary) created by feldspar dissolution (Figure 2e) are considered as the important diagenetic changes that enhances the porosity and permeability and make the porous media highly productive.

Mechanical disintegration of kaolinite books during the fluid flow through the pore spaces and subsequent deposition results decrease in permeability. Moreover, the development of outgrowth of quartz within the sandstone may significantly reduce the porosity and permeability in certain portion of the porous media.



Fig. 1(a): Photomicrographs showing well sorted texture. The intergranular pore spaces are filled up by residual hydrocarbon. Most of the grains are angular to sub-round. Quartz overgrowths are also observed. Quartz (Qtz) is dominating over other minerals.

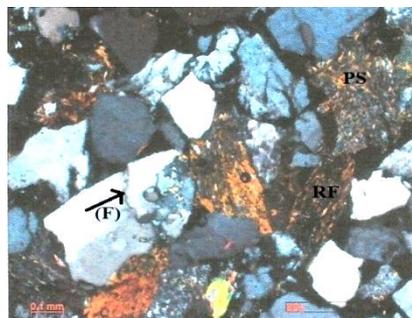


Fig. 1 (b): Photomicrographs showing rock fragments (RF), pseudomatrix (PS) and fractured quartz (F) under cross-polarized light

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 12, December 2016

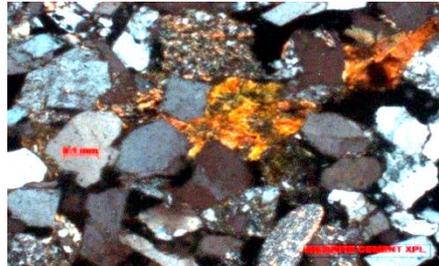


Fig. 1 (c): Photomicrographs showing secondary precipitation of argillaceous cement along with metamorphic rock fragments which reduces the porosity



Fig. 1(d). Photomicrographs showing sandstone undergone the compressional forces resulting intergranular fractures in framework grains which enhances the secondary porosity

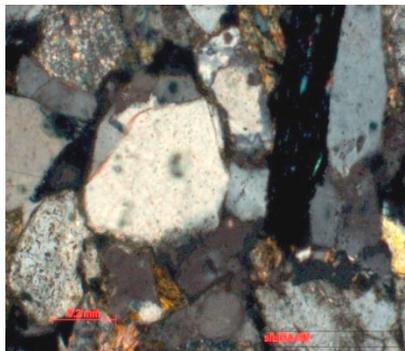


Fig. 1(e): Photomicrographs showing quartz overgrowth which reduces the petrophysical properties of the rock

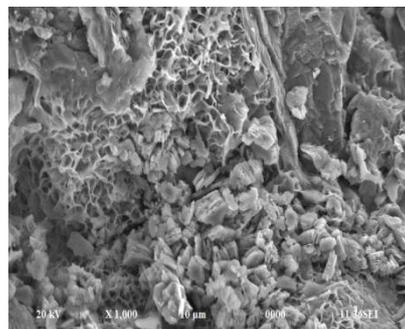


Fig. 2 (a). SEM photomicrograph showing kaolinite clay (depth=2504-2506m) with typical 'stacking of book pattern' and smectite developed in the pore spaces

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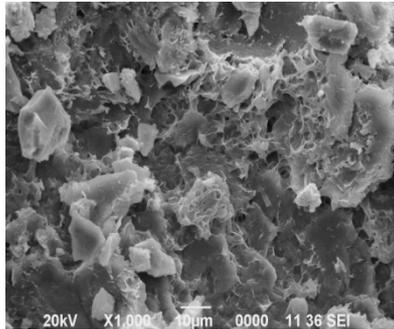


Fig. 2(b). SEM photomicrograph (depth=2483-2487m) showing framework grains coated with clay minerals (smectite). Presence of fine detrital grains over quartz grains inhibits overgrowth. Mineralogically immature. Chlorite crystal can also be seen.

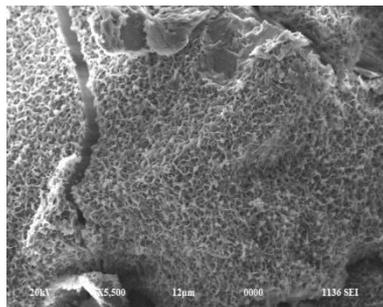


Fig. 2 (c).SEM photomicrograph of sandstone porous media of Upper Assam Basin (depth=2483-2487m) showing pore filling smectite

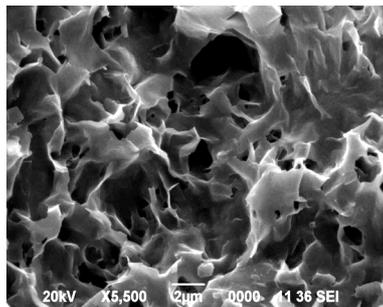


Fig. 2(d).SEM photomicrograph (depth=2483-2487m) showing smectite with typical honeycomb structure. Intra-matrix porosity can be seen.

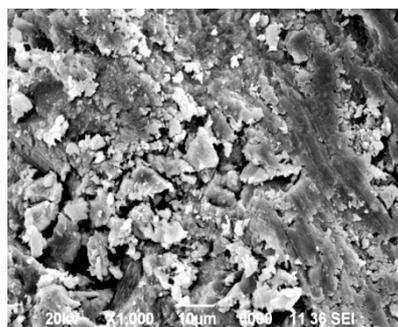


Fig. 2 (e). SEM photomicrograph (depth=2504-2506m) showing good secondary porosity created by feldspar dissolution, thereby enhancing the porosity and permeability

International Journal of Innovative Research in Science, Engineering and Technology

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V. CONCLUSION

The petrographic study reveals that feldspars are very less in number and constitute only few varieties of plagioclase type, lesser the amount of feldspar within the sandstone more the maturity of the sandstone. Less amount of feldspar indicates either the provenance (source area) constitutes of rocks devoid of feldspar or the feldspars are dissolved during the transportation period from source to the depositional basin. The rock fragments of all the three varieties namely viz., igneous, metamorphic and sedimentary are reported. It indicates that the samples are derived from multiple source areas. However the metamorphic and sedimentary sources are dominating over the igneous rocks in the sandstone of present study. Dominance of quartz grain over other constituent grains indicates that the sandstone is matured. The sandstone has undergone different types of diagenetic changes after deposition. The dissolution and partial replacement of quartz and feldspar by cementing material, fracturing of framework grains are some of the important diagenetic properties which develop secondary porosity and permeability and thereby enhance the reservoir quality. On the other hand, quartz overgrowth is some diagenetic properties which reduce the reservoir properties. Certain samples showed low-grade metamorphic rock-fragments which are found to transform to pseudo-matrix under later stages of diagenesis. Secondary precipitation of argillaceous material in the pore spaces was also observed. So the diagenetic effect on the sandstones is not uniform and varies from horizon to horizon within the same well and thereby affects the petrophysical properties of the sandstone porous media. SEM study reveals the clay minerals i.e., kaolinite, illite, chlorite, montmorillonite, smectite and corrensite are present in the porous media. Kaolinite $[Al_2Si_2O_5(OH)_4]$ occurs in stacking of books pattern. The books of kaolinite present in the core samples under study reduce permeability in the porous media [12]. The presence of chlorite restrict pore throat and consequently reduce permeability.

From all the analysis and the results obtained of the research work, it is understood that the sandstone porous media under study is matured, heterogeneous, contain certain fractures, highly porous and permeable with low reservoir temperature and are suffering from high water production due to channeling problems. The slow rate of pressure decline shows that the reservoir formation is aquifer support. The reservoir temperature at 72-76°C, with initial and current pressure 242-246 Ksc followed by 210-230 ksc, API degree (oil) 23-25° API is considered to be suitable for polymeric gel treatment. All such findings of the research work show that the sandstone porous media under study is suitable for polymeric gel water shut off treatment by in-situ blockage of permeable flow channels otherwise would be available for water to flow into the well.

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