Sedimentary Petro Graphic Characteristics of Zeit Formation (Suakin -1 Well) in Sudanese Red Sea Basin

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Abstract – The study area lies in NE Sudan along the eastern coast of the Sudanese Red Sea. The coastal plain is geologically characterized by Cenozoic siliciclastic and shallow marine rift related sedimentary sequences. Pliocene-Pleistocene interval is represented by the thick older gravel unit and the emergent reef terraces. The main objectives of this study is to determine the mineralogical composition and to classify the sandstone types to obtain information on their source areas, depositional environments, palaeoclimate, digenetic processes and to infer the tectonic history of the study area. Five sandstone samples were selected from the previous one mentioned conventional core from Suakin -1 Well depth (2308-2316m). The samples were selected during the core description and lithofacies analysis for the preparation of thin sections. Thin section investigations analysis of core samples from Zeit Formations has reveal of that the feldspar accounts for 19.8 – 23 %, quartz and the lithic fragments are ranging between 75.7 – 85.2 % and 0.0 – 7.3 % respectively. Consequently the sandstones are classified as sub litharenite. Thin section investigations analysis for the sandstones of Zeit Formation (Suakin -1 Well) have revealed, that their reservoir quality has been affected positively and negatively by several digenetic processes.

Keywords – Petrography, Digenetic Processes, Sandstone, Depositional Environment.

I. INTRODUCTION

The study area lies in NE Sudan and is situated in the Red Sea State. It is bounded by longitudes 37° 30’ E & 38° 15’ E and latitudes 19° 00’ N & 22° 00’ N. (Fig 1). The main physiographic features in the study area which can be considered are the Red Sea Hills in the west and coastal plain in the est. Generally, high elevation in the west and gradually decreases towards the east. Red Sea Hills are classified as a rugged area with high variation in elevation while coastal plain is smooth and level, without raised or hollow areas.

II. GENERAL GEOLOGY

The geology of the study area constituted by the following lithological units:
(A) Basement Complex: which includes the following groups: (i) High-grade gneisses. (ii) The low-grade Volcano sedimentary group. (iii) Igneous Intrusive assemblages. (B) Cenozoic Coastal Sedimentary Sequences. (C) Cenozoic Volcanics. (D) Quaternary Sediments.

The coastal plain is geologically characterized by Cenozoic siliciclastic and shallow marine rift related sedimentary sequences. Pliocene-Pleistocene is represented by the thick older gravel unit and the emergent linear reef terraces [3].
III. OBJECTIVES OF THE STUDY

This study deals with the petrography of the sandstones of Zeit Formation. It’s main objective is to determine the mineralogical composition and to classify the sandstone types to get information about their source areas, depositional environments, palaeoclimatic, diagenetic processes and to infer the tectonic history of the study area by relating the detrital composition of the studied sandstones to the tectonic setting of its provenance region.

IV. METHODOLOGY

Five sandstone samples were selected from the previous mentioned conventional core from Suakin -1 well. The samples were selected during the core description and lithofacies analysis for the preparation of thin sections. The thin sections were studied using a polarizing microscope with different magnifications. The identification of minerals was based on their optical properties such as color, form, relief, extinction angle, pleocroism, twinning and birefringence. Ribbon traverses were drawn on the slides to facilitate the counting of the minerals for quantitative estimation of the minerals percentages in each slide.

V. MINERALOGICAL DESCRIPTION

The composition of the sandstone depends mainly on the nature of the source rocks and on the weathering processes. The minerals and components which were recognized in the thin sections include: quartz, feldspar, micas (mainly biotite and muscovite), carbonates, iron oxides, and rock fragments.

A. Quartz

The most common mineral in the studied sandstones is quartz. It appears in thin sections as relatively clear colourless grains having a weak birefringence and a low refractive index that is only slightly higher than that of the mounting medium [1]. Both polycrystalline quartz (Qp) and monocrystalline quartz (Qm) are present. Some of the polycrystalline and monocrystalline quartz crystals exhibit undulose extinction. Moreover, some of the composite quartz grains (polycrystalline quartz grains) are elongated and within some of them, the crystals boundaries are sutured. Many of the quartz grains incorporate mineral inclusions such as rutile, zircon, iron oxides and tourmaline. Fractured quartz grains are also common (Plates 1, 2 and 3). The studied sandstones have high percentages of quartz ranging between 34 – 36% (Table 1). In all of the examined samples, polycrystalline quartz, occurs in lower percentages than monocrystalline quartz (Table 1 and Plates; 1, 2 and 3). The low ratios of polycrystalline to monocrystalline quartz suggest a metamorphic source region (Basu et al., 1975). The monocrystalline quartz grains are sub rounded to rounded and are moderately to well sorted (Plates 1, 2 and 3). This could be attributed to longer distance of sediments transportation.

B. Feldspar

Like quartz, feldspars in thin sections are clear, colourless and show low birefringence, but they can be distinguished from quartz by their cleavage, twinning and refractive indices. Nevertheless, distinguishing between untwined orthoclase and quartz can be difficult. However, feldspar grains may sometimes be partly decomposed, and then they appear cloudy or turbid in contrast to quartz grains, which are invariably unaltered and relatively clear [1].
Of the different types of feldspar, the potash feldspar (KF), orthoclase (Or), and microcline (Mi) (Plates 1, 2 and 3) are much more common in the studied sandstones than the plagioclases (Pl) (Table 1). There are two reasons for this: K-feldspar has a greater chemical stability than plagioclase [7], and so the latter is altered preferentially in the source area. In addition, K-feldspar is much more common in continental basement rocks (acid gneisses) [7], which are probably the provenance of many sandstones in the study area. However, the percentages of the sodic plagioclase (e.g. Albite) tend to increase in the deeper horizons of Zeit Formation (Table 1 and Plates 1 and 3). This increase of plagioclase could be due to albitization of the detrital plagioclases and K-feldspars, which could be attributed to the relatively shorter distance of transportation.

C. Micas

Biotite (Bi) and muscovite (Mu) were identified by their platy habit and parallel extinction. Biotite has a brown-green pleochroism, which masks the interference colours whereas, muscovite is colourless in the plane-polarized light, but has bright second-order interference colours under crossed polars [7]. They were observed with rather low concentrations in most of the investigated samples. The highest percentage of biotite (6.4%) was recorded at depth 2313m, whereas that of muscovite (1.2%) was recorded at depth 2308.43m (Table 1). Biotite occurs as large detrital flakes, which are concentrated along partings, laminae and bedding planes. This distribution is primarily a function of sorting and is determined largely by the hydraulic behaviour of the mica flakes [7].

D. Rock Fragments

Only minor amounts of rock fragments were observed in the studied samples (Table 1). These rock fragments include shale, mudstone and siltstone ranging between trace to 1.8%.

E. Carbonates

Siderite (FeCo₃) and calcite (CaCo₃) were observed as patchy cements in most of the examined samples (Plates 1-3), with a concentration ranging between trace — 1.8 % (Table 1). Both siderite and calcite can be identified by their perfect rhombohedral cleavage and a pearl grey interference colour of higher order. Calcite is colourless, but it is often cloudy, usually anhedral. Siderite resembles calcite, but may often be distinguished by the brown stain around the borders of the grains and along cleavage cracks (Plate 2).

VI. RESULTS AND DISCUSSION

A. Sandstone Classification

The scheme of Folk (1974) and Pettijohn et al. (1987) was used to classify the sandstones of zeit formation. The triangular diagram shown in (Fig. 3) is based on plotting the percentages of quartz, feldspar and rock fragments, which were counted under the polarized microscope (Table 1). Sandstones are generally accepted as arkoses when they contain more than 25 % feldspar, not more than 75 % quartz and less than 50 % lithic fragments [4]. In the studied samples, the feldspar percent is between 23.5- 19.8 %. Whereas, that of the quartz and the lithic fragments are ranging between 77.5 - 80.2 % and 0.0-7.3 % respectively (Table 1). Consequently, the studied sandstones are classified as sub litharenite (Fig. 3). Besides quartz and feldspar, detrital micas are present. The feldspars are usually altered.

![Fig 3. Classification of sandstones in the study area (after [4] - [6].](image-url)
Plate 1. Sample depth (2308.43m) A (PPL): A photomicrographic image showing the quartz and feldspar grains of medium sand size being floated in anhydrite cement. B (XPL): As above.
Sample depth (2309.38m) C (PPL): This image shows the very fine quartz sand and silt grains are embedded in patchily oxidized iron-rich clay. D (XPL): As above.

Plate 2. Sample depth (2310.70m) A (PPL): This image shows an argillaceous sandstone fragment, with altered feldspar grains being embedded in clay matrix. B (XPL): As above.
Sample depth (2313m) C (PPL): This image shows the quartz grains being dispersed and embedded in partly oxidized iron-rich clay matrix. D (XPL): As above.
Plate 3. Sample depth (2314m) A (PPL): A photomicrographic image showing the quartz, feldspar, and mica grains are embedded in patchily oxidized iron-rich clay. B (XPL): As above.

Table 1. The petrographic point counting results of samples from the Suakin-1 well.

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Sample Depth (m)</th>
<th>Quartz</th>
<th>Feldspars</th>
<th>Micas</th>
<th>Cements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M &amp; C</td>
<td>M &amp; C %</td>
<td>M &amp; C %</td>
<td>M &amp; C %</td>
</tr>
<tr>
<td>Suakin-1</td>
<td>2308.43</td>
<td>10.8</td>
<td>28.8</td>
<td>16.8</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>2309.38</td>
<td>18.8</td>
<td>15.8</td>
<td>18.4</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
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<td>25.8</td>
<td>11.4</td>
<td>16.8</td>
<td>7.8</td>
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<tr>
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<td>2313</td>
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<td>2314</td>
<td>29.8</td>
<td>11.8</td>
<td>19.4</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Note: *=traces

B. Reservoir Quality

Sandstones of Zeit Formation (Suakin - 1 Well) have revealed, that their reservoir quality was affected positively and negatively by several digenetic processes. These processes include: mechanical compaction factors (grain slippage and crushing of the ductile grains), quartz overgrowths, precipitation of siderite and calcite, feldspar and clay minerals authigenesis, dissolution of carbonate and of the labile detrital grains and clay infiltration. The reservoir quality of the study intervals was not only affected by the above mentioned digenetic processes, but also in a large-scale by the type of depositional environment (lacustrine, fluvial and deltaic environments), which controlled the distribution of the facies types within the basin as well as by the subsidence of the basin besides the structural relief variations that happened during the initiation of the second rifting phase, which led to the fast transportation and rapid burial of the sediments. Furthermore, the reservoir quality was influenced by the detrital composition of the sandstones, by their textures and the grain-size distribution.

VII. CONCLUSION

Thin section investigations analysis of core samples from Zeit Formations reveals that feldspar accounts for 19.8 – 23 %, quartz and the lithic fragments are ranging between 75.7 – 85.2 % and 0.0 – 7.3 % respectively. Consequently the sandstones are classified as sub litharenite. Thin section investigations analysis for the sandstones of Zeit Formation (Suakin -1 Well) have revealed, that their reservoir quality has been affected positively and negatively by several digenetic processes.

ACKNOWLEDGEMENT

Authors were indebted to Ministry of Petroleum, Petroleum Labs, Researches and Studies most of core samples, data and direct support during field work in the study area; and also thanks to the ministry of science and technology and International University of Africa, Faculty of Minerals and Petroleum for generous support which helped to improve the manuscript.
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