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HYDROCARBONS

Scanning electron microscope description of the Afowo oil sand deposits in south-western Nigeria

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ABSTRACT.

The Afowo oil sand deposits in parts of Southwestern Nigeria were described by scanning electron microscope for characterizing the reservoir sands, based on their clay content.

Twelve core oil sand samples were collected, six of which were selected for analysis based on the similarities in their physical and textural characteristics. The prepared oil sand samples were then described by scanning electron microscope studies (VEGA TESCAN/LMU scanning electron microscope-SEM).

The analysis revealed that the oil sands contained minerals which had been precipitated and occurred as pore filling cement; these minerals included sheet kaolinite, vermiform kaolinite, k- feldspar, pyrite crystals, and corrosion quartz and corrosion feldspar. The SEM images also showed 2-4 μm micro pores and 2-5μm fractures.

The study showed that the clay minerals contained in the Afowo formation's reservoir rocks were mainly kaolinite which was not expected to have any negative effects on reservoir quality, especially during enhanced oil recovery operations.

Keywords: Tar sand, textural characteristics, kaolinite, fracture, pore cement, reservoir and clay.

RESUMEN

Los depósitos de arenas bituminosas de la Formación Afowo en algunas partes de suroeste de Nigeria fueron analizados con microscopio electrónico para caracterizar las arenas del reservorio, basados en el contenido de arcilla. Doce corazones de arenas bituminosas fueron recolectados, de estos, se seleccionaron seis para análisis basados en las similitudes de sus propiedades físicas y texturales. Las muestras de arena bituminosa preparadas fueron estudiadas con el microscopio electrónico (VEGA TESCAN/LMU Microscopio Electrónico de Barrido-SEM).

El análisis reveló que las arenas bituminosas contuvieron minerales que fueron precipitados y que llenaron espacios de poros con cemento; estos minerales incluyen caolinita laminar, caolinita vermiforme, feldespato potásico, pirita, cuarzo y feldespato corroído. Las imágenes SEM mostraron micro poros de 2-4 μm a y fracturas de 2- 5μm.

El estudio indicó que los minerales arcillosos contenidos en la rocas del yacimiento de la Formación Afowo, son esencialmente caolinita la cual no tiene efectos negativos sobre la calidad del yacimiento, especialmente durante las operaciones de recobro mejorado.

Palabras clave: renas bituminosas, características texturales, caolinita, fractura, cementado poro, depósito y arcilla.

Record

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Introduction

Tar sands, also known as oil sands, consist of bitumen which is a soluble organic matter derived from crude oil degradation, either as seeps coming to the surface or within shallow subsurface reservoirs, and host sediment with associated minerals excluding natural gas.

The tar sands deposit found in Nigeria outcrops along an East- West 120km long, 4-6km wide belt extending from the boundary of Edo and Ondo to Ogun states (Enu, 1987). These deposits have been known about for quite sometimes now. However, intense investigation started around the 1970's and has lasted until now. These deposits' geology, oil saturation, reserves estimates and, the textural characteristics of the associated sand as well as the physical-chemical characteristics, have been previously described: Adegoke *et al.*, (1980), Enu,(1987), Oshinowo *et al., (*1982), Ekweozor and Nwachukwu (1989), Nton (2001) and Akinmosin *et al., (*2005 and 2006).

A detailed understanding of the geology of bitumen-impregnated sands will provide vital information regarding the sands' reservoir quality.

A good knowledge of tar sand beds reservoir quality vis-à-vis tar recovery is also very important; hence the present study has been aimed at determining the tar sand deposits' sedimentological characteristics for characterising the reservoirs based on their clay content.

Dahomey basin's stratigraphy.

The study area was located in the Dahomey basin's tar sands belt extending from latitude 4° 15' E – 4° 47'E and longitude 6° 36' N- 6° 43'N, (Fig 1). The stratigraphy of the eastern margin of Dahomey basin's Cretaceous to Tertiary sedimentary sequence can be divided following in order of age: the Abeokuta group, the Imo group, the Ilaro formation, coastal plain sands and recent alluvium (Table 1).

The Dahomey basin's sediments range in age from Cretaceous to recent. Thickness exceeds 2.2km on the coast in Western Nigeria which thickens markedly into the offshore and then down deep water (Whiteman, 1982). The bituminous sands appear to be restricted to the Abeokuta group; this unit

Table 1: Regional Stratigraphic Setting of the Eastern Dahomey basin (after Idowu *et al*., 1993)

<table>
<tr><td rowspan="2">Age</td><td colspan="4">Formation</td><td rowspan="2">Lithology</td></tr>
<tr><td>Ako et al., 1980</td><td colspan="3">Omatsola and Adegoke, 1981</td></tr>
<tr><td rowspan="3">Tertiary</td><td>Eocene</td><td>Ilaro formation</td><td colspan="2">Ilaro formation</td><td>Sandstone</td></tr>
<tr><td rowspan="2">Palaeocene</td><td>Oshosun formation</td><td colspan="2">Oshosun formation</td><td>Shale</td></tr>
<tr><td>Ewekoro formation</td><td colspan="2">Ewekoro formation</td><td>Limestone</td></tr>
<tr><td rowspan="3">Cretaceous</td><td>Maastrichtian</td><td rowspan="3"></td><td rowspan="3">Abeokuta group</td><td>Araromi formation</td><td>Shale.</td></tr>
<tr><td>Turonian</td><td>Afowo formation</td><td>Sandstone/ shale.</td></tr>
<tr><td>Berremian</td><td>Ise formation</td><td>Sandstone.</td></tr>
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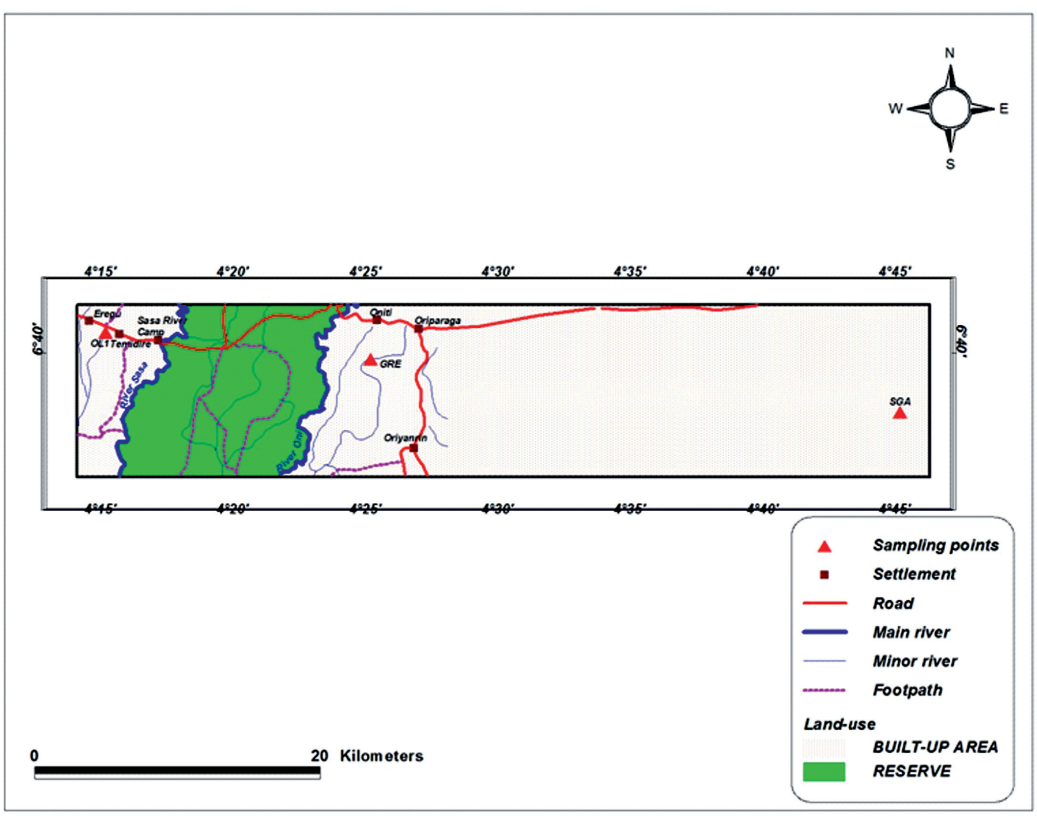


Figure 1: Topographical map of the study area, showing sampling locations.

extends throughout the entire basin, unconformably overlying the basement complex. The basin has also been considered to be a positive shallow depression which received a relatively thin sediments supply and was formed during the Campanian stage associated with the Benue – Abakaliki anticlinorium and the subsidence of the Anambra platform which gave rise to the Anambra basin.

The Dahomey basin falls within latitude 6° 00' N – 8° 30' N and longitude 0° 15' E – 6° 00' E extending from the Volta delta area in Ghana to the Okitipupa ridge; (Figure 2). The miogeosynclinal wedge of the sediments developed through the early Cretaceous to tate Cretaceous period. The distance from the mouth of the Volta to the axis of the Okitipupa ridge is about 780 miles and the width of the measured northern onshore margin in Benin is 9,840ft (300m); the bathymetric contour lies about 140 miles offshore. The basin thickens towards the republic of Benin and dips down towards the Atlantic; and floored by crystalline basement complex rocks from a block which became faulted into a series of graben and horst

The samples for this study consisted of samples collected from two holes.

Study materials and methods.

Twelve core oil sand samples were collected; six of these samples were selected for analysis based on similarities regarding their physical and textural characteristics. The prepared oil sand samples were then subjected to scanning electron microscope (SEM) VEGA TESCAN/LMU scanning electron microscope (at IBM- China Research Laboratory).

The SEM creates images by focusing a high-energy electrons beam onto the surface of a sample and detecting signals from incident electron interaction with a sample's surface. The type of signals gathered by SEM varies and may include secondary electrons, characteristic x-rays, and back-scattered electrons. SEM produce high-resolution images of a sample's surface in its primary use mode, secondary to electron imaging. Depending on how such image has been created, SEM images have great field depth, yielding characteristic three-dimensional appearance which is useful for understanding a simple surface structure.

The prepared oil sand samples were trimmed to an appropriate size into fit in the specimen chamber, they were embedded in resin with further polishing to a mirror-like finish and mounted on a holder for analysis.

Electrons are thermionically emitted from a tungsten or lanthanum hexaboride (LaB_6) cathode and are accelerated towards an anode in typical SEM; alternatively, electrons can be emitted via field emission (FE). Tungsten is used because it has the highest melting point and lowest vapour pressure of all metals, thereby allowing it to be heated from a few hundred eV to 100keV, focused by one or two condenser lenses into a beam having a very fine 0.4nm to 5nm focal spot. The beam passes through pairs of scanning coils or pairs of deflector plates in the electron optical column, typically in the objective lens, horizontally and vertically deflecting the beam so that it scans in a raster fashion over a rectangular area of a sample's surface.

Results and Discussion

Quantifying clay mineralogy provides sufficient information evaluating the effect of clay minerals on reservoir characteristics. Microscopic distribution of small proportions of authigenic clay minerals may have a profound effect on a reservoir regardless of each clay mineral's specific proportions (Sommer, 1978; Seeman, 1979; Palatt *et al.,* 1984).

The oil sand samples were identified having minerals which had become precipitated and occurred as pore filling cement; these included: sheet kaolinite, vermiform kaolinite and k – feldspar, pyrite crystal, corrosion quartz and corrosion feldspar. The SEM images were found to have of 2 - 4µm micro pores and 2 – 5µm fractures.

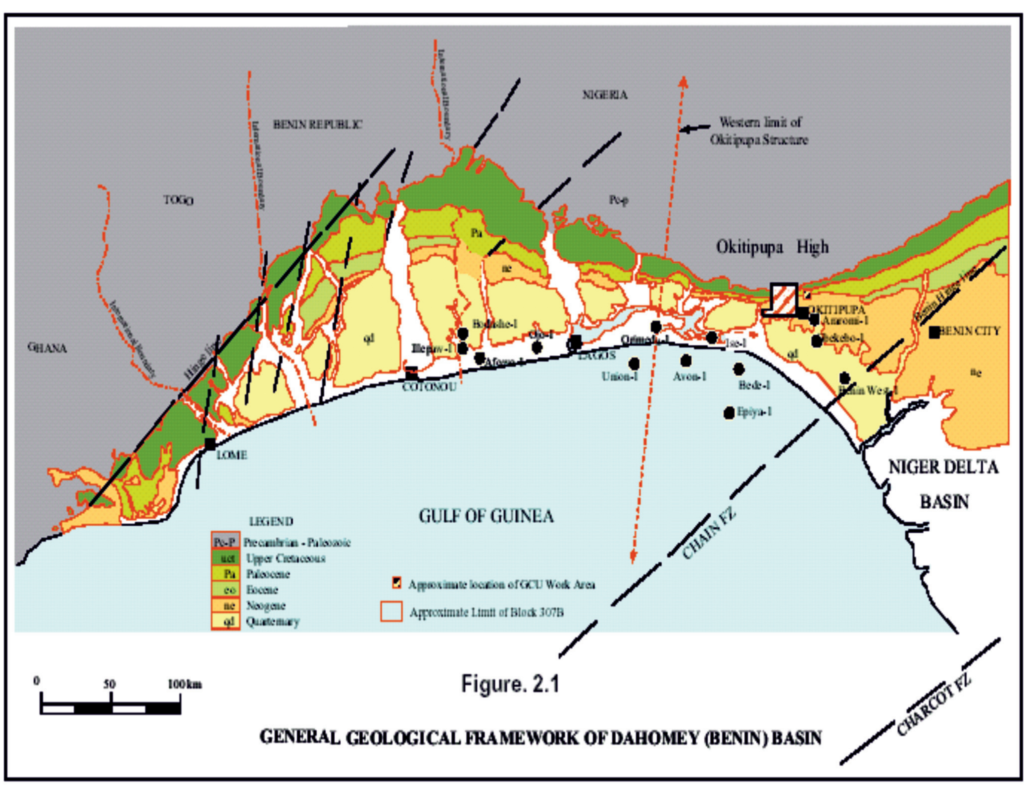


Figure 2: The Dahomey basin's overall geological framework. (modified from Bilman, 1992).

a. *Sheet kaolinite*

Kaolinite is a clay mineral consisting of hydrous alluminosilicates having a sheet or layered structure. It is one of the most common authigenic clay minerals in sands and also, as pore filling cements and clay, rims up to 50ìm thick around grains.

A authigenic kaolinites characteristically form books of stacked pseudo-hexagonal plates within pores between grains. They are usually formed from feldspar alteration (Plate 1).

b. *Vermiform kaolinite*

Vermiform kaolinite also occurs as a result of k-feldspar alteration. However, vermiculite occurrence in small particles as a clay constituent has been recognised and is said to have an expanding lattice; in that expansion can only take place to a limited degree (MacEwan, 1948). Vermiform kaolinite could thus exhibit vermiculites characteristics (Plate 2).

c. *K-feldspar*

K-feldspar is derived from feldspar hydrolysis because its chemical stability is generally low. Feldspar alteration takes place at the weathering site (it is rather chemical than physical weathering) and during diagenesis, either on burial or subsequent uplift (Plate 3).K-feldspar corrosion results from chemical erosion (Plate4).

d. *Corrosion quartz*

This is the most common mineral in sands and the most stable of all minerals in sedimentary conditions. Corrosion quartz shows the outer parts' erosion or modification as a result of dissolution (Plate 5).

e. *Pyrite crystals*

Pyrite crystals are the most common iron sulphide mineral and are constituents of many iron-rich and other sediments but rarely form major parts. Pyrite occurs as localised concretions due to precipitation (Plate 6).

f. *Micro pores*

These are small opening in the interstices of rocks. Micro pores are smaller than 2nm in diameter and movement through them is by activated diffusion. The micro pores range in size from 2-4µm, (Plate 7).

g. *Fracture*

This is secondary porosity in rock, which often enhances a rock's overall porosity. This can be result from the chemical leaching of minerals or the generation of a fracture system. Fracture width ranges in size from 2-5µm, (Plate 8)

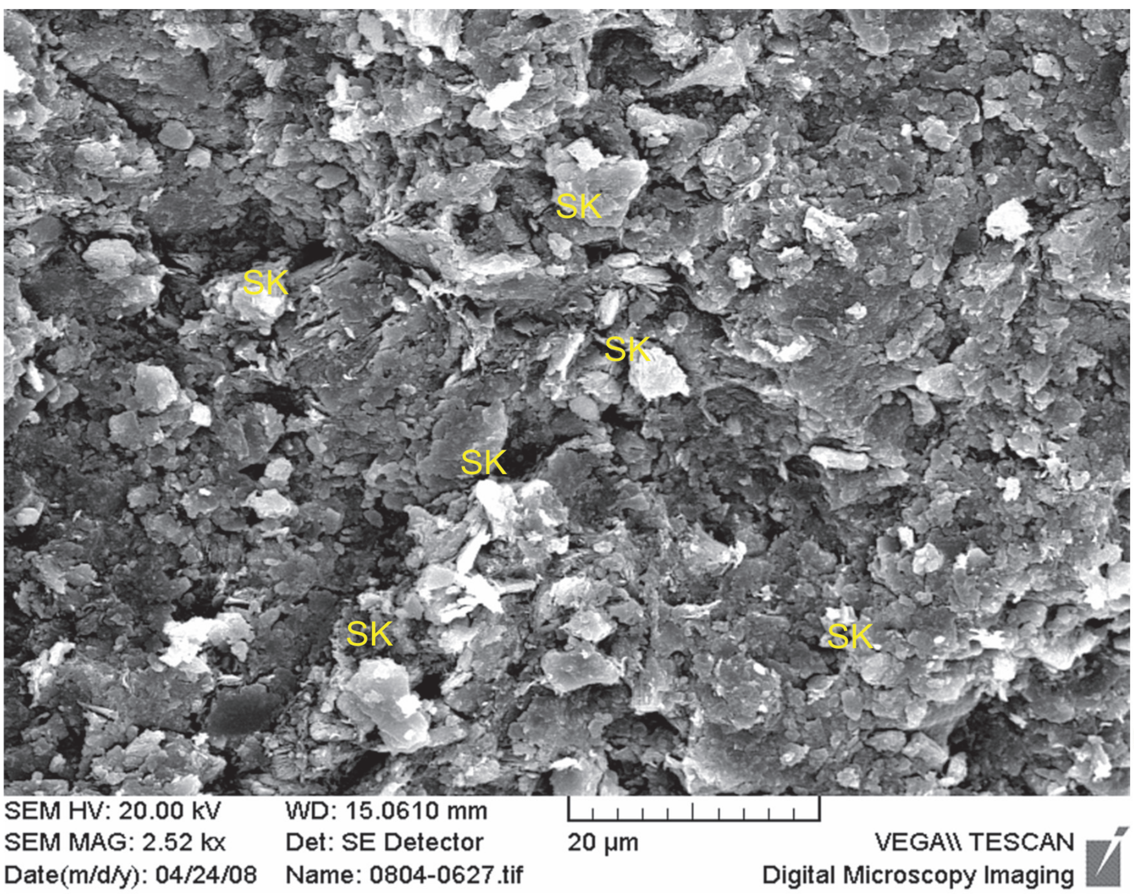


Plate 1: Scanning electron micrograph of sheet kaolinite.

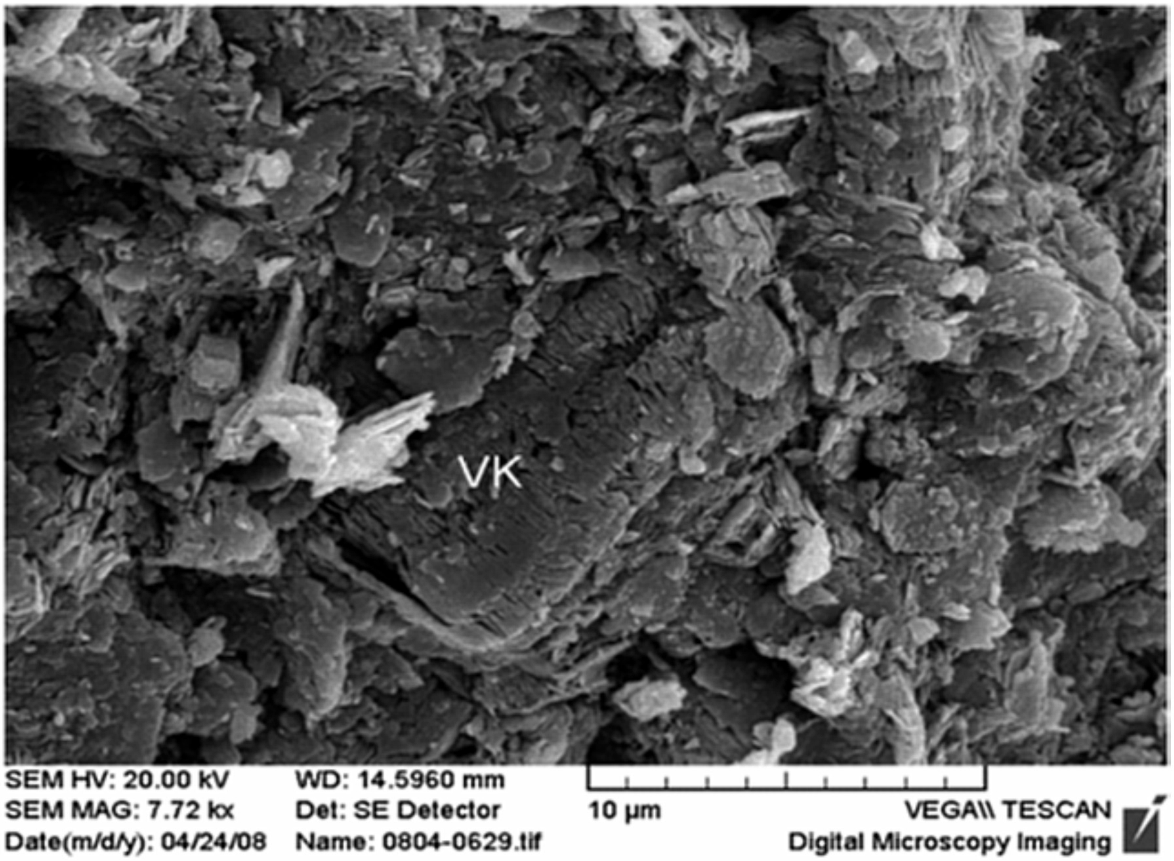


Plate 2: Scanning electron micrograph of vermiform kaolinite

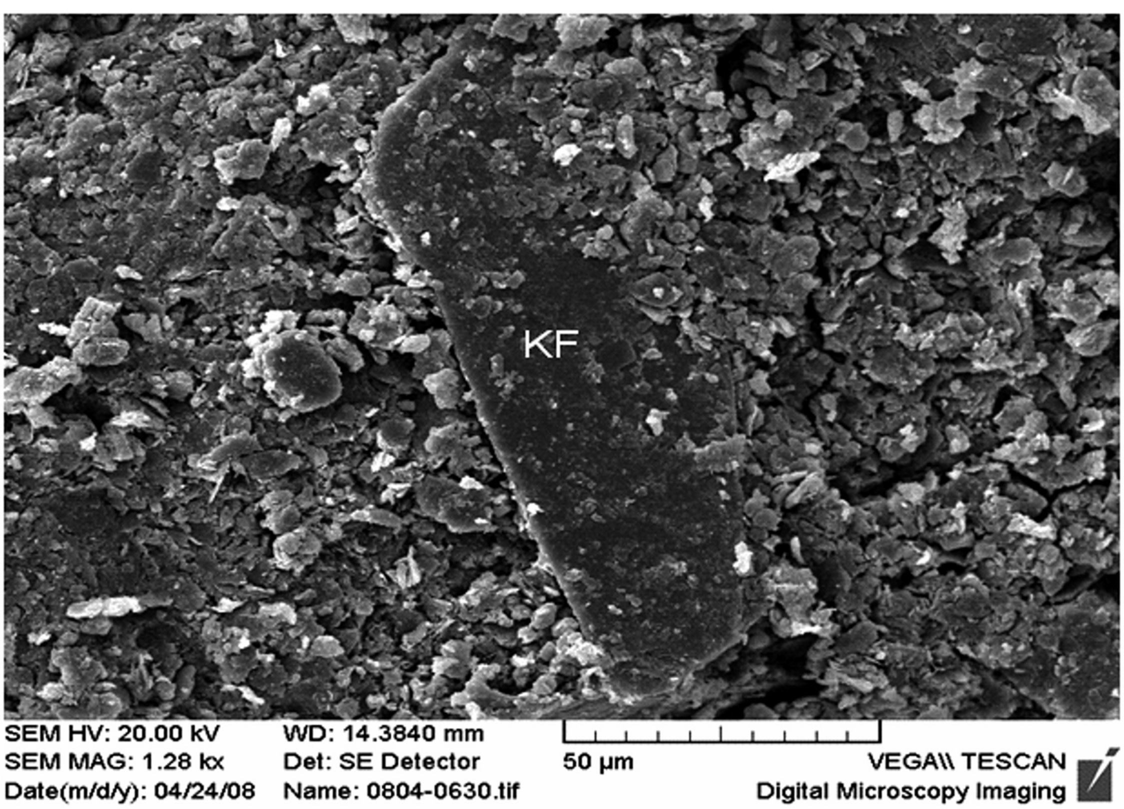
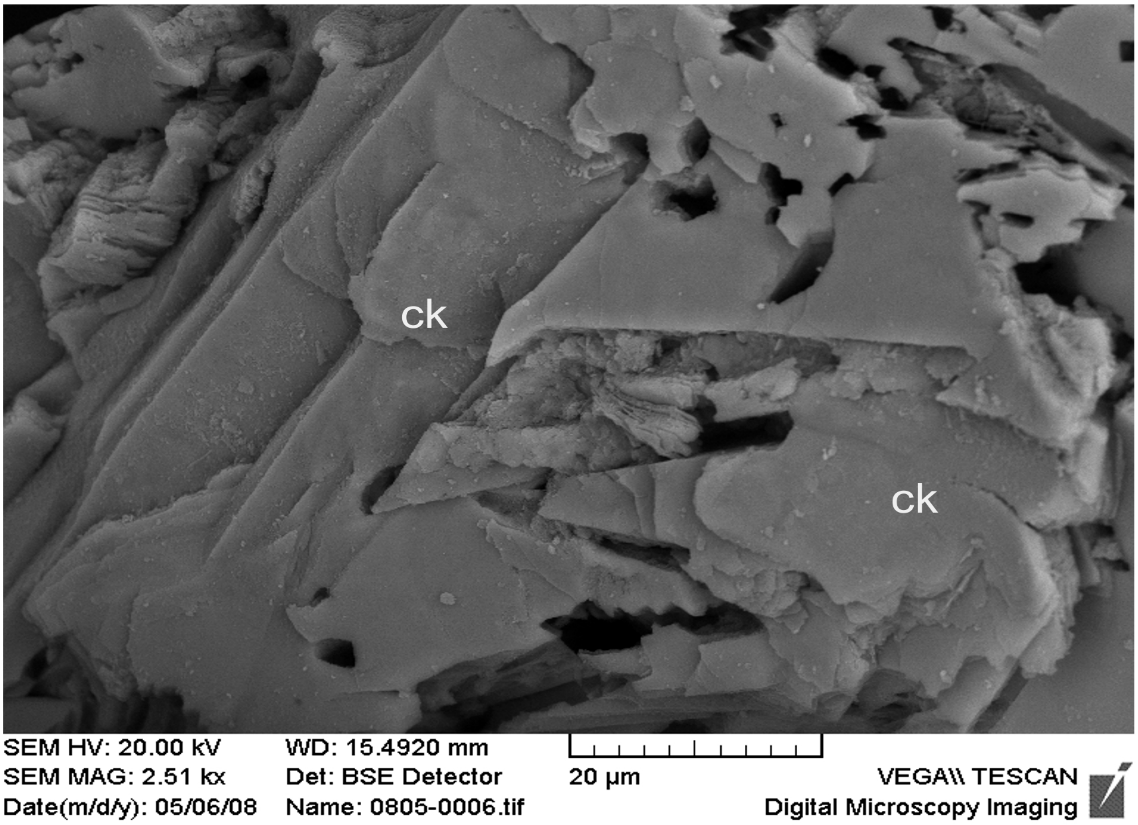
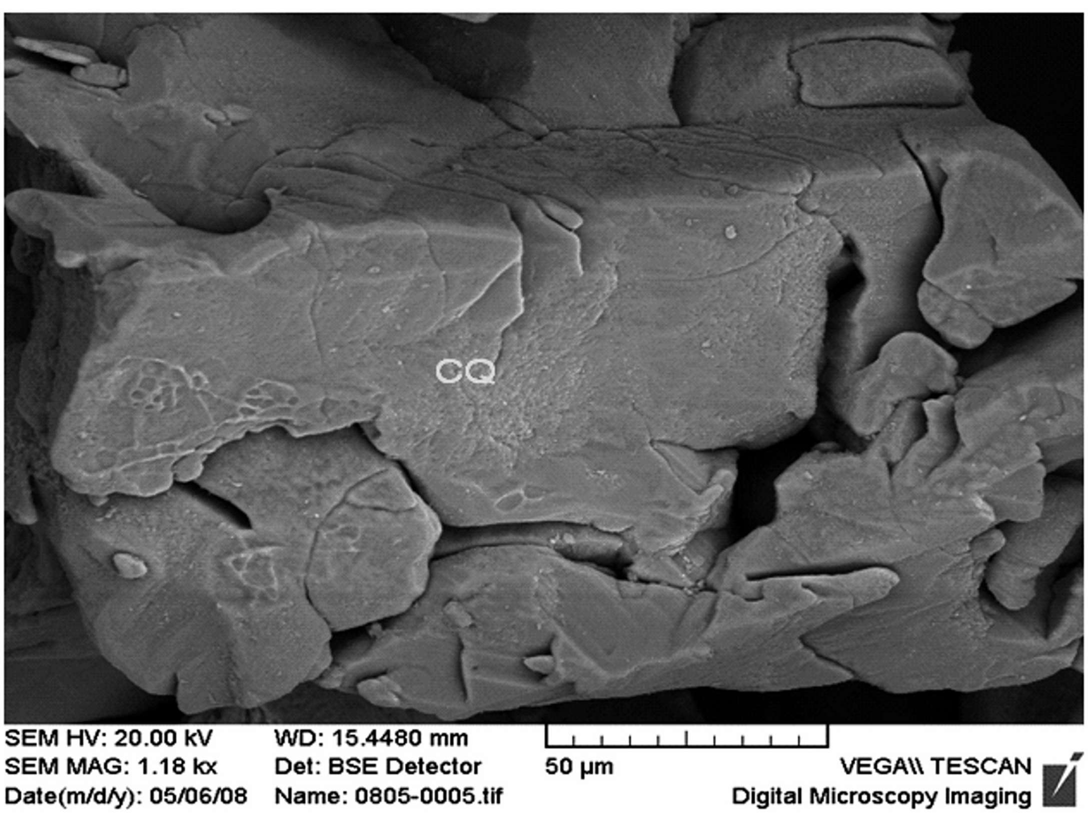


Plate 3: Scanning electron micrograph of k-feldspar



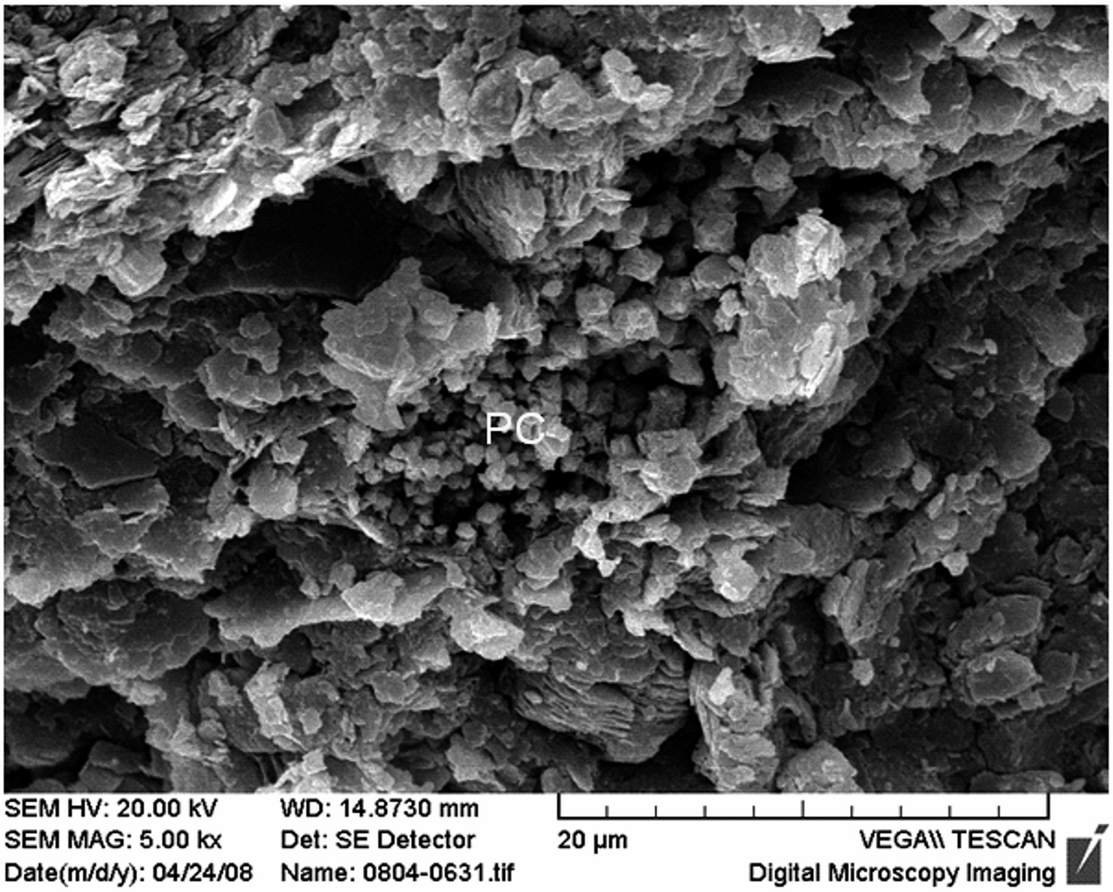
CK = Corrosion K-Feldspar

Plate 4: Scanning electron micrograph of corrosion k-feldspar.



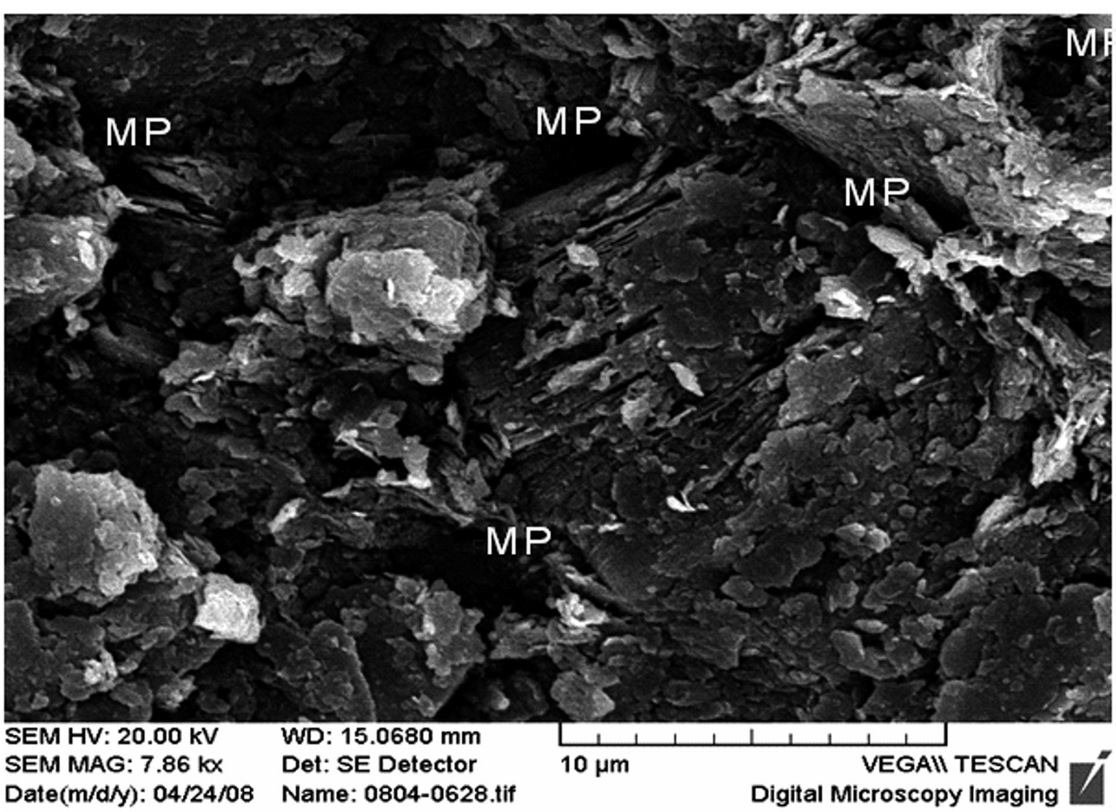
CQ = Corrosion Quartz

Plate 5: Scanning electron micrograph of corrosion quartz.



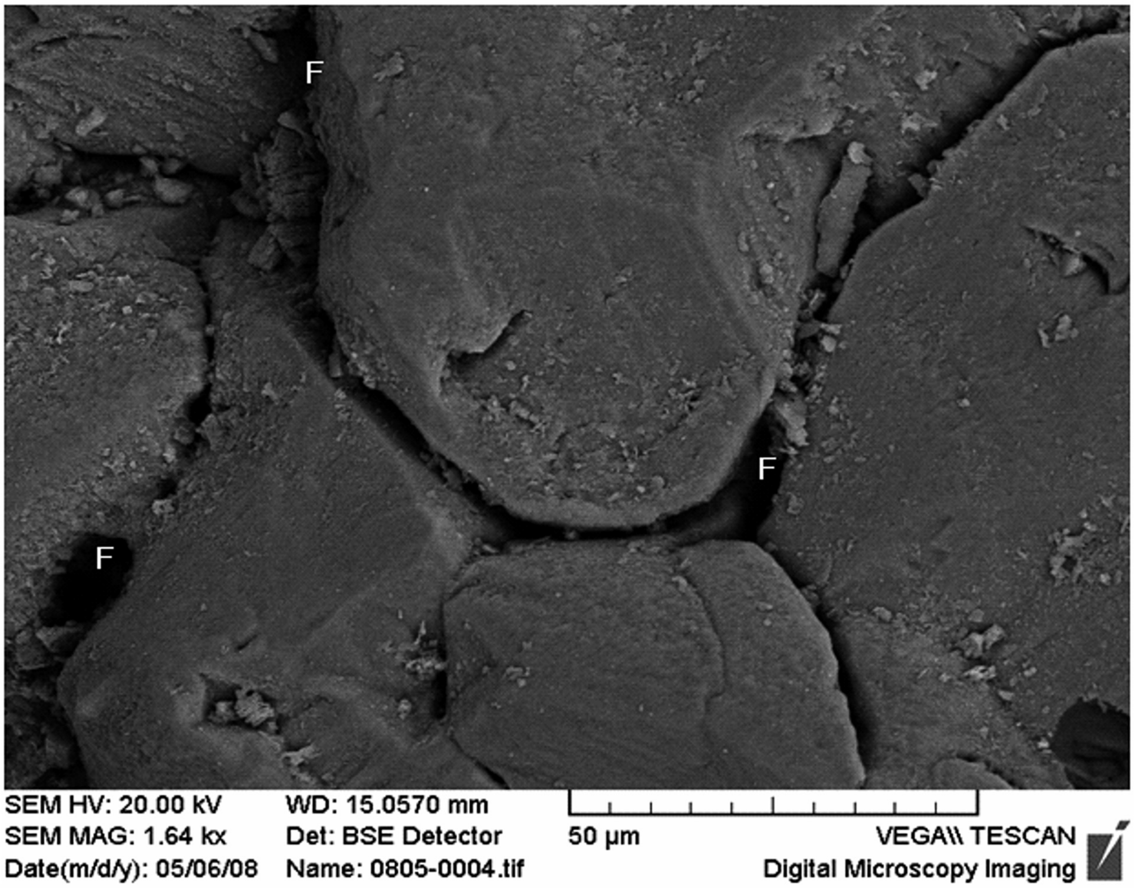
PC = Pyrite Crystals

Plate 6: Scanning electron micrograph of pyrite crystals.



MP = Micro pores

Plate 7: Scanning electron micrograph of micro pores.



F = Fracture

Plate 8: Scanning electron micrograph of fracture.

Conclusion

A scanning electron microscopic description of the Afowo oil sand deposits in parts of southwestern Nigeria was aimed at characterising reservoir sands based on their clay content.

The study revealed that the oil sands contained minerals became precipitated and occurred as pore fillings. These minerals include sheet kaolinite, vermiform kaolinite, k- feldspar, pyrite crystals, corrosion quartz and corrosion feldspar. The SEM images also showed 2-4 μm micro pores and 2-5μm fractures.

Furthermore, the study has shown that the clay minerals contained in Afowo formation reservoir rocks are mainly kaolinite which is not expected to have any negative effects on reservoir quality, especially during enhanced oil recovery operations.

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