



## Multiscale analysis of Bioturbation induced heterogeneity in Bhuj formation ,Kachchh Basin

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### Keywords

Bioturbation, PDPK, Spontaneous Imbibition, SEM

### Summary

In order to understand the flow behavior through any rock formation, it is essential to understand the inherent heterogeneity. Bioturbation is one such type of heterogeneity that greatly influence the flow behavior, which is physical modification in primary sedimentary fabric by animal & organism activity. Our work aims at characterization the same by performing experiments at multiscale namingly from Core level to Pore level so as to ascertain the effects of Bioturbation in the formation, which would help in better volumetric estimates and flow modeling. Based upon the result, it was observed that much of the heterogeneity associated with the rock was cylindrical and ranging in 1-2cm in diameter, aligned vertical to almost vertical to the bedding plane, this enabled vertical core to include them in longitudinal direction while horizontal core in transverse direction. The effect of bioturbation can be understood by analyzing the contrasting values of the horizontal n vertical core. The vertical core in higher Bioturbation Index samples had higher porosity and permeability. The PDPK analysis showed considerable permeability variation in Bioturbated and Non Bioturbated part. The spontaneous imbibition further assisted the results by indicating a greater mass imbibed in the vertical cores compared to the horizontal core primarily because of the enhanced connected pore volume along the length. In order to corroborated the core level results the SEM image analysis based qualitative results indicated contrasting connected pore structures in Bioturbated samples.

### Introduction

A major problem associated with many of the producing basin of the world is inaccurate description of reservoir by not properly acknowledging the scale and effect of heterogeneity. In India amongst all the hydrocarbon producing basin the same problem is persisting. Due to recent gas discovery in Kutch

Offshore this basing is developing a lot of interest for economic viability. Therefore a better understanding of the reservoir storage and flow capacity would be helpful in both efficient and economic exploitation of the basin.

Our work mainly focuses with one such type of heterogeneity existing in the Bhuj formation of the Kachchh Basin. The formation is divided into three member, our zone of interest which is Guneri member is characterized by repetition of ferruginous sandstones and variegated shales. Consisting of coarse grain ferrogitized sandstone with varying scale with of bioturbation.

The outcrop samples of Guneri member were plugged to measure their porosity and permeability, thin slab of the two distinct zones were chosen for Pressure Decay Profile Permeametry (PDPK). In order to assess the effects of Bioturbation a Spontaneous Imbibition experiment was carried out with brine. The samples were also imaged using FEG-SEM for better visualization of pore structure and validate the presence of distinct pore structure and connectivity in Bioturbated and non Bioturbated part.

### Method

In Bhuj formation is evenly exposed throughout the Kachchh basin as shown in figure 1. The samples were collected from the Outcrop exposures of Guneri member, Bhuj formation from the Kachchh basin. The formation is primarily a ferrogitized sandstone with wide range of Bioturbation making it suitable candidate for such analysis. The exposed Guneri Member at the location had Bioturbation Index (i.e. the degree of Bioturbation) amongst its five zone from 2 to 5. The rock samples were selected to plug a total of 32 cylindrical plug of 1.5 inch dia and 5 to 8 cm length for the laboratory study.

Routine core analysis were conducted, Helium Porosimeter was used to measure the grain density and core porosity, Liquid permeability was measured

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by performing flow experiment through core mounted in Hydrostatic type Hassler Core holder

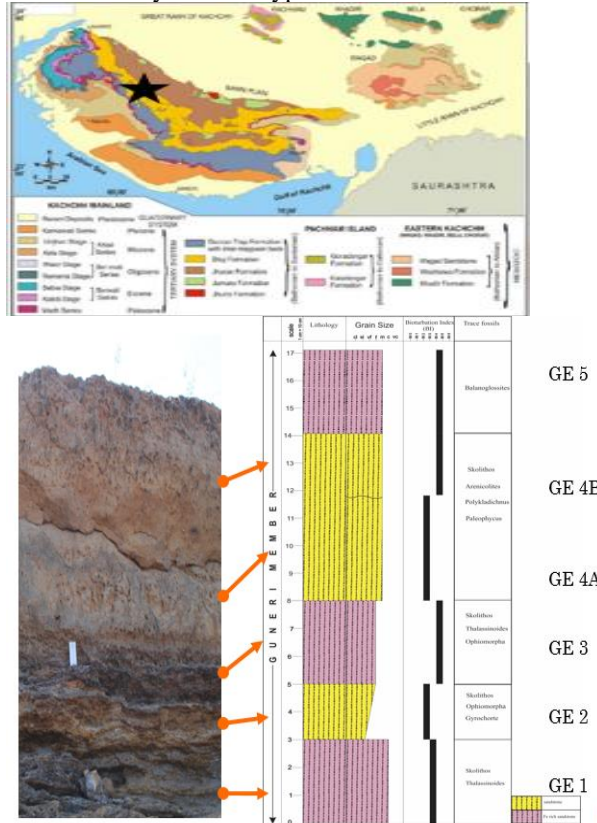


Figure 1.a) Location of the study area Guneri Member, Bhuj Formation, Kutch Basin with sampling location marked b) Photograph of studied section c) Lithostratigraphic column of the studied section

Afterwards Spontaneous Imbibition analysis and analysis was conducted. The SCA based study was done to measure total mass imbibed as a function of time, and SEM image provided for qualitative analysis of inherent pore architecture.

### PDPK Study

Profile Permeability measurement were conducted on the sections of the slabbed samples using PDPK-400 at approximately 10 cm. The analysis aimed at understanding variation in Permeability across the slabbed section

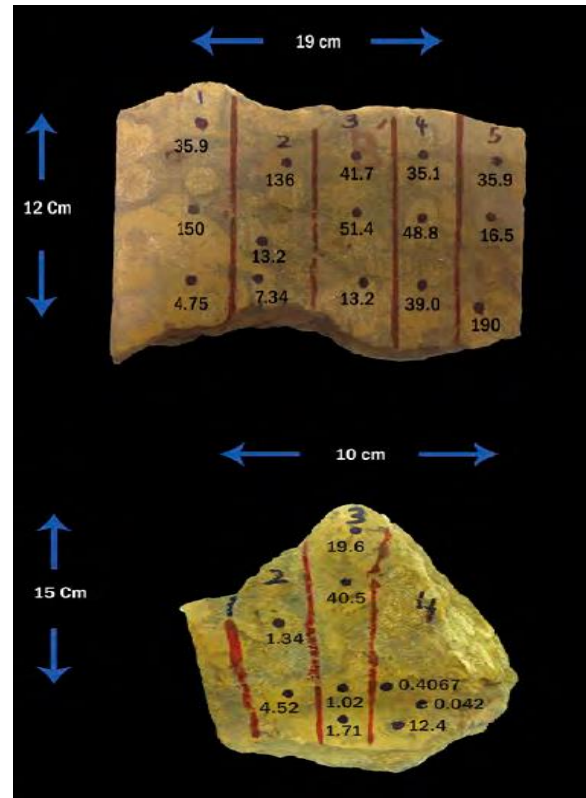
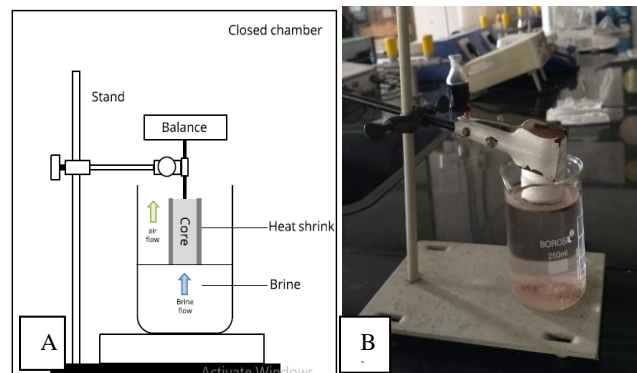


Figure 2 a)PDPK result of the slabbed GE 3 b)PDPK result on slabbed GE 2 specimen

### Spontaneous Imbibition Experiment

Spontaneous Imbibition is the influx of water under Capillary pressure in the rock. This phenomenon can be utilized to assess the connectivity of pore volume in the specimen. The mass gain in the specimen due to Spontaneous water imbibition is measured as a function of time and then comparative analysis between vertical and horizontal core is done

Figure 3. a)Schematic layout of Spontaneous experiment b)Adopted layout for the experiment



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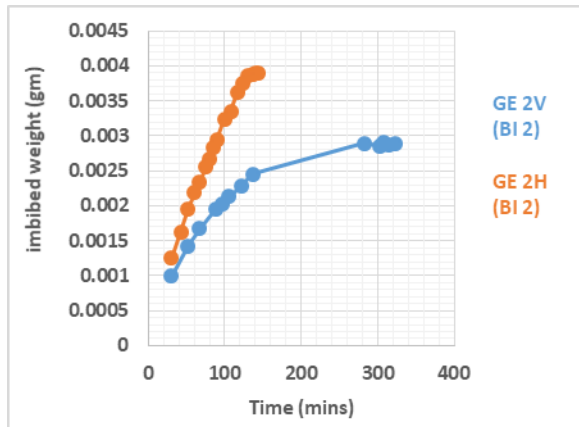
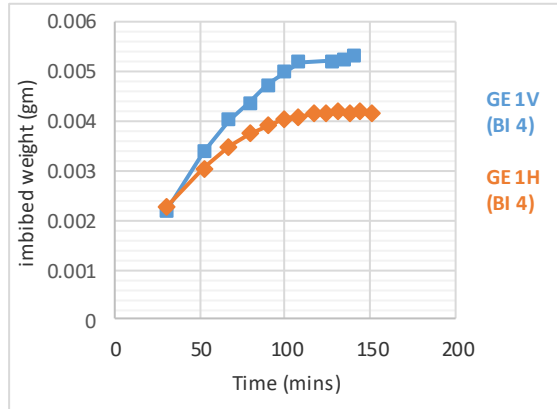


Figure 4. Comparative analysis of a) GE 1 V & H b) GE 2 V & H

**SEM study**

For SEM analysis freshly broken sample from the specimen GE 2 and GE 3 specimen. The specimen were imaged using JEOL JSM-7600F and SE and BSE were captured at magnification ranging from (X1000) to (X10,000) so as to resolve the resolution to submicron scale both SE and BSE image were taken.

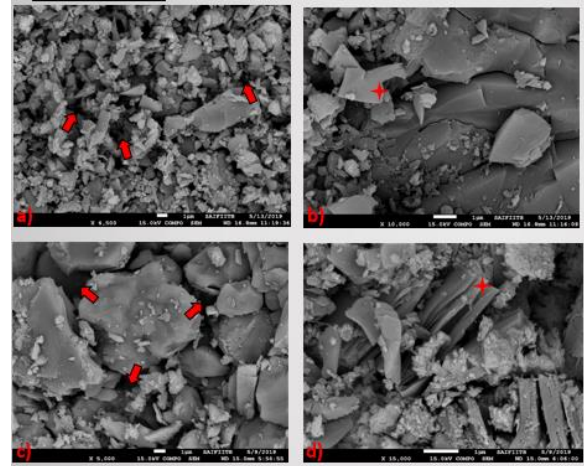


Figure 5. BSE image of GE 3 Nonbioturbated part at a) X5,000 b) X10,000 BSE image of Bioturbated part at c) X5,000 d) X10,000 respectively

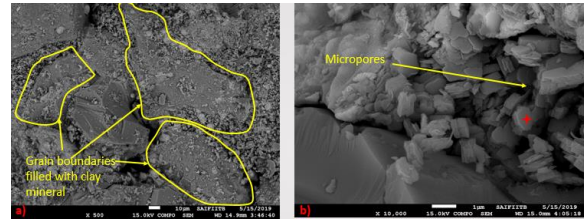


Figure 6 BSE image of GE 2 specimen at a) X500 showing higher clay presence along the grain boundary b) X10,000 showing Kaolinite present in the pores

**Result**

The RCA of the GE 2 specimen showed porosity ranging from 9 to 16% and permeability from 0.4 mD to 5.3 mD, while for GE 3 porosity varied from 12.7 to 18.4 % and permeability from 28mD to 67mD

The PDPK study showed GE2 slabbed sample with permeability from 0.042mD to 40.5 mD, while for GE 3 it varied from 4.75mD to 190 mD. The SCAL analysis for GE 2H showed higher mass imbibed than GE 2V while the reverse was found true for GE 3H & GE 3V respectively

SEM based pore characterization showed higher intragranular porosity in the GE 3 Bioturbated part



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than non Bioturbated part. The dominant clay was identified as Kaolinite infilling the pore spaces resulting in micro porosity.

The GE 2 sample had large precipitation of clay along the grain boundary thereby considerably decreasing the pore space and reducing permeability evident from the routine core analysis.

**Conclusions**

Based upon the study following conclusion can be drawn from it

- 1) The Bioturbation result in greater increase in heterogeneity by altering the storage and flow capacity
- 2) The cylindrical vertically aligned heterogeneity caused due to bioturbation results in increased porosity and permeability in vertical extent
- 3) Spontaneous Imbibition experiments display that higher Bioturbation enhances connectivity in pore spaces
- 4) Based upon SEM analysis it can be inferred that Bioturbated portion has greater connected pore spaces thereby exaggerating the porosity and permeability

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