PaperID **AU175**

Author **Dr. Bhawanisingh G. Desai , Pandit Deendayal Petroleum University , India**

Co-Authors **Ajendra Singh*, Neela Pharate#, Mithil Pandey*, Harsh Saini***

Assessing porosity-permeability heterogeneity in bioturbated sediments: implication for clastic reservoir characterization

Ajendra Singh*, Neela Pharate#, Mithil Pandey*, Harsh Sahani* Bhawanisingh G. Desai*[1]

*School of Petroleum technology, Pandit Deendayal Petroleum University, Gandhinagar-382007
Nowrosjee Wadia College, 19 Jogpath Pune 411001
1: corresponding author. bhawanigd@gmail.com

Abstract:

Evaluation and quantification of petrophysical heterogeneity in the sandstones as a function of bioturbation has a challenging scope. Correct modeling of porosity-permeability data enables better prediction of hydrocarbons. It is well known that bioturbation significantly alters the petrophysical properties of the reservoir rock, either by reducing or enhancing the porosity-permeability. Several studies have well documented the reduction in porosity as a function of bioturbation. However, recent global studies have demonstrated that most of the well know hydrocarbon producing fields are bioturbated. This implies, bioturbation enhances the porosity-permeability and improves better reservoir quality. To test this hypothesis, we analysed several bioturbated samples from outcrops of Early Cretaceous Ghuneri Member exposed in Kachchh basin. The samples were analysed for porosity estimation by helium porosimeter and Saturation method. Permeability was estimated by core flooding apparatus. The data generated were analyzed for reservoir heterogeneity parameters. Results suggest (a) increase in bioturbation improves reservoir quality by enhancing the permeability (b) presence of clay-lined burrow walls obstruct the flow paths by increasing tortuosity (c) presence of dominant passive filled vertical/inclined burrows enhances the vertical permeability.

Introduction:

Reservoir characterization is a most honest representation of the homogeneous reservoir used for forecast ting reservoir behavior and production scenario. Precise estimation of porosity-permeability anisotropy enables an accurate or near accurate estimation of production rate and hydrocarbons recovery. Several factors affect the petrophysical characteristics of the reservoir, including the effect of cementation and di, agenesis. However, one of the least studied factors is the effect of bioturbation on the resulting petrophysical heterogeneity of the reservoir.

Bioturbation is essentially the reworking of sediments by organism causing a contrasting fill of a different material in the deposited sediments. Bioturbation is quantified as the degree of bioturbation which the ratio of burrows (disturbed sediments) versus primary sedimentary structures (undisturbed sediments). Bioturbated sediments are classified into six categories ranging from Bioturbation index (BI) 1 corresponding to 0% disturbance to 100% disturbed sediments. Thus, bioturbation results in a range of heterogeneity in clastic rock. It was earlier assumed that bioturbation reduces permeability and porosity of the rock. However several global case studies from oil and gas fields suggest that bioturbation enhances storage capacity and flow characteristic and thus improves reservoir quality. The present paper tests the hypothesis and discusses possible reasons for improvement of reservoir quality as a function of bioturbation. The samples studied in this paper are from Early Cretaceous Ghuneri Member exposed in Kachchh basin. The Ghuneri Member is bioturbated sequences of cyclic nature, consisting of all degrees of bioturbation ranging from non-bioturbated sandstone to entirely bioturbated sequence deposited in a deltaic environment (Desai, 2016). Ghuneri Member samples offer an excellent opportunity for detailed analysis and modeling of bioturbated sandstone. Ghuneri Member is best exposed in its type section near the village of Ghuneri in the western part of the Kachchh Basin (Biswas, 2016). It exposes the whole succession of Bhuj Formation starting

from base of Ghuneri Member to top of Upper Member, including Ukra Member. Five large blocks of approximately 60 X 60 cm were retrieved from the field, considering the degree of bioturbation. The blocks were then further subsampled detailed analysis. The bioturbation index varied from BI-2 to BI-5 in the samples, few other smaller samples consisting of non-bioturbated sandstones were also selected from other locality. All the samples belong to Early Cretaceous age. In this paper, we focus on (1) estimating porosity and permeability in bioturbated rocks and (2) Classifying degree of heterogeneity in bioturbated sequence.

Method:

The sample blocks were cored to take cores in horizontal and vertical direction considering burrow orientation. The degree of bioturbation and nature of burrows were documented the on outcrop itself. These different bioturbated sections also a present a variety of burrows ranging from unlined burrows with contrasting burrow fill to clay lined burrows of vertical and horizontal inclinations. A field study was conducted to collect samples of Ghuneri

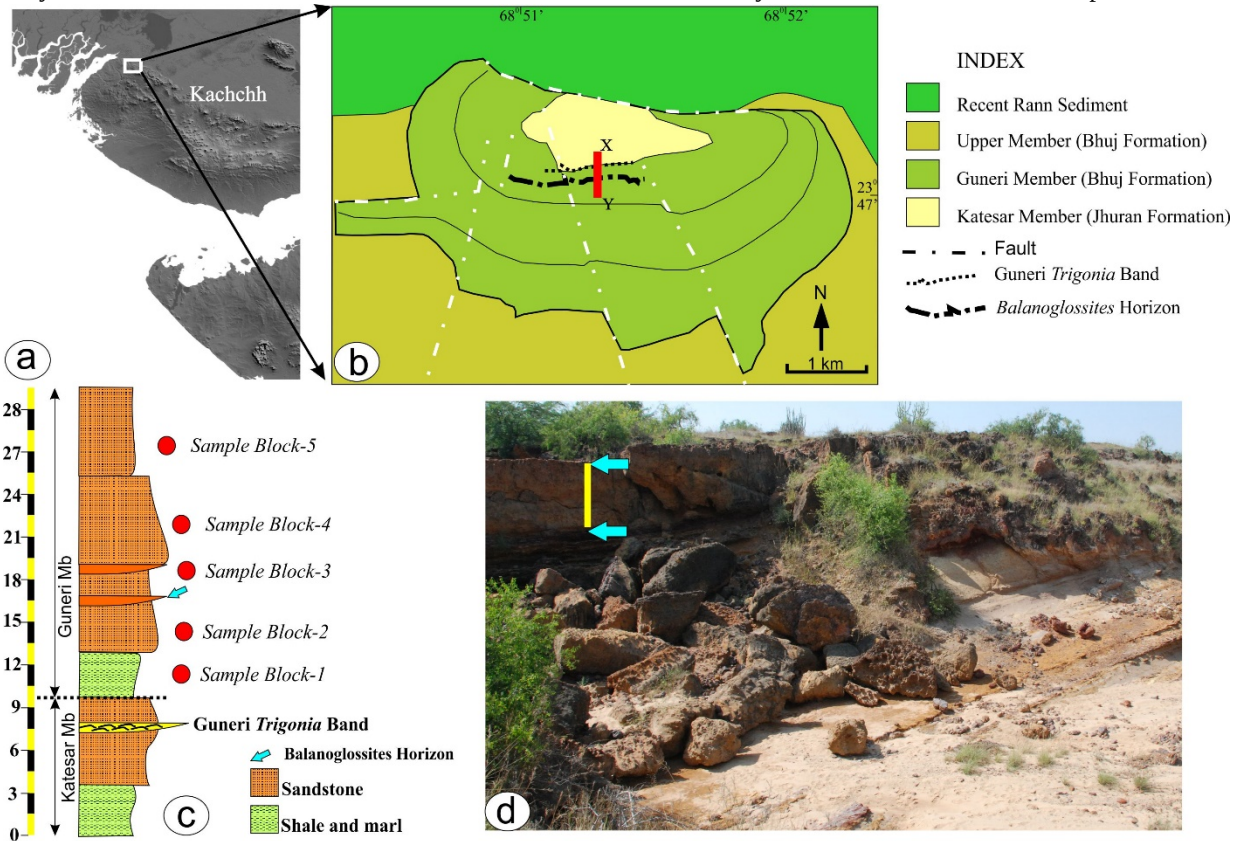

Figure 1 Geological details of the studied samples (a) Location of the Kachchh basin in Western India (b) Geological map of the Ghuneri dome exposing Ghuneri Member (C) Details of the studed section with sample locaiton, large blocks were retrived and subsectioned for horizonta and vertical cores. (d)deailed field photograph of the section. Figure Modified after Desai and Saklani, 2012.

Member. These sections were prepared for comprehensive investigation. This was followed by rock typing of the core samples. The cores were subjected to analysis for porosity estimation by helium porosimeter and Saturation method, while a core flooding apparatus was used to calculate the permeability at the in-situ condition. This was followed by plotting of data of porosity-permeability cross plot of Windland R35 for determining flow units. To evaluate the degree of heterogeneity in bioturbated clastic reservoirs Lorenz coefficient, L, Dykstra-Parsons permeability variation V_k. were used.

Results and Conclusion:

The compiled results suggest

a) Winland R35 plots suggest the degree of bioturbation increases from BI-2 to BI-5 both porosity and pore throat increases from mesoporous to mega-porous units.
b) Based on Dykstra-Parson co-efficient, the Value of V_k varied from (V=0.49) Heterogeneous to (V=0.87) Extremely Heterogeneous.
c) Bioturbation with a higher percentage of unlined vertical /inclined burrows resulted in higher vertical permeability.
d) Further analysis is proposed for modeling of the relation of bioturbation and porosity-permeability.

Acknowledgments: Authors (BGD and AS) are thankful to the management of Pandit Deendayal Petroleum University for providing support for analysis of the samples.

References:

Desai, B. G., 2016. Ichnological Events Associated with Evolution of Kachchh Rift Basin, Western India. In Thakkar, M. G. (Ed) Recent Studies on the Geology of Kachchh, Special Publication of Geological Society of India, 6, 114-128.

Desai, B. G and Saklani, R.D. (2012) Significance of the trace fossil *Balanoglossites* Mägdefrau, 1932 from the Lower Cretaceous Guneri member (Bhuj formation) of the Guneri dome, Kachchh, India. Swiss Journal of Palaeontology, Vol 131 (2), pp 255-263.