

Chemical, Petroleum and Environmental Engineering

Geological Model of the Tight Reservoir (Sadi Reservoir-Southern of Iraq)

Ameer Kadhum Noori*

Petroleum Technology Dept. -University of Technology
Iraq, Baghdad
E-mail: amirkazim90@gmail.com

Dr.Samaher A. Lazim

Petroleum Technology Dept.-University of Technology
Iraq, Baghdad
E-mail: samaher2013@yahoo.com

Dr. Ahmad A. Ramadhan

Petroleum Technology Dept. -University of Technology
Iraq, Baghdad
E-mail: ahmad_2009_61@live.com

ABSTRACT

A 3D geological model was constructed for Al-Sadi reservoir/ Halfaya Oil Field which is discovered in 1976 and located 35 km from Amara city, southern of Iraq towards the Iraqi/ Iranian borders.

Petrel 2014 was used to build the geological model. This model was created depending on the available information about the reservoir under study such as 2D seismic map, top and bottom of wells, geological data & well log analysis (CPI). However, the reservoir was sub-divided into 132x117x80 grid cells in the X, Y&Z directions respectively, in order to well represent the entire Al-Sadi reservoir.

Well log interpretation (CPI) and core data for the existing 6 wells were the basis of the petrophysical model (Porosity, Water saturation, & Permeability) that were distributed for all the created grids and then upscaled.

Keywords: Geological model, Halfaya oil field, Sadi reservoir.

الموديل البتروفيزيائي لمكمن قليل النفاذية (مكمن السعدي اجنوب العراق)

الخلاصة

تم إنشاء نموذج جيولوجي ثلاثي الأبعاد لمكمن السعدي / حقل حلفايا النفطي والذي تم اكتشافه عام 1976، ويقع على بعد 35 كم من مركز مدينة العمارة جنوب العراق باتجاه الحدود العراقية الإيرانية.

تم استخدام برنامج بيتزل 2014 لبناء النموذج الجيولوجي. تم إنشاء هذا النموذج اعتماداً على المعلومات المتوفرة حول المكمن قيد الدراسة مثل الخريطة الزلزالية ثنائية الأبعاد، أعلى وأسفل الآبار، والبيانات الجيولوجية وتحليل سجل الآبار (CPI). ومع ذلك، تم تقسيم المكمن إلى 132 × 117 × 80 خلية في اتجاهات X و Y و Z على التوالي، من أجل تمثيل كامل لمكمن السعدي. كان تفسير الآبار (CPI) وبيانات النماذج للآبار الستة الموجودة أساساً في التوزيع البتروفيزيائي (المسامية، تشبع الماء، والنفاذية) التي وزعت على جميع الشبكات المنشأة.

الكلمات الرئيسية: النموذج الجيولوجي، حقل حلفايا النفطي، مكمن السعدي.

*Corresponding author

Peer review under the responsibility of University of Baghdad.

<https://doi.org/10.31026/j.eng.2019.06.03>

2520-3339 © 2019 University of Baghdad. Production and hosting by Journal of Engineering.

This is an open access article under the CC BY-NC license <http://creativecommons.org/licenses/by-nc/4.0/>.

Article received: 28 / 2 /2018

Article accepted: 28 /6 /2018

1. INTRODUCTION

Tight reservoirs characterized with low permeability and porosity, diminutive emptying radius and low productivity. Typical lithology of tight reservoirs is sandstone/siltstone and sometimes carbonate with permeability as low as ($<0.1\text{md}$), **Lee, and Hopkins, 2013**.

Tight oil reservoirs require some form of stimulation once the well has been drilled. The most common type of stimulation used by the oil and gas industry is referred to as hydraulic fracturing or fracking. This process applies pressure by pumping fluids into the wellbore which opens existing or creates new fractures or pathways in the reservoir through which the oil can flow to the wellbore. In conventional oil reservoirs, the reservoir permeability is sufficient that hydraulic fracturing may not be needed to achieve economic production rates. In unconventional oil, the reservoir permeability is typically very low and additional pathways must be created to enable the flow of hydrocarbons, **CSUR, 2013**.

Unconventional tight oil reservoirs typically have a porosity of less than 10% and a permeability of less than 0.01 md , **Gary, et al., 2015**.

In reservoir simulation studies, data of different types have been processed separately, leading to several different models, the geologic model, geophysical model, and production-engineering model. Indicator geostatistics provide an approach to merge all of the relevant information and then produce reservoir models consistent with that information, **Agboada, and Ahmadi, 2013**.

Halfaya oil field, is one of the largest oil fields in Missan province, south-East of Iraq, is located within the south area of Iraq towards the border with Iran, 35 km from center of the Amara city, **Fig.1**. The field structure is an anticline, trends from NW- to SE, with several oil bearing reservoirs of Cretaceous to Miocene age.

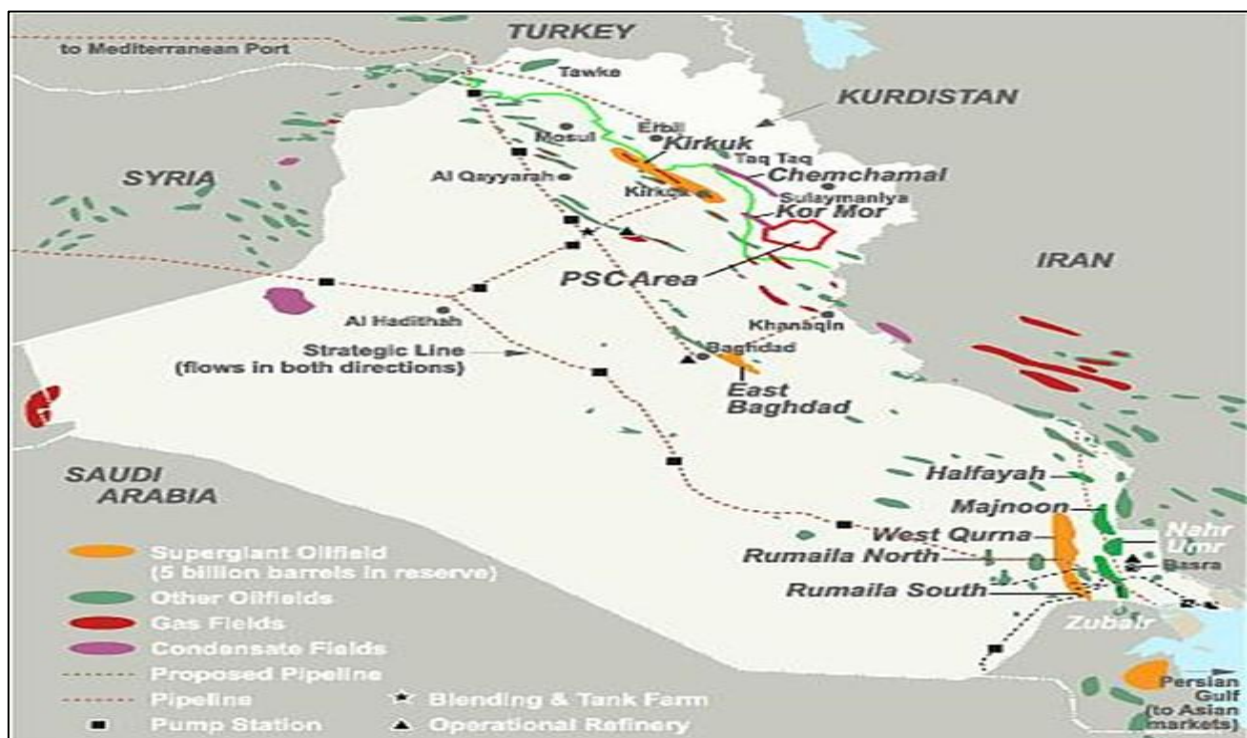


Figure 1. Location Map of Halfaya Oil Field SE of Iraq.



Missan Oil Company (MOC) 2013, proposed a geological and reservoir study for Al- Halfaya Oil Field. The reservoir under study is Sadi formation which is divided into three units and these units also subdivided into 80 layers depending on the variation of facies. Petrel software was used to model the reservoir by subdividing the formation into 616,226 grids based on data from six wells which drilled in this reservoir. The petrophysical properties of the Sadi reservoir were distributed in geological model and the OOIP was calculated to be 3957 MMSTB which is approximately the same results from a volumetric method, **MOC, 2013**.

The main units of Al-Sadi reservoir are B1, B2 and B3 depending on well logging interpretation and geological information's. The top of these units i.e. the structure maps were created based on a 2D seismic map, bottom, and top of drilled wells, **Fig.2, 3 & 4**.

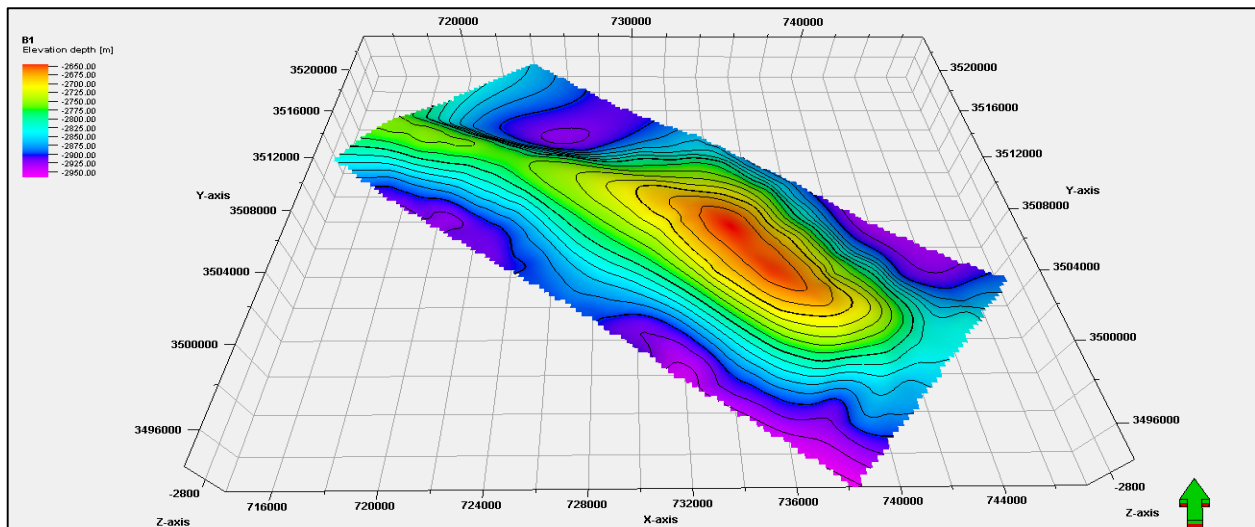


Figure 2. The generated structural map for B1 unit.

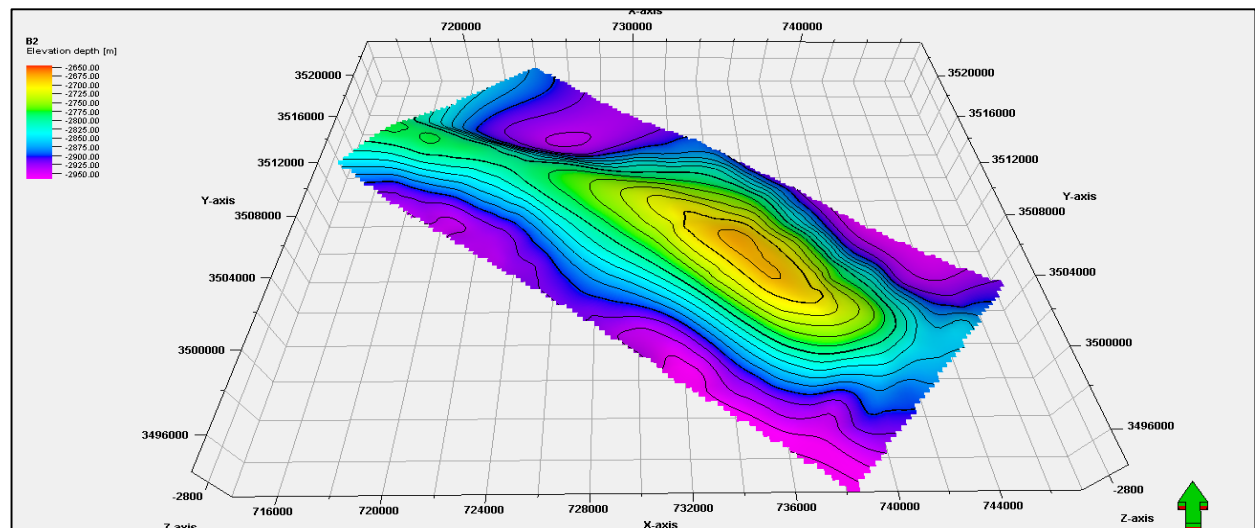


Figure 3. The generated structural map for B2 unit.

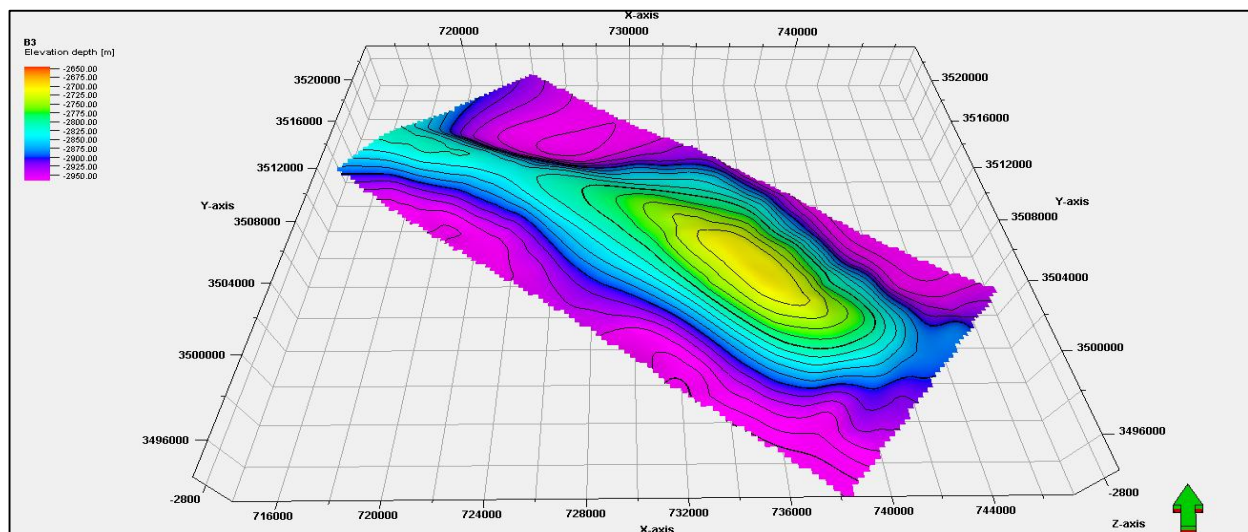


Figure 4. The generated structural map for B3 unit.

2. PETROPHYSICAL MODELING

The petrophysical model of the reservoir, defined in the log quantitative interpretation phase which based on the well log analysis (CPI) for six drilled wells that penetrate Al- Sadi formation, **Fig.5**, can be extended to the whole reservoir by means of the stochastic modeling approach. This can be done by attributing average petrophysical properties, **Cosenteno, 2001**.

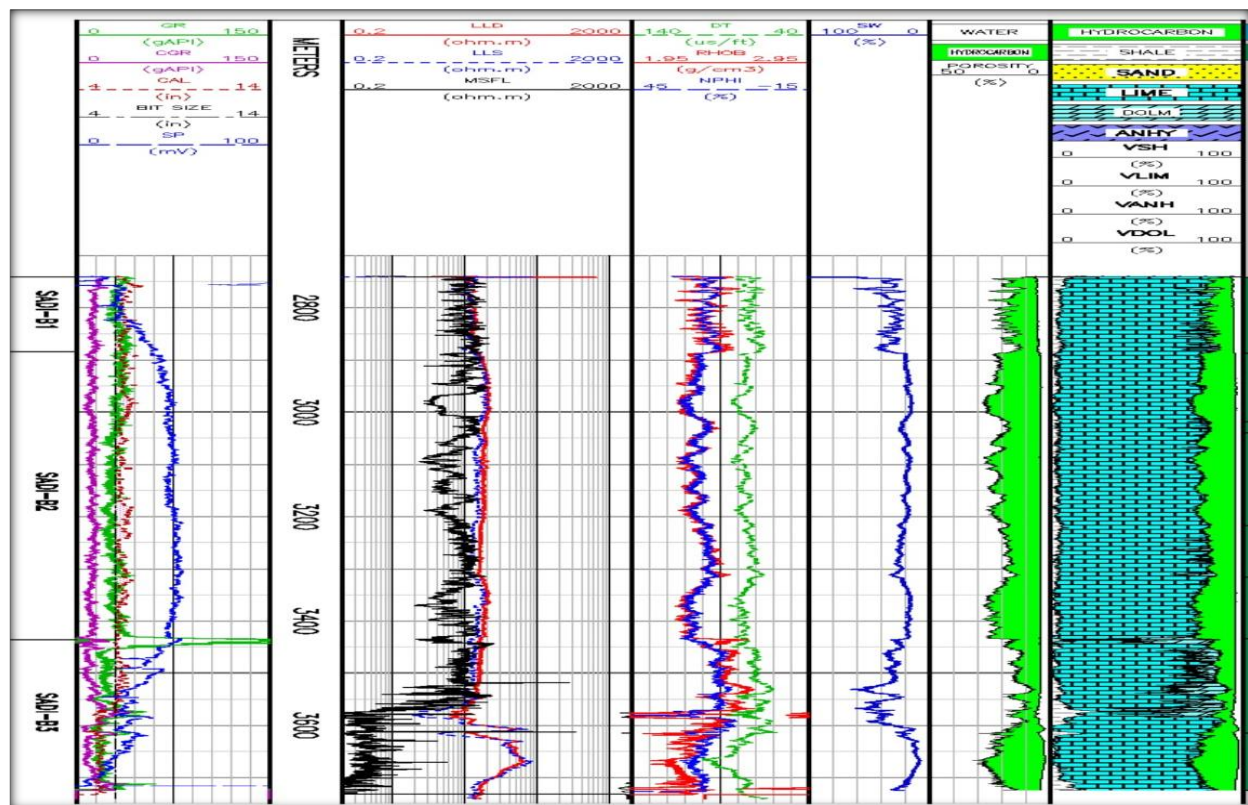


Figure 5. CPI for one existing well.



2.1. Porosity Modeling

Effective Porosity (\emptyset) log from Computer Processed Interpretation results (CPI) was scaled up using arithmetic averaging. Porosity was modeled using Sequential Gaussian simulation..A good matching was observed between the upscaled Porosity logs and the distributed porosity in the model, **Fig.6**. The Porosity model which is built for all unit of Sadi formation is shown in **Fig.7**.

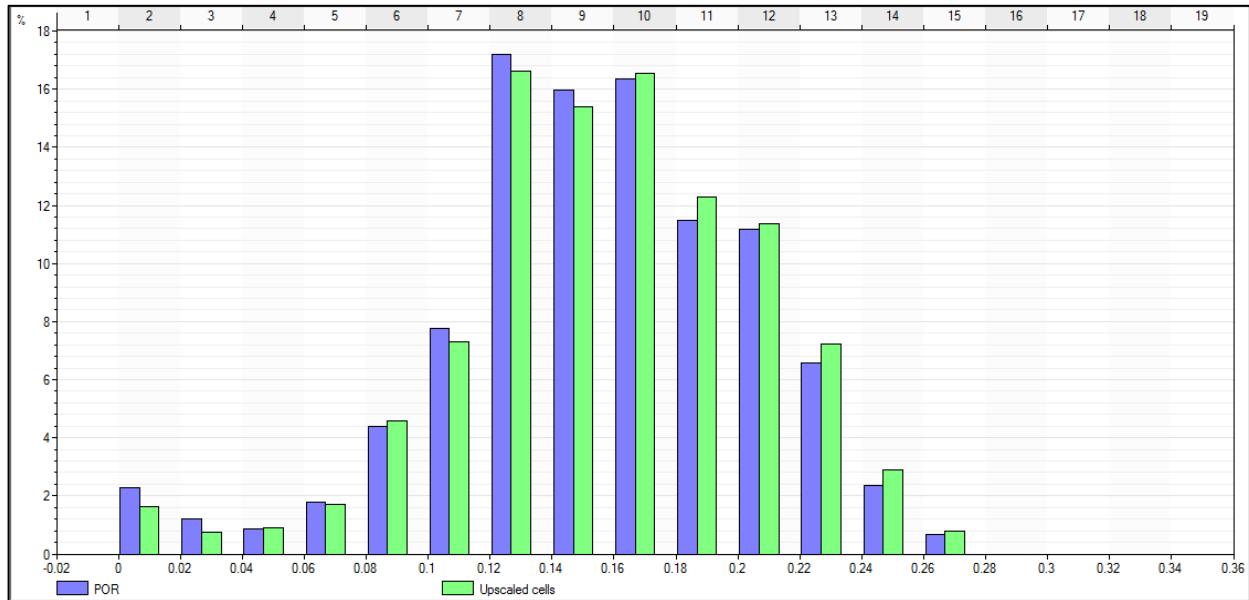


Figure 6. Statistical comparison of log, upscaled and modeled of porosity.

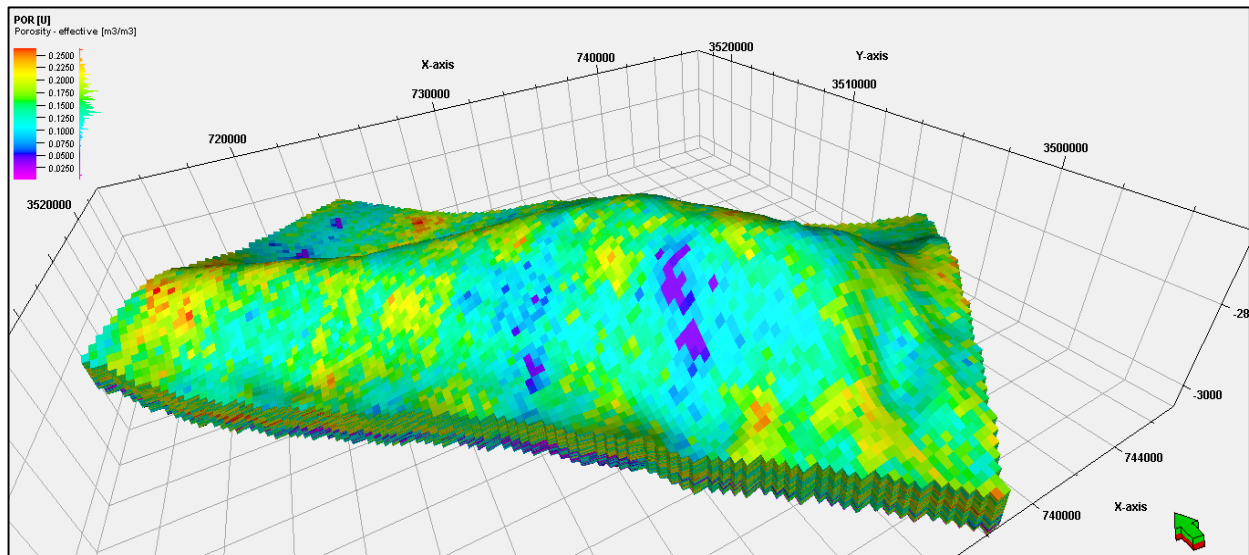


Figure 7. 3D map of porosity distribution for Sadi reservoir.

2.2. Permeability Model

As known, the well logging techniques cannot measure permeability directly, therefore, the permeability can be calculated by establishing the porosity- permeability relationship from core data, and this method can give a reasonable result for most sandstone and carbonate reservoirs.



Permeability was distributed for the entire studied reservoir in the geological model using Sequential Gaussian technique.

The relationships between the porosity and horizontal and vertical permeabilities, shown in **Figs.8&9**, are used to distribute these properties as depicted in **Figs. 10 &11**.

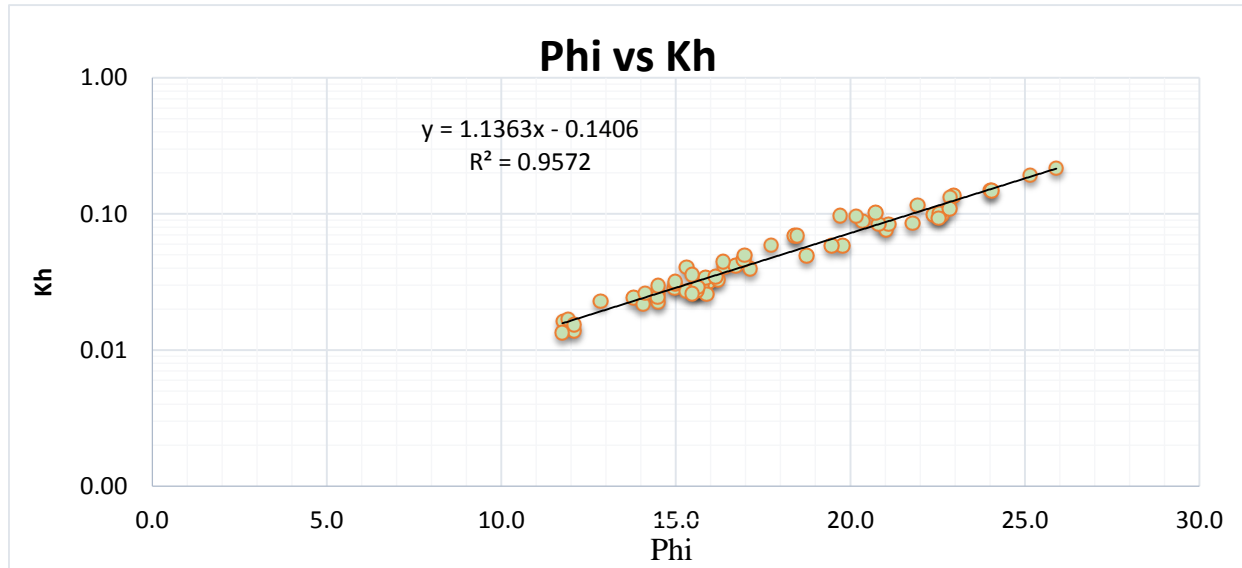


Figure 8. k_H vs. ϕ relationship.

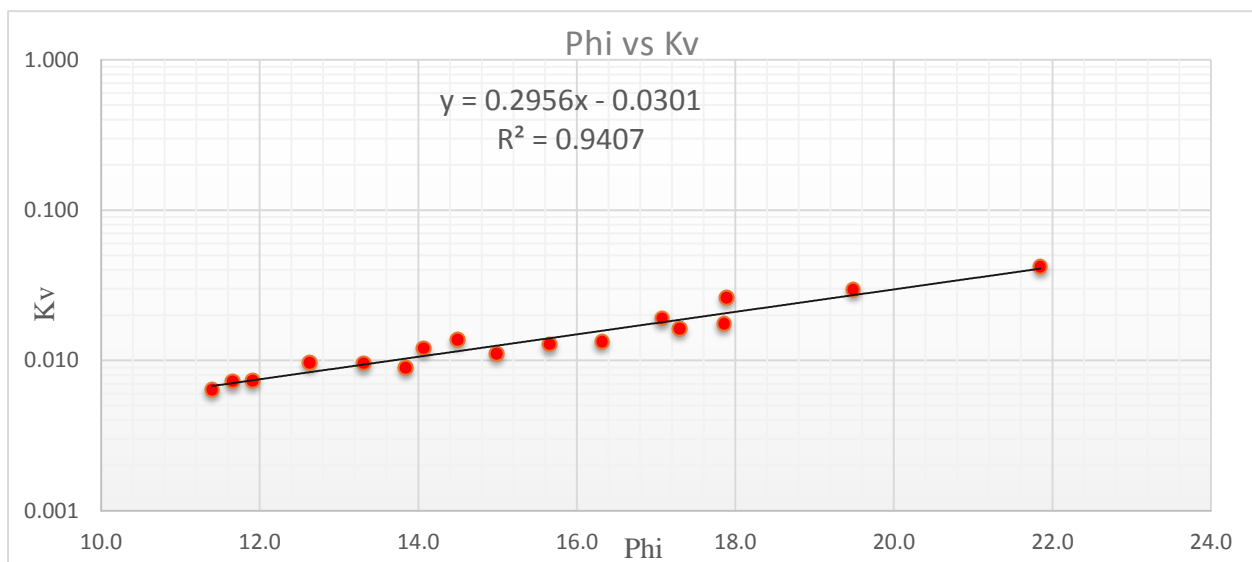


Figure 9. k_V vs. ϕ relationship.

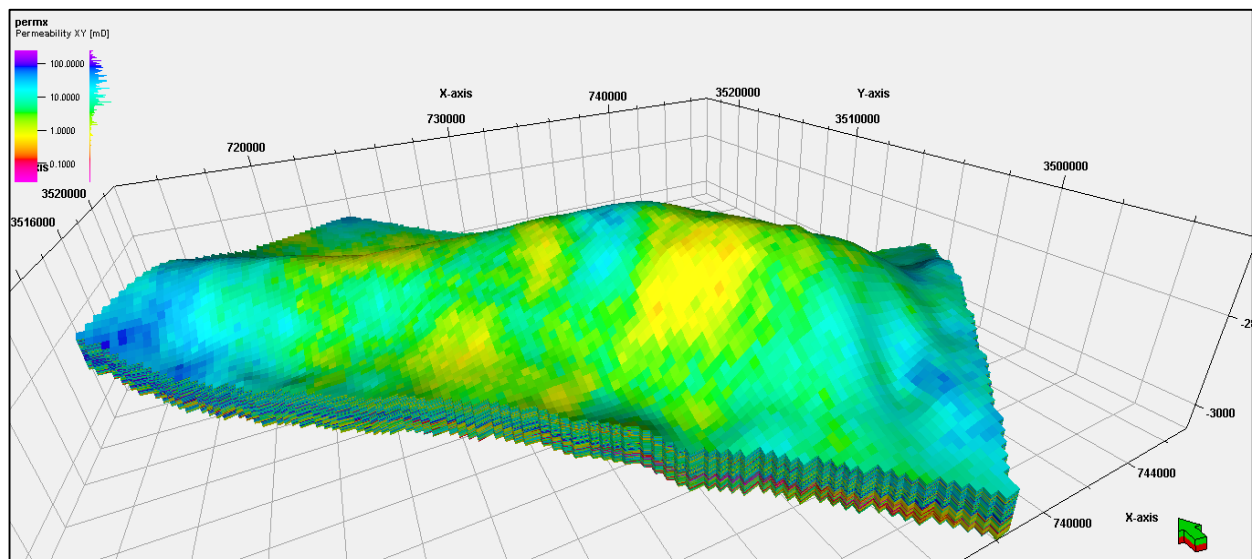


Figure 10.3D map of horizontal permeability distribution for Sadi reservoir.

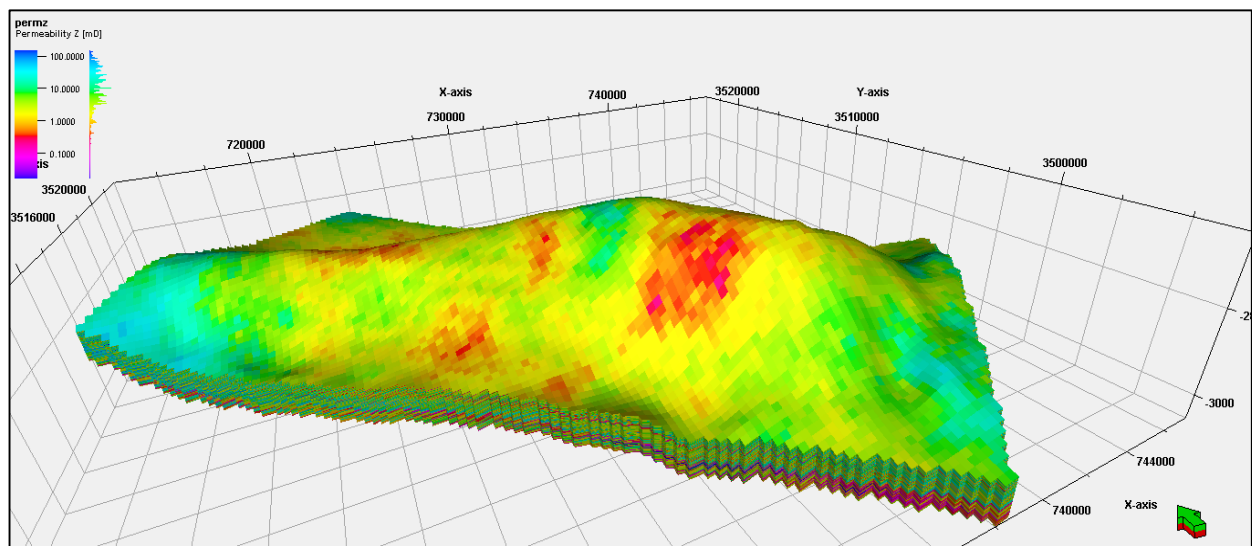


Figure 11.3D map of vertical permeability distribution for Sadi reservoir.

2.3. Water Saturation Model

Water saturation was calculated for all reservoir under study based on well log data using Archie's equation. However, the water saturation was distributed and scaled up by using Petrel 2014, using sequential Gaussian method **Fig. 12**. A reliable matching was achieved for the upscaled S_w logs and the distributed S_w in the model, **Fig.13**.

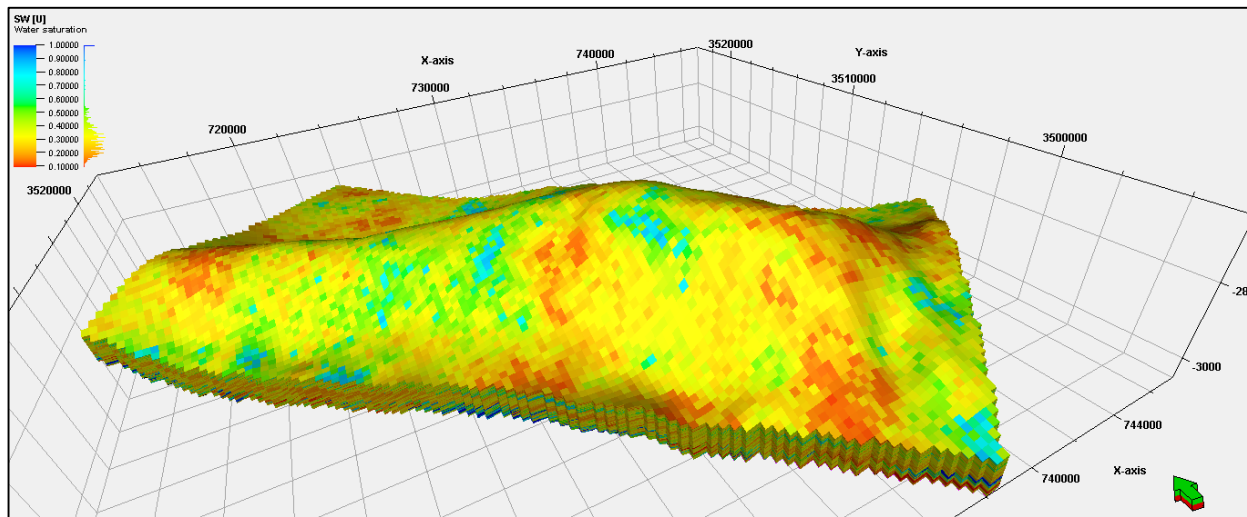


Figure 12. 3D map of water saturation distribution for Sadi reservoir.

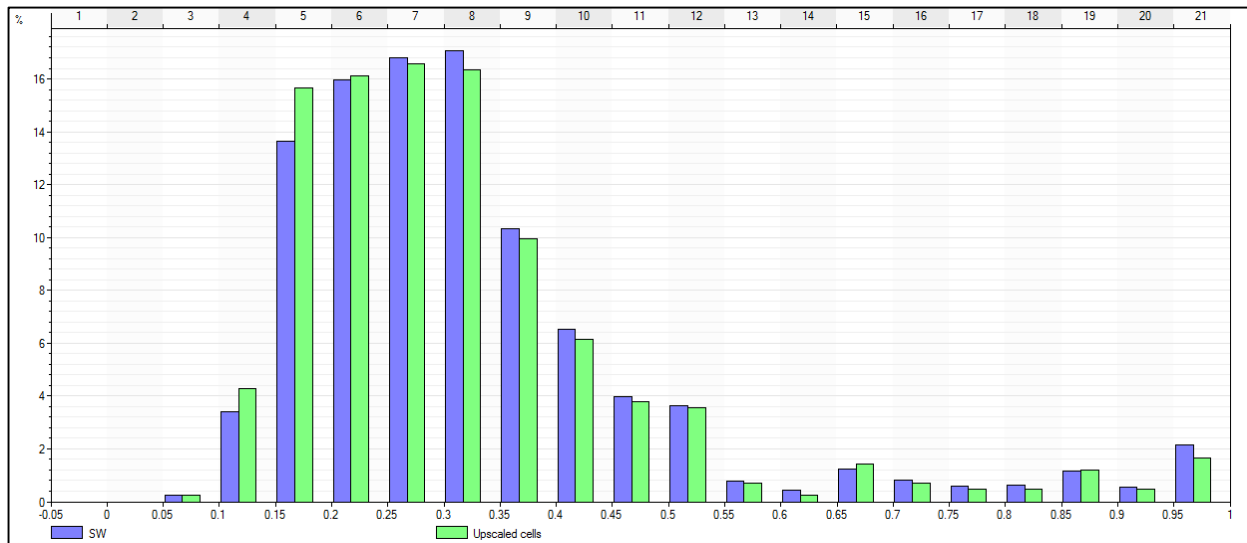


Figure 13. Statistical comparison of log, upscaled and modeled Water Saturation.

2.4. Petrophysical Properties Cut-off:

Cut-offs are simply limiting values of petrophysical properties which are S_w , ϕ , V_{sh} , and k and these properties become limiting values of formation parameters in the context of integrated reservoir studies. However, the purpose is to eliminate those rock volumes that do not contribute significantly to the reservoir evaluation and they have typically been specified in terms of the physical character of a reservoir, **Worthington, and Consentino, 2005**.

A suitable shale volume cut-off, V_{sh} , should be used to discriminate reservoir rock from shales. The cut-off value of V_{sh} is in the range from 20% to 25%. In Sadi formation, 25% was chosen as V_{sh} cut-off value depending on porosity cut-off, as shown in Fig. 14.

In relation to formation evaluation, this parameter is used to separate between formation rocks that are useful for hydrocarbon production and formation rocks that are not.

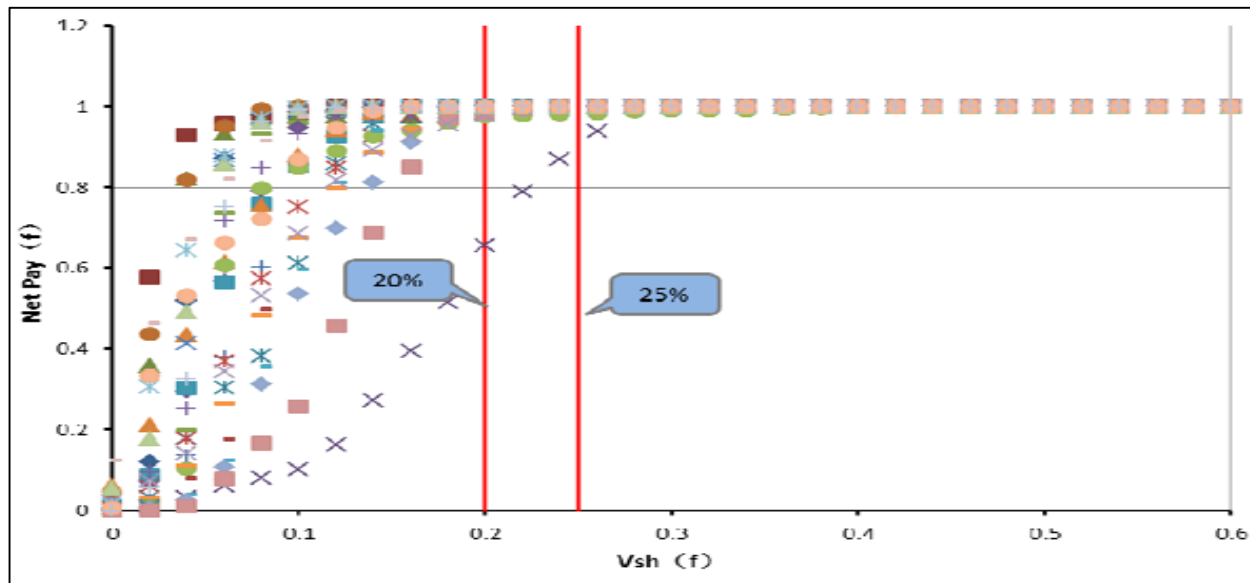


Figure 14. Vsh cut-off from Net Pay.

The relationship between porosity and permeability is basically qualitative in nature **Worthington, and Consentino, 2005**. Certain rocks may have high porosity but near zero permeability, whereas in case of rocks like fractured igneous rocks permeability may be as high as several dozen Darcy, but with corresponding total porosity of one or two percent only, however, the porosity-permeability relationship is the most traditional tool for determining porosity cutoff. Using the relationship porosity cut-off values are established through assuming permeability cut-off, with permeability values of 0.01 md or 0.1 md as the most commonly used values depending on reservoir fluid type and information from core laboratory measurement. Since the carbonate reservoir of Sadi Formation, permeability is the principal control of hydrocarbon deliverability. The cut-off criterion of permeability for this reservoir is generally 0.01 md for oil. **Fig. 15** shows a cross plot of porosity vs. permeability measured using core samples taken from the Sadi formation of the Halfaya Oil Field. From this plot, it was found 0.01 md in core permeability corresponds to approximately 8% in core porosity, which is similar to estimated value by Equivalent Hydrocarbon Column (EHC) as calculated from log interpretation data, **Fig.16**. In addition, water saturation cut-off could be estimated by EHC calculation for different porosity cut-offs. It was calculated as shown in **Fig. 17** and the saturation cut-off was found to be about 50%. The criterion for the net pay is water saturated along with the effective porosity. Accordingly, and based on these cross-plots, the cut-off criteria for the net pay of the Sadi formation were determined as follows:

- Permeability ≥ 0.01 md;
- Porosity $\geq 8\%$; &
- Water saturation $\leq 50\%$.

The average net pay, water saturation, %PV & average effective porosity was found by EHC calculation (Eq. (1)) after estimating shale volume, permeability, & porosity cut-offs for Sadi



Formation (B1, B2 & B3 Units), and it was found about 75 m, while the average thickness of Sadi Formation is about 125 m.

$$EHC = \phi_{avg} * (1 - S_w) * \sum h_{net} \quad (1)$$

Net to gross was assigned by the following equation, **Bouffin, 2007**.

$$NTG = \text{If } (PHIE \geq 0.08 \text{ And } SW \leq 0.50, 1, 0) \quad (2)$$

The net to gross distribution is shown **Fig. 18**.

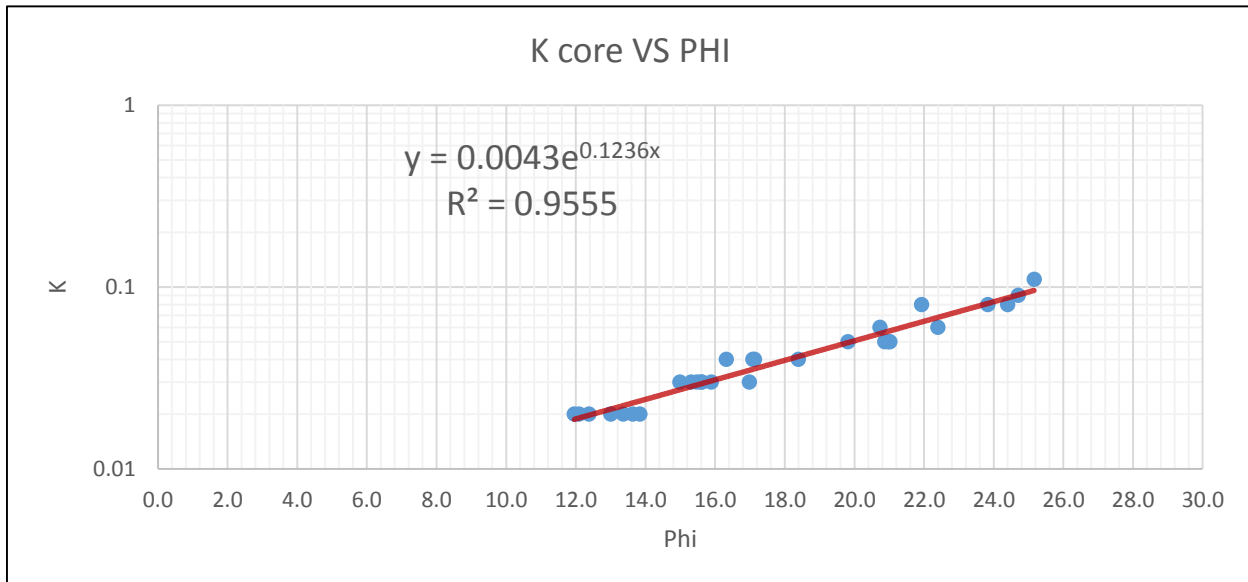


Figure 15. Porosity Cut-off for Sadi Formation.

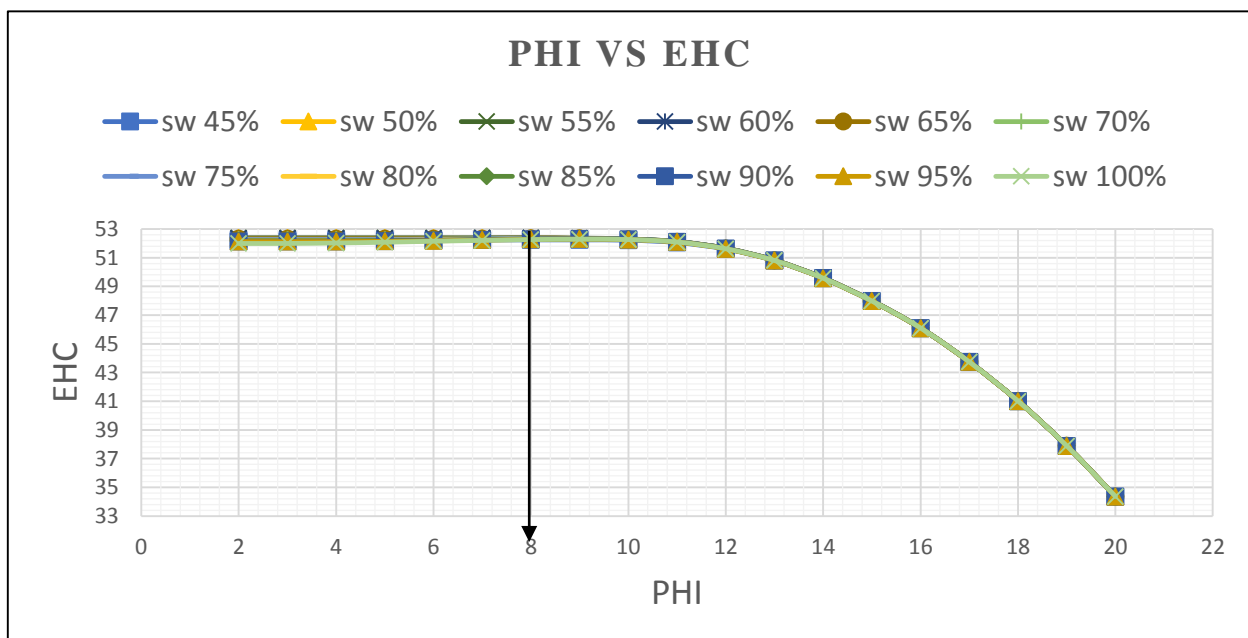


Figure 16. Porosity cut- off from EHC Calculations.

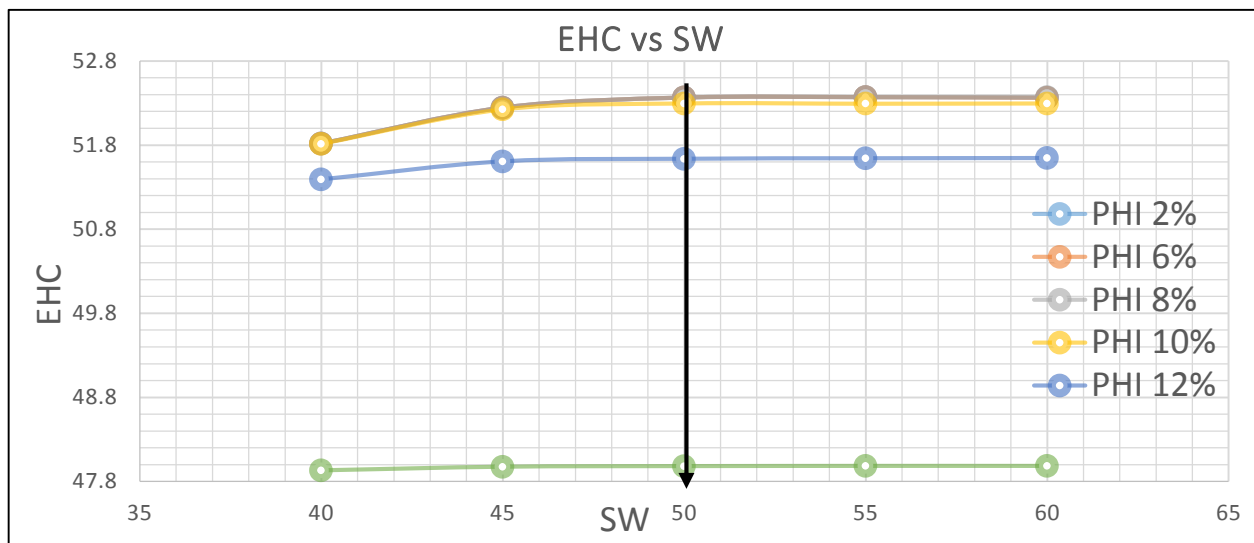


Figure 17. Sw Cut-off from EHC Calculations.

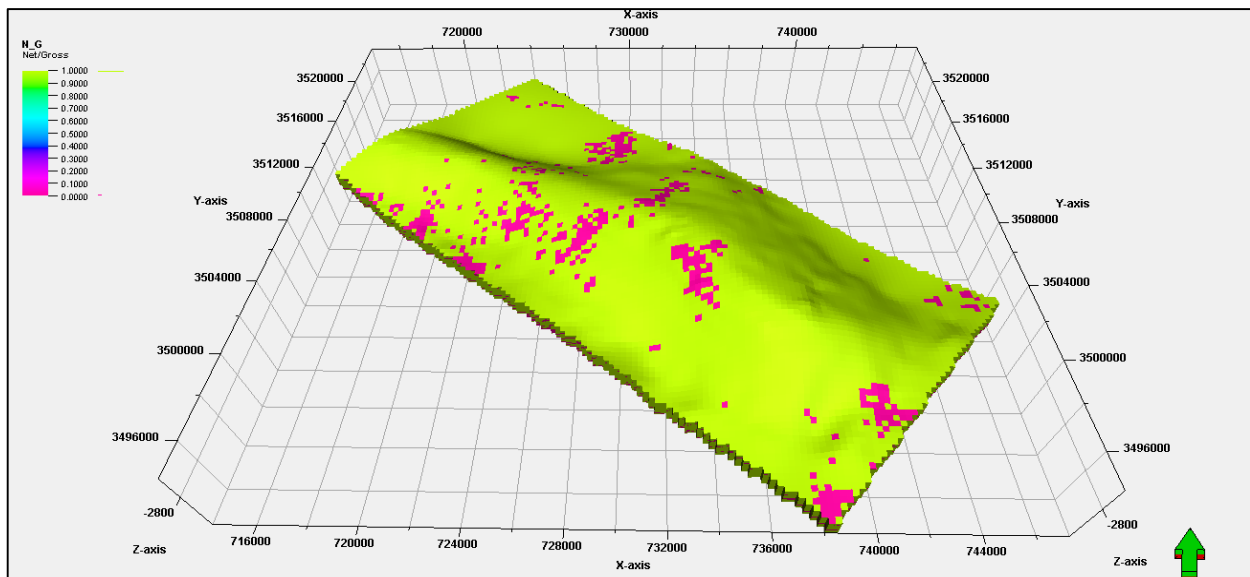


Figure 18.3D map of Net to Gross distribution.

2.5. Well Cross Section

Well cross section was carried out by Petrel software. The Sadi B formation consists of a gentle elongated anticline trending NW-SE to NEW-SEE. **Figs. 19** and **20** show the distribution of petrophysical properties.

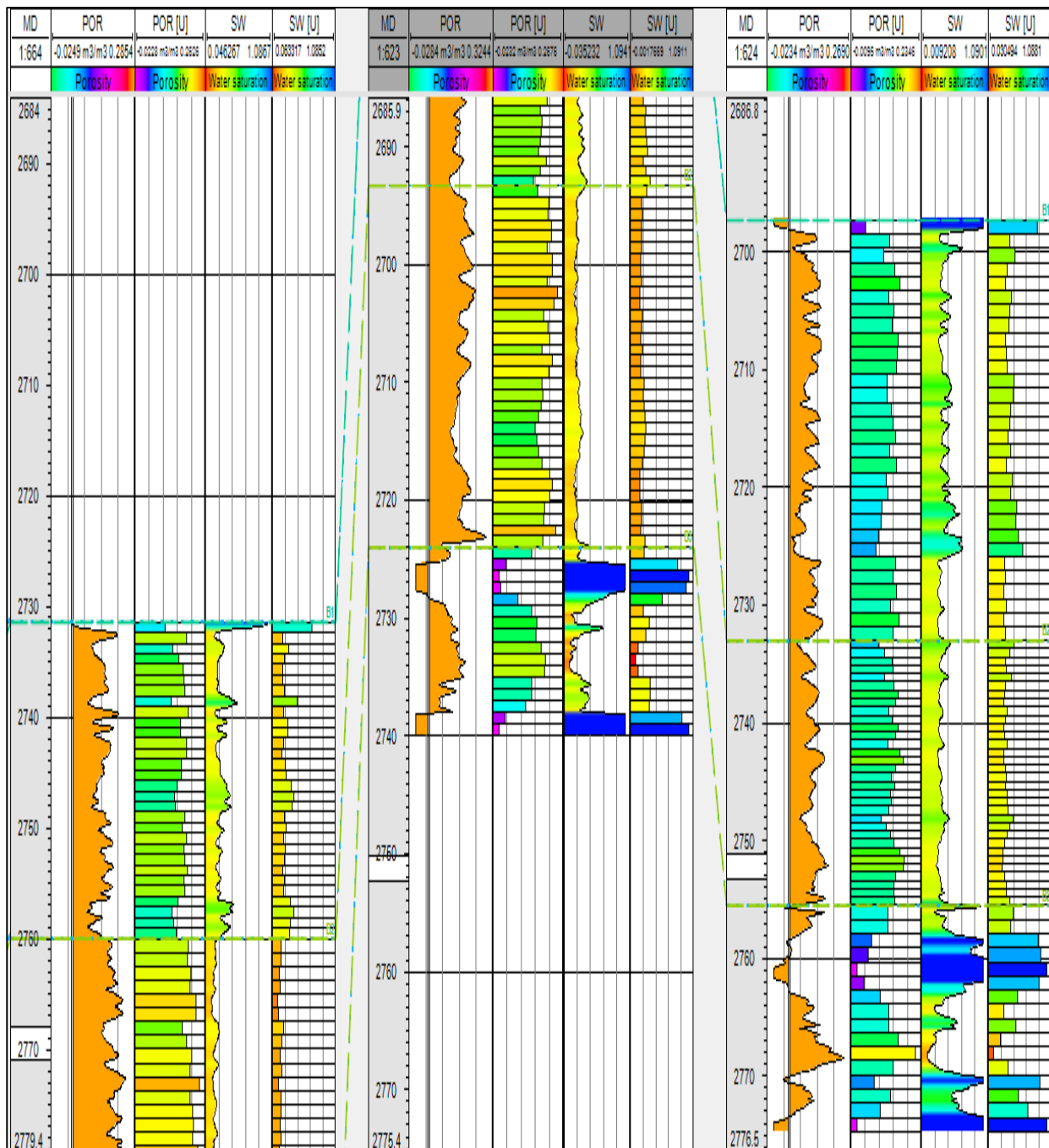


Figure 19. Well correlation of wells (M276, M316 and N055).

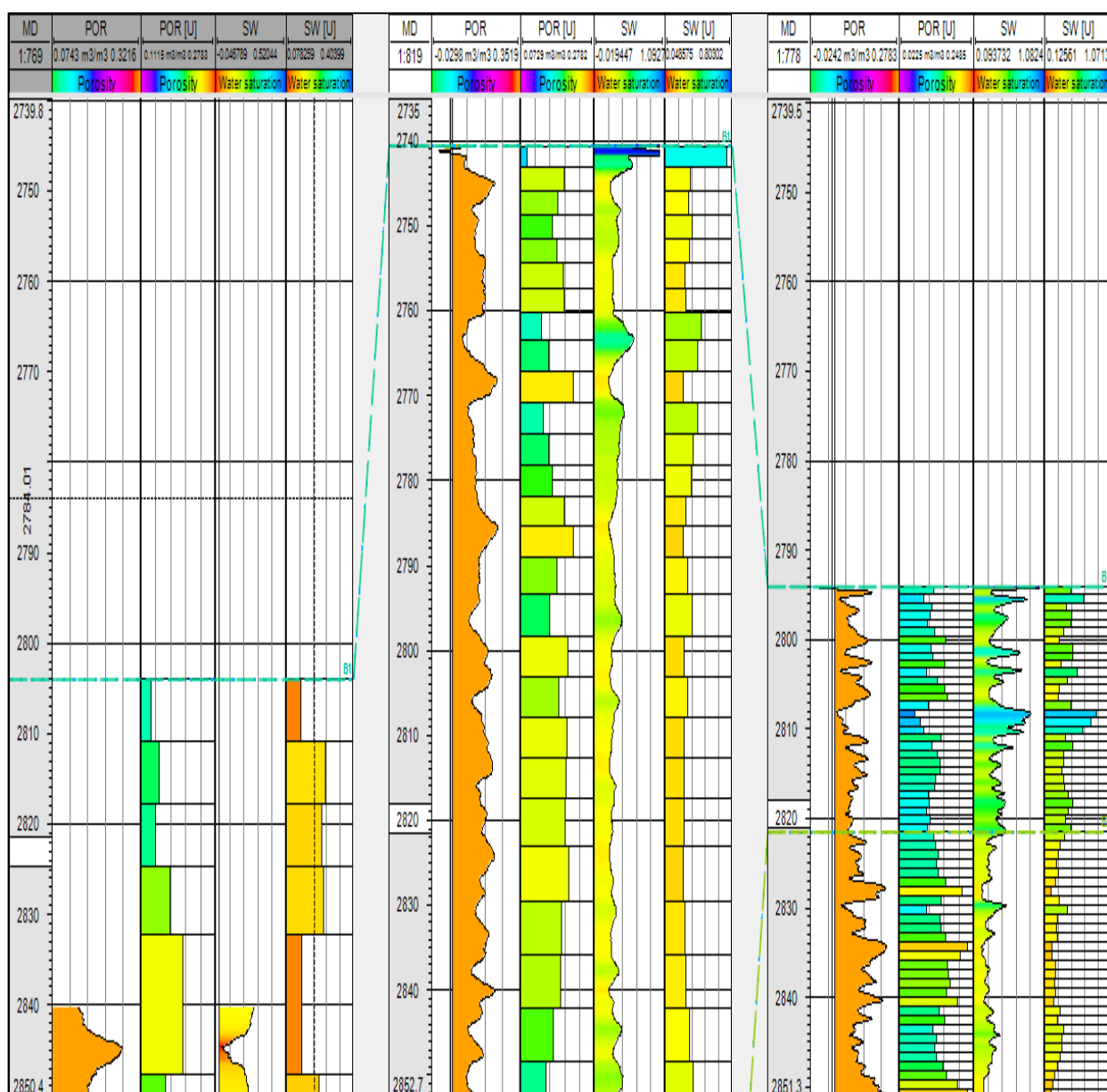


Figure 20. Well correlation of wells (S001H, S007H and N021).

3. CONCLUSION

The main conclusions of this study can be summarized as follows:

- Geological model of Halfaya Oil Field / Sadi reservoir has been constructed depending on a base contour map, CPI, and core data for six wells.
- Petrophysical distribution models of porosity, permeability, and water saturation were built for each unit in Sadi Formation. These models show that unit B2 is the best unit in Sadi Formation in comparison with B1 and B3 units.
- The estimated Oil in place volume by static model equals 3.37MMMSTB.



4. REFERENCES

- Agboada, D., & Ahmadi, M., 2013, *Production Decline and Numerical Simulation Model Analysis of the Eagle Ford Shale Oil Play*. SPE 165315 presented at the SPE Western Regional & AAPG Pacific Section Meeting, 2013 Joint Technical Conference held in Monterey, California, USA (Sep 19-25, 2013).
- Bouffin N., August 2007, *Net Pay Evaluation: Comparison of Methods to Estimate Net Pay and Net-to-Gross Ratio Using Surrogate Variables*.
- Cosentino L., 2001, *integrated reservoir studies*, Editions Technip, Paris.
- CSUR, Canadian Society for Unconventional Resources 2013, *Information about Canada's emerging energy resources, Understanding Tight Oil*.
- MOC, 2013, *Final Development Plan of Halfaya Contract Area*.
- Gary A Simpson and Neil S. Fishman, 2015. 16-21 August 2015, *Unconventional tight oil reservoirs: a call for new standardized core analysis workflows and research*. St. John's, Newfoundland and Labrador, Canada.
- Lee W.J, Hopkins C.W., 2013, *Characterization of Tight reservoirs*, SPE-183661-MS.
- Worthington, P.F. and Consentino, L., 2005, *the role of cut-offs in integrated reservoir studies: SPE Reservoir Evaluation and Engineering*, vol. 8, no. 4, p. 276-290.

ABBREVIATIONS

FDP	final development plan
EHC	equivalent hydrocarbon column
CPI	computer processed interpretation
SW	water saturation, %PV
Φ_{avg}	average effective porosity