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Karst Heterogeneities Captured Through Integration of Static & Dynamic Data

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SUMMARY

Karst impact on Cenomanian – Turonian M carbonates is one of the most challenging aspect related to geologic modelling in the Southern Iraq.

This diagenetic process that encompasses the uppermost 20 to 40 m of the reservoir and enhances reservoir connectivity and permeability, is documented by secondary porosity features like vugs and small solution enlarged fractures related to an emersion period of the carbonate ramp (Late Cenomanian to Turonian).

Karst permeability was recognized at well scale and zones of permeability enhancement were assessed within the upper M sequence integrating all the available static and dynamic data.

The present workflow guarantees an appropriate reconstruction of the internal reservoir and fluid path architecture, resulting in a predictive tool for field development planning.

Introduction

Southern Iraq Mesopotamian basin is one of most attractive region for hydrocarbon exploration and production. Reservoir studies, which capture the hydrocarbon in place and the intra reservoir architecture, are a solid tool for development strategy and economics determination. Full integration of all available static and dynamic data plays a fundamental role in reliable geologic modelling and fluid path reconstruction, leading to a robust model with a high degree of predictability.

The most prolific plays in the studied field are the Cenomanian to Turonian carbonate M Formation (“second pay”), which is the subject of this paper, and the Hauterivian-Barremian clastic Z Formation (Third and fourth pay”). The internal geometry of the formation consists of five stratigraphic sequences of ramp limestones with overall aggrading to prograding geometries, capped by the Top M regional scale unconformity. The reservoir quality is excellent in the rudist and bioclast-rich packstone-rudstone deposited in the middle ramp high energy setting, good to moderate in the fine grained middle ramp low energy packstone-wackestone, and rather poor in the inner ramp packstone and outer ramp wackestone-packstone.

The inner ramp deposits occurring in the upper M section show secondary porosity, like vugs and small solution enlarged fractures, as a result of diagenetic alterations associated to the Top M unconformity and documented in the uppermost 20 to 40 m of the reservoir. The karst event, related to an emersion period spanning from Late Cenomanian to Turonian (about 4,5 Million Years), impacts the reservoir properties of the upper M sequence enhancing reservoir connectivity and permeability.

Since most historical production was attributed to the Karst, capturing its presence and thickness at well and field scale is essential to model the production performance of the field. Karst related permeability was recognized at well scale analyzing cores, image logs, well tests, PLTs, production data, RFT and information from analogous fields. Zones of permeability enhancement were subsequently mapped within the upper M sequence including the seismic data, thereby ensuring high reliability of the reconstructed framework.

Karst heterogeneity characterization and modelling

In the upper M the permeability enhancement is directly connected to karst dissolution effects that generated a wide network of connected vugs. The impact on reservoir properties is confirmed by different type of data. Isotopes (C and O in carbonate matrix and cements) and secondary porosity on cores highlight the emersion phase and the subsequent meteoric alteration; however, due to the scale factor, the core plugs are not capable to record/measure the enhanced permeability. Image logs show high vuggyness, and occasionally aligned connected vugs along small solution enlarged fractures. The continuity seismic attribute exhibits on top of M inferences of sinkholes of karst origin. Well test and PLTs reveal the presence of layers characterised by very high permeability nested in a low permeable matrix (figure 1). Furthermore RFT data confirm that the enhanced permeability layers are generally affected by relatively higher depletion than the matrix background due to high relative production potential over other less permeable perforated zones.

Due to the high complexity in quantifying and reproducing the karst heterogeneity and its related permeability enhancement away from well bore, integration of all the relevant data represented the main challenge for the static modelling of M reservoir. A conventional approach for permeability evaluation only based on routine core analysis, was considered inadequate to match the high levels of production. In order to avoid a permeability multiplier required to address all the inconsistencies between routine core analysis and production data, karst effect was reconstructed inside the static grid, capturing this geologic feature using static and dynamic data sources.

Both PLT and RFT data were used in sync to qualify zones in the field where karst is intersected by wells. Where PLT data was unavailable, RFT was used alone to capture zones of high depletion that were qualitatively assigned to represent the karst presence. Combined interpretation of Well Test results and PLTs allowed to specify the underlying permeability of the karst zone as seen in and around tested wells. Through combination of dynamic information with core descriptions and image logs, a karst influenced area was delimited in the field and the thickness of the karst zone was adjusted based on production results. The average thickness of the karst is about 25 m but there are areas in which this effect is more pronounced and could be much higher.

The continuity cube, in addition to the above mentioned data, was qualitatively used to endorse the karst region evaluation. Sinkholes features were inferred on top M surface and these elements represent zones of potential more pronounced karst effect. Moreover wells in vicinity of sinkholes highlight the highest permeability values, whereas, moving away from the mapped region the permeability range becomes wider. Therefore karst permeability model was constrained to the mapped sinkholes ensuring high reliability to the reconstructed fluid path framework.

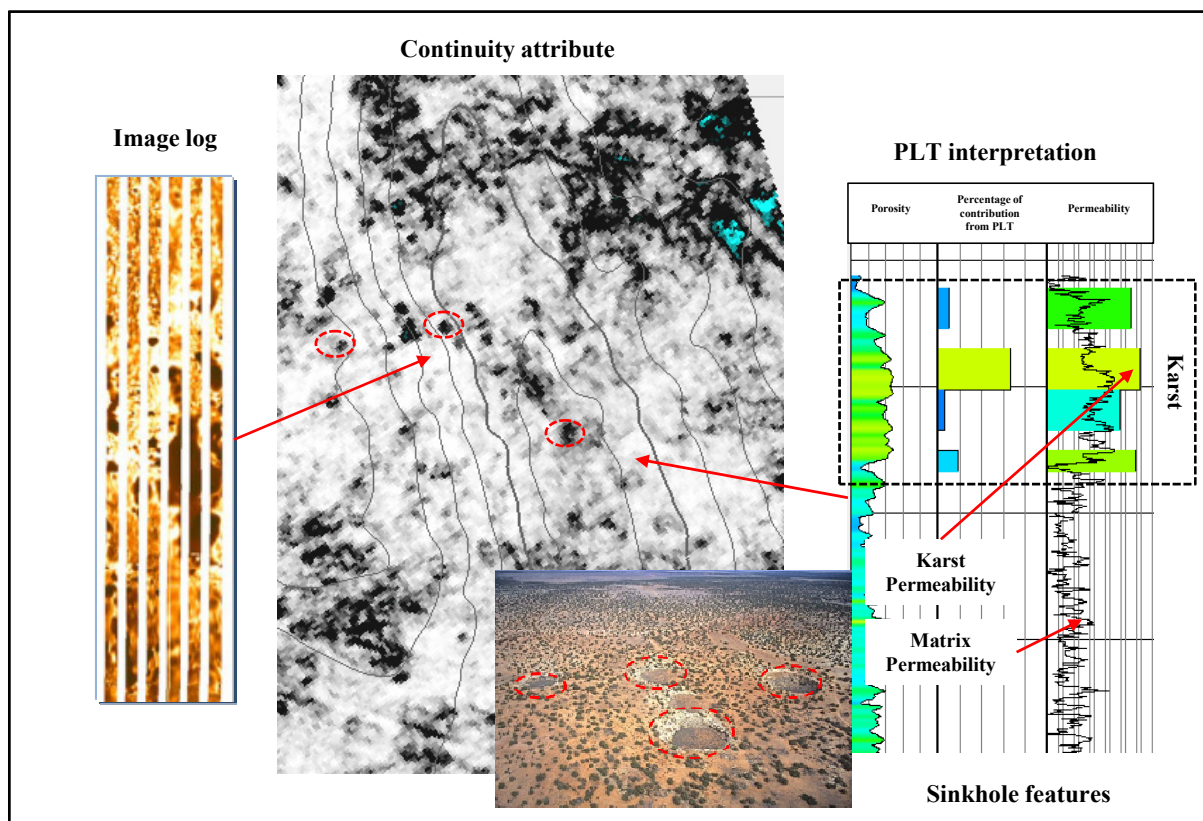


Figure 1 Karst dissolution effects on upper M Carbonate; vugs and sinkhole features from image log and continuity attribute. The consequent permeability enhancement is captured from production data (PLT)

Conclusion

Karst impact on M carbonates represents one of the most challenging tasks of Southern Iraq Mesopotamian basin geological modelling. This important feature was satisfactorily captured both areally and vertically by combining all available sources of static and dynamic data.

The robust modelling of karst results in a model consistent with geology that honours all measured engineering. The model is superior to others where karst would not be captured in this manner and

hence provides a high degree of predictability specially in zones where all available static and dynamic data was duly integrated.

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References

Bigoni, F., Francesconi, A., Albertini, C., Camocino, D., Distaso, R.E., Borromeo, O., and Luoni, F. [2010] Karachaganak Field – Dynamic Data to Drive Geological Modelling, *SPE Caspian Carbonates Technology Conference 2010*, SPE-139881-MS

Burchette, T.P. and Britton, S.R. [1985] Carbonate facies analysis in the exploration for hydrocarbons: a case study from the Cretaceous of the Middle East. In Brenchley and Williams (Eds) *Sedimentology, Recent Developments and Applied aspects*. London Geol. Soc. Spec. **18**, p. 311-338

Aqrawi, A.A.M., Thehni, G.A., Sherwani, G.H. and Kareem, B.M.A. [1998] Mid-Cretaceous rudist bearing carbonates of Mishrif formation: An important reservoir sequence in the Mesopotamian Basin, Iraq, *Journal of Petroleum Geology* **21**(1), 57-82

Sullivan, M., Belanger, D. and Skalinski, M [2006] A New Method for Deriving Flow Calibrated Permeability from Production Logs – *SPWLA 47th Annual Logging Symposium*, June 2006

Holden, A., Lehmann, C., Ryder, K., Scott, B. and Almond, K [2014] Integration of Production Logs helps to Understand Heterogeneity of Mishrif Reservoir in Rumaila. *SPWLA 55th Annual Logging Symposium*, May 2014

Nicholls, C., Hulea, I. and Forkner, R, [2011] Carbonate rock typing – Modelling Heterogeneity, A Case Study Comparison of Whole Core and Core Plug Permeability Data. *AAPG Annual Conference and Exhibition*, April 2011