Asian Journal of

Earth Sciences

ISSN 1819-1886

Academic Journals Inc.

www.academicjournals.com

Asian Journal of Earth Sciences 8 (1): 24-31, 2015
ISSN 1819-1886 / DOI: 10.3923/ajes.2015.24.31

3D Predrill Pore Pressure Prediction Using Basin Modeling Approach in a Field of Malay Basin

Iftikhar Ahmed Satti, Deva Ghosh and Wan Ismail Wan Yusoff
Department of Geosciences, Universiti Teknologi PETRONAS, Tronoh, Perak, 31750, Malaysia

Corresponding Author: Iftikhar Ahmed Satti, Department of Geosciences, Universiti Teknologi PETRONAS, Tronoh, Perak, 31750, Malaysia Tel: 0060192903309

ABSTRACT

Predrill overpressure prediction is an integral part of exploration and drilling in the frontiers areas. Various pore pressure prediction methods such as Eaton and Bowers methods are commonly used for post drill pore pressure prediction using sonic logs and predrill pressure prediction using seismic velocity. The 3D basin modeling is an emerging technique for predrill pore pressure prediction in the frontier areas and it provides an alternative approach. In this study, 3D basin modeling approach is used to evaluate the pressure distribution in the study area. The predicted pore pressure using the default values of porosity, effective stress and permeability, did not match with the measured pressure data in the well. However, after calibration of the porosity-effective stress, porosity- permeability relationship and changing the sealing/non-sealing properties of the faults, the predicted pressure showed a good match with the measured pressure data at blind well locations.

Key words: Pore pressure, basin modeling, predrill, calibration, effective stress

INTRODUCTION

The Malay Basin is NW-SE trending basin, approximately 500 km by 250 km in extent and underlain by Pre-Tertiary basement of metamorphic and igneous terrains. Malay Basin is one of the deepest extensional basin in the region and formed during Early Tertiary times. Narathiwat High separates the Malay Basin from the Thailand's Pattani Basin and the Tenggol arch separates the Malay Basin from Penyu Basin. The basin is bounded by relatively shallow (<1.5 km) basement areas: The Narathiwat High to the northwest, Con Son Swell to the northeast Terengganu Platform and Tenggol Arch to the southwest (Madon *et al*., 1999). The structural framework of Malay Basin is shown in Fig. 1. The Malay Basin is asymmetrical along its length and in cross section. Its southwestern flank is slightly steeper than its northeastern flank. The Malay Basin is a complex rift composed of numerous extensional grabens, most of which have not been penetrated because of their greater depth.

The depth to the start of overpressure varies across the Malay Basin. Top of overpressure is shallower in the basin center (i.e., 1.9-2.0 km) and gradually deepens towards the basin flanks (i.e., 3.0 km) (Hoesni, 2004). The study area is located in the southwestern part of the Malay Basin (Fig. 1). The depth to start of overpressure is variable and it shows very complex behavior in the study area.

There are two main approaches for 3D predrill pore pressure estimation: (1) Geological using basin modeling and (2) Geophysical using seismic velocity. Basin modelling can be used to analyze

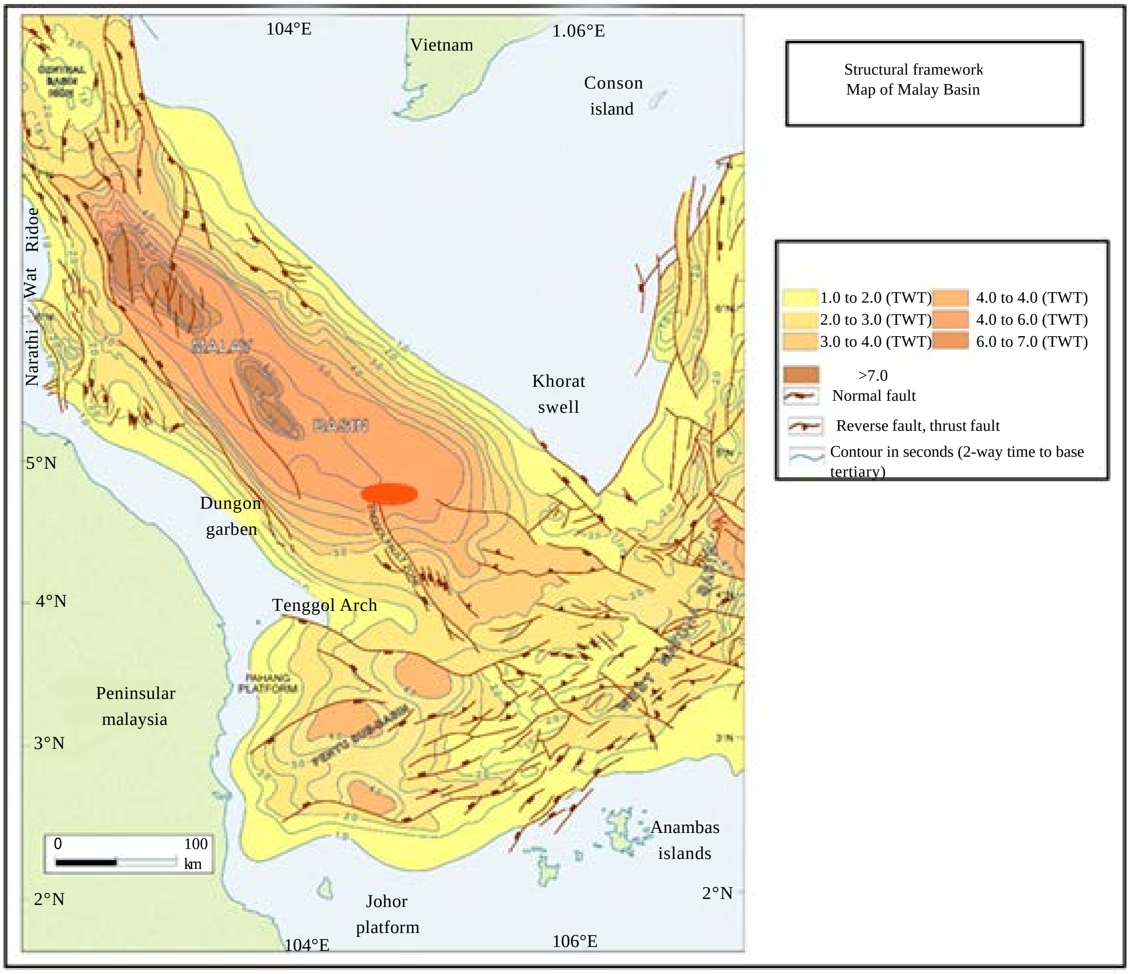

Fig. 1: Structural framework map of Malay Basin after IHS Energy in 2010. The red oval shape shows the location of the study area

the loading and unloading history of the sediments, as well as impact of diagenetic reactions. The velocity of seismic waves depends on the porosity and pore pressure, as well as the burial history of the sediments. Both compressional and shear velocity change with burial depth. Information provided by basin modelling can help establish the correct velocity-pressure relation to use in the pore pressure analysis (Bowers, 1995). A large part of the sediment fill in sedimentary basins is made up of shales. A proper description of the shale sequences is therefore important both for the interpretation of seismic data and for accurate estimation of the overburden properties.

Integrated basin modeling combines a broad range of geologic, geophysical and geochemical data to produce a temporal reconstruction of basin history. It allows the establishment of a sequential record of the changes in controls and products that have occurred during the geologic history of a basin (Poelchau *et al.*, 1997). It can therefore provide detailed information on petroleum formation and occurrence within a sedimentary basin and is routinely used as a quantitative tool in exploration to predict hydrocarbon volume and type ahead of drilling (Thomsen, 1998). Basin modeling is useful to reduce risk in exploration by a better integration of geological, physical(pressure prediction) and geochemical data. In this study, 3D basin modeling technique is used for 3D predrill pore pressure prediction in a field of Malay Basin.

MATERIALS AND METHODS

3D basin model building: PetroMod 3D is used to develop the 3D basin models for the study area. PetroMod combines the seismic, well and geological information to model the evolution of sedimentary basin. The input parameters required to build the 3D basin mode includes:

- Depth converted horizon and fault maps/surfaces
- Facies maps and environment of deposition
- Boundary condition (i.e., PWD, SWIT and Heat Flow etc.)

The depth converted horizons and fault surfaces are obtained from 3D seismic data interpretation. The data set included 3D Pre-Stack Time Migrated (PSTM) seismic data, wireline logs and check-shot data. The seismic data interpretation started with the wavelet extraction from the seismic data at the well location and synthetic seismogram generation. Time contour maps and surfaces of all the interpreted horizon and faults are converted to depth using seismic velocity model.

Facies mapping is one of very important tasks in modelling of oil and gas reservoirs. Different facies has different lithology and lithology have great effect on overpressure generation. To define the lithofacies, lithology is interpreted using GR and density log from all the wells. Different lithology groups are defined and their percentage wise distribution is studied in all the wells. Facies maps for the interpreted horizon are prepared based on well logs data and available biostratigraphy reports. PetroMod map editor utility is used to prepare the facies maps. The boundary conditions such as basal heat flow will be utilized from 1D basin model results. The complete basin model using all these input parameters is shown in Fig. 2.

Basin model calibration and pore pressure prediction: After performing an initial 3D simulation of the model, the model was calibrated for pore pressure prediction. The workflow for model calibration is shown in Fig. 3 and it consist of two steps:

- Adjusting porosity
- Adjusting permeability and fault properties

The porosity-effective stress data from 8 wells was used in basin model calibration for pore pressure prediction. The porosity data is taken from the same depths for which pore pressure data are available. The effective stress was calculated by subtracting the RFT pressure measurements from overburden pressure generated by PertoMod. In the lithology editor, six lithologies were created and four of them used in model calibration for pore pressure prediction. The porosity-effective stress data of the selected lithologies was transferred into the PetroMod lithology editor for the porosity calibration.

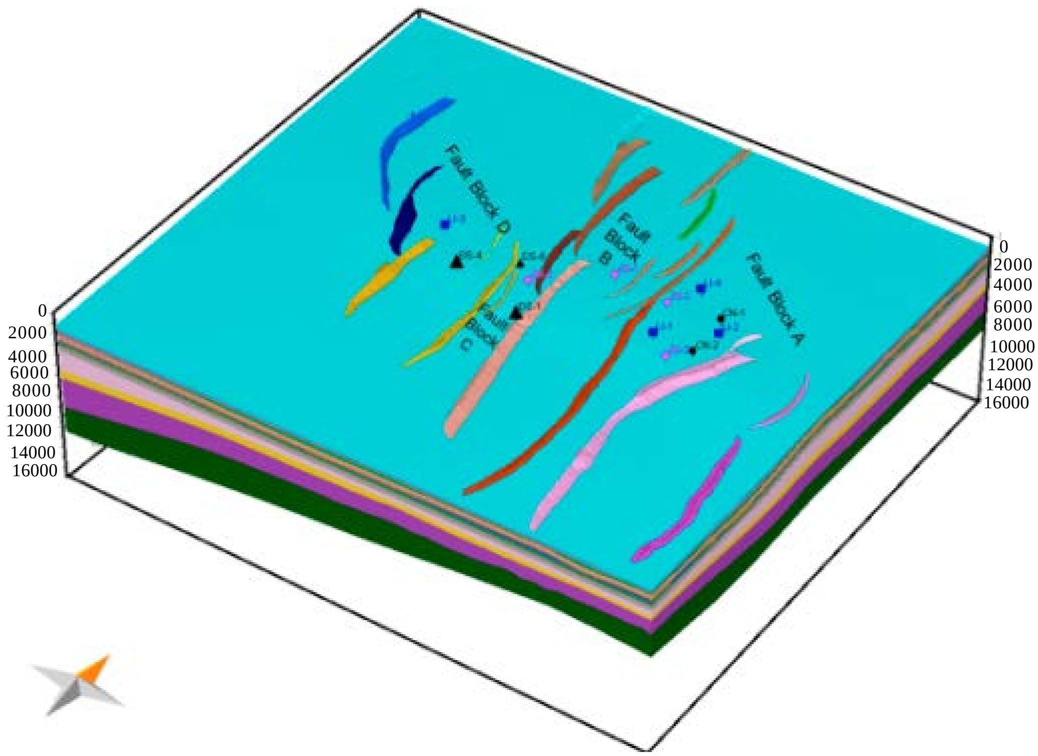

Fig. 2: Complete 3D basin model of the study shows the location of the wells and fault blocks

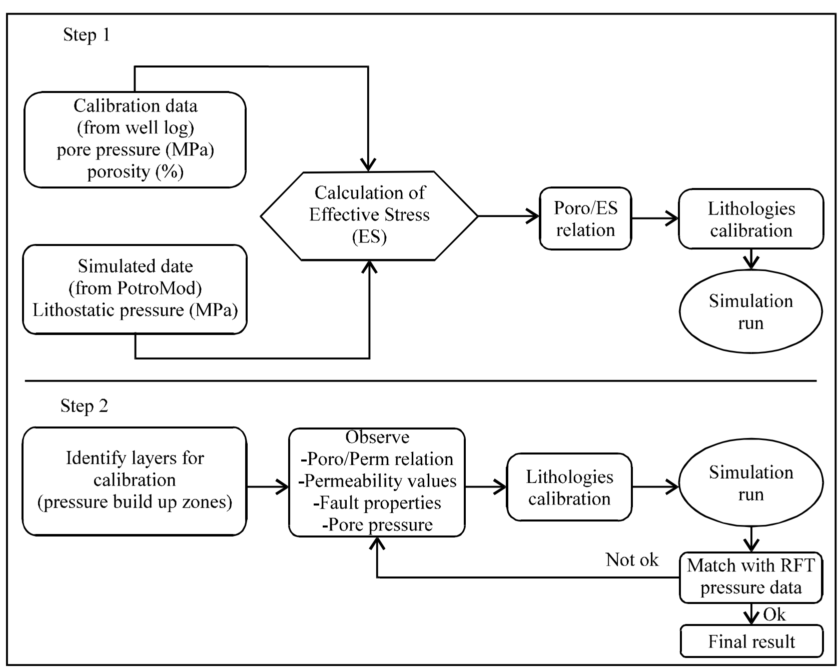

Fig. 3: 3D basin model calibration workflow for pore pressure prediction (Modified from PetroMod manual)

The second step of the model calibration is to adjust the permeability of lithologies that build pressure. The calibration of the permeabilities of the relevant lithologies is the major part of the model calibration for pore pressure prediction. The pressure profile extracted at 1D location gives the information that the permeability of which layers needs to be changed. The permeability of the selected layers is changed under the "Permeability" tab of the lithology editor. After porosity-permeability adjustment the faults area also incorporated in the calibration process. In this study twenty-two faults are used in model calibration.

The first 3D model was run using the default values of porosity, effective stress and permeability. The pressure prediction results using default values were compared with the RFT pressure measurements (Fig. 4).

More than 50 simulations were run using the different values of porosity-permeability and changing properties of the faults (i.e., closed or open) in each simulation. The effect of faults on pore pressure prediction is shown in Fig. 5.

After every simulation the predicted pressure was extracted at well location and compared with the RFT data. This simulation process continued by changing the porosity-permeability relation and fault properties until a better match was found between the predicted and measured RFT pressure data.

The final 3D pressure model is shown in Fig. 6. The model was then validated by exporting the predicted pressure at blind well locations in different fault blocks. The predicted pressure was compared with the RFT pressure measurements at these blind well locations. The porosity, effective stress and permeability trends of the lithologies used in final calibration are shown in Fig. 7a-c.

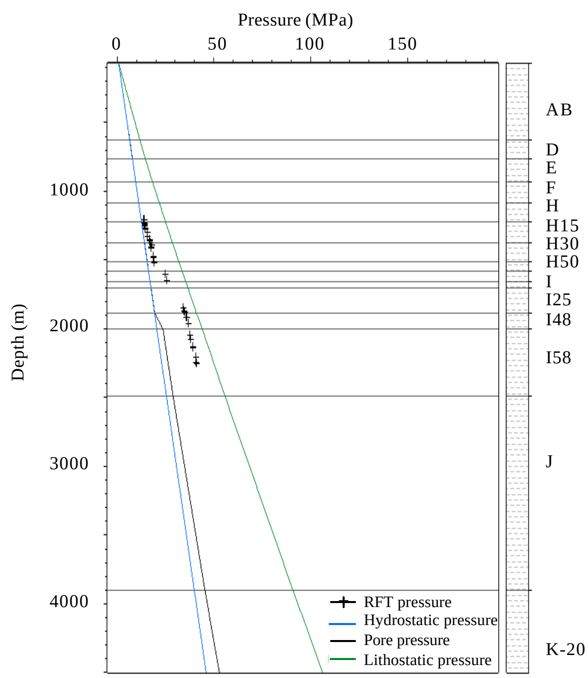

Fig. 4: Pore pressure at a well location (CN-2), extracted from 3D basin model before pore pressure calibration

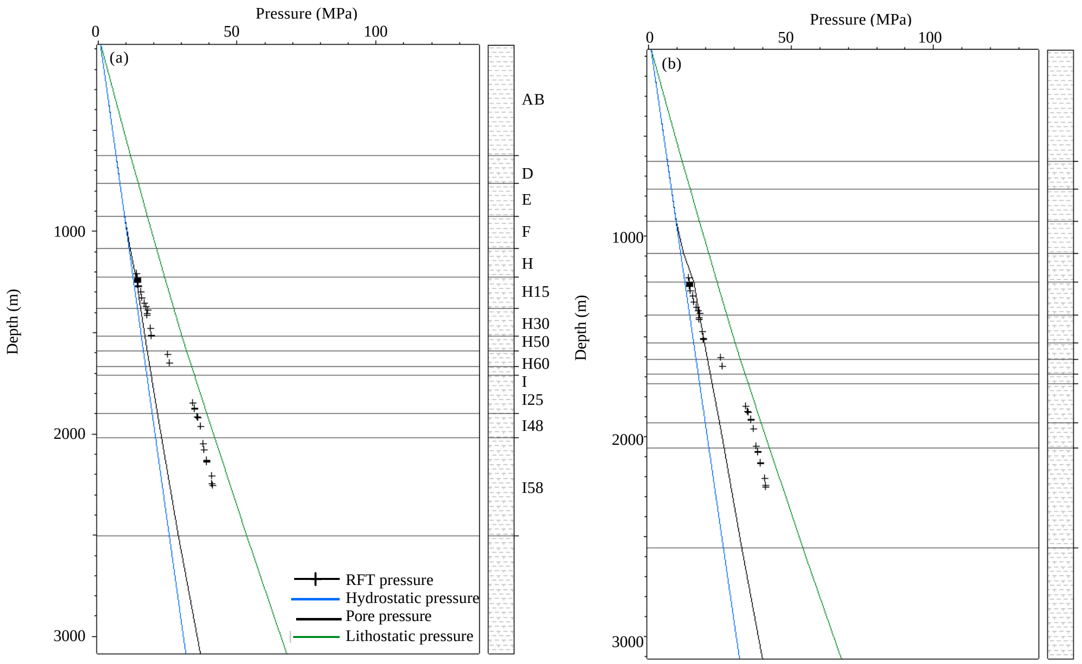

Fig. 5(a-b): Effect of faults on pore pressure calibration. Pore pressure calibration when (a) The fault properties set as open and (b) The fault properties set as closed

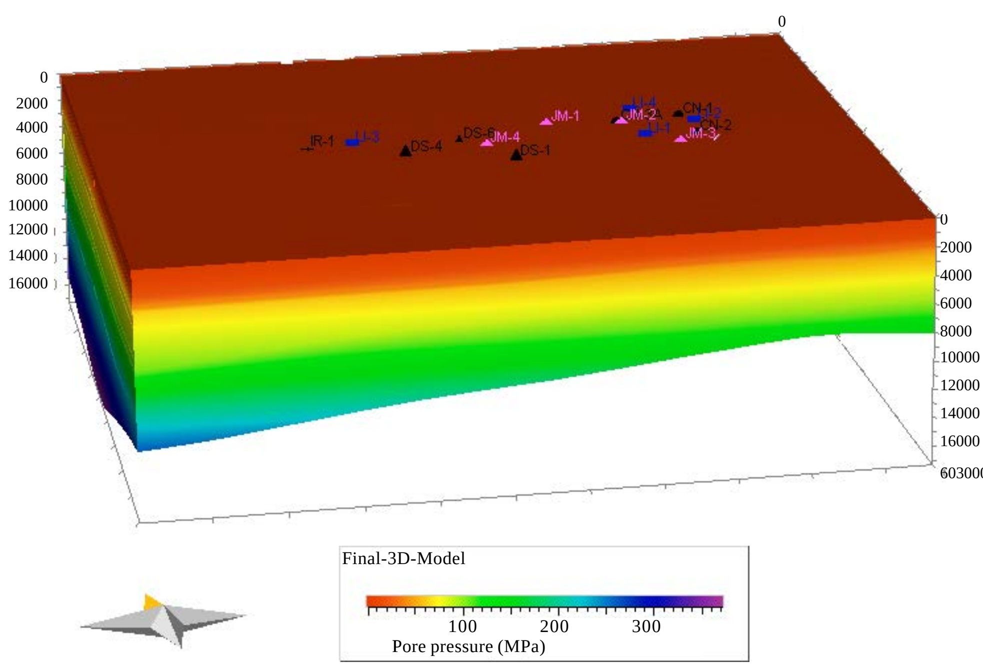

Fig. 6: Final 3D calibrated basin model overlain by pore pressure

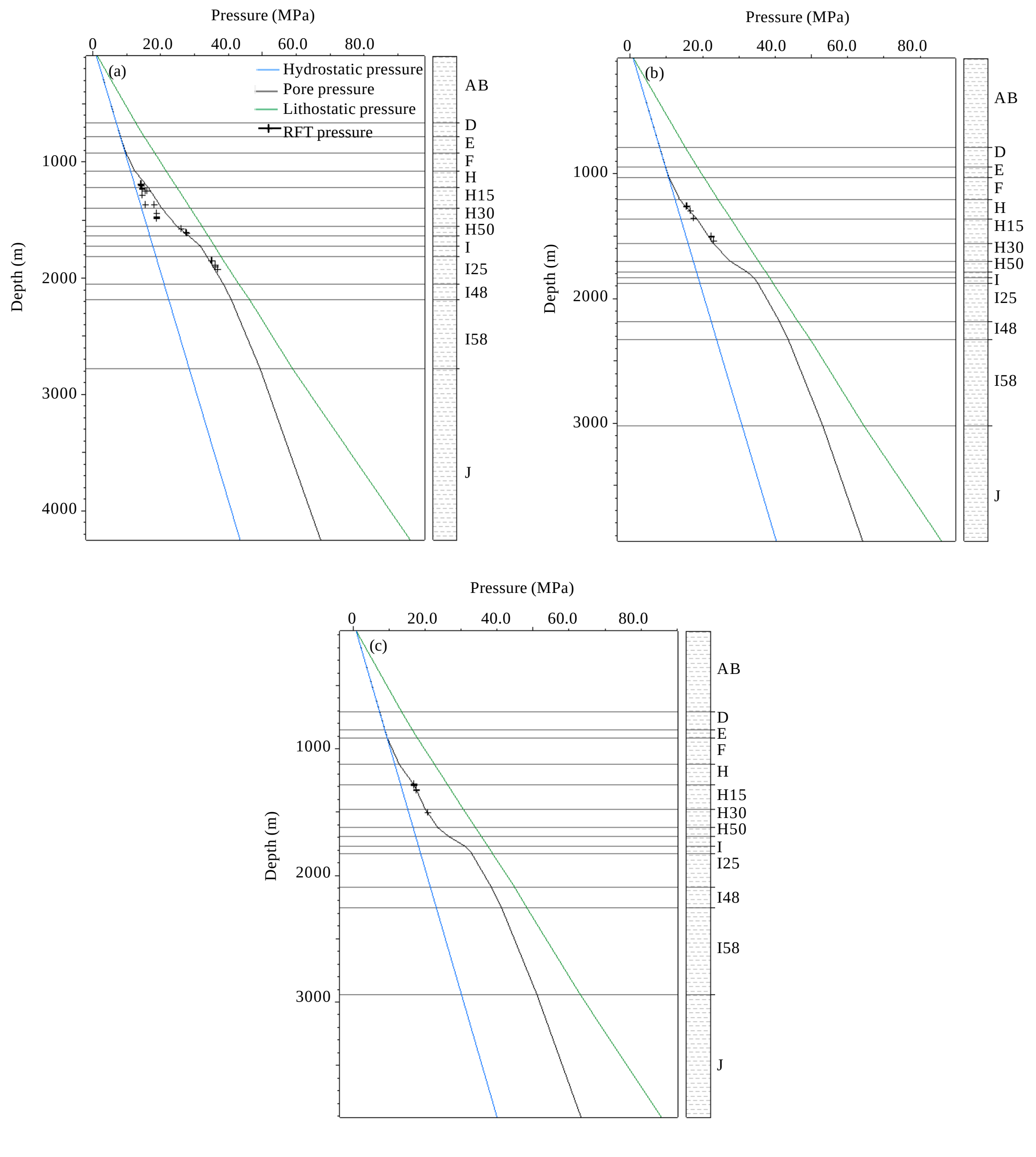

Fig. 7(a-c): Predicted pore pressure extracted at a blind well location in fault (a) Block A, (b) Block C and (c) Block D. The predicted pressure is compared with the RFT pressure data

RESULTS

The basin model building requires a lot of input parameters that need to be correctly defined to get good pore pressure prediction results. The lithologies with default parameters, failed to reproduce the overpressures demanded by the measured calibration data (RFT). The calibration of porosity-effective stress, porosity-permeability and properties of fault showed significant impact on pore pressure prediction. After the model calibration, the predicted pressure showed a good match with the RFT pressure data at blind well locations. The model calibration showed that in the study area, most of the faults were sealing/closed faults.

DISCUSSION

The results of this study showed that along with the conventional pore pressure prediction methods that uses the wireline logs and seismic velocity, basin modeling techniques can also provide an alternative approach for pore pressure prediction in the moderately explored areas.

The basin model calibration results showed that the basin modelling can be used for 3D pore pressure prediction in the study area, provided that all the input parameters are correctly defined. Porosity-effective stress and porosity-permeability relationship plays and important role in model calibration for pore pressure prediction. The default relationship between porosity-effective stress and porosity-permeability is not useful for pore pressure prediction. Therefore, it is required to calibrate the default values of porosity, effective stress with the measured data from the well and adjust the permeability values. Along with porosity, effective stress and permeability calibration, the faults also plays a significant role in pore pressure prediction. Different properties of faults (i.e., open or closed) have different effect on pore pressure prediction. In the study area, facies variation also occurs and controls the pressure distribution. Therefore, it is believed that both faults and facies control the pressure distribution.

ACKNOWLEDGMENTS

We wish to thank Universiti Teknologi PETRONAS (UTP) and PETRONAS Carigali for providing the data and permitting to publish these findings. We are also thankful to Dr. Jamaal Hoesni, Peter Abolins and Ismatul Hani from PETRONAS Carigali and Dr. Swapan Kumar from UTP for their valuable suggestion and discussion. Thanks are also due to Mr. Zailani Abdul Kadir from Schlumberger (Malaysia) for providing the software support. Special thanks to Center of Seismic Imaging (C.S.I.), Universiti Teknologi PETRONAS for providing facilities to carry out this research work.

REFERENCES

Bowers, G.L., 1995. Pore pressure estimation from velocity data: Accounting for overpressure mechanisms besides undercompaction. SPE Drilling Completion, 10: 89-95.

Hoesni, M.J., 2004. Origins of overpressure in the Malay Basin and its influence on petroleum systems. Ph.D. Thesis, University of Durham, Durham.

Madon, M., P. Abolins, M.J. Hoesni and M.B. Ahmad, 1999. Malay Basin. In: The Petroleum Geology and Resources of Malaysia, Madon, M. and P. Abolins (Eds.). Petronas, Kuala Lumpur, Malaysia, ISBN-13: 9789839738100, pp: 173-217.

Poelchau, H.S., D.R. Baker, T. Hantschel, B. Horsfield and B. Wygrala, 1997. Basin Simulation and the Design of the Conceptual Basin Model. In: Petroleum and Basin Evolution, Welte, D.H., B. Horsfield, D.R. Baker (Eds.). Springer, Berlin, Heidelberg, ISBN-13: 978-3-642-60423-2, pp: 3-70.

Thomsen, R.O., 1998. Aspects of applied basin modelling: Sensitivity analysis and scientific risk. Geol. Soc., 141: 209-221.