# PREDICTING THE QUALITY OF MIDDLE MIOCENE RESERVOIR OF SOME UNDRILLED PROSPECTS IN NORTH SONG HONG BASIN

**Nguyen Duong Trung, Tran Nhu Huy**
*Petrovietnam Domestic Exploration Production Operating Co., Ltd*
**Nguyen Quoc Quan**
*Vietgazprom Joint Operating Co.,*

**Summary**

***Song Hong basin evolution was related to the extrusion and clockwise rotation of the Indochina block, which were caused by the collision of the Indian and Eurasian Plates. The extrusion along the Red River Fault Zone, accompanied by clockwise rotation of the Indochina block, controlled the Tertiary sedimentation and deformation of the North Song Hong basin. As the deformation varied along the Red River Fault Zone, the strong uplift and erosion in Late Miocene were only recorded in the North Song Hong basin. There will be a great uncertainty if we use the relationship of porosity versus depth of drilled wells in uplifted and eroded prospects to predict that relationship for undrilled prospects of which the uplift and erosion are unknown.***

***A combination of seismic data and surrounding well data could help minimise the uncertainty in predicting the relationship of porosity versus depth in the undrilled prospects. This approach was presented in this paper and applied to Middle Miocene reservoir of prospects KL and DL in the North Song Hong basin.***

## 1. Introduction

The Song Hong basin, about 600km in length, is elongate seaward of the Red River Fault Zone and developed NW-SE, NNW-SSE to the South of Hainan Island. The basin was formed in the Paleogene and Neogene Periods. The thickest Tertiary sediments at the depocenter exceed 17km in thickness [3]. In the North Song Hong basin, due to uplift and erosion, the current depth of the reservoir does not reflect what depth it was in the past.

The Song Hong basin evolution is very complex, however the authors agreed that deformation and uplift took place in the North of Song Hong basin (mainly in the Hanoi Trough and offshore Blocks 102, 103, 107 - Fig.1) from 10.5Ma to 5.2Ma [2, 3, 5]. Uplift and erosion were found in some areas to exceed 1,000m[7]. In conclusion, the uplift and erosion are strong and variable, so that prediction of the relationship of reservoir porosity versus depth is challenging.

## 2. Predicting reservoir quality by using seismic velocity ($V_p$) and reference well data

Generally, the velocity ($V_p$) depends on the elastic modulii and density via:

$$Vp = \sqrt{(K+3/4\mu)/\rho} \quad (1)$$

Where:

- $V_p$ is compression wave velocity;
- K is bulk modulus;
- $\mu$ is shear modulus;
- $\rho$ is rock density.

From the $V_p$ equation, the elastic constants, and densities, in turn depend on the properties that the geologist or engineer uses to characterise the rock, such as porosity, fluid saturation and texture, etc. However, the main factors that affect compression velocity are as follows:

- Rock porosity;
- Rock matrix elastic properties (usually depend on compaction process, cementation process, and diagenesis);
- Formation pressure.
- A very rough rule due to Wyllie is the so-called time average relationship:

$$\frac{1}{Vbulk} = \emptyset/V_{fluid} + (1-\emptyset)/V_{matrix} \quad (2)$$

Where $\phi$ is the porosity

This is not based on any convincing theory but is approximately correct when the effective pressure is high and the rock is fully saturated[1]. From the above equation (2), assumption of $V_{fluid}$ and $V_{matrix}$ are background so that seismic velocity is directly related to porosity.

The methodology of using seismic velocity to predict undrilled prospect reservoir quality:

- Build the relationship of porosity versus depth of surrounding wells. From that chart, we can define the upper boundary and the lower boundary of porosity decay versus depth. By comparing the seismic velocity of undrilled prospects to that in the wells we can predict what the trend of porosity versus depth should be.

- Use the processed seismic velocities of one vintage to minimise unconformity of velocity due to seismic noise, manual velocity picking and different processing sequences. In this study, the seismic velocities used were from PVEP 2011 2D seismic survey and processed by Fairfield Vietnam in 2011 - Fig.2). The charts of surface seismic interval velocities and well interval velocity were built together to verify the quality of surface seismic velocity. If all velocities fit each other, we consider that the surface seismic velocities are qualified for predicting reservoir quality.

- Build the relationship of surface seismic interval velocities in the undrilled prospects and overlay the surrounding well velocities. If undrilled prospect seismic velocities are faster than the well velocities at similar depth, it is predicted that the porosity trend should be in the boundary (low reservoir quality) of the porosity versus. depth chart of wells built previously. Otherwise, if undrilled prospect seismic velocities are slower than well interval velocity, the high trend reservoir porosity and depth is predicted for that prospect.

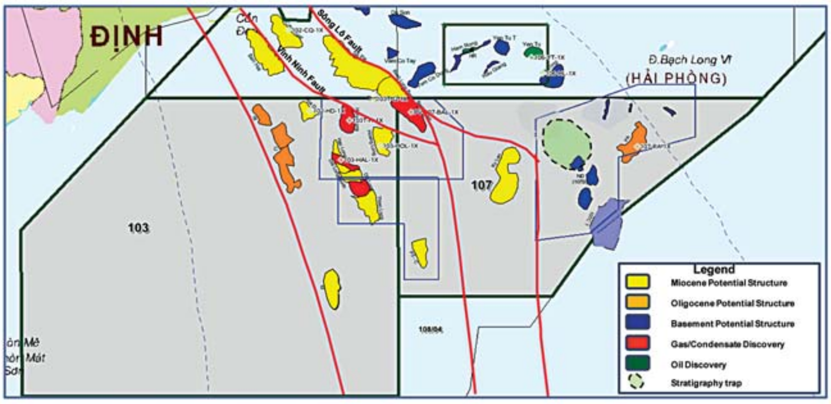


***Fig.1.*** *Block 103 & 107 and prospect inventory*

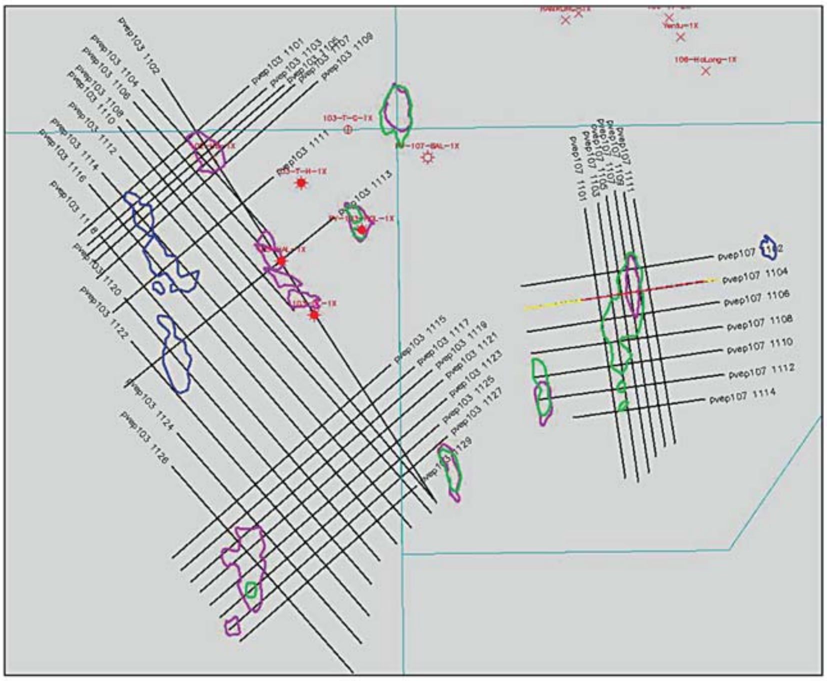

***Fig.2.*** *Seismic survey 2D lines vintage PVEP 2011 - Processed by Fairfield Vietnam in 2011*

**3. Predicting reservoir quality of undrilled prospects in Block 103&107**

Blocks 103 & 107 are located offshore North of Viet Nam (Bac Bo Gulf), in the Northwest of the Song Hong basin (Fig.1). In these blocks, besides basement high and stratigraphy play types, there are two other important play types: Oligocene traps and Miocene traps. The Oligocene traps are located in the West flank of basin (in Block 103). In that play type, the Oligocene and Miocene rocks were uplifted and Miocene formations almost entirely eroded to form a Base Pliocene regional unconformity in the North Song Hong basin during the Late Miocene inversion. The exposed Oligocene rock was overlaid by Pliocene formations. The other play type comprises Miocene traps. These traps were developed in the centre of the basin, in which the Miocene rocks were uplifted and eroded. Even though, Miocene strata were strongly eroded to the Southwest of Song Lo faults, the thick remaining Miocene rock is the main reservoir of that play type. The Miocene play type is located in the basin depocenter. The Oligocene reservoir is too deep for hydrocarbon exploration (> 4,000m).

The undrilled prospect/lead B, C were classified to the Oligocene play type and prospects DL and KL were classified to the Miocene play type. For the exploration wells in the blocks, the porosity versus depth relationship is presented in Fig.3 [4]. From that relationship, it could be seen that at the same depth the porosity is scattered in the range of 10%. Predicting the porosity of undrilled prospect actually following either upper trend or lower trend is valuable.

Before using surface seismic interval velocities and well velocities, both velocities in the drilled prospects were built in 1 chart of interval velocity (x axis) and two way times (y axis) to define the deviation of surface seismic interval velocities and true velocities from well. Fig.4 is a chart of surface seismic interval velocities of HAL and DL prospects versus true velocities from wells (103-HAL-1X and 103-DL-1X) and Fig.5 shows a chart of surface seismic interval velocities of HD prospect and true velocities from 102-HD-1X well. The charts in Figs.4 and 5 confirm that there is no deviation between surface seismic interval velocities and true velocities from wells and no adjustment is needed.

Surface seismic interval velocities in lead B and C are shown in Fig.6. The true velocities from wells 102-HD-1X and 102-CQ-1X were overlain in the same chart. We found that surface seismic interval velocities are much slower than the velocity in drilled 102-CQ-1X well, and a bit quicker than the velocity in drilled 102-HD-1X well. In combination with the chart porosity versus. depth in Fig.3, the 10% porosity of that prospect is predicted to the depth of 2,000m. That prediction may have some uncertainty due to the chart in Fig.3 being mainly for Miocene rock.

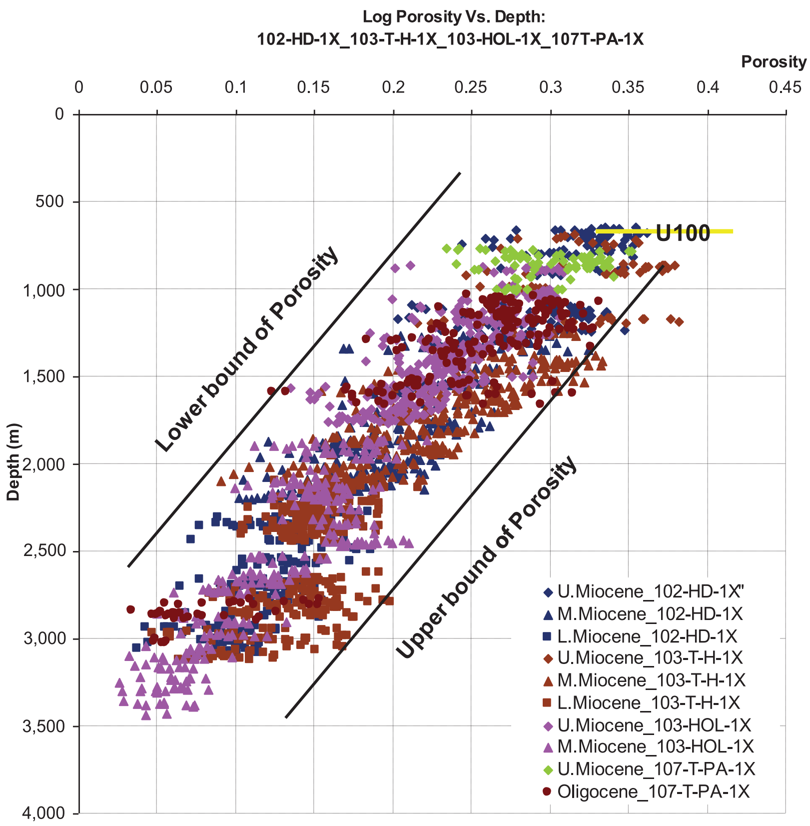


***Fig.3.*** *Log porosity versus depth of wells in the study area*

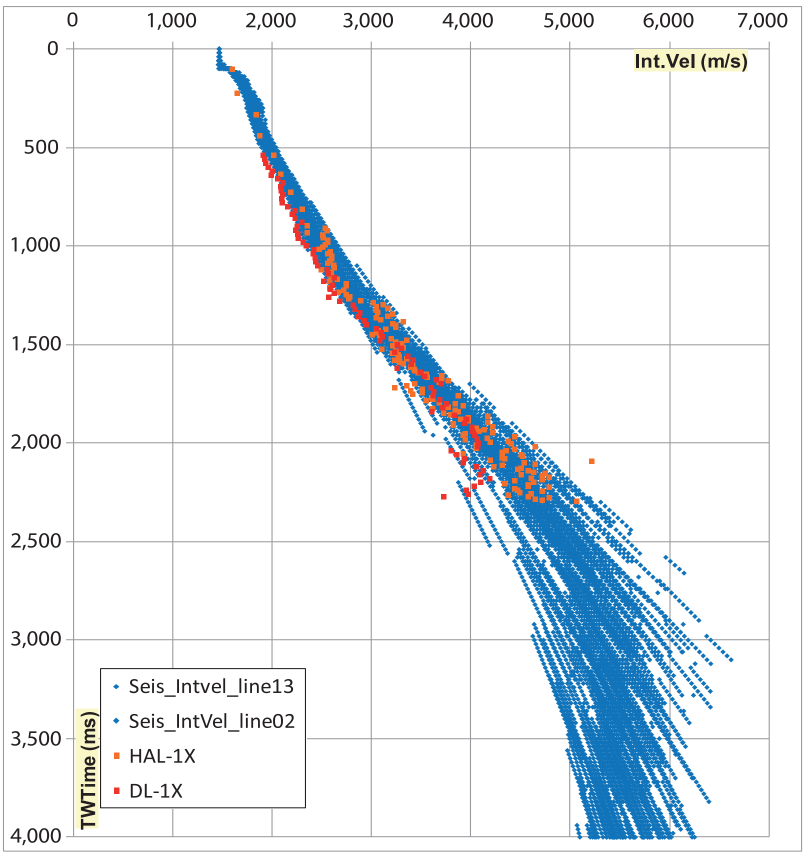


***Fig.4.*** *Interval surface seismic velocities and well velocities over HAL and DL prospects*

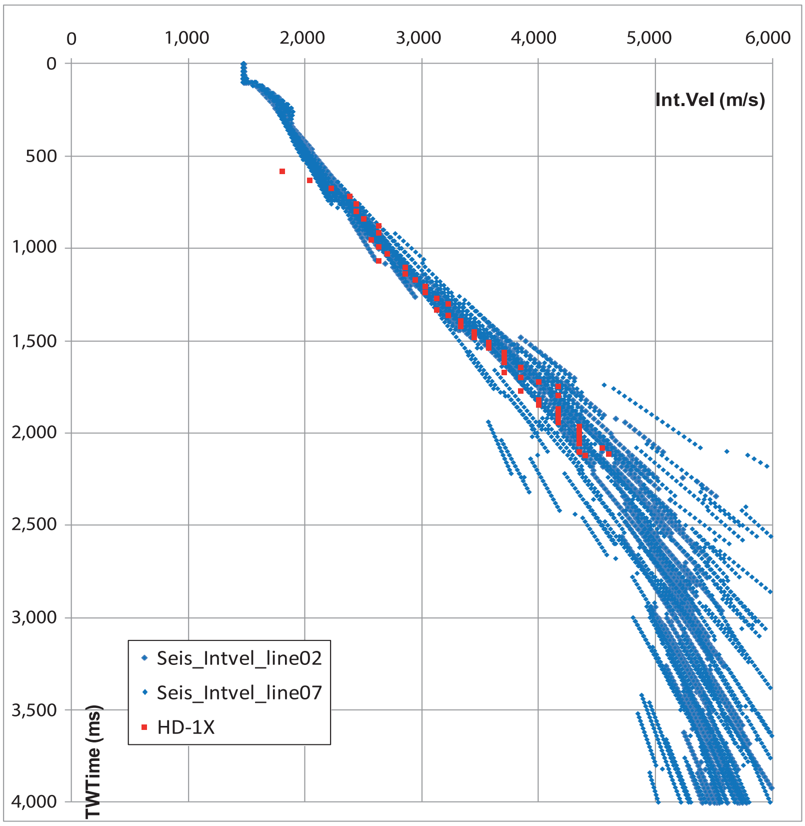


***Fig.5.*** *Interval surface seismic velocities and well velocities over HD prospect*

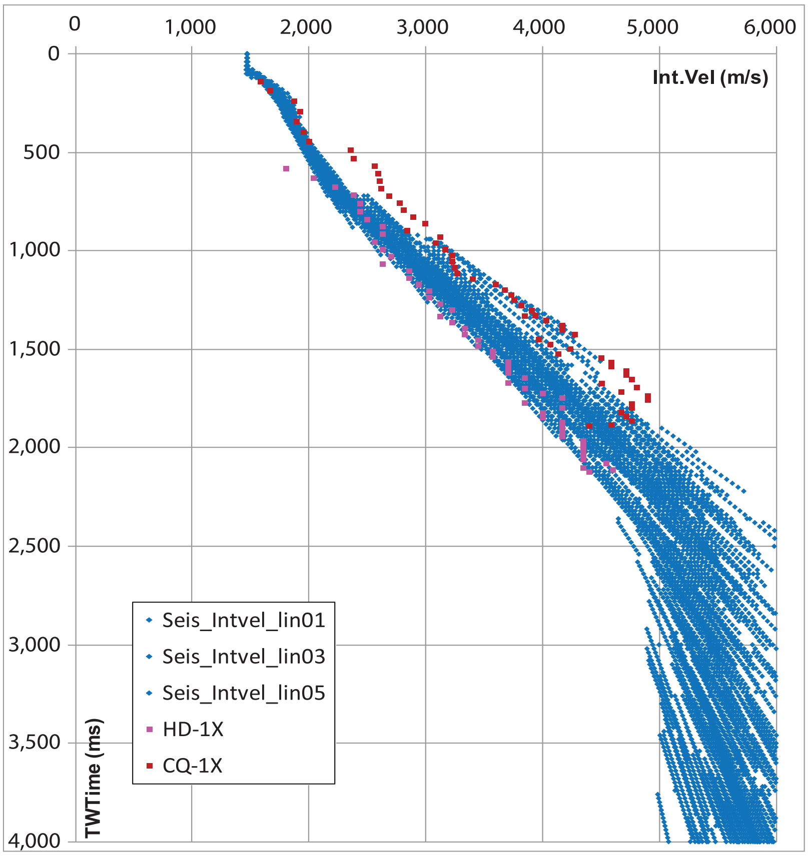


***Fig.6.*** *Interval surface seismic velocities over B, C prospect and velocities of well 102-HD-1X, 102-CQ-1X*

For prospect D, surface seismic interval velocities were built in a chart with true velocities from 103-HAL-1X well - Fig.7. From the interval velocity chart, we found that down to 2 seconds, the porosity versus depth relationship of undrilled prospect D was similar to that of 103-HAL-1X well, however below 2 seconds (~2,800m), the velocities deviated to two trends; one trend followed the 103-HAL-1X velocity and the other trend a slower velocity. It means that the reservoir quality in prospect D is predicted to be similar or a bit better than 103-HAL-1X.

KL prospect is a very large four-way closure (over 50km$^2$) in Block 107. That prospect is classified to the Miocene play type. Actually, KL prospect is not located in the Miocene Inversion southwest of Song Lo Fault, rather it is located in the northeast of Song Lo Fault, where the inversion and erosion were very little. The reservoir quality of KL prospect was considered uncertain due to a depth of almost below 3,000m. All the wells drilled in the Miocene inversion play type in Blocks 103 & 107 show that reservoir quality below 3,000m is bad. To predict how reservoir quality of KL prospect compares with surrounding drilled wells, we built a chart of surface seismic interval velocity of that prospect and 103-DL-1X well interval velocity - Fig.8 (the well 103-DL-1X was chosen because DL prospect was the least uplifted and eroded prospect in the area). The chart shows that seismic velocity in KL prospect is much slower than velocity in 103-DL-1X well. That result allows us to predict that the reservoir quality in KL prospect should be better than that of DL prospect at the same depth (at the depth ~3,200m in the 103-DL-1X reservoir quality is fair, average porosity ~11% and MDT gas sample was collected). From the porosity versus depth chart in Fig.3, the porosity of KL prospect is predicted to follow the high porosity trend (prospective trend - due to slower seismic velocity in comparison with well's reference), which means that the 10% porosity would be preserved at least to ~3,500m, and more optimistically up to 4,000m. The reservoirs in KL prospect of Middle Miocene age or younger are also indicated as higher quality reservoirs.

## 4. Conclusions and possibility of extending study

Theoretically, there is no convincing reason that seismic velocity is only related to porosity, rather the matrix and pore pressure are affected factors as well.

In the above-mentioned method to predict reservoir quality of undrilled prospects, the assumption that matrix and pressure are homogeneous may let in some uncertainty. If we have knowledge of the depositional environment with results of seismic stratigraphy to support prediction, it may be more helpful.

Abnormal pore pressure is a factor making seismic velocity slower and may affect the prediction, however the abnormal pore pressure helps to preserve porosity.

The method was applied only for clastic sections. In the case of carbonates we do not have any conclusion. For clastics, to reduce uncertainty of the matrix, it should be better if the whole section was divided to syn-rift and post-rift sequences.

More well data from nearby undrilled prospects with the same tectonic regime would be more helpful for reservoir quality prediction.

## References

1. Jack Dvorkin, Amos Nur. *Time-average equation revisited*. Deparment of geophysics, Stanford University, Stanford. CA 94305-2215

2. Lê Tuấn Việt, Vũ Sĩ Lý, Nguyễn Hồng Minh. *Các hoạt động kiến tạo và ảnh hưởng của nó đến quá trình hình thành và phát triển khu vực Tây - Bắc bể trầm tích Sông Hồng từ kết quả phân tích tài liệu trọng lực và địa chấn mới*. 2002.

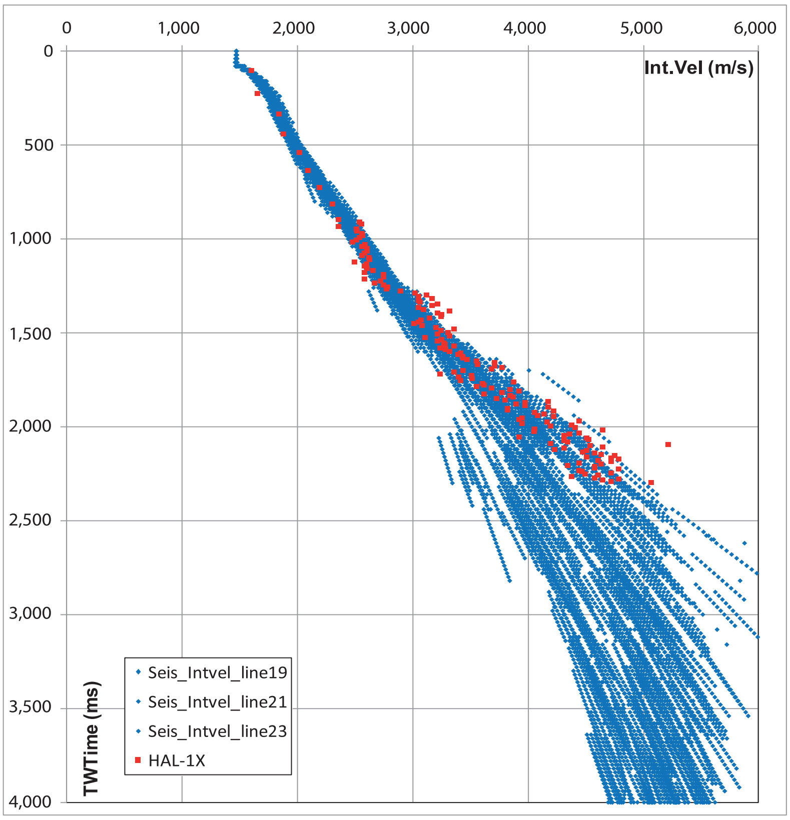


***Fig.7.*** *Interval surface seismic velocities over D prospect and velocities of well 103-HAL-1X*

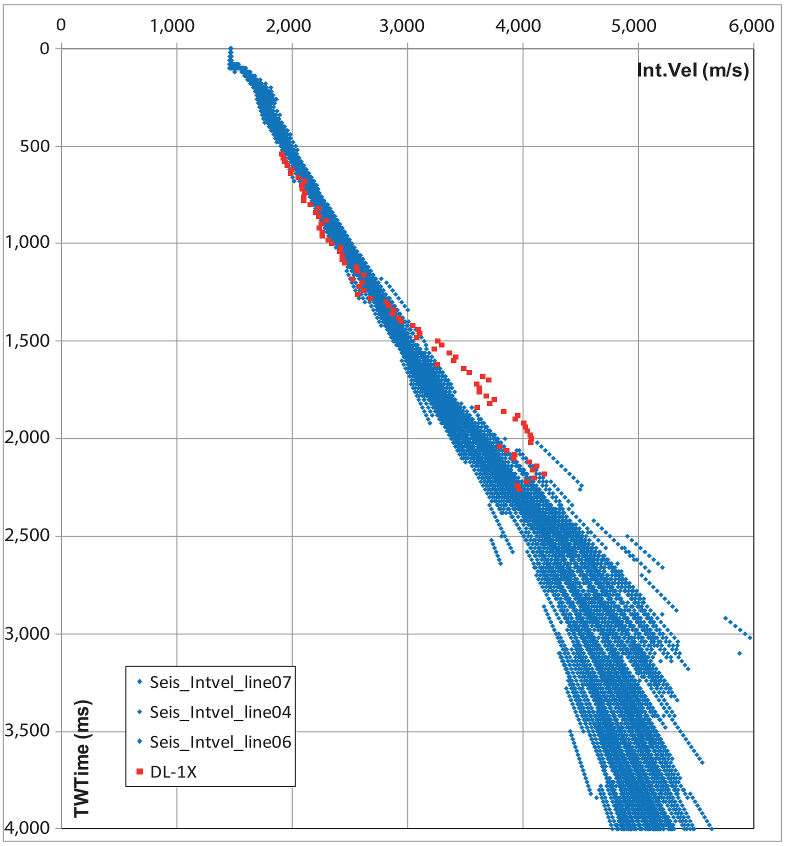


***Fig.8.*** *Interval surface seismic velocities over KL prospect and velocities of well 103-DL-1X*

3. Ren Jian-Ye, Lei Chao, Wang Shan, Li Tao, Zhang Xiao-Li. *Tectonic stratigraphy framework of Yinggehai Quidongnan basin and its implication for tectonic province division in South China Sea*. 2011.

4. Doan Tham, Le Hai An et al. *Regional geology correlation Blocks 103 & 107*. 2008.

5. Petronas. *Sequence stratigraphic study of Block 102 & 106, Song Hong basin Vietnam*.

6. Anzoil. *Hanoi basin, Geological evaluation*. 1995.

7. Idemitsu. *Block 102 evaluation report*. 1995.

8. Total. *103-T-G-1X correlation and comparison with well 103-T-H-1X*.

9. Idemitsu. *Final well report (Geology) 102-CQ-1X*.

10. Idemitsu. *Final well report (Geology) 102-HD-1X*.

11. Petronas. *Post-drill evaluation report 106-YT-1X*.

12. Total. *Final well report (Geology) 103T-H-1X*.

13. Total. *Final well report (Geology) 103T-G-1X*.

14. Total. *Final well report (Geology) 107T-PA-1X*.

15. PIDC. *Final well report (Geology) 103-HOL-1X (in Vietnamese)*.

16. PIDC. *Final well report (Geology) 103-BAL-1X (in Vietnamese)*.

17. Petronas. *Final well report (Geology) 102-TB-1X*.

18. Petronas. *Final well report (Geology) 106-YT-1X*.

19. PIDC. *Exploration master plan, offshore Red River basin (in Vietnamese)*. 2004.

20. Total, Vietnam. *Evaluation report, Gulf of Tokin*. 1991.

21. PVEP-BD, Provision of AVO Study services Blocks 103&107 (Landmark Graphics Malaysia, 2010).

22. PVEP-POC. *Blocks 103 & 107 Hong Long - Hac Long - Dia Long - Bach Long HIIP & Reserves Assessment Report*. 2011.


*Hac Long platform. Photo: PVEP*