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Logical depth modeling of a reservoir layer with the minimum available data-integration geostatistical methods and seismic attributes

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ABSTRACT

For rational depth modeling of a prominent reservoir layer in north of Iran (Gorgan plain, Chelekan top), geostatistical methods were proposed to use with the minimum available data. This data consisted of ten wells, five 2D seismic lines (three vertical lines perpendicular to two horizontal ones) which covers the area, and one small 3D seismic area, which was applied solely for evaluation of findings and optimizing our choices. Because the expansion of this area was limited as opposed to region aimed for modeling. Hence, for a reasonable geostatistical modeling, an appropriate secondary variable (soft data) was crucial. Initially, the reservoir layer should be pursued in five seismic lines with a suitable seismic attribute and achieved its time model (TWT) all over the Gorgan plain due to existing a few number of lines, linear form of data set (located on the seismic lines) and the smoothing effect of kriging, the estimate and average simulated realizations (E-type) could not give acceptable results in time modeling of the layer based on merely five seismic lines. Therefore, one of 100 realizations related to sequential quassian simulation (SGS) selected as the best secondary data after probing their correlation and similarity with the real 3D seismic data and obtaining a proper correlation coefficient. Moreover, this realization revealed the best correlation with the depth amounts of 10 wells, reproducing geostatistical and statistical parameters of input data. For this reason, it was utilized as secondary data in kriging with an external drift method (KED). Having been applied it, the smoothing effect was diminished dramatically in comparison with one variable model and consequences of final modeling, investigation of uncertainty and estimate error prior to using secondary data and after that, all of them signified the final model was much more reasonable than initial one (without secondary data).

Introduction

Among all geostatistical simulation methods, sequential quassian simulation (SGS) has the most application in industry owing to having more flexibility and simplicity. This method solve the trouble of the smoothing effect with producing a variety of realizations and equal probabilities while this effect ruins the estimation of kriging (Goovaerts, 1997; Deutsch and Journel, 1998; Deutsch, 2002). Perceived variations on these realizations could be a sign of spatial uncertainty (Goovaerts, 1997). Opting for the best realization has always been a challenge. In addition, it is feasible to achieve an average all realizations. Although it equals simple kriging theoretically, in practice there are some considerable discrepancies (Wilde and Deutsch, 2005).

Another geostatistical estimate method, which is more beneficial for surface modeling, is kriging with an external drift (KED) (Goovaerts, 1997; Deutsch, 1991). Seismic data can be used as external drift in this method and if kriging is not able to estimate a location (out of variogram range), the consequences would be the same as secondary data (external drift). For structural modeling, first it is preferred to achieve velocity model and then using time model, and finally ultimate estimation is obtained. This procedure has numerous advantages, the most important one is that the velocity model has been very substantial in geophysical interpretations (Coleou, 2001). However, it will be possible to utilize depth data directly in modeling if there is no sonic data or they are not appropriate (Dubrule, 2003). The KED approach has the most application in sand reservoir modeling (specially gas one), because remarkable picks (bright spot) on seismic sections is detected and pursuing of the surfaces would be more straightforward and subsequently more accurate findings (Gastaldi et al., 1997; Filho and Castro, 2001; Caers, 2005).

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In reservoir modeling, Seismic attributes or the results of inversion (regarding to type of modeling) are frequently used instead of raw seismic data because of they are more beneficial. Instantaneous amplitude attribute is the best one for pursuing a special layer on seismic sections (Rezvandehy et al., 2011) because it is directly related to acoustic impedance differences (Taner and Sherif, 1977; Taner, 2000). Fig. 1 exemplifies the method of getting instantaneous amplitude. As can be seen, the amplitude amounts of this attribute are between zero and maximum value of trace. In other words, the zero amounts are omitted.

Gorgan plain situated in the north of Iran and southeastern part of Caspian Sea includes hydrocarbon potential specially gas. The most important formation in this region is called Chelecan, which belongs to middle Pliocene period. This formation is mostly watery and lots of hydrocarbon specially gas and highly conformable (Rezvandehy, 2006). Therefore, determining its exact depth model all over this plain is very critical. All available data for modeling this formation of Gorgan plain consist of 10 wells, five 2D seismic lines with approximate length of 240 km. Moreover, there was one 3D seismic area done after hitting a high-pressure gas layer in Go-3A well. Fig. 2 shows the location of wells, seismic lines and 3D seismic area in this plain. Clearly, the small expansion of 3D seismic area was not considerable for modeling and it was just used for finding the optimum realization of 2D seismic lines simulation. The main aim of this paper is the rational depth estimation of Chelekan top. Due to not having adequate well locations for a perfect modeling, so it was decided to use seismic data as secondary variable in geostatistical technique (KED) for wise results. For doing this procedure, firstly, Chelekan top should be pursued on all five seismic lines, modeled in Gorgan plain based on Two Way Time (TWT), and finally applied as secondary data in ultimate modeling (Rezvandehy, 2006).

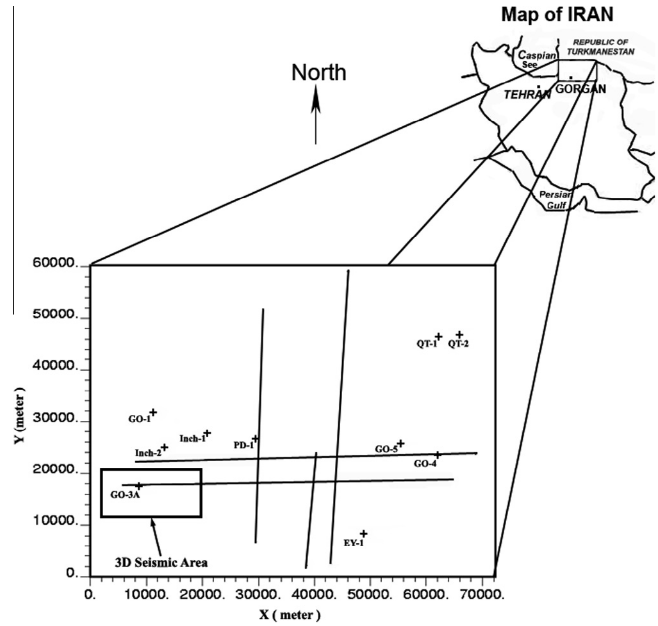

Fig. 2. Location of ten wells, five seismic lines and one small 3D seismic area in Gorgan plain.

One variable estimation of Chelekan top depth

It was not possible to compute variogram of chelekan top (depth amounts) owing to a few numbers of well points (10 wells). For solving this problem variogram of seismic data was used, so at first, Chelekan top should be pursued on the all-seismic lines and quantities of time (Two Way Time) related to this surface is achieved at each coordinate. The best attribute for doing this target was instantaneous amplitude. The high amounts of this attribute, is observed when entering into Chelekan formation due to existing high acoustic impedance discrepancy with upper formation because it is full of water and including hydrocarbon potential as opposed to upper formations, which are mainly day clay and silty layers (Rezvandehy et al., 2011). Fig. 3 exhibits the way of pursuing Chelekan top on the lines and 3D area. It must be noted that check-shot operations were done in GO-3A, PD-1 and GO-4 wells. Fig. 4A and B shows the time quantities of Chelekan top and its histogram, which is normal. As can be seen, Chelekan has the lowest depth in the eastern part and the highest one in the west.

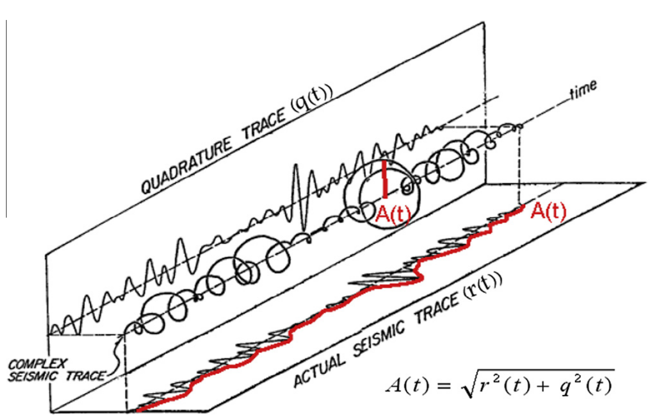

Fig. 1. The method of obtaining the instantaneous amplitude attribute, quadrature trace (q(t)) through Hilbert transform of the real seismic trace (r(t)) which is later achieved and instantaneous amplitude attribute (A(t)) by calculating the numerical amount of the seismic traces is obtained (Taner and Sherif, 1977).

It was not feasible to compute directional variograms with these data because of not having proper distribution. Therefore, omnidirectional variogram (Azimuth 0° and Tolerance 90°) was calculated (Deutsch, 2002): Fig. 5 exhibits this variogram beside its fitted theoretical model. The theoretical model is;

$$\gamma(h) = 0.001 + 0.64\ Gaussian_{\substack{h_{\max} = 1200 \\ h_{\min} = 1200}} + 0.399\ Spherical_{\substack{h_{\max} = 1600 \\ h_{\min} = 1600}}$$

In terms of this variogram, one variable estimation of Chelekan top depth with solely 10 wells was obtained (Fig. 6), which was used simple kriging method. It is obvious there are huge amounts of smoothing in farther distances of well locations, which is characteristic of Kriging (Deutsch, 2002). As can be seen, the Fig. 6 is not reliable and obviously needs a secondary variable and the only available soft data is five seismic lines, so Chelekan top should be modeled by using seismic times (Two Way Time) in Fig. 4A.

Temporal modeling of Chelekan top using 2D seismic lines

Regarding to existing 3D seismic data in this region, in spite of its tiny expansion in comparison with the whole Gorgan plain, the findings of this area related to 3D seismic area (Fig. 2), can be compared with real data of this area so as to realize how much each model is able to produce 3D seismic data. Subsequently, the best model can be selected as secondary data. The more this obtained model resembles 3D data, the more accurate it would be. Fig. 7A shows time modeling of Chelechan top by 3D seismic data. However, this model will be better for comparison with subsequent estimated ones if the fine variations is dwindled and obtained