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Automatic First Break Picking from Pre-stack Seismic Section – Application in Sufyan Oil Field, Sudan

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ABSTRACT

First break picking involves detecting the onset arrivals of refracted signals from a single signal source at the individual receiver in a receiver array. First-break picking can be done manually or automatically. This work outlines the procedures and benefits of automatic picking from first arrivals using monitor records obtained from reflection survey in Sufyan Oil Field, Sudan. The first breaking was done using SeisOptPicker. Reliable picking was ensured by applying linear move out (LMO) to the data before picking. This was reversed after picking. The length, in milliseconds, of the time window for the automatic picker to look for the first arrival on a trace was set to a value of 20-ms to accommodate the large distance between the nearest and farthest offset. The start time search from last first break pick was set at 0 milliseconds. This means that it will not look for the pick at a time earlier than the current pick. Traces where the first arrival comes in earlier than the preceding trace were rejected. The results obtained from the automatic picks were compared with results from conventional refraction survey. The Sufyan prospect Low Velocity Layer (LVL) consists mainly of three layers from both refraction survey and parameters computed from first break automatic picks from production survey. The average thickness of first layer obtained from refraction is 20.0m as against 22.4m obtained from automatic picks. The velocities calculated for these layers are 435m/s and 400m/s from the refraction and automatic picks respectively. The second layer thicknesses obtained from the refraction survey and automatic picks from production survey approaches are 52.8m and 50.0m. Their velocities in the same order are 931m/s and 800m/s. The consolidated layer average velocity calculated from refraction survey and automatic picks from production survey are 1850m/s and 1848m/s respectively. The LVL parameters obtained from automatic first break picks from production survey can be used for static corrections in the Sufyan oil field without conducting dedicated refraction surveys.

Key words: First break; automatic picking; refraction; Low Velocity Layer; Sufyan Oil Field

1. INTRODUCTION

Static corrections are made to eliminate the distortions from the information relayed by seismic waves as they travel through irregular or changing topography and near-surface velocity variations. Corrections are applied so that the processed data refer to a specified datum that is taken to be horizontal and to contain no lateral variations in seismic velocity. Datum corrections compensate for the different lengths of ray paths associated with a reflector to a spread of geophones over an irregular topography and low velocity layers. If these adjustments are not made, reflections on adjacent traces may be shifted in time, producing irregular and incoherent events. The information needed for these corrections are traditionally derived from dedicated refraction or up hole surveys. This approach is quite expensive in terms of material and human costs which often constrain

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the number of surveys planned per block. An alternative to the use of refraction or uphole crew is to use the first breaks on the reflection records. Refraction wave paths cross boundaries between materials having different velocities in a way that energy travels from source to receiver in the shortest possible time according to Fermat's Principle. How effective a static correction is in correcting the anomalies for which it is intended depends on the accuracy and reliability of the first break picking[2].

Manual picking involves visual inspection of the amplitudes and waveform changes and reading the first arrival travel time from each trace. This is a very time-consuming activity which relies on the picking-operator subjectivity and is therefore prone to human bias. The first arrival times are picked from the seismograph record, at the point where the seismograph trace starts to bend. Care is often taken to ensure that each trace is picked at the same point; at the first point of movement or the point of maximum curvature. This procedure makes the interpretation a more uniform process and reduces the bias and inconsistency, as the data will be consistent from one trace to the next.[3]

First break picking from reflection records required for static corrections involves a huge volume of data that cannot be handled with manual picking. This challenge is overcome by interactive automatic picking and interpretation available as private computer programmes by different seismic companies. A computer assisted method of picking first arrivals from digitally recorded field data has been presented by Hatherly[4] and Hunter[5]. With the development of modern computers, dedicated software such as SeisOptPicker have been developed to carry out the picking interactively and facilitated the process. Although in general the whole procedure is still time consuming, the time and rigour have been reduced appreciably.

The first attempts on automatic first break picking were based on the cross correlation of adjacent traces to find the delay time between first breaks.[6] A first arrival picking method that combines linear prediction with inflexion correction was proposed by Song and Cao[7]. Hatherly[8] proposed some statistical tests that would be employed to identify the first breaks like the works of Yung and Ikelle[9] which developed a first break picking method that involves the use of higher-order statistics. Gelchinsky and Shtiyelman[10] proposed a technique based on a combination of the correlation properties of the signal

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[2] Yilmaz, O. (2001) Seismic Data Analysis: Processing, Inversion, and Interpretation of seismic Data. Invest. *Geophysics.ser*,10.
[3] Shulin, P., Lei, G., and Zhou, B. (2005). A method to realize the first picking *Journal of Geophysical Prospecting for Petroleum*, 44 (2): 163-166.
[4] Hatherly, P. (1982). A computer method for determining seismic first arrival times: *Geophysics*, 47: 1431–1436.
[5] Hunter, J. H. (1981). Software listing of program for shallow seismic exploration using Apple components. *Geological Survey of Canada Open File Report 552* Mcgrew-Hill, New York: 282-287.
[6] Peraldi, R., and Clement, A. (1972). Digital processing of refraction data: Study of first arrivals: *Geophysical Prospecting*. 20: 529–548.
[7] Song, J., Cao, X., XU., W. and Yang, J. (2013). First Arrival Time Auto-Picking Method Based on Multi-Time Windows Energy Ratio. Energy Science and Technology, 6(1): 79-89
[8] Hatherly, P. (1982). A computer method for determining seismic first arrival times: *Geophysics*, 47: 1431–1436.
[9] Yung, S. K., Ikelle, L. T. (1997). An example of seismic time picking by third-order bicoherence: *Geophysics*, 62: 1947–1951.
[10] Gelchinsky, B., and Shtivelman, V. (1983). Automatic picking of first arrivals and parameterization of travel time curves: *Geophysical Prospecting*, 31: 915–928.

and a statistical criterion. Taillandier et al[11] built a near-surface velocity-depth model from first break picks by refraction tomography and noted that primary statics based on this improved the long/medium wavelength character of the structures in the stack. Various commercial software packages have focused on the detection of a sudden increase in the signal energy, the energy ration method proposed by Coppens [12]. Spagnolini,[13]also based his adaptive picking method on the detection of abrupt changes in the energy. Xiao et al[14] demonstrated that automated data-adaptive high-accuracy first-break picking and refraction tomography statics have successfully solved the most difficult statics challenges.

Different seismic companies have developed their first break automatic pick programmes. WesterGeco uses a module in Omega 2 processing software for first break picking. Bureau of Geophysical Prospecting (BGP) utilizes GeoFBPicking module incorporated in GEOEAST processing software for first break picking while PCMODULE which is incorporated in TIPEX processing software is used for first break picking by Halliburton Geophysical Services. SeisOptPicker is commercially available as a first break picking tool.

The aim of this paper is to outline the procedures and benefits of automatic first break picking from pre-stack seismic section using Sufyan Oil Field in Sudan as a case study.

2. Geology

Sufyan oil field is in the southwest of Sudan. The terrain is relatively flat with elevation ranging from 457m to 482m and a maximum height difference about 25m. This oil field is situated in the Muglad basin which is the major sedimentary basins in Sudan. Sufyan Depression consists of two subsystems; Abu Gabra subsystem and Bentiu channel sandstone. The Neocomian Abu Gabra Formation is mainly composed of dark brown, light to moderate grey, blocky mudstone, and shale[15]. Bentiu Formation is a major sandstone reservoir rock in the Muglad Basin. Gravel sandstone dominates the upper part[16].

3. Methodology

The first break picking was done using SeisOptPicker in a set time window of 20-ms. The start time search from last First Break Pick (FBP) was set to 0 milliseconds and

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[11] Taillandier, C., Deladerrière, N., Therond, A. and Le Meur, D. (2011). First arrival travel-time tomography: when simpler is better. *73 European Association of Geoscientists and Engineers Conference & Exhibition, Extended Abstracts*, I034.

[12] Coppens, F. (1985). First arrivals picking on common-offset trace collections for automatic estimation of static corrections: *Geophysical Prospecting*, 33: 1212–1231.

[13] Spagnolini, U. (1991). Adaptive picking of refracted first arrivals: *Geophysical Prospecting*, 39: 293–312.

[14] Xiao F., Yang, J., Liang, B., Zhang, M., Li, R., Li, F., Xiao, H., Lei, X., Liu, Q. and Heesom, T. (2014). High-density 3D point receiver seismic acquisition and processing – a case study from the Sichuan Basin, China. *First Break*, 32: 81-90

[15] Mohamed, A.Y., Pearson, M. J., Ashcroft, W. A., Whiteman, A. J. (2002). Petroleum maturation modelling, Abu Gabra–Sharaf area, Muglad Basin, Sudan. *Journal of African Earth Sciences*, 35: 331–344.

[16] Zhang, Y. and Gu, Q. (2009). Petroleum System of the Sufyan Depression at the Eastern Margin of a Huge Strike-slip Fault Zone in Central Africa. *Acta Geologica Sinica*, 83(6):1182-1187

anything outside the set FBP frequency was not picked. Computation of velocity and thickness of the subsurface layers were based on the slope method and intercept formula from refraction time-distance plot.

SeisOptPicker is a first arrival, picking module that reads raw data recorded in many different formats and perform automatic picking of first breaks. The picks can be used directly by SeisOpt @2D, Optim's refraction interpretation software. The module also allows the user to interactively input and edit survey geometry, perform Automatic Gain Control (AGC) and filtering and display and edit trace header values[17]. SeisOptPicker re-scales the amplitude of the traces so that the maximum amplitude is 1. All dead and bad traces were killed using the "Kill traces" option. Red marks appear on all the traces corresponding to the automatic first break pick as estimated by the automatic picker unless the minimum amplitude of automatic first break picker was too low. Automatic Gain Control and filtering module were used to enhance the first arrivals before running the automatic picker.

The picking was made on given number of cross-lines and in-lines. First arrivals generally show a linear dip across the record and are often followed by almost parallel refraction events particularly on longer off set traces. Reliable picking was ensured by applying linear move out (LMO) to the data. The linear move flattens the event for easy first break picking (Figure 1). Once picking was done, the LMO correction was reversed.

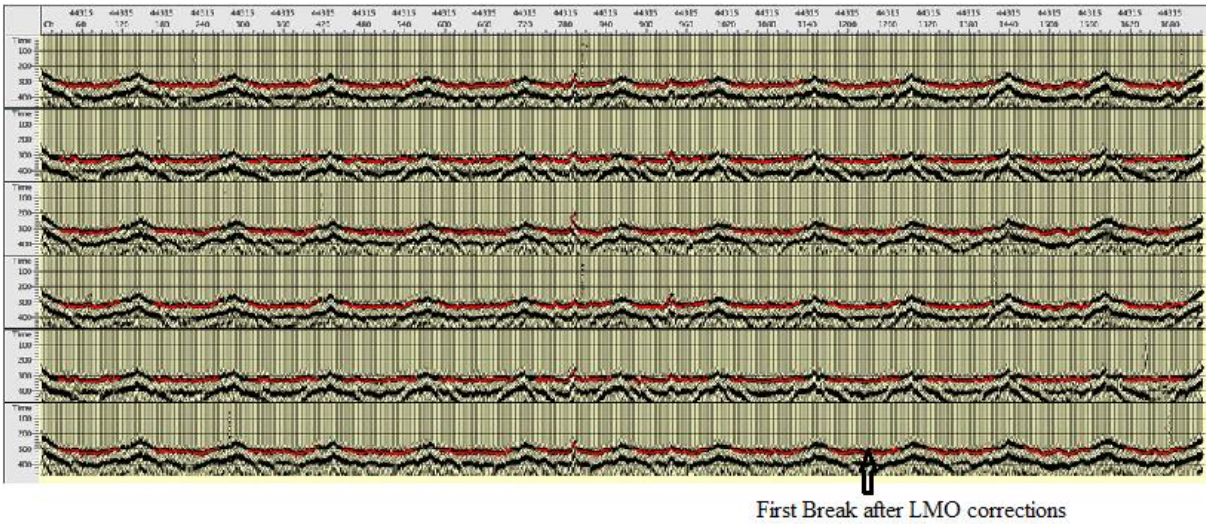

Figure 1: Automatic First Break Picking in an LMO Section

Window length

The difference between the nearest and farthest offset in a production seismic survey is always significantly large. This implies that the travel time gap between the adjacent first-break arrivals is large. The length, in milliseconds, of the time window for the

[17] *SeisOpt Picker User's Manual*, (2003)

automatic picker to look for the first arrival on a trace was therefore set to a large value of 20-ms. Another reason for selecting a large window is because when the window contains noise, and the length of the window is several times longer than the noise, the effect of noise on the quality of the pick will be highly limited. This window length was considered neither too large nor too small to cause the automatic picker to pick spurious arrivals or mix closely spaced events.

Start time search from last First Break Pick (FBP)
Start time search from last *FBP* in milliseconds, controls the time from which the automatic first break picker starts looking for the first break pick on the adjacent trace. This time was set at 0 milliseconds so that the automatic picker will start looking for the first break pick on the adjacent trace, at a larger source-receiver offset, starting at the same time as the current pick. This also means that it will not look for the pick at a time earlier than the current pick. Traces where the first arrival come in earlier than the preceding trace were therefore not picked.

FBP frequency:
The offsets increase in a regular interval and the first break arrivals follow in the same interval. This frequency was set such that any arrival outside the set frequency was most likely noise and was not picked.

Pick Criteria
The first break time was picked based on the peaks. A peak is defined as a sample on the original trace when the direction of the trace changes. The values within the peak array were subjected to a series of tests, starting from the earliest time on. The first peak to satisfy all the criteria was regarded as the first break. The first test was the polarity test. A peak was acceptable only if it had the specified polarity. It was already required that the value of the peak amplitude of an acceptable trace be significantly greater than the average trace energy in front of it. This was because the energy ratio recognises the first break as a sudden or "unpredictable" burst of energy. If an acceptable first break was not found within a search window, a time of 0 was registered, indicating no pick. Seismic traces with rejected picks are interpreted as bad or dead traces or as traces

Velocity and Thickness Computation
The velocity of the low velocity layer (LVL) and the sub-weathering velocity were computed using the slope method. The near offset geophones receive energy traveling through the first medium while geophones further away receive energy from deeper layers (Figure 2). The onset time; at which the amplitude is distinguishable from the surrounding noise was finally calculated. The first break picks associated with the refracted arrival times were then used to estimate the near-surface parameters (Figure 3).

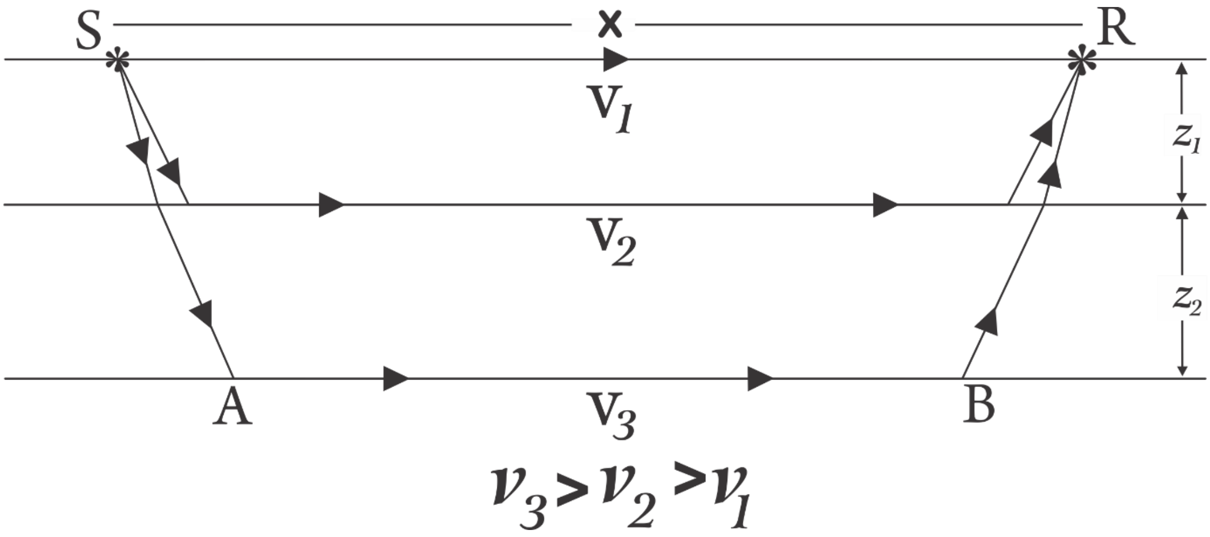

Figure 2: Refraction Arrangement for a Three Layer Case

The total time t for the refracted wave from Figure 2 is

$$t = \frac{SA}{v_1} + \frac{AB}{v_2} + \frac{BR}{v_1} \qquad (1)$$

Equation (1) can be shown to become

$$t = \frac{2z_w}{v_1}\sqrt{1 - \frac{v_1^2}{v_2^2}} + \frac{x}{v_2} \qquad (2)$$

Equation (2) is of a straight line where $\frac{1}{v_2}$ is the slope of the line and $\frac{2z_w}{v_1}\sqrt{1 - \frac{v_1^2}{v_2^2}}$ is the slope of the line.

When the z_2 is considered in the three-layer case, then

$$t = \frac{2z_1}{v_1}\sqrt{1 - \frac{v_1^2}{v_3^2}} + \frac{2z_2}{v_2}\sqrt{1 - \frac{v_2^2}{v_3^2}} + \frac{x}{v_3} \qquad (3)$$

A change in layer is represented by a change in slope on the graph. From the refraction theory the, inverse of the slope of the segment of line associated with wave arrivals from a layer is equal to the velocity of the layer[18]. The extension of that slope to the time axis is the time intercept t_i. The calculations of depth and thickness of the subsurface layers are based on data on the time-distance curve.

[18] Grant, F.S., and G.F. West, (1965): "*Interpretation theory in Applied Geophysics*", Mcgrew-Hill, New York.pp.282-287.

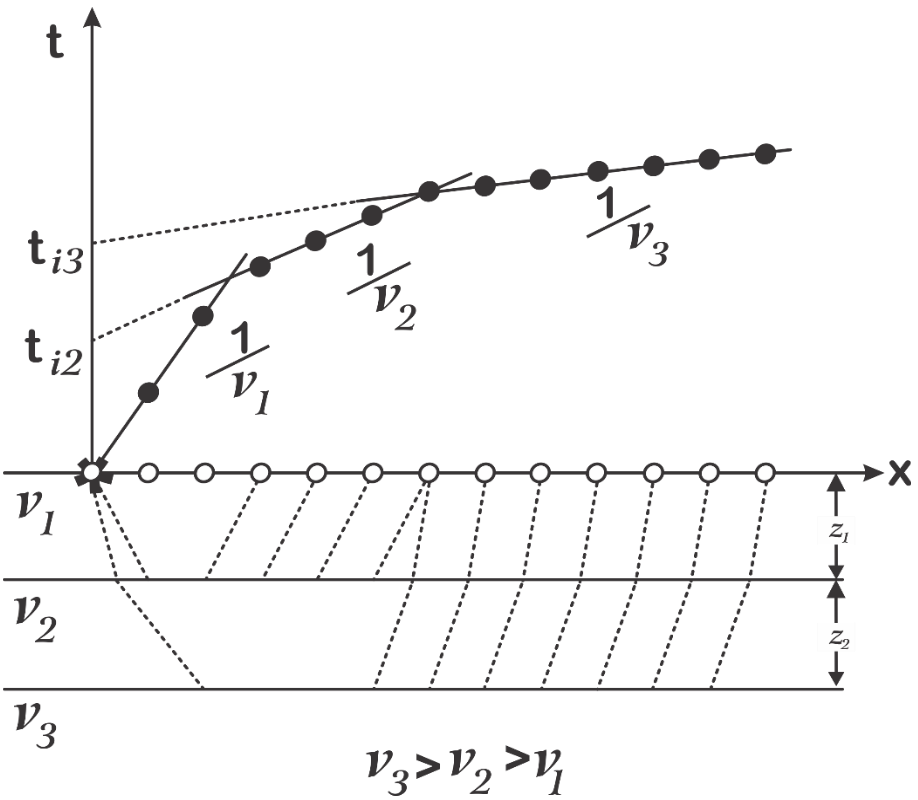

Figure 3: Refraction Time-Distance Plot for a Three Layer Case.

The calculation of the thickness was based on the time intercept formula for depth calculation equation.

$$Z_w = \frac{V_b V_w t_i}{2\left(V_b^2 - V_w^2\right)^{\frac{1}{2}}} \qquad (4)$$

The assumption in the calculations are that each successive velocity layer is faster than the layer immediately above it and each layer is thick enough to be represented in the time-distance.

The average LVL velocity and thickness results obtained were compared with the average LVL parameters used in the static corrections in the field which were based on the results of many refraction surveys.

4. RESULTS AND DISCUSSIONS

The average results obtained from the automatic picking of refracted first arrivals on the production surveys were compared with the average results from conventional refraction surveys (Table 1). The results were comparable in terms of the number of layers of the low velocity region, the thickness of the layers and their corresponding velocities. The Sufyan prospect LVL consists mainly of three layers from both refraction survey and parameters computed from first break automatic picks from production survey. The average thickness of first layer obtained from refraction is

20.0m as against 22.4m obtained from automatic picks. The velocities calculated for these layers are 435m/s and 400m/s from the refraction and automatic picks respectively. The second layer thicknesses obtained from the refraction survey and automatic picks from production survey approaches are 52.8m and 50.0m. Their velocities in the same order are 931m/s and 800m/s. The consolidated layer average velocity calculated from refraction survey and automatic picks from production survey are 1850m/s and 1848m/s respectively (Table 1). The results show that generally automatic picks give higher values in terms of layer thickness and lower values in terms of velocities

Table 1: Comparison of Refraction Survey and Automatic Picks from Refractions on Reflection Survey

Parameter	Refraction Survey	Automatic Picks from Refractions on Reflection Survey
V1	435m/s	400m/s
V2	931m/s	800m/s
V3	1850m/s	1848m/s
z_1	20m	22.4m
z_2	52.8m	50.0m

CONCLUSIONS

In this paper, a procedure has been presented to show the benefits of automatic first break picking from production survey. It is evident that applying automatic picks from refractions on reflection survey in sufyan oil field will save cost of conducting dedicated refraction surveys since it is much faster and equally accurate. Whereas automatic picking out rightly rejects noise traces, in manual picking when no clear first arrival can be seen, a pick can still be made by interpolating between good arrivals. Automatic picks will therefore be more reliable particularly on noisy data.