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Repeatability in geophysical data processing: A case study of seismic refraction tomography.

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ABSTRACT

This research work was carried out to determine the extent to which a geophysical data could give similar results (anomalies) when reprocessed under the same condition. Hence seismic refraction tomography processing which depends on picked arrival times was carried out to ascertain this fact. The processing flow started from importing raw seismic data, down to generation of the tomography model that represent the distribution of seismic velocities within the subsurface. Each of the two different raw seismic data collected from two profiles was reprocessed for three times, under the same condition, using the same software. The major factor that naturally varied during the data processing was the picked first arrival travel times. The results showed similar velocity distribution within the subsurface in each of the three models, that is, areas of low velocities corresponding with areas of low velocities and vies versa. The average thickness of the overburden and depth to basement appeared to be the same in all the tomographic models. However, subtle features like the subsurface geometry and basement topography did not show much similarity in appearance. It was concluded that geophysical data should be processed at least three times along with other constrain, and the extent of repeatability observed, before any meaningful interpretation can be drawn from it. This has also revealed that in the event of time laps investigation, geophysical data should be reprocessed several times to ensure that the observed changes are not due to processing artefact, rather that geological changes.

Keywords: Repeatability, geophysical data processing, tomography, arrival times picks.

INTRODUCTION

This research work was carried with an objective of determining to what extent a geophysical data can give similar results, especially when they is a variable input, each time the data is reprocessed. It has been observed in seismic refraction tomography, that the first arrival time, picked for a particular trace varies when picked several times under the same condition. Hence the need to investigate the extent to which this variability in these travel times picks will affect the repeatability of the final result, which is the tomographic model, is of paramount importance. Earlier investigation carried out by other researchers has shown that:

It is well established that 4D repeatability depends strongly on repeating the acquisition parameters, such as source and receiver positions, wavelet and noise conditions, and subsequent processing (Rodney, 2005).

For data processing, relative preservation of amplitude, frequency, phase, and waveform are keys to effectively remove the non-repeatability effects. Even for legacy land data, with careful processing, it is possible to have difference reflecting the reservoir change (Ling et al, 2007).

According to Li, 2004, a good 4D seismic repeatability can be achieved if 4D tailored processing with a careful 4D Quality Controlled is implemented.

Spatially consistent flight paths are required for repeatability analysis of the EM data. Caution should be used in examining repeatability of the EM data because poor repeatability could result from flight-path variations (Haoping and Allen, 2006).

Tomography model was used to determine the velocities distribution within the subsurface. It was able to map out the depth and thickness of the various strata within the subsurface. (Collins and Aboh, 2012)

2.0 Location of the study area

The study area is located within the basement complex of central northern Nigeria. It is bounded by latitude 11^{o} 10' 27.76”N, longitude 007^{o}40' 22.90”E and latitude 11^{o} 10' 20.52”N, longitude 007^{o}40' 26.06”E. The imagery map of the study area is shown at figure 1.

Figure 1: Satellite image map of the survey area, Adapted from Google Earth image 2011 Digital Globe.

3.0 Geology of the study area

Zaria is underlain by Precambrian basement rocks which comprise of older granite, gneisses and low grade meta-sediment. It has been established that the Zaria batholiths intruded into the gneissic and meta-sediment complex which form the country rock. The granitic batholith belongs to a suite of syn and late tectonic granites and granodiorites that marked the intrusive phase of the late Precambrian to early Palaeozoic Pan-African Orogeny in Nigeria (McCurry, 1973).

4.0 Methodology and Data Acquisition

The sampling interval used for the survey (to record the seismogram) was 250 μs, and the total number of sample was 4096. These two values determine the record length of 1 second used for the data acquisition. The geophones were inserted into the ground, and care was taken to ensure that they remained vertical and maintained good contact with the ground. The geophones were laid out at an interval of 5 m. The Terraloc Mk6 was then placed at the center of the spread, and the cables were connected to their appropriate channels on the seismograph. The trigger geophone was placed close to the shot point and was connected to the instrument with the aid of the trigger coil. When the instrument was armed ready to receive signals, seismic energy was deployed into the ground with the aid of hammer blow. This triggered the instrument, which recoded the ground vibration. Shots were taken before the first geophone, at each geophone point and beyond the last geophone.

5.0 Data Processing

The data processing was carried out using seismic data processing software, which allows activating the programme a second time on a different window. This gave room for multiple processing at the same time, and under the same condition. The processing flow started with importing of the raw seismic data recorded in SEG2 format, into the processing software. The Bandpass filter was applied, with a lower cut-off 5Hz and an upper cut-off of 50 Hz. This was used to remove surface waves and other seismic noise of high frequency. Gain filter was applied to remove the effect of geometrical spreading that led to the attenuation of the seismic energy. The first arrival times was manually picked base on the "first kink" on the seismic traces. The picked arrival times were inverted to generate the initial starting model for the final tomography models. The tomography model was iteratively generated using a number of 10 iteration. The same processing flow was subsequently applied to the same raw seismic data for two other consecutive times, and the resulting models in each case were saved for onward comparison.

RESULTS AND DISCUSSION

The picked first arrivals during the data processing for the two different profiles are shown in table 1. Each column represent the first arrival times that was picked for the first 24 traces of each data set, that was recorded by the 24 channels digital seismograph. Despite they were picked with the same software and under the same condition, it was practically impossible to completely eradicate slight variability in the picked travel times.

The total picked arrival times put together, for each processed models, using the same raw seismic data under different windows was put together for the purpose of comparison as shown in Figure 2 and 3. The three travel times picks sections in figure 2 was generated from the raw data of the first profile, while the three travel times picks sections in figure 3 was generated from the raw data of the second seismic profile. The three travel time picks sections in figure 2 showed striking similarities despite the slight variability existing between them. The travel times picks in all the sections were clustered in the same area, circled with red and also dispersed on the same area, circled with blue in the three sections with the same raw seismic data, thereby showing remarkable resemblance. The same condition applies to the three travel time picks sections in figure 3.

Table 1: Sets of picked arrival times comparing extent of variability in the travel times picked

First set of picked arrival times for each set of the processing in profile 1			First set of picked arrival times for each set of the processing in profile 2		
Picked arrival times for the first processing	**Picked arrival times for the second processing**	**Picked arrival times for the Third processing**	**Picked arrival times for the first processing**	**Picked arrival times for the second processing**	**Picked arrival times for the Third processing**
1.94	1.94	1.94	13.58	13.58	13.58
11.64	15.52	11.64	15.52	17.45	17.45
15.52	19.39	13.68	15.52	17.45	17.45
19.39	19.39	19.39	17.45	19.39	17.45
23.27	21.33	23.27	21.33	21.33	21.33
27.15	29.09	27.15	25.21	25.21	27.15
23.27	29.09	29.09	23.27	23.27	23.27
31.03	31.03	32.97	25.21	23.27	29.09
34.91	34.91	36.85	27.15	27.15	27.15
36.85	36.85	36.85	27.15	27.15	29.09
40.73	40.73	40.73	27.15	27.15	32.97
42.67	42.67	40.73	25.21	27.15	31.03
42.67	44.61	42.67	27.15	27.15	34.91
46.55	44.61	44.61	29.09	29.09	34.91
50.42	50.42	46.55	31.03	29.09	36.85
56.24	54.3	50.42	38.79	36.85	46.55
56.24	58.18	58.18	34.91	36.85	40.73
56.24	54.3	60.12	34.91	36.85	48.48
62.06	62.06	64	38.79	36.85	46.55
60.12	64	62.06	36.85	38.79	50.42
58.18	60.12	60.12	34.91	34.91	46.55
58.18	64	62.06	38.79	40.73	44.61
60.12	62.06	64	44.61	40.73	44.61
64.00	69.82	65.94	42.67	42.67	46.55

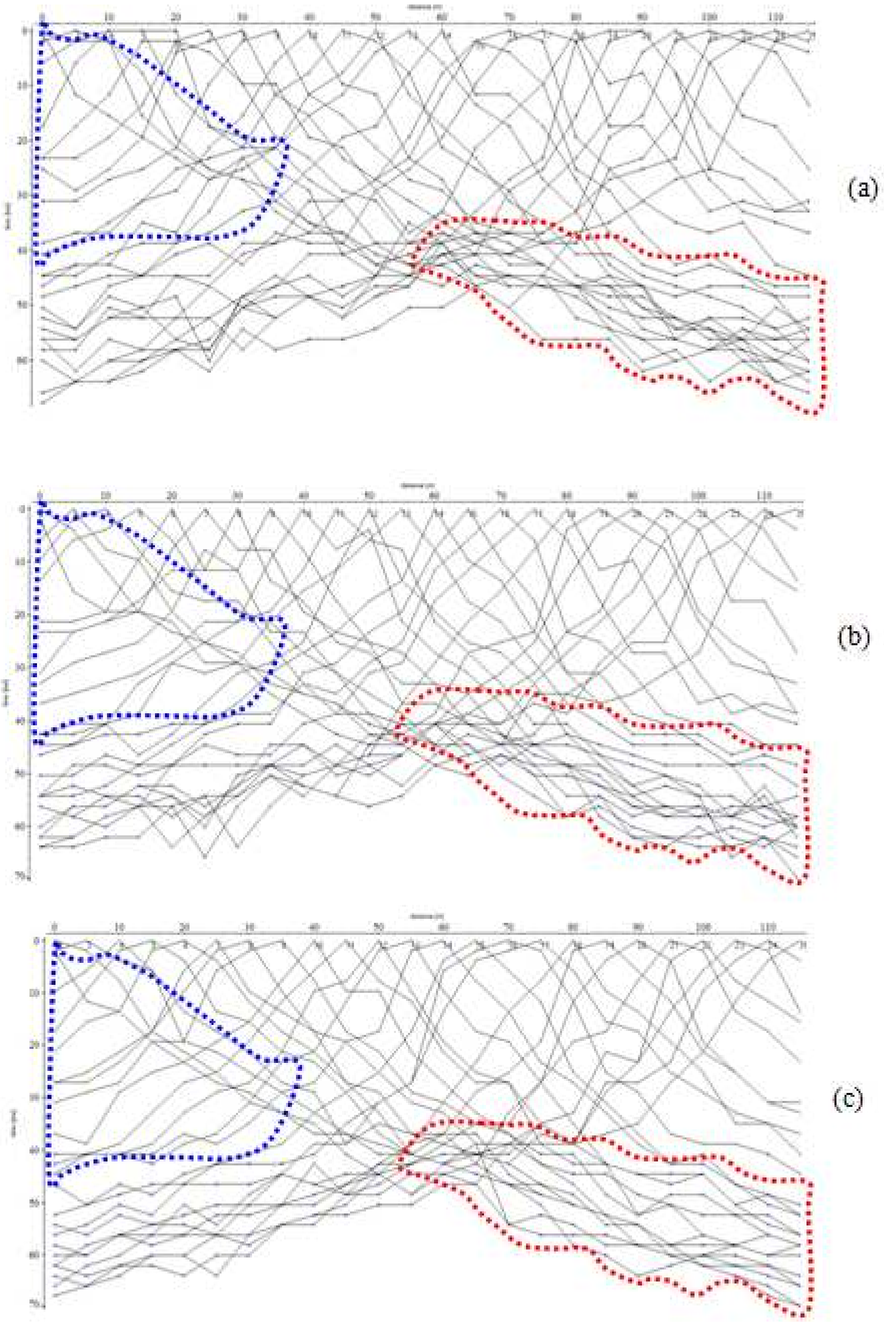

Figure 2: Travel time picks from first profile (a) First processing (b) second processing (c) third processing of the same raw seismic data.

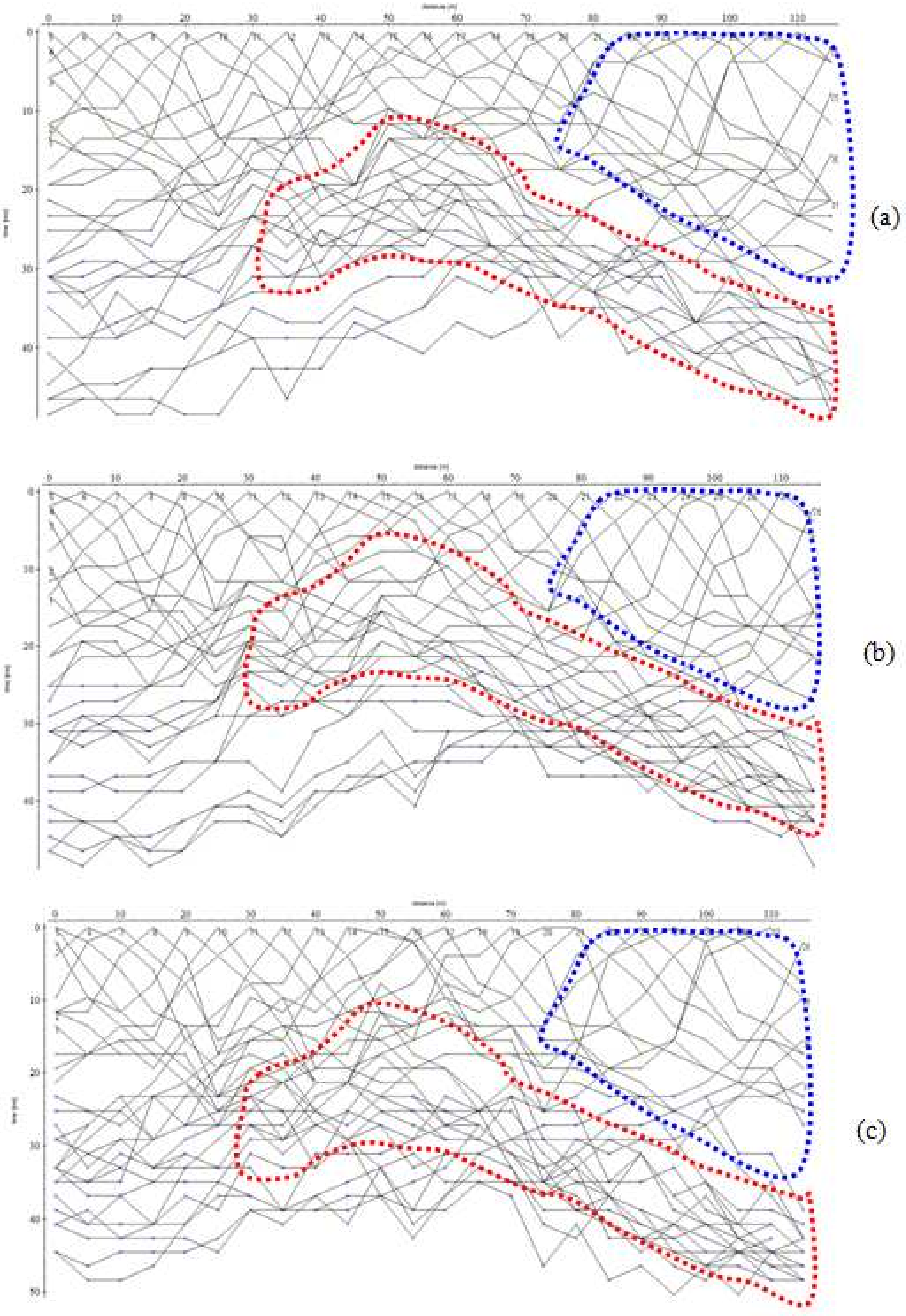

Figure 3: Travel time picks from second profile (a) First processing (b) second processing (c) third processing of the same raw seismic data.

The generated tomography model indicating overburden, weathered basement and fresh basement is shown in figure 4. This classification into various layers was made base on their velocities values. The tomography models in figure 5 generated from the first profile shared great resemblance characteristics, which is even more noticeable in figure 6 generated from second profile. From the models in figure 5 and 6, it was evident that an area of low velocity corresponds with area of low velocity in the same set of corresponding models. Similarly, areas of high velocity also showed good correlation to area of high velocities in the same model set. The range of velocities indicated by the "velocity bars", by the sides of each model was consistent in the same models set. The average thickness of the overburden and depth to basement was consistent in the same model set.

However subtle futures like the subsurface geometry and the basement topography did not show much correlation, except for obvious features in figure 6, generated from second profile, where noticeable depression and elevations within the subsurface correspond with each other.

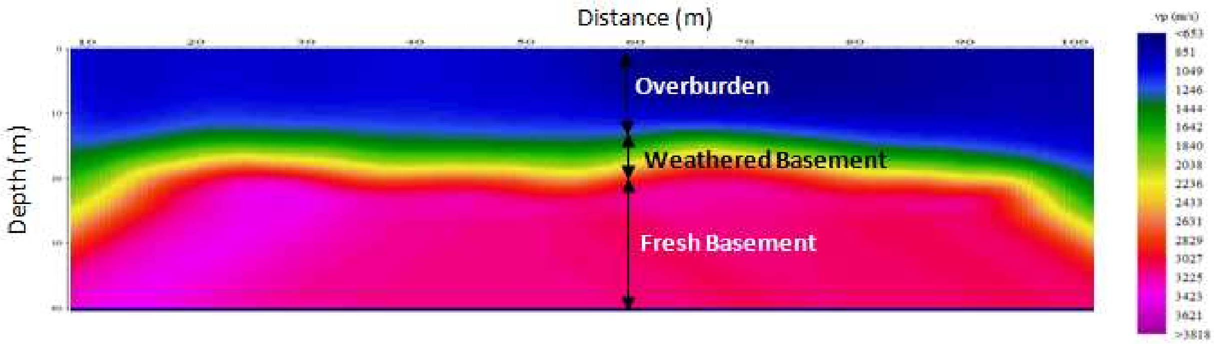

Figure 4: Generated Tomography profile, indicating the various layers within the subsurface

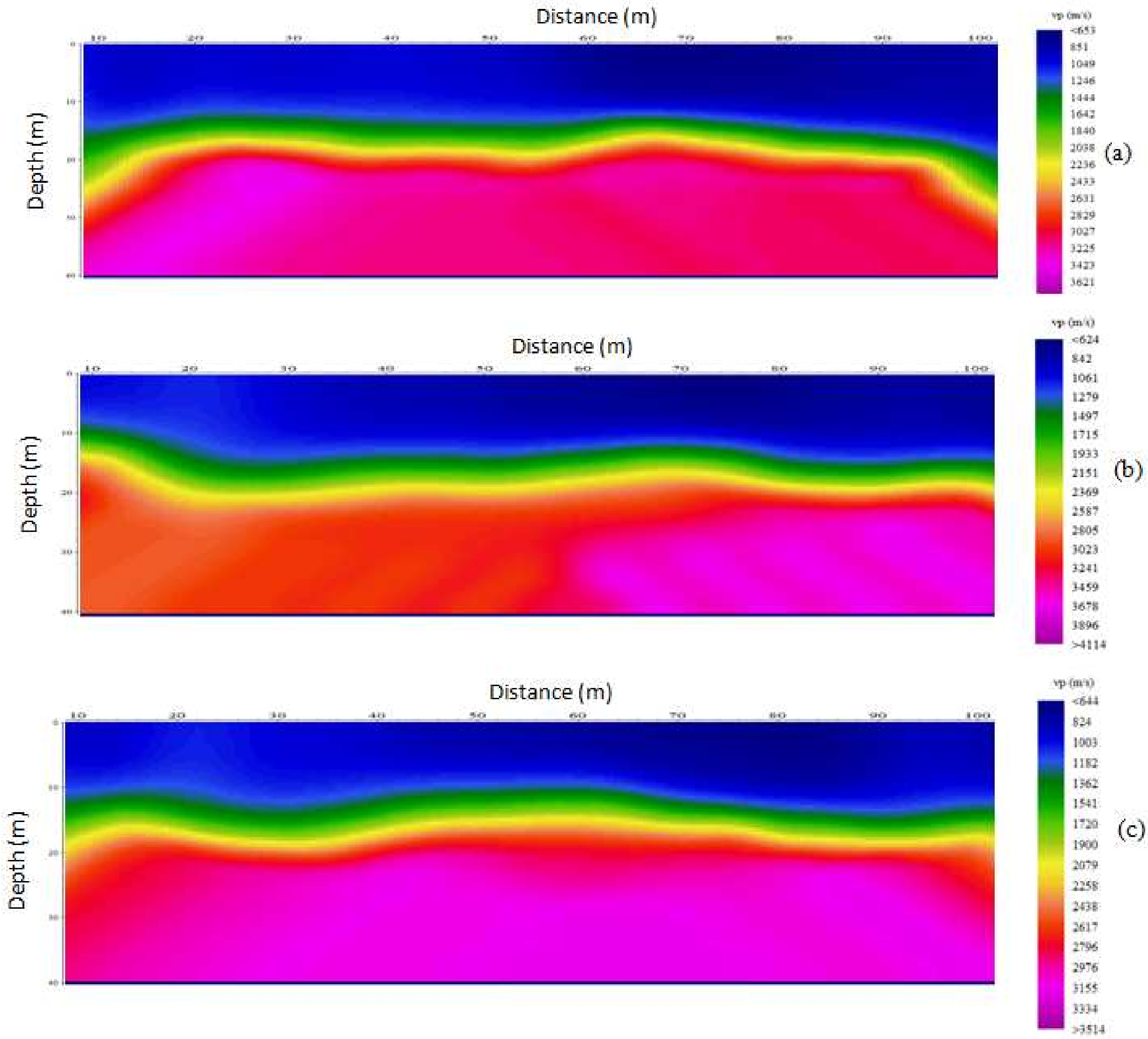

Figure 5: Generated Tomography Models for first profile (a) First processing (b) second processing (c) third processing of the same raw seismic data.

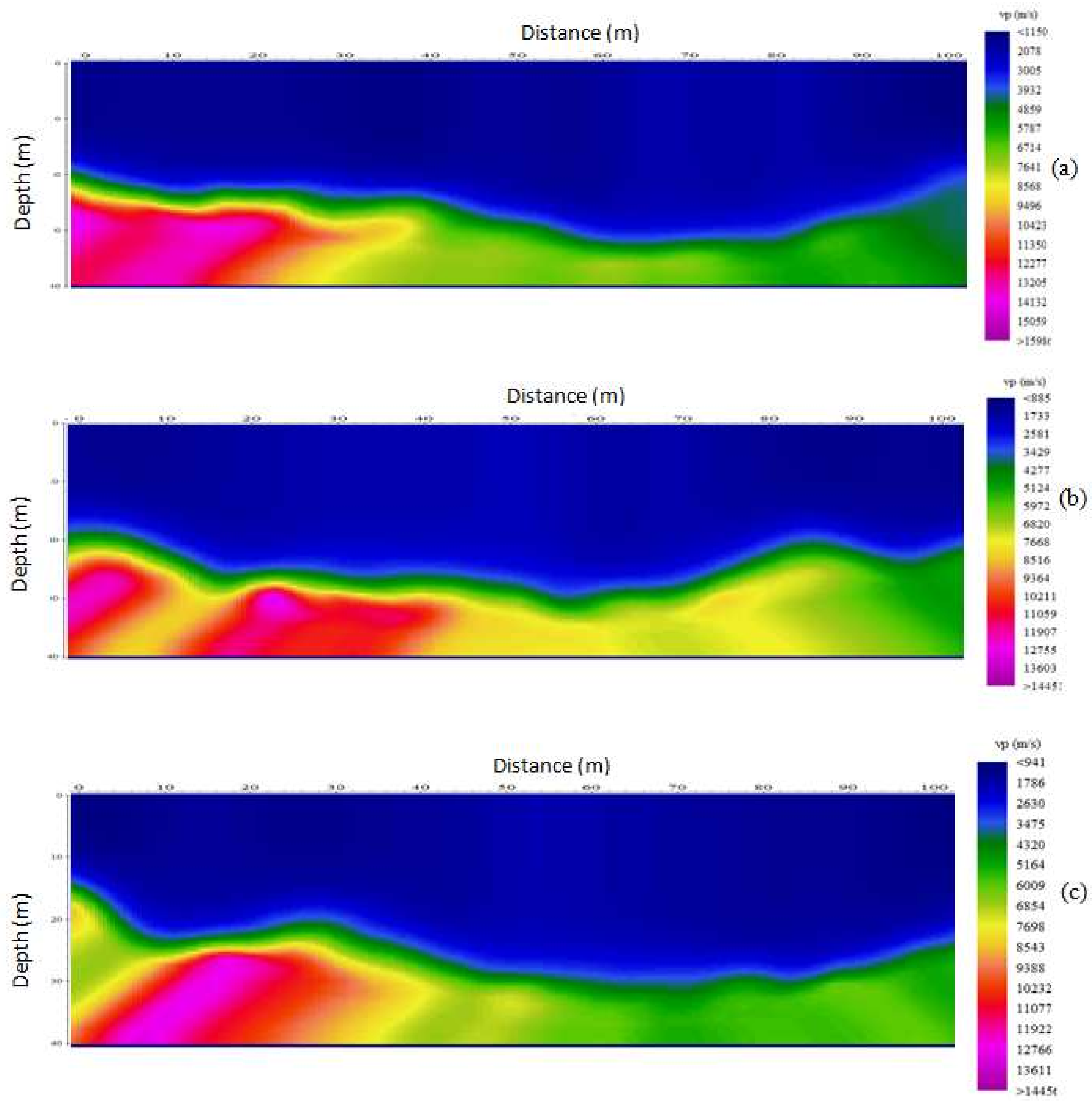

Figure 6: Generated Tomography Models for second profile (a) First processing (b) second processing (c) third processing of the same raw seismic data.

CONCLUSION

Processing geophysical raw data once, especially if there is a variable input, could give a misleading result and interpretation. The same geophysical data should be reprocessed at least three times, and the resulting models compared for the extent of repeatability with each other. It is only when the extent of repeatability is high, that it can be compared with another data taken at different time in the same location, in the event of "time laps" seismic data analysis. This is to ensure that the observed changes due to "time laps" are not due to processing artefact, rather that geological changes. The developer of geophysical software which has a variable parameter input (like variable travel times), should consider the option of providing opportunity for inputting the variable parameter several times so that the average value will give a more accurate result than one single value.

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