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Joint inversion of high resolution seismic reflection data and seismic refraction tomography model to illuminate the very near surface structures

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ABSTRACT

Information within less than 50 ms of seismic reflection data are often masked by surface wave. These amplitude and velocity information within this region are needed to delineate the very near surface structure and for proper static correction of reflection seismic data. This research was carried out with a bid to developing a technique that could solve the problems of near surface reflection within the upper low velocity zone. High resolution seismic reflection data was carried out using split spread techniques to characterise the subsurface structure, however, the near surface information was marred with ground roll. The data was reprocessed to extract seismic refraction tomography model, which has a better resolution of the very near surface structure even within the loose sand. The result obtained from the tomography model showed accurate distribution of seismic velocity, and the structural geometry within the very near surface. These information were used to effect static correction on the reflection data that delineated the deeper structures with the subsurface. A combination of the two techniques serves as better way to delineate the subsurface structure both at depth and in the very near surface.

Keywords: inversion, tomography, reflection, high resolution, near surface.

INTRODUCTION

Information within less than 50 ms on most seismic reflection data are lost to surface wave and the effect of the near surface layer. Hence this research work was carried out to solve the problem of near surface reflection. Seismic refraction tomography model, which is an imaging technique, was extracted from the high resolution reflection data with the objective of illuminating the very near surface structure. Earlier investigation carried out by other researchers has shown that:

Containment of air blast is essential, particularly when reflections at times of less than 30 ms are needed. Near-surface alluvial materials are highly heterogeneous and sometimes anisotropic, therefore detailed velocity analyses are often necessary to extract reflections within alluvium and from shallow bedrock when using the CDP method (Steeples and Miller, 1990).

Reflection imaging of the shallowest interfaces (< 10 metres) is difficult because reflections are present on only a small number of short-offset traces for any shot gather; and those reflections present are usually masked by strong coherent noise which must be strongly attenuated before imaging the reflections (David et al, 2002). The proposed method, which analyzes the structure and velocity of near-surface layers and monitors their effects on reflection data, may be considered a basis for selecting an appropriate processing method or workflow and attenuating the near-surface effects. (Congde et al, 2009). Some of the pitfalls an interpreter may face when dealing with near-surface data include the spatial aliasing of ground roll (Steeples and Miller, 1998).

Precise static correction application to conventional/deep seismic reflection data helps in imaging of subsurface in fold belt areas (Arun et al, 2011).

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} 04.900' N, longitude 007^{o}43.123' E and latitude 11^{o} 04.899' N, longitude 007^{o}43.177' E. The imagery map of the study area is shown at figure 1.

Figure 1: Satellite image map of the survey area, with red line indicating survey point

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 granite 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).

MATERIALS AND METHODS

The instrument that was used for the survey include 24 channel Terraloc mark6 seismograph, 25 vertical geophone with one acting as the trigger geophone, sledge hammer strike on base plate and two reels of cables with take out. The split spread technique was employed for the data acquisition. The receivers where set at 1 m interval. After a stack of five shots at each shot point, the connection of the receiver to each of the take-outs on the cable was swapped in the direction of increasing profile, and the shots were move at a predetermined distance. The shots were then repeated, and the generated seismogram was stored for onward processing.

Data processing

The data processing flow started with importing of the raw seismic data that was recorded in SEG2 format into the ReflexW processing software. The data was initially processed for seismic refraction tomography model, and then subsequently for seismic reflection. In processing the raw seismic data for refraction tomography, the Bandpass filter was applied, with a lower cut-off 5Hz and an upper cut-off of 50 Hz. The gain filter was applied to remove the effect of the geometrical spreading. The first arrival times were picked based on the principle of "first kink" on the traces. The picked travel times were inverted using finite element model to generate the initial model. This was used for the ray-tracing process using the data travel time. This in conjunction with the initial model was iteratively used to generate the tomography model that represents the distribution of seismic velocity within the subsurface.

In processing the raw seismic data for seismic reflection, the Bandpass filter with a lower cut-off of 60 Hz and with an Upper Cut-off of 300 Hz was employed to remove the ground roll, with very low frequency. The gain filter was applied to remove the effect of geometrical spreading, due to energy attenuation as the wave spreads out from the source. *fk* filter was applied to remove every other undesired onset outside the reflection signals. The common midpoint seismic reflection data was subjected to semblance analysis, to generate a 2D velocity model of the subsurface. The generated 2D velocity model was used for dynamic correction and the stacking of the common midpoint trace. The stacked common midpoint trace, was migrated in time to produce time and depth migrated seismic section.

RESULTS AND DISCUSSION

The extracted seismic refraction tomography model showed the distribution of seismic velocity within the subsurface (Fig.3). The beginning of the profile shown in figure3, down to a distance of 40 m along the profile showed areas of high velocity within the range of 1152 m/s to 2184 m/s. This is relative to moving toward the end of profile between 41 m to 70 m along the profile that showed low velocity, within the range of 579 m/s to 1038 m/s, down to a depth of 5 m. the velocity range of the tomography model showed that it is still within the weathered basement. The tomography model was able to delineate the geometry within the near surface layer less than 10 m, by delineating the topography of the weathered basement and the thickness of the sediments which is about 5 m.

The high resolution seismic reflection section (Fig.4) was able to delineate the near surface structures that conform to a very reasonable extent to the seismic refraction tomography model, but the resolution was not as much as that of the refraction tomography model in the near surface. The seismic reflection profile was able to delineate structure down to a depth of 30 m, which could represent the interface between the weathered basement and the fresh basement figure 5.

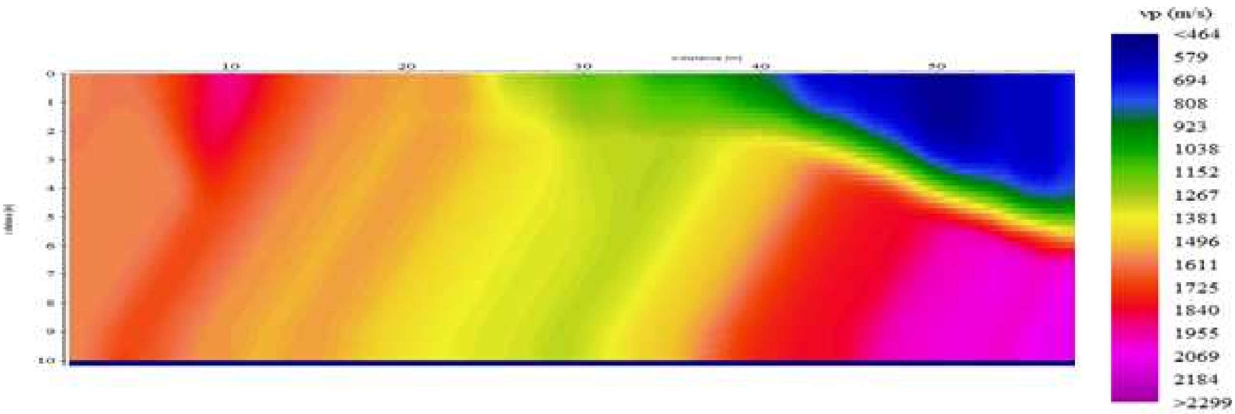

Figure 3: Seismic refraction tomography model which represent the distribution of velocity with the subsurface, extracted from the reflection data

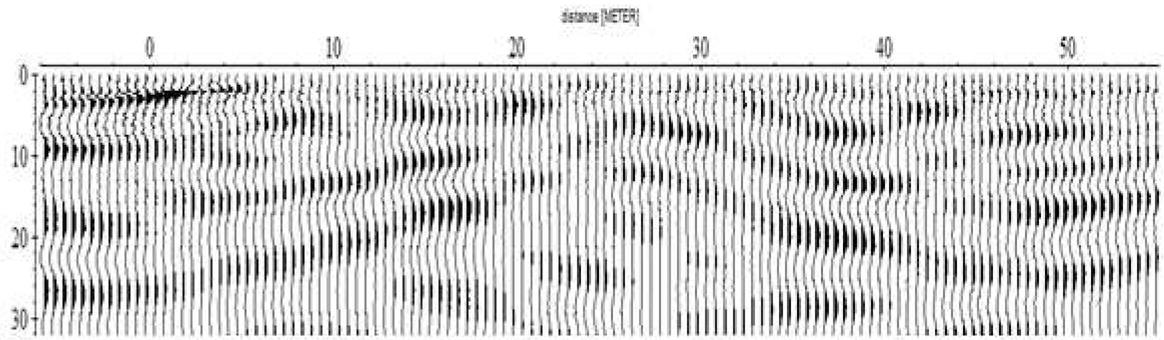

Figure 4: Seismic reflection section showing the geometry of the subsurface structures

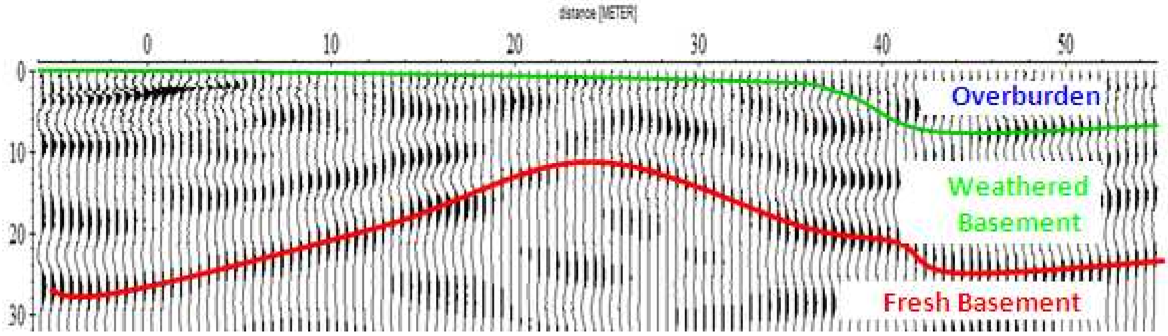

Figure 5: the same Seismic reflection section depicting the subsurface structures

CONCLUSION

This research has revealed that, tomography model which represents the distribution of seismic velocity within subsurface, can be extracted from seismic reflection data. Joint inversion of seismic refraction tomography and high resolution seismic reflection data will help tremendously to illuminate the very near surface structure, which has been a problem in seismic reflection processing. It will also help in the delineation of structural geometry at depth, when the information from the seismic refraction tomography data are adequately utilised.

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