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Joining Diverse 3D Geometries in PSTM

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SUMMARY

Unique set of 4 overlapped 3D hard rock seismic surveys was processed jointly after successful merging. All four data sets had significant differences in design parameters so that nominal bin size, fold, source/receiver spacing, source line/receiver line interval, azimuthal and offset distribution were quite diverse. Hence the main objective became to attenuate strong footprint caused these geometrical differences. To do so we firstly utilised unique CMP binning followed by surface consistent processing and relative amplitude preservation. Excellent PSTM results were subsequently achieved by appropriate operations performed in the offset planes and by zeroing all the extrapolated migration artefacts. This comprehensive approach resulted in amplitude consistent, fully merged 3D seismic cube with continuous reflectors across entire area which made interpretation reliable and provided assistance to the drilling program.

Introduction
A 2D/3D high resolution seismic acquisition campaign was conducted in the vicinity of the existing mine area in the Iberian Pyrite Belt on behalf of Lundin Mining Corporation in 2011 and 2012. Processing of the seismic data began soon after acquisition and continued with the major objective of integrating all 2011 and 2012 3D seismic datasets together into a single volume. The mineralised zone consists mainly of massive sulfides that produce reasonable good seismic response in this area. In 2011 3D seismic data were acquired over an area of 25 sq.km covering the known deposits using mid-range vibrators (38,000 Lb). Data were recorded by a high density receiver patch consisting of around 1,100 active channels. Data processing utilised AGC and post-stack migration for an increased turnaround time. Subsequently two tranches (N-W 42 sq.km and S-W 10 sq.km) of 3D data were recorded in 2012 and processed independently using the same processing flow. The third 3D dataset of a 10 sq.km acquired in 2012, over an active tailings dam was processed using both post and pre-stack migration algorithms. Sparse and irregular receiver distribution of the tailing data set resulted in substantial variations in offset and azimuth distribution that lead to severe degradation in the quality of the post-stack migrated output. Considerable improvement was achieved through the application of pre-stack time migration (PSTM) algorithm. This inspired further processing and analysis which aimed to deploy PSTM for merging of the final volume as well. The main challenge was to overcome the effects of different geometries, sources and variable coupling (seasonal variations) on imaging quality.

Experimental seismic surveys
The final merged volume was processed using two processing flows. The first utilised AGC in order to expedite the processing turnaround time as well as enhance subtle structures. The second approach maintains relative amplitude variation between seismic events. The second product was favoured for the direct targeting based on previously observed amplitude anomalies that could be associated to the occurrences of massive ore. It must also be noted that a VSP acquired nearby known mineralisation provided the only calibration point. Therefore, the depth position of seismic events becomes more ambiguous the further the event was from the borehole.

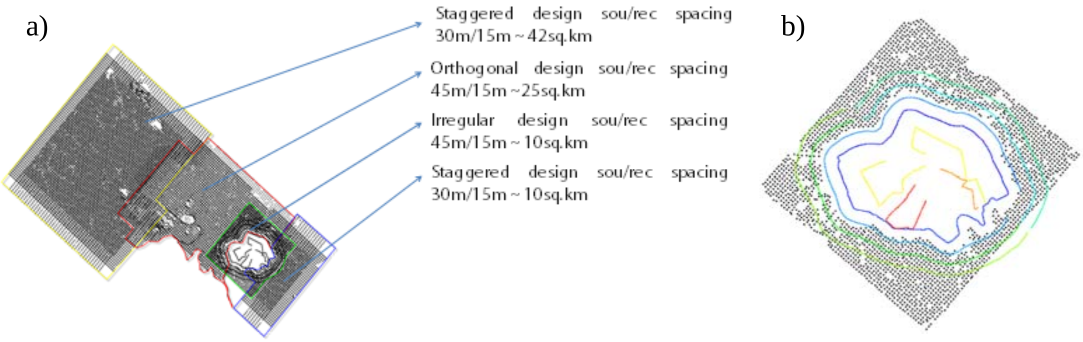

Figure 1: *3D geometries of four 3D datasets acquired in period 2011-2012 (left) and enlarged view of the Tailings Dam (TD) irregular design (right).*

The main challenge in merging these four dataset was to overcome the foot print created by vastly diverse 3D geometries utilised for the acquisition of these four volumes. Receiver and source spacing, receiver and source line interval, survey azimuth, fold coverage, offset and azimuth distribution were all different (Figure 1). However as the first coherent images appeared the interest grew and the data merge became one of the primary objectives. The TD-3D survey can be regarded as a non-conventional or even experimental as it was designed to prospect under an active tailings dam. The access restrictions resulting in less than optimal offset distribution and severe acquisition footprint. Its location was essential to provide seamless integration between the 2011 and 2012 seismic surveys (Figure 1b). An initial success with pre-stack imaging of TD-3D, justified the use of PSTM algorithm for the merged volume. This imaging technique, based on Kirchhoff integral solution allowed us to utilise unique bin size for all datasets. Initial challenge was the application of amplitude consisted processing of merged geometries. These issues included the diverse spacing between sensors, S/N ratio and different source strength and frequency content. While all vintages were acquired by vibrators, the vibrating trucks type, sweep length, frequency and the number of sweeps were different. Diverse offset distribution was addressed by using large offset bins for pre-migration trace normalization. The normalization of the offset planes was critical for the imaging success, as offset planes have highly irregular fold coverage and severe fold footprint (Figure 2).

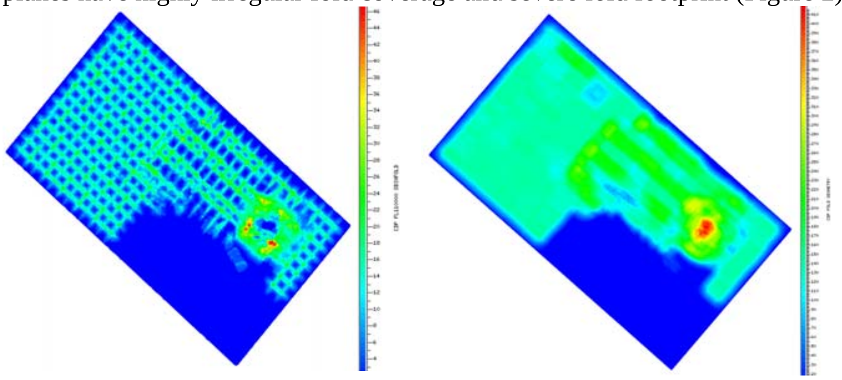

Figure 2: *CMP fold coverage of offset plane 1200m-1420m (left), CMP nominal fold coverage of merged datasets (right)*

The most critical difference in offset distribution was in TD-3D area. Absence of near offsets over most the area and the existence of very large maximum offsets (twice larger than found in other vintages) characterised this data set. However these large offsets had to be kept for migration since they contained information about the orebody and the major faults being indicated by the previous processing. The large-offset problem was treated by constraining the post migration geometry of the offset planes. It consisted of elimination of the extrapolated migration swings that migration aperture creates in areas where pre-migration traces do not exist (Figure 3).

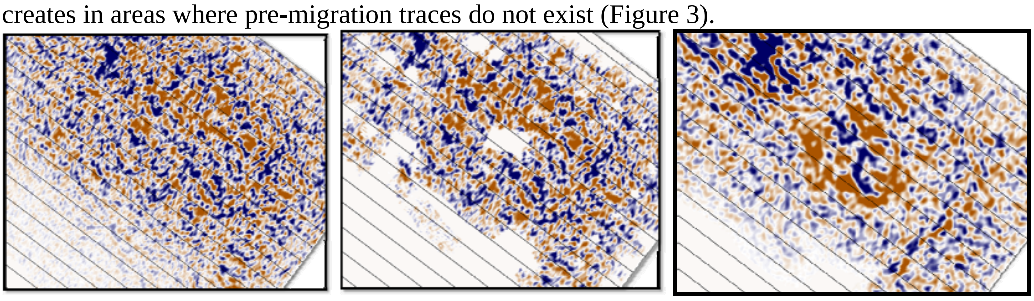

Figure 3: *Figure 3: Time slices from PSTM cube over tailings dam area (350ms). Migrated offset planes after trace normalisation (left), without extrapolated traces (center) and migrated and stacked 3D volume (right).*

Conclusions

One of the assumptions of 3D seismic data imaging is that offsets and azimuths have consistent distribution and that the trace density is regular. Hence straightforward merging of seismic datasets with diverse geometries will create processing and imaging problems that need to be addressed. For that purpose we utilised pre-stack Kirchhoff migration algorithm and applied it on the merged seismic volumes after successful implementation of relative amplitude preservation through iterative surface consistent approach. Excellent results were achieved by appropriate operations performed in the offset planes and by zeroing all the extrapolated migration artefacts. This comprehensive approach resulted in amplitude consistent, fully merged 3D seismic cube with continuous reflectors across entire area which made interpretation reliable and targeting precise.

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