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Vintage 2D Reflection Seismic Data for Use in 3D Structural Modeling: Case Study from the Witwatersrand goldfields, South Africa

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This project examines the potential use of an archive of legacy, processed and migrated 2D reflection seismic data, to construct pseudo 3D structural models. These 3D models are used to test and expand existing regional structural models for both the Witwatersrand and Transvaal basins. The choice not to reprocess the data is critical if the vast archive of over 500 2D reflection lines is to be properly utilized without extensive reprocessing. The primary study area encompasses the northwestern Witwatersrand Basin between the cities of Ventersdorp, Potchefstroom and Klerksdorp.

One of the major challenges of using the onshore 2D reflection seismic data in the 3D environment is the acquisition geometry of the seismic lines. Onshore 2D reflection seismic data are typically acquired along crooked roads. Additionally, due to technical difficulties, acquisition of the seismic lines may have been stopped or restarted after repositioning of equipment with a slightly different offset geometry. This may result in shot point indexing and spatial dislocation anomalies that are due to the orientation of the common depth point (CDP) bin, which places the CDP spatially behind or in front of the succeeding shot point.

The manifestation of these indexing and spatial anomalies in plan (map) view, results in shot points which are numerically out of sequence and spatially discordant. In 3D, the under or overlapping shot points and duplicated data, often stretch the seismic reflections and place them in the wrong positions. The distorted or cross-cutting reflections render the 2D data unusable in modern 3D interpretation space.

In order to correct the physical geometry of the individual 2D seismic lines for use in 3D space, it is necessary to rebuild/restore the relative shot point - trace geometry. An iterative set of linear and cubic spline trace interpolation calculations is used to re-project the geographic coordinates for each seismic trace within the SEG-Y binary header. This process eliminates overstepping location data, and reproduces the approximate shot point and trace common midpoint geometry originally used during acquisition.

When working with 2D reflection seismic data, it is it is unlikely that the imaged subsurface structure(s) were located orthogonal to the acquisition line. Therefore, the reflection from a structure will display the apparent dip (ϕa) rather than the true dip (ϕt). Using the apparent dips, we can verify the geological structures by calculating the true dip and strike of a structure. This allows reflections in non-adjacent seismic lines to be mapped with great confidence as real and continuous structures. Crooked line reflection seismic data are unique in that each segment of the seismic line with its differing strike orientation may be treated as a separate section, and individual structural measurements taken from the different segments thus satisfying the mathematical proof.

Mapping of 2D structures in 3D space, combined with mathematical verification of structural orientation and continuity, adds extraordinary value and insights into the regional geology of the Witwatersrand and Transvaal basins. 3D modelling results derived from the 2D seismic data in Potchefstroom have produced a new model for the timing of strato-structural evolution of the area. Additionally, thrusting (in 3D) in the Basement Complex of the Witwatersrand Basin has been mapped with the use of cross-cutting 2D seismic lines, this information can be used to develop 3D structural models of the basin within the context of the on-going development of the Kaapvaal Craton.