Application of reflection seismic to mineral exploration, world-class Century Zn-Pb-Ag deposit, northwest Queensland, Australia

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Talk Outline

Reprocessed and re-interpreted government acquired (Geoscience Australia) regional seismic dataset is useful in mineral exploration industry.

- Location and geological setting of Century deposit;
- Seismic data acquisition;
- Processing of seismic data;
- Interpretation of reprocessed data;
- Magnetotelluric survey (comparison);
- Geological implication related to new interpretation; and
- Conclusion.
Century world-class clastic–dominated Zn-Pb-Ag deposit

- Approximately 250km NNW of Mt Isa (NW Queensland, Australia);

- Western succession of Proterozoic Isa Superbasin – the world richest zinc belt (HYC, Hilton/George Fisher, Mt Isa, Dugald River, Cannington);

- Hosted in shale and siltstone of Lawn Hill Formation;

- Unmetamorphosed, weakly deformed deposit, preserved as a downthrown block;

- Pre-mining resource 118Mt@10.2%Zn, 1.5%Pb and 36g/t Ag; mining rate of 6Mt/annum.
Seismic line 06GA_M2 in relation to Century Mine and major structures Termite Range Fault (TRF) and Riversleigh Lineament (RL).

2D regional seismic reflection survey has been conducted to help understand Lawn Hill Basin architecture and nature of the underlying basement and geometry of TRF.
Geoscience Australia (GA), Predictive Mineral Discovery Co-Operative Research Centre (pmd*CRC) and Zinifex Limited conducted seismic survey as part of the G14 Project in June 2006.

- Seismic line 06GA_M2 is 62 km long and extends across the Lawn Hill Basin near the Century deposit.
Data Acquisition

- Three IVI Hemi 60 Vibes were source of seismic energy (with 15 m pad-pad 15m moveup);

- 240 active seismic channels were deployed for this survey.
Data Processing

Raw shot data - purchased from Geoscience Australia and re-processed by HiSeis Ltd consultancy.

Processing efforts - computation of the refraction and residual reflection statics and seismic velocity analysis.

Problems during data processing:

- Strong lateral variation of the seismic velocities (caused by very large fault systems and lithology) - required implementation of the old fashioned constant velocity stack analysis;

- Seismically very heterogeneous zone near surface (alluvium, sandstones, shale and limestone) - required every shot record to be individually picked and used for computing of refraction statics;

- High bending of seismic line combined with some reflection events (especially in vicinity to Century deposit).
Data Processing

- Occasional occurrence of “blind zones” due to presence of alternating high and low seismic velocity layers. HiSeis Ltd - computed refraction statics of both refracted and reflected events.

Raw shot record before (left) and after (right) application of refractions static. Continuity of refracted (arrows) and reflected (yellow lines) events was improved with application of refraction statics.
Processing flow – implemented by HiSeis

1. Specification of survey geometry, crooked line binning;
2. Trace edit;
3. Root-mean-square (RMS) shot energy equalisation;
4. True relative amplitude recovery;
5. First arrival (first break) picking and refraction static calculations;
6. Noise analysis (filter test, deconvolution test);
7. Application of spiking deconvolution followed by broad band-pass filtering;
8. Surface wave noise attenuation (2D filter in frequency domain);
9. Constant velocity stacks – sparse velocity lows;
10. Stack;
11. Residual reflection static computation;
12. Stack;
13. Dip move-out correction (DMO (Deep Move-out) or partial pre-stack migration);
14. Interactive velocity analysis II – final velocity lows;
15. Stack;
16. F-X deconvolution (noise supression);
17. Post-stack time migration;
18. Depth conversion.
Interpretation of reprocessed seismic line

Undertaken by Minerals and Metals | MMG and HiSeis Ltd using:

- Multiple passes of constant velocity stack analysis model – model which preserved both steep and flat laying reflectors;

- Interpretation started with a perigram section computed on DMO migrated stack section.

- Interpretation was refined using amplitude sections.
Interpretation of reprocessed seismic line

- Depth converted sections - a scaled down version of the smoothed velocity field derived after DMO application and inverse normal move out corrections.

Migrated perigam section converted to depth

Migrated DMO stacks section converted to depth

Velocity field section from constant velocity stacks (CVS) - transformed to average
Perigram section

Migrated perigram (continuity* energy) of 06GA_M2

Perigram sections - enhance major structural features;
Interpretation of major structures

Perigram (continuity* energy) section of 06GA_M2. Major faults are marked by red arrows and zone of disturbed reflectors in green circles.
TRF zone consists of multiple westerly dipping (60 degrees) fault planes and is associated with easterly dipping antithetic fault. Century is located in the hanging wall of the TRF.
Interpretation of Termite Range Fault (TRF) zone
Constant velocity stack (CVS) 6000 m/s section
Century deposit and TRF details

CVS (6000 m/s) section

migrated DMO stuck section
Interpretation results

Identified main structural features controlling the basin architecture show a significant improvement from previous interpretation:

- Riversleigh Lineament (RL) is a major basin bounding fault easterly dipping (45º) with a hangingwall downthrown (> 9 km); it displays a listric nature with a flower splay in the upper section; across fault is present an intense change of seismic reflectors nature - stratigraphic thickness;

- Termite Range Fault (TRF) is a westerly dipping (60º) basinal fault, antithetic to RL fault; TRF controls structural geological emplacement of Century deposit.

- Presence of possible diapiric bodies in lower stratigraphy.
Interpretation of 06GA_M2 seismic line by GA (2010)

Linking deep seismic reflection profiling to known and potential mineral deposits by Hutton et al. (2010).
Interpretation of seismic reflection profile by MMG (2011)
Magnetotelluric sounding (MT) survey

High Definition MT surveys near Century Mine, Lawn Hill Platform, Northern Australia and crustal architecture by T., Jong Lee at all (2006).

- MT was conducted on two lines to the north and west of the Century mine with a aim to image the intermediate and deep level structure and stratigraphy.

- Specific focus was to delineate the position and depth extent of the TRF, a major structure that controls Century mineralisation.
Magnetotelluric sounding - interpretation

2-D inversion sections using MT mode for Line-1 by T., Jong Lee at all (2006) (re-interpreted by MMG)
Implication on geology

- Lawn Hill Platform is an asymmetrical half-graben basin; north-westerly elongated with the deepest part on the western margins along the RL;

- RL is a major basin bounding easterly dipping fault (45º) with a hangingwall downthrown (> 9 km);

- TRF is a westerly dipping (60º) basinal fault, antithetic to RL fault; along with RL controlled sedimentation;

- Century deposit is located in the hangingwall of TRF;

- Presence of salt diapirs (drag geometry and distortion of seismic reflectors);

- Inversion tectonic style (partly inverted) – extensional basement faults display full and partial reactivation, and basin faults are activated flat with reverse sense – displaying a thin-skinned tectonic style.
Conclusion

- Interpreted seismic data are important for understanding models concerning the migration of metal-bearing fluids through the fault and fracture systems and potential structural trap for mineral precipitation – in our case - hangingwall anticline of the reactivated basin fault (TRF);

- In the Lawn Hill region seismic methods can be used for detailed exploration (favorable flat laying geology);

- Further improvements can be achieved by positioning 2D surveys strictly in the dip direction of the dominant structures;

- However, direct target generation in mineral exploration requires 3D seismic methodology;

- Opportunity exists in re-processing old government surveys (public domain) with a more powerful software with a low cost to help creating future exploration strategies.