

Olympic Dam seismic revisited: reprocessing of deep crustal seismic using partially preserved amplitude processing

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Introduction

Deep seismic reflection data is collected around the world in order to image the structure of the crust. Two-dimensional seismic data can be processed in a variety of ways, each technique permitting investigation of different aspects of the data and thus of the geology the line is transecting. A focus of deep crustal seismic surveys has been to investigate the nature of the lower crust, the geometry across the Moho, or the geometry of paleosuture zones between crustal blocks (Hammer et al. 2010; Kennett et al. 2013). The processing methods that are applied to image the Moho at depths of 30–50 km can smooth over higher order reflectivity features in the upper crust. For example, the application of a low-pass filter emphasises continuity between individual seismic traces, which enhances consistency between individual traces to produce a 'smooth' image.

An alternative method to extract more detail on the upper crust is to apply a processing method known as partially preserved amplitude processing, a proprietary method of HiSeis Pty Ltd (Jakica and Pridmore 2014). This processing technique emphasises variation in signal strength by preserving the temporal relative amplitude ratio, which has the effect of sharpening the output image. This resulting image is designed to be more sensitive to fabric within a rock, particularly in the upper crust, but also to the presence of discontinuities.

In this paper we provide new observations on the upper and middle crust around the Olympic Dam Cu–Au–U deposit, South Australia, from seismic data reprocessed using the partially preserved amplitude technique. Olympic Dam is the type example of hematite breccia iron oxide

copper–gold (IOCG) style deposits (Williams, Barton, Fontboté et al. 2005; Skirrow 2009) and lies buried ~400 m beneath sedimentary cover of the Stuart Shelf (Fig. 1). A major challenge to exploration in much of the Olympic Copper–Gold Province is thick sedimentary cover that results in a reliance on geophysical data and limited drillholes to obtain an understanding of the geology. In 2003, two orthogonal deep crustal seismic lines were acquired by Geoscience Australia, centred on the Olympic Dam deposit – 03GA-OD1 and 03GA-OD2 (Figs 1, 2; Goleby et al. 2003).

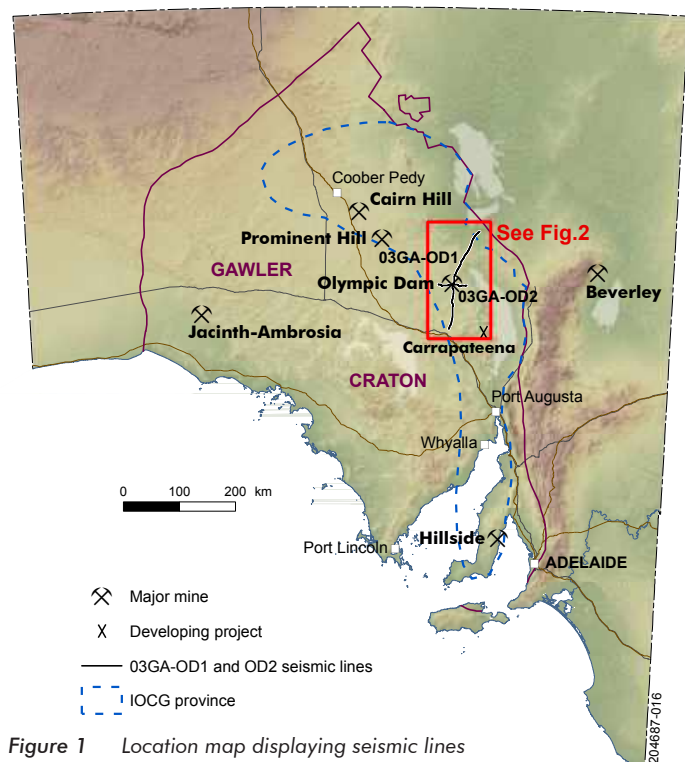


Figure 1 Location map displaying seismic lines 03GA-OD1 and 03GA-OD2 in the context of the Gawler Craton and the IOCG province.

Seismic images with original Geoscience Australia processing were downloaded from the Geoscience Australia website (Geoscience Australia nd). Following a brief outline of the geological context for Olympic Dam and a description of the processing methodology, we discuss some of the geological features that appear to be enhanced using partially preserved amplitude processing and suggest that seismic data may be directly imaging the hematite alteration associated with the Olympic Dam deposit.

Geological setting

The eastern Gawler Craton in the vicinity of Olympic Dam is underlain by Neoproterozoic crystalline basement that is intruded by a c. 1850 Ma batholith known as the Donington Suite and overlain by c. 1790–1750 Ma Paleoproterozoic metasedimentary units of the Hutchison Group and Wallaroo Group (Jagodzinski 2005; Hand, Reid and Jagodzinski 2007; Skirrow et al. 2007; Fig. 2a). The Paleoproterozoic intrusive and sedimentary rocks of the eastern Gawler Craton have been intruded by c. 1585–1595 Ma A-type granites of the Hiltaba Suite, and are in places overlain by similarly aged felsic and mafic volcanics of the associated Gawler Range Volcanics. These early Mesoproterozoic magmatic rocks are the result of a craton-wide thermal event associated with deformation in the eastern and northern Gawler Craton and with the major tectonic event of the adjacent Curnamona Province, the Olarian Orogeny (Conor and Preiss 2008; Conor et al. 2010; Forbes et al. 2011). During this early Mesoproterozoic tectonic event, the eastern Gawler Craton underwent extensive hydrothermal alteration and mineralisation, with IOCG deposits such as Olympic Dam, Prominent Hill, Carrapateena and Hillside all forming at this time (Cross, Daly and Flint 1993; Skirrow et al. 2007; Reid et al. 2013). The Olympic Dam deposit is underlain by a ~5 km thick sill of Mesoproterozoic granite of the Hiltaba Suite known as the Burgoyne Batholith, including the Roxby Downs Granite that hosts the IOCG mineralisation (Johnson and Cross 1995; Jagodzinski 2005). Olympic Dam has a distinctive geophysical signature (Figs 2b, c) marked by a prominent gravity high related to extensive hematite alteration within which Cu–Au–U– rare earth elements mineralisation is developed (Ehrig, McPhie and Kamenetsky 2012).

The eastern Gawler Craton is overlain by a number of sedimentary basins of variable thickness including the Carriewerloo Basin of probable Mesoproterozoic age (c. 1450 Ma); the flat-lying Adelaidean–Cambrian sedimentary rocks of the Stuart Shelf; Permian sediments of the Arkaringa Basin; Mesozoic sediments of the Eromanga Basin; along with a veneer of Miocene–Pliocene and Holocene fluvio-lacustrine sediments. The total sedimentary cover thickness across the Stuart Shelf ranges from ~300 m to >1 km (Reeve et al. 1990).

The geology of the Olympic Dam region has been reviewed in a number of publications to which the reader is referred to for more detail (e.g. Cross, Daly and Flint 1993; Daly, Fanning and Fairclough 1998; Drummond et al. 2006; Direen and Lyons 2007; Hand, Reid and Jagodzinski 2007; Skirrow et al. 2007; Reid and Hand 2012).

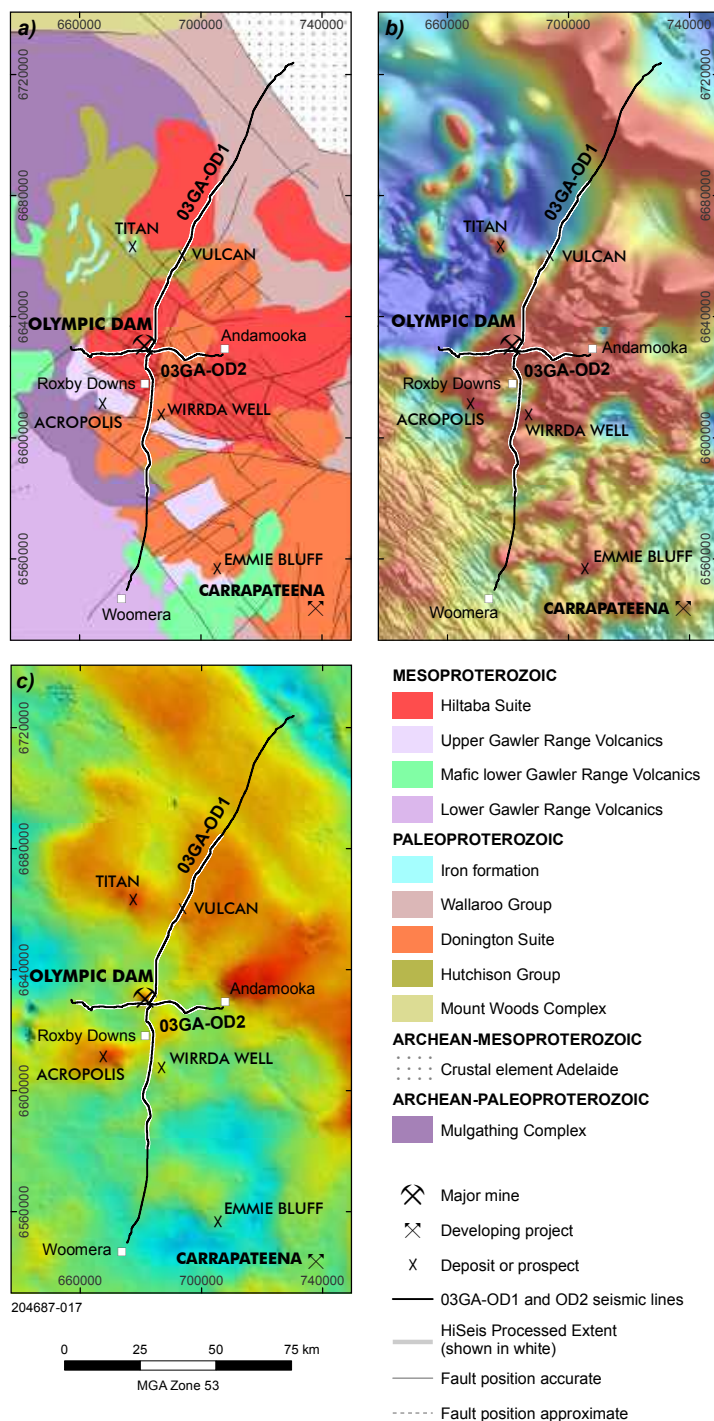


Figure 2 Reprocessed extent of seismic lines 03GA-OD1 and 03GA-OD2 over (a) basement geology, (b) regional aeromagnetics and (c) gravity imagery.

Seismic data acquisition and processing

The seismic reflection data was collected in 2003 along two broadly orthogonal lines totalling ~250 km (Jones, Johnstone and Goleby 2005). The longer of the two lines, 03GA-OD1, was 193 km long and oriented approximately north–south, broadly orthogonal to the regional strike. The shorter line, 03GA-OD2, was 57 km long and oriented approximately east–west, thus providing a 3D image of the Olympic Dam region (Fig. 2). The lines were recorded to 18 s two-way time, equivalent to ~55 km depth at a sample rate of 2 m/s using three in-line 60 000 lb vibrators (IVI HEMI60) as the energy source. Vibration points were 80 m apart and three upsweeps of 12 s duration, with a frequency sweep of 7–56, 12–80 and 8–72 Hz at each vibration point. Receiver groups were spaced

at 40 m intervals with 12 geophones being spaced at 3.33 m apart. The data were correlated in SEG-Y format (Jones, Johnstone and Goleby 2005).

The original processing of surveys 03GA-OD1 and 03GA-OD2 was conducted by Geoscience Australia using the Disco software package. The processing workflow was designed to image the entire crust while avoiding downgrading the data in the near surface (Jones, Johnstone and Goleby 2005). The processing workflow summarised in Table 1 consists of crooked line processing, refraction statics corrections, velocity analysis, spectral equalisation, sort to common mid-point gathers, dip moveout corrections, stack, post-stack migration, bandpass filtering, and, in some cases, semblance filtering (Table 1).

Table 1 Processing work flows used by Geoscience Australia and HiSeis

Geoscience Australia	HiSeis P/L
Line geometry and crooked line definition (fixed common depth-point interval)	SEG-Y input
Field SEG-Y to Disco format: resample to 4 m/s and 8 s	Geometry assignment and quality control – bin size 20 m
Quality control display. Selected trace edits and 50 Hz notch	First break picking and refraction static computation: final datum at 120 m; replacement velocity 4500 m/s
Spectral equalisation (with 1000 m/s gate automatic gain control)	Quality control of the refraction static solution (on shot records, every 20th shot)
Common mid-point sort (bin wide open)	Surface consistent amplitude recovery
Gain recovery (spherical divergence)	Spherical divergence correction: time-power 1.2
Application of refraction statics, datum 0 m (AHD)	Application surface consistent spiking deconvolution – operator length 80 m
Application of automatic residual statics (autostatics calculated on 0.25–4.0 s gate)	Surface wave noise attenuation (apparent velocity of 2200 m/s)
Band filtered	Air-blast attenuation
Time (s) Bandpass (Hz)/slope (db/octave)	Bandpass filter (Ormsby, 5–12–80–100 Hz)
0.0–1.5 20/36 – 80/36	Automatic gain control based trace normalisation 3000 m/s
2.0–8.0 10/36 – 80/36	Noise attenuation
Velocity analysis using VELEX. First pass after refraction statics. Second pass after autostatics. Third pass after dip moveout (DMO)	Constant velocity stack analysis
Normal moveout correction on common offset gathers	Time gate picked for residual static calculation
Stretch mute used as front end mute	Computation of surface consistent residual reflection statics (delay time based) normal moveout and application of residual statics
DMO correction on common offset gathers	Application of top/bottom mute
Common mid-point stack	Application of T-X DMO
Trace amplitude balance	Interactive velocity analysis on DMO-corrected data
F-X migration using 90% of modified velocities	Final stack (DMO)
3 trace running mix (weights 1:1:0)	Post-stack phase-shift time migration
Signal enhancements (digistack 0.8)	Post-stack F-X deconvolution, TV bandpass filter and trace mix (3/2)
Trace amplitude scaling	Generation of seismic attributes – perigram x cosine phase
	Time/depth conversion using average velocities
	SEG-Y files to specification

HiSeis reprocessed ~160 km (Fig. 2) of surveys 03GA-OD1 and 03GA-OD2 with the aim to enhance structural and stratigraphic features in the top 5 km as well as attempting to image alteration related to IOCG mineralisation (Jakica and Pridmore 2014) whilst preserving the amplitude integrity. The processing workflow used by HiSeis is summarised in Table 1, and seismic terms used are defined in the glossary. Attention was paid to attenuating strong noise trains (such as vehicles travelling along the seismic line whilst data was being acquired) during the pre-processing phase to better image shallow features (Jakica and Pridmore 2014). The main difference to the Geoscience Australia processing workflow (Jones, Johnstone and Goleby 2005) is that HiSeis used partially preserved amplitude processing and in deeper areas a low-pass filter, and did not use 3-trace running mix nor digistack.

Initially, constant velocity stacks were used to obtain a velocity function for input into the residual static calculation and dip moveout (DMO). The final interactive velocity analysis was carried out on DMO-corrected gathers to reduce velocities of dipping reflectors and obtain the velocity model that was used for migration. Quality control stacks were created and used as the basis on which to judge improvement of the data after subsequent processing steps. The application of DMO correction, or partial pre-stack migration, removes any dipping component to seismic events in common depth-point (CDP) gathers, and solves conflicting dips at consecutive CDP positions. The edges of faults are more clearly defined and the resolution of events is increased. The application of DMO also facilitates the use of a post-stack

migration algorithm as the final processing step of the data. A post-stack phase-shift migration was applied to migrate the seismic events to their true geological position. This typically results in dipping events steepening and moving updip. The algorithm migrates data within the 2D plane regardless of where the energy was originally recorded and therefore geological features out of the 2D plane will appear within the 2D plane.

Observations on the reprocessed data

While broadly similar features can be observed with both processing techniques (Fig. 3), the partially preserved amplitude technique enables several distinct features to be observed. Four features of particular interest in the partially preserved amplitude processed data near the Olympic Dam deposit are described herein.

Location of the Burgoyne Batholith and detection of iron oxide alteration associated with Olympic Dam deposit

The Burgoyne Batholith, a large Hiltaba Suite granite in which the Olympic Dam deposit is hosted, has previously been identified by potential field data and drillhole intersections. It is broadly imaged as a non-reflective zone within both 03GA-OD01 and 03GA-OD02 allowing interpretation of its extent both laterally and vertically (Fig. 4). Of particular interest is a zone with numerous strong reflectors within this generally non-reflective body (Fig. 5). On the north-south line the reflective zone narrows at depth and is made up of subhorizontal reflectors typically several hundred metres long at depths ranging from

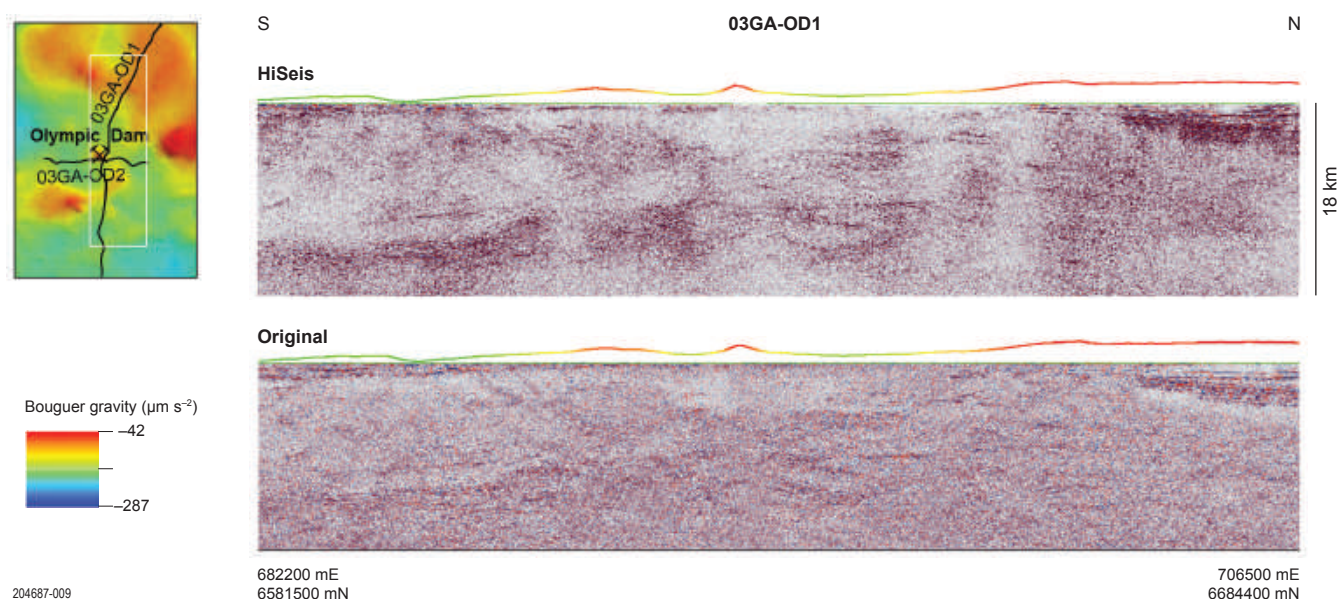


Figure 3 North-south line 03GA-OD1: HiSeis partially preserved amplitude processing (top) and Geoscience Australia original processing (bottom). Olympic Dam gravity anomaly shown on gravity profile. Note that all seismic data has been displayed and captured from GoCad using the same gain for both original and reprocessed images.

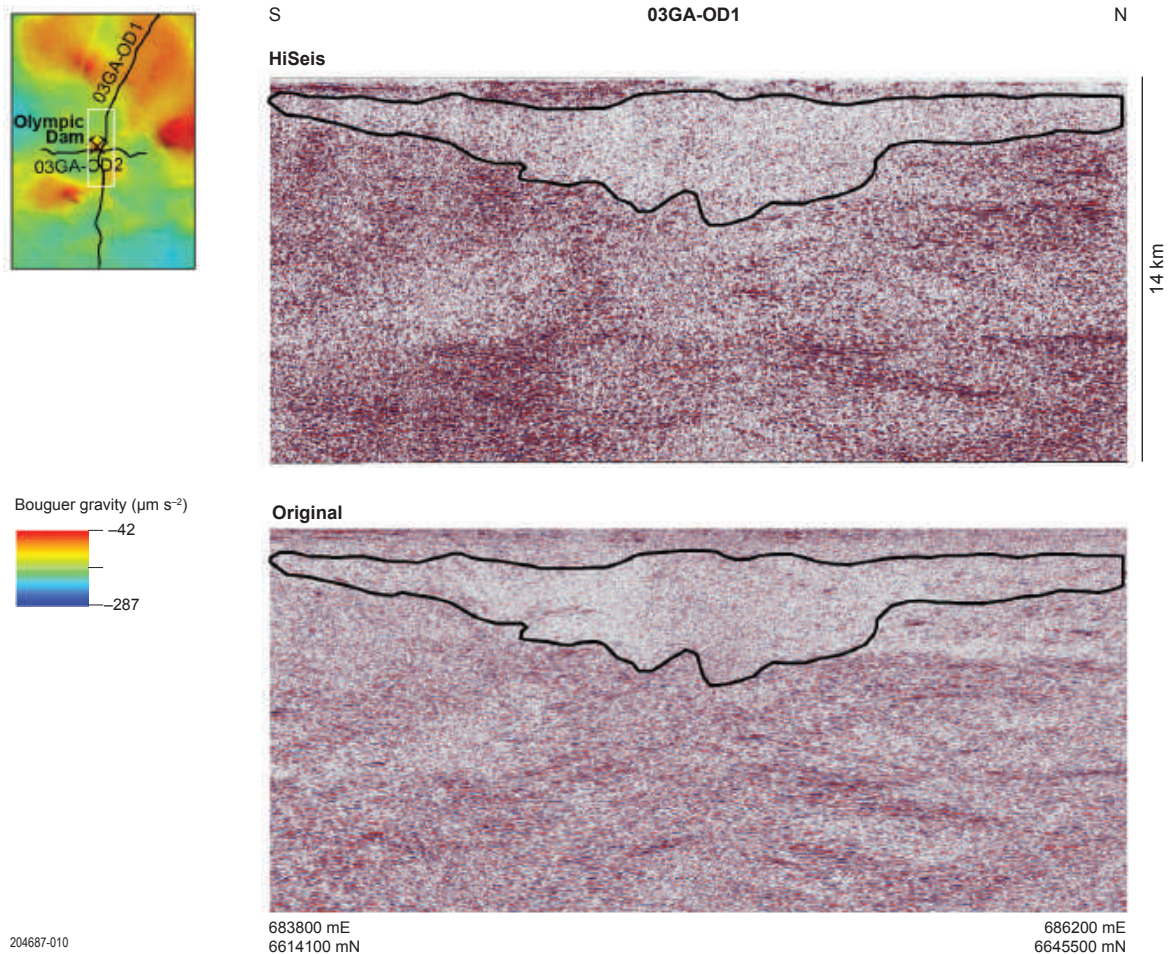


Figure 4 Central section of north-south line 03GA-OD1 displaying low reflectivity zones associated with the Burgoyne Batholith: HiSeis partially preserved amplitude processing (top) and Geoscience Australia original processing (bottom). Note that all seismic data has been displayed and captured from GoCad using the same gain for both original and reprocessed images.

~400 to 4000 m (between 683000mE 6628500mN and 684300mE 6631450mN) with a width of ~3000 m (Figs 5a, c, d) and corresponds to the known location of the Olympic Dam orebody. These reflectors are bound by narrow, semi-continuous, subvertical and non-reflective features. This more reflective zone correlates with a high gravity (and elevated magnetic) response (Fig. 5 locality insert). One interpretation is that this feature could be a large mafic body, such as a gabbro. However, the seismic feature occurs on the margin of the Olympic Dam gravity anomaly (Fig. 5) known to be caused by iron-rich breccias. An isolated gabbro would be unlikely to have an associated gravity anomaly of the magnitude seen over the Olympic Dam orebody. Taken together, the seismic and potential field data suggest that these seismic features are likely imaging the iron oxide alteration of the Hiltaba Suite granite associated with the Olympic Dam deposit. This observation is consistent with rock property studies and synthetic seismic modelling of the Olympic Dam Breccia Complex (Jakica and Pridmore 2014), which demonstrated that the contact between iron oxide alteration and silica-rich lithologies should be

reflective, and hence can be imaged with reflection seismic techniques.

An approximate section through Olympic Dam can be projected onto line 03GA-OD1 (N-S line; Figs 5d, e). This shows an approximate correlation between the known distribution of >5% total Fe in Hiltaba granite from Ehrig, McPhie and Kamenetsky (2012) and the more reflective zone. This suggests that the seismic data can directly map the extent of iron alteration and may be a potential exploration tool for this style of deposit in deeply covered terrains.

Similar seismic features appear on the east-west line at depths from ~900 to 2500 m (Fig. 6), which is slightly deeper than on the north-south line (Fig. 5). This apparent difference in depth may be a result of out-of-plane effects, imaging reflectors not directly beneath the line. In such a situation, the reflectors coming from the dense body take longer to return to the receivers, and hence appear deeper in a 2D section. This apparent displacement of the seismic feature is consistent with the reflectors being derived from the dense iron alteration related to the Olympic Dam system.

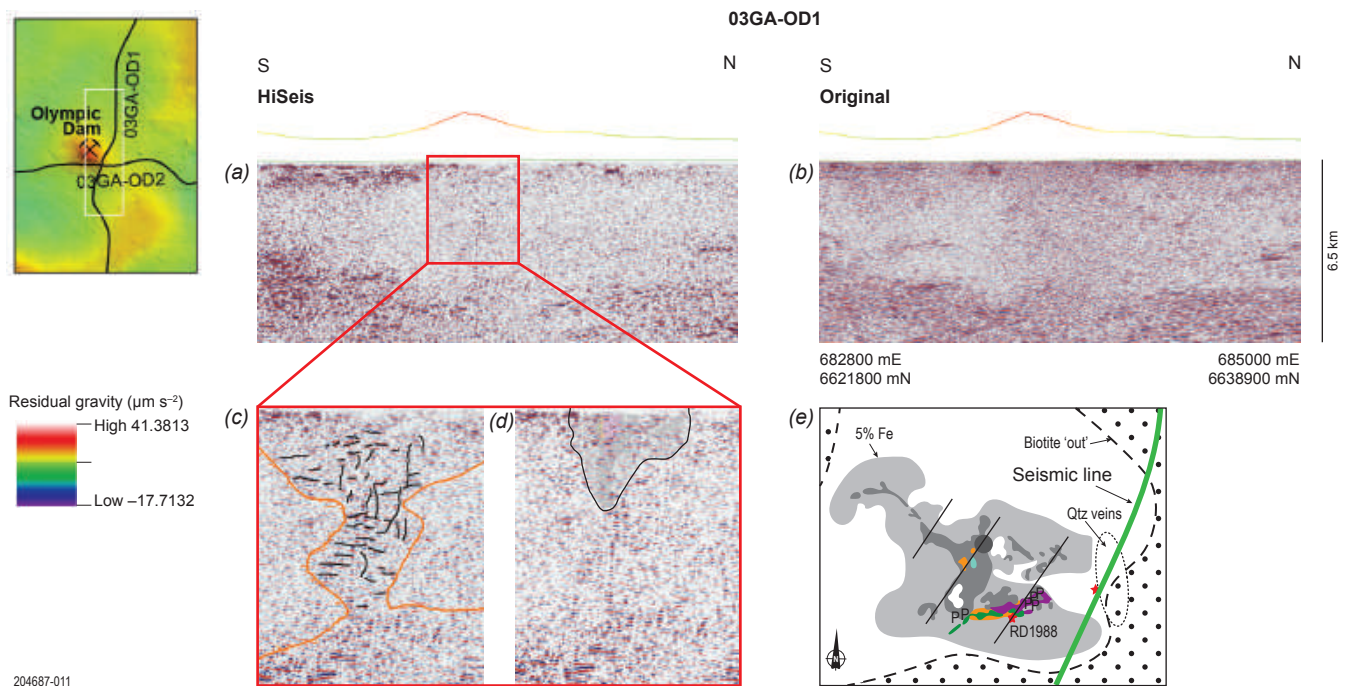


Figure 5 North-south line 03GA-OD1. (a) HiSeis partially preserved amplitude processing displaying the zone of high reflectivity (red box) within the non-reflective zone of Hiltaba Suite granite. (b) Geoscience Australia original processing. (c) Enlarged section of HiSeis processed line showing increased reflectivity and possible vertical fractures (examples highlighted in black). Unmodified low reflectivity zones shown in orange. (d) Enlarged section of HiSeis processed line superimposed over Ehrig, McPhie and Kamenetsky (2012) breccia complex cross-section. This shows a correlation between the known distribution of >5% total Fe in Hiltaba Suite granite and the zone of high reflectivity made up of subhorizontal reflectors typically several hundred metres long (~300 m wide at ~400–4000 m depth). (e) Ehrig, McPhie and Kamenetsky (2012) plan view of the Olympic Dam breccia complex. The cross-section displayed in (d) is positioned ~3 km east, and is subparallel to the seismic line. Note that all seismic data has been displayed and captured from GoCad using the same gain for both original and reprocessed images.

Apparent doming of highly reflective basement beneath Olympic Dam

A highly reflective zone below ~5000 m depth that is ~3000 m thick and shallows to the east is evident on the east-west line, directly beneath the base of the interpreted Hiltaba Suite granite (Fig. 7b). This highly reflective zone has an undulating surface. Directly beneath the Olympic Dam deposit, on line 03GA-OD2 (E-W line), the upper surface of this zone dips away to the east and west forming what appears to be a broadly symmetrical open fold (Fig. 7b). On the north-south line, this highly reflective zone, although much less distinct, also appears to define a broad fold structure (Fig. 7a). This suggests an apparent 3D doming of the highly reflective package beneath Olympic Dam. The significance of this doming is uncertain; however, since it lies beneath the Olympic Dam deposit it could be related in some way to mineralisation perhaps indicative of the structural control on the location of hydrothermal fluid flow.

Steep faults within the upper crust

The processing sequence used by HiSeis enables imaging of steeper structures than that used by

Jones et al. (2005). One of the dominant features of the east-west profile in both the HiSeis and Geoscience Australia processed lines is a highly reflective zone beneath the interpreted Hiltaba Suite granite (Fig. 8). Using both methods, this zone appears to be disrupted by major west-dipping faults. However, using the partially preserved amplitude reprocessed image, the lateral continuity of reflectors appears to stop against a zone of low reflectivity that forms an apparent wedge shape, the edges of which are orientated at ~70° and ~45° (Fig. 8b). The original interpretation emphasised the lower bound of this zone and hence the area was considered to represent a low-angle, west-dipping fault (Fig. 8d). In the reprocessed data, the eastern boundary of this low-amplitude zone is much steeper, and could be interpreted as a wedge of rock between two faults.

Regional subvertical zones of low seismic reflectivity

One of the features evident in the seismic data is a mid-upper crustal zone of high reflectivity at 10 km depth which is particularly prominent in the north-south line (Fig. 7). In the original processed image, the top of this mid-crustal layer is well defined and

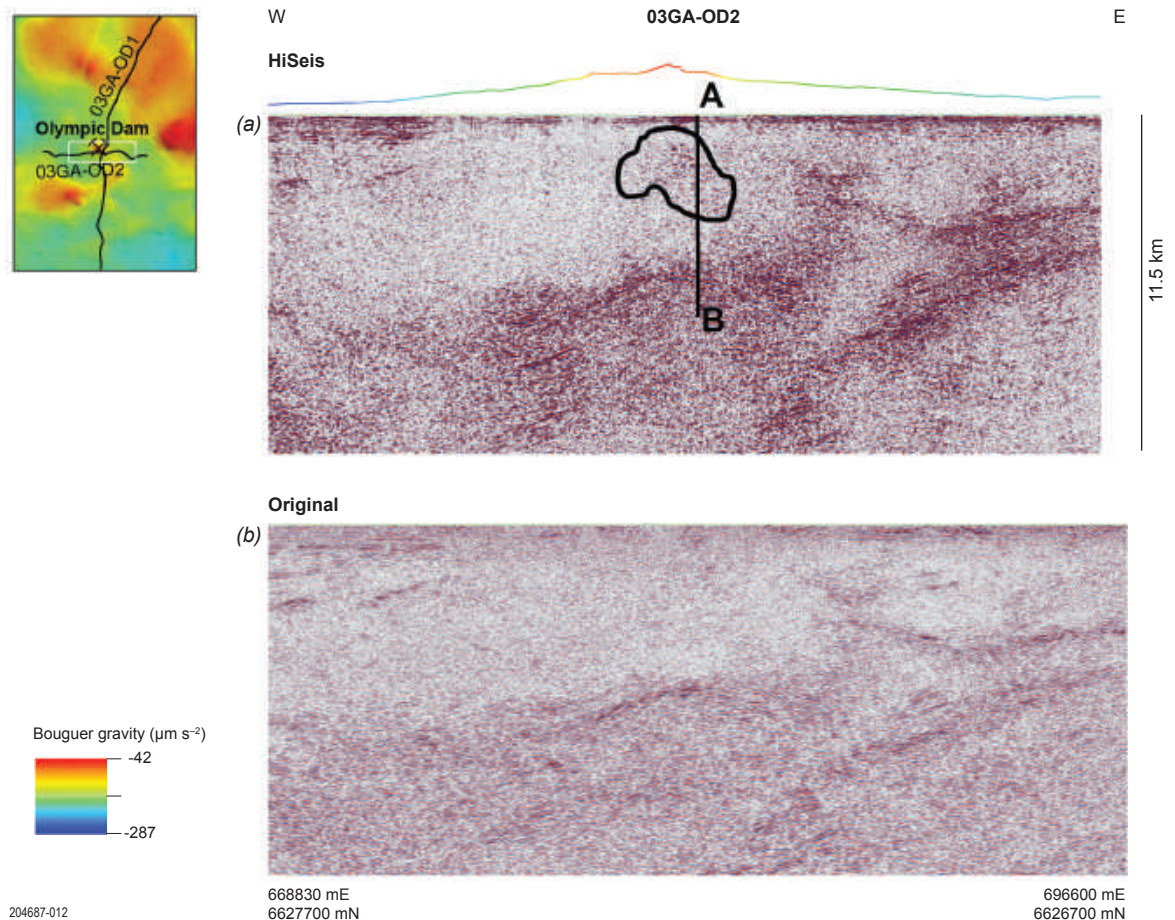


Figure 6 East–west line 03GA-OD2. (a) HiSeis partially preserved amplitude processing imaging a zone of high reflectivity appearing slightly deeper than the same feature on the north–south line (section shown in Fig. 5a intersects on plane A–B) as a result of an out-of-plane reflector. (b) Geoscience Australia original processing. Note that all seismic data has been displayed in GoCad using the same gain for both original and reprocessed images.

appears to shallow to the northeast. Drummond et al. (2006) described this zone as being dominated by laterally continuous subhorizontal reflectors, between which lateral reflections of limited extent vary from subhorizontal to north dipping. These reflectors were interpreted from the original imagery as being faults associated with apparent rollover structures, indicating thrust faulting due to a fold-thrust belt-like deformation style (Drummond et al. 2006).

In the reprocessed image this reflective zone, while still evident, does not show the same evidence for dipping reflectors. Rather, disruption to the lateral continuity is evident as a series of broadly subvertical zones of lower reflectivity with widths up to ~5 to 10 km (Fig. 9). These apparent subvertical zones appear throughout the north–south line and correspond to the position of known IOCG deposits or prospects (Olympic Dam, Vulcan, Titan, Wirrda Well; Fig. 9). These zones of low reflectivity appear to extend through the mid-crust to zones in the lower crust.

Discussion

Direct detection of the Olympic Dam deposit

Due to the density contrast created by intense iron alteration, seismic techniques should theoretically be able to map the variation of iron content within an IOCG system with high resolution. Furthermore, there is expected to be variation in the amplitude of the reflections at key interfaces such as between granite and hematite breccias and granite and granitic breccias. Using the conventional automatic gain control processing, these amplitude differences between seismic events are normalised and hence the change in reflectivity is more difficult to detect. Partially preserved amplitude processing preserves the amplitude differences of the reflections to the extent the data permits, and better represents the amplitude variation related to contacts of different lithologies and textures. Using partially preserved amplitude processing, a zone with distinct reflectors is imaged underneath the Olympic Dam deposit and is interpreted to reflect different lithologies of the deposit, with narrow, subvertical non-reflective features potentially mapping the location of faults

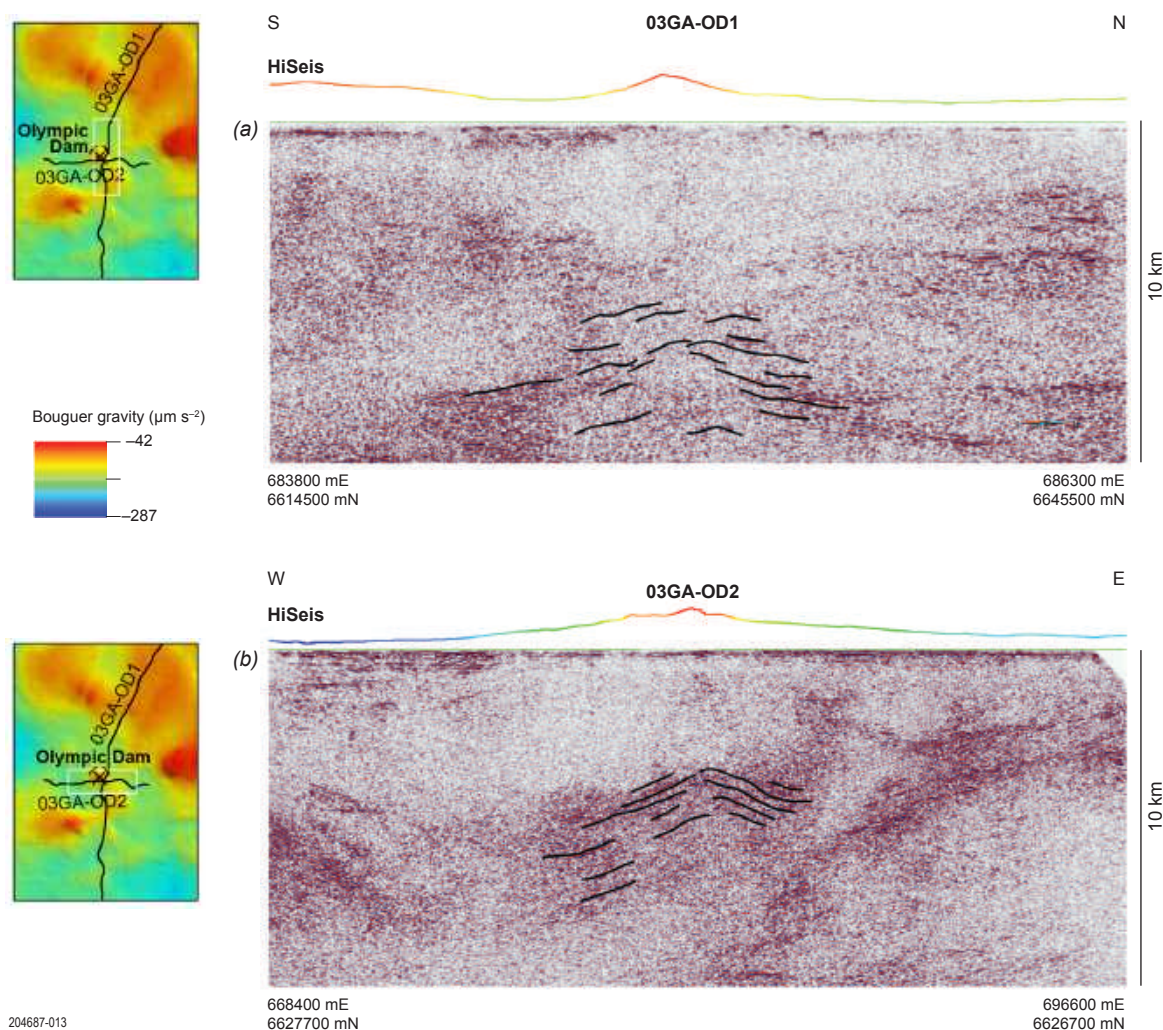


Figure 7 HiSeis partially preserved amplitude processing imaging a possible dome structure. (a) North-south line 03GA-OD1. (b) East-west line 03GA-OD2. Individual reflectors have been traced in black. Note that all seismic data has been displayed in GoCad using the same gain for both original and reprocessed images.

through the system (Figs 5 and 6). A series of short but distinct reflectors extends from the base of the projected section of known iron alteration at Olympic Dam (Fig. 5d) and may represent the extension of iron alteration within narrow structures at depth.

Steep structures

The preservation of the amplitude of reflectors using the partially preserved amplitude processing technique enables the identification of steep structures. Whilst one example is highlighted by this paper, a thorough interpretation of these reprocessed lines is warranted as it may have significant implications for the structural architecture and style in the region. A possible inference that could be drawn from the identification of more steep structures in this region is that deformation in the Olympic Dam region may not have developed as a purely fold-thrust regime as proposed by Drummond et al. (2006).

Subvertical zones of reduced reflectivity

Broad, subvertical and near-continuous zones of reduced reflectivity that extend from at least the mid-upper crust to the near-surface are evident in a number of locations on the north-south line. Examples include: ~5 km north of Wirrda Well, under Olympic Dam; and ~5 km south of Vulcan (also along strike from Titan; Fig. 9). Such zones of reduced reflectivity are potentially caused by pervasive textural destruction of large regions of the crust. This appears evident on a vertical scale of >15 km and up to 5–10 km wide. Textural destruction on this scale may be caused by geological processes such as fluid migration either in the form of partial melt migration or via pervasive hydrothermal alteration. Melt movement through subvertical vein networks (e.g. Brown 1994; Diener, White and Hudson 2014) could readily explain the lack of laterally continuous reflectors observed in these regions of the crust. Large-scale granitic plutonism is observed above, or proximal to, these broad zones of reduced reflectivity, e.g. Burgoyne

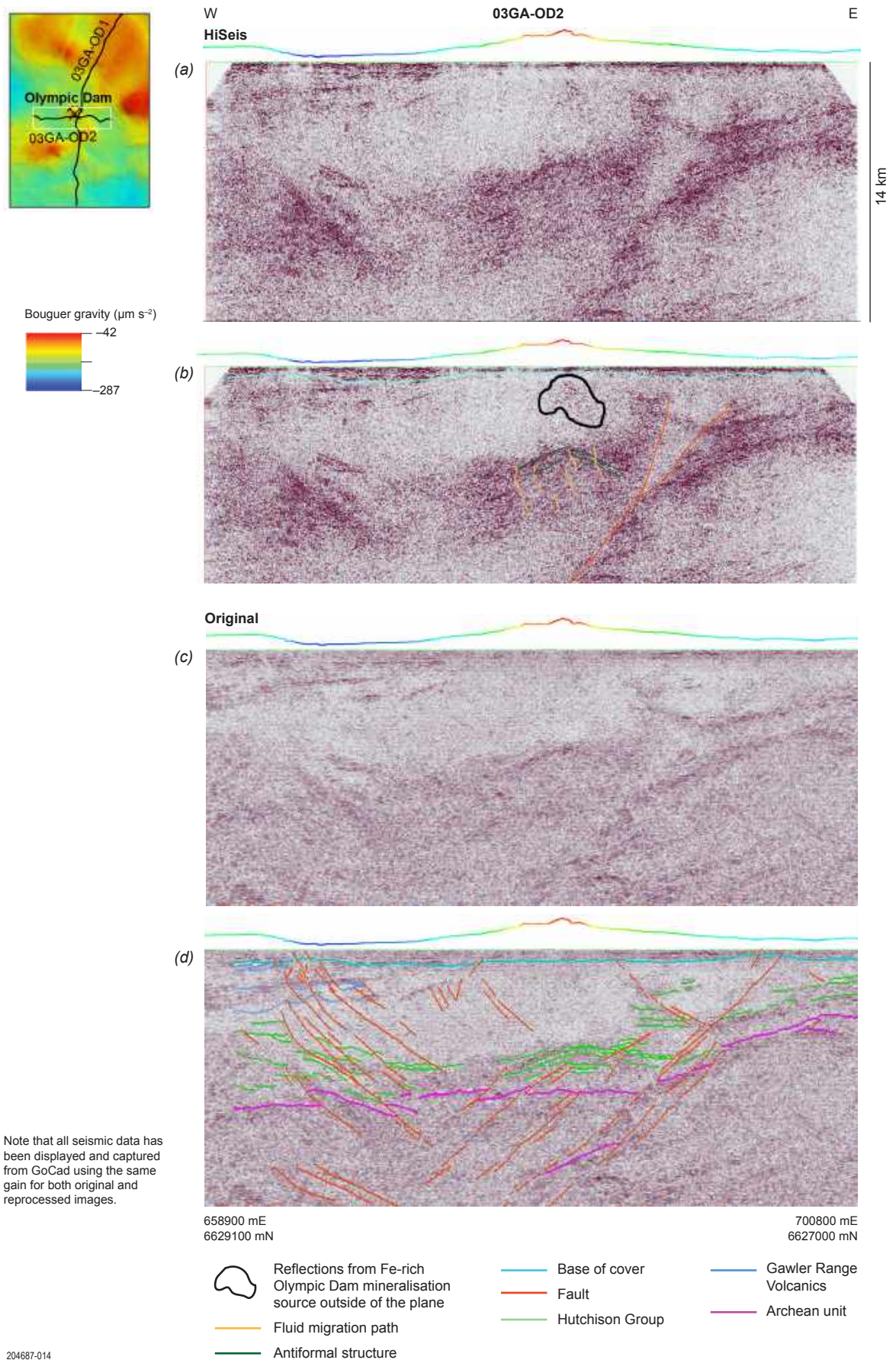


Figure 8 Central section of east-west line 03GA-OD2 displaying differing geometries of folding and faulting. HiSeis partially preserved amplitude processing: (a) un-interpreted seismic data; (b) partially interpreted seismic section (note that only interpretations in the middle part of the section are shown in this figure). Geoscience Australia original processing: (c) un-interpreted seismic data; (d) original Geoscience Australia interpretations (Drummond et al. 2006).

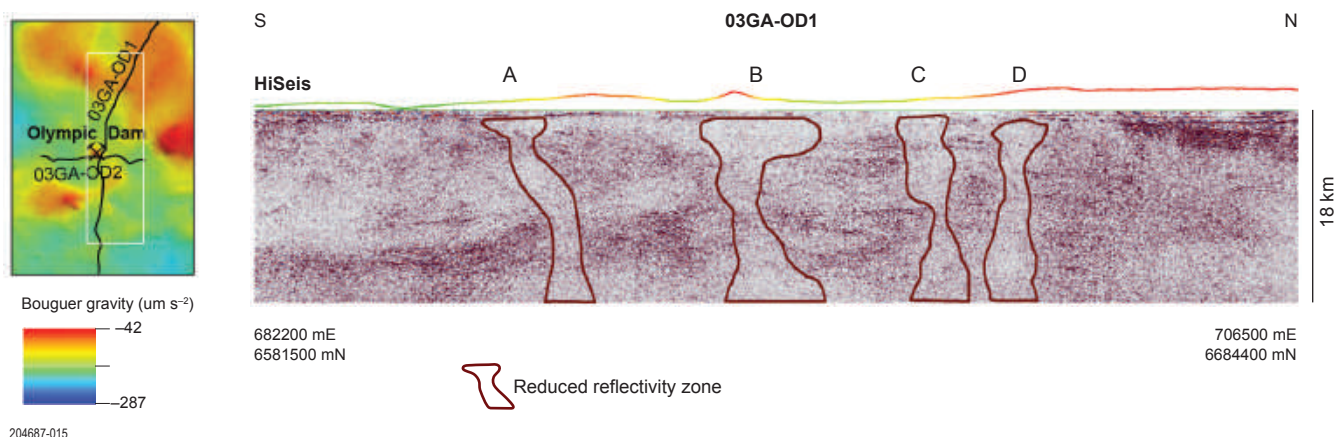


Figure 9 HiSeis partially preserved amplitude processing imaging subvertical zones of reduced reflectivity on north-south line 03GA-OD1. A – Wirrda Well; B – Olympic Dam; C – Titan (15 km NNW of section); D – Vulcan.

Batholith, which is consistent with this notion. Hydrothermal alteration, as suggested above, may link these features to the broad zones of enhanced electrical conductance observed in regional magnetotelluric data in the vicinity of Olympic Dam (Heinson, Direen and Gill 2006; Thiel and Heinson 2015).

An interesting observation regarding the large zones of reduced reflectivity is the apparent lack of similar features in the east-west line. Assuming surface conditions/line geometry is not responsible, a possible geological explanation for the lack of observed zones of reduced reflectivity in the east-west line could be due to anisotropy within the interpreted melt/alteration pathways. Given these features are observed in the north-south line only, it is possible that such pathways are parallel/subparallel to the east-west profile, hence not being resolved. A number of roughly east-west fault structures are visible in the regional aeromagnetic imagery (Fig. 2b). A possible, though speculative inference, is therefore that the derived orientation for these melt/alteration pathways could provide information, in conjunction with geophysical interpretation, as to the principle stress orientations at the time of upward movement.

Conclusion

To obtain a crustal-scale image of reflection seismic data certain processing techniques are favoured. This necessarily limits the degree to which certain upper crustal features can be imaged/and or enhanced. However, there is a range of processing techniques available and each can emphasise various aspects of the data. The partially preserved amplitude technique is interpreted to have detected features that relate to iron alteration around the Olympic Dam orebody and has revealed

steeper structures than were imaged with previous processing techniques. Several kilometre-scale, subvertical 'bland' zones that extend from at least the mid-upper crust to the near-surface in the vicinity of several known IOCG deposits have been identified and may relate to partial melt migration or pervasive hydrothermal alteration. Thorough re-evaluation and interpretation using a variety of processing techniques is recommended to provide further insight into the structural regime of the Olympic region.

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Glossary

Automatic gain control. A circuit that automatically controls the gain of a signal.

Bandpass. A range of frequencies passed by a filter.

Bandpass filter. Filters specified by listing their low-cut and high-cut component filters.

Common depth-point (CDP). The common reflection point at depth on a reflector, shared by multiple sources and receivers. In the case of flat layers, the CDP is vertically below common mid-point. Dipping beds have no CDP, hence DMO is applied.

Common mid-point. In multichannel seismic acquisition, the point on the surface halfway between source and receivers.

Constant velocity stack. Velocity analysis involves making trial stacks assuming several trial velocities that are constant in time and space to determine the stacking velocities that produce the best results.

Digistack. Indicates the dip weight and sum method.

Dip moveout (DMO). The difference in the arrival time of a reflected wave, measured by receivers at two different offset locations, that is produced when reflectors dip.

Frequency sweep. Changing the frequency of Vibroseis source during a 'sweep' period. In an upsweep, frequencies are generally increased linearly during the sweep, in a downsweep they are decreased linearly.

Gain. A change in signal amplitude from system input to output. Gain usually means time invariant unless specified otherwise.

Geophone. The instrument used to transform seismic energy into an electrical voltage.

Interactive velocity analysis. Root mean square velocity analysis using semblance, CDP gather and constant velocity stacks.

Low-pass filter. A filter that passes frequencies below some cutoff frequency while substantially attenuating higher frequencies.

Migration. An inversion operation involving rearrangement of seismic information elements so that reflections and diffractions are plotted at their true locations.

Post-stack migration. Migration of stacked data, as opposed to migration before stacking.

Phase-shift migration. A method of migration in the frequency-domain by phase-shifting at each step in downward continuation. The process can be used to discriminate against dipping coherent noise. Phase-shift refers to the change in position of the peaks of a sinusoidal electromagnetic wave as it passes through the formation.

Quality control stack. Stacked seismic section for the purpose of processing parameters validation.

Relative amplitude ratio. Measurements of amplitudes over a reference amplitude value.

Receiver. A sensor, the part of an acquisition system which senses the information signal, such as geophone or hydrophone.

Refraction statics correction. Corrections to reflection traveltimes based on first arrivals attributed to refraction travel paths that involve the base of the near-surface low-velocity layer.

Residual static calculation. Processing stage in which high-resolution static is computed by picking horizons of high signal to noise ratio in stacked volume.

Semblance filtering. Filtering by a measure of multichannel coherence.

Spectral equalisation. Balancing of amplitude spectrum.

Stacking velocity. Used to correct arrival times of events in the traces for their varying offsets prior to summing or stacking the trace to improve signal-to-noise ratio of the data.

Sweep. Band of frequencies in the seismic vibrator. The frequency of a vibroseis source is varied continuously during a 'sweep' period, commonly 7 s or longer.

Two-way time. The elapsed time for a seismic wave to travel from its source to a given reflector and return to a receiver at the earth's surface.

Upsweep. Vibroseis sweep in which the frequency increases with time (usually linearly).

Velocity analysis. The process of calculating seismic velocity, typically by using common mid-point data, to better process seismic data.

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FURTHER INFORMATION

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