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Interpreting the Past, Discovering the Future

Examples of the use of seismic reflection to re-invigorate a mature field: Tennant Creek

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SUMMARY

Recently seismic reflection has been gaining prominence as a tool for the minerals industry for orebody delineation and exploration in known mineralised terrains particularly where mineralisation extends to depths beyond a few hundred metres. We believe it can also play an important role in establishing the structural architecture of an area due to its unrivalled ability to map the orientation of structures at depth. In this paper we present recent results from an exploration program in the Tennant Creek Mineral Field (TCMF) in the Northern Territory of Australia for both of these objectives.

The program included the completion of 2 x 4km seismic lines close to the Gecko mine and a 60km N-S seismic line centred on Tennant Creek together with borehole full waveform sonic and vertical seismic profile data.

The borehole measurements confirm that the ironstone bodies and associated alteration that host the mineralisation provide a strong acoustic impedance contrast within the Warramunga sediments that otherwise show relatively little acoustic impedance variation.

The 4km seismic lines have generated two targets both at approximately 1km depth. Shallow imaging was hampered by strong surface wave noise but it is the targets that are not detectable by gravity and magnetics that motivated the use of seismic at Gecko and Chariot.

The regional survey was acquired to improve the understanding of the mineralising systems and underlying structural architecture around Tennant Creek. The survey mapped major structures that control mineralisation, such as the Southern Shear Zone, Mary Lane Fault and Gecko Fault. The seismic survey also showed that these structures were north verging and identified similar structural positions that lack surface expression but show many of the characteristics of the mineralised structures.

Key words: seismic reflection, exploration, minerals, gold, copper, geological architecture, structure, faults, Tennant Creek.

INTRODUCTION

Recently seismic reflection has been gaining prominence as a tool for the minerals industry for orebody delineation and exploration in known mineralised terrains (e.g. Cook et al, 2015, Malehmir et al, 2012) particularly where mineralisation extends to depths beyond a few hundred metres. We believe it can also play an important role in establishing the structural architecture of an area due to its unrivalled ability to map the orientation of structures at depth. In this paper we present recent results from an exploration program in the Tennant Creek Mineral Field (TCMF) in the Northern Territory of Australia for both of these objectives.

The Tennant Creek area hosts a number of high grade gold and copper deposits. The orebodies are hosted in magnetite-haematite-chlorite-quartz bodies of hydrothermal origin locally known as ironstones. The ironstones themselves form within fault zones. Magnetics and gravity have proven to be effective tools for exploring for these deposits at shallow depth however the size of the bodies is such that they would not be detected below a few hundred metres depth.

The seismic reflection geophysical technique utilises changes in acoustic impedance to image the sub-surface geology. Acoustic impedance of a rock type is equal to the product of two rock properties, namely its density and seismic velocity. Seismic energy in the form of sound waves reflects off boundaries where there is an acoustic impedance contrast. Magnetite and haematite are significantly denser than the siltstones in which they are usually found and therefore should act as strong reflectors or diffractors.

In this paper we present results from two 4km 2D seismic lines near the Gecko mine (Lines 3 and 4) in the Tennant Creek Mineral Field to evaluate the seismic reflection technique.

We also present the results of a 60km N-S seismic line (Line 101) centred on Tennant Creek acquired to improve the understanding of the mineralising systems and underlying structural architecture around Tennant Creek. The objective of this deep imaging seismic line was to locate new previously unidentified areas that may be prospective for similar mineralisation.

A full waveform sonic (FWS) log and vertical seismic profile (VSP) were subsequently acquired in a 1279m deep drillhole (GODD032) located close to Line 3 to assist the seismic imaging and interpretation.

The locations of Gecko survey Lines 3 and 4, the regional line are shown in Figure 1. GODD032 was collared close to the centre of Line 3.

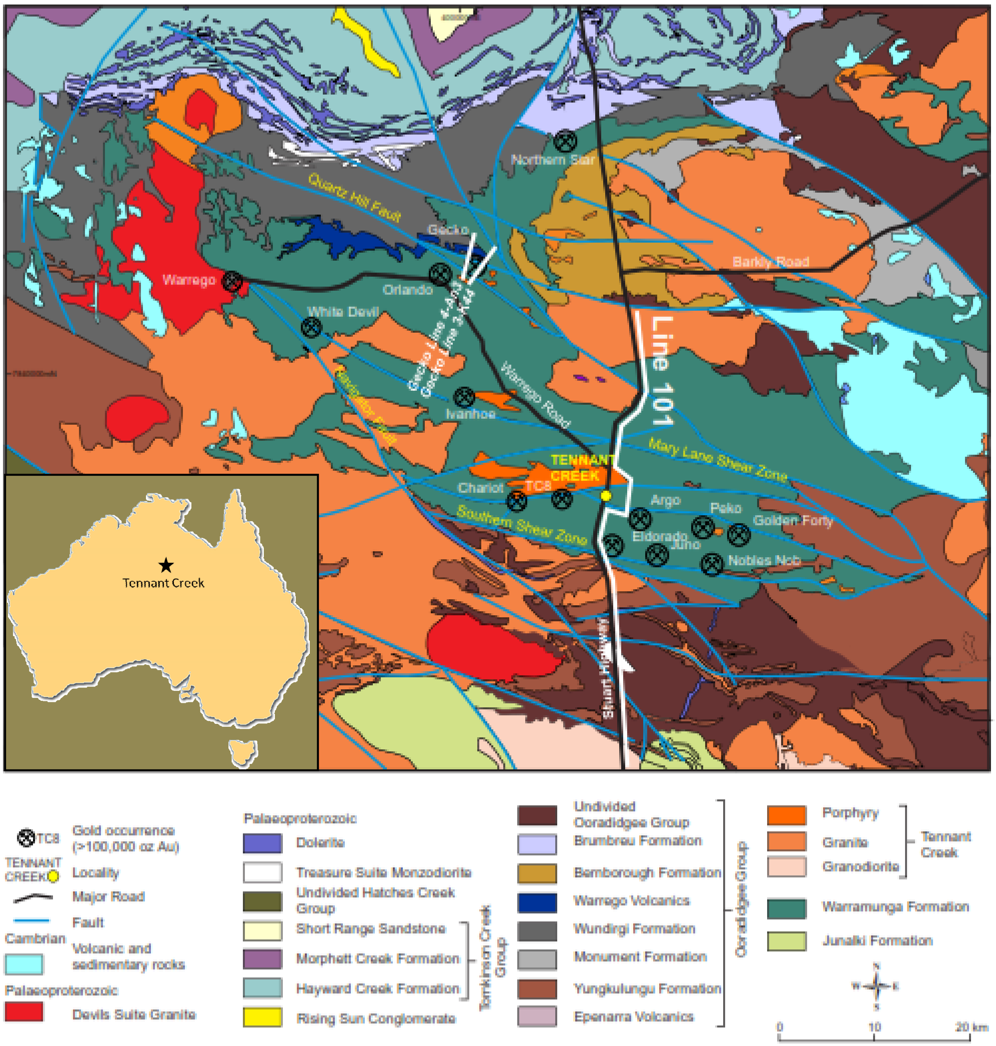

Figure 1 Location of the Gecko seismic lines (Lines 3 and 4) and the regional seismic line (Line 101) overlain on a geological map of the Tennant Creek Mineral Field

ROCK PROPERTIES

Full wave sonic data and core density measurements from GODD032 (see Figure 2) showed that there were only relatively minor variations in the acoustic impedance within the sediments of the Warramunga formation, which host the prospective ironstone bodies. There was however a very strong and encouraging contrast between these rocks and the ironstone zone intersected near the base of the hole (see Figure 3) as well as the neighbouring alteration (eg quartz dolomite), which is commonly associated with copper-gold mineralisation. This provided justification that such features will provide strongly anomalous seismic reflectivity.

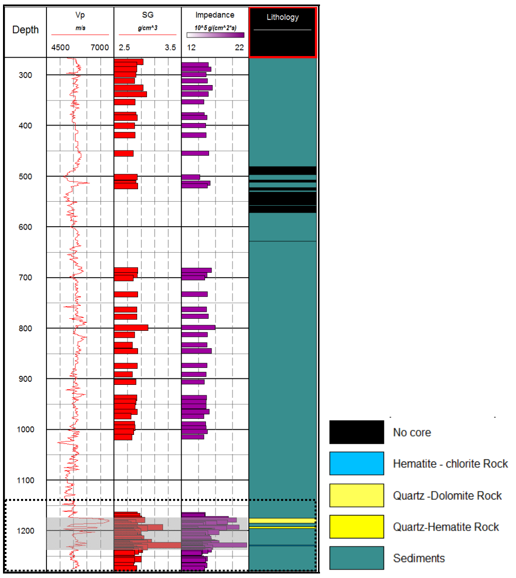

Figure 2 Plot showing the FWS log, core density measurements, the acoustic impedance derived from these and a simplified lithology log for GODD032. The logs show little variability except for the strong contrast associated with alteration near the base of the hole (highlighted by grey shading). The dashed box shows the extent of the zoomed area shown in Figure 3.

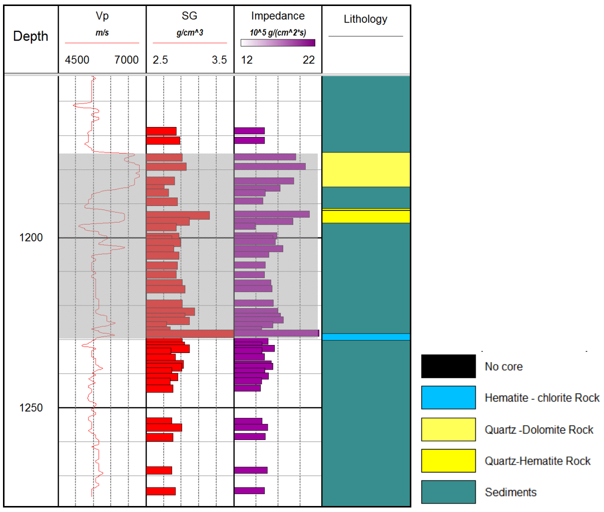

Figure 3 Zoomed in section of the results shown in Figure 2 showing more detail of the variations in seismic velocity, density and acoustic impedance associated with the quartz dolomite, quartz hematite and hematite chlorite rock near the base of the GODD032. The grey shading shows the extent of the anomalous zone highlighted in Figure 2.

GECKO SEISMIC SURVEYs

The survey parameters for the two 4km seismic line are summarised in Table 1.

Source Type	11.5KJ F10 Gravity weightdrop
Source spacing	10m
Number of stacks	5-7
Record length	3s
Receiver type	Groups of 6 SM-20 equivalent geophone arranged at approximately 3.3m intervals along the survey line
Receiver Spacing	5m
No. of channels	800 (Full line active)

Table 1 Survey parameters for the Gecko seismic lines

The final data sets were processed using post-stack time migration.

Line 3 was surveyed over the top of the K44 orebody. The data from this line is shown in Figure 4.

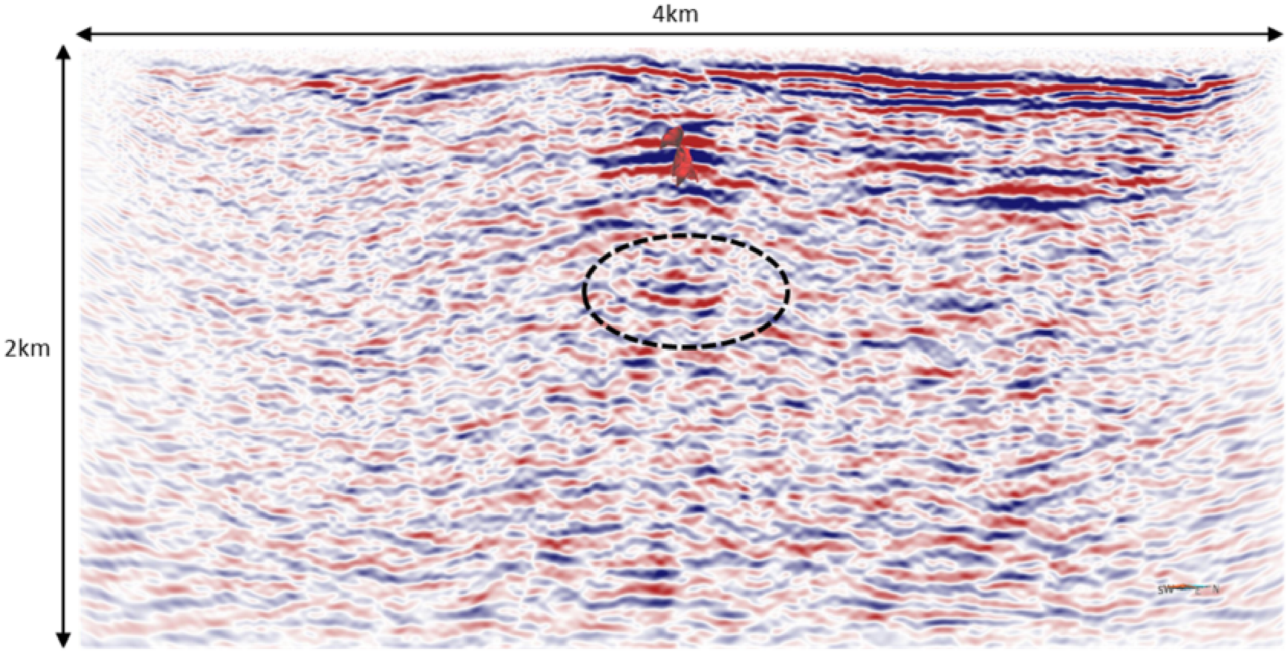

Figure 4 Depth converted seismic image from Line 3. The wireframe of the K44 orebody is overlain on the centre top of the image. A zone of anomalous reflectivity within the host fault zone is highlighted by the dashed black oval beneath this at approximately 1km depth.

There is a broad zone of flat lying reflectors centred on the K44 orebody. The remainder of the seismic section mostly shows low reflectivity consistent with the borehole sonic and density data through the host materials. There is, however an interesting separate zone of reflectivity below the K44 orebody at approximately 1km depth. Drillhole GODD032, which was co-funded by the Northern Territory Geological Survey (NTGS), was drilled to test the position immediately below the survey line (amongst other objectives). The reflectivity is consistent with the presence of the quartz dolerite and quartz haematite, which have high acoustic impedances, intersected in that hole. To be detected from the surface, an anomalous zone would need to be at least several tens of metres in extent.

The source of the shallow flat lying reflectors on the right hand side of the image is not known but they do not fit the conceptual target which is dense bodies within the fault zone near the centre of the line. The data at these shallow depths were strongly overprinted by surface wave noise associated with the thick weathering layer. Thus seismic imaging in the top few hundred metres is challenging. This was not the primary objective for the use of seismic at Gecko as gravity and magnetics are effective at these depths.

Line 4 was surveyed over the An3 orebody approximately 800m west of Line 3. After revision of the seismic velocities used in processing, the data set from this line show an isolated strong diffractor below An3 at a depth of approximately 1km. This response is exactly the type of response expected from the ironstones that were the target of this survey. Whilst a target has been located, there is some rotational ambiguity in its position around the survey line (i.e. The seismic data shows that the reflector is approximately 1km from the survey line but it may not be directly below the survey line. It could be from positions on an arc with a 1km radius around the survey line (in a vertical plane perpendicular to the survey line). There are a number of options which exist to localise the target. These include 3D seismic surveying (which does not suffer the same ambiguity) or drilling a hole and, if necessary, using borehole seismic, borehole magnetics or borehole gravity to vector towards any acoustic impedance, magnetic or density anomalies detected.

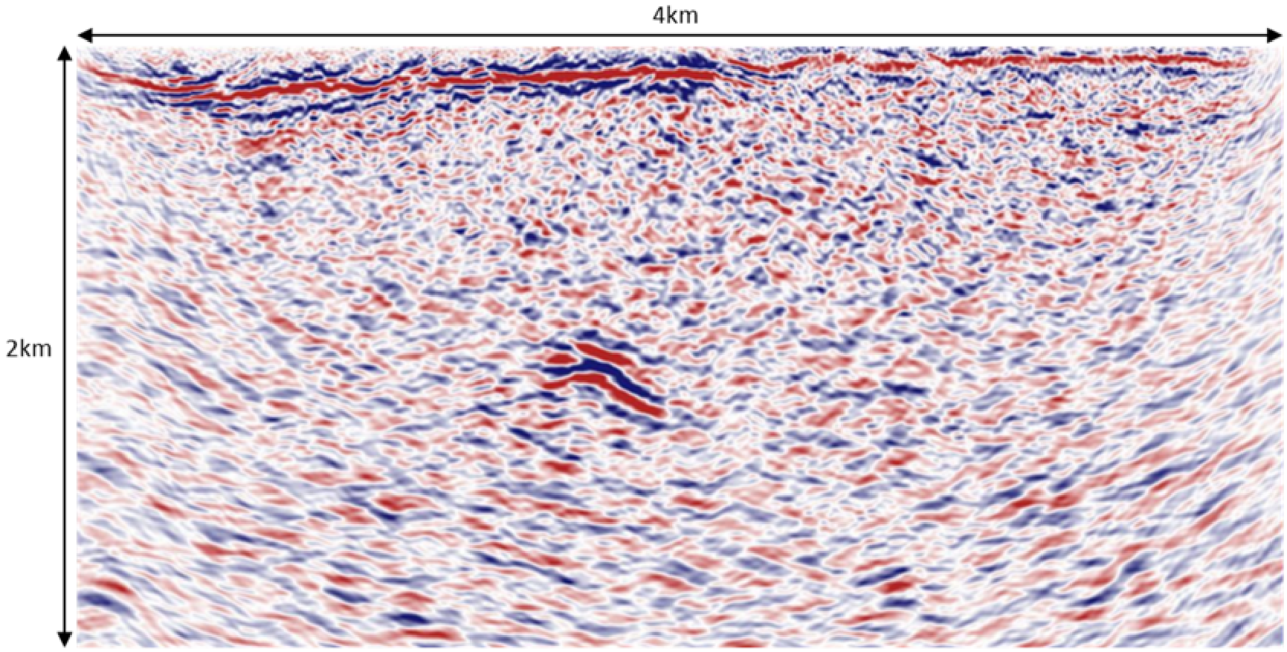

Figure 5 Seismic reflection image from Line 4. There is a distinct strong reflector at approximately 1km depth.

TENNANT CREEK REGIONAL SEISMIC SURVEY

The survey parameters for the Regional seismic line are summarised in Table 2.

Source Type	60,000lb Inova AHV-IV
Source spacing	30m
Sweep	Linear 8-130Hz
Sweep length	14s
Record length	10s
No. of stacks	2-3
Receiver type	Single SM-20 equivalent geophone
Receiver Spacing	15m
No. of active channels	600

Table 2 Survey parameters for the Tennant Creek regional seismic line

The data were processed so as to as far as possible preserve relative amplitude relationships associated with changes in reflectivity.

The final data set was processed using a post-stack phase shift migration following dip move-out (DMO). Pre-stack time migration was run but proved less effective due to the bends in the survey line which were introduced to avoid surveying down the main street of Tennant Creek.

Several key regional features observed in the data are highlighted in Figures 6 and 7. These include:

1. All major faults hosting gold copper deposits appear to be associated with northward verging thrust faults (e.g. see Figure 6);
2. A number of thrusts that lack surface expression and known mineralisation but are in many respects similar to mineralised thrusts were identified;
3. Several felsic intrusives appear to have been imaged as zones of suppressed reflectivity (e.g. see Figure 7). The base of the zone in Figure 7 is defined by strong reflectors, which we interpret to represent the base of the granite (mapped south of the Southern Shear Zone) on this section.

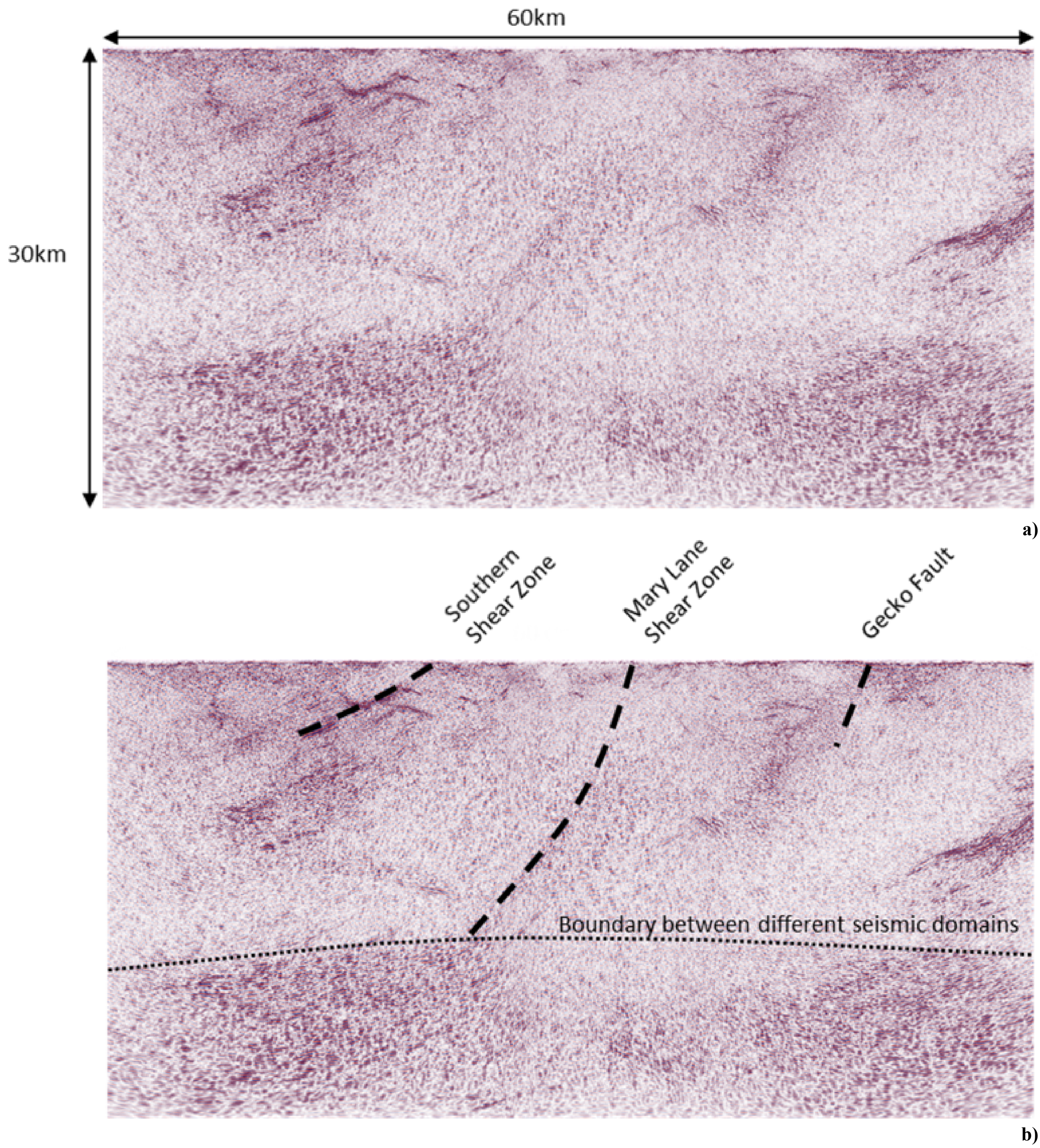

Figure 6 Depth converted seismic image from the Tennant Creek regional survey line crust (a. without interpretation and b. with interpretation showing location of key faults and significant boundary imaged by the seismic at approximately 20km depth)

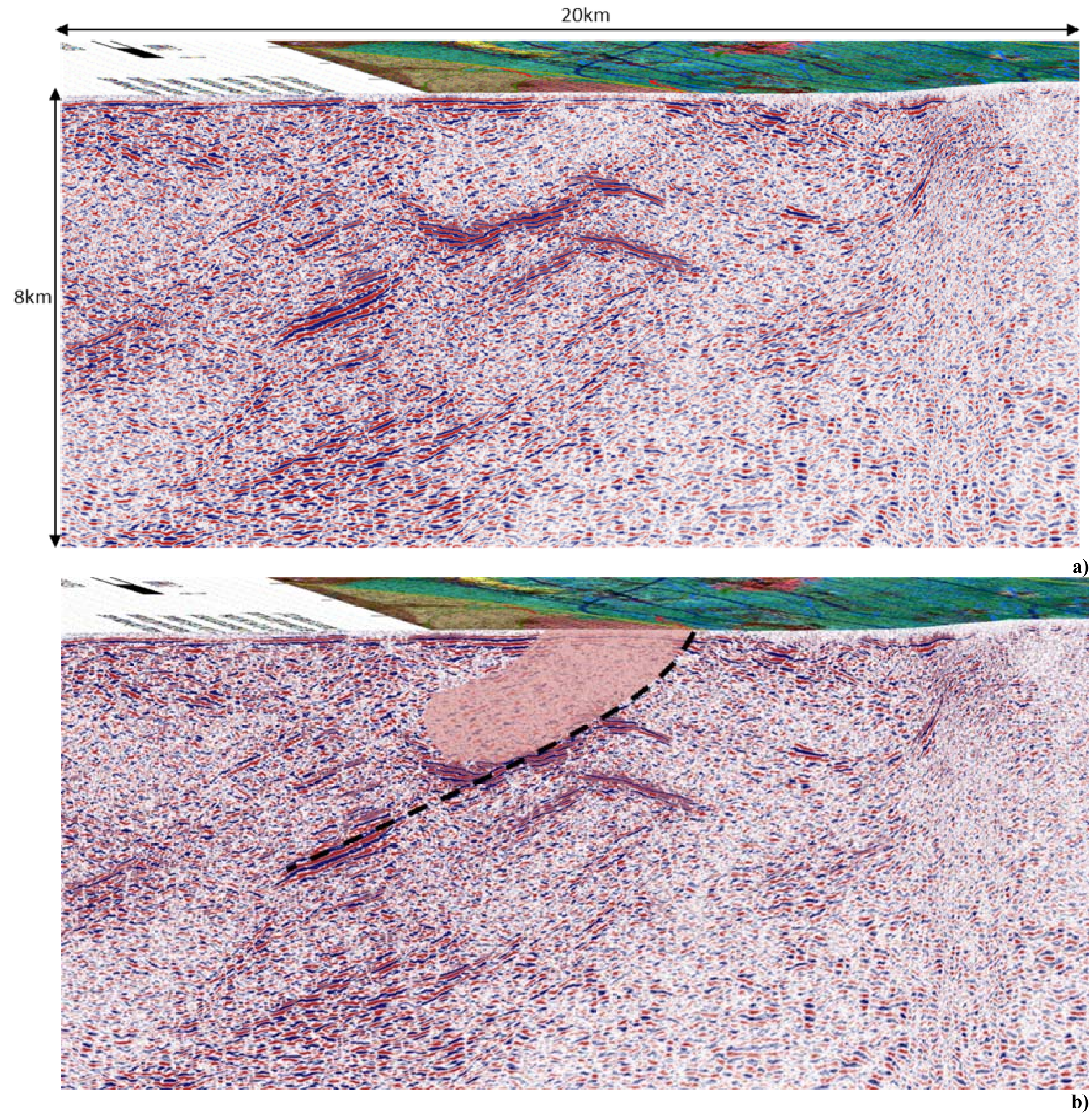

Figure 7 Zoomed in portion of the depth converted seismic image from the Tennant Creek regional survey line shown together with the interpreted surface geology (a. without interpretation and b. with interpretation showing the depth extent of a granite intrusion next to the Southern Shear Zone)

CONCLUSIONS

The examples from Tennant Creek presented in this paper demonstrate a role for 2D reflection seismic in the minerals industry both for detailed exploration in known mineralised domains and to help resolve the geological architecture of a region. The attributes of the seismic reflection method that make it an important tool for these applications are its ability to image at high resolution over a great range of depths allowing new targets to be generated in mature terrains and the nature of major control structures to be understood to aid the location of new prospective zones.

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