EL10124 EL28777 EL28907 EL30167 MCC365 ML30712
Collaboration Final Report

Recipient: Emmerson Resources Limited

Program Title: Regional 2D Seismic Reflection Survey at Tennant Creek, Northern Territory

Tenements: EL10124, EL28777, EL28907, EL30167, MCC365, ML30712

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Evolution Mining Limited
Northern Territory Department of Mines and Energy

1. Executive Summary:

Over 9 days during June 2015 HiSeis Pty Ltd acquired two-dimensional (2D) regional seismic reflection data proximal to the Tennant Creek town site and mining facilities on behalf of Emmerson Resources Limited. One 60km 2D seismic reflection line (Line 101) was acquired following the Stuart Highway 30km to the north, and 30km to the south, of the town of Tennant Creek, diverted to the east of the town site for logistical reasons.

The objective of the 2D survey was to outline previously unidentified areas of prospectivity in the Tennant Creek Mineral Field by seismically imaging the upper crust along the line to improve understanding of regional geological architecture. This was achieved by acquiring 60km of 2D data with a total of 2,032 unique source points. Acquisition of this 2D dataset utilised one source, a 60,000lb Vibroseis Vehicle, as a means of producing seismic energy, delivering a linear 14 second sweep through a frequency range of 8-130Hz. The record length was 10 seconds, in an attempt to catch reflections at 10km+ in depth. Two to three identical sweeps were acquired at each individual VP (vibe position) depending on intensity of ambient noise sources (mostly traffic). All seismic vibrations were measured with a rolling spread of 600 single point geophones using the Aries II seismic acquisition system. The spacing between VPs was 30m and the spacing between geophones was 15m.

Two products were produced for Line 101. These were:

a) A product targeted to assist the determination of regional geological architecture down to a depth of approximately 30km.

b) A product with a focus on the shallow geology within the top 2km below the surface.

HiSeis Pty Ltd adapted a conventional processing flow to the acquisition parameters, survey objectives and geology known to exist in this area. Parameter testing was conducted and the results of these tests determined an optimum flow in order to image the complex structural geology for each of the two products: regional processing and shallow processing.

While care must be taken interpreting 2D sections because reflections that are observed may not originate from directly below the survey line and may be distorted due to the 3D complexity of the earth, initial results suggest all of the major gold-copper deposits in proximity to line 101 are associated with northward-verging thrust faults which extend down to about 13 kilometres depth. There are also a number of thrusts without expression at the surface, and these have no known mineralization, but where the thrusts are known at the surface, there is a positive correlation with mineralization. The survey also imaged many more felsic intrusives than were expected. A major sub-horizontal boundary is clearly visible at approximately 20km depth and represents the top of a different seismic domain which may be analogous to the top of the Ooratippra Seismic Province defined on the line 09GA-GA1 (Georgina Basin-Arunta Region) located 210km to the South East. A washed-out zone above this domain represents the basement on which the Warramunga Formation and younger units were deposited.

The links between gold-copper mineralization, felsic intrusives and thrust faults have long been postulated for the Tennant Creek Mineral Field but this data provides the first validation of the concept and should permit exploration to focus on previously unknown thrusts.

Final interpretation of the data is pending.

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Appendix 2 HiSeis - Tennant Creek. Processing of the 2D Line 101. September 2015. Author - Denny Rompotes.

Appendix 3 HiSeis - Tennant Creek Regional 2D Survey Interpretation Report. December 2015. Author - Graeme Hird.

Introduction

A 60km 2D seismic reflection line (Line 101) was acquired following the Stuart Highway 30km to the north, and 30km to the south, of the town of Tennant Creek, diverted to the east of the town site for logistical reasons (Figure 1). As there is a 5m buffer on either side of the Stuart Highway, the line was surveyed as far away from the road as possible, on the left hand side, heading in a North-South orientation. The survey line crosses the following mineral tenements from North to South: EL28777, EL10124, EL28907, EL30167, ML30712, and MCC365.

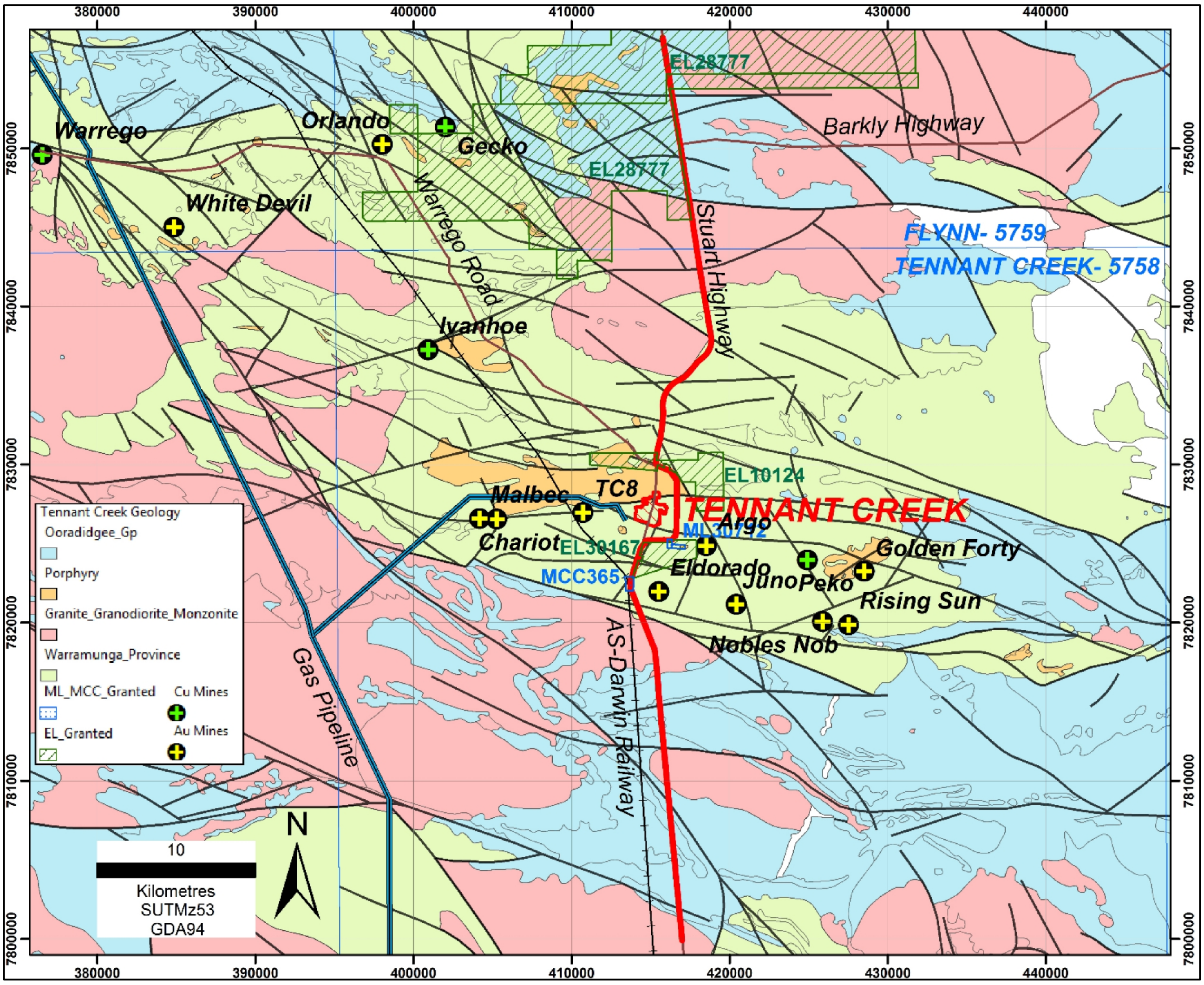

Figure 1: Simplified Regional Geology of the Tennant Creek Mineral Field modified after Johnstone and Donnellan (2011) showing the location of line 101. The location of the main asphalt roads, the gas pipeline, the railway and the townsite built-up area are shown as well as the main Au-Cu mines (Yellow cross=Au-dominant, Green cross=Cu-dominant) and tenements crossed by the survey. Survey line 101 (red) is centred on the town of Tennant Creek extending approximately 30km to the north and 30km to the south.

Regional Context

The Tennant Creek Mineral Field (TCMF) has produced more than 5.5 Moz of gold, 488,000 t of copper, 14,000 t of bismuth, 220 t of selenium and 55 t of silver from approximately 130 mines (Donnellan, 2013). Gold was first discovered in the district in 1874. Significant mining and prospecting did not take place until 1932, when two small batteries were constructed near the site of the present town, and by 1936 several small mines were in operation.

The geology of the Tennant Creek Mineral Field (TCMF) comprises three principal units: the Warramunga Formation, which hosts the Au-Bi-Cu mineralisation; the Tennant Creek Supersuite (TCS) granitoids, related high-level porphyries and coeval intermediate-mafic intrusives (Budd *et al.,* 2002), and the younger Ooradidgee Group meta-sediments and felsic extrusives (1843 ±4 Ma and 1841 ±8 Ma; Hill, 2015 - Figure 2).

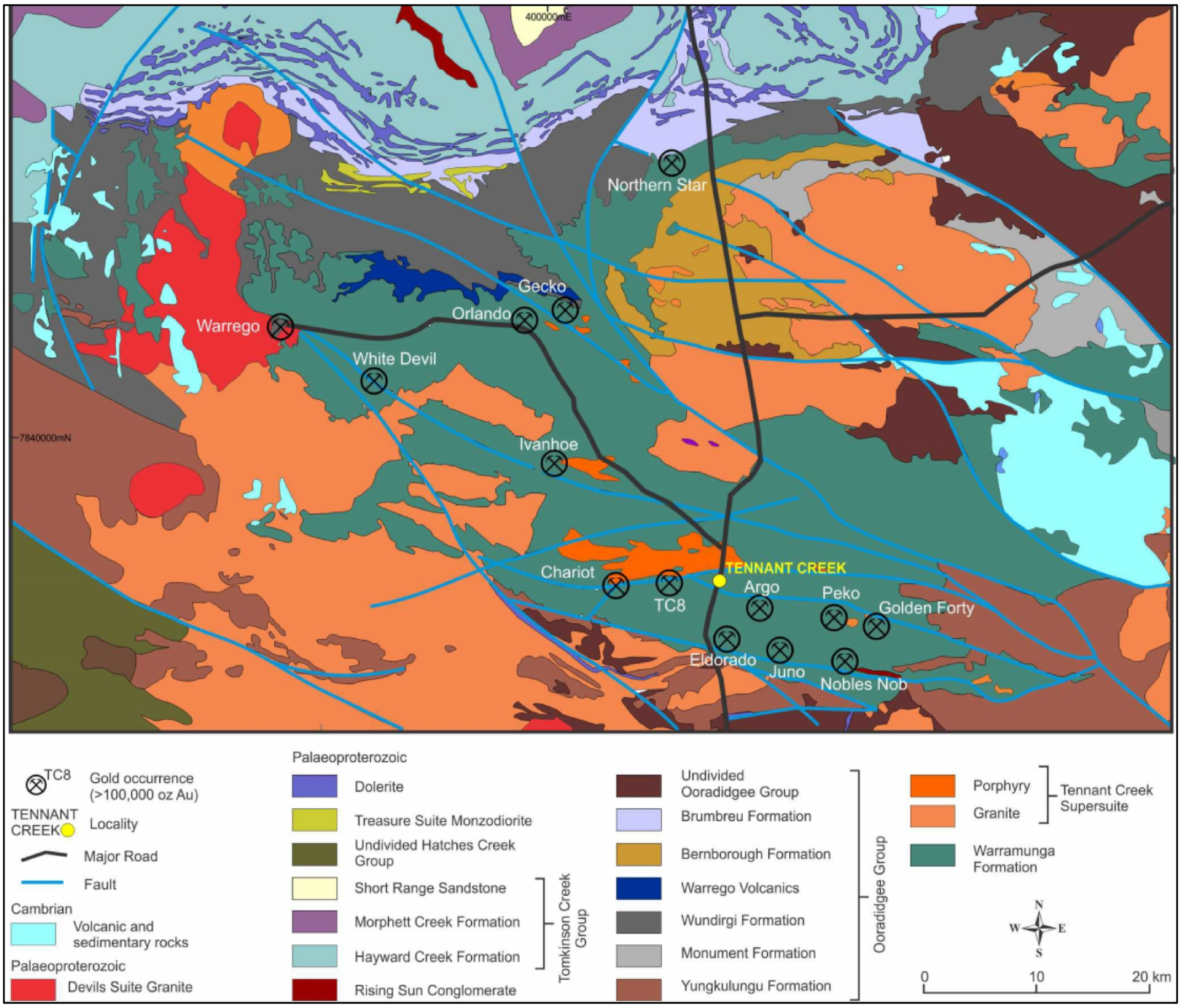

Figure 2: Regional Geology of the Tennant Creek Mineral Field showing the location of all gold mines with >100,000ozs production. The Stuart Highway runs NS through the town of Tennant Creek (Source: Cuison et al, 2014).

The basement to the Warramunga Formation is unknown. On the basis of reconnaissance seismic refraction data Finlayson (1981) determined its thickness to vary from 1.2km in the vicinity of Warrego to 2.6km near the Nobles Nob mine although the same author notes that there is little evidence that the “basement” is compositionally or lithologically different from the surface rocks.

Detrital zircon dating of the Warramunga Formation indicates that this unit was deposited from 1866 Ma to 1854 Ma (Hill, 2015). Intrusive magmatism of the TCS was assigned to the Tennant Event by Maidment *et al* (2013) and includes the Red Bluff Granite (1854 ± 7 Ma, Hill, 2015), the Tennant Creek Granite (1850 ± 4 Ma; Maidment *et al.,* 2006) and the Hill of Leaders Granite (1846 ± 3 Ma; Maidment *et al.,* 2006). SHRIMP U-Pb geochronology of the intermediate-mafic intrusives shows a narrow age range of 1852 Ma – 1849 Ma (Hill, 2015), slightly older than the 1847 Ma age of the quartz-feldspar porphyries reported by Maidment *et al* (2013), but within analytical uncertainty of the Red Bluff Granite. Consequently based on cross-cutting relationships, it is interpreted that the intermediate-mafic intrusive rocks are coeval with, and probably represent a more primitive variant of the TCS (Cuison *et al*, 2013).

Cuison *et al* (2013) proposed the following evolution of the Gecko Corridor:
D_0: Rifting of unknown basement prior to 1858 Ma triggers deposition of Warramunga Formation sediments into WNW–west-trending basins.
D_1: N–S compression generates basin inversion and bedding-parallel thrusting of the Warramunga Formation sediments about E–W axial planes. Circulating basinal brines leached iron from the sedimentary pile, which was redeposited as tabular ironstones within axial planar shears, or in axial hinge zones of folds.
D_2: The TCS was emplaced at 1851–1847 Ma. Granites and quartz porphyries were volumetrically predominant, with minor intermediate-mafic intrusions located in pre-existing major structures.
D_3: Transcurrent shearing: An early sinistral phase was responsible for the deformation/brecciation of the ironstones accompanied by Au-Cu-Bi mineralisation. Subsequent minor dextral reactivation remobilised existing Cu mineralisation.

Cuison *et al* (2014) proposed that the majority of the Tennant Creek Au-Bi-Cu mineralization is commonly hosted by iron-oxides (known locally as ironstones) and associated alteration. These authors identified two styles of Au-Bi-Cu mineralization (Figure 3); A) predominantly ironstone-hosted, and B) shear-hosted ironstone. Ironstone-hosted ore is localized along fractures and margins of magnetite and/or hematite-altered magnetite. Gold mineralisation in this style is generally found at the apical and lower sections of ironstone bodies with the gold occurring as minute to large grains associated with sulfides and bismuth sulfosalts hosted in pervasive chlorite – hematite alteration. In shear-hosted ironstones, gold mineralisation is localized in zones of high strain surrounding narrow, rhombic or sigmodal ironstone pods. Here, the gold occurs as coarse grains disseminated in intensely foliated, chlorite-altered shear zones locally associated with hematite.

Previous Exploration

The history of exploration in the TCMF can be broadly grouped into 4 eras as discussed below.

1935 – 1955 (Prospecting Era)

The TCMF was a late starter by Australian standards, partly because alluvial gold was rare and the gold and copper mineralisation was hosted by ironstones on top of hills rather than in the abundant quartz veins within the lower lying regions. Once this association between ironstone and mineralisation was recognised, there was an expansion of gold production from outcropping ironstones. Discoveries were by classical prospecting methods. The Eldorado, Nobles Nob and Peko mines are notable examples from this period.

1956 – 1989 (Magnetic Era)

In 1956, the Bureau of Mineral Resources (BMR) flew a detailed aeromagnetic survey which led to a second wave of mineral discoveries. During this period the potential of Peko was recognized and blind discoveries were made by drilling Juno in the eastern part and the Warrego, Gecko and Orlando deposits in the western part of the TCMF.

Following the initial successes targeting larger magnetic anomalies, selected second and third order magnetic anomalies were drill tested by various companies including Geopeko, ADL, Cuprex and Placer. This phase of exploration resulted in the discovery of the smaller but high grade TC8 and Argo mines. The full size of the White Devil deposit was also realised late in this period. This period relied heavily on detailed magnetic modeling and interpretation for locating or confirming the presence of ironstone bodies prior to drilling. Down-hole magnetic surveying was also developed and acts as a valuable tool in targeting deeper ironstones where drilling has penetrated to depths greater than 100m however has not intersected ironstone target bodies.

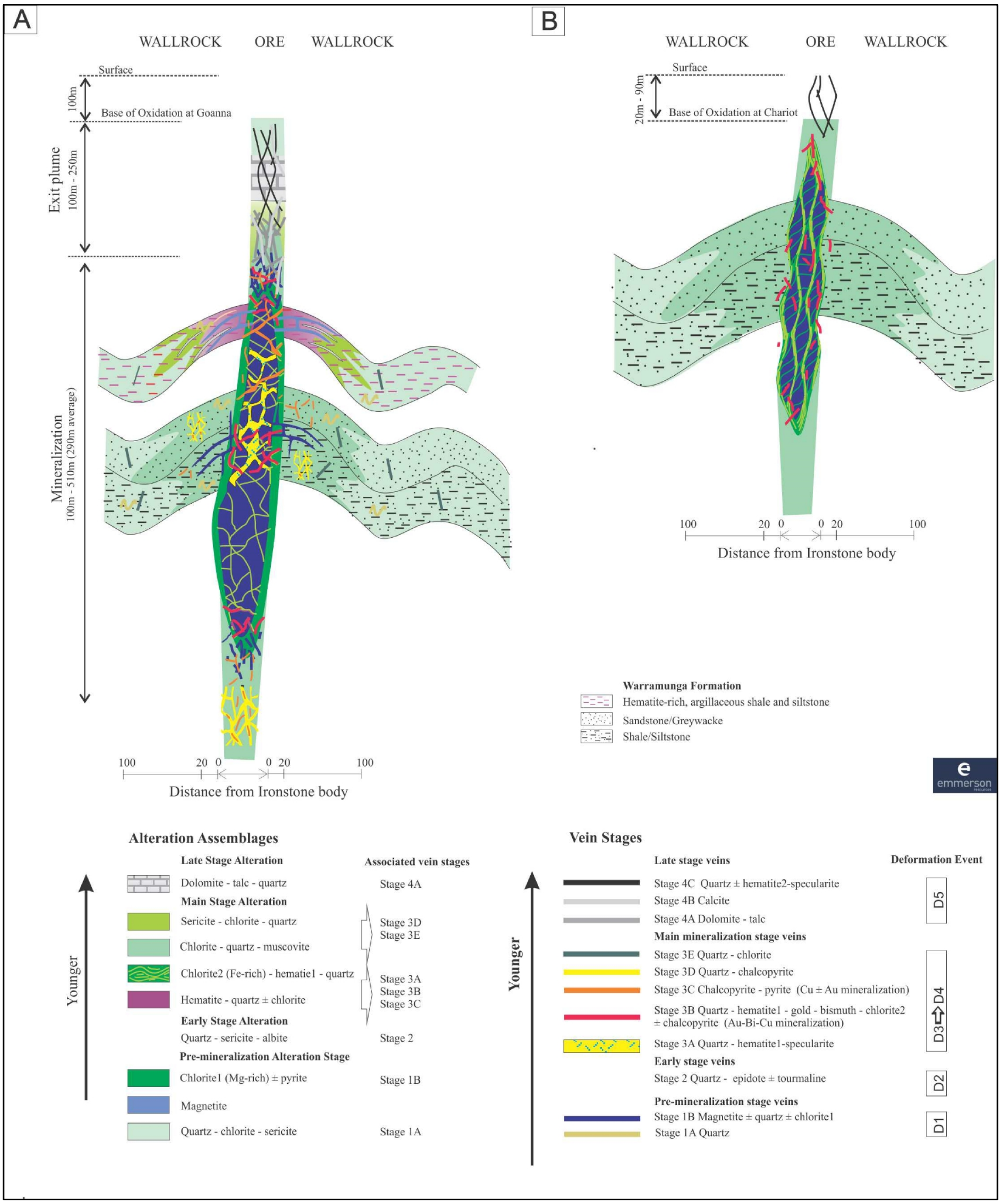

Figure 3: Schematic diagrams showing the two styles of mineralization in the TCMF and their associated alteration assemblages and vein stages. A = predominant ironstone-hosted type, B = shear-hosted ironstone type (Source: Cuison et al, 2014)

A reconnaissance seismic refraction survey was undertaken by the BMR in 1979 to investigate the use of seismic methods to determine geological structures in areas where younger cover rocks prevent direct examination of rocks of potential economic importance (Finlayson, 1981). The survey concluded that the Warramunga Formation rocks have P-wave velocities of 5.22-5.55 km/s (average 5.42 km/s) and S-wave velocities of 3.26-3.41 km/s (average 3.34 km/s), with the P-wave velocity beneath these surface rocks being 6.06 km/s. A simple layered model for the thickness of the Warramunga Group gave values of about 2.6 km near Nobles Nob mine, thinning to about 1.2 km near Warrego mine. Finlayson noted that the nature of the change between the surface and “basement” rocks is likely to be complex, resulting in a velocity transition zone rather than a simple boundary and therefore the estimated depths to “basement” are minimum estimates. (Finlayson, 1981).

In 1988 GeoPeko trialled the use of seismic reflection in the Tennant Creek region. Two short NS lines were executed over the One-Oh-Two ironstone 1.3km east of the Orlando mine (line length 800m), and over the R54 ironstone at Gecko (100m east of the K44 ironstone, line length 1km). The trial is documented in a University of Tasmania Honours thesis by Root (1989) but the original data is unavailable. Root found that a weathered layer and some deeper reflectors thought to reflect “basement” could be interpreted at both, and while ore bodies and their associated alteration envelope could not be detected at Gecko, acoustic impedance measurements from drill core suggested that these may be detectable with improved survey resolution. At One-Oh-Two the ore zone (i.e. ironstone) appeared to have disrupted the bedding of the host rocks near a large N-dipping reverse fault. Root concluded the main use of shallow seismic techniques in mineral exploration to be as a supplement to drilling, but that some knowledge of the subsurface geology is required for a meaningful interpretation of seismic sections in complex terrains (Root, 1989).

1990 – 2005 (Brownfields Era)
During this period most exploration successes were of a brownfields nature including the location and mining of extensions to several deposits such as Gecko, White Devil, Orlando and Eldorado by Normandy and further definition of the Chariot Resource by Giants Reef Exploration. This era was characterised by a combination of near mine exploration techniques, more regional but limited application of gravity geophysics, and trial surveys utilising electrical geophysics.

2007- present (New Technology and Concepts)
Emmerson Resources Limited (Emmerson) was listed in December 2007, taking the assets of the former Giants Reef Mining out of administration. Emmerson recognised that previous explorers had conducted thorough and systematic exploration over most of the field utilising the best exploration methods and technology at that time. Thus the opportunity was not in repeating previous exploration, but rather in applying the very best geoscientific thinking and innovative technology to unlock a new generation of gold-copper deposits. Furthermore, the exploration strategy required a strong business case as like in the pharmaceutical industry, the application of new technology is high risk and needed patient shareholders that were willing to take a longer term view of unlocking additional mineral wealth.

In 2009, Emmerson sole-funded a province-wide, detailed, ground gravity survey to assist in identifying a new style of iron-oxide copper gold (IOCG) mineralisation – the hematite hosted endmember that was largely overlooked by previous companies. Some examples of this style of mineralisation include the Nobles Nob and Chariot deposits in the TCMF, but also in other IOCG provinces such as the giant Olympic Dam deposit in South Australia.

In parallel, Emmerson embarked on erecting a new geological and structural framework to support the targeting of a new generation of gold-copper deposits. This included funding new, applied research into the TCMF such as a major PhD study under Dr John Miller (from the Centre of Exploration Targeting, Western Australia), a Masters (from Monash University in Victoria) and various Honours students (from James Cook University in Queensland and CODES in Tasmania) – all tasked with establishing new insights to the geology and mineralisation of the TCMF.

Underpinning this was a $28m Joint Venture with Ivanhoe Australia – aimed at funding the testing of these new concepts and targets.

In 2011, the Joint Venture between Emmerson Resources and Ivanhoe Australia deployed the first "state of art", helicopter-borne electrical survey – the first application of a new generation of very powerful electro-magnetic technology in the TCMF. This combined with new geological concepts directly lead to the discovery of the Goanna and Monitor copper mineralisation in 2012 (Osborne *et al*, 2012).

On the withdrawal of Ivanhoe in 2014, Emmerson secured a new joint venture partner, Evolution Mining Limited. This JV is underwriting further innovative exploration within the TCMF – building on the learnings from earlier work and also drawing on the experience of the exploration team at Evolution Mining.

Exploration Concept

It was postulated as early as 1989 that the ironstones in the Tennant Creek Mineral Field are related to, and perhaps even emplaced in, thrust faults developed during basin inversion. The idea appears to have been first documented by Etheridge (1989), was further developed by Rattenbury (1990, 1994) and linked to mineralization by Skirrow and Walshe (2002). Simply stated the concept is that thrust faults developed during basin inversion serve as loci for development of iron oxide bodies ("ironstones") that are subsequently mineralized during a brittle transcurrent or transpressional fault event, the fault planes themselves serving as the conduits for the mineralized fluids associated with felsic intrusives of the TC Supersuite.

The relatively shallow exploration efforts in the TCMF to date (<600m) linked with the commonly mapped steeply dipping foliations have prohibited the observation of typically shallower thrust geometries, but it was decided to trial four shallow (ca 1.6km deep) lines of 2D Seismic reflection in late 2014, over the Gecko, Goanna and Chariot deposits. This survey was specifically optimised to identify shallow reflectors such as ironstones (associated with the mineralization), the hematite shale (a critical horizon associated with most of the major deposits in the TCMF), and the controlling structures or fluid conduits associated with the deposits, as little information is available on the geology and structure below the known deposits. Interpretation of these 2D seismic lines is ongoing, however the results are encouraging and have provided some very new and surprising insights into the near mine geology at Gecko (Figure 4). Details of the co-funded diamond hole (GODD032) drilled to test interpreted seismic anomalies underneath the Gecko K44 deposit are contained in the report titled ML23969_2015_Collaboration_Final_Report.

Preliminary interpretation of this 2D seismic line suggests flat lying stratigraphy, except in the vicinity of the Goanna mineralization. Furthermore it pinpoints the base of oxidation and a number of different zones of reflectivity – one at around 300m below the surface (dashed green line on figure 3) that may represent an intense alteration front above a regional thrust. Another zone at around 1,000m depth may correspond with structures associated with duplexes and basement decollement. In addition there are a number of sub vertical "flower" structures where the "washed out" appearance likely represents major zones of fluid flow (i.e. the feeder zone to the Goanna mineralization). If correct, this interpretation substantially rewrites the current geological understanding, not only at the scale of the deposit but potentially could rewrite the regional setting – where thin skinned tectonics, folds and sub vertical zones of dilation play a critical role to mineralisation.

Observation of what appear to be shallowly dipping structures in the shallow trial 2D seismic sections raised the possibility that such structures might well be visible in a deeper crustal seismic section and lead to the idea of executing a regional seismic line across the Warramunga Formation, the overlying Ooradidgee Group and the Tennant Creek Supersuite Intrusives. The objective of the 2D survey would be to outline previously unidentified areas of prospectivity in the Tennant Creek Mineral Field by seismically imaging the upper crust along the line to improve understanding of regional geological architecture.

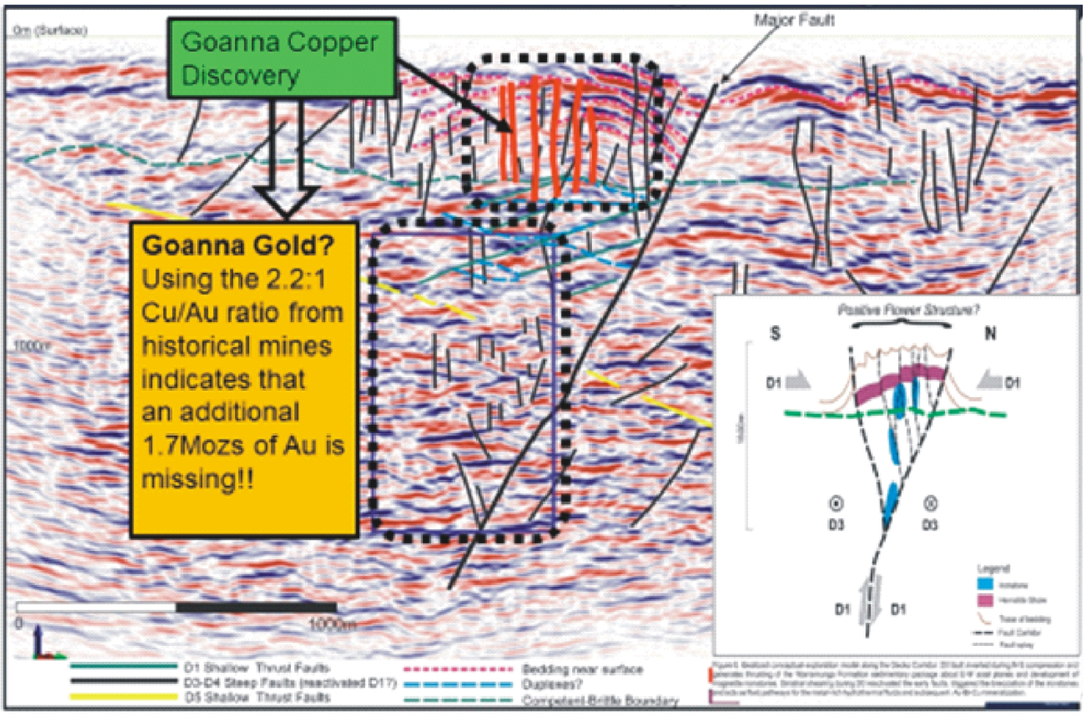

Figure 4: 2D seismic section across the Goanna Copper Discovery (looking west). The lower dotted box represents the area of interest below the Goanna Deposit where it is postulated the gold-rich portion of the mineralization may be located. The inset shows the postulated geological model of a positive flower structure (pop-up) developed in the hanging wall of a major transpressional fault.

Details of the Collaborative Program

One 60km 2D seismic reflection line (Line 101) was acquired following the Stuart Highway 30km to the north, and 30km to the south, of the town of Tennant Creek, locally diverted to the east of the town site for logistical reasons (figure 1). 60 linear kilometres of 2D data with a total of 2,032 unique source points were acquired utilising one source, a 60,000lb Vibroseis Vehicle, as a means of producing seismic energy, delivering a linear 14 second sweep through a frequency range of 8-130Hz.

The record length was 10 seconds in an attempt to catch reflections at 10km+ in depth. Two to three identical sweeps were acquired at each individual VP (vibe position) depending on intensity of ambient noise sources (mostly traffic). All seismic vibrations were measured with a rolling spread of 600 single point geophones using the Aries II seismic acquisition system. The spacing between VPs was 30m and the spacing between geophones was 15m. The data acquisition procedure are listed in Table 1 with detailed descriptions contained in Appendix 1.

Surveying was undertaken by qualified surveyors from HiSeis Staff and is detailed in Appendix 1. As there was a 5m buffer on either side of the Stuart Highway, the line was surveyed as far away from the road as possible, to the left hand side, heading in a North-South orientation. This allowed sufficient room for the vibroseis and crew to travel and transport equipment safely.
Surveying was conducted in a vehicle by one surveyor and one helper working ahead of the active seismic crew, flagging and collecting receiver coordinates to within an accuracy of 10cm. These personnel were also responsible for reconnaissance and reporting of obstacles and obstructions to survey designs and plans. Coordinates were collected using handheld Leica 1200 surveying equipment with a base station.
Source point surveying was interpolated from the receiver coordinates. In addition to this, the vibe mounted Omnistar GPS system collected differential GPS known as the COG (centre of gravity) from the vibe base place after each VP. This COG position was then saved into the system for a processing option. All surveying was conducted in MGA94 UTM Zone 54S coordinates.

Table 1 – Parameters of 2015 2D Seismic Survey (details in Appendix 1)

The nominal survey parameters were as follows:

Line Length	60km
Total Number of Receiver Stations	4000
Total Number of Source Stations	2000
Active Receiver Spread (min)	300
Full Receiver Spread (max)	600
Receiver station spacing	15m
Total Number of Source Points	2000
Source Point Spacing	30m
Nominal Fold	600
Max offset	+/- 4500m
Start and End VP	1001 - 5001 (North - South)
Start and End date Start	14/6 & End 21/6

The following statistics cover the project:

Total Planned Lines	1
Total Lines Acquired	1
Source Points (Acquired)	2032
Days to Acquire (Shooting Days + Movement Days)	8
Average Shots per Day	254

Field System Recording Parameters

Instrument	Aram Aries II
Total Number of Channels	1100
Tape Format	SEGD Revision 1
Filters	Hi Cut: 205 Hz
Sample Rate	1ms
Record Length	10 seconds
Correlation type	After stack
# of stacks	2 - 3

Receivers

Receiver group interval	15m
Spread	Symmetrical split (m), 4500,-7.5,0,7.5,4500
Geophones	Sensor SM24 10Hz
Array	Single point, 1 every 15m
Connection	5515 KCK

Standard Sweep Definition

Vibrators	Inova AHV IV
Electronics	Pelton VibPro
Sweep Frequency Range	8-130Hz
Sweep Duration	14 seconds
Sweep Type	Linear
Tapers	300ms (cosine)
Vibrator Array	1 vibe inline, centred between station
Record Length	10 seconds
Operating Force (terrain dependant)	70-80%
Phase locking	Ground Force
Amplitude Control	Peak to Peak

Results and Interpretation

Two products were produced for Line 101 comprising:

a) A product targeted to assist the determination of regional geological architecture down to a depth of approximately 30km.

b) A product with a focus on the shallow geology within the top 2km below the surface.

HiSeis Pty Ltd adapted a conventional processing flow to the acquisition parameters, survey objectives and geology known to exist in this area. Parameter testing was conducted and the results of these tests determined an optimum flow in order to image the complex structural geology for each of the two products: regional processing (Table 2) and shallow processing (Table 3). Additional details can be found in Appendix 2.

Table 2 – Regional Processing Flow of 2015 2D Seismic Survey (details in Appendix 2)

1. SEGY input
2. Geometry assignment and QC – bin size 7.5m
3. First break picking and refraction static computation: final datum at 400m and a replacement velocity: 4000 m/s
4. Quality control (QC) of the refraction static solution (on shot records, every 20th shot)
5. Resample to 4ms
6. Air blast attenuation
7. Surface wave noise attenuation (apparent velocity of 3400 m/s)
8. Spiking deconvolution – operator length: 160
9. Predictive deconvolution – gap & operator length: 48/160
10. 1st Pass Velocities: Constant Velocity Stack (CVS) analysis
11. 2nd Pass Velocities: Interactive Velocity Analysis (IVA) using the CVS velocities as a guide function, every 1,875m
12. Computation of surface consistent residual reflection statics
13. Application of residual statics
14. True amplitude recovery, 1/(time*vel^2)
15. Dip Move-Out, FK based
16. 3rd Pass Velocities: Interactive Velocity Analysis (IVA), every 1,875m
17. NMO
18. AGC 1000ms window
19. Stack (DMO)
20. FX Deconvolution
21. Band-pass filter
22. Post stack phase-shift time migration
23. SEGY time output
24. Time to depth conversion using migration interval velocity
25. SEGY depth output

Table 3 – Shallow Processing Flow of 2015 2D Seismic Survey (details in Appendix 2)

1. SEGY input
2. Geometry assignment and QC – bin size 7.5m
3. First break picking and refraction static computation: final datum at 400m and a replacement velocity: 4000 m/s
4. Quality control (QC) of the refraction static solution (on shot records, every 20th shot)
5. Data taken from this Step 4 above
6. Air blast attenuation
7. Surface wave noise attenuation (apparent velocity of 3400 m/s)
8. Spiking deconvolution – operator length: 160
9. Predictive deconvolution – gap & operator length: 48/160
10. 2nd Pass Velocities: Interactive Velocity Analysis (IVA) using the final velocity field from the regional processing. Run at a 750m interval
11. Computation of surface consistent residual reflection statics
12. Application of residual statics
13. True amplitude recovery, 1/(time*vel^2)
14. Dip Move-Out, FK based
15. 3rd Pass Velocities: Interactive Velocity Analysis (IVA), every 750m
16. NMO
17. AGC 500ms window and 1900ms window for Partially Preserved Amplitudes (PPA)
18. Stack (DMO)
19. FX Deconvolution
20. Band-pass filter
21. Post stack phase-shift time migration
22. SEGY time output
23. Time to depth conversion using migration interval velocity
24. SEGY depth output

Interpretation of the final profile was undertaken jointly by staff of Emmerson Resources Limited, Evolution Mining and HiSeis at the HiSeis offices on October 19th 2015. Geologist Nigel Donnellan represented the NTGS at this session. Interpretation was done iteratively directly within the GOCAD software environment where all relevant historical cross geological sections and plans, and magnetic and gravity imagery as well as 3D inversions, and existing mineral occurrences could be interrogated and viewed together with the seismic section as documented in Appendix 3.

The final 2D seismic section is shown in Figure 5 and the interim interpretation is shown in Figure 6. More details on the interpretation session and panel views of the shallow profile can be found in Appendix 3.

Initial results suggest all of the major gold-copper deposits in proximity to line 101 are associated with northward-verging thrust faults which extend down to about 13 kilometres depth (Figure 6). There are also a number of thrusts without expression at the surface, and these have no known mineralization, but where the thrusts are known at the surface, there is a positive correlation with mineralization, suggesting that future exploration should focus on the previously unknown thrusts. The survey also imaged many more felsic intrusives than were expected. The links between gold-copper mineralization, felsic intrusives and thrust faults have long been postulated for the Tennant Creek Mineral Field as summarized in Skirrow and Walshe (2002) but this data provides the first validation of the concept.

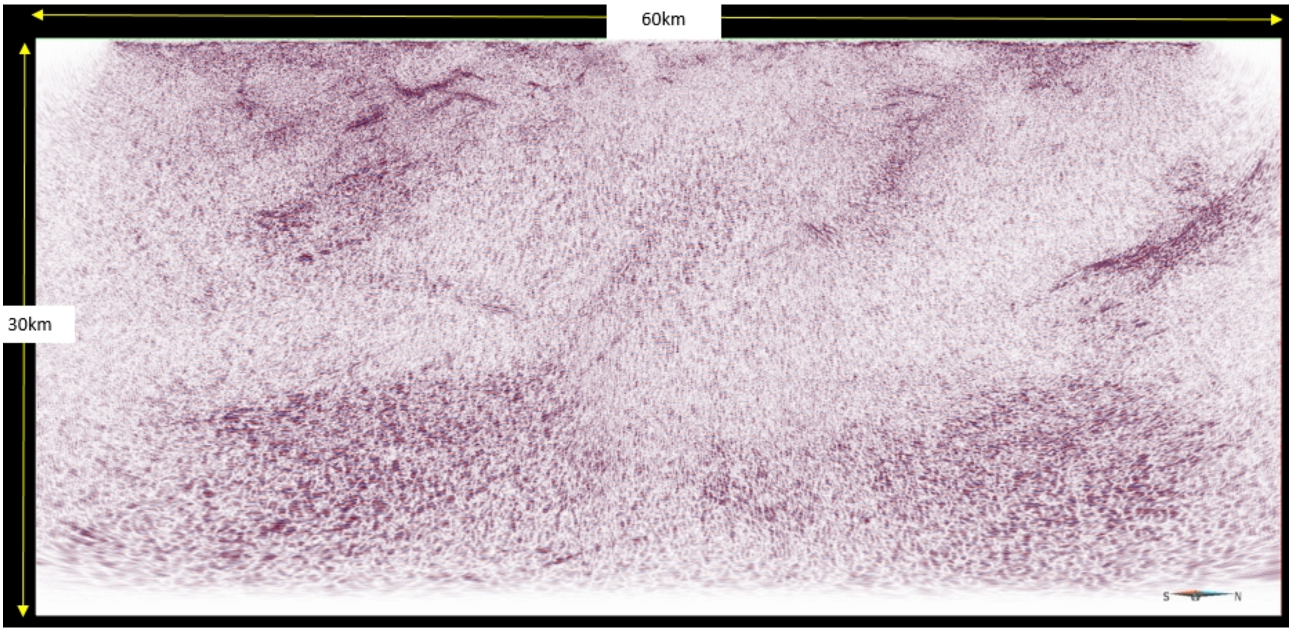

Figure 5: Final image of the 2D reflection seismic section 101. Although the section images down to 30km below surface there is no indication that the Moho (usually represented by a zone of washed out low reflectivity) has been detected.

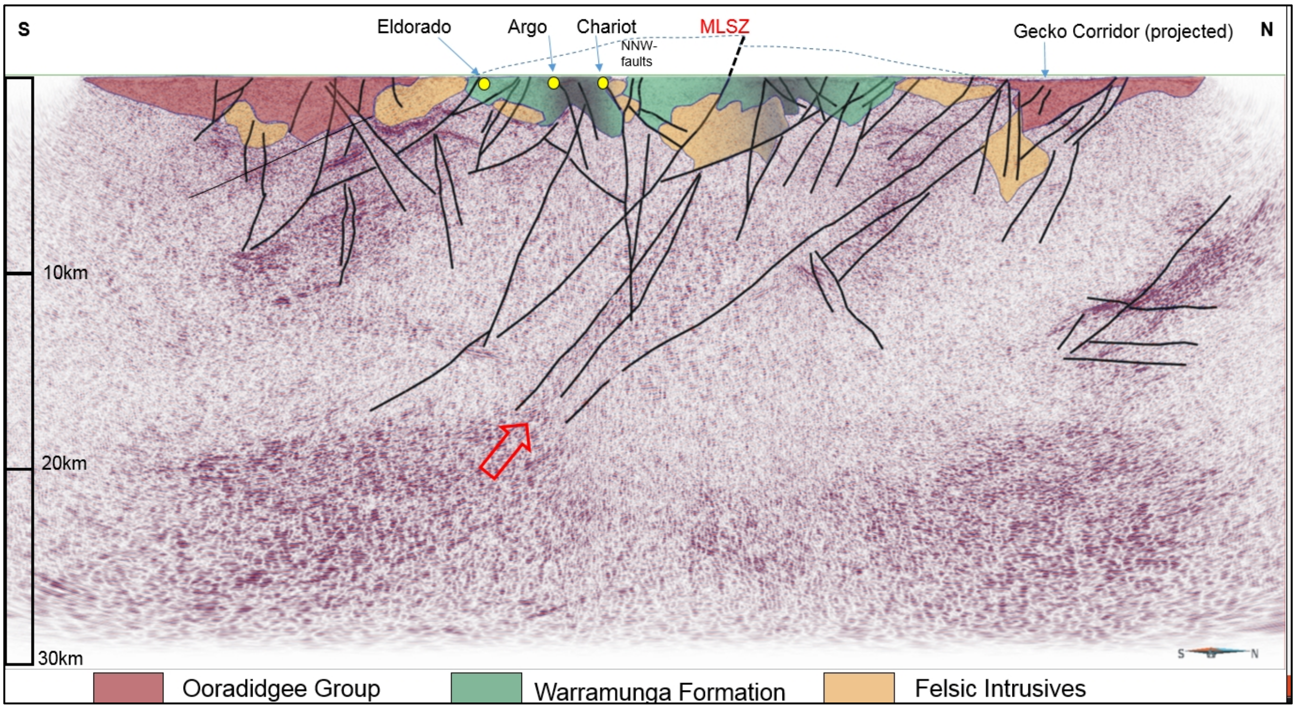

Figure 6: Preliminary geological interpretation of the upper portion of regional seismic profile 101. Major gold mines within close proximity to the line are shown and the Gecko Corridor has been projected. The Mary Lane Shear Zone (MLSZ) appears as a major structure dipping 65°S (arrowed), although it may also be represented by the 50°S fault immediately to the south. Both these faults as well as a strong reflector on the RHS of the image appear to initiate at the top of the zone of increased seismic reflectivity below 20km depth. The dashed blue line marks the postulated unconformity between the Warramunga Formation and the Ooradidgee Group, now domed.

It is interpreted that the Warramunga Formation and the overlying Ooradidgee Group are less than 5km thick in agreement with the observations of Finlayson (1981).

A major subhorizontal boundary is clearly visible at approximately 20km depth (Figures 5 and 6) and represents the top of a different seismic domain. It may be analogous to the top of the Ooratippra Seismic Province, defined on the line 09GA-GA1 (Georgina Basin-Arunta Region) located 210km SE by Korsch *et al* (2011). According to these authors the Ooratippra Seismic Province is highly reflective and is separated from the overlying zone by a change in seismic reflectivity, with a pattern of strong, south-dipping reflections below a subhorizontal surface. It is also marked by a change in electrical conductivity, with the lower crust being much more conductive than the more resistive middle to upper crust. Korsch et al (2011) postulate further that the washed-out zone above the Ooratippra Seismic Zone is probably the basement to the Davenport Province, on which the Warramunga Formation and younger units were deposited. This description is not dissimilar to that observed on the lower portion of Seismic line 101.

Due to the relative lack of experience in seismic interpretation of those involved in the session it was decided that all the historical data and data from Seismic line 101 would also be forwarded to a structural geologist with experience in seismic experience for a second opinion. The person chosen was Dr Armelle Kloppenburg of 4DGeo/Applied Structural Geology in The Hague, The Netherlands (http://www.4d-geo.com/). Dr Kloppenburg has over 14 years' experience in delivering innovative structural geology solutions to the petroleum and mineral exploration and mining sectors, using kinematic techniques and tools that apply balancing principles and comprise algorithms that mimic rock deformation through time. She has worked in extensional, contractional, and strike-slip settings, throughout sedimentary, metamorphic, igneous and salt-rich terrains, globally. At the time of submission of this report Dr Kloppenburg's interpretation is pending.

Conclusion

The links between gold-copper mineralization, felsic intrusives and thrust faults have long been postulated for the Tennant Creek Mineral Field as summarized in Skirrow and Walshe (2002) but this data provides the first validation of the concept. Linking the most recent geochronological data for the Tennant Creek Mineral field presented in Cuison *et al* (2014) with this new structural framework provides a powerful tool to focus exploration on previously unknown blind thrusts.

This collaboration between Emmerson Resources Limited, Evolution Mining Limited, HiSeis Pty Ltd and the Northern Territory Department of Mines and Energy has shown that seismic reflection is an effective technique to establish the overall architecture of the structural setting for gold mineralisation at Tennant Creek. Faults and lithologies previously identified using potential field data and geological mapping are afforded extra dimensionality through the seismic data set, and seismic techniques can delineate "blind" structural target zones.

References

Budd A, Wyborn L, and Bastrakova I, 2002. The metallogenic potential of Australian Proterozoic granites. Geoscience Australia Record 2001/12.

Cuison ALG, Osborne GA and Bills RT. 2013. Evolution of the Gecko Corridor, Tennant Creek Goldfield. *in* 'Annual Geoscience Exploration Seminar (AGES) 2013. Record of abstracts'. Northern Territory Geological Survey, Record 2013-001, pp51-54.

Cuison ALG, Osborne GA, Russell SC and Bills RT, 2014, An Integrated Geological Model for Tennant Creek style Au-Bi-Cu Mineralization. *in* 'Annual Geoscience Exploration Seminar (AGES) 2014. Record of abstracts'. Northern Territory Geological Survey, Record 2014-001, pp56-65.

Donnellan N, 2013. Warramunga Province, *in* Ahmad M and Munson T. J., compilers, Geology and mineral resources of the Northern Territory: Northern Territory Geological Survey, 9:1 – 9:61.

Etheridge M. 1989. Structural Setting of Au/Cu Mineralization in the Tennant Creek District, N.T. Unpublished preliminary draft report dated 22/9/1989 by Tectonex Geoconsultants Pty Ltd to GeoPeko. August-October 1989. 33p, 3 appendices.

Finlayson DM. 1981. Reconnaissance of upper crustal seismic velocities in the Tennant Creek Block, Northern Territory. BMR Jour. Aus. Geol. & Geophys. V6, No3, pp245-252

Hill MP, 2015 (In Prep) Structural, magmatic and hydrothermal evolution of the gold-copper-bismuth systems in the Tennant Creek Mineral Field, Northern Territory, Australia. Unpublished PhD thesis, The University of Western Australia

Johnstone A and Donnellan N, 2001. Tennant Creek 1:250,000 Integrated Interpretation of Geophysics and Gapped geology. Edition 1. Northern Territory Geological Survey, Alice Springs.

Korsch R, Blewett RS, Close DF, Scrimgeour IR, Huston DL, Kositicin N, Whelan JA, Carr LK and Duan J. 2011. Geological interpretation and geodynamic implications of the deep seismic reflection and MT line 09GA-GA1: Georgina Basin-Arunta Region. *in* 'Annual Geoscience Exploration Seminar (AGES) 2011. Record of abstracts'. Northern Territory Geological Survey, Record 2013-003, pp67-76.

Maidment DW, Lambeck L, Huston DL, and Donnellan N, 2006. New geochronological data from the Tennant Region: *in* ‘Annual Geoscience Exploration Seminar (AGES) 2006. Record of abstracts.’ Northern Territory Geological Survey, Record 2006/002, pp32-35.

Maidment DW, Huston DL, Donnellan N, and Lambeck A, 2013. Constraints on the timing of the Tennant Event and associated Au–Cu–Bi mineralisation in the Tennant Region, Northern Territory: Precambrian Research, 237, 51-63.

Osborne GA, Bills RT, and Russell SC. 2012. Cracking the code of the Tennant Creek Mineral Field. *in* 'Annual Geoscience Exploration Seminar (AGES) 2012. Record of abstracts'. Northern Territory Geological Survey, Record 2012-002, pp23-25.

Rattenbury MS. 1990. The Mary Lane Shear and a Fold–Thrust Model for the deformation of the Tennant Creek Goldfield, Northern Territory. CODES Proterozoic gold-copper project – Workshop Manual No.4. May 1990, pp93-109.

Rattenbury MS. 1994. A linked Fold–Thrust Model for the deformation of the Tennant Creek Goldfield, northern Australia. Mineralium Deposita, v29, pp302-308.

Root J. 1989. Shallow Seismic Reflection Techniques in the Tennant Creek Field. Unpublished Honours Thesis at the University of Tasmania. 145p.

Skirrow RG, and Walshe J.L. 2002. Reduced and Oxidized Au-Cu-Bi Iron Oxide Deposits of the Tennant Creek Inlier, Australia: An Integrated Geological and Chemical Model. Econ. Geol, v97, pp1167-1202.