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CRUSTAL SCALE SEISMIC REFLECTION SURVEYS IN SEARCH FOR CARRAPATEENA STYLE CU-AU DEPOSITS.

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Abstract

The discovery of Olympic Dam Cu-U-Au deposits in 1975 has subjected the entire Gawler Craton to serious scrutiny in search of similar deposits. Though potential methods routinely used for iron oxide copper gold (IOCG) exploration seems effective, they lack the needed resolution to detect deeper mineral deposits >500 m of sediment cover. Seismic method provides a distinct advantage over all other geophysical methods due to its great depth of penetration and superior spatial resolution. Despite these potentials, no arguments for seismic exploration at large scale have been proposed; because a cost-benefit analysis has never been conducted at such scale. In this study we analyse such a case by modelling 10 by 2 km Carrapateena IOCG deposit scenario where 2D seismic with relatively sparse source-receiver geometry is used to detect the presence of possible intrusive package. Interpreted results revealed that seismic reflection techniques could be an exploration tool for mapping deep seated IOCG even when hosted in very complex structures. The migrated section was not only able to identify and trace various layers as well as the complex structures but also shows reflections around the edges of intrusion. Thus, looking for such intrusive where there are possible fault pathways from depth, seismic methods should do well to warrant exploration confidence.

Keywords: *Cu-Au deposits, modelling, regolith cover, seismic method, source-receivers.*

INTRODUCTION

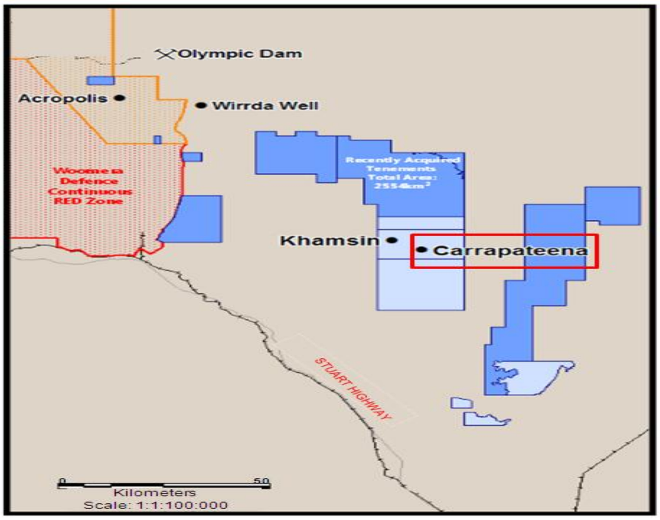
Copper and gold deposits remain important source of revenue in Australia. These deposits are generally found in complex geological structures associated with crustal scale shear zones. Though they occurs in acoustically transparent, low impedance setting, the deposits themselves are well defined and dominated by hematite and magnetite which also have high impedance contrast thus making both deposits types to be datable by seismic method. Whilst potential field methods that are traditionally used for IOCG exploration are effective, they lack the resolution needed to confidently detect deeper mineral deposits. Most of the prospective areas in the Gawler craton lie under >500 m of sediment cover; thus, potential field methods are only good for finding very extensive, and often low grade deposits.

Early applications of seismic profiling for mineral exploration were faced with huge challenges due to the inability to adapt oil exploration based design and interpretation of seismic surveys to suit the 3D geometry of mineral deposits. However, recent application of seismic reflection techniques seems promising due to its superior resolution with depth compared to other geophysical methods (Malemire et al 2014, et al 2012). The seismic reflection method can provide images of high quality; locate small and high grade orebodies up to 3km depth (Ehrig, 2013, Malemir et al 2012; Milkereit et al 2000; Pretorius et al 2000, Robert et al 1983 Juhlin et al, 2003; Drummond, 2000; Salisbury, 1997; Greenhalgh, 1997). Thus, the seismic method would seem well suited to exploring for Carrapateena style of deposits in the Gawler Craton.

STUDY AREA

Carrapateena deposit (Figure 1) located approximately 160 km north of Port Augusta, within the eastern margin of the Gawler Craton, South Australia was discovered in 2005 by Rudy Gomez under the South Australian Government's PACE exploration incentive program (Daly, 1998). It is a 'blind' copper-gold deposit with 500m of Stuart Shelf sedimentary cover rocks and occupies a north-south elongated area of approximately 800 x 600 m at the unconformity surface with the underlying Palaeoproterozoic host rocks.

The deposit is hosted by strongly brecciated granitoids and occurs within the core of a north-south oriented, 30 x 100 km mass of that suite, that is overlain 10 to 15 km to the west by ~1590 Ma mafic and felsic volcanic rocks of the Gawler Range Volcanic, which are comagmatic with the Hiltaba Suite granitoids that host the Olympic Dam deposit. Mineralisation is confined to a steeply plunging, pipe-like body of hematite and hematite-granite breccia, called the Carrapateena Breccia Complex (CBC), which is interpreted to be cut at its centre by an east-west- to eastnortheast-trending complex zone of faulting. To the north of this inferred zone of faulting, the mineralised mass is wedge-shaped, tapering rapidly downward into the fault zone and maybe conceivably follow that structure to depth. Mineralisation is zoned laterally outward, and to the north, vertically downward, from bonite to chalcopyrite-bonite to chalcopyrite to chalcopyrite-pyrite. The principal alteration minerals are hematite, chlorite and sericite, with locally abundant quartz and carbonate and secondary barite, monazite, anatase, magnetite, apatite, fluorite and zircon.



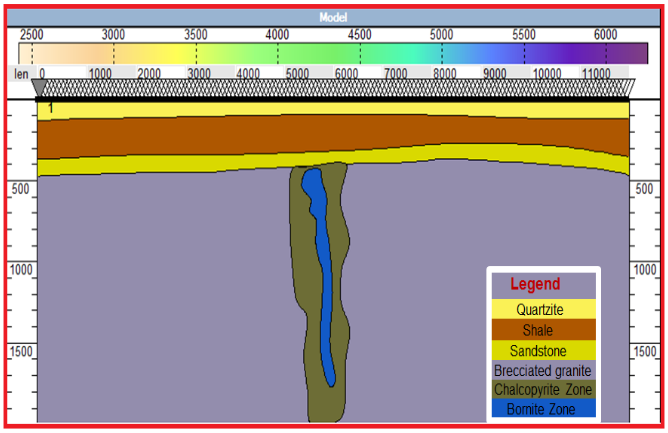
Fig(1) Location of the study area

METHODOLOGY

Petrophysical measurement and Survey Design

Before the geological model was created, an investigation was carried out to ascertain the viability survey achieving its geological objectives. This involves petrophysical measurement which provides adequate understanding of the physical properties of both cover sequences and basement rocks in the study area. Analysis from the core measurements demonstrated that petrophysical characteristics of basement samples from Carrapateena are dominated by the presence of iron-oxide, mainly hematite, with magnetite and sulphides playing a lesser part.

The synthetic survey was then designed to reflect this situation; a 10 km by 2 km geological model, of which the primary zones of interest Carrapateena Breccia Complex (CBC)) were situated within the central kilometres Figure (2). A split-spread geometry was used with the source nominally at the centre of the spread while two different survey parameters were used to collect the data. A total of 1000 and 500 vertical receivers with a 10 m and 20 m interval were placed along the model while 480 and 240 synthetic shots with 20 and 40 m interval were placed at the surface over 10 km of the model. Velocity and density values were imputed to the various units of the geological model with a 40Hz Ricker wavelet which served as the dominant frequency.



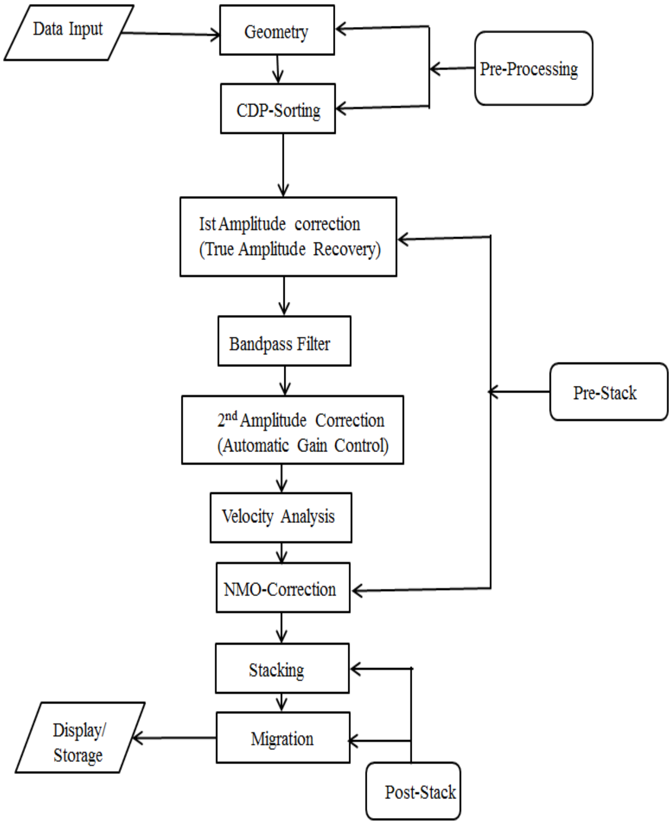
Fig(2) Synthetic geology model of Carrapateena copper-gold deposit showing ore distribution at around 500 m.

Modelling and Processing of Synthetic Data

The Synthetic seismograms from the modelling were computed using stress-velocity formulation (Virieux, 1986) implemented in Tesseral-2D modelling software. The created shot records in SEG-Y format were processed adequately using RadexPro package with basic processing steps shown in (Figure 3). After SEG-Y data files were imported to RadexPro software, geometry was assigned after which data were sorted into Common Depth Point (CDP) bins already defined in the geometry. The CDP bins were defined at 10 m intervals based on the source-receiver midpoint locations while all traces from any shots which had source-receiver midpoints that fell within the predefined CDP location bins were gathered into the same CDP bin. We then applied first amplitude correction to the data to account for the spherical divergence of the seismic energy as it propagates from the source followed by band pass filter to remove noise outside the seismic sweep signal frequency band. Stacking velocity analysis was performed using velocity estimation and plotting module to defined CDP gathers according to user specified velocity functions. Velocity picks for reflections were made on the basis of maxima in coherency, flattening across the CDP gather and the quality of narrow stack panels. We made several passes, including initial estimates of velocity.

Table(1) Acquisition parameters used for Carrapateena synthetic modelling

Parameters	Survey one	Survey two
Source depth	6m	6m
Receivers depth	6m	6m
Shot interval	20	40
Maximum frequency content	35	35
Receivers length	1000	500
Receivers spacing	10	20
Sampling time	2 s	2 s
Time step (ms)	0.1	0.1
Number of shots	480	240

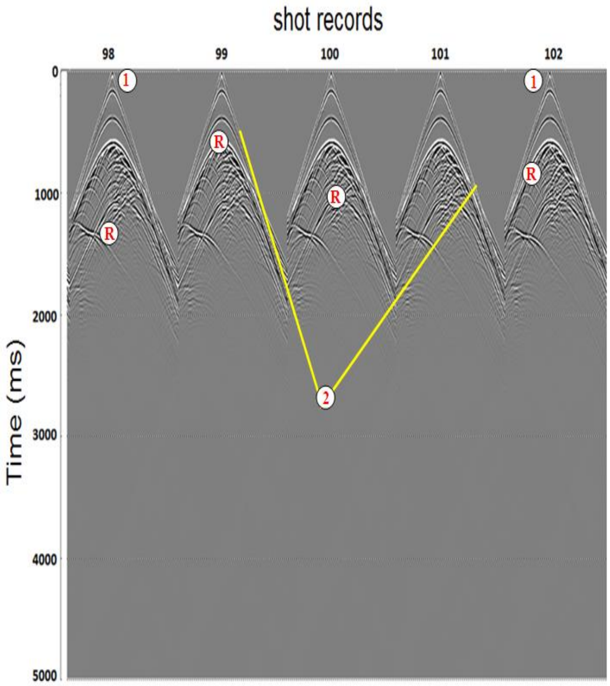


Fig(3) Basic processing flow used for the synthetic modelling

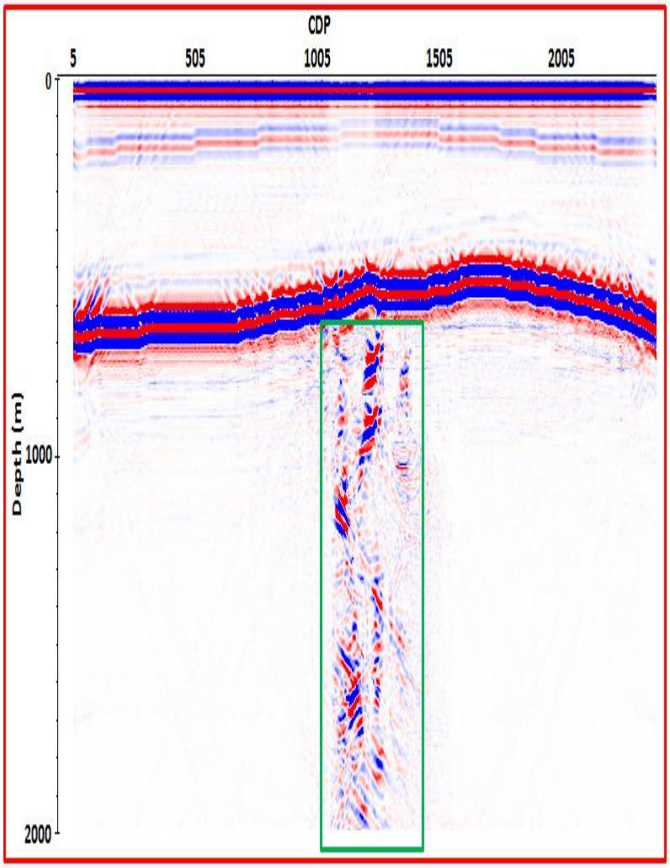
RESULTS AND DISCUSSION

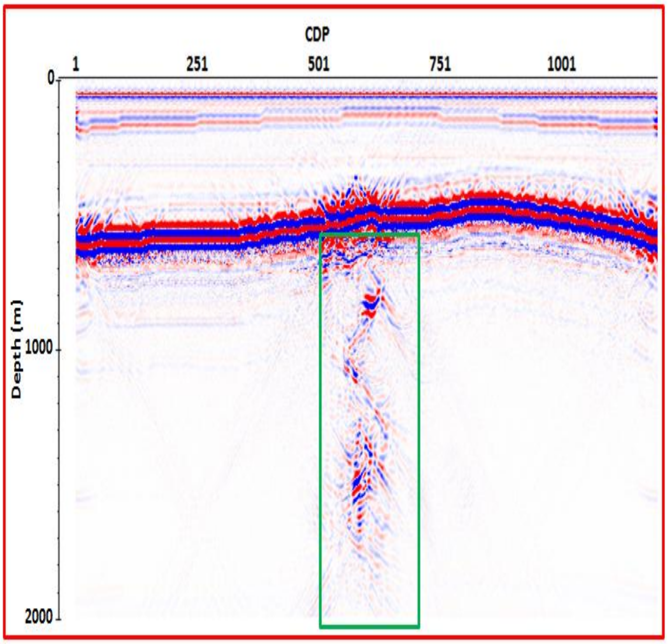
Results from Carrapateena deposits with buried cover located at 500m using two different survey parameters are presented below. Figure (4) is an example of noise free synthetic shot record for source numbers 98-102 displayed from 0-5000ms

The layers within the sediments have weak reflections due to the low impedance contrast (low velocity-density values initially assigned). Strong reflection as expected was observed between the granitic basement rock and sediment cover contact in both parameters tested and this might be due to high impedance contrast. The almost vertical structures of the CBC model shown in Figure 2 were imaged down to a depth of 2km (Figures 5A-B and 7A-B). We can also see anomalous or spurious changes in reflection character at the base of the large intrusive area indicated with green triangle. The Carrapateena Breccia Complex (CBC) host to the Carrapateena deposit is imaged as a region of non-reflectivity.



Fig(4) Noise free synthetic shot records for source number 98-102 from the Carrapateena breccia complex model shown in Figure 2 (1) direct arrival signals, (2) direct/refracted signals (R) reflection signals. The shots are displayed using true relative amplitude and no correction for spherical divergence. Shot depth for all gathers is 0 m. Gathers are generated using Ricker wavelet source cantered at 35Hz. Record displaced from 0-5000 ms but reflections event are visible up to 2000ms





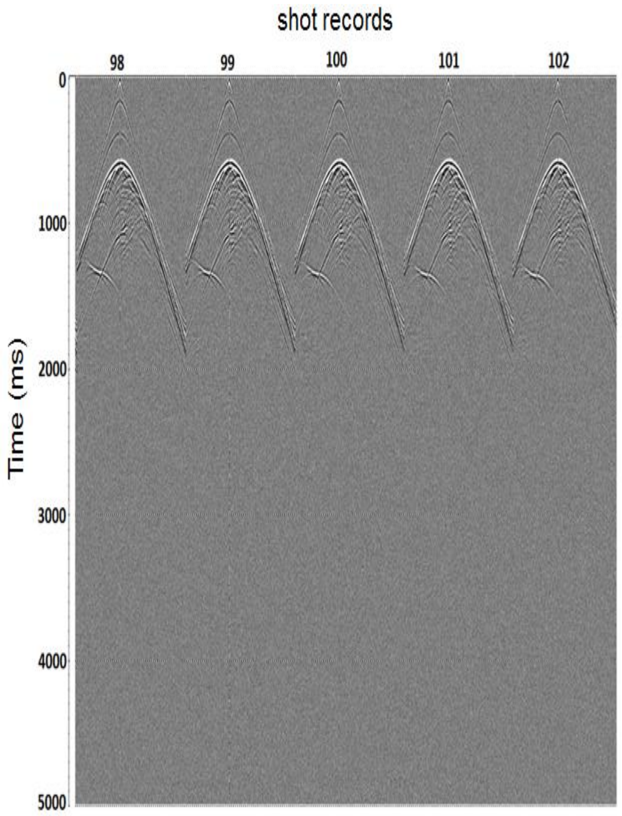
Fig(5) Noise free depth migrated sections at 500m burial cover tested with different survey parameters; A) 20m source and 10 m receivers spacing, B) 40m source and 20 m receivers spacing. The layers within the cover sediment have low impedance are fully recovered while the intrusive package itself (chalcopyrite and bonite zone) are partially recovered due to the almost vertical nature.

To establish the stability of the method in the presence of noise which prevails in hard rock environment, 35% Gaussian noise was added to the synthetic seismogram before processing, resulting in noisy data. Figure 6 is a typical example of the seismogram containing 35% Gaussian noise. As expected, there is a considerable difference between the noise free seismogram shown in Figure 4.

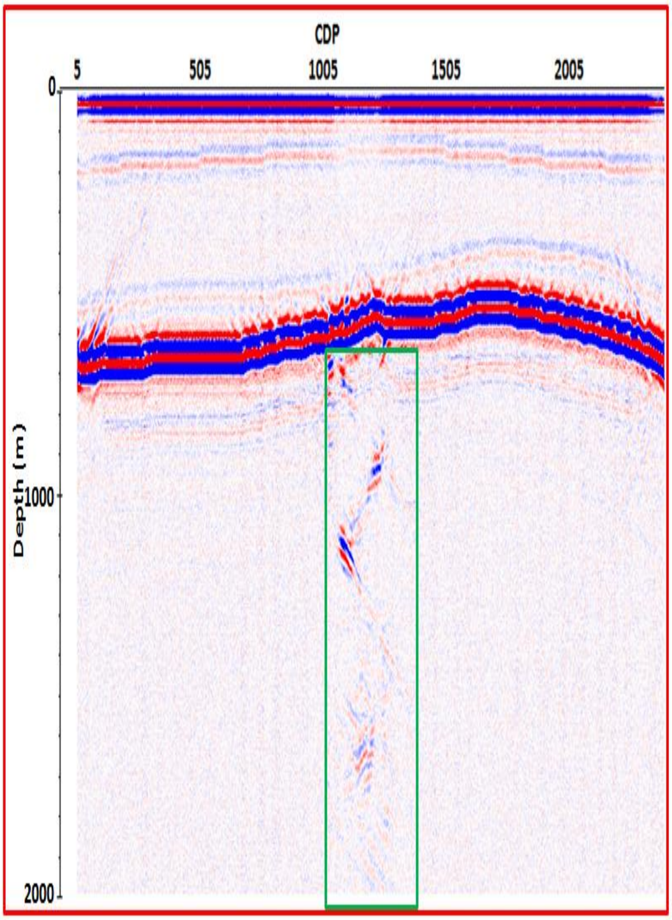
The depth migrated sections from 35% Gaussian noise is shown in Figure (7) while expanded sections from both noise free and 35% Gaussian noise is shown in Figure 8 for better comparison. We observed that the images from the noisy data are slightly blurred, but compared favourably well with the noise free migrated sections except that geological boundaries within the sediments are partially recovered. The contact between the cover sediments and granitic basement rock as well Carrapateena Breccia Complex (CBC) structure are largely recovered when compared to the noise free migrated section.

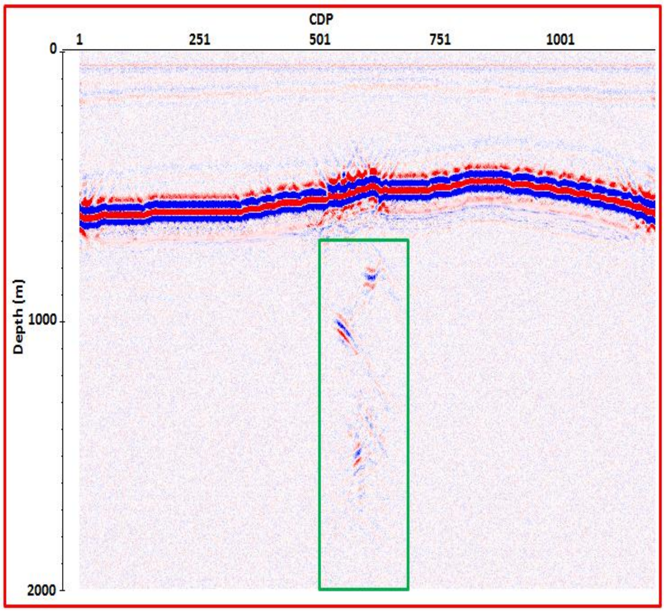
CONCLUSION

This modelling study has demonstrated that seismic reflection technique can be successfully implemented to generate high quality results for the subsurface mapping of deep seated deposits in the Gawler Craton. The migrated sections were able to resolve the various horizontal layers as well as vertical intrusive structures to a reasonable degree. Despite these encouraging results, an issue still to be resolved is whether steep near-surface reflectors of limited extent can be satisfactorily imaged, in view of the vertical and horizontal resolution obtainable. The vertical fault and structures that is well identified in the results above in my view is largely because the fault is imaged by its effect and may not necessary by reflections from it.



Fig(6) Typical synthetic shot records for source number 98-102 from Olympic Dam breccia complex model with 35% Gaussian noise. Record displaced from 0-5000 ms.





Fig(7) Migrated sections with 35% Gaussian noise from. A) 20m source and 10m receivers, B) 40m source and 20m receivers. The images from the noisy data are slightly blurred compared with the noise free migrated sections in Figure 5. However, the contact between the basement rock and that of the cover sediments as well as the intrusive structure are substantially recovered when compared to the noise free migrated sections.

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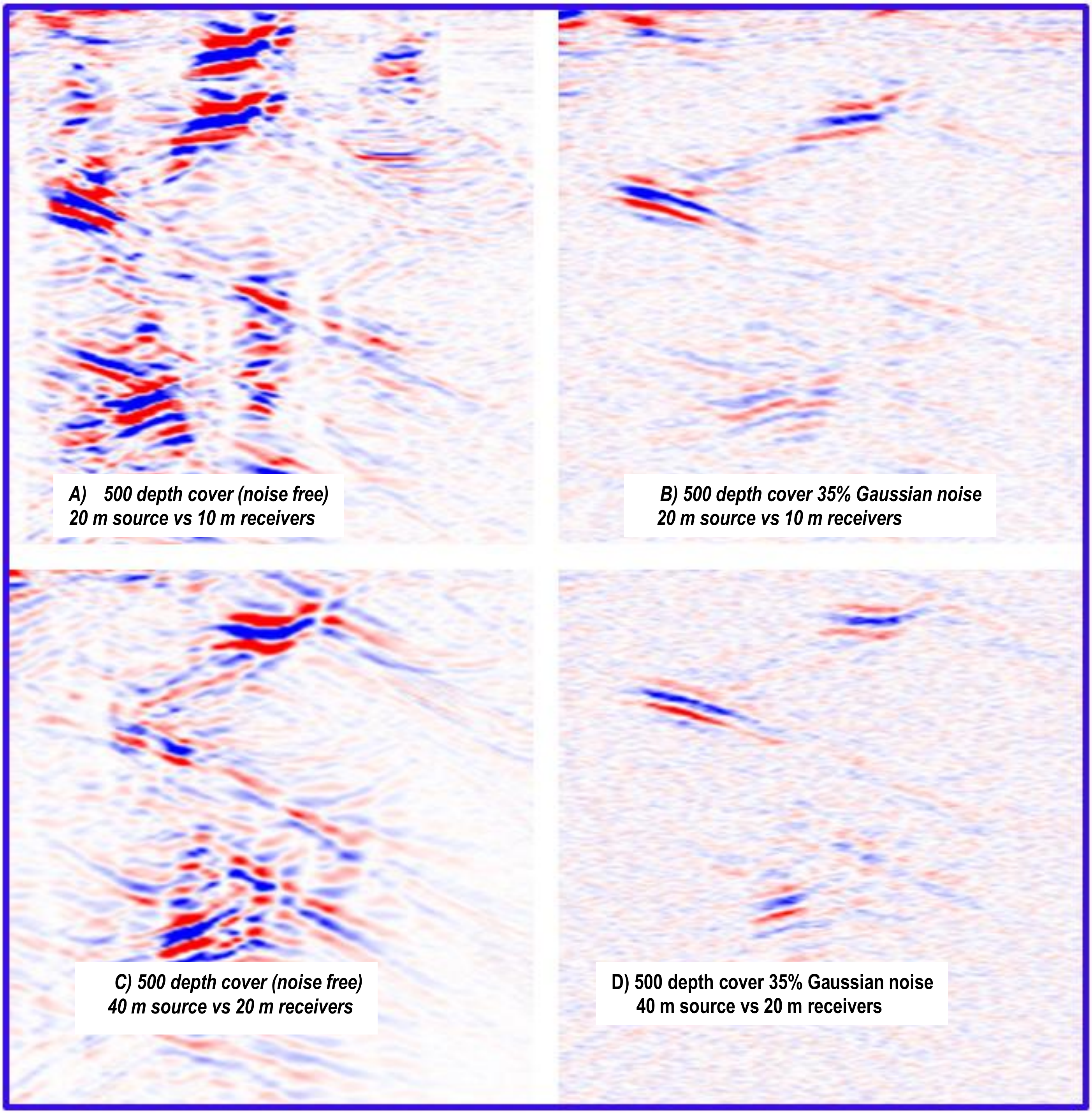

Fig(8) Expanded sections noise free vs 35% Guassian noise. A) noise free section from 20m source and 10m receivers, B) with 35% Guassian noise from 20m source and 10m receivers, C) noise free section from 40m source and 20m receivers, D) with 35% Guassian noise from 40m source and 20m receivers.