

DEEP GEOLOGIC

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FOR OPG's LOW & INTERMEDIATE LEVEL WASTE

Supporting Technical Report

2D Seismic Survey of the Bruce Site

February 2009

Prepared by: Intera Engineering Ltd.

NWMO DGR-REP-01330-0001-R000



Note:

The Nuclear Waste Management Organization (NWMO) is managing the development of a Deep Geologic Repository for low and intermediate level radioactive waste, at the Bruce nuclear site, on behalf of Ontario Power Generation (OPG).

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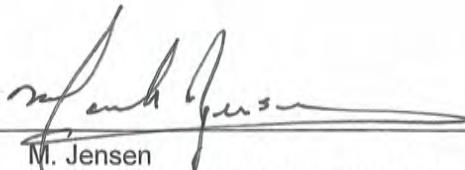
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February 13, 2009

Date

Intera Engineering DGR Site Characterization Document		
Title:	2D Seismic Survey of Bruce Site	
Document ID:	TR-07-15	
Revision Number:	0	Date: February 13, 2009
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Document Revision History		
Revision	Effective Date	Description of Changes
0	February 13, 2009	Initial Issue

Executive Summary

A two-dimensional (2D) seismic survey was conducted on the Bruce site as part of geoscientific investigations to assess the suitability of the Paleozoic sedimentary sequence, particularly the Ordovician bedrock formations, for implementation of the proposed Ontario Power Generation Deep Geologic Repository for Low and Intermediate Level Radioactive Waste. The purpose of the seismic survey was to obtain preliminary deep bedrock geological, stratigraphic and structural information. This document describes the seismic survey design and data interpretation.

Twenty line kilometres of 2D seismic data were acquired on the 9 km² Bruce site in October 2006. The seismic survey followed detailed design and preparation to, among other factors, take into account previous geophysical survey experience within the Paleozoic setting of Southern Ontario, local site infrastructure, and access limitations arising from operation on a licensed nuclear facility. Conventional oil and gas technology and expertise were used to acquire these data so as to mitigate environmental noise and obtain the best achievable data quality. Data processing was performed by two independent consultants and interpreted using synthetic seismograms consistent with geophysical and bedrock core logging at boreholes DGR-1 and DGR-2 on the Bruce site. Interpretation of these data considered multiple lines of evidence including coincidence of seismic reflection events on both processed datasets, consistency with bedrock stratigraphy and lithology observed at deep boreholes DGR1, DGR-2, DGR-3 and DGR-4 and experience with other similar types of geophysical and stratigraphic data elsewhere in Southern Ontario.

The interpretations of the 2D seismic data provide a reasoned assessment of possible geologic features and trend regimes that might be present beneath the Bruce site. Uncertainty in these interpretations is influenced by variable data quality resulting, in part, from the regionally experienced poor seismic energy coupling between the low velocity, variably thick and heterogeneous glacial drift and underlying bedrock, and anthropogenic and natural background noise. Despite such limitations the data suggests the possible presence of a sub-vertical fault structure trending NNW-SSE to the east of a crystalline basement high and to the west of this high. Within the Ordovician sediment several distinct elevation-lows, possibly associated with graben-type structure, are apparent. This occurs specifically at the tie point of Lines 1 and 5, on Line 9 close to where it ties with Line 7, and near the tie of Lines 3 and 7. It is noteworthy that the seismic data quality are not good enough to say with certainty how interpreted faults are oriented or whether some features tentatively identified as faults are instead persistent noise artefacts, which remain following data processing

These structural interpretations must be considered in light of site-specific lithologic petrophysical, hydrogeochemical, isotopic and physical hydrogeologic data gathered during DGR site investigations. Further consideration and integration of these data into an internally consistent Descriptive Site Geosphere Model coupled with the results of an inclined coring program at deep bores DGR-5 and DGR-6 will provide a basis to verify geologic structure and demonstrate far-field site suitability.

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1 Introduction

Intera Engineering Ltd. (Intera) has been contracted by Ontario Power Generation (OPG) to implement the Geoscientific Site Characterization Plan (GSCP) for the Bruce site located near Tiverton, Ontario. The purpose of this site characterization work is to assess the suitability of the Bruce site to construct a Deep Geologic Repository (DGR) for the long-term management of low and intermediate level radioactive waste. The GSCP is described by Intera Engineering Ltd.(2006a).

This report summarizes the results of the 2D seismic survey activities completed at the Bruce site as part of Phase I of the GSCP. Work described in this Technical Report was completed in accordance with Test Plan TP-06-05 – 2D Seismic Surveys (Intera Engineering Ltd., 2006b). Work described in this Technical Report was completed following the general requirements of the DGR Project Quality Plan (Intera Engineering Ltd., 2007).

2 Background

Intera Engineering Ltd. issued a Request for Proposal for a 2D seismic survey on the Bruce site in May 2006. Conquest Seismic Services Inc. (formerly Geophysical Applications Inc. or GAPS, based in Guelph, Ontario), in partnership with Aguila Exploration Consultants Ltd. (based in Calgary, Alberta), were retained as Intera Engineering Ltd. subcontractors to provide the data acquisition, geophysical technical input and interpretation for the project.

The final 2D seismic survey included a total of 19.7 km of data collection, spaced over nine lines, on and around the Bruce site. Figure 1 (Appendix A), shows the relative location of each seismic line with respect to on-site infrastructure and location of the proposed DGR. Each seismic line is represented by several datasets, including [1] a smoothed red line (common depth point line created during processing), [2] a complete series of green dots (every tenth receiver station) showing the actual path of seismic sources and receivers, and [3] a segmented partial-series of blue dots (every source point where vibroseis units were not able to access the area by receiver points). Source points (vibroseis points) are generally every third receiver point. The on-site parameter testing and 2D seismic data collection field activities were completed at the location indicated of Figure 1, between October 10 and 22, 2006.

The collected data were processed in Calgary by Key Seismic Solutions using seismic processing algorithms and methodology routinely employed in oil and gas exploration. To allow improved interpretation, the survey data were re-processed by Seiscraft in Calgary to include overburden thickness information and a revised processing run-stream. Interpretation of the 9 lines was completed and integrated with regional geological information and detailed geology from 4 stratigraphic test holes drilled at the Bruce site (DGR-1, DGR-2 and preliminary data from DGR-3 and DGR-4), the locations of which are shown in Figure 1.

Figure 2 shows the interpreted bedrock formation contact depths/elevations and subsurface nomenclature for the Bruce site based on the drilling and core logging activities completed at DGR-1 and DGR-2. The rationale for these formation picks are described in TR-07-05 (Intera Engineering Ltd., 2009). Figure 3 shows a schematic cross section drawn through an historical off-site oil and gas well (Texaco Well #6) and the recently drilled DGR wells (DGR-1, DGR-2 and DGR-3). Figure 4 shows the location of oil and gas exploration wells registered with the MNR that are referenced in this report. Also included on this figure is the distance in km away from DGR-1/2, as shown in brackets beside each well name.

3 2D Seismic Project Objectives

The purpose of this 2D seismic survey was to obtain preliminary deep bedrock geological, stratigraphic and structural information for the Bruce site. The bedrock units of primary interest include the shales and argillaceous limestones at depths of about 400 to 800 m. These strata include the Middle Ordovician limestones

(Cobourg, Sherman Fall, Kirkfield, Coboconk, and Gull River Formations) and overlying Ordovician shales (Queenston, Georgian Bay and Blue Mountain Formations). Ideally, the seismic survey would allow for assessment of the predictability and continuity of the host rock for the DGR (Cobourg Formation) and the mapping of possible faults and other geologic structures within the bedrock units of primary interest.

This 2D seismic survey is part of a broader Geoscientific Site Characterization Plan (Intera Engineering Ltd., 2006a) that includes deep bedrock drilling/coring, borehole geophysical logging, and geological, hydrogeochemical, hydrogeological and geomechanical testing.

4 Data Acquisition

The project involved testing and production recording of nine 2D seismic lines, totalling approximately 19.7 km. The design, methodology and parameter selection for data acquisition were carried out to maximize vertical and lateral resolution in the host rock unit for the DGR. Technical geophysical and operational objectives were adjusted to meet OPG, Bruce Power, and Hydro One requirements as discussed in Section 7.2.

A vibroseis energy source provided high frequency signal generation for the survey and conformed to site requirements. A high frequency sweep was selected to enhance vertical resolution and a small subsurface sampling interval (3 m) was chosen to provide fine detail for structural and stratigraphic interpretation. High-level electrical and cultural noise was expected in this field setting and the choice of high fold vibroseis and a high capacity distributed seismic recording system was made to best mitigate these detrimental effects. The seismic wave field was recorded using a multichannel distributed recording system to best mitigate the electrical noise expected. Comprehensive testing was completed to optimize the source and recording parameters. Production recording commenced the morning following completion of field tests and proceeded without significant delay until completion.

4.1 Seismic Source

Vibroseis was selected as the source of elastic waves due to operational restrictions on drilling holes on site and the ability to collect data in noisy environments. Three small buggy-mounted vibroseis units were selected to allow access to areas where the terrain would have precluded use of larger truck-mounted equipment and a fourth buggy was available as a spare.

Vibroseis source enables highly repeatable, data specific focusing of frequency and energy. It is less intrusive than dynamite as it is a surface source that does not require drilling holes. Multiple sweeps for multiple seconds are collected, correlated with the input signal and stacked together. Within this process there are multiple filtering options. The observer can choose to include or exclude particular sweeps in the composite record should electronic errors or noise bursts become an issue. As well there are noise blast editing features that can be turned on to effectively edit out traffic or burst type noise prior to correlation and stacking of the individual source points. Within the type of data collection environment experienced at the Bruce site, the vibratory source was the optimum source energy choice for this study.

4.2 Parameter Selection and Testing

A 2.4km long 2D line recorded by Shell Canada in 1978 was purchased and re-processed as a guide to the selection of the field acquisition and processing parameters for this survey. These historical 2D seismic data were the closest seismic data previously collected to the proposed DGR location and are located approximately 8.5 km southeast of the Bruce site. The reprocessed, interpreted line A00300540 is shown in Figure 5. This line was acquired using single 350 gm dynamite charges in 2m shot holes 40 m apart and 96 channels with a 10 m receiver interval. These historical data provided a preliminary look at the quality of 2D seismic data to be expected near the Bruce site and enabled a preliminary range of parameters to be selected. These historical

data were collected with a much older and a less capable generation of technological equipment with a more limited dynamic range, lower number of receiving channels, using a cable system which is much more receptive to inductive electromagnetic (EM) noise as analogue to digital conversion was done in the recorder versus modern equipment that converts at the receiver.

Figure 5 shows interpreted tops of several horizons that are strong seismic reflectors and are indicative of bedrock formations (e.g., Salina A2 Unit evaporite, Manitoulin, Queenston, Cobourg and Precambrian). Horizon 1 shown in Figure 5 does not coincide with the top contact of any formation however it exhibits a significant change in seismic signal and is therefore worthy of noting on the seismic section. Horizon 1 which appears as a trough between two reflectors may represent intervening shale sandwiched between two carbonate hard beds in the Queenston Formation.

In an effort to better select optimal acquisition parameters for the production recording of 2D data a test program was designed using the preliminary information gained from the Shell Canada 2D seismic data prior to the commencement of data acquisition. The testing utilized the production equipment on one of the proposed survey lines so results were relevant to the final acquired data. The test location was chosen on Line 2 near the intersection with Line 5 (Figure 1). This location was deemed to be representative of the program area but safely removed from traffic. The objective was to obtain the highest bandwidth and highest signal to noise ratio possible. Appendix B provides a description of the 2D Seismic Field Testing program completed prior to data collection.

Due to the high noise level on site the determination of optimal acquisition parameters was difficult given the limited display and signal processing capability available in the field equipment. To improve confidence in the decisions a test recording of Bruce data was electronically transmitted to a seismic data centre in Calgary where deconvolution and filter tests were run overnight. The results were critical in final parameter selection and were available the next morning in time for production work to begin.

Appendix C provides a summary of the final data acquisition parameters used for this study.

4.3 Survey Positioning

Closely spaced subsurface sampling requires accurate survey to correctly position the midpoint reflection data, referred to as the Common Depth Point (CDP). Figure 6 shows a detailed layout of each seismic line with an indication of every tenth receiver point. Figure 6 also contains ground surface elevation data that shows the relatively flat nature of the ground surface at the Bruce site, with minor topographic relief near landfills and the shore of Lake Huron. As indicated in Appendix C, receiver points (group of 6 evenly spaced geophones near the surveyed receiver point) were spaced every 6 m along the survey line and vibroseis source points were positioned every 18 m (i.e. every third receiver point). With three vibroseis buggies being used for each source point (SP), this layout positioned a vibroseis buggy close to each receiver point, and the source point being measured to the middle vibroseis unit. All source and receiver points, as well as skids and offsets were marked in the field and the position of every third receiver point (i.e. each source point) was recorded with GPS equipment to within decimetre accuracy both horizontally and vertically. Skids and offsets were generally within 2 m of the original targeted location. Offsets of source (vibroseis points) are shown as blue dots on Figure 1. Survey data are projected in Transverse Mercator using UTM Zone 17N and NAD 1983 for a datum.

For the purpose of this report, as is standard practice in 2D seismic studies, and to assist in pinpointing a precise location along a seismic survey line, the numbering of surveyed receiver/source points will be referred to as "Source Point (SP) number". Using this terminology it is understood that every SP number (i.e. 101, 102, 103, etc) represents an evenly spaced cluster of 6 geophones (receiver point) and every third receiver point (i.e. 101, 104, 107, etc.) represents a source (vibroseis) point.

4.4 Ground Motion Monitoring

Geophysics GPR International Inc., of Longueuil, Quebec was retained by Conquest to independently record and assess the ground motion caused by the seismic sources. This assessment was a requirement of the 2D seismic survey to determine the safe setback distance from existing infrastructure and to demonstrate to OPG, Hydro One and Bruce Power that the vibroseis machines would not adversely affect these structures.

Appendix D contains the report produced by Geophysics GPR that summarizes the ground motion monitoring assessment. Prior to data collection and during vibroseis testing described in Section 4.2, the largest vibration reading recorded 1 m from the vibroseis source was 11.6 mm/s (parallel) and 15.1 mm/s (perpendicular). Similarly, at a distance of 4 m, the largest vibration recorded was 6.9 mm/s (parallel) and 7.6 mm/s (perpendicular) and at a distance of 10 m, only parallel recordings were noted and the maximum reading was 1.9 mm/s. Compared to other site conditions, the vibroseis units did not dominate the ground vibrations as was noted during windy conditions at a distance of approximately 89 m from the vibroseis units when vibration measurements of up to 13.7 mm/s were recorded. Similarly, on-site vibrating paving equipment caused ground motion vibrations of up to 33.6 mm/s at a distance of 3 m from equipment and 14.6 mm/s at a distance of 10 m from equipment. For comparison, non-vibrating Bruce site maintenance vehicles caused ground motion readings of up to 0.9 mm/s at a distance of approximately 20 m.

5 Data Processing

Based on experience with seismic data collection, processing and interpretation within Bruce County and in particular observation of the raw field dataset collected at the Bruce site, data quality would be considered poor gauged against typical oil and gas exploration data collected elsewhere, outside of southwestern Ontario, due to the sharp contrast of seismic velocity between the overburden and bedrock. Based on this fact, in combination with the heterogeneity of the glacial overburden, difficult data processing was anticipated. The previous re-processing of the nearby purchased Shell line confirmed these difficulties. Therefore, the objective for data processing was to incorporate as much resolution as possible into data and improve on the low signal to noise characteristics. Raw field records have no identifiable coherent reflections, which is common for most Bruce and Huron County field data. Often reflection data can only be seen once high multiplicity common depth point stacks have been completed. Additional refraction analysis and many other processing techniques can be used to improve these stacks.

5.1 Initial Processing (Key Seismic Solutions)

Key Seismic Solutions, based in Calgary, using commercial seismic processing techniques for noise reduction to improve the seismic image, initially processed all field data. Line 3 was selected as a research line and it was tested and processed to its best image. The remaining 8 lines were then processed with this flow. Enhancements and tuning made to the remaining lines were then applied back to Line 3.

Noise was addressed pre-stack with tau-p and post-stack with F/X deconvolution. CDP stack was found to be a valuable tool in reducing noise and in the end, adjacent CDP's (also known as subsurface reflection points) were summed to double fold from the natural number 40 to 80. The sacrifice in lateral spatial resolution from 3 m to 6 m subsurface (summing two receivers together), and minor vertical "smearing" of resolution was a necessary trade off.

Appendix E contains a report prepared by Key Seismic Solutions titled, "Bruce Ontario 2D Processing Summary", which provides a detailed description of the techniques used during processing.

5.2 Re-Processing (Seiscraft)

In February 2008, upon review of the initial seismic processing, it was decided to complete a second processing of the data. Multiple processing of seismic data is typical with oil and gas exploration seismic data. The data were forwarded to Seiscraft of Calgary, a firm with substantial experience processing seismic data from southern Ontario. The re-processing differences can be summarized as follows:

- 1) Incorporating known overburden thickness in the refraction analysis with a view to accurately calculating static corrections so that these data tie and do not have residual static affects that could be confused with structure;
- 2) 3 m subsurface (40 fold) versus Key Seismic Solutions' processing with 6 m binning (80 fold), thus providing twice the lateral resolution while possibly trading off signal/noise;
- 3) Trace-by-trace deconvolution versus surface-consistent deconvolution, which is slightly more aggressive in terms of increasing the higher frequencies;
- 4) Pre-stack time migration versus post-stack fx migration, to better focus on faults and dipping structure.

The comparison of the original processed results by Key Seismic Solutions to the re-processed data by Seiscraft proved to be a valuable and worthwhile exercise. Areas where characteristics and potential fault zones occur in both data sets increase the confidence in the data at these locations. Alternatively, lower confidence in the data was assigned to areas where the appearance of reflectors is different between the two data sets. Both scenarios help to determine which seismic features are more likely to exist.

When a line bends along a curve in the road or around a building reflection points in the subsurface become scattered. The error distance in Bruce data was up to 50 m for some points and this contributed to some of the data quality problems. The mapped locations of the CDP's represent the best estimate of where these data lie in the sub-surface and locations do not correspond with the surface locations of shots and receivers as these lines were recorded.

Figure 7 shows the centre portion of Line 5 after original processing (Key Seismic) and new re-processing (Seiscraft), respectively. These figures depict the centre portion of Line 5 within which the Silurian section (shallowest picks shown as blue) exhibits different structure and reflection continuity on the two data sets. These differences indicate decreased confidence within this portion of the line.

6 Data Quality

6.1 Data Quality for Interpretation

Figure 6 depicts the final trend interpretation overlying a representation of the three levels of data quality referred to as "Good", "Fair" or "Poor" based on the following criteria:

Good quality: Data is interpretable on its own with high confidence. Queenston and Cobourg horizons are relatively consistent and interpretable; both sets of processing are similar in structure and consistency;

Fair quality: Data is interpretable on its own with medium confidence. Scenario # 1 - Queenston horizon is irregular but Cobourg horizon is still interpretable; scenario # 2 - each set of processing gives a different image;

Poor quality: Data is either not interpretable on its own, or is only interpretable with low confidence.

By interpretable we mean that the seismic section structure represents true geologic structure and that the amplitude represents the geology or specifically the acoustic impedance (reflection coefficient) at the lithologic boundaries.

6.2 Limitations / Constraints with 2D Seismic Data Collection

The 2D geophysical survey was planned and carried out under very strict plant regulations so as to not affect plant operations. Many unavoidable constraints were imposed on the design of the 2D seismic survey that influenced the quality of the data collection, however many efforts were made to minimize this negative influence by altering the design of the survey. As such, although the overall 2D seismic data quality collected as part of this study is considered to be adequate as an interpretable dataset on its own, it is considered to be the best possible under the given circumstances. A brief description of each limitation or constraint and the mitigating measures taken are provided below, in order of influence (most influential listed first).

1) Regional Geology - contrast between seismic signals in overburden vs. bedrock - By far, the most influential of these data quality limitations was the regional geology. The high contrast of seismic velocity at the sharp bedrock contact reflector made the interpretation difficult. Although this was a major problem contributing to a lower data quality, this condition is common to seismic surveys in southwestern Ontario and was expected. Due to the sensitive nature of site operations and site security, dynamite sources were not acceptable for use, however, as discussed in Section 8, it is not apparent that dynamite would have provided better data. Therefore, buggy-style vibroseis units were used, which allowed for easier access to off-road conditions. Although there was virtually no control over these conditions, data acquisition parameters were optimized to minimize the effects during data recording.

2) Line Layout and Orientation - The final line orientation included relatively short, non-orthogonal, curvilinear lines that were not ideal for interpretation. Also, short line overlaps resulted in sub-optimal ties between intersecting lines, which lowered the confidence in data interpretation at those locations. Shallow targets with high spatial resolution requirements need straight survey lines and therefore the bends in the survey lines reduced the data quality collected and made interpretations of structural features and formation contacts more difficult. In addition, several unavoidable site conditions resulted in poor data or a data gap, such as: Line 1, that traversed an environmentally sensitive wetland where data collection was not possible, and Line 2, that traversed a closed landfill.

The initial line layout was thoroughly reviewed on-site with representatives of OPG, Intera, Conquest and Aguila and all possible amendments were made prior to finalizing the program. Figure 1 shows the layout of all nine seismic lines relative to the Bruce site boundaries and on-site infrastructure.

3) Background noise due to electrical power lines - 60 Hertz EM interference in the seismic data is an expected consequence of working near power lines and therefore working in a power station environment would be considered to be an extreme example. Although seismic equipment has been designed to partially filter this EM interference, recording instruments can also include 60 cycle notch filters to mitigate this effect. As these filters can cause phase difficulties in the recorded data they should only be used in extreme circumstances. Although the interference from surrounding power plant operations variably lowered the quality of the data collected along the seismic lines, it was concluded through testing that the added benefit of using a notch filter did not overcome the difficulties in data recording, and therefore a notch filter was not used. In addition, data acquisition parameters were tested prior to data collection and the parameters were optimized to reduce the EM interference as much as technically possible.

4) Background noise due to weather - Although EM interference was less of an issue than anticipated, background noise from windy weather conditions was stronger than expected. Although there was virtually no control over these conditions, data acquisition parameters were optimized to minimize the interference effects of

the wind during data recording.

5) Background noise due to traffic - Bruce plant operations required minimal interruption to on-site traffic and therefore unavoidable background noise due to passing vehicles existed. A benefit of vibroseis is that it is a process that correlates the received acoustical signal with a copy of the input signal, which helps to filter out unwanted noise. Efforts to minimize the background noise due to traffic driving by the seismic data acquisition equipment included scheduling data collection along roadways during non-peak traffic hours (i.e. busy roads and intersections were scheduled on weekends or opposite shift changes). In addition, the duration of the sweep, sweep sums, and the vibrator force were selected to maximize the signal-to-noise ratio and minimize the interference from nearby traffic.

6) Background noise due to nearby construction - Another unanticipated source of background noise was a paving crew constructing a new road at the main entrance gate. Specifically the road compaction equipment was generating noise several times the signal levels of the vibroseis units and led to deterioration in data quality in that area. As the contractor for the construction work was held to their own contract schedule and also worked throughout the daylight hours, it was not possible to stop the construction operations while the 2D seismic data was being collected. Therefore, the only method to minimize interference with seismic data collection was to attempt scheduling seismic data acquisition immediately adjacent to the construction during a time when the compaction equipment was not being used as frequently.

7 Geological Understanding

The geologic control for interpretation of the seismic data was primarily derived from detailed on-site logging of two boreholes (DGR-1 and DGR-2) where continuous core with a diameter of 3-inches (76 mm) was produced (Intera Engineering Ltd., 2008). Geologic unit contacts were based on core observations combined with borehole geophysical logs (spectral gamma, compensated density and dual neutron). Interpreted bedrock formation contact depths/elevations and subsurface nomenclature for the Bruce site is shown in Figure 2 and is described in greater detail by Intera Engineering Ltd. (2009).

7.1 Stratigraphy

The stratigraphy in southern Ontario is well understood (e.g., Johnson et al., 1992, Armstrong and Carter 2006), and the stratigraphic units recognized in the DGR cores fit well into the regional stratigraphic framework. The Paleozoic section penetrated at the DGR site includes the Middle Devonian Lucas Formation dolostones down to Cambrian Formation sandstones at 843.8 m below ground surface (mBGS) (823.8 m below top of bedrock) in DGR-2; the Paleozoic section is overlain by 0 to 20 m of unconsolidated Pleistocene drift.

In general, the Ordovician formations (Queenston Fm through Shadow Lake Fm) exhibit a very consistent thickness varying by less than about 2 metres across the Bruce site; the exception being formations that are defined by more gradational contacts such as the Queenston Formation and the Blue Mountain Formation, which vary by approximately 4 m and 3 m in thickness, respectively, between DGR-1/2, DGR-3 and DGR-4. The total thickness of the Ordovician formations in DGR holes ranges from 396.1 to 398.5 m. The Middle Ordovician Trenton Group (comprising in ascending order, the Kirkfield, Sherman Fall and Cobourg Formations) is also remarkably uniform in thickness at the DGR site, ranging from 109.9 m to 111.4 m thickness in DGR holes. This thickness is comparable to those reported in Armstrong and Carter (2006) for the three nearest reference wells T004854, T006056 and T007544, where Trenton thickness are 128 m, 102 m and 118 m, respectively. Other nearby wells show Trenton Group thicknesses of 146 m, 142 m and 142 m (T002636, T001942, T002238, respectively). Within the Trenton Group, limestones of the Cobourg Formation (including repository strata) at the DGR site are 35.9 to 36.5 m thick – this is also within the range of 22 to 51 m for these strata as recorded in the above six reference wells.

Even though they occur above the repository strata of the Cobourg Formation, dolostones of the Guelph Formation at the DGR site are of particular interest. In southwestern Ontario, the Guelph Formation is well known for its pinnacle reefs, which act as important oil and gas reservoirs, as well as subsurface storage for natural gas. Their hypothesized preferential development and thickening at the upturned edges of Sanford et al.'s (1985) rotated fault blocks implies nearby faults. In addition, they are also thought to act as preferential pathways for cross-formational fluid flow (e.g., Coniglio et al., 2003). The hypothesized faults in southwestern Ontario are also implicated in the dissolution and collapse of overlying Salina and Devonian units due to Salina evaporite dissolution (Sanford et al., 1985).

Based on regional trends, Guelph facies at the DGR site are located paleogeographically on the middle Silurian basin slope, and in the pinnacle reef belt. It remains unclear, however, as to whether pinnacle reefs in this part of the basin are as abundant or as large as they are in southwestern Ontario and Michigan. Subsurface control is comparatively sparse. The DGR site is proximal to a probable pinnacle reef encountered in the nearby Union Gas Co. Kincardine #1 well located approximately 6.2 km southwest of the DGR-2 on the Bruce site. In this borehole, the Guelph Formation is 128m thick, a thickness comparable to what is commonly encountered in southwestern Ontario (e.g., Coniglio et al., 2003), and did not encounter any appreciable quantities of natural gas.

Guelph strata at the DGR site are only 4.1 to 5.4 m thick, which is consistent with the small thickness of Guelph Formation interpreted as non-reefal, inter-pinnacle facies on the basin slope (Carter et al., 1994; Armstrong and Carter, 2006). There is no compelling evidence of proximity of Guelph pinnacle reefs in the DGR boreholes. However, laminates dipping at up to $\sim 30^\circ$, in the overlying Salina A0 Unit versus 0.6° in underlying strata from DGR-1 and DGR-2 core may reflect drape on the flank of a Guelph reef or possibly an underlying small reefal accumulation. If these dipping strata reflect drape on the flank of a reef, it remains unclear as to why the Guelph Formation immediately below is so thin.

Borehole DGR-2 includes 17 m of Cambrian sandstones and sandy dolostones immediately overlying the Precambrian basement. Cambrian strata are not recognized in two out of the three reference wells (T004851 and T006056) used by Armstrong and Carter (2006) near the study area, but a third well used in their study (T007544) indicates a Cambrian thickness of 25.8 m. Another nearby well (T001942) has 10 m of Cambrian strata. In southwestern Ontario, stratigraphic hydrocarbon traps are generated where the Cambrian sandstones pinch out against the Precambrian rocks of the Algonquin Arch, the top seal being the lowermost Middle Ordovician strata of the Shadow Lake Formation. Elsewhere along the Arch, structural traps in the Cambrian are associated with faulting. Cambrian strata are generally thin and vary considerably in thickness, as a result of erosion associated with the development of the Middle Ordovician Knox unconformity, which also explains the lack of Lower Ordovician strata from southwestern Ontario (Dorland, 2004).

7.2 Structural Geology

Paleozoic strata at the Bruce site are located on the eastern margin of an intracratonic crustal depression known as the Michigan Basin. These strata are structurally undeformed, but they do dip gently south-westward toward the depositional centre of the Michigan Basin at 4.8 to 7.6 m/km (Liberty and Bolton, 1971). Armstrong (1993a) reported similar dips of 6.64 m/km from the southern Bruce Peninsula. Recent drilling of DGR boreholes also reports similar apparent dips in the range of 5 to 11 m/km (0.3 to 0.6 degrees) between Texaco Well #6 and DGR-1/2 (~ 5.4 m/km for Shadow Lake Formation and ~ 10.6 m/km for Salina E Unit) and 7 to 15 m/km (0.4 to 0.9 degrees) between DGR-1/2 and DGR-3 (~ 6.8 m/km for Queenston Formation and ~ 15.4 m/km for Bass Islands Formation), as shown in Figure 3. Triangulation of key marker beds between DGR-1/2, DGR-3 and DGR-4 indicate that true dips within the Upper Silurian (formations that overlie the Salina B-Unit salt) are approximately 17.5 m/km (1.0 degree) and true dips for the formations situated below the Salina B-Unit salt are approximately 10.5 m/km (0.6 degree). The difference in dips may be attributed to the collapse of the Salina B-Unit salt beds due to dissolution.

Knowledge of the local structural geology of the Paleozoic section in this part of the Michigan Basin is minimal. Extensive outcrop studies, both historically and more recently in the various publications by Armstrong and co-authors (e.g., Armstrong, 1993a; 1993b; Armstrong and Carter, 2006; Armstrong et al., 2002), focus on stratigraphic characteristics and correlations, and shed little light on the structural characteristics of the rocks in this area. These various sources describe the regional jointing patterns from outcrops on the Bruce Peninsula, as well as a small number of bedrock release fractures referred to as “pop-ups”, which likely have a neotectonic origin (e.g., Karrow and White, 2002). Liberty and Bolton’s (1971) field study of the Bruce Peninsula led them to conclude that “no faults are known within the map area.” Elsewhere in Ontario, outcrops studies have identified or inferred faulting. For example, in the Lake Simcoe region, small-scale normal faults as well as mineralized (e.g., calcite, pyrite, barite) fractures and faults occur (Melchin et al., 1994). Some of the mapped faults were inferred based on cuesta displacements, not direct observation.

Importantly, the validity of extrapolating the overarching, conceptual, fault-bounded megablock model of Sanford et al. (1985) into the study area remains thoroughly untested and is speculative at best, and this is largely the result of the sparse subsurface control proceeding northward from southwestern Ontario.

8 Data Interpretation

The expected outcome of the 2D seismic program was a structural and stratigraphic understanding of the DGR site. Time structure ribbon plots for the Queenston, Cobourg and Precambrian were prepared and an attempt was made to map fault trends. There is not sufficient spatial sampling to resolve small features and definitively predict fault trends within these data. Small features are defined for the purpose of this report to be less than 10 m vertically or less than 3 seismic traces horizontally. Due to the different bin sizes between the Key Seismic original processing (6 m) and the Seiscraft re-processing (3 m), this translates to small features being defined as less than 18 or 9 m, respectively. It is possible, however, to interpret “potential” fault zones, and where applicable some trends have been identified and confidence levels assigned.

8.1 Interpretation Methodology

Interpretation of the seismic reflection sections involves identifying major acoustical boundaries between formations that exhibit different seismic acoustic impedance; for example, a carbonate/shale interface. Within a seismic time section, lithologic boundaries are interpreted to exist where there is lateral continuity of reflectors or “markers”. This acoustic boundary represents a change in acoustic impedance usually corresponding to a rock type boundary. It is important to note that these layers between boundaries must be thick enough relative to the wavelength of the seismic signal at the reflection marker. A typical minimum thickness in seismic interpretation of “high quality” data is estimated as $\frac{1}{4}$ of the seismic wavelength or a minimum thickness of 14 m for the Bruce site data to be “seen” with the seismic wavelet.

For portions of the Bruce site seismic dataset that have a lower interpretable quality, the minimum thickness for interpretation is larger than $\frac{1}{4}$ of the seismic wavelength, and remains up to the individual(s) completing the seismic interpretation. Therefore, data quality is a key element to successful interpretation. Some uncertainty in depth and continuity will arise if data are noisy or reflectors are weak. This will cause inaccuracies in determining times, velocities and, ultimately, depths. As well, if the target boundary or feature is similar in acoustical properties to the surrounding host material, or the contact is gradational, or is simply not thick enough, it will not be resolved by the frequency content of the seismic data. When this happens, the feature in question will be more difficult to identify on the seismic sections. As well, significant lithologic changes may occur that result in only weak acoustical contrast and therefore poor reflectivity on the seismic section. Such lithological changes may be un-interpretable or invisible on seismic sections.

Faults are interpreted when these continuous boundaries are broken or when there are offsets of time laterally along these boundaries. The decision of whether a particular seismic break or offset is “real” (i.e. fault), or alternatively a result of poor quality seismic data, starts with an understanding of what might be geologically plausible. Next, the orientation, length and dip of this fault needs to be assessed, and if these parameters are deemed to be geologically plausible, a determination of how far up into the section it extends and if it has origins within the Precambrian basement is made. Sometimes faults can be explained away with re-processed sections (i.e. interpreted faults were a manifestation of problems in the static resolution), hence the need for re-processing these sections.

Faults noted in the various seismic profiles are meant to illustrate the potential style of structure rather than a definite feature at an exact location, orientation or other structural characteristics, with absolute certainty.

8.2 Correlation with Synthetic Seismogram from DGR-1 & DGR-2 Data

A comprehensive suite of borehole geophysical logs (including sonic, natural gamma, and compensated density logging) were completed in DGR-1 and DGR-2, which are located at the approximate intersection of seismic Line 1 and Line 2. Technical Report TR-07-08 - Borehole Geophysical Logging in DGR-1 and DGR-2 (Intera Engineering Ltd., 2008) describes the borehole geophysical testing program in detail. Seismic event correlation is good based on the sonic data.

Correlation of geologic formation contacts (horizon correlation) is based on a synthetic seismogram prepared from sonic and density logs from DGR-1 and DGR-2. Figures 8 and 9 show the synthetic seismogram based on DGR-1 (0 to 460 mBGS) and DGR-2 (450 to 860 mBGS) borehole geophysical data, respectively, while Figure 10 shows the combined profiles from DGR-1 and DGR-2 (0 to 860 mBGS). This combined synthetic seismogram correlates quite well with the known geology in DGR-1 and DGR-2 as depicted in Figures 11 and 12, which show the synthetic seismogram inserted into Line 2 at the correct relative surface location.

The Salina A2 Unit evaporite, Queenston, and Cobourg horizons tie quite well. These new wells refine the preliminary correlations brought in from the abandoned oil and gas wells Texaco #4 and Texaco #6. The abandoned wells are approximately 5.7 km to the northeast, and 2.9 km to the southeast, respectively, of DGR-2 and no sonic logs were available for them.

8.3 Correlation with Stratigraphic Core Logs from DGR-1 & DGR-2

The P-wave sonic log obtained from DGR-1 and DGR-2 was used to correlate reflection events with known geology. Comparing the P-wave sonic log results to the 2D seismic data at this location provides a transit time for incremental depth intervals that can be associated with particular rock boundaries observed at the borehole locations. Examples of this are the sharp velocity contrasts between a shale and a limestone such as the Cabot Head Formation shale and the underlying Manitoulin Formation dolostone or the shales of the Blue Mountain Formation and Upper Cobourg Formation (Collingwood Member) overlying limestones of the Lower Cobourg Formation.

Using the transit times, effectively translated as interval velocities in depth, the geophysical markers corresponding to geologic horizon tops are converted to an acoustical reflection sequence in time. This reflectivity sequence is a time sequence with amplitude +/- spikes representative of the velocity/density contrasts. This sequence is then mathematically convolved with a representative wavelet (what the “earth” filter does to a spike function) to generate a synthetic seismogram with known geologic picks. This combined synthetic seismogram can be inserted into the reflection section and used to identify the reflection horizons seen on the seismic section depicted in time as corresponding to particular geologic formations as seen in Figures 11 and 12. Horizon 1 shown in Figures 11 and 12, as well as subsequent seismic section figures is not associated with the top contact of any formation, however due to the significant change in seismic signal it is included in the

figures.

Note the markers identified on the synthetic (in-time) seismogram correlated to the sonic, density and times within the wells. Similarly, the sonic velocity has been overlain on the seismic section in Figure 16a to depict the idea that large increases/decreases in velocity result in large amplitude reflections on the seismic trace. Increases in velocity are represented as a peak whereas negative acoustic impedances or decreases in velocity are troughs on the seismic trace.

Figures 11 and 12 also show an approximate non-linear depth scale along the right hand side Y-axis. The approximate non-linear seismic depth scale was based on best fitting a curve to seismic time/horizon depth pairs taken from DGR-1 and DGR-2. The correlation of two-way travel time to a geologic horizon was made using the synthetic seismogram constructed from the merged sonic and density logs from the two wells, as discussed above.

The shallowest marker visible on the seismic reflection sections corresponds to the top of the bedrock unit just under the weathered layer and is the Lucas Formation. Due to its shallow depth and high velocity, this reflection event is contaminated with the incorrect stacking of the refraction event. It is simply too shallow to reliably map on the seismic reflection sections.

A reflector near the Guelph Formation was picked in the attempt to identify potential reefs. Although there may be character change at this depth on the seismic sections, the change is attributed to either data processing artefacts, or possibly, but less likely, structure and faulting rather than presence of reefs. Inherent within data processing, shallower events have less fold multiplicity, hence less reliability in terms of observing true structure. Noise within the data tends to affect the shallower data more than the deeper higher fold data.

The top of the Queenston was picked as a strong trough corresponding to the carbonate to shale transition in velocity and density. The Cobourg reflector appears as a distinct seismic event (positive reflection coefficient) in most of the area. At this depth the fold multiplicity hence data reliability is highest, providing more confidence in the observations of faults depicted at this deeper event.

Within the deeper borehole DGR-2, 17 m of Cambrian sandstone were encountered above the Precambrian basement. Due to the lower quality of seismic data in this area, and based on the idea that layers thinner than $\frac{1}{4}$ wavelength are not even "seen" on a "high quality" time section, the minimum interpretable thickness is considered to be greater than 17 m under these conditions at this location. The presence of Cambrian sandstone and determination of its thickness are therefore very difficult to discern in this 2D seismic survey.

The Precambrian seismic character suggests some faulting and the reflectivity at the Precambrian pick changes along the seismic lines indicating different rock properties at, or just above, that surface.

8.4 Planar Ribbon Time Displays – Time Structure

Figures 13, 14 and 15 show time structure maps for the Queenston, Cobourg and Precambrian horizons, respectively. These figures show the interpreted two-way vertical seismic signal travel time from ground surface to the geologic formation in question at each source point. Horizon ties at line intersections are not perfect due to end-of-line effects and near surface problems noted on several lines. These figures can be used to interpret structural highs or lows relative to surrounding source points (i.e. other lines).

8.5 Seismic Line Interpretation

Interpretation of these data has focused on features that would be critical to the project objectives, namely identifying potential faults as they may affect the continuity and integrity of the host strata for the DGR, the Cobourg Formation, and gas drilling hazards associated with reef build-ups in the Guelph Formation. Although some seismic features may be explained by noise and problems in resolving statics, the seismic data quality is not good enough to say with certainty how faults are oriented or whether some features tentatively identified as faults are instead persistent noise artefacts, which remain following data processing. However, some conditions provide higher confidence with interpretation of seismic anomalies, for example, where shallow seismic reflection events appear to be continuous and flat, confidence is gained in the quality of the data at such locations. If deeper seismic data directly below a high confidence dataset show non-continuous reflection events, these non-continuous events are interpreted as a fault zone. Surface conditions, data processing limits, noise or static resolution issues have been taken into account during the interpretation of potential fault zones.

A fault zone is defined for this report as a zone on the seismic section within which there is likely a fault or series of faults. Although the exact location (i.e. a particular SP) is not clearly visible on the seismic section due to data quality there is sufficiently high confidence that a fault exists. These interpreted zones have been correlated between seismic data collection lines, thus improving confidence that they do exist.

Figures 16 through 24 show the original and re-processed seismic data, for each of the nine seismic lines collected, including annotated interpreted fault zones. These figures also show an approximate non-linear depth scale (right hand y-axis) relative to the 2-way seismic travel time (left hand y-axis), as discussed in Section 9.4. Figure 1 shows the relative position of each 2D seismic line to existing infrastructure (roads, buildings, wetlands, landfills, etc.) at the Bruce site. It is important to note that there is a large area in the middle of the project, almost 2 square km in size within which there is no data, making correlation between lines difficult. The characteristics identified on one side of the project site have been compared to those on the other, including amplitude, phase and frequency characteristics of the wavelets which indicate lithological similarities.

A brief overview of the interpretation of each seismic line is discussed in the following sections. Table 1 summarizes the interpretation for each of the nine seismic lines collected, including a brief description of surface/recording environment, quality of seismic data collected, list of interpreted seismic features, and level of confidence of this interpretation with reasoning.

8.5.1 Seismic Line 1

Figure 16a shows the original processed seismic data by Key Seismic Solutions for Line 1 and Figure 16b shows the same seismic data after re-processing by Seiscraft. Comparing the processing results between the two figures indicates that the seismic data collected along Line 1 is of good data quality in the west (SPs 300-568) and is influenced by a large gap under a wetland and wooded area in the east. Shallow horizons are very broken up east of the gap. Data quality on both line ends suffers as the fold tapers off. This line suggests a Trenton low between SPs 332-393 which is not observed on adjacent Line 6 to the north and but can be seen on the tying Line 5 to the south. The interpretation of a graben-type feature within the Trenton low suggests an anomalous area within which there are possible faults with a NNW-SSE trend. The tying Line 5 did suggest a zone of potential faulting at the eastern side of the Line 1 Cobourg Formation low.

This line was not useful for interpreting the geology or faulting within close proximity of DGR-1 and DGR-2 due to the large gap in source points. To the NW of the anomalous area (SP400 – 568) there does not appear to be any substantial geologic features. Between SPs 335 and 185 there is a basement high which includes the location of DGR-1 and DGR-2.

8.5.2 Seismic Line 2

Figures 17a and 17b show the original and re-processed seismic data for Line 2, which demonstrates a data quality change north to south. The southern portion crosses a closed landfill site and a road that contribute to poor data quality and the crooked line east of SP 375 contributes to the poor stack in that area. Data improves toward DGR-1 and DGR-2 and a significant time offset occurs in the Salina A2 Unit evaporite to Queenston Formations at SPs 235-300, possibly a result of poor data quality.

Within 100 m to the southeast of DGR-1 and DGR-2, there is a significant drop in the section from the Queenston down to the Precambrian basement. This seismic anomaly coincides with the location of a wetland area and a closed landfill at surface reducing interpretation confidence

As can be seen on the Cobourg "ribbon" (Figure 14), most if not all of this line is within the basement high which ties into lines 6 and 5 in the north near the wells and Line 9 in the south. The location of the 2D seismic field testing program is indicated near the intersection of Line 2 and Line 5 on Figure 1.

8.5.3 Seismic Line 3

Figures 18a and 18b show the original and re-processed seismic data for Line 3, which indicate good data quality with few structural features. A feature at the south end of this line at about SP 210 (Ordovician) to SP 175 (Precambrian) could be attributed to end-of-line fold taper but a similar feature appears on Line 7 in the same vicinity, strongly suggesting faulting. The shallow angle suggests we are at an oblique angle to this fault.

The seismic section indicates a depression at the Cobourg of 5-6 ms or approximately 10m. Apparent dip (i.e. less than true dip) from a Precambrian high at about SP 246 to the low SP 169 is 32.8m/km over a straight line distance of about 458 m assuming a velocity of 3,800 m/s and a time difference of 7.9 milliseconds. This observed dip is about 3 times greater than the true regional dip for Ordovician Formations (triangulated between key marker beds in DGR-1/2, DGR-3, and DGR-4), which is about 10.5 m/km.

8.5.4 Seismic Line 4

Figures 19a and 19b show the original and re-processed seismic data for Line 4 and indicate a very poor data quality with lots of character changes and apparent structural movement. . Although only low confidence is associated with any interpretation of the data along Seismic Line 4, features at the Queenston level (SPs 225-275 and 370-380) are interpreted as possible pop-up style structures (positive flower structures) common in trans-compressional strike-slip fault environments.

Faults could not be accurately interpreted on the edges of the shallow structural depression in the Lucas Formation. Most of these features have been discounted due to the absence of faults within the shallow section and the very poor quality assigned to this line. It is of particularly poor quality in the north where it follows a bend in the road.

8.5.5 Seismic Line 5

Figures 20a and 20b show the original and re-processed seismic data for Line 5 and indicate fair data quality with the exception of the ends, which are considered poor quality. The fault zone interpreted on Line 6 similarly appears on this line, which is about 250 m to the south. The eastern boundary of this low is not present on Line 5 as it may be situated off the end of the line within the very poor data quality section. The central portion of this line appears to be on a basement high as observed on other lines within this same area.

On the re-processed Seiscraft lines, which have better static control, there is a high between SPs 313-205 from the Silurian down to the Precambrian. This high is consistent across Lines 6, 5, 2 and 1. All lines have different surface conditions, orientation, and overburden thickness suggesting a high probability this is a reasonable interpretation of these 2D seismic data. There is a potential fault zone identified between SPs 315 and 340 very near to a similar feature on Line 1. This zone of potential faulting does not seem to extend north onto Lines 6 and 8 in areas also interpreted as good quality data. There are no lines to confirm this feature to the south until we reach Line 9, which is more than 1.5 km away.

8.5.6 Seismic Line 6

Figures 21a and 21b show the original and re-processed seismic data for Line 6 and indicate good data quality with the exception of the ends, which are considered to have poorer quality. The most convincing evidence of a fault zone is between SPs 235 and 255. This zone may be connected to a basement low that starts at about SP 235 and extends to the east. A character change in the Precambrian going from a single peak to a doublet on the re-processed (Seiscraft) section (Figure 21b), and similarly depicted as a weaker peak on the original processed (Key Seismic) section (Figure 21a), indicates a drop in the basement that corresponds to a drop in the Silurian section. The feature between (SPs 235-255) on Line 6 may extend to the south on Line 5 between SP 190 and 220, however, data quality along this portion of Line 5 is very poor.

At the eastern side of this low or slump, and even though the data quality towards the end of the line is poor, there appears to be another fault zone after which the structure from basement to Silurian appears to be high again. The eastern extent of this low ends at about SP 180 suggesting a possible graben-type feature that is ~300 m wide ending at the eastern edge of the fault zone about SP 235. An alternative interpretation is that there is regional dip to the west into the Michigan Basin and that the area including DGR-1/2 is a faulted block, however, there is not enough data to determine which interpretation is correct.

8.5.7 Seismic Line 7

Figures 22a and 22b show the original and re-processed seismic data for Line 7 and indicate good quality seismic data with reflectors that dip to the west. Near the western end of the line there is a feature that is also seen on Line 3. There is a dipping event in the basement between SPs 240-290 that stops abruptly, suggesting a fault diffraction or side-swipe as shown in greater detail in Figure 25. Likely this line crosses a steeply dipping fault (SP 155) such as a strike-slip type basement fault at a very oblique angle.

As seen on the ribbon plot (Figure 15), there appears to be a basement high across the middle of this line, bounded on the west by the fault. Similar to Line 3, apparent dip (i.e. less than true dip) from the Precambrian high at about SP 326 to the low SP 156 is 35.6m/km over a straight line distance of about 986m assuming a velocity of 3,800 m/s and a time difference of 18.5 milliseconds.

8.5.8 Seismic Line 8

Figures 23a and 23b show the original and re-processed seismic data for Line 8 and indicate good seismic data quality particularly within the Cobourg and Precambrian sections. This line lacks indications of structure except for a shallow feature at SP 160 within the Queenston section that looks different on both versions of the processing, suggesting that this is a statics issue that may not be resolved.

8.5.9 Seismic Line 9

Figures 24a and 24b show the original and re-processed seismic data for Line 9 and indicate quite poor quality that worsens towards either end. There are many changes down the line and it is difficult to differentiate between noise, structural, stratigraphic and static related causes. Reef-like character changes in the Salina

Formation are frequent but not credible, and are more likely the result of low fold and noise on the shot records.

There is a basement high (between SP 230 and SP 400), corresponding to the rest of the lines as shown in the Precambrian ribbon plot (Figure 15). The difference between both versions of the processing makes it difficult to confidently pinpoint any apparent fault zones within this line. There is a basement low centred on SP 185, which is consistent on both processed sections. The northeast extent of the basement high seems to be bounded by a fault at SP 362 (basement level) beyond which both sections dip off to the north.

9 Seismic Interpretation

9.1 Confidence in the Interpretations

A large portion of the 2D seismic data collected as part of this study, interpreted on its own, do not have sufficient resolution and are too ambiguous to determine the existence or locations of structural features with high confidence. Therefore, geological and 2D seismic interpretation experience based on similar types of data, geologic models and interpretations from southwestern Ontario within similar rock and seismic environments strengthens the interpretations of the Bruce site 2D seismic data.

Much of this experience includes hundreds of kilometres of proprietary seismic data acquired and observed within southwestern Ontario. The interpretations presented in this report are a reasoned attempt to identify features and structural discontinuities, and the geologic mechanisms that may have been important. The interpretations certainly extend beyond what can be interpreted from the seismic data alone. In a relative sense several of the identified features are associated with a higher degree of confidence that stems in part from the following:

- No faults within the Silurian bedrock formations have been observed in nearby quarries or rock outcroppings (e.g., Armstrong, 1993a; 1993b; Armstrong et al., 2002), therefore confidence is low in any data that suggests faulting at the Silurian level. Numerous observed "fault-like structures" within the Silurian bedrock formations have been highly discounted due to the lack of confidence in these data and the fact that no such structures have been observed, however some of these "structures" may be faults.
- Similarity and coincidence of identified features between the original and re-processed data sections provides a higher level of confidence in the interpretation.
- Sections of survey lines of known surface culture (e.g. construction landfill), as well as, the bending of these lines in a planar sense, which leads to subsurface bin smearing of the reflection points, were considered in determining confidence in interpretation.
- The identification of specific reflections or seismic markers was based on stratigraphy as determined from the sonic logs from boreholes DGR-1 and DGR-2.

9.2 Key Structural Features

Figure 26 depicts apparent fault trends and structures interpreted to occur in the Cobourg Formation based on the consideration of the seismic sections discussed in Section 8.5, and acquired knowledge of geologic and geophysical characteristics particular to this area of southwestern Ontario. These interpretations, consider data quality as discussed in Section 9.1.

The following key observations pertaining to structural features at the Bruce site were interpreted with relative confidence from the 2D seismic data:

- No credible pinnacle reef-type structures were observed along the interpreted survey lines. However, it is noteworthy that the poor fold at this shallow depth and the limited data quality would make it difficult to reveal pinnacle reef-type structures unless such structures were in close proximity to a survey line.

- A steeply dipping fault is observed, located approximately 1.25 km southwest of the proposed repository site that cuts at an oblique angle to Line 7, and near the south end of Line 3.
- There is an apparent bedrock high as depicted on the Precambrian ribbon plot (Figure 15) which is bounded on the west by this graben-like feature and to the east by a potential fault zone, within which there may be a fault or series of faults, which cannot be accurately resolved due to the quality of the data. However marker offsets in the Precambrian up through the Queenston likely represent a normal fault relatively close to vertical as depicted on Line 1, dipping slightly to the east.

9.3 Assessment of Fault Structure and Identification

Previous studies of these strata and nearby outcrops from the Bruce Peninsula did not reveal faulting, but the seismic survey data has identified apparent fault structures on the Bruce site. Several investigations of Middle Ordovician oil and gas fields in southwestern Ontario, Michigan, Ohio and New York provide conceptual models of fault structure and associated reservoir development that may be relevant to understanding the structure and lithologies of such fault structures (Colquhoun, 2004; Colquhoun and Johnston, 2004; Smith, 2006; Davies and Smith, 2006). These investigations have suggested that strike-slip faulting, in the context of regional trans-tensional basin tectonics, is important.

Many of these Ordovician reservoirs have long been known to be structurally controlled and the result of porosity and permeability enhancement associated with the dolomitization of otherwise non-porous limestones in the vicinity of faults. Appendix F summarizes the key ideas on these dolomitized reservoirs, derived from the above-mentioned studies, as well as Coniglio et al., (1994), who included dolomitized Ordovician strata from the Manitoulin Island area.

The dolomitized reservoirs are variable in size, ranging from a few kilometres upwards to, for example, the Albion-Pulaski-Scipio field in central Michigan, which is some 58 km (35 miles) in length (Prouty, 1988). Southwestern Ontario fields are comparatively small, reaching up to 6 km in length and 1 km wide (Middleton et al., 1993). These types of reservoirs are recognized seismically by subtle structural sags or graben-like depressions at the top of the Trenton succession (Appendix F). These narrow, elongated fields are arranged in an echelon configuration, suggesting an origin related to regional strike-slip movements. The recent work on these reservoirs (references cited above) considers these sags to be related to trans-tensional (strike slip and extensional) shear zones, with the structural lows being the expression of negative flower structures where strata were released (faulted) downward. The faults defining these flower structures are not discernible seismically in the overlying shales sequence (unlike the apparent faults in this investigation), and thus appear to die out upwards, and they merge to a master wrench fault at depth, likely rooted in the basement. Flower structures are interpreted throughout Essex and Kent counties in southwestern Ontario, and similar features have been identified in Lambton County (Colquhoun, 2004).

Colquhoun and Johnston (2004) suggested that negative flower structures are expected in southwestern Ontario because the reservoirs sit on a Precambrian high (Algonquin Arch - Findlay Arch) which separates the Michigan Basin and Appalachian Basin. Extension in this setting was related to arch uplift while the adjacent basins subsided and reacted to regional tectonic activity. The structural setting, in conjunction with a favourable paleo-hydrology (Appendix F), resulted in the reservoirs (Davies and Smith, 2006).

The physical properties of the dolomitized reservoir rocks are distinct from the generally non-porous, impermeable limestones from which they were derived. In his review of southwestern Ontario examples, Colquhoun (2004) indicates that dolostone matrix porosities can reach 15%. Associated vug and fracture porosities range from 18% to greater than 45% in the case of open fractures. Likewise, permeabilities are variable, typically up to a few hundred millidarcies, while large open fractures can reach permeabilities of 10 darcies ($1 \times 10^{-12} \text{ m}^2$). Compartmentalization of the reservoirs is also common, a reflection of the heterogeneities in rock properties on a variety of scales.

The literature cited above interprets the structural features observed in the Ordovician carbonates of southwestern Ontario in the context of trans-tensional basin tectonics. The quality of the existing seismic information at the DGR site does not allow us to conclude more definitively about the nature of the faulting in these strata, if such faulting is present. It remains highly speculative, therefore, as to whether extrapolation of the structural style from southwestern Ontario is a valid approach to understanding potential faults interpreted from the seismic sections at the DGR site.

Moreover, trans-tensional tectonics may be unimportant at the Bruce site because the geologic setting of the Bruce site is fundamentally different from that of southwestern Ontario. Extensional stresses in southwestern Ontario, which Colquhoun (2004) considers essential in the structural model for that area, are associated with the Algonquin Arch, a regional basement high. No comparable regional arch exists on the eastern margin of the Michigan Basin, although the DGR site does sit on the edge of an intracratonic basin and the Precambrian basement does rise toward the basin margin. However, there seems to be a localized basement high at the DGR site. How these features of the Precambrian basement at the DGR site affected the structural behaviour of the overlying Paleozoic rocks, if at all, is the subject of ongoing investigations.

Even if the structural settings were similar and trans-tensional tectonics governed the structural behaviour of the rocks at the DGR site, the simple presence of cross-cutting faults does not necessarily imply that the faults acted as transmissive pathways. Faults commonly act as reservoir seals, attesting to the low permeabilities of the rocks in the fault zone.

Most importantly, cores from DGR-1 and DGR-2 do not reveal the distinctive and well-documented styles of matrix and hydrothermal dolomitization associated with the fault zones in southwestern Ontario. Even if these rocks were dolomitized as they are in southwestern Ontario, this does not necessarily mean the strata are more porous and permeable. Cementation by dolomite and other late-stage minerals may totally occlude pore space.

The key messages from the above discussion are the following:

1. Ordovician reservoirs in southwestern Ontario and elsewhere provide a possible structural analog with which to interpret the faults suggested by the seismic work beneath the Bruce site, given that both southwestern Ontario and the Bruce site are on the margin of the Michigan Basin. The quality of the 2D seismic data alone does not allow a sufficiently rigorous assessment of the validity of the structural analog.
2. Even if it could be determined that trans-tensional tectonics were important to understanding the structure and nature of interpreted faults at the DGR site, the DGR-1 and DGR-2 cores do not show the distinctive styles of matrix and hydrothermal dolomitization exhibited in southwestern Ontario and elsewhere. A possible explanation is that faults may have not been transmissive and/or dolomitizing fluids may have been absent.

10 Conclusions

The field acquisition was well executed, as per seismic industry standards, with no major problems. A 240 channel state of the art distributed ARAM Aries II recording system and four (4) IVI Envirovibes loaded with I/O electronics enabled accurate high frequency sweep testing. RTK – GPS surveying enabled sub-decimetres survey orientation and a trained crew of seismic workers ensured accurate placement of receivers.

The Bruce site is a difficult environment for seismic recording due to cultural, structural, as well as surface disturbances. Overall seismic data quality is rated as fair to poor. High velocity bedrock is covered with low velocity material that is highly variable in thickness and relatively heterogeneous making seismic energy coupling difficult. Strong source-generated noise trapped in the near surface dominates weak reflection signals on individual source records that are stacked or combined with high statistical multiplicity when processed. State of

the art processing algorithms from two independent Calgary-based processing centres have been presented in an attempt to isolate the areas within which more confidence in the final interpretation can be placed.

A total of 19.7 km of surface seismic data was acquired (within an approximate 9 square kilometre area) of which approximately 9.1 km was of good quality (45%). Although very sparse in coverage, the inclusion of 4 deep test holes DGR-1, DGR2, DGR-3, & DGR-4, a sonic log within DGR-2, regional geology including nearby deep boreholes previously drilled (T002636, T001942, T002238) enabled the identification of a possible basement high and apparent faulting beneath the Bruce site. The focus during interpretation has been placed on the continuity of marker horizons along the 2D seismic lines and the "potential" location of faults and fault zones,

Within this project design the limitations discussed in Section 6.2 have been considered in the original field work, however due to surface access restrictions we accept that these data are the best possible we could have achieved within these circumstances. Extensive testing of the vibratory source, good technical deployment of the equipment by a recognized expert crew and careful selection of field filtering parameters have optimized these data.

Within the 2D data area no reef type features have been interpreted within the Guelph Formation. However, it is noteworthy that the poor fold at this shallow depth and the limited data quality would make it difficult to reveal pinnacle reef-type structures unless such structures were in close proximity to a survey line

There is an apparent basement structural high of as much as 10m within the project area where DGR-1 and DGR-2 were drilled (Figure 15). Basement highs are commonly associated with faulting unless the result of an erosional remnant. Without several borehole intersections with the Precambrian on the Bruce site (only borehole DGR-2 intersects the Precambrian basement), Paleozoic formation depths can be used to assess the reliability of the inference of the apparent Precambrian bedrock high and possible associated fault presence. Although the elevation of Ordovician and Silurian bedrock formations in DGR-3, interpreted to be off this basement high, were approximately 8 to 16 m deeper (7.7 m for Queenston Formation, 16.3 m for Salina F Unit) compared to the same formations in DGR-1 and DGR-2, the uniform thicknesses and elevations of Paleozoic formations in DGR-3 are entirely consistent with the true formation dips determined by triangulation of key marker bed elevations in DGR-1/2, DGR-3 and DGR-4. Consequently, the formation depth information in available DGR boreholes does not support the interpretation of the presence of local bedrock high or associated faulting near DGR-2. However, the triangulated formation dips at 10.5 to 17.5 m/km on the Bruce site between DGR boreholes are greater than regional dips reported in Section 7.2 of about 5 to 8 m/km. But this increased dip of formations may also be due to increasing proximity to the centre of the Michigan Basin where increasing formation dips are expected.

To the east of this basement high there appears to be an area within which there is a potential for normal faults striking NNW-SSE. There are inflections that support this interpretation on lines that were within close proximity of each other, acquired at different times and having different surface conditions. These areas also appear on both the original and re-processed sections. As well, there is strong evidence that there is a basement / lower Ordovician fault near the intersection of Lines 3 and 7 as evidenced by a basement diffraction pattern on Line 7. This fault has been interpreted as not extending above the Ordovician suggesting it is limited to Ordovician age before deposition of the overlying strata.

Despite the above considerations, there remains uncertainty with the interpretation of the 2D seismic survey for identification of structural features and faults within the Ordovician formations at the Bruce site. Ultimately, this uncertainty can only be resolved through targeted drilling, core logging and testing. To address this uncertainty and to assess the general reliability of structural interpretations of the Ordovician formations based on the 2D seismic survey, inclined core drilling of two of the identified structural features shown in Figure 26 are planned. Borehole DGR-5 will be core drilled to intersect the extension of the potential fault intersecting Line 9 located south of DGR-1 and DGR-2. Borehole DGR-6 will be core drilled to intersect the potential fault area located east

of the structural high that intersects Lines 5 and 6 east of the proposed DGR footprint.

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APPENDIX A















Tables and Figures

Table 1. Summary of Interpretation of 2D Seismic Lines

Line number	Surface/Recording Environment	Quality	SP from	SP to	Feature	Confidence level
Line 1	E-W along road through plant in West, open field in the middle, then crossed a marshy area and disturbed, backfilled areas at the East end.	Good, western 2/3 deteriorates to poor through the marshy and backfilled disturbed areas where it crosses lines 2 & 9 in the East	332 185 368	394 335 368	Graben type feature Ordovician Basement high Test borehole #1	High, consistent between both sections, good quality data
Line 2	NW – SE line primarily a low traffic road for the 1 st 2/3 rd of the line, ending within landfill area. DGR1/2 drilled on this line at or near the point it crosses Line #1	Centre section of the line was good quality and the data to the south of DGR1/2 fair to poor.	185 335	335 EOL	Basement high Basement low	Low confidence however consistent on both processed sections
Line 3	Along a good paved road, nominal traffic.	Good quality	150 182	380	NW-SE trending fault at or near the intersection point with line #7 Sag within Queenston down to Cobourg of 5ms (~10m)	High confidence due consistency with high quality Line 7 depicting a similar feature and similar appearance on both processed versions of the seismic
Line 4	Curved line along a NS road at the North-eastern perimeter of the project area	Data quality was fair to poor, least straight line leading to lower confidence in results	225 370	275 380	Pop-up style in Silurian Pop-up style in Silurian	Low confidence in pop-up style features at the Queenston very low confidence due to crooked binning and poor quality data on both processing versions
Line 5	Shot along a railroad corridor, irregular ground alongside the track, poor surface conditions for seismic in general	Western ½ of line was fair, eastern portion was poor	315 190	340 220	Faulted zone, basement high to the east, lower to the west. Faulted zone, basement high to west, lower to east	Medium confidence, processed versions were similar but data quality fair to poor
Line 6	Along major hydro corridor, significant electrical noise.	Good quality in western ½, fair to poor along the hydro corridor on the eastern ½ of the line	235 235	255 EOL	Faulted zone, basement low	Medium to low confidence, poor quality data from BOL (SP101) to about SP 220 then relatively good to end of line, both sections similar
Line 7	E-W line shot along a gravel road	Best quality line	247 155	155	Apparent dip ~69m/km much greater than regional dip Cobourg sag feature	High confidence due to the below basement side swipe or out of plane reflection and similar appearance on both processed versions of the seismic
Line 8	E-W line shot along paved road	Good quality line			No significant features	Good quality seismic on both processed sections
Line 9	NE-SW road beginning at the southern property boundary	Fair to poor quality	185 362		Structural low Precambrian Fault	Medium confidence, depicted on both processed sections but poor quality data

OPG DGR
Site Characterization Project

Legend

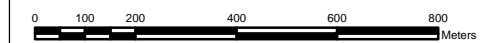
-  2D Seismic Survey Lines - Line Through Common Depth Points (CDP)
-  2D Seismic Survey Lines - Geophones Only
-  Every 10th Receiver Station
-  Source Points Offset From Original Receiver Points
-  2D Seismic Test Area
-  Location of DGR-1, 2 & 3
-  Shallow Bedrock Monitoring Wells with Westbay Multi-level System
-  Proposed DGR Layout
-  Buildings
-  Roads
-  Railway
-  Transmission Line
-  Pits or Landfills
-  Stream or Drainage

2D Seismic Line Layout
at Bruce Site

Figure 1



Scale 1:15,000

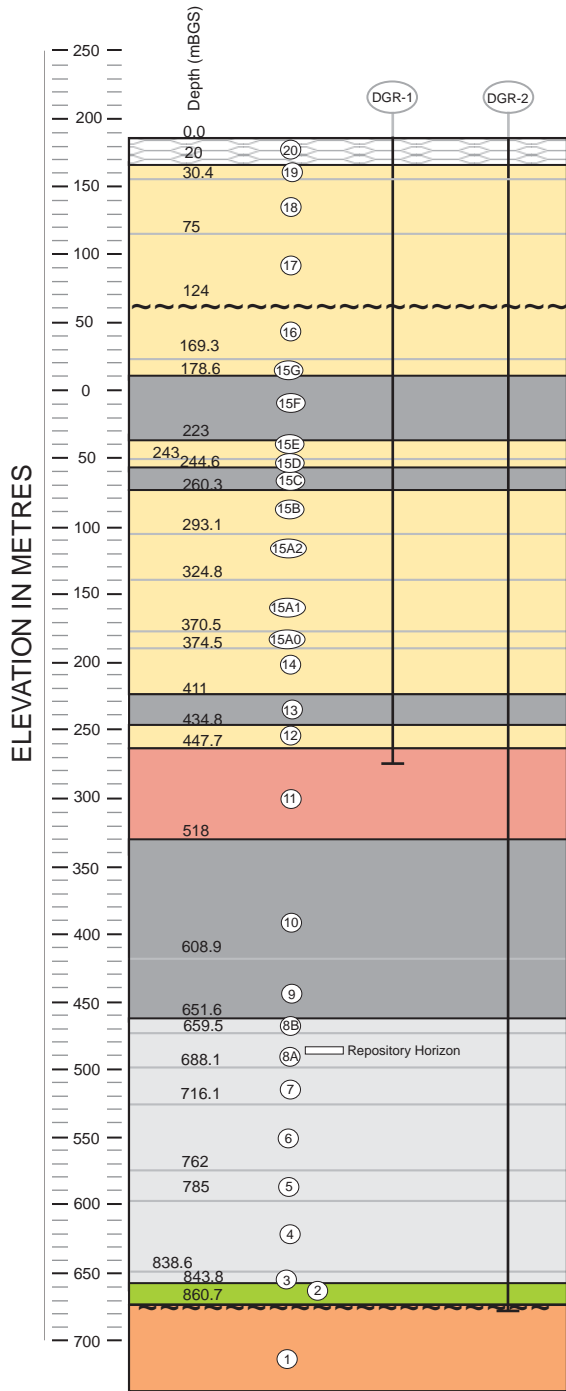


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Projection: UTM Zone 17N and Datum: NAD83

Data Credits:
NRVIS/OBM, MNR, Ontario Power Generation, Bruce Power





LEGEND - BRUCE SITE STRATIGRAPHY

- PLEISTOCENE
 - 20 SURFICIAL DEPOSITS
- MIDDLE DEVONIAN
 - 19 LUCAS FORMATION - DOLOSTONE
 - 18 AMHERSTBURG FORMATION - DOLOSTONE
- LOWER DEVONIAN
 - 17 BOIS BLANC FORMATION - CHERTY DOLOSTONE
 - ~~~~~ SILURIAN / DEVONIAN DISCONTINUITY
- UPPER SILURIAN
 - 16 BASS ISLANDS FORMATION - DOLOSTONE
 - 15 SALINA FORMATION
 - 15G G UNIT - ARGILLACEOUS DOLOSTONE
 - 15F F UNIT - DOLOMITIC SHALE
 - 15E E UNIT - BRECCIATED DOLOSTONE AND DOLOMITIC SHALE
 - 15D D UNIT - ANHYDRITIC DOLOSTONE
 - 15C C UNIT - DOLOMITIC SHALE AND SHALE
 - 15B B UNIT - ARGILLACEOUS DOLOSTONE AND ANHYDRITE
 - 15A2 A2 UNIT - DOLOSTONE AND ANHYDRITIC DOLOSTONE
 - 15A1 A1 UNIT - ARGILLACEOUS DOLOSTONE AND ANHYDRITIC DOLOSTONE
 - 15A0 A0 - BITUMINOUS DOLOSTONE
- MIDDLE SILURIAN
 - 14 GUELPH, GOAT ISLAND, GASPORT, LIONS HEAD AND FOSSIL HILL FORMATIONS - DOLOSTONE AND DOLOMITIC LIMESTONE
- LOWER SILURIAN
 - 13 CABOT HEAD FORMATION - SHALE
 - 12 MANITOULIN FORMATION - CHERTY DOLOSTONE AND MINOR SHALE
- UPPER ORDOVICIAN
 - 11 QUEENSTON FORMATION - RED SHALE
 - 10 GEORGIAN BAY FORMATION - GREY SHALE
 - 9 BLUE MOUNTAIN FORMATION - DARK GREY SHALE
- MIDDLE ORDOVICIAN
 - 8 COBOURG FORMATION
 - 8B COLLINGWOOD MEMBER - BLACK CALCAREOUS SHALE AND ARGILLACEOUS LIMESTONE
 - 8A LOWER MEMBER - ARGILLACEOUS LIMESTONE
 - 7 SHERMAN FALL FORMATION - ARGILLACEOUS LIMESTONE
 - 6 KIRKFIELD FORMATION - ARGILLACEOUS LIMESTONE
 - 5 COBOCONK FORMATION - BIOTURBATED LIMESTONE
 - 4 GULL RIVER FORMATION - LITHOGRAPHIC LIMESTONE
 - 3 SHADOW LAKE FORMATION - SILTSTONE AND SANDSTONE
- CAMBRIAN
 - 2 CAMBRIAN SANDSTONE
 - ~~~~~ CAMBRIAN / PRECAMBRIAN UNCOMFORMITY
- PRECAMBRIAN
 - 1 PRECAMBRIAN BASEMENT - GRANITIC GNEISS

NOTE:
 1. SUBSURFACE STRATIGRAPHIC NOMENCLATURE AFTER ARMSTRONG AND CARTER (2006)

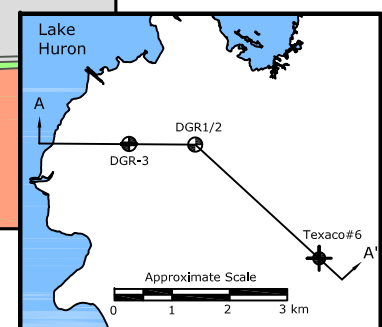
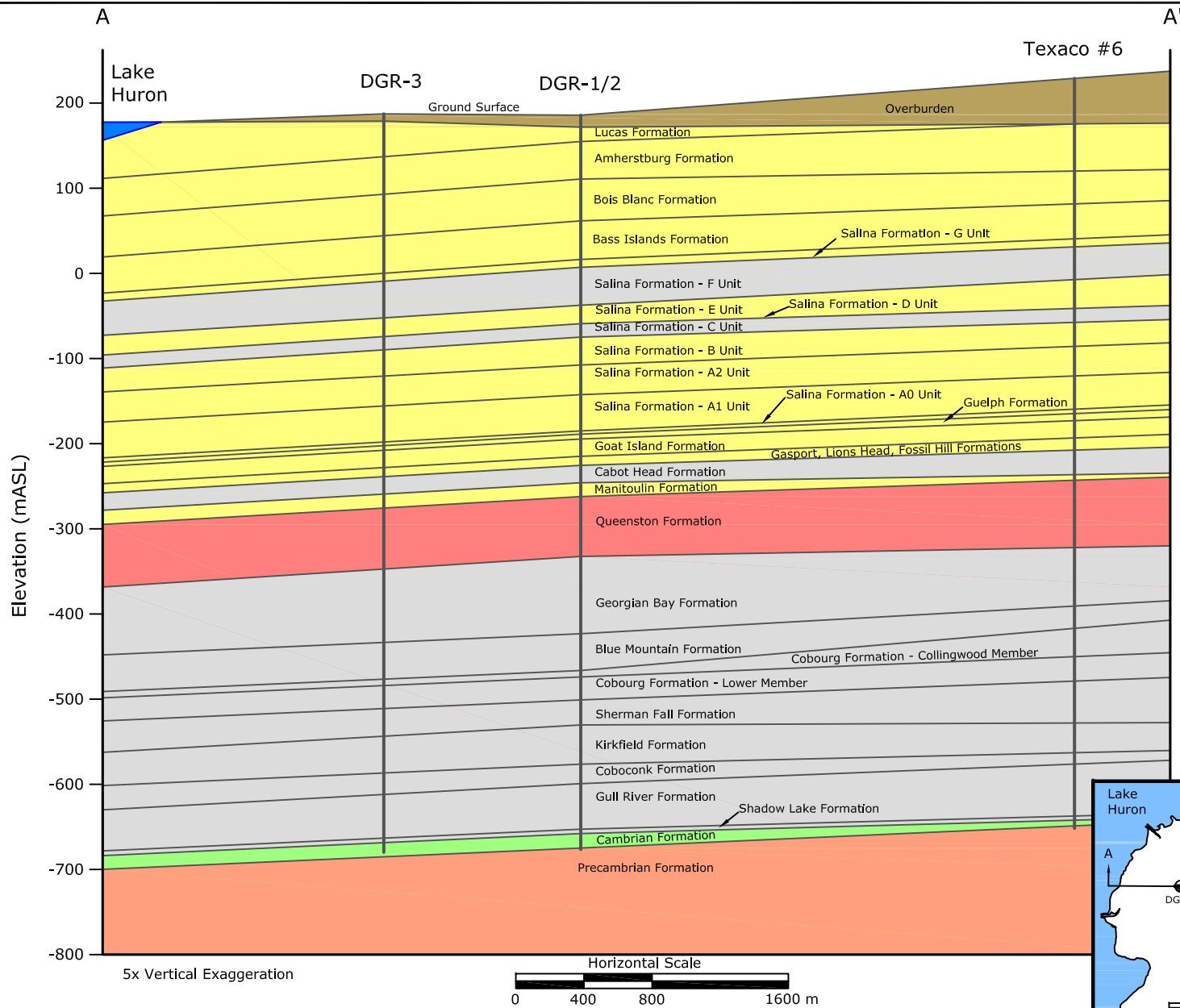
**Interpreted Bedrock Stratigraphy at Bruce Site from DGR-1 and DGR-2
 2D Seismic Report**

Prepared by: ADG
 Reviewed by: KGR
 Date: Jan 23, 2009



FIGURE 2

Doc. No.: TR-07-15_Figure 2_R0.cdr



Regional Cross Section Through Texaco Well #6, DGR-1, DGR-2 and DGR-3 2D Seismic Survey






Prepared by: SNG, ADG
 Reviewed by: SNS
 Date: 29-Jan-09

FIGURE 3 Doc. No.: TR-07-15_Figure 3_R0.dwg



OPG DGR
Site Characterization Project

Legend

-  Location of Oil and Gas Well Referenced in Text
- (58.7 km)** Distance between DGR-2 and Well
-  City/Town
-  Roads
-  County
-  Bruce Site

Location of Registered MNR Oil and Gas Wells Referenced in Report

Figure 4



Scale 1:550,000



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Project: 06-219.10.05 Checked: SNS
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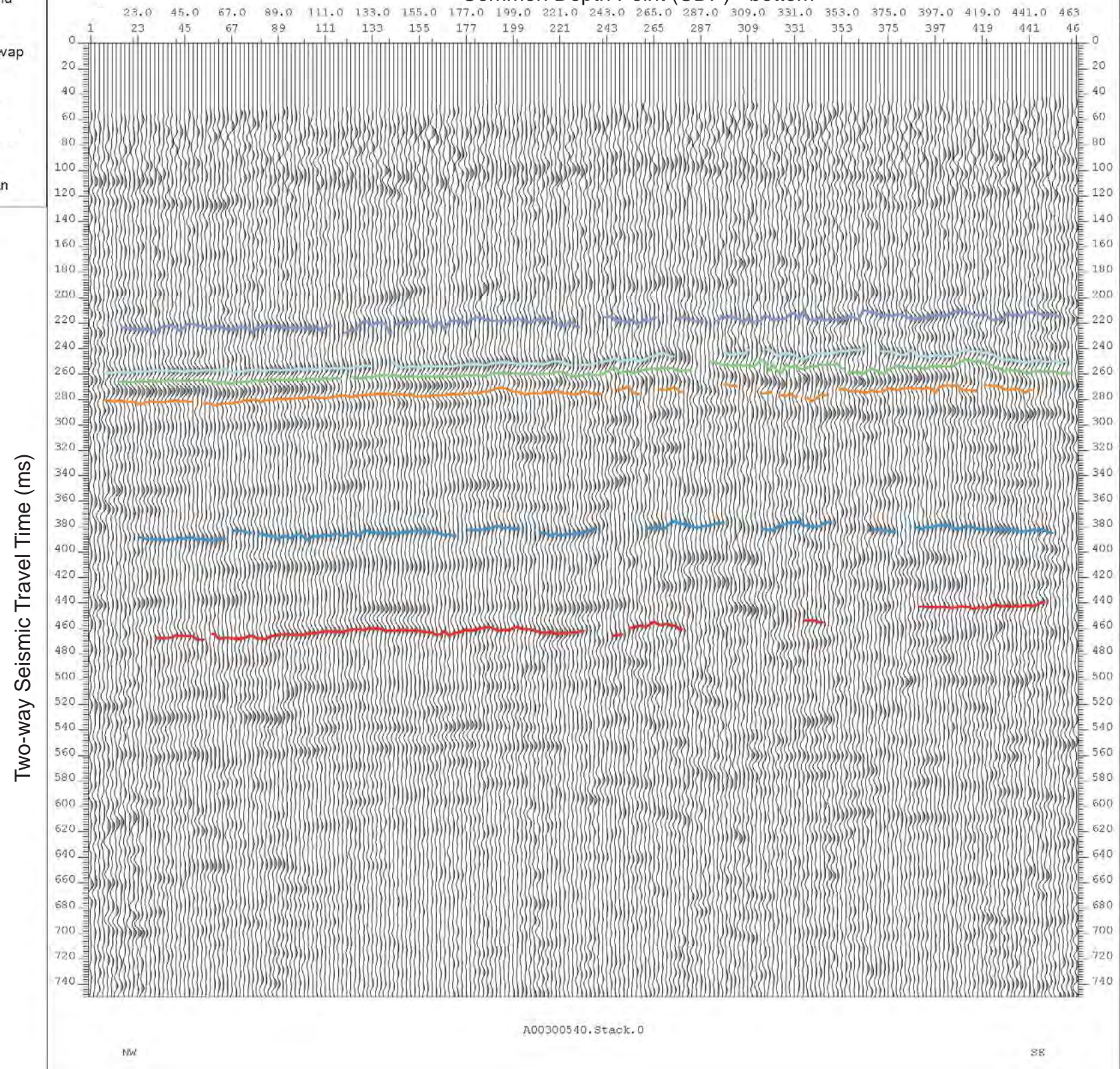
Projection: UTM Zone 17N and Datum: NAD83

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Source Point (SP) Number - top
Common Depth Point (CDP) - bottom

- Horizon Legend
- Salina A2 evap
 - Manitoulin
 - Queenston
 - Horizon 1
 - Cobourg
 - Precambrian



Interpreted Seismic Data - Shell Line A00300540
2D Seismic Survey

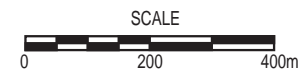
Prepared by: ADG

Reviewed by: SNS

Date: 29-Jan-09

FIGURE 5

Doc. No.: TR-07-15_Figure 5_R0



OPG DGR
Site Characterization Project

Legend

- 2D Seismic Survey Lines - Poor Data Quality
- 2D Seismic Survey Lines - Fair Data Quality
- 2D Seismic Survey Lines - Good Data Quality
- 2D Seismic Survey Lines - Geophones Only
- Every 10th Receiver Station
- 301 Receiver Station Numbers
- Source Points Offset From Original Receiver Points
- Location of DGR-1, 2 & 3
- Shallow Bedrock Monitoring Wells with Westbay Multi-level System
- Proposed DGR Layout
- Buildings
- Roads
- Railway
- Transmission Line
- Pits or Landfills
- Stream or Drainage
- Digital Elevation Model (mASL)
- 240
- 175

Seismic Location Map and Assessment of Data Quality

Figure 6



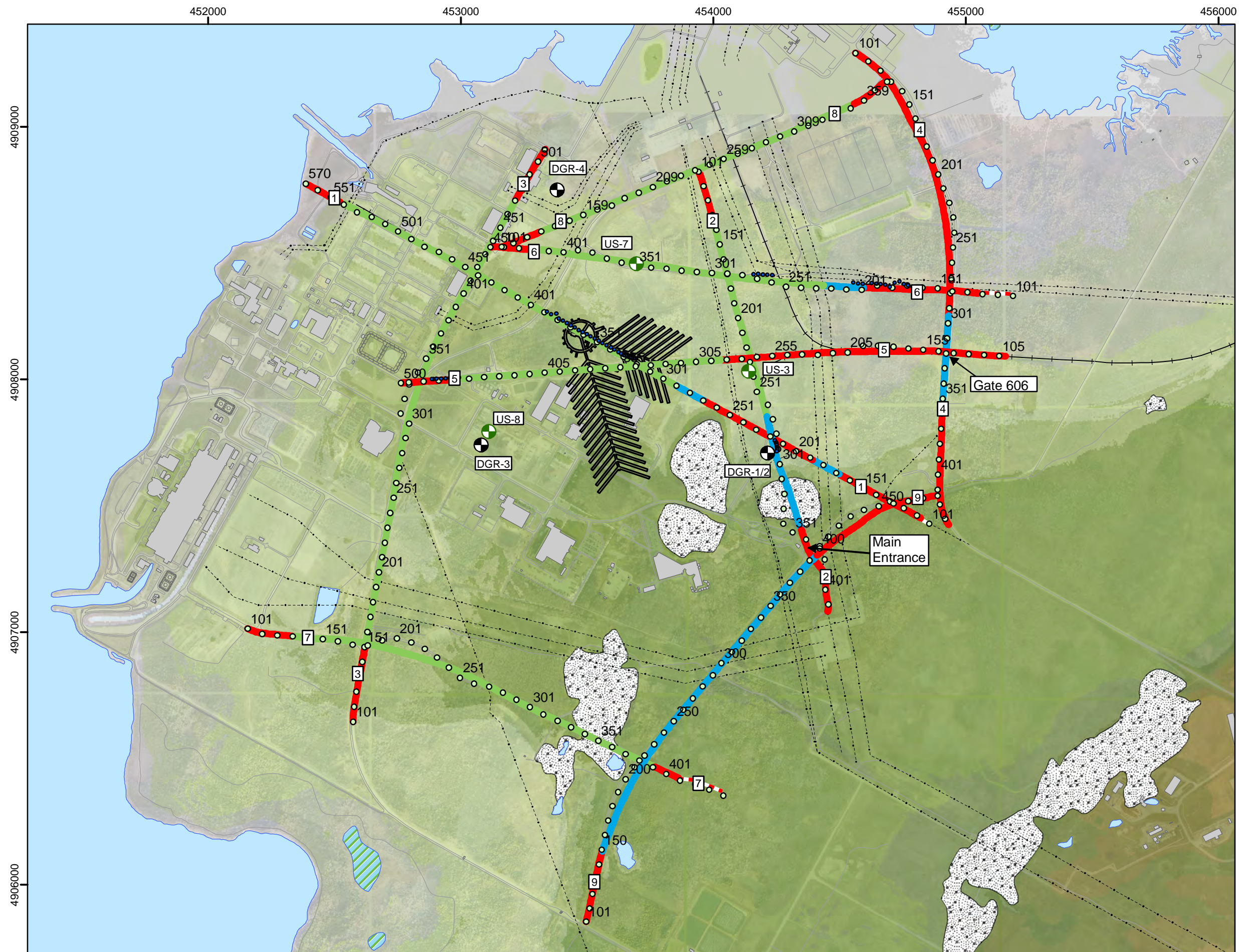
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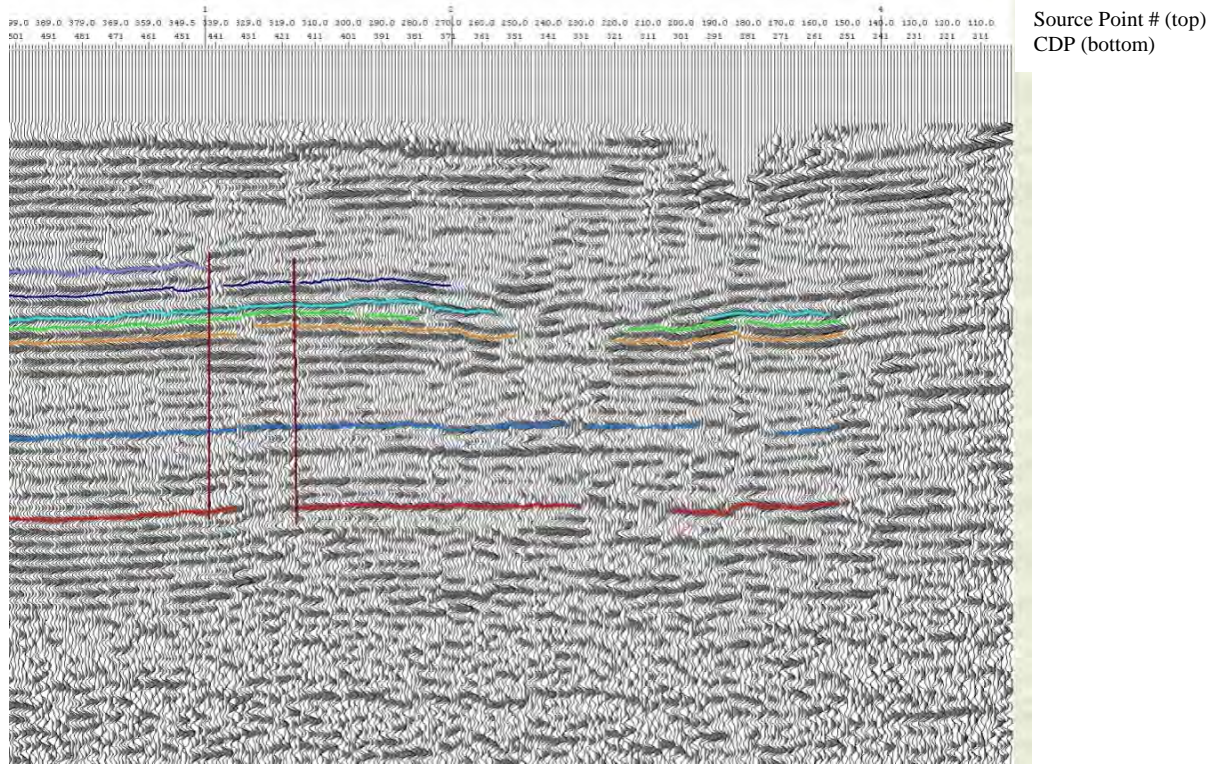


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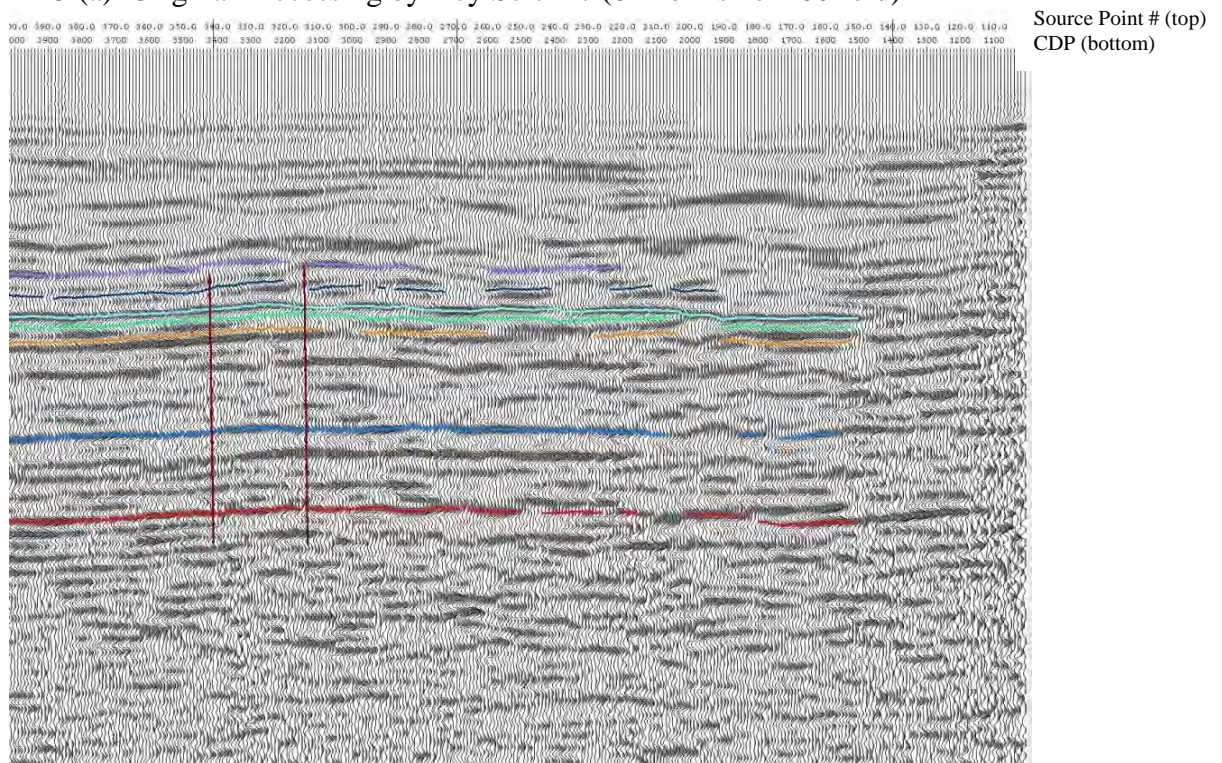
Projection: UTM Zone 17N and Datum: NAD83

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5 (a) Original Processing by Key Seismic (6 m bin size – 80 fold)



5 (b) Re-processing by Seiscraft (3 m bin size – 40 fold)

Example of Variable Processing Results for Centre Portion of Line 5
2D Seismic Report

Prepared by: ADG
Reviewed by: SNS
Date: 29-Jan-09

FIGURE 7

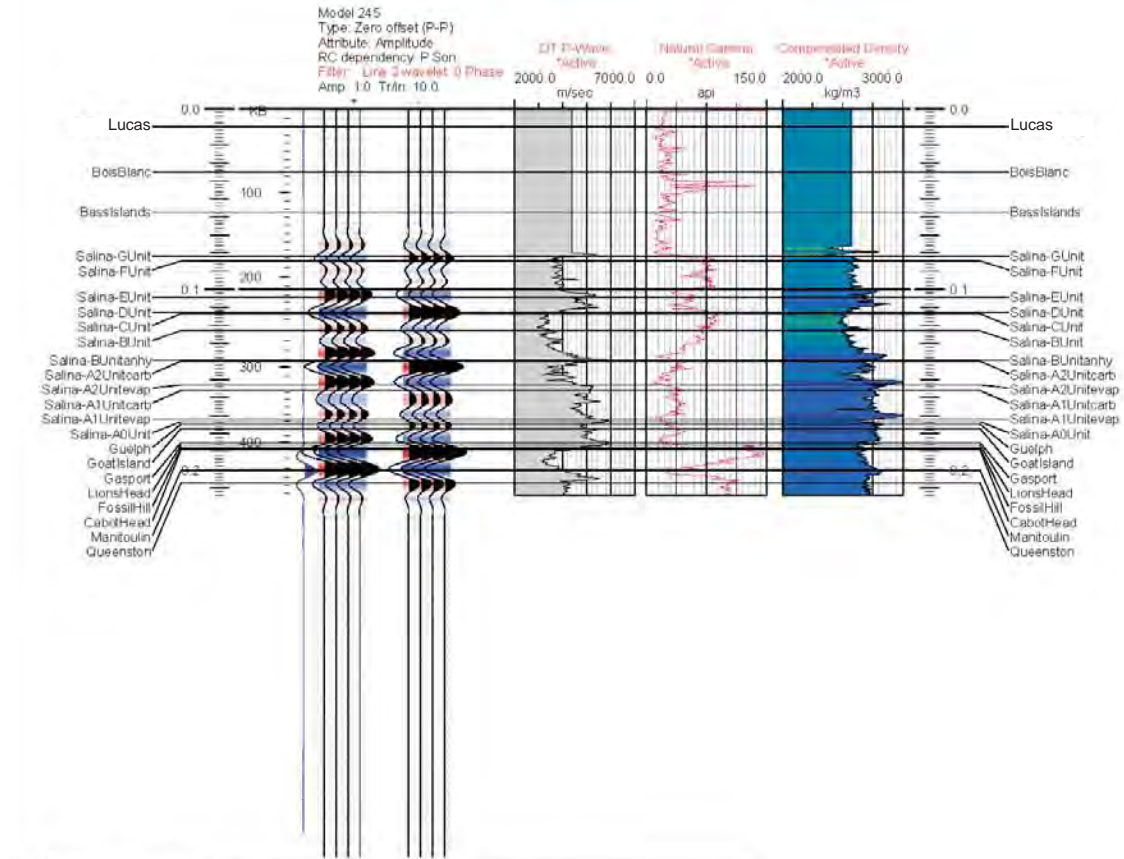
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DGR-1
08:45 AM Fri May 09, 2008 GeoSyn software

DGR-1 DGR-2 Merged
 Northing = 4907753.243m Easting = 4542
 Intera Engineering, LTD
 DGR-1DGR-2Merged

File location: U:\Agulair\OPG\OPG synthetics\DGR-1_xgi.syn
 KB elevation: 185.7 m amsl Vertical scale: 15.0 m/insec
 Depth range (KB): -1.93 to 462.96 m MD to TVD correction: No
 Depth range (SS): 181.83 to -277.26 m
 Time range: 0.0 to 0.2145 secs
 Sample rate: 0.5 ms



DGR-1DGR-2Merged

Tops	Depth KB m	Depth SS m	Time 2 way sec	Vav m/sec	Vint m/sec	Isochron sec	Isopach m
Kelly bushing = 185.7 above msl, Top of log data = -1.93 KB, Bottom of log data = 462.96 KB. (m)							
Tops lists - User Tops							
Lucas	20.00	165.70	0.01002	4378.4	4384.8	0.02509	55.00
BoisBlanc	75.00	110.70	0.03510	4382.9	4384.8	0.02235	49.00
BassIslands	124.00	61.70	0.05745	4383.6	4438.7	0.02434	54.00
Salina-GUnit	178.00	7.70	0.08180	4399.4	3979.8	0.00251	5.00
Salina-FUnit	183.00	2.70	0.08431	4388.9	4002.2	0.01999	40.00
Salina-EUnit	223.00	-37.30	0.10430	4313.1	4728.1	0.00846	20.00
Salina-CUnit	243.00	-57.30	0.11270	4344.3	4258.8	0.00075	1.60
Salina-BUnit	244.80	-58.90	0.11351	4343.7	3316.2	0.00947	15.70
Salina-BUnitanthy	260.30	-74.60	0.12298	4264.6	3817.8	0.01619	30.90
Salina-A2Unitcarb	281.20	-105.50	0.13917	4212.8	5546.7	0.00069	1.90
Salina-A2Unitvap	293.10	-107.40	0.13985	4219.1	4119.8	0.01306	26.90
Salina-A1Unitcarb	320.00	-134.30	0.15291	4210.7	5012.2	0.00319	8.00
Salina-A1Unitvap	328.00	-142.30	0.15610	4227.0	4869.5	0.01602	39.00
Salina-A0Unit	367.00	-181.30	0.17212	4286.8	5739.2	0.00122	3.50
Guelph	370.50	-184.80	0.17334	4297.1	5534.1	0.00145	4.00
GoatIsland	374.50	-188.80	0.17479	4307.3	4903.8	0.00224	5.50
Gasport	380.00	-194.30	0.17703	4314.8	5128.4	0.00799	20.50
LionsHead	400.50	-214.80	0.18502	4350.0	5848.9	0.00128	3.75
FossilHill	404.25	-216.55	0.18631	4360.3	5166.3	0.00157	4.05
CabotHead	408.30	-222.80	0.18787	4367.0	5628.5	0.00096	2.70
Manitoulin	411.00	-225.30	0.18883	4373.4	3821.0	0.01132	20.50
Queenston	431.50	-245.80	0.20016	4330.9	4637.8	0.00896	16.15
Queenston	447.65	-261.95	0.20712	4341.2			

Synthetic Seismograph - DGR-1
2D Seismic Survey

FIGURE 8

Doc. No.: TR-07-15_Figure 8_R0

Prepared by: ADG

Reviewed by: SNS

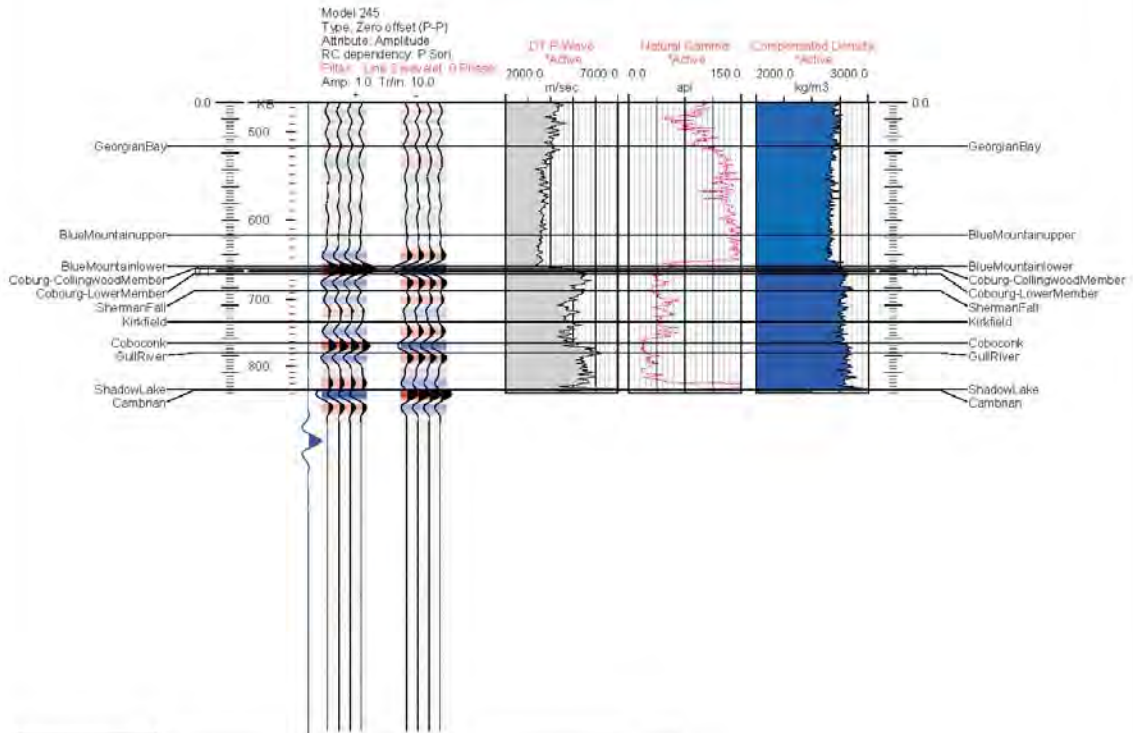
Date: Sep 28, 2008



DGR-2
08:43 AM Fri May 09, 2008 GeoSyn software

DGR-1 DGR-2 Merged
 Northing = 4907753.343m Easting = 4542
 Intra Engineering, LTD
 DGR-1 DGR-2 Merged

File location: U:\Agula\OPG\OPG_synthesis\DGR-2_xgr.syn
 KB elevation: 185.7 m amsl Vertical scale: 15.0 m/sec
 Depth range (KB): 463.01 to 850.41 m MD to TVD correction: No
 Depth range (SS): -277.31 to -684.71 m
 Time range: 0.0 to 0.1725 sec
 Sample rate: 0.5 ms

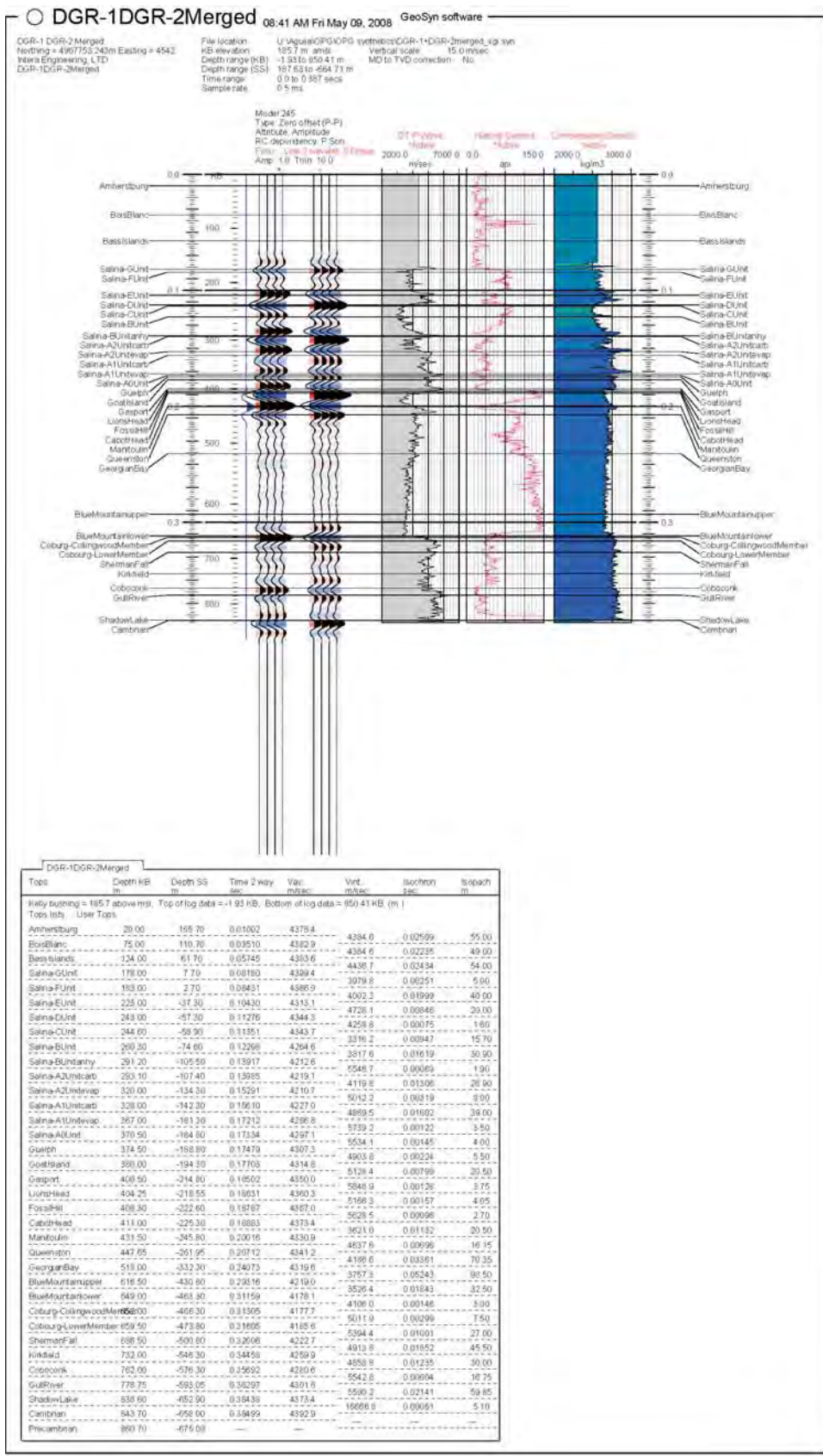


DGR-1 DGR-2 Merged

Tops	Depth KB m	Depth SS m	Time sec	2 way m/sec	V _{av} m/sec	V _{int} m/sec	Isechron sec	Ispach m
Kelly Dushing = 185.7 above msf, Top of log data = 463.01 KB, Bottom of log data = 850.41 KB (m)								
Tops lists: User Tops								
Georgian Bay	518.00	-332.30	0.02623	4192.4	3757.6	0.05243	98.50	
Blue Mountain upper	616.50	-430.80	0.07868	3902.6	3526.4	0.01843	32.50	
Blue Mountain lower	649.00	-483.30	0.09709	3831.2	4084.7	0.00147	3.00	
Cobourg-Collingwood Member	659.50	-466.30	0.09856	3835.0	5003.0	0.00300	7.50	
Cobourg-Lower Member	659.50	-473.80	0.10156	3869.5	5394.9	0.01001	27.00	
Sherman Fall	686.50	-500.80	0.11157	4006.3	4914.0	0.01852	45.50	
Kirkfield	732.00	-546.30	0.13009	4135.5	4857.5	0.01235	30.00	
Cobocook	762.00	-576.30	0.14244	4198.1	5542.2	0.00604	16.75	
Gull River	778.75	-593.05	0.14848	4252.9	5586.9	0.02142	59.85	
Shadow Lake	838.60	-652.00	0.16991	4421.1	10886.5	0.00061	5.10	
Cambrian	843.70	-658.00	0.17052	4465.0				
Precambrian	860.70	-675.00						

Synthetic Seismograph - DGR-2		Prepared by: ADG
2D Seismic Survey		
FIGURE 9	Doc. No.: TR-07-15_Figure 9_R0	Reviewed by: SNS
		Date: July 28, 2008





Synthetic Seismograph - Combined DGR-1 and DGR-2 2D Seismic Survey

Prepared by: ADG
 Reviewed by: SNS
 Date: July 28, 2008

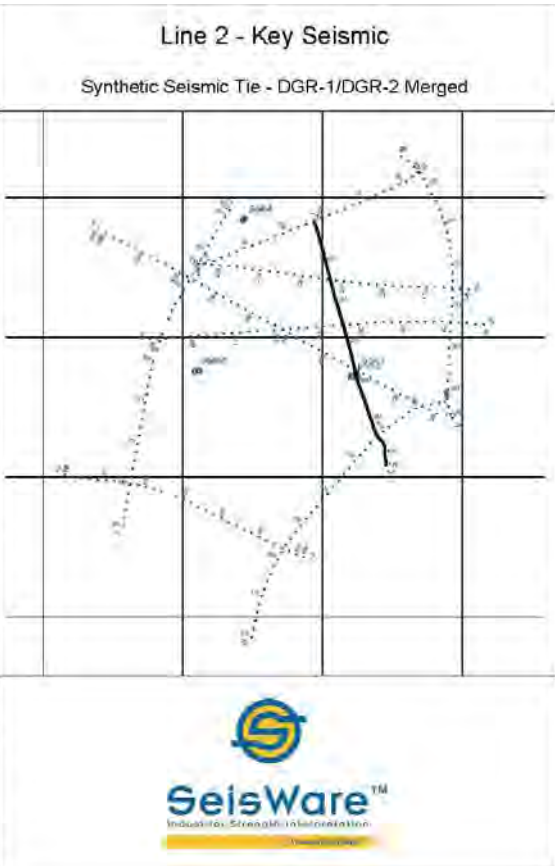
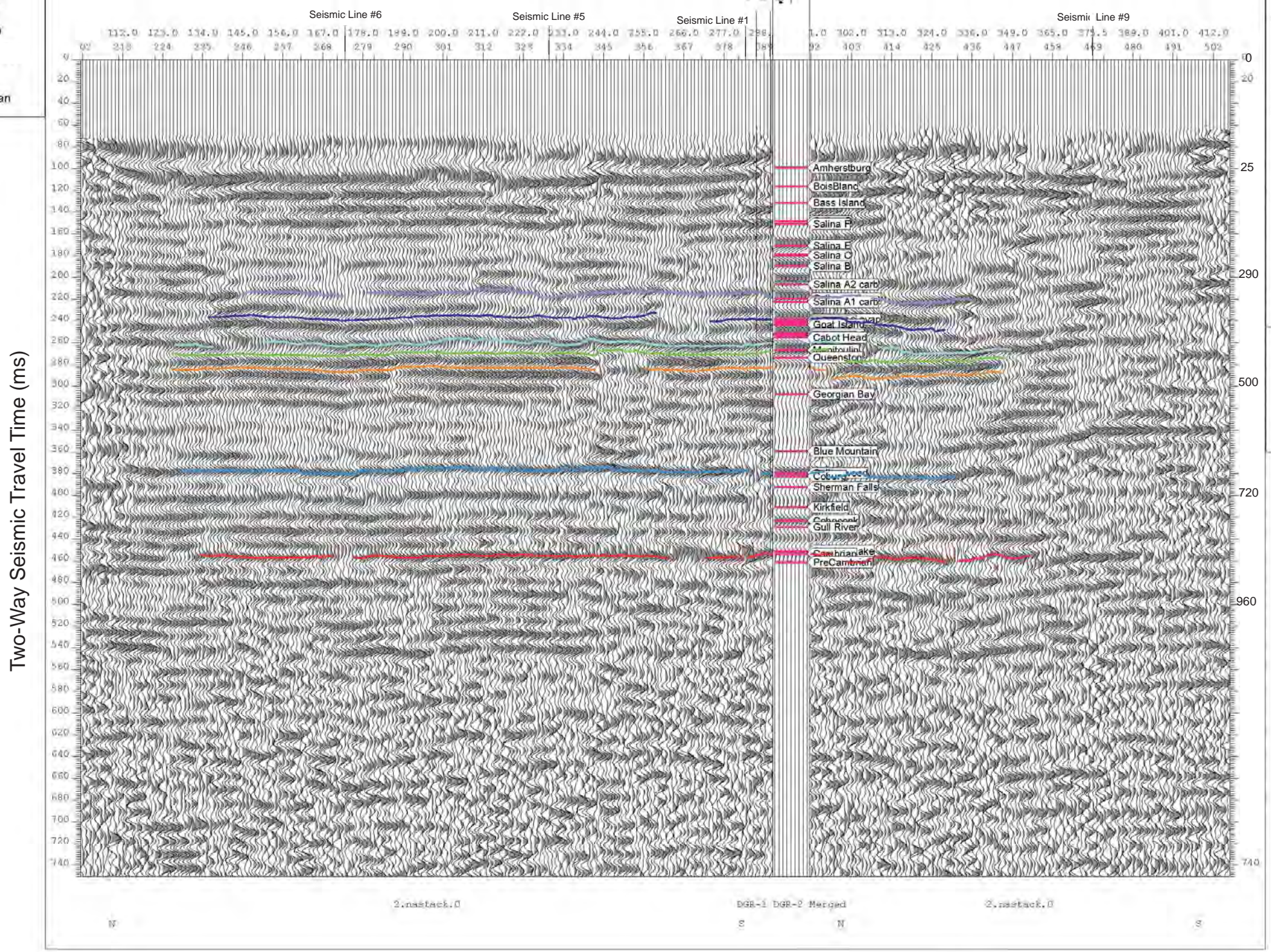
FIGURE 10

Doc. No.: TR-07-15_Figure 10_R0





Receiver Station Number - Top
Common Depth Point (CDP) - Bottom



Approximate Non-linear
Depth Scale (m bgs)

Synthetic Correlation Along Line 2 - Original Processing [Key Seismic]
2D Seismic Survey

Prepared by: ADG
Reviewed by: SNS
Date: 28-Sep-08



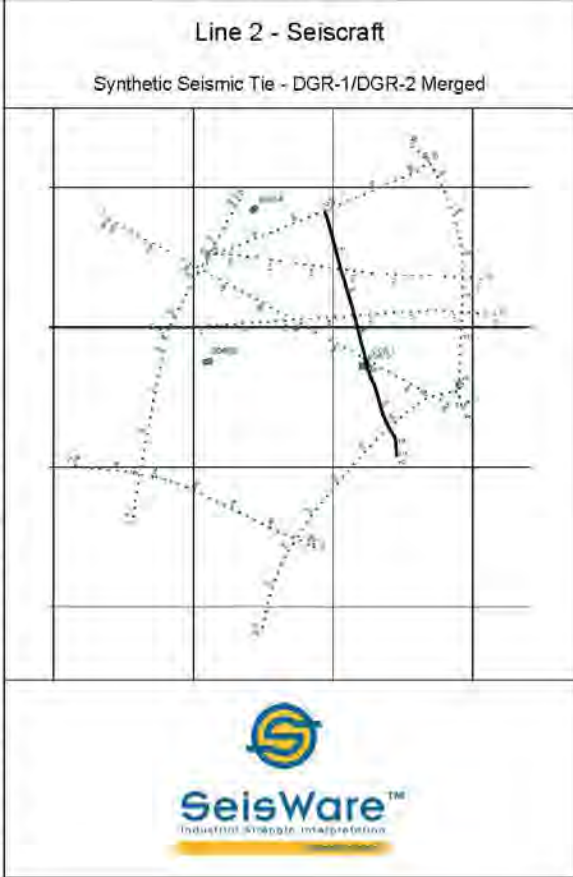
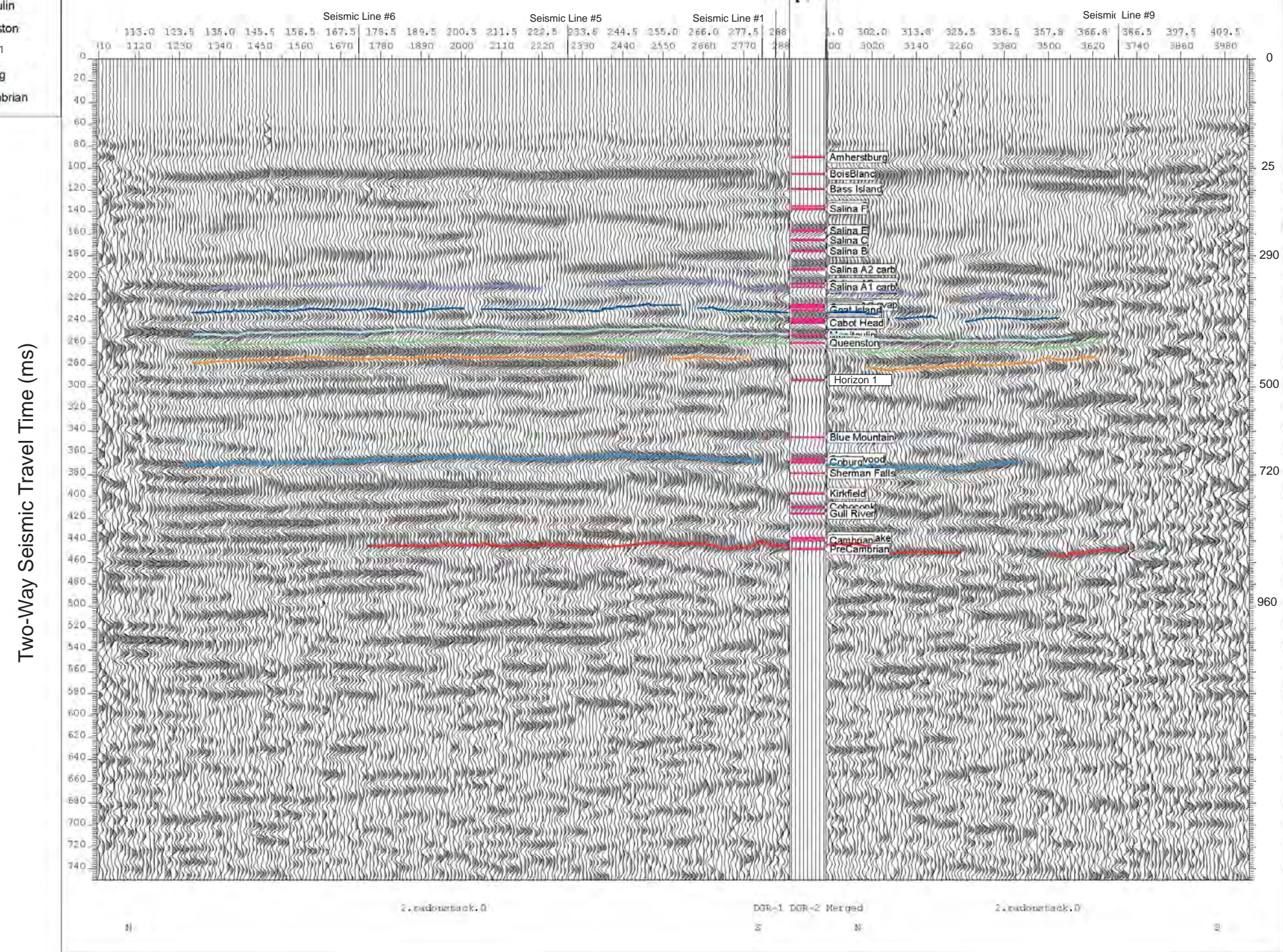
FIGURE 11

Doc. No.: TR-07-15_Figure 11_R0





Receiver Station Number - Top
Common Depth Point (CDP) - Bottom



Approximate Non-linear
Depth Scale (m bgs)

Synthetic Correlation Along Line 2 - Re-processing [Seiscraft]
2D Seismic Survey

Prepared by: ADG
Reviewed by: SNS
Date: 29-Jan-09

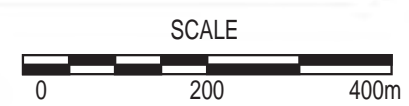
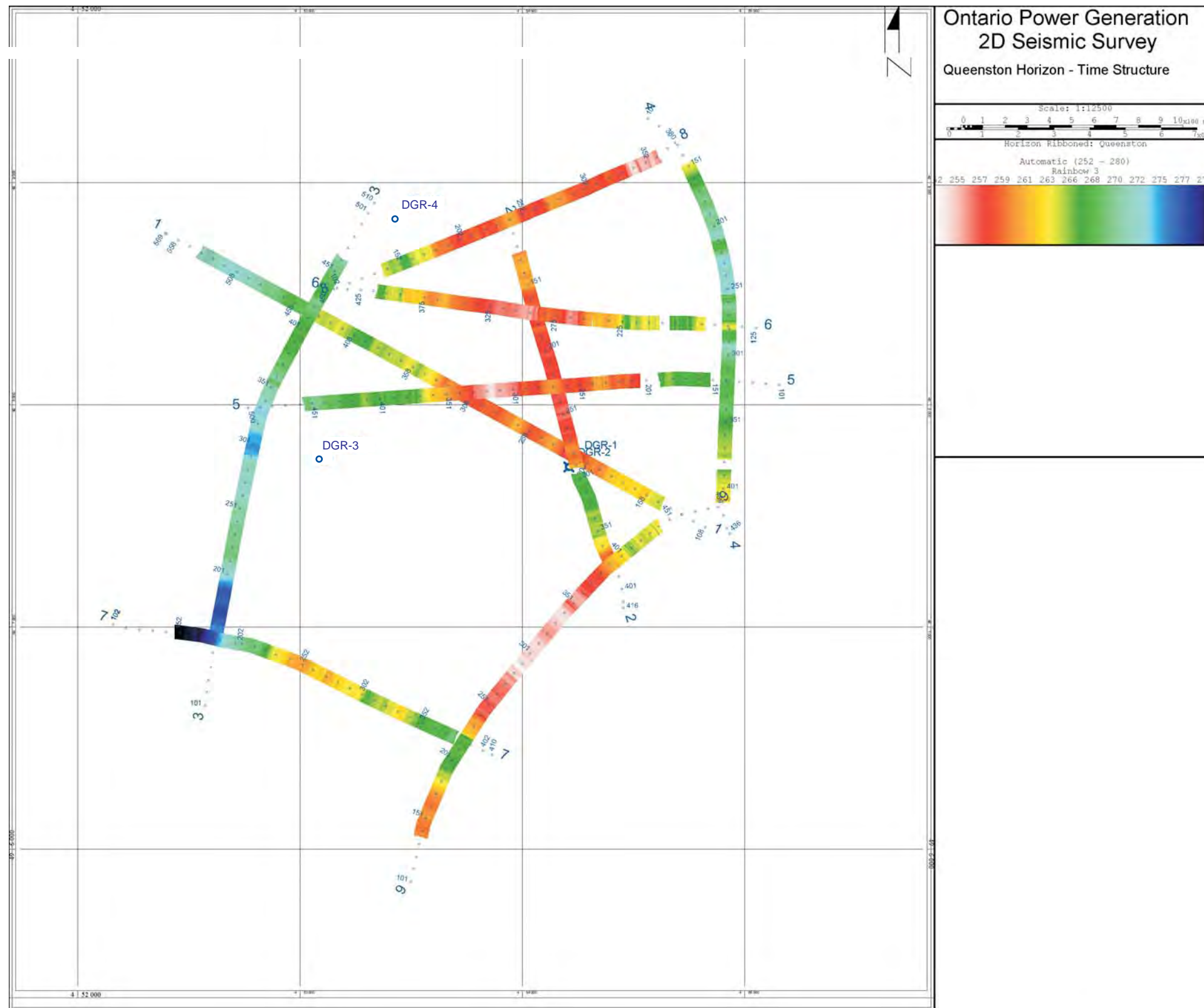


FIGURE 12

Doc. No.: TR-07-15_Figure 12_R0





Queenston Horizon - Time Structure Map
2D Seismic Survey

FIGURE 13

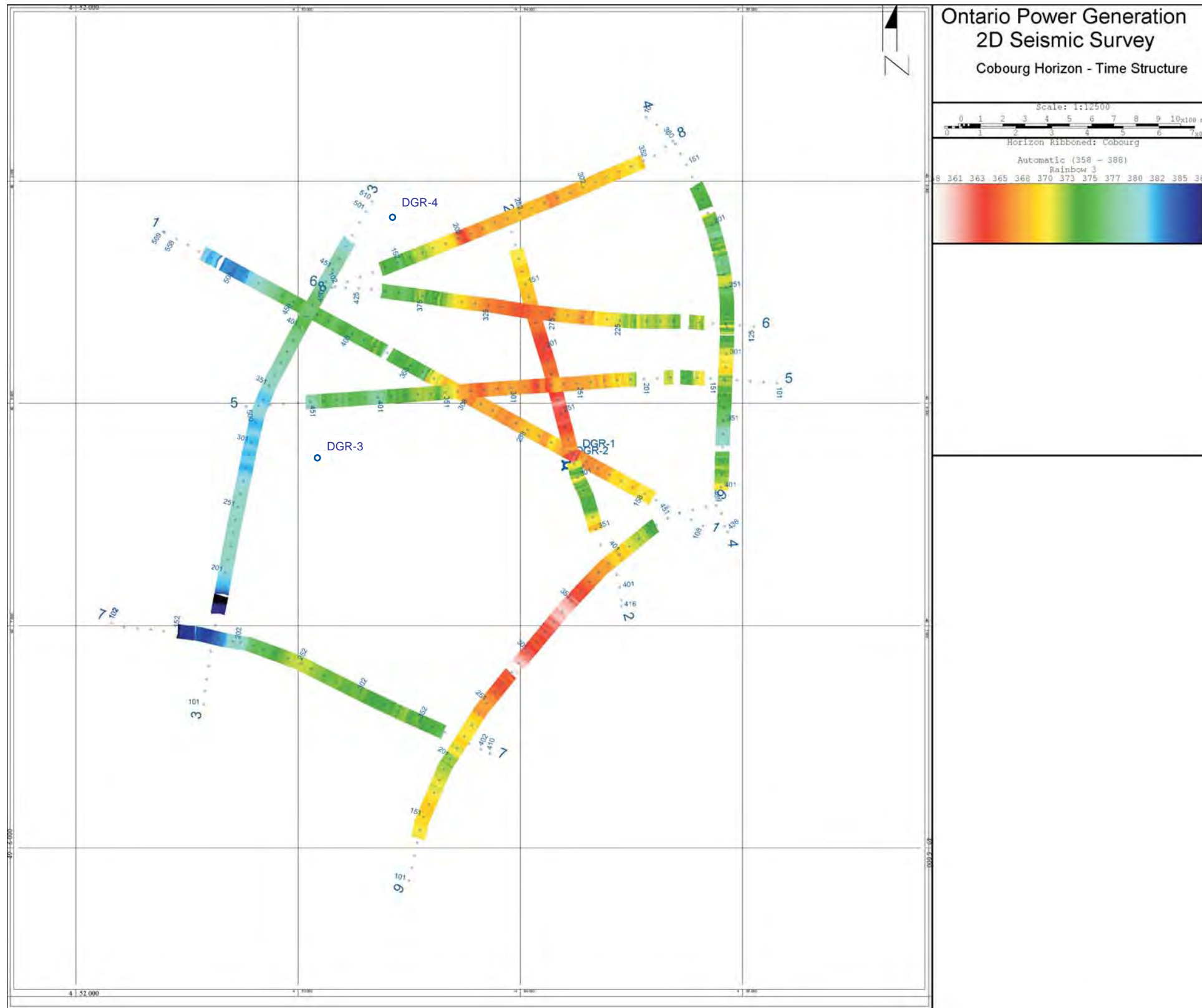
Doc. No.: TR-07-15_Figure 13_R0

Prepared by: ADG

Reviewed by: SNS

Date: 28-Oct-08





Cobourg Horizon - Time Structure Map
2D Seismic Survey

FIGURE 14

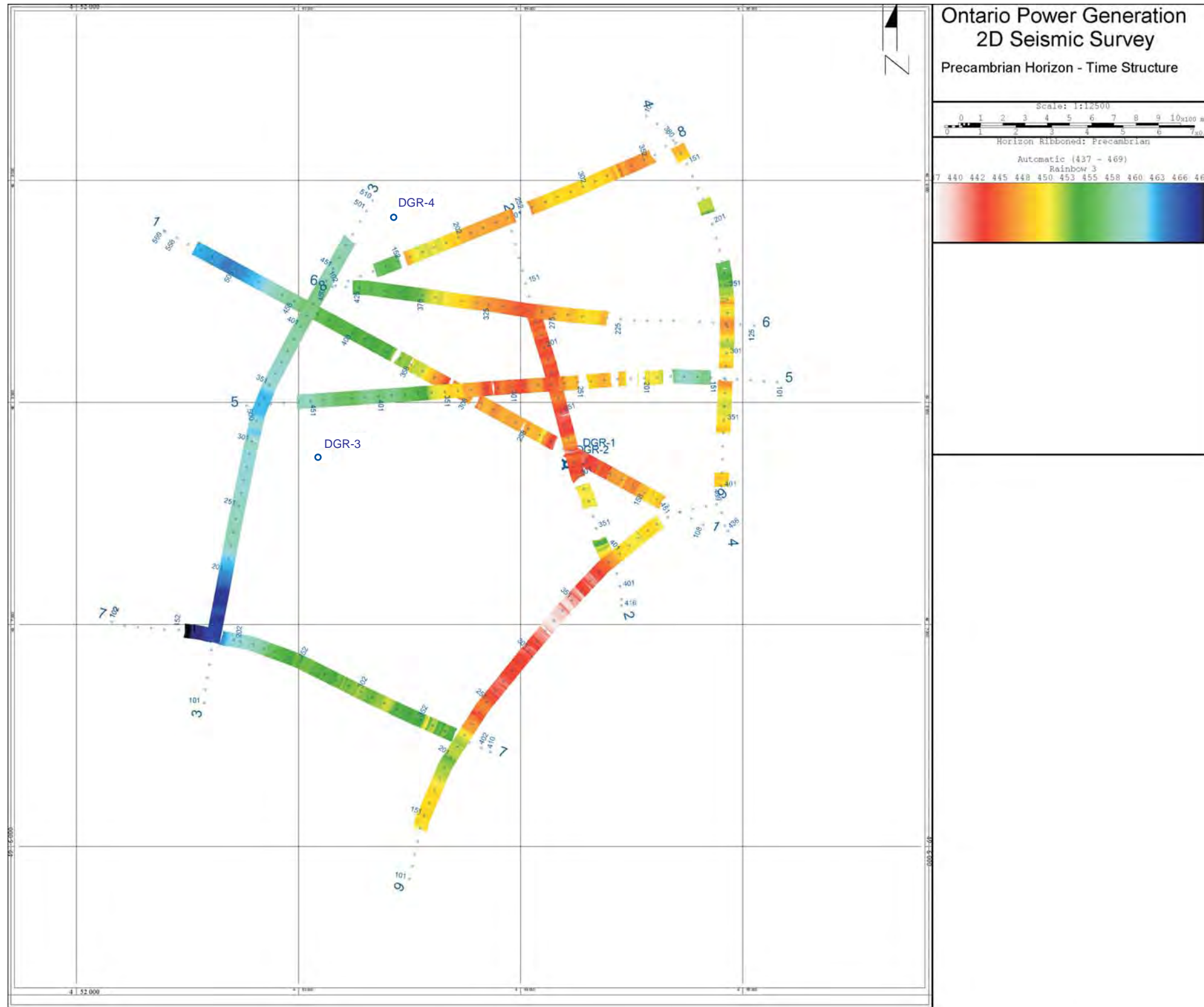
Doc. No.: TR-07-15_Figure 14_R0

Prepared by: ADG

Reviewed by: SNS

Date: 28-Oct-08





Precambrian Horizon - Time Structure Map
2D Seismic Survey

FIGURE 15

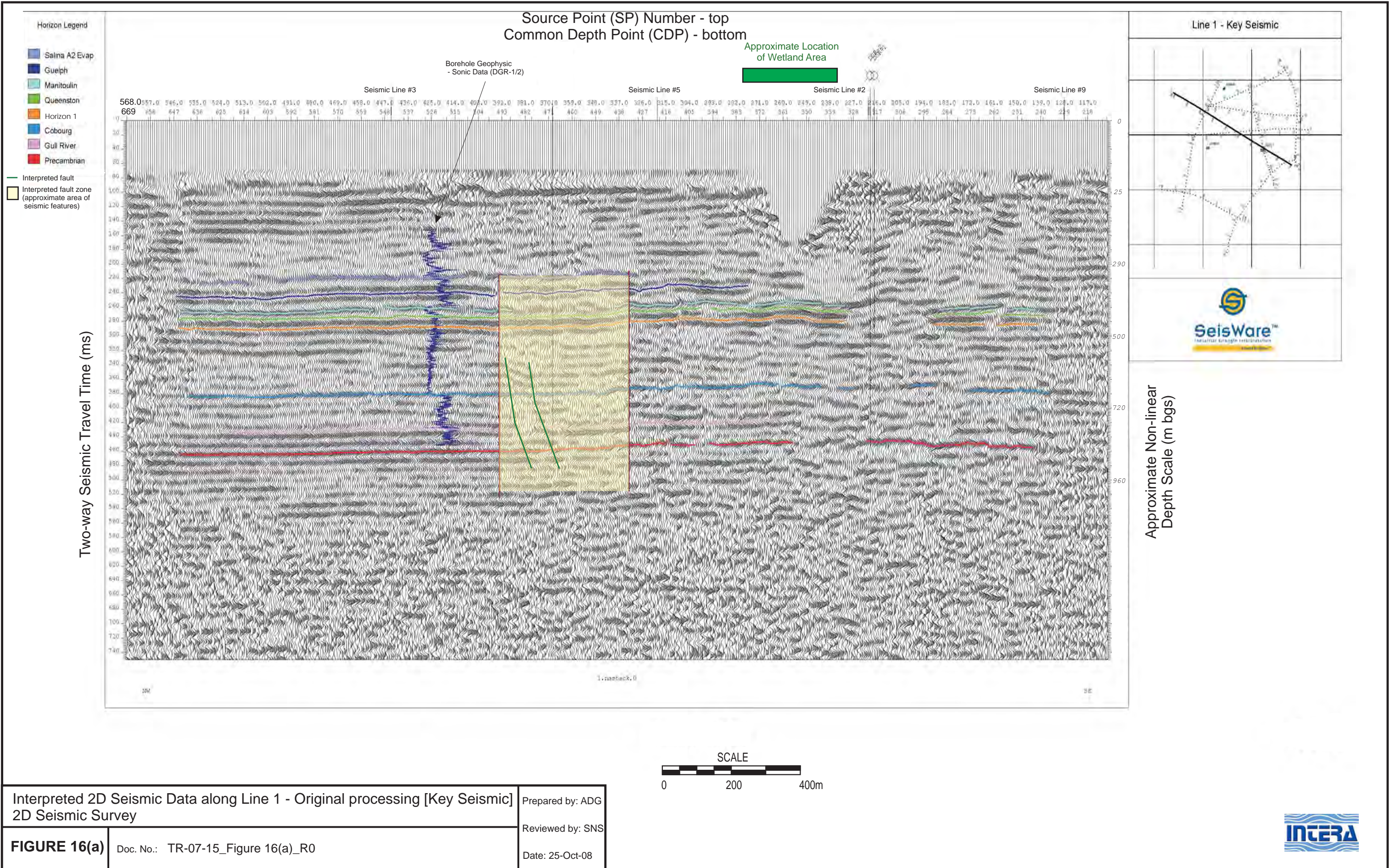
Doc. No.: TR-07-15_Figure 15_R0

Prepared by: ADG

Reviewed by: SNS

Date: 28-Oct-08





Interpreted 2D Seismic Data along Line 1 - Original processing [Key Seismic]
2D Seismic Survey

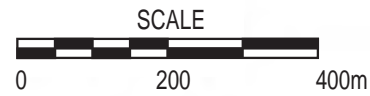
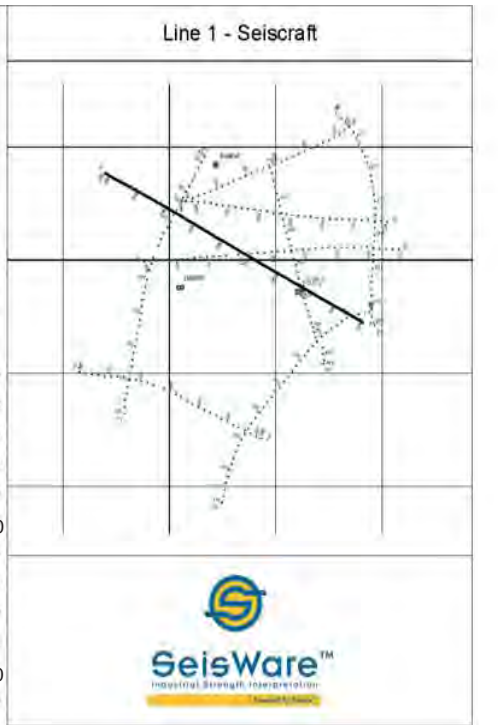
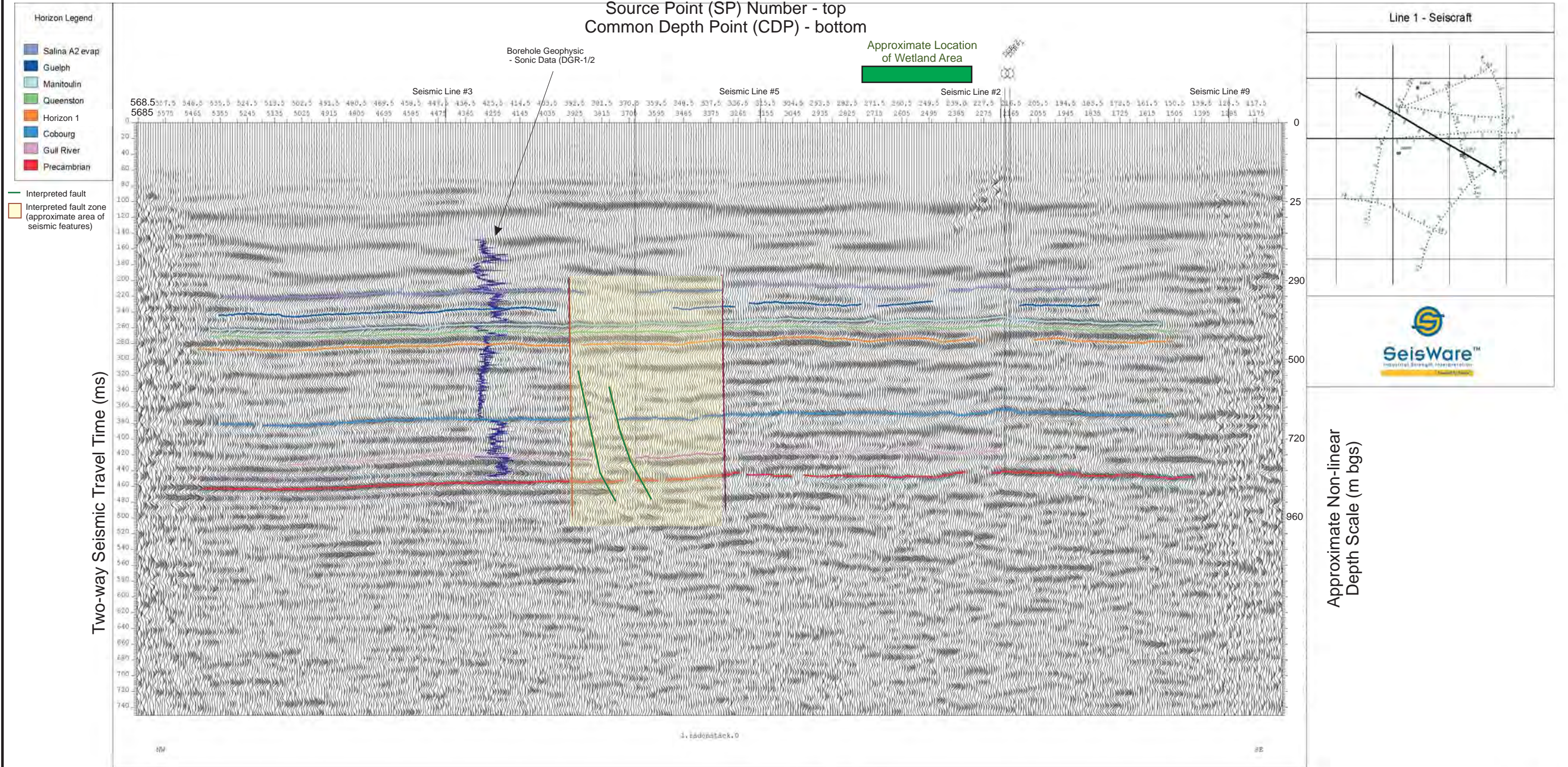
FIGURE 16(a)

Doc. No.: TR-07-15_Figure 16(a)_R0

Prepared by: ADG
Reviewed by: SNS
Date: 25-Oct-08



Source Point (SP) Number - top
Common Depth Point (CDP) - bottom



Interpreted 2D Seismic Data along Line 1 - Re-processing [Seiscraft]
2D Seismic Survey

FIGURE 16(b) Doc. No.: TR-07-15_Figure 16(b)_R0

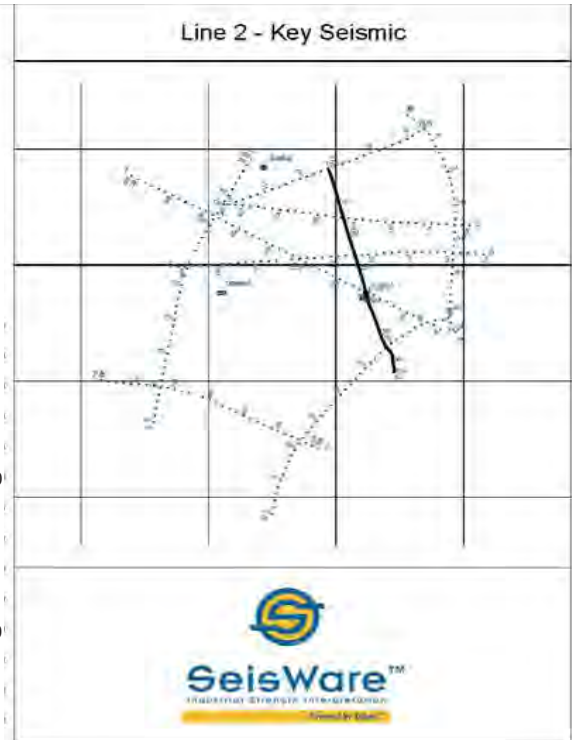
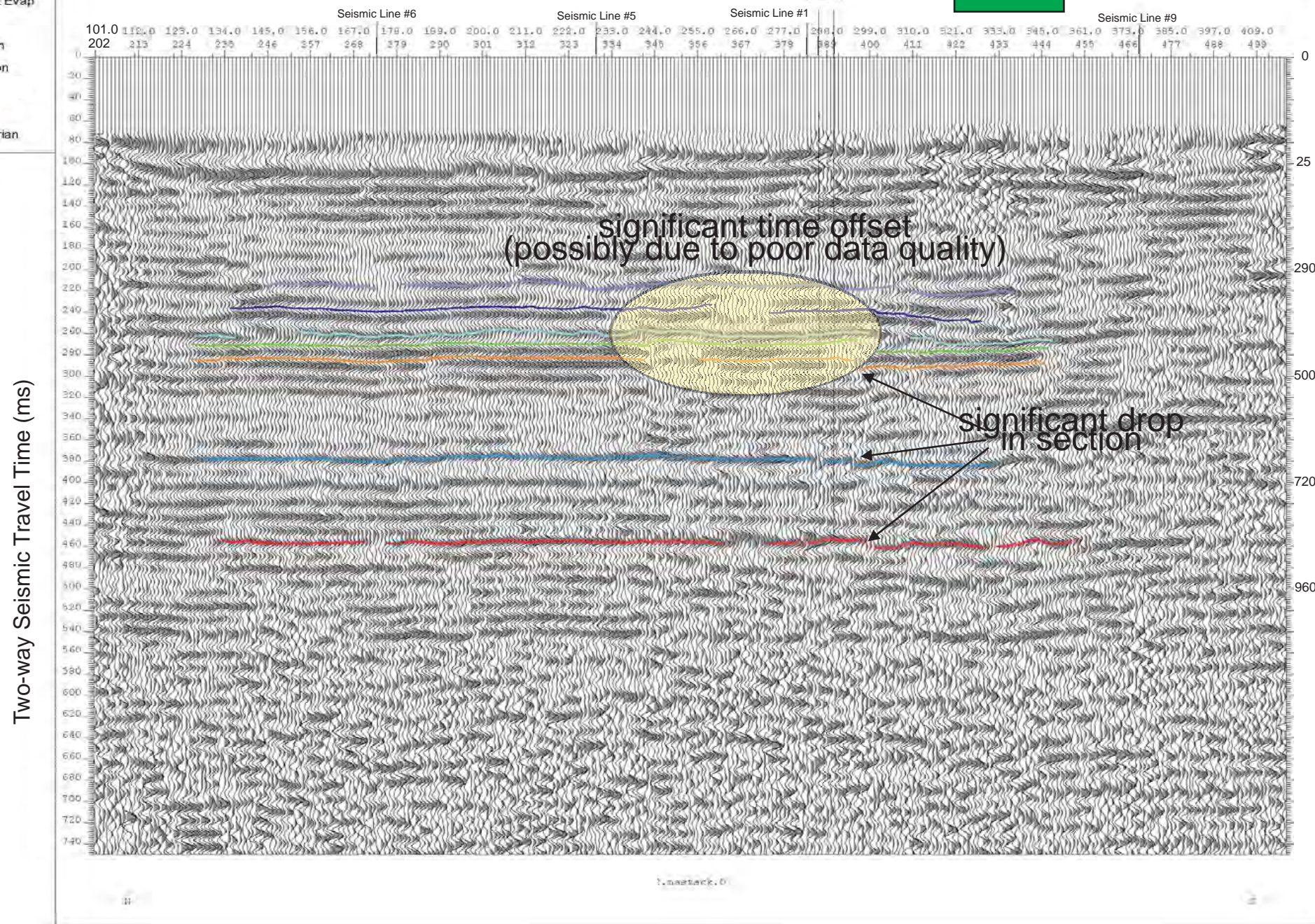
Prepared by: ADG
Reviewed by: SNS
Date: 25-Oct-08



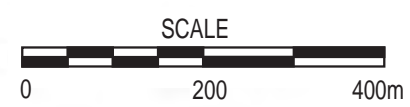
Source Point (SP) Number - top
Common Depth Point (CDP) - bottom

Approximate Location
of Closed Landfill

- Horizon Legend
- Salina A2 Evap
 - Guelph
 - Manitoulin
 - Queenston
 - Horizon 1
 - Cobourg
 - Precambrian



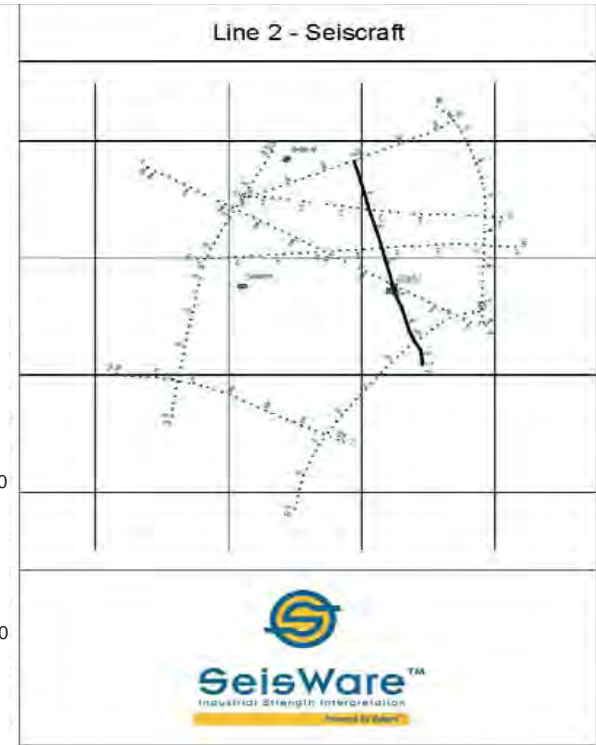
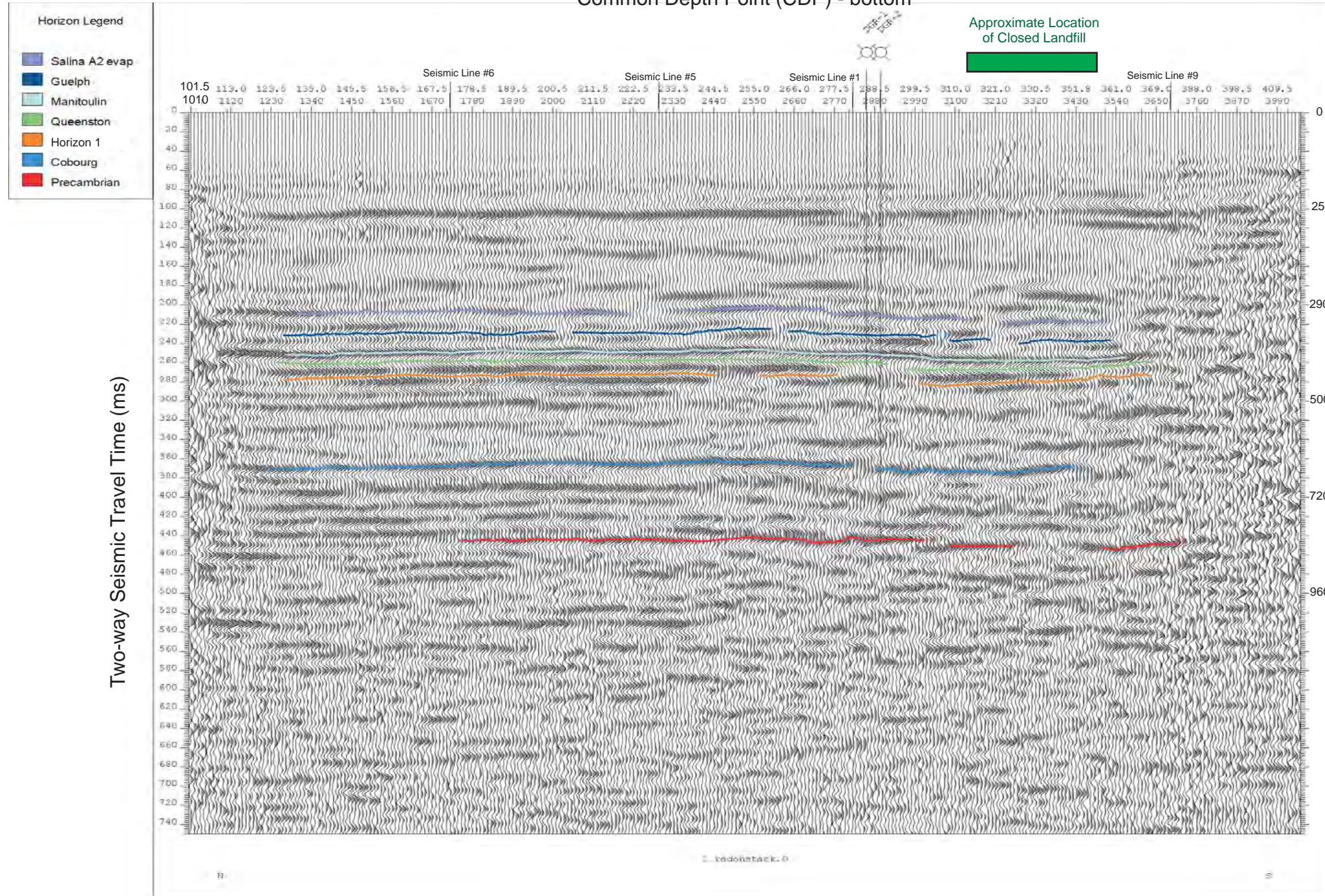
Approximate Non-linear
Depth Scale (m bgs)



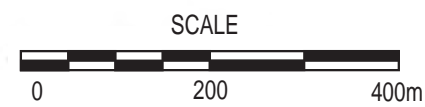
Interpreted 2D Seismic Data along Line 2 - Original Processing [Key Seismic] 2D Seismic Survey		Prepared by: ADG
FIGURE 17(a)		Reviewed by: SNS
Doc. No.: TR-07-15_Figure 17(a)_R0		Date: 29-Jan-09



Source Point (SP) Number - top
Common Depth Point (CDP) - bottom



Approximate Non-linear
Depth Scale (m bgs)



Interpreted 2D Seismic Data along Line 2 - Re-processing [Seiscraft]
2D Seismic Survey

Prepared by: ADG

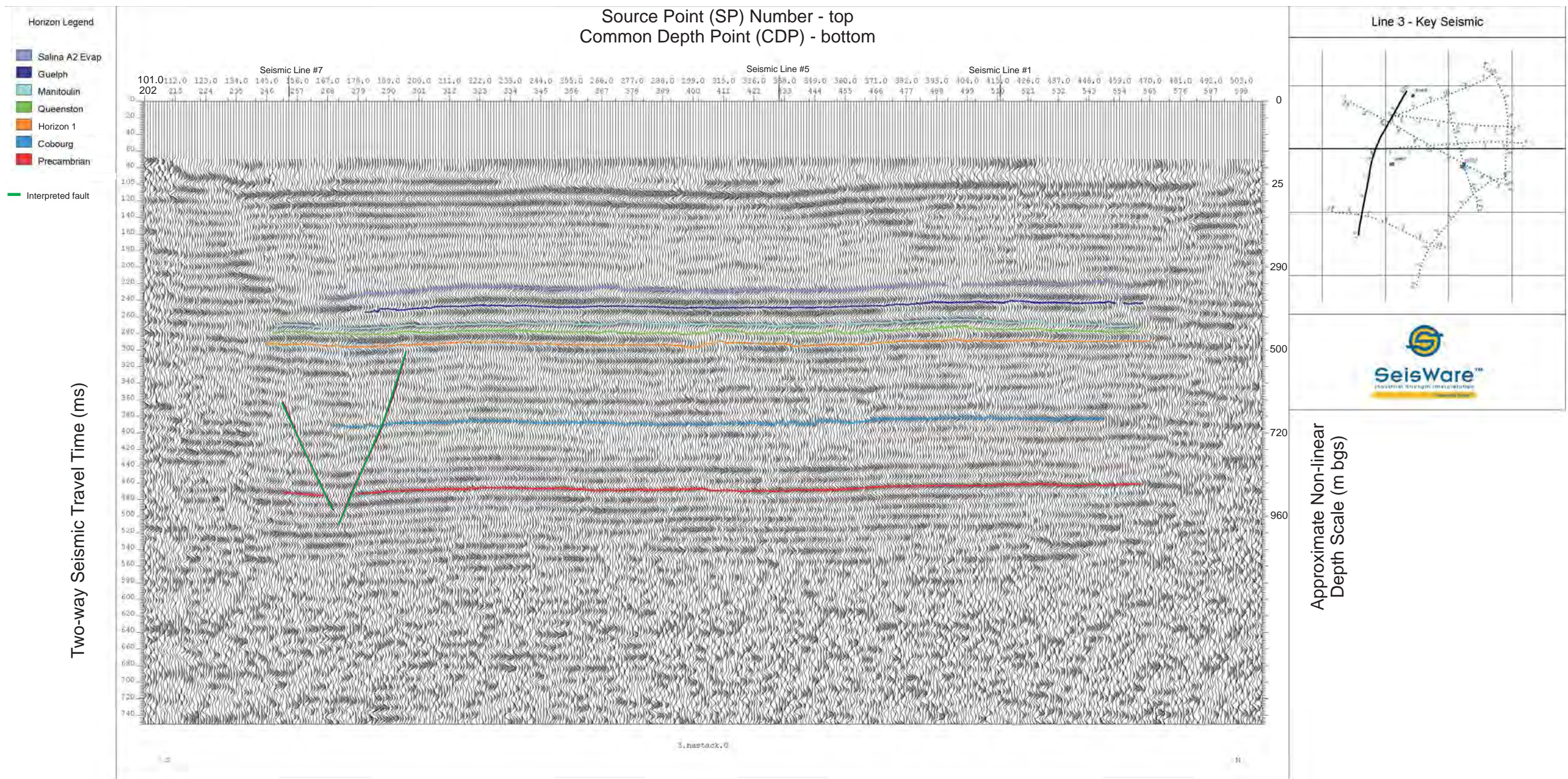
Reviewed by: SNS

Date: 29-Jan-09

FIGURE 17(b)

Doc. No.: TR-07-15_Figure 17(b)_R0

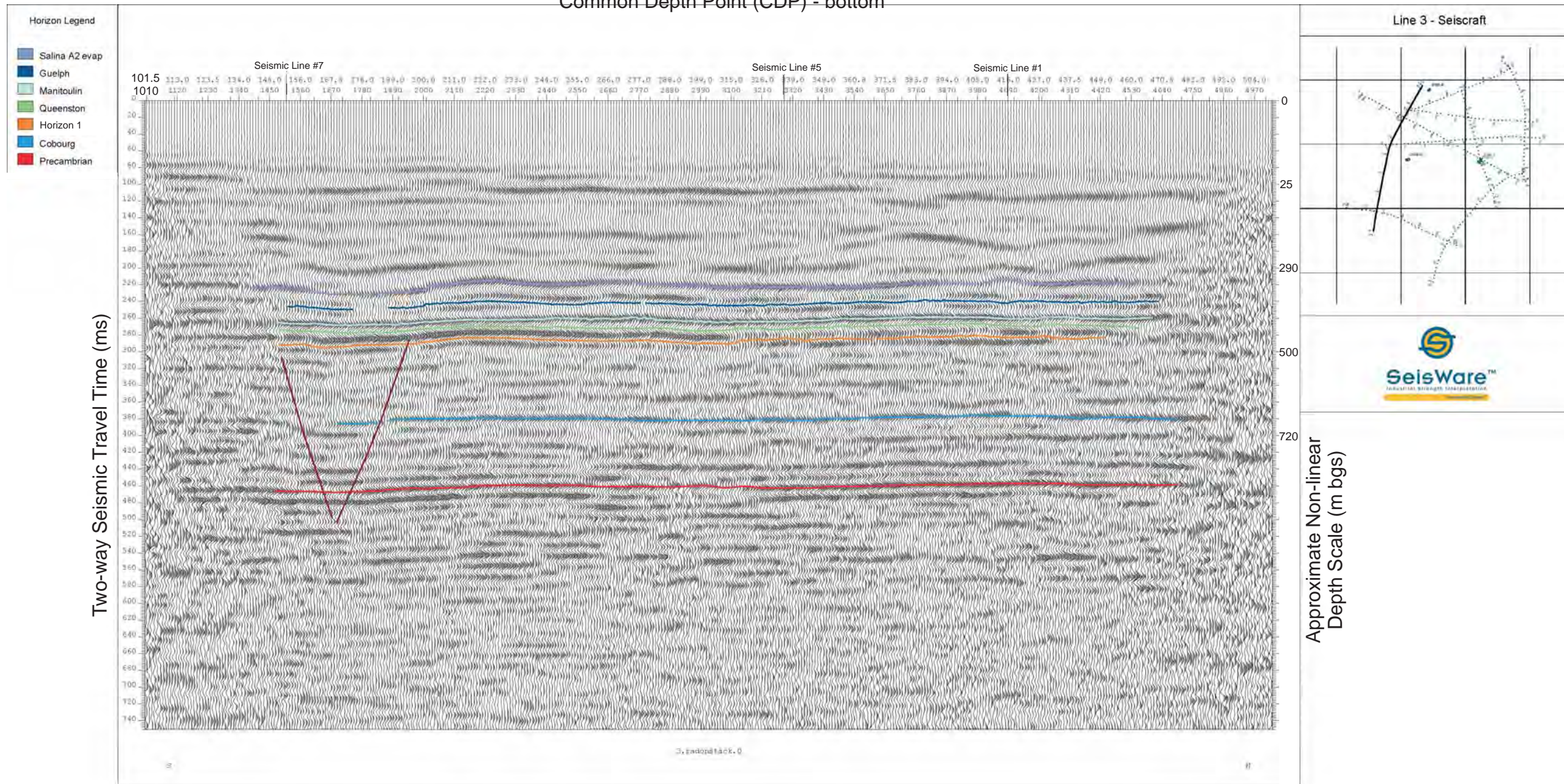




Interpreted 2D Seismic Data along Line 3 - Original Processing [Key Seismic] 2D Seismic Survey		Prepared by: ADG
FIGURE 18(a)		Reviewed by: SNS
Doc. No.: TR-07-15_Figure 18(a)_R0		Date: 29-Jan-09



Source Point (SP) Number - top
Common Depth Point (CDP) - bottom



Interpreted 2D Seismic Data along Line 3 - Re-processing [Seiscraft]
2D Seismic Survey

FIGURE 18(b)

Doc. No.: TR-07-15_Figure 18(b)_R0

Prepared by: ADG

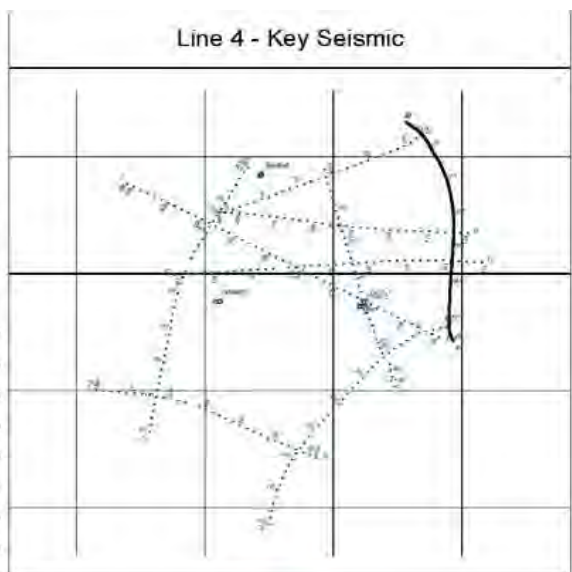
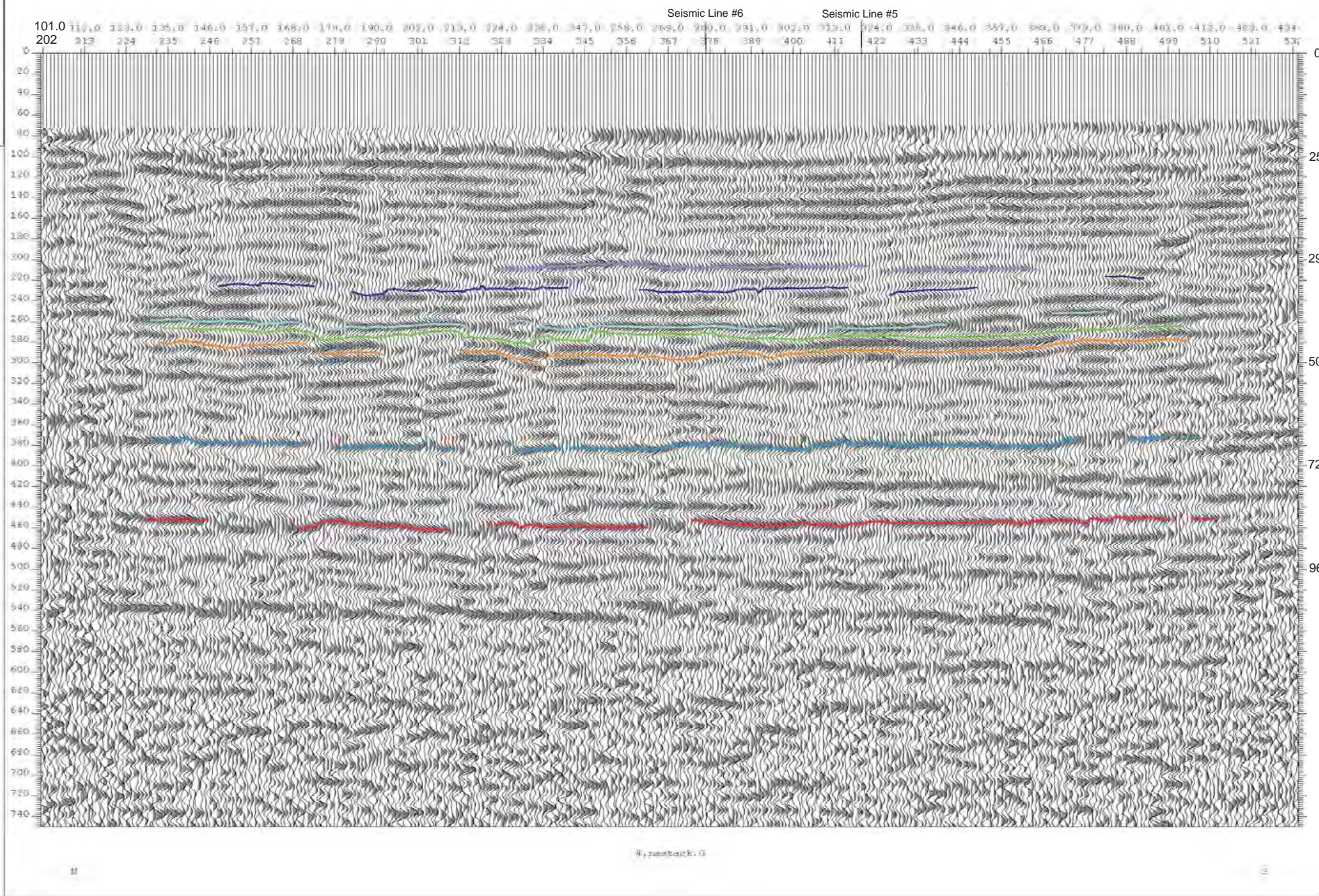
Reviewed by: SNS

Date: 29-Jan-09

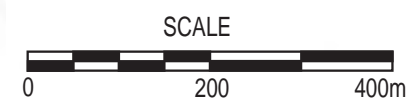


Source Point (SP) Number - top
Common Depth Point (CDP) - bottom

- Horizon Legend
- Salina A2 Evap
 - Guelph
 - Manitoulin
 - Queenston
 - Horizon 1
 - Cobourg
 - Precambrian



Approximate Non-linear
Depth Scale (m bgs)



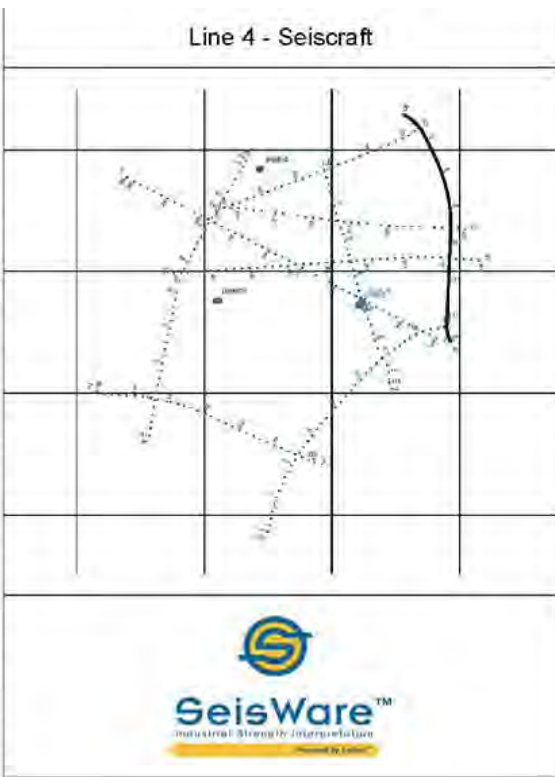
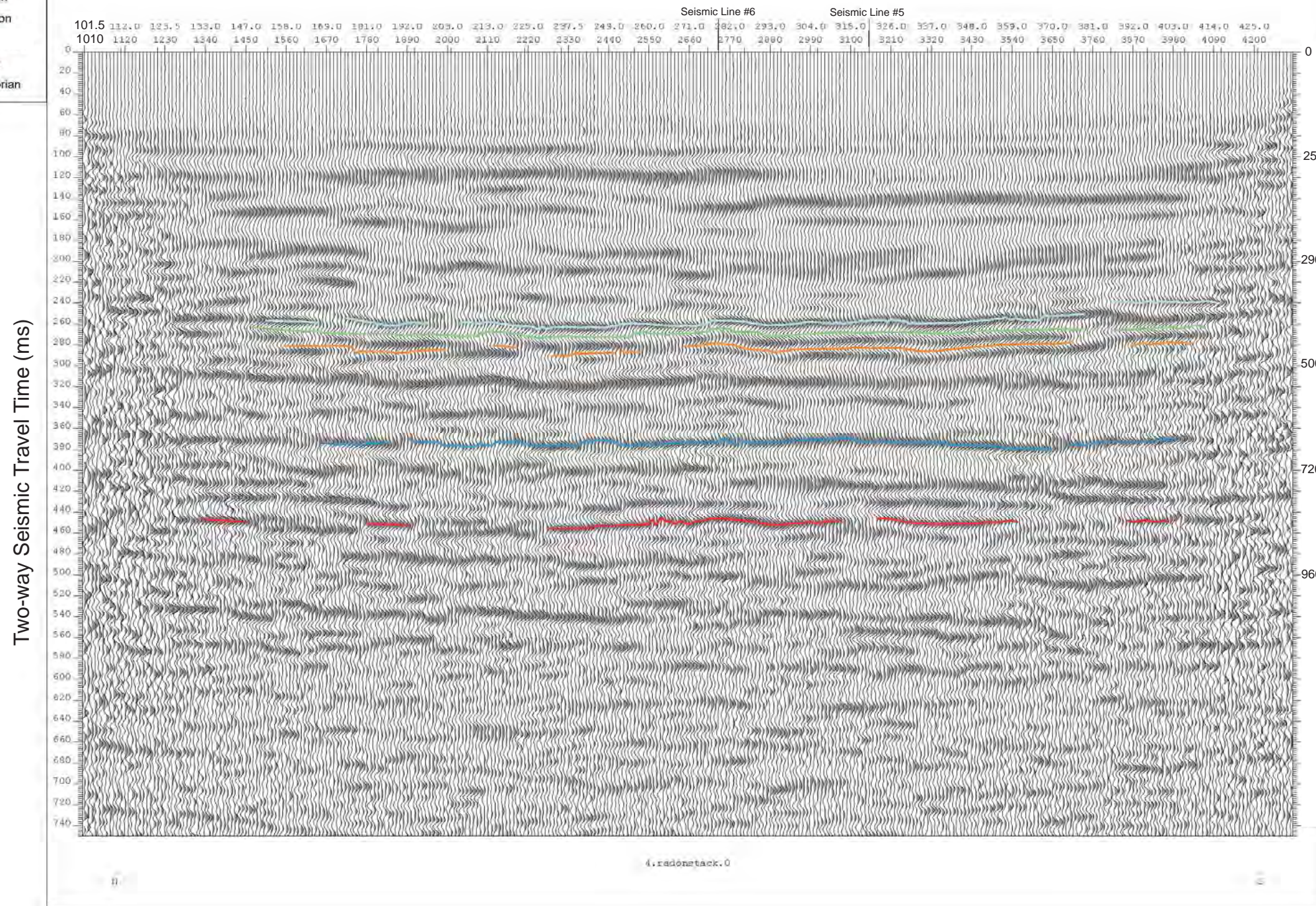
Interpreted 2D Seismic Data along Line 4 - Original Processing [Key Seismic] 2D Seismic Survey		Prepared by: ADG
FIGURE 19(a)		Reviewed by: SNS
Doc. No.: TR-07-15_Figure 19(a)_R0		Date: 28-Sep-08



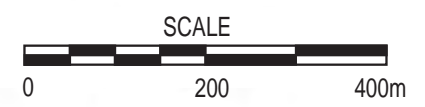
Source Point (SP) Number - top
Common Depth Point (CDP) - bottom

Horizon Legend

- Manitoulin
- Queenston
- Horizon 1
- Cobourg
- Precambrian

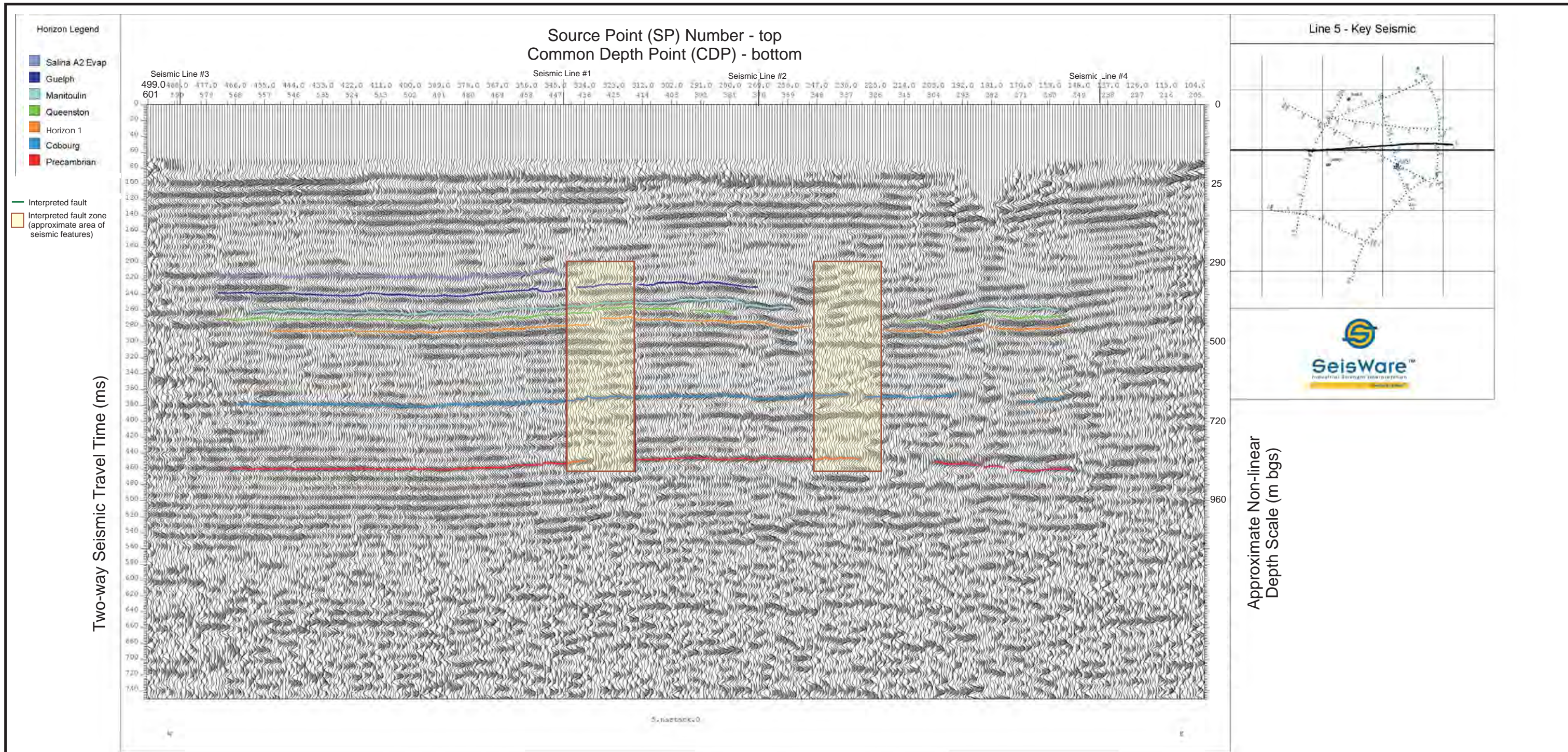


Approximate Non-linear
Depth Scale (m bgs)



Interpreted 2D Seismic Data along Line 4 - Re-processing [Seiscraft] 2D Seismic Survey	Prepared by: ADG Reviewed by: SNS Date: 28-Sep-08
FIGURE 19(b)	Doc. No.: TR-07-15_Figure 19(b)_R0





Interpreted 2D Seismic Data along Line 5 - Original Processing [Key Seismic]
2D Seismic Survey

FIGURE 20(a)

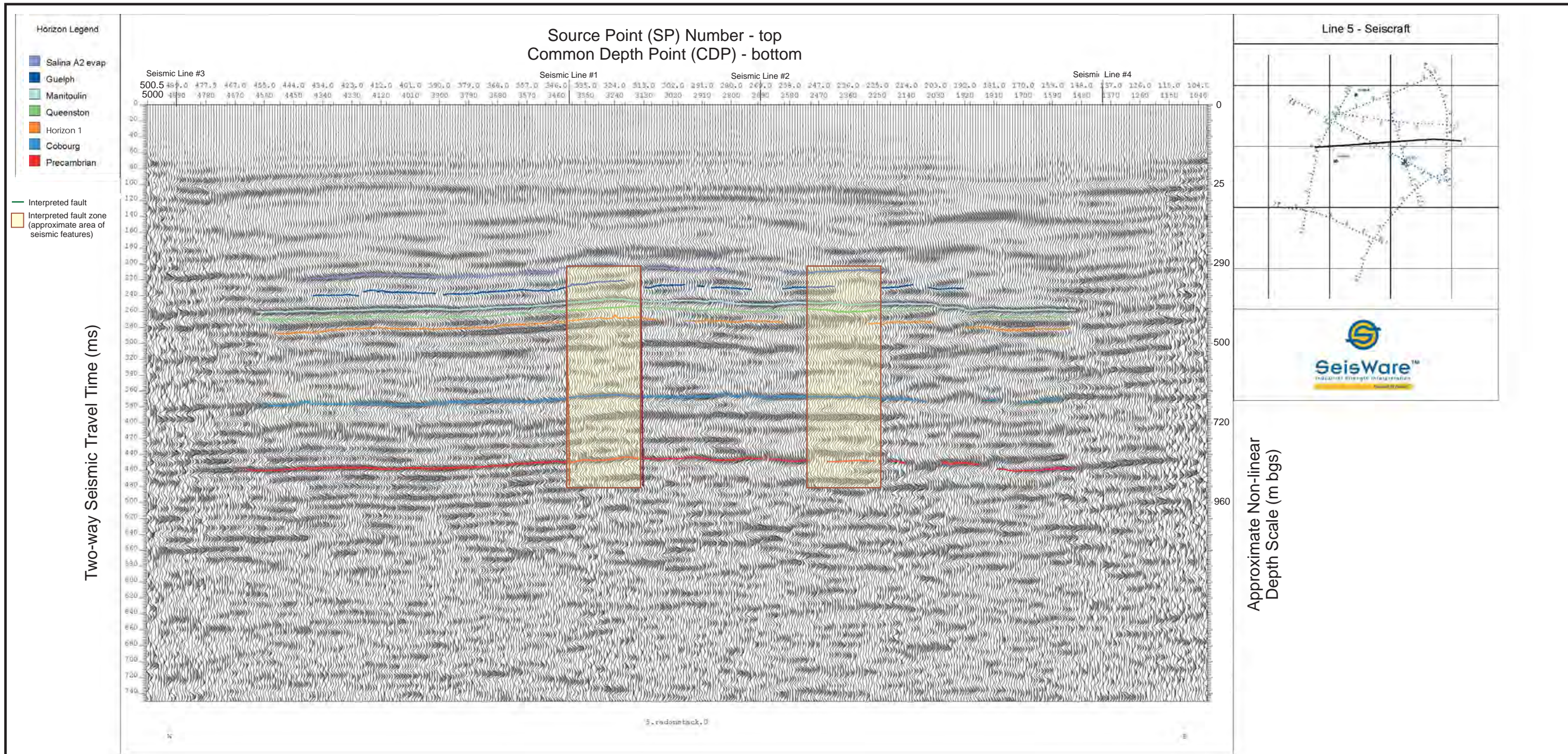
Doc. No.: TR-07-15_Figure 20(a)_R0

Prepared by: ADG

Reviewed by: SNS

Date: 28-Sep-08





Interpreted 2D Seismic Data along Line 5 - Re-processing [Seiscraft]
2D Seismic Survey

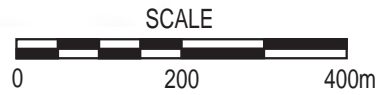
FIGURE 20(b)

Doc. No.: TR-07-15_Figure 20(b)_R0

Prepared by: ADG

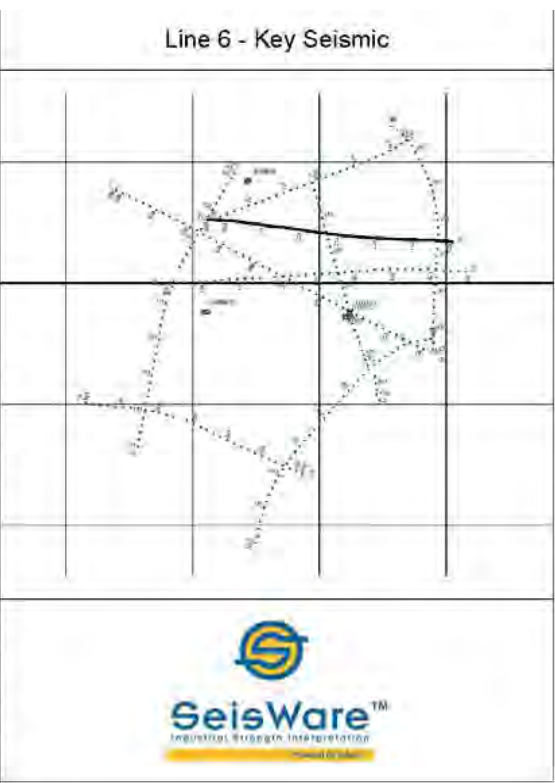
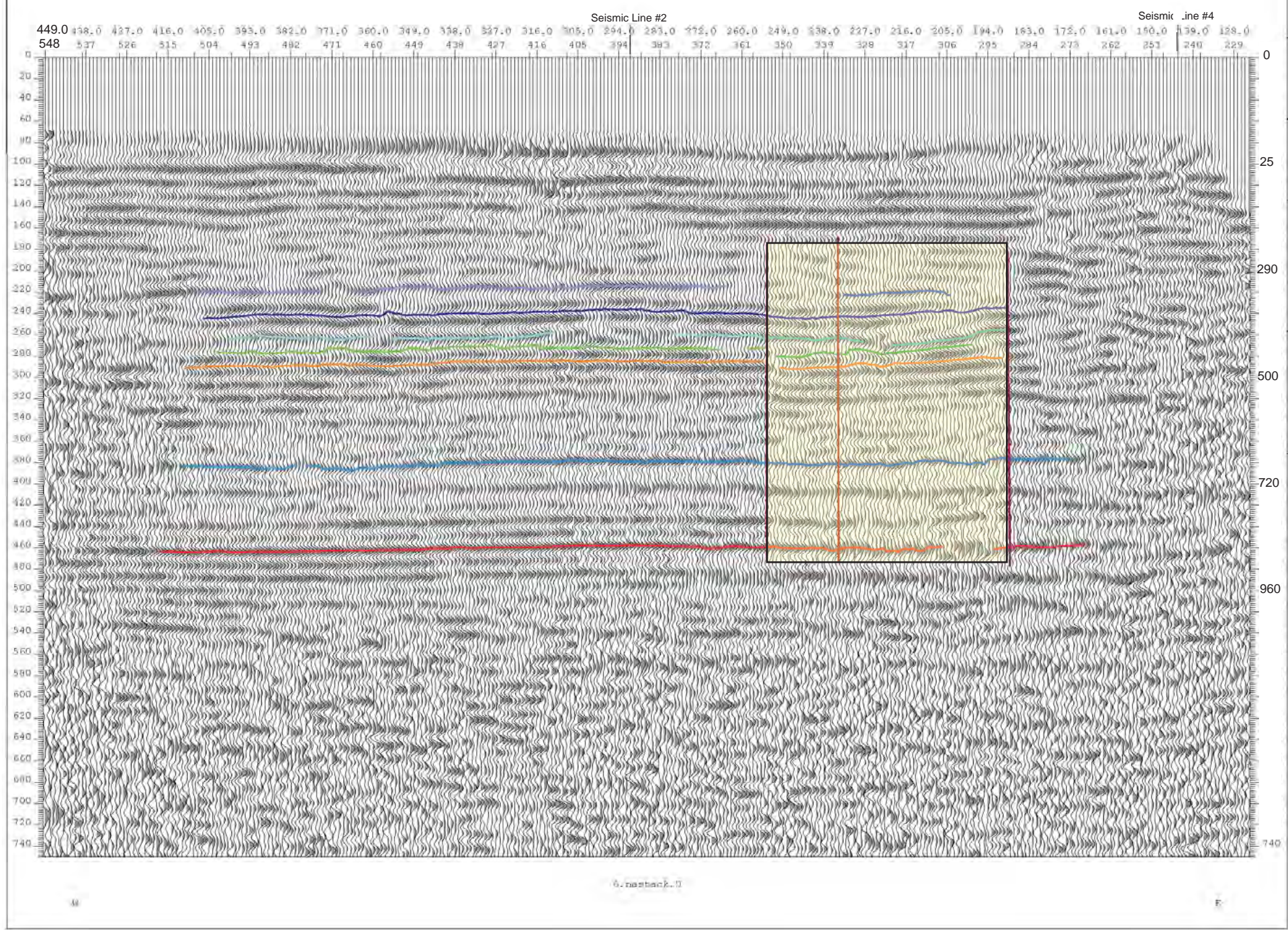
Reviewed by: SNS

Date: 28-Sep-08



Source Point (SP) Number - top
Common Depth Point (CDP) - bottom

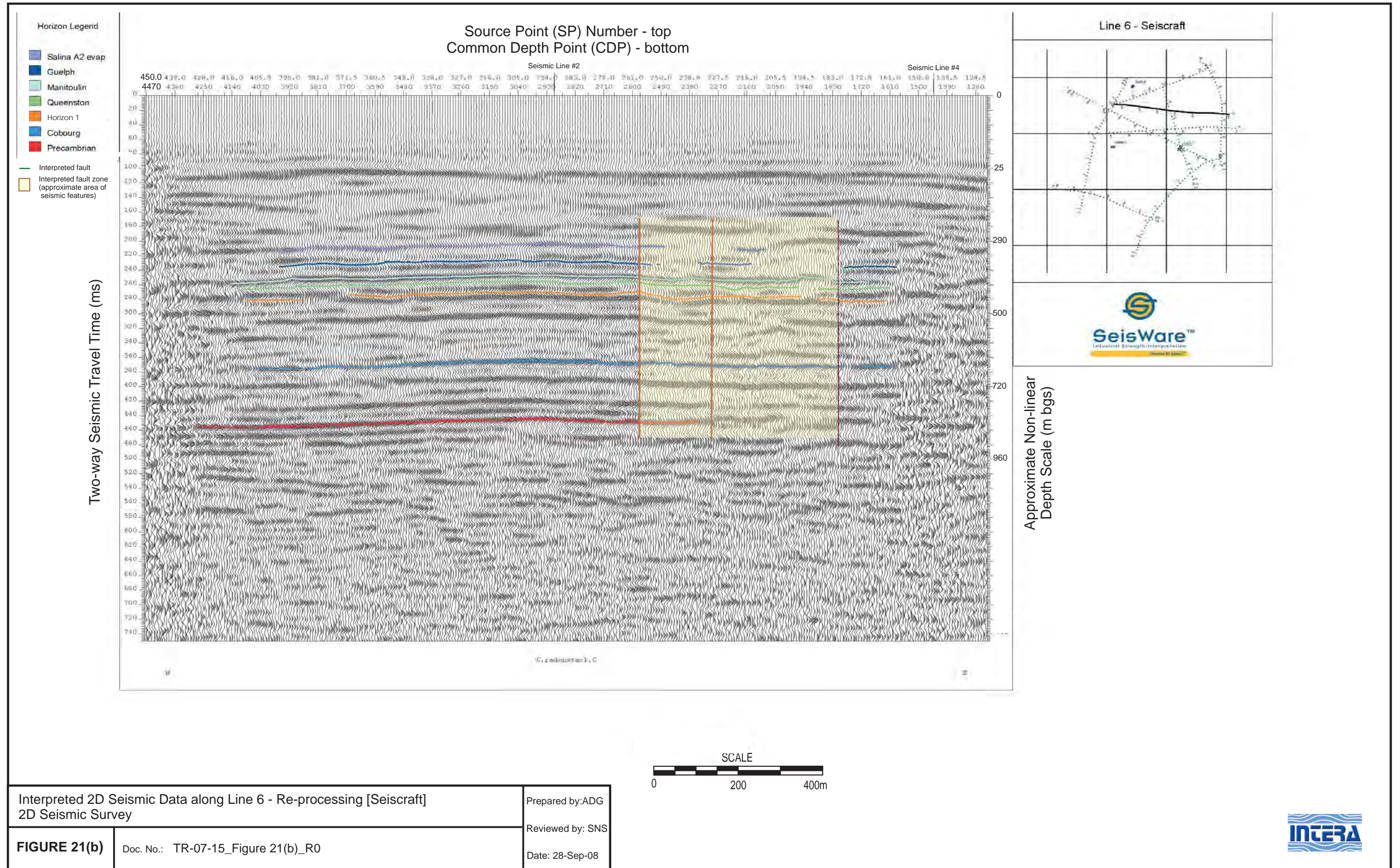
- Horizon Legend
- Salina A2 Evap
 - Guelph
 - Manitoulin
 - Queenston
 - Horizon 1
 - Cobourg
 - Precambrian
- Interpreted fault
Interpreted fault zone (approximate area of seismic features)



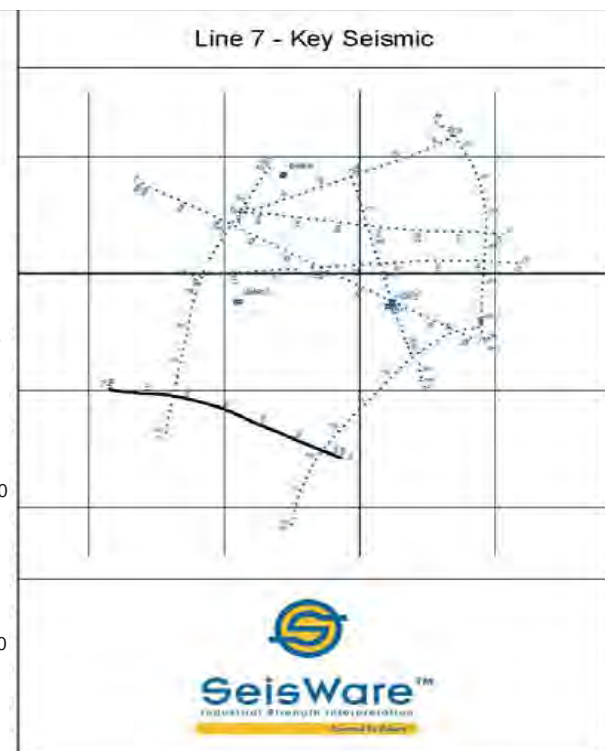
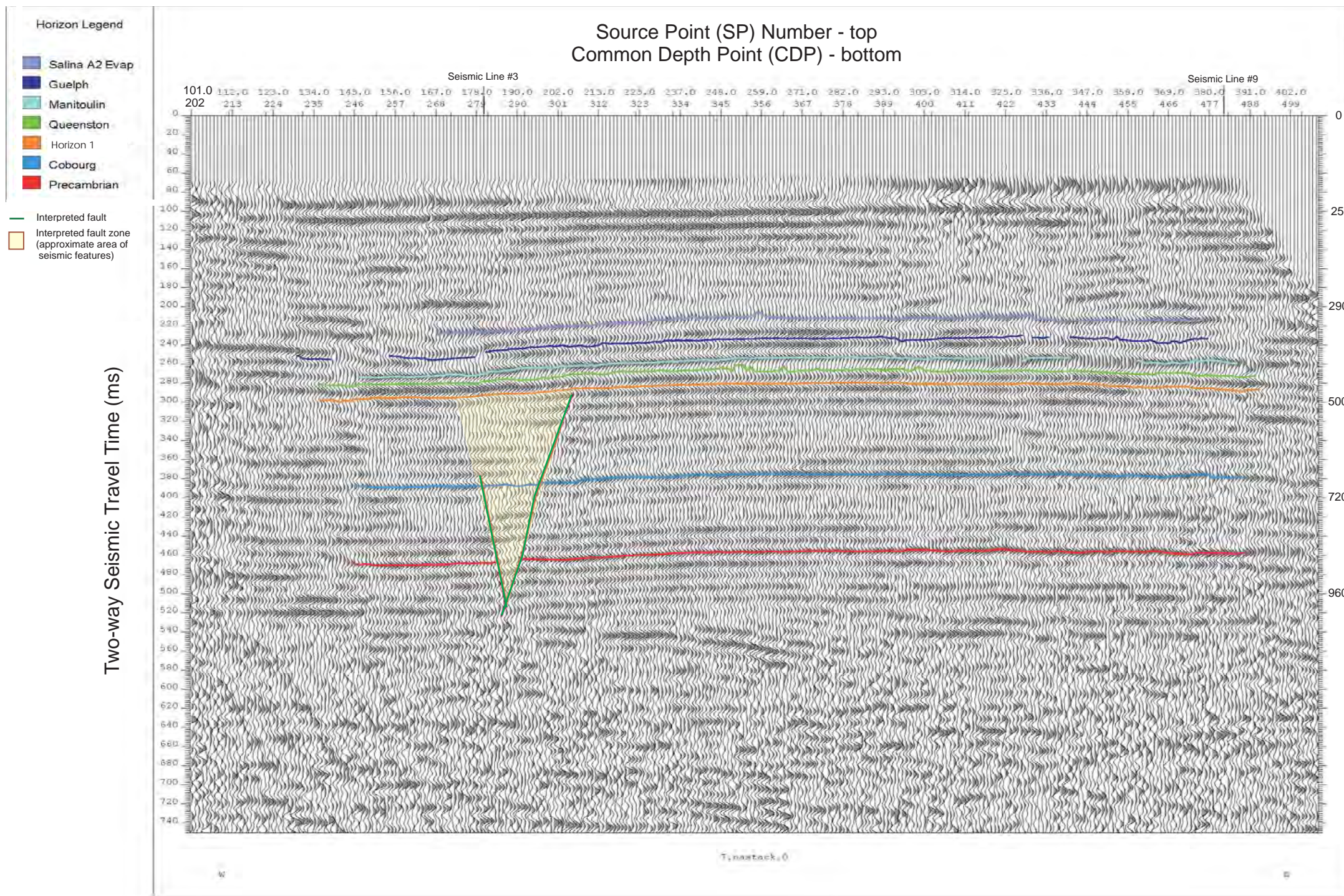
Approximate Non-linear
Depth Scale (m bgs)

Interpreted 2D Seismic Data along Line 6 - Original Processing [Key Seismic] 2D Seismic Survey		Prepared by: ADG
FIGURE 21(a)		Reviewed by: SNS
Doc. No.: TR-07-15_Figure 21(a)_R0		Date: 28-Oct-08

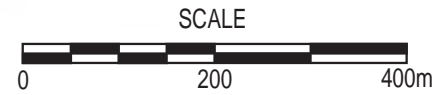




Source Point (SP) Number - top
Common Depth Point (CDP) - bottom



Approximate Non-linear
Depth Scale (m bgs)



Interpreted 2D Seismic Data along Line 7 - Original Processing [Key Seismic]
2D Seismic Survey

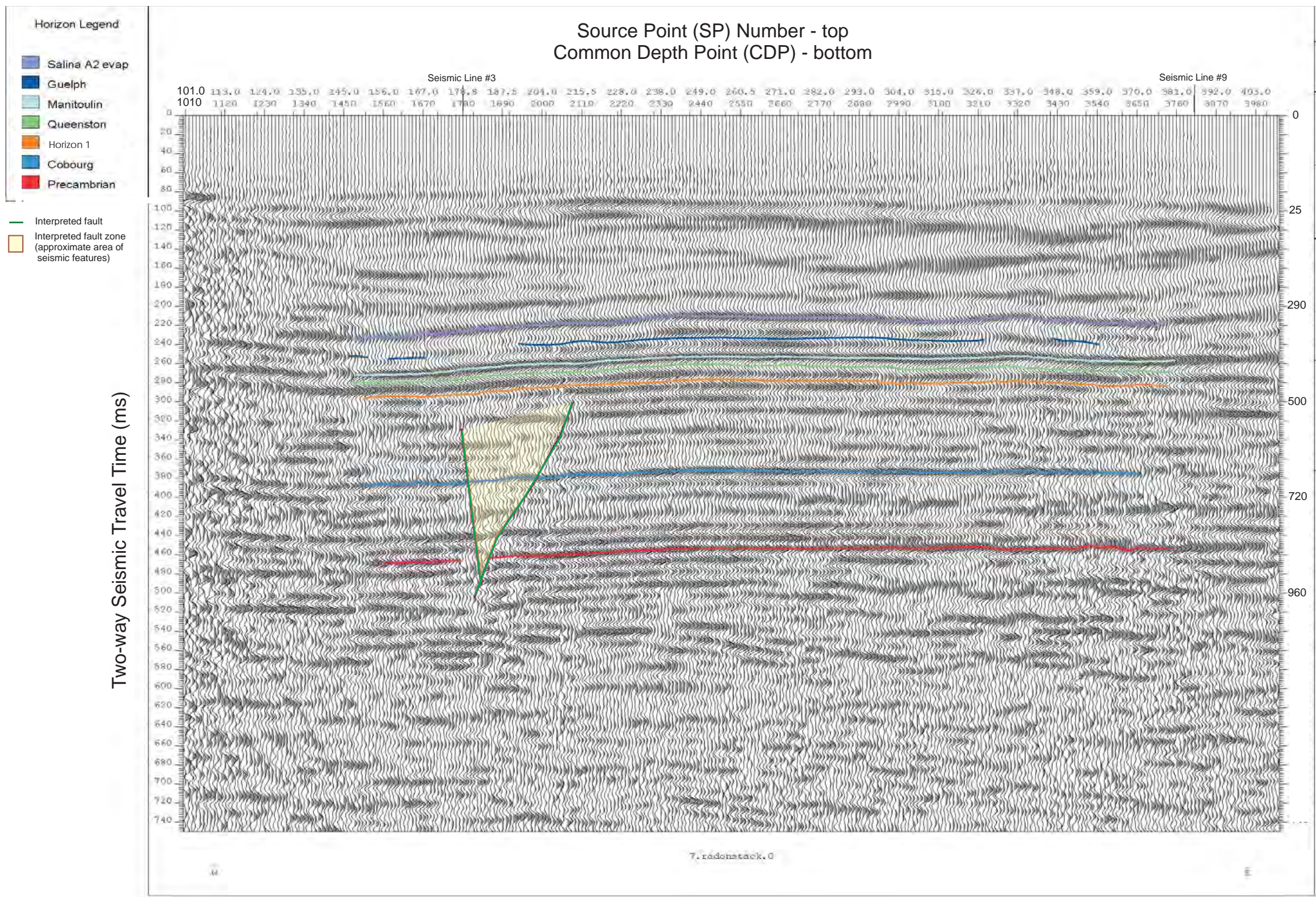
Prepared by: ADG
Reviewed by: SNS
Date: 28-Sep-08

FIGURE 22(a)

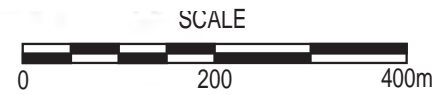
Doc. No.: TR-07-15_Figure 22(a)_R0



Source Point (SP) Number - top
Common Depth Point (CDP) - bottom



Approximate Non-linear
Depth Scale (m bgs)



Interpreted 2D Seismic Data along Line 7 - Re-processing [Seiscraft]
2D Seismic Survey

Prepared by: ADG
Reviewed by: SNS
Date: 28-Sep-08

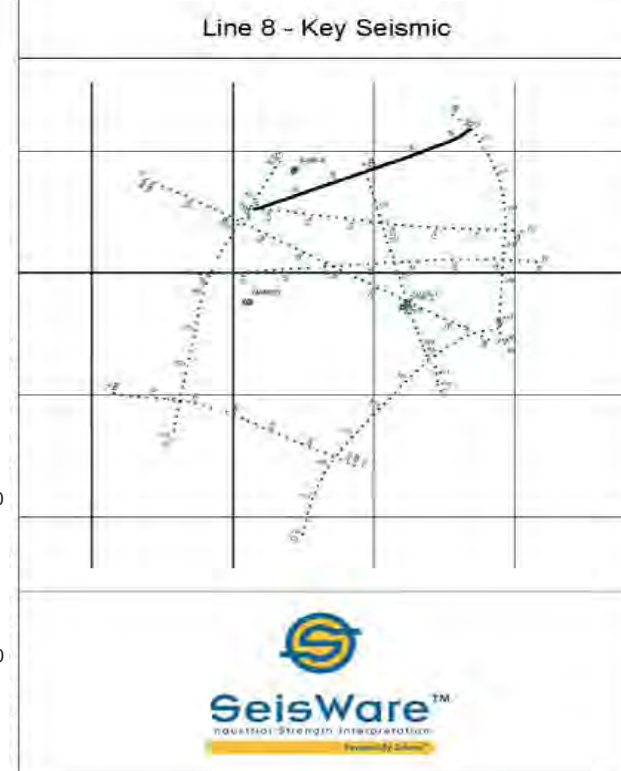
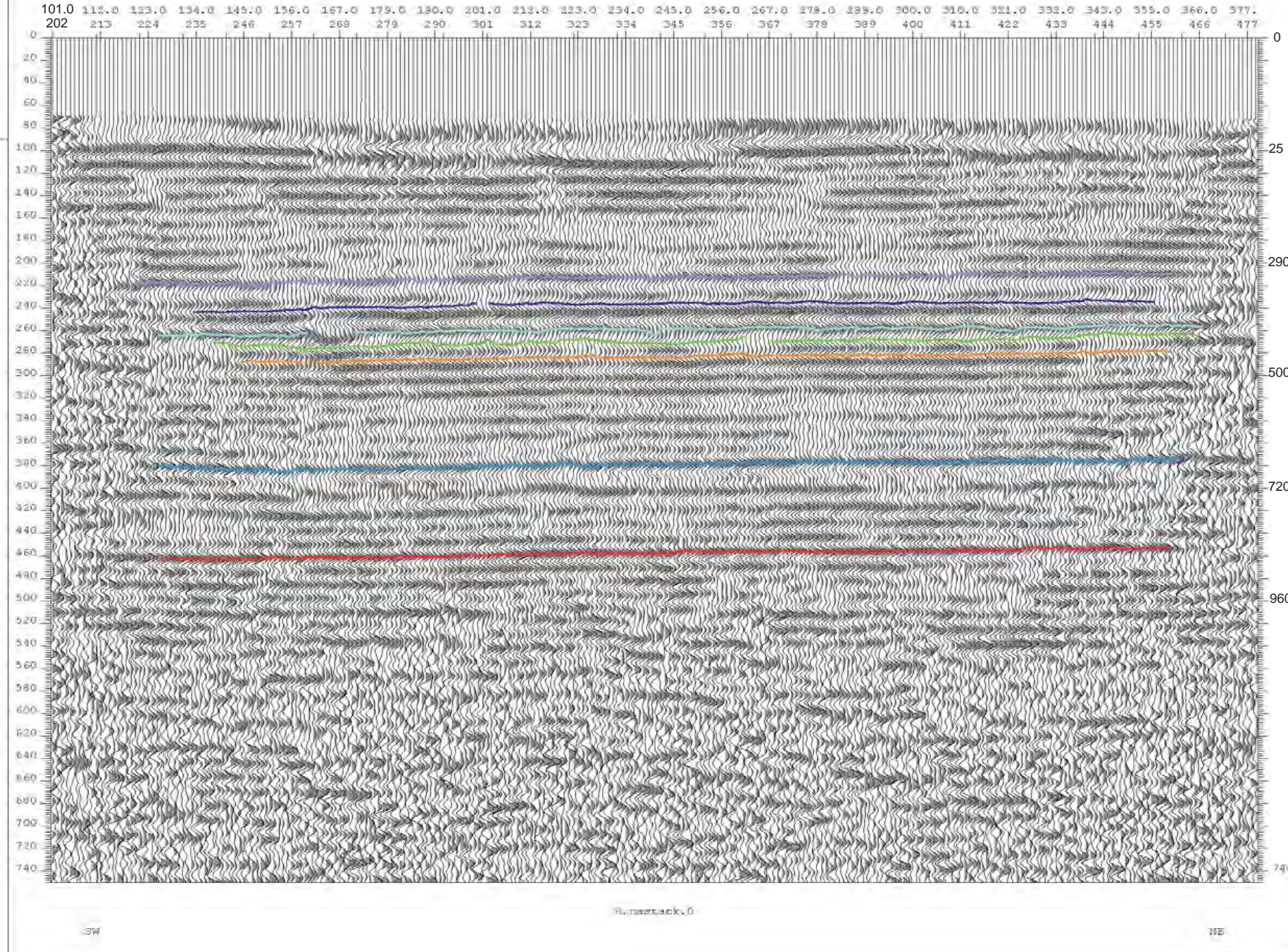
FIGURE 22(b)

Doc. No.: TR-07-15_Figure 22(b)_R0

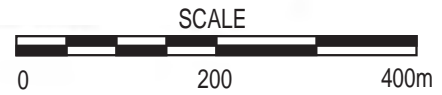


Source Point (SP) Number - top
Common Depth Point (CDP) - bottom

- Horizon Legend
- Salina A2 Evap
 - Guelph
 - Manitoulin
 - Queenston
 - Horizon 1
 - Cobourg
 - Precambrian



Approximate Non-linear
Depth Scale (m bgs)

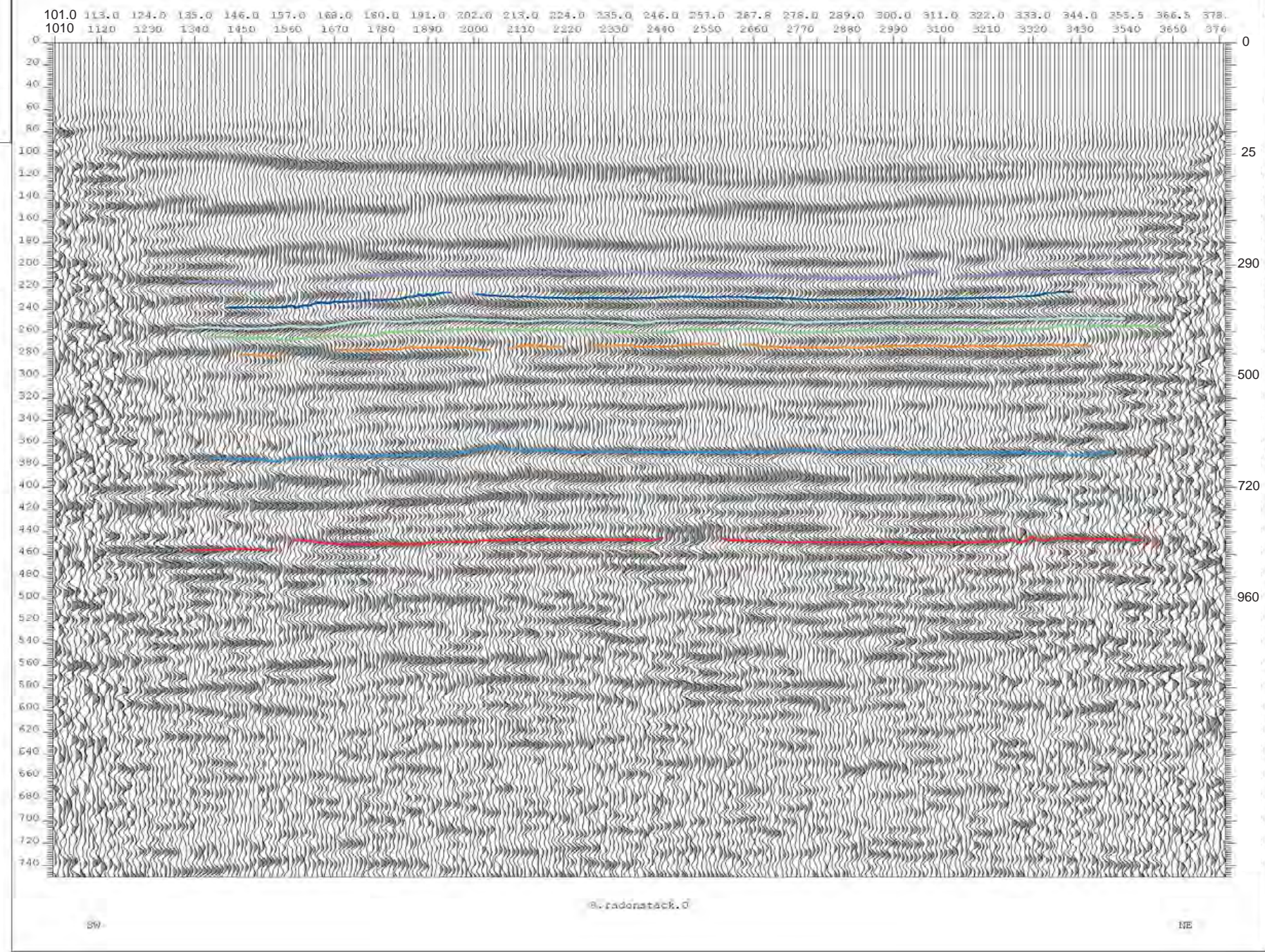


Interpreted 2D Seismic Data along Line 8 - Original Processing [Key Seismic] 2D Seismic Survey		Prepared by: ADG
FIGURE 23(a)		Reviewed by: SNS
Doc. No.: TR-07-15_Figure 23(a)_R0		Date: 28-Sep-08

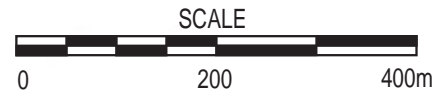


- Horizon Legend
- Salina A2 evap
 - Guelph
 - Manitoulin
 - Queenston
 - Horizon 1
 - Cobourg
 - Precambrian

Source Point (SP) Number - top
Common Depth Point (CDP) - bottom



Approximate Non-linear
Depth Scale (m bgs)



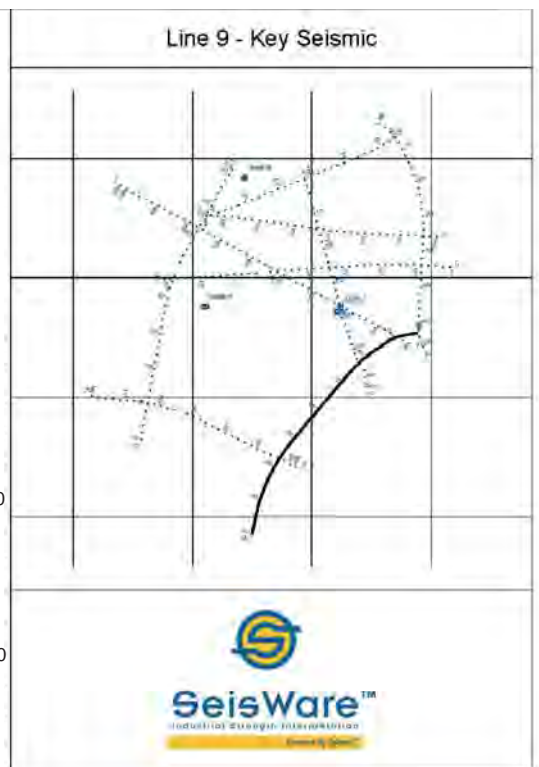
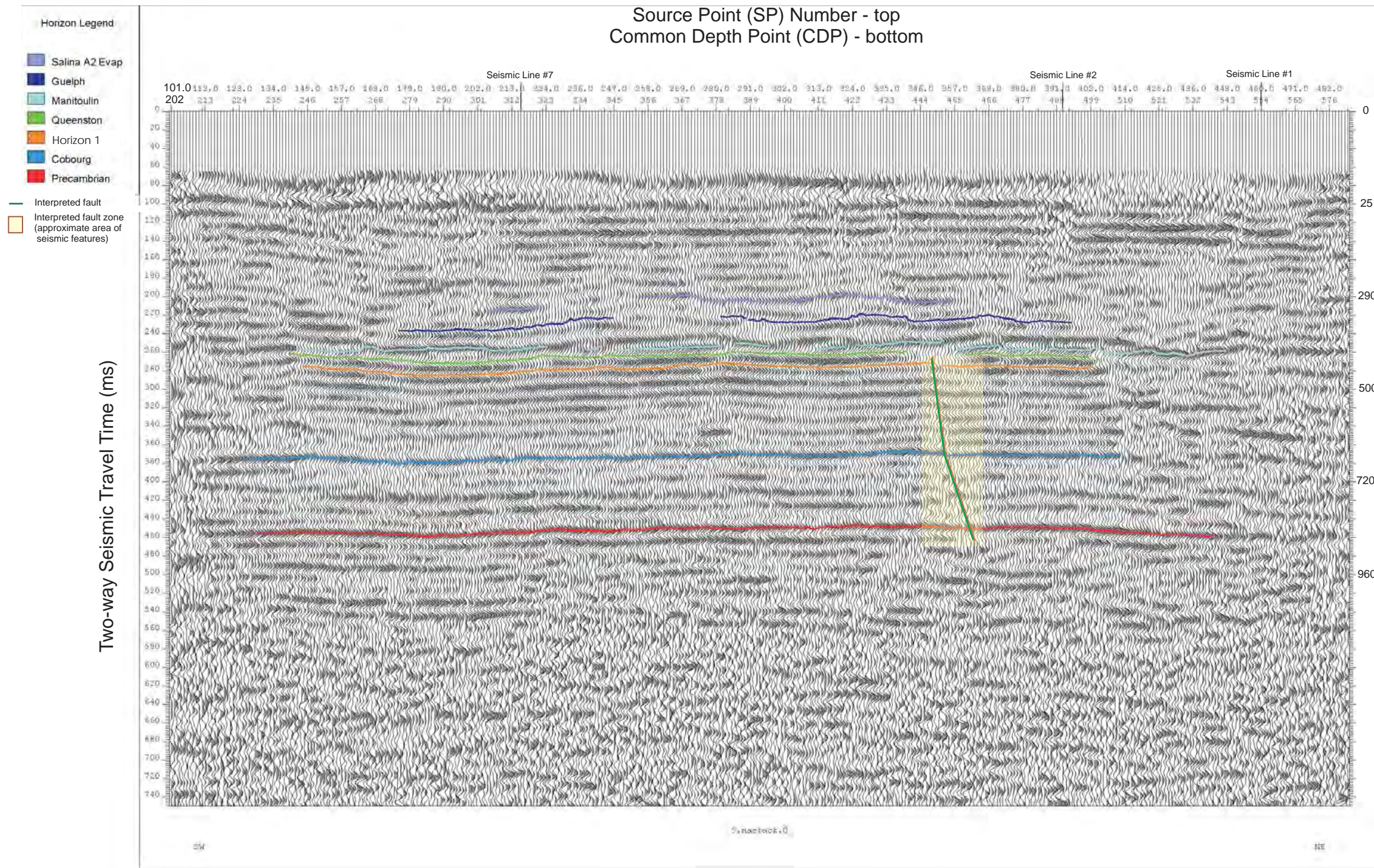
Interpreted 2D Seismic Data along Line 8 - Re-processing [Seiscraft]
2D Seismic Survey

Prepared by: ADG
Reviewed by: SNS
Date: 28-Sep-08

FIGURE 23(b) Doc. No.: TR-07-15_Figure 23(b)_R0



Source Point (SP) Number - top
Common Depth Point (CDP) - bottom

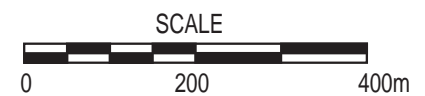


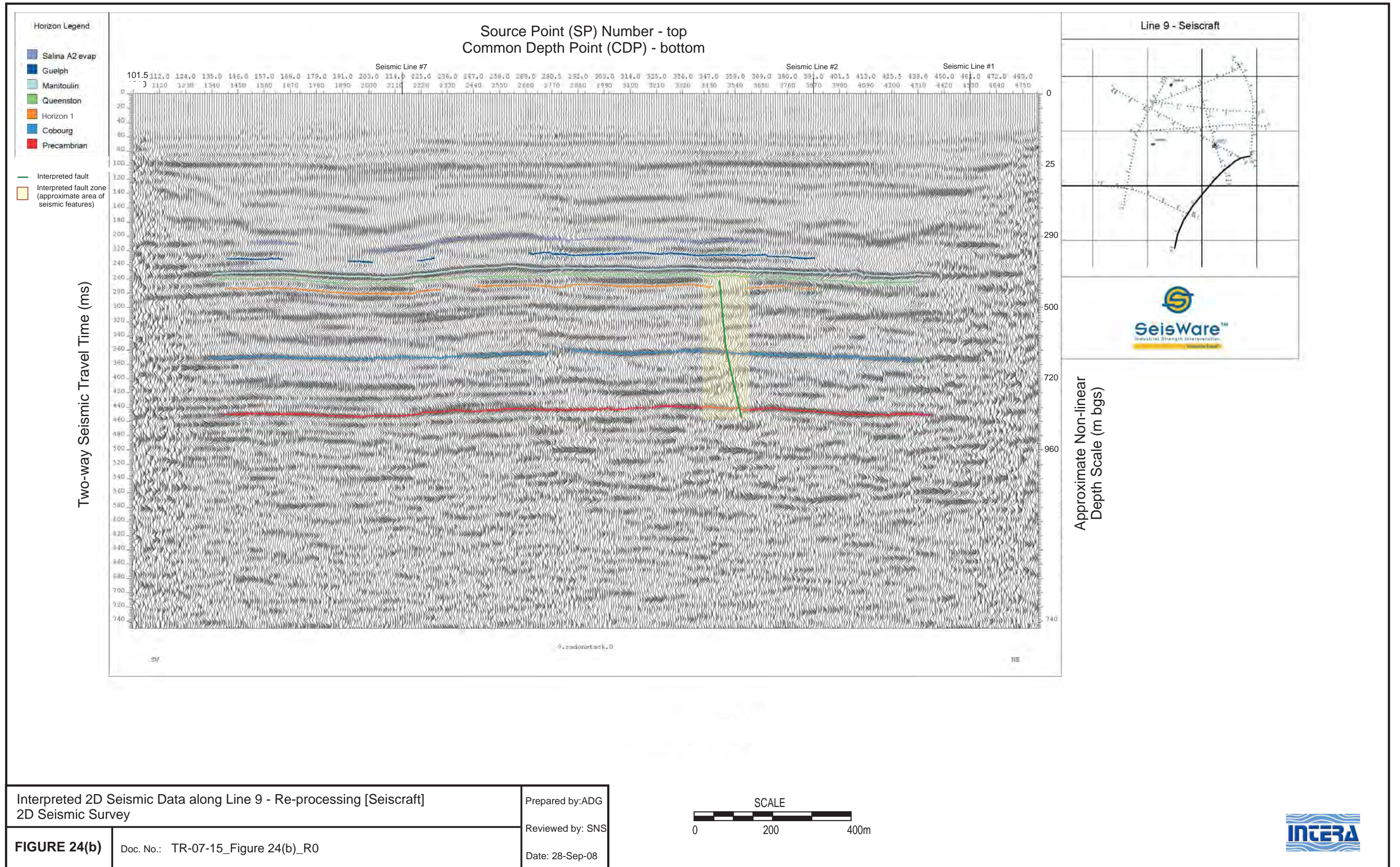
Interpreted 2D Seismic Data along Line 9 - Original Processing [Key Seismic]
2D Seismic Survey

FIGURE 24(a)

Doc. No.: TR-07-15_Figure 24(a)_R0

Prepared by: ADG
Reviewed by: SNS
Date: 28-Sep-08





Interpreted 2D Seismic Data along Line 9 - Re-processing [Seiscraft]
2D Seismic Survey

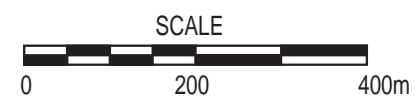
FIGURE 24(b)

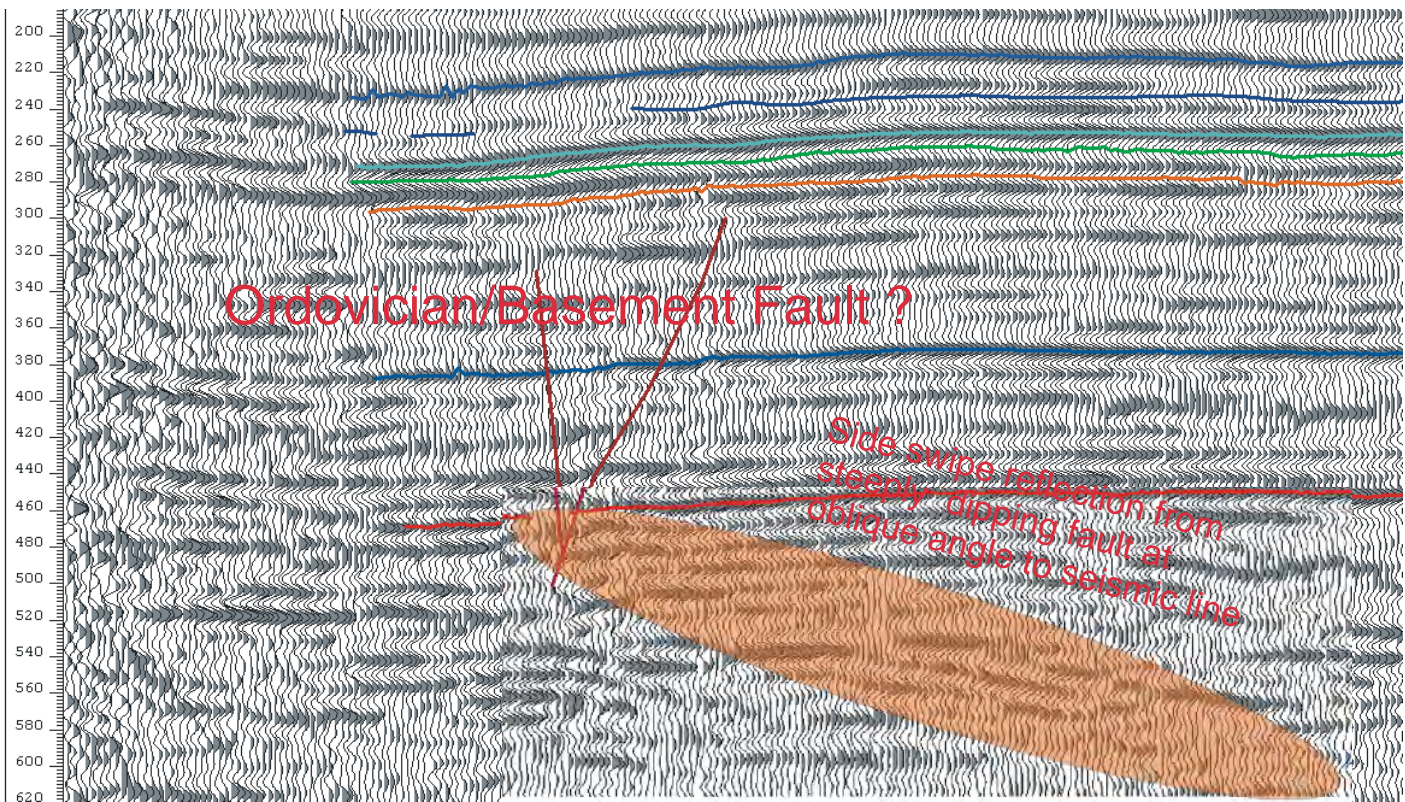
Doc. No.: TR-07-15_Figure 24(b)_R0

Prepared by: ADG

Reviewed by: SNS

Date: 28-Sep-08





Detailed View of Possible Fault Along Seismic Line 7
2D Seismic Report

Prepared by: ADG

Reviewed by: SNS

Date: 29-Jan-09

Figure 25

Doc: TR-07-15_Figure 25_R0



OPG DGR
Site Characterization Project

Legend

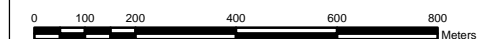
- 2D Seismic Survey Lines - Line Through Common Depth Points (CDP)
- 2D Seismic Survey Lines - Geophones Only
- Every 10th Receiver Station
- Location of DGR-1, 2 & 3
- Shallow Bedrock Monitoring Wells with Westbay Multi-level System
- Proposed DGR Layout
- Buildings
- Roads
- Railway
- Transmission Line
- Pits or Landfills
- Stream or Drainage
- Fault
- AECL Lands
- OPG Retained Land Within Bruce Site
- Bruce Power Leased Premises
- OPG Easements to Third Parties
- OPG Retained Land Outside of Bruce Site

Interpreted Faults Within
Cobourg Formation

Figure 26



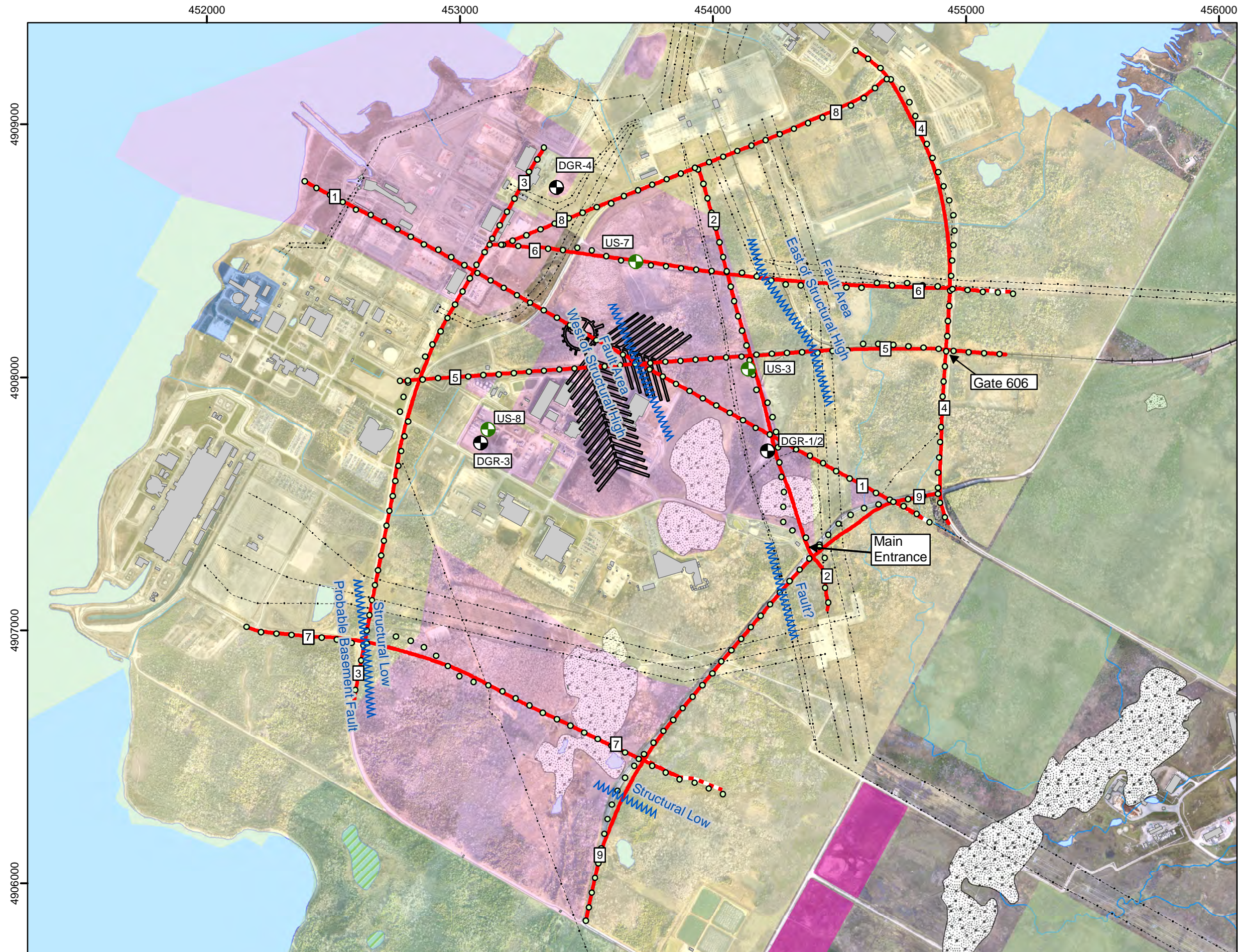
Scale 1:15,000



Date: 29/01/2009 Rev. 0 Drawn: NKP
Project: 06-219.10.05 Checked: SNS
P:\Projects\QMS_DGR\TR_WorkingFiles\TR-07-15 2D Seismic Survey\Figures/
Current Versions\ROH\TR-07-15_Figure 26_ROA.mxd

Projection: UTM Zone 17N and Datum: NAD83

Data Credits:
NRVIS/OBM, MNR, Ontario Power Generation, Bruce Power



452000 453000 454000 455000 456000

4909000

4908000

4907000

4906000

APPENDIX B

Seismic Testing Description

Testing included:

- Vibration monitoring for the effects of vibroseis on structures
- 60 Hertz EM interference on the recording equipment
- Plant equipment and traffic acoustic noise interference
- Combinations of Vibroseis sweeps from 8-180 Hz
- Vibrator sweep lengths from 8-12 seconds
- Vibrator arrays 6, 12 and 18 m
- Linear and non-linear (+3db sweeps)
- 2, 4 and 6 stacked sweeps before correlation

Parameters Selected Based on Tests:

- Set back from structure 18 m
- 60 Hz Notch filter out
- Sweeps per station 4
- Sweep length 8 seconds, non-linear +3db
- Source sweep 10-110 Hz
- Vibroseis units per VP 3 (centered on flag over 12 m, no drag)
- Receiver array 6 geophones over 2m (potted)

Testing involved the layout of a production spread of receivers and recording using different source parameters. Line 2 was the active test line, with 6 m groups and 6 geophones per group. The source tests are designed to determine the optimum source parameters.

Peak particle velocity and displacement are critical in evaluating potential damage to buildings and equipment. Measured values are dependent not only on the source energy, but also on the type of material the source waves are generated in and the geometry of the rock layers around the source. Testing was done on Line 2 at distances of 0-180 m (in 6 m increments) from the Vibroseis source.

60 Hertz EM interference in the seismic data is an expected consequence of working in a power station environment. Seismic equipment has been designed with this in mind but we expected the Bruce site to be an extreme example. Recording instruments include 60 cycle notch filters to mitigate this effect. As these filters can cause phase difficulties in the recorded data they should only be used in extreme circumstances. The test program included a noise test with "notch in" and "notch out". No notch filter was required.

"Cultural noise" was expected to be high on the Bruce site. Operating equipment and traffic that are normally avoided during seismic recording were unavoidable in this situation. Vibroseis is effective in noisy environments as it is a process which correlates the received acoustical signal with a copy of the input signal. This technique attempts to filter out unwanted noise. The duration of the sweep, sweep sums, and the vibrator force can also be controlled to maximize the signal-to-noise ratio. Peak force can be reduced to mitigate risk to equipment and structures.

APPENDIX C

Summary of Data Acquisition Parameters

Technique	- 40 fold common depth point recording
Recording System	- ARAM ARIES II
Sample Rate	- 1 ms
Record Length	- 3 seconds
Low Cut Filter	- 3 Hz
High Cut Filter	- 246 Hz
Group Interval	- 6 m
Geophone Type	- Mark Products L40A 10 Hz
Geophone Array	- 6 geophones evenly spaced between receiver points
Channels	- 240
Source Interval	- 18 m
Vibrator Make	- ENVIROVIB
Vibrator Type	- buggy mount 12,000 pound peak force
Source Array	- 3 vibrators over 12 m
Sweep	- 10-110 Hz, non-linear +3db
Sweep Length	- 8 seconds
Sweep Taper	- 300 ms

APPENDIX D

Ground Motion Monitoring Report produced by Geophysics GPR International Inc.

**Geophysics GPR International Inc.
2D Seismic Vibration Testing
Bruce Site, October 11-15, 2006**

Testing completed by Patrick Coriveau

October 11, 2006

Testing Vibration Diminution: Parallel to vibroseis rig

Test #	Reading (mm/s)	Distance
1	11.6	1m
	8.48	
2	11.7	1m
	8.45	

Test #	Reading (mm/s)	Distance
1	1.41	8m
	0.591	
2	1.50	8m
	0.532	

Test #	Reading (mm/s)	Distance
1	0.616	15m
	0.729	
2	0.611	15m
	0.393	

Test #	Reading (mm/s)	Distance
1	5.81	2m
	1.69	
2	5.79	2m
	1.67	

Test #	Reading (mm/s)	Distance
1	1.12	9m
	0.452	
2	1.13	9m
	0.467	

Test #	Reading (mm/s)	Distance
1	0.472	16m
	0.302	
2	0.505	16m
	0.255	

Test #	Reading (mm/s)	Distance
1	4.69	3m
	3.91	
2	4.69	3m
	3.9	

Test #	Reading (mm/s)	Distance
1	1.94	10m
	0.456	
2	1.94	10m
	0.439	

Test #	Reading (mm/s)	Distance
1	0.521	17m
	0.283	
2	0.552	17m
	0.303	

Test #	Reading (mm/s)	Distance
1	5.04	4m
	1.93	
2	6.9	4m
	1.89	

Test #	Reading (mm/s)	Distance
1	1.17	11m
	0.643	
2	1.14	11m
	0.709	

Test #	Reading (mm/s)	Distance
1	1.37	18m
	0.333	
2	0.545	18m
	0.357	

Test #	Reading (mm/s)	Distance
1	3.65	5m
	0.890	
2	3.61	5m
	0.863	

Test #	Reading (mm/s)	Distance
1	1.47	12m
	0.748	
2	1.48	12m
	0.674	

Test #	Reading (mm/s)	Distance
1	1.11	19m
	0.369	
2	1.12	19m
	0.387	

Test #	Reading (mm/s)	Distance
1	2.07	6m
	1.17	
2	2.11	6m
	1.30	

Test #	Reading (mm/s)	Distance
1	1.37	13m
	0.319	
2	1.4	13m
	0.333	

Test #	Reading (mm/s)	Distance
1	0.429	20m
	0.627	
2	0.289	20m
	0.608	

Test #	Reading (mm/s)	Distance
1	1.69	7m
	0.763	
2	1.65	7m
	0.769	

Test #	Reading (mm/s)	Distance
1	0.853	14m
	0.764	
2	0.882	14m
	0.772	

Trigger level was at 0.16 mm/s

October 11, 2006

Testing vibration diminution: Perpendicular to vibroseis rig

Test #	Reading (mm/s)	Distance
1	15.1	1m
	9.29	
2	15.8	
	8.92	

1	8.22	2m
	3.41	
2	8.11	
	3.22	

1	7.95	3m
	3.60	
2	8.11	
	3.62	

1	7.27	4m
	2.91	
2	7.59	
	2.92	

Trigger level was at 0.16 mm/s

October 12, 2006

Testing hydro one 1st Tower of line B22D

Test #	Reading (mm/s)	Distance
1	1.72	89m
2	6.49	
3	1.18	
4	13.7	
5	11	
6	5.61	
7	4.6	
8	5.21	
9	0.222	

Trigger level was at 0.16 mm/s

Note: Those recordings are probably due to the wind

October 12, 2006

Recording at construction field.

These are the results of the Dynpack compacting machine, in front of light SIO. P 13

Distance	Reading mm/s	Condition of Use
20m	2.82	Dynamic
20m	1.68	Dynamic
10m	11.9	Dynamic
3m	33.6	Dynamic
3m	4.01	Static
3m	30.9	Dynamic
10m	14.6	Dynamic
15m	6.39	Dynamic

Trigger level was at 0.16 mm/s

October 14, 2006

Vibration testing during data collection along Seismic Line 6

Roving crews site maintenance (B24)

Location: The first corner of the building nearby the main entrance

Test #	Reading (mm/s)	Distance
1	4.67	57m
2	4.82	
3	3.99	
4	2.46	

Trigger level was at 1.00 mm/s

Note: The wind was really strong, recording probably due to the wind

October 14, 2006

Vibration testing during data collection along Seismic Line 6

Location: direction on US-7 well

Test #	Reading (mm/s)	Distance
1	0.0476	On the well
2	0.0979	
3	0.0674	
4	0.0476	
5	0.0476	

Manual recording mode, therefore no trigger level.

October 14, 2006

Vibration testing during data collection along Seismic Line 3

Bruce Power main office building

Location: Nearby the flags [Can., Ont., Bruce]

Test #	Reading (mm/s)	Distance
1	nothing	65
2	nothing	37

Trigger level was at 1.00 mm/s

October 15, 2006

Vibration testing during data collection along Seismic Line 3

Western Region Supply Chain Warehouse (B23)

Location: Corner of the building nearby main entrance

Test #	Reading (mm/s)	Distance
1	0.67	20m
2	0.684	
3	0.68	
4	0.668	
5	0.747	
6	0.511	
7	0.75	
8	0.562	

Trigger level was at 0.50 mm/s

October 15, 2006

Vibration testing during data collection along Seismic Line 3

Location: Front of transformer box 34-5314-T1

Test #	Reading (mm/s)	Distance
1	0.698	18m
2	0.553	
3	0.843	
4	0.882	
5	0.209	
6	0.543	

Trigger level at 0.50 mm/s

October 15, 2006

Vibration testing during data collection along Seismic Line 3

Roving crew site maintenance (B24)

Location: Nearby main entrance

Test #	Reading (mm/s)	Distance
1	0.701	21m
2	0.729	
3	0.744	
4	0.721	

Trigger level at 0.50 mm/s

October 15, 2006

Vibration testing during data collection along Seismic Line 3

Roving crew site maintenance (B24)

Location: Front door 146

Test #	Reading (mm/s)	Distance
1	0.527	18m
2	0.529	
3	0.543	
4	0.548	
5	0.866	
6	0.897	
7	0.913	
8	0.926	

Trigger level at 0.50 mm/s

October 15, 2006

Vibration testing during data collection along Seismic Line 3

Bruce Power Large Bore Shop

Location: Left side of transformer PD-53140-T2

Test #	Reading (mm/s)	Distance
1	0.169	9m
2	0.853	
3	0.869	
4	0.901	
5	0.901	
6	0.642	
7	0.732	
8	0.989	
9	0.702	

Trigger level was at 0.50 mm/s

Note: Monitoring location was in soft ground (loose gravel)

October 15, 2006

Vibration testing during data collection along Seismic Line 3

OBD Building

Location: Fire hydrant 0-71400-V296

Test #	Reading (mm/s)	Distance
1	1.18	15m
2	1.16	
3	1.35	
4	1.3	
5	0.983	

Trigger level was at 0.50 mm/s

October 15, 2006

Vibration testing during data collection along Seismic Line 8

Hydro One Office

Location: Parking lot in front of fire hydrant

Test #	Reading (mm/s)	Distance
1	nothing	33

Trigger level was at 0.50 mm/s

APPENDIX E

Preliminary Processing Summary Report produced by Key Seismic Solutions

AGUILA EXPLORATION CONSULTANTS LTD.

BRUCE , ONTARIO

2D PROCESSING SUMMARY

Seismic Data Processing By :

KEY SEISMIC SOLUTIONS LTD.
(Calgary , Alberta)

January , 2007

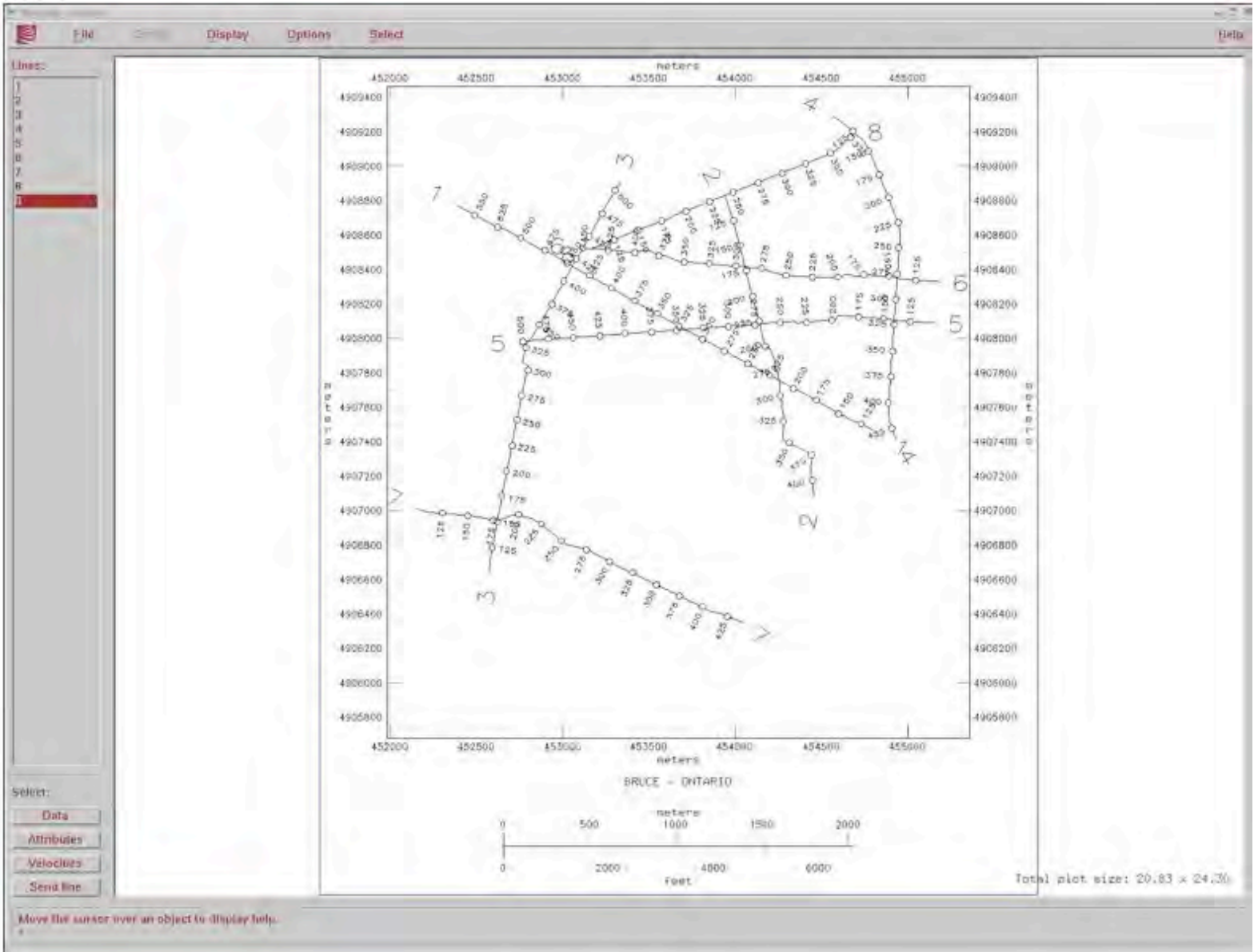
KEY
SEISMIC

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Slide 16	Velocity Semblance Display
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<u>LINE ID</u>	<u>TR/SHOT</u>	<u>STATIONS</u>	<u>#SHOTS</u>	<u>#KM</u>
06-OPG-01	240	101-569	171	2.808
06-OPG-02	240	101-415	111	1.884
06-OPG-03	240	101-510	144	2.454
06-OPG-04	240	101-436	118	2.010
06-OPG-05	240	101-500	146	2.394
06-OPG-06	240	101-450	110	2.094
06-OPG-07	240	101-442	99	2.046
06-OPG-08	240	101-379	99	1.668
06-OPG-09	240	101-490	139	2.334

TOTAL:			1137	19.692



Field	Value
1) Project	10580N. Bruce Nuclear 20
2) Principal	OPG
3) Geoph. Co.	Geophysical Applications Ltd.
4) Contact Phone	(519)763-3437
5) Survey Co.	Geophysical Applications Ltd.
6) Line	06-OPG-01. Receiver
7) Area	Bruce
8) Survey Date	October, 2006
9) Survey System	Triable 4800 DGPS, Topcon GTS-235W
10) Projection Type	Transverse_Mercator
11) Projection	UTM_Zone_17N
12) Datum	NAD_1983
13) Units	Meter, 1 Implied Decimal
14) Spheroid	GRS_1980
15) Prime Meridian	Greenwich
16) Semi-major axis =	6378137. Flattening = 0.003352810681
17) False Northing =	0. False Easting = 500000
18) Origin Latitude =	00 00 00.0000, Origin Longitude = 75 00 00.0000
19) Scale Factor =	
20) Coordinate Format	SEGPI Line:2-17 Station:18-25 Lat:27-35 Long:36-45 X:46-53 Y:54-61 Z:62-66
21) reclin...	ss. xxxxxx.yyyyyy.zzzz.
22) R-06-OPG-01	101 44190733N081335799W 454856449074274 1916
23) R-06-OPG-01	102 44190743N081335823W 454851249074303 1916
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41) R-06-OPG-01	120 44190926N081340239W 454759449074875 1915
42) R-06-OPG-01	121 44190935N081340262W 454754249074904 1915
43) R-06-OPG-01	122 44190945N081340286W 454748949074933 1915
44) R-06-OPG-01	123 44190954N081340310W 454743649074962 1915
45) R-06-OPG-01	124 44190963N081340334W 454738449074991 1916
46) R-06-OPG-01	125 44190972N081340358W 454733149075020 1917
47) R-06-OPG-01	126 44190982N081340382W 454727849075049 1917
48) R-06-OPG-01	127 44190987N081340409W 454721949075067 1913
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SEISMIC

RECORDING PARAMETERS

RECORDED BY:	CONQUEST	DATE RECORDED:	OCTOBER 2006
INSTRUMENT TYPE:	ARAM II	PARTY:	106
FILTER:	3/246 HZ	NOTCH FILTER:	OUT
SAMPLE RATE:	1 MS	RECORD LENGTH:	3000 MSEC
GEOPHONE TYPE:	MARK L40A - 10HZ	GEOPHONE ARRAY:	6 OVER 10M
SOURCE TYPE:	VIBROSEIS (MODEL: ENVIROVIB)	SOURCE ARRAY:	3 OVER 12M
SWEEP:	4 SWPS AT 8 SEC	STATION INT:	6 M
SWEEP FREQ:	10-100HZ 30B/OCT	SOURCE INT:	12 M
NOMINAL FOLD:	80	CHANNELS:	240 TRACES

SPREAD CONFIGURATION:

TR1-----	TR120 X	TR121-----	TR240
717M	3M	3M	717M

FIELD PARAMETERS

PROCESSING FLOW

1. REFORMAT

Convert from SEGY to internal format (32 bit floating point)

2. GEOMETRY DEFINITION

Computed survey supplied by Geophysical Applications Ltd.
Spread Information from field trace headers and observers logs
Crooked line binning for subsurface

3. DATUM AND WEATHERING STATICS (GMG DELAY TIME SOLUTION)

Datum: 300 meters
Weathering Velocity: 1000 meters/sec
Replacement Velocity: 3300 meters/sec

4. GAIN RECOVERY

T**N Scaling with N=0.5

5. SURFACE CONSISTENT DECONVOLUTION

Type: Surface Consistent Spiking
Components: Line, Shot, Receiver
Operator Length: 80 ms
Prewhitening: 3.0%
Design Window 50 – 500 msec at 0 Meters
50 – 500 msec at 100 Meters
250 - 600 msec at 717 Meters
Design Offset 50 – 717 Meters

6. SPECTRAL WHITENING

Type: Signal referenced
Reference Bandwidth: 10/15 – 60/70 Hz
Output Bandwidth: 1 – 101 Hz by 5 Hz increments
DB boost: 0 db

7. VELOCITY ANALYSIS (PRELIMINARY)

Surface referenced interactive velocity analysis
constant velocity stacks / semblance type

8. RESIDUAL REFLECTION STATICS

Type: Surface Consistent
Window: 70 – 550 ms
Allowable Shift: 16 msec

9. VELOCITY ANALYSIS (REVISED)

Surface referenced interactive velocity analysis
constant velocity stacks / semblance type

10. RESIDUAL REFLECTION STATICS (2nd Pass)

Type: Surface Consistent
Window: 70 – 550 ms
Allowable Shift: 12 msec

11. NMO

Surface referenced

12. MUTE

Distance (m)	110	300	800	1000
Time (ms)	0	100	220	350

13. TRIM STATICS

Type: Trim to a model trace
Window: 100 – 550 ms
Allowable Shift: +/- 8 msec

14. NOISE ATTENUATION

Type: taup (shot domain)
Window: 0 – 1000 ms
Freq Range: 5 – 100 Hz
Noise Threshold : 0.4

15. VELOCITY ANALYSIS (REVISED)

Surface referenced interactive velocity analysis
constant velocity stacks / semblance type

16. STACK

Type: Median

17. NOISE ATTENUATION

Type: FX DECONVOLUTION

Noise removed: 50%

18. MIGRATION

Type: Finite Difference

Velocities: 100% stacking

19. FILTER

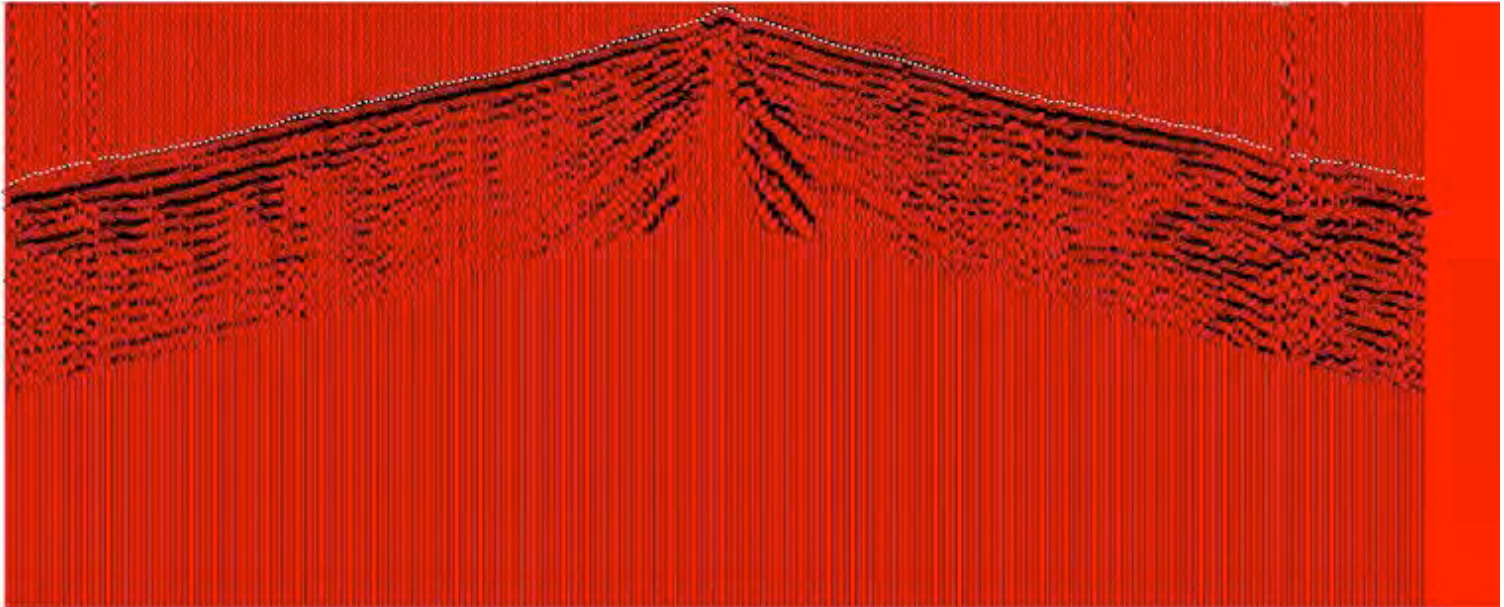
Type: Ormsby

Bandpass: 10/15 – 80/100 hz

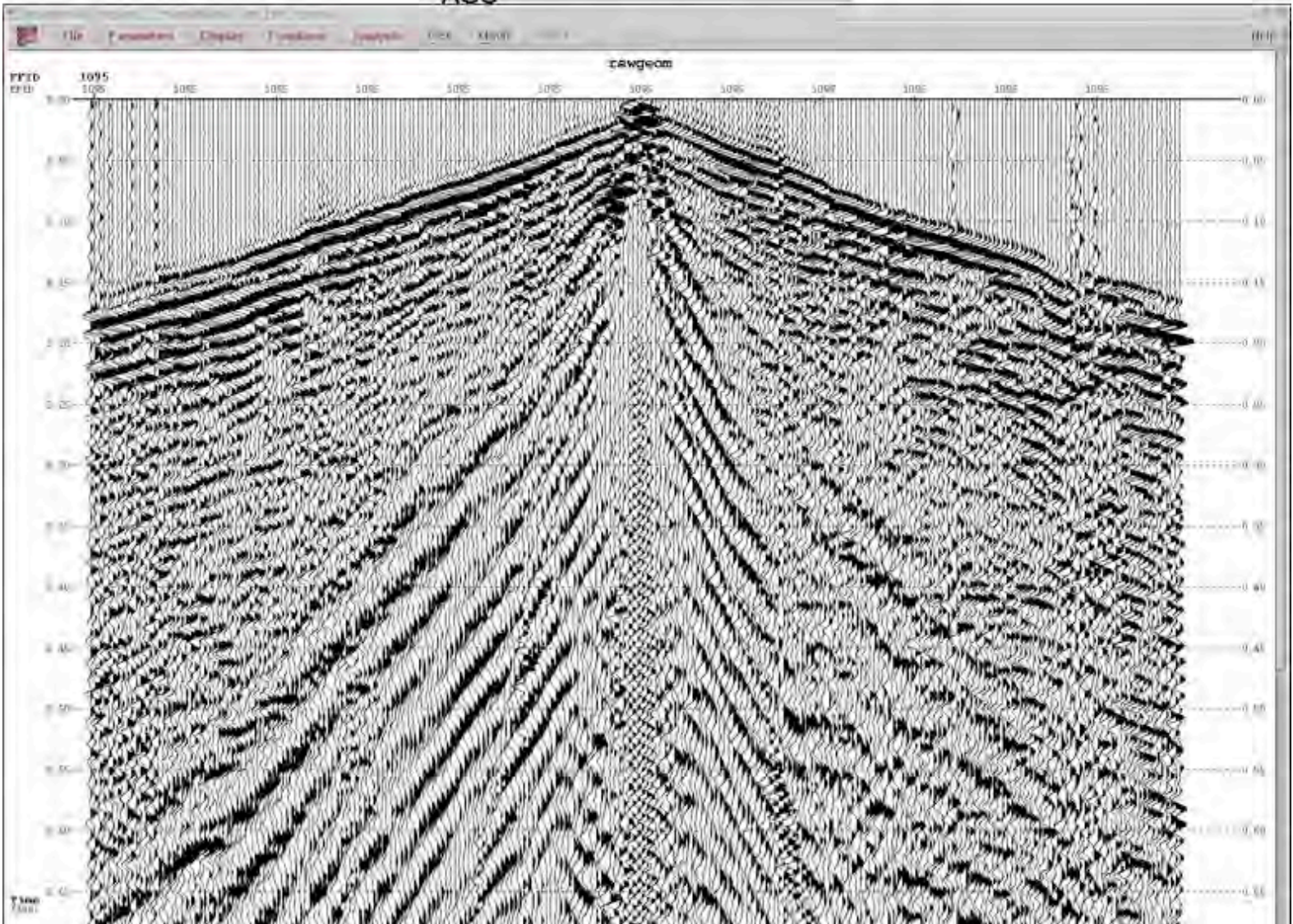
20. SCALING – Multigate Windows

FIELD SHOT RECORD WITH FIRST BREAK PICKS

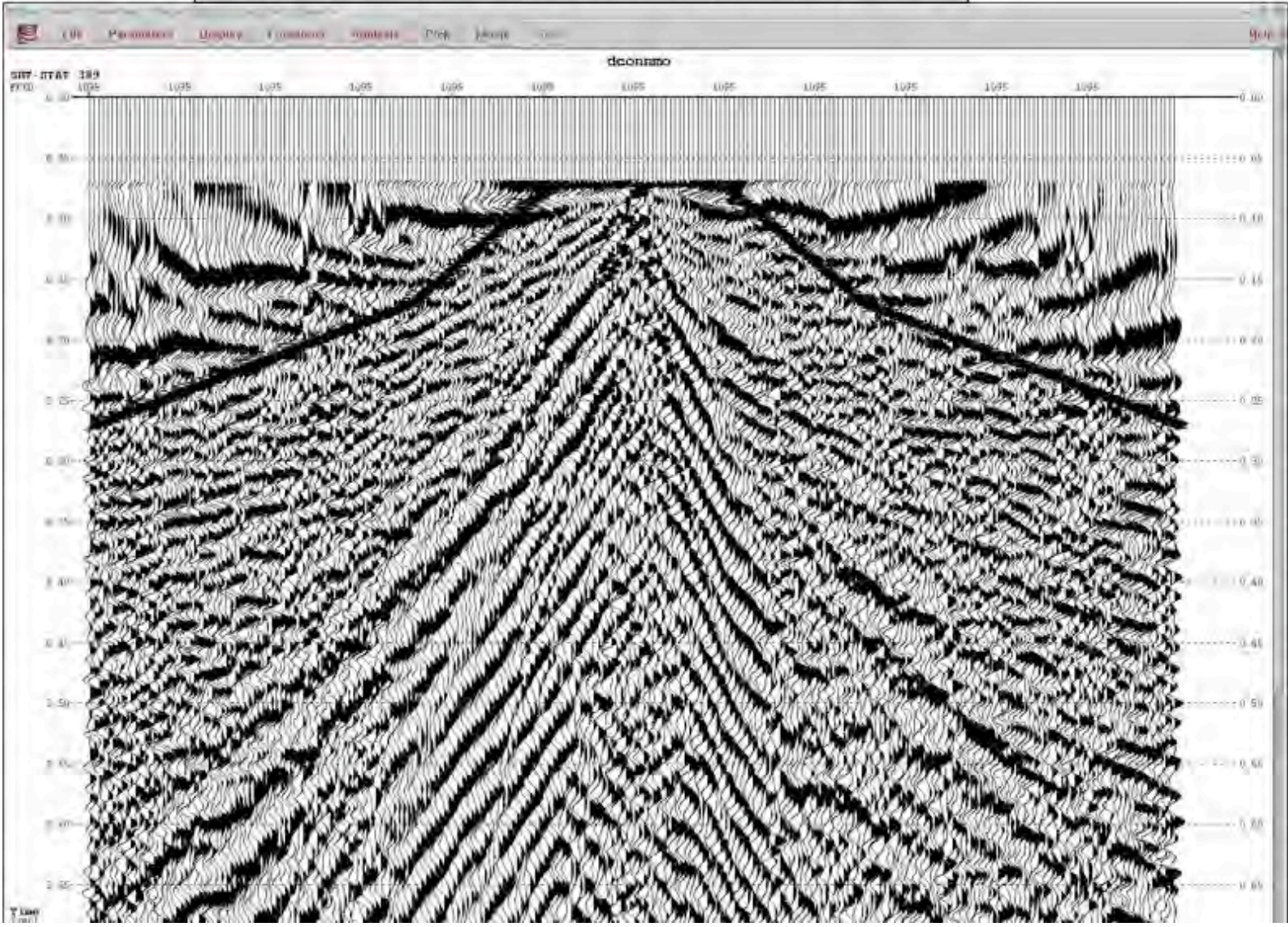
F 1095
S 389



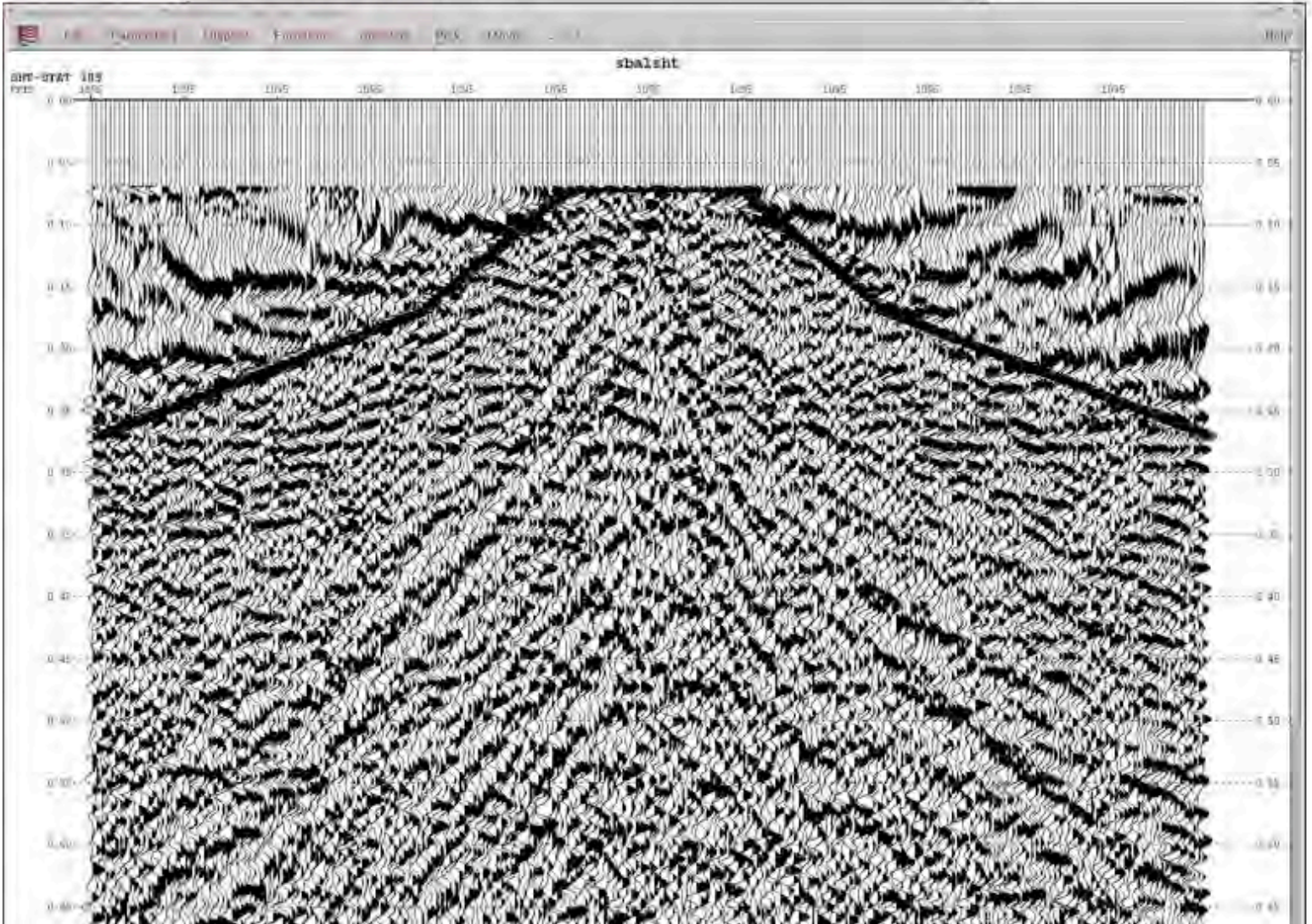
FIELD SHOT RECORD WITH AGC



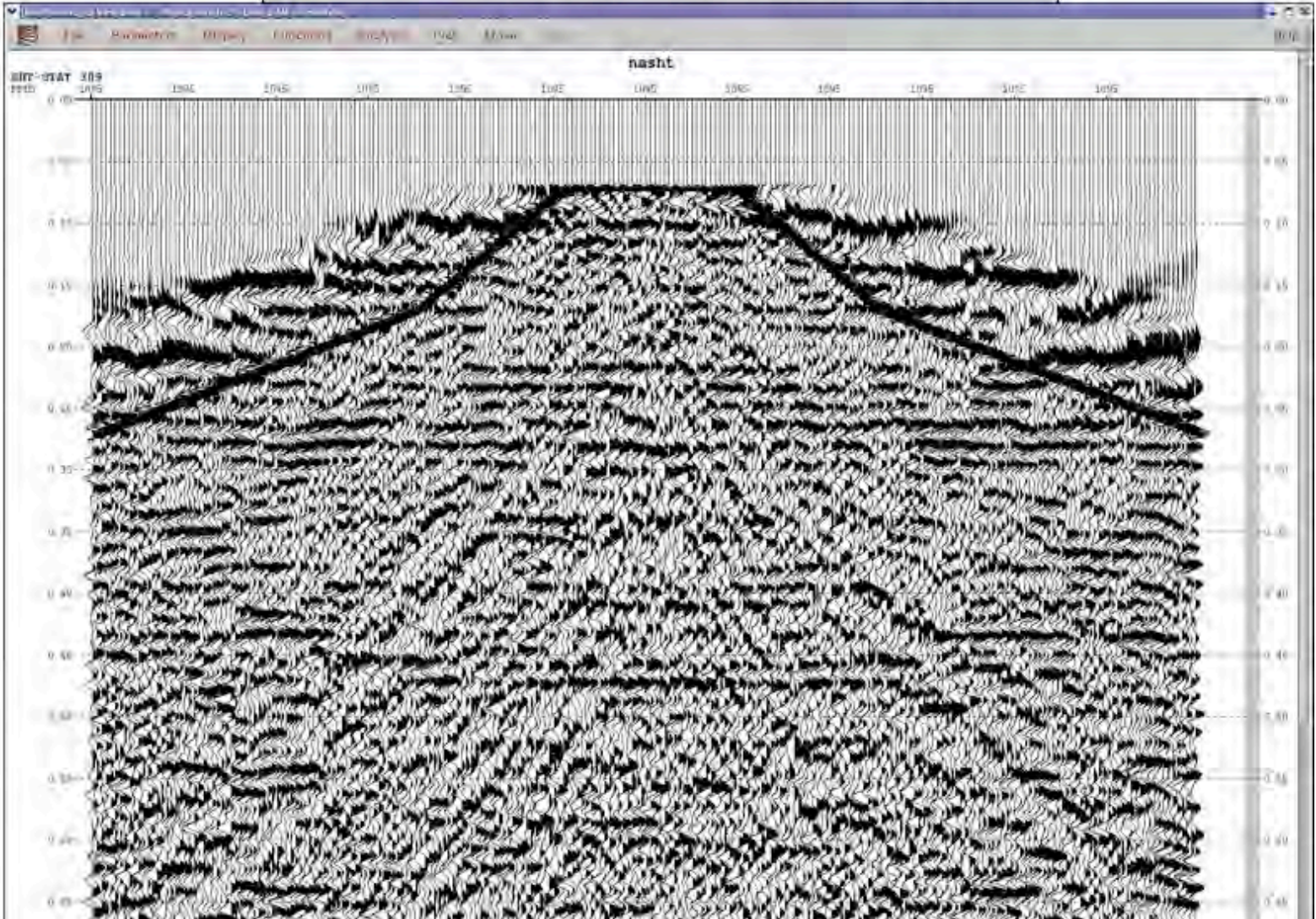
FIELD SHOT RECORD WITH DECON / WX STATICS / NMO



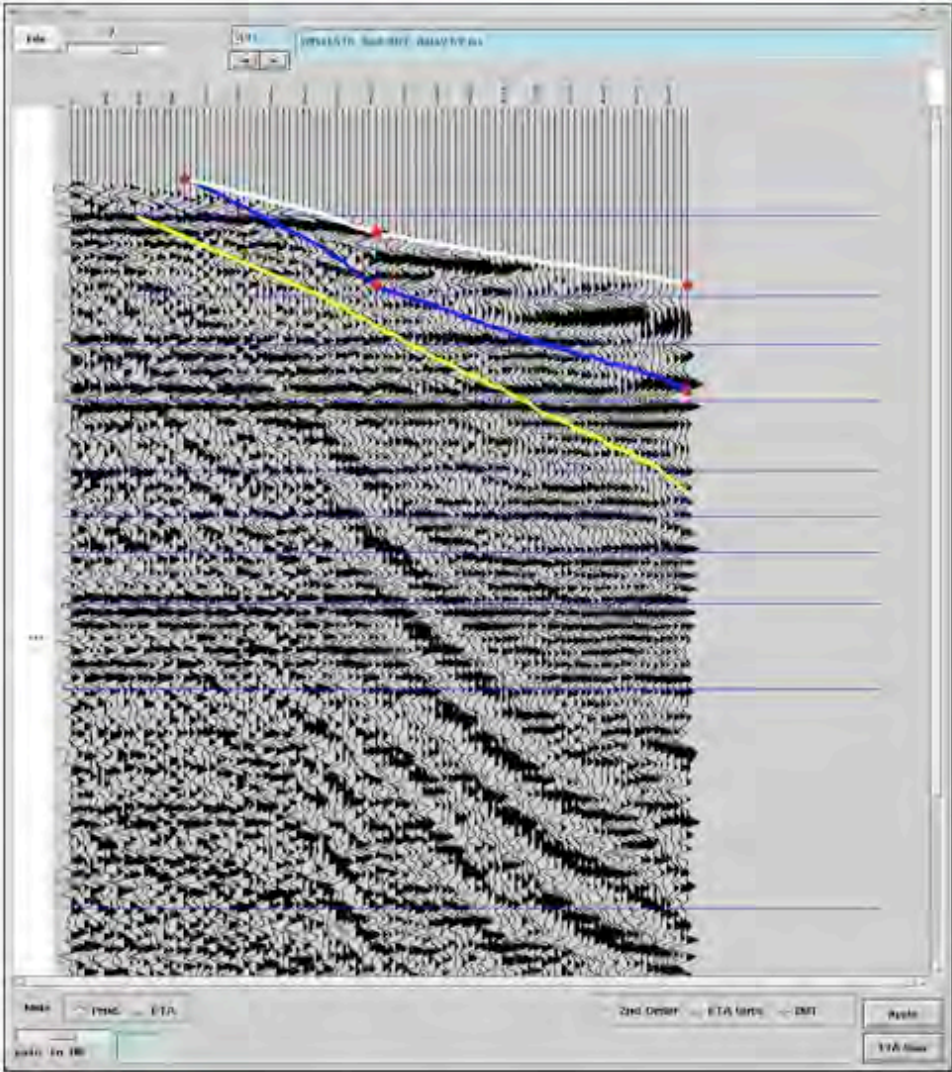
FIELD SHOT RECORD WITH DECON / WX-STATICS / NMO /
SPECTRAL BALANCING



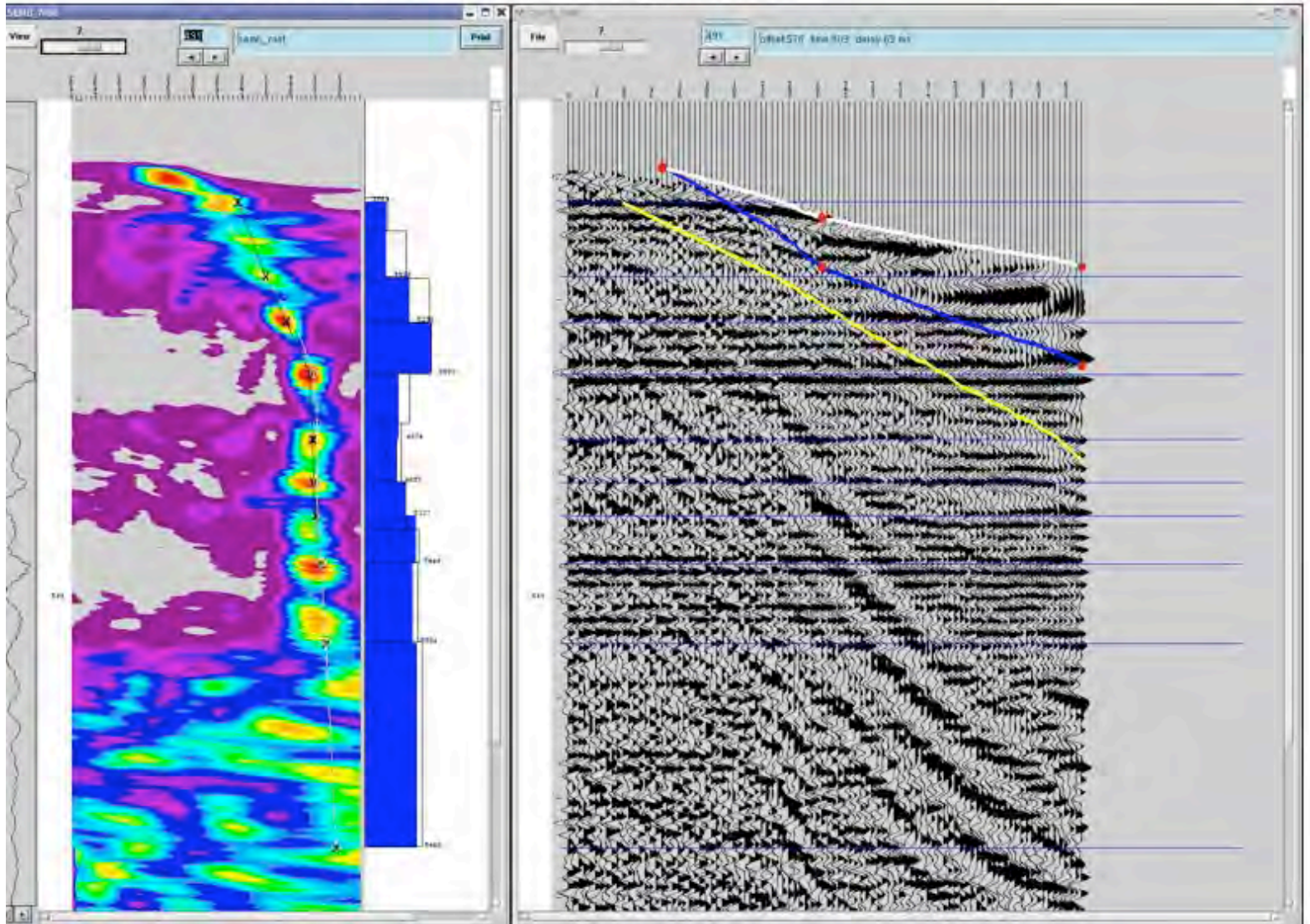
FIELD SHOT RECORD WITH DECON / WX STATICS / RESIDUAL
STATICS / SPECTRAL BALANCING / NMO / NOISE ATTEN



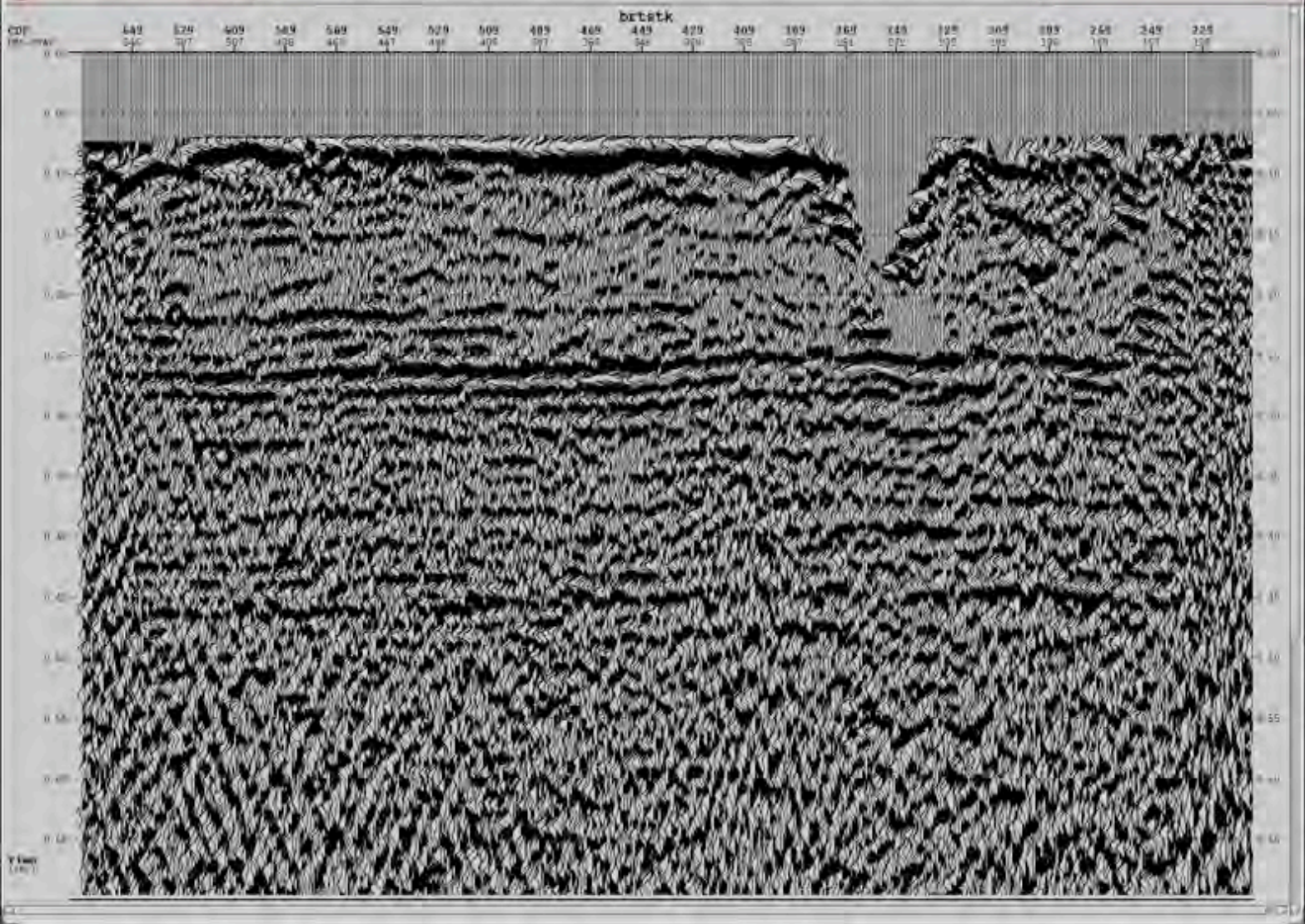
COMMON OFFSET STACK



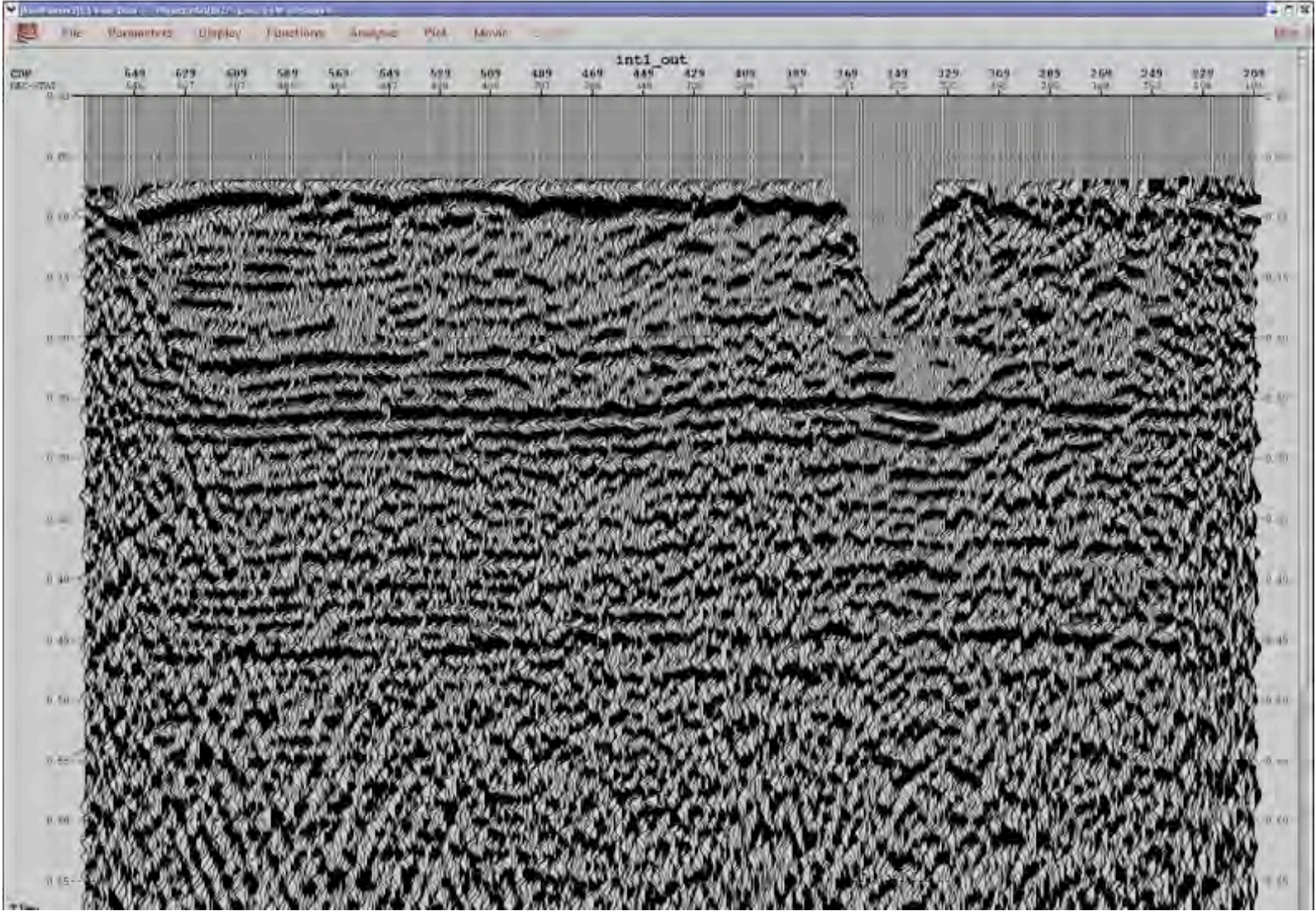
VELOCITY SEMBLANCE & INTERVAL VELOCITY PROFILE /
COMMON OFFSET STACK WITH NMO APPLIED



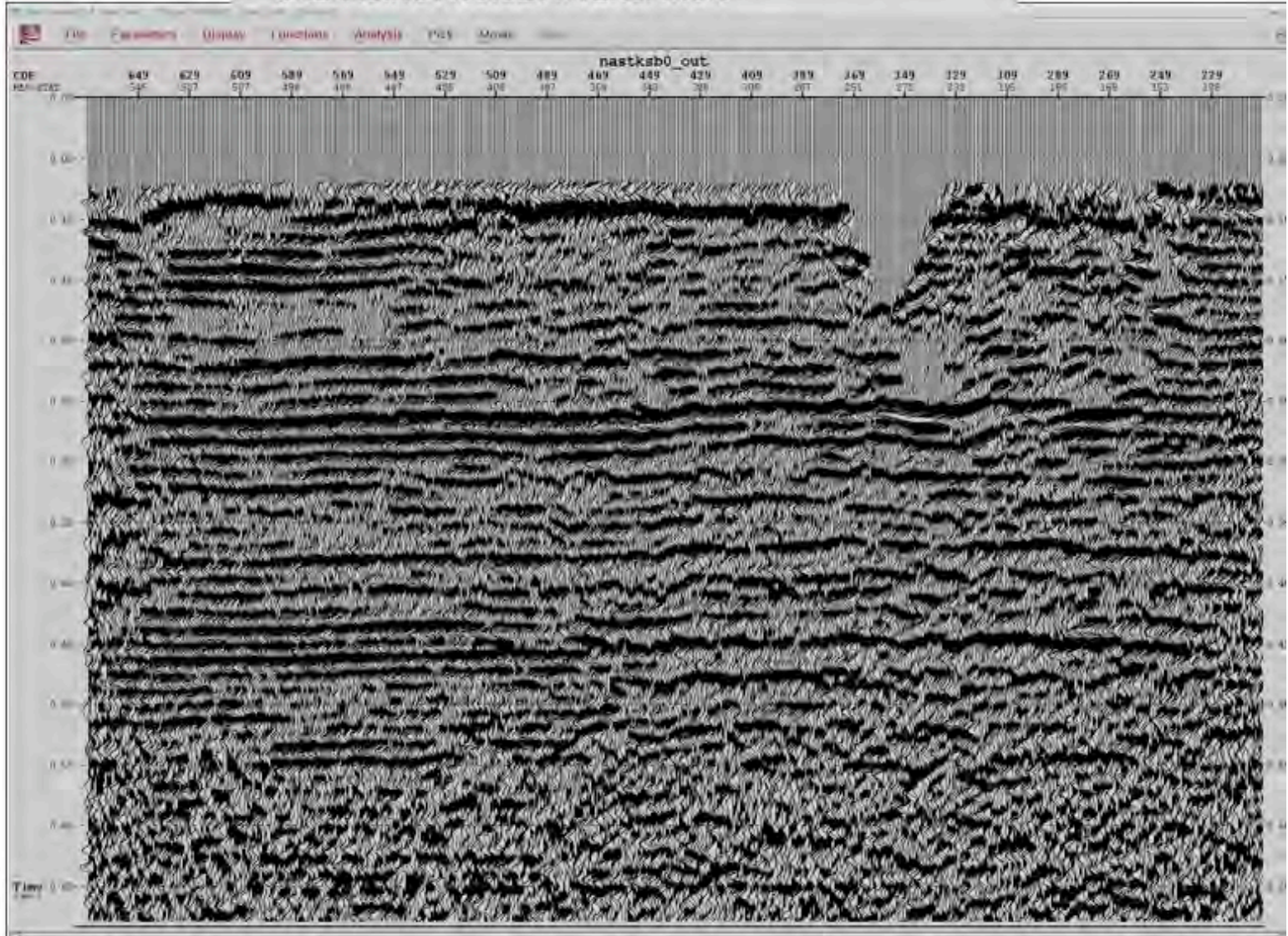
LINE 1 - STACK WITH DECON



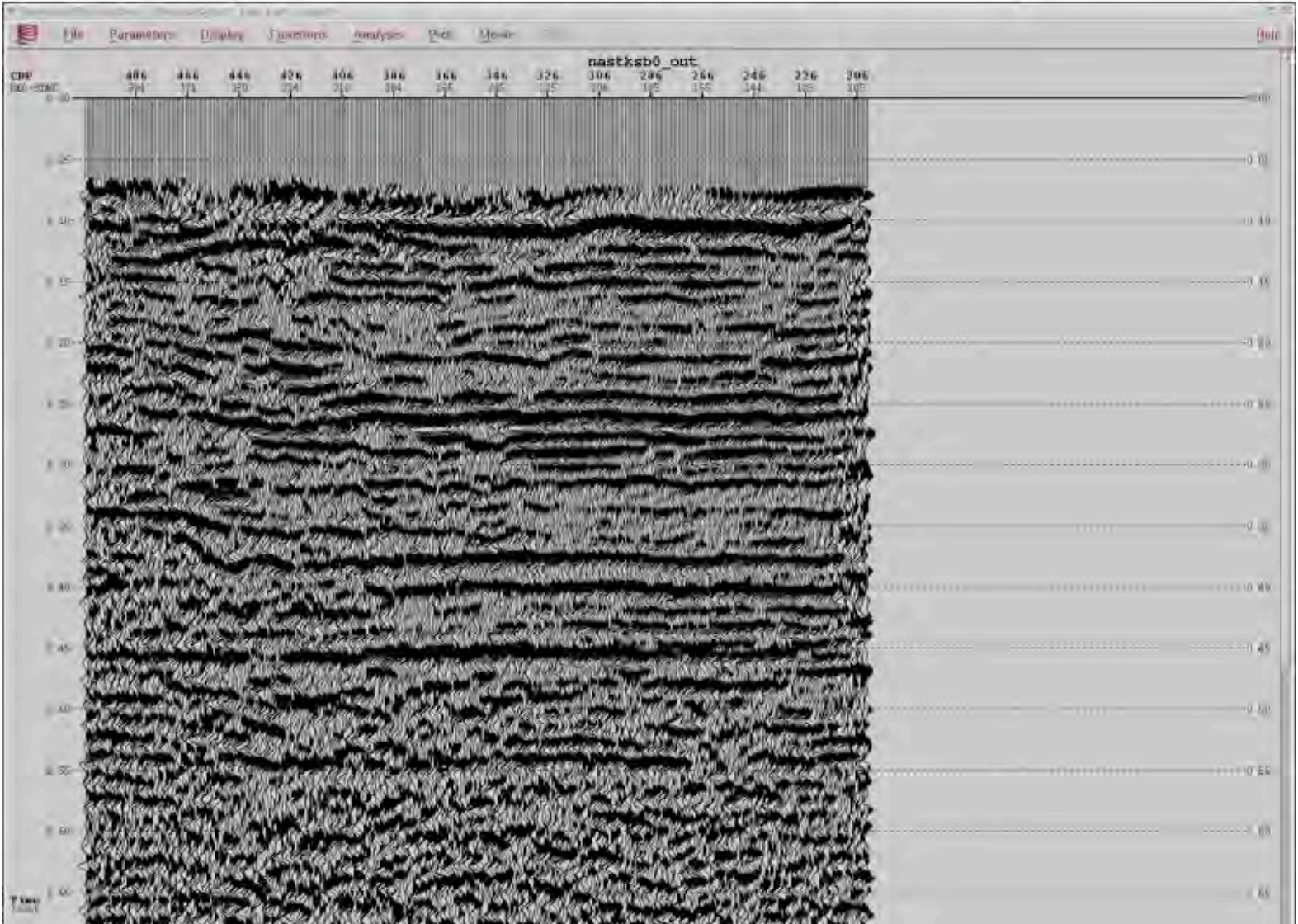
LINE 1 – STACK WITH DECON / RESIDUAL STATICS



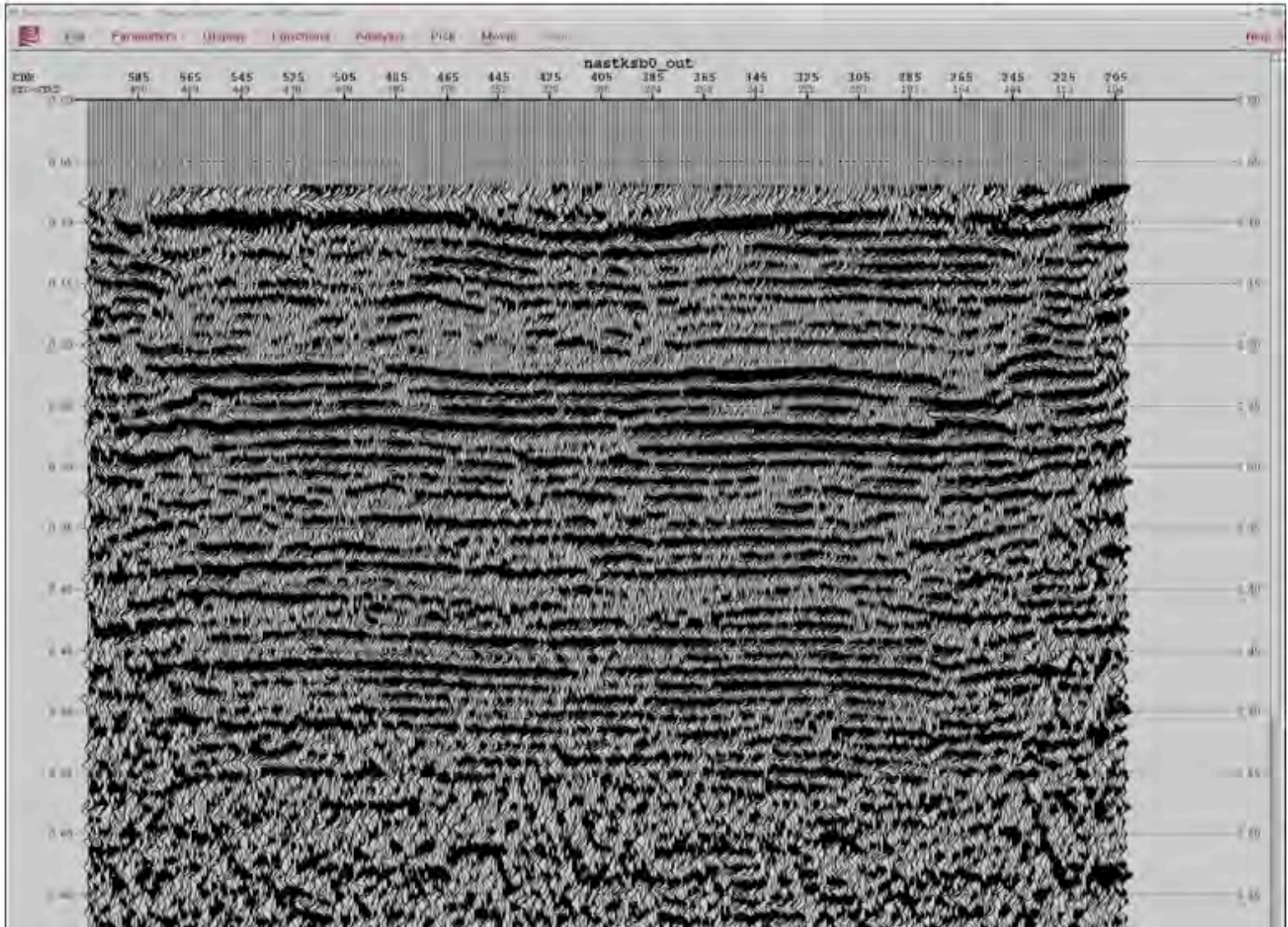
LINE 1 WITH DECON / RESIDUAL STATICS / SPECTRAL BALANCING / NOISE ATTENUATION



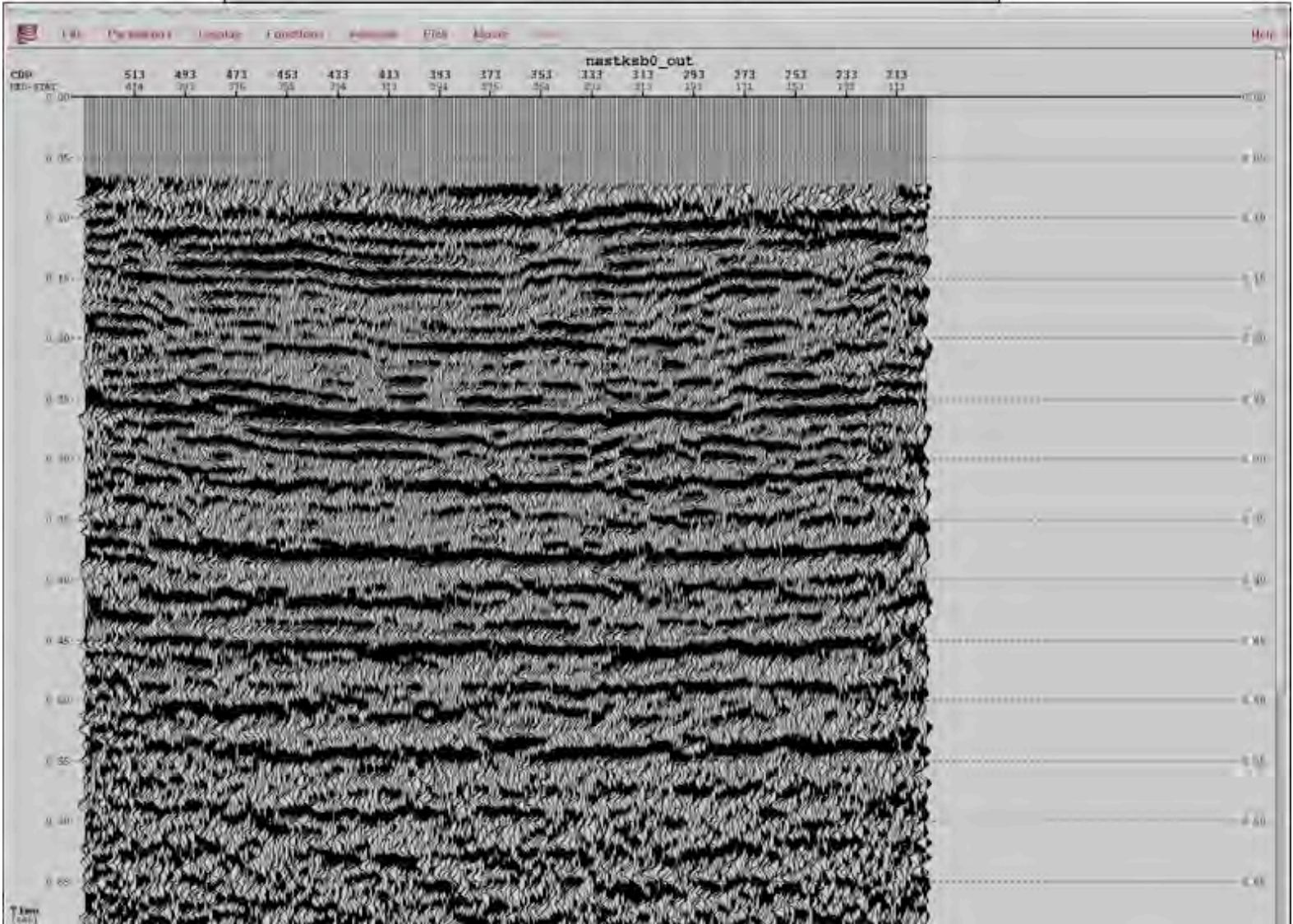
LINE 2 – STRUCTURE STACK



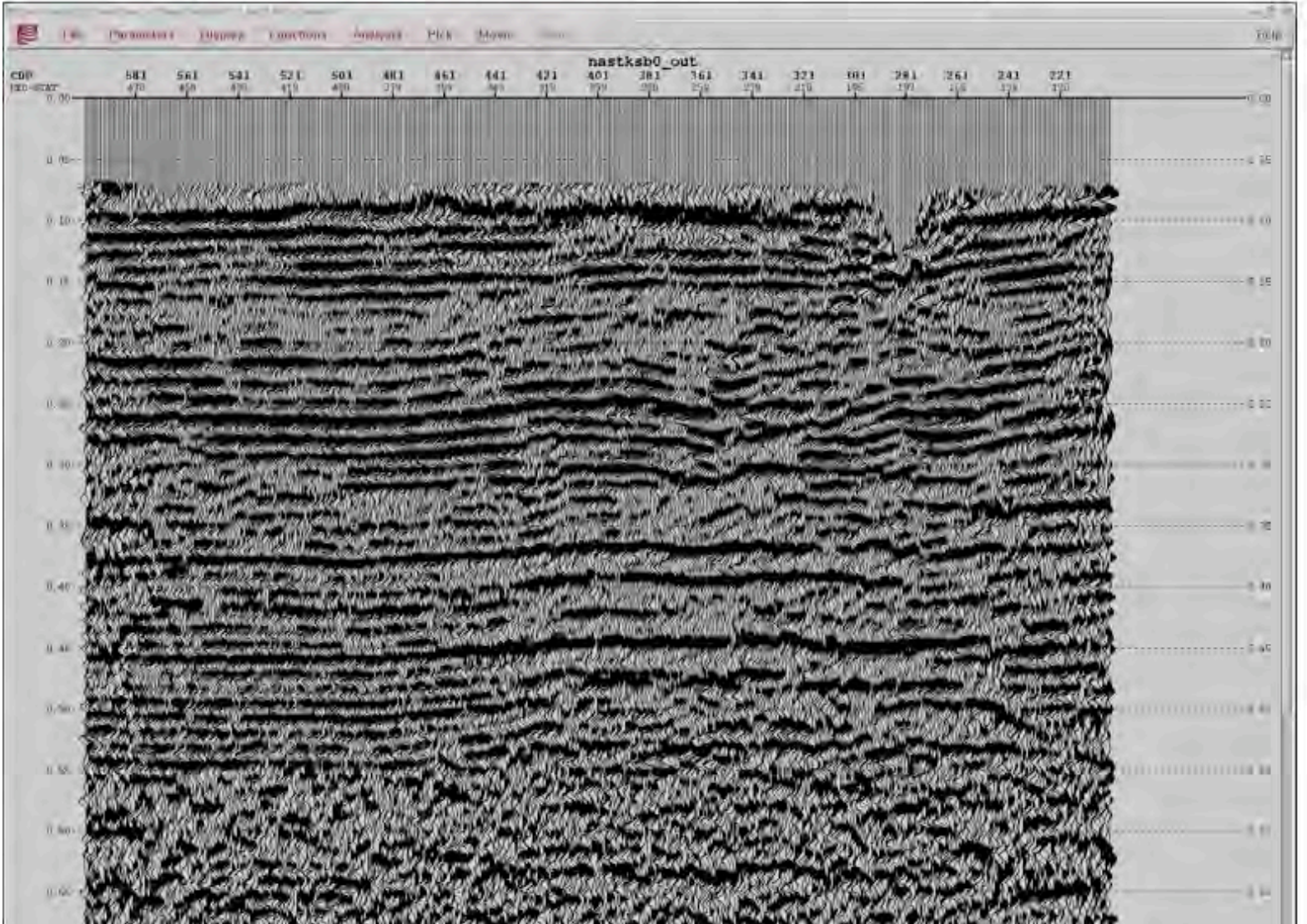
LINE 3 - STRUCTURE STACK



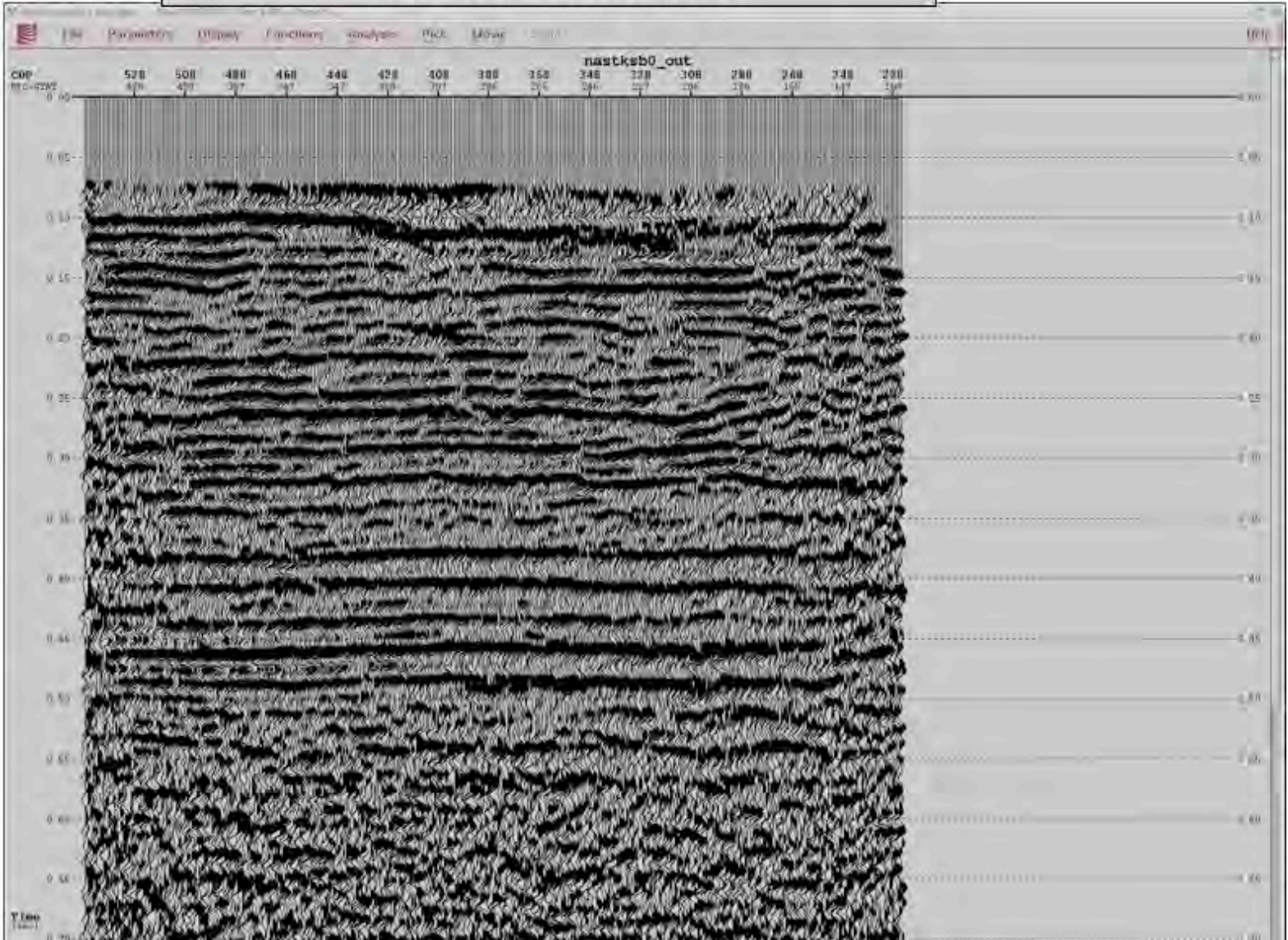
LINE 4 - STRUCTURE STACK



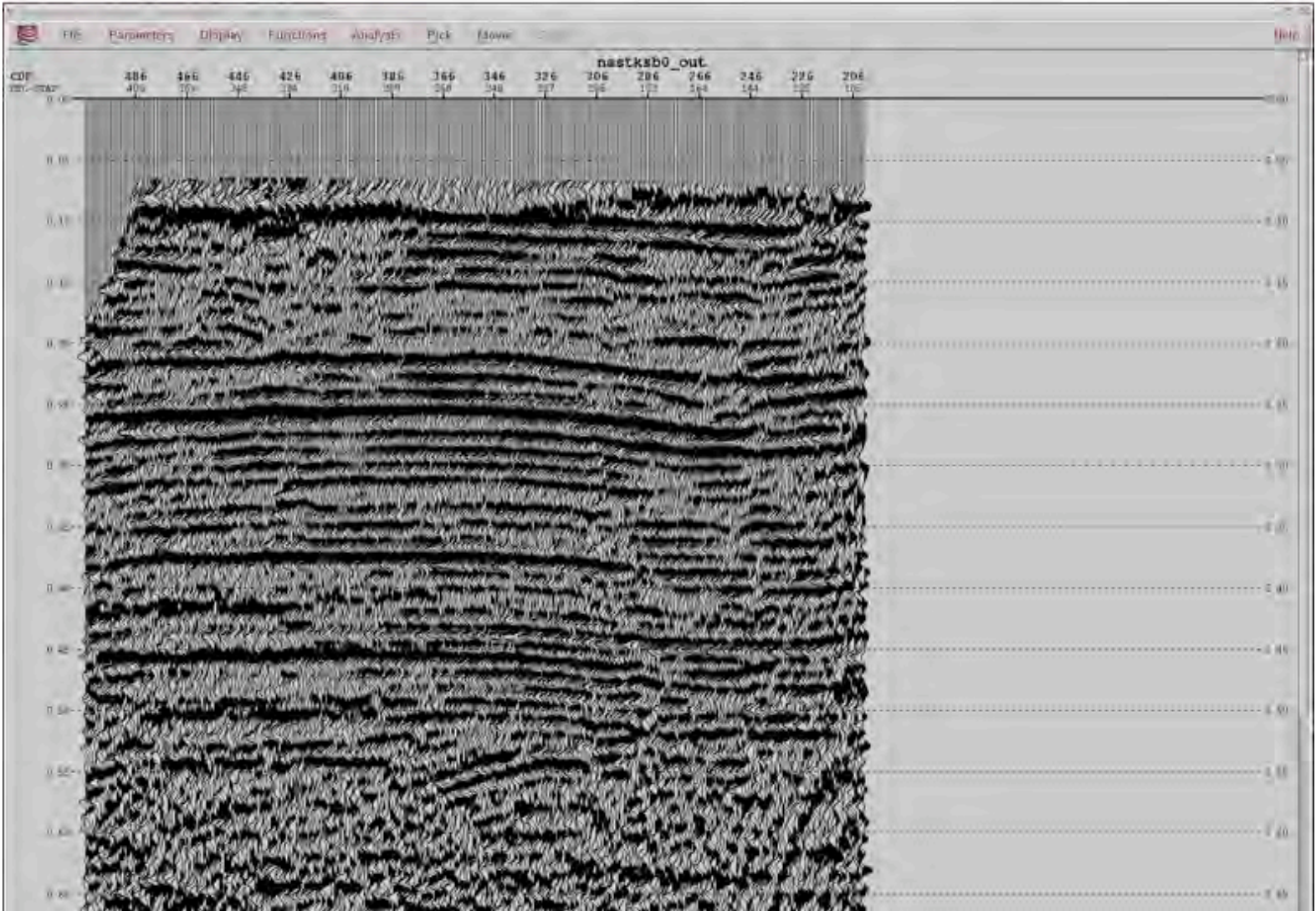
LINE 5 – STRUCTURE STACK



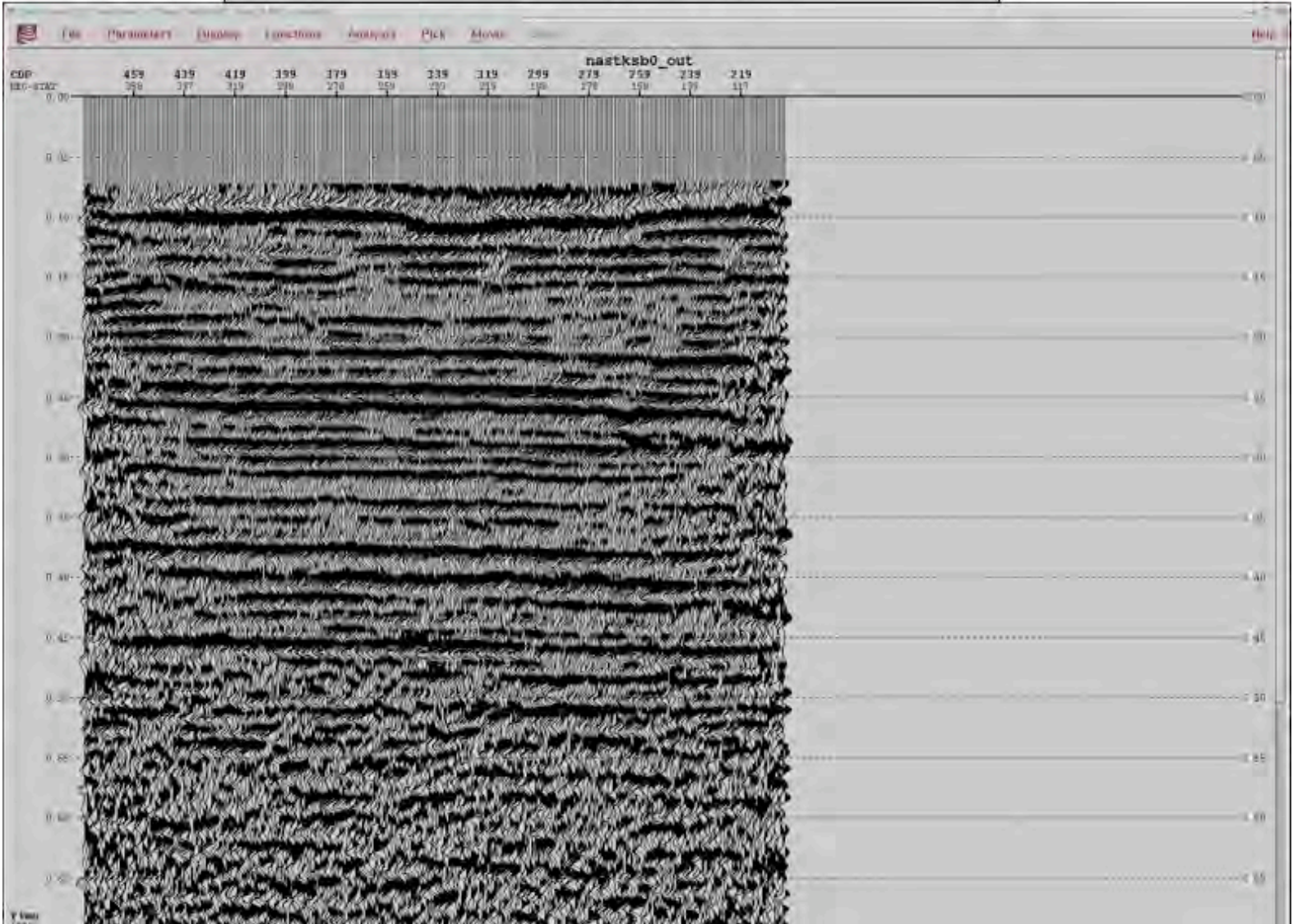
LINE 6 – STRUCTURE STACK



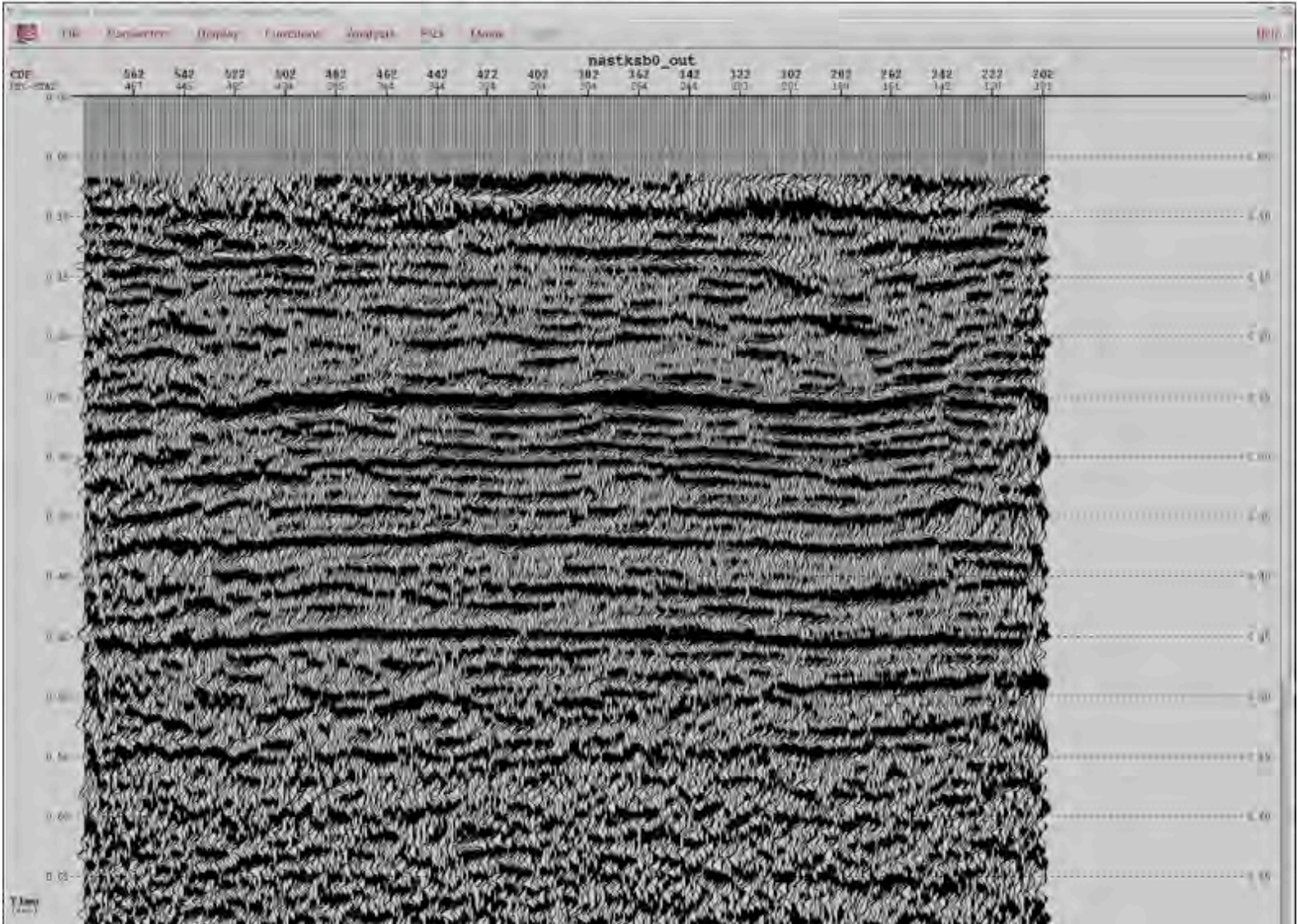
LINE 7 – STRUCTURE STACK



LINE 8 - STRUCTURE STACK



LINE 9 - STRUCTURE STACK



APPENDIX F

Dolomitized Hydrocarbon Reservoirs in Southwestern Ontario

Diagram showing key characteristics of dolomitized hydrocarbon reservoirs in southwestern Ontario.

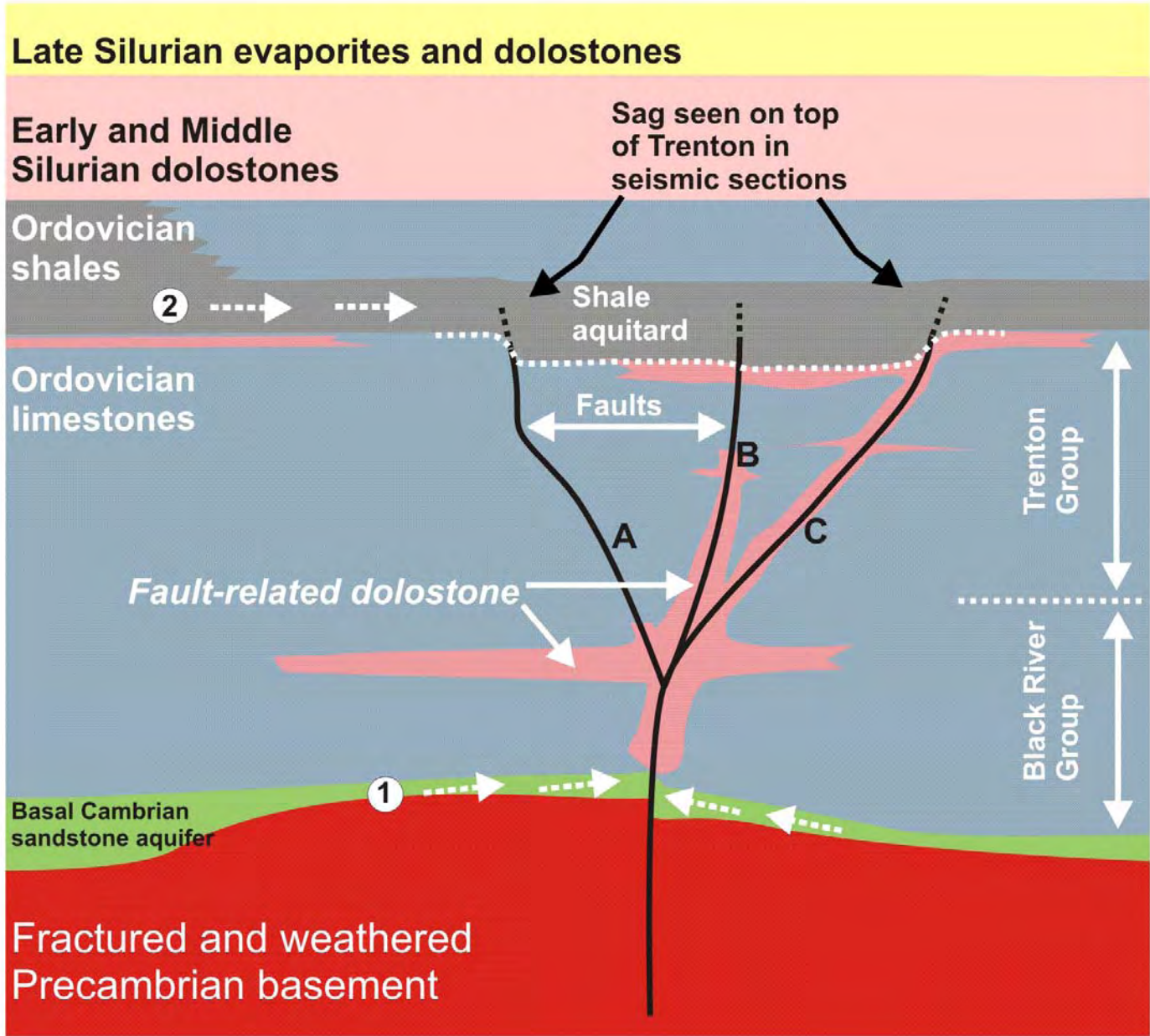
This diagram synthesizes and simplifies information from various sources: Coniglio et al. (1994), Colquhoun (2004), Colquhoun and Johnston (2004), Davies and Smith (2006) and Smith (2006). The sag or structural low at the top of the Trenton is interpreted by most recent researchers as the seismic expression of a negative flower structure associated with regional transtensional tectonics. Faults are rooted in the basement and were intermittently active. Faults penetrate upward to varying degrees – they are generally thought to mainly die out in the overlying shale succession.

Ordovician limestones cut by faults may be locally dolomitized if faults acted as pathways for dolomitizing fluids. Faults A, B and C show progressively increasing amounts fault-related dolomitization (“chimneys”). Fault A was effectively sealed and did not allow dolomitizing fluids to migrate up-section. Dolomitization and brecciation associated with Faults B and C may be associated with increases in porosity and permeability. However, if cementation was complete, Faults B and C may be nonporous and impermeable. Even though Fault C shows the most extensive dolomitization associated with faulting, porosity and permeability may both be low if cementation was extensive.

There are 2 possible sources of Mg-rich brines (labelled 1 and 2) shown in the diagram. Coniglio et al. (1994) also consider refluxing brines associated with the overlying Silurian evaporites as a possible source of Mg for dolomitization, but more recent work does not consider this possibility as a source of Mg for dolomitization.

1. Cambrian sandstones may have acted as conduits for dolomitizing fluids that were generated from deeper within the basin, and that travelled towards the basin margin via compaction flow. Faults penetrating these strata allowed dolomitizing fluids to migrate upwards into Ordovician limestones.
2. Dolomitizing fluids may have been generated from the Ordovician shale succession in deeper parts of the Michigan Basin and focussed up-dip into the basin margin by compaction flow within these strata.

Both mechanisms above are unlikely to generate the high-temperature dolomitizing fluids that precipitate hydrothermal dolomite, unless the Mg-rich brines are incorporated into deeply circulating convection cells.



Conceptual Understanding of Dolomitized Hydrocarbon Reservoirs in Southwestern Ontario
2D Seismic Report

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Reviewed by: SNS
Date: Nov 20, 2008

Figure F-1

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