Final Report Of The

Shi'h Ehtah Thelaa

Slavey for "Cluster of Mountains"

Geophysical Operations of 1998.

Big Island-3D program EL366/SDL99

Chevron Canada Resources

Robert Taerum *PGEOPH*

22 June, 1999

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Operator: Chevron Canada Resources
Contractors: Veritas; MWH Geo-Surveys Ltd
Operations: Gravity & Seismic
Location: 25 km NNW of Fort Liard
Date: June 8, 1998 September 1, 1998
NEB Authorization Number: 9229 C4-12

Abstract

Seismic and gravity data were recorded in the mountains of the Liard Plateau during the summer of 1998. The operations were centred about 25 kilometres north-northwest of Fort Liard over the Liard syncline. The purpose of the survey was to delineate the Fort Liard structure that had been drilled by the D-29 and F-25a wells. A 3-D seismic and gravity program was operated over the structure. The 3-D was named Big Island. These operations are in partial requirement of the Work Commitment for EL366

Seismic Operations

Seismic reflection data was recorded to image the subsurface structure. The program was designed as a 3-D low fold program. The purpose of the 3-D program was to properly image the subsurface reservoir in a 3 dimensional manner so the gas pool could be developed optimally. The rugged terrain and sensitive ground cover necessitated a low impact Heli-portable system. The 3-D method was used to improve our understanding of the structural shape of the reservoir. The 2-D method does not provide sufficient information for placing a well bore in the most optimum location in the reservoir. The low fold is an attempt at reducing the cost and environmental impact of the program. The following is a summary of the seismic acquisition and processing parameters.

Chevron Canada Resources Program Name: Big Island

Contracting Crew: Veritas

Acquisition Dates

- Start Survey: June 8, 1998
- Start Recording: August 3, 1998
- Finish Recording: August 20, 1998
- Length of Survey: 57 square kilometres, 212 linear kilometres
- Average Acquisition Rate: 3.3 square kilometres per day

Spread Parameters

- Number of Traces: 1170
- Geophones per Group: 6
- Geophone spacing: 1 metre; 2X3 box array
- Shot Point Interval: 170 metres in line, 120 metres binning
- Group Interval: 60 metres
- Patch Dimensions: 4320 metres x 5340 metres
- Active Patch: 10 lines x 90 stations
- Source Line Interval: 900 metres
- Receiver Line Interval: 480 metres
- Bin Size: 60 metres x 30 metres

Source Parameters

- Source: Dynamite
- Number of Holes: 1
- Hole Depth: 20 metres
- Charge Size: 20 kilograms
- Shot Point Location: On shot Line Location
- Drilling Method: Heli-portable

Recording Equipment

- Recording System: I/O System Two
- Geophones: Geospace Model CT 10 Hz marsh phones

Surveying System

- Mix of Conventional and GPS survey techniques
- Data collected in NAD83 and converted to NAD27

Terrain

- Mountainous, Rugged, Variable
- Variable Ground Cover: Muskeg, Cliffs, Stunted Trees, Bush
- Isolated, Access by Helicopter and by foot

Personnel

- 45 people on slashing, surveying and drilling
- 35 people on the seismic recording crew including 5 professional mountain climbers
- 4 people on 2 gravity crews

Weather

- Eighteen days lost due to morning fog, rain or afternoon winds

Processing Flow

Performed at Veritas Geophysical Services

- Define Geometry
- Edit Dead, Noisy or Reverse Traces
- Compute Mutes
- Pick First Breaks
- Apply Refraction Statics
- Set Final Datum Elevation = 1250m, Replacement Velocity = 4500m/s
- Processing Datum Set:
- True Amplitude Recovery 1/(time*velocity**)
- Surface Consistent Decon (Source, Receiver)
- Apply Residual Statics (Correlation Autostatics)
- Apply Normal Moveout Correction
- Apply Non-surface Consistent Trim Statics
- Pre-stack Time Migration

Gravity Operations

The gravity data was acquired along side of the seismic program. A gravity reading was recorded every 2 receiver stations for a station spacing of 120 metres. Gravity was not recorded on the source lines. The following is a summary of the gravity acquisition and processing parameters.

Chevron Canada Resources Program Name: Big Island 3-D

Contracting Crew: MWH Geo-Surveys Ltd

Acquisition Dates

- Start Survey: June 16, 1998
- Finish Survey: August 9, 1998
- Length of Survey: 212 linear kilometres
- Average Acquisition Rate: 4.7 kilometres per day

Recording Equipment

- Three Lacoste & Romberg G model Gravity Meters
- Serial numbers 371, 332 & 689

Surveying System

- Mix of Conventional and GPS survey techniques
- Data collected in NAD83 and converted to NAD27

Field Procedures

- All Readings taken within closed loops
- All Loops tied to ISGN gravity monument in Fort Liard
- Inner Terrain Corrections (Annulus A to D) visually estimated
- 1058 unique stations and 34 repeat stations recorded
- Gravity Stations are located at the Geophone station
- Elevation and coordinates of Geophone station used for Gravity

Processing

- Bouguer Reduced with density = 2.55 gm/cm3
- Latitude correction uses 1967b Geodetic Reference System
- Outer Terrain Corrections from 170m to 37000m

Project Overview

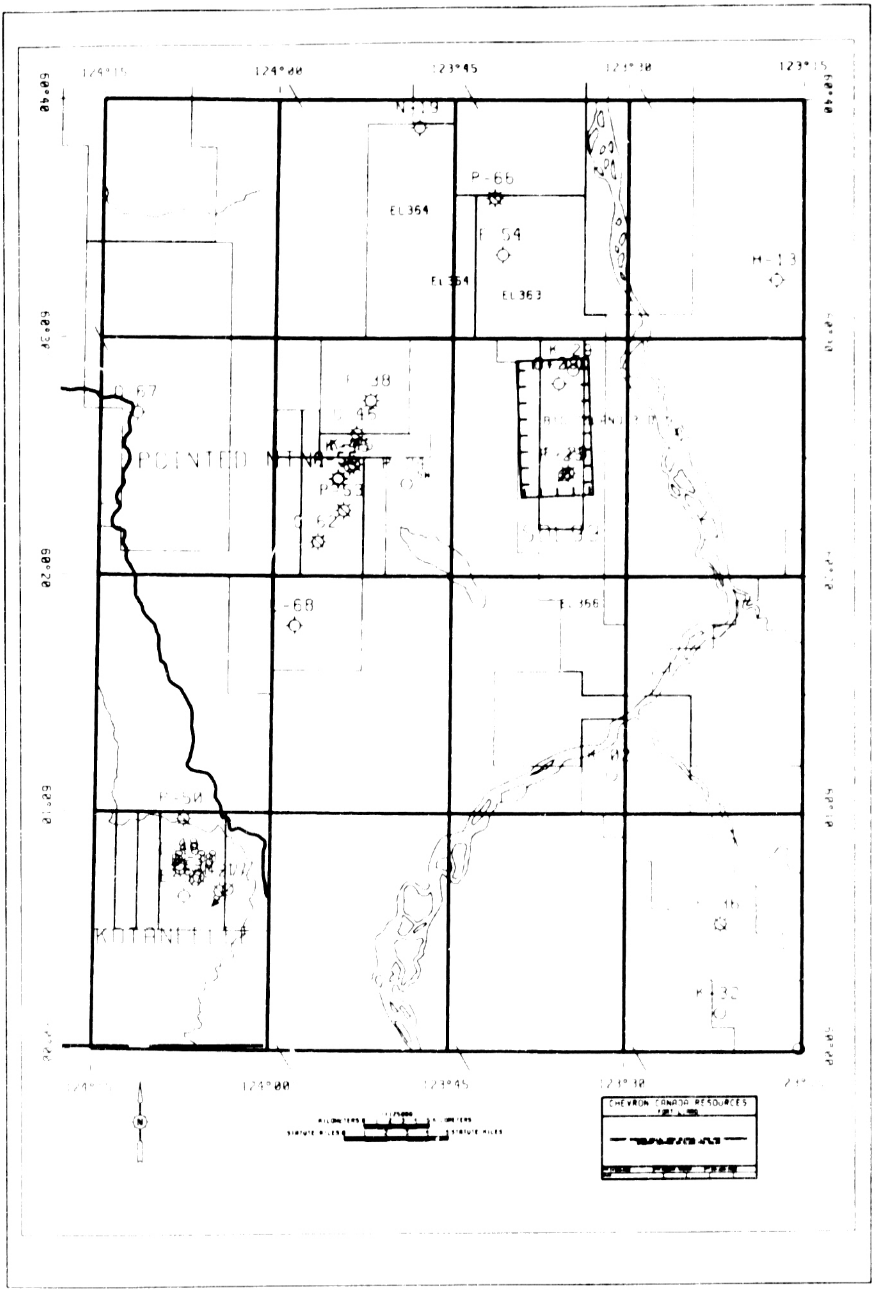
Locality

The program was centred on the Liard Plateau that is situated between the Rocky Mountains to the southwest and the Mackenzie Mountains to the north. The gross location of the program is shown on figure 1. South of the 60th parallel the stratigraphy plunges to the south into the Liard Basin. North of the map the reservoir rock outcrops in the Mackenzie Mountains. To the west the reservoir shales out into a deep paleo basin. To the east there is only minor structural deformation. Figure 2 shows a close up of the Exploration License 366 and Significant Discovery Lease 99, wells, and the seismic and gravity program completed in 1998. The seismic and gravity program was named Big Island 3-D. Figure 3 shows the topography of the area. Figure 4a shows a close up of the Big Island 3-D and figure 4b shows all of the seismic data Chevron currently possesses over SDL99.

Purpose

The purpose of the geophysical program was to image the Fort Liard Reservoir. The D-29 and F-25a wells had both tested gas from the reservoir, however, the production rates were sub-economic and they both had a large pressure draw down resulting in high water production. It was thought that if we could place a borehole in the reservoir where it was highly fractured due to high deviatoric stress that the well would be economic. Highly deformed folds and faults (typically at the reservoirs leading edge of the thrust sheet) are often locations where wells have high production rates.

At surface, the Fort Liard structure is a complexly folded and faulted anticlinorium, characterized by exposures of Mattson, Flett, and Besa River Formations. In the subsurface, thrust faulted and uplifted Besa River and Nahanni Formations core the Fort Liard Structure. The latter of which is Middle Devonian in age and forms the objective reservoir interval. Geophysical techniques such as gravity and seismic are necessary to image the subsurface structures that form the reservoir.


124°00
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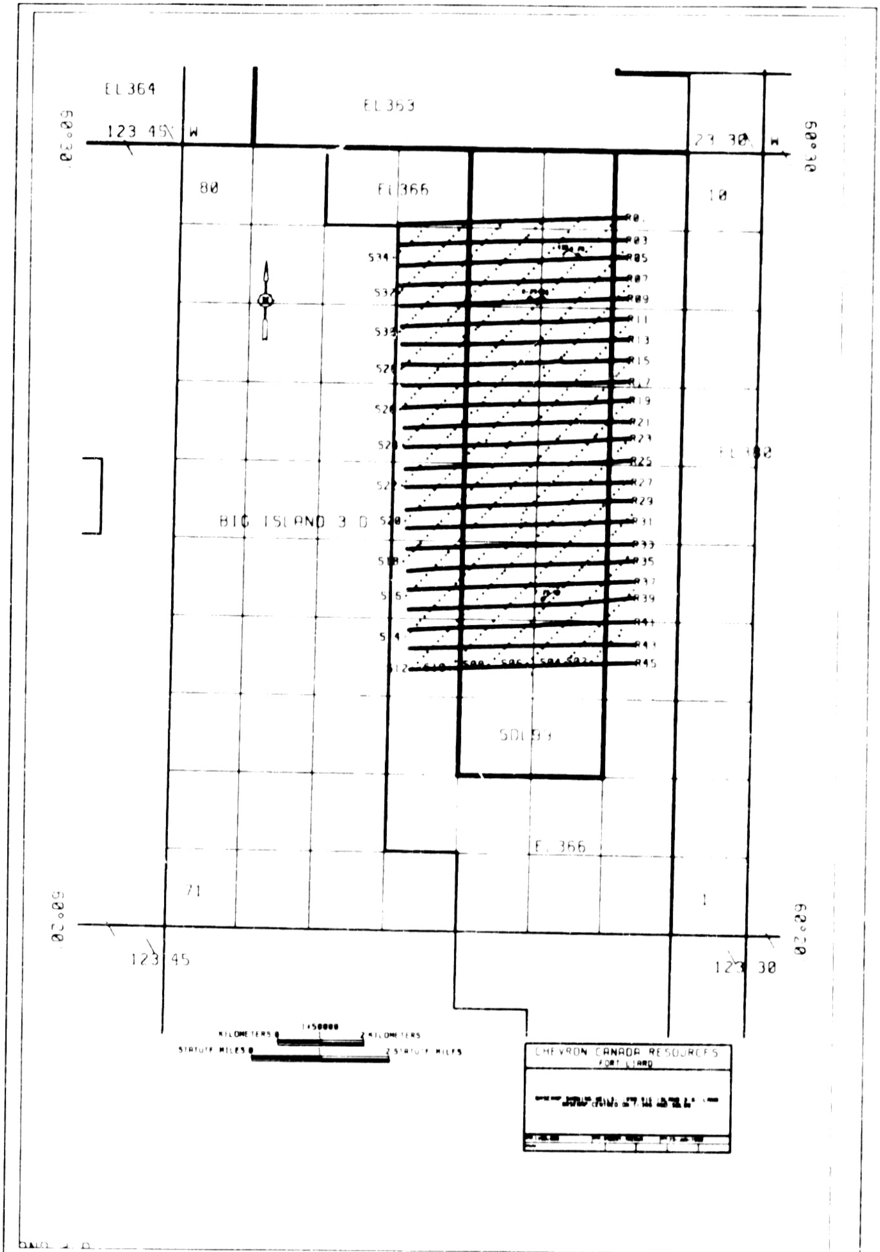

Figure 2 Big Island 3-D and SDL99 and EL366

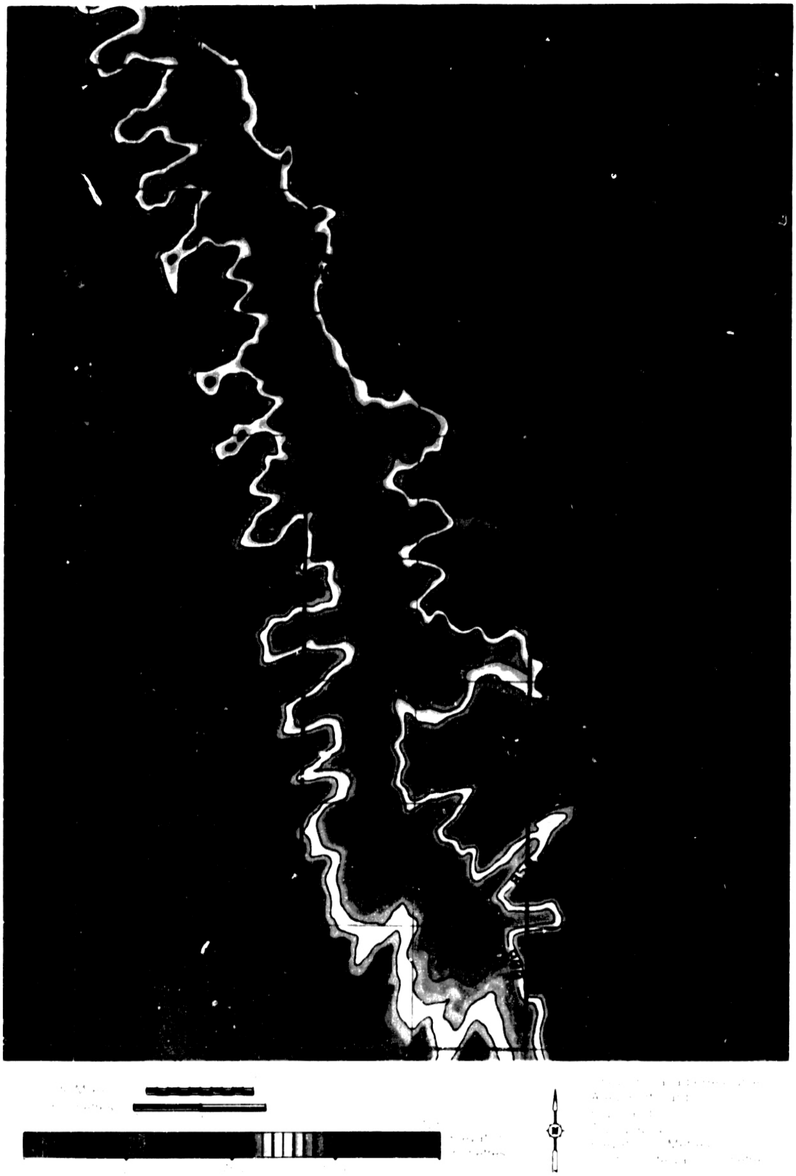

Figure 3 Topography of SDL99 1

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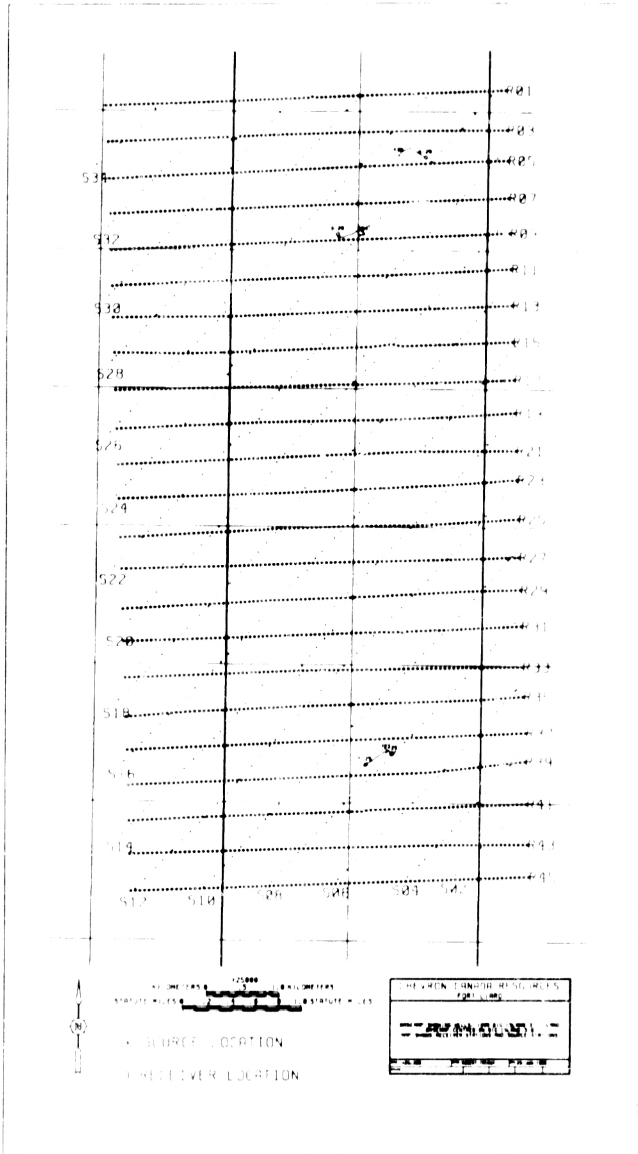

Figure 4a Big Island 3-D

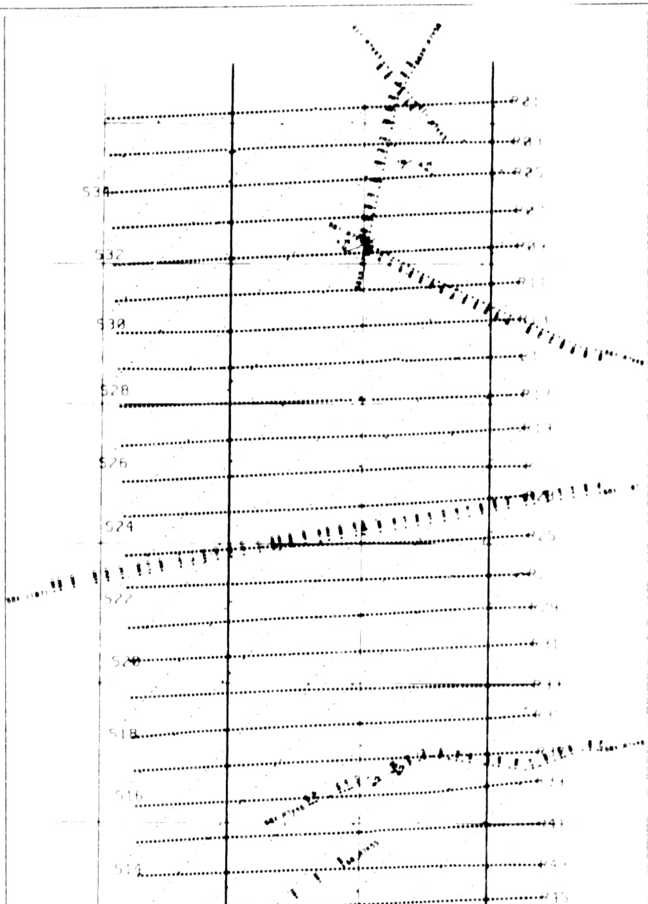

Figure 4b All Chevron Seismic 1

Results and Interpretation

Stratigraphy

The stratigraphies discussed in this report are summarized in the stratigraphic chart that follows (figure 5). The stratigraphic column consists of three major packages. The youngest is the Mississippian through Cretaceous limestones, sandstones and interbedded shales. Structures in this upper package are responsible for most of the topographical variation in the region. The competent rocks of the Fantasque, Mattson and Flett form a resistive cap protecting mountaintops from erosion and adding to the rugged nature of the terrain. The second package is composed of a monotonous sequence of Middle Devonian through Mississippian shales and minor siltstones of the Besa River Formation. The uppermost portions of this package are exposed at the surface, locally only at surface anticlines where the upper packages has been breached. The N-19, P-66, E-54, K-29 and D-29 surface locations are all on breached anticlines where the upper most Besa River is exposed. Due to the incompetent nature of the Besa River shales the rock is easily deformed. It acts as a major zone of structural detachment under EL-364 and EL-363. The oldest package is the Precambrian through Middle Devonian carbonates and clastics. This is the lowest and most competent package, the uppermost portion of which is the reservoir of interest.

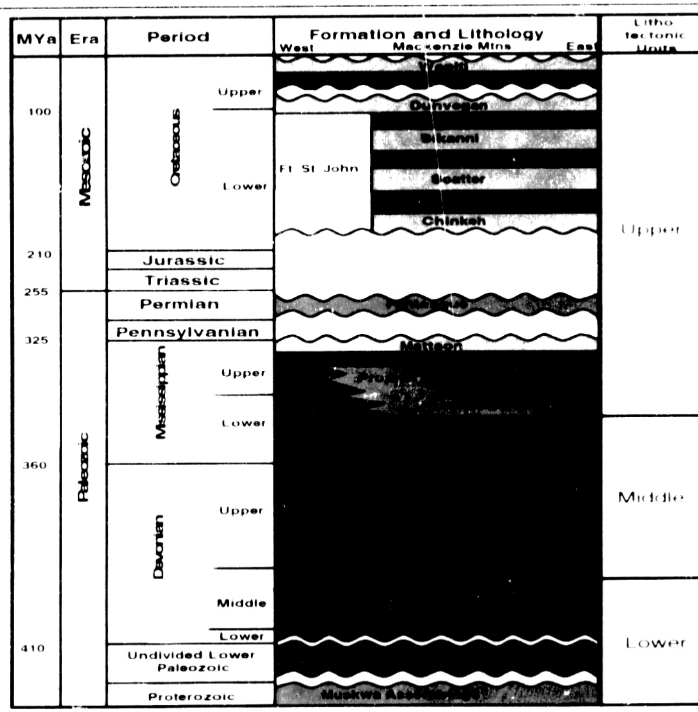

Figure 5

Results and Interpretation

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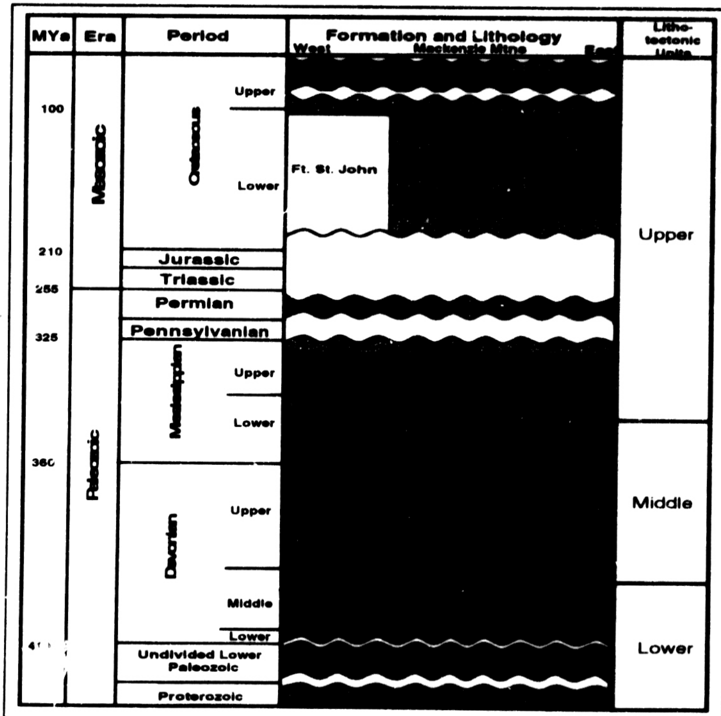

Figure 5

Structure

The Fort Liard structure is composed of a north-trending, uplifted thrust sheet of Middle Devonian carbonates. Uplift of the thrust sheet is interpreted to have occurred during the late stages of the Laramide orogeny, and is probably late Cretaceous or earliest Tertiary in age. The youngest strata involved in the deformation are the Wapiti Fm. believed to be Campanian-Maastrichtian in age. A sinuous, west dipping thrust fault forms the eastern

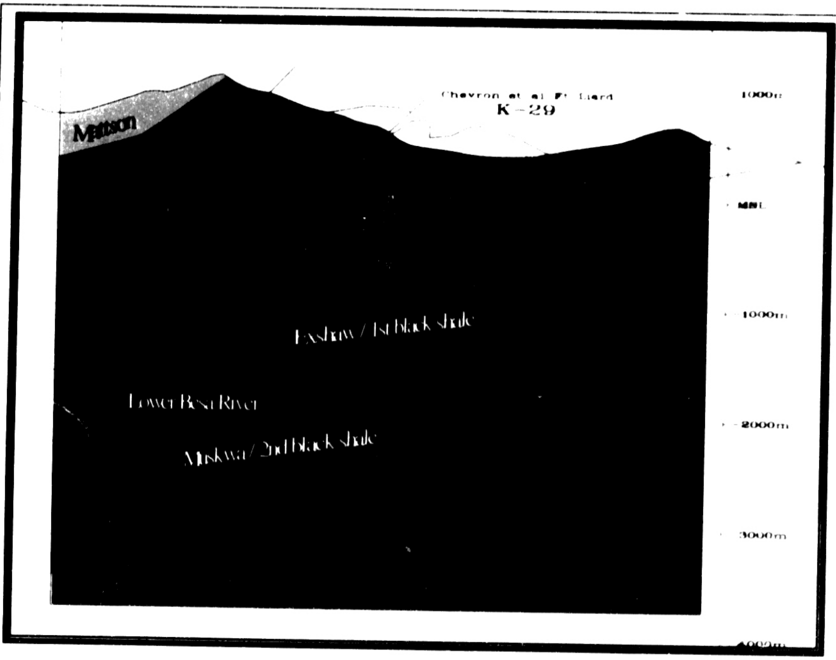

Figure 6 Cross section through the Fort Liard structure at K-29 location. Line of section is approximately east-west with little vertical exaggeration.

boundary of the gas reservoir as illustrated on the cross section (Figure 6) and the accompanying structure map (Figure 7). The thrusted sheet of Nahanni is composed of two subsidiary, en-echelon culminations, both of which are carried by the same thrust fault. A lateral ramp in the fault causes it's map view trace to swing dramatically east west resulting in the two subsidiary culminations (Figure 7). D-29 and K-29 were drilled in the northern culmination and F-25a penetrated the southern culmination.

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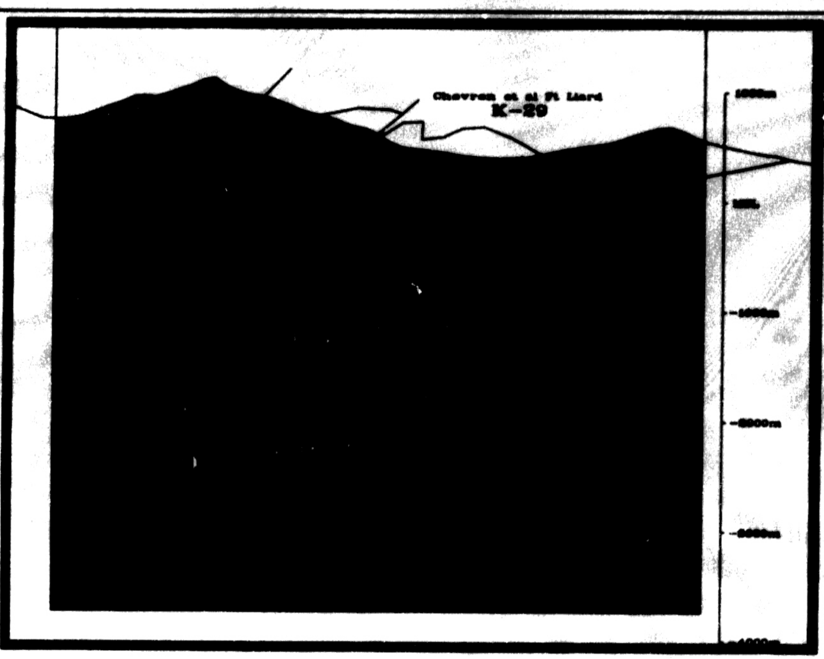

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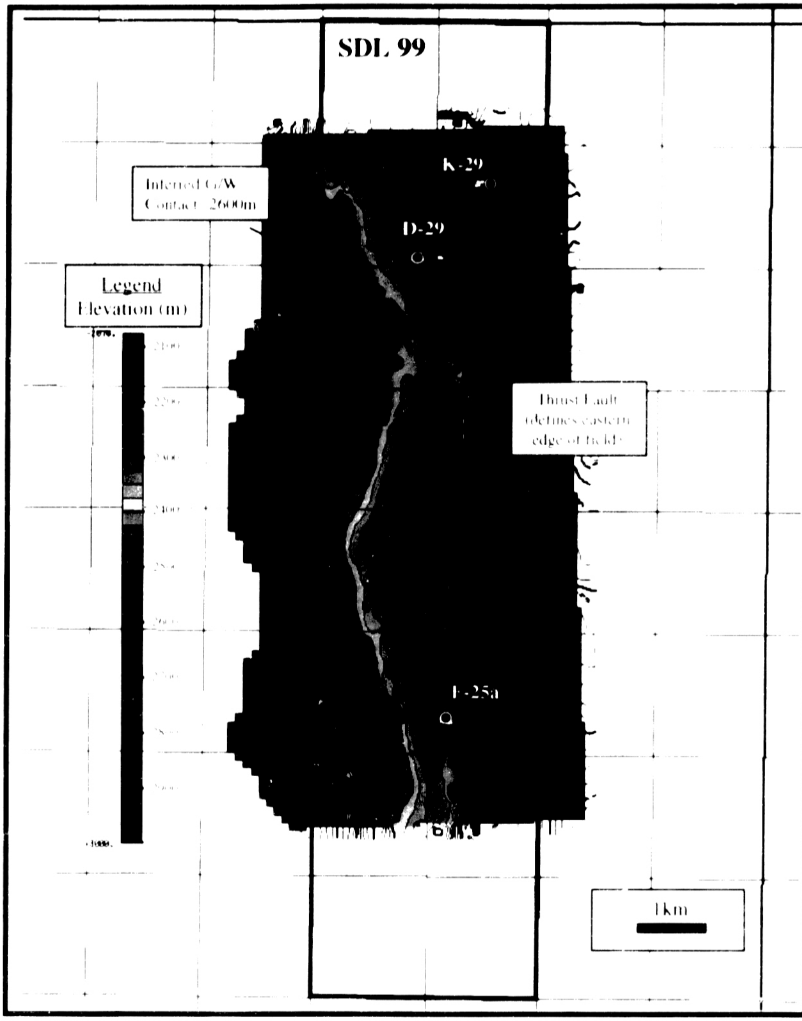

Figure 7 Structure map on top of Nahanni Formation

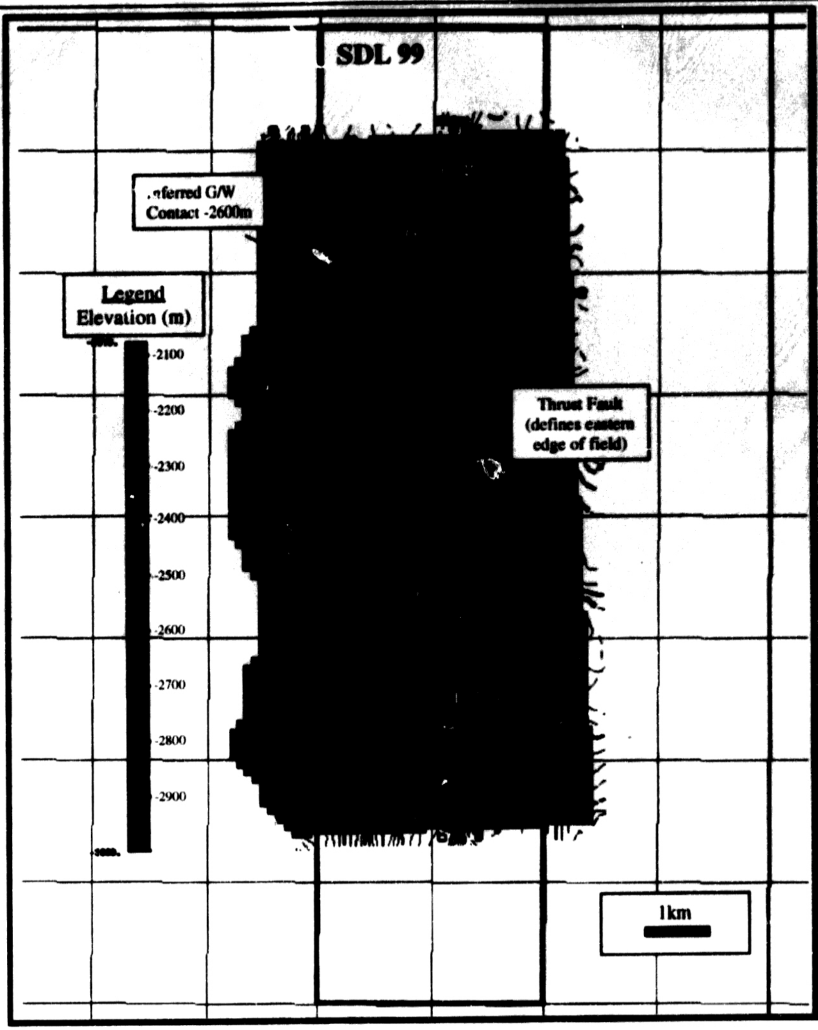

Figure 7 Structure map on top of Nahanni Formation

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Reservoir

Middle Devonian carbonates, presumed to be largely equivalents of the Nahanni, Arnica and Landry Formations (informally grouped as Nahanni or Middle Devonian Carbonates in this report), comprise the reservoir interval in this region. The interval is almost entirely dolomite and has been extensively altered both diagenetically and tectonically. Typical matrix porosities are low, ranging from 0 to 6%. Superimposed on the diagenetic fabric is a series of fractures that are probably associated with the regional Laramide stress-field and the development of the Fort Liard structure. This fracture system forms the main permeability network within the Middle Devonian reservoir interval.

Nearby Analogies

Three nearby fields (Beaver River, Kotaneelee and Pointed Mountain) have produced significant quantities of gas from the Nahanni Formation since the early 1970's. A number of other nearby wells such as F-25 and D-29 had also encountered hydrocarbons, though their rates were not commercial. These known gas pools are found in thrust faulted and uplifted Nahanni Formations. A surface anticline is often associated with the thrust fault, however, there can be a significant amount of offset (in the dip direction) between the uplifted Nahanni and surface anticline.

Big Island 3-D Program

Due to the complexity of the Fort Liard structure (see figures 6 & 7) a 3-D seismic program was recorded during the summer of 1998. The 3-D seismic data enable us to create a 3 dimensional picture of the structure of the reservoir rock. The cross-section (figure 6) and structure map (figure 7) were both based on the interpretation of the 3-D seismic data. An index map of the seismic program is shown in figure 8 and three cross-sectional slices of the seismic data are shown in figures 9, 10 and 11. Cross-sectional slice (figure 9) shows the northern culmination discussed before. Cross-sectional slices (figures 10 and 11) show the southern culmination. Comparison of the three cross sectional slices shows the structure character (e.g. thrust angle, throw, folding, etc.) vary significantly along the Fort Liard structure. The types and amounts of deformation of the reservoir rock that we observe on the seismic data provides important information on the fracture network which is important for a high deliverable well.

High resolution cross-lines and in-lines are included with this report. They are wiggle trace variable area and are plotted at 7.5 inches per second at 10 traces per inch. The grid of cross lines and in-lines are sufficiently regular and dense to make a reasonable time structure map of the horizons. Figures 8 through 11 are included in this grid of seismic lines.

Figure 8. Index map of Big Island 3-D Survey. Red X-lines included in figures 9, 10 and 11

Figure 8 Index map of Big Island 3-D Survey. Red X-lines included in figures 9, 10 and 11

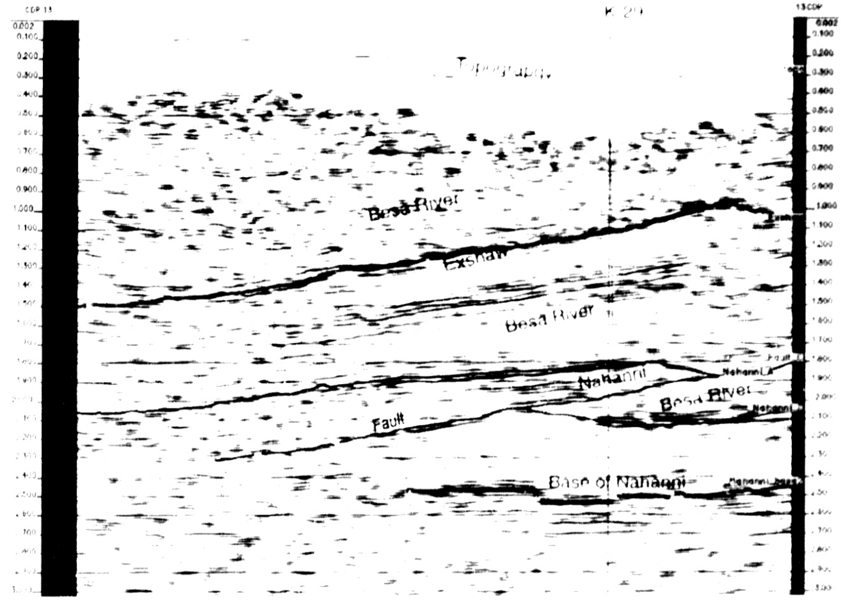


Figure 9 X-line 13 going through K-29

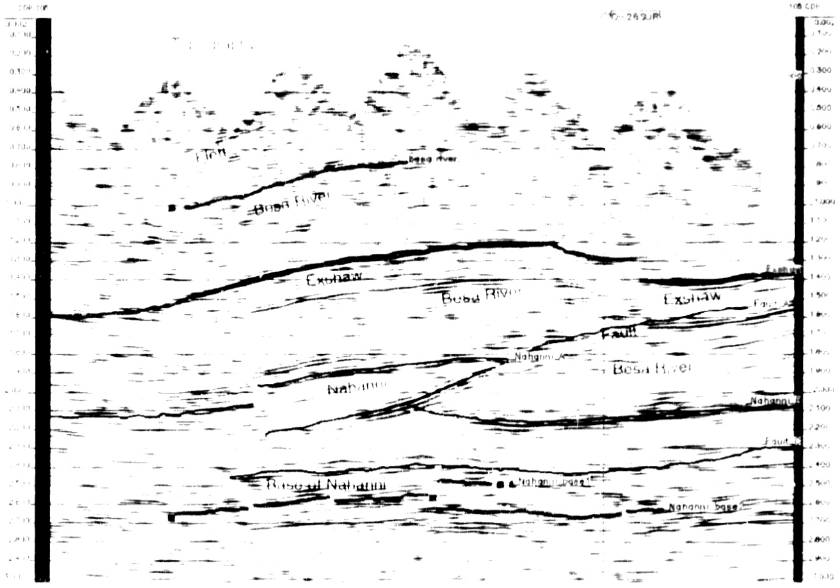


Figure 10 X-line 105

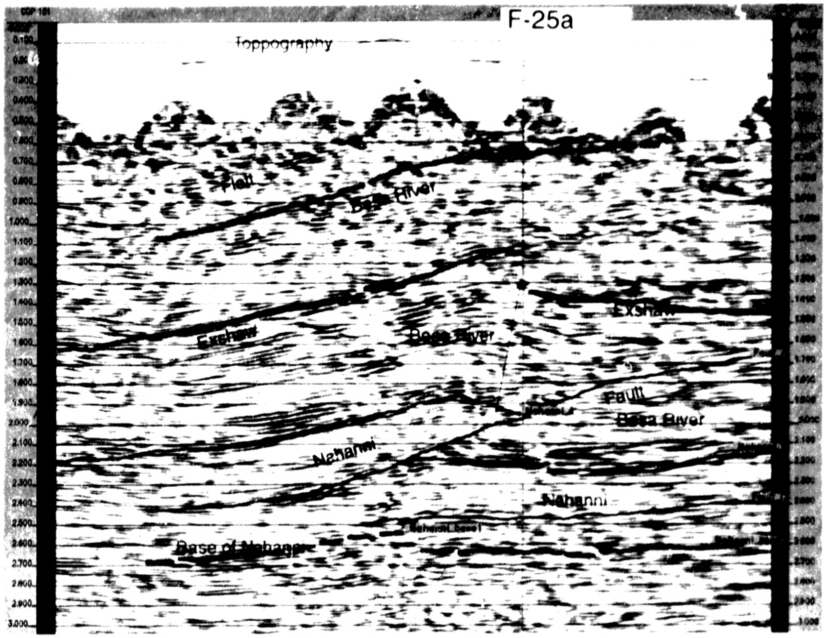
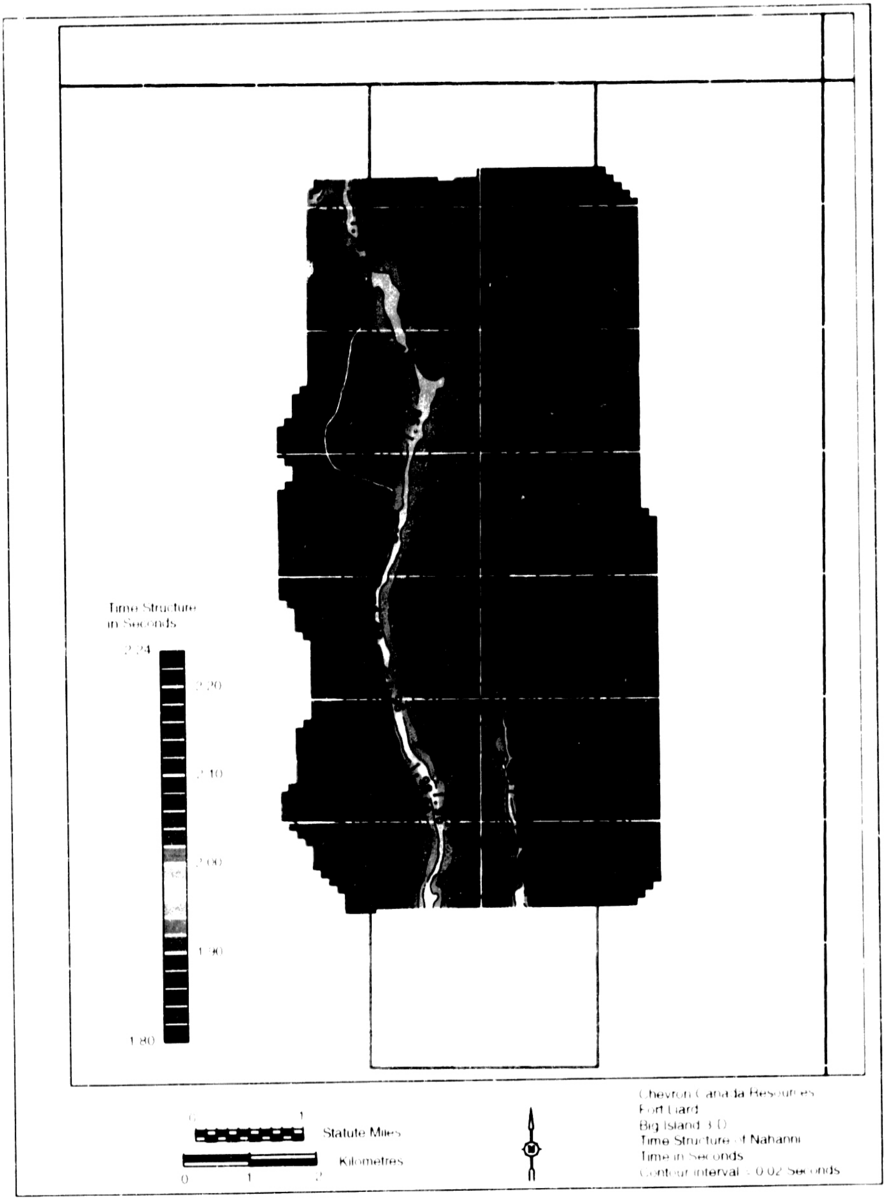


Figure 11 X-line 151 going through F-25

Nahanni Structure

The Structure map of Figure 7 was derived from a time structure grid and an average velocity grid. The time structure grid was derived from the horizon picks of the top of the Nahanni and the average velocity grid was derived from the D-29 well, the F-25a well, surface geology and an interpretation. Initial attempts to simply use a constant average velocity to convert from time to depth resulted in a bust of nearly 200 metres between F-25a and D-29. F-25a has a check shot survey but the horizon pick on the 3-D is somewhat interpretive because the east dipping limb of the Nahanni at that point is not well imaged. The seismic at the Nahanni level is well imaged at D-29 but D-29 does not have a check shot survey nor a complete sonic log. The nearly 200 metre bust between the two wells is likely due to the high velocity Flett being eroded away at D-29 but 600 metres thick at F-25a. The final velocity grid used the average velocity derived from the F-25a check shot. It was slightly modified so the 3-D seismic and velocity would tie the well. Next the velocity over D-29 was derived to ensure the seismic and velocity would tie the well. The velocity was then interpolated between the two wells using surface geology as a constraint. The low average velocity around D-29 was constrained to the valley where the low velocity Besa River shale nearly outcrops. The velocity was smoothly increased away from the valley to reflect the increasing thickness of the high velocity Flett. Figure 12 shows the time structure map of the Nahanni and Figure 13 shows the average velocity grid used to derive the depth structure map


Time Structure in Seconds
2.24
2.20
2.10
2.00
1.90
1.80
0 1 Statute Miles
Kilometres
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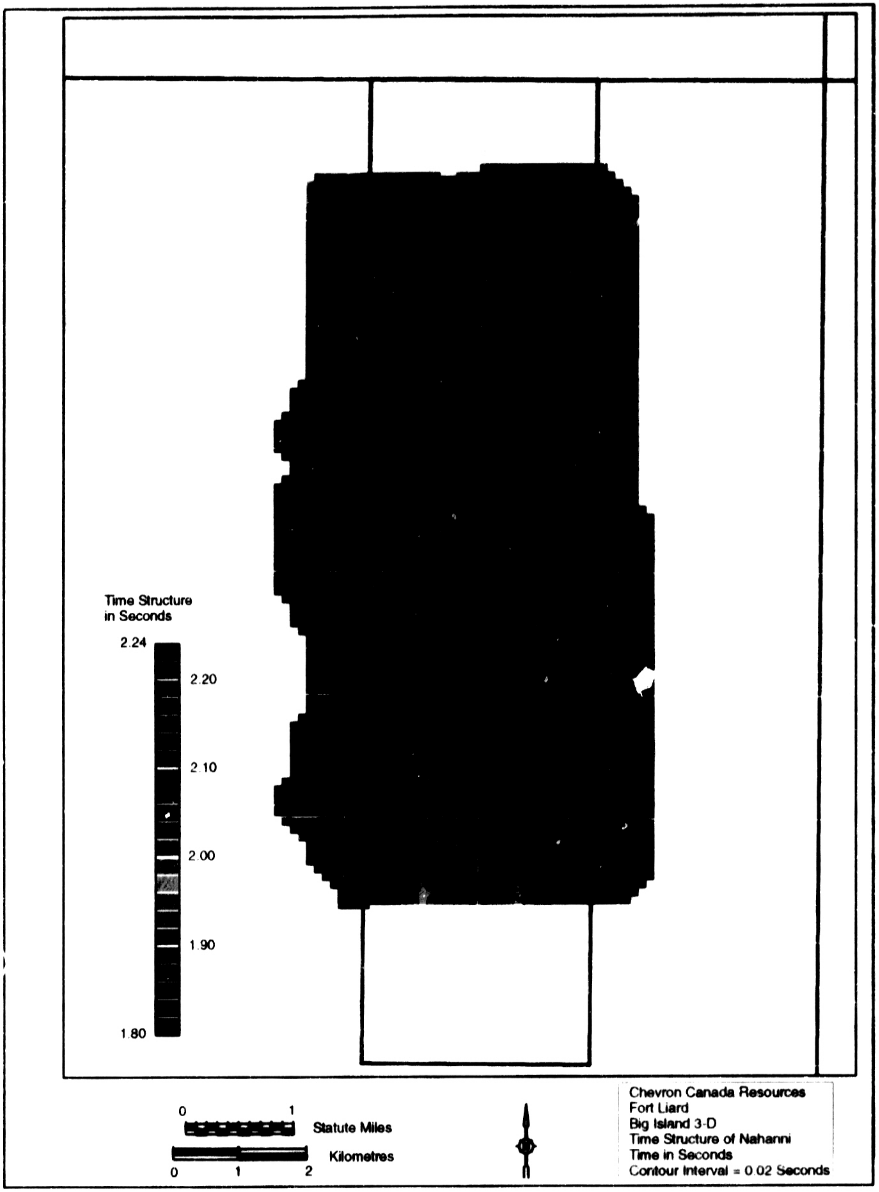
Chevron Canada Resources
Fort Liard
Big Island 3 D
Time Structure of Nahanni
Time in Seconds
Contour interval = 0.02 Seconds



Time Structure in Seconds
2.24
2.20
2.10
2.00
1.90
1.80
0
1
Statute Miles
Kilometres
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Chevron Canada Resources
Fort Liard
Big Island 3-D
Time Structure of Nahanni
Time in Seconds
Contour Interval = 0.02 Seconds

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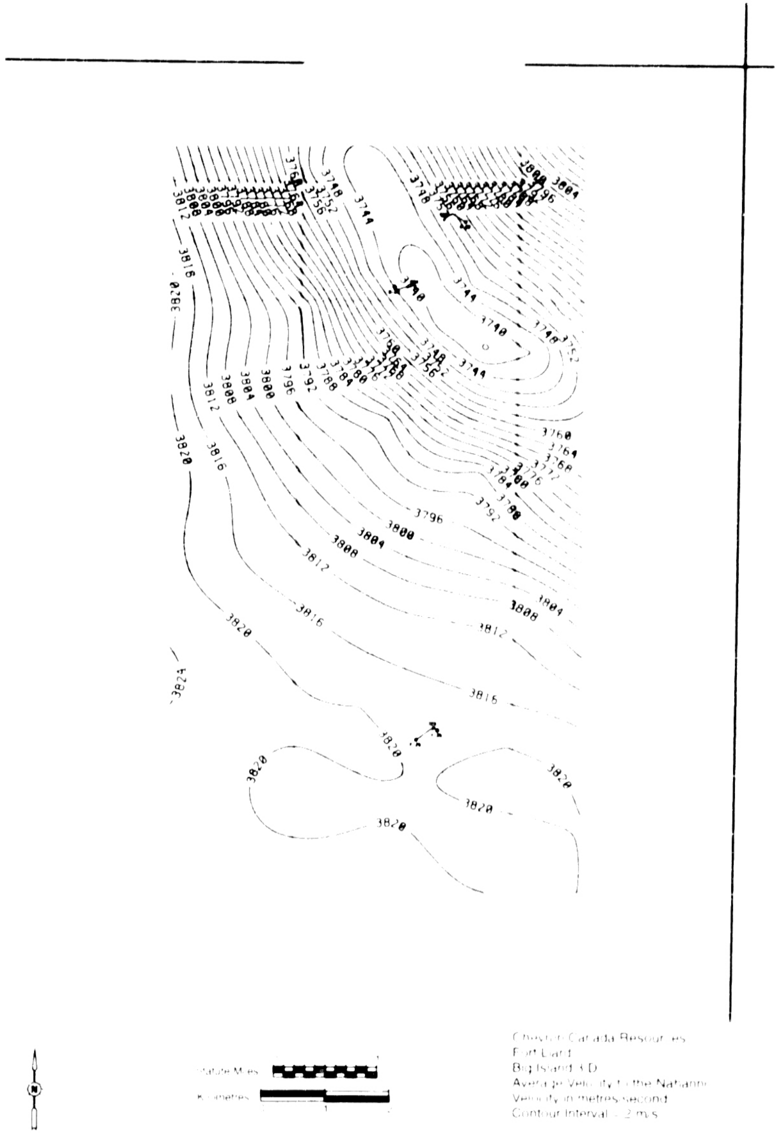

Figure 13 Average Velocity

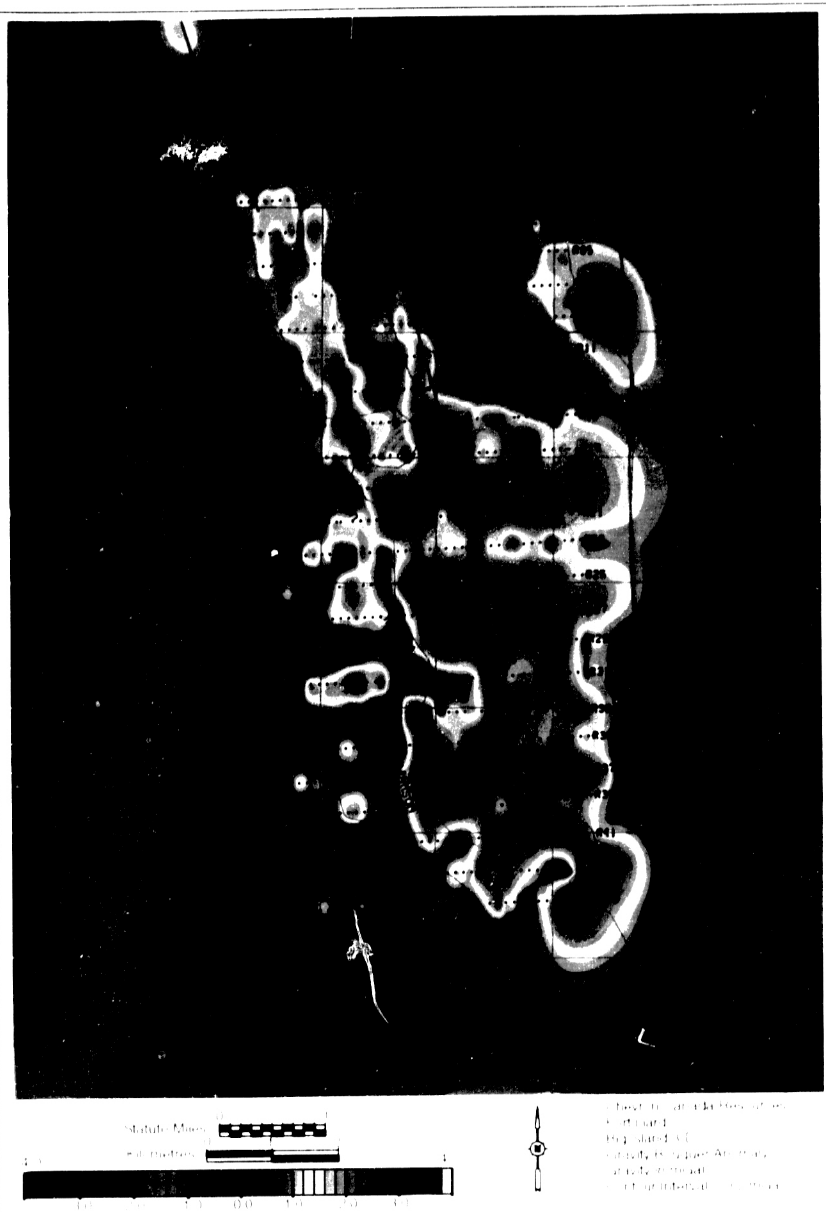

Figure 14 Bouguer Gravity Anomaly

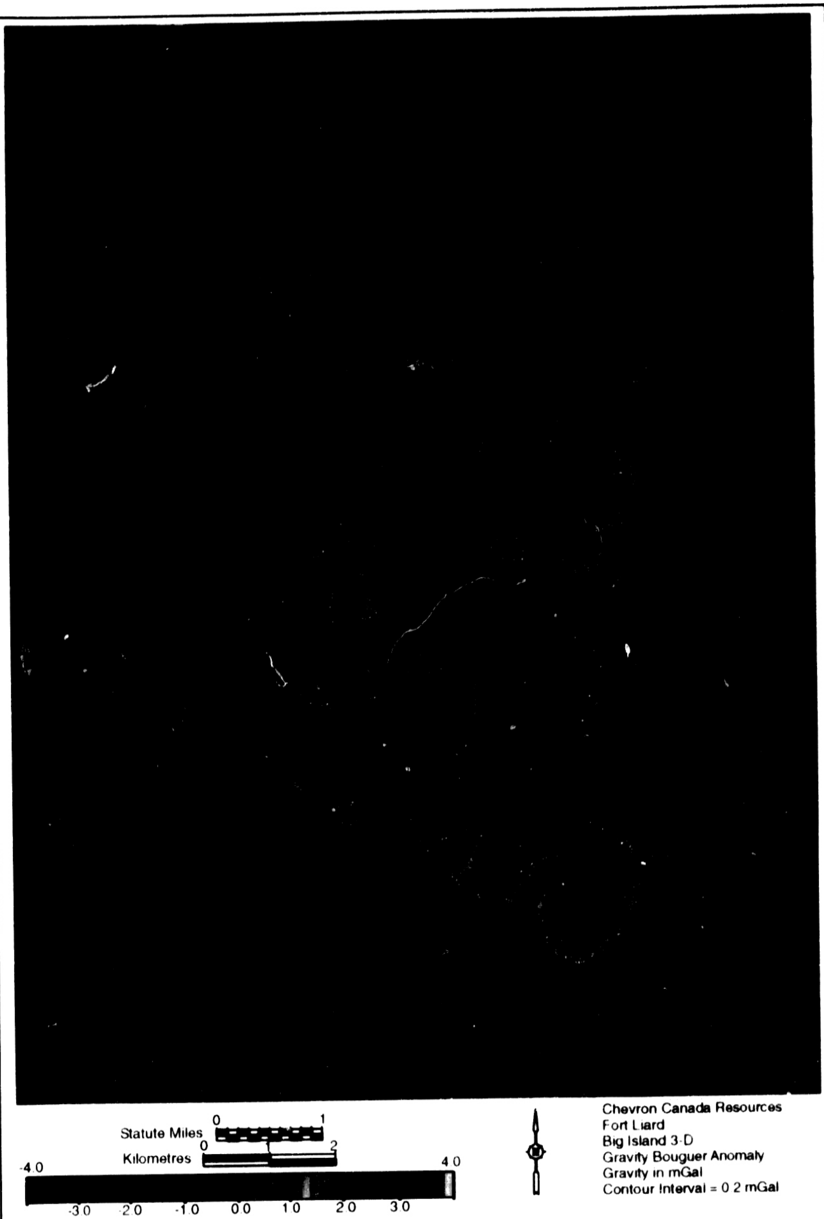

Figure 14 Bouguer Gravity Anomaly

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Seismic Ties to Wells

Figures 15 to 20 show the logs and synthetic seismograms for D-29, F-25a and K-29. All 3 wells are located in SDL99 and they all terminated in the Nahanni. Figure 15 shows the K-29 logs in depth and Figure 16 shows the logs converted to time along with a synthetic seismogram. The quality of the logs is excellent and the K-29 synthetic seismogram tie with seismic is excellent. The Exshaw has a clean trough, the Lower Besa River is clean and the Muskwa has a triple peak followed by the Nahanni peak. Figures 17 and 18 show the logs for the F-25a well. Figure 17 shows the logs in depth and Figure 18 shows the logs converted to time along with a synthetic seismogram. The borehole conditions are average quality and so the quality of the sonic log is average. The borehole trajectory for F-25a was through a significant fault so ties to the seismic are difficult in some places. Figures 19 and 20 show the logs for the D-29 well. Figure 19 shows the logs in depth and Figure 20 shows the logs converted to time along with a synthetic seismogram. The borehole conditions are average quality and so the quality of the sonic log is average. Typical seismic in the area shows a strong trough at the Exshaw, some reflections in the Lower Besa River, a triplet in the Muskwa and a peak at the Nahanni. Full sized plots of Figures 15 to 20 are included with this report. The synthetics are plotted at the same time scale as the seismic lines (7.5 inches per second).

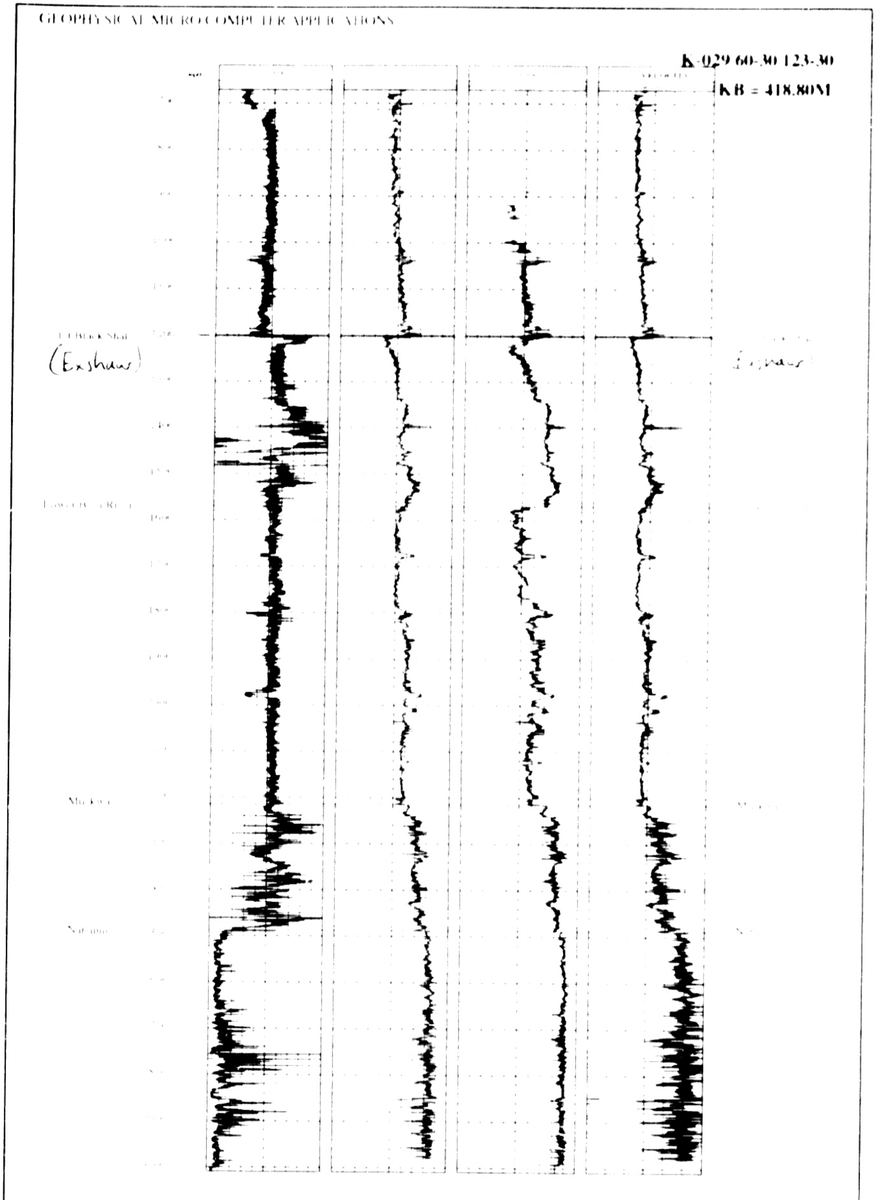

Figure 15 K-29 logs

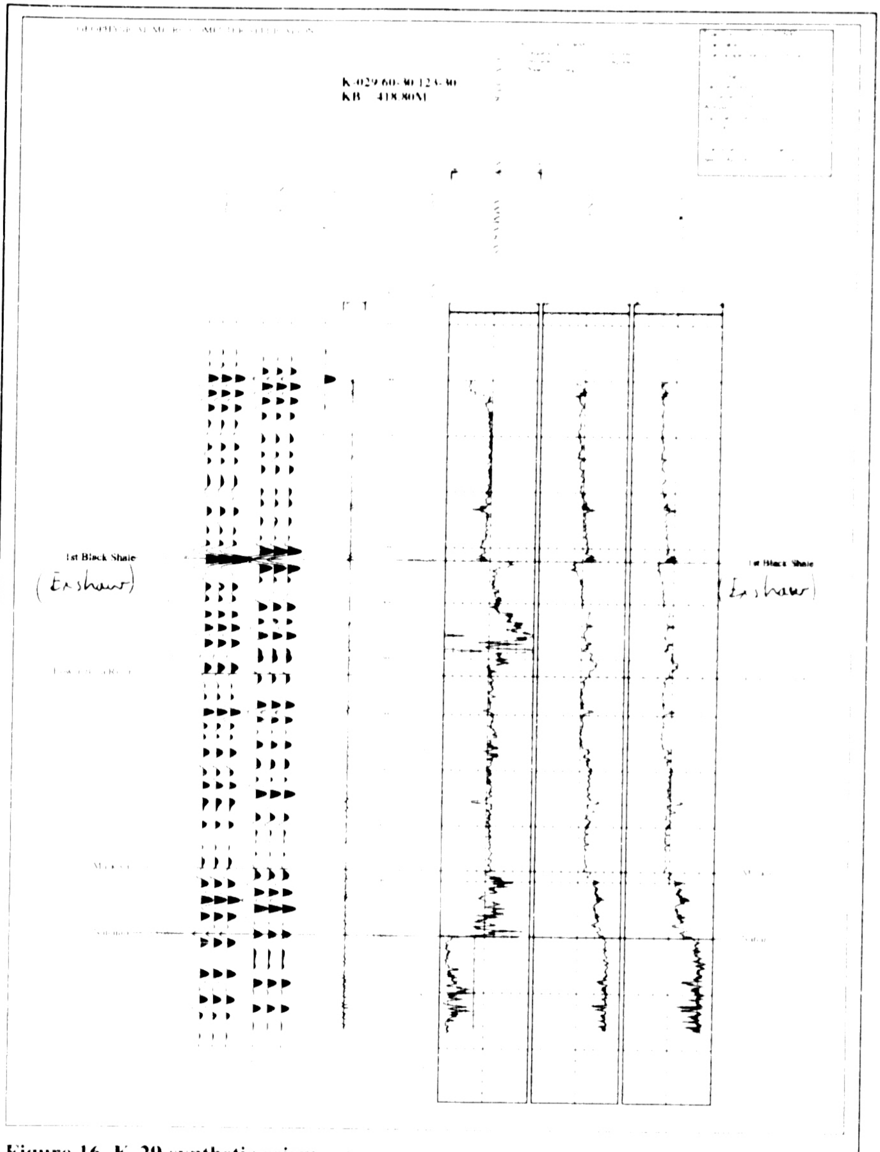

Figure 16 K-29 synthetic seismogram

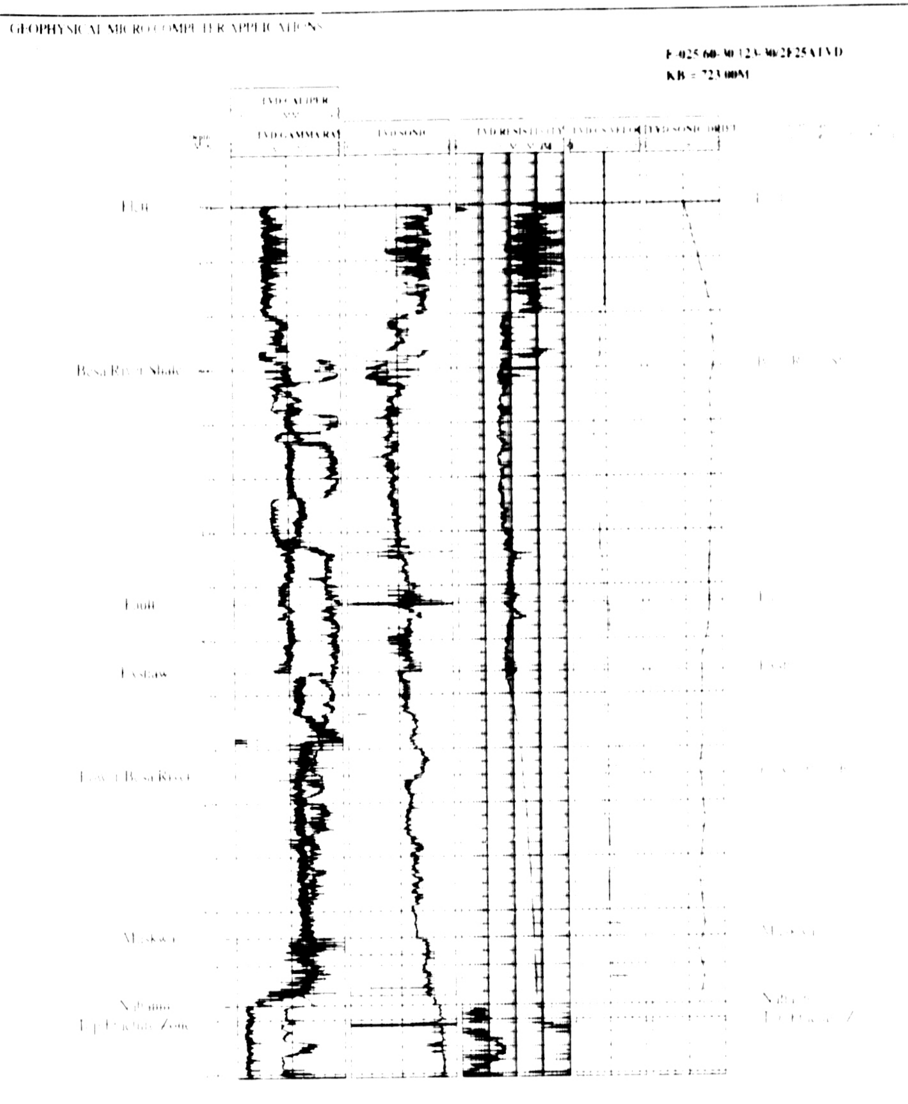

Figure 17 F-25a logs 1

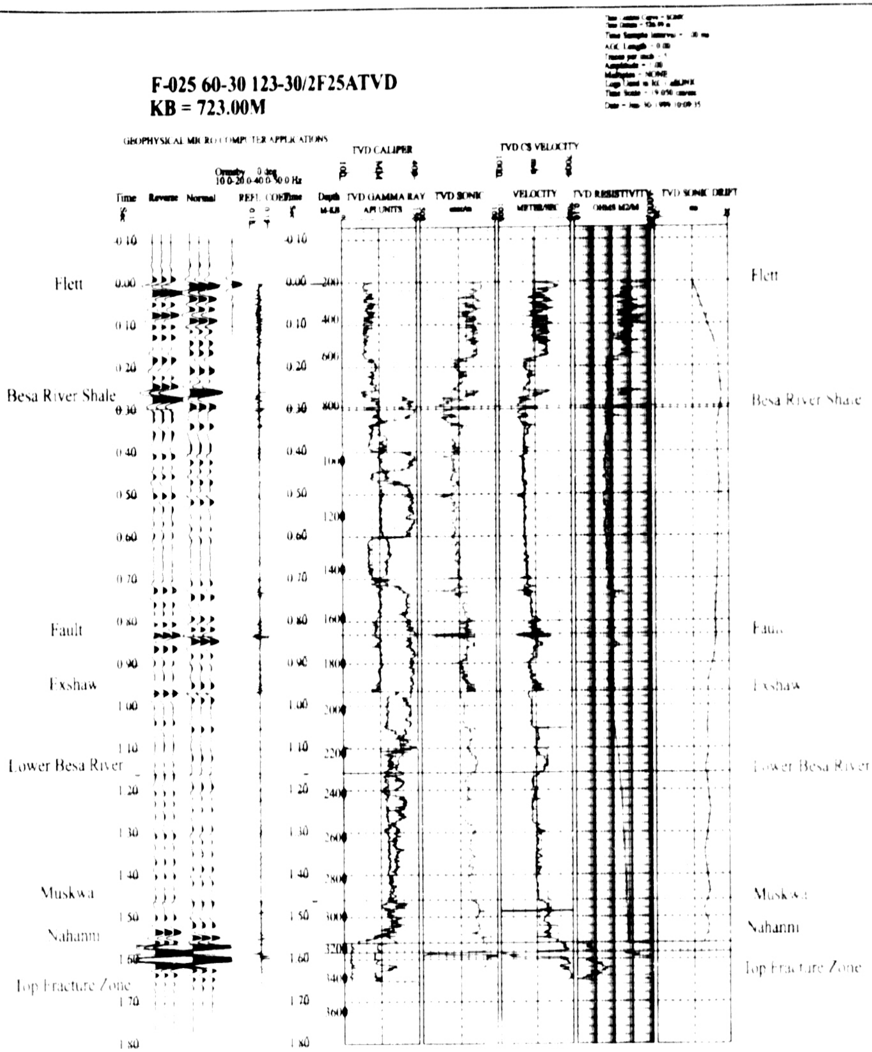

Figure 18 F-25a synthetic seismogram 1

GEOPHYSICAL MICRO COMPUTER APPLICATIONS

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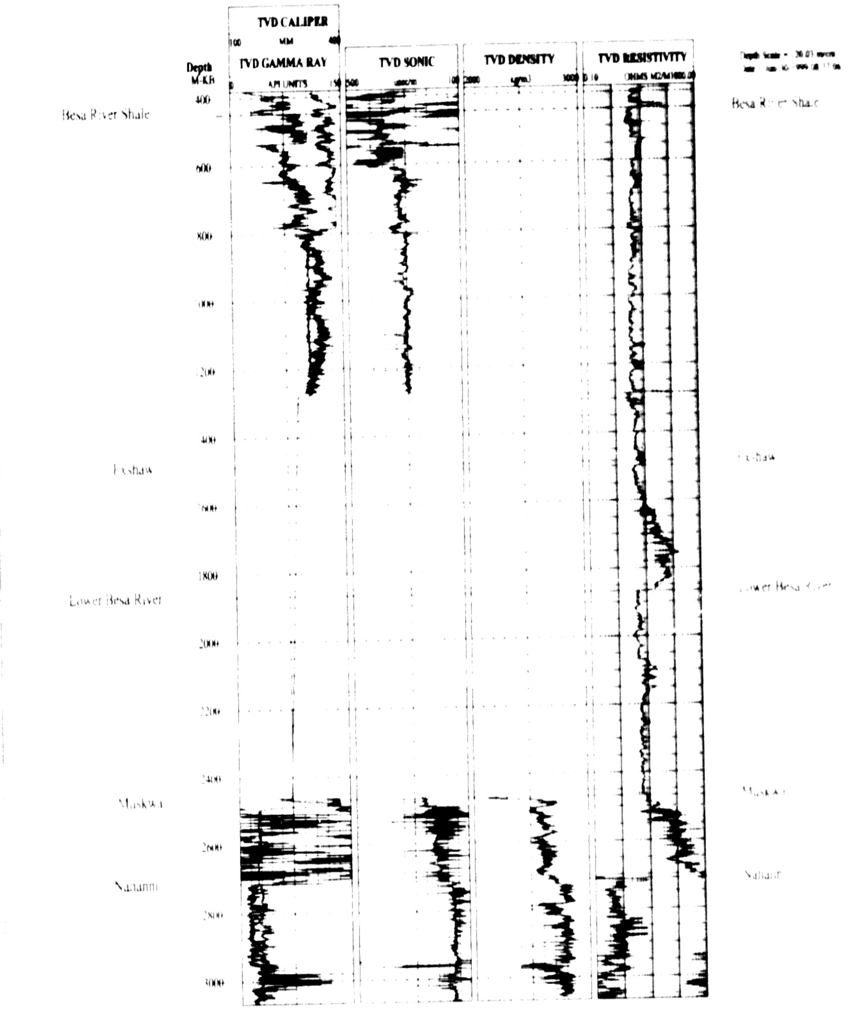

Figure 19 D-29 logs 1

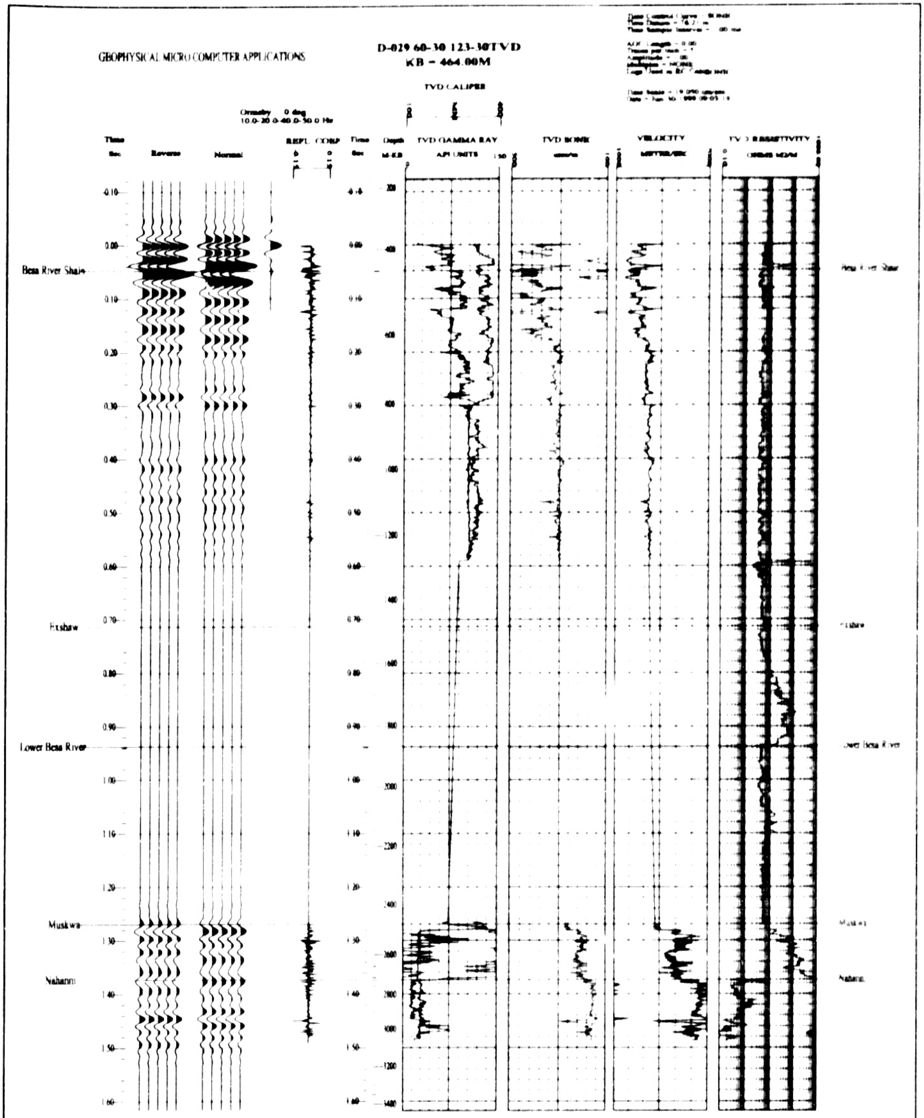

Figure 20 D-29 synthetic seismogram