

East Coast offshore exploration

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Abstract

The Westech-Orion Joint Venture holds petroleum exploration permits 38325, 38326 and 38333 in the offshore East Coast Basin, covering Hawke Bay and the Wairarapa shelf. A 594 km² exploration 3D seismic survey was acquired in Hawke Bay in April-May 1999, and 685 km of 2D seismic were acquired in March 2000.

The prospectivity of the area has been highgraded by recent maturation and reservoir studies in Hawke Bay, and by gas discoveries in Westech-Orion wells onshore northern Hawke Bay. Maturation studies identified six offshore kitchen areas with oil migration commencing in the Late Miocene. Seismic stratigraphy and correlation with onshore wells identified submarine fan deposits of Eocene, Early Miocene, Middle Miocene and Pliocene age.

Preliminary interpretation of the 3D survey has yielded five prospects, each covering 20-90 km². One prospect is a lowstand fan identified by stacked mounding and bidirectional downlap, correlated with the onshore Middle Miocene Tunanui Sandstone. High amplitude seismic events of Middle-Late Miocene ages are inferred to be pulses of submarine fan development, in places associated with direct hydrocarbon indicators (DHIs). High amplitude seismic events in the Pliocene include a package of discontinuous reflectors interpreted as a shingled turbidite sequence, and a DHI truncated by a major unconformity.

On the Wairarapa shelf, there are three high quality prospects with closures in the Miocene up to 44 km². One structure has associated DHIs interpreted as gas charged Late Miocene sands. New 2D seismic data acquired in March 2000 detail these prospects.

Introduction

The Westech-Orion Joint Venture was awarded Petroleum Exploration Permits 38325 and 38326 in offshore Hawkes Bay in May 1996 and subsequently PEP38333 offshore Wairarapa to the south in January 1998 (Figures 1 & 2). Only two offshore wells have been drilled in the East Coast Basin. BP-Shell-Aquitaine-Todd (BPSAT) drilled Hawke Bay-1 in 1975 and Amoco drilled Titihaoa-1 off the Wairarapa coastline in 1994. Both wells encountered significant gas shows, but not in commercial quantities.

In 1998 the Westech-Orion Joint Venture drilled its first well, Kauhauroa-1, within the onshore PEP 38329 resulting in the first gas discovery in the East Coast Basin. Thereafter, five additional wildcats and five appraisal wells have been drilled by the Joint Venture. Davies et al. (2000) present the onshore East Coast drilling results in a paper in these Proceedings.

The success of the onshore drilling program has elevated the prospectivity of the offshore permits. The Joint Venture acquired the first offshore exploration 3D seismic survey in the East Coast Basin in April-May 1999. The survey area covered 594 km² encompassing parts of offshore PEPs 38325

and 38326. Additionally 685 km of 2D seismic data have been acquired in March 2000; 333 km in 38325 and 38326 and 352 km in 38333.

Hawke Bay seismic acquisition

Offshore hydrocarbon exploration in the East Coast Basin of the North Island of New Zealand began in 1966 when the BPSAT consortium shot several lines in Hawke Bay and off the east coast of the Mahia Peninsula. A second survey of 1000 km along the East Coast followed in 1968. These data sets are generally considered to be very poor quality.

In 1972 Australia Gulf shot approximately 1200 km of 2D seismic in Hawke Bay. The lines were shot at 5 km spacing with additional lines shot around the eventual location of the Hawke Bay-1 well. In 1972 and 1973 Australia Gulf and Mobil shot 10,000 km of long zigzag reconnaissance seismic lines along the East Coast and out to the Hikurangi Trough area. Other operators acquired smaller surveys during this time.

In 1990 Conquest acquired an additional 1000 km of 60 fold 2D seismic data in Hawke Bay. Eighteen lines were spaced



Figure 1: East Coast Basin, New Zealand index map.

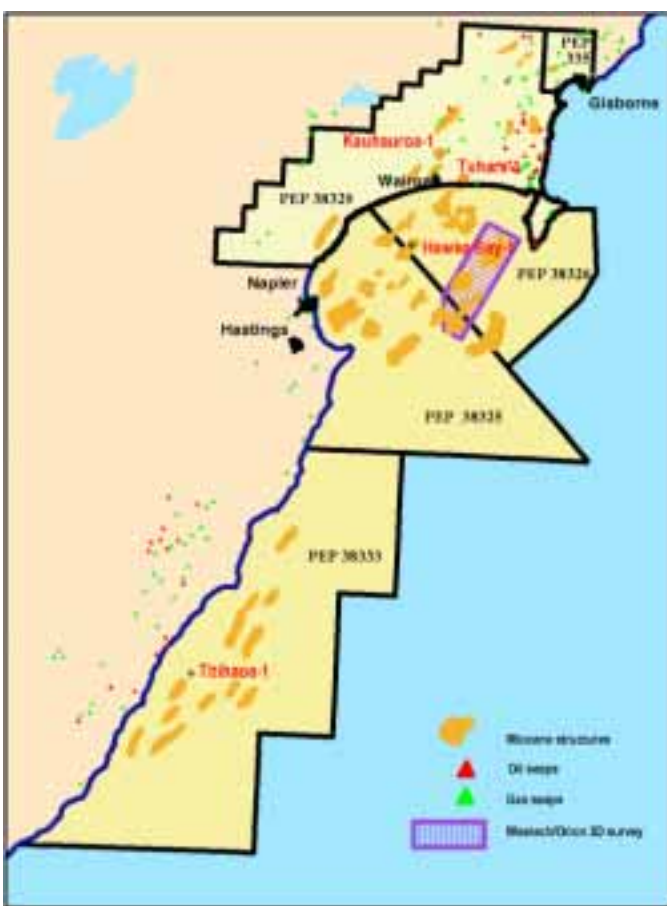


Figure 2: Westtech-Orion East Coast offshore joint venture exploration permits.

approximately 5 km apart in a dip and strike orientation. The data quality of this survey is very good.

In 1999 the Westtech-Orion Joint Venture acquired a 594 km² 3D seismic survey in Hawke Bay southwest of the Mahia Peninsula (Figure 3). Preliminary analysis of the current interpretation forms the basis for this paper. An additional 685 km of 2D seismic were acquired in March 2000. These data will further delineate several leads identified on the current 2D grid.

Hawke Bay-1 well

In November 1975 BPSAT spudded the Hawke Bay-1 well (Figure 4), at a water depth of 57 m in the central portion of Hawke Bay, 27 km SSW of Wairoa. The well bottomed in the Oligocene Weber formation at 2372 m. Due to hole problems the well never reached the planned total depth of 3300 m. No indications of abnormal pressures were encountered while the well was being drilled. Gas shows were encountered continuously through the Early Pliocene section and also in a trapping position at the top of ?Early Miocene recrystallized limestone at 2255 m (Heffer et al. 1976).

The primary reservoir target of the well was a section of porous Pliocene sandstones and limestones, equivalent to the Te Aute Limestone that outcrops immediately south in Hawke Bay. An 8 m-thick limestone bed was the only significant Pliocene reservoir with sonic log porosity exceeding 25%, but no closure was indicated at this level and the interval was water-bearing. The secondary reservoir targets were sandstones of Late Miocene age, equivalent to the onshore Makaretu Sandstone of central and northern Hawke Bay. A silty clay, partly turbiditic facies, replaced these sandstones. It is underlain by a Middle Miocene lithic sandstone, correlated with the Makaretu-D Sandstone (Figure 4).

Seismic line H90-7 (Figure 5), acquired by Conquest Energy in 1990, trends NW-SE and ties the Hawke Bay-1 well. The Kidnappers Ridge, Lachlan Basin, and Lachlan Ridge are located east of the well toward the mouth of Hawke Bay. When flattened on top Miocene, this line dramatically shows the depositional thickening of the Miocene immediately east of Hawke Bay-1 (Figure 6). The extra section is interpreted to be of Early to Middle Miocene age deposited in the area between Hawke Bay-1 and Kidnappers Ridge. To the east of Kidnappers Ridge lies the Lachlan Basin, a deep pull-apart basin containing approximately 2000 m of Miocene sediment.

Figure 7 is a 2D seismic traverse comprising lines H90-7, H90-16, H90-11, H90-14 and WEC 8B, tying the Hawke Bay-1 well with the Westtech-Orion Opoho-1 well. The traverse (Figure 3) demonstrates that the thick Middle Miocene section, including the Tunanui Sandstone, extends offshore from Opoho-1 into the area of the 3D seismic survey and then thins toward the Hawke Bay-1 well.

Hawke Bay 3D seismic

Westtech-Orion acquired the first exploration 3D seismic survey in the East Coast Basin in April-May 1999 after

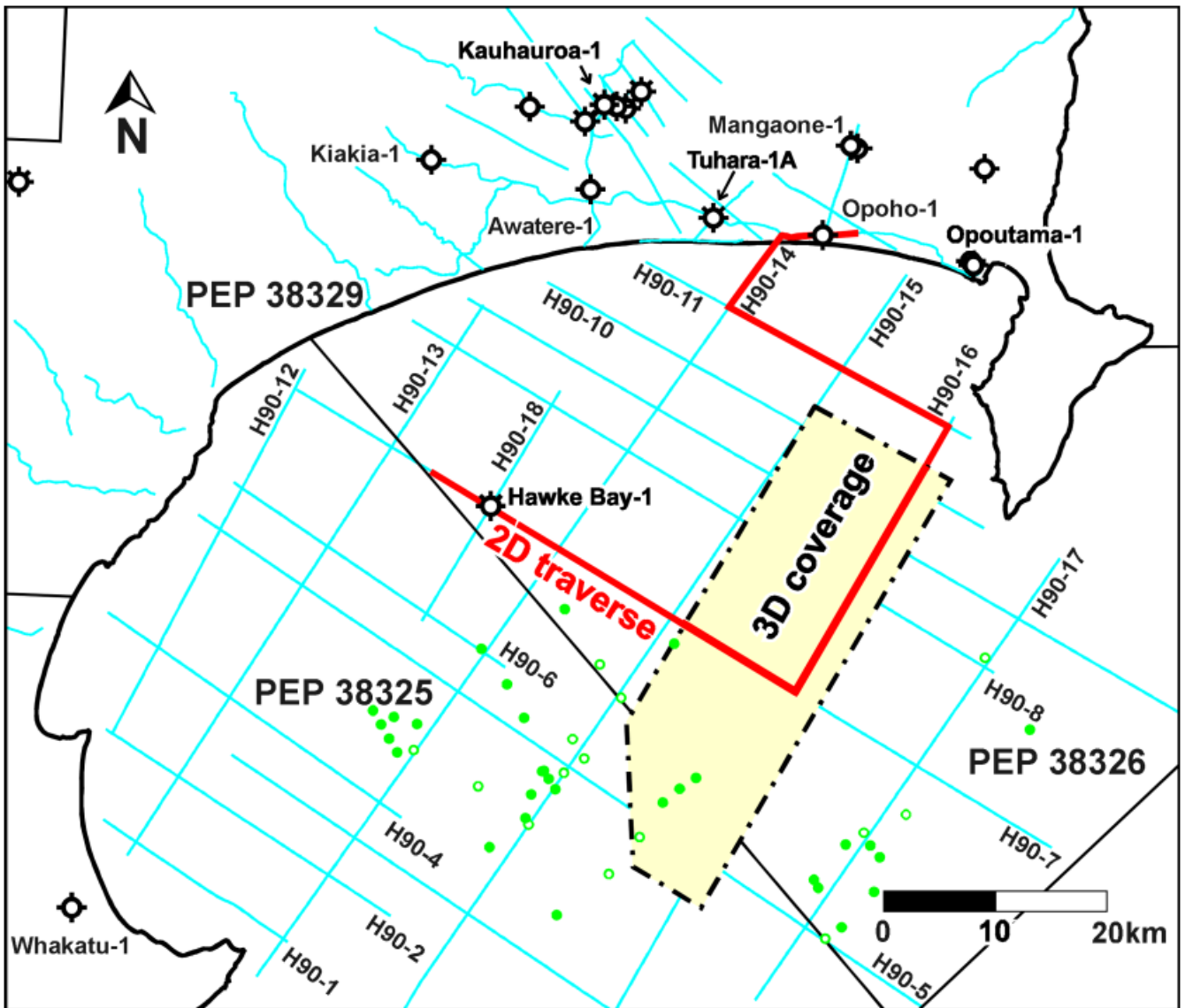


Figure 3: Location map of Hawke Bay 3D seismic survey acquired in 1999. Dashed lines are 2D seismic 1990 vintage; solid lines are 2D seismic acquired in 2000. Solid circles are seafloor core sampling sites with a value greater than 8 on a scale of 15, open circles have values less than 8 (GERG 1989).

interpreting the existing 2D onshore and offshore seismic and well data. The survey encompassed 594 km² of full fold coverage over PEPs 38325 and 38326; the majority of the survey was located in 38326 (Figure 3). The seismic survey was acquired by Geco Prakla's Geco Resolution seismic vessel in 32 days. The subsurface data bin size is 12.5 m by 25 m with a resulting processed square bin size of 12.5 m by 12.5 m. The data were acquired utilizing a six streamer configuration separated by 600 m between each streamer and a 3000 m cable length.

Kitchen areas, potential reservoirs, structural trapping and seal dictated the survey placement, located just southwest of Mahia Peninsula.

Source rock

Funnell et al. (1999) evaluated the hydrocarbon generating potential of the Hawke Bay area both onshore and offshore. The Waipawa Black Shale was determined to generate 104 bbl/acre-ft and the Whangai Formation was predicted to

generate 16 bbl/acre-ft using a best fit linear geothermal gradient of 24°C/km and a surface temperature of 14°C.

Nine kitchen areas were identified, six of which are located in the offshore region (Figure 8) covering areas of 130 km² to 500 km². The source rock in the kitchen area adjacent to the 3D survey is conservatively predicted to have expelled 665 million barrels. The greatest uncertainty in the modeling is the thickness of the source rock; a modest increase in source rock thickness or quality could expel in excess of a billion barrels of oil. Oil migration from the kitchen area into adjacent Miocene and older structures probably started in the Late Miocene with the greatest potential for migration in the Plio-Pleistocene.

In 1989 Texas A&M University Geochemical and Environmental Research Group undertook a seafloor sampling survey for Conquest Exploration (Figure 3). Based upon good to very good fluorescence and gas chromatographic readings, the study concluded that significant oil seepage exists within the area (GERG, 1989).

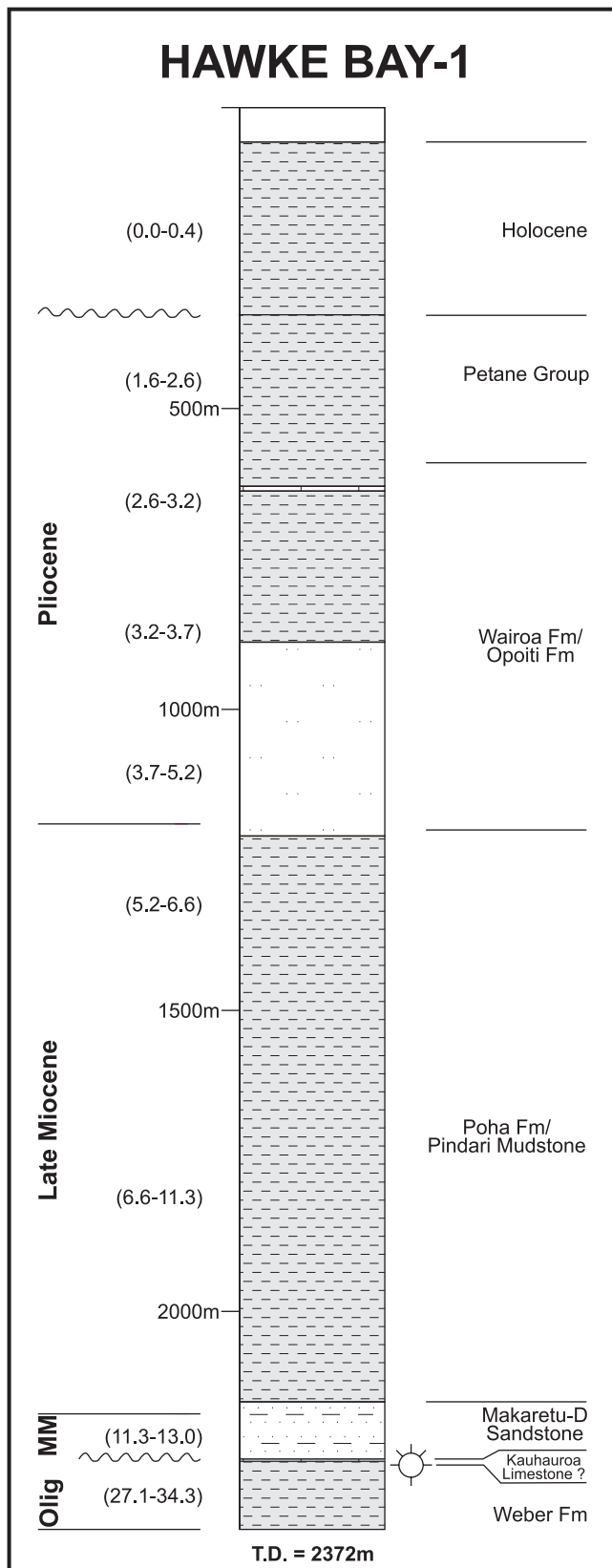


Figure 4: Hawke Bay-1 summary well log (after Heffer et al. 1976), with formation and group names extrapolated from onshore Hawkes Bay.

Reservoir

The primary offshore reservoir targets are seismically defined submarine fan deposits recognized in the Eocene and Miocene. Secondary objectives comprise marine Oligocene and Pliocene

sandstones and Miocene limestones penetrated in the onshore wells (Figure 9). A summary of potential reservoirs follows.

Eocene

Browne et al. (1999) seismically identified two localized Middle Eocene submarine fans with an origin in the northwest and prograding to the southeast. They also interpreted a basin floor fan system prograding from the southwest near Cape Kidnappers to the northeast and terminating in the central portion of Hawke Bay. This system appears to be Early Paleocene in age.

Oligocene

The Oligocene Weber Formation is generally a massive mudstone differentiated from underlying Eocene strata by its higher carbonate content. Within the Weber several intervals of fine- to very fine-grained sandstone are present. A 45 m interval in the Opoho-1 well drilled near the coastline at the northern end of Hawke Bay correlates well with the "Basal Waitakian Greensand" in the Mangaone-1 well. Development of this sand is likely to continue offshore and within the area covered by the 3D survey.

Early Miocene

Seismic mapping of the Early Miocene within Hawke Bay indicated that deposition occurred primarily east of Kidnappers Ridge (Field and Uruski et al. 1997). Mudstone dominated sedimentation with subordinate deposition of turbidite sandstones. The base of the Early Miocene interval may coincide with an influx of sand into the area as erosion occurred in the western part of the onshore Hawke Bay.

The Kauhauroa Limestone is an Early Miocene reservoir identified onshore (Figure 9). In the Kauhauroa-1 gas discovery the Kauhauroa Limestone is the primary reservoir, and described as a sandy, glauconitic bryozoan and foraminiferal limestone. Longman (1998) identified the Kauhauroa limestone as a cool-water shelf limestone with an estimated 10% porosity from intraparticle voids, pinpoint vugs, molds and fractures. Virtually all production is attributed to fracture induced porosity and permeability.

Hawke Bay-1 encountered a limestone of uncertain Middle to Early Miocene age. This limestone is interpreted to be a high-energy grainstone deposited in a shoaling environment, and may be correlative with the Kauhauroa Limestone. Although samples of the limestone showed no visible porosity, fracture permeability likely contributed to a gas increase of 35%.

The Rere Sandstone (Early Miocene) is present onshore in various localities and may also be developed offshore, based on seismic stratigraphic interpretation of isolated submarine fan sequences at several levels. A full diameter core and several sidewall cores were taken from the Rere Sandstone in the Kauhauroa-3 well, and yielded porosities from 22% to 33% and permeabilities up to 18 mD.

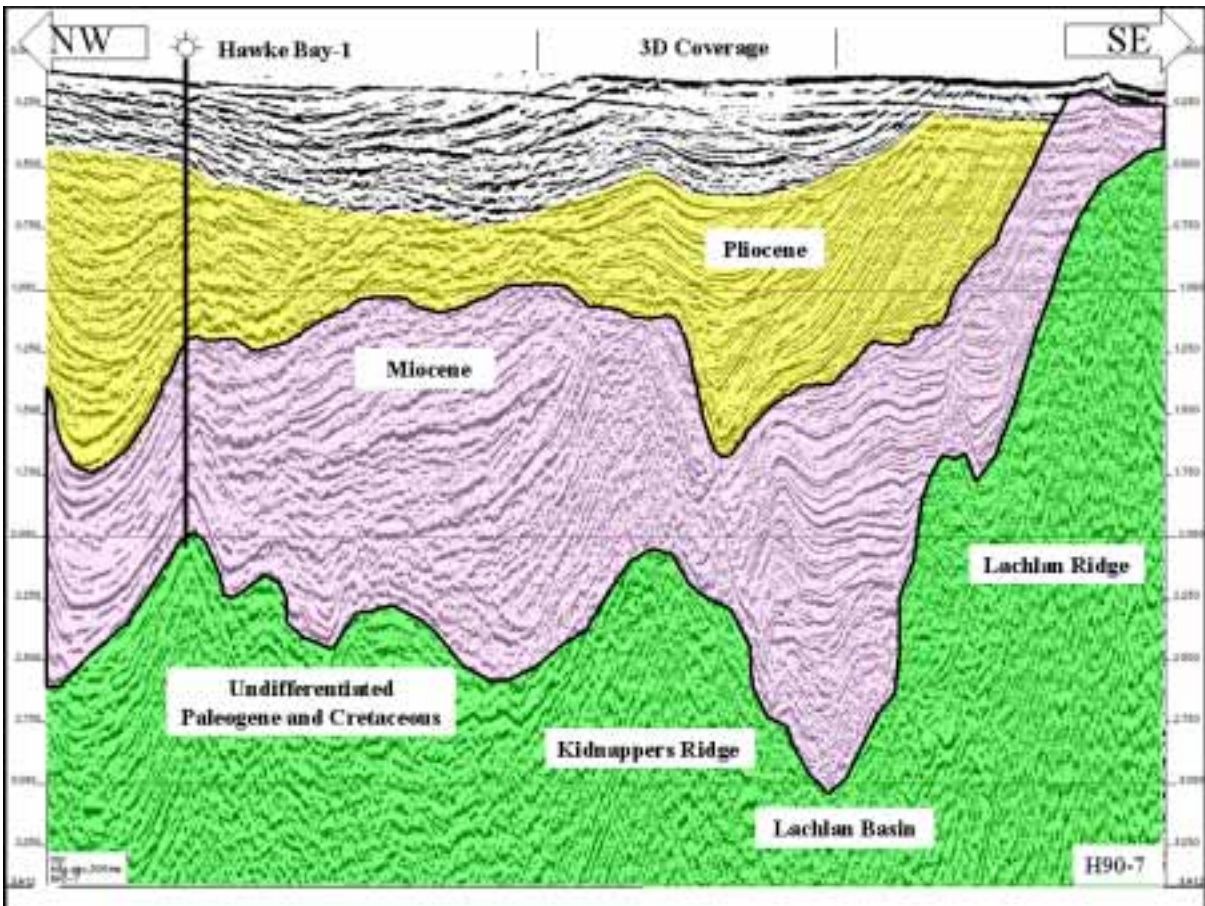


Figure 5: Seismic line H90-7.

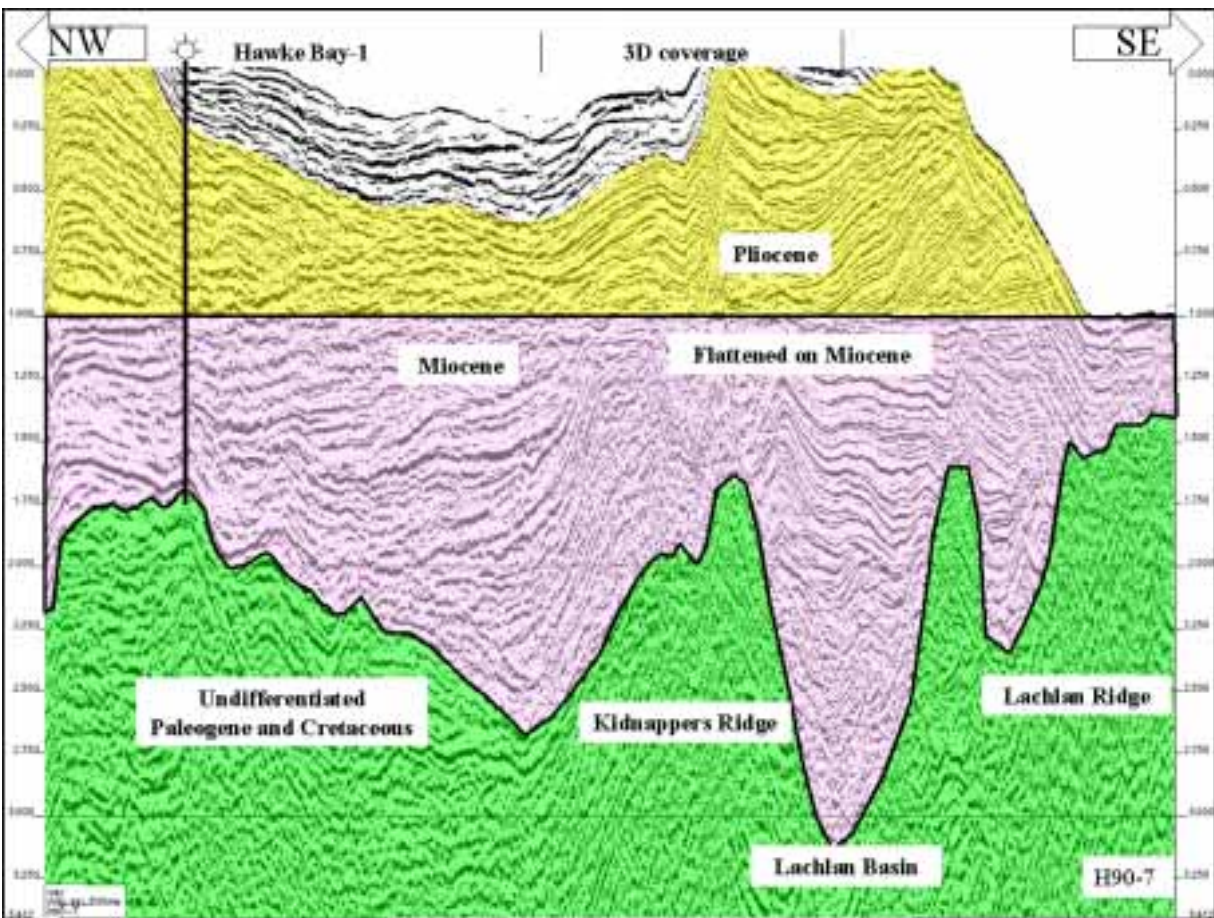


Figure 6: Seismic line H90-7 flattened on top Miocene.

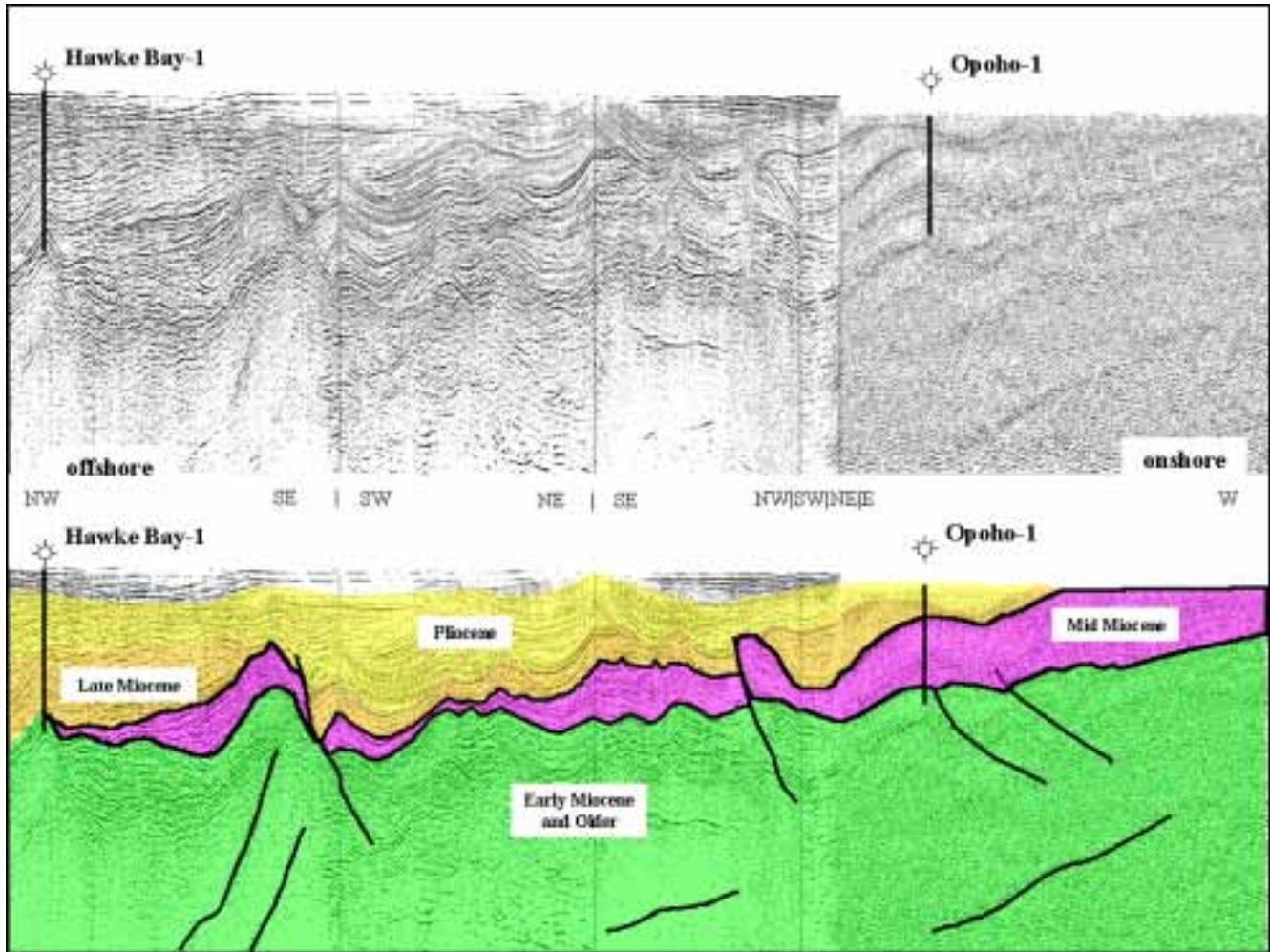


Figure 7: 2D seismic traverse from offshore Hawke Bay-1 to onshore Opoho-1. Presence of Mid-Miocene in Opoho-1 thins dramatically at Hawke Bay-1. Uninterpreted line at top, interpreted line below.

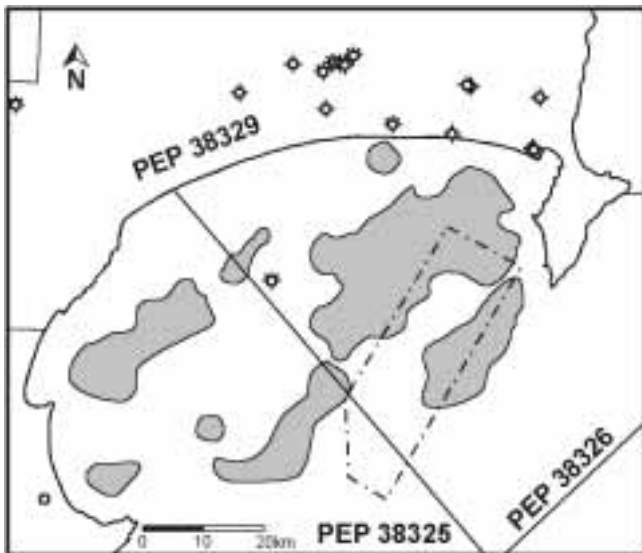


Figure 8: Source rock "kitchen" areas in Hawke Bay (after Funnell et al 1999).

Mid Miocene

The Middle Miocene is considered to be the best reservoir section onshore. The more prominent reservoirs are the well developed Late to Middle Miocene Makaretu A-D and

Tunanui sandstones (Davies et al. 2000) that are preserved in onshore Hawke Bay. The Makaretu A, B, and C sands were sourced from the northwest whereas the lowest Makaretu D and the Tunanui sands were sourced from the north (Figure 10).

The Tunanui sands are prime reservoir targets in the northern portion of Hawke Bay. In Opoho-1, 1000 m of Tunanui section was penetrated. Ten kilometres to the west, in Tuhara-1, 260 m of Tunanui was penetrated. The sands are fine- to very-fine grained, friable, weakly calcite-cemented, moderately well sorted, angular to sub-rounded quartz, with lithic fragments and a clay-silt matrix with poor to fair visible porosity. Wireline log porosities in the sandstones in the Tuhara-1 Tunanui section are as high as 24% with an average porosity of 20%.

Figure 11 is a NE-SW seismic traverse from the 3D seismic survey exhibiting a significant Middle Miocene lowstand fan development. The NW-SE seismic line in Figure 12 perpendicularly intersects Figure 11 near the apex of the fan. Figure 13 is an expanded view of the fan shown in Figure 11, which exhibits stacked mounding with bidirectional downlap in the NE-SW direction and covers an area of 35 km². Within the fan complex four way dip closure is mapped. An isochron of Middle Miocene (Figure 14) demonstrates the variability of deposition with the particularly striking fan development

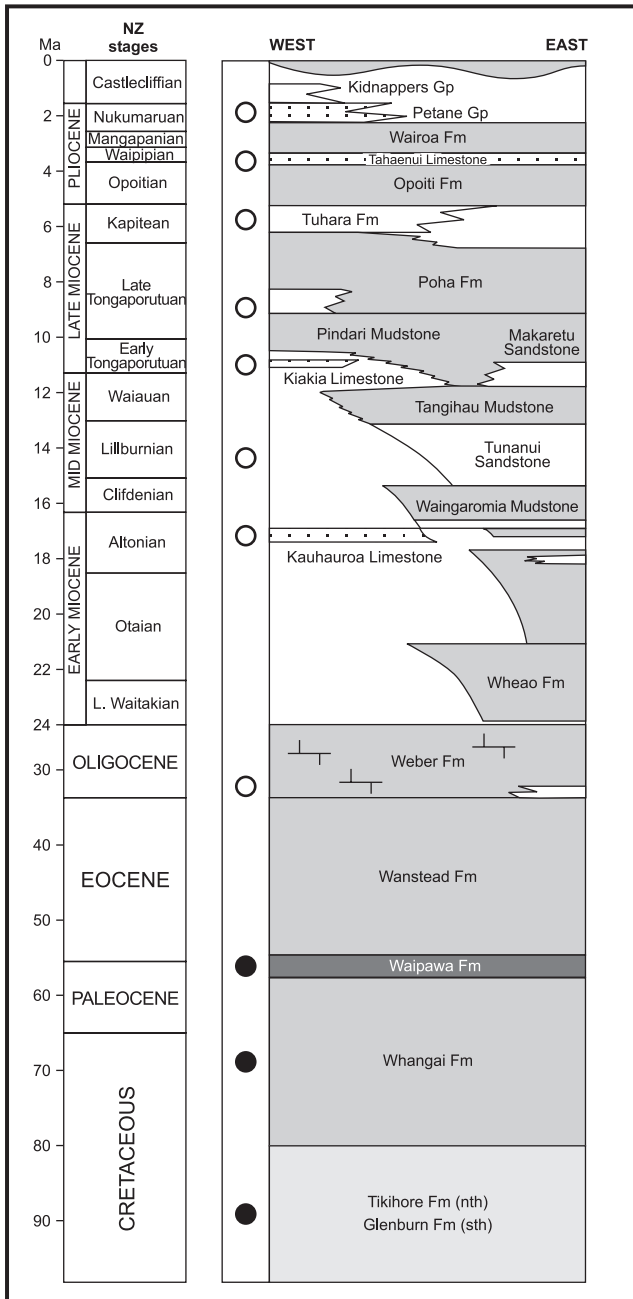


Figure 9: Stratigraphic column, Hawke Bay Area, East Coast Basin (Davies et al., this volume, after Field and Uruski et al. 1997).

described above. This fan complex is correlated with the Tunanui Sandstone, with probable sourcing from the north (Figure 10) and from the Lachlan Ridge to the east.

Middle-Late Miocene high-amplitude seismic events

The area south and east of the Hawke Bay-1 well and the Late Miocene section in the Lachlan sub-basin may contain better quality reservoirs, as there are several sequences with numerous reflections implying stratigraphic onlap and truncation. The primary reservoir rocks of this age onshore are the Makareao and Tuhara sandstones (Figure 9). In Awatere-1, sidewall cores in the latter sandstone confirmed log porosities up to 28%.

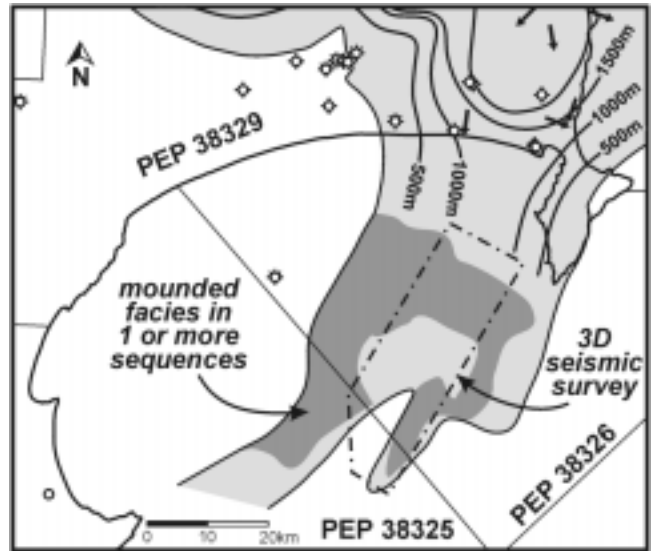


Figure 10: Extent of Middle Miocene sandstone-dominated sequences, from onshore data (Davies et al., this volume) and 2D offshore seismic control (B. Field, IGNS, unpublished).

Within the Middle to Late Miocene, areas of high-amplitude multicycle seismic events may correspond to alternating pulses of coarse-grained and fine-grained sedimentation. The bland low-amplitude reflectors surrounding these high-amplitude cycles are interpreted to be mudstones deposited between pulses of submarine fan development.

Figure 15 illustrates an off-structure high amplitude DHI event within the Middle-Late Miocene. The event is truncated by a fault and extends over an area of 10 km² (Figure 16). These amplitudes are interpreted as hydrocarbon charged sandstones. Off-structure high-amplitude events such as this one have yet to be drilled and constitute viable exploration targets.

Pliocene

Pliocene sedimentation was widespread in the Hawke Bay region, sourced from erosion along the prominent northeast-trending highs of the Kidnappers and Lachlan Ridges. Thick sedimentation, up to 1 second TWT, occurred west of the Hawke Bay-1 well and also between the Kidnappers and Lachlan Ridges.

Within Hawke Bay, high-amplitude seismic events are interbedded with zones of low reflectivity. These reflectivity changes may indicate restricted submarine channel and slump structures within an overall mudstone facies. Within the 3D survey, a prominent package of discontinuous seismic reflectors interpreted as a shingled turbidite sequence is depicted in Figure 17. Mapping of this interval, up to 300 ms thick (Figure 18), indicates that the sediment was sourced from the northwest and filled a structurally low area.

Another prominent high-amplitude Pliocene seismic event (Figure 19) extends across 130 km² of the 3D survey area (Figure 20). This shallow event, interpreted as a hydrocarbon charged sandstone or limestone, is truncated by a major intra-Pliocene unconformity. Francis (1998) described high quality

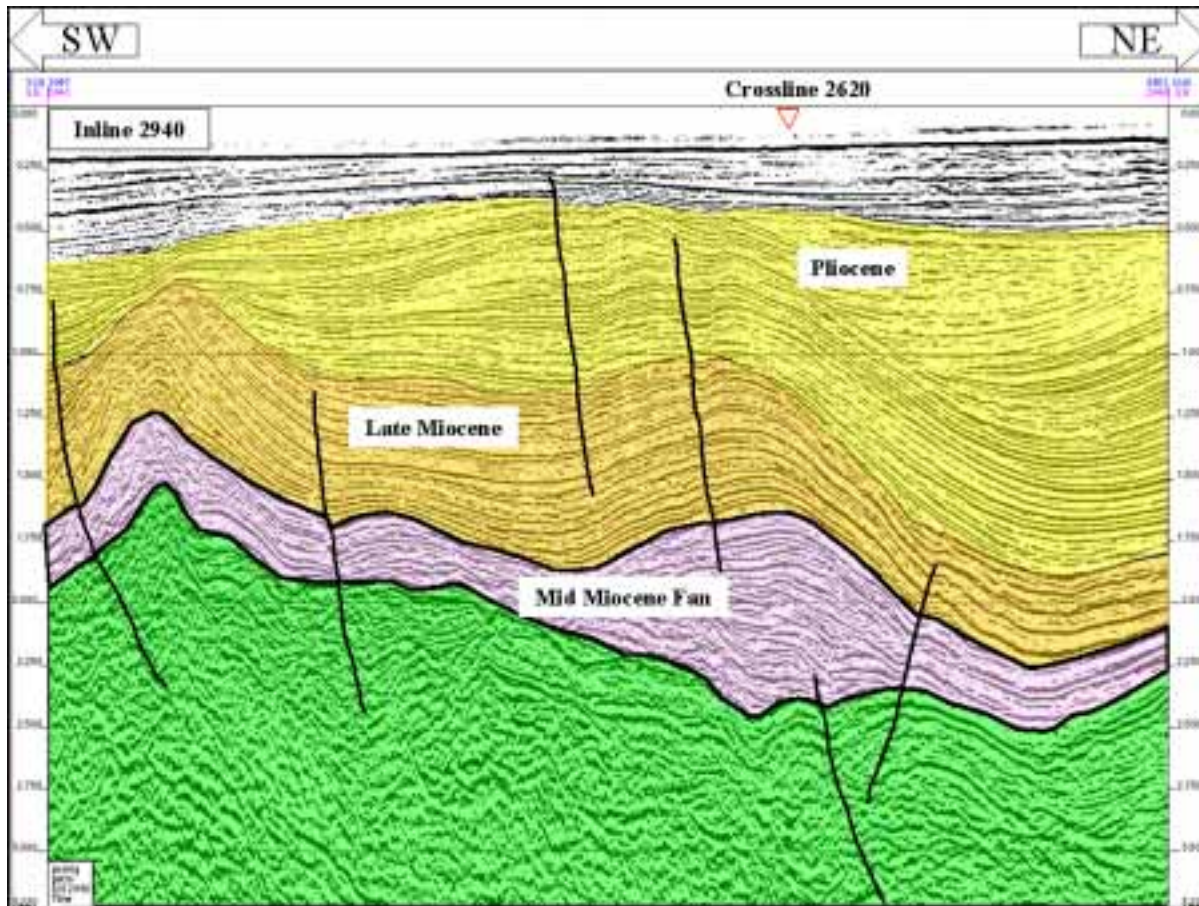


Figure 11: NE-SW seismic traverse from 3D seismic data showing significant Middle Miocene fan development.

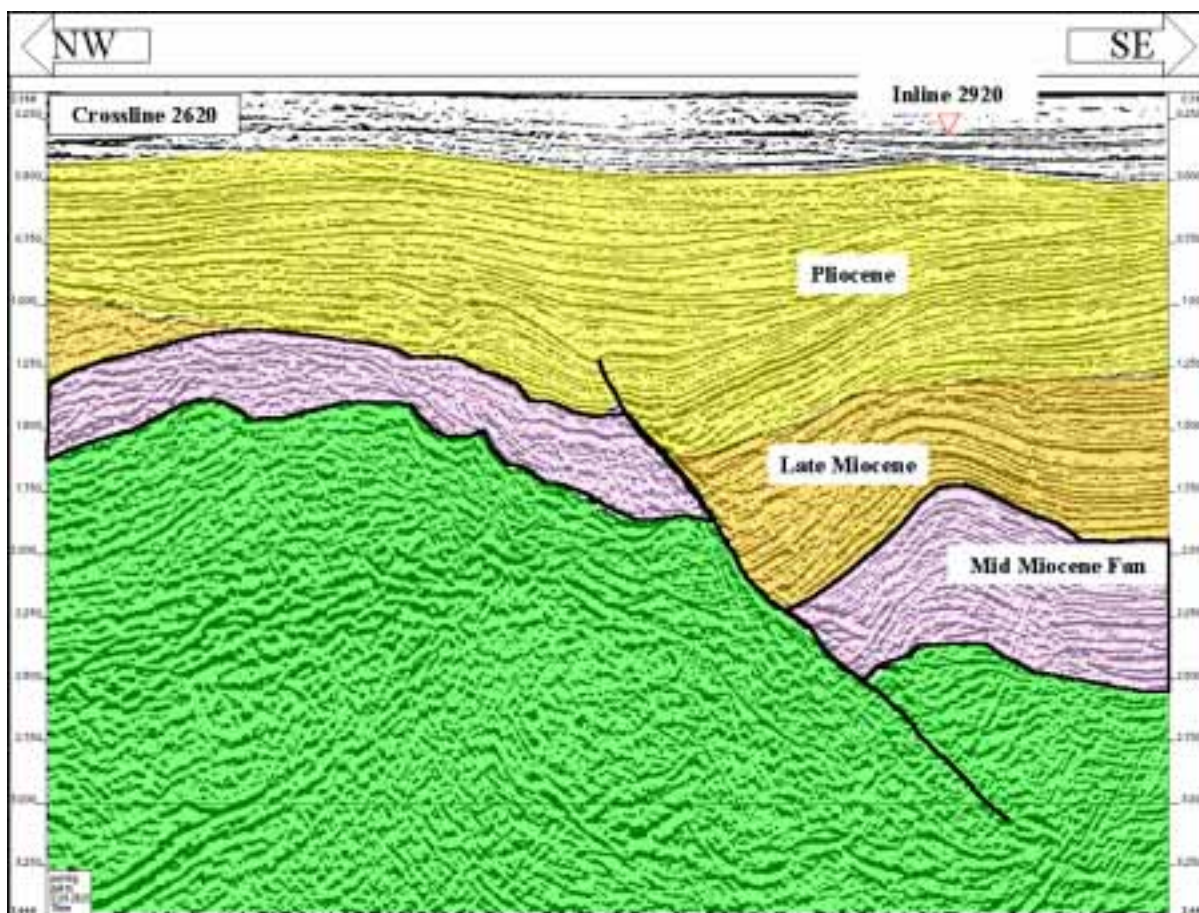


Figure 12: NW-SE seismic traverse from 3D seismic data intersecting figure 11 at thickest Middle Miocene fan buildup.

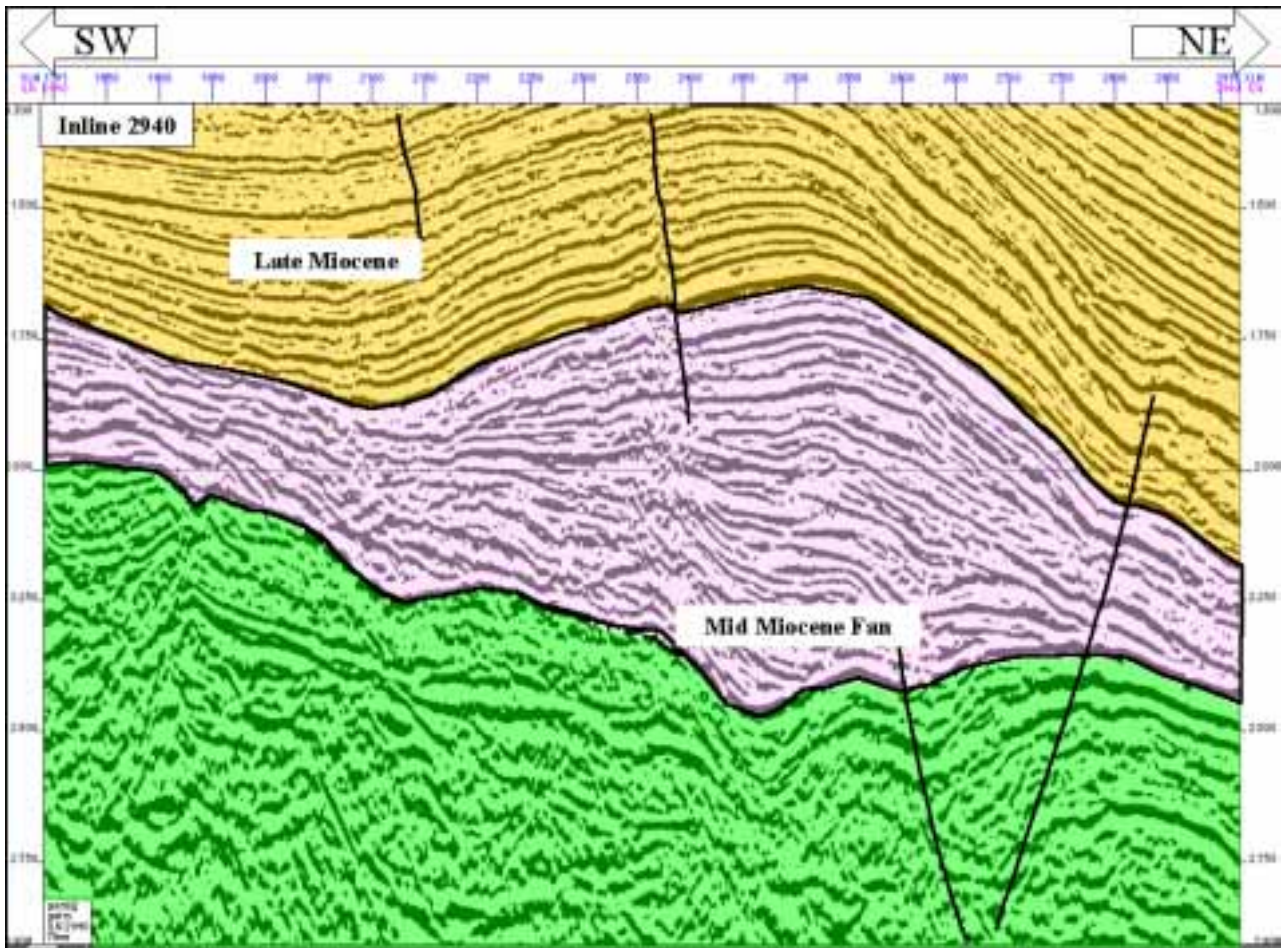


Figure 13: Close-up view of Middle Miocene fan development (from figure 11).

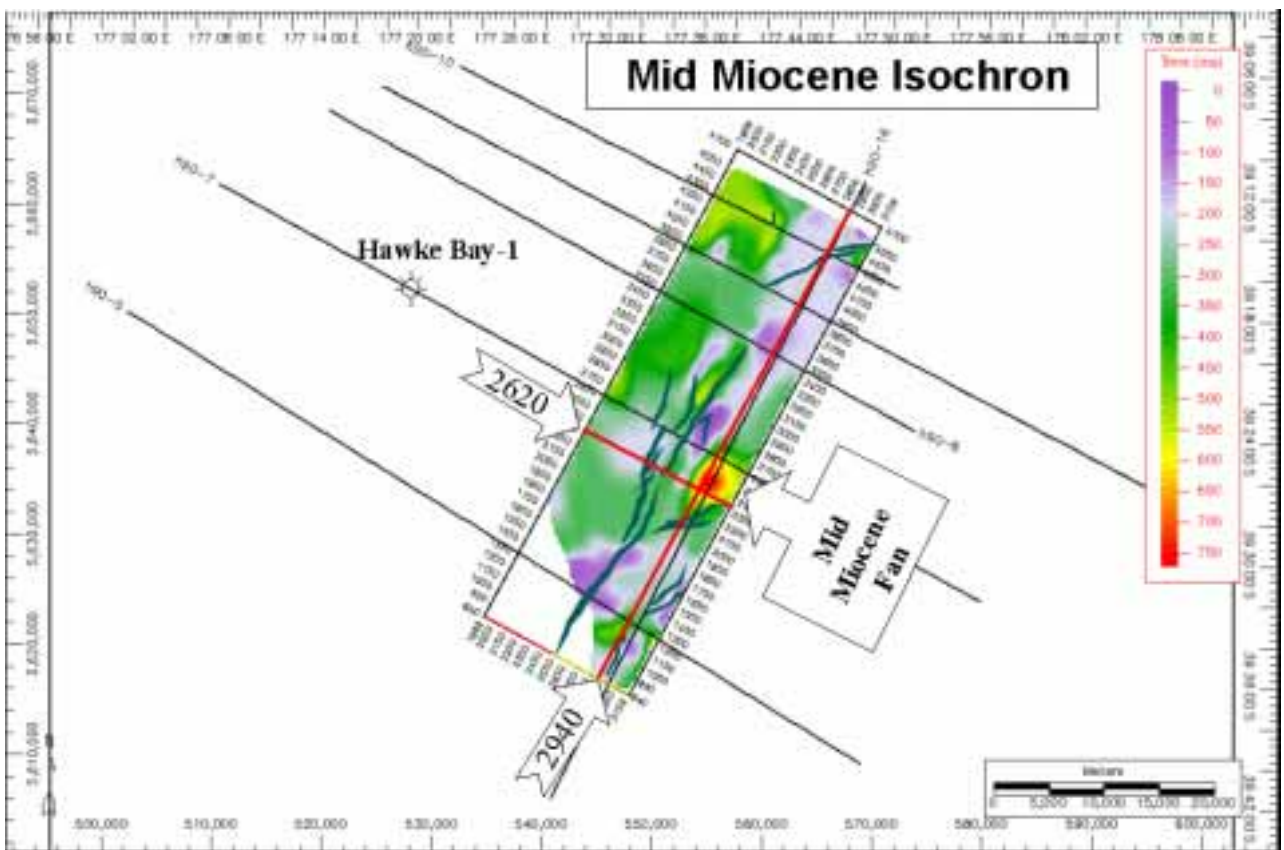


Figure 14: Isochron of Middle Miocene. Fan development in southeast portion of survey thought to be sourced partly from the NE and partly from the Lachlan Ridge immediately east of the 3D survey.

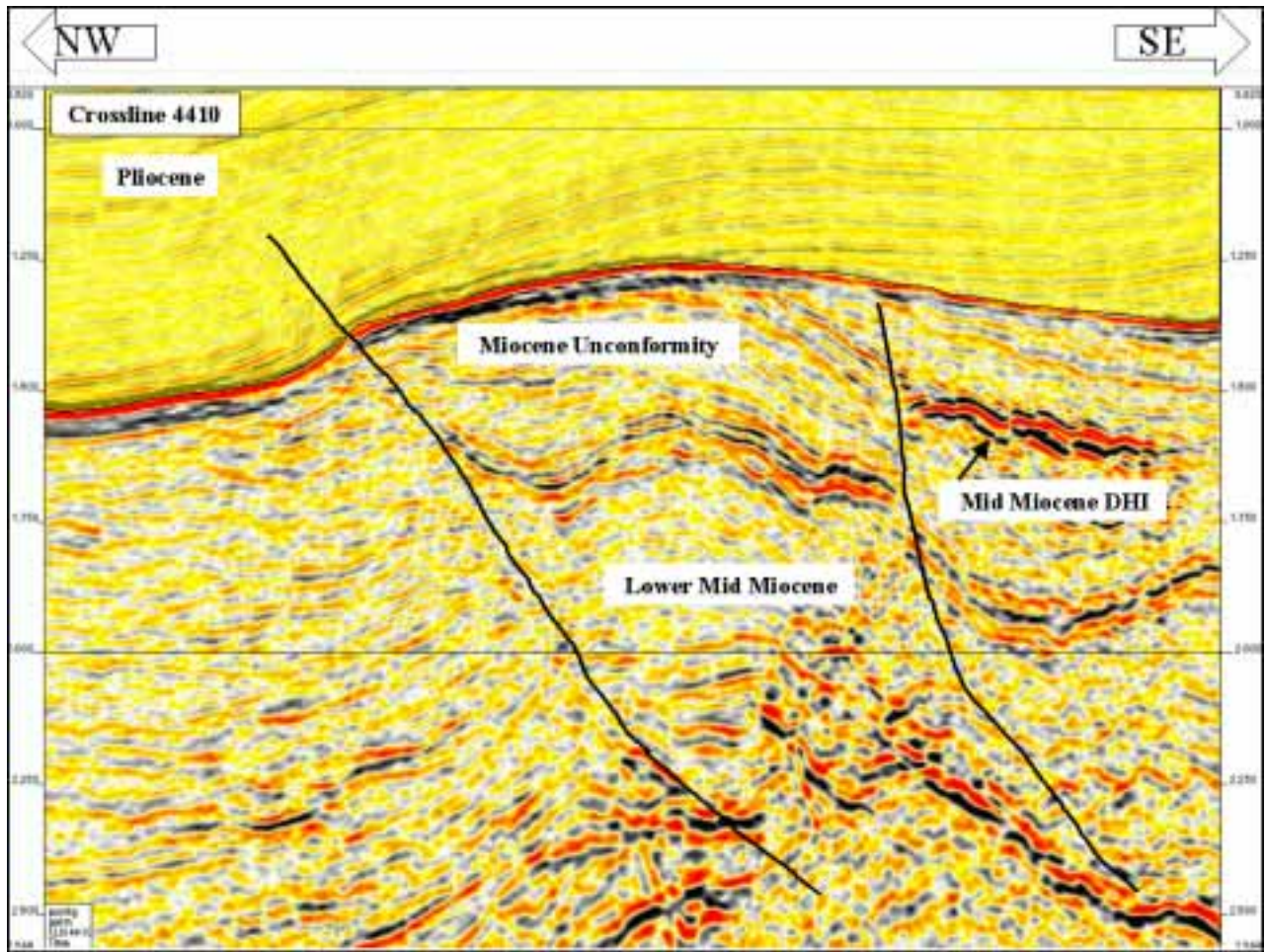


Figure 15: Middle Miocene off structure high-amplitude seismic event interpreted to be caused by hydrocarbon accumulation.

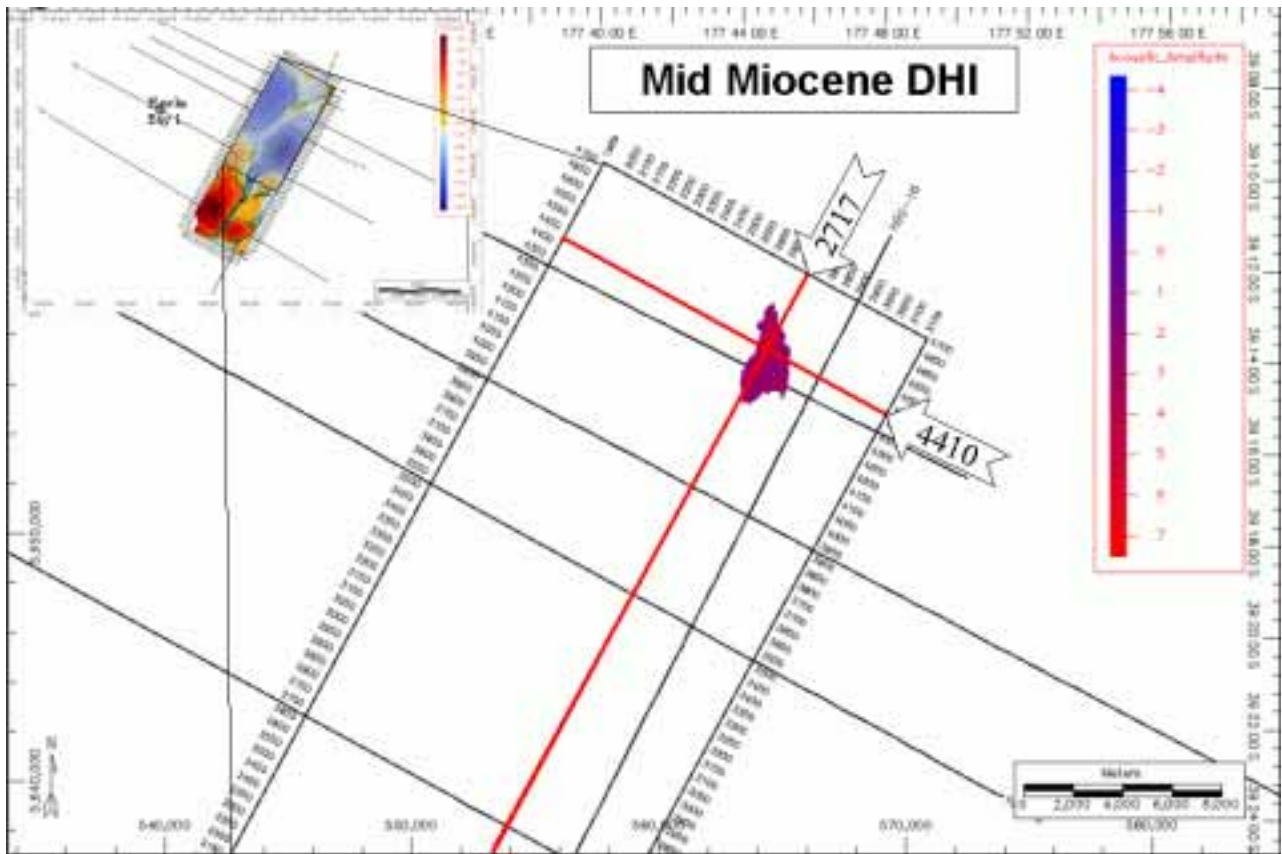


Figure 16: Map view of Middle Miocene direct hydrocarbon indicator.

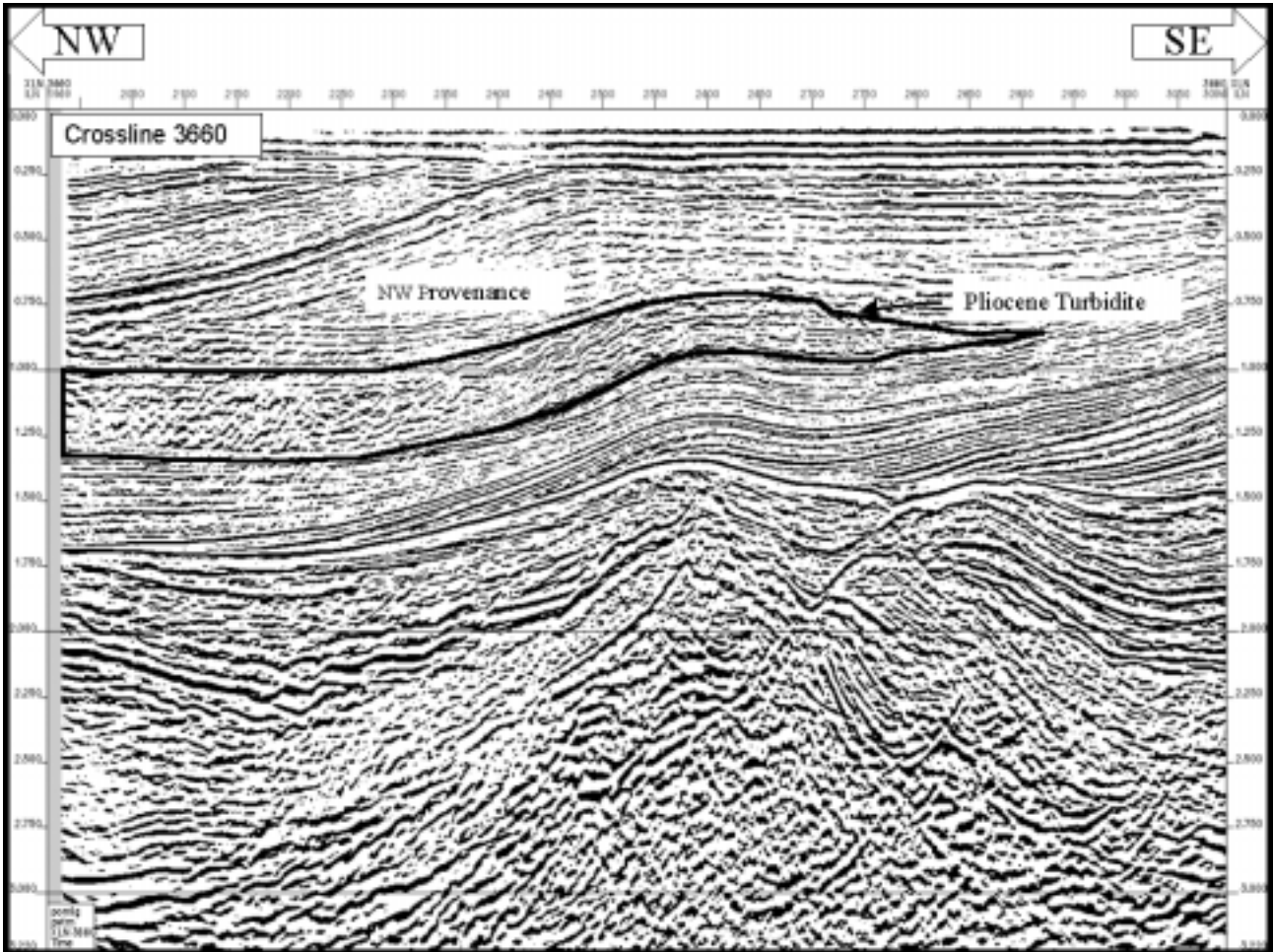


Figure 17: NW-SE seismic traverse showing interpreted Pliocene turbidite system, sourced from the northwest.

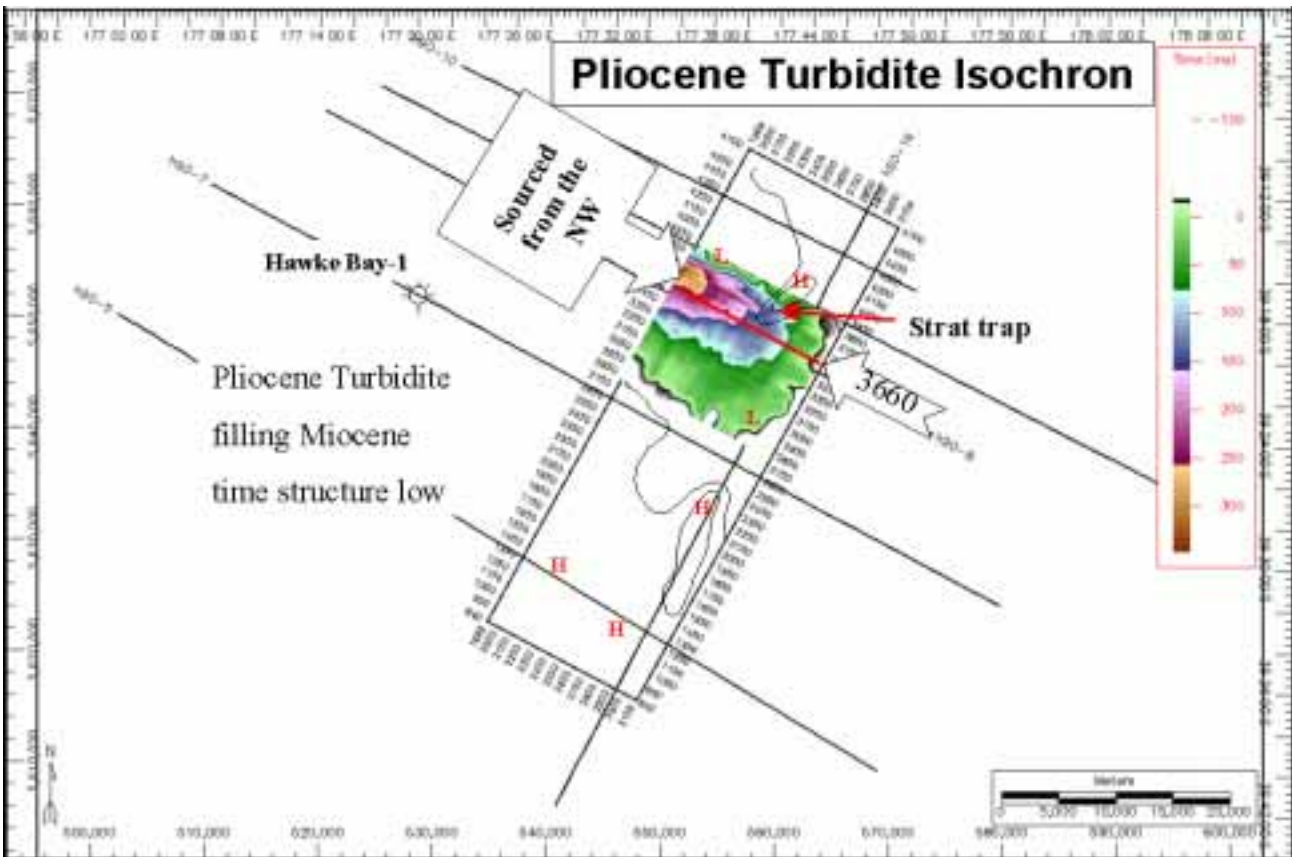


Figure 18: Isochron of Pliocene turbidite system.

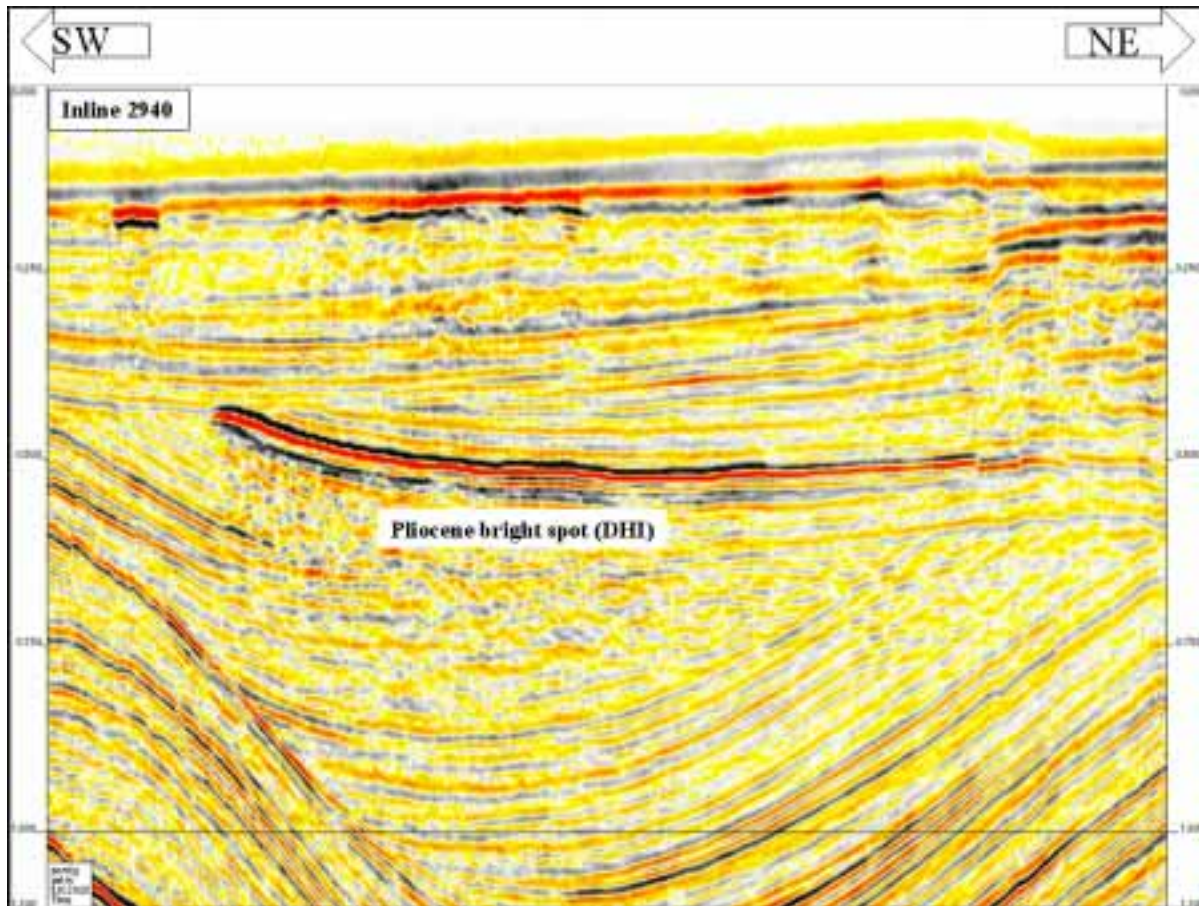


Figure 19: Pliocene high-amplitude seismic event. Note the abrupt termination of the event by an overlying intra-Pliocene unconformity.

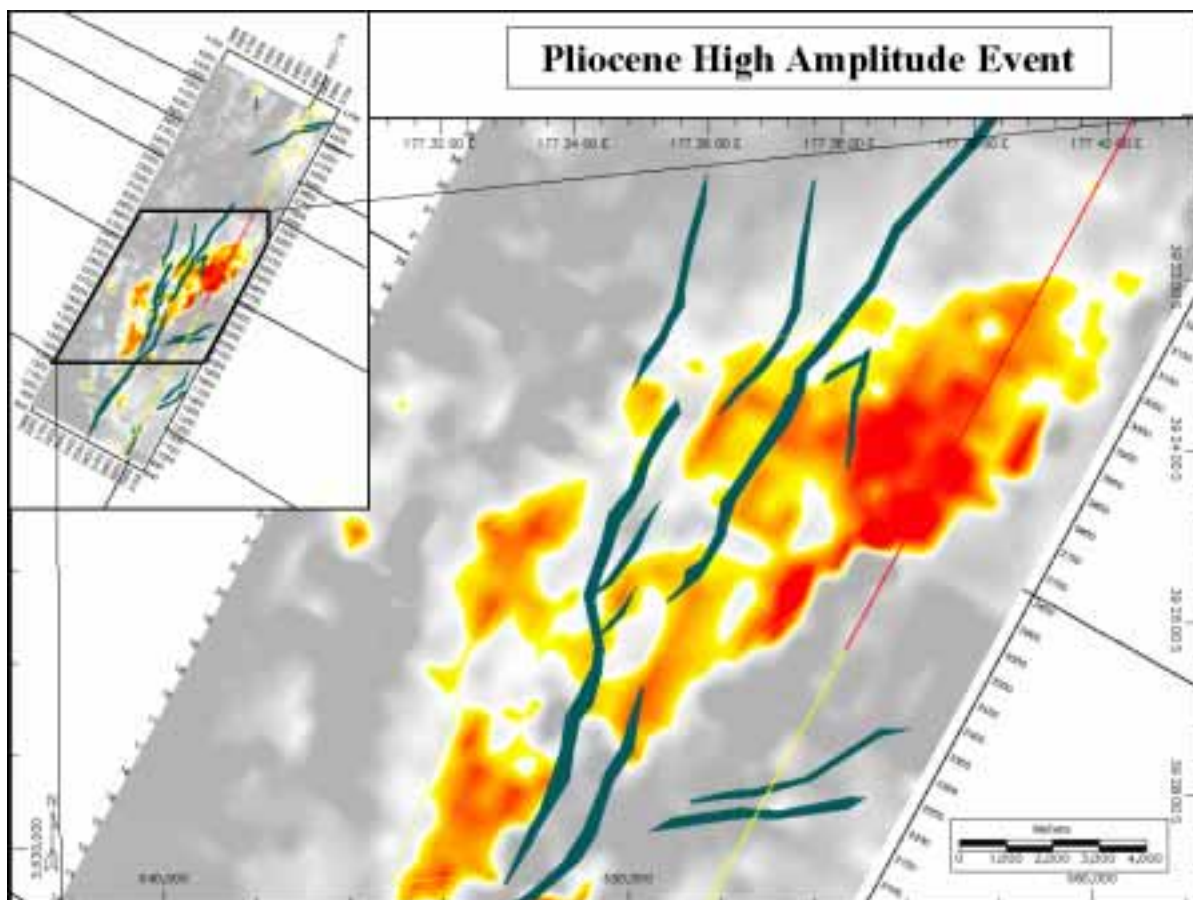


Figure 20: Map view of Pliocene high amplitude seismic event.

Pliocene coquina limestone and thick shelf sandstones in outcrop, which are probable facies equivalents of the seismic event. Hydrocarbon charged reservoirs of this age are secondary exploration objectives.

Structure

The East Coast is a forearc resulting from an oblique subduction of the Pacific Plate under the Indo Australian plate. Compressional, strike-slip, and extensional tectonics dominate the region, (Field and Uruski et al. 1997 and references therein). Periods of compressional deformation occurred in the Early Miocene and throughout Pliocene to Recent time.

The onshore western region of Hawkes Bay is dominated by tightly folded anticlines. Westech-Orion has tested these structures with the Kauhauroa-1, Makareao-1, Kiakia-1, Awatere-1, Tuhara-1, and Opoho-1 wells, with positive results at Kauhauroa and Tuhara.

Offshore Hawkes Bay, the structural amplitude is more subdued than the onshore western region. Trap integrity should be enhanced as a result of less intense fracturing across the anticlinal crests.

Uruski (1998) mapped several structural closures of up to 80 km² within the Westech-Orion permit areas. The decision to position the offshore 3D seismic survey was based upon a prospect ranking scheme which included: area of closures, reservoir presence, proximity to potential hydrocarbon kitchen areas and known hydrocarbon occurrences, trap integrity, and direct hydrocarbon indicators. Preliminary interpretation of the 3D indicates five prospects ranging from 20 to 90 km² in areal extent. In March 2000 Westech-Orion acquired an additional 333 km of 2D seismic in Hawke Bay to confirm seven additional prospects of similar size.

Wairarapa coast

South of Hawke Bay, along the Wairarapa coastline, PEP 38333 covers 9485 km² of the shelf and much of the continental slope to 1000 m water depth. Apart from a few reconnaissance seismic lines by BP, Gulf and Mobil in the 1960s and 1970s, no exploration was undertaken in this area until Amoco acquired permits in 1989. Amoco carried out a program of onshore mapping and reservoir characterization, offshore gravity and magnetic surveys and seep detection, and in 1990 shot over 1400 km of 2D seismic data on a 3 x 6 km grid.

Titihaoa-1 well

Titihaoa-1 (Figure 21), drilled in 1994, was located on a NW-SE reversal, but according to Uruski (1998), post-drill interpretation suggests that the well is located off-structure in a saddle. The original objectives were the Early Miocene Takiritini and Oligocene Akitio Sandstones. However, the Late Miocene section was much thicker than predicted and the well reached total depth of 2740 m in the Middle Miocene, short of the prognosed objectives. Although significant

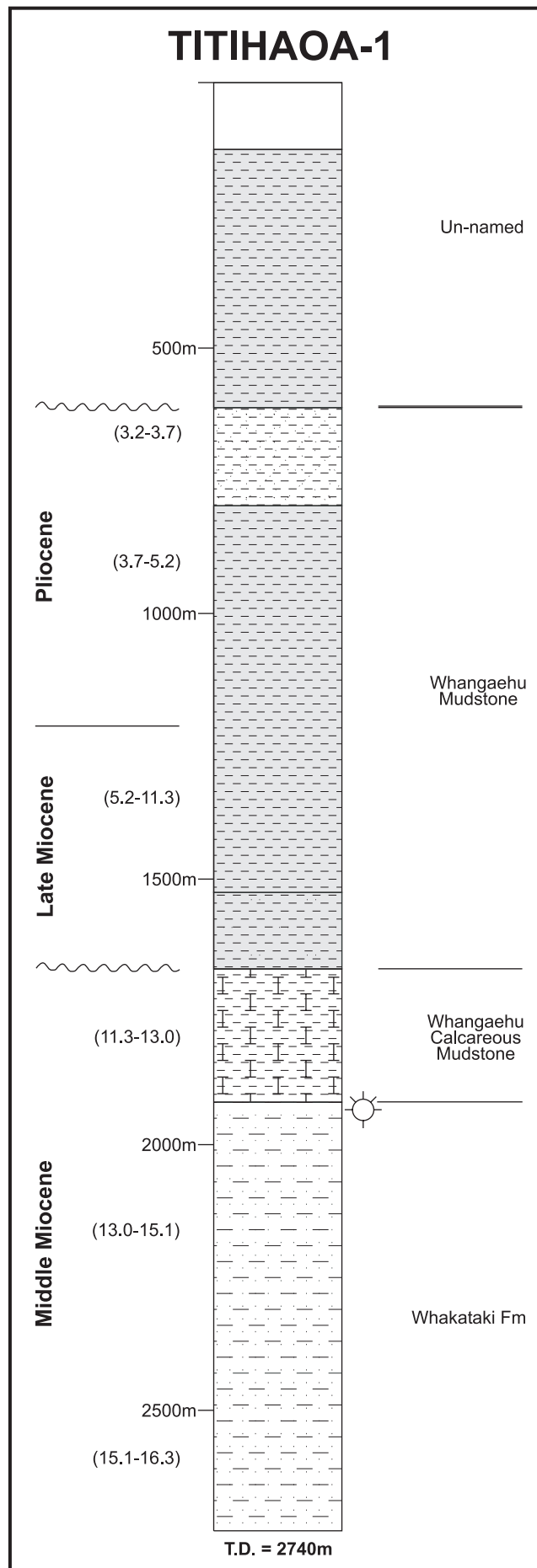


Figure 21: Titihaoa-1 summary log (after Biros et al. 1995).

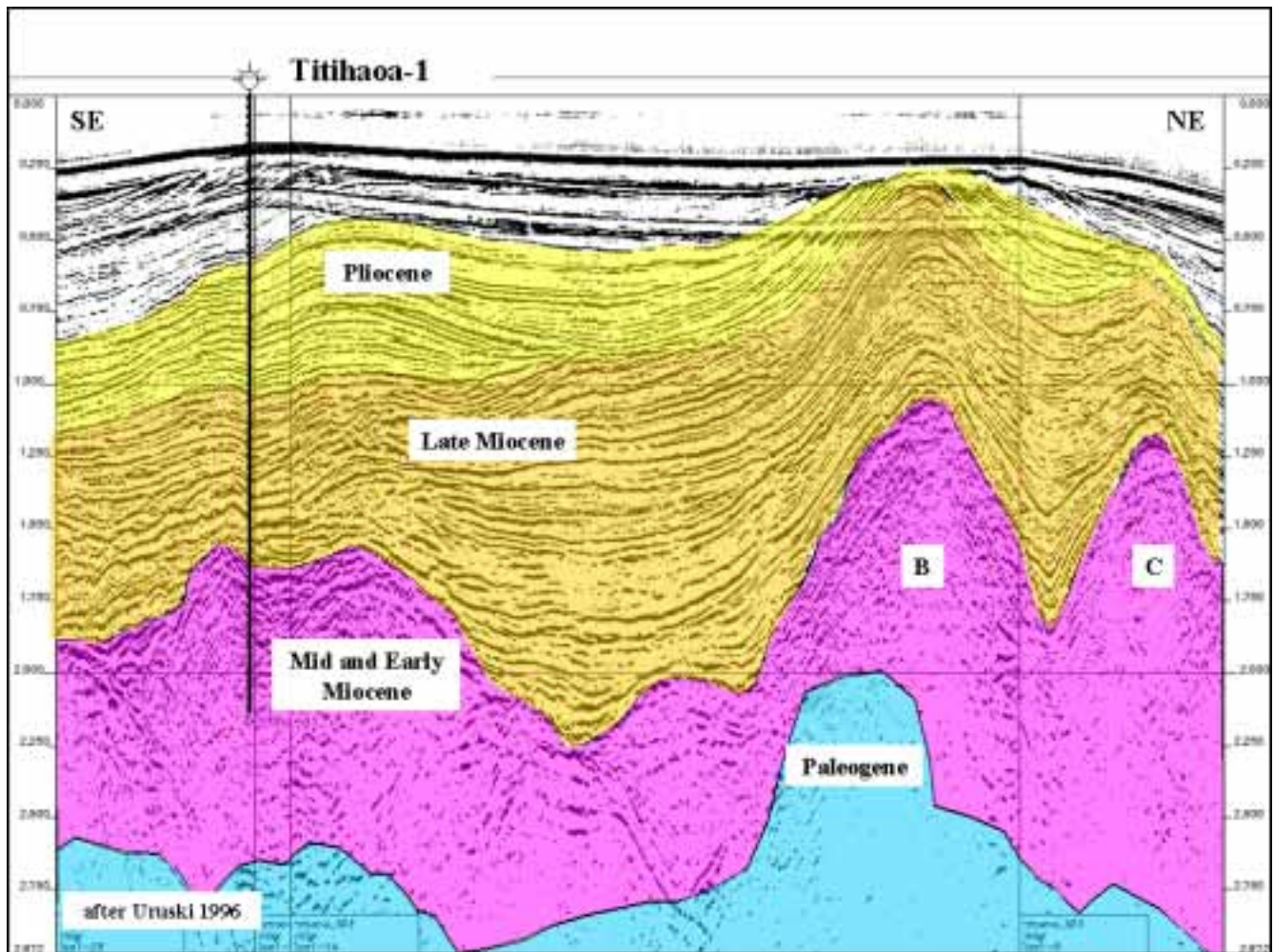


Figure 22: 2D seismic traverse tying Titihaoa-1 to structures B and C (after Uruski, 1998).

hydrocarbon gas (predominantly C₁) was recorded throughout the well, the lack of quality reservoirs within the Middle and Late Miocene contributed to the failure of Titihaoa-1 (Biros et al. 1995).

Post-Titihaoa-1 opportunities

Uruski (1995) mapped fourteen different Miocene structural closures on PEP 38333. The southern half of the permit is dominated by older structures with thin or non-existent Miocene section on the apex of the structures.

North of Titihaoa-1, eight structures exist which have potential closures in the Miocene. Among the structures mapped by Uruski, Structures B and C (Figure 22) are ranked highly based upon potential reservoir targets in the Paleogene through Miocene, DHIs, and areal extent. Structures B and C cover approximately 44 km² and 24 km² respectively (Figure 23).

An interpreted Late Miocene gas sand on Structure C causes a “bright spot” (Figure 24) which may be potentially as large as 35 km². Uruski (1998) identified these direct hydrocarbon indicators on line IAE1-8, and recent analysis by Westech indicates that there may be three or four stacked sands of 20-30 m each which cause the anomaly. Amoco recorded a full-waveform sonic log at Titihaoa-1, and Westech is currently

utilizing the shear wave velocities to evaluate AVO processing to obtain additional information on potential reservoirs.

In March 2000 Westech acquired a 352 km grid of tightly spaced 2D seismic data over structures B and C with 1 km spacing in the dip direction and 4 km strike spacing (Figure 23). These data will be utilized to establish the exploration potential of the mapped structures and the inferred direct hydrocarbon indicators.

Conclusions

Prospectivity of the offshore East Coast Basin has been enhanced by recent maturation and reservoir studies, gas discoveries in adjacent onshore structures, and new 3D seismic data.

- Several reservoir packages have been identified offshore, ranging in age from Eocene to Pliocene. The 3D seismic details a prominent Middle Miocene submarine fan, correlated with the onshore Tunanui Sandstone. High amplitude seismic events in the Middle-Late Miocene and Pliocene are viable exploration targets.
- Maturation modelling of the Paleogene-Cretaceous Waipawa and Whangai formations indicates kitchen areas of 130-500 km². The source rock in the main kitchen area

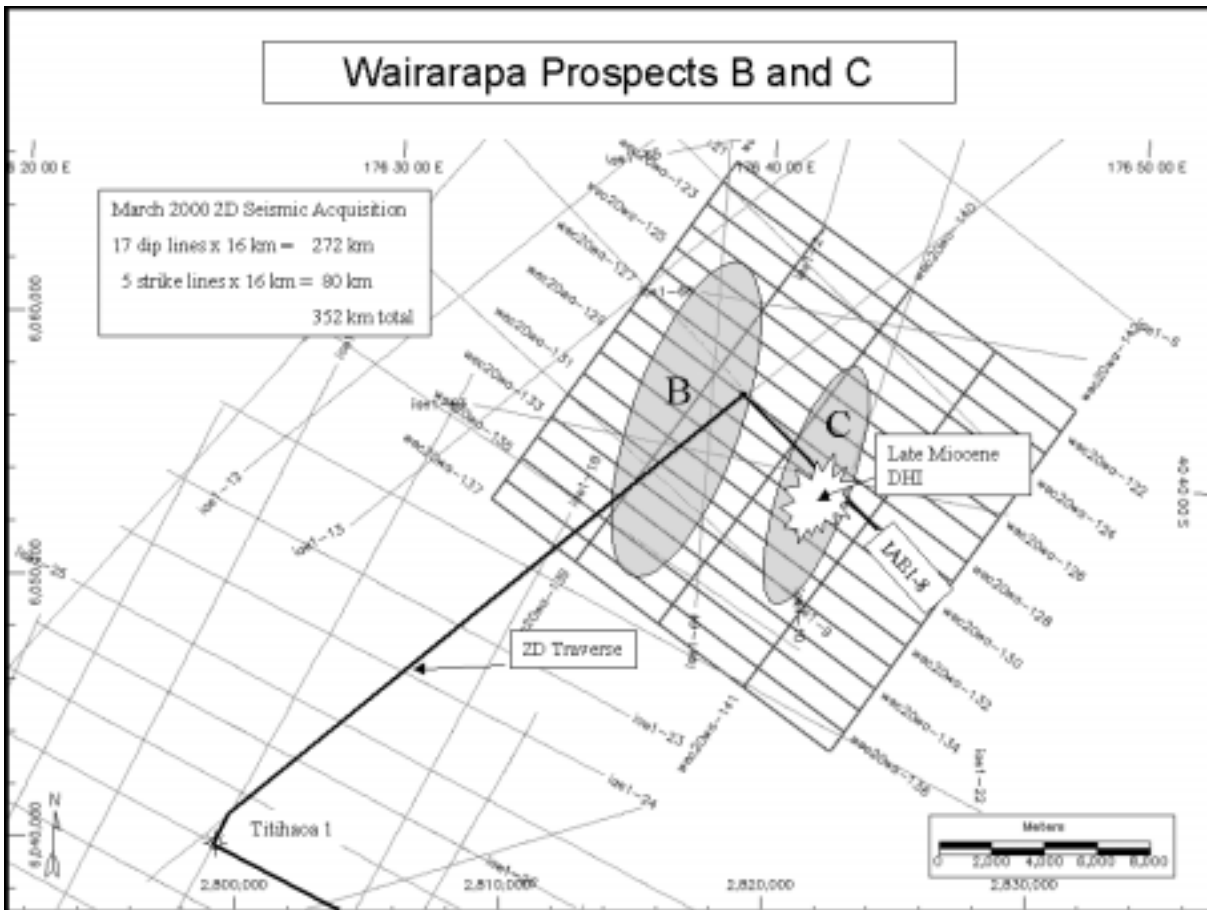


Figure 23: Map view of structures B and C in PEP 38333 with Westech-Orion year 2000 seismic acquisition.

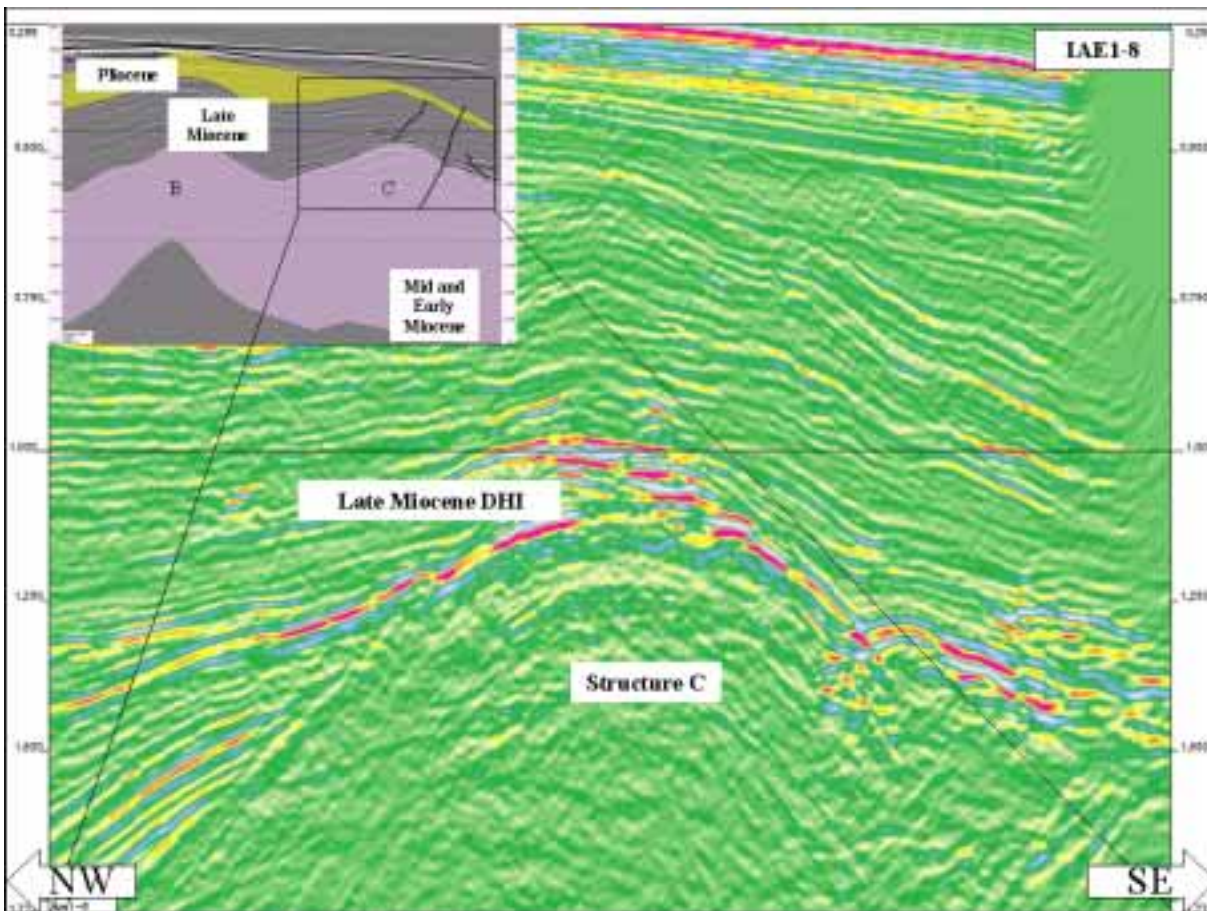


Figure 24: Late Miocene direct hydrocarbon indicator (DHI) on seismic line IAE1-8.

adjacent to the 3D survey is conservatively predicted to have expelled 665 million barrels of oil.

- Gas discoveries in onshore Westech-Orion wells have proven an active petroleum system.
- Trap development is dominated by mildly compressional structures, developed during the latest Miocene and Pliocene. The offshore structures have less intense amplitude than onshore and thus enhanced trap integrity.

Within both Hawke Bay and off the Wairarapa coast, there are numerous, untested structural trap prospects, with multiple reservoirs, adjacent to a series of kitchen areas, with favorable timing of structural development and hydrocarbon migration. The potential for large commercial discoveries exists.

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