

Tariki sandstone prospectivity in PEP 38718, onshore Taranaki

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Abstract

The Tariki Sandstone Formation was deposited along what is now the easternmost edge of the onshore Taranaki Basin and was first drilled in the mid 1980s. It is interpreted as an Oligocene-aged outer shelf to bathyal turbidite deposit and forms the reservoir in the Tariki (EUR 57 bcf) and Ahuroa (EUR 22 bcf) gas-condensate fields. The Tariki Sandstone was sourced from eroded Kapuni Group sediments east of the Taranaki Fault on the Patea-Tongaporutu High and the thickest section is deposited between the Tariki and Ahuroa fields and the Taranaki Fault.

Whilst Tariki Sandstone discoveries have been made in the overthrust structures, the formation has not been drilled in the interpreted depocentre of turbidite sedimentation. This is primarily because very poor seismic imaging had prevented definition of a valid structure. The PC-98 series seismic data shot recently by Fletcher Challenge Energy has now revealed stratigraphic and four-way dip closure in the Tariki Sandstone section in PEP 38718.

The depocentre is optimally located with respect to reservoir presence, good-quality sandstone deposition, hydrocarbon generation, charge, and with seismically controlled seal and trap definition. An important new prospect has been identified. Current reserve estimates indicate potential for significant volumes of hydrocarbons to be trapped. The play also has significant follow up potential.

Fletcher Challenge Energy is preparing to test this play and is planning to drill in mid-2000.

Introduction

Petroleum Exploration Permit (PEP) 38718 (Figure 1) lies within the highly productive eastern margin of the onshore Taranaki Basin, adjacent to and east of the Tariki (EUR 57 bcf) and Ahuroa (EUR 22 bcf) gas-condensate discoveries, and northeast of the Waihapa-Ngaere oil fields (EUR 28 mboe). Combined peak daily production from these onshore fields was over 12,000 bopd and 35 mmscfd although these fields are now in decline. The block covers a major interpreted onshore kitchen area between the productive Tarata Thrust Belt trend and the Taranaki Fault to the east.

Various interpreters have mapped the PEP 38718 area identifying Tikorangi Limestone and Kapuni Group structural prospects, however in 1999, after incorporating new 2D seismic acquired in 1998, a structural/stratigraphic feature within the lower Otaraoa Formation equivalent was identified which had previously not been recognised. This prospect is named the Tuihu prospect and is currently interpreted as a submarine fan or turbidite complex, however a number of depositional models can be applied to fit the current data and regional setting. Fletcher Challenge Energy is preparing to drill the Tuihu prospect in the second half of 2000.

PEP 38718 was granted under the terms of the Crown Minerals Act 1991 to Fletcher Challenge Energy for 5 years from 1/12/1995. The Year 4 work programme was fulfilled on April 30 1999 and the proposed Tuihu-1 exploration well will complete the Year 5 commitment.

Regional stratigraphy

A predicted stratigraphy for the Tuihu region is shown in Figure 2.

A widespread unconformity, marked primarily by an absence of Early Oligocene (e Lwh) sediments, is present across much of the Taranaki Basin's southeastern and southern paleo-margin (King & Thrasher, 1996). The unconformity separates primarily terrestrial Kapuni Group sediments from the overlying marine Ngatoro Group. This unconformity has some features in common with the mid-Oligocene Marshall Paraconformity (Carter 1985, Fulthorpe et al. 1996) and King & Thrasher (1996) suggested it may be a correlative of it.

Deposition of the Otaraoa Formation and Tariki Sandstone Member in the Waihapa-1 and Toko-1 wells, typical offset wells to the west of Tuihu, occurred in outer shelf to upper

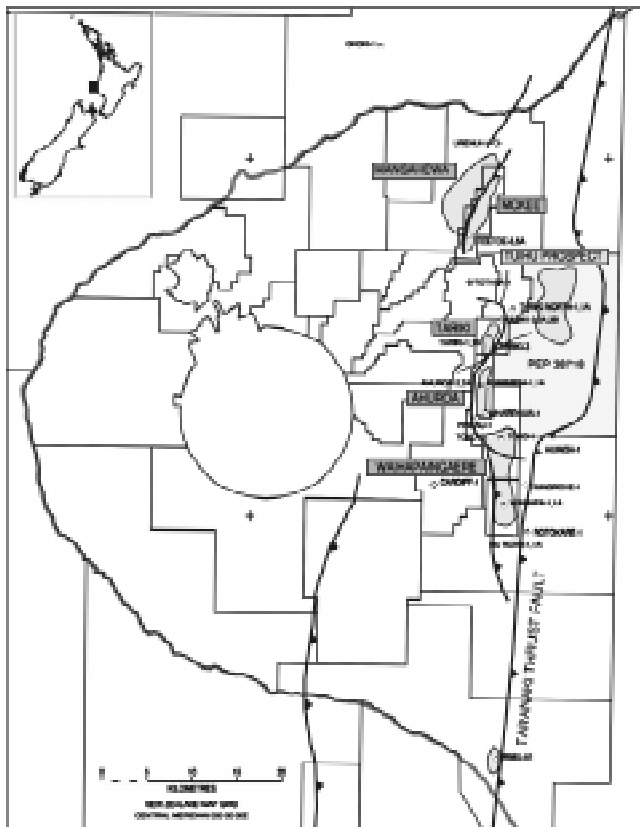


Figure 1: Location map PEP 38718 and Tuihu prospect.

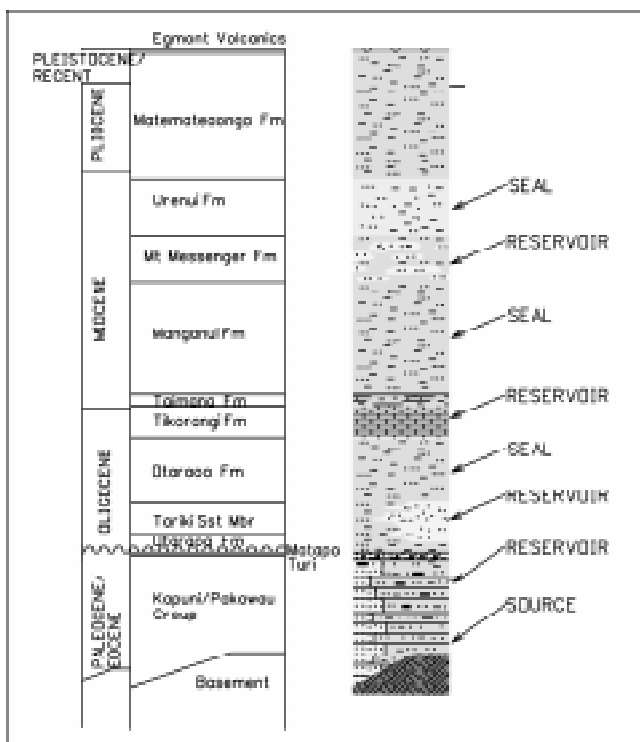


Figure 2: Predicted stratigraphy PEP 38718.

bathyal conditions during the late Whaingaroan and Duntroonian times with the deposition of the Tikorangi Limestone commencing in the very latest Duntroonian. Deposition of the limestone continued through the early Waitakian in mid- to outer shelf conditions in the Toko-1 well, although paleoenvironments are reported as upper

bathyal in Waihapā-1. By the end of the earliest Waitakian renewed clastic sedimentation marked the end of limestone deposition and the Taimana Formation was deposited in upper to mid-bathyal conditions during the mid and late Waitakian. Thickness changes of the Taimana Formation along the Tarata Overthrust trend indicate that a fully compressional tectonic regime was in place by the beginning of formation and uplift of the overthrust structures.

Wells to the east of the Tuihu area such as Toko-1 and Waihapā-1 show an unconformity or condensed section during the early Whaingaroan NZ Stage interval with the foraminiferal *Globigerina angiporoides* Zone not represented in any onshore Taranaki Basin well drilled to date. It is suggested that the recommencement of clastic sedimentation in the very earliest late Whaingaroan, i.e. at the basal Otaraoa Limestone Member, marks the first evidence of transpressional tectonics and coincides with renewed sedimentation into the developing depocentre at these (Toko-1/Waihapā-1) localities. The initiation of this subsidence phase at 32 Ma (Stern & Davey 1990) however suggests there may be basal Oligocene (early Whaingaroan) sediments deposited further to the east. These basal Oligocene sediments may represent a thicker and equivalent but proximal facies to the Matapō Greensand or they may rest directly on a typical Matapō condensed section and represent a formation or facies not yet observed in the eastern Taranaki Basin. The nature of these sediments is highly speculative. They could range from coarse-grained, poorly sorted talus or slump sediments through to submarine fan or turbidite deposits.

Evidence for fault activation and significant movement during the mid- and Late Oligocene comes from the presence of reworked Kapuni Group palynomorphs within the Tariki Sandstone which suggests that Kapuni Group sediments overlying the basement blocks were being subaerially exposed and eroded. In the Wharehuia-1 well, the presence of reworked *Nothofagus matauraensis* and *N. flemingii* in coal fragments from the Tariki Sandstone indicate a pre-Runangan age (Raine 1999). This suggests, albeit very speculatively, that the latest Eocene Kapuni Group (ie the Runangan deposits) had already been removed from the emerging thrust blocks. These sediments may have contributed to early Whaingaroan deposits occurring in the eastern proximal (Tuihu) part of the depocentre.

Regional structural setting

The eastern margin of the present day Taranaki Basin is formed by the Taranaki Fault, a major east-dipping reverse fault, active from the Oligocene with maximum activity in the Miocene. The fault vertically offsets basement by up to 6 km and forms the western edge of the onshore Patea-Tongaporutu High (King & Thrasher 1996).

Various authors have proposed different models for the Oligocene subsidence west of the Taranaki Fault:

1. Westerly downthrow on the Taranaki Fault and associated development of a large half graben within an oblique extensional setting. (King and Robinson 1988).

2. A flexural foredeep trough developing within the basin in response to isostatic loading by a developing fold-thrust belt in the Taranaki Fault Zone (Stern and Davey 1990).
3. Subduction induced platform subsidence (Stern and Holt 1994).

In all models, however, significant accommodation space was created along the eastern Taranaki Basin in which the proposed Tuihu sediments (Tariki Sandstones) and/or equivalents were deposited. This sedimentary depocentre can be observed in Figure 3, which shows an eastwards-thickening wedge of sediment between the Tikorangi Limestone and Turi Formation with a hinge or flexural point about 10 to 15 km west of the Taranaki Fault. Seismic character in the lower part of the wedge or “flexural trough” onlaps the Turi horizons suggesting accumulation to the west of a prograding wedge of sediments. Figure 4 shows the same thickening in the Tuihu area where the depocentre appears broader.

The mid-Oligocene sea level drop (Marshall Paraconformity) may be a useful division of sediments within the Eastern Taranaki Basin Oligocene “Flexural Trough”. Sediments deposited above or later than the sea level drop can be considered equivalent to the Tariki Sandstone. Sediments below or older than the unconformity have not been encountered as yet (unless equivalent to the condensed Matapo Greensand).

Tuihu prospect geological model

Geophysical interpretation

Seismic coverage over the Tuihu Prospect is moderate with an average 1 km dip-line spacing. Most of the data was acquired by Fletcher Challenge Energy in 1996 and 1998. A small amount of earlier vintage data has been reprocessed. Most of these data are of good quality by onshore standards for the eastern Taranaki Basin margin. The data quality deteriorates towards the Taranaki Fault where basement is involved.

There are no direct well ties into the prospect. The closest wells are in the Tariki Field, approximately 8 km southwest. These are all on the other side of the Tariki Thrust, which precludes any direct tie, although they provide a basis for the facies model in the prospect. Ties to well to the south and southwest are tentative. All 2D seismic lines have been internally tied using time shifts to form a consistent data set.

The structure has been recognised, in one form or another, for a number of years. Until early 1999 it was mapped as a modest four-way dip structural closure at Kapuni Group level with a closure also inferred at Tariki Sandstone level, although this had never been separately mapped. However, in 1999 after incorporating new 2D seismic acquired in 1998, a new structural/stratigraphic feature within the lower Otaraoa Formation was identified. A Tariki Sandstone fan envelope and an associated seismic event defining separate mounds

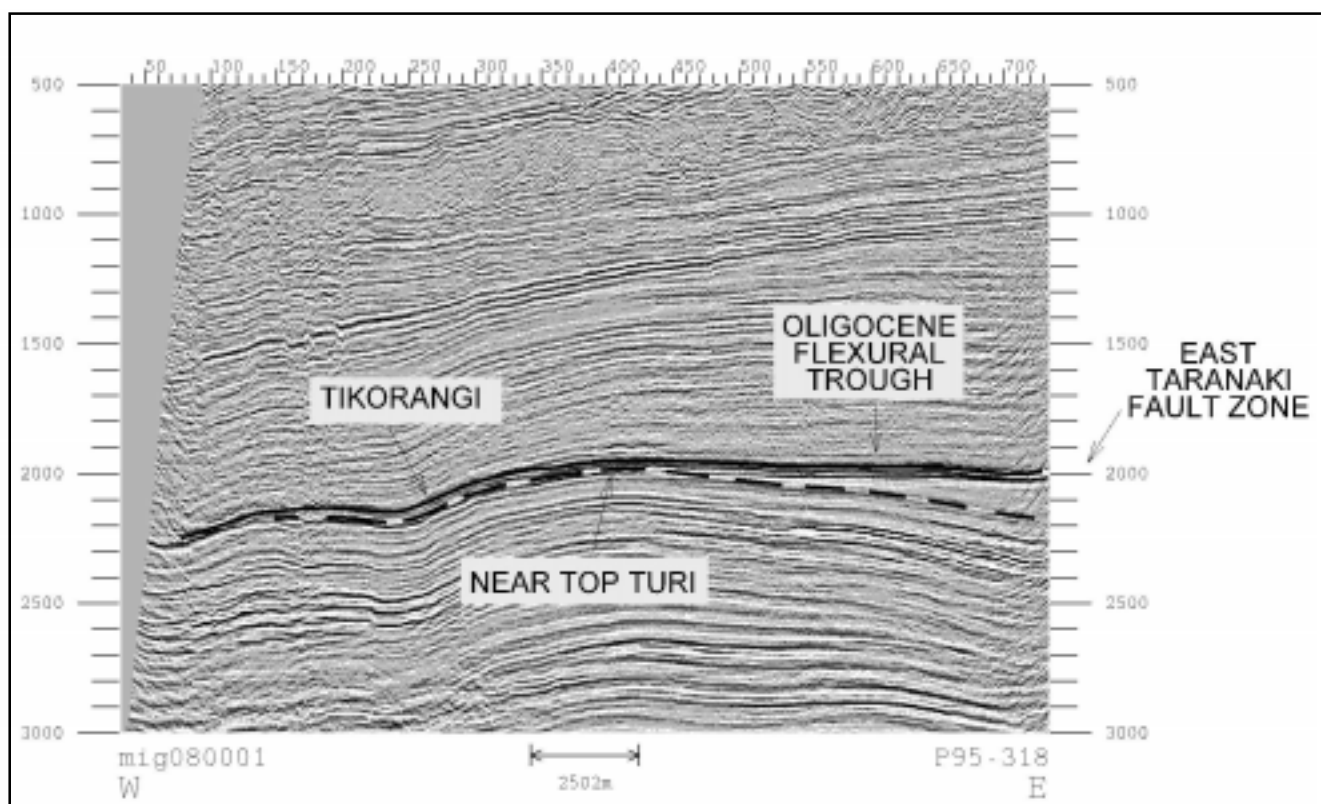


Figure 3: Seismic section showing easterly thickening sedimentary wedge between Tikorangi Limestone and Turi Formation.

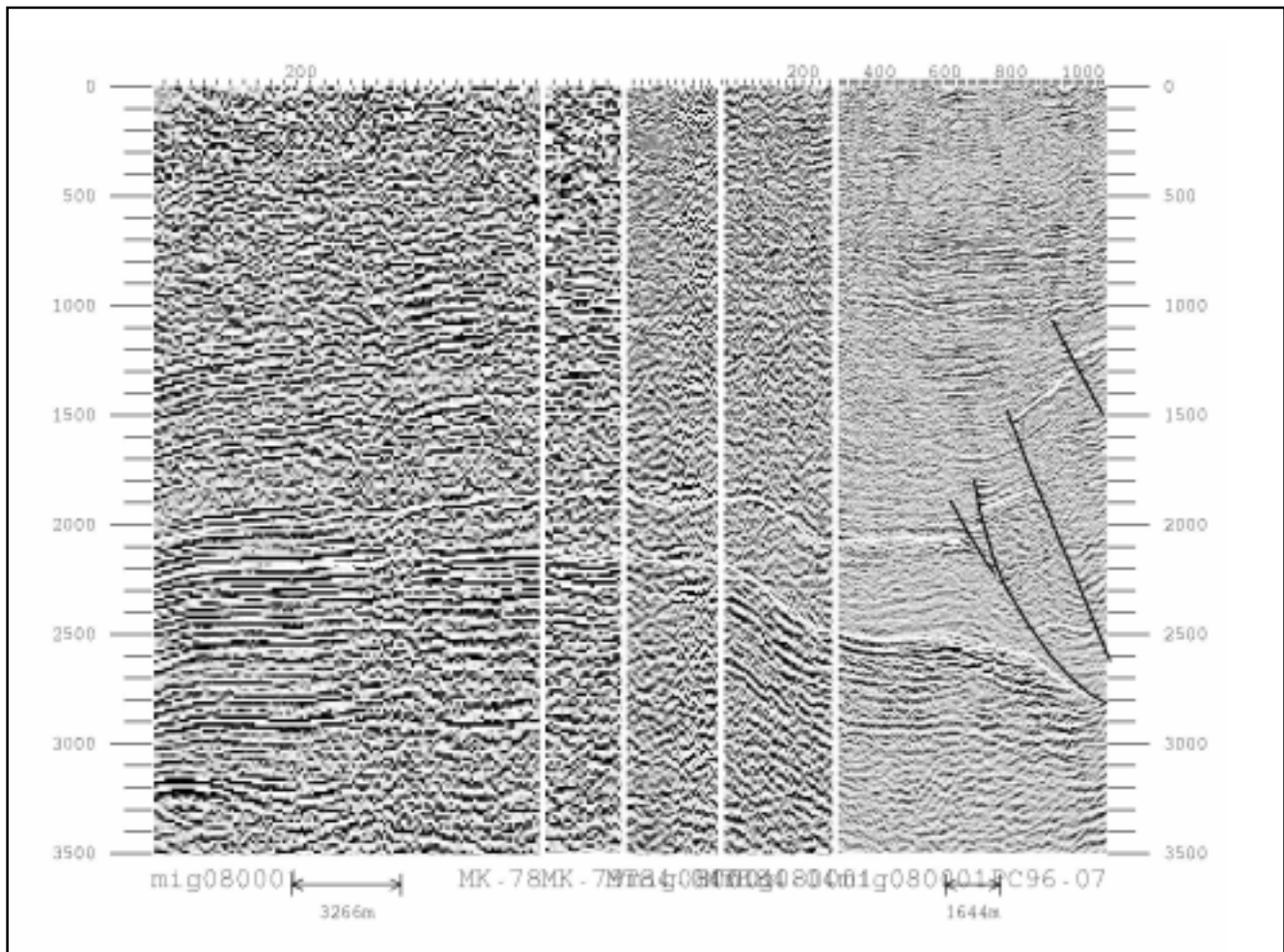


Figure 4: Seismic section through the Tuihu Area showing thickening of the Tariki Sandstone section into the Taranaki Fault Zone.

were interpreted on prospect at this stratigraphic level. Figure 5 is an interpreted seismic line across the Tuihu prospect demonstrating east west closure at Tikorangi, Tariki and Kapuni horizons.

The present seismic interpretation was carried out on a workstation using Landmark seismic interpretation software. Time interpretations for four key horizons have been completed over the prospect area. These horizons include the top Tikorangi Limestone, top Tariki 'fan envelope', top Tariki mound and near top Kapuni Group. The top Tikorangi Limestone and top Kapuni Group events are picked on the basis of regionally consistent character and available well ties. The Tuihu Fan events (both the 'fan envelope' and mounding within it) are picked wholly on the basis of character and geometries.

Detailed TWT, depth and relevant isopach maps have been produced. The west-east well cross section (Figure 6) and the isopach map (Figure 7) both show that the Tariki interval (sandstones, shale and siltstone) thickens considerably towards the east, which is consistent with seismic data.

Reservoir

The primary target for the Tuihu prospect is the lower Otaraoa Formation coarse clastic sequence, also referred to as the Tuihu Fan. It is proposed that the Tuihu Fan is a more

proximal or older facies of the Tariki Sandstone, which was deposited between the Tariki and Ahuroa field areas and the Taranaki Fault during the early and middle Oligocene.

The Tariki Sandstone is named after the Tariki-1A discovery well and consists of a sequence of sandstones with siltstones and mudstones, interpreted as a turbidite sequence (De Bock, Palmer and Lock 1989). Well-developed sandstone beds occur at the Tariki and Ahuroa locations, while thin discontinuous sandstone beds, pebble beds and beds containing coal fragments extent north to the McKee area. Figure 8 is a composite well log of a typical Tariki sandstone reservoir in Ahuroa-2A. The sandstones appear to be continuous southwards to the Wharehuia, Piakau, Toko and Waihapa locations where they become increasingly more interbedded and finer grained with thick intervals of claystone.

The Tariki Sandstone along the Tarata Thrust Belt consists of interbedded sequences of thin to thick, sometimes graded, sandstone, calcareous mudstone and limestone. The sandstones are composed of white to light grey, well consolidated, generally clean, fine- to medium-grained quartz and feldspar grains, with minor lithic grains and ubiquitous calcareous cement. Detrital coal fragments, up to 3 cm across, are common locally. The reservoir quality of the sandstone deteriorates rapidly from north to south. The Tariki Sandstone is interpreted as a Kapuni Group erosional product.

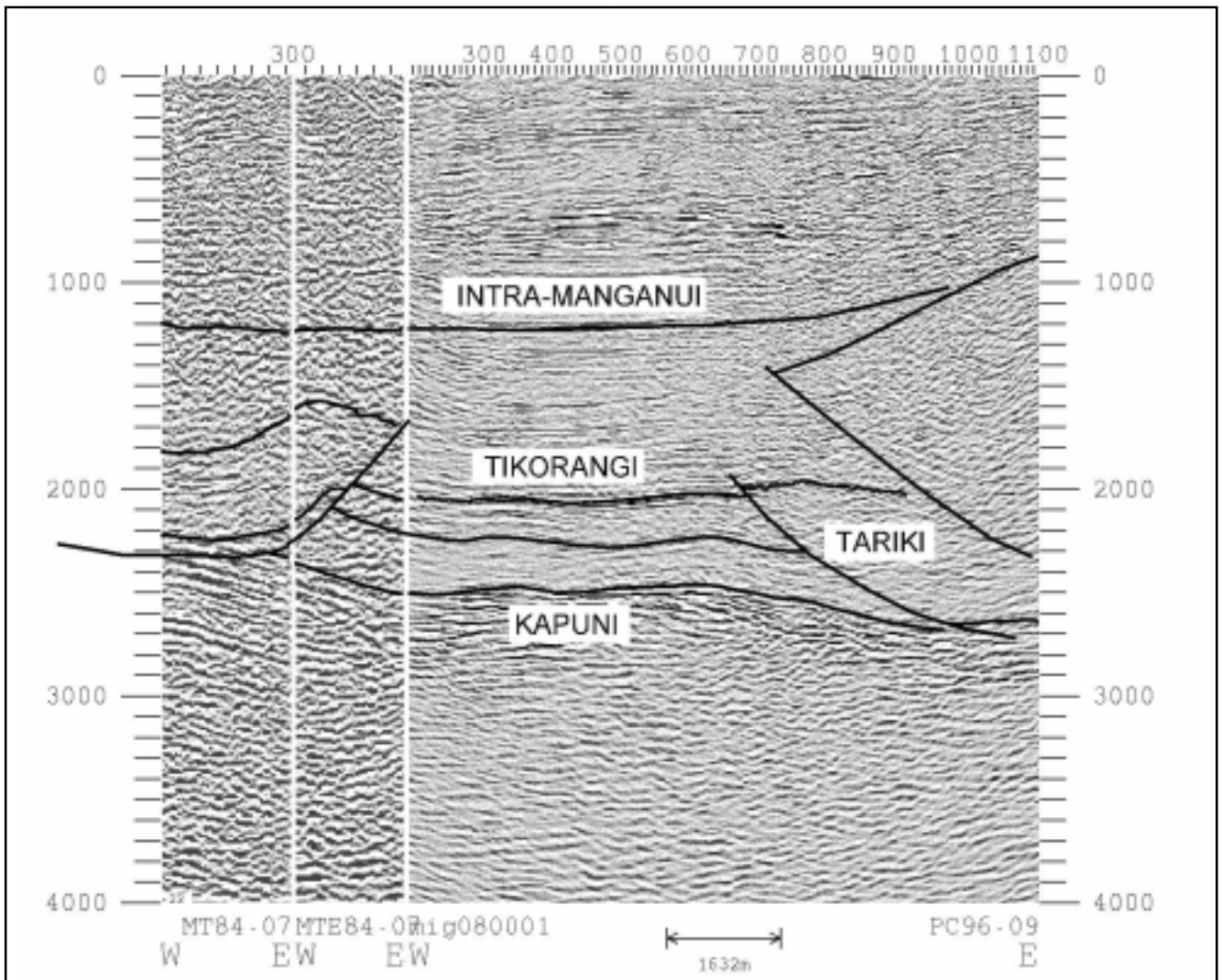


Figure 5: Interpreted seismic line across the Tuihu prospect.

Mudstones of the Otaraoa Formation immediately overlying the Tariki Sandstone possess foraminiferal assemblages indicative of outer-shelf to upper-bathyal depths. In places the Tariki Sandstone contains a mixed shallow and outer shelf fauna which suggests downslope reworking of shelf sediments. Stacked channel sequences, composed of sandstone with claystone and fine rip-up clasts with erosional contacts, occur in the Tariki and Ahuroa wells. The Tariki Sandstone is a more proximal facies at Ahuroa-1 and -2 than at Tariki-1, Tariki North-1A and other wells.

Sands in the Tuihu Fan are expected to be erosional products from the escarpment formed by the Taranaki Fault uplift, with predominantly terrestrial sandstone/siltstone/shale/coal cyclo-themes from the Kapuni Group being eroded.

A porosity/permeability cross-plot for core in the Tariki wells is shown in Figure 9. Generally average porosity varies from 15 to 19% with equivalent permeabilities ranging from 10 to 500 mD. The Tuihu prospect, being in a more proximal setting, is expected to have a coarser-grained fraction of sand possibly improving porosity-permeability characteristics. However, depth of burial may have adversely effected reservoir quality.

Source

Source is a very low risk for the Tuihu area. The prospect immediately overlies proven source rocks of the Kapuni and Pakawau groups, which have charge the nearby producing fields. Vitrinite reflection studies suggest that maturation and expulsion of oil exists at depths of 4000 to 5000 m.

Seal

In the Taranaki Basin, the marine shales of the Otaraoa Formation act as an excellent seal for fields producing from the Tariki Sandstone, Kapuni Group and McKee Sandstone. Similarly the Otaraoa Formation claystone/shales cap the sandstone fan envelope mapped at the Tuihu prospect. Usually the seal between top reservoir and base Tikorangi Limestone is several hundreds of meters thick, however seismic data at the Tuihu prospect suggests some reduction in thickness may occur.

Charge and migration

Charge and migration are also a low risk for the Tuihu prospect. The prospect overlies a rich, mature kitchen, which

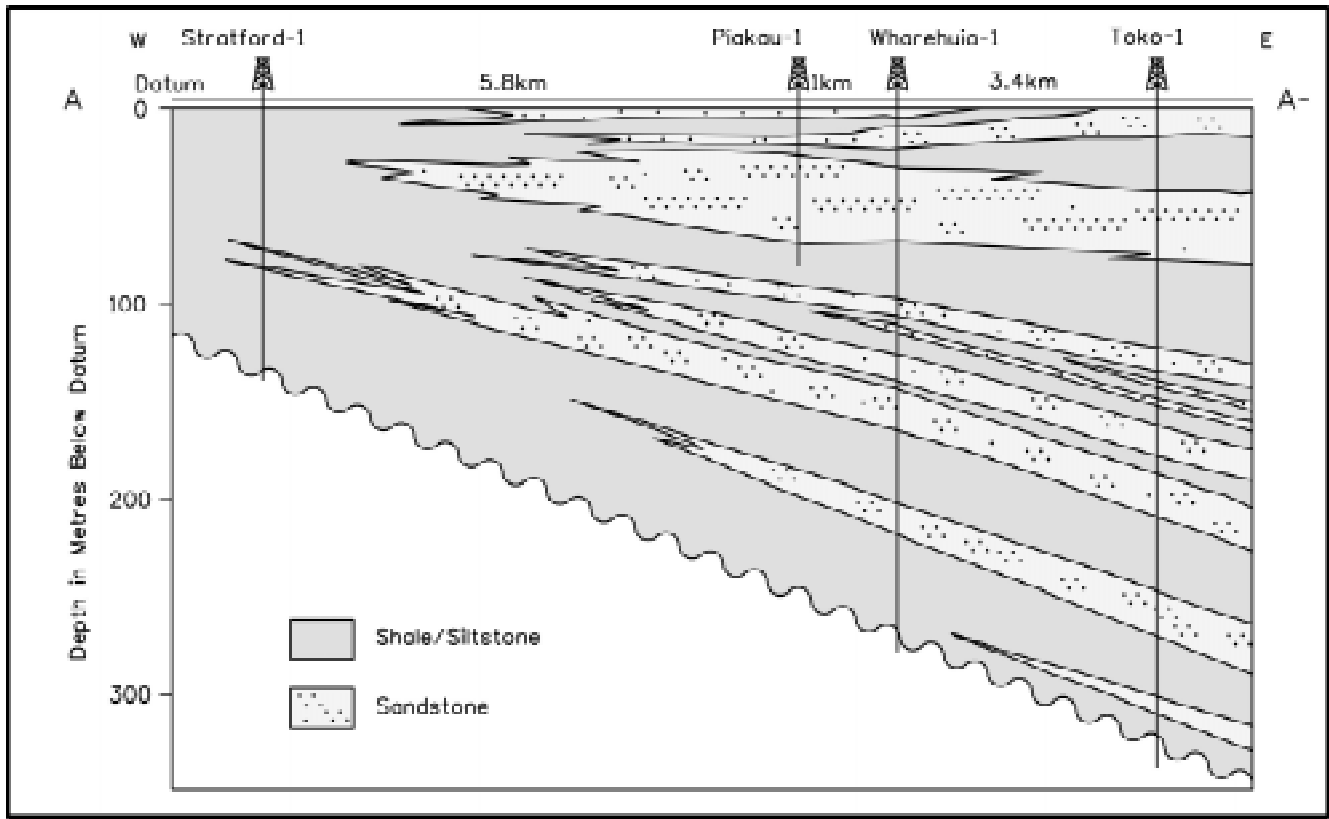


Figure 6: West-east well cross section at Tariki Sandstone level.

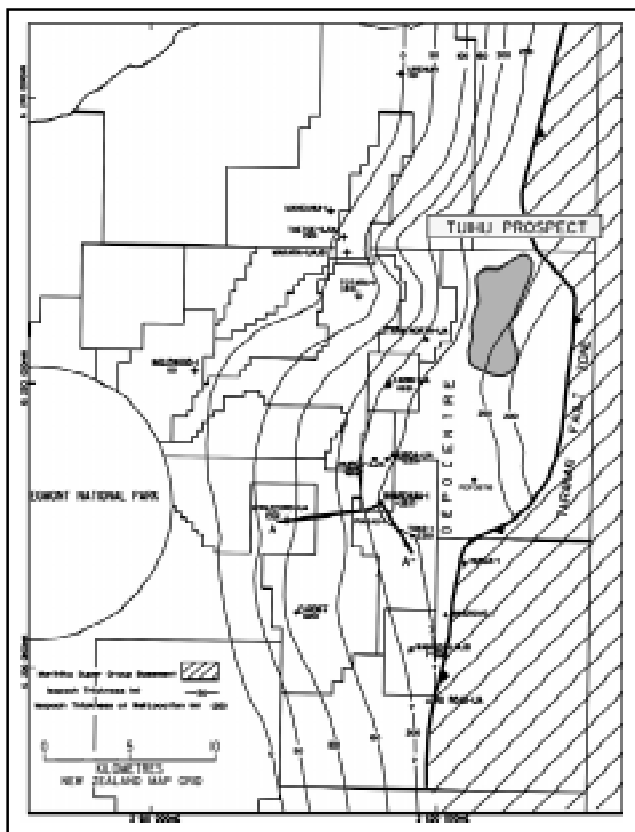


Figure 7: Tariki Sandstone isopach map.

has been expelling hydrocarbons for at least the last 5 million years (Figure 5). Several faults intersect the reservoir section, which should form excellent conduits for hydrocarbon migration. The trap is a direct-age analog to fields to the west

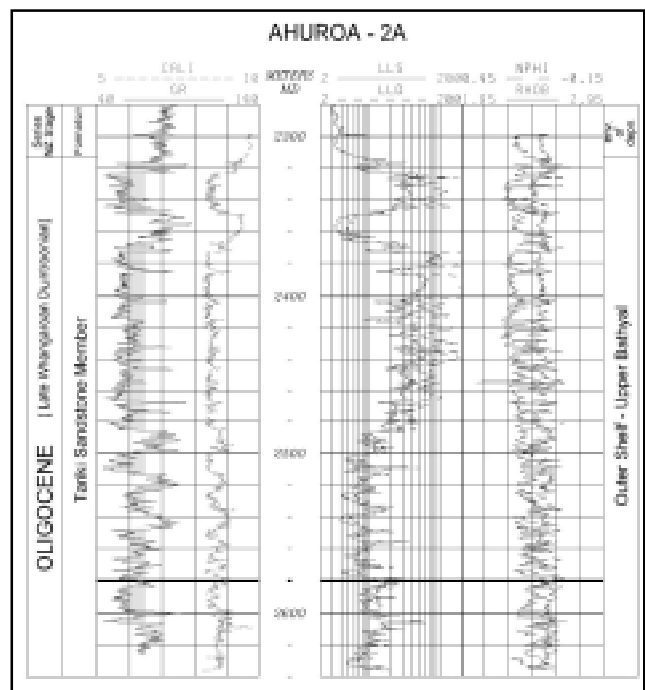


Figure 8: Tariki Sandstone composite log – Ahuroa-2A.

of the prospect and there is no evidence of post-fill tectonics, which could breach or destroy a trap.

Secondary objectives

Tikorangi limestone fractured reservoir

The Tikorangi Limestone is considered a secondary target for the Tuihu prospect. Studies of the Oligocene Tikorangi

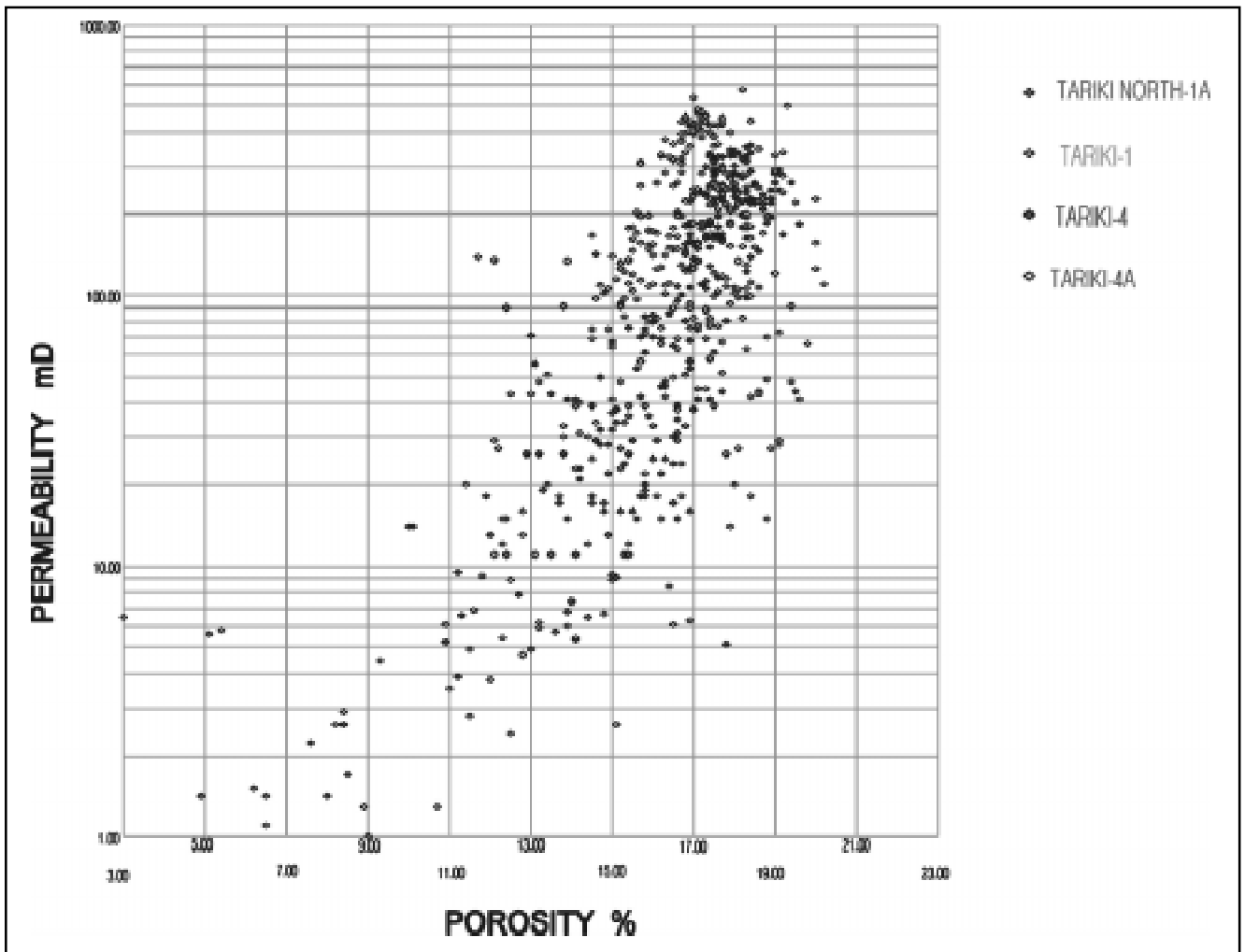


Figure 9: Tariki Sandstone core porosity-permeability crossplot.

Limestone and the Tariki Sandstone indicate that deposition of both units was confined to a north-south trending basin as a result of syn-depositional structural controls on bathymetry. Both formations should therefore be well developed within PEP 38718. The Tikorangi Limestone is the fractured reservoir in the Waihapa-Ngaere Field, immediately to the southeast of PEP 38718.

Seismic analysis shows that the Tikorangi Formation interval thickens to the east, toward the Tuihu prospect. A recent facies analysis on the Tikorangi Formation, using the Waihapa and Ngatoro cores, suggest the facies becoming shallower and possibly more clastic towards the east which will very probably make it more susceptible to fracturing. The Tikorangi Formation reflector at the Tuihu well location does not show any closure, however closure has been identified within PEP 38718.

Mt Messenger Formation

The Mt Messenger Formation is currently producing in the Kaimiro and Ngatoro fields. Thin-bedded lower-slope turbidites, with some thicker-bedded intervals possibly representing more proximal or channelised facies dominate the reservoir at Kaimiro. By comparison, the reservoir units in the vicinity of the Waihapa-8 and Waihapa-2 wells are dominated by thicker-bedded sands which appear to be better

quality than those at Kaimiro. The short (~2 hour), open-hole Waihapa-8 DST from Mt Messenger sands indicates that these sands can be highly productive. Rates up to 750 bopd were measured in this short test.

At Tuihu the Mt Messenger Sandstone is predicted to have similar properties as seen in the Waihapa area, being more proximal to its easterly source.

Kapuni Group and McKee equivalent sandstones

Historically, the Kapuni Group and the McKee Sandstone formed the main reservoir targets in the Taranaki Graben, until the Mt Messenger and Tikorangi and Tariki Sandstone formations became proven and producing reservoirs. To the northwest of the Tuihu prospect, the McKee Field produces from the McKee sandstones. Kapuni Group sandstones form the producing reservoirs in the Maui, Kapuni and Mangahewa fields.

Kapuni Group sediments consist predominantly of fluvial deposits with sands of varying reservoir quality. The transgressive and marine McKee Sandstone overlying the Kapuni Group sediments may be present at the Tuihu prospect, but is under minimal closure. The Tuihu well is also designed to drill and evaluate the first 100 to 150 m of the Kapuni Group sediments and to determine its potential

as a hydrocarbon-bearing reservoir in the area east of the Tarata Thrust. The depth of burial at this location may have adversely affected its reservoir properties.

Summary

Recent seismic data has revealed a tectonically controlled depocentre, which may contain a proximal facies of the productive Tariki Sandstone or an older and as yet undrilled coarse clastic sequence. The Tuihu prospect has been mapped with four-way dip closure and is optimally located with respect to reservoir development, hydrocarbon generation, charge and seal. Tuihu is close to producing fields and infrastructure and Fletcher Challenge Energy is preparing to drill in the second half of 2000.

The well will also provide key stratigraphic and geological data in the centre of a large, unexplored area of the highly prospective eastern onshore Taranaki Basin.

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