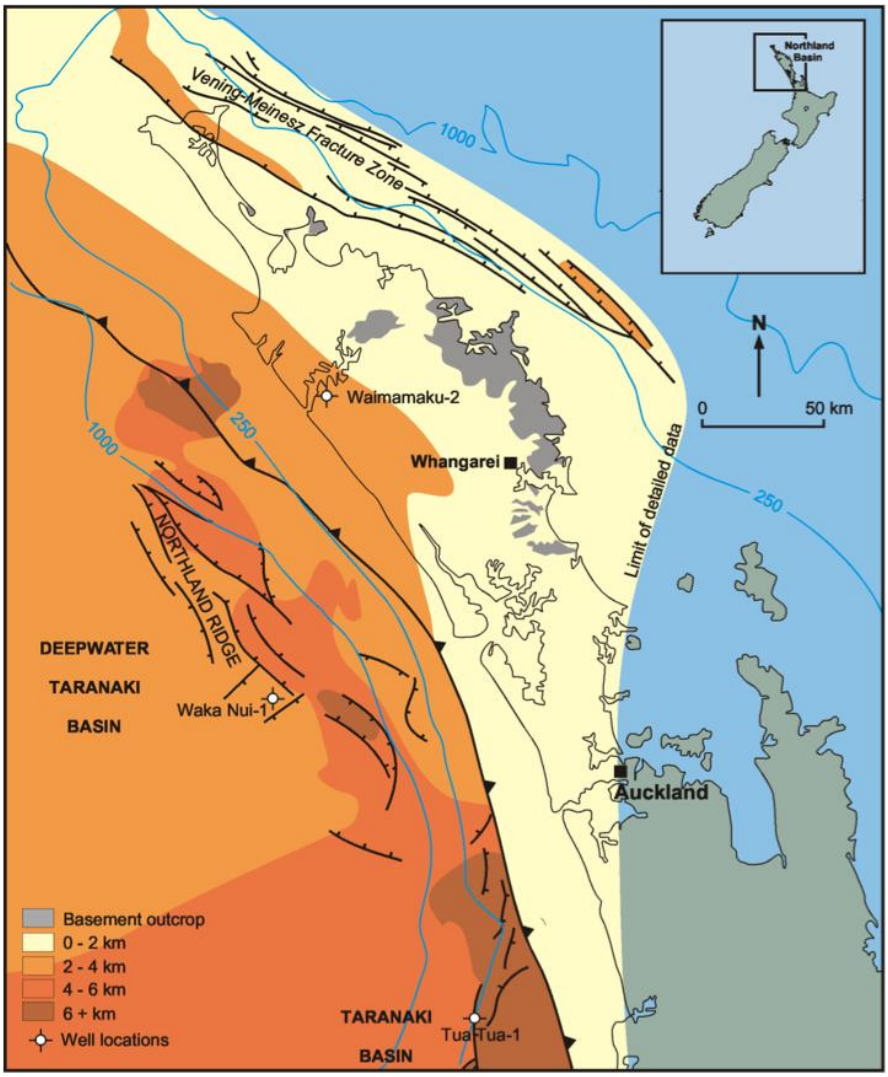
1.1 OFFSHORE NORTHLAND BASIN

The offshore Northland Basin is perhaps the most under-explored near-shore basin in New Zealand. It is a huge basin, approximately 120,000 km² in area, yet it contains only one exploration well. To the south it is geologically contiguous with the Taranaki Basin, on the boundary of which the most recent gas discovery, Karewa, was announced in February 2004. The basin has a number of depocentres with sediment fill in excess of 6,000m. Water depth increases quickly to the west of the Northland Peninsula and much of the western part of the basin is at more than 1,500m water depth.

The basin extends onshore to include all of the Northland Peninsula, north of Auckland. Despite the fact that gas was first discovered in an onshore well south of the Hokianga Harbour, the onshore part of the basin is not considered prospective because of the thinness of sediment cover on basement. It has not been the subject of recent conventional exploration, although there are a number of coal bed methane permits in the area south of Auckland.

Figure 4.2-1: Offshore Northland Basin Map



Source: Crown Minerals Group, 2004

1.1.1 EXPLORATION HISTORY

There are currently two exploration permits and one appraisal extension permit, although the latter, PEP 38602, arguably lies within the Taranaki Basin (Table 2.33). The two newer permits were awarded as a result of the 2005 Offshore Northland Blocks Offer. Water depth is clearly an issue, since all of these permits are in the shallower part of the basin.

Table 1.1.1-1: - Northland Basin Permits

Permit	Area (km²) Term	Parties	Work Programme
PEP 38618	**4,867** 5 years from 1/05/06	Origin Energy Resources NZ Ltd (50%; operator) OMV New Zealand Ltd (50%)	**2005 Northland Blocks Offer** Within 12 months acquire 1,224 km of 2D seismic; within 24 months reprocess 2,100 km; Within 33 months, commit to spudding exploration well within 45 months or drop the acreage
PEP 38619	**6,706** 5 years from 1/05/06	Origin Energy Resources NZ Ltd (50%; operator) OMV New Zealand Ltd (50%)	**2005 Northland Blocks Offer** Within 12 months acquire 1,990 km of 2D seismic; within 24 months reprocess 2,300 km of 2D and acquire 430 km² of 3D seismic; Within 33 months, commit to spudding exploration well within 45 months or drop the acreage
PEP 38602	**244.00** Appraisal extension to 30/6/2009	Todd Petroleum Mining Company Ltd (100%)	**PEP Appraisal Extension** *Appraisal of Karewa-1 gas discovery* Permit extensions have been granted annually since 2003

The PEP 38602 permit was originally awarded to a Conoco subsidiary in April 1993. The original permit was huge: over 113,899 km², extending from Kawhia Harbour in the south to north of Cap Reinga in the north and offshore. The original permit application anticipated an exploration well would be drilled before April 1998. In January 1995 four more companies, including Todd Petroleum Mining (8.90%) and the Minister of Energy (11.00%), farmed in to the permit.

A partial relinquishment (of the south-western part of the permit area) was made in 1997 and two of the five co-venturers exited. The work programme was amended to delay the drilling requirement until end-March 2001. A further partial relinquishment (of the northern half of the permit) was made later in 1997, reducing its acreage to 48,864 km². At this time the Conoco joint venture (with Inpex and Todd) was granted a second 5-year term.

The Waka Nui-1 exploration well was spudded on 30 April 1999 and completed on 25 June 1999. It was drilled with Conoco's new drillship (see next section). Subsequently, the shallow Karewa-1 exploration well was spudded on 26 December 2002 and completed on 2 January 2003 (see next section).

On 30 March 2003 the joint venture relinquished the majority of the remaining permit area, retaining only the present permit area around the Karewa-1 discovery well. Within a month both Conoco and Inpex had assigned their interests to Todd, which became Operator and sole owner of the permit.

Since Todd took over sole ownership of the block, the permit has been extended by CMG, most recently until June 2009.

In 2005 the remaining offshore Northland acreage was offered in the first Blocks Offer in the area. This offer was the first 'deepwater' permit area to be offered, following the failure of the 2003 Deepwater Taranaki offer to attract any bids. The offshore Northland blocks were offered with a requirement for a commitment to an exploration well within 3 years (*i.e.,* in mid-2009).Origin Energy and OMV were awarded PEPs 38618 and 38619 in early 2006 as a result of the Blocks Offer. In fact the granted permits have work programmes with early 2D and, in PEP 38619 only, 3D seismic acquisition and reprocessing commitments, leading to a 'drill or drop' option to be exercised by end-March 2009. If the drill option is exercised, the Operator will have to spud an exploration well by end-March 2010.

1.1.2 EXPLORATION SEISMIC DATA

A number of speculative seismic surveys were carried out from 1969 to the mid-1990s, when Conoco acquired the PEP 38602 permit. Conoco shot 7,500 km of 2D seismic data in 1995 and further data in 1998. Spectrum reprocessed 9,100 km of 2D data, which was available in the 2003Offshore Taranaki Blocks Offer. Very little seismic data has been acquired in the western part of the offshore Northland basin (water depth >1,500 m) and the boundary with the deepwater Taranaki Basin is thus unclear.

Origin Energy has acquired three seismic surveys since 2006:

- Two 2D surveys in 2007: Pantheon and Akira (3,164 km of 2D data)
- One 3D survey in 2007: Nimitz (432 km^2)

Origin Energy also reprocessed 4,642 km of 2D data in 2006. The Nimitz survey was carried out over a Pliocene structural lead due north of the Karewa-1 discovery.

1.1.3 EXPLORATION DRILLING

The offshore Northland Basin is grossly under-explored with only one well drilled in its history. (Note: Karewa-1 is located in the northern part of the Taranaki Basin)

Table 1.1.3-1 – Northland Basin Exploration Drilling

Well	Year	Depth (m)	WD (m)	Comments
Wakanui-1	1999	3,681	1,455	Dry hole; no shows or tests
Karewa-1	2002			Dry hole; no shows or tests

1.1.3.1 Wakanui-1 Exploration Well Results

Wakanui-1 was New Zealand's first deepwater exploratory well, drilled in 1,455 m of water about 100 km west of Kaipara Harbour. The well was drilled with one of Conoco's first drillships and is reputed to have cost in excess of US$ 100 million. The well was sited on the eastern edge of the Northland Ridge, a regional high between the western depocentres and the main Northland Graben, approximately 150 km northwest of Auckland and in 1,470 m of water. The well was drilled to 3,681 m (KB).

The well was targeted at a large tilted Cretaceous fault block, thought to contain both Middle Cretaceous syn-rift sediments and post-rift transgressive sandstones (Uruski and Stagpoole, 2004). Neither was penetrated in the well: the fault block contained Jurassic coal measures with onlapping Paleocene transgressive sands above. A moderate-quality Paleocene sandstone flowed fresh water but there were no significant hydrocarbons.

The presence of a Middle Jurassic coal measure succession was unexpected and leads to the conclusion that, whilst the Wakanui structure was dry, the prospectivity of the basin may be higher than originally anticipated (Uruski ***et al.,*** 2004). Thermal modelling showed that Jurassic, Cretaceous and Paleocene source rocks are mature.

1.1.3.2 Karewa-1 Exploration Well Results

The Karewa-1 well was located approximately 40 km off Raglan and is drilled in the northern part of the North Taranaki Graben, which extends up towards the Auckland region. This graben contains about 2,000 m of Cretaceous-Paleogene rocks and 5,000 m of Neogene strata. The well was targeted at early Pliocene Mangaa Sandstones, which demonstrated a bright spot anomaly.

At the time Todd Petroleum Mining indicated that the reserves in the field (and satellite structures were between 60 and 150 BCF, reservoired in both Mangaa and Pliocene sands at about 2,000 m. However, it appears the gas in this well is predominantly biogenic in nature.

Todd made very positive statements about the Karewa Field in 2004 but there has been little overt activity since then. Forecasts of up to 50 PJ of gas being available to the market by 2012 from Karewa are unlikely to be met, since further appraisal (and satellite structure) drilling has yet to take place.

Todd Energy subsequently acquired two further 100% permits, PEPs 38486 and 38487 and an interest in an OMV-operated permit, PEP 38485.

1.1.4 PETROLEUM SYSTEM

The first indications of a working petroleum system came from onshore, at Waimamuku-2 on the south side of the Hokianga Harbour. The Waimamuku-2 well was drilled by Petrocorp in 1971 and tested non-commercial gas before being plugged and abandoned. No further wells have been drilled onshore.

1.1.4.1 Source Rocks

There are three principal source rock intervals:

1. **Middle Jurassic coal measures** (Murihiku Group)

   These coal measures were unexpectedly penetrated in Wakanui-1 and provide an additional deeply buried source interval.

2. **Cretaceous-Eocene coal measures and marine mudstones**

   These include Taniwha Formation and Rakopi Formation coal measures, the latter being a source rock in the Maui Field.

3. **Paleocene Waipawa Black Shales**

This widely distributed and prolific source rock also occurs in the Taranaki and East Coast Basins. Oil recovered from Kora-1 in the northern part of the Taranaki Basin are typed to this source rock.

1.1.4.2 Hydrocarbon Generation and Migration

The offshore basin has unusually high heat flow, possibly resulting from Early Miocene volcanism. Thermal modelling indicates that, in the deeper parts of the basin, oil expulsion began as early as the Late Jurassic (>144 MaBP). Younger Miocene sediments are now thermally mature for oil generation, whilst the older formations have gone through the oil window and are thermally mature for gas generation. Basin modelling by IGNS has indicated that migrating oil is likely to be trapped at the top Cretaceous level.

1.1.4.3 Reservoir Rocks

Potential hydrocarbon reservoir rocks are found at most levels in the Northland basin.

- Cretaceous syn-rift sandstones and post-rift transgressive sandstones
- Paleocene sandstones
- Pliocene Mangaa Sandstones (massive-bedded turbidites)

1.1.4.4 Seal Rocks

Intraformational shales and coals seal Cretaceous coal measure sandstones. There is a widespread blanket of Paleocene-Eocene mudstones, Oligocene limestones and Miocene shales. Plio-Pleistocene shales will seal shallow Pliocene turbidites, although there may be a problem of the timing of closure of these seals.

1.1.4.5 Traps

The most common traps are likely to be basement fault blocks as well as post-rift pinch-out and drape structures overlying these fault blocks. Channel sandstones are likely in the Pliocene turbiditic sandstones.

1.1.4.6 Critical Moment

This is difficult to assess as hydrocarbon migration has clearly been occurring from the Late Jurassic to the present.

1.1.5 PLAY TYPES

Two principal petroleum types have been identified in the offshore part of the Northland Basin:

1. **Basement High-related Traps**

There are a number of potential structural traps established by the draping of post-Cretaceous sediments on the Jurassic basement faulted blocks.

2. **Pliocene Turbidite Sandstones**

These turbidite sandstones can form sheet, fan or channel bodies at the foot of the prograding Pliocene sediment wedges. They may also be draped over submarine volcanic features, which have been known to trap oil, for example, in the Kora Structure, southwest of the offshore basin (Uruski et al., 2004).

1.1.5.1 Basement High-related Traps

The basement high play relies on the draping of Late Cretaceous sedimentary rocks over Jurassic - older basement highs.

Table 1.1.5.1-1 Basement High-related Play Concept Characteristics

Component	Description	Issues
Source	Cretaceous coal measures Paleocene Waipawa black shales	Source rocks in deeper parts of basin are over-mature and may be generating gas
Migration	Post-rift shales provide a regional top seal	
Reservoir	Cretaceous coal measure sandstones; Paleocene sandstones	Porosity up to 20% in Wakanui-1
Trap	Range of fault-block related structures, including faulted anticlines, drape, pinch-out and unconformity traps	Some very large structural closures have been mapped
Seal	Regional Paleocene-Eocene shales and mudstones	
Timing	Migration began in Late Jurassic	
Risks	1. No working examples of this play concept has been successfully demonstrated	

The only drilled example of this play concept is the Wakanui-1 well. However, there are a large number of similar structures of significant size, which remain to be investigated.

1.1.5.2 Pliocene Turbidite Sandstones

In the southern part of the basin, *i.e.,* the extension of the Taranaki Basin, there are a number of potential Miocene turbiditic channel and sheet sandstones (Table 2.36).

A large number of potential turbidite sheet, fan and channel sandstones have been identified in the northern part of the Taranaki Basin, where Todd Energy is currently investigating the Karewa discovery.

Karewa: Todd Energy announced that Karewa-1, 40 km west of Raglan, was a gas discovery in March 2004. P_{50} reserves are thought to be between 60 and 130 PJ in the Pliocene Mangaa Sandstones. Todd will need to investigate additional prospects in adjacent permits to accumulate sufficient reserves (300 PJ) to justify an offshore development.

Origin Energy have identified and published a number of very large prospects:

D1: A 440 km^2 regional closure

D2: A 150 km^2 regional closure

These structures are so large, however, that it is questionable whether either could be filled, since there are questions about the available source rock volumes to fill such large structures. They are also located in deep water (700 – 1,000+ m). Origin's mapping has also identified three further prospects in PEP38619, in shallower water and at limited depths:

Korimako: A tilted fault-block at both Top Miocene and Top Ngatoro Group levels with. The Korimako structure has a 13 km² area at a closing contour of around 3,650 m subsea and a vertical relief of 510 m. This is overlain by a smaller Miocene closure of 3 km² at a closing contour of 1,680 m subsea and 190 m of vertical relief.

Korimako S: A Miocene amplitude / AVO anomaly

Kokako: This is a horsted fault-block at Top Miocene level, which also has closure at Base Ngatoro Group level. At the Miocene level the closure is 7.5 km² at 1,670 m subsea with a vertical relief of 200 m, whilst at the deeper level, the closure is 36 km² at 3,620 m subsea with a potential column height of 410 m.

Tarapunga: A potential Pliocene submarine fan system located above the Korimako and Kokako prospects and identified on the basis of seismic amplitude anomalies. This fan system may have entrapped Pliocene biogenic gas.

Table 1.1.5.2-1 Pliocene Turbidite Play Concept Characteristics

Component	Description	Issues
Source	Cretaceous coal measures Paleocene Waipawa black shales	Paleocene Waipawa Shales are generative but thin
Migration	Onset of thermal maturity was very early and some deeper parts of basin may no longer expelling	Oil, rather than gas, is likely Migration from pre-Paleocene source rocks may be difficult
Reservoir	Pliocene turbidite sandstones, e.g., Mangaa Sandstones	Excellent reservoir properties Porosity 20 – 30% Permeability 1,000 mD
Trap	Range of fault-block related structures, including faulted anticlines, drape, pinch-out and unconformity traps	These structures are inadequately mapped at present
Seal	Regional Plio-Pleistocene basin fill mudstones	
Timing	Dependent on the compaction of young shales becoming sufficient to establish adequate seals	Some evidence that shales have not been sufficiently buried to act as seals
Risks	1. Short hydrocarbon columns	The poor quality of juvenile seals may prevent long columns

1.1.6 PROSPECTS FOR FUTURE EXPLORATION SUCCESS

The offshore Northland Basin is one of the most prospective basins in New Zealand coastal waters, lying just north of the productive Taranaki Basin. The greatest prospectivity probably lies in the southern coastal part of the basin, which is geologically contiguous with the Taranaki Basin and where water depths are less than 1,000 m. Beyond the buried Northland Ridge (Figure 4.2-1), water depth, distance from shore and unfamiliar geology are likely to defer, if not deter, future exploration, particularly after the failure of the Wakanui-1 well. This is the area that is likely to be gazetted shortly.

Further exploratory wells will be drilled in the two newer permits but probably not before June 2009. Water depth over much of the Northland Basin may force exploration companies, in absence of any deep water drilling capability or success, to limit their drilling activities to near-coastal locations, where water depths are more acceptable.

Table 4.2.6-1 SWOT Analysis of Offshore Northland Basin

Strengths	Weaknesses
• Similar to Taranaki and South Australia • Established petroleum system (*cf.* Karewa-1) • Multiple very large potential prospects (IGNS report up to 20 prospects some with areas over 100 km², *cf.* Maui) • Relative closeness to Auckland market	• Limited shallow water acreage • Deep water acreage likely to remain economically unattractive • Absence of infrastructure • Volcanics
Opportunities	**Threats**
• Grossly under-explored but prospective basin • Blocks Offer may lead to some new exploration wells in next 5 years	• Length of time to develop infrastructure and market • Likely requirement for "*cornerstone*" gas buyer • Lack of a current gas market