

Reservoir plays of the East Coast region

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Abstract

More than 300 gas and oil seeps show that hydrocarbons are generated, expelled and migrate in the East Coast region. There are numerous large trapping structures, but no commercial production. There is a perception that the sandstone units present have poor reservoir characteristics. As a result, little of the region has been adequately explored.

The East Coast region consists of a number of sub-basins whose geometry and fill have varied through time in response to local uplift and subsidence. Many basins were quite ephemeral. The presence, or absence, of good reservoir units is therefore difficult to predict without knowledge of local conditions through time.

In the Neogene, thick shelf sands with excellent reservoir properties are known from outcrop, but are unlikely to be common in the present offshore region. This is because the shelf through the Miocene was generally inboard of the present-day coastline. The most common types of Neogene reservoirs were deposited on the slope as channel and overbank sands and across basin floors as turbidite sheet sands. The best known of these are the Whakataki and Tunanui formations. The Paleogene has been described as a transgressive passive margin succession and it is thought to have less potential for clastic reservoirs than the Neogene. The Paleogene consists of generally fine grained rocks and, as its depth of burial is greater than the Neogene, labile lithic grains and glauconite are likely to have compacted, severely reducing the porosity and permeability of Paleogene sandstones. There is, however, potential for fractured shale gas plays.

Additional reservoir potential is available from fracture porosity which should be very common as the East Coast Basin has been deformed over the last 24 million years. Clastic reservoirs could have flow properties enhanced by fractures. In northern Hawke's Bay and Raukumara, a regional northeast-southwest fracture set strikes almost parallel to the present principal horizontal shortening (PHS) direction. The Tunanui Formation exhibits an open set of northeast-southwest fractures both in outcrop and on FMI logs from exploration wells and is a useful analogue for hybrid clastic and fracture reservoir potential. To the south of Hawke's Bay, the PHS direction changes and the northeast-trending fracture set is likely to be closed. However, there is a second set in this region, which strikes northwest-southeast and this set is more likely to be open.

Rising thrust anticline highs and subsiding basin floors were likely to have deflected and focussed turbidite flows along the axes of synclines. Thicker sands may be expected along the flanks of active anticlines than across their crests and stratigraphic traps are likely to assume a greater importance in future exploration. Predicting the presence of reservoirs therefore requires knowledge of the interplay between structural evolution, depositional systems and paleogeography which, in the offshore region, means good quality seismic control.

Keywords: *East Coast, reservoir, basin, seismic, fracture, stress*

Introduction

The recently released compilation of reservoir data for the northern and central parts of the East Coast region (released by Crown Minerals on DVD) provides many outcrop analogue, petrographic, stratigraphic, well log motif, image log depiction and seismic facies data and images, as well as porosity-permeability digital data tables and MICP results. Part of this compilation is available on line (Field et al., 2005). More detailed information on reservoir potential can be obtained from the DVD and links at <http://www.crownminerals.govt.nz/petroleum/blocks/eastcoast.html>. The 2005 Crown Minerals seismic survey (Fig. 1), undertaken to promote exploration in the region, is already providing many new leads (Uruski et al., in press).

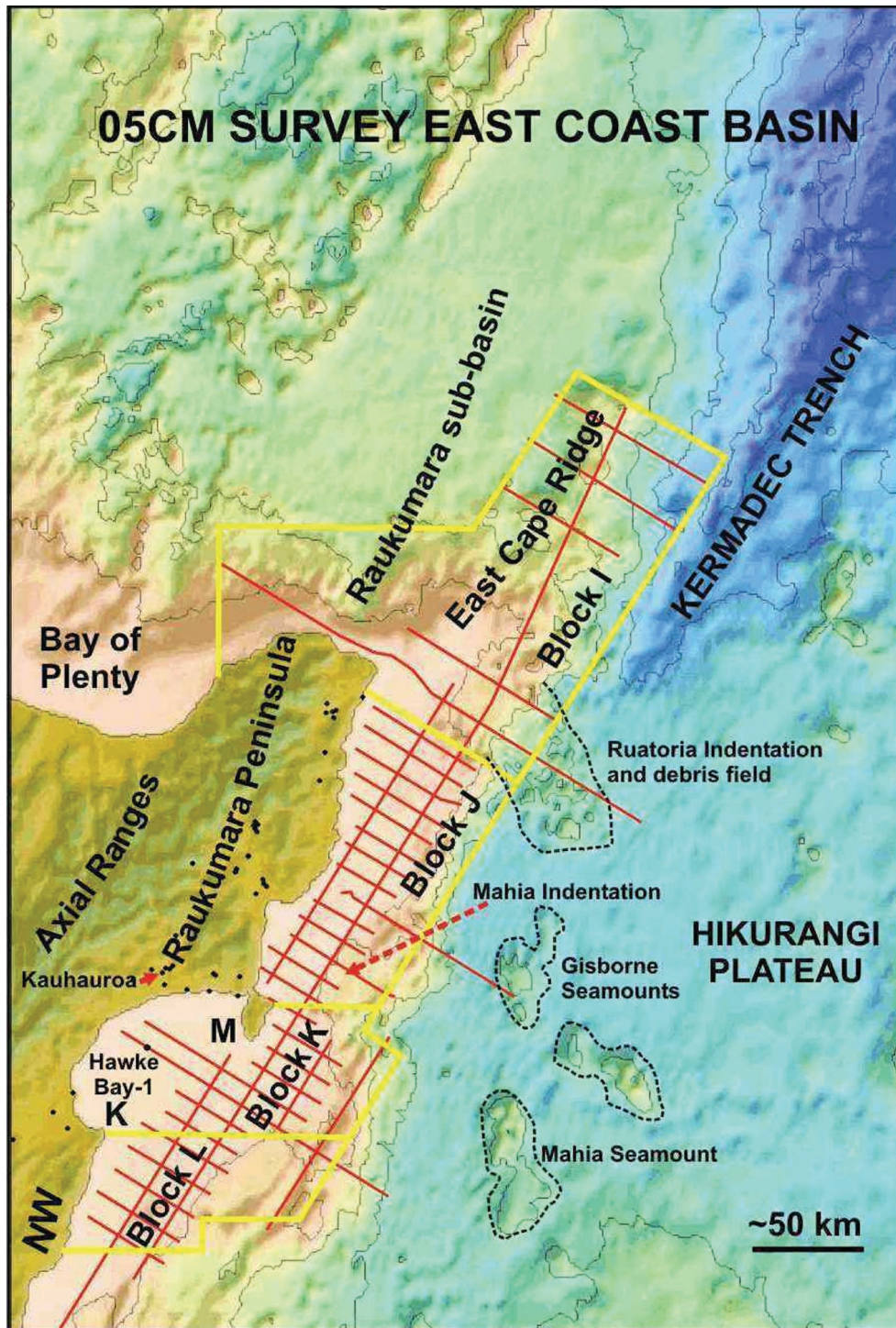


Fig. 1. Locality map for the 05cm seismic survey. For an interactive view of all seismic lines and wells of the region, see <http://maps.gns.cri.nz/website/PDQmap/>.

Clastic reservoirs – the potential is there

A common perception of East Coast clastic reservoirs is that they have low porosities and low permeabilities and this is true for some units as exposed in outcrop (e.g., Tokomaru Formation) and, for a few, as drilled. However, there are shallow marine-shelfal units with good porosities and permeabilities in the onshore forearc region (e.g., basal Ngarata Formation) and upper bathyal sands with excellent qualities (e.g., McCartie Sandstone). These units indicate periods in the region's development when there were well sorted sands being deposited and correlatives of them might well be present further east in the subsurface offshore. Thick, deepwater sands of the Whakataki and Tunanui Formations have variable but commonly low permeabilities (generally tens of mD) in outcrop but are voluminous and have, at least locally, open natural fractures. The Whakataki Formation includes thin beds deposited in suprafan channel overbank settings (Field 2005, Pollock et al., 2005, Field et al., submitted-b & -c). Mud weight balancing and completion methods will be critical to reservoir assessment, which may also be complicated in some areas by overpressuring.

Regional uplift events in the Early Miocene (Altonian), Middle Miocene (Waiauian) and Early Pliocene (Opoitian) are each associated with shallow marine limestones and sandstones in the inner forearc and have probably given rise to deep water, sand-rich units further east.

Fractures may hold the key

The Kauhauroa Limestone, near Wairoa, is a fractured Early Miocene limestone gas reservoir discovered by Westech. The recognition of this type of play on the East Coast raises several questions:

1. Do more such plays exist, given that the limestone is known to occur patchily from at least Tinui in the south to Tolaga Bay in the north?
2. Could other brittle lithologies provide fracture plays?
3. Are many “clastic reservoirs” really hybrid, clastic-fracture systems, given that open fractures are observable in outcrop and image logs? i.e., could units with lower clastic permeability have greater flow potential than expected?
4. Would strongly deviated wells be better for assessing fractured reservoir potential? How difficult would they be to drill (considering overpressures) and would deviated wildcat wells be regarded as too expensive and high-risk?

There appear to be two main, regional fracture sets on the East Coast margin (striking NNE and SSE) and strain analysis from earthquake first motion studies, GPS and well breakouts indicates there are two main stress fields: north of Hawke Bay, principal horizontal stress trends NNE-NE and south of Hawke Bay it trends SE (Field et al., 2004). This regional data can be used to help predict fracture potential and optimum deviation directions prior to drilling. Fracture scaling, based on outcrop analogues and using image log data, so far in its infancy on the East Coast, will allow better prediction of fracture apertures and spacings in the subsurface (Field et al., submitted-a).

Fractured shale gas plays may be present in the Whangai Formation, and a comparison with some North American examples was tabulated by Field et al (2004). Small remnants of core from Morere-1 show fractures millimetres wide are present in the subsurface, though they were sealed in that well. There are no open-file image logs for the Whangai Formation.

Basins come and go

The East Coast region is sometimes referred to as the East Coast Basin but in the Neogene it was really a series of small basins, commonly a few tens of kilometres long and 5-20 kilometres wide, elongated SW-NE, with restricted life-spans, set within a broader tectonic framework comprising inner and outer forearc elements (Field & Uruski et al., 1997). Definition of basins in the Cretaceous and Paleogene

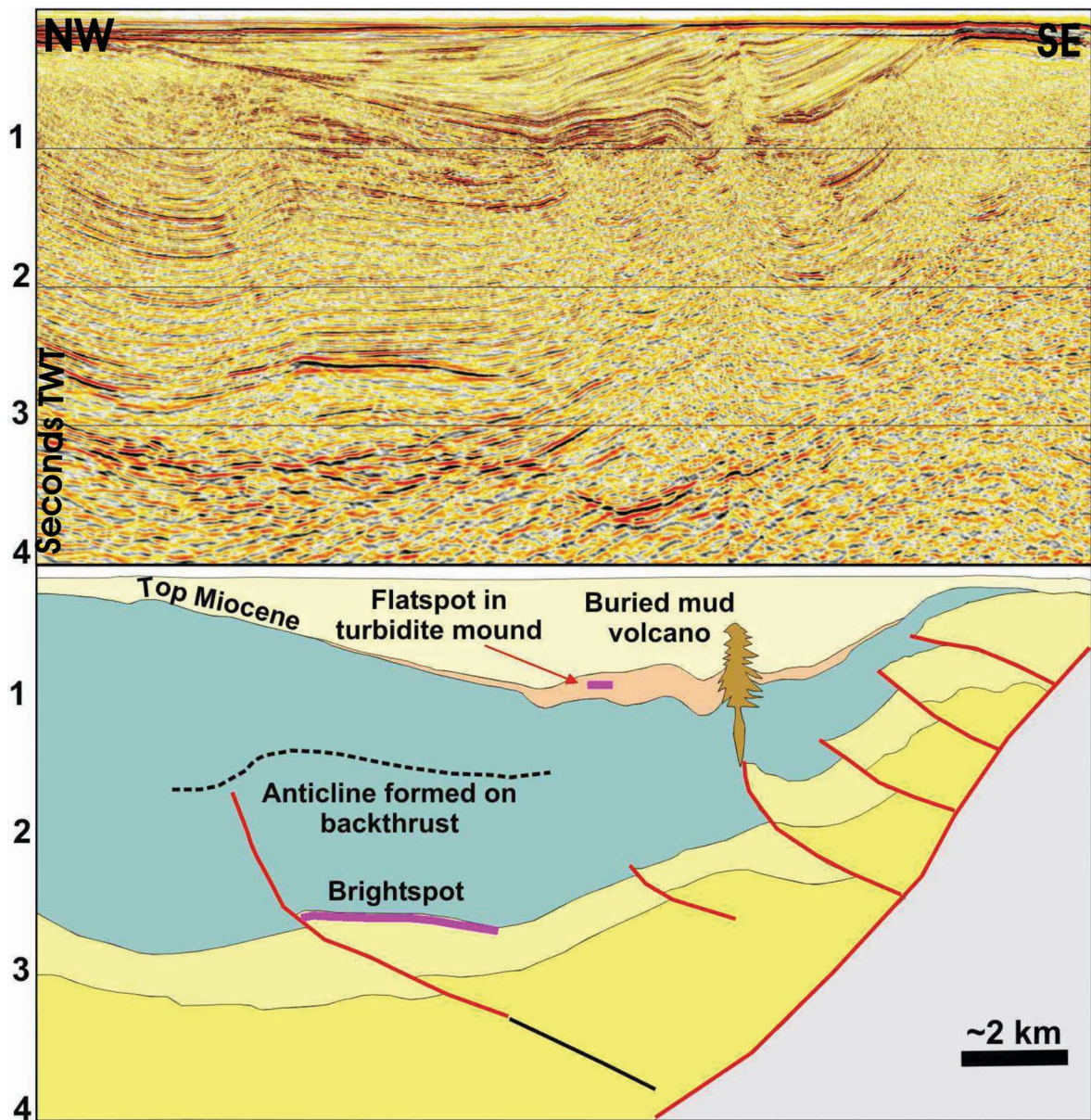


Fig. 2. Part of line 05cm-45 from the Gisborne shelf. See text for discussion.

is less clear, though the region can be subdivided into a series of fault-bounded blocks (Moore 1988) with differing stratigraphies. Consequences of the mobility of the Neogene include:

1. Modelling of generation and expulsion needs to be on a local scale, as geohistory curves can vary significantly over tens of kilometres;
2. Sediment onlapping highs provide a higher chance of stratigraphic traps developing;
3. Outboard highs probably led to mass flow ponding and hence more sand-rich facies;
4. Potentially reduced preservation, though main generation is recent: Pliocene-to-now.

An example of the dynamic nature of the basin is provided in Fig. 2, which shows part of line 05cm-45 from the Gisborne shelf. Three main sequences are imaged; a shallow mini-basin to about 1 second twt, an intermediate, moderately deformed unit to nearly 3 seconds two-way time (twt) and a deeper, highly deformed unit to more than 4 seconds twt. The southeast part of the section lies close to the shelf edge and is formed by a complex rising thrust anticline. The shallow unit has been deformed by continuing movement on the thrust anticline and has been pierced by a diapiric structure. The diapir fed a small mud volcano that was progressively buried by later deposition. The basal seismic package

to the youngest succession is a mounded high-amplitude package likely to represent a turbidite fan. A flatspot is observed in part of the mound, which may have been over steepened by shale withdrawn to feed the mud volcano. The thick intermediate succession has been gently folded by backthrusts antithetic to the thrust ridge complex and a high-amplitude reflector suggests that hydrocarbons may have seeped upwards along the back-thrust until they entered a reservoir bed.

Seismic coverage

Seismic coverage in the offshore East Coast is patchy. Some areas, such as Hawke Bay and the Wairarapa shelf are well covered by seismic data, while other regions are very poorly covered. Until there is good coverage across the region, the true potential of the East Coast will remain unknown.

For example, one region that needs better coverage is the Raukumara sub-basin to the north of the Raukumara Peninsula. The presence of a sedimentary basin there has been known for many years and the basin was described from single channel seismic data in 1986 (Gillies and Davey, 1986). Ten years later a deep crustal seismic line was acquired across the sub-basin showing that up to 13 km of sediments fill this depression (Davey et al, 1999). Recently, one line from the Crown Minerals' 2005 survey crossed part of the basin showing that it appears to have originated as a Cretaceous rift basin (Nicol and Uruski, 2005). This line was the first to be of high enough resolution to allow facies analysis, suggesting the presence of a variety of reservoir rocks in the Raukumara sub-basin. A more complete coverage would test the extent of thick sedimentary accumulations, it would help elucidate the tectonic and structural history of the region and would allow prediction of the presence of reservoir facies.

Conclusions

Successful exploration will not only depend on the availability of good quality seismic data but also on:

1. facies, sequence stratigraphic interpretations and modelling that take account of the dynamics of basin formation;
2. recognition that some elements of the petroleum system may vary significantly on a scale of tens of kilometres;
3. more and deeper well data: most clastic reservoirs in the eastern part of the region might be fine grained and contain labile clasts, but there are too few wells to test this; there were periods further in-board when relatively clean sands were abundant, so there might have been pulses of good quality sands passing further east;
4. consideration of fractures: fractures are virtually ubiquitous and are might enhance flow rates in some clastic units;
5. good control of the stability of deviated wells: drilling vertical wildcat wells is not likely to reliably test reservoirs with significant fracture permeability. Wells north of Hawke Bay deviated to the WNW (or, south of Hawke Bay, deviated to the ESE) might intersect greater numbers of open fractures.
6. recognition of the wide range of clastic reservoir play types, from high porosity shelf sands in the west (inner forearc), thick ponded turbidites and overbank thin beds, the presence of clastic, hybrid and fracture reservoir potential, the abundance of structural closures and the likelihood of stratigraphic traps due to dynamic contemporaneous basin evolution.

The East Coast region holds a lot of promise but more seismic data and more wells, particularly deeper or deviated wells, are needed to fully assess its reservoir potential.

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