New insights into the condensed nature and stratigraphic significance of the Late Neogene Ariki Formation, Taranaki Basin

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Abstract

The Ariki Formation is a distinctive Late Miocene – Early Pliocene marl facies rich in planktic foraminifera, reaching thicknesses in the range 70 - 109 m in most exploration holes drilled into the Western Platform northwest of Taranaki Peninsula. In Awatea-1 and Mangaa-1 in the Northern Graben, however, there are two marl units separated by the Mangaa "B" Sands. The lower unit has the same upper Tongaporutuan and Kapitean age as the lower part of the marl on the Western Platform, and the upper marl has an Upper Opoitian - Waipipian age, similar to the upper part of the Ariki Formation on the platform. In other holes located on the margins of the graben there can be one thin marly horizon, which usually correlates with the upper marl unit in Awatea-1 and Mangaa-1.

The presence of two marly units in the Northern Graben, which are probably amalgamated on the western Platform, suggests two periods of late Neogene condensed sedimentation in northern Taranaki Basin arising from siliciclastic sediment starvation, separated by a period of submarine fan accumulation (Mangaa 'B' sands) following subsidence of the Northern Graben. We attribute the initial interval of marl accumulation mainly to a marked landward shift in the position of coastal onlap in central and southern Taranaki and in the region east of the Taranaki Fault Zone (southern King Country and northern Wanganui regions), which effectively shut-off the supply of siliciclastic sediment to northern Taranaki Basin, thereby enabling marl to accumulate. The start of accumulation of the upper part of the Ariki Formation and its marly correlatives in and around the Northern Graben, is attributed to a younger (upper Opoitian) landward shift in the position of coastal onlap, this time involving the formation of the Wanganui Basin depocentre and Toru Trough, which trapped the contemporary siliciclastic sediment being supplied from the south. A lower Opoitian phase of progradation between these two phases of retrogradation led to accumulation of the lower part of the Mangaa Formation (Mangaa 'B' sands), which was limited in its extent to the Northern Graben because bounding normal faults had by then developed sea floor relief precluding mass-emplaced siliciclastic sediment from being deposited on the higher standing Western Platform. The accumulation of Ariki Formation marl in northern Taranaki Basin ended during the mid-Pliocene due to progradation of a thick continental margin wedge (Giant Foresets Formation) across the Northern Graben and Western Platform.

Key words:
Ariki Formation; Mangaa Formation; Giant Foresets Formation; Late Miocene; Early Pliocene; marl; Western Platform; Northern Graben; Taranaki Basin.

Introduction

The Ariki Formation is a distinctive and comparatively time-rich (Late Miocene – Early Pliocene) marl in Taranaki Basin intersected in wells drilled into northern parts of the Western Platform, where it is up to 109 m thick in Ariki-1 (King & Thrasher, 1996). Similar facies, also of Late Neogene age, have been identified in well sections in the Northern Graben and on its flanks (Hansen & Kamp, 2004, 2006). The distinctive lithology of the Ariki Formation contributes to it being a prominent seismic reflection horizon and it has been used to map the base of the Pliocene succession in northern parts of the basin (King & Thrasher, 1996).

The origin and significance of the Ariki Formation are unclear and somewhat of a conundrum. It occurs as marl within a thick, variably siliciclastic and volcaniclastic, Neogene terrigenous succession, regarded overall as a regressive (progradational) continental margin wedge starting with deposition of basin floor hemipelagic mudstone (Manganui Formation) and culminating with rapid Pliocene and early Pleistocene progradation of a shelf-slope system (Giant Foresets Formation). Throughout the Miocene and Pliocene the siliciclastic sediment supply to Taranaki Basin increased, reflecting the increasingly convergent tectonic character and

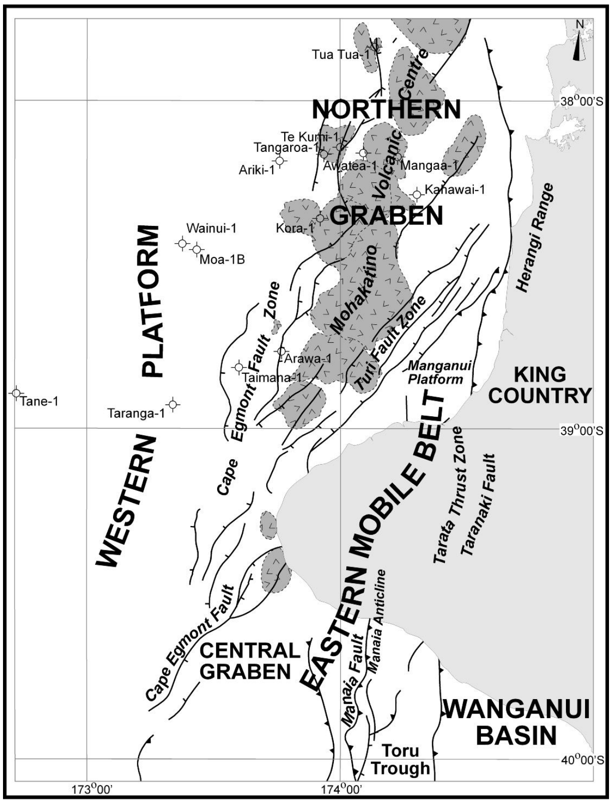


Fig. 1. *Structural and tectonic elements of Taranaki and Wanganui basins. Figure modified from King & Thrasher (1996), with Mohakatino Volcanic Centre after Thrasher et al. (2002).*

rates of exhumation within the evolving Australia-Pacific plate boundary zone sourcing the bulk of the sediment, and in this context it is surprising for there to be marl intercalated with thick siliciclastic facies. We describe here the characteristics, distribution and age of the Ariki Formation and discuss its origin in the wider context of Taranaki Basin.

Characteristics of the Ariki Formation

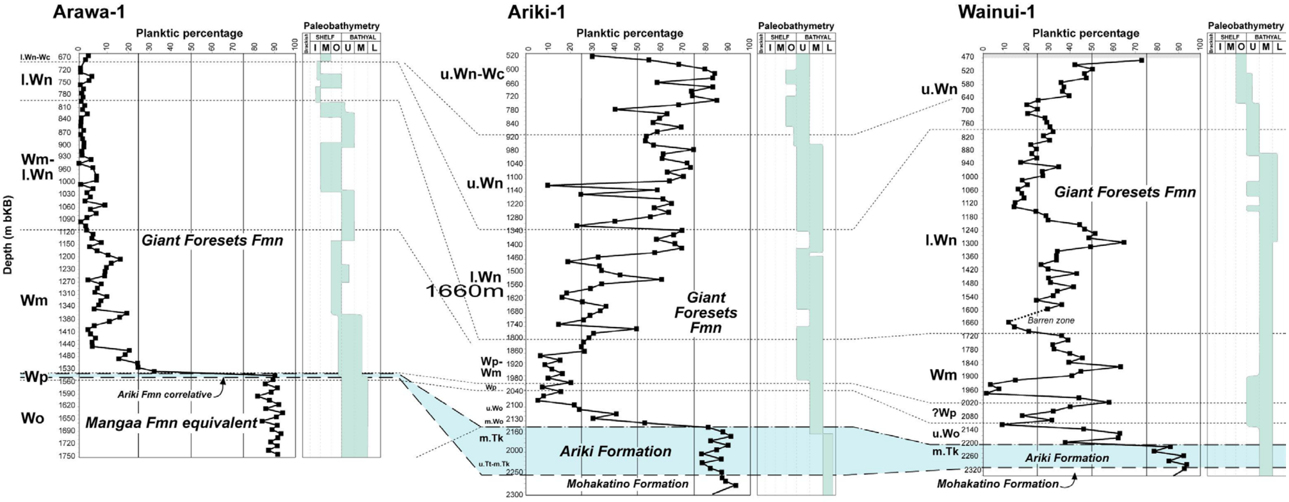
The Ariki Formation is encountered in exploration holes Ariki-1, Tangaroa-1, Wainui-1, Te Kumi-1, Tane-1, Taranga-1, and Moa-1B (Fig. 1). In well reports, this formation is described as a soft to firm, light grey-white to dark greenish grey, calcareous fine-grained mudstone, with thin intercalated sandstone units (Shell BP Todd Oil Services Ltd, 1976, 1981, 1982, 1984, 1992). At several sites (e.g. Tangaroa-1, Wainui-1) volcaniclastic material occurs in the basal part of the Ariki Formation. The formation is characterised by a high abundance of planktic foraminifera (up to, and greater than, 90 %; e.g. Hayward, 1985; Hansen, 2003) (Fig. 2), deposited under deep water (open ocean) conditions, and as a result of extremely low sedimentation rates. The top boundary of the Ariki Formation is emphasized in the foraminiferal record by a marked decrease in planktic foraminifer abundance, with percentages dropping to less than 50 % in the basal part of the Giant Foresets Formation (Fig. 2). This contact is often accentuated by a distinct change in the planktic faunal assemblage, including the abrupt disappearance of Miocene planktic foraminiferal components, and the appearance of restricted Pliocene and Pleistocene planktics within the Giant Foresets Formation (Hayward, 1985; Waghorn et al., 1996; Hansen, 2003). While there appears to be a significant water-mass change across the Ariki Formation-Giant Foresets Formation contact, there was no marked decrease in paleobathymetry (Fig. 2).

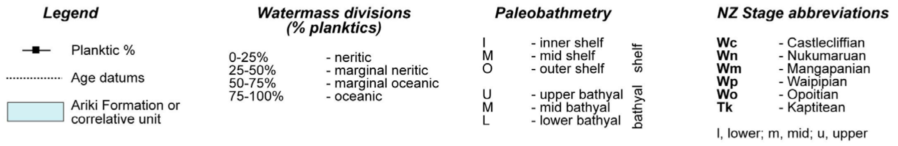
On geophysical wireline logs the Ariki Formation usually shows low radioactivity (GR) and muted SP response, which reflects the carbonate content and hemipelagic nature of this interval (e.g. Villamil et al., 1998) (Fig. 3). Higher density and sonic values for the Ariki Formation compared with enclosing formations, reflects its higher degree of compaction and carbonate cementation, while the resistivity log is variable. Tight log serrations reflect a degree of lithologic variability throughout the formation. Combined, these log signatures present as distinctive barrel-, bell- or blocky-shaped wireline motifs (Fig. 3) that clearly identify the Ariki Formation and distinguishes it from underlying and overlying formations. These motifs also indicate little connected porosity and limited permeability, consistent with low rates of terrigenous sedimentation.

On high quality seismic reflection lines, the condensed nature of the Ariki Formation translates to a pair of bold, parallel to sub-parallel, bright, high amplitude reflectors encompassing a thin reflection-free zone, which correlate well to the marked deflections observed in the wireline records. It is often used as a proxy for mapping the Base-Pliocene horizon in northern Taranaki Basin (Thrasher & Cahill, 1990). The Ariki Formation is thus a distinctive unit and seismic horizon across the Western Platform and beneath parts of the Northern Graben.

Correlative thin marly horizons

Thin correlatives of the Ariki Formation are encountered in several well sections both within the Northern Graben (Awatea-1, Mangaa-1 two thin units below and within the Mangaa Formation), on its eastern (Kahawai-1) and western flanks (Tua Tua-1), and to the south at Arawa-1 and Taimana-1 (Figs 4 & 5). The formation in these wells shows similar wireline character, although somewhat more





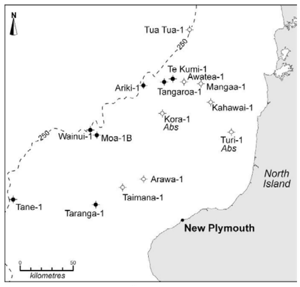


Fig. 2. Planktic percentage and inferred paleobathymetry for Arawa-1, Ariki-1 and Wainui-1 exploration holes in northern Taranaki Basin. The dramatic reduction in planktic percentage observed between the Ariki Formation (in Arawa-1, a correlative of the Ariki Formation) and the overlying Giant Foresets Formation is reflected in a change from oceanic to neritic water-mass conditions, but only a minor shift in paleobathymetry. Water-mass divisions from Hayward et al. (1999).

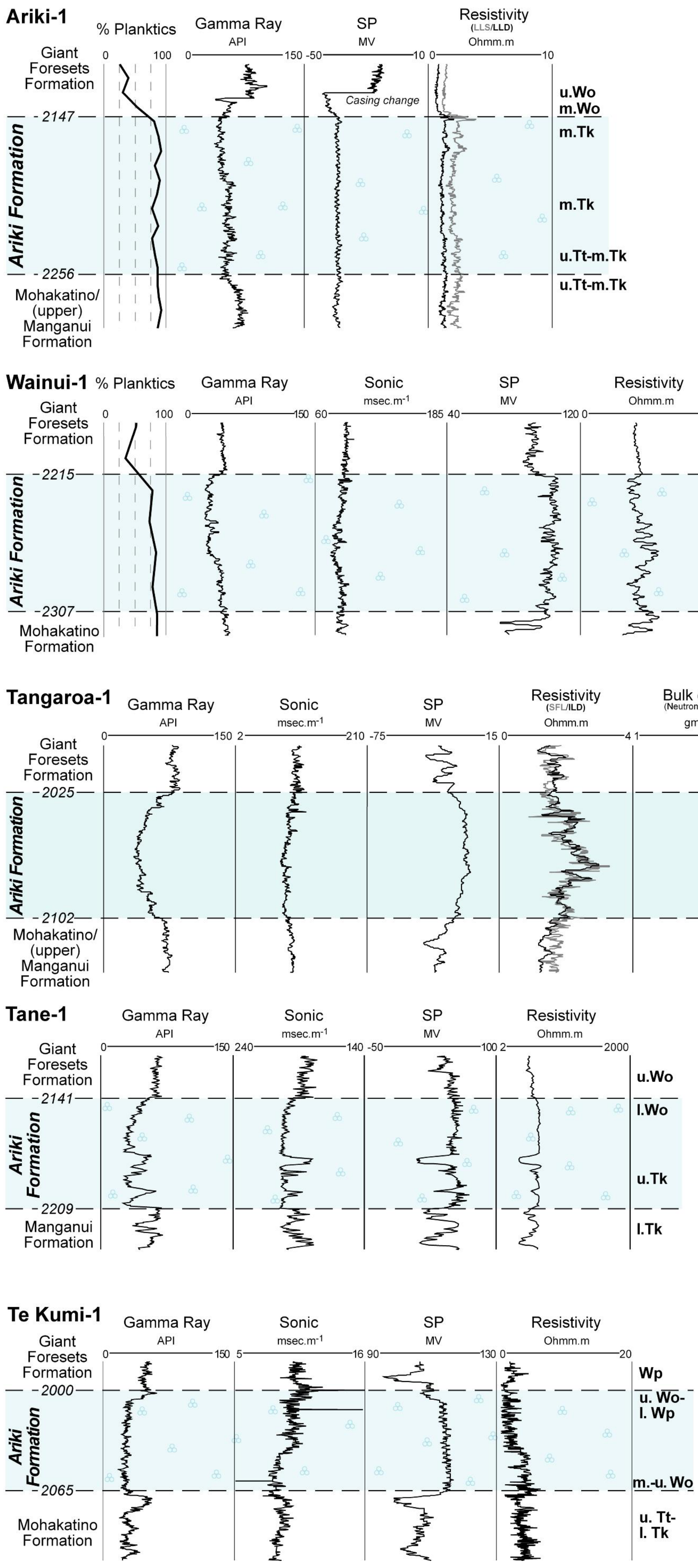
variable, than those described above. In Arawa-1 and Taimana-1 where detailed foraminiferal census work has been completed, planktic abundance decreases dramatically near the top of the marly interval (Hansen, 2003; Scott et al., 2004) (Arawa-1, Figs. 2 & 4). At both Arawa-1 and Taimana-1 the thin marl unit corresponds to a bold and continuous (single) reflector horizon that can be traced between Arawa-1 and Taimana-1, and from Taimana-1 towards Wainui-1. In Kahawai-1, a thin (< 10 m) upper Opoitian siltstone to marl has a high concentration of foraminiferal tests (NZ Oil & Gas Services Ltd, 1990), and lies unconformably above Tongaporutuan to ?Kapitean volcaniclastic sediment. The 42 m-thick interval intersected at Tua Tua-1 (Ariki Formation equivalent of King & Thrasher, 1996) (Fig. 4) is a calcareous claystone, with rare to common foraminifera; this marl formed on a Miocene volcanic massif emergent above the surrounding sea floor during the latest Miocene and earliest Pliocene (Rankin & Barbaresig, 1988).

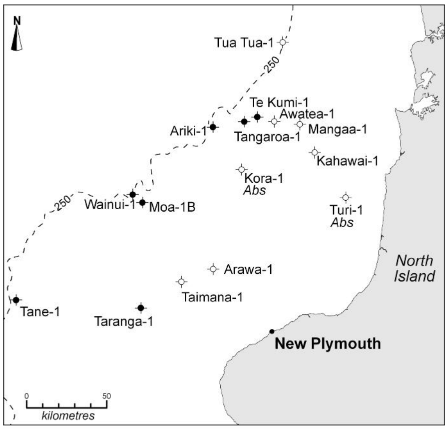
Two wells drilled within the Northern Graben (Awatea-1 and Mangaa-1) each intersect two marly horizons (Fig. 5). One horizon is Late Miocene in age (uppermost Tongaporutuan – lower Kapitean) and the other is mid-Opoitian in age (Strong et al., 1996; Waghorn et al., 1996; Hansen & Kamp, 2004, 2006) (Fig. 5). Although these two horizons cannot be directly correlated across the Northern Graben bounding faults to the Ariki Formation on the Western Platform, they can be correlated via sesimic lines between these two wells and across large parts of the graben itself; the upper unit pinches out against volcanic massifs to the north and south, while the lower unit seems to be truncated by the upper unit to the south (Hansen & Kamp, 2004). Wireline logs are highly variable for these two units, but lithologic descriptions report both of these units as being calcareous to highly calcareous mudstone and in places distinctly marly (Hematite Petroleum (NZ) Ltd, 1970; Murray & de Bock, 1996).

Distribution and age of the Ariki Formation and correlative marly horizons

The Ariki Formation is extensive across the northern part of the Western Platform, extending at least as far north as Te Kumi-1, and as far south as Taranga-1, south of which the formation is considered to grade laterally into contemporaneous mudstone and turbidite facies (King & Thrasher, 1996). The thickness of the formation varies from a maximum of 109 m (Ariki-1), to a minimum of 65 m (Te Kumi-1) and is generally thickest to the west and north (Fig. 6).

Figure 7 illustrates the distribution of biostratigraphically determined ages within the Ariki Formation for seven well sections across the Western Platform. A general difficulty experienced in de-





New Zealand Stage abbreviations

Nukumaruan ....Wn (2.28-1.6 Ma)
Mangapanian.......Wm (2.79-2.28 Ma)
Waipipian ....Wp (3.50-2.79 Ma)
Opoitian ....Wo (5.20-3.50 Ma)
Kapitean ....Tk (6.60-5.20 Ma)
Tongaporutua ......Tt (11.30-6.60 Ma)

Stage divisions
l, lower; m, mid; u, upper

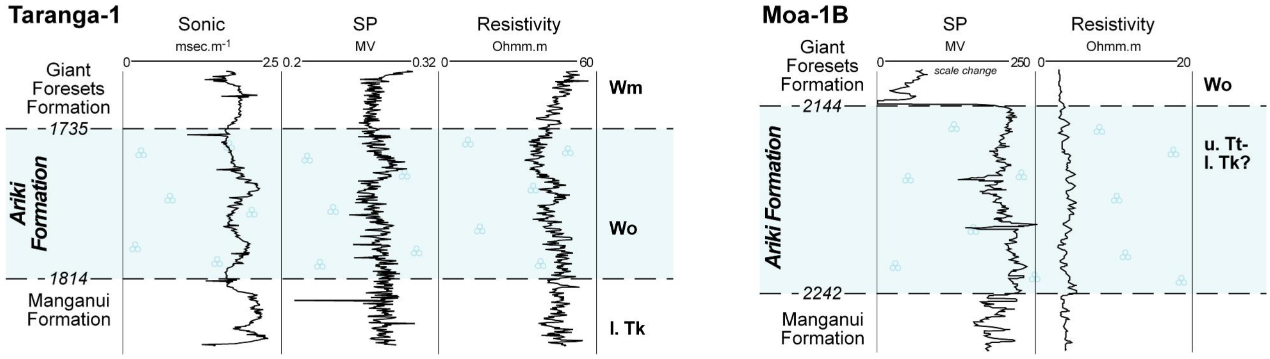


Fig. 3. Wireline records for the parts of Ariki-1, Wainui-1, Tangaroa-1, Tane-1, Te Kumi-1, Taranga-1 and Moa-1b intersecting the Ariki Formation on the Western Platform. Note the abbreviations for the New Zealand stages.

termining the biostratigraphy of the Ariki Formation arises from the partially dissolved and broken nature of the foraminifera it contains, particularly the planktic foraminifera upon which the stage designations are based. This difficulty is compounded by the wide separation of the exploration sample interval (typically 10 m) and the mixing of sediment inherent with cuttings samples. In the results, this is expressed in the inability to identify parts of stages in certain well sections (Fig. 7). Historically, this difficulty has led to the concept of a Miocene-Pliocene unconformity in and around the Ariki Formation. However, with the exceptions we describe below, we consider the missing parts of stages as merely reflecting the lack of occurrence, and problems in identification of, key taxa; the corresponding time is probably represented by condensed facies, and aside from possible local channel erosion we do not envisage widespread erosion of parts of the Ariki Formation across the Western Platform during the Late Miocene or Early Pliocene.

In many wells on the Western Platform (Moa-1, Wainui-1, Ariki-1 and Tangaroa-1) the Ariki Formation clearly started to accumulate during the upper Tongaporutuan (Fig. 7). This is probably also the case for the lower marl unit in Mangaa-1 within the Northern Graben (Hansen & Kamp, 2006), and probably also for Ariki Formation in Tua-Tua-1 (Fig. 4). The well sections containing marl closest to Taranaki Peninsula, which are amongst the thin Ariki Formation correlative units (Fig. 4), have ages markedly younger than upper Tongaporutuan (mid-Opoitian in Taimana-1; Waipipian in Arawa-1). In Tane-1 near the present-day shelf edge west of New Plymouth (Fig. 7) the age of the base of the Ariki Formation is about mid-Kapitean. In Taranga-1 to the east, the Ariki Formation may be older than Opoitian as sediments of lower Kapitean age have not been identified there. The age of the base of the Ariki Formation at Te Kumi-1 is determined to be Opoitian, which is younger than for neighbouring well sections. Te Kumi-1 lies west of a significant Northern Graben fault and some erosion could have accompanied footwall uplift during the uppermost Kapitean or lowermost Opoitian.

The age of the cessation of Ariki Formation accumulation is variable in Northern Taranaki Basin, mostly reflecting progradation of the Giant Foresets Formation across the region. Over the Western Platform the accumulation ended during the upper Opoitian (Ariki-1) or Waipipian (Tangaroa-1, Te Kumi-1, Taranga-1). The extended accumulation at Tangaroa-1 and Te Kumi-1 is related to the proximity of these wells to the western slightly up-tilted edge of the Northern Graben and hence a delay in deposition of bottom-sets of the Giant Foresets Formation (Hansen & Kamp, 2004).

In the Northern Graben the lower marly unit accumulated during the uppermost Tongaporutuan and lower Kapitean (Hansen & Kamp, 2006), with deposition of the lower part of the Mangaa Formation ("Mangaa B Sands") starting during the lower Opoitian (Hansen & Kamp, 2006) (Fig. 5). The intra-Opoitian upper marly unit in Awatea-1 and Mangaa-1 is a distinctly younger interval of accumulation of condensed sediment, which over the Western Platform is amalgamated into one long interval of condensed sedimentation, halted only by deposition of terrigenous bottom-sets of the Giant Foresets Formation. The age of the marly unit on the eastern edge of the Northern Graben intersected in Kahawai-1, as well as the thin Ariki Formation marly units in Arawa-1 and Taimana-1 lying in southern parts of the Northern Graben, indicate accumulation only during the younger interval (upper Opoitian-Waipipian) of marl deposition.

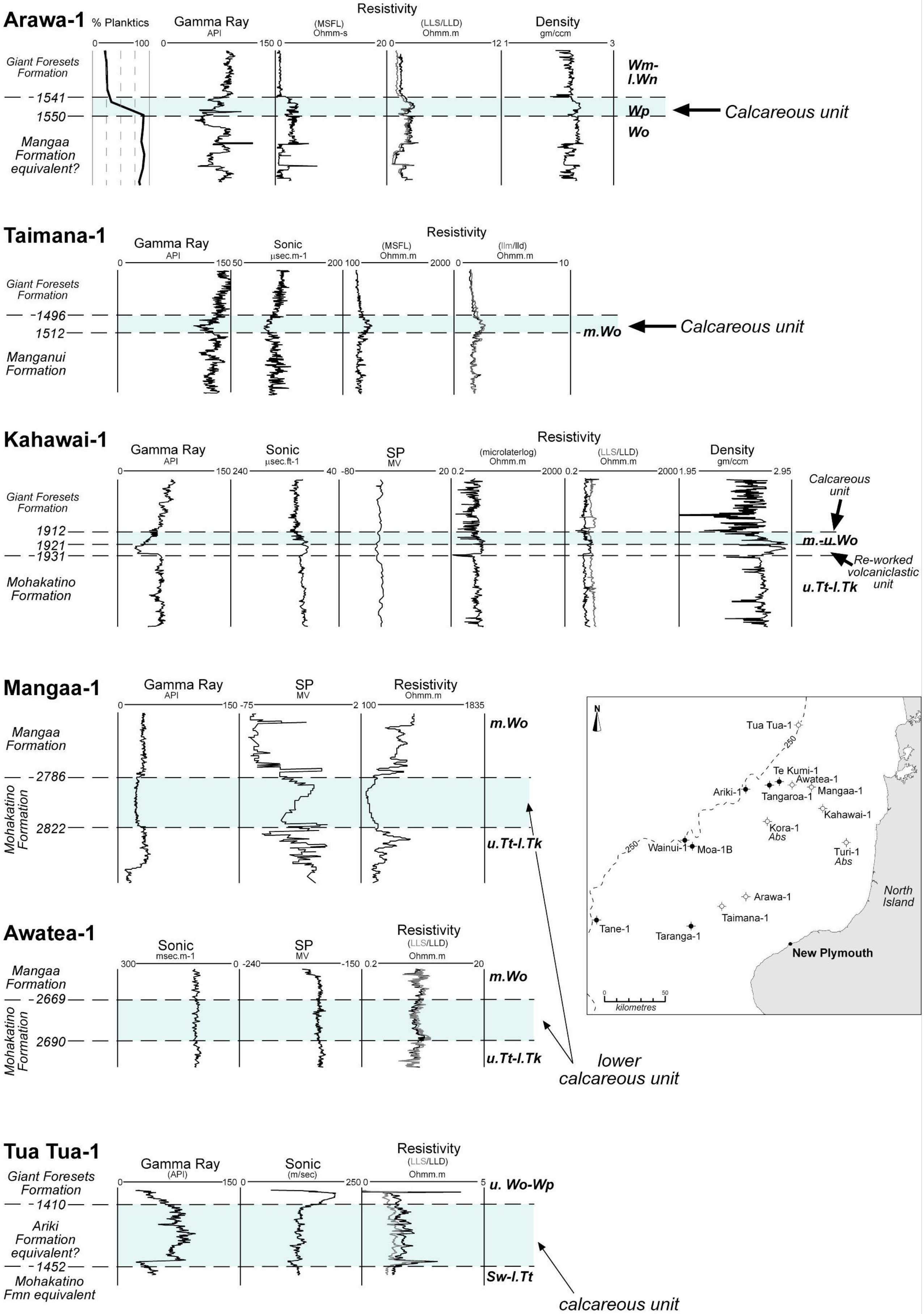


Fig. 4. *Wireline records for parts of six exploration holes identifying the stratigraphic extent of Ariki Formation correlative marly units. The holes (Awara-1, Taimana-1, Kawahi-1, Mangaa-1, Awatea-1 and Tuatua-1) are located within the Northern Graben or on its flanks. See Fig. 2 for explanation of the New Zealand stage abbreviations.*

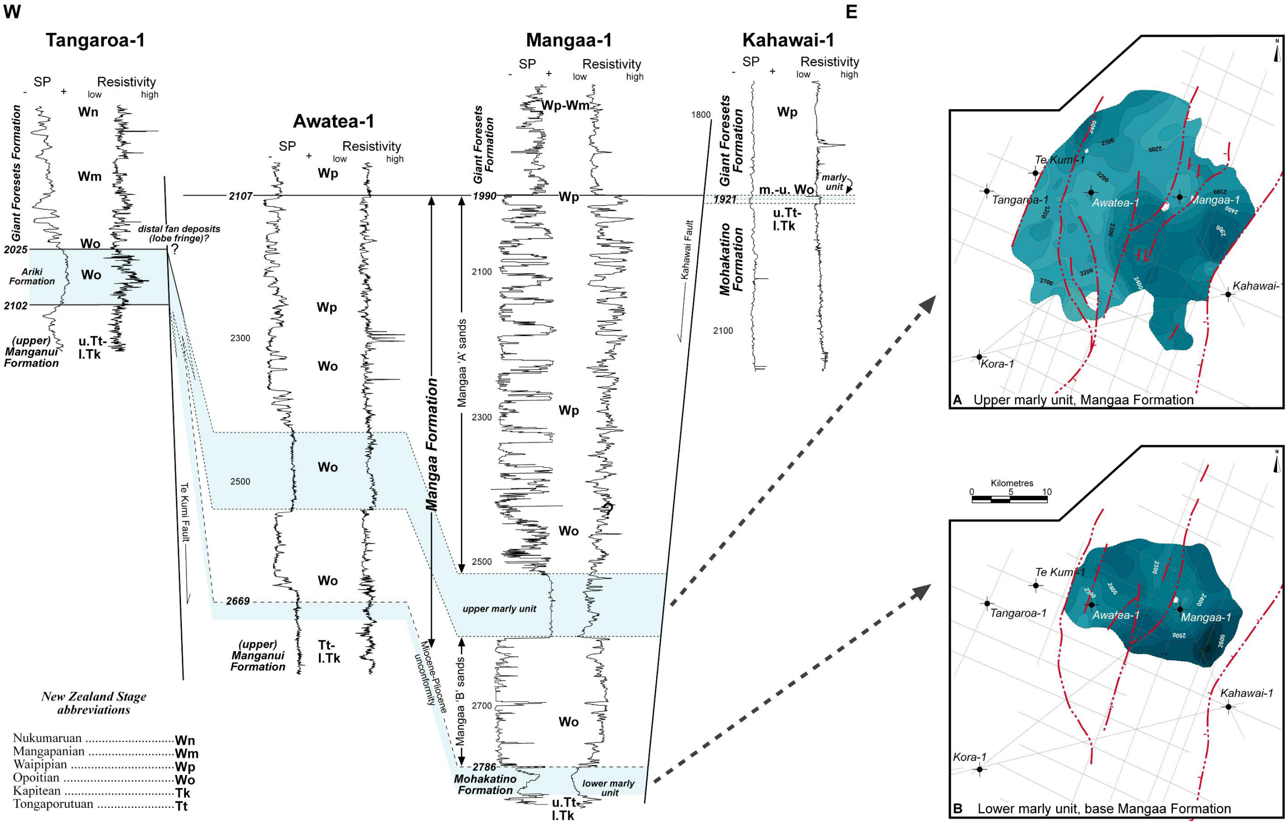


Fig. 5. Correlation panel involving Tangaroa-1, Awatea-1, Mangaa-1 and Kahawai -1 across the Northern Graben from its western to eastern flanks, showing selected wireline records, formational stratigraphy and biostratigraphic ages, and in particular the stratigraphic position and correlation of Ariki Formation in Tangaroa-1 with two thin correlative marly horizons in the Northern Graben and one on the eastern flank of the graben. The inset maps show the extent within the Northern Graben of the two marly horizons intersected in Awatea-1 and Mangaa-1, based on seismic reflection mapping (Hansen, 2003).

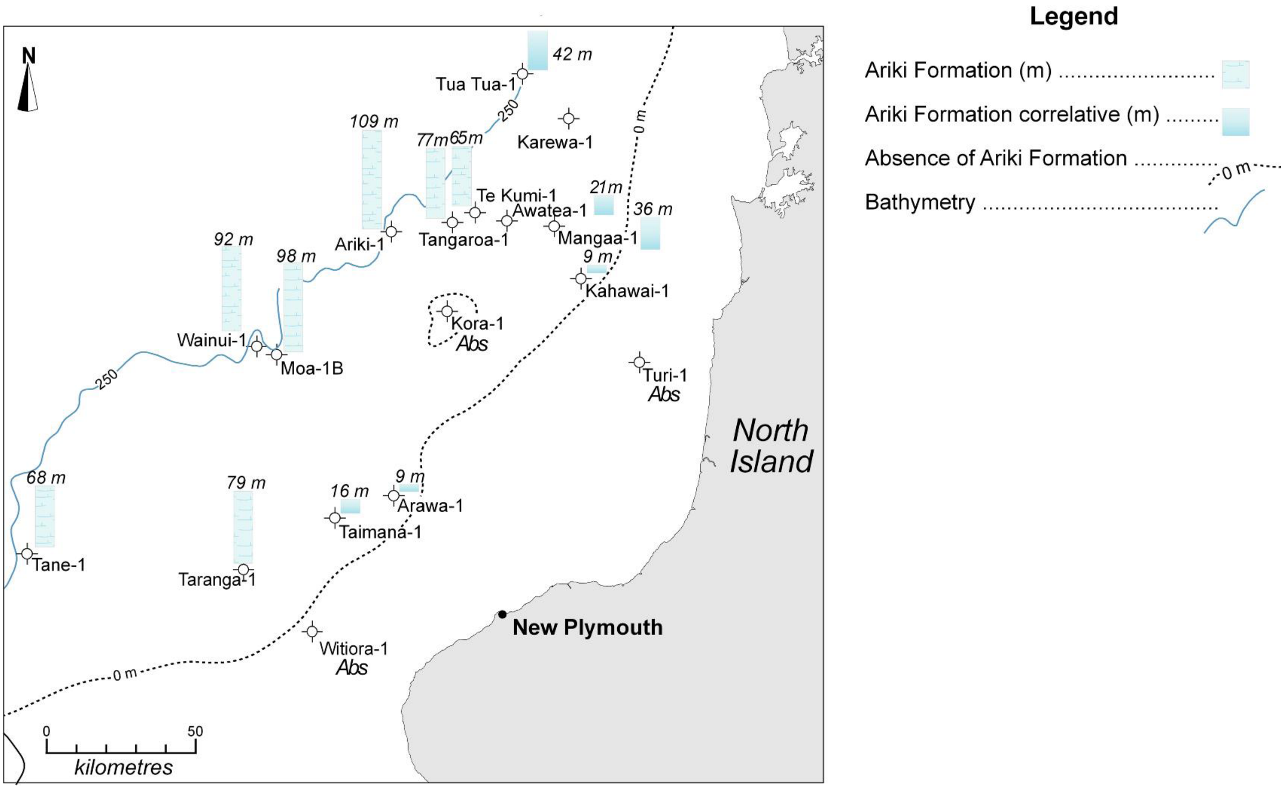
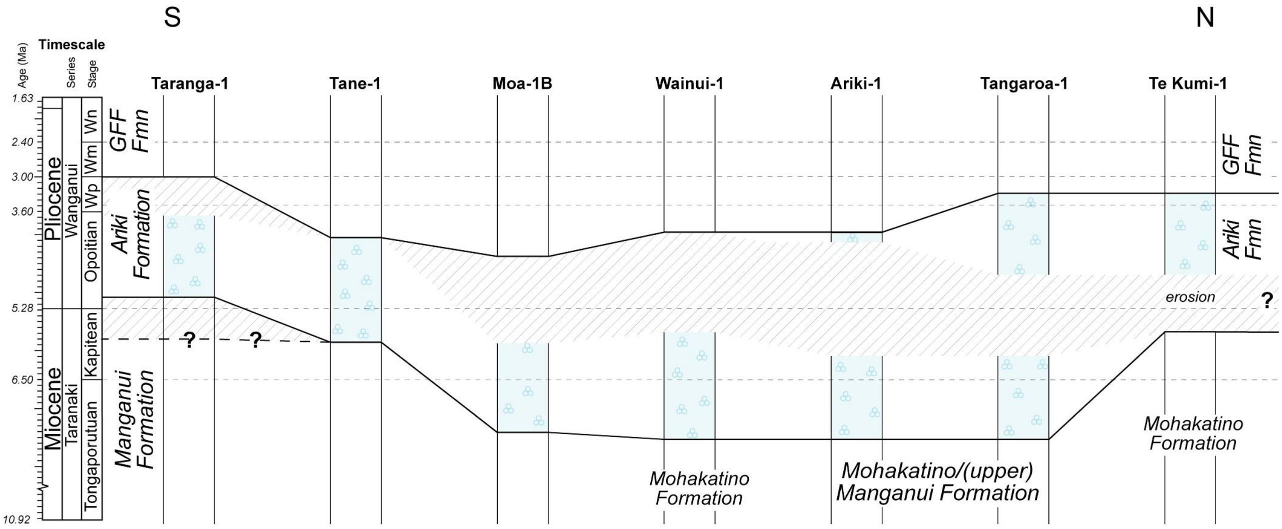


Fig. 6. Distribution and thickness of the Ariki Formation over the Western Platform, and thin Ariki Formation correlatives in the Northern Graben, northern Taranaki Basin.



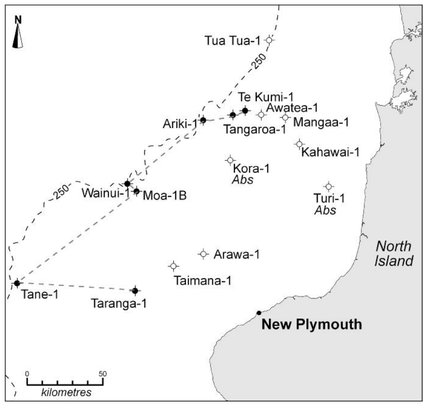


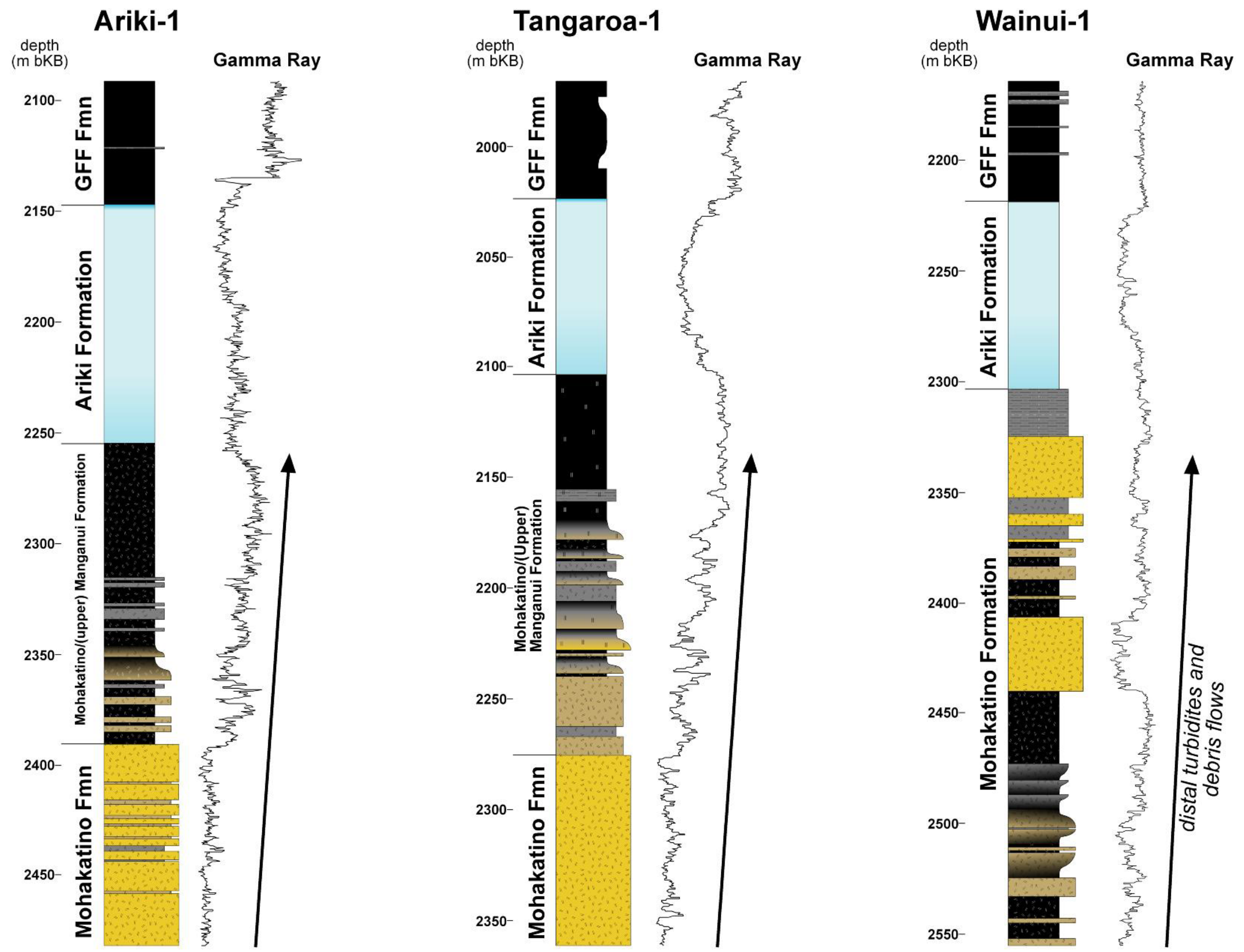
Fig. 7. Late Neogene chronostratigraphic panel linking selected Western Platform exploration holes, illustrating the distribution of biostratigraphically determined age for the Ariki Formation and enclosing units. Timescale after Cooper et al. (2004). Abbreviation: GFF, Giant Foresets Formation.

Origin of Ariki Formation

Identification in the Northern Graben of two intervals of condensed sedimentation, one during the Late Miocene (upper Tongaporutuan – Opoitian) and another shorter-lived interval during the Early Pliocene (upper Opoitian – Waipipian), is considered to have significance for the wider tectonic and sedimentation patterns in Taranaki and Wanganui basins, which we explore below. That the Ariki Formation over the Western Platform comprises the one longer-lived interval (upper Tongaporutuan – Waipipian) of condensed sedimentation, incorporating the time within, and between, the two marly units in the Northern Graben, is also significant and points to two intervals of condensed sedimentation that must have parallels higher up on the contemporary continental margin.

We have previously identified the possible reasons for accumulation of Ariki Formation (Hansen & Kamp, 2004), highlighting the roles of (i) the cessation of andesitic volcanism (Mohakatino Volcanic Centre, Fig. 1) in leading to the start of accumulation of the marl, (ii) the progradation of the Giant Foresets Formation in overwhelming and ending the accumulation of marl, and (iii), footwall uplift on the margins of the Northern Graben allowing marl to continue to accumulate on sea floor topographically above the surrounding lower bottom-sets of the Giant Foresets Formation.

Andesitic flows and fragmental volcanism have been semi-continuously erupting in northern Taranaki Basin since about 14 Ma but there is evidence that the rate in and around the Northern Graben slowed from about 8 Ma (Thrasher et al., 2002). Erosion of the flanks of the volcanoes and redeposition outwards by various types of submarine mass flow processes continued into the latest Miocene. The contribution that primary (fall/flow) and secondary (reworked) volcaniclastic products made to Late Miocene sedimentation is clearly evident in lithologic and wireline logs in most well sections in northern Taranaki Basin. This includes sites that were proximal to active volcanic centres (e.g. Ariki-1 and Tangaroa-1), as well as sites more distal to volcanic centres such as near Wainui-1 (Fig. 8). Figure 8 illustrates that Miocene volcanism contributed substantially to the sedimentary pile in northern Taranaki Basin right up to the base of the Ariki Formation, and log descriptions for Ariki-1 and Tangaroa-1 indicate ash fall intercalations within Ariki Formation. The waning of volcanism in and around the Northern Graben cannot on its own explain the start of Ariki Forma-



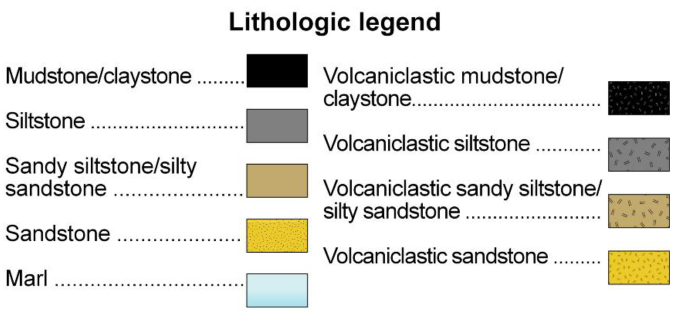


Fig. 8. *Gamma ray records with lithologic logs and formational stratigraphy for three exploration holes (Ariki-1, Tangaroa-1 and Wainui-1) on the Western Platform, northern Taranaki Basin. The records are interpreted as reflecting the waning of volcaniclastic sediment input to Mohakatino and Manganui formations prior to the start of accumulation of marl within the Ariki Formation.*

tion accumulation, however, because (i) it is extensive over the Western Platform in places where the volcaniclastic Mohakatino Formation is not well developed and where Ariki Formation overlies siliciclastic Manganui Formation, and (ii), siliciclastic sediment previously delivered to the Western Platform was shut off from it for several million years.

We identify a new and more important factor in leading to Ariki Formation accumulation, being the Intra-Kiore (Formation) pulldown in central parts of Taranaki Basin (Peninsula). Vonk & Kamp (this volume) outline evidence for extensive intra-upper Tongaporutuan inversion in central and southern Taranaki Basin, and refer to this as the Southern and Central Taranaki Inversion Phase (SCTIP). They show that the well known Late Miocene inversion in the southern parts of the basin and on structures such as the Manaia Anticline (Knox, 1982; Kamp & Green, 1990; King & Thrasher, 1996) also involved central parts of Taranaki Basin, with the shoreline at the peak of inversion (7.5 Ma) lying west-east midway across Taranaki Peninsula (Fig 9A). Leading up to this inversion phase, siliciclastic sediment was fed more proximally into deeper-water parts of the King Country region and northern Taranaki Basin as a result of the tectonic uplift and shallowing both north and south of the shoreline (Fig. 9A). After the 7.5 Ma peak in tectonic inversion, the central parts of Taranaki Basin and northern parts of Wanganui Basin where tectonically pulled down with marked southward depositional onlap onto older rocks to-

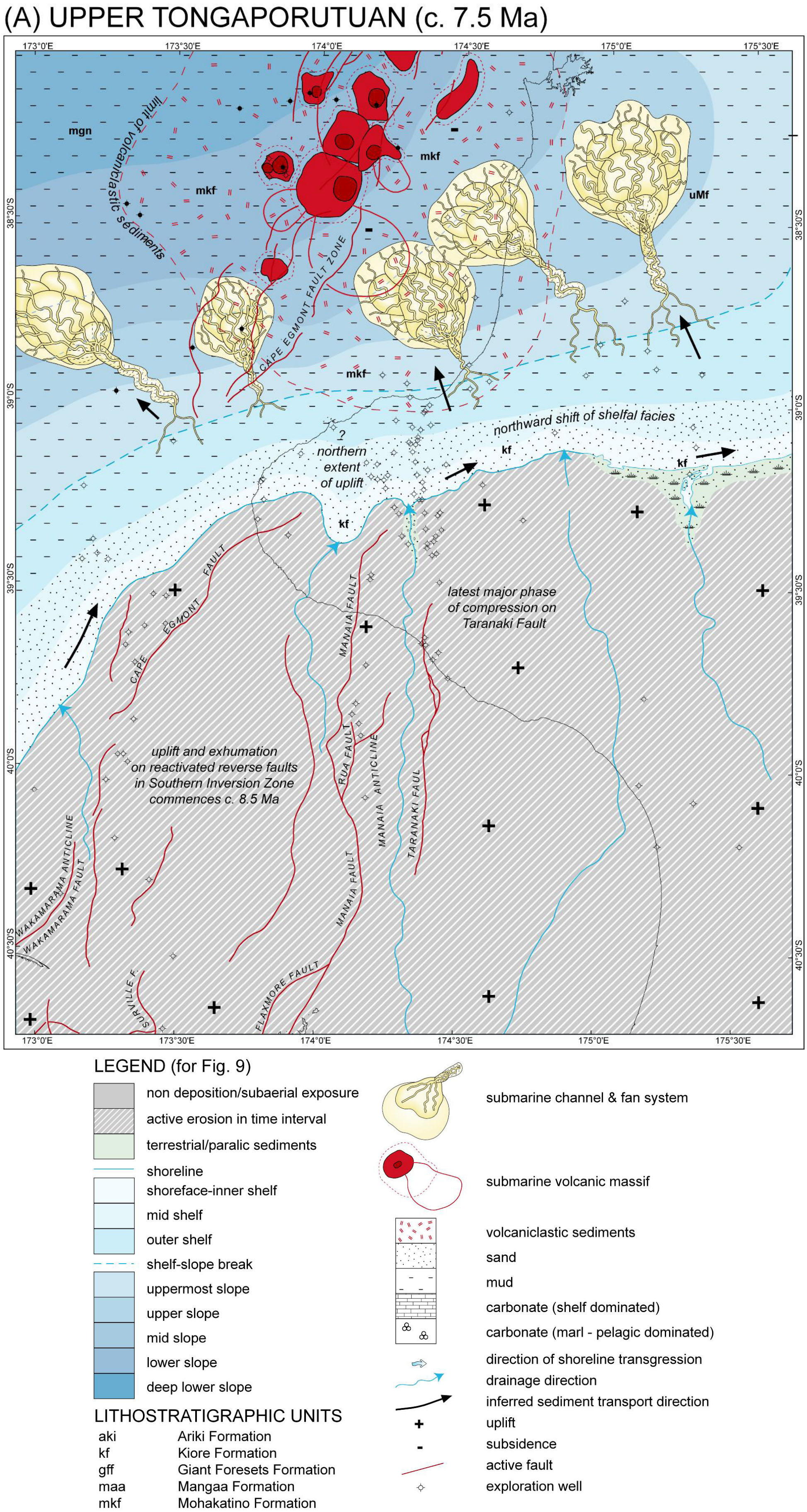
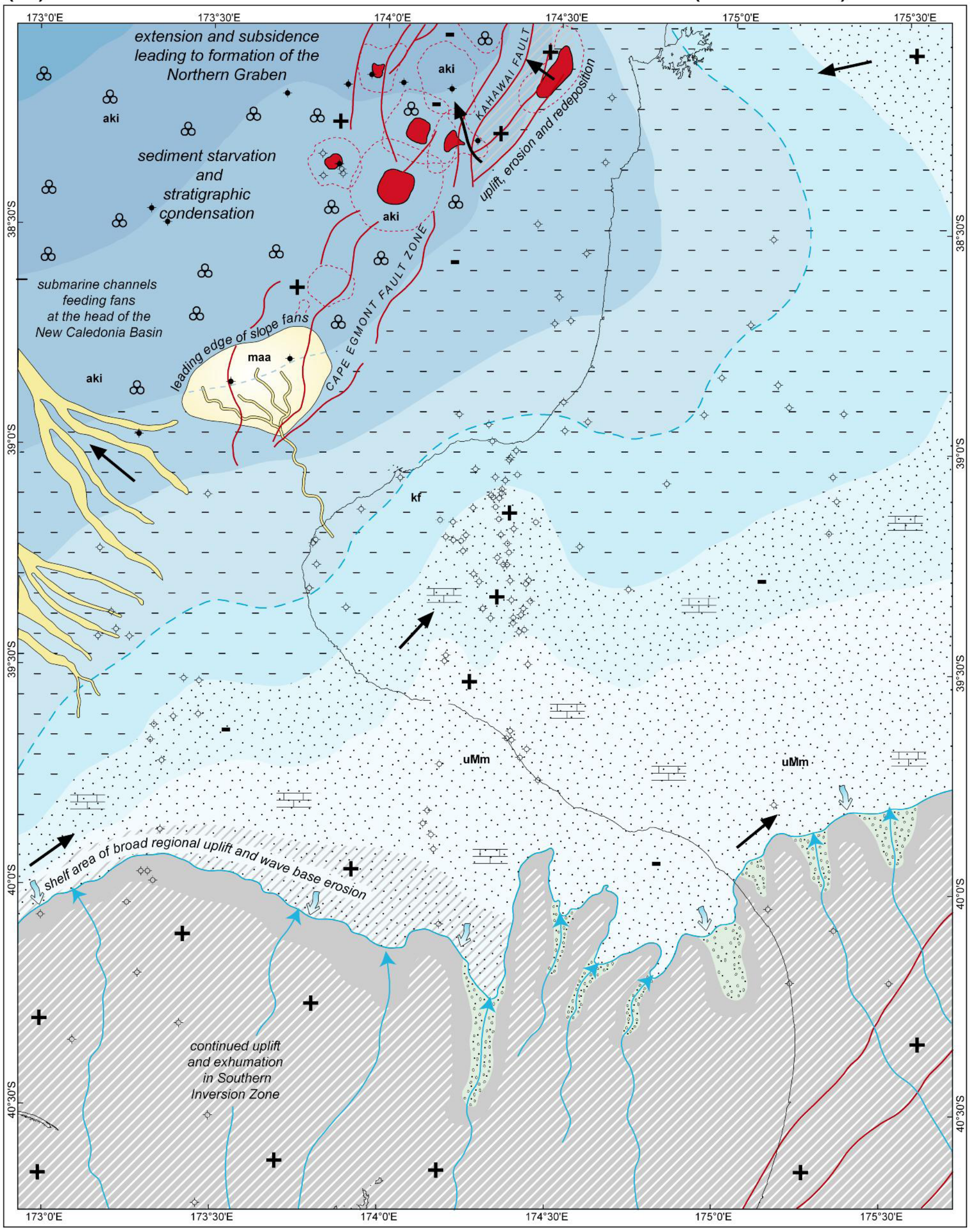


Fig. 9. *Eastern Taranaki Basin paleogeographic reconstructions (from Vonk & Kamp, this volume) drawn for the upper Tongaporutuan (in **A**) and lower-upper Kapitean boundary (in **B**), showing the shoreline and related facies belts at the peak of the Late Miocene inversion phase and for two million years later when there had been substantial southward onlap and shift in facies belts.*

(B) LOWER-UPPER KAPITEAN BOUNDARY (c. 5.5 Ma)



gether with retrogradation of facies belts until around 5.5 Ma (lower-upper Kapitean boundary) (Fig 9B), resulting in accommodation in central Taranaki Basin and northern Wanganui Basin for most of the sediment being supplied to the margin during the 7.5 - 5.5 Ma interval. We consider the depositional response to the Intra-Kiore Pulldown to have effectively shut off siliciclastic sediment supply to more northern parts of Taranaki Basin, including the Western Platform and what became the Northern Graben (Awatea-1, Mangaa-1), thereby allowing foraminiferal marl to accumulate in those areas. At this time northern Taranaki Basin resided at mid- to lower bathyal water depths (600-2000 m; Waghorn et al., 1996; Strong et al., 1996; Hansen, 2003) and the absence of reworked shallow-water foraminiferal taxa amongst the benthic assemblages in Ariki Formation is consistent with southward shoreline retreat in central Taranaki and northern Wanganui, thereby inhibiting the delivery through the contemporary shelf-slope system of siliciclastic sediment to the northern bathyal parts of the basin, where siliciclastic sedimentation was occurring prior to the start of accumulation of Ariki Formation marl.

During the lower Opoitian, siliciclastic sediment supply to northern parts of Taranaki Basin resumed, resulting in renewed depositional offlap (progradation) north of Taranaki Peninsula, concurrent with continuing southward onlap in the northern Wanganui area due to ongoing subsidence. This led to development of the maximum extent of the Matemateaonga shelf and northward outbuilding of the contemporary continental slope involving Kiore, Urenui and Mt Messenger formations (Kamp et al., 2004; Vonk & Kamp, this volume). We consider the accumulation of the lower part of the Mangaa Formation ("Mangaa B Sands", Fig 6) to have occurred at this time (lower Opoitian), sourced from the progradational shelf-slope system in the northern Taranaki Bight area, guided by the fault topography bounding the newly formed Northern Graben. The submarine relief on the flanks of the graben did not allow the flow deposits to reach the Western Platform, however, where Ariki Formation continued to accumulate, whereas in the Northern Graben, particularly around Awatea-1 and Mangaa-1, the accumulation of marl was overwhelmed by siliciclastic sedimentation.

Another tectonic pulldown (Tangahoe Pulldown) occurred at about 4.7 Ma, which resulted in the formation of the main Wanganui Basin depocentre (Kamp et al., 2004). The depositional response to this event was similar to that for the Intra-Kiore Event, with marked southward onlap and retrogradation of facies belts (Vonk & Kamp, this volume). This led to the second phase of accumulation of marl in the Northern Graben through cessation of siliciclastic sediment being delivered to it. We have described these deposits as the Ariki Formation correlative marly horizons, which are of upper Opoitian and Waipipian age. Over the Western Platform the accumulation of marl continued, as it had not been interrupted by siliciclastic sedimentation, and this younger section simply amalgamated with the lower marl section to extend the overall thickness (Fig. 5). The accumulation of marl ended diachronously across northern Taranaki Basin as bottom-sets of the Giant Foresets Formation started to accumulate as a consequence of marked Early to mid-Pliocene northwestward progradation of the continental margin across the Northern Graben and Western Platform. Locally, depending upon submarine high topography, either associated with Mohakatino volcanoes (e.g. Tua Tua-1) or the flanks of the Northern Graben (e.g. Tangaroa-1 and Te Kumi-1), accumulation of marl continued later into the Pliocene (Waipipian).

Conclusions

The key messages in this paper include the following: (i) Ariki Formation on the Western Platform comprises an extended phase of condensed sedimentation that corresponds to two cycles of marl and siliciclastic sedimentation in the Northern Graben, one of Late Miocene age and another of Early Pliocene age. (ii) These two cycles can be related to a widespread phase of Late Miocene basin inversion and subsequent pulldown (Vonk & Kamp, this volume), and a second phase (Pliocene, mid-Opoitian) of tectonic pull down that formed the main Wanganui Basin depocentre (Kamp et al., 2004). The Ariki Formation and associated beds are therefore elements in a depositional system that can be traced from contemporary shorelines to bathyal environments, and indeed, proximal areas of tectonic inversion. Moreover, the deep-water Ariki Formation can now be related more clearly to Late Miocene – Pliocene third-order continental margin sequences, associated stacking patterns and sedimentation dynamics. At the third-order sequence scale, one can identify and observe in a backarc convergent margin setting the deep water sedimentation response to phases of tectonic inversion driven by continent-continent convergent tectonics along the neighbouring sector of the plate boundary zone, and the subsequent transition to subduction-driven foreland basin subsidence (Kamp & Furlong, 2006).

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