

Copyright is owned by the Author of this thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**NEW ZEALAND OLIGOCENE LAND CRISIS:  
INTEGRATED MICROPALAEONTOLOGY OF WAIKATO COAL  
MEASURES AND ASSOCIATED SEDIMENTS IN CENTRAL  
NORTH ISLAND, NEW ZEALAND**

A thesis presented in partial fulfilment of the  
requirements for the degree of

Master of Science

in

Earth Science

at Massey University, Palmerston North,  
New Zealand.

**Claire Louise Shepherd**

**2012**

# ABSTRACT

---

The topic of complete inundation of the New Zealand landmass during the Oligocene is a contentious one, with some proponents arguing the possibility that Zealandia became completely submerged during this time, and others contesting the persistence of small islands. The outcome of this debate has significant implications for the way in which modern New Zealand flora and fauna have evolved. This research project addresses the topic from a geological point of view by analysing late Oligocene–early Miocene sediments in the Benneydale region, in order to establish the timing of marine transgression in this area.

Samples from two cores drilled in the Mangapehi Coalfield were analysed for palynological and calcareous nannofossil content, and these data were used to determine the age and paleoenvironment of Waikato Coal Measures, Aotea Formation and Mahoenui Group. Additionally, data from 28 boreholes in the coalfield were utilized to construct a series of isopach maps to elucidate changes in the paleostructure through time. All data were combined to develop a series of paleogeographic maps illustrating the development of coal measures and associated sediments across the Benneydale region.

The results of this study indicate a Waitakian (late Oligocene–early Miocene) age for Waikato Coal Measures in the Benneydale region. Although this finding is consistent with the idea that Waikato Coal Measures young to the south, it appears that deposition occurred later than previously thought. Additionally, palynological data signify the persistence of a well vegetated pollen source throughout the late Oligocene–early Miocene sequence. Isopach analysis reveals the presence of paleohighs in the eastern and southern regions of the coalfield. While there is no direct evidence of land persisting in the Benneydale region, the pollen and isopach results support the hypothesis that some land remained above sea level during the Oligocene.

## ACKNOWLEDGEMENTS

---

First and foremost I would like to thank my family and friends who have joined me on this crazy ride. Mum and Dad, your continual love and support provided me with the impetus to keep going whenever my self-belief began to waver. Thanks for everything you have done, including the cash injections, re-stocking my pantry, and looking after my psychotic cat. Esther, who rescued me from student living, words cannot express my gratitude for your generosity and friendship over the last two years. I have had so much fun as the sous chef of Ridgeview Restaurant, experimenting on unsuspecting neighbours and family, thank you. Meg and Polly, my faithful companions during long days of writing, your toothy grins and doggy antics never failed to bring a smile to my face. To Clel and Nicky, thank you for your friendship and encouragement throughout; Fridays will forever be known as “party” Fridays. Thanks to Phil and Sue for letting me be part of your family, I have enjoyed spending time with you and your beautiful girls. Additional thanks to Phil for proofing my final draft. To Elsie, thanks for the deep philosophical conversations out by the garden swing.

Huge thanks to Johnny Irons, who also comes under the heading of friend, but deserves special acknowledgement as field/laboratory assistant extraordinaire. Thank you for accompanying me into the middle of nowhere, lugging drill cores around the core shed, and dressing up in the scientific equivalent of a teletubby suit, all of which was done without question or complaint.

Thanks also to my supervisor Julie Palmer, who was responsible for my inclusion on this project, and to my co-supervisor Nick Mortimer. I greatly appreciate your input throughout the project and review of my final draft.

I would also like to extend my thanks to staff members at GNS Science, whose contribution to this study was invaluable. To Denise Kulhanek, who so graciously spent time teaching me the ins and outs of nanofossil preparation and identification, reviewing my conference abstract and poster, and generally answering any questions I threw her way. To Dallas Mildenhall and Liz Kennedy,

for palynological analysis and photography. To Mike Isaacs, for braving the librarians and hunting down the hard-to-find references that I needed. To Sonja Fry, for painstakingly explaining the process of pollen extraction. Thanks also to Dallas and Denise for reviewing the relevant sections of my draft manuscript.

I would like to acknowledge the assistance of Solid Energy NZ Limited, in particular Grant Gillard for authorising access to drill cores, and Hadley Craig for assisting with access to the Huntly core shed. Special thanks also, to Hadley and Steph for their warm hospitality during our visit to the grand metropolis of Huntly.

Finally, I acknowledge GNS Marsden Fund Project (GNS0803), Massey University Graduate Scholarship and Geoscience Society of New Zealand Hastie Award for providing funding assistance for this study.

# TABLE OF CONTENTS

---

<b>ABSTRACT</b> .....	<b>I</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>II</b>
<b>TABLE OF CONTENTS</b> .....	<b>IV</b>
<b>LIST OF FIGURES</b> .....	<b>VIII</b>
<b>LIST OF PLATES</b> .....	<b>X</b>
<b>LIST OF TABLES</b> .....	<b>XI</b>
<b>CHAPTER 1 - INTRODUCTION</b> .....	<b>1</b>
1.1 BACKGROUND .....	1
1.1.1 The Oligocene land crisis.....	1
1.1.2 Importance of Coal Measures and their associated sediments .....	2
1.2 PURPOSE AND SCOPE OF STUDY.....	2
1.3 PREVIOUS WORK .....	4
1.3.1 Geology and mining - Mangapehi Coalfield.....	4
1.3.2 Palynology of Waikato Coal Measures .....	10
1.3.3 Paleontology of shallow marine sediments associated with the Waikato Coal Measures in the Mangapehi Region.....	16
1.3.4 The Fossil Record Electronic Database (FRED).....	17
<b>CHAPTER 2 - WAIKATO COAL REGION</b> .....	<b>19</b>
2.1 INTRODUCTION.....	19
2.1.1 Extent of Waikato Coal Region .....	19
2.1.2 Physiography .....	22
2.2 REGIONAL GEOLOGICAL SETTING.....	22
2.2.1 Tectonic history and structural development.....	22
2.2.2 Stratigraphy.....	25
2.2.2.1 Mesozoic basement rocks.....	25
2.2.2.2 Late Paleogene rocks - Te Kuiti Group .....	26
2.2.2.3 Miocene Rocks .....	27
2.2.2.4 Late Neogene Rocks - Tauranga Group.....	27
2.3 MANGAPEHI COALFIELD .....	29
2.3.1 Introduction.....	29

2.3.2	Geological structure .....	29
2.3.3	Stratigraphy.....	32
<b>CHAPTER 3 - STUDY AREA.....</b>		<b>38</b>
3.1	INTRODUCTION.....	38
3.2	DRILLHOLE DESCRIPTIONS.....	38
3.2.1	Drillhole 8790.....	38
3.2.2	Drillhole 8791.....	38
3.2.3	Drillhole 8792.....	41
3.2.4	Drillhole 8793.....	41
3.2.5	Drillhole 8794.....	41
3.2.6	Drillhole 8795.....	41
3.2.7	Drillhole 8796.....	43
3.2.8	Drillhole 8797.....	43
3.2.9	Drillhole 8798.....	43
3.2.10	Drillhole 8799.....	45
<b>CHAPTER 4 - METHODOLOGY .....</b>		<b>46</b>
4.1	CORE SAMPLING.....	46
4.1.1	Introduction.....	46
4.1.2	Sample collection and preparation.....	46
4.2	NANNOFOSSIL ANALYSIS .....	47
4.2.1	Introduction.....	47
4.2.2	Sampling .....	47
4.2.3	Slide preparation.....	47
4.2.4	Data collection.....	48
4.2.5	Taxonomy.....	48
	4.2.5.1 <i>Cyclicargolithus</i> .....	49
	4.2.5.2 <i>Helicosphaera</i> .....	49
	4.2.5.5 <i>Reticulofenestra</i> .....	49
4.2.6	Biostratigraphic zonation .....	50
4.3	PALYNOLOGICAL ANALYSIS.....	52
4.3.1	Introduction.....	52
4.3.2	Pollen extraction and slide preparation.....	52
4.3.3	Interpretation of palynological data .....	54

4.4	ISOPACH ANALYSIS.....	55
4.4.1	Introduction.....	55
4.5	PALEOGEOGRAPHIC MAPS .....	55
4.5.1	Introduction.....	55
	<b>CHAPTER 5 - RESULTS .....</b>	<b>56</b>
5.1	NANNOFOSSIL ANALYSIS .....	56
5.1.1	Drillhole 8795.....	56
5.1.1.1	Aotea Formation .....	56
5.1.1.2	Summary of assemblage .....	57
5.1.2	Drillhole 8798.....	59
5.1.2.1	Mahoenui Group .....	59
5.1.2.2	Summary of assemblage .....	61
5.1.2.3	Aotea Formation .....	61
5.1.2.4	Summary of assemblage .....	63
5.1.2.5	Waikato Coal Measures.....	65
5.1.2.6	Summary of assemblage .....	66
5.2	PALYNOLOGICAL ANALYSIS.....	70
5.2.1	Drillhole 8795.....	70
5.2.1.1	Aotea Formation .....	70
5.2.1.2	Waikato Coal Measures.....	70
5.2.2	Drillhole 8798.....	73
5.2.2.1	Mahoenui Group .....	73
5.2.2.2	Aotea Formation .....	73
5.2.2.3	Waikato Coal Measures.....	73
5.2.2.4	Manaia Hill Group.....	74
5.3	ISOPACH ANALYSIS.....	78
5.3.1	Mahoenui Group .....	78
5.3.2	Aotea Formation.....	78
5.3.3	Waikato Coal Measures.....	78
	<b>CHAPTER 6 - DISCUSSION .....</b>	<b>84</b>
6.1	DETERMINATION OF AGES.....	84
6.1.1	Palynological analysis.....	84
6.1.2	Integration of nannofossil data.....	87



6.1.3 Comparison with previous studies.....	88
6.2 PALEOENVIRONMENT INTERPRETATION.....	93
6.3 PALEOSTRUCTURE INTERPRETATION .....	96
6.4 SYNTHESIS OF AGE, PALEOENVIRONMENT AND PALEOSTRUCTURE.....	98
<b>CHAPTER 7 - CONCLUSIONS.....</b>	<b>102</b>
<b>REFERENCES.....</b>	<b>104</b>
<b>APPENDIX 1 - SUMMARY OF PREVIOUS SAMPLING.....</b>	<b>111</b>
<b>APPENDIX 2 - DRILLHOLE LOGS.....</b>	<b>115</b>
<b>APPENDIX 3 - CALCAREOUS NANNOFOSSIL TAXONOMIC LIST.....</b>	<b>125</b>
<b>APPENDIX 4 - UNIT THICKNESSES FOR ISOPACH ANALYSIS .....</b>	<b>126</b>
<b>APPENDIX 5 - PALYNOLOGY COUNTS.....</b>	<b>127</b>

## LIST OF FIGURES

---

<b>Figure 1.1:</b> Simplified diagram showing the stratigraphic relationships of the major lithological units focused on in this study .....	3
<b>Figure 1.2:</b> Map showing the location of Benneydale and the Mangapehi Coalfield, North Island, New Zealand.....	5
<b>Figure 1.3:</b> Diagram showing the location of four bores drilled underground at the Mangapehi Coal Mine.....	6
<b>Figure 1.4:</b> Stratigraphic column for the Mangapehi Coalfield area .....	9
<b>Figure 1.5:</b> Geological timescale showing international epochs and New Zealand stages and series .....	11
<b>Figure 1.6:</b> Diagram illustrating the four biozones proposed by Pocknall (1991) for the Waikato Basin, and their application in correlating stratigraphic sections across the Waikato Coal Region.....	15
<b>Figure 1.7:</b> Location map for samples collected in the Mangapehi/Benneydale region .....	18
<b>Figure 2.1:</b> Coalfields within the Waikato Coal Region .....	20
<b>Figure 2.2:</b> Physiographic features of the Waikato Coal Region.....	21
<b>Figure 2.3:</b> Diagram showing the structure of the Hakarimata-Taupiri (H-T) block and surrounding area .....	24
<b>Figure 2.4:</b> Generalised section through the Waikato region (North to South) showing the distribution of Te Kuiti Group formations .....	28
<b>Figure 2.5:</b> Location of major faults within the King Country Basin.....	31
<b>Figure 2.6:</b> Map of Mangapehi Coalfield showing the location of main faults and mine entrances .....	33
<b>Figure 2.7:</b> Stratigraphic column for drillhole 8794 showing the section of the Waikato Coal Measures that includes a fossiliferous sandstone bed 20 m above the Mangapehi Seam.....	35
<b>Figure 3.1:</b> Location of all holes drilled in the Mangapehi Coalfield up to 2007 .....	39
<b>Figure 3.2:</b> Map showing simplified stratigraphy for holes drilled in the Mangapehi Coalfield between 1996 to 2007 .....	40
<b>Figure 3.3:</b> Summarised stratigraphic column for drillhole 8795 showing the thicknesses of major units and placement of the Mangapehi coal seam within the Waikato Coal Measures.....	42

<b>Figure 3.4:</b> Summarised stratigraphic column for drillhole 8798 showing the thicknesses of major units and placement of the Mangapehi coal seam within the Waikato Coal Measures.....	44
<b>Figure 4.1:</b> Chart showing the zones used by Martini (1971) and Okada & Bukry (1980) correlated with the New Zealand geological time scale.....	51
<b>Figure 5.1:</b> Relative pollen diagram for Drillhole 8795 showing dominant spore and pollen types.....	72
<b>Figure 5.2:</b> Relative pollen diagram for Drillhole 8798 showing dominant spore and pollen types.....	75
<b>Figure 5.3:</b> Isopach map showing the thickness of Mahoenui Group in the Mangapehi Coalfield.....	80
<b>Figure 5.4:</b> Isopach map showing the thickness of Aotea Formation in the Mangapehi Coalfield.....	81
<b>Figure 5.5:</b> Isopach map showing the thickness of Waikato Coal Measures in the Mangapehi Coalfield.....	82
<b>Figure 5.6:</b> Simplified stratigraphic columns showing the thickness of coal measures and coal seams for boreholes in the Mangapehi Coalfield, superimposed on isopachs of Waikato Coal Measures.....	83
<b>Figure 6.1:</b> Pollen zonation schemes for the Tertiary of New Zealand.....	91
<b>Figure 6.2:</b> Representative stratigraphic section for Mangapehi Coalfield correlated with the New Zealand timescale, palynology zones, and key nannofossil datums.....	92
<b>Figure 6.3:</b> Climate curves for the New Zealand Cenozoic.....	94
<b>Figure 6.4:</b> Paleogeographic reconstruction during the early Waitakian showing the development of an extensive peat swamp in the Mangapehi Coalfield.....	99
<b>Figure 6.5:</b> Paleogeographic reconstruction of the Mangapehi Coalfield during early-mid Waitakian, illustrating marine transgression across the area and the deposition of Aotea Formation.....	100
<b>Figure 6.6:</b> Paleogeographic reconstruction of the Mangapehi Coalfield during mid-late Waitakian, illustrating marine transgression across the area and the deposition of Mahoenui Group.....	101

## LIST OF PLATES

---

<b>Plate 5.1:</b> LM images of representative nannofossil specimens from Aotea Formation, core 8795.....	57
<b>Plate 5.2:</b> LM images of representative nannofossil specimens from Mahoenui Group, core 8798 .....	61
<b>Plate 5.3:</b> LM images of representative nannofossil specimens from Aotea Formation, core 8798.....	64
<b>Plate 5.4:</b> LM images of representative nannofossil specimens from Waikato Coal Measures, core 8798 .....	67
<b>Plate 5.5:</b> Photomicrographs of representative palynomorphs from Mangapehi cores 8795 and 8798.....	76
<b>Plate 5.6:</b> Photomicrographs of representative palynomorphs from Mangapehi cores 8795 and 8798.....	77

## LIST OF TABLES

---

<b>Table 1.1:</b> Summary of ages determined for Waikato Coal Measures by previous studies .....	14
<b>Table 4.1:</b> Summary of samples collected from the Mangapehi cores for pollen analysis by GNS Science .....	54
<b>Table 5.1:</b> Relative abundance of individual species and overall abundance of nannofossils in samples taken from core 8795 .....	58
<b>Table 5.2:</b> Relative abundance of individual species and overall abundance of nannofossils in samples taken from core 8798 .....	68
<b>Table 6.1:</b> Age ranges of selected spore-pollen species in Southland and Central Otago, New Zealand .....	85