



# Late Quaternary terrestrial vertebrate coprolites from New Zealand



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## ARTICLE INFO

### Article history:

Received 29 April 2014

Received in revised form

21 May 2014

Accepted 22 May 2014

Available online 17 June 2014

### Keywords:

Birds

Caves

Coprolites

New Zealand

Reptiles

Rock shelters

Stratigraphy

Taphonomy

## ABSTRACT

Over the past decade, concerted efforts to find and study Late Quaternary terrestrial vertebrate coprolites in New Zealand have revealed new insights into the diets and ecologies of New Zealand's prehistoric birds. Here, we provide a broader review of the coprolites found in natural (non-archaeological) Late Quaternary deposits from New Zealand. We summarise the morphological diversity of the coprolites, and discuss the taphonomy of the sites in which they are found. Since the 1870s more than 2000 coprolites have been discovered from 30 localities, all restricted to the South Island. The distribution of coprolite localities appears to reflect the presence of geological and climatic factors that enhance the potential for coprolite preservation; coprolites require dry conditions for preservation, and have been found on the ground surface within drafting cave entrances and at shallow (<300 mm) depths beneath rock overhangs with a northerly aspect. We classify the coprolites into eleven morphotypes, each of which may represent a range of different bird and/or reptile species. A review of genetically identified specimens shows that coprolites of different bird species overlap in size and morphology, reinforcing the need for identifications to be based on ancient DNA analysis.

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## 1. Introduction

The fossil record of New Zealand's Late Quaternary terrestrial fauna is impressively complete (Worthy and Holdaway, 2002). Abundant fossil bones from caves, mires, dunes, and loess deposits have provided detailed insights into not only the identity of the faunal species that once inhabited New Zealand, but also their ecology and distribution from the last ice age until the arrival of humans in the 13th Century AD (Worthy and Holdaway, 2002). Analyses of Late Quaternary bones continue to reveal new information about the biology of New Zealand's extinct species, and technological advances (particularly in the field of ancient DNA analysis) continue to open up exciting new research possibilities (Worthy and Scofield, 2012).

Evidence for New Zealand's Late Quaternary fauna is not restricted to bones. Further proxies include Maori rock art depictions (McCulloch and Trotter, 1971), preserved feathers and integument (reviewed by Rawlence et al., 2013), nests (Hartree, 1999; Wood, 2006, 2008a), eggshell (Gill, 2000, 2006; Oskam et al., 2010), footprints and trackways (reviewed by Worthy and Holdaway, 2002), sedimentary ancient DNA (Willerslev et al., 2003; Haile et al., 2007) and coprolites (Horrocks et al., 2004,

2008; Wood et al., 2008, 2012a, 2012b, 2012c, 2013a, 2013b; Wood and Wilmshurst, 2013). Coprolites are rich sources of paleoecological information, and can reveal aspects of the paleoenvironments (Yil et al., 2006), paleodiets (Poinar et al., 1998), ecosystem function (Wood et al., 2012a) and parasites (Schmidt and Duszynski, 1992) of prehistoric extinct fauna. Late Quaternary coprolites of extinct terrestrial fauna were first discovered in New Zealand approximately 140 years ago (Cockburn-Hood, 1873), and until recently remained relatively scarce. Within the past decade, concerted efforts to identify and recover Late Quaternary coprolites from New Zealand for study have greatly expanded our understanding of this unique paleoecological resource, making it timely for a broader review. Here, we review the history of Late Quaternary coprolite (hereafter simply referred to as coprolites) discoveries in New Zealand, assess the morphological diversity of the coprolites, and discuss the taphonomy of the sites in which they occur. Many coprolites, mainly of the Polynesian dog (*Canis familiaris*), have also been found in association with archaeological sites throughout New Zealand (e.g. Horrocks et al., 2002, 2003) but are not reviewed here, as we focus specifically on non-archaeological specimens.

## 2. A brief history of coprolite discoveries in New Zealand

The first coprolites discovered in New Zealand were found during excavations at Earnsclough Cave (Fig. 1) in Central Otago

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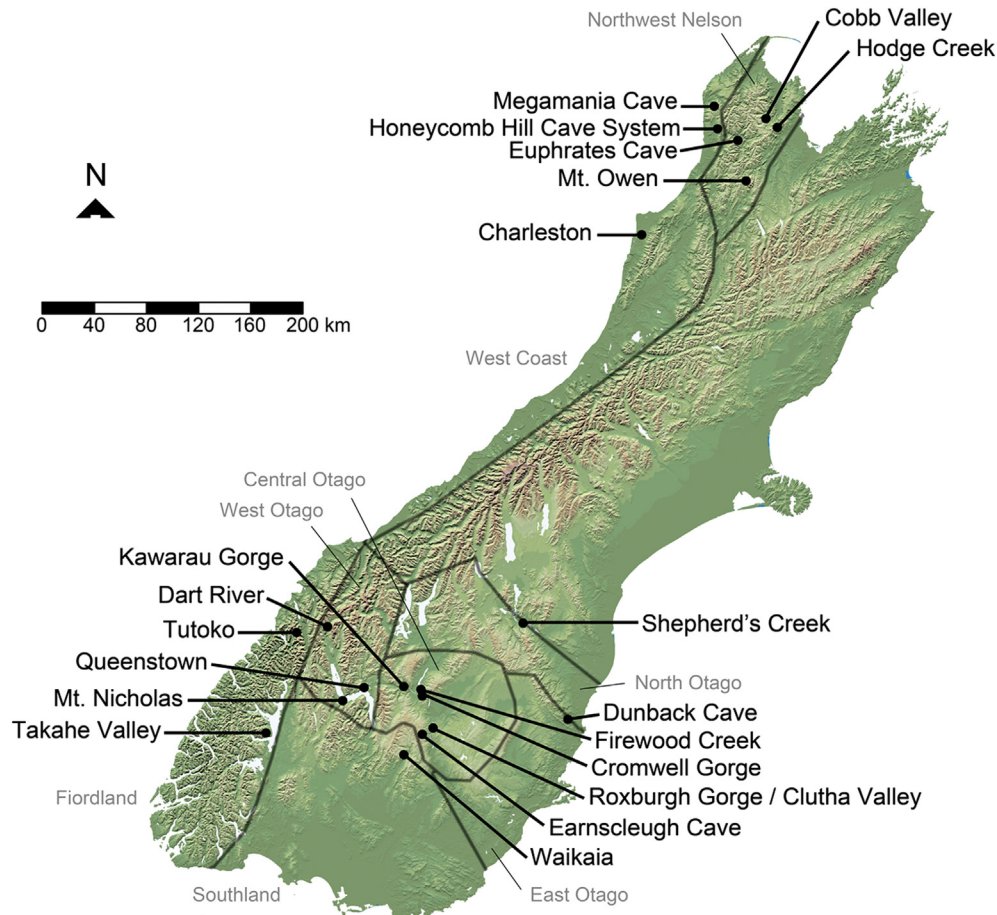


Fig. 1. Location of sites containing natural Late Quaternary terrestrial vertebrate coprolites in New Zealand. Names of regions are shown in grey text.

during the early 1870s. Cockburn-Hood (1873) noted that “The flat ground near [the cave] had probably been a favourite camping ground, from the quantity of droppings—which are, no doubt, those of the large birds—swept in by the wind”. Five coprolites from Earnsleugh Cave are held by Otago Museum, and one of these has been genetically identified as having been deposited by a coastal moa (*Euryapteryx curtus*) (Wood et al., 2008).

Around the same period, White (1875) discovered a cave near Mt. Nicholas (Fig. 1) on the western shore of Lake Wakatipu, and reported that “Excrement of a large bird was also found [in the cave] ... Some of this consisted of undigested fragments of what looked like the stalk of the fern”. White (1875) also mentioned that across the lake, in a cave at Queenstown, “... a quantity of double-shafted feathers of a brown colour ... appeared to be chiefly in a layer of hard-trodden excrement ... Perfect droppings were also found ... and a few specimens of a similar outward appearance, contained undigested vegetable fragments, some of which seemed to be branches and stalks of fern broken into short pieces of three-quarters of an inch in length”. One of the coprolites from Mt. Nicholas is held in the collections of the Museum of New Zealand Te Papa Tongarewa, however no evidence was found to indicate whether more specimens were ever collected from this site. The Mt. Nicholas cave was revisited by Wood et al. (2012c) but the sediments in the cave were found to have been heavily disturbed by rabbit (*Oryctolagus cuniculus*) burrowing and no further coprolites were found there. However, a new deposit of coprolites was found in a rock shelter adjacent to the cave (Wood et al., 2012c).

Hamilton (1894) visited a small cave near Waikaia (Fig. 1), in northern Southland, after the desiccated leg of an upland moa

(*Megalapteryx didinus*) was discovered there. Hamilton reported finding many feathers and several owl pellets in the cave. Although his description (Hamilton 1894) does not mention coprolites, a small number of coprolites from this cave are held in the collections of Otago ( $n = 3$ ) and Canterbury ( $n = 5$ ) Museums. One of these coprolites was genetically identified as having been deposited by *M. didinus* (Wood et al., 2008).

An accumulation of coprolites was discovered during the excavation of a rock shelter at Takahe Valley (Fig. 1), Fiordland, in 1949 (Duff, 1952). Plant remains from five of these coprolites were identified by Horrocks et al. (2004), and although the coprolites were inferred to have been deposited by *M. didinus*, this identification has only recently been confirmed by molecular analysis for one of the Takahe Valley coprolites (Supplementary Table 2 in Huynen et al., 2010).

Several more discoveries of coprolites were made in the late 20th Century, during hydroelectric-scheme mitigation excavations of rock shelters in the Central Otago and North Otago regions. In 1964, coprolites were recovered from a rock shelter near Shepherd's Creek (Fig. 1), in the upper Waitaki Valley, North Otago (Trotter, 1970). Pollen analysis of one of these provided the first micropaleontological study of a coprolite from New Zealand (Trotter, 1970). In ca 1980, a sample of putative moa nesting material, preserved within a compacted earth layer believed to be moa excreta, was excavated from the Rockfall II rock shelter (Fig. 1) in Cromwell Gorge, Central Otago (Ritchie, 1982; Wood, 2008b). A sample of this material was sent to Canterbury Museum at the time for examination but almost three decades later could not be relocated by Wood (2008a). In ca 1990, a significant number of moa

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