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– ARTICLE –

'Buried With His Boots On': An integrated life course case-study of a liminal burial from the New Zealand goldrushes

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ABSTRACT

The New Zealand goldrushes of the mid nineteenth century saw an influx of, mostly, men surging into the Otago region in search of riches. Times were tough and the men had to cope with harsh weather and dangerous work practices to survive. Many lost their lives and most of these men remain anonymous. This paper presents a detailed life-course case study of a middle-aged to older man who lived, and died, in this biosocial landscape. The integration of osteological, chemical and molecular data reveals a life of hardship in his early years, improved nutrition from adolescence, and poor oral health as an adult. He also experienced injury as an adult and possible periodic nutritional deficiency in the last few years of his life. Morphological and molecular analyses attest to this man being of European ancestry, despite local stories of him being a 'black man' who drowned. His grave was liminal, located far from any formal cemetery, and the grave and been disturbed, possibly due to looting. While his identity remains unknown, his earthly remains encapsulate a typical early gold diggers life with experiences of poor beginnings and an ignoble, often anonymous end.

INTRODUCTION

In 1983 Neville Ritchie, then of the New Zealand Historic Places Trust (NZHPT, now Heritage New Zealand), conducted a rescue excavation of a historic-period burial in the Cromwell Gorge, in Central Otago, New Zealand, prior to the development of the hydro-electric Clyde Dam. The lone grave had been reported by the old landowner, who understood that it had been the grave of a 'black man' who had drowned in the Clutha River. The skeleton was transported to the Anatomy Department of the University of Otago for analysis, where it is still held.

Examination of the skeleton at the time of discovery indicated that it was the remains of a European male (Houghton 1983; *Otago Daily Times* 29 June 1983), but many analytical approaches that are standard practice now were not then available. Most pertinent is the development of bioarchaeological theory to include consideration of a life course approach (Argarwal and Glencross 2011) and the Bioarchaeology of Personhood (Boutin 2019). These models consider the health and wellbeing of an individual throughout the life course and tell the narrative of a person's life that is accessible to people outside of the specialist fields of archaeology and osteology. The manner of this person's burial, evidence of post-deposition disturbance of the grave, local stories of his ancestry and cause of death all exemplify the divide that exists between the historical narrative of this period of New Zealand's history and the direct and more nuanced evidence that can be gleaned from bioarchaeology enquiry.

To date this person's life story has remained enigmatic and relegated to a single line in the Clutha Valley Development project report and two newspaper stories (*Otago Daily Times* 24 June 1983; 29 June 1983; Ritchie 1990). Two companion papers are presented here that consider in detail this person's life and death in the nineteenth-century Otago Goldfields: this one concentrates on the bioarchaeological enquiry, and a companion focussing on the histori-

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cal and archaeological context. The present paper discusses the Cromwell Gorge burial (E224) using current osteological, molecular and chemical techniques to form an integrated case study of this individual's life course.

HISTORICAL BACKGROUND: THE OTAGO GOLDFIELDS

In the second half of the nineteenth century there were a series of major international goldrushes, which can be very broadly summarised as California (1840s), Australia (1850s), New Zealand (1860s), and South Africa (1880s). The first small rush in Otago occurred at the Lindis Pass in 1861, but the discovery of gold at Gabriel's Gully soon eclipsed it and by mid-September, J.T. Thomson estimated that there were 3,000 men camped at Gabriel's Gully and 6,000 in the overall area (OPC Gazette 26th September 1861: 238; (Pyke 1962 [Originally published 1887]) Salmon 1963: 54). In 1862 an even larger gold rush struck Otago, after two miners deposited in Dunedin 1,047 oz. of gold that they had recovered from the Molyneux (now Clutha) River near where Cromwell now stands (Oliver 1990); OPC V&P Session XVI 1862: 18; (Salmon 1963). By the 5th of September of that year some 3,000 people, mostly men, had arrived in that area, and prospectors quickly moved further afield. By 1869 seven Otago goldfields had been declared: Tuapeka, Dunstan, Teviot, Nokomai, Wakatipu, Mt. Ida and Taieri (Salmon 1963).

The prospectors and miners that flocked to the new goldfields were predominantly, but not exclusively, of British origin and most came across the Tasman from the Australian goldfields. They were overwhelmingly male (87% of those arriving from Victoria were men), and were generally in their 20s or 30s (Phillips and Hearn 2008). One of the many hazards that travellers had to contend with was river crossing. Before ferries (and later bridges) were established, river crossings could be particularly treacherous, and drowning became known as 'the New Zealand death' with around 100 deaths nationwide a year in the 1890s (Ell and Ell 1995); *Lake County Press* 31st December 1885; *Otago Witness* 1st February 1894).

CURRENT THEMES IN HISTORICAL ARCHAEOLOGICAL AND BIOARCHAEOLOGICAL RESEARCH

One of the current themes in New Zealand historical archaeology is the examination of identity, and how this is expressed in the archaeological record (Jones 2012, King *et al.* 2021b, Smith 2004, Smith 2008). There has been a lot of historical and archaeological research carried out on historic-era New Zealand settlement (Hamel 2001, Phillips and Hearn 2008), but what do we really know about these early settlers? While conventional archaeological research has involved the excavation and analysis of the places that these people lived and worked (*e.g.* (Bedford 1986, Hamel 2004, Petchey 1999, Ritchie 1986), a more direct way of studying peoples' origins, health and diet is to study the people themselves, through analysis of their skeletal remains using modern bioarchaeological methods.

Since 2016 the Southern Cemeteries Project has undertaken the excavation and exhumation of individuals from unmarked and previously 'lost' graves in the Otago region of New Zealand. One of the aims of this project is bring the individual stories of these people to light through integrated case studies (Snoddy *et al.* 2020) and broader cemetery-based reports (Petchey *et al.* 2018a, Petchey *et al.* 2017, Petchey *et al.* 2018b, Buckley *et al.* 2020). The application of bulk and incremental isotope analyses of these people's diet throughout the life course has provided direct evidence to build and support these narratives which would otherwise remain unknown (King *et al.* 2020, King *et al.* 2021b). Ancient DNA analyses have also contributed to identifying their likely ancestry information (King *et al.* 2021a) and may provide further evidence of infectious diseases that impacted the individuals and population.

THE 1983 ARCHAEOLOGICAL EXCAVATION

The excavation of the grave is covered in detail in Petchey *et al.* (this issue), and only a brief overview is presented here. During the late 1970s and the 1980s the Ministry of Works and Development (MWD) and the New Zealand Electricity Department (NZED) conducted wide-scale investigations into the hydro-power generation potential of the Clutha Valley (the Clutha Valley Development Project, CVD), which led to the construction of the Clyde Dam on the Clutha River at the mouth of the Cromwell Gorge. As part of the required environmental work the Clutha Valley Archaeological Project operated from 1977 until 1987, funded by MWD and NZED, and administered by the NZHPT. Neville Ritchie was appointed as director of the project, and he and a team of archaeologists were based in Cromwell (Ritchie 1990). Within the Cromwell Gorge several archaeological investigations were undertaken, including the subject of this paper, the recovery of a grave of an unknown individual (Ritchie 1990). The grave site had been reported by the landowner, the local story being that it was of a 'black man' who had drowned in the river and been buried on the hillside above where the body was found (*Otago Daily Times* 24 June 1983; site record form S133/327) (Figure 1).

THE BURIAL CONTEXT AND INVENTORY OF SKELETAL MATERIAL

The grave was marked by a rectangular outline of placed rocks on the surface (Figure 2). The excavation was undertaken in June 1983 and found a single human burial in a wooden coffin at a depth of 1.3 metres below the surface, with the head to the west. The individual was wearing a

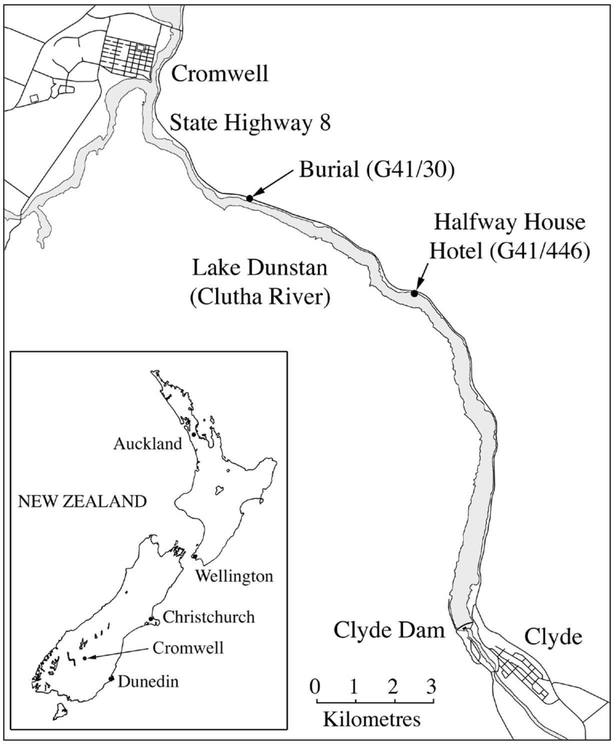

Figure 1. Map showing location of Cromwell, Otago in the South Island of New Zealand and the location of the burial site.

pair of well-preserved leather boots, but only a buckle and some buttons remained of any other clothes. The preservation of the bones was excellent, but the remains had been extensively disturbed at some time after burial. Most of the skeleton was disarticulated and disturbed at different levels within and beside the grave shaft. Only the feet (inside the boots), part of the lower legs, the scapulae and one humerus were *in situ* (see Petchey *et al.* this issue for detailed description of burial context).

The near complete and well-preserved skeleton is curated in the Anatomy Department, University of Otago. This includes the complete cranium and mandible, with dentition (Figure 3). The lack of phalanges of the hands is likely due to loss during excavation. These bones can be lost if they are disarticulated and if the burial matrix is not thoroughly sieved. The right femur was excavated, but is not present in the collection and it is not known where this bone currently is. The right anterior superior iliac spine has been cut with a sharp instrument. The colour of the cut edges is the same as the rest of the bone indicating that this trauma did not occur during the 1983 excavation and more likely occurred during the early disturbance of the burial (see Petchey *et al.* this issue).

The feet were still contained in the leather boots. Computed tomography was undertaken to record the position of the feet within the boots (Figure 4) and the bones of the left foot were later removed for osteological assessment.

Figure 2. The grave prior to excavation of the burial with schist rocks.

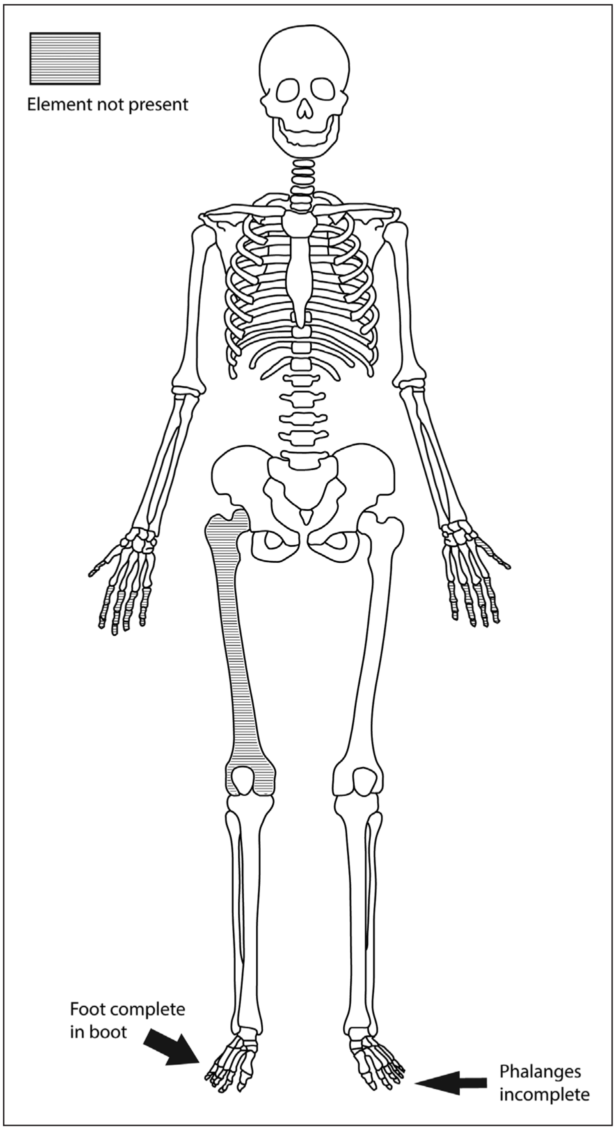

Figure 3. A diagrammatic representation of the presence of the skeletal elements of E224. All bones present were well preserved and complete.

Removal of the right foot bones would have required destruction of the boot and so was not attempted.

The retention of anatomical articulation for some of the bones (*e.g.* the pelvis) suggests that decomposition was not complete at the time of their disturbance. The joints of the pelvis are among the last of the body to release during decomposition (Duday 2006). Therefore, it is likely the disturbance of the grave occurred within months or even weeks of burial. The motivation for this disturbance may include looting in search of valuables. The burial context, post-burial disturbance, and material culture (including his boots) is discussed in Petchey *et al.* (this issue).

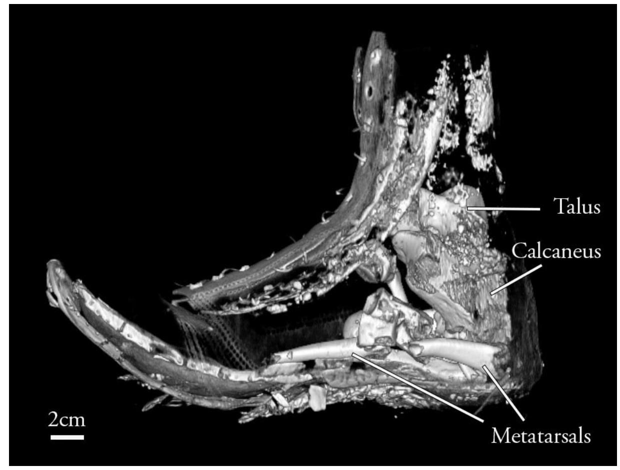

Figure 4. A computed tomography 3D rendering of the left boot with bones still inside.

BIOLOGICAL IDENTITY

The biological identity or osteobiography of an individual includes estimation of age, sex, ancestry and stature based on macroscopic observations from the skeletal and dental remains of an individual (Stodder and Palkovich 2012). An account of a person's life-course, how health experience alters throughout life, can also be assessed from investigation of pathological processes in the bones and teeth that develop at different life stages (Argarwal and Glencross 2011). The following is an account of the osteobiography and life course that integrates molecular and chemical evidence of E224's biological identity, origins, and diet.

Age and Sex Estimation

The age and sex of the individual were assessed using the methods compiled in Buikstra and Ubelaker (1994). Overall, the cranial and pelvic features suggest a probable male individual. The estimation of age was based on the left auricular surface only (Phase 4; Meindl and Lovejoy 1989) in the pelvis as the pubic symphyses were damaged. All late fusing epiphyses were closed and there was minimal to no degeneration in the limb joints. The cranial suture closure was assessed and yielded an age range of 35–49 years old. Overall, the estimation of the age of this individual placed him within the mid to old age range (30–50 years).

Stature

The equations of Sjøvold 1990 were used for the estimation of stature as this method was specifically developed for use in cases where an individual's ancestry is unknown (Sjøvold 1990). The left femur was used to produce the final stature estimate as the femur has been shown to produce the most accurate estimation of living height of any single element. Estimated stature from the left femur was 188.78 cm (6ft 2in) ± 3.85 cm.

ANCESTRY

Morphology and non-metric traits

The local story surrounding E224 was that he was coloured (variously given as 'Black,' 'Coloured' and 'Negro') (Otago Daily Times 24 June 1983; 29 June 1983; NZAA site record form S133/327). In the nineteenth century New Zealand context this 'label' could have meant he was of any dark-skinned ancestry. Edward Peters for example was one of the pioneers of the Otago goldrushes and was known as 'Black Peter' due to his being of Indian descent. The local stories surrounding E224's possible ancestry therefore do not necessarily give any meaningful information regarding his ancestry or identity.

Indeed, over the last few decades there has been a strong pull away from the determination of ancestry or 'race' in biological anthropology due to the increasing recognition that these typologies have no biological basis and perpetuate the racist views that people can be classified into biological 'types' with inherent characteristics. Most recently there has been a call to abandon all attempts to assign ancestry to skeletal remains (Bethard and DiGangi 2020.) However, in a New Zealand context differentiating kōiwi tangata (Māori ancestral remains) from non-Māori is essential to ensure any remains found accidentally are able to be handled appropriately by mana whenua, the Māori group(s) who have guardianship over the land (Cox *et al.* 2006). Thus, ancestry estimation was undertaken as part of the initial reporting on the individual.

Traditionally, the anthropological estimation of ancestry (or 'race') in human skeletal remains has focused exclusively on cranial features and is based on differences in anatomical variation and morphology between major population groups due to factors influenced by migration and genetic drift. These methods have included assessments of both craniometric, binary non-metric and macromorphoscopic features. All of these have been criticized for depending on pre-defined criteria that have little consideration of mixed ancestry, relying too heavily on database reference data and generally failing to take human inter-population variation fully into account (Jantz 2013, Sierp and Henneberg 2015, Elliot and Collard 2009).

E224 displays predominantly 'European' cranial features, with sloping orbits, a narrow nasal cavity (leptorrhine; index: 44.7), a narrow face (leptoprosopic; index: 91.5), a flat facial profile (orthognathous; index: 90.0), and a slightly 'round-headed' (brachycranic; index: 80.3) cranium that displays a slight pentagonal shape. The cranial vault, however, is slightly asymmetric, with a left lateral projection of the temporal and parietal squama. Furthermore, the cranium displays a marked nasal spine, an irregular palatine suture and a moderately projecting chin which are also traits commonly observed in European skulls (Gill 1998).

However, we now recognise that while certain anatomical features and skeletal variations are more common in some population groups than others, they are not particular and specific determinants of ancestry. In our assessment we also applied multivariate statistical methods that assess macromorphoscopic cranial and postcranial features, and craniometric variables to give more nuanced ancestry estimations. Spiros & Hefner's (2020) method based on data in the Macromorphoscopic Databank at the Michigan State University (Spiros and Hefner 2020) perfectly predicts E224 as being of European ancestry (κ=1.000, 95% CI (0.986 to 1.000). However, this method is currently only used for differentiating anatomical variation between European and sub-Saharan skeletons (Spiros and Hefner 2020), the result can only be interpreted as an indication that the individual is very unlikely to be of Sub-Saharan ancestry.

Alternatively the AncesTrees program uses a random-forest machine-learning assemble algorithm to predict ancestry based on a compiled craniometric database of over 1,700 crania of individuals from six major ancestral groups (European, African, Austro-Melanesian, Polynesian, Native American and East Asian) (Navega *et al.* 2015). The results of this analysis placed the cranial shape of individual E224 as being most similar to the European populations, at moderate agreement prediction level (κ=0.765, 95% CI (0.901 to 0.947)). Through validation analyses, AncesTrees has been shown to be successful in predicting ancestry for 79% for European crania, and 94% accurate when differentiating between African and European crania (Navega *et al.* 2015). The results from these multivariate analyses therefore suggests that, at least based on its similarity to current reference databases, the ancestry of E224 is unlikely to have been African or Polynesian, and they were more likely of European ancestry.

MtDNA

MtDNA analysis was conducted on the second molar at the dedicated aDNA lab at the University of Otago (Knapp *et al.* 2012). Preparatory and analytical procedures are detailed in Supplementary Methods. A complete mitogenome sequence was recovered, with an average read-depth of 57.6X. The mitochondrial haplogroup was determined using HaploGrep (Kloss-Brandstätter *et al.* 2011) for Phylotree Build 17 (van Oven 2015) which indicated that MS10669 (E224) belongs to Haplogroup H1e2. Mitochondrial haplogroup H is one of the most common haplogroups in Western Europe, representing more than 40% of modern mitochondrial lineages in the region (Brotherton *et al.* 2013). Lineages belonging to the H1 sub-branch represent over 50% of the H lineages and are estimated to have emerged around 22,500 years ago, becoming more common and widespread as a result of the Neolithic expansion. H1 lineages are found throughout Eurasia and North Africa, with the highest frequencies found in Iberia, Southwest France and Sardinia. The subgroup H1e is found in Neolithic German samples (Brotherton *et al.* 2013) and today, the lineage

H1e2 is not uncommon in Western Europeans including in the UK (FamilyTree 2020).

The mtDNA haplogroup determined for this individual, H1e2, is a Western European lineage which indicates that the maternal ancestry of this individual is unlikely to have been sub-Saharan African or African American. African derived mitochondrial lineages most commonly fall into Haplogroup L. While it is not impossible for a person of African American ancestry living in the mid to late 1800s to have a Western European mitochondrial lineage, it is highly unlikely (Ely *et al.* 2006, Johnson *et al.* 2015).

HEALTH AND DISEASE

Oral health

Assessments of tooth wear and oral conditions can provide information regarding diet, oral health, lifestyle factors and physiological stress such as inadequate nutrition or disease during tooth development (Hillson 2014, Ogden 2008). In this study, the maxillae and mandible of E224 were assessed under florescent and incandescent lighting using (1.75 ×) magnification and a dental pick when necessary. Tooth wear and oral conditions were assessed using standard methods for wear (Scott 1979, Smith 1984), caries (Hillson 2008), antemortem tooth loss (Hillson 2014), calculus (Brothwell 1981), alveolar lesions (Dias and Tayles 1997, Willis and Oxenham 2013), linear enamel hypoplasia (LEH) (Hillson 2014), and staining.

E224 displayed high rates of caries, calculus, alveolar lesions, antemortem tooth loss and showed evidence for periodontal disease. Carious lesions affected 28.6% of his teeth (6/21) on the interproximal, occlusal and root surfaces. Two massive caries destroyed the entire crown and most of the roots of the upper right and lower left first molars, leaving only residual root fragments behind (Figure 5). For the lower molar, this crown destruction likely occurred early in life because the adjacent second and third molars shifted forward to fill in the space of the first molar crown.

Mild to moderate calculus deposits were present on 89.5% of his intact teeth (17/19) (Brothwell 1981) (Figure 5). Four alveolar lesions were observed, three of which were in the form of periapical granulomas (< 3 mm) and one presented as a likely acute abscess that had formed secondarily from a periapical cyst (Dias and Tayles 1997). Including the two teeth with residual roots remaining from massive caries, a total of six posterior teeth were lost antemortem. From the presence of the massive caries elsewhere in his mouth, it is feasible that these teeth also succumbed to caries infections. He had advanced periodontal disease

Figure 5. A. Anterior view of E224 cranium showing the pipe facet (straight arrow) and interproximal caries and brown staining (wavy arrows). B. Buccal view of right anterior cranium showing periapical granulomas above the right premolar and first molar and possible acute abscess in the sockets of the second and third molars (straight arrows). The wavy arrow points to the remaining root of the first molar that had been destroyed by a massive caries. Advanced periodontal disease can be seen on the alveolar bone.

on both the maxillae and mandible. The tooth wear was mild to moderate (Scott grades 1–3 for molars and Smith grades 1–4 for anterior teeth and premolars) and the heaviest wear was located on the maxillary incisors. There were pipe facets present on the right and left sides of the mouth (Figure 5) and some brown staining on the lingual and interproximal surfaces of the teeth, suggesting that this man was a habitual tobacco pipe smoker.

LEH, which manifests as band-like defects in the enamel associated with periods of stress or disruption during development, was observed on most teeth (12/16; 75.0%) and over half of these teeth (8/11; 72.7%) displayed more than one defect per tooth (Figure 6). Anterior teeth are thought to be more susceptible to LEH formation (Goodman and Armelagos 1985) but LEH was also observed on the premolars of E224. The age of formation of LEH on the anterior teeth can be estimated using the LEH chronology calculator for northern Europeans (Cares Henriquez and Oxenham 2019). From these equations, it is proposed that the LEH formed episodically between the ages of 1.8 and 4.5 years old (Table 1). LEH was also on both the lower and upper parts of the first and second premolar crowns that form between 3.5 and 7.5 years (AlQahtani *et al.* 2010), indicating growth disruption occurred into later childhood. Mottled hypocalcifications were also observed on the second and third left mandibular molars.

Figure 6. A. Buccal view of left mandible of E224. Straight arrows denote three teeth with LEH defects, black arrows detail the position of the LEH. Pipe facets are present on teeth 33 and 34. The mesial root of tooth 36 that had been destroyed by a massive caries is shown by the wavy arrow. Note that the second and third molars have shifted mesially, indicating this tooth loss likely occurred earlier in life. The labial aspect of mandibular incisors is covered by moderate calculus deposits. B. Occlusal view of the mandible. Antemortem tooth loss of first and second right and left first molars is demarcated by the squiggle arrows. Mottled hypocalcifications of the left second and third molars are shown by the straight arrows.

Table 1. *Timing (years) of LEH formation for the anterior teeth of E224.*

Tooth[1]	Wear %[2]	Timing 1[3]	Timing 2[3]	Timing 3[3]	Timing 4[3]	Timing 5[3]
11	5	2.2	2.8			
21	5	1.8	2.0			
22	10	3.3	3.5			
23	10	3.1	3.3			
43	15	2.7	3.0	3.2	3.7	4.5
33	20	3.1	3.3	3.7	4.0	

1 Tooth ID using FDI system; 11 = right upper central incisor, 21 = left upper central incisor, 22 = left upper lateral incisor, 23 = left upper canine, 43 = right lower canine, 33 = left lower canine
2 Wear % calculated using Smith (1984) wear grades for anterior teeth: Grade 1: 2.5%, Grade 2: 5%, Grade 3: 10%, Grade 4: 15%, Grade 5: 20%
3 Timing in years of LEH formation from Cares Henriquez and Oxenham (2019), multiple timings mean that there were multiple LEH defects on a single tooth

Skeletal Pathology

All the bones were extremely well preserved allowing an assessment of any pathological bone change present. All synovial joints of the limbs were present (except some joints of the hands which were absent) and were clear of degeneration. There was also minimal to no degenerative changes in the hands or spine. There was porosity and some subchondral bone alteration of both temporomandibular joints (TMJ) of the skull, suggesting some degeneration. The right mandibular condyle was very slender compared to the left, but with no associated bony change indicating pathology, such as trauma, and may be related to the asymmetry of the cranial vault mentioned above. The occipital condyles where the neck vertebra meets the base of the skull were also free of degenerative changes. The right scapula has *os acromiale* which is an unfused secondary epiphysis of the acromial process. Extensive porosity on the surfaces between the two elements suggest some degenerative changes were occurring (Figure 7). In bioarchaeology this lesion has been interpreted as a consequence of over use of the shoulder joint in adolescence (Stirland 1984, Stirland and Waldron 1997). More recent studies that account for ancestry and workload differences in cohorts, have argued the phenotype is more likely genetically controlled and may be exacerbated by strenuous activity (Case *et al.* 2006, Hunt and Bullen 2007). Regardless of the ultimate aetiology, the defect is usually asymptomatic, however it can cause impingement and trauma to the rotator cuff muscles making shoulder movements limited and painful (Edelson *et al.* 2001, Hunt and Bullen 2007). Bilateral assessment was hindered by postmortem damage to the left scapula.

The right tibia has ossification of the distal tibiofibular syndesmosis ligament attachment sites (Figure 8). These bony changes are likely the result of trauma to the joint between the two bones, leading to ossification of the damaged ligament. There is also slight osteophyte formation around the margins of the distal tibia articular surface, suggesting some degeneration to the joint. Injury to the ligaments can be of greater clinical significance than bone fracture as ligaments are formed of a tissue that is less vascularised than bone and heals very slowly (Hauser *et al.* 2013).

Slight abnormal porosity of the greater wing of the sphenoid is present and clearer abnormal porosity is present on the pterygoid plates. Abnormal porosity and remodelled new bone are present on the zygomatic bones in areas associated with muscle attachment sites (Figure 9). The posterior maxillae exhibit regions of abnormal porosity and vascular impressions and there is active new bone on the alveolar ridge above the third molar (Figures 10 and 11). Porous new bone is present bilaterally surrounding the external auditory meatus (EAM) and an accessory foramen (non-pathological) was also present just superior and posterior to the left EAM (Figure 12). The left femur has diffuse, slight and remodelled subperiosteal bony reaction of all surfaces of the diaphysis except the anterior surface. The reaction at the proximal end is more haematoma-like in its form and is associated with muscle attachment sites (adductors) (Figure 13), but also extends in patches to the

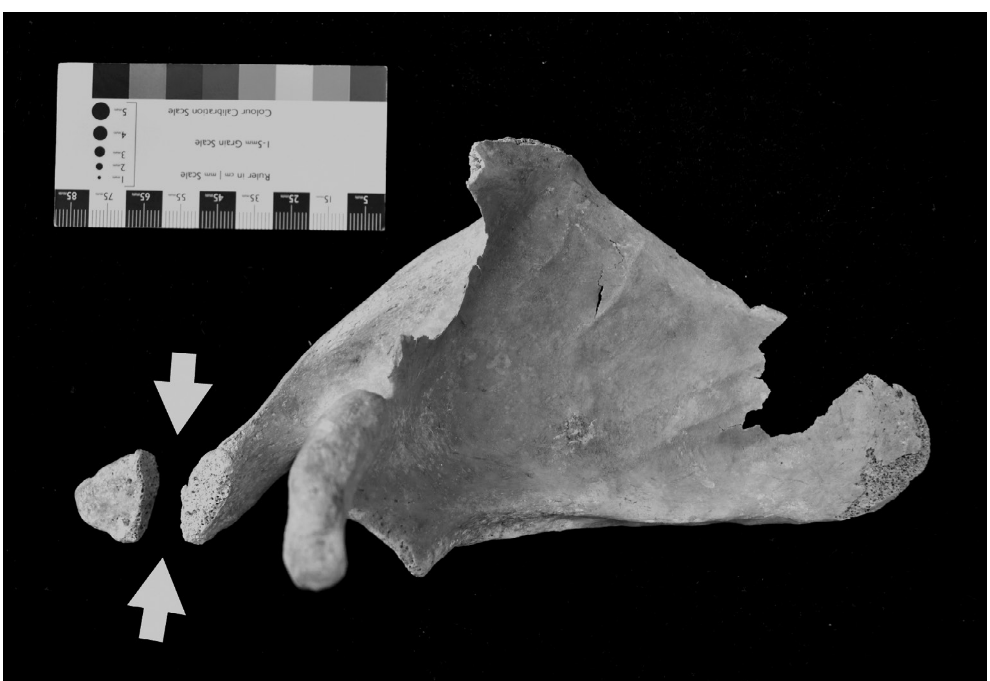

Figure 7. An *Os Acromiale* defect, and unfused secondary epiphysis, of the right scapula acromial process is indicated by the arrows.

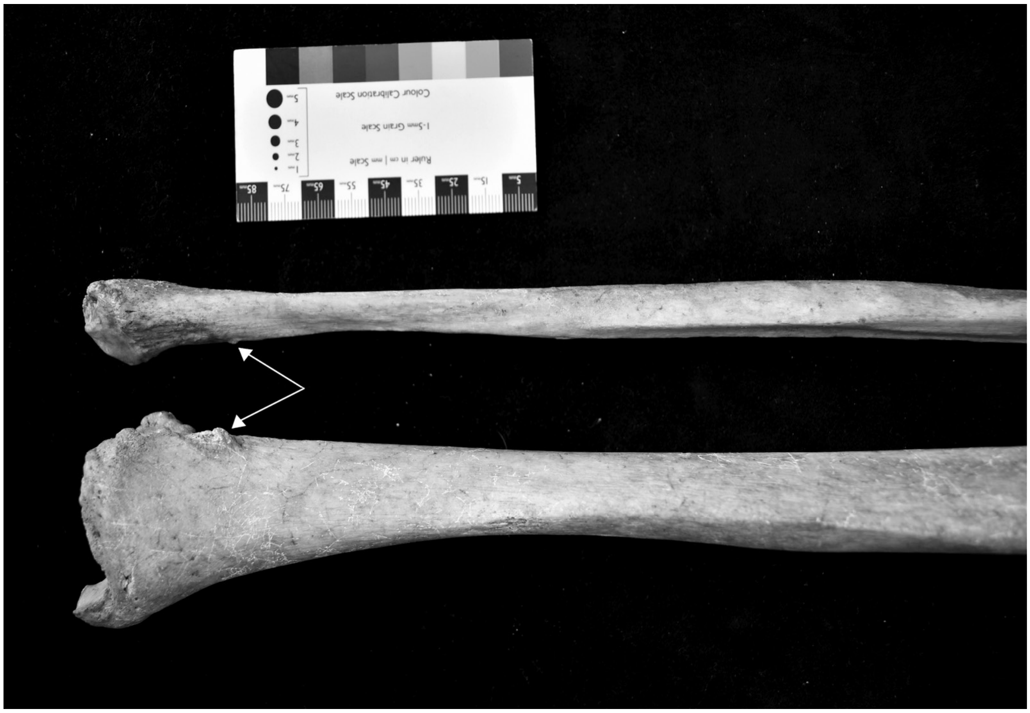

Figure 8. Distal right tibia and fibula. Ossification of the distal tibiofibular syndesmosis ligament attachment sites is indicated by the arrows.

distal portion. Both tibiae have remodelled osteoblastic lesions on the mid-shaft lateral surfaces and very slight discrete ossified haematomas on the posterior surfaces.

Causes of this type and pattern of bony change include a non-specific infection, trauma (Ortner 2003) and a haemorrhagic response to periodic vitamin C deficiency or scurvy (Brickley and Ives 2008, Brickley *et al.* 2020). Traumatic injury to the limbs is usually unilateral and limited in the region of bone affected (Lovell 1997) although

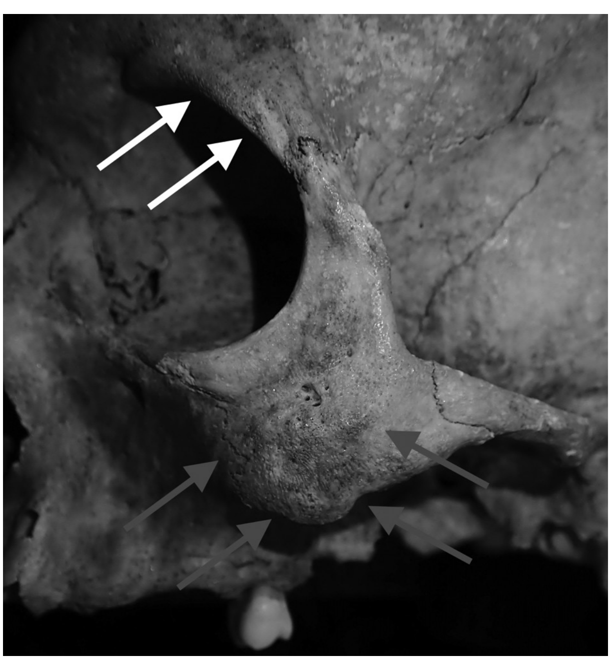

Figure 9. Left orbit and zygoma region. The arrows indicate regions of slight abnormal new bone production and porosity.

Figure 10. Right posterior maxilla. There is generalised abnormal porosity and vascular impressions in the region (arrowheads). There is also active new bone on the alveolar ridge above the socket for the third molar.

Figure 11. Left posterior maxilla. Generalised porosity and vascular impressions (arrowheads) and abnormal porosity of the pterygoid plate (dashed arrowhead).

extreme and multiple cases of trauma have been reported from an early colonial context previously (Petchey *et al.* 2018b). The uniform and severe loss of alveolar bone in the jaws is also a characteristic of adult scurvy (Maat 2004, Geber and Murphy 2012). The diagnosis of scurvy in dry bone of adults compared to infants and children is notoriously difficult due to the more accelerated rate of tissue production during growth (Snoddy *et al.* 2018). However, femoral lesions on the surfaces associated with vasculature and muscle attachment sites (Buckley *et al.* 2014, Geber and Murphy 2012), in combination with the cranial lesions known to be affected by microtrauma to weakened connective tissues in scorbutic episodes (Ortner and Ericksen 1997), suggest that this individual may have suffered from scurvy. A more definitive diagnosis is not possible due to the non-specific and subtle nature of the lesions exhibited. The formation of periosteal new bone in scurvy only occurs once some vitamin C has been reintroduced into the diet, allowing the production of new bone (Brickley *et al.* 2020). Therefore, the lesions present in E224 may represent a period (or several periods) when access to fresh foods was re-established, likely due to seasonal variation in the availability of produce.

CHEMICAL ANALYSIS OF MOBILITY AND DIET

Isotopic analysis was used to complement the osteological and archaeological techniques applied in this case study. In studying the isotopic composition of tissues forming in

Figure 12. Generalised abnormal porosity around the external auditory meatus. A non-pathological accessory foramen is also present (arrowhead with dotted line.

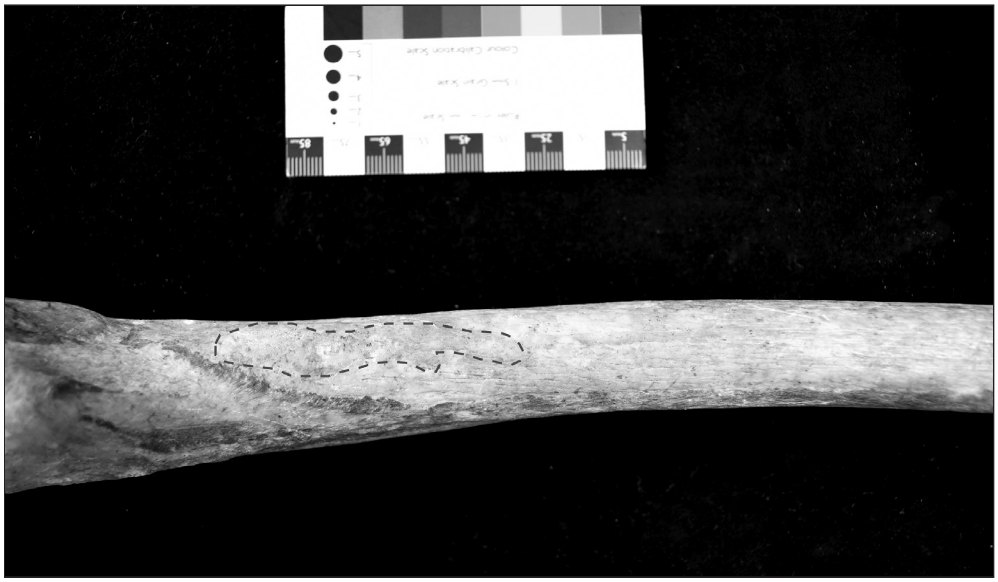

Figure 13. The left femur with the slight haematoma-like periosteal reaction (highlighted with dotted outline).

childhood (*i.e.* dentition), we can gain insight into E224's potential place of origin, as well as their childhood diet. Carbon and nitrogen stable isotopes (denoted at $\delta^{13}C$ and $\delta^{15}N$) from bone collagen will provide additional evidence of broad-scale diet during adulthood, and potentially how disease affected their diet.

Mobility

Strontium isotope ($^{87}Sr/^{86}Sr$) analysis of tooth enamel primarily provides a means of investigating migration and mobility of people who lived in the past (Bentley 2006, Montgomery *et al.* 2005). The interpretation of movement using strontium isotope analysis rests upon the assumption that the $^{87}Sr/^{86}Sr$ ratios of an individual's tooth enamel will generally reflect the $^{87}Sr/^{86}Sr$ ratios of the underlying geology in which they lived while the tooth was forming. Unlike lighter elements such as carbon and nitrogen, strontium does not undergo any substantial fractionation as it moves from the underlying bedrock and into the local biosphere (Evans *et al.* 2010, Price *et al.* 2002). Some caution in interpretation needs to be exercised, as other factors may cause bioavailable strontium ratios in an area to differ from those of the underlying groundrock. For example, in coastal areas bioavailable strontium can be affected by marine-based diets, sea spray (saltwater spray from the waves or high winds), and marine-derived precipitation (Laffoon *et al.* 2012, Burton and Price 1999, Whipkey *et al.* 2000), and movement of sediments through wind or glacial action may also result in unexpected bioavailable strontium isotope ratios (see Hoogewerff *et al.*, 2019 for a review). Strontium isotope analysis was conducted at the Department of Earth Sciences (Durham University). A 10mg chip of dental enamel was taken from the upper left second molar (tooth 27), representing early childhood to early adolescence (AlQahtani *et al.* 2010). Strontium was purified using established methods of column chemistry (Font *et al.* 2008) and analysis was undertaken using a ThermoFisher Neptune Multi Collector-Inductively Coupled Plasma-Mass Spectrometer (MC-ICP-MS) (see supplementary methods for more detail on the analytical procedure).

E224 has an 87Sr/86Sr ratio of 0.708599 ± 0.000013 (2SE). This value does fit within the known range for the pelitic schist of the area in which the burial was found (Duxfield *et al.* 2020). However, it is unlikely that he spent his childhood here–E224 is an individual with European ancestry, and his burial likely dates to the earliest period of European settlement of the Cromwell area. We can therefore be fairly confident that he had his origins outside of New Zealand. Most workers on the goldfields originated from Britain, Ireland or continental European regions such as the German states and Scandinavia (Phillips and Hearn 2008). If this is the case there are a myriad of potential regions of origin for E224. His Sr isotopic ratio aligns with many of the chalk and limestone formations in Europe, for example, much of southern and central England (Evans *et al.* 2010) central Ireland (Snoeck *et al.* 2020) northern and eastern France (Willmes *et al.* 2018), western Germany, Denmark and Switzerland (Bataille *et al.*). As many of those on the goldfields had British/Irish origins it is perhaps most likely that he hailed from the chalk and limestone formations that comprise much of southeastern England, and parts of Yorkshire, or the limestones of Ireland and/or the Pennines of England (Evans *et al.* 2010, Kendall *et al.* 2013). However, with limited information on this individual it is impossible to narrow down his place of origin.

Dietary isotope analysis

Carbon and nitrogen stable isotope values ($\delta^{13}C$ and $\delta^{15}N$ respectively) in bone and dentine collagen reflect the diet of an individual and allow the differentiation of marine and terrestrial diets – marine foods have less negative $\delta^{13}C$ and elevated $\delta^{15}N$ values (Ambrose and Norr 1993, Schoeninger and DeNiro 1984). $\delta^{13}C$ and $\delta^{15}N$ can also provide an estimate of the proportion and type of animal protein input in the diet, as $\delta^{15}N$ values (and $\delta^{13}C$ to a lesser extent) relate to trophic position within the food web. Omnivores have higher $\delta^{15}N$ values than herbivores, while apex carnivores exhibit the highest values (DeNiro and Epstein 1981). For diachronic data such as incrementally sampled dentine, $\delta^{13}C$ and $\delta^{15}N$ values may also measure changes in metabolic state. While parallel and corresponding changes in $\delta^{15}N$ and $\delta^{13}C$ likely reflect dietary change, negative (or opposite) covariance may signify either; (1) catabolism of the body's tissues during nutritional stress, as in the case of increasing $\delta^{15}N$ alongside decreasing $\delta^{13}C$; or (2) anabolism (growth or increase in body mass), in the case of increasing $\delta^{13}C$ with decreasing $\delta^{15}N$ (Mekota *et al.* 2006, Fuller *et al.* 2005).

We extracted and analysed both bone collagen (200 mg rib fragment) and dentine collagen (from the permanent left maxillary second molar, tooth 27 in FDI notation) in this study. Bone collagen isotope values reflect a time-averaged dietary signal from the years immediately preceding death (Fahy *et al.* 2017) while dentine can be analysed in serial sections to study diet at specific periods during childhood (Beaumont *et al.* 2013). In this case study, we aimed to examine childhood and early adolescence, capturing a time period likely unaffected by the weaning process and focusing on the individual's dietary changes as they grew up. The second molar forms between 2.5–15.5 years of age (AlQahtani *et al.* 2010), making it ideal for this purpose. Comparison of collagen results from tooth and bone therefore allows assessment of dietary change over the person's life course.

Collagen samples were analysed at the Stable Isotope Biochemistry Laboratory (SIBL, Durham University) according to methods provided in King *et al.* (2020). Standard collagen quality control parameters were used (DeNiro and Hastorf 1985); see supplementary table 1 for details). The period of life represented by each increment of dentinal collagen was calculated using the method of (Beaumont *et al.* 2015).

Dietary isotope results are given in full in supplementary table 1 and shown visually on Figure 14. The isotopic profiles (Figure 14) show that during childhood and adolescence isotopic values fluctuated between −19.4‰ and −18.5‰ ($\delta^{13}C$) and 11.0‰ and 12.2‰ ($\delta^{15}N$). Overall these values are consistent with a C3-plant and terrestrial meat dominated diet. During some periods of childhood (*e.g.* between approx 4–6 years of age) there are corresponding rises in $\delta^{13}C$ and $\delta^{15}N$ values which may reflect dietary fluctuations, such as periodic access to sugary foods (sugarcane being a C4 resource), or herbivore meat. Sugar consumption was rife in 19th Century Britain; even the lower classes would spend up to 2% of their income on its

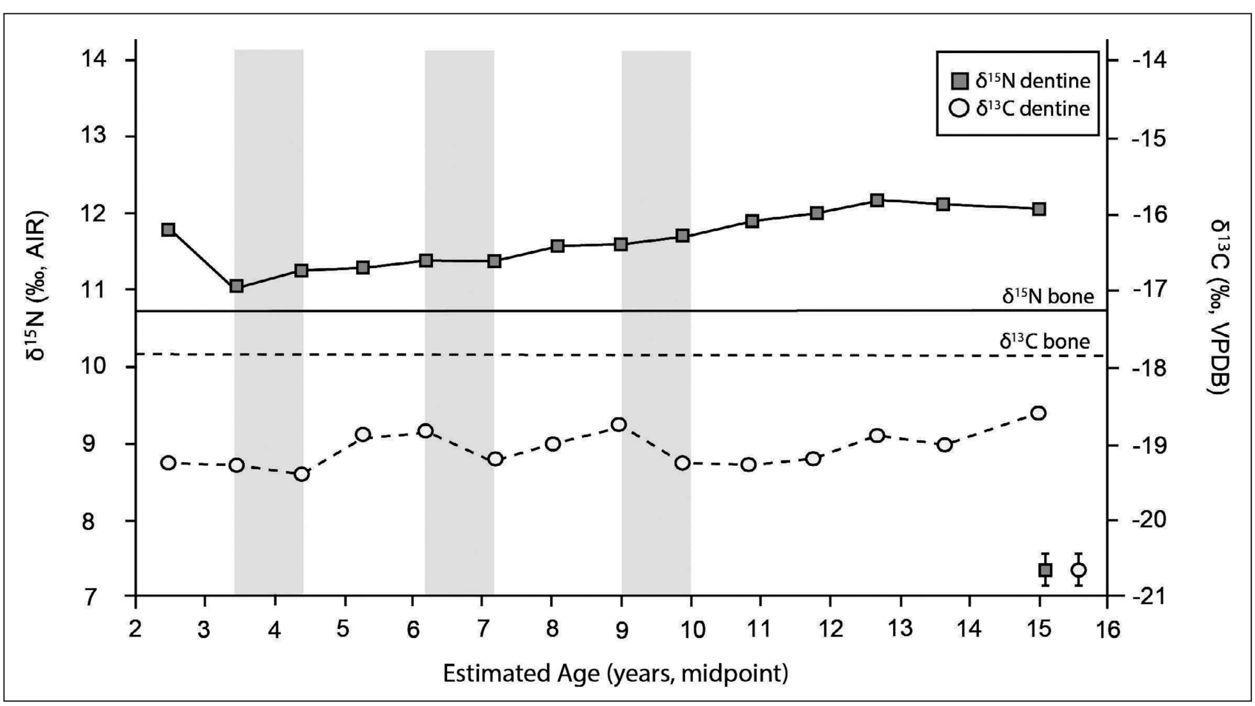

Figure 14. Results of dietary isotopic analyses. Grey boxes highlight areas where $\delta^{13}C$ and $\delta^{15}N$ values negatively covary or do not covary, suggesting periods of protein insufficiency.

consumption when they could (Gazeley 1989). It is possible that these isotopic changes represent periodic ability to buy sugar and associated products (*e.g.* condensed milk and treacle).

There are also other parts of E224's isotopic history where $\delta^{13}C$ value changes do not correspond with changes in $\delta^{15}N$ values, suggesting that non-dietary factors may also be a factor. In a study on the effects of anorexia on $\delta^{13}C$ and $\delta^{15}N$, Mekota (2006) suggested that while $\delta^{15}N$ had an inverse relationship with body mass index (BMI), $\delta^{13}C$ became more elevated with increasing BMI during recovery, reasoning that increased protein and fat intake accounted for the increased $\delta^{13}C$ values. It is possible that the $\delta^{13}C$ profile for E224 represents a record of fluctuating access to protein due to periodic food insecurity. This interpretation is supported by dental health data, with the period of elevated $\delta^{15}N$ alongside depressed $\delta^{13}C$ values in early childhood (< 4.5 years of age) correlating with a period of systemic stress represented by LEH. It is likely that this individual grew up in some poverty and precarity, with variable access to sources of animal protein during periods of nutritional demand and body growth. The increase in $\delta^{13}C$ seen in later adolescence, suggests that the fortunes of E224 may have improved as he moved from childhood to adolescence, despite later possible micronutrient deficiencies. With the lower values of $\delta^{13}C$ reflecting a diet high in C3 plants, the high prevalence of caries observed in E224 might not be a result of C4 foods such as sugar cane, but rather consumption of refined flour.

Later adult $\delta^{15}N$ values are approximately 1.5‰ below values from the end of tooth formation, and adult $\delta^{13}C$ values are over 0.5‰ above. These differences are not so significant as to suggest any major change in diet – they retained a C3 plant and terrestrial meat-dominated diet throughout their life. However, the pattern of an approximately 1.5–2.0‰ shift in $\delta^{15}N$ values in adulthood is one that has also been observed in early New Zealand colonial settlers, at the rural settlement of St. John's Milton (King *et al.* 2021b). King *et al.* (2021) attributed this pattern of change to baseline foodweb differences between the individuals' home countries and the New Zealand agricultural context. Specifically, nitrogen isotope values tend to be higher in European contexts, where fertilisation of agricultural land has been the norm for centuries. We therefore expect New Zealand $\delta^{15}N$ values to be lower, even with similar levels of meat consumption. It is likely that the isotopic changes between bone and tooth in this study are evidence of E224 having moved to New Zealand sometime between the end of tooth formation and later adulthood, rather than evidence of real dietary change.

THE LIFE COURSE AND POSTMORTEM EXPERIENCE

The macroscopic biological identity assessment of E224 is of a tall middle to old aged male of Western European ancestry, an assessment supported by the mtDNA and isotopic analyses. His cause of death and liminal burial location remain a mystery but this is not unusual in the New Zealand colonial context (Petchey *et al.* this issue). Another more gruesome aspect to consider is that his identification after drowning was simply not possible. Bloating and skin slippage can alter a person's appearance dramatically to the point where ancestry and even sex are not possible to determine. Skin colour also changes dramatically over time with decomposition in a wet environment and after a period of weeks the skin becomes very dark (Caruso 2016). Nevertheless, despite E224 being a single individual of unknown identity and enigmatic burial, his earthly remains encapsulate a typical early gold digger's life with experiences of poor beginnings and an ignoble, often anonymous end. An integration of the osteology, molecular and chemical information of this person's life course is outlined below.

Early Life

The high number of linear enamel hypoplasia (LEH) defects on the anterior dentition indicate that he experienced periods of disrupted growth between the ages of 1.8 and 4.5 years of age. LEH were also present across the crowns of the maxillary and mandibular first and second premolars, which form between 3.5–7.5 years (AlQahtani *et al.* 2010) indicating that the growth disruption continued into later childhood. Although not mutually exclusive, the most common environmental stressors that may adversely affect child health are inadequate nutrition and disease (Lewis 2007). Evidence from dietary isotopes supports the interpretation of nutritional stress in early childhood, which may have arisen from undernutrition, infection, or a synergistic interaction between the two.

Strontium isotope analysis indicates a place of origin in an area of marine sedimentary geology, with potential regions including much of southern England, central Ireland and Western Europe. Dietary isotopic shifts in later life suggest that he was born elsewhere and moved to New Zealand sometime in early adulthood. The interpretation of origins in Industrial Revolution period Europe is supported by the dental indicators of stress in early life. Unhealthy living conditions during this period of increased urbanisation and industrialisation resulted in high rates of infectious and metabolic diseases exacerbated by inadequate food resources among the urban and rural poor in mid-nineteenth-century England, and children were generally most severely affected by these issues (Roberts and Cox 2003a, King *et al.* 2005, Walker 2012). However, incremental isotope analysis also demonstrated that E224's protein consumption increased from childhood to adolescent life, suggesting a probable improvement in his circumstances as he entered the workforce and became financially independent.

Adulthood

E224 had poor oral health and likely suffered from discomfort, pain and halitosis during life as a result. He may have had an increased risk for developing infectious and systemic diseases as a result of these conditions, especially periodontal disease (Li *et al.* 2000). The causes of tooth decay are multifactorial and are influenced by factors such as salivary flow and composition, clearance time for food, diet, oral microbe diversity, fluoride consumption, tooth morphology and lifestyle factors including socio-economic position, poor oral hygiene, smoking, and drug use (Selwitz *et al.* 2007, Simón-Soro and Mira 2015). The low degree of tooth wear on his posterior teeth suggests his diet was relatively soft and, from historical accounts, likely consisted of flour-based foods (*e.g.* damper or gruel), meat, canned foods such as sardines, and fresh fruits and vegetables when they were (rarely) available (Eldred-Grigg 2008). The soft, high carbohydrate diet, limited oral hygiene and smoking likely contributed to the poor oral health of this individual (Geber and Murphy 2018). Tobacco use through pipe smoking was a ubiquitous habit among men during this period and increases susceptibility to tooth decay (Voelker *et al.* 2013) and periodontal disease (Kinane and Chestnutt 2000).

Poor oral health is a common observation in nineteenth-century skeletal populations from the United States, Canada, Europe (Saunders *et al.* 1997, Roberts and Cox 2003a, Buzon *et al.* 2005, Roberts and Cox 2003b) and New Zealand (Buckley *et al.* 2020). High rates of caries (especially cervical and root caries), calculus, antemortem tooth loss and periodontal disease have also been observed in mid-nineteenth-century adults buried at the Kilkenny Union Workhouse famine burial ground in Ireland. The low cariogenicity of the diet of these individuals, likely to be almost exclusively made up of potatoes and milk, led to the conclusion that lifestyle factors, especially smoking, poor oral hygiene and lack of available dentistry due to poverty, were likely the biggest contributors to the poor oral health observed in the sample (Geber and Murphy 2018). People of higher socio-economic status were also plagued by poor oral health; in London during the late eighteenth and early to mid-nineteenth-century, populations displayed caries rates above around 30% for adult 26 years and older (Henderson *et al.* 2013, Whittaker 1993). However, dental treatment was more readily available to this group (Roberts and Cox 2003b). In Britain, and likely in New Zealand at the same period in history, poor dental health was associated with the consumption of refined flour and cane sugar, especially in tea (Gazeley 1989), and the almost non-existent oral hygiene and dentistry. For the especially poor, dentistry would have consisted of pulling affected teeth and lancing abscesses (Roberts and Cox 2003b). Isotopic evidence for diet suggests that E224 retained a traditional British dietary base of C_3 crops and terrestrial meat in adulthood. However, there is no isotopic evidence of significant consumption of C_4 plants (*e.g.* sugar) in the later life dietary data of E224 (cf. possible indicators of periodic sugar consumption in his early life). We therefore suggest it is probable that the cariogenic influence in his diet is more likely to have come from refined flour than sugar.

Scurvy was known to be rife in the early period of the Otago goldfields, due to very limited access to fresh foods such as green vegetables and fruit (Pyke 1962) and is a possible cause of some of the inflammatory skeletal lesions in E224. If he was a tobacco user, then this, too, may have played a part, as smoking is an independent risk factor for the development of scurvy, apart from diet (Schectman *et al.* 1989). Archaeological evidence from the nearby site of the Halfway House Hotel in the Cromwell Gorge suggests that beef and sheep meat were important, with chicken (and eggs), goose, fish and shellfish all present in small amounts. Unfortunately, archaeological evidence of vegetable and flour consumption does not generally survive, but the presence of fruit kernels show that peaches and apricots were also being eaten, when seasonally available (Bedford 1986; Petchey *et al.* this issue).

The trauma causing the ossification of the ligaments in his leg is most frequently caused by rotation of the ankle joint in collision sports (*e.g.* football, rugby) and skiing accidents (Rammelt *et al.* 2008), but in the late nineteenth century is more likely to have been related to work or travel by foot on poor tracks. This type of injury may represent a period of pain and disability for this individual at some point in the last few years of his life. As this injury was healing, even if not severe, the use of the leg would have been limited for some time. Severe trauma on the goldfields is well documented historically (White 2017) and injuries requiring periods of care have been reported elsewhere in the Otago bioarchaeological record (Petchey *et al.* 2018b, Buckley *et al.* 2020). In this frontier context of limited health care and social welfare, he may have required support from a caregiver or the community for a period of up to 2–3 months.

Death

The cause of death remains unknown, although drowning as suggested by the local story does remain the most logical possibility, given the proximity of the grave to the river and the documented contemporary high incidence of drownings. The circumstances of the burial and the subsequent disturbance of the grave are explored in more detail in Petchey *et al.* (this issue). Liminal burials were not unusual in frontier New Zealand, where deaths often occurred some distance from the nearest settlement or formal cemetery (Dwyer 2007): further downstream at Horseshoe Bend is the well-known grave of 'Somebody's Darling,' probably Charles Alms who drowned in the Clutha River in 1865 and was buried on the valley side above where his body was found.

CONCLUSIONS

An aspect of the Bioarchaeology of Personhood model is to tell an individual's narrative using 'fictive narrative' (Boutin 2016) which is embedded in the story told by the individuals earthly remains. The following is a brief attempt to tell this man's story in his own words:

> After a hard-days walk, the man struggled to the top of the ridge capped with enormous schist slabs and hardy golden tussocks clinging to the thin earth. He looked down into the gorge and sighed. The milky river twisted and roared far beneath him. Another few hours before he could make camp for the night. But a short smoko wouldn't hurt. The nor'wester was strong up on the tops so he found a small nook within the schist, shrugged off his pack and dug out his pipe. Wincing and groaning as he sat down, hard cool rock against his back, he rubbed at his ankle that still gave him trouble after all this time. The boots he had bought cheap really weren't suited to the life of a digger and they had put him crook on a number of his treks through the hills. Sucking on his teeth and wincing again he smiled wryly to himself; maybe with summer on its way there will be some good fresh food on the offing and he would be able to track down a tooth puller to sort out the nagging pain in his jaws. Things weren't so easy as a young boy back home but a man doesn't know hard 'til he's tried to scratch out a living in this grey and black land awhile. Lighting his pipe, he sucked hard and drew in the hot comforting clouds of smoke and relaxed awhile. Rising stiffly and shouldering his pack, he looks down the track he must follow and hopes his boots carry him through the slippery slopes.

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