Archaeologies: Journal of the World Archaeological Congress (© 2023)
https://doi.org/10.1007/s11759-023-09469-2

The Impact of Contact: Isotope Geochemistry Sheds Light on the Lives of Indigenous Australians Living on the Colonial Frontier in Late 19th Century Queensland

RESEARCH

Shaun Adams, Australian Research Centre for Human Evolution, Griffith University, Nathan, QLD 4111, Australia; Everick Foundation, 9/110 Mary St, Brisbane, QLD 4000, Australia
E-mail: adams.archaeo@gmail.com

Mark Collard, Department of Archaeology, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A 1S6, Canada

David McGahan, Australian Research Centre for Human Evolution, Griffith University, Nathan, QLD 4111, Australia

Richard Martin, School of Social Sciences, University of Queensland, St Lucia, QLD 4072, Australia

Susan Phillips, New South Wales and Queensland Bar Associations, 13 St James Hall, Sydney, NSW 2000, Australia

Michael C. Westaway, School of Social Sciences, University of Queensland, St Lucia, QLD 4072, Australia

Accepted: 13 February 2023 / Published online: 20 March 2023

ABSTRACT

Here, we report the first attempt to use isotope geochemistry to improve understanding of the experiences of Indigenous Australians living on the colonial frontier in late 19th century CE Australia. In the study, we analysed strontium ($^{87}Sr/^{86}Sr$), carbon ($\delta^{13}C$), and oxygen ($\delta^{18}O$) isotope ratios from the tooth enamel and dentine of six individuals who died in Normanton, Queensland, in the 1890s. The study was a collaboration between scientists and the local Traditional Owners, the Gkuthaarn and Kukatj people, and was carried out to promote truth and reconciliation. The enamel $^{87}Sr/^{86}Sr$ results suggest that the individuals moved to Normanton from three geologically distinct regions during the period of European expansion into the Gulf of

Carpentaria, Cape York. This is consistent with the oral histories and historical documents, which suggest that many Indigenous people in the Gulf Country were displaced to camps on the outskirts of towns like Normanton because of European settlement. The $\delta^{13}C$ values we obtained indicate that the individuals mostly ate C_4 plants and/or C_4-plant-consuming herbivores. When combined with the fact that some of the individuals' teeth had dental caries, this suggests that the individuals may have had regular access to introduced foods. The enamel $\delta^{18}O$ values are high compared to an international comparative sample, at 0.72–4.69‰ VPDB. We suspect the elevated values are due to a combination of a high degree of preferential loss of ^{16}O through evaporation of surface water, the amount effect associated with the Australian monsoon, and high prevalence of introduced infectious diseases. Together, the results of our study demonstrate that isotopic analysis of human remains has the potential to further illuminate the effects of European colonisation on Indigenous people in Australia. Perhaps most importantly in connection with this, our study's results show that isotopic analyses of human remains can provide surprisingly detailed information about the lives of a category of Indigenous Australians who rarely appear in the documents written by early ethnographers and colonial officials—subadults. That the analysis of the skeletal remains of Indigenous Australians can now contribute to the truth and reconciliation process is an unexpected, interesting, and welcome development in the story of bioarchaeology in Australia.

Resume: Nous faisons ici état de la première tentative d'utilisation de la géochimie isotopique pour mieux comprendre les expériences des Australiens autochtones qui vivaient à la frontière coloniale de l'Australie centrale à la fin du 19e siècle. Durant notre étude, nous avons analysé des rapports isotopiques de strontium ($^{87}Sr/^{86}Sr$), de carbone ($\delta^{13}C$) et d'oxygène ($\delta^{18}O$) provenant de l'émail dentaire et de la dentine de six personnes décédées à Normanton au Queensland dans les années 1890. L'étude, dirigée pour promouvoir la vérité et la réconciliation, est le fruit de la collaboration de scientifiques et de propriétaires terriens ancestraux, les peuples Gkuthaarn et Kukatj. Les résultats des rapports d'analyse de l'émail 87Sr/86Sr suggèrent que les sujets de l'étude sont arrivés à Normanton de trois régions uniques au point de vue géologique durant la période d'expansion européenne à l'intérieur du golfe de Carpentaria à Cape York. Cela concorde avec les récits oraux et les documents historiques existants qui suggèrent que plusieurs peuples autochtones de la région du golfe ont été déplacés vers des camps aux limites de villes comme Normanton pour faire place aux colonies européennes. Les valeurs $\delta^{13}C$ obtenues démontrent que les sujets consommaient principalement des plantes C4 ou des herbivores mangeurs de plantes C4, ou les deux. Certains sujets

présentaient des caries et cela suggère que ces derniers avaient probablement accès à des aliments introduits. Les valeurs d'émail δ^{18}O sont élevées en comparaison à celles d'un échantillon comparatif international de 0,72 à 4,69% VPDB. Nous supposons que ces valeurs élevées sont dues à une combinaison de facteurs, soit le haut degré de perte préférentielle de 16O par l'évaporation de l'eau de surface, l'effet volumétrique associé à la mousson australienne et la forte prévalence de maladies infectieuses introduites. Collectivement, les résultats de notre étude démontrent que l'analyse isotopique des dépouilles peut faire la lumière sur les effets de la colonisation européenne sur les peuples autochtones en Australie. Point possiblement encore plus important dans ce contexte, les résultats de notre étude démontrent que les analyses isotopiques de dépouilles humaines peuvent fournir des renseignements étonnamment détaillés sur la vie d'une catégorie d'Australiens autochtones dont il est rarement question dans les documents écrits par les ethnographes de jadis et les représentants—subadultes coloniaux. Le fait que l'analyse d'ossements d'Australiens autochtones puisse aujourd'hui contribuer au processus de vérité et de réconciliation constitue un développement inattendu, intéressant et bienvenu dans l'histoire de la bioarchéologie en Australie. Resume Nous faisons ici état de la première tentative d'utilisation de la géochimie isotopique pour mieux comprendre les expériences des Australiens autochtones qui vivaient à la frontière coloniale de l'Australie centrale à la fin du 19e siècle. Durant notre étude, nous avons analysé des rapports isotopiques de strontium (87Sr/86Sr), de carbone (δ^{13}C) et d'oxygène (δ^{18}O) provenant de l'émail dentaire et de la dentine de six personnes décédées à Normanton au Queensland dans les années 1890. L'étude, dirigée pour promouvoir la vérité et la réconciliation, est le fruit de la collaboration de scientifiques et de propriétaires terriens ancestraux, les peuples Gkuthaarn et Kukatj. Les résultats des rapports d'analyse de l'émail 87Sr/86Sr suggèrent que les sujets de l'étude sont arrivés à Normanton de trois régions uniques au point de vue géologique durant la période d'expansion européenne à l'intérieur du golfe de Carpentaria à Cape York. Cela concorde avec les récits oraux et les documents historiques existants qui suggèrent que plusieurs peuples autochtones de la région du golfe ont été déplacés vers des camps aux limites de villes comme Normanton pour faire place aux colonies européennes. Les valeurs δ^{13}C obtenues démontrent que les sujets consommaient principalement des plantes C4 ou des herbivores mangeurs de plantes C4, ou les deux. Certains sujets présentaient des caries et cela suggère que ces derniers avaient probablement accès à des aliments introduits. Les valeurs d'émail δ^{18}O sont élevées en comparaison à celles d'un échantillon comparatif international de 0,72 à 4,69% VPDB. Nous supposons que ces valeurs élevées sont dues à une combinaison de facteurs, soit le haut degré de perte préférentielle de

16O par l'évaporation de l'eau de surface, l'effet volumétrique associé à la mousson australienne et la forte prévalence de maladies infectieuses introduites. Collectivement, les résultats de notre étude démontrent que l'analyse isotopique des dépouilles peut faire la lumière sur les effets de la colonisation européenne sur les peuples autochtones en Australie. Point possiblement encore plus important dans ce contexte, les résultats de notre étude démontrent que les analyses isotopiques de dépouilles humaines peuvent fournir des renseignements étonnamment détaillés sur la vie d'une catégorie d'Australiens autochtones dont il est rarement question dans les documents écrits par les ethnographes de jadis et les représentants—subadultes coloniaux. Le fait que l'analyse d'ossements d'Australiens autochtones puisse aujourd'hui contribuer au processus de vérité et de réconciliation constitue un développement inattendu, intéressant et bienvenu dans l'histoire de la bioarchéologie en Australie.

Resumen: Aquí informamos el primer intento de utilizar la geoquímica de isótopos para mejorar la comprensión de las experiencias de los indígenas australianos que vivían en la frontera colonial a fines del siglo XIX en Australia. En el estudio, analizamos las proporciones de isótopos de estroncio ($^{87}Sr/^{86}Sr$), carbono ($\delta^{13}C$) y oxígeno ($\delta^{18}O$) del esmalte dental y la dentina de seis personas que murieron en Normanton, Queensland, en la década de los 1890. El estudio fue una colaboración entre científicos y los propietarios tradicionales locales, los pueblos gkuthaarn y kukatj, y se llevó a cabo para promover la verdad y la reconciliación. Los resultados del esmalte 87Sr/86Sr sugieren que los individuos se trasladaron a Normanton desde tres regiones geológicamente distintas durante el período de expansión europea en el Golfo de Carpentaria, Cabo York. Esto es consistente con las historias orales y los documentos históricos, que sugieren que muchos indígenas en la región del Golfo (Gulf Country en inglés) fueron desplazados a campamentos en las afueras de pueblos como Normanton debido al asentamiento europeo. Los valores de $\delta^{13}C$ que obtuvimos indican que los individuos en su mayoría comieron plantas C4 y/ o herbívoros que consumen plantas C4. Cuando se combina con el hecho de que algunos de los dientes de las personas tenían caries dental, esto sugiere que las personas pueden haber tenido acceso regular a los alimentos introducidos. Los valores de $\delta^{18}O$ del esmalte son altos en comparación con una muestra comparativa internacional, entre 0,72 y 4,69‰ VPDB. Sospechamos que los valores elevados se deben a una combinación de un alto grado de pérdida preferencial de 16O a través de la evaporación del agua superficial, el efecto de cantidad asociado con el monzón australiano y la alta prevalencia de enfermedades infecciosas introducidas. Juntos, los resultados de nuestro estudio demuestran que el análisis isotópico de restos humanos tiene el potencial de iluminar aún más los efectos de la colonización europea en los pueblos indígenas de Australia. Quizás lo más importante en relación con esto es que los resultados de nuestro estudio muestran que los análisis isotópicos de restos humanos pueden proporcionar información sorprendentemente detallada sobre las vidas de una categoría de indígenas australianos que rara vez aparecen en los documentos escritos por los primeros etnógrafos y funcionarios coloniales: subadultos. El hecho de que el análisis de los restos óseos de los indígenas australianos ahora pueda contribuir al proceso de verdad y reconciliación es un desarrollo inesperado, interesante y bienvenido en la historia de la bioarqueología en Australia.

KEY WORDS

Community archaeology, Bioarchaeology, Indigenous archaeology, Isotopes, Archaeological science, Aboriginal Australians

Introduction

This paper reports a study in which isotopic data were used to shed light on the lives of six young Indigenous Australians who died in the town of Normanton, far north Queensland, in the 1890s. The study was a collaboration between scientists from several institutions and the local Traditional Owners, the Gkuthaarn and Kukatj people.

During the late 19th century CE, many Indigenous Australians living in northern Queensland were displaced to camps on the outskirts of towns like Normanton due to frontier violence associated with the spread of the pastoral and mining industries, as well as the availability of items like flour, sugar, tobacco, tea, and opium (Martin 2019). Conditions in the camps were crowded and communicable disease caused the deaths of many people (Campbell 2007). The remains of some of these individuals were acquired by Dr Walter Roth, who was a medical doctor, ethnologist, and the first North Queensland Protector of Aborigines (Khan 1993). In 1905, Roth sold the human remains he had collected in northern Queensland to the Australian Museum in Sydney, New South Wales. The six sets of remains that were the focus of the present study were among those acquired by the Australian Museum.

In the 1990s, the museum repatriated the skeletal remains to the Gkuthaarn and Kukatj Aboriginal people at Normanton, and the individuals were interred near the town. In 2015, some of the remains were exposed by erosion. Shortly after their rediscovery representatives of the

Gkuthaarn and Kukatj people asked MCW to help them re-inter the individuals in a secure location. The representatives of the Gkuthaarn and Kukatj people also expressed a wish to participate in a collaborative research project to carry out scientific analyses to find out more about the lives of the individuals. They hoped the analyses could provide information on injustices in Australia's colonial period and therefore aid the truth and reconciliation process (Adams et al. 2018).

In a previous paper in this journal, Adams et al. (2018) provided a description of the excavation and an assessment of the individuals' health status based on palaeopathological indicators. They also reported the results of interviews with a number of Gkuthaarn and Kukatj people. These interviews were carried out with a view to connect the repatriated individuals with genealogies prepared for the Gkuthaarn and Kukatj people's native title claim (QCD2020/002) and to better understand Gkuthaarn and Kukatj people's perspectives on the remains and on bioarchaeology and repatriation.

The study reported here builds on Adams et al. (2018). We measured three isotope proxies—carbon ($\delta^{13}C$), strontium ($^{87}Sr/^{86}Sr$), and oxygen ($\delta^{18}O$)—in the teeth of the six individuals. When obtained from teeth, $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ can provide information about childhood diet and residence, respectively. Oxygen isotope ratios offer insights into ingested water and the local climate during the period of dental development. Accordingly, the goal of the study was to shed light on the individuals' diets, where they grew up, and their consumption of water, which would have had implications for their health status. The isotope results are compared with the findings of ethno-historic research about the impacts of colonisation on Indigenous Australians in far north Queensland, especially the movement of people in response to pastoralism and mining. The study was approved by Griffith University in 2018 (GU ref. no. 2018/858).

Background

The Normanton Region and Traditional Owners in the Late 19th Century

Normanton can be found in the south-west corner of Far North Queensland, in an area commonly referred to as the Gulf Country (Figure 1). The town is around 40 km southeast of the Gulf of Carpentaria, about 500 km west of the city of Cairns, and approximately 800 km south-west of the most northerly tip of Australia. The town is situated on the Norman River, which flows west across the Gulf Country and terminates at the Gulf of

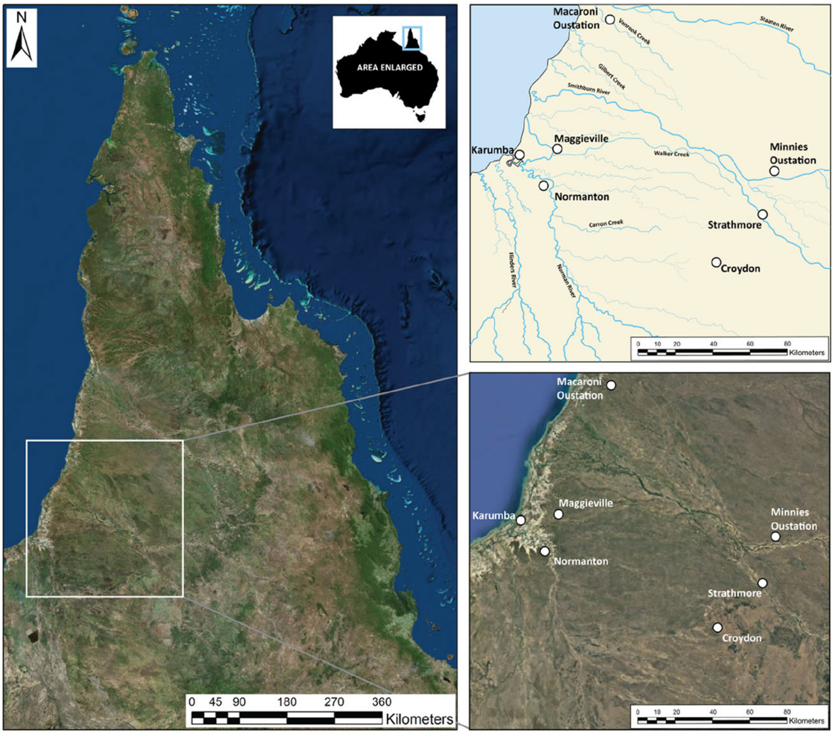

Figure 1. Maps showing the location of Normanton relative to the Gulf Plains region and Cape York

Carpentaria. Founded in the 1860s to facilitate mining and pastoral exports, the town remains an important economic hub for the region.

Normanton is in the Gulf Plains Bioregion, which comprises 219,000 km^2 of low-lying alluvial plains dissected by major rivers such as the Norman, Nicholson, Gregory, Leichardt, Flinders, and Cloncurry (EHP 2015). At only 18 m above sea level, the plains around Normanton are low and flat compared to the eastern ranges where many of the aforementioned rivers have their headwaters. The Gulf Plains Bioregion's climate is influenced by the Australian monsoon, which means that the maximum precipitation falls in the summer months, from November to April (Woinarski et al. 2007).

With regard to geology, the western side of Cape York and the adjacent Gulf Plains are a largely homogenous mix of sediments derived from uplands to the east. These sediments date to the Jurassic and Cretaceous periods (201–66 million years ago) and have created the Carpentaria Geological Basin (Vanderstay and Reeves 2000). In the Gulf Plains region, the

Basin is almost completely covered by younger Pliocene–Holocene alluvial sand and gravels. Normanton, however, sits on an outcrop of the older Normanton Formation, which is made up of fine-grained mid-Cretaceous–Tertiary soils and colluvium. This distinct underlying geology in the Normanton region makes it an ideal place to use biogeochemistry for provenancing.

Normanton is in the traditional lands of the Gkuthaarn (or Kutharn) and Kukatj Aboriginal people. In the anthropological literature, these groups are also referred to as the 'Karunti' (Curr 1887); 'Gooran' (Parry-Okeden 1897); 'Karrandee' (Roth 1897); the 'Ka-run-thee' (Bulleta 1897); the 'Goothanto' (Mathews 1899); the 'Karantee' (Mathews 1900); the 'Kurandi', 'Kutandi', or 'Kutanda' (Sharp 1939); the 'Karundi' (Tindale 1974); the 'Garundi' (Capell 1963); the 'Gudhanda' (Breen 1972); the 'Garandi' (Oates 1975); and the 'Kuthant' (Black 1975). Ethnographic evidence indicates that Gkuthaarn-speaking people traditionally occupied lands around Normanton and to the west, while Kukatj speakers lived west and south-west of the Gkuthaarn people (Tindale 1974).

The anthropological literature records the presence of several other ethnolinguistic groups in the area, including the Kurtijar (or Kurtjar), the Ariba (or Rib), and the Walangama. The Kurtijar people lived to the north and north-east of Normanton. The Ariba are poorly attested in the literature but are generally indicated to have lived to the east of the Kurtjar (Black 1980; Roth 1897; Tindale 1974). Tindale (1974) stated that the Walangama people inhabited the land between Normanton and Croydon. Tindale also suggested that Walangama-speaking people joined with Ariba-speaking people and moved west to Normanton where their westernmost camp was situated (Tindale 1974; see also Roth 1897). Recent research by Martin (2019) indicates that the Kurtjar, Rib, and Walangama were closely related at the time Europeans began to settle in the Gulf Country, and that the Kurtjar succeeded under traditional law and custom to estate areas previously occupied by Rib and Walangama speakers who did not survive colonisation. Martin's research for the Gkuthaarn and Kukatj and Kurtjar native title claims has also shown that the Gkuthaarn, Kukatj, and Kurtjar were closely linked with a range of other peoples across the region, include the Rib and Walangama, forming a regional society that encompassed a body of persons united by their acknowledgement and observance of a shared set of traditional laws and customs (see *George on behalf of the Gkuthaarn and Kukatj People v State of Queensland* [2020] FCA 1310, and *Rainbow on behalf of the Kurtjar People v State of Queensland (No 2)* [2021] FCA 1251).

At the time of European expansion into the Gulf Country, the Gkuthaarn, Kukatj, and Kurtjar peoples maintained a patrilineal and patrilocal clan system involving an ideology of conception filiation that established totemic links between people and places. Economically, Indigenous Australians in the region lived a hunting and gathering lifestyle involving 'hearth-based' strategies for ecological management across the region (Chase and Sutton 1981; Hynes and Chase 1982), with Aboriginal peoples exploiting the resources of their patri-linked 'estate' as well as matrikin countries and other areas in adaptive and dynamic ways (Hiatt 1984). Across the region, Aboriginal peoples shared a structurally similar system of clan estate groups, with minor variations (see Sharp 1939). These groups also shared the same system of four named sections, known in English as 'skins' or 'heads', with these 'heads' known in Kurtjar as *weergh, rduaang, yeerdiny,* and *loord*. In addition, the groups are reported to have shared a range of ceremonies, including male initiation ceremonies, and to have interacted peaceably at Normanton in the 1890s (Bulleta 1897) notwithstanding their different languages, territories, and histories.

As noted earlier, the Gulf Country is subject to monsoonal rains. These inundate much of the region's low-lying floodplains, rejuvenating wetlands and attracting edible water birds. The Gkuthaarn, Kukatj, and Kurtjar relied heavily on these seasonal resources. They also relied on the resources of the west-flowing rivers mentioned above. Game, fish, and birds (known locally as *minya*) were common along the river corridors, along with many species of edible plants (or *mayi*).

Indigenous Australians of the Gulf Country had their first contact with Europeans in the early 17th century CE when Dutch navigators sailed through the Gulf of Carpentaria (Ash 2011). However, it was not until overland expeditions in the mid-19th century CE that the Gulf Country was explored by Europeans and subsequently stocked with sheep and cattle (Lack 1962). This led to substantial changes to the way of life of the Indigenous Australians of the region. The arrival of stock in a seasonally arid region placed pressure on local water resources, and affected Aboriginal people's access to water, with flow-on effects impacting the system of local organisation. These pressures resulted in conflict between Indigenous Australians and European settlers, and the colonial government intervened by dispatching the Queensland Native Police.

The Queensland Native Police sent patrols into the Norman River area in 1868 (Queenslander 1872). Violent clashes resulted in the death and further displacement of many Indigenous Australians. Pastoralism and mining grew rapidly during the late 1800s, further isolating Aboriginal people from their lands and forcing them into crowded fringe camps around places like Normanton. These overcrowded conditions were discussed in colonial correspondence in 1897. The document in question states that "over 600 blacks have been in Normanton at one time, being principally from the north-east" (Parry-Okeden 1897:10). Overcrowded conditions and the spread of infectious diseases in the camps led to ill-health and epidemics (Khan 1993).

Thirty years after Normanton was proclaimed as a township, Dr Walter Roth was appointed the Chief Protector of Aborigines for North Queensland (Khan 1993). He proceeded to provide detailed reports on the displacement of Indigenous groups in the region. In 1900, he wrote, "[a]s each new block of country gets taken up, the blacks are forcibly hunted off their water supplies and hunting grounds both in it and in its immediate neighbourhood" (Roth 1900:2). The following year he stated, "[w]hen they find the blacks on the run any distance from the river, they race their horse on to the blacks, cut them right and left with their stock whips, break their spears and take their tomahawks" (Roth 1901:6). Based on these and other similar observations, Roth advocated forcefully for the creation of Aboriginal reserve areas, arguing that if "all the land in the north [were] to be thus leased, all the blacks would be hunted into the sea. The poor wretches must be allowed the wherewithal to live" (Roth 1901:6). Roth's humanitarian calls went unheeded.

The treatment of Aboriginal people by Europeans and the Queensland Native Police was also recounted by a local Kurtjar man, Rolly Gilbert. He explained that "[t]he white men would drive us away from the places they wanted. They drove us away from our soak…so that their cattle could have the water. They shot many of our people there…The white men or the Native Police also shot up whole camps of our people…The neighbouring tribes were probably worse off than ours was—at least there seem to be fewer of these people left today" (Gilbert and Black 1980:1–2). Related accounts from other Aboriginal people indicate the widespread impact of colonial violence across the region, with Melba Casey, for example, recalling a location north-east of Normanton where white men saw the smoke of Kurtjar people's campfire and "*nighan 'bhaarr rdigha.yi dhalngi.nhabh…* melkergh.ingk", that is "completely killed them [with] guns" (Black et al. 1986:79).

Following the easing of frontier violence around the turn of the 20th century CE, many Aboriginal people began to work on cattle stations across the region, including on their traditional lands. In cattle station camps, and in the camps on the fringe of the towns of Normanton, Croydon, and Karumba, members of the Gkuthaarn, Kukatj, and Kurtjar intermixed. As Rolly Gilbert recalls, "[s]ome of the people to the east…came to live among us when we came to be working on the cattle stations in later years…and we've come to accept them as part of our tribe" (Gilbert and Black 1980:4). Over the course of the 20th century CE, Aboriginal peoples from the region became increasingly concentrated at Normanton, particularly in the decades after the Second World War, although sizeable numbers of Aboriginal people returned to live at Delta Downs Station north of

Normanton when that lease was purchased by the Kurtjar people in the 1980s. In recent years, the Gkuthaarn, Kukatj, and Kurtjar have pursued native title recognition of their traditional rights and interests in land and waters around Normanton. The Gkuthaarn and Kukatj People native title claim (QCD2020/002) was successfully concluded in September 2020. This outcome secures the rights of the Gkuthaarn and Kukatj People in perpetuity, including rights of exclusive access to Conwell Flat. The Kurtjar people's native title claim over areas to the north-east of Normanton was resolved in 2021.

Background Information on the Human Remains Analysed in the Present Study

Dr Walter Roth was a physician and anthropologist with a strong interest in the Aboriginal groups of Northern Australia. He worked closely with many Aboriginal people, recording their customs, language, and material culture (Roth 1897). During the time Roth was a surgeon in Cape York and the Chief Protector of Aborigines for North Queensland, he collected Indigenous skeletal remains as scientific specimens. Roth was well known to local pastoralists and government officials in the region, who procured remains for his scientific endeavours (Roth 1897).

In 1890, Roth stated that he had been able to obtain 50 skulls and skeletons from north Queensland. Fifteen years later, at the end of his time in Australia, Roth sold these remains to the Australian Museum in Sydney for £450 (Khan 1993). The individuals were housed in the Australian Museum for almost a century before eight crania and two sets of fibula/tibia were repatriated to the Gkuthaarn and Kukatj people in the 1990s. Records of the repatriation date and specimen numbers were kindly provided by the Australian Museum. The remains of these eight individuals were eventually reinterred on the outskirts of Normanton, at Conwell Flat. Members of the community confirmed this and guided the scientists to the exposed remains. The remains were buried in plastic specimen bags. Fibula/tibia were held together with thin wire. Some of the remains retained identifying catalogue numbers.

When Roth sold the collection to the Australian Museum, he provided a manifest that lists the skeletal element(s) preserved, the date and place of acquisition, and, in some cases, the sex of the individual (Table 1). The manifest also includes a notes column that provides additional information, including the name of one of the individuals. In addition to the manifest, we have records of the remains released by the Australian Museum and oral testimony from Gkuthaarn and Kukatj people recording their reburial in the 1990s.

Table 1 Information from the manifest that Dr Walter Roth provided to the Australian Museum in 1905, when the museum purchased the human remains discussed in the present study

No.	Element	Date	Location	Sex	Notes
3	Tibiae/fibula × 2	1897	Normanton	–	"'Boomerang shins' from amongst the graves on Hospital Hill, Normanton"
4	Skull	1895	Cloncurry	F	"'Dolly', Karunti Tribe (Normanton Station), employed at Cloncurry Barracks"
25	Skull	1897	Normanton	–	"Patient, died in hospital"
26	Skull	1897	Normanton	–	"Patient, died in hospital"
27	Skull	1897	Normanton	–	"Patient, died in hospital"
28	Skull	1897	Normanton	F	"Died in hospital"
29	Skull	1897	Normanton	–	"Patient, died in hospital"
39	Skull	–	–	M	"Karunti Tribe, my last patient, a syphilitic"
74	Skull	1902	Normanton	F	"Given to me by Inspector Galbraith"

In 2015, the remains were exposed through erosion, and shortly thereafter MCW was invited to excavate and analyse the individuals and help with their reburial. The team he put together found the cranial remains of eight individuals and two sets of tibia/fibula eroding from an exposed elevated surface in the floodplain of the Norman River. The location was an Aboriginal camp from the late 19th century until the Second World War, with an established (colonial era) cemetery sited on an elevated area to the west (Adams et al. 2018).

A detailed description of the excavation and bioarchaeological assessments of the remains were published by Adams et al. (2018). Due to the fragmentary nature of the remains, Adams et al. (2018) found it difficult to match the individuals with those listed in Roth's manifest. Accordingly, they referred to most of the individuals by their excavation number (N1–N7). The exception was N8. Adams et al. (2018) identified this individual as Roth's 'acquisition No. 4', whose name was Dolly, according to Roth's manifest.

Based on cranial suture closure, dental eruption, and/or enamel wear, Adams et al. (2018) concluded that two of the eight sets of cranial remains belonged to adults, five belonged to adolescents, and one belonged to a child (Table 2). In carrying out the present study, we clarified the age of the individuals with the aid of photographs and the standards outlined in Buikstra and Ubelaker (1994) and Brothwell (1981). This resulted in some changes. We concluded that two of the eight sets of cranial remains belonged to adults, four belonged to juveniles, and two belonged to individuals in the subadult to young adult age range (Table 2).

Adams et al. (2018) also reported assessments of the health status of the remains (Table 2). The tibiae and fibulae exhibited anterior–posterior curvature, which they attributed to yaws or congenital syphilis. Dental hypoplasia was evident in two individuals suggesting nutritional and/or pathological stress during enamel formation. Dental caries were identified in three of the individuals and these were interpreted as evidence of the consumption of a significant amount of carbohydrate-rich European foodstuffs. Two of the individuals exhibited extreme occlusal wear, which Adams et al. (2018) suggested may be indicative of the individuals having consumed traditionally prepared foods for a substantial period. Lastly, one individual showed signs of trauma to the back of the cranium, with no signs of bone remodelling. Adams et al. (2018) interpreted this as potential evidence for trephination, a pre-colonial medical procedure to relieve pressure in the cranial vault.

Table 2 Cranial remains reported by Adams et al. (2018) with revised age-at-death assessments

Adams et al. (2018) #	Roth #	Original age-at-death estimate	Health status	Revised age-at-death estimate
N1	Uncertain	15 ± 3 years	Adams et al. (2018) identified caries on the first and second maxillary molars. They also identified dental hypoplasia on a molar and suggested therefore that the individual had experienced a period of chronic nutritional stress around the age of three	Juvenile
N2	Uncertain	Adolescent	Adams et al. (2018) noted that three molars exhibited considerable occlusal wear and interpreted this as evidence of consumption of traditionally processed food for much of their life. They also noted that one of the molars exhibited caries, which they argued suggested consumption of some European food as well. Lastly, Adams et al. (2018) identified a significant trauma on the left parietal, which they interpreted as possible evidence of trephination	Subadult to young adult
N3	Uncertain	Adolescent (12 ± 2.5 years)	Adams et al. (2018) noted the presence of caries on the teeth in both the maxilla and mandible and interpreted this as evidence of consumption of European food for an extended period. They also identified hypoplasia in the teeth and suggested therefore that the individual had experienced either nutritional stress or infectious disease	Subadult to young adult
N4	Uncertain	Adolescent	No palaeopathological indicators recorded by Adams et al. (2018); too damaged and matrix-encrusted to assess	Juvenile
N5	Uncertain	Adult	No palaeopathological indicators recorded by Adams et al. (2018); too damaged to assess	Adult
N6	Uncertain	Child (7–11 years)	Adams et al. (2018) identified the presence of dental caries, which they interpreted as evidence of a European diet	Juvenile

Table 2 continued

Adams et al. (2018) #	Roth #	Original age-at-death estimate	Health status	Revised age-at-death estimate
N7	Uncertain	Teenager	No palaeopathological indicators noted by Adams et al. (2018)	Juvenile
N8	4	Adult	Adams et al. (2018) identified this individual as Roth's 'acquisition No. 4', whose name was Dolly, according to Roth's manifest. Adams et al. (2018) recorded the possible presence of caries sicca, which is a destructive lesion associated with tertiary syphilis	Adult

Isotope Geochemistry and Its Use in Australian Archaeology

In the study reported here, we employed three isotope ratios—strontium ($^{87}Sr/^{86}Sr$), carbon ($\delta^{13}C$), and oxygen ($\delta^{18}O$) isotope ratios. Isotopes of the element strontium (Sr), ^{87}Sr and ^{86}Sr, align with the surrounding geology and are commonly expressed as a ratio, $^{87}Sr/^{86}Sr$. ^{87}Sr is formed from the radiogenic decay of ^{87}Rb, which has a half-life of 48.8 billion years (Faure 1986). Because of this long decay it essentially remains the same over archaeological timescales. As rock weathers, it transfers geological $^{87}Sr/^{86}Sr$ into the water that is taken up by plants and animals. This portion of Sr is known as 'bioavailable Sr' and is determined by preferential weathering of different minerals (Bentley 2006; Montgomery 2002). Bioavailable Sr enters body tissues of humans and fauna via food and water and substitutes for calcium although it serves no metabolic function (Willmes 2015). It is transferred with little to no alteration due to the large atomic mass of Sr isotopes and the small differences between their masses (Price et al. 2002; Wright 2005).

The bioavailable Sr portion taken up by organisms substitutes for biogenic apatite in the formation of teeth and bone (Faure 1986). The dental tissues sampled in isotope studies are enamel and dentine. Dental enamel and dentine is a dense mineral structure that does not contain blood vessels or nerves and therefore does not remodel (Ross et al. 2006:485). Dentine is also a dense stable structure and once formed there is also little to no further isotope uptake (Goldberg et al. 2011; Nanci 2012:194; Radhakrishnan 2011; Vital et al. 2012). Unlike dental enamel, however, once buried, dentine can become diagenetically altered, taking on the local $^{87}Sr/^{86}Sr$ signature (Budd et al. 2000). Therefore, by comparing dentine and enamel $^{87}Sr/^{86}Sr$ ratios it is sometimes possible to discern whether an individual was buried where they grew up. However, at present there is no way to test the rate of alteration and caution must be used when interpreting offsets between these tissues as partial replacement may result in intermediate values that can confound results (Budd et al. 2000).

Before $^{87}Sr/^{86}Sr$ can be used to infer a specimen's provenance, an understanding of regional $^{87}Sr/^{86}Sr$ variability is required. In the study reported here, we compared the $^{87}Sr/^{86}Sr$ values obtained for the Normanton skeletal remains to the environmental $^{87}Sr/^{86}Sr$ values for the Gulf Plains region of Cape York that were reported by Adams et al.'s (2019).

Carbon isotope studies compare two isotopes (^{12}C and ^{13}C) as a ratio using the delta notation ($\delta^{13}C$), against a standard, which is normally Vienna Pee Dee Belemnite (VPDB) (Peterson and Fry 1987). The $\delta^{13}C$ composition of body tissue reflects the $\delta^{13}C$ of dietary inputs and can be used to discriminate between terrestrial and marine diets and infer plant-based diet based on the three carbon fixation pathways: C_3, C_4, and Crassulacean Acid Metabolism (CAM) (Schoeninger and DeNiro 1984; van der Merwe and Vogel 1978). C_3 plants are isotopically distinct from C_4 plants: C_3 vegetation presents $\delta^{13}C$ values between -33 and -23‰ VPDB (Tokui et al. 2000), while C_4 plants generally fall between -16 and -9‰ VPDB (Stantis et al. 2015). Unfortunately, herbivorous animals also carry these signals within their body tissues, so it is not possible to distinguish between consumption of plant foods and consumption of plant-food-eaters via analysis of Carbon isotopes extracted from human skeletal remains.

Seeds, tubers, and fruits were integral to the diet of pre-contact Indigenous Australians, but so were grass seeds, which were ground up to make flour (Fullagar and Field 1997). The type of grass gathered and eaten by Indigenous Australians depended largely on latitude (Thorp et al. 1986). C_3 grasses are adapted to cooler seasons and are commonly found in the southern regions of Australia (Hattersley 1983). Examples include weeping grass (*Microlaena stipoides*) and common wheat grass (*Elymus scaber*) (Murphy and Jones 1999). In contrast, C_4 grasses are adapted to warm (dry and moist) seasonal conditions and are found north of the 25° latitude in Australia (Murphy and Bowman 2007). Common varieties include kangaroo grass (*Themeda triandra*) and wire grass (*Eriachne obtuse)* (Murphy and Jones 1999).

Archaeological studies generally focus on measuring the carbon isotope composition of bone collagen ($\delta^{13}C_{collagen}$) and dental enamel bioapatite ($\delta^{13}C_{bioapatite}$) (Kellner and Schoeninger 2007). While $\delta^{13}C_{collagen}$ represents dietary protein, $\delta^{13}C_{bioapatite}$ reflects the macronutrient sources of protein, carbohydrates, and lipids (de Laeter et al. 2003; DeNiro and Epstein 1976). Dental enamel $\delta^{13}C_{bioapatite}$ is precipitated from blood plasma bicarbonate with carbon dioxide expired from diet and metabolism (Fernandes et al. 2012; Passey et al. 2005). This forms carbonated calcium-deficient hydroxyapatite $Ca_{10-x}(PO_4)_{6-x}(HPO_4)_x(OH)_{2-x}$, which is a hydroxyl endmember of the apatite group (Prodan et al. 2014). $\delta^{13}C_{bioapatite}$ can be used to estimate dietary input if metabolic fractionation is considered. Kellner and Schoeninger (2007) completed controlled feeding experiments on a range of omnivores to calculate the $\delta^{13}C_{diet}$ to $\delta^{13}C_{bioapatite}$ offset. This work was revised by Froehle et al. (2010) who used a graphic model to distinguish C_3 and C_4/marine diet from body tissue. Fernandes et al. (2012) added to these earlier studies and used regression analyses to focus on the macronutrient routing between diet and tissue. This research resulted in a robust model for calculating omnivore dietary carbon routing in bioapatite: $\delta^{13}C_{bioapatite} = 10.1 + \delta^{13}C_{diet}‰$, revised to: $\delta^{13}C_{bioapatite = 11.3 + \delta}{}^{13}C_{diet}‰$ for humans when considering body size effects.

Oxygen isotopes obtained from human body tissues are also often employed to understand mobility (e.g. Bentley et al. 2007; Cox et al. 2011;

Dupras and Schwarcz 2001; Fricke et al. 1995; Kenoyer et al. 2013; Knudson 2009). Two of the three isotopes of Oxygen, ^{18}O and ^{16}O, are entered into the following formula: $\delta^{18}O = [(^{18}O/^{16}O \text{ sample}/ ^{18}O/^{16}O \text{ standard}) - 1] \times 10^3$. The standard is generally Standard Mean Ocean Water (SMOW) (Peterson and Fry 1987). In mammalian teeth, oxygen isotopes form part of the oxyhydroxide group (OH-) of calcium hydroxyapatite ($Ca_{10}(PO4)_6(OH)_2$ (Faure 1986; Turner et al. 2009). Oxygen is present in both the phosphate ($PO_4{}^{3-}$) and carbonate ($CO_3{}^{2-}$) of tooth enamel apatite and the ratios derived from the two tissues are strongly correlated ($r^2 = 0.98$) (Bryant et al. 1996; Lacumin et al. 1996; Sponheimer and Lee-Thorp 1999).

The $\delta^{18}O$ composition of meteoric water varies globally because ^{18}O condenses more readily than the lighter ^{16}O. The same processes result in the preferential retention of the heavier isotope ^{18}O in evaporated water bodies (Longinelli 1984; Luz et al. 1984). ^{18}O is higher in abundance in areas of higher rainfall, warmer climate, and closer to the coast due to the so-called amount effect (Eastoe and Dettman 2016; Gerling 2015:125). Three mechanisms result in the amount effect: evaporation of falling raindrops, change in moisture source between seasons, and progressive regional rainout (Dansgaard 1954). These processes dictate geographic $\delta^{18}O$ distribution, and $\delta^{18}O$ in body tissue can therefore be used to infer climate and geography (Bowen et al. 2005; Craig 1961; Dansgaard 1954; Epstein and Mayeda 1953; Kinaston et al. 2009).

Predictable hydrological processes make it possible to map $\delta^{18}O$ throughout the landscape and use it to understand the movement of animals. Isotope maps are known as 'isoscapes' and oxygen isotopes are one of many that can be mapped as an isoscape. Two Australian oxygen isoscapes that predict annual $\delta^{18}O$ in precipitation for the Gulf Country have been produced (Bowen et al. 2005; Hollins et al. 2018). Bowen et al. (2005) compiled $\delta^{18}O$ data from the Global Network for Isotopes in Precipitation and predicted modern annual precipitation $\delta^{18}O$ values around Normanton between -5 and -4.1 ‰ (SMOW). Hollins et al. (2018) utilised a further eight Australian sampling sites and predicted annual precipitation $\delta^{18}O$ values in the Gulf Country at − 7 to − 5 ‰ (SMOW). It should be noted that confounding factors related to seasonal variability, exogenous inputs, and anthropogenic alteration can shift $\delta^{18}O$ values in ingested water, which complicates the use of $\delta^{18}O$ isoscapes.

The oxygen isotope composition of hydroxyapatite in teeth can be used to estimate the initial drinking water value. Chenery et al. (2012) calculated drinking water $\delta^{18}O$ from human tooth enamel carbonate. This was done by reviewing Coplen et al.'s (1983) equation for enamel phosphate $\delta^{18}O_{DW} = 1.590 \times \delta^{18}O_C - 48.634$. However, employing $\delta^{18}O$ to trace movement is not straightforward due to equifinality. Although human tissue $\delta^{18}O$ reflects drinking and food water $\delta^{18}O$, it can become enriched through cooking, disease, and other types of metabolic fractionation. In metabolic fraction, light oxygen isotopes (^{16}O) are lost preferentially over heavier ones (^{18}O) via perspiration, respiration, and urination (Bryant and Froelich 1995; Kohn 1996). Other biological processes, including disease and nursing, can also offset $\delta^{18}O$ values in teeth by up to 2‰ (SMOW), with incisors, canines, and the first molars being the most likely to be influenced (Ash et al. 2003:54; Evans et al. 2006; Smits et al. 2010; White et al. 2004).

To date, three bioarchaeological studies in Australia have investigated carbon, oxygen, and strontium isotope ratios in the remains of Indigenous Australians (Adams et al. 2021; Theden-Ringl et al. 2011; Westaway et al. 2004). Results from these studies indicate that the bioavailable $^{87}Sr/^{86}Sr$ signature is transferred into human remains with little fractionation and can be used as a robust geochemical tracer. Westaway et al.'s (2004) study, which was conducted in Victoria, was able to discriminate between two sites and provenance human remains taken from the region in the 19th Century CE. Theden-Ringl et al.'s (2011) study concerned the provenance of remains found buried on a beach in Arnhem Land. $^{87}Sr/^{86}Sr$ values from Arnhem Land proved to be higher than those retrieved from the remains and the remains were therefore interpreted as being Macassan fishermen. The isotope study presented by Adams et al. (2021) combined Sr, C, N, and O isotopes from tooth enamel, dentine, and bone collagen to infer mobility between island and mainland populations on the eastern side of Cape York around 500 years ago. These three studies indicate that isotopes have considerable potential to contribute to our understanding of Australia's history.

Two other isotope analyses of human remains recovered from archaeological sites in Australia have been published—Owen and Casey (2017) and Adams et al. (2022). Owen and Casey (2017) examined $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ in the dental enamel of ten early colonial era human remains from Sydney, New South Wales. They compared their results to published data from potential source populations in Britain and Ireland and found close matches for two of the individuals. Adams et al. (2022) measured $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ in the tooth enamel and dentine from 13 individuals from unmarked colonial era graves in Adelaide, South Australia. Their results suggested that one individual was born locally while eight were likely from the British Isles.

Materials and Methods

Only six of the repatriated Normanton individuals had teeth that could be reliably associated with them (Table 2). The teeth we analysed were maxillary premolars and molars. These teeth develop between birth and approximately 16 years of age (Buikstra and Ubelaker 1994), so the dental enamel isotope values we obtained reflect residence, diet, and water consumption during childhood. As explained earlier, the dentine isotope results likely represent post-mortem uptake of exogenous isotopic signatures.

Laser-ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) was used to measure $^{87}Sr/^{86}Sr$ in the teeth. Teeth were cut along the mesiodistal plane to expose enamel and dentine and were then mounted in aluminium trays. The ablation system used a 25 × 8 mm beam exciting laser, projected and demagnified via a long working distance triplet lens. At a wavelength of 193 nm the laser delivered fluence of 10 J/cm^3 (Grün et al. 2014). A spot size of 205 μm cleaned the cut surface before 120 s analyses with 30 s pre and post ablation using 160 μm spot size at 10 Hz. Enamel was analysed at three locations from the dentine to the crown, while dentine was analysed at two locations from the superior surface of the pulp to the enamel–dentine junction. Measurements were carried out on a Finnigan MAT Neptune configured to run three measurements: ten seconds of whole mass recording, one second of half mass recording, and one second of recording mass 71 to track polyatomic interference from Argon and Phosphorous oxides. Argon and Phosphorous oxides can interfere with mass 87. This interference stems from the high levels of phosphorous in teeth, which can lead to the polyatomic compounds $^{40}Ar + {}^{31}P + {}^{16}O$ and $^{40}Ca + {}^{31}P + {}^{16}O$ on mass 87 (Hortswood et al. 2008; Simonetti et al. 2008). Willmes et al. (2016) developed

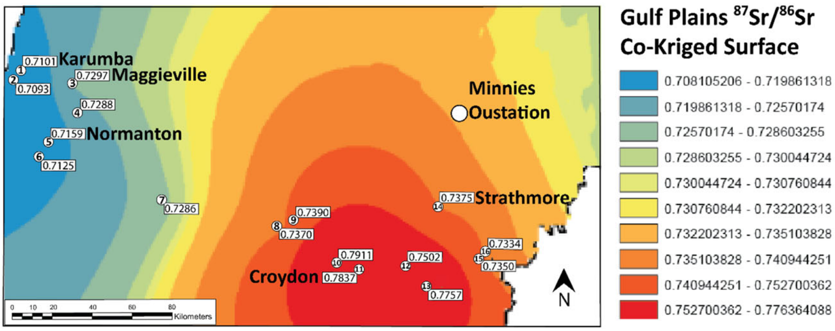

Figure 2. Gulf Plains region of Cape York soil, plant, and faunal $^{87}Sr/^{86}Sr$ results modelled as a Co-Kriged interpolated surface in Adams et al. (2019)

tuning techniques to lower oxide production to minimise this interference. This procedure was carried out by adding 8 cc/min nitrogen to the plasma to drop the gas flow rate and increase particle residence time. A *Dugong dugon* tooth was used as a standard, and rare earth elements were recorded to assess the likelihood of diagenesis (Willmes et al. 2016).

As mentioned earlier, to interpret the Sr results, we employed Adams et al.'s (2019) $^{87}Sr/^{86}Sr$ results for the Gulf Plains region of Cape York (Figure 2). Adams et al. (2019) found that soil, plant, and faunal $^{87}Sr/^{86}Sr$ results exhibited a strong east–west gradient between Croydon/Strathmore and the Gulf of Carpentaria. Within 100 km of Normanton, the three major lithologies return distinct $^{87}Sr/^{86}Sr$ ranges. The early Cretaceous shallow marine conglomerate of Normanton yielded a narrow $^{87}Sr/^{86}Sr$ range of 0.7125–0.7159, while the Pliocene alluvial sediments east of Normanton returned a wide range of 0.7286–0.7390. The marine derived Quaternary sediments from the coast produced a range of 0.7093–0.7094, which is close to the modern marine $^{87}Sr/^{86}Sr$ signature (0.7092). Over 100 km east of Normanton values change abruptly due to ancient igneous lithologies around Normanton. In this area Mesoproterozoic felsic intrusives and extrusives exhibit extremely high $^{87}Sr/^{86}Sr$ values that elevate nearby lowland alluvial values (Figure 2). We compared these $^{87}Sr/^{86}Sr$ results for soil, plant, water, and fauna to the $^{87}Sr/^{86}Sr$ results for the enamel and dentine of the six Normanton individuals.

The first step in measuring the $\delta^{13}C$ and $\delta^{18}O$ ratios was to remove a portion of dental enamel from the occlusal surface of each tooth (~ 2 mm × 2 mm). These bulk samples were used to provide averages of isotopic input during tooth formation; we did not try to identify isotopic change during tooth formation. The dental enamel was ground to fine powder using a mortar and pestle. Ground enamel was placed in an ultra-cleaned teflon tube and covered in 0.1 M acetic acid (CH_3COOH), before sonication for 15 min. This was followed by a further 15 min of reaction. The solution was centrifuged at 4000 rpm for 15 min and then acetic acid was removed. The sample was rinsed three times with Milli-Q ultrapure water (18.2 Ψ at 25 °C), centrifuging between steps. Excess Milli-Q ultrapure water was evaporated at 40̊C. Thereafter, analyses were run on a Finnigan MAT 251 and Kiel carbonate device. The working gas used was 2009-2, and data were corrected for ^{17}O interference using Santrock et al.'s (1985) method: $R_{17} = k\ (R_{18})^a$. Raw ions were converted to delta values for analysis, and Vienna Pee Dee Belemnite (VPDB) was used as the standard for all $\delta^{18}O$ and $\delta^{13}C$ measurements. All samples had a standard deviation less than 0.04. Drinking water $\delta^{18}O$ values were calculated using the equation in Chenery et al. (2012), based on Daux et al.'s (2008) equation: $\delta^{18}O_C$ ($\delta^{18}O_{DW} = 1.590 \times \delta^{18}O_C - 48.634$. VPDB values were converted to Vienna Standard Mean Ocean Water (VSMOW) with the following equation: VSMOW‰ = (1.03092 × VPDB‰) + 30.92 (Coplen et al. 1983). Although Pestle et al. (2014) showed that in some instances isotope results can differ between labs, we carried out a comparison with global human $\delta^{18}O$ and $\delta^{13}C$ results to illustrate general population trends and to assess the contribution of introduced foods to the diets of the six Normanton individuals.

Measurement of all three isotopes was conducted at the Research School of Earth Sciences at the Australian National University in Canberra, Australia.

Results and Discussion

Strontium Isotope Ratios

$^{87}Sr/^{86}Sr$ enamel results for the six individuals vary substantially and suggest three distinct locations of childhood residence (Table 3, Figure 3). N1 and N3 exhibit the highest $^{87}Sr/^{86}Sr$ values at 0.73183 and 0.73204, respectively. These values are close and therefore are interpreted as evidence that the individuals were in a similar geological setting during tooth formation. N4, N6, and N7 values all have lower values. They are between 0.72764 and 0.72933. These results are also close and are interpreted as indicating a similar geology during tooth formation. Dolly's enamel results are markedly lower at 0.71080, which is 0.017 from the closest result (N4). Individual laser ablation results for each specimen can be found in Supplementary Data 1 and illustrates that there is limited within-tooth variation at $<$ 0.002.

As we explained earlier, Adams et al. (2018) concluded that N8 was the individual Roth identified as Dolly. The $^{87}Sr/^{86}Sr$ results support this. Dolly is recorded in Roth's manifest as a member of the Karunti Tribe. The Karunti are now known as the Gkuthaarn and Kukatj people, whose traditional lands were originally at Normanton and to the west. Dolly's enamel Sr value (0.71080) aligns well with this; it is lower than that seen in the other individuals and is close to the modern marine value of 0.7092. The Co-Kriged surface presented in Figure 2 visualises the gradient in $^{87}Sr/^{86}Sr$ results in the region and illustrates these lower values close to the coast.

Figure 2 suggests that the other five individuals originated outside the traditional lands of the Gkuthaarn and Kukatj people. The values for N1 (0.73183) and N3 (0.73204) are within the range measured for the Pliocene alluvial plains directly east of Normanton, as displayed in the box plot in Figure 3. The $^{87}Sr/^{86}Sr$ results for N4, N6, and N7 (0.72764 to 0.72933) also lie within the range measured east of Normanton. This may indicate that all five individuals grew up east or north-east of Normanton. Ethno-

Table 3 The $^{87}Sr/^{86}Sr$, $\delta^{18}O$, and $\delta^{13}C$ results from teeth of Normanton Individuals

Sample	Tooth	Age during crown formation (years)	Enamel $^{87}Sr/^{86}Sr$	Dentine $^{87}Sr/^{86}Sr$	$\delta^{13}C$ (VPDB)Carbon-ate	$\delta^{18}O$ (VPDB)Carbon-ate
N1	M^1	0–3	0.73183 (2se = 0.000070)	0.72477 (2se = 0.000060)	− 11.44 ± 0.05	0.72 ± 0.08
N3	M^2	3–6	0.73204 (2se = 0.000083)	0.71310 (2se = 0.000265)	− 10.19 ± 0.05	− 1.17 ± 0.08
N4	M^1	0–3	0.72764 (2se = 0.000287)	0.72413 (2se = 0.000378)	− 13.39 ± 0.05	− 2.09 ± 0.08
N6	M^1	0–3	0.72846 (2se = 0.000178)	0.72623 (2se = 0.000160)	− 10.35 ± 0.05	− 0.7 ± 0.08
N7	PM^1	2–6	0.72933 (2se = 0.000148)	0.71776 (2se = 0.000164)	− 10.59 ± 0.05	0.47 ± 0.08
N8	M^1	0–3	0.71080 (2se = 0.000288)	0.71581 (2se = 0.000263)	− 8.76 ± 0.05	4.69 ± 0.08

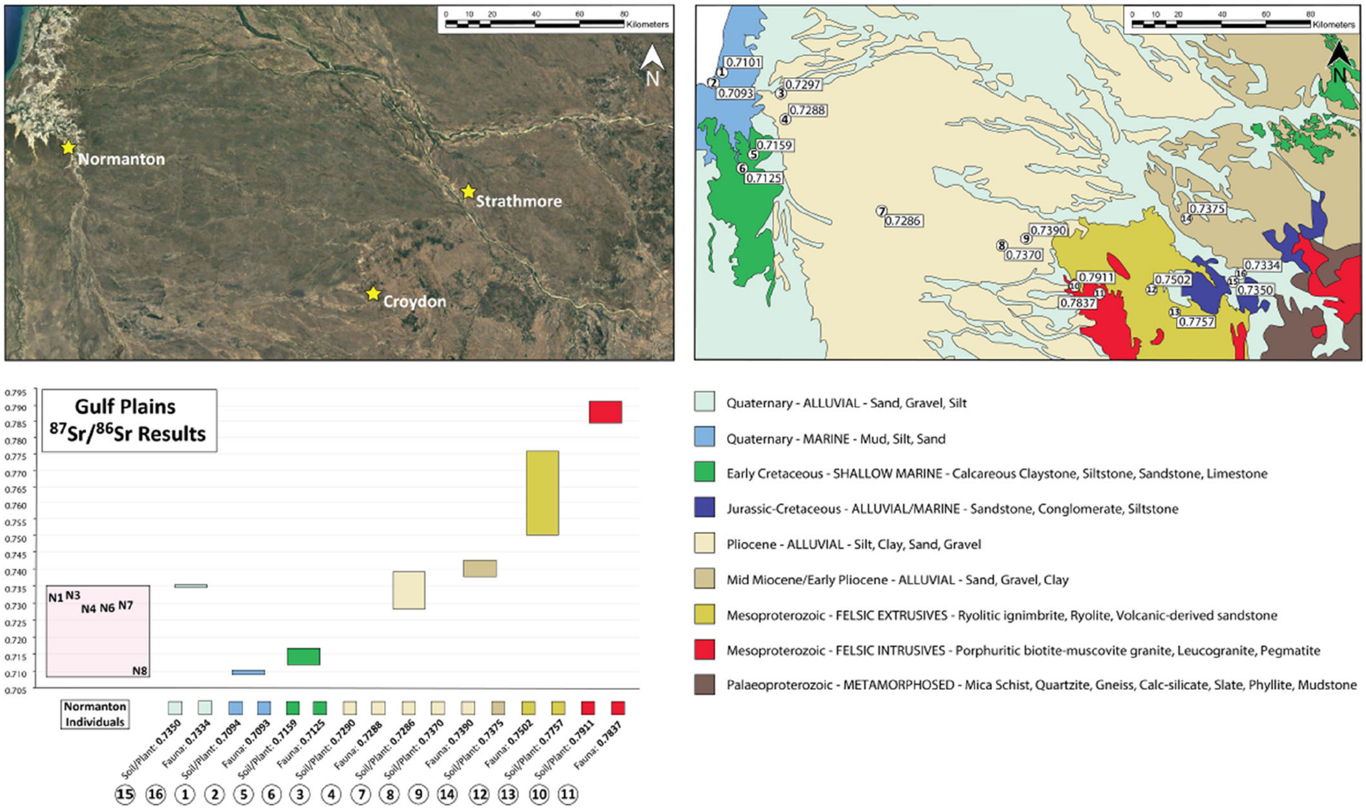

Figure 3. Regional centres of the Gulf Plains, sample sites, Normanton human results, and results from Adams et al. (2019). Results are presented on underlying lithologies and as ranges in the boxplots. Human results are also presented in the boxplot

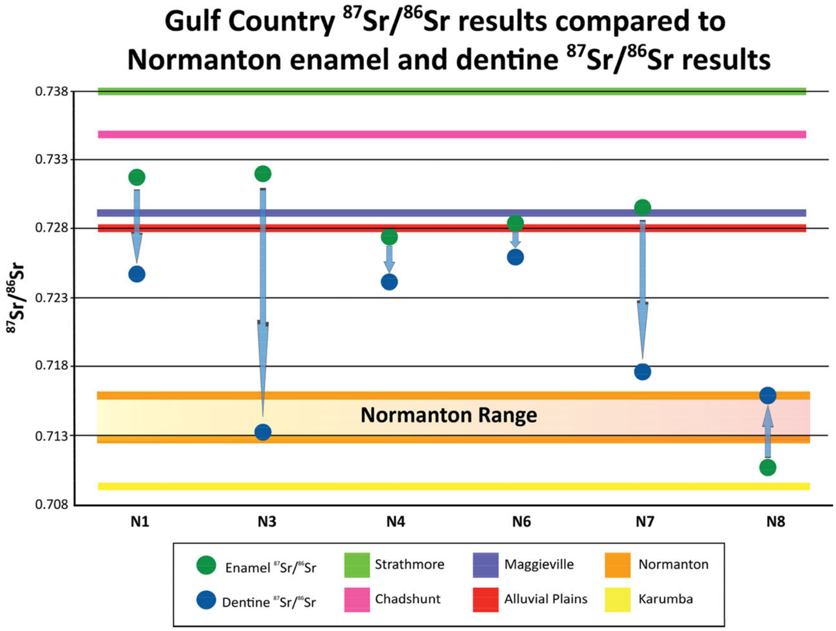

Figure 4. Normanton individuals' enamel and dentine $^{87}Sr/^{86}Sr$ results (N1, N3, N4, N6, N7, and N8) with local soil, plant, and faunal $^{87}Sr/^{86}Sr$ values presented as coloured bands from Adams et al. (2019)

historic information assists with the interpretation of these isotope results. To reiterate, when Europeans moved into the Gulf Plains, fringe camps developed around Normanton. Aboriginal groups from across the region intermingled in these camps, while generally living in distinct areas. These camps included peoples who are described in the ethno-historical literature with labels including Rib (or Ariba) and Walangama, as well as Gkuthaarn, Kukatj, and Kurtjar. As we did not obtain any enamel results from the five individuals that align with the soil, plant, and faunal values recovered from Normanton it suggests that all teeth examined in this study had developed by the time these individuals had relocated to Normanton.

It is possible that enamel $^{87}Sr/^{86}Sr$ results from N1, N3, N4, N6, and N7 relate to values from outside of the study area, but considering the ethno-historical evidence of groups east and north-east of Normanton being displaced from their traditional country and relocating into camps around Normanton at the time these people died, it seems more likely that these individuals were from areas associated with the Walangama and Rib (Ariba) languages, to the east of Normanton. The Walangama and Rib people suffered severe demographic collapse after colonisation and did not survive. Little is known about them beyond traces of their languages. They are largely forgotten in the region, with few families tracing descent via forebears associated with these groups. The 2021 judgement in the Kurtjar people's native title claim confirms that the Kurtjar people succeeded to their country (see *Rainbow on behalf of the Kurtjar People v State of Queensland (No 2)* [2021] FCA 1251: 217).

The dentine $^{87}Sr/^{86}Sr$ results differ from the dental enamel results in a manner that is consistent with partial diagenetic $^{87}Sr/^{86}Sr$ replacement. In this case, we can see that the dentine values for N1, N4, and N6 are all lower than their corresponding enamel results, sitting between 0.72413 and 0.72623 (Figure 4, Table 2). N3's and N7's dentine values are also lower than their corresponding enamel results, between 0.71310 and 0.71776. In contrast, Dolly's dentine $^{87}Sr/^{86}Sr$ results are higher than her enamel value of 0.71581. In Figure 4, we can also see that the $^{87}Sr/^{86}Sr$ results from Normanton sit between 0.71250 and 0.71590. All six individuals' dentine $^{87}Sr/^{86}Sr$ results display a shift from their enamel $^{87}Sr/^{86}Sr$ values towards the local Normanton $^{87}Sr/^{86}Sr$ value (Figure 4). Although dental enamel is a hard substance that is robust to the processes of diagenesis, dentine is a porous matrix that may absorb the burial setting $^{87}Sr/^{86}Sr$ over time (Budd et al. 2000). The processes acting on dentine $^{87}Sr/^{86}Sr$ uptake following burial are not well understood. However, Budd et al. (2000) found in their study of Sr abundance and isotope ratios on archaeological tooth dentine that diagenesis is highly variable with soil-derived Sr in some cases leading to a compete turnover of the original signal. In a floodplain setting, where remains are degrading heavily over a short period of time, we might expect to see the results of diagenetic uptake of local $^{87}Sr/^{86}Sr$ in dentine. We acknowledge that the processes acting on dentine in archaeological settings is understudied but considering the highly destructive taphonomic processes that have taken place on the Normanton remains since their burial in the 1990s, partial turnover of $^{87}Sr/^{86}Sr$ towards the local geological signal seems highly likely. These processes may have resulted in an uneven uptake of $^{87}Sr/^{86}Sr$ in the dentine, due to the placement of the remains relative to each other in the burial setting and the portion of the dentine sampled.

Carbon Isotope Ratios

Enamel $\delta^{13}C$ results for N1, N3, N6, and N7 exhibit a narrow range of − 11.4 to − 10.2‰ (VPDB). Dolly's enamel $\delta^{13}C$ value is higher than the other individuals', at − 8.76‰ (VPDB). N4 is also considered an outlier

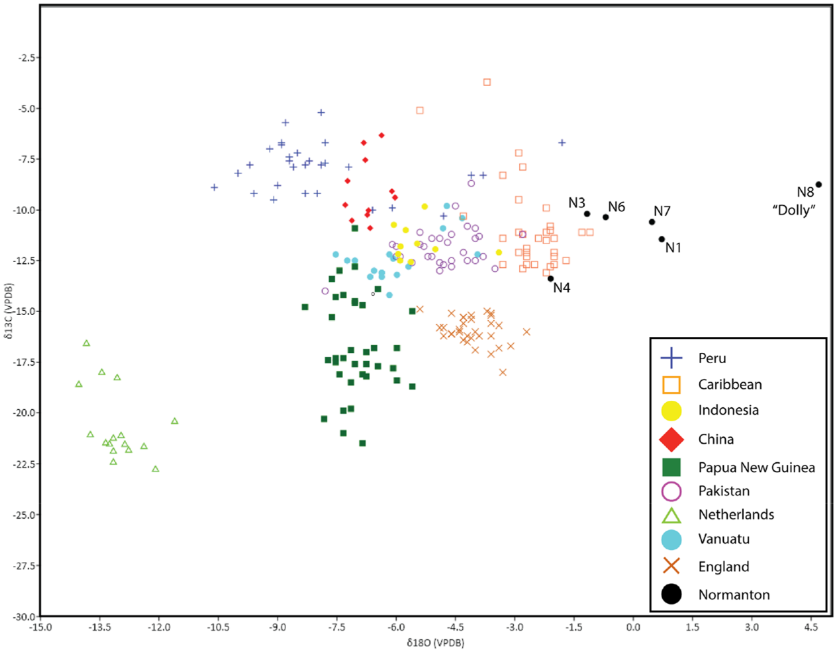

Figure 5. Global oxygen and carbon enamel isotope results compared against the Normanton individuals (Bentley et al. 2007; Fenner et al. 2016; Kenoyer et al. 2013; Kinaston et al. 2014; Knudson 2009; Laffoon et al. 2012; Neil et al. 2017; Shaw et al. 2010, 2011; Smits et al. 2010; Zhang et al. 2014)

yielding an enamel δ^{13}C result of − 13.4‰ (VPDB), which is the lowest value of the six individuals.

As noted earlier, bone collagen-derived carbon isotope ratios between − 16 and − 9‰ are thought to be indicative of a diet of C_4 vegetation (Stantis et al. 2015). δ^{13}C values can also discriminate between terrestrial and marine diets, with marine input elevating δ^{13}C values (Kinaston et al. 2014). Loftus and Sealy (2012) recorded an average enamel to collagen offset of 3.8 ± 1‰ for C_4 vegetation consumption, calculated to an enamel range of − 12 to − 5‰.

Our δ^{13}C results suggest that all Normanton individuals had a diet high in C_4 plants, C_4 plant-eating herbivores, and/or marine foods when they were growing up. The narrow range of δ^{13}C results for N1, N3, N6, and N7 suggests that they subsisted on a similar diet throughout tooth formation. N4's diet contained less C_4 plants, C_4 plant-eating herbivores, and/or marine foods. Dolly's elevated δ^{13}C results support the hypothesis that she was a member of the Gkuthaarn and Kukatj people who occupied the land along the Gulf of Carpentaria coast and therefore likely had a diet with a high proportion of marine foods.

To assess the likelihood of introduced crops in diet, the results for the six individuals were compared against a global comparative dataset (Figure 5). The Normanton individuals sit within a similar range to Indonesia, the Caribbean Islands, and Pakistan. European prehistoric $\delta^{13}C$ results are indicative of a diet of C_3 plants like wheat (Tokui et al. 2000) and sit lower on the plot. Interestingly, prehistoric $\delta^{13}C$ enamel results from Papua New Guinea also occupy this lower range. This global comparison suggests that in the 1890s C_3 grains like wheat did not represent a substantial part of the diet of these Aboriginal people, notwithstanding the distribution of flour (*maay bhilaw* in Kurtjar) in rations [alongside tobacco, tea, sugar, and beef (Black et al. 1986)]. This contradicts Adams et al.'s (2018) hypothesis regarding the caries they identified on the teeth of N3 and N6 and suggests instead that the caries were a consequence of consuming C_4 plants. Sugar is the obvious candidate in this regard, perhaps in the form of sugar in tea (*maay lngkirgh ey*… 'teylibh in Kurtjar). Access to reliable and sustainable food supplies was a significant issue for Aboriginal people living during the post contact period on the fringes of European settlements across north Queensland (Morrison et al. 2010), and the distribution of rations by white employers and officials created an attraction to, and dependency on the developing colonial society of the Gulf Country (Black et al. 1986; Martin 2019; Trigger 1985).

Oxygen Isotope Ratios

The enamel $\delta^{18}O$ results for the six individuals are presented in Table 4 and plotted alongside values for an international comparative sample in

Table 4 Normanton tooth enamel carbonate δ13C and δ18O results and ingested water values calculated using Chenery et al. (2012)

Sample	Tooth	Age during crown formation (years)	Enamel $\delta^{13}C$ (VPDB)	Enamel $\delta^{18}O$ (VPDB)	Enamel $\delta^{18}O$ (SMOW)	Ingested water $\delta^{18}O$ (SMOW)
N1	M^1	0–3	− 11.44	0.72	31.662	1.709
N3	M^2	3–6	− 10.19	− 1.17	29.714	− 1.389
N4	M^1	0–3	− 13.39	− 2.09	28.765	− 2.897
N6	M^1	0–3	− 10.35	− 0.7	30.198	− 0.619
N7	PM^1	2–6	− 10.59	0.47	31.405	1.299
N8	M^1	0–3	− 8.76	4.69	35.755	8.217

Figure 5. The enamel $\delta^{18}O$ values for the Normanton individuals range from − 2.09‰ VPDB to 4.69‰ VPDB (28.8–35.8‰ SMOW). These values are relatively high. Those for N3, N4, and N6 are close to the upper end of the range of the comparative sample, while the values for N1, N7, and Dolly are well above the highest value among the individuals in the comparative sample.

There are some environmental factors that could elevate ^{18}O in ingested waters and account for the relatively high $\delta^{18}O$ values exhibited by the Normanton individuals. For example, Ayliffe and Chivas (1990) found that there is a high degree of preferential loss of ^{16}O through evaporation of surface water in many parts of Australia. They concluded that this may lead to elevated $\delta^{18}O$ results in mammalian body tissues.

Similarly, a wealth of research indicates that ^{18}O isotopes are higher in abundance in monsoonal regions due to the so-called 'amount effect' (e.g. Eastoe and Dettman 2016; Gerling 2015). In the amount effect $\delta^{18}O$ is elevated by evaporation of falling raindrops, change in moisture source between seasons, and progressive regional rainout (Eastoe and Dettman 2016; Gerling 2015). As we explained earlier, the climate of the Gulf Country is influenced by the Australian monsoon, so it is highly likely that precipitation in the region is enriched in ^{18}O during the wet season, which normally runs from November to April (Woinarsky et al. 2007).

With the potential impact of these environmental factors in mind, we converted the Normanton results to ingested water values (Table 3) and then compared them to $\delta^{18}O$ values in the Australian Global Network of Isotopes in Precipitation (GNIP) dataset, which covers the last 60 years (Hollins et al. (2018). The 12 highest values in the GNIP dataset are listed in Supplementary Data 2. All of these results are higher than those for N1, N3, N4, N6, and N7, and a third of them are higher than the $\delta^{18}O$ value for Dolly. Hence, while the $\delta^{18}O$ value for the Normanton individuals are high compared to our comparative sample, they are not out of line with precipitation $\delta^{18}O$ values in Australia.

It is noteworthy that the most elevated values in the GNIP dataset (9.02–13.24‰ SMOW) were recorded at Mount Isa, which is only 100 km from Cloncurry where Dolly is reported to have worked at the police barracks (Table 1). This may indicate that she was in the Cloncurry–Mount Isa region while her M^1 was forming (birth to ten years of age [Ash and Nelson 2003]). On the face of it, this does not align with the enamel $^{87}Sr/^{86}Sr$ value for Dolly, which suggests she grew up close to Normanton. However, the discrepancy may be more apparent than real. In the $^{87}Sr/^{86}Sr$ analyses, we sampled just the outer enamel crown of the M^1. This portion of the tooth is formed by 2.5–3 years of age. We utilised a different approach in the $\delta^{18}O$ analyses. $\delta^{18}O$ was measured in ground whole tooth enamel, which records a wider breadth of age (i.e. from birth up to ten years of age). It is feasible, then, that the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values for Dolly indicate that she moved from the Normanton area to the Cloncurry–Mount Isa area between the ages of three and ten.

We suspect that a high degree of preferential loss of ^{16}O through surface water evaporation and the amount effect may not be the only factors responsible for the Normanton individuals' elevated $\delta^{18}O$ results. A number of physiological processes are known to have the potential to elevate $\delta^{18}O$ values in mammalian body tissues. These processes include body water loss through perspiration, urination, disease, and nursing (Abeni et al. 2015; Kohn 1996). Significantly in connection with this, historic documents indicate that Indigenous men, women, and children living in Gulf Country at the turn of the 20th century suffered greatly from infectious diseases that had been brought into the region by European settlers (Campbell 1983; McMichael and McMichael 2001; Levine 2013). For example, a government report from 1900 states that in Cloncurry, "the few remaining Aboriginal people are all diseased". The same document also indicates that all of the Indigenous people living at Camooweal were suffering from disease and that syphilis was widespread in the Indigenous community at Mount Garnet (Roth 1900). The report further states that half of the approximately 170 inhabitants of the Aboriginal camp at Normanton were suffering from infectious diseases at the time of data collection (Roth 1900). It seems highly likely, therefore, that most, if not all, of the individuals analysed in the present study had suffered from one or more infectious diseases during the period their teeth were forming, and that this may partly explain the relatively high $\delta^{18}O$ results for the Normanton individuals.

Conclusions

The study reported here is the first to utilise isotope geochemistry to better understand Indigenous life on the Australian colonial frontier during the late 19th century. In the study, we analysed strontium ($^{87}Sr/^{86}Sr$), carbon ($\delta^{13}C$), and oxygen ($\delta^{18}O$) isotope ratios from the tooth enamel and dentine of six individuals who died in Normanton, Queensland, in the 1890s. The results we obtained align with oral histories and historical records that indicate that many Indigenous people were displaced from their traditional territories in the Gulf Country in the 1860s, 1870s, and 1880s, before settling in and around the township of Normanton, where many of them died prematurely due to disease.

Our enamel $^{87}Sr/^{86}Sr$ results suggest that five of the six individuals included in this study spent their formative years living to the east or north-east of Normanton. While the enamel $^{87}Sr/^{86}Sr$ results for the sixth individual, who we believe is the person that Dr. Walter Roth called Dolly, not only indicate that she was from a different region from all the other individuals but also suggest that she began her life close to the coast in the Gulf of Carpentaria. This is consistent with Roth's notes on Dolly.

Our enamel carbon results suggest that the six individuals ingested little by way of European C_3 grains like wheat, and instead subsisted on native C_4 grasses, C_4-plant-consuming animals, and/or marine foods. This supports our interpretation of the $^{87}Sr/^{86}Sr$ results that the six individuals grew up in their traditional lands before being displaced to Normanton in the late 19th century CE.

The enamel the $\delta^{18}O$ results we obtained were high compared to those we collated for an international comparative sample. Those for N1, N7, and Dolly were especially high. We suspect the elevated values for the Normanton individuals can probably be explained by a combination of factors. One of these is a high degree of preferential loss of ^{16}O through evaporation of surface water. Another is the amount effect that is associated with the Australian monsoon. Infectious diseases are also likely to have played a role. This is because infectious diseases are known to be capable of elevating $\delta^{18}O$ values and historical documents indicate that Indigenous men, women, and children living in the Gulf Country often suffered from infectious diseases that had spread into the region with European settlers.

By comparing our isotope results for Dolly with each other, we were able to add valuable additional detail to our knowledge of her life. The available historical documents indicate that Dolly was one of the Gkuthaarn and Kukatj people and therefore was likely born in Normanton or its environs. The historical documents also tell us that later in life Dolly worked at the police barracks in Mount Isa, which is about 500 kms or 84 h southwest of Normanton by foot. Our $^{87}Sr/^{86}Sr$ results supported the first of these observations, and our $\delta^{18}O$ results supported the second. By considering the timings of the formation of the portions of the tooth that were sampled in the $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ analyses, we were able to estimate the age at which Dolly moved from the Normanton area to Cloncurry–Mount Isa area. It seems to have happened between 2.5 and 3 years of age and ten years of age. The upper end of this range is consistent with Roth's (1900, 1902, 1903) reports from the Gulf Country. These indicate that many Indigenous girls were taken from their families and made to work on stations and in hotels, and that it was not uncommon for such individuals to succumb to disease at a young age (Roth 1900, 1902, 1903).

Recent work has demonstrated that, when conducted within the individualising framework of osteobiography, isotope geochemistry has the potential to shed light on the lives of Indigenous Australians who lived prior to European colonisation (Adams et al., 2021). The study reported here shows that this approach also has the potential to illuminate the experiences of

Indigenous Australians who lived during the colonial period, providing insights that complement the information that can be gleaned from oral histories and historical documents. Perhaps most importantly in connection with this, the study shows that isotopic analyses of human remains can provide surprisingly detailed information about the lives of a category of Indigenous people who rarely appear in the documents written by early ethnographers and colonial officials—subadults. This is significant not only from an academic perspective but also from a sociopolitical one, since Indigenous Australians are increasingly demanding a truth-telling of the country's colonial era as part of reconciliation. That the analysis of the skeletal remains of Indigenous Australians can now contribute to the truth and reconciliation process is an unexpected, interesting, and welcome development in the story of bioarchaeology in Australia.

Funding

Open Access funding enabled and organized by CAUL and its Member Institutions. This study was supported by Australian Research Council (Grant No. LP140100387), Canada Research Chairs (Grant Nos. 203808, 231256), Canada Foundation for Innovation (Grant Nos. 203808, 36801), and British Columbia Knowledge Development Fund (Grant Nos. 862-804231, 962-805808).

Supplementary Information

Below is the link to the electronic supplementary material. Supplementary file1 (DOCX 21 KB)

References

Abeni, F., Petrera, F., Capelletti, M., Dal Prà, A., Bontempo, L., Tonon, A., & Camin, F.
(2015). Hydrogen and oxygen stable isotope fractionation in body fluid compartments of dairy cattle according to season, farm, breed, and reproductive stage. *PLoS ONE, 10*(5), e0127391.

Adams, C., Owen, T. D., Pate, F. D., Bruce, D., Nielson, K., Klaebe, R., Henneberg, M., & Moffat, I.
(2022). 'Do dead men tell no tales?' The geographic origin of a colonial period Anglican cemetery population in Adelaide, South Australia, determined by isotope analyses. *Australian Archaeology, 88*(2), 144–158.

Adams, S., Westaway, M. C., McGahan, D., Williams, D., Zhao, J. X., Feng, Y., Nguyen, A., Pearce, J., Flinders, C., & Collard, M.
(2021). Isotopic analyses of prehistoric human remains from the Flinders Group, Queensland, Australia, support an association between burial practices and status. *Archaeological and Anthropological Sciences, 13*(7), 121.

Adams, S., Grün, R., McGahan, D., Zhao, J. X., Feng, Y., Nguyen, A., Willmes, M., Quaresimin, M., Lobsey, B., Collard, M., & Westaway, M. C.
(2019). A strontium isoscape of north-east Australia for human provenance and repatriation. *Geoarchaeology, 34*(3), 231–251.

Adams, S., Martin, R., Phillips, S., Macgregor, C., & Westaway, M.
(2018). Truth-telling in the wake of European contact: Historical investigation of Aboriginal skeletal remains from Normanton. *Archaeologies, 14*(3), 412–442.

Ash, M. C.
(2011). French mischief: A foxy map of new Holland. *The Globe, 68*, 1.

Ash, M., & Nelson, S.
(2003). *Wheeler's dental anatomy, physiology and occlusion* (8th ed.). Saunders.

Ayliffe, L. K., & Chivas, A. R.
(1990). Oxygen isotope composition of the bone phosphate of Australian kangaroos: Potential as a palaeoenvironmental recorder. *Geochimica et Cosmochimica Acta, 54*(9), 2603–2609.

Bentley, R. A.
(2006). Strontium isotopes from the earth to the archaeological skeleton: A review. *Journal of archaeological method and theory, 13*(3), 135–187.

Bentley, R. A., Buckley, H. R., Spriggs, M., Bedford, S., Ottley, C. J., Nowell, G. M., Macpherson, C. G., & Pearson, D. G.
(2007). Lapita migrants in the Pacific's oldest cemetery: Isotopic analysis at Teouma. *Vanuatu. American Antiquity, 72*(4), 645–656.

Black, P.
(1975). Kukatj: final report. AIATSIS document, Canberra: MS686.

Black, P.
(1980). Norman Pama historical phonology. *Pacific Linguistics. Series A. Occasional Papers, 59*, 181.

Black, P., Adam, B., Casey, M., & Gilbert, R.
(1986). *Kurtjar stories.* Unpublished manuscript held by the Australian Institute of Aboriginal Studies.

Bowen, G. J., Wassenaar, L. I., & Hobson, K. A.
(2005). Global application of stable hydrogen and oxygen isotopes to wildlife forensics. *Oecologia, 143*(3), 337–348.

Breen, G.
(1972). Report on field trip to western Queensland and adjacent areas, April–July 1972. AIATSIS document, Canberra, MS159(8).

Bryant, J. D., & Froelich, P. N.
(1995). A model of oxygen isotope fractionation in body water of large mammals. *Geochimica et Cosmochimica Acta, 59*(21), 4523–4537.

Bryant, J. D., Koch, P. L., Froelich, P. N., Showers, W. J., & Genna, B. J.
(1996). Oxygen isotope partitioning between phosphate and carbonate in mammalian apatite. *Geochimica et Cosmochimica Acta, 60*(24), 5145–5148.

Brothwell, D.
(1981). Digging up bones: the excavation, treatment, and study of human skeletal remains. Cornell University Press, Cornell.

Budd, P., Montgomery, J., Barreiro, B., & Thomas, R. G.
(2000). Differential diagenesis of strontium in archaeological human dental tissues. *Applied geochemistry, 15*(5), 687–694.

Bulleta (pseud.).
(1897). Aborigines of the Gulf. *Queenslander, 23*(51), 183.

Buikstra, J.E., & Ubelaker, D. H. (1994).Standards for Data Collection from Human Skeletal Remains. *Fayeteville, Arkansas: Arkensas Archaeological Survey Report, 44.*

Campbell, J.
(1983). Smallpox in Aboriginal Australia: 1829–31. *Historical Studies, 20*(81), 536–556.

Campbell, J.
(2007). *Invisible Invaders: Smallpox and Other Diseases in Aboriginal Australia, 1780–1880*. Melbourne University Press.

Capell, A., 1963. *Linguistic survey of Australia.* AIATSIS document.

Chase, A., & Sutton, P.
(1981). Hunter-gathers in a rich environment: Aboriginal coastal exploitation in Cape York Peninsula. In A. Keast (Ed.), *Ecological biogeography of Australia*. Junk.

Chenery, C. A., Pashley, V., Lamb, A. L., Sloane, H. J., & Evans, J. A.
(2012). The oxygen isotope relationship between the phosphate and structural carbonate fractions of human bioapatite. *Rapid Communications in Mass Spectrometry, 26*(3), 309–319.

Coplen, T. B., Kendall, C., & Hopple, J.
(1983). Comparison of stable isotope reference samples. *Nature, 302*(5905), 236.

Cox, K. J., Bentley, R. A., Tayles, N., Buckley, H. R., Macpherson, C. G., & Cooper, M. J.
(2011). Intrinsic or extrinsic population growth in Iron Age northeast Thailand? The evidence from isotopic analysis. *Journal of Archaeological Science, 38*(3), 665–671.

Craig, H.
(1961). Isotopic variations in meteoric waters. *Science, 133*(3465), 1702–1703.

Curr, E. M.
(1887). *The Australian Race: Its Origin, Languages, Customs, Place of Landing in Australia and the Routes by Which it Spread Itself Over That Continent, in Four Volumes.* Government Printer.

Dansgaard, W.
(1954). Oxygen-18 abundance in fresh water. *Nature, 174*(4422), 234.

Daux, V., Lécuyer, C., Héran, M. A., Amiot, R., Simon, L., Fourel, F., Martineau, F., Lynnerup, N., Reychler, H., & Escarguel, G.
(2008). Oxygen isotope fractionation between human phosphate and water revisited. *Journal of Human Evolution, 55*(6), 1138–1147.

de Laeter, J. R., Böhlke, J. K., De Bièvre, P., Hidaka, H., Peiser, H. S., Rosman, K. J. R., & Taylor, P. D. P.
(2003). Atomic weights of the elements. Review 2000 (IUPAC Technical Report). *Pure and Applied Chemistry, 75*(6), 683–800.

DeNiro, M. J., & Epstein, S.
(1976). You are what you eat (plus a few‰): The carbon isotope cycle in food chains. *Geological Society of America, 6*, 834.

Dole, M., Lane, G. A., Rudd, D. P., & Zaukelies, D. A.
(1954). Isotopic composition of atmospheric oxygen and nitrogen. *Geochimica et Cosmochimica Acta, 6*(2–3), 65–78.

Dupras, T. L., & Schwarcz, H. P.
(2001). Strangers in a strange land: Stable isotope evidence for human migration

in the Dakhleh Oasis. *Egypt. Journal of Archaeological Science, 28*(11), 1199–1208.

Eastoe, C. J., & Dettman, D. L.
(2016). Isotope amount effects in hydrologic and climate reconstructions of monsoon climates: Implications of some long-term data sets for precipitation. *Chemical Geology, 430*, 78–89.

EHP.
(2015). Biodiversity Planning Assessment Gulf Plains Bioregion v1.1. Summary Report: Department of Environment and Heritage Protection, Queensland Government, Brisbane.

Epstein, S., & Mayeda, T.
(1953). Variation of O^{18} content of waters from natural sources. *Geochimica et Cosmochimica Acta, 4*(5), 213–224.

Evans, J. A., Chenery, C. A., & Fitzpatrick, A. P.
(2006). Bronze Age childhood migration of individuals near Stonehenge, revealed by strontium and oxygen isotope tooth enamel analysis. *Archaeometry, 48*(2), 309–321.

Faure, G.
(1986). *Principles of Isotope Geochemistry*. Wiley.

Fenner, J. N., Gagan, M. K., Cowley, J., Armstrong, R., & Prasetyo, B.
(2016). Investigating the presence of foreigners and pig husbandry in ancient Bali: Stable isotopes in human and domestic animal tooth enamel. *Journal of Archaeological Science: Reports, 10*, 272–281.

Fernandes, R., Nadeau, M. J., & Grootes, P. M.
(2012). Macronutrient-based model for dietary carbon routing in bone collagen and bioapatite. *Archaeological and Anthropological Sciences, 4*(4), 291–301.

Fricke, H. C., O'Neil, J. R., & Lynnerup, N.
(1995). Oxygen isotope composition of human tooth enamel from medieval Greenland: Linking climate and society. *Geology, 23*(10), 869–872.

Froehle, A. W., Kellner, C. M., & Schoeninger, M. J.
(2010). FOCUS: Effect of diet and protein source on carbon stable isotope ratios in collagen. *Journal of Archaeological Science, 37*(10), 2662–2670.

Fullagar, R., & Field, J.
(1997). Pleistocene seed-grinding implements from the Australian arid zone. *Antiquity, 71*, 300–307.

George on behalf of the Gkuthaarn and Kukatj People v State of Queensland [2020] FCA 1310.

Gerling, C.
(2015). *Prehistoric Mobility and Diet in the West Eurasian Steppes 3500 to 300 BC: An Isotopic Approach*. Walter de Gruyter.

Gilbert, R., & Black, P.
(1980). *About Kurtjar Land: A statement by the Kurtjar people of Normanton, Queensland*. Unpublished manuscript held by the Australian Institute of Aboriginal and Torres Strait Islander Studies.

Goldberg, M., Kulkarni, A. B., Young, M., & Boskey, A.
(2011). Dentin: Structure, Composition and Mineralization: The role of dentin ECM in dentin formation and mineralization. *Frontiers in Bioscience, 3*, 711.

Grün, R., Eggins, S., Kinsley, L., Moseley, H., & Sambridge, M.
(2014). Laser ablation U-series analysis of fossil bones and teeth. *Palaeogeography, Palaeoclimatology, Palaeoecology, 416*, 150–167.

Hattersley, P. W.
(1983). The distribution of C 3 and C 4 grasses in Australia in relation to climate. *Oecologia, 57*(1–2), 113–128.

Hiatt, L.R.
(1984). Your mother-in-law is poison. *Man,* 183–198.

Hollins, S. E., Hughes, C. E., Crawford, J., Cendón, D. I., & Meredith, K. M.
(2018). Rainfall isotope variations over the Australian continent–Implications for hydrology and isoscape applications. *Science of the Total Environment, 645*, 630–645.

Horstwood, M. S. A., Evans, J. A., & Montgomery, J.
(2008). Determination of Sr isotopes in calcium phosphates using laser ablation inductively coupled plasma mass spectrometry and their application to archaeological tooth enamel. *Geochimica et Cosmochimica Acta, 72*(23), 5659–5674.

Hynes, R., & Chase, A.
(1982). Plants, sites and domiculture: Aboriginal influence upon plant communities in Cape York Peninsula. *Archaeology in Oceania, 17*(1), 38–50.

Khan, K.
(1993). Catalogue of the Roth Collection of Aboriginal artefacts from north Queensland, Volume 1, Items collected from Archer River, Atherton, Bathurst Head, Bloomfield River and Butcher's Hill, 1897–1901. *Technical Reports of the Australian Museum, 10*, 1–205.

Kellner, C. M., & Schoeninger, M. J.
(2007). A simple carbon isotope model for reconstructing prehistoric human diet. *American Journal of Physical Anthropology, 133*(4), 1112–1127.

Kenoyer, J. M., Price, T. D., & Burton, J. H.
(2013). A new approach to tracking connections between the Indus Valley and

Mesopotamia: Initial results of strontium isotope analyses from Harappa and Ur. *Journal of Archaeological Science, 40*(5), 2286–2297.

Kinaston, R. L., Buckley, H. R., Halcrow, S. E., Spriggs, M. J., Bedford, S., Neal, K., & Gray, A.
(2009). Investigating foetal and perinatal mortality in prehistoric skeletal samples: A case study from a 3000-year-old Pacific Island cemetery site. *Journal of Archaeological Science, 36*(12), 2780–2787.

Kinaston, R., Buckley, H., Valentin, F., Bedford, S., Spriggs, M., Hawkins, S., & Herrscher, E.
(2014). Lapita diet in Remote Oceania: new stable isotope evidence from the 3000-year-old Teouma site, Efate Island, Vanuatu. *PLoS ONE, 9*(3), e90376.

Knudson, K. J.
(2009). Oxygen isotope analysis in a land of environmental extremes: The complexities of isotopic work in the Andes. *International Journal of Osteoarchaeology, 19*(2), 171–191.

Kohn, M. J.
(1996). Predicting animal δ18O: Accounting for diet and physiological adaptation. *Geochimica et Cosmochimica Acta, 60*(23), 4811–4829.

Lack, C. L.
(1962). History and potential future of Cape York Peninsula. *Journal of the Royal Historical Society of Queensland, 6*(4), 942–1013.

Lacumin, P., Bocherens, H., Mariotti, A., & Longinelli, A.
(1996). An isotopic palaeoenvironmental study of human skeletal remains from the Nile Valley. *Palaeogeography, Palaeoclimatology, Palaeoecology, 126*(1–2), 15–30.

Levine, P.
(2013). Prostitution, race, and politics: policing venereal disease in the British Empire, Routledge, Abingdon-on-Thames.

Loftus, E., & Sealy, J.
(2012). Technical note: Interpreting stable carbon isotopes in human tooth enamel: An examination of tissue spacings from South Africa. *American Journal of Physical Anthropology, 147*, 499–507.

Longinelli, A.
(1984). Oxygen isotopes in mammal bone phosphate: A new tool for paleohydrological and paleoclimatological research? *Geochimica et Cosmochimica Acta, 48*(2), 385–390.

Laffoon, J. E., Davies, G. R., Hoogland, M. L., & Hofman, C. L.
(2012). Spatial variation of biologically available strontium isotopes ($^{87}Sr/^{86}Sr$) in an archipelagic setting: A case study from the Caribbean. *Journal of Archaeological Science, 39*(7), 2371–2384.

Luz, B., Kolodny, Y., & Horowitz, M.
(1984). Fractionation of oxygen isotopes between mammalian bone-phosphate and environmental drinking water. *Geochimica et Cosmochimica Acta, 48*(8), 1689–1693.

Martin, R.
(2019). *The Gulf Country: The Story of People and Place in Outback Queensland*. Allen & Unwin.

Mathews, R. H.
(1899). Divisions of some Aboriginal tribes, Queensland. *Votes and Proceedings of the Royal Society of New South Wales, 33*, 108–114.

Mathews, R. H.
(1900). The origin, organization and ceremonies of the Australian Aborigines. *American Philosophical Society, 39*(164), 556–578.

McMichael, T. & McMichael, A.J.
(2001). Human frontiers,environments and disease: past patterns, uncertain futures. Cambridge University Press.

Montgomery, J.
(2002). *Lead and Strontium Isotope Compositions of Human Dental Tissues as an Indicator of Ancient ERxposure and Population Dynamics*. Unpublished PhD thesis, University of Bradford, UK.

Morrison, M., McNaughton, D., & Shiner, J.
(2010). Mission-based Indigenous production at the Weipa Presbyterian Mission, Western Cape York Peninsula (1932–66). *International Journal of Historical Archaeology, 14*(1), 86–111.

Murphy, M. A., & Jones, C. E.
(1999). Observations on the genus *Elymus* (Poaceae: Triticeae) in Australia. *Australian Systematic Botany, 12*(4), 593–604.

Murphy, B. P., & Bowman, D. M.
(2007). Seasonal water availability predicts the relative abundance of C_3 and C_4 grasses in Australia. *Global Ecology and Biogeography, 16*(2), 160–169.

Nanci, A.
(2012). *Ten Cate's Oral Histology Development, Structure, and Function*. Elsevier.

Neil, S., Montgomery, J., Evans, J., Cook, G. T., & Scarre, C.
(2017). Land use and mobility during the Neolithic in Wales explored using isotope analysis of tooth enamel. *American Journal of Physical Anthropology, 164*(2), 371–393.

Nelson, S. J.
(2014). *Wheeler's Dental Anatomy, Physiology and Occlusion*. Elsevier.

Oates, L.
(1975). *The 1973 Supplement to A Revised Linguistic Survey of Australia.* Armidale Christian Book Centre.

Owen, T., & Casey, M.
(2017). The Old Sydney Burial Ground: Using isotopic analysis to infer the origin of individual skeletons. *Australasian Historical Archaeology, 35*, 24–33.

Parry-Okeden, W.
(1897). *Report on the North Queensland Aborigines and the Native Police, with appendices*. Government Printer.

Passey, B. H., Robinson, T. F., Ayliffe, L. K., Cerling, T. E., Sponheimer, M., Dearing, M. D., Roeder, B. L., & Ehleringer, J. R.
(2005). Carbon isotope fractionation between diet, breath CO2, and bioapatite in different mammals. *Journal of Archaeological Science, 32*(10), 1459–1470.

Pestle, W. J., Crowley, B. E., & Weirauch, M. T.
(2014). Quantifying inter-laboratory variability in stable isotope analysis of ancient skeletal remains. *PLoS ONE, 9*(7), e102844.

Peterson, B. J., & Fry, B.
(1987). Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics, 18*(1), 293–320.

Price, T. D., Burton, J. H., & Bentley, R. A.
(2002). The characterization of biologically available strontium isotope ratios for the study of prehistoric migration. *Archaeometry, 44*(1), 117–135.

Prodan, D., Moldovan, M., Prejmerean, C., Silaghi-Dumitrescu, L., Boboia, S., Popescu, V., Pascalau, V., Molea, A., Diana, L., & Perhaita, I.
(2014). Synthesis and characterization of an experimental Zn-hydroxyapatite powders with application in dentistry. *Key Engineering Materials, 587*, 43–51.

Queenslander.
(1972). Normanton. *The Queenslander,* 4 May 1872. QLD State Archives. Colonial Secretary's Office, Item ID 846890, 1871/2269, corr. 8.8.1871.

Radhakrishnan, R.
(2011). Chewing the very teeth because it bites: An anthropological forensics by stable isotope profiling. *Journal of forensic dental sciences, 3*(1), 1.

Rainbow on behalf of the Kurtjar People v State of Queensland (No. 2) [2021] FCA 1251.

Ross, M. H., Kaye, G. I., & Pawlina, W.
(2006). *Histology: A text and atlas* (5th ed.). Lippincott Williams & Wilkins.

Roth, W.
(1897). *Ethnographic studies amongst the NW central Aborigines*. Cambridge University Press.

Roth, W.
(1900). Annual Report of the Northern Protector of Aboriginals for 1899, QLD Government, Brisbane, C. A. 1-1901

(1901). Annual Report of the Northern Protector of Aboriginals for 1900, QLD Government, Brisbane, C. A. 61-1902.

(1902). Annual Report of the Northern Protector of Aboriginals for 1901, QLD Government, Brisbane, C. A. 61–1903.

Roth, W.E.
(1903). Report to Under Secretary. Department of Public Lands, Brisbane Doctoral Disertation, Research School of Earth Sciences, ANU, Canberra.

Santrock, J., Studley, S. A., & Hayes, J. M.
(1985). Isotopic analyses based on the mass spectra of carbon dioxide. *Analytical Chemistry, 57*(7), 1444–1448.

Schoeninger, M. J., & DeNiro, M. J.
(1984). Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta, 48*(4), 625–639.

Sharp, L.
(1939). Tribes and totemism in north-east Australia. *Oceania, 9*, 439–461.

Shaw, B., Buckley, H., Summerhayes, G., Anson, D., Garling, S., Valentin, F., Mandui, H., Stirling, C., & Reid, M.
(2010). Migration and mobility at the Late Lapita site of Reber-Rakival (SAC), Watom Island using isotope and trace element analysis: A new insight into Lapita interaction in the Bismarck Archipelago. *Journal of Archaeological Science, 37*(3), 605–613.

Shaw, B., Buckley, H., Summerhayes, G., Stirling, C., & Reid, M.
(2011). Prehistoric migration at Nebira, South Coast of Papua New Guinea: New insights into interaction using isotope and trace element concentration analyses. *Journal of Anthropological Archaeology, 30*(3), 344–358.

Simonetti, A., Buzon, M. R., & Creaser, R. A.
(2008). In-situ elemental and Sr isotope investigation of human tooth enamel by laser ablation (MC)-ICP-MS: Successes and pitfalls. *Archaeometry, 50*(2), 371–385.

Smits, E., Millard, A. R., Nowell, G., & Pearson, D. G.
(2010). Isotopic investigation of diet and residential mobility in the Neolithic of the Lower Rhine Basin. *European Journal of Archaeology, 13*(1), 5–31.

Sponheimer, M., & Lee-Thorp, J. A.
(1999). Oxygen isotopes in enamel carbonate and their ecological significance. *Journal of Archaeological Science, 26*(6), 723–728.

Stantis, C., Kinaston, R. L., Richards, M. P., Davidson, J. M., & Buckley, H. R.
(2015). Assessing human diet and movement in the Tongan maritime chiefdom using isotopic analyses. *PLoS ONE, 10*(3), e0123156.

Theden-Ringl, F., Fenner, J. N., Wesley, D., & Lamilami, R.
(2011). Buried on foreign shores: Isotope analysis of the origin of human remains recovered from a Macassan site in Arnhem Land. *Australian Archaeology, 73*(1), 41–48.

Thorp, J. L., Sealy, J. C., Hobson, K. A., & Collier, S.
(1986). On Australian aboriginal diets. *Current Anthropology, 27*(1), 54.

Tindale, N. B.
(1974). *Aboriginal Tribes of Australia: Their Terrain, Environmental Controls, Distribution, Limits, and Proper Names*. University of California Press.

Tindale, N. B., & Lindsay, H. A.
(1963). *Aboriginal Australians*. Jacaranda Press.

Tokui, N., Minari, Y., Kusunoki, K., Yoshimura, T., Yamamoto, T., & Minagawa, M.
(2000). Evaluation of dietary intake using carbon and nitrogen isotopic analysis of human of Chinese living in southern part of China. *Journal of UOEH, 22*(3), 219–228.

Trigger, D.
(1985). *Doomadgee: A Study of Power Relations and Social Action in a North Australian Aboriginal Settlement*. Unpublished PhD thesis, University of Queensland Department of Anthropology.

Turner, B. L., Kamenov, G. D., Kingston, J. D., & Armelagos, G. J.
(2009). Insights into immigration and social class at Machu Picchu, Peru based on oxygen, strontium, and lead isotopic analysis. *Journal of Archaeological Science, 36*(2), 317–332.

Van der Merwe, N. J., & Vogel, J. C.
(1978). 13C content of human collagen as a measure of prehistoric diet in woodland North America. *Nature, 276*(5690), 815.

Vanderstay, L., & Reeves, I.
(2000). Geology and Geomorphology of Western Queensland Magazine, Technical Notes: WQ31, QLD Government, Brisbane.

Vital, S. O., Gaucher, C., Bardet, C., Rowe, P. S., George, A., Linglart, A., & Chaussain, C.
(2012). Tooth dentin defects reflect genetic disorders affecting bone mineralization. *Bone, 50*(4), 989–997.

Westaway, M., Muller, W., Harradine, H., & Chatfield, J.
(2004). Resolving complex provenance issues through isotopic analysis of human bones and the potential benefits to Aboriginal communities. *Artefact: The Journal of the Archaeological and Anthropological Society of Victoria, 27*, 91.

White, C., Longstaffe, F. J., & Law, K. R.
(2004). Exploring the effects of environment, physiology and diet on oxygen isotope ratios in ancient Nubian bones and teeth. *Journal of Archaeological Science, 31*(2), 233–250.

Willmes, M.
(2015). Strontium isotope tracing of prehistoric human mobility in France.

Willmes, M., Kinsley, L., Moncel, M. H., Armstrong, R. A., Aubert, M., Eggins, S., & Grün, R.
(2016). Improvement of laser ablation in situ micro-analysis to identify diagenetic alteration and measure strontium isotope ratios in fossil human teeth. *Journal of Archaeological Science, 70*, 102–116.

Woinarski, J., Mackey, B., Nix, H., & Traill, B.
(2007). *The nature of Northern Australia: It's natural values, ecological processes and future prospects*. ANU Press.

Wright, L. E.
(2005). Identifying immigrants to Tikal, Guatemala: Defining local variability in strontium isotope ratios of human tooth enamel. *Journal of Archaeological Science, 32*(4), 555–566.

Zhang, X., Burton, J., Jin, Z., Xiao, M., Fan, A., & Xu, J.
(2014). Isotope studies of human remains from Mayutian, Yunnan Province, China. *Journal of Archaeological Science, 50*, 414–419.