A Radiocarbon Chronology for Estadio de Quillota in the Aconcagua Valley, Central Chile, with reference to the adoption of intensive maize agriculture and revisiting the timing of Inka influence on the southern frontier

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Abstract

Estadio de Quillota (EDQ) is the largest known pre-Columbian cemetery site within the Aconcagua Valley of Central Chile. Despite its importance, existing chronological data for EDQ are limited and questions remain regarding the prehistory of the Valley, particularly around the adoption and intensification of maize agriculture, as well as the timing of Inka influence reaching the region.

Seventeen new AMS radiocarbon dates presented here indicate two distinct phases of use at EDQ: An earlier phase (339-196 cal BC to cal AD 128-339), and a later phase (cal AD 1280-1387 to cal AD 1413-1458). Accompanying stable isotope ($\delta^{13}C$ and $\delta^{15}N$) analyses of human bone collagen (n=22) demonstrate diachronic dietary changes corresponding to these phases, with a reliance on terrestrial C_3 resources during the earlier period, followed by a heavy dependence on C_4-based (maize) resources during the later use.

Bayesian modelling of the dates from Late Period contexts suggests Inka influence arrived in Central Chile by c. cal AD 1400, decades before the traditionally recorded used date, AD 1471. The expansion likely occurred with an initial phase of interaction and exchange preceding a later phase of integration. This finding supports growing evidence that the traditional chronology of the Inka Empire requires reconsideration.

Introduction

Estadio de Quillota (EDQ) is the largest known pre-Columbian cemetery site within the Aconcagua Valley and has been described as one of the most important sites for the archaeology of Central Chile (Ávalos and Saunier 2011). The use of the cemetery has been presumed to be relatively continuous from at least the beginning of the Early Ceramic (c.300 BC) through until the Late Period when the region came under Inka influence (c. AD 1450–1536) (Gajardo-Tobar and Silva 1970; Didier and Ávalos 2009a, 2009b). This time span encompasses an array of technological, social and cultural developments, from hunting and gathering, to the initial use of ceramics, early exploitation of cultigens, the intensification of maize (*Zea mays*) farming, and the burgeoning influence of the Inka Empire. The use of a cemetery at a single location seeing all of these developments would, in principle, provide an excellent opportunity to explore their impacts on human diet and health, changes in demographics, lifeways and mortuary practices. However, detailed contextual information for individual burials is lacking and existing chronological data for EDQ are limited. Questions remain regarding the prehistory of the site and the Aconcagua Valley, particularly around the timing and nature of the adoption and expansion of maize agriculture, as well as the timing of Inka influence in the region.

The Aconcagua Valley lies on the periphery of intensive maize agriculture in the Americas and also on the southern frontier of the Inka Empire. Despite the rich cultural heritage of the region, there are few existing radiocarbon dates for the large cemetery site at EDQ, or indeed the Aconcagua Valley, and a robust chronological framework is lacking. Much of the extant research and knowledge of the Valley's archaeology is confined to the excavation and salvage reports of specific sites, especially for the mid to lower reaches of the river system. Temporal associations have so far largely been assigned using ceramic typo-chronologies and thermoluminescence (TL) dating alongside limited radiocarbon dates (Sánchez et al. 2004; Ávalos and Saunier 2011; Cornejo 2014).

This paper aims to establish an initial radiocarbon chronology for EDQ, and determine where it fits within the chronology of the Aconcagua river valley system. This is important in terms of providing a framework within which to address questions around the timing of socio-political transitions and variations in subsistence strategies in the Aconcagua Valley that warrant further investigation. To this end, we present a preliminary radiocarbon chronology for EDQ by dating human bone collagen from 17 selected burials. New dietary stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$) of human bone collagen for the 22 EDQ burials with direct dates (including five pre-existing dates from Fuenzalida [2014]) are also presented to address dietary change.

Given the putative long timescale of burial at EDQ, stable isotope data from directly dated individuals can inform on changes in diet over time, particularly regarding the introduction and intensification of maize agriculture. The presence of culturally heterogeneous groups has been postulated for both EDQ and the Aconcagua Valley as a whole (Sánchez et al. 2004; Sánchez Romero 2004; Ávalos and Saunier 2011; Fuenzalida 2014). Limited previous stable isotope ($\delta^{13}C$ and $\delta^{15}N$) evidence supports this by demonstrating considerable dietary variability among pre-Columbian groups in the Valley, particularly concerning the consumption of maize and marine resources (Swift et al., 2017). The stable isotope data when combined with radiocarbon dating can also address the extent to which dietary variability is diachronic or synchronic, the latter suggesting that distinct communities with different dietary practices utilised the same cemetery to bury their dead (cf. Santana-Sagredo et al. 2015).

There is also a question around the timing of the arrival of Inka influence in Central Chile, on the southern frontier of the Empire. Traditionally, the southward expansion of the Inka Empire has been based on a date of AD 1471, though nowadays many sources place it some decades earlier, at c. AD 1450 (Uribe and Sánchez 2016). However, Bayesian modelling of radiometric dates from other frontier regions of the Inka Empire in Ecuador and neighbouring regions of Argentina is increasingly suggesting that the traditional chronology of Inka expansion derived from the historical accounts of Spanish chroniclers may be incorrect (Ogburn 2012; Marsh et al. 2017). Of the EDQ burials with direct radiocarbon dates, nine have been identified as belonging to Late Period contexts, of which seven were buried with ceramics of a style termed '*Local Inka Phase*' (Fuenzalida 2014; Dávila et al. 2018). Direct dating of these burials should aid in clarifying the timing of the transition between the Late Intermediate Period and the Late Period, which saw the expansion of Inka influence into Central Chile, on what became the southern frontier of their Empire.

The new radiocarbon dates, along with associated stable isotope analysis and chronometric modelling presented here provide a greater understanding not only of this important site and where it fits within the occupation sequence of the Valley, but also of the region's broader archaeology, and questions surrounding the use and control of food resources on the southern frontier of intensive maize agriculture in the Americas, as well as the expansion of the Inka into their southern frontier.

Background

The Aconcagua Valley extends from the Andes in the east to the Pacific Ocean in the west and encompasses diverse ecological zones. Prehistoric sites have been recorded along the length of the river valley, the course of which can be divided into several geographic zones: the lower course, from the coast to the coastal cordillera; the middle course, which includes the broad, fertile inland valley area running from north to south between the coastal cordillera and the Andean cordillera; and the upper course, comprising the upper basin of the Aconcagua in the foothills of the Andes. The tumulos-style cemetery at Estadio de Quillota is situated on the inland side of the coastal cordillera on the broad fluvial terrace of the middle course of the Aconcagua River. It is located within the modern city of Quillota, approximately 83 km northwest of Santiago, and 38 km northeast of the port city of Valparaíso (Figure 1).

Insert Figure 1

There have been multiple excavations at EDQ beginning in 1955-1956 (Gajardo-Tobar and Silva 1970) with subsequent commercial salvage excavations in 2009 and 2010 (Didier and Ávalos 2009a, 2009b; Baeza 2010). Over 200 burials have been excavated, estimated to represent only a proportion of the total number at the site. Human remains have also been recovered from salvage excavations at the adjoining site of Calle Arauco, which forms an extension of the EDQ cemetery, and is also included in this study.

It is thought that the large cemetery at EDQ was in use from the Early Ceramic Period (ECP) (c. 300 BC – AD 1000/1200), through the Late Intermediate Period (LIP) (c. AD 1000/1200 – 1450), and into the Late Period (LP) (c. 1450 AD – 1536) (Gajardo-Tobar and Silva 1970; Didier and Ávalos 2009a; Baeza 2010; Ávalos and Saunier 2011). The Late Holocene in Central Chile, from ECP to LP, has been characterised by heterogeneous enclaves of at least partly contemporaneous local cultures (Bato, Llolleo and Aconcagua) alongside other cultural groups that expanded into the area from the semi-arid north, such as the Diaguita, followed by the expanding influence of the Inka Empire (Sánchez et al. 2004; Ávalos and Saunier 2011; Falabella et al. 2016; Uribe and Sánchez 2016) (Table 1).

Insert Table 1

The contextual information available for individual burials at EDQ is extremely limited, largely due to the time constraints of salvage excavations. However, analysis of the ceramics from a subset of the burials (Fuenzalida 2014), combined with limited descriptions and photographs of other burials has allowed for the attribution of some individuals to the Early Ceramic (ECP), Late Intermediate (LIP) and Late Periods (LP). LP ceramics, specifically of the *Local Inka Phase* style, have been identified from the grave goods of seven of the 23 individuals included in this study, and radiocarbon dates have previously been reported for six of those individuals (Fuenzalida 2014), confirming use of the site into the early 15th century. Two thermoluminescence dates from pots not associated with burials have also been reported from one of the previous excavations: an anthropomorphic jug from the ECP (AD 405 ± 170) (typical of the Llolleo culture) and a cup with a stepped trichrome motif, identifiable as an LP style (AD 1420 ± 45) (reported without lab codes in Didier and Ávalos 2009a).

Grave goods at EDQ predominantly comprised pottery of varying forms, the majority being of local styles such as '*Aconcagua Local'* or '*Local Inka Phase'* ceramics (Fuenzalida 2014). External influences, predominantly from the Diaguita culture of the semi-arid north, but also from the Inka are described in LP burials (Gajardo-Tobar and Silva 1970; Didier and Ávalos 2009a; Baeza 2010). Other burial offerings included ceramic pipes, bone instruments, copper and stone jewellery, stone tools and projectile points. The presence of pipes, in particular, has led to an interpretation of special ritual and spiritual significance for this site (Ávalos and Saunier 2011).

Excavation reports note three distinct strata across the site at EDQ (Gajardo-Tobar and Silva 1970; Baeza 2010); however, this information is not available for each individual burial. It is recorded that burials from the upper two strata have been attributed to the LIP and LP, with many interred in tumuli with stones surrounding the body. These burials were often also accompanied by funerary ceramics with many of the LP burial offerings demonstrating influence of Diaguita and Inka styles (Gajardo-Tobar and Silva 1970; Didier and Ávalos 2009b; Baeza 2010). The majority of LIP and LP burials were in a prone position, but some were supine, with body and limbs extended and typically oriented with the head pointing east or northeast. Burials attributed to the ECP, on the other hand, were generally found in the lowest strata and interred in a flexed position. Many burials, however, were considerably damaged due to previous construction work on the site, meaning that burial position often could not be recorded during excavation.

Maize Agriculture in Central Chile

The appearance and subsequent intensification of maize agriculture in the archaeological record of the Americas is an important indicator of agricultural expansion and is often concomitant with social and political developments (Hastorf and Johannessen 1993;

Emerson et al. 2005; Finucane et al. 2006; Gil et al. 2006). The South Central Andes (north-western Argentina and Central to Central-South Chile) was home to some of the southernmost agriculturalists of South America, and the final region to adopt cultivation of pre-Hispanic crops (Gil 2003). The broad fertile river valleys of Central Chile were ideally suited for large-scale agriculture, with chroniclers from the post-contact period describing the Aconcagua Valley in particular as an epicentre for the production of maize (Frézier 1717). Yet the majority of Central Chilean archaeological research, including stable isotopic studies, has concentrated on the Maipo-Mapocho basin around Santiago and the Cachapoal river to the south (Falabella et al. 2016). The only previous isotopic study from the Aconcagua Valley incorporated a handful of sites from coastal and inland valley settings, and found considerable variability in dietary practices from the ECP to the LP. This study found an increase in mean $\delta^{13}C$ values during the LIP, suggesting that intensification of maize took place during this period (Swift et al. 2017). Isotopic reconstructions of diet in the Maipo-Mapocho basin to the south indicate that some of the inland communities of the ECP were among the first in Central Chile to adopt maize (Falabella et al. 2008). However, intensive maize agriculture did not appear until c. AD 1000-1200 (Falabella et al. 2008; Falabella et al. 2016).

Stable carbon and nitrogen isotopic analyses are particularly suited to answering questions regarding the consumption of maize. Most wild plants and cultigens follow a C_3 photosynthetic pathway, while maize uses the C_4 pathway. The $\delta^{13}C$ signature of C_4 plants is distinct from C_3 plants, such that incorporation of maize in the diet will result in significantly elevated stable carbon isotope values in body tissues. Maize is the only true Americas cereal and often recognised as the only C_4 plant contributing significantly to diet in Central Chile (Falabella et al. 2020). However, in southern Peru, Cadwallader et al. (2012) have identified various other C_4 plants from the *Graminae*, *Chenopodiaceae*, *Asteraceae* and *Amaranthaceae* families, which include several important edible plants for both humans and animals. Hence, the possibility of C_4 plants other than maize contributing to elevated $\delta^{13}C$ values cannot be entirely excluded, though there is no palaeobotanical evidence for intensive use of C_4 plants apart from *Zea mays*.

Stable nitrogen ($\delta^{15}N$) isotope analysis complements the interpretation of the $\delta^{13}C$ data by providing information about dietary trophic level, which can be useful in distinguishing mixed C_3-C_4 terrestrial diets from mixed marine diets. However, it is important to bear in mind that some agricultural practices, such as fertilising crops, can substantially raise $\delta^{15}N$ values in horticultural produce (Szpak et al. 2012; Santana-Sagredo et al. 2021). Climate changes can also cause variation in $\delta^{15}N$, with increased aridity, and $\delta^{13}C$, with proportional variations in

C_4 plants linked to temperature. Central Chile is subject to a Mediterranean climate with dry summers and wet winters. The current climatic conditions, however, have remained much the same for the last 3,000 years with seasonal and inter-annual variations in rainfall influenced by El Niño Southern Oscillation fluctuations (Villagrán and Varela 1990; Jenny et al. 2002; Villa-Martínez et al. 2003).

The Inka Empire in the Aconcagua Valley

The Inka Empire, *Tawantinsuyu*, the 'Land of the Four Quarters', comprised four regions of expansion: *Antisuyu*, *Cuntisuyu*, *Chinchasuyu* and *Collasuyu*, with Cuzco located at the nexus of the quarters. *Collasuyu* was the southernmost and the largest quarter of the Empire, incorporating parts of modern southern Peru, western Bolivia, northwestern Argentina, northern Chile and extending as far south as Central Chile (Moseley 2001; D'Altroy 2002). The Aconcagua Valley of Central Chile held strategic significance in the Inka State during the Late Period as an administrative centre for the southern reaches of the Empire (Mariño de Lobera 1970 [1580]; Vivar 1988 [1558]; Valdivia 1991 [1555]; de Góngora Marmolejo 2010 [1524-1575]).

Inka control of Central Chile is generally held to have been via a system of indirect government (Silva 1978; Falabella 1994; Stehberg 1995; Uribe 2000; Sánchez Romero 2002; Hermosilla et al. 2005). Recent discussions surrounding the nature of the expansion of *Tawantinsuyu* into the Maipo-Mapocho basin surrounding Santiago have presented arguments for an initial phase of Inka influence in the region, followed by a secondary phase of Imperial occupation (eg. Alconini 2016; Dávila et al. 2018; Pavlovic et al. 2019; Puerto Mundt and Marsh 2021). In the Aconcagua Valley it is proposed that the initial phase of Inka influence involved varied interaction between the Inka and the local populations and included the circulation of ideas, material culture, political negotiation and redistribution, while the subsequent phase saw the consolidation of Central Chile into the Empire's southern frontier and the appearance of Inka structures, *tambos* (state-owned lodgings located on Inka roads), *qollqas* (storehouses), *pukaras* (fortified sites), *huacas* (shrines), high altitude ceremonial sites and cemeteries. Inka emplacements are present at various intervals along the Aconcagua Valley from coast to mountains (Coros and Coros 1999; Sánchez Romero 2002, 2004; Troncoso et al. 2012; Pavlovic et al. 2014; Dávila et al. 2018).

The existing local culture, the Aconcagua, persisted into the early stages of the Late Period, but exhibited signs of 'foreign' Diaguita and Inka influences in their material culture. The heterogeneity observed in Late Period ceramic morphology and technology has been interpreted as a representation of different degrees of local integration with the Inka State, where principles of exclusion and inclusion operated between *Tawantinsuyu* and different local communities (Martínez 2011; Fuenzalida 2014; Dávila et al. 2018; Pavlovic et al. 2019). A burgeoning Inka occupation subsequently saw various Imperial structures used for ceremonial, defensive and administrative purposes established at strategic points along the river valleys and longitudinal roads (Stehberg 1995; Coros and Coros 1999; Troncoso et al. 2012).

Even though such a substantial Inka presence has been recorded in the Aconcagua Valley from the coast to the Andes, radiocarbon dating of Inka contexts has been limited to the sites of El Tigre, a site with monumental Inka architecture (Pavlovic et al. 2012), and Los Nogales, a domestic site where Inka metallurgical practices had been adopted (Plaza and Martinón-Torres 2015). The body of a frozen and naturally mummified child sacrificed in an Inka *capacocha* ritual has also been recovered from a high altitude ceremonial site on Mt Aconcagua, which lies over the modern border in Argentine but sits directly at the head of the Aconcagua Valley, and dated to cal AD 1407–1491 (GX-19991-AMS: 370±70 ^{14}C yr BP; and Beta-88785: 480±40 ^{14}C yr BP, 453±35 ^{14}C yr BP, χ^2, T=1.8 (5%3.8)) (Fernández et al. 1999; Marsh et al. 2017). Each of these established sites are from the later phase of Imperial occupation in the region. However, there have been no efforts thus far towards dating earlier contexts likely to represent the initial dispersion of Inka influence into central Chile.

The traditional chronology of Inka expansion was derived from the historical accounts of Spanish chroniclers. In particular, the writings of Caballo Balboa (1951 [1586]) were accepted as reliable accounts and from these, a traditional chronology and succession of Inka kings was proposed by Rowe (1944, 1945). Despite some opposing views, Rowe's chronology dominated the argument and thus became the most widely accepted and utilised (Pärssinen 1992). According to this chronology, there was a pre-Imperial phase in Cuzco from c. AD 1200 to 1438, after which the Inka began conquering nearby neighbouring regions of the four quarters under the reign of Pachacuti Inka Yupanqui. The majority of expansion south into *Collasuyu* supposedly took place after incursions north into Peru and Ecuador, and after Topa Inka Yupanqui succeeded his father, from AD 1471 to 1493 (Figure 2). However, the chronicle of Betanzos (1987 [1551]), which was published after Rowe had already determined his chronology, indicates that certain parts in the north of *Collasuyu* were incorporated into the Empire during the reign of Pachacuti Inka Yupanqui (c.1438-1463), and therefore several decades earlier than postulated by Rowe.

Insert Figure 2

There is now growing evidence to support the hypothesis that the Inka may have expanded into the four quarters of Tawantinsuyu earlier than recorded in Rowe's chronology; various radiocarbon dates from Inka contexts indicate that the expansion of the Empire towards its southern limits may have taken place several decades before AD 1471 (Rodríguez et al. 1993; Williams and D'Altroy 1998; Raffino and Stehberg 1999; Sánchez Romero 2004; Hermosilla et al. 2005; Ogburn 2012; Cornejo 2014; Alconini 2016; Puerto Mundt and Marsh 2021). Recent Bayesian modelling of radiometric dates from other sites along the Empire's southern reaches in Argentina (Marsh et al., 2017) has also suggested an Inka presence up to 100 years earlier than the historically recorded date, with an estimated arrival of *cal AD 1350–1440 (95% probability)*. These findings have been followed by calls for more radiometric dating of Inka contexts from frontier zones of the Empire, and have not only raised questions about the timing of the Inka expansion, but also the order in which each of the territories were subjugated by Inka forces (Ogburn 2012; Marsh et al. 2017).

Materials and Methods

Samples of human bone were obtained from 23 individuals held in the Museo Historico-Arqueologico de Quillota's collections from the sites of Estadio de Quillota and Calle Arauco; two adjacent sites that formed part of the same pre-Columbian cemetery complex (Table 2; Figure 3). AMS radiocarbon dating was carried out on bone collagen for 17 of the individuals, the remaining six of the 23 having been previously dated (Fuenzalida 2014), but lacking $\delta^{13}C$ and $\delta^{15}N$ measurements. Stable carbon and nitrogen isotope measurements were made separately for all 23 samples of human bone collagen.

Insert Table 2

The age-at-death of each individual sampled was estimated based on dental eruption for subadults (Ubelaker 1989) and dental attrition for adults (Lovejoy 1985). Sex was estimated, where possible, by morphological assessment of pelvic and skull fragments (Buikstra and Ubelaker 1994). Where available, information regarding burial location, position, orientation and grave goods is taken from the excavation reports (Baeza 2010). The human bone samples analysed here derive from burials in four adjoining sectors of the cemetery. The majority of individuals at EDQ were buried in an extended prone position, which is reflected in the sample for radiocarbon dating. There is information available for 18 of the 23 individuals included in this study regarding burial position, with 13 in an extended prone position, one in an extended lateral to prone position, three in an extended supine position, and one in a flexed position.

Insert Figure 3

Pre-treatment and Collagen Extraction

Collagen was extracted from the bone samples using a modified Longin (1971) protocol. Bone fragments were cleaned by shot blasting with aluminium oxide pellets. Sub-samples were crushed and demineralised in 0.5M HCl at 5°C for several days. The HCl solution was changed periodically until the samples ceased to produce observable CO_2. The demineralized samples were placed into sealed tubes of pH3 H_2O and gelatinized at 70°C for 48 hours. The supernatant was filtered to remove insoluble residue using 45-90 μm Ezee-filters™ and then freeze-dried for approximately 48 hours.

Stable Isotope Analysis

Approximately 1mg of collagen for each of the samples was weighed into tin capsules. All samples were analysed using a Sercon 20/22 Isotope Ratio Mass Spectrometer in continuous flow mode at the University of Oxford's Research Laboratory for Archaeology and the History of Art. All material was analysed in duplicate to ensure reproducibility, with a precision greater than ± 0.2‰ based on repeat runs of standards. Alanine standards of known value ($\delta^{13}C$ = -27.2 ± 0.1‰, $\delta^{15}N$ = 1.6 ± 0.2‰) were included at intervals throughout runs to allow for drift correction. Matrix-matched, in-house standards of cow ($\delta^{13}C$ = -24.3 ± 0.1 ‰, $\delta^{15}N$ = 7.9 ± 0.2 ‰) and seal collagen ($\delta^{13}C$ = -12.5 ± 0.1‰, $\delta^{15}N$ = 16.1 ± 0.2‰) were also included to allow for two-point calibration of the results (Coplen et al. 2006). The mean calibrated $\delta^{13}C$ and $\delta^{15}N$ measurements for all samples are reported in units per mil (‰) relative to international standards for $\delta^{13}C$ (VPDB) and $\delta^{15}N$ (AIR).

AMS Radiocarbon Dating

Approximately 5mg of collagen from the 17 samples to be dated were combusted, graphitised and pressed into targets following routine protocol for the Oxford Radiocarbon Accelerators Unit (ORAU) (Brock et al. 2010). Collagen was prepared following the protocol outlined above and was not subjected to ultrafiltration. Radiocarbon dating was undertaken at ORAU's High Voltage Engineering Europa (HVEE) AMS. The resulting stable isotope corrected ^{14}C dates were calculated following Bronk Ramsey et al. (2004).

Calibration and Modelling

All calibrations and Bayesian models were determined using OxCal version 4.4 (Bronk Ramsey 2020). The radiocarbon dates were calibrated to a 95.4% probability range, using the SHCal20 southern hemisphere atmospheric curve (Hogg et al. 2020). Bayesian modelling utilises a statistical approach to interpreting radiocarbon dates, incorporating assumptions known as priors, to constrain the resulting calibrated probability distributions for groups of dates (Bayliss and Bronk Ramsey 2004; Bronk Ramsey 2015). Bayesian modelling of prior assumptions alongside radiocarbon dates can be used to obtain improved chronological resolution for sites and events, e.g., the timing of Inka expansion. Kernel Density Estimates are employed as summed probability distributions and modelled boundaries to summarise groups of dates (Bronk Ramsey 2017). Modelled results are presented in italics. Both individual dates and modelled ranges are presented at 95.4% confidence.

Statistics

Apart from the Bayesian modelling and Kernel Density Estimates of radiocarbon dates in OxCal 4.4, all other statistical analyses were carried out using R version 3.5.0 (RCoreTeam 2018) with RStudio 1.3.1056 (RStudioTeam 2020). Shapiro-Wilk tests indicated that subgroups of radiocarbon dates and stable isotopic data did not depart significantly from a normal distribution ($p > 0.05$). Therefore, parametric two-sided Student's t-tests were employed, with $\alpha = 0.05$, for all statistical comparisons of means.

Assessment of Collagen Quality

The quality of collagen preservation for both radiocarbon dating and stable isotope analysis was assessed by collagen yield (% wt greater than 1%), % wt of carbon and nitrogen relative to the combusted collagen (30-50% C; 11-16% N), and the atomic ratio of carbon to nitrogen (C:N between 2.9 and 3.6) (DeNiro 1985; Ambrose 1990; Van Klinken 1999; Brock et al. 2010). All collagen analysed within this study, except for EDQ17037 (UGAMS 13208), fell within ranges indicating acceptable preservation. The stable isotope results for EDQ17037 and the corresponding previous radiocarbon date (UGAMS 13208), for which collagen quality data were not originally reported, were excluded from further analysis, interpretation and chronometric modelling.

Results

Radiocarbon Dates

The new radiocarbon dates for Estadio de Quillota range from 399-196 cal BC (OxA-V-2735-19) to cal AD 1413-1458 (OxA-V-2735-18) (Table 3). The four earliest dates 339-196 cal BC to cal AD 128-339 (OxA-V-2737-44) are followed by a gap of roughly 1000 years before a cluster of thirteen later dates between cal AD 1280-1387 (OxA-2730-55) and 1413-1458.

Stable Isotopes

The $\delta^{13}C$ results have a wide range from -21.5‰ to -8.4‰ ($\bar{X}$ = -12.8‰ ± 4.2, $n = 22$) (Table 3). The $\delta^{15}N$ results range from 4.4‰ to 8.6‰ ($\bar{X}$ = 7.0‰ ± 1.3, $n = 22$). There is a strong positive linear correlation between $\delta^{13}C$ and $\delta^{15}N$ ($r^2 = 0.84$, $p < 0.001$). It is clear that the $\delta^{13}C$ and the $\delta^{15}N$ results are distributed bimodally with one smaller group of lower values ($\bar{X}$ $\delta^{13}C$ = -21.1‰ ± 0.5; $\delta^{15}N$ = 4.7‰ ± 0.6, n = 4) and one of higher values ($\bar{X}$ $\delta^{13}C$ = -11.0‰ ± 1.4; $\delta^{15}N$ = 7.5‰ ± 0.8, n = 18). The group of four lower $\delta^{13}C$ and $\delta^{15}N$ values corresponds to the four earlier radiocarbon dates reported above, while the group of higher values correspond to the cluster of later dates. EDQ is an inland site and – despite the correlation between the two isotopes (see below) – there is no indication of any significant consumption of marine or freshwater resources that would skew the radiocarbon dates, meaning no reservoir corrections are necessary.

Insert Table 3

Discussion

Chronology of Estadio de Quillota

The radiocarbon dates from EDQ fall into two distinct phases of use, which correspond to the new isotopic data for dependence on maize-based resources, discussed further below. These two phases, with an interval of approximately 1000 years between them, contrast with previous expectations of a continuous and extended use of the cemetery. The samples were selected to provide coverage of the different sectors of the cemetery. However, a considerable number of burials are known to remain *in situ* at EDQ, so it is important to acknowledge that this 1000 year gap (which would correspond to the majority of the ECP and the first half of the LIP using the existing chronological framework for Central Chile) could be the result of a sampling bias. Future efforts towards conservation and analysis of the ceramics recovered from EDQ, coupled with further radiometric dating, would help to confirm the finding here of two distinct phases of use.

The earlier phase with four dates from 399-196 cal BC (OxA-V-2735-19) to cal AD 128-339 (OxA-V-2737-44) aligns with the beginning of the ECP in the existing Central Chilean chronological framework (c.300 BC – AD 1000/1200), particularly the period when the Initial Ceramic Communities (ICC) (c.300 BC – AD 200) appear in the archaeological record of the region. One of two available TL dates (AD 405±170) for EDQ, from a Llolleo pot (Didier and

Ávalos 2009a, reported without lab code), falls after this cluster of radiocarbon dates, but within the range of the Llolleo culture (c.AD 200-1200).

Based on the current chronological framework for the region, the appearance of the ICC at the beginning of the ECP, for which the defining material correlate is the presence of ceramics, is assumed to have occurred around c.300 BC (Sanhueza and Falabella 1999). However, recent Bayesian modelling of the earliest dated ceramics from Central Chile indicates this technology most likely appeared around ~180 cal BC (Marsh 2017), coincident with other adjacent regions, suggesting that the current chronological framework requires some reconsideration regarding the commencement of the ECP.

The two more recent of the four dated individuals from this earlier phase of use at EDQ ((EDQ16099: 146 cal BC-cal AD 22 (OxA-V-2730-57) and EDQ17061: cal AD 128-339 (OxA- V-2737-44)) were recorded with ceramic offerings as well as lithics and faunal remains, and EDQ16099 was also found with shells. There are no further details regarding the pottery styles or descriptions of the other artefacts. However, these two new radiocarbon dates fall within Marsh's (2017) proposed starting boundary for the ECP in Central Chile around ~180 cal BC. Of the other two individuals from this earlier phase of use, EDQ17034 was not interred with any funerary offerings, and for Ar16016 there are no records to reveal whether any grave goods accompanied this burial.

A possible shift in the style of burial position may also be indicative of cultural differences. EDQ17034 was buried in a flexed position, which is characteristic of ECP and earlier burials. However, the site plan for EDQ suggests that EDQ16099 and EDQ17061 were buried in an extended position, a burial style more usually considered to be associated with LIP burials (Saunier and Ávalos 2010).

The early phase dates from EDQ are followed by a hiatus of c.1000 years before a later phase of eighteen dates with a start boundary of *cal AD 1290-1380* to an end boundary of *cal AD 1420-1460* (Table 4). The cluster of later dates from EDQ is noticeably constrained with this modelled phase lasting for a span of only *46 to 143 years* (95.4%). The later phase of use falls within what is currently accepted as the terminal stages of the LIP. However, eight of these burials have been identified as LP contexts with pottery defined as '*Local Inka Phase*' Aconcagua ceramics (Figure 4), which are vessels made following the local (Aconcagua) pottery traditions, but with new decorative and morphological features (e.g., inscribed angles and handles attached to the lip), and the incorporation of other foreign references (e.g., Inka or Diaguita) (Fuenzalida 2014; Dávila et al. 2018). This suggests the transition to the LP and arrival of Inka influence may have occurred slightly earlier than the commonly used date of c.1450 cal AD (or the 1471 cal AD date from Rowe's chronology of Inka expansion) for the beginning of the LP.

Insert Table 4

Insert Figure 4(a and b)

A TL date of AD 1420±45 from an LP vessel with a stepped trichrome pattern (Didier and Ávalos 2009a, reported without lab code) falls within the late cluster of new radiocarbon dates from EDQ and is another example of Inka influence appearing in the archaeological record and the transition to the LP occurring slightly before the currently accepted start date of c.1450 cal AD. There are no further details available regarding the style of pottery found with the other individuals from the later phase of use at EDQ who were also recorded with ceramic grave offerings.

All of the individuals from this phase were buried in an extended position, mostly prone, but two were supine (EDQ16079 and EDQ17011), and one was lying on their left-hand side (EDQ17045). These trends are comparable to descriptions of burial patterns from other Central Chilean sites, in which flexed positions dominate in the ECP, and extended prone positions dominate in the LIP and LP (Saunier and Ávalos 2010).

Diet and maize at Estadio de Quillota

The stable isotope results demonstrate a strong diachronic shift in dietary practices, particularly regarding the consumption of C_4 resources, i.e., maize. The inland location of the site (approximately 25km from the coast and on the inland side of the coastal cordillera) and the low $\delta^{15}N$ values indicate terrestrially based diets, with little or no input from marine resources. The wide range of $\delta^{13}C$ values (-21.5‰ to -8.4‰) particularly points towards increased inclusion of maize in the diet over time. There is a significant dietary split between the earlier and later phases of the burials dated at EDQ, with the four lower $\delta^{13}C$ and $\delta^{15}N$ values corresponding to the four earlier dates, and the higher $\delta^{13}C$ and $\delta^{15}N$ values corresponding to the later cluster of dates (Figure 5).

Insert Figure 5

The relatively low mean $\delta^{13}C$ ($\bar{X}$ = -21.1‰ ± 0.5) of the earlier group indicates dependence on C_3-based resources, with little to no inclusion of maize in the diet. At this time, only *curagua*, an early endemic variety of maize, is known to have been present in the region

(Planella M.T. et al. 2014). The isotopic results show no significant consumption of this or other wild C_4 grasses (cf. Cadwallader et al. 2012). The low mean $\delta^{15}N$ value ($\bar{X}$ = 4.7‰ ± 0.6) suggests a diet that was extremely low in animal proteins, possibly supplemented by the consumption of nitrogen-fixing legumes, which were present in Central Chile in several varieties of beans (*Phaseolus* spp.) and peanuts (*Arachis hypogaea*) (Planella M. T. and Tagle 2004; Pardo and Pizarro 2013). Since these would be expected to have $\delta^{15}N$ values near 0‰ (Tieszen and Chapman 1992), their consumption might be masking the contribution of animal protein; even so, it is unlikely to have been high. The isotopic results are similar to those previously observed at three other ECP sites in the inland valley of the Aconcagua Basin: Pocochay, Santa Cruz, and Las Chilcas ($\delta^{13}C$ = -19.0‰ ± 1.6, $\delta^{15}N$ = 5.4‰ ± 1.0, n = 10) (Swift et al. 2017), and to those more specifically identified as ICC (the initial cultural phase of the ECP) in the Maipo-Mapocho and Rancagua Basins immediately to the south of the study area ($\delta^{13}C$ = -20.1‰ ± 0.3, $\delta^{15}N$ = 4.5‰ ± 0.7, n = 6) (Falabella et al. 2007).

Even though incipient use of C_4 resources has been observed at some ECP sites in Santiago and Rancagua – usually those attributed to the Llolleo culture, a period not represented by the radiocarbon dates from Estadio de Quillota – it was not until the LIP and the arrival of the Aconcagua culture that a substantial uptake of maize is observed. This was followed by a marked intensification in the late 14th and early 15th centuries (Falabella et al. 2020), which is contemporary with the later phase of use at EDQ. The elevated $\delta^{13}C$ ($\bar{X}$ = -11.0‰ ± 1.4) values among the group of 18 individuals from the later phase of EDQ likewise indicate a subsistence strategy that was heavily dependent on C_4 resources. The $\delta^{15}N$ values for this group ($\bar{X}$ = 7.5‰ ± 0.8) are also higher than those observed during the earlier phase of use at EDQ. A positive linear relationship between $\delta^{13}C$ and $\delta^{15}N$ data from EDQ suggests either an increasing inclusion of animal protein in the diet or the manuring of maize (cf. Spzak et al. 2012). The possibility of a marine component is discounted based on the low $\delta^{15}N$ values, the site's distance from the coast, the lack of evidence of fishing technology at the site, and the lack of zooarchaeological evidence of marine fish or shellfish.

There was no significant difference between the $\delta^{13}C$ and $\delta^{15}N$ results for the individuals accompanied by *Local Inka Phase* Aconcagua pottery at EDQ (n = 8) compared to the other contemporary individuals lacking this affiliation (n = 10) ($\delta^{13}C$ t = 0.30, p = 0.76; $\delta^{15}N$ t = -0.44, p = 0.67). However, despite the small sample size, there is a significant difference observed between the sexes, with adult males (n = 6) being higher in both isotopes than adult females (n = 6) ($\delta^{13}C$ t = -3.35, p = 0.01; $\delta^{15}N$ t = -2.63, p = 0.03). This result suggests sex-based differential access to resources, with apparently greater availability of maize products and either higher trophic level protein sources, such as camelids foddered on maize stover, or increased access to fertilised maize crops for adult males when compared to adult females. A similar trend has recently been interpreted as greater consumption of maize-foddered camelids by adult males at sites ascribed to the Aconcagua culture further to the south (Falabella et al. 2020). Taken together, this indicates the possibility of widespread gendered patterns of maize consumption in Central Chile.

Chronology of the Aconcagua Valley

Existing TL and ^{14}C dates for the Aconcagua Valley have been collated in combination with the new dates from EDQ (see supplementary material APPENDIX A). This collation of dates establishes a sequence of use for the Aconcagua Valley and a span of approximately 7000 years with the earliest date from a coastal shell midden at the site of S-Bato 1 (5561-5474 cal BC; Beta128761 (Seelenfreund and Westfall 2000)) to the latest date from the occupation of El Tigre, an Inka site in the Upper Basin (cal AD 1501-1649; UGAMS5980 (Pavlovic et al. 2012)). The earliest dates predominately come from coastal sites, reflecting a similar pattern of use to that reported in the Maipo-Mapocho and Cachapoal Valleys of Central Chile, particularly in regards to earlier hunter-gatherers utilising coastal sites and resources (Falabella et al. 2007).

The radiocarbon dates from EDQ fall within the constraints of the overall occupation sequence for the Aconcagua Valley. With only six sites in the inland valley of the Aconcagua having either ^{14}C or TL dates, there is a relative dearth of radiometric dates for the inland valley outside those presented here. In fact, there are no radiocarbon dates from any other inland valley sites apart from EDQ.

The question of the arrival of the Inka

Bayesian modelling of the radiocarbon dates for the eight identified LP burials at EDQ indicates the timing of the arrival of Inka influence to the Aconcagua Valley (Table 5). The start boundary for this model is *cal AD 1290 to 1400.* The end boundary is modelled as *cal AD 1410-1470*. Querying the chronometric model of these *Local Inka Phase* contexts using OxCal's 'Difference' command demonstrates that Inka influence was likely present at EDQ from *73 to 189 years* before cal AD 1471, or from *50 to 160 years* before cal AD 1450. The model of Late Period contexts with *Local Inka Phase* ceramics at EDQ accords with previous estimates based on an accumulated probabilities model for arrival of the Inka in northern Chile by the late 14th century AD (Cornejo 2014).

Insert Table 5

Kernel Density Estimates were generated in OxCal to compare the ^{14}C dates from EDQ's later phase of use (*n* = 18), as well as the identified *Local Inka Phase* burials from EDQ (*n* = 8), with ^{14}C dates from other known Late Period contexts from the Aconcagua Valley (*n* = 6), and also the ^{14}C dates from other known Late Intermediate Period contexts from the Aconcagua Valley (*n* = 4) (APPENDIX B). It is important to note that the sample size for some of the KDEs is very small, particularly for the LIP contexts with only four other ^{14}C dates available for comparison. This will have a large impact on the estimated start and end ranges. By contrast, there are approximately 35 TL dates from LIP contexts. Likewise, for the LP there are six ^{14}C dates and 25 TL dates. However, a different pattern is apparent for the TL dates compared to the ^{14}C dates in both the LIP and LP contexts and indeed there is a statistically significant difference in the median calibrated ^{14}C and TL dates (LIP t = 3.59, p > 0.000; LP t = 3.16, p = 0.004). A recent critique of the reliability of TL vs ^{14}C in the Southern Andes concluded that ^{14}C dates should be used in favour of TL dates to support cultural chronologies (Marsh et al. 2021) and discrepancies have also previously been noted regarding TL dates in Chile (Schiappacasse et al. 1991; Pavlovic et al. 2012). For these reasons, only the Aconcagua Valley ^{14}C dates were used in the KDEs produced for direct comparison with KDEs of the ^{14}C dates from EDQ.

These KDEs (Figure 6) indicate that the later phase of use observed at EDQ (start boundary *~cal AD 1344 (1320-1380, 68.3%)* to end *~cal AD 1441 (1430-1450, 68.3%)*), and indeed the burials identified with *Local Inka Phase* material culture (start boundary *~cal AD 1379 (1370-1400, 68.3%)* to end *~cal AD 1430 (1420-1440, 68.3%)*), fall just before the beginning of the known LP dates (start boundary *~cal AD 1457 (1420-1490, 68.3%)*) from the rest of the Aconcagua Valley and towards the end, or later than, the known LIP dates (end boundary *~cal AD 1399 (1330-1430, 68.3%)*) from the rest of the Valley.

Insert Figure 6

The KDE for the *Local Inka Phase* material culture at EDQ indicates that Inka influence had arrived at this southern reach of the empire by the late 14^{th} or early 15^{th} century. The distribution of this KDE falls at the end boundary of the LIP dates for the Aconcagua Valley, and before the start boundary of other LP dates from the Aconcagua Valley. The *Local Inka Phase* material at EDQ likely represents the earlier stages of Inka influence in the Aconcagua Valley, whereas the radiocarbon dates from the other known LP contexts in the Aconcagua are likely from a later stage of the imperial expansion in this region as sites with a much more established physical Inka presence often in the form of substantial architecture. The available ^{14}C dates from the other LP contexts in the Aconcagua are limited to only three other sites: El Tigre, a site with monumental Inka architecture; Mt Aconcagua, the site of an Inka child sacrifice; and Los Nogales, a domestic site where Inca metallurgical practices were adopted. The earlier dates from *Local Inka Phase* contexts at EDQ suggest imperial expansion in this region followed a process of increasing influence and integration over time: an initial phase of interaction, visible through the circulation of ideas, influence and material culture such as at EDQ, followed by a greater physical presence and occupation as seen at sites such as Mt Aconcagua and El Tigre. There are at least 10 other sites with Inka contexts in the Aconcagua Valley (see Figure 1), but as yet without any radiocarbon dating. Further efforts towards radiocarbon dating of Inka contexts in the Aconcagua Valley would make a beneficial contribution towards refining both the local Central Chilean chronology as well as the timing of Inka expansion towards their southern frontier.

The new radiocarbon dates and chronometric models from EDQ presented here add to the growing evidence that Inka expansion commenced earlier than has been historically documented, and provides a strong indication that Imperial influence had already arrived in Central Chile by at least c. cal AD 1400. The early arrival of Inka influence in Central Chile has important implications, not just for the Empire's expansion into this region, but also supports an argument that the Imperial phase in Cuzco began earlier than AD 1438, and that the order of the expansion into the different quarters should be reconsidered. The EDQ Late Period model presented here pre-dates the Bayesian model of Inka expansion for the neighbouring Mendoza province on the eastern side of the Andes (boundary start date *cal AD 1350-1440*) (Marsh et al. 2017). Both the model presented here for EDQ and the previous Marsh et al. (2017) model from Mendoza, collectively making up a considerable portion of the southern frontier of the Inka Empire, pre-date the Bayesian model from Chamical in southern Ecuador (boundary start date *cal AD 1412-1457*), which was part of *Chinchasusyu* and the northern quarter of the Empire (Ogburn 2012). In contrast to the sequence of Imperial expansion proposed by the traditional chronologies, a reinterpretation of Inka Imperial chronology based on these Bayesian models of radiometric dates suggests that the southern expansion of the Empire into *Collasuyu* probably took place before conquering parts of northern Peru and the more resistant and hostile regions of Ecuador in *Chinchasuyu*.

This new evidence has implications for understanding the nature of Inka control in these regions. The earlier radiometric dates seen from the southern frontier territory, such as the new dates from EDQ, possibly reflect the initial arrival of material culture and ideological influence of the Inka. This initial phase was then followed by an increased investment at a later stage in the Imperial rule, which saw the creation of a more substantial and visible physical presence, in the form of Inka structures, fortifications and an Inka *capacocha* child sacrifice on Mt Aconcagua. The results presented here support the hypothesis of Ogburn (2012) and Marsh *et al.* (2017) that the traditional chronology of the Inka Empire, including the sequence of expansion into the four regions of *Tawantinsuyu,* needs to be reconsidered, and can be usefully investigated with further efforts towards radiometric dating and Bayesian modelling of Inka contexts on the frontiers of the Empire.

Conclusion

The new radiocarbon dates presented here place the large pre-Columbian cemetery site of Estadio de Quillota within the chronology of the Aconcagua Valley, which was located on both the southern frontier of intensive maize agriculture and the Inka Empire. The AMS ^{14}C dates on human bone collagen from selected burials indicate that there were two distinct phases of use at EDQ separated by c.1000 years: An early phase from cal BC 339-196 to cal AD 128-339, roughly coincident with the Initial Ceramic Communities at the start of the Early Ceramic Period in Central Chile; and a late phase from cal AD 1280-1387 to cal AD 1413-1458 during which time Aconcagua, Diaguita and Inka cultural influences are observed in the Valley.

The accompanying $\delta^{13}C$ and $\delta^{15}N$ stable isotopic analysis of the human bone collagen from the 22 dated EDQ burials demonstrates a change in diet over time. The wide range of $\delta^{13}C$ values point towards a reliance on C_3 terrestrial resources during the earlier period of use, around the time of the Initial Ceramic Communities, followed by a heavy dependence on maize-based produce during the later phase of use observed at the EDQ cemetery. Due to the c.1000 year gap, such that most of the Early Ceramic Period is unrepresented in the dates from EDQ, it is not possible to give a more precise estimation of when or how quickly this transition in diet and subsistence strategy occurred. However, the isotopic data presented here appear to follow a similar pattern to that which has been observed at sites further to the south where the use of maize was established at some point during the Early Ceramic Period, but more substantial uptake occurred in the Late Intermediate Period and marked intensification followed into the late 14th and early 15th centuries (Falabella et al. 2020), coincident with the findings from the later phase of use at EDQ.

Finally, the dates presented here support growing evidence that the traditional chronology of the Inka Empire, which has been based on historical documentary sources, requires reconsideration. Eight of the radiocarbon dates from the later phase of use at EDQ are from the bone collagen of individuals buried with ceramic items from the Late Period, many of a *Local Inka Phase* style indicative of a process of social transformations having already reached the region. These burials, however, predate the traditionally accepted date of Inka expansion to the south (AD 1471) as well as the date that has recently become more commonly used for the beginning of the Central Chilean Late Period (AD 1450). It is proposed that the expansion may have taken place in two phases: an initial phase of interaction including the circulation of ideas and the emerging influence of a new socio-political context, followed by a second phase of occupation with the construction of architectural complexes and consolidation of the region into the Empire. Bayesian modelling of the dates presented here supports a conclusion that Inka influence had arrived at its southern reaches by the late 14th or early 15th century, and with increasing evidence that the initial phase of Inka influence occurred several decades earlier. The findings presented here reinforce calls (cf. Ogburn 2012; Marsh et al. 2017) to abandon the traditional chronology based upon ethnohistoric sources and consider a major revision of Inka chronology with greater importance placed on evidence from radiometric dating.

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