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Radiocarbon vs. luminescence dating of archaeological ceramics in the southern Andes: a review of paired dates, Bayesian models, and a pilot study

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Abstract

Archaeologists have been using luminescence to date pottery in South America since the late 1970s, inspired by early success in northern Chile. However, luminescence dates have not been rigorously compared to independent dating methods, which this paper's goal. First, we present a compilation of 94 paired ^{14}C and luminescence dates from the southern Andes, which reveals discrepancies across a range of contexts and ages. Second, we compare two Bayesian models of sets of ^{14}C and thermoluminescence (TL) dates from three ceramic styles in the Azapa Valley, Chile, and the Inca occupation of Mendoza, Argentina. We find that only the ^{14}C models produce results that agree with expectations based on independent data. Third, we present results from a pilot study in Mendoza that dated 6 sherds with 3 luminescence methods each and closely associated ^{14}C dates. The reasons for disagreement between methods remain unclear, but Andean sediments with low and unstable luminescence sensitivity seem to be an important factor. Even though some luminescence ages are accurate, the clear trend of inconsistent results leads us to recommend that archaeologists use ^{14}C rather than luminescence dates to build cultural chronologies.

Keywords: paired ^{14}C dates, luminescence dates, archaeological ceramics, southern Andes

Recent improvements in radiocarbon dating methods and Bayesian models have led to significant refinements to the cultural chronologies of many regions of South America, even the short-lived Inca empire (e.g. Rick et al. 2009; Marsh 2012; Koons and Alex 2014; Korpisaari et al. 2014; Marsh et al. 2017, 2019). Improve chronologies has required researchers to identify problematic dates that suffer from issues such as old wood, inadequate pretreatment, and unclear artifact associations. This paper continues that endeavor with a critical evaluation of the discrepancies between ^{14}C and luminescence dates.

In the late 1970s, thermoluminescence (TL) dating was a boon to archaeologists, since it provided cultural chronologies at lower costs. Many projects in South America turned to TL for its main advantage over ^{14}C: it can directly date decorated pottery styles. However, the reliability of luminescence dating has not been adequately evaluated with comparisons between laboratories or methods such as optically-stimulated luminescence (OSL) and ^{14}C. The first major effort to compare luminescence laboratories showed there was a higher-than-expected 18% standard deviation for sediment samples (Murray et al. 2015). Despite potential issues, there is a consensus among Chilean archaeologists that TL dates are reliable for building cultural chronologies (e.g. Falabella et al. 2015). In contrast, most luminescence dates in Argentina have produced unexpected results (e.g. Angiorama 1998; Bárcena 1998; Stenborg 2001). With no clear reason for this, inconsistent luminescence dates are often discarded and not mentioned beyond theses and conference presentations, which has hindered a broader assessment of the method.

This paper's goal is to assess the reliability of luminescence ages in the southern Andes by comparing these with ^{14}C and historic dates. We address the problem with three approaches: 1) a compilation of individual paired ^{14}C–TL and historic–TL dates from Argentina and Chile, since nearly all paired dates in South America are from these two countries (Figure 1), 2) comparisons of two Bayesian models of four sets of ^{14}C and TL dates, and 3) a pilot study in Mendoza of 6 sherds dated by 4 methods each: TL, OSL, infrared stimulated luminescence (IRSL), and ^{14}C. Comparisons suggest that luminescence ages do not meet temporal expectations from ^{14}C dates or historic documents. Although issues remain with ^{14}C dates, especially ones run decades ago, the method is continuously updated with inter-laboratory tests and compares well to independent dating methods such as historic documents and crucially, dendrochronology. This is not the case for luminescence dating, which produces inconsistent results in the southern Andes. Hence, we recommend using ^{14}C rather than luminescence dates for building archaeological chronologies.

Background: early success with thermoluminescence dating of archaeological ceramics

Beginning in the late 1970s, the laboratory at the *Pontificia Universidad Católica de Chile* (UCTL) made promising headway with TL dates that agreed with ceramic sequences in northern Chile (Brito et al. 1979; Román and Deza 1985; Berenguer et al. 1986; Muñoz Ovalle and Chacama Rodríguez 1988; Schiappacasse et al. 1991). Initial efforts mentioned similar ^{14}C dates, but these were often generalized comparisons to dates associated with similar ceramic styles from other sites. Early on, it was acknowledged that TL dates tended to underestimate ^{14}C dates, in both Chile and Ecuador (Stothert 1988; Schiappacasse et al. 1991). However, minor differences did not significantly impact low-resolution regional chronologies or ceramic sequences. This made it common to ignore inconsistencies, which were not even apparent because of large error ranges. For example, at the site Turi Aldea in northern Chile, there are 3 ^{14}C and 2 TL dates from a single occupation layer (Castro et al. 1994; Sinclaire 2004). The TL dates' medians are 145–225 years older, but the error ranges of 120–215 years make them statistically indistinguishable (Figure 2; Table 2).

In Ecuador, phases for the Valdivia culture were defined with TL dates that had large error ranges of ±245–578 years, even though the sherds had excellent characteristics for TL dating (Marcos and Michczyński 1996; Galli et al. 2020: 190). Phasing based on TL and ^{14}C dates tends to agree, but for a few ceramic phases, TL dates consistently underestimate age (Martini and Sibilia 2001: 243; Galli et al. 2020: Figure 5). Comparisons have only been made between regional ceramic phases, rather than more rigorous tests of paired dates from the same depositional event. Recently, calibrated ^{14}C dates on pottery residues suggest that early pottery in Ecuador is much older than the TL-based chronology (Tabarev et al. 2016; Kanomata et al. 2019), a significant finding for some of the oldest pottery in the Western Hemisphere.

The accumulation of TL dates led researchers to build cultural and ceramic sequences with both TL and ^{14}C dates, despite some inconsistencies. In part, the paucity of dates motivated using as many as possible. It was also more legitimate to question ^{14}C dates in the 1980s, prior to methodological refinements, extensive inter-laboratory comparisons, and refined calibration curves (Bayliss 2009), in addition to potential problems with old wood and sample–artifact associations. A significant factor in the popularity of TL dates in both Chile and Ecuador was price: they were 75% cheaper than ^{14}C dates (Berenguer et al. 1988: 343; Marcos and Michczyński 1996: 102). Generally, TL dates fit stratigraphic sequences, which built trust in the method. This may partly explain why recent efforts tend to be less careful about using on-site dosimetry and reporting contextual details.

Dates in Chile have the additional advantage of comparability: all dates have been estimated with the same procedures at the same laboratory. UCTL measures the equivalent dose with three methods: plateau, additive with superlinearity correction, and pre-dose (Supplementary Material 1; Brito et al. 1979; Concha et al. 1980; Román et al. 1983; Román and Deza 1985; Deza and Román 1986; Román and Deza 1998). UCTL reported that for younger sherds, they prefer the pre-dose method since the luminescence signal is weaker and there is a greater chance of uncertainty; for older sherds, they prefer the plateau method (Bárcena 1998: 365). The laboratory's procedures have not changed for decades. They are considered reliable and are used at other luminescence laboratories (for updates to luminescence methods, see Roberts et al. 2015).

Elsewhere in the Andes, results are mixed. Some TL dates match high-precision ^{14}C dates such as the exemplary Bayesian chronology of the Sipán tomb complex, even though problematic dates are discarded (Aimi et al. 2016; see also Roque et al. 2004). Near Lake Titicaca, TL ages on ceramics from raised fields seem unreliable and have unwieldy error ranges of 90–660 years (Erickson 1988: 194; Janusek and Kolata 2004: 410). At the lakeshore site Huajje, TL dates were corrected for feldspar fading and mostly matched temporal expectations (Schultze 2008: 391–7). In the southern Lake Titicaca Basin, TL dates from Qeya-style museum pieces in France underestimate the style's expected date range, based on Bayesian models of ^{14}C dates and stratigraphy (Marsh et al. 2019; A. Roddick, personal communication 2021). In the southern Nazca region in Peru, a large OSL study (Vaughn et al. 2014) had a number of unexpected results compared to both ceramic seriation and Bayesian models of ^{14}C dates (Unkel et al. 2012). Since so many factors affect archaeological dates, it is challenging to identify the cause of disagreement between methods, especially when dates do match in some cases. To begin to do this, the next section assesses individual paired dates.

Approach 1: individual paired dates

To evaluate associated ^{14}C and TL samples that archaeologists expect to be the same age, we have adapted Waterbolk's (1971) categories for more or less certainty of the depositional association between dated samples. Date pairs with higher grades are more reliable data points for testing dating methods.

A. Very high probability. For example, a ^{14}C date on organic residue from a pot and a luminescence date from the same vessel, or when a production stamp or seal indicates the production date of the vessel.
B. High probability. For example, both samples are from a single depositional event such as a hearth or occupational floor. Samples are spatially close to one another and the context is small and carefully excavated. This includes tombs that were not looted or reused (otherwise tombs are C).
C. Probability. For example, the two samples are from the same architectural structure or occupational layer. Contexts are larger and excavations less controlled.
D. Reasonable Possibility. For example, the samples are from the same occupational layer but different sectors of a site, or from a site with only one period of occupation. These pairs are of little relevance to testing the dating methods and not generally included here.

Since ^{14}C and luminescence date different events, we should expect a lag between them. Luminescence dates a pot's firing, which should be earlier than its use or deposition, which is dated by ^{14}C dates. Heirloom vessels in graves may have been fired generations prior to the death of the associated individual (e.g. Fitzpatrick et al. 2009), but in most cases, the lag is likely no more than a few decades so the dates' probability ranges should overlap. This overlap can be evaluated with a chi-square test (Ward and Wilson 1978) implemented with the Combine command in OxCal 4.4 (Bronk Ramsey 2009a). Here, we use this approach to compare normal TL distributions, irregular ^{14}C calibrations, and uniform distributions for historic ranges. If a date pair passes the test, "we have no statistical evidence to doubt the consistency of the two determinations" (Ward and Wilson 1978: 30). Radiocarbon dates are calibrated with SHCal20 (Hogg et al. 2020), the most appropriate curve for the southern Andes (Marsh et al. 2018); calibrated medians and probability ranges are rounded by ten years. Modeled results are presented in italics. We compare medians in years and percentages (Tables 2–4), for example, the ^{14}C date Beta-69935 from Chile is ~780 years old (calibrated) and its pair UCTL-540 is 240 years younger, a difference that is 31% of its ^{14}C age. This follows the convention in luminescence dating of reporting errors as a percentage of the age, for example, Alpha-2076 from Mendoza was reported as AD 1490±20%. When available, UCTL uses on-site $CaSO_4:D_y$ dosimeters to correct TL ages (Deza and Román 1986). In this region, most dosimetry corrections are small, reflecting the generally low external dose (Table 1).

Date pairs from Chile and Argentina

Despite the fact that the UCTL laboratory has run over three thousand TL dates, surprisingly few are paired with ^{14}C or historic dates. We identified 59 luminescence–^{14}C date pairs and 28 TL dates on items with known historic production ages from Chile and Argentina (Tables 2 and 3).

Chile

In northern Chile, there are 15 date pairs from 9 sites, which were mostly processed in the 1980s. Most have poor ^{14}C–TL sample associations (C and D), since they are from looted cemeteries, early excavations, or museum collections. There are only four paired dates in Berenguer et al.'s (1986, 1988) original set of TL dates that established the method's credibility. Most of these early dates had dosimetry corrections but still have large error ranges, allowing 12 of 15 dates to pass the chi-square test. A large body of ^{14}C dates from the same sites tend to be later than TL dates (Pestle et al. 2021; Torres-Rouff and Hubbe 2013).

In central and south–central Chile, we identified 10 pairs from 6 sites. Seven pairs pass the chi-square test but they have low association grades. Some TL dates are earlier than expected, for example at the site Blanca Gutiérrez. While not paired, 8 TL dates from this site are centuries earlier than 6 ^{14}C dates (Pavlovic et al. 2000: 179; Soto 2018: 53). Similarly, at the cemetery Los Jazmines, ^{14}C dates from graves with Inca-period ceramics are earlier than TL dates run on the same ceramic styles at other sites (Cornejo 2014; Cortés 2017; Puerto Mundt and Marsh 2021). In south-central Chile, there is a high-grade pair from an occupation surface at Maicoyakuel. The TL date is much older than the ^{14}C date (Dillehay and Saavedra Zapata 2014), similar to many historic-period TL dates. At El Arenal I, paired dates associated with prehispanic chicken bones have lower association grades but in fact pass the chi-square test (Storey et al. 2013), similar to others from around the Inca period. Farther south, a study around the Reloncaví Sound reports the only luminescence dates in Chile not run at UCTL, but these dates were not paired (Itaci and Flores 2010).

Northwestern Argentina

In Northwestern Argentina, we identified 11 paired dates from 5 sites. They all had grade-B associations and four passed chi-square tests. These dates include a preliminary study aimed at comparing ^{14}C dates and TL ages run by a Peruvian laboratory (Greco 2012). TL dates underestimate paired ^{14}C dates, which could have been due to difficulties in the laboratory (Greco, personal communication 2019). At El Alamito, results were similar, despite corrections with an on-site dosimeter (Angiorama 1998). A study in the Abaucán Valley included 68 sherds, mostly from the surface, but none had paired ^{14}C dates (De La Fuente et al. 2010). This study used results from petrography, magnetic susceptibility, and soil samples to improve results, which were processed at the Missouri University Reactor Research Center, USA. The 17 Inca-style sherd dates are later than expected, with most medians falling between AD 1600 and 1700, during the historic period. It is not impossible that Inca-style ceramics were produced after the fall of the Inca empire, but such late dates have not been documented anywhere else and are likely underestimates. The dates are notably later than ^{14}C-based estimates that the Inca empire was in the area roughly AD 1400–1550 (Greco 2012; Marsh et al. 2017).

At the site of El Pichao in the Tucumán province, 4 Inca-period contexts were also underestimated, in this case by OSL and TL dates run in Denmark (Stenborg 2001). This is the trend in the large set of 42 luminescence ages, though most have acceptable probability ranges. Eight luminescence dates (19%) were discarded with differences of multiple centuries or more. TL and feldspar dates had larger error ranges, so OSL on quartz was preferred (Cornell and Johansson 1993). The site of Casas Viejas in the Tafí Valley is known for its large carved monoliths placed atop a mound; ^{14}C dates from the mound's base strongly agree with medians of AD 90–130 (González and Lagilgia 1973; Oliszewski 2017). Excavation details are too imprecise to treat these as paired dates but one TL date does agree, with a median of AD 120, while another seems to underestimate the context's age with a median of AD 370 (Núñez Regueiro and García Azcárate 1996). Overall, dates from northwestern Argentina have been processed at different laboratories that have all taken different types of error into consideration, but nearly all ages underestimate paired ^{14}C dates.

Mendoza

Luminescence dating has been used extensively in Mendoza, including a significant study by Bárcena (1998) that included a number of paired dates. This study used both on-site and travel dosimeters (Table 1), resulting in minor age corrections of 10–45 years (-3–8.3%), and at one Inca-period site, 60–90 years (15–20%). Bárcena worked closely with UCTL, which refined dates based on dosimeters as well as other sherds from the same sites. The study included ten TL dates on sherds with known historic production ages (AD 1632–1930). Eight were produced at identified locations in Europe (Schávelzon 2001). These are grade-A date pairs with known production ages that confidently date the firing. Despite this, only three of ten sherds pass the chi-square test and age is overestimated in six sherds (Table 3). This can happen when vessels are fired at very high temperatures such as stoneware, though this is not the case for these sherds. In contrast, age was underestimated in one sherd from a large colonial vessel that was probably made locally. The inscribed date, 19 April 1632, could indicate the vessel's production or perhaps another date the potters deemed important. The trend of overestimating historic ages continues in a set of seven floor tiles and bricks from Mendoza's historic town hall. Four are from the same level, but the TL ages do not agree; all seven fail a chi-square test against the building's historically documented construction and use, AD 1749–1861. These deposits are sealed below the rubble of a significant AD 1861 earthquake, a clear and well-dated stratigraphic boundary. The adjacent plaza fountain was in use AD 1810–1858 (Bárcena 1998: 314), but all 12 TL dates estimate ages that are 60–300 years earlier (a 3–16% difference). None of these 24 date pairs pass the chi-square test; however, two colonial sherds from the same excavation do.

For the 11 paired dates older than AD 900, all but one fail the chi-square test. In one case, a single sherd was TL-dated in two different laboratories as UCTL-334 and Alpha-2076. The second date was run by Alpha Analytic, a now-defunct laboratory from Florida, USA, which reported good signal stability and a stable plateau for this sample (Bárcena 1998: 180). The two luminescence ages overlap, but both underestimate the paired ^{14}C date by more than a millennium. In stark contrast, 10 Inca-period date pairs all pass the chi-square test, as well as 3 historic sherds. TL dates gravitate toward this temporal range: sherds that should be older or younger often have Inca-period TL dates, for example, 8 of the 11 sherds from contexts that are older than AD 900 (Bárcena 1998: 215, 221, Figure 20). This unexpected pattern was not repeated in our pilot study nor at sites in northwestern Argentina, where luminescence ages from Inca-period sherds underestimate paired ^{14}C dates. There are a number of other studies with unpaired TL dates in the provinces of Mendoza and San Juan (Durán and Novellino 2003; Cahiza et al. 2008; Gil et al. 2008; Prieto Olavarría and Chiavazza 2010; Bárcena and Ots 2012; Guráieb et al. 2015; Chiavazza 2016). Some dates agree with expectations based on nearby ^{14}C dates or stratigraphic sequences, but many others do not, echoing the trend in paired dates.

Overall, the compilation of paired dates suggests luminescence ages are inconsistent, but each individual case may have factors that might explain mismatched dates. With such a variety of sites, environmental conditions, and laboratory procedures, it is difficult to isolate sources of error for individual date pairs. To assess sets of dates, the next section compares sets of dates with Bayesian models.

Approach 2: Bayesian models of ^{14}C and TL dates

We compared ^{14}C-only and TL-only Bayesian models for 3 ceramic styles in northern Chile and the Inca occupation of Mendoza. Since we cannot assess all factors in individual date pairs, we turn to larger samples that should be less sensitive to case-specific problems. Independent Bayesian models for each dating method should show overlap in Kernel Density Estimates (KDE) and starting and ending boundaries (Bronk Ramsey 2017).

We modeled temporal ranges for three ceramic styles with dates from cemeteries in the Azapa Valley in northern Chile, where there are 66 ^{14}C and 60 TL dates (Muñoz Ovalle 2019). The lack of agreement between the dates has led to long-running debates on the ceramic sequence (see Korpisaari et al. 2014: 411–4). The models for Maytas-Chiribaya, Cabuza, and San Miguel ceramics all had acceptable agreement indices (Supplementary Material 2). For the Cabuza models, 3 outliers were removed from the ^{14}C model and 2 from the TL model, following Korpisaari et al. (2014).

For Maytas-Chiribaya ceramics, the TL and ^{14}C models agree: the phase boundaries overlap and the KDE trends are similar (Figure 3). In contrast, the models for both the Cabuza and San Miguel ceramics strongly disagree. The TL dates are internally coherent but fall centuries earlier than the ^{14}C dates associated with the same ceramic styles. The TL dates significantly overestimate the radiocarbon dates, the opposite trend seen in individual date pairs. It is unclear why the two dating methods agree for Maytas-Chiribaya ceramics but not for Cabuza ceramics, since microscopic and chemical analysis of the 2 styles show they have very similar paste compositions, firing patterns, and were likely made with local temper and water (Ogalde 2019: 143–4, 175–6). The reporting and use of dosimetry corrections is inconsistent, a trend seen elsewhere in Chile, but this probably would not have had a major effect on the results (Korpisaari et al. 2014: 422; Puerto Mundt and Marsh 2021). Most dates were run on individual sherds, which could have been out of primary context since many of these cemeteries have been looted. It is also possible that some of these are heirloom vessels, which would explain the older TL dates. However, individual outliers should not affect Bayesian trends. The ^{14}C models agree with the interpretation that all three styles emerged from the post-Tiwanaku diaspora and should fall after Tiwanaku's collapse ~AD 950–1000. This is supported by a large set of ^{14}C dates from textiles and human bones (Cassman 1997; Sutter 2000). Hence, future research may find it productive to proceed without the TL dates.

The apparent reliability of Inca-period TL dates led Marsh et al. (2017: 126) to include them in a Bayesian model of the Inca occupation of Mendoza. This model required complex outlier models that discarded 10 (19%) of 54 dates. Here we compare two single-phase models, one for each dating method (Figure 4, Supplementary Material 2). The ^{14}C model has 31 dates, including eight dates not included in the previous model (Bárcena 2010; Morgan et al. 2017; Terraza et al. 2019; Durán et al. 2021a). Two dates (6%) had low agreement indices (A=22 and 33), which follows the general expectation that a set of dates will have around 5% outliers (Bronk Ramsey 2009b). The agreement indices are above 60 and hence acceptable (A_{model}=84, $A_{overall}$=76). The Bayesian algorithm converged on a precise starting boundary, *cal*

AD 1380 (1350–1430, 95% probability), despite dispersed medians and large error ranges. This agrees with estimates for the earliest evidence of the Inca empire in northwestern Argentina, which has the same boundary medians, *cal AD 1380* and *1520* (Greco 2012: 408–11). The ending boundaries are coherent with the sequence of historically-documented events: the first Spanish expedition into northwestern Argentina in AD 1536 (Vitry 2007), the initial Spanish occupation of Santiago in AD 1540, the founding of Mendoza in AD 1561, and two travelers' reports that the Inca sites were in ruins by AD 1595 (Parisii 1994: 55).

In contrast, the TL-only model would not converge unless constrained by an ending date of AD 1595. We included two additional dates not included in the previous model (Bárcena et al. 2015). The model's agreement indices are just below the acceptable threshold (A_{model}=58, $A_{overall}$=48). Four of the 21 dates (19%) have low agreement indices (A=28–42), more than expected. Compared to the ^{14}C model, the two boundaries do not overlap and the TL starting boundary is later and much less precise. The KDE suggests continued Inca occupation until AD 1595, which disagrees with historically documented events. The TL model underestimates the dates of Inca occupation, even though overlapping error ranges allow individual date pairs to pass chi-square tests. Hence, we suggest that the updated ^{14}C-only model is our current best estimate of the timing of the Inca occupation in Mendoza.

Approach 3: a pilot study of paired ^{14}C, TL, OSL, and IRSL dates in Mendoza

The final approach was a pilot study with a set of six sherds from Mendoza paired with ^{14}C dates, all run at the same laboratory in Argentina. The luminescence dates were run at the University of Washington by James Feathers, who used three methods for each sherd: TL, OSL, and IRSL. All sherds were undecorated (Table 4; for methods and photos see Supplementary Materials 3 and 4). These sites were excavated in 5-cm levels, so they have grade-B associations between dated pairs.

One limitation is the lack of on-site dosimeter corrections. Studies in the region show low external rates (Bárcena 1998; Schmidt et al. 2012), so we use dates that assume a low dose of 0.5% K, 6 ppm Th, and 2 ppm U, as suggested by the laboratory (Supplementary Material 3). Most likely, on-site dosimeters would result in minor adjustments to the dates, as they did in Bárcena's (1998) study (Table 1). TL dating showed anomalous fading in all sherds, and despite fading corrections, only one sherd produced useful data with a high error of ~30% (UW-3759). This is a notable result, since anomalous fading may not have been fully considered at UCTL (Román et al. 1983: 10). Hence, for the pilot study, only OSL and IRSL ages are considered.

Barrancas, B61. In the southern Andes, ceramics were first adopted in multiple regions around *150 cal BC* (Marsh 2017). This includes Barrancas, a lowland area with the region's earliest cemetery (Novellino et al. 2013) and pit house at the site B61, which has two very similar ^{14}C samples (LP-2997 and LP-3088; Marsh 2017). The first was from a hearth adjacent to the ramp entrance; the second is from a carbon concentration on the other side of the house (Figure 5). The luminescence-dated sherd is from the same depth (10–15 cm) on the house's original floor. All three samples are from the better-preserved northern half of the structure, which included details such as the impressions left by branches used to build wattle-and-daub walls.

Structures like this are rarely maintained for more than a generation, so floor refuse is often deposited within a few decades and covered by roof fall, reducing the possibility of

mixing with earlier or later material. The sherd from the house floor returned a luminescence date of AD 560±100 (UW-3758). This is many centuries later than the date suggested by the two paired ^{14}C dates, which have a combined median of 50 cal BC. While unlikely, we cannot rule out the possibility that the sherd washed into the pit from a later occupation. It is also possible that differential radioactivity above and below the floor surface affected the age.
El Manzano Histórico. At this site, a similar pit house was found below a modern road. Carbon and artifact concentrations were dense within the house. A ^{14}C date from the floor returned a median of AD 1000 (LP-1637; Cambria 2010; Marsh et al. 2014), which is consistent with expectations for the associated Agrelo pottery. An undecorated sherd from a different part of the house was submitted for luminescence dating (UW-3757). Unlike other sherds in the pilot study, the recovered dose was higher than the administrated dose, which may explain the overestimated OSL age, AD 480±100. Only OSL was used, since the TL and IRSL signals suffered from anomalous fading. A high b-value hinted that the age may be underestimated, but in fact, the OSL age is centuries older than the ^{14}C date and all other regional ^{14}C dates associated with this ceramic style (García 2004).

Paso de Paramillos I. This rock shelter is near a mountain pass west of Mendoza (Bárcena 1998: 220–2). The deposition of the site is cleanly divided into two layers. The lower one has sparse bits of carbon and very few, small lithic flakes. The upper layer has a distinct soil texture and color and includes a much higher density of artifacts and some ceramics. The sherd dated by luminescence (UW-3759) was found lying flat on the stratigraphic boundary between the two layers. The IRSL signal was too weak to obtain an age, but OSL dated the sherd to AD 780±90. It was found within a few centimeters of a dated carbon concentration (LP-3629), which has a median of AD 350, consistent with regional expectations for early highland pottery. The luminescence age underestimates the ^{14}C date by multiple centuries. While there was no sign of stratigraphic disturbance near the sherd, rodent activity could have moved this sherd. A ^{14}C–TL date pair from the site's upper layer site did pass the chi-square test, though the association between samples is less certain (Bárcena 1998: 222; Table 2).

Las Cuevas 2. This is a high-mountain rock shelter in the Cuevas River Valley (3160 masl). The area has lush summer pastures and is located along the natural pass between Mendoza and Santiago (Gasco et al. 2021). Excavation material suggested an occupation from around AD 1300 to Spanish contact. The paired samples are from a depth of 30–35 cm in a stratum with carbon and ash lenses and a clayey matrix (Figure 6). The samples were found immediately below field stones that were part of an informal wall. The radiocarbon date has a median of AD 1490 (LP-3602), consistent with diagnostic Inca-period ceramics from this level and the other Inca ^{14}C dates from northern Mendoza. In contrast, the luminescence age of AD 180 (UW-3756) is much older, and there is little agreement between the individual TL, OSL, and IRSL ages. While highly unlikely, it is not impossible that the sherd was made more than a thousand years before it was deposited in this site's layers of refuse.

Agua de la Cueva. This site has the most complete sequence of human occupation in the province. Occupation began in the Late Pleistocene (García 2003), but its intensity was much higher over the last two thousand years (Durán and García 1989; Castro and Yebra 2018). With one exception (AD-1562, level 29), the nine ^{14}C dates follow the stratigraphic sequence, consistent with the generally undistributed and horizontal deposition of strata (Figure 7; Durán et al. 2021b). The most recent luminescence date (UCTL-1172, level 11) fits stratigraphic expectations, similar to other Inca-period TL dates. Three other luminescence ages (UCTL-1173, UCTL-1173, and UW-3755) underestimate the date of the strata where they were found, which fits the overall trend for individual paired dates. One age (UW-3754, level 24) agrees very well with the ^{14}C date from the same level; both have medians of AD 860. Another luminescence date from the same level (UW-3755) barely passes the chi-square test, but its median is 3 centuries younger. This difference between the luminescence ages is difficult to explain because the sherds' depositional histories should be very similar. This part of the sequence has few pits or burning events that might affect luminescence ages.

The pilot study of ceramics in Mendoza shows that luminescence ages are inconsistently older and younger than paired ^{14}C dates. One possibility is that there was a residual signal left in the sherds that resulted in partial bleaching, but on the other hand, they had good plateaus. Another possibility is that energy levels vitrified the quartz, but it is quite unlikely they were heated above 1000°C. The dose rate calculations could clearly be improved with local corrections using on-site dosimeters. This may have a minor effect, like Bárcena's (1998) dosimeter corrections (Table 1), or be significantly higher, since luminescence sensitivity is unstable in the Andes. In this case, the dates may be accurate, but with error ranges that are far too large to be useful in constructing archaeological chronologies. It is also possible that post-depositional processes moved samples out of primary position; hence, these are not grade-A date pairs. Overall, the pilot study's inconsistent results echo those of the other two approaches.

Discussion: disagreement between ^{14}C, historic, and luminescence ages

We took three approaches to comparing dating methods, which all show that luminescence dates are inconsistent. Of the 94 paired dates from the literature and the pilot study, 56% fail the chi-square test, with a median difference between paired dates of 300 years or 27% (Figure 8; Tables 2–4). For date pairs that passed the test, agreement was not strong, with a median difference of 90 years or 12%. For date pairs that failed the test, differences increase with age, marking a clear trend line (r^2=0.50). This trend line crosses the horizontal axis at AD 1500, which may reflect the fact that some laboratories use this date as an *a priori* reference point for sherd age, since it is usually clear whether sherds are pre- or post-Hispanic. This may help explain why most Inca-period dates pass individual chi-square tests. Method choice may also help explain this; for example, UCTL prefers pre-dose for younger sherds and plateau for older sherds (Bárcena 1998: 365). The Mendoza pilot study identified anomalous fading in all sherds, which may be another confounding factor for some TL dates.

Dates that failed the test showed different tendencies for three lapses. First, older luminescence dates underestimate ^{14}C dates, a tendency identified in the 1980s (Stothert 1988; Schiappacasse et al. 1991). Second, during the Inca period, 78% of pairs pass the chi-square test. Third, in the historic period, dates overestimate the true age. In Mendoza, 25 of 28 TL dates on European-fired sherds, floor tiles, and bricks fail the chi-square test; all but one overestimate the expected dates based on historic records. Sediment dates from northern Mendoza have also reported this trend. In a stratum with three consistent ^{14}C dates, with medians of AD 1760–1850, the associated OSL age was some three centuries older (Schmidt et al. 2012: 71). In sediments from Chile, refined p-IRIR methods also overestimated the age of two historic events (Brill and Cisternas 2020: 9).

UCTL ran 83% of the luminescence dates compared here, but laboratories in Denmark, Peru, and the United States have had no more success despite using updated methods. It is possible that this trend reflects unclear geological variability in northern Mendoza, where 60% of the date pairs come from. However, within this region and others, there is no apparent spatial trend in chi-square results (Figure 1). Furthermore, date pairs with higher association grades are no more reliable: 8 of 11 grade-A pairs fail chi-square tests.

Luminescence challenges in the Andes

Some of the disagreement between ^{14}C and luminescence ages seems to be related to the young age of the Andes. Sediments have low and unstable luminescence sensitivity and strong regional variation, in contrast to those in Brazil (Sawakuchi et al. 2018: 158; del Río et al. 2019). Younger sediments may also show significant variability between grains and dose rate can change over time (Preusser et al. 2009; Degering and Degering 2020). Areas with higher erosion may be more susceptible to this, but this needs to be assessed in each region. In Peru, an age offset between OSL and IRSL ages was attributed to unstable OSL signal components (Steffen et al. 2009). In Chile, feldspar IRSL has proven more reliable than OSL (del Río et al. 2019), and quartz OSL underestimated control ages (Brill and Cisternas 2020), perhaps because it saturates earlier than feldspar and has low sensitivity. In Argentina, quartz OSL is more often used (Espizua 1999; Robinson et al. 2005; Moreiras et al. 2015). In northwestern Argentina, Spencer and Robinson (2008) used post-IR-blue stimulated luminescence to help improve on OSL ages with poor accuracy and precision. In northern Mendoza, Schmidt et al. (2012) used IR-OSL stimulation to remove the feldspar OSL signal from quartz aliquots.

Not all of these adjustments may be relevant to quartz or feldspar temper in archaeological ceramics, since firing should reset TL signals, sensitize quartz, and de-sensitize feldspar. Ceramics are less complex than sediments in terms of partial bleaching or mixing. Since they usually have more clay, they tend to have a higher content of radionuclides, which may make them less sensitive to external dose rates. Some researchers prefer OSL for ceramics because single-aliquot methods are more precise (Roberts et al. 2015: 46; Ideker et al. 2017). Others prefer single- and multi-aliquot TL (Galli et al. 2020: 190). The depositional history of each sherd is essential but is often missing from published luminescent ages. Initially, sherds could only be reliably dated from deep homogenous layers (Aitken 1990: 153), but with updated methods, it is increasingly common to date sherds from the surface, complex burial contexts, and museum collections (Dunnell and Feathers 1995; Hood and Schwenninger 2015; Hood and Highcock 2019). In the field, collection procedures and adequate contextual information are often lacking, which is likely a contributing factor in some of the inconsistencies identified here. For any study, myriad issues must be addressed to produce reliable luminescence ages.

Conclusion and implications for future research

This paper took three approaches to evaluate luminescence ages' reliability: individual paired dates, Bayesian models of sets of dates, and a pilot study with four methods per sherd: TL, OSL, IRSL, and closely associated ^{14}C samples. These approaches all show that luminescence ages are inconsistent, but there have been some encouraging results such as the Maytas-Chiribaya ceramics in the Azapa Valley. Some TL dates appear to be useful for low-resolution chronologies or relative markers (Berenguer et al. 1988; Bárcena 1998; Schultze et al. 2009). However, they may be no more reliable or precise than well-documented stratigraphic sequences, which is a much simpler approach. Even sherds fired in European kilns with grade-A associations fail chi-square tests more often than not, which casts a long shadow over the luminescence ages that do seem to be accurate.

This result has significant implications for Chilean cultural and ceramic chronologies, which depend heavily on TL dates, though some are based on ^{14}C dates (e.g. Sierralta et al. 2019). For unpaired TL dates, we cannot say if they 1) place ceramics accurately in time such as the Maytas-Chiribaya style and 44% of individual paired dates, 2) overestimate ages by multiple centuries such as the Cabuza and San Miguel styles, or 3) underestimate age such as 56% of individual paired dates. The general tendency to underestimate ^{14}C dates runs counter to the expectation that luminescence ages of a vessel's firing should be older than ^{14}C dates associated with its deposition. Coincidences with ^{14}C dates may be masked by large error ranges, which seems to be the case for early dates from northern Chile and Inca period dates in Mendoza. For the Inca dates, individual paired dates pass chi-square tests, but Bayesian models show that TL dates underestimate the age of the Inca occupation. In other parts of the Andes,
results are also mixed, probably for similar reasons.

The reasons for the lack of agreement between methods remain unclear, but it is clear that young Andean sediments present a challenge to luminescence dating. We encourage continued work to produce reliable and reproducible ages of both sediments and ceramics in the Andes, as has been done in other regions with older and more stable sediments such as Australia, Brazil, and Uruguay (Feathers and Nami 2018; Roberts et al. 2015; Sawakuchi et al. 2018). In these efforts, comparisons between multiple methods and laboratories will be essential. The gold standard may be with pairing luminescence ages with radiocarbon dates of lipids extracted from the same sherd (Casanova et al. 2020). Despite continuing challenges, reliable luminescence ages would be a boon to South American archaeology. At the moment, however, our message to archaeologists working in the Andes is that luminescence dates are not reliable enough for constructing or revising cultural chronologies.

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Supplementary material

1. English translation of Román and Deza (1998), which briefly describes UCTL methods.
2. OxCal code for Bayesian models of dates from the Azapa Valley, Chile, and the Inca occupation of northern Mendoza.
3. Laboratory report from the pilot study, prepared by James Feathers.
4. Photos of the sherds and sherd profiles (×40 magnification) from the pilot study.

References cited

Aimi A, Alva W, Chero L, Martini M, Maspero F. 2016. Hacia una nueva cronología de Sipán. In: Aimi A, Makowski K, Perassi E, editors. Lambayeque: nuevos horizontes de la arqueología peruana. Milan: Ledizioni. p. 129–55.

Aitken, MJ. 1990. Science-based dating in archaeology. London: Taylor & Francis.

Aldunate, C, Berenguer J, Castro V, Cornejo L, Martínez JL, Sinclaire, C. 1986. Sobre la cronología del Loa superior. Chungará 16–17:333–46.

Angiorama CI, 1998. Nuevos aportes a la cronología de Condorhuasi-Alamito. Palimpsesto 5:100–5.

Bárcena JR. 1998. Arqueología de Mendoza: las dataciones absolutas y sus alcances. Mendoza: Editorial Universidad Nacional de Cuyo.

Bárcena JR. 2010. Dataciones por radiocarbono en el sector con grabados rupestres del Arroyo Campos Borbarán (Estancia Tierras Blancas, Departamento de San Carlos, Provincia de Mendoza). In: Bárcena JR, editor. Arqueología del Centro Oeste Argentino: aportes desde las IV Jornadas Arqueológicas Cuyanas. Mendoza: INCIHUSA. p. 17–46.

Bárcena JR, Ots MJ. 2012. La Arboleda de Tupungato: nota preliminar sobre el sitio fundacional hispánico del Valle de Uco, Mendoza. Comechingonia 16:147–65.

Bárcena JR, Terraza V, Iniesta ML. 2015. Estudios tecnoestilísticos y de dataciones TL de materiales cerámicos del sitio La Chanchería (Valle de Uspallata, Noroeste de Mendoza, Argentina). In: Bárcena JR, editor. Arqueología y etnohistoría del Centro Oeste Argentino: aportes desde las V Jornadas Arqueológicas Cuyanas, Xama Serie Monografías. Mendoza: INCIHUSA. p. 95–117.

Bayliss A. 2009. Rolling out revolution: using radiocarbon dating in archaeology. Radiocarbon 51(1):123–47.

Berenguer J, Deza A, Román A, Llagostera A. 1986. La secuencia de Myriam Tarragó para San Pedro de Atacama: un test por termoluminiscencia. Revista Chilena de Antropología 5:17–54.

Berenguer J, Roman A, Deza A, Llagostera A. 1988. Testing a cultural sequence for the Atacama Desert. Current Anthropology 29:341–6.

Brill D, Cisternas M. 2020. Testing quartz and feldspar luminescence dating to determine earthquake and tsunami recurrence in the area of the giant 1960 Chile earthquake. Quaternary Geochronology 58:101080. https://doi.org/10.1016/j.quageo.2020.101080.

Brito O, Deza Á, Román Á, Concha G. 1979. Fechamiento por termoluminiscencia de cerámicas del sitio Toconce 2 B. In: Actas del VII Congreso Nacional de Arqueología de Chile, Altos de Vilches, 1977, Vol. I. p. 53–8.

Bronk Ramsey C. 2009a. Bayesian analysis of radiocarbon dates. Radiocarbon 51:337–60. https://doi.org/10.1017/S0033822200033865.

Bronk Ramsey C. 2009b. Dealing with outliers and offsets in radiocarbon dating. Radiocarbon 51:1023–45. https://doi.org/10.1017/S0033822200034093.

Bronk Ramsey C. 2017. Methods for summarizing radiocarbon datasets. Radiocarbon 59:1809–33. https://doi.org/10.1017/RDC.2017.108.

Cahiza P, Llorca JG, Aguilar JP. 2008. Aportes para el análisis de la configuración del espacio colonial temprano de Valle Fértil, San Juan. Revista de Arqueología Histórica Argentina y Latinoamericana 2:79–114.

Cambria M, 2010. Estudios arqueológicos en el Área Natural Protegida El Manzano Histórico (Tunuyán, Mendoza) [unpublished undergraduate thesis]. Mendoza: Universidad Nacional de Cuyo.

Campbell R, Quiroz D. 2015. Chronological database for Southern Chile (35°30'–42° S), ~33000 BP to present: human implications and archaeological biases. Quaternary International 356:39–53. https://doi.org/10.1016/j.quaint.2014.07.026.

Casanova E, Knowles TDJ, Bayliss A, Dunne J, Barański MZ, Denaire A, Lefranc P, di Lernia S, Roffet-Salque M, Smyth J, Barclay A, Gillard T, Claßen E, Coles B, Ilett M, Jeunesse C, Krueger M, Marciniak A, Minnitt S, Rotunno R, van de Velde P, van Wijk I, Cotton J, Daykin A, Evershed RP. 2020. Accurate compound-specific 14 C dating of archaeological pottery vessels. Nature 580:506–10. https://doi.org/10.1038/s41586-020-2178-z.

Cassman V. 1997. A reconsideration of prehistoric ethnicity and status in northern Chile: the textile evidence [unpublished PhD Dissertation]. Tempe (AZ): Arizona State University.

Castro SC, Yebra L. 2018. Ocupación tardía de la precordillera de Mendoza: organización tecnológica en Agua de la Cueva Sector Norte (ca. 1700-470 años cal. AP). Anales de Arqueología y Etnología 73(1):7–40.

Castro, V, Aldunate C, Berenguer J, Cornejo L, Sinclaire C, Varela, V. 1994. Relaciones entre el Noroeste Argentino y el Norte de Chile: el sitio 02-TU-002, Vegas de Turi. In: Albeck ME (editor). Taller de costa a selva: producción e intercambio entre los pueblos agroalfareros de los Andes Centro Sur. Buenos Aires: Instituto Interdisciplinario Tilcara, Universidad de Buenos Aires. p. 215–39.

Chiavazza H. 2016. Vivir y moverse en el desierto: la ocupación humana en entornos áridos (noreste de Mendoza, Argentina). Sociedades de Paisajes Áridos y Semi-Áridos 9:13–34.

Cocilovo J, Llagostera A, Varela H. 2011. Armando el rompecabezas en San Pedro de Atacama: el sitio Coyo Oriental y la cuestión de los sectores del Padre Le Paige desde la antropología biológica. Revista Chilena de Antropología 23:149–72. https://doi.org/10.5354/rca.v0i23.15566.

Concha G, Román Á, Brito O, Deza, Á. 1980. Thermoluminescent dating of ancient Toconce potteries. Ancient TL 10:9–11. http://ancienttl.org/ATL_L4-1.pdf.

Cornejo L. 2014. Sobre la cronología de la imposición cuzqueña en Chile. Estudios Atacameños 47:101–16.

Cornell P, Johansson N. 1993. Desarrollo del asentamiento del sitio STucTav 5 (El Pichao), Provincia de Tucumán: comentarios sobre dataciones de 14C y luminiscencia. Publicaciones del Instituto de Arqueología, Universidad Nacional de Tucumán 2:31–43.

Cortegoso V, Durán V, Gasco A, editors. 2014. Arqueología de ambientes de altura de Mendoza y San Juan (Argentina). Mendoza: EDIUNC.

Cortés C. 2017. Sitio Los Jazmines, Melipilla: contacto cultural en Chile Central entre las poblaciones locales, el Tawantinsuyu y los españoles: una aproximación desde las prácticas funerarias [unpublished undergraduate thesis]. Santiago: Universidad de Chile.

Costa, MA, Llagostera A, Cocilovo JA. 2008. La deformación craneana en la población prehistórica de Coyo Oriente, San Pedro de Atacama. Estudios Atacameños 36:29–41. https://doi.org/10.4067/S0718-10432008000200003.

Degering D, Degering A. 2020. Change is the only constant: time-dependent dose rates in luminescence dating. Quaternary Geochronology 58:101074. https://doi.org/10.1016/j.quageo.2020.101074.

De La Fuente GA, Rasmussen KL, Ferguson JR, Glascock MD. 2010. Cronología por termoluminiscencia (TL) de cerámicas pertenecientes al Horizonte Inka (ca. AD 1480-AD 1532) y el Período Tardío (ca. AD 900-AD 1450) en el sur del valle de Abaucán: análisis comparativos y resultados preliminares (Dpto. Tinogasta, Catamarca, Argentina). In: Actas del XVII Congreso Nacional de Arqueología Argentina, Vol. III. p. 1339–44.

del Río I, Sawakuchi AO, González G. 2019. Luminescence dating of sediments from central Atacama Desert, northern Chile. Quaternary Geochronology 53:101002. https://doi.org/10.1016/j.quageo.2019.05.001.

Deza Á, Román Á. 1986. La dosimetría termoluminiscente en arqueología. Chungará 16–17:403–7.

Dillehay TD, Saavedra Zapata J, 2014. The archaeological record. In: Dillehay TD, editor. The teleoscopic polity: Andean patriarchy and materiality. Cham, Switzerland: Springer. p. 143–220.

Dunnell RC, Feathers JK. 1995. Thermoluminescence dating of surficial archaeological material. In: Beck C, editor. Dating in exposed and surface contexts. Albuquerque: University of New Mexico. p. 115–37.

Durán V. 2000. Poblaciones indígenas de Malargüe: su arqueología e historia. Mendoza: Universidad Nacional de Cuyo, Facultad de Filosofía y Letras.

Durán V, García C. 1989. Ocupaciones agroalfareras en el sitio Agua de la Cueva Sector Norte (NO de Mendoza). Estudios Regionales 3:29–64.

Durán V, Novellino P. 2003. Vida y muerte en la frontera del imperio español: estudios arqueológicos y bioantropológicos en un cementerio indígena post-contacto del centro-oeste de Argentina. Anales de Arqueología y Etnología 54/55:115–68.

Durán V, Novellino P, Menéndez L, Gasco A, Marsh EJ, Barberena R, Frigolé C. 2018. Barrio Ramos I: funebria y modos de vida en el inicio del período de dominación inca del valle de Uspallata (Mendoza, Argentina). Relaciones de la Sociedad Argentina de Antropología 43:55–86.

Durán V, Zárate S, Yebra L, Frigolé C, Gasco A, Castro S, Winocur D, Barberena R, Cortegoso V, Marsh E, Lucero G, Andreoni D, Zonana I. 2021a. La apropiación y control estatal de ambientes de altura en el extremo meridional del Tawantinsuyu. Estudios Atacameños. In press.

Durán V, Gasco A, Paiva J, Zonana I, Barberena R. 2021b. El aprovechamiento de camélidos y ambientes de altura en sociedades agropastoriles prehispanas del NO de Mendoza (Argentina). Relaciones de la Sociedad Argentina de Antropología. In press.

Erickson C. 1988. An archaeological investigation of raised field agriculture in the Lake Titicaca Basin of Peru [unpublished PhD dissertation]. Champaign (IL): University of Illinois at Urbana-Champaign.

Espizua LE. 1999. Chronology of Late Pleistocene glacier advances in the Río Mendoza Valley, Argentina. Global and Planetary Change 22:193–200. https://doi.org/10.1016/S0921-8181(99)00036-3.

Falabella F, Cornejo LE, Sanhueza L, Correa I. 2015. Trends in thermoluminescence date distributions for the Angostura micro region in Central Chile. Quaternary International 356:27–38.

Feathers JK, Nami H. 2018. Luminescence dating of Late Pleistocene and Holocene sediments in Uruguay. Latin American Antiquity 29:495–513. https://doi.org/10.1017/laq.2018.9

Fitzpatrick SM, Kaye Q, Feathers J, Pavia JA, Marsaglia KM. 2009. Evidence for inter-island transport of heirlooms: luminescence dating and petrographic analysis of ceramic inhaling bowls from Carriacou, West Indies. Journal of Archaeological Science 36:596–606. https://doi.org/10.1016/j.jas.2008.08.007.

Galli A, Sibilia E, Martini M. 2020. Ceramic chronology by luminescence dating: how and when it is possible to date ceramic artefacts. Archaeol Anthropol Sci 12:190. https://doi.org/10.1007/s12520-020-01140-z.

Gasco A, Llano C, Durán V, Winocur D, Zonana I, Paiva J. 2021. Aprovechamiento de recursos animales y vegetales en un contexto asociado al Qapac Ñan de la frontera sur del Tawantinsuyu. Unpublished manuscript.

García A. 2003. La ocupación temprana de los andes centrales argentinos (ca. 11.000-8.000 años C14 AP). Relaciones de la Sociedad Argentina de Antropología 28:153–65.

García A. 2004. La cronología del estilo cerámico Agrelo y sus implicancias para el estudio de las sociedades tardías de Mendoza. Estudios Regionales 26:29–39.

Gayo EM, Latorre C, Santoro CM. 2015. Timing of occupation and regional settlement patterns revealed by time-series analyses of an archaeological radiocarbon database for the South-Central Andes (16°–25°S). Quaternary International 356:4–14. https://doi.org/10.1016/j.quaint.2014.09.076.

Gil AF, Giardina MA, Neme G, Ugan A. 2014. Demografía humana e incorporación de cultígenos en el centro occidente argentino: explorando tendencias en las fechas radiocarbónicas. Revista Española de Antropología Americana 44:523–33.

Gil A, Neme G, Hernández A, Novellino P, Giardina M, Salgán L, Tucker H, Albarrán E. 2008. Rincón del Atuel-1 (San Rafael, Mendoza): evidencias arqueológicas e implicancias regionales. Intersecciones en Antropología 9:113–32.

González AR, Lagiglia HA. 1973. Registro nacional de fechados radiocarbónicos: necesidad de su creación. Relaciones de la Sociedad Argentina de Antropología 7:291–312.

Greco C. 2012. Integración de los datos arqueológicos, radiocarbónicos y geofísicos para la construcción de una cronología de Yocavil y alrededores [unpublished PhD dissertation]. Buenos Aires: Universidad de Buenos Aires.

Guráieb AG, Carro D, Rambla M. 2015. Por hoyada, valles y quebradas: el uso del espacio a través de la tecnología lítica en el norte de la sierra de Valle Fértil (San Juan). Cuadernos del Instituto Nacional de Antropología y Pensamiento Latinoamericano – Series Especiales 2:79–101.

Hood AGE, Highcock EG. 2019. Using DosiVox to reconstruct radiation transport through complex archaeological environments. Methods and Protocols 2:91. https://doi.org/10.3390/mps2040091.

Hood AGE, Schwenninger J-L. 2015. The minimum extraction technique: a new sampling methodology for optically stimulated luminescence dating of museum ceramics. Quaternary Geochronology, LED14 Proceedings 30:381–5. https://doi.org/10.1016/j.quageo.2015.06.007.

Hogg AG, Heaton TJ, Hua Q, Palmer JG, Turney CS, Southon J, Bayliss A, Blackwell PG, Boswijk G, Ramsey CB, Pearson C, Petchey F, Reimer P, Reimer R, Wacker L. 2020. SHCal20

Southern Hemisphere calibration, 0-55,000 years cal BP. Radiocarbon 62(4):759–778. https://doi.org/10.1017/RDC.2020.59.
Ideker CJ, Finley JB, Rittenour TM, Nelson MS. 2017. Single-grain optically stimulated luminescence dating of quartz temper from prehistoric Intermountain Ware ceramics, northwestern Wyoming, USA. Quaternary Geochronology 42:42–55. https://doi.org/10.1016/j.quageo.2017.07.004.
Itaci F, Flores C. 2010. Explotación de ambientes costeros, intensificación de recursos y transformaciones culturales en la transición Holoceno Medio a Holoceno Tardio en la costa de los canales patagónicos septentrionales, Chile. In: Actas del XVII Congreso Nacional de Arqueología Argentina, Mendoza, Vol. I. p. 321–6.
Janusek JW, Kolata AL. 2004. Top-down or bottom-up: rural settlement and raised field agriculture in the Lake Titicaca Basin, Bolivia. Journal of Anthropological Archaeology 23:404–30. https://doi.org/10.1016/j.jaa.2004.08.001.
Kanomata Y, Marcos J, Popov A, Lazin B, Tabarev A. 2019. New data on early pottery traditions in South America: the San Pedro complex, Ecuador. Antiquity 93:e17. https://doi.org/10.15184/aqy.2019.56.
Koons ML, Alex BA. 2014. Revised Moche chronology based on Bayesian models of reliable radiocarbon dates. Radiocarbon 56(3):1039–55. https://doi.org/10.2458/56.16919.
Korpisaari A, Oinonen M, Chacama J. 2014. A reevaluation of the absolute chronology of Cabuza and related ceramic styles of the Azapa Valley, northern Chile. Latin American Antiquity 25(4):409–26. https://doi.org/10.7183/1045-6635.25.4.409.
Le Paige RPG. 1976. Nuevas fechas radiocarbónicas de la zona de San Pedro de Atacama. Estudios Atacameños 4:131–5.
Marcos JG, Michczyński A. 1996. Good dates and bad dates in Ecuador. Andes 1:93–114.
Marsh EJ. 2012. A Bayesian re-assessment of the earliest radiocarbon dates from Tiwanaku, Bolivia. Radiocarbon 54(2):203–18. https://doi.org/10.2458/azu_js_rc.v54i2.15826.
Marsh EJ. 2017. La fecha de la cerámica más temprana en los Andes sur: una perspectiva macrorregional mediante modelos bayesianos. Revista del Museo de Antropología 10:83–94.
Marsh EJ, Bruno MC, Fritz SC, Baker P, Capriles JM, Hastorf CA. 2018. IntCal, SHCal, or a mixed curve? choosing a 14C calibration curve for archaeological and paleoenvironmental records from Tropical South America. Radiocarbon 60(3):925–40. https://doi.org/10.1017/RDC.2018.16.
Marsh E, Frigolé C, Moyano R. 2014. La casa-pozo del sitio El Manzano, Tunuyán, Mendoza: una mirada comparativa y experimental a las técnicas decorativas de la cerámica Agrelo. Presented at the II Jornadas Salvador Canals Frau, Universidad Nacional de Cuyo, Mendoza.
Marsh EJ, Kidd R, Ogburn D, Durán V. 2017. Dating the expansion of the Inca Empire: Bayesian models from Ecuador and Argentina. Radiocarbon 59(1):117–40. https://doi.org/10.1017/rdc.2016.118.
Marsh EJ, Roddick AP, Bruno MJ, Smith SC, Janusek JW, Hastorf CA. 2019. Temporal inflection points in decorated pottery: a Bayesian refinement of the Late Formative chronology in the southern Lake Titicaca Basin, Bolivia. Latin American Antiquity 30(4):798–817.
Martini, M, Sibilia, E. 2001. Radiation in archaeometry: archaeological dating. Radiation Physics and Chemistry, 8th International Symposium on Radiation Physics - ISRP8 61:241–6. https://doi.org/10.1016/S0969-806X(01)00247-X.

Méndez C, Grasset S, Jackson D, Troncoso A, Santander B. 2016. Ocupaciones humanas del Holoceno Medio en los Andes del norte Semiárido de Chile (31°S, Combarbalá): función del sitio e implicancias para el uso regional del espacio. Chungará 48:225–41. https://doi.org/10.4067/s0717-73562016005000003.

Moreiras SM, Hermanns RL, Fauqué L. 2015. Cosmogenic dating of rock avalanches constraining Quaternary stratigraphy and regional neotectonics in the Argentine Central Andes (32° S). Quaternary Science Reviews 112:45–58. https://doi.org/10.1016/j.quascirev.2015.01.016.

Morgan C, Neme G, Sugrañes N, Salgan L, Gil AF, Otaola C, Giardina M, Llano C. 2017. Late prehistoric high-altitude hunter-gatherer residential occupations in the Argentine southern Andes. Journal of Field Archaeology 42:214–27. https://doi.org/10.1080/00934690.2017.1308749.

Muñoz Ovalle I. 2019. Cronología del periodo medio en el Valle de Azapa, norte de Chile: estilos, fechados y contextos culturales del poblamiento humano. Chungará 51:595–611. https://doi.org/10.4067/S0717-73562019005001801.

Muñoz Ovalle I, Chacama Rodriguez J. 1988. Cronología por termoluminiscencia para los Períodos Intermedio Tardío y Tardío en la Sierra de Arica. Chungará 20:19–45.

Murray A, Buylaert J-P, Thiel C. 2015. A luminescence dating intercomparison based on a Danish beach-ridge sand. Radiation Measurements, 14th International Conference on Luminescence and Electron Spin Resonance Dating, 7–11 July, 2014, Montréal, Canada 81:32–8. https://doi.org/10.1016/j.radmeas.2015.02.012.

Nielsen A. 2007. El Período de Desarrollos Regionales en la Quebrada de Humahuaca: aspectos cronológicos. In: Williams V, Ventura B, Callegari AB, Yacobaccio H, editors. Sociedades precolombinas surandinas: temporalidad, interacción y dinámica cultural del NOA en el ámbito de los Andes Centro-Sur. Buenos Aires. p. 235–47.

Niemeyer H, Schiappacasse V, Solimano I. 1973. Patrones de poblamiento de la quebrada de Camarones (Provincia de Tarapacá). In: Actas del VI Congreso de Arqueología Chilena. Universidad de Chile, Santiago, 1971. p. 115–37.

Novellino P, Barchetta Aporta N, D'Addona LA, Estrella D, Bernal V, Devincenzi S, Cortegoso V, Durán V. 2013. Sitios de entierro de la localidad arqueológica Barrancas, Maipú (Mendoza, Argentina). Intersecciones en Antropología 14:271–7.

Núñez L. 1976. Registro regional de fechas radiocarbónicas del norte de Chile. Estudios Atacameños 4:74–123.

Núñez Regueiro VA, García Azcárate J. 1996. Investigaciones arqueológicas en El Mollar, Dto. Tafí del Valle, Pcia. de Tucumán. In: Actas y memorias XI Congreso Nacional de Arqueología Argentina (13° Parte), Revista del Museo de Historia Natural de San Rafael (Mendoza) XXV. p. 87–97.

Ogalde JP. 2019. Sobre el origen cultural del quero Cabuza: los grupos sociales detrás de su tecnología de producción y uso [unpublished PhD dissertation]. Universidad de Tarapacá, Chile.

Oliszewski N. 2017. Las aldeas "Patrón Tafí" del sur de Cumbres Calchaquíes y norte del sistema del Aconquija. Comechingonia 21:205–32.

Ots MJ, Oliszewski N, Llorca JG. 2011. Estrategias alimentarias y de subsistencia prehispánica en el Centro-Oeste de Mendoza: consumo y descarte en el sitio arqueológico Agua Amarga. Revista del Museo de Antropología 4:65–80.

Parisii MG. 1994. Algunos datos de las poblaciones prehispánicas del norte y centro oeste de Mendoza y su relación con la dominación inca del área. Xama 4–5:51–69.

Pavlovic D, Sánchez R, Pascual D, Martínez A, Cortés C, Dávila C, La Mura N. 2019. Rituales de la vida y de la muerte: dinámicas de interacción entre el Tawantinsuyu y las poblaciones locales en la cuenca del Maipo-Mapocho, Chile central. Estudios Atacameños 63:43–80. https://doi.org/10.22199/issn.0718-1043-2019-0022.
Pavlovic D, Troncoso A, Massone M, Sánchez R. 2000. El sitio RML 008 - Blanca Gutiérrez y su aporte a la comprensión de los sistemas de asentamiento y subsistencia de la cultura Aconcagua en Lampa, valle central de Chile. In: Actas del XIV Congreso Nacional de Arqueología Chilena, Copiapó, Vol. II. p. 161–90.
Pestle WJ, Torres-Rouff C, Pimentel G, Hubbe M. 2021. Bounding Middle Period cemetery use in San Pedro de Atacama, Chile. Radiocarbon 63:229–63. https://doi.org/10.1017/RDC.2020.105.
Prieto Olavarría C, Chiavazza H. 2010. La alfarería Viluco y los contextos del área fundacional: aportes al estudio de la dominación incaica y los primeros años de la colonia en el valle de Mendoza. In: Actas del XVII Congreso Nacional de Arqueología Argentina, Vol. II. p. 807–12.
Preusser F, Chithambo ML, Götte T, Martini M, Ramseyer K, Sendezera EJ, Susino GJ, Wintle AG. 2009. Quartz as a natural luminescence dosimeter. Earth-Science Reviews 97:184–214. https://doi.org/10.1016/j.earscirev.2009.09.006.
Puerto Mundt S, Marsh EJ. 2021. La expansión Tawantinsuyu en Chile central: bases para la construcción de una cronología arqueométrica e integración etnohistórica. Boletín de la Sociedad Chilena de Arqueología. In press.
Quiroz D, Sánchez M. 2005. La secuencia Pitrén-El Vergel en Isla Mocha: soluciones de continuidad y distinciones culturales. In: Actas del XVI Congreso Nacional de Arqueología Chilena, Tomé, 2003. Concepción, Chile: Museo de Historia Natural de Concepción. p. 369–78.
Rick JW, Mesia C, Contreras D, Kembel SR, Rick RM, Sayre M, Wolf J. 2009. La cronología de Chavín de Huántar y sus implicancias para el Periodo Formativo. Boletín de Arqueología PUCP 13:87–132.
Roberts RG, Jacobs Z, Li B, Jankowski NR, Cunningham AC, Rosenfeld AB. 2015. Optical dating in archaeology: thirty years in retrospect and grand challenges for the future. Journal of Archaeological Science 56:41–60. https://doi.org/10.1016/j.jas.2015.02.028.
Robinson R, Spencer J, Strecker M, Richter A, Alonso R. 2005. Luminescence dating of alluvial fans in intramontane basins of NW Argentina. Geological Society, London, Special Publications 251:153–68. https://doi.org/10.1144/GSL.SP.2005.251.01.11.
Román Á, Deza Á. 1985. Fechamiento por termoluminiscencia de algunos fragmentos cerámicos de los sitios Chiu Chiu-200 y Parque La Quintrala. In: Actas del IX Congreso Nacional de Arqueología Chilena, La Serena, 1982. La Serena: Museo Arqueológico La Serena. p. 345–50.
Román Á, Deza Á. 1998. Apéndice: fechados arqueológicos por luminiscencia. In: Bárcena JR, editor. Arqueología de Mendoza: las dataciones absolutas y sus alcances. Mendoza: Editorial Universidad Nacional de Cuyo. p. 399–407. For English translation, see Supplementary Material 1.
Román Á, Deza Á, Brito O. 1983. Pontificia Universidad Católica de Chile TL dates (II). Ancient TL 1:10–2. http://ancienttl.org/ATL_01-2_1983/ATL_01-2.pdf.
Roque C, Guibert P, Vartanian E, Vieillevigne E, Bechtel F. 2004. Changes in luminescence properties induced by thermal treatments; a case study at Sipan and Trujillo Moche

sites (Peru). Radiation Measurements 38:119–26. https://doi.org/10.1016/S1350-4487(03)00249-X.
Sánchez M. 1997. El período alfarero en la Isla Mocha. In: Quiroz D, Sánchez M, editors. La isla de palabras rotas. Santiago: Biblioteca Nacional. p. 103–31.
Sawakuchi AO, Jain M, Mineli TD, Nogueira L, Bertassoli DJ, Häggi C, Sawakuchi HO, Pupim FN, Grohmann CH, Chiessi CM, Zabel M, Mulitza S, Mazoca CEM, Cunha DF. 2018. Luminescence of quartz and feldspar fingerprints provenance and correlates with the source area denudation in the Amazon River basin. Earth and Planetary Science Letters 492, 152–162. https://doi.org/10.1016/j.epsl.2018.04.006
Schávelzon D. 2001. Catálogo de cerámicas históricas de Buenos Aires (siglos XVI-XX): con notas sobre la región del Río de la Plata. Buenos Aires: Fundación para la Investigación del Arte Argentino.
Schiappacasse V, Román Á, Muñoz I, Deza Á, Focacci G. 1991. Cronología por termoluminiscencia de la cerámica del extremo norte de Chile. In: Niemeyer H, editor. Actas del XI Congreso Nacional de Arqueología Chilena. Santiago: Sociedad Chilena de Arqueología. p. 43–59.
Schmidt S, Tsukamoto S, Salomon E, Frechen M, Hetzel R. 2012. Optical dating of alluvial deposits at the orogenic front of the Andean precordillera (Mendoza, Argentina). Geochronometria 39:62–75. https://doi.org/10.2478/s13386-011-0050-5.
Schultze CA. 2008. The role of silver ore reduction in Tiwanaku state expansion into Puno Bay, Peru [unpublished PhD dissertation]. Los Angeles (CA): University of California.
Schultze CA, Stanish C, Scott DA, Rehren T, Kuehner S, Feathers JK. 2009. Direct evidence of 1,900 years of indigenous silver production in the Lake Titicaca Basin of southern Peru. Proceedings of the National Academy of Sciences 106:17280–3. https://doi.org/10.1073/pnas.0907733106.
Sierralta S, Delgado A, Kelly P, Rebolledo S. 2019. Cronología absoluta en los canales septentrionales, el mar interior, y la costa pacífica austral. In: Arqueología de la Patagonia: el pasado en las arenas. Actas de Las X Jornadas de Arqueología de La Patagonia. Puerto Madryn, Argentina. p. 167–79.
Sinclaire C. 2004. Prehistoria del Período Formativo en la cuenca alta del Río Salado (región del Loa Superior). Actas del XV Congreso Nacional de Arqueología Chilena, Arica, 2000, Vol. II. Chungará 36:619–39.
Soto MA. 2018. Explotación de camélidos durante el Periodo Intermedio Tardío en la cuenca del Maipo-Mapocho [unpublished undergraduate thesis]. Santiago: Universidad de Chile.
Spencer JQG, Robinson RAJ. 2008. Dating intramontane alluvial deposits from NW Argentina using luminescence techniques: problems and potential. Geomorphology, Challenges in Geomorphological Methods and Techniques 93:144–55. https://doi.org/10.1016/j.geomorph.2006.12.021.
Steffen D, Preusser F, Schlunegger F. 2009. OSL quartz age underestimation due to unstable signal components. Quaternary Geochronology, Dating the Recent Past 4:353–62. https://doi.org/10.1016/j.quageo.2009.05.015.
Stenborg P. 2001. Holding back history: issues of resistance and transformation in a post-contact setting, Tucumán, Argentina c. A.D. 1536–1660 [published PhD dissertation]. Gothenburg, Sweden: Department of Archaeology, University of Gothenburg.

Storey AA, Quiroz D, Beavan N, Matisoo-Smith E. 2013. Polynesian chickens in the New World: a detailed application of a commensal approach. Archaeology in Oceania 48:101–19. https://doi.org/10.1002/arco.5007.
Stothert KE. 1988. La prehistoria temprana de la Península de Santa Elena, Ecuador: cultura Las Vegas. Guayaquil: Museo del Banco Central del Ecuador.
Sutter RC. 2000. Prehistoric genetic and culture change: a bioarchaeological search for pre-Inka altiplano colonies in the coastal valleys of Moquegua, Peru, and Azapa, Chile. Latin American Antiquity 11(1):43–70. https://doi.org/10.2307/1571670.
Sutter RC. 2005. A bioarchaeological assessment of prehistoric ethnicity among early Late Intermediate Period populations of the Azapa Valley, Chile. In: Reycraft RM, editor. Us and them: archaeology and ethnicity in the Andes. Los Angeles: Cotsen Institute of Archaeology, University of California. p. 183–205.
Tabarev AV, Kanomata Y, Marcos JG, Popov AN, Lazin BV. 2016. Insights into the earliest Formative Period of coastal Ecuador: new evidence and radiocarbon dates from the Real Alto site. Radiocarbon 58(2):323–30. https://doi.org/10.1017/RDC.2015.23.
Terraza V, Bárcena JR, Aguilar JP. 2019. Primeros resultados de las investigaciones arqueológicas en el sitio inca El Chacay (Uspallata, N. O. de Mendoza). Anales de Arqueología y Etnología 74:73–98. http://revistas.uncuyo.edu.ar/ojs3/index.php/analarqueyetno/article/view/2864
Torres-Rouff C, Hubbe M. 2013. The sequence of human occupation in the Atacama Oases, Chile: a radiocarbon chronology based on human skeletal remains. Latin American Antiquity 24:330–44. https://doi.org/10.7183/1045-6635.24.3.330.
Torres-Rouff C, Hubbe M, Pestle WJ. 2018. Wearing the marks of violence: unusual trauma patterning at Coyo Oriental, northern Chile. American Journal of Physical Anthropology 167:32–45. https://doi.org/10.1002/ajpa.23600.
Unkel I, Markus R, Hermann G, Johny C, Bernd K, and Volker S. 2012. A comprehensive numerical chronology for the pre-Columbian cultures of the Palpa valleys, south coast of Peru. Journal of Archaeological Science 39:2294–2303. https://doi.org/10.1016/j.jas.2012.02.021.
Vaughn KJ, Eerkens JW, Lipo C, Sakai S, Schreiber K. 2014. It's about time? Testing the Dawson ceramic seriation using luminescence dating, southern Nasca region, Peru. Latin American Antiquity 25:449–461. DOI: https:/doi.org/10.7183/1045-6635.25.4.449.
Vitry C. 2007. La ruta de Diego de Almagro en el territorio argentino: un aporte desde la perspectiva de los caminos prehispánicos. *Escuela de Historia* 1:325–51. http://portalderevistas.unsa.edu.ar/ojs/index.php/reh/article/view/394.
Ward GK, Wilson SR. 1978. Procedures for comparing and combining radiocarbon age determinations: a critique. Archaeometry 20:19–31.
Waterbolk HT. 1971. Working with radiocarbon dates. Proceedings of the Prehistoric Society 37:15–33. https://doi.org/10.1017/S0079497X00012548.

Figure[s and] Captions

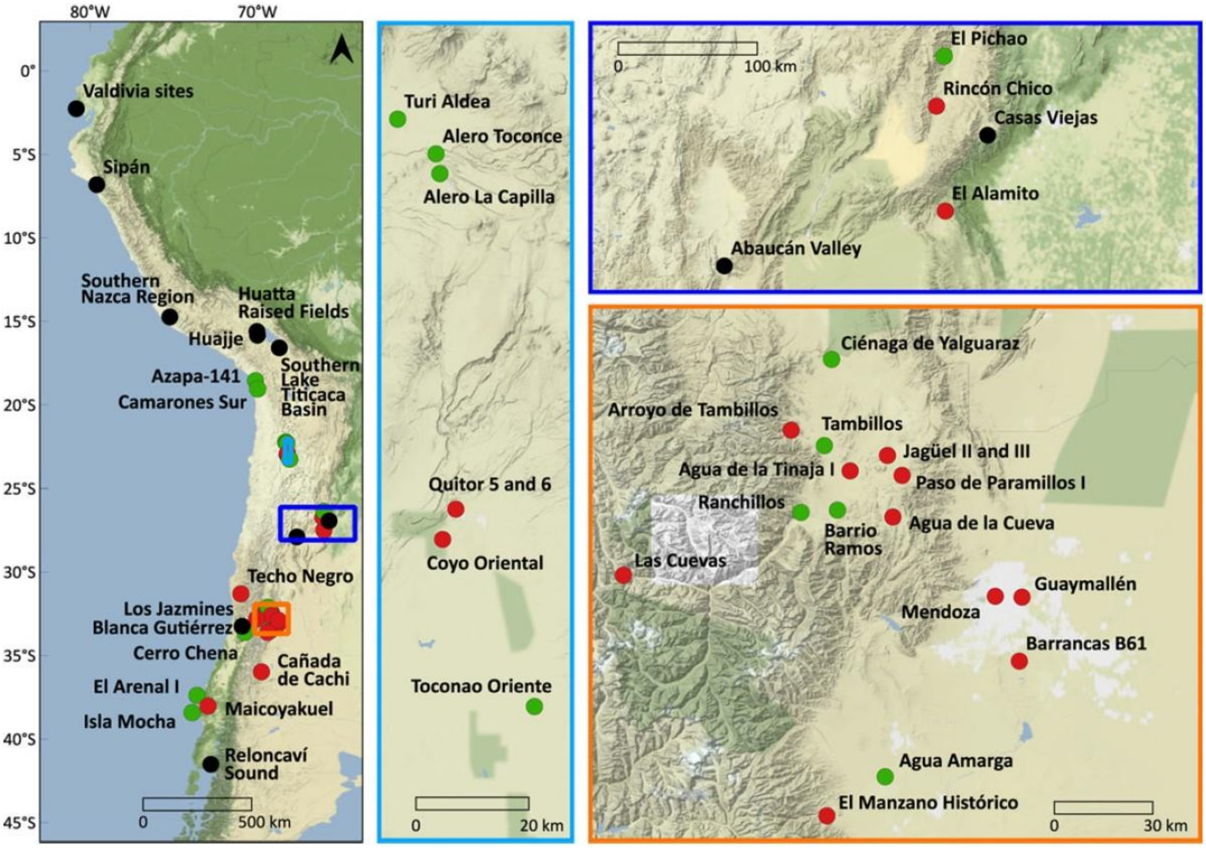

Figure 1. Map of archaeological sites with luminescence dates in western South America. Summary results of paired-dates tests are indicated by color: if more than half the pairs at a site pass the chi-square test, dots are green, otherwise they are red (Tables 2–4). Black dots indicate sites mentioned in the text but not included in the paired-date tables. The inset map for northern Chile has a light blue border, for northwestern Argentina, dark blue, and for northern Mendoza, orange. The dot labelled Mendoza includes the sites Mendoza plaza, Mendoza town hall, and San Francisco. Las Cuevas includes Las Cuevas 2 and Paramillos de Las Cuevas. Azapa-141 also indicates the location of the Azapa Valley. Made in QGIS 3.18 with a Stamen base map (http://maps.stamen.com/).

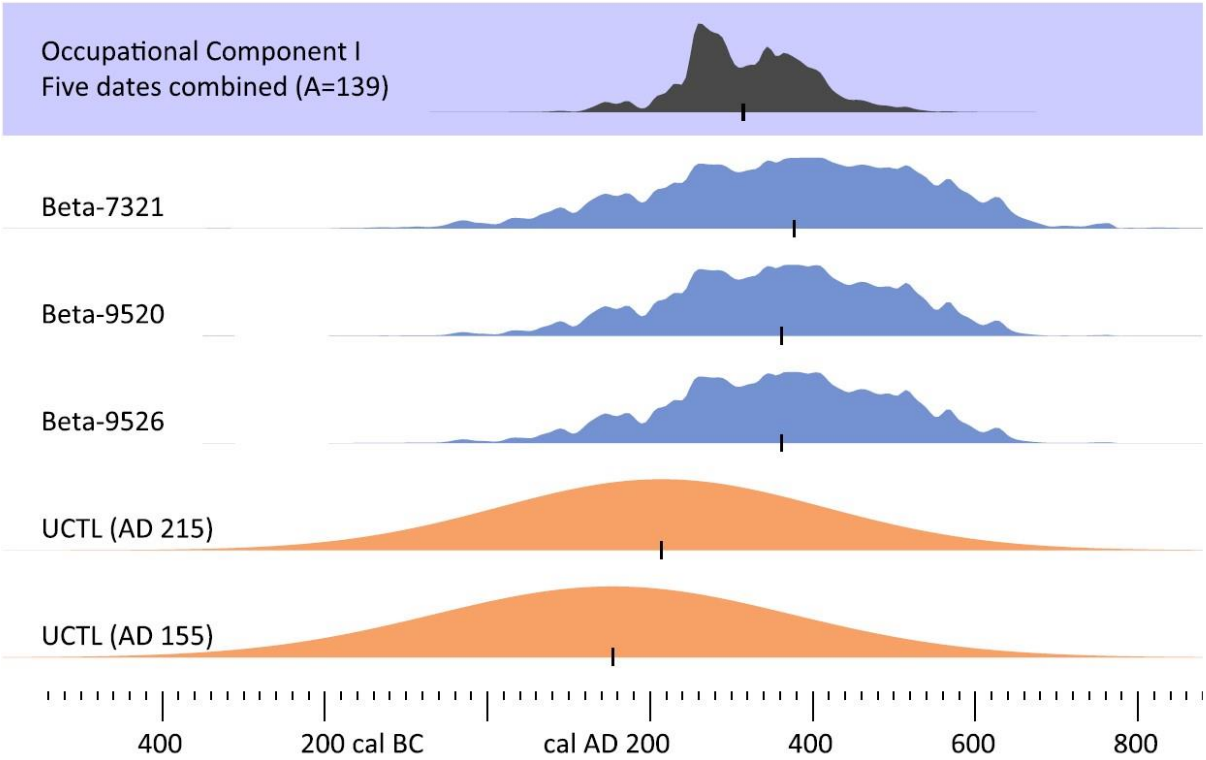

Figure 2. ^{14}C and TL dates from occupational component I at the site Turi Aldea in northern Chile. Because of their large error ranges, these dates pass individual and group chi-square tests. They can be statistically combined with a high agreement index (A=139). ^{14}C probability ranges are in blue; TL in orange. Medians indicated as vertical lines at the base of each distribution. UCTL lab codes were not published.

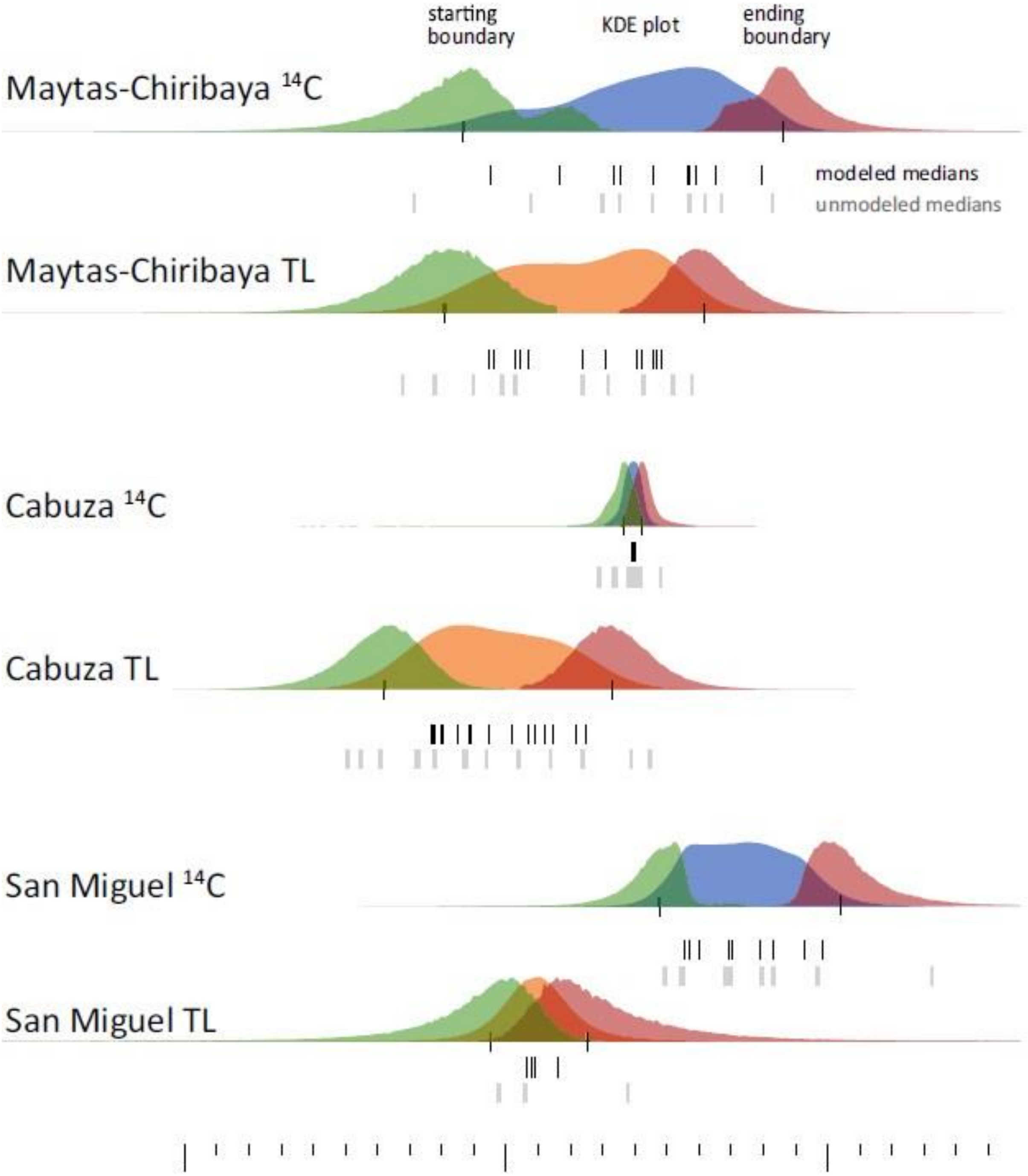

Figure 3. Bayesian models of ^{14}C and TL dates for three ceramic styles from the Azapa Valley, Chile. Green and red curves indicate starting and ending boundaries, respectively. Kernel density estimates (KDE) are indicated in between the boundaries, in blue for ^{14}C dates and orange for TL dates. Vertical lines below the curves indicate modeled and unmodeled medians.

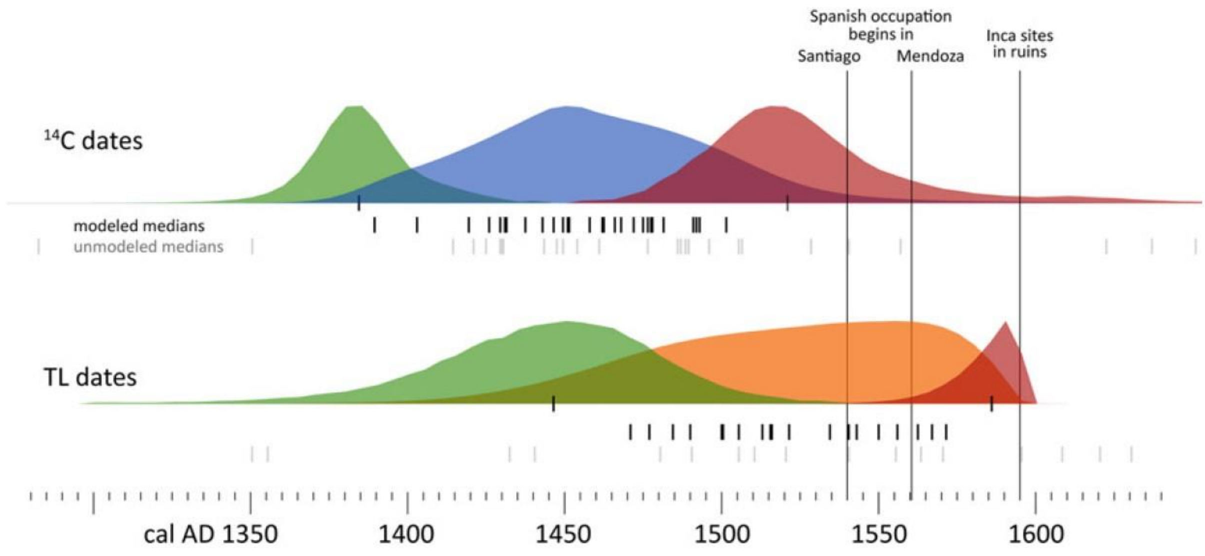

Figure 4. Bayesian models for the Inca occupation of northern Mendoza, as in Figure 3.

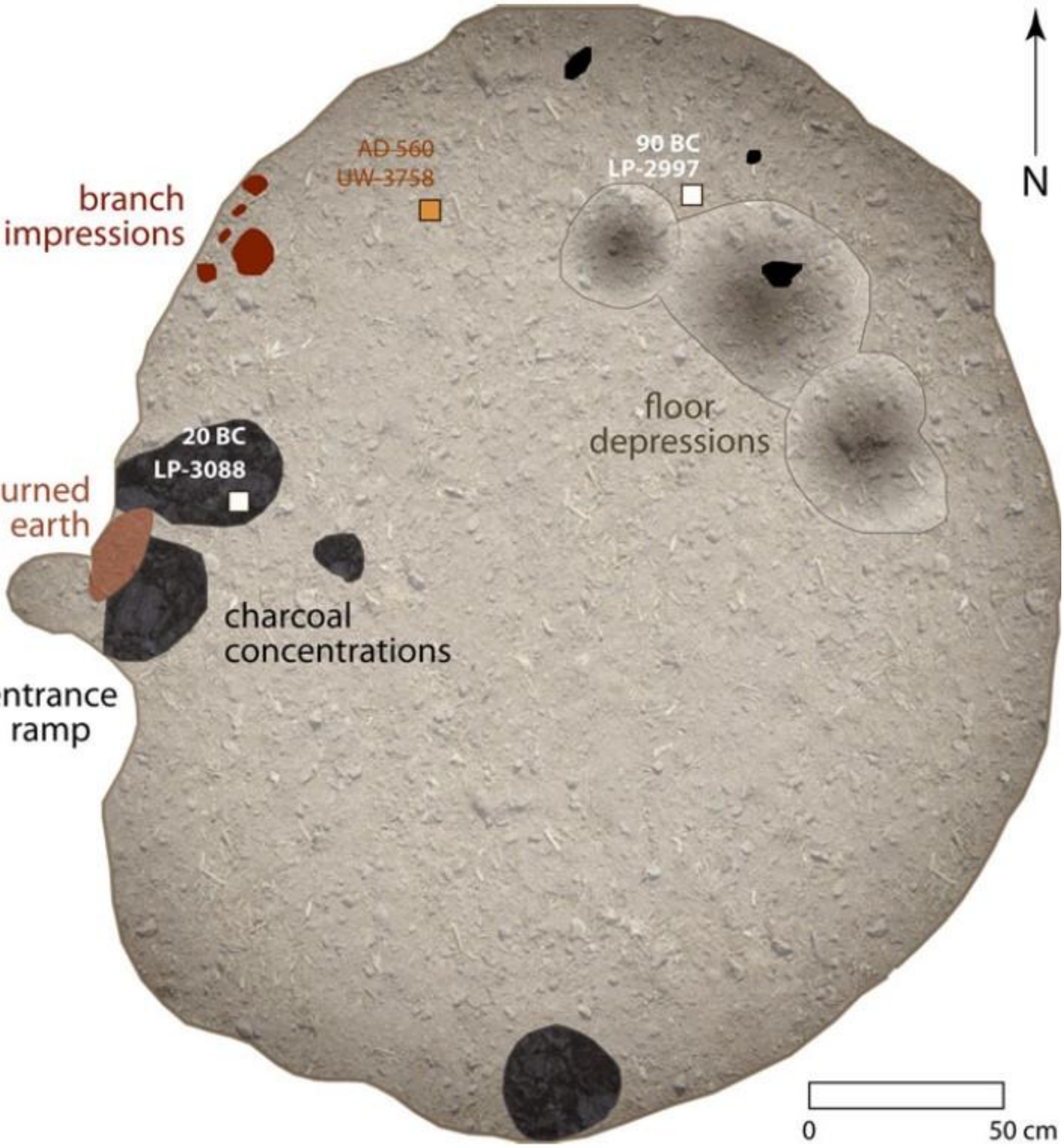

Figure 5. Early pit house from Barrancas, site B61, northern Mendoza, indicating the location, calibrated median, and lab code for each date. ^{14}C samples marked as white squares and the sherd dated by OSRL and IRSL marked as an orange square. Based on original drawing by Diego Estrella.

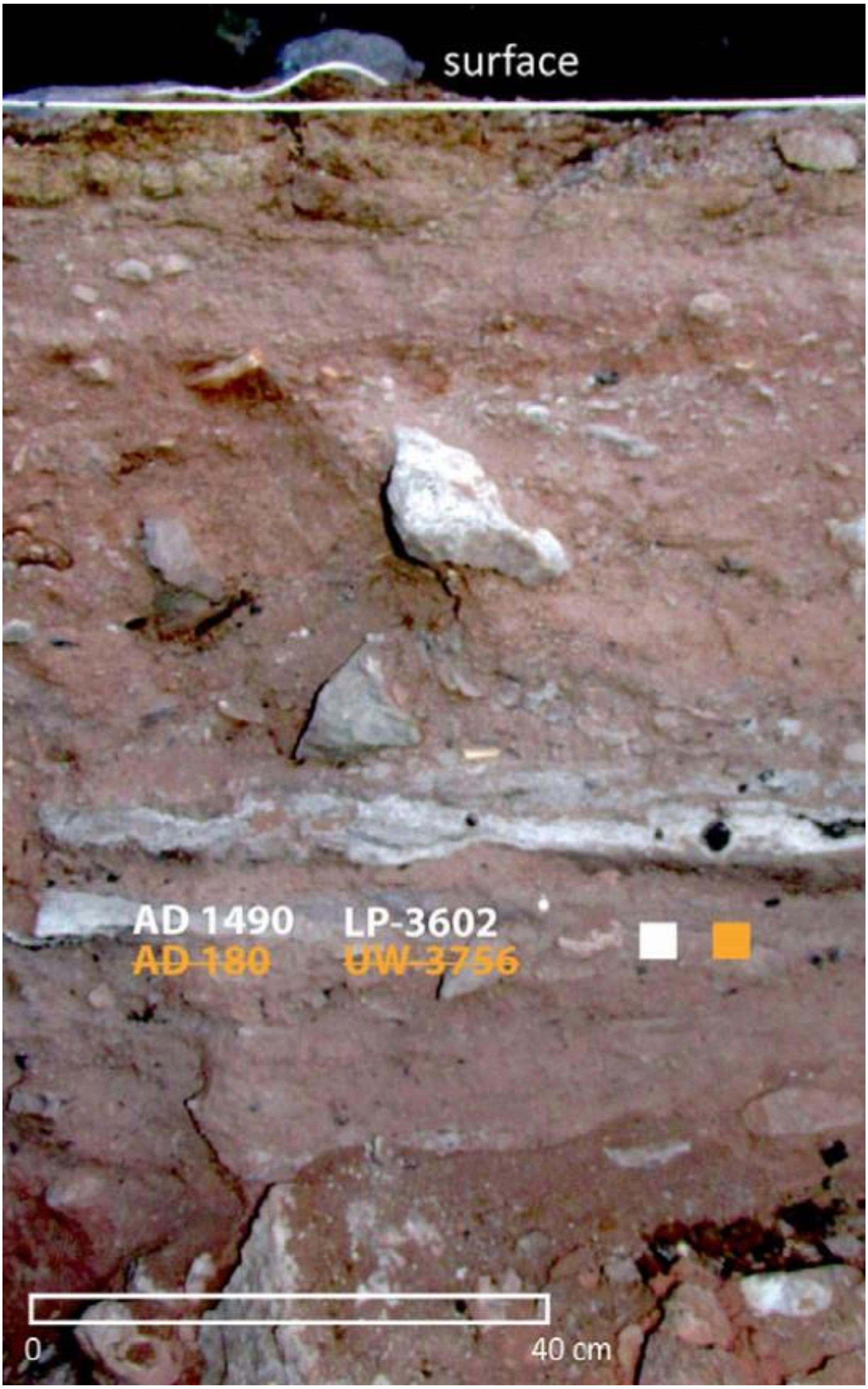

Figure 6. West profile of unit B7, Las Cuevas 2. The white square indicates the approximate depth of the ^{14}C sample with its calibrated median and laboratory code; the orange square indicates the same for the sherd dated with luminescence. It is crossed out because it does not match expectations based on diagnostic decorated ceramics or stratigraphy.

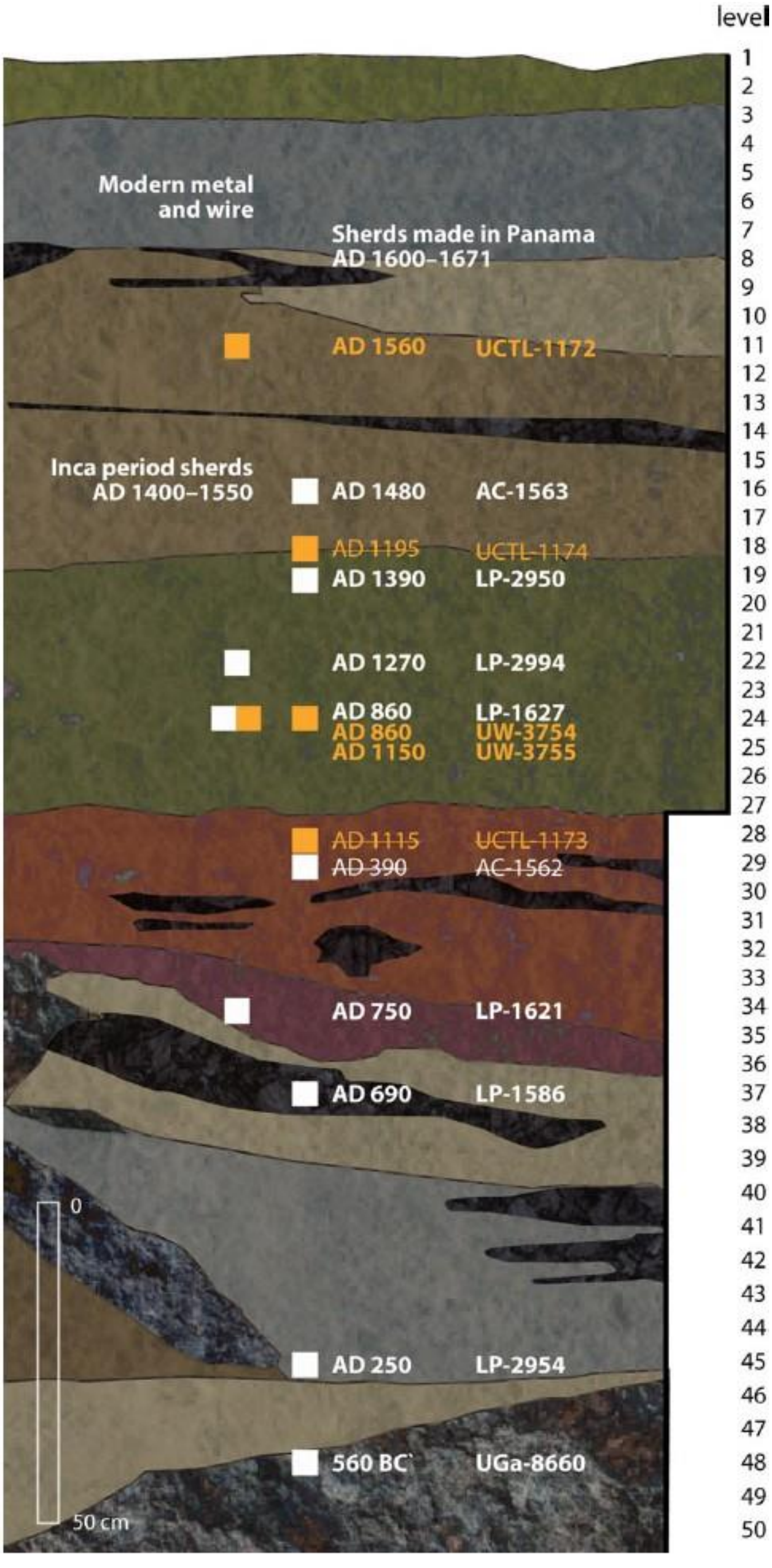

Figure 7. East profile of unit B, Agua de la Cueva (North) with dates, as in Figure 6. UW-3755's median is three centuries too young, but it does barely pass a chi-square test (Table 4). Squares shifted to the left are from unit A, which is adjacent to unit B. Dates recalibrated from Cortegoso et al. (2014), Durán et al. (2020b), and Gil et al. (2014). Profile redrawn from Castro and Yebra (2018: Figure 4), based on original drawings by Víctor Durán and Gustavo Lucero.

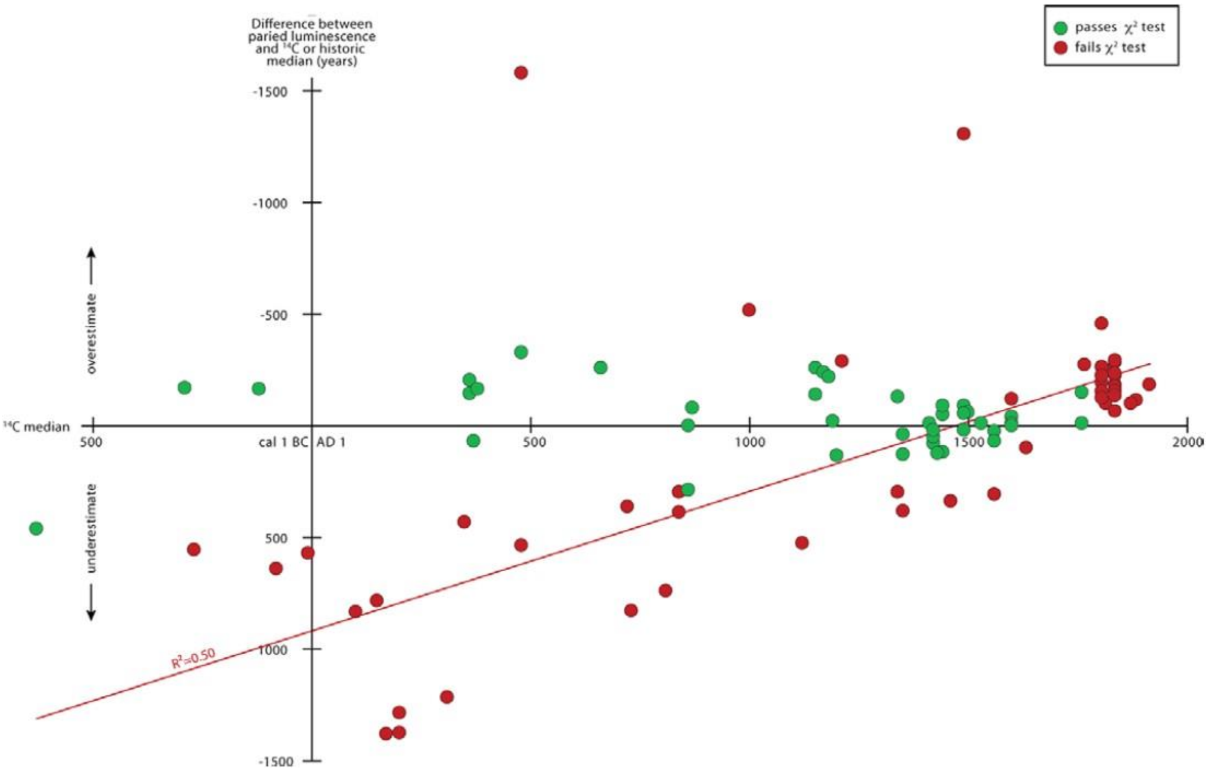

Figure 8. Summary of differences between paired luminescence and ^{14}C or historic medians for 94 date pairs (Tables 2–4). Most luminescence dates underestimate paired dates while historic-period nearly always overestimate age.

Table[s and] Captions

Code	Name	Days in ground	Area	number of TL dates corrected	Average age differences
First round					
1	Tambillos	42,9	Uspallata Valley	10	No difference from uncorrected
2	Cabildo 2	43,1	City of Mendoza	11	5.4% different from Cabildo 5
3	Jagüel III	33,9	Uspallata Valley	3	2.6% differrent from uncorrected
Second round					
1	Yalguaraz	91	Uspallata Valley	3	18% different from uncorrected
2	Tambillitos	88	Uspallata Valley	1	No different from Tambillos or uncorrected
3	Ranchillos	88,2	Uspallata Valley	2	2% different from Tambillos
4	Plaza de Mendoza	74,8	City of Mendoza		
5	Cabildo 5	83,9	City of Mendoza	12	5.4% different from Cabildo 2

Table 1. Dosimeters used in Bárcena's (1998: 197–8) TL dates from northern Mendoza. The second round of dosimeters incorporates corrections from a travel dosimeter included during travel by bus or car from Mendoza to Santiago. The dose readings from the dosimeters are not published, so this table compares date corrections made with different dosimeters as a general approximation of their impact on TL dates from northern Mendoza.

Region	Site	Dated material, description, or sherd code	Context and depth	Lab code	Median age (AD, -BC)	±	Dosimeter or correction to TL date	Degree of association (A–D)	Lab Code	Age ^{14}C (BP)	±	Calibrated median (AD, -BC)	Difference between medians: years	Difference between medians: %	χ^2 test	References
Northern Chile	Toconao Oriente	Sample 3. Large red bottle, polished	Tomb 4340	UCTL-19	-170	180	Deza and Román 1986	C	?	2530	?	-630	-460	-18	pass	Le Paige 1976: 145; Berenguer et al. 1986: 26
Northern Chile	Alero Toconce		Area M, C.e (4)	UCTL-58	-460	240	Sinclaire 2004	B	Beta-1993	2300	70	-290	170	8	pass	Aldunate et al. 1986; Sinclaire 2004
Northern Chile	Alero Toconce		Area M, C.e (4)	UCTL-57	-285	230	Sinclaire 2004	B	Beta-1992	2140	70	-120	165	8	pass	Aldunate et al. 1986; Sinclaire 2004
Northern Chile	Quitor 5	Sample 20. Bowl black, polished	Tomb 3397	UCTL-13	440	100	Deza and Román 1986	C	I-1205-D-4	1715	80	370	-70	-4	pass	Berenguer et al. 1986: 31; Gayo 2015 (incorrect date in Núñez 1976)
Northern Chile	Turi Aldea		Component I	UCTL	155	220	Deza and Román 1986	D	Beta-9520	1720	120	360	205	13	pass	Aldunate et al. 1986; Castro et al. 1994; Sinclaire 2004
Northern Chile	Turi Aldea		Component I	UCTL	215	200		D	Beta-9526	1720	120	360	145	9	pass	Aldunate et al. 1986; Castro et al. 1994; Sinclaire 2004
Northern Chile	Turi Aldea		Component I	UCTL	215	200	Deza and Román 1986	D	Beta-7321	1700	150	380	165	11	pass	Aldunate et al. 1986; Castro et al. 1994; Sinclaire 2004
Northern Chile	Alero La Capilla		Cuad A, C4, N4	UCTL-938	400	160	Sinclaire 2004	B	Beta-117562	1430	60	660	260	20	pass	Sinclaire 2004
Northern Chile	Coyo Oriental		Tomb 4049	UCTL-1488	1085	100		C	AA-107716	1362	25	720	-365	-30	fail	Costa et al. 2008: Table 1; Torres-Rouff et al. 2018: Table 1
Northern Chile	Quitor 6	Sample 38. Brown bowl, smoothed	Tomb 35	UCTL-17	1140	70	Deza and Román 1986	C	?	1240	70	840	-300	-27	fail	Berenguer et al. 1986: 35
Northern Chile	Coyo Oriental		Tomb 4174	UCTL-1489	1230	80		C	AA-107730	1237	25	840	-390	-35	fail	Costa et al. 2008: Table 1; Torres-Rouff et al. 2018: Table 1
Northern Chile	Coyo Oriental	Sample 43. Black kero, polished	Tomb 4060	UCTL	790	70	Deza and Román 1986	C	AA-107720	1218	28	870	80	7	pass	Berenguer et al. 1988: Table 1; Cocilovo et al. 2011: 167
Northern Chile	Azapa-141		Tomb 24	UCTL-163	1010	110	on site	C	I-13780	930	80	1150	140	18	pass	Schiappacasse et al. 1991: 53–4; Sutter 2005: Table 1
Northern Chile	Azapa-141		Tomb 24	UCTL-165	890	100	on site	C	I-13780	930	80	1150	260	33	pass	Schiappacasse et al. 1991: 53–4; Sutter 2005: Table 1
Northern Chile	Camarones Sur		Recinto 25	UCTL-109	1210	85	yes	C	I-5610	680	90	1340	130	21	pass	Niemeyer et al. 1973: 130; Schiappacase et al. 1991: 47
Central Chile	Techo Negro		Stratrigraphic unit 1, 0–10 cm	UCTL-1793	1015	120		C	Beta-246499	1630	40	480	-535	-36	fail	Méndez et al. 2016: 230
Central Chile	Cerro Chena	Mixed or Local Inca	Unidad 8B	UCTL-3032	1585	45		C	UGAMS-29811	370	25	1560	-25	-6	pass	Pavlovic et al. 2019
South-central Chile	Isla Mocha, P-21-1	Pitrén culture	Stratum 5, 280 and 286 cm	UCTL-540	930	90		B	Beta-69935	910	70	1170	240	31	pass	Quiroz and Sánchez 2005: 376
South-central Chile	Isla Mocha, P-21-1	Pitrén culture	Stratum 5, 298 and 300 cm	UCTL-541	960	100		B	Beta-181243	900	60	1180	220	29	pass	Quiroz and Sánchez 2005: 376
South-central Chile	Isla Mocha, P-25-1		Stratum 2	UCTL-538	1170	100		C	Beta-62819	890	70	1190	20	3	pass	Sánchez 1997: 127–8
South-central Chile	Isla Mocha, P-21-1	Pitrén culture	Stratum 5, 258 and 260 cm	UCTL-539	920	100		B	Beta-162421	870	60	1210	290	39	fail	Quiroz and Sánchez 2005: 376
South-central Chile	El Arenal I	El Vergel culture	Stratum III or IV / Layer B	UCTL-1618	1390	55		C	NZA 26115	622	35	1350	-40	-7	pass	Storey et al. 2013
South-central Chile	El Arenal I	El Vergel culture	Stratum III or IV	UCTL-1618	1390	55		D	NZA 28271	510	30	1440	50	10	pass	Storey et al. 2013
South-central Chile	El Arenal I	El Vergel culture	Stratum III or IV / Layer A	UCTL-1617	1350	65		C	NZA 28272	506	30	1440	90	18	pass	Storey et al. 2013
South-central Chile	Maicoyakuel (PU-220)		Stratum 2, floor	UCTL-1555	1575	40		B	Beta-167558	160	40	1830	255	213	fail	Dillehay and Saavedra Zapata 2014: 212
Northwestern Argentina	El Alamito H-0	Ceramic tube	Recinto 2A, floor	UCTL-644	935	100	on site	B	LP-513	1950	50	100	-835	-45	fail	Angiorama 1998: Tabla 2, 3
Northwestern Argentina	El Alamito H-0	Ceramic tube	Recinto 2A, floor	UCTL-644	935	100	on site	B	LP-528	1910	60	150	-785	-44	fail	Angiorama 1998: Tabla 2, 3
Northwestern Argentina	Rincón Chico 1	Santa María	Sector VIII, Estructura 116, UP 421	Peru	1649	30		B	AC-1493	950	130	1120	-529	-64	fail	Greco 2012: Table 8.14
Northwestern Argentina	Muyuna	Isla/Alfarcito style	Top of feature 3, 40 cm	UCTL-1483	1335	60		B	LP-1460	880	60	1200	-135	-18	pass	Nielsen 2007: Table 4
Northwestern Argentina	Rincón Chico 15	Undecorated	Estructura 1, UP 187,8	Peru	1636	36		B	LP-416	680	110	1340	-296	-49	fail	Greco 2012: Table 8.14
Northwestern Argentina	Rincón Chico 15	Santa María Bicolor	Montículo Oriental, UP 511A	Peru	1734	50		B	LP-401	660	70	1350	-384	-64	fail	Greco 2012: Table 8.14
Northwestern Argentina	El Pichao		Sector XII, unit 9	R-961908	1500	30		B	Ua-13903	540	54	1420	-80	-15	pass	Stenborg 2001; Greco 2012: 246–50
Northwestern Argentina	El Pichao		Sector XII, structure 2, unit 5, lower level	R-971906	1560	40		B	Ua-17487	515	70	1440	-120	-24	pass	Stenborg 2001; Greco 2012: 246–50
Northwestern Argentina	Rincón Chico 15	Undecorated	Área Norte, UP 815	Peru	1796	32		B	LP-2225	480	50	1460	-336	-69	fail	Greco 2012: Table 8.14
Northwestern Argentina	El Pichao		Sector XII, structure, unit 6, occupation layer	R-961906	1630	20		B	Ua-17488	375	65	1560	-70	-18	pass	Stenborg 2001; Greco 2012: 246–50
Northwestern Argentina	El Pichao		Sector XII, structure 2, unit 5, upper level	R-961905	1870	10		B	Ua-12077	360	60	1560	-310	-79	fail	Stenborg 2001; Greco 2012: 246–50
Southern Mendoza	Cañada de Cachi	Undecorated	Level IIIb	UCTL-960	285	170	on site	B	LP-410	2260	120	-270	-555	-25	fail	Durán 2000: 77
Northern Mendoza	Mendoza plaza	Plaza Mendoza 41	Level with earth oven, 300–320 cm	UCTL-429	1550	40	Plaza de Mendoza	C	Beta-60658	2150	160	-140	-1690	-81	fail	Bárcena 1998: 131–5, 265–70
Northern Mendoza	Mendoza plaza	Plaza Mendoza 57	Level with earth oven, 305 cm	UCTL-467	1560	40	Plaza de Mendoza	C	Beta-60658	2150	160	-140	-1700	-81	fail	Bárcena 1998: 131–5, 265–70
Northern Mendoza	Jagüel III	Jagüel 23	Single component site	UCTL-335	1550	40	Jagüel	B	GaK-9957	1890	110	170	-1380	-78	fail	Bárcena 1998: 213–215
Northern Mendoza	Jagüel II	Jagüel 22. Agrelo, incised (same as UCTL-334)	Level 2	Alpha-2076	1490	92		C	UZ-1383	1860	80	200	-1290	-74	fail	Bárcena 1998: 126, 179–80, 209–13
Northern Mendoza	Jagüel II	Jagüel 22. Agrelo, incised (same as Alpha-2076)	Level 2	UCTL-334	1575	50	Jagüel	C	UZ-1383	1860	80	200	-1375	-79	fail	Bárcena 1998: 209–213
Northern Mendoza	Arroyo Tambillos, Alero	Alero 18	Southern sector, level III, 20 cm	UCTL-320	1530	40	Tambillos	B	AC-0441	1770	100	310	-1220	-74	fail	Bárcena 1998: 215–217
Northern Mendoza	Mendoza plaza	Plaza Mendoza 44	Wall of earth oven, 310–320 cm	UCTL-432	-1100	300	Plaza de Mendoza	A	I-17,185	1620	80	480	1580	107	fail	Bárcena 1998: 131–5, 265–70
Northern Mendoza	Mendoza plaza	Plaza Mendoza 79	Wall of earth oven, 310–320 cm	UCTL-489	150	150	Plaza de Mendoza	A	I-17,185	1620	80	480	330	22	pass	Bárcena 1998: 131–5, 265–70
Northern Mendoza	Agua de La Tinaja I	Tinaja 24. Undecorated	Level II, 17–38 cm	UCTL-336	1560	40	Tambillos	C	Beta-6589	1360	70	730	-830	-68	fail	Bárcena 1998: 217–20
Northern Mendoza	Mendoza plaza	Plaza Mendoza 56	Level with hearth, 240–260 cm	UCTL-466	1550	50	Plaza de Mendoza	C	Beta-60657	1280	200	810	-740	-65	fail	Bárcena 1998: 131–5
Northern Mendoza	Ranchillos	Ranchillos 81. Undecorated	Sector II, Unidad B, Recinto 2	UCTL-499	1480	50	Ranchillos	B	Beta-69934	640	50	1350	-130	-22	pass	Bárcena 1998: 238–9
Northern Mendoza	Barrio Ramos	Ramos 16	Vessel left as grave good	UCTL-308	1400	60	Tambillos	B	AA-98708	583	43	1410	10	2	pass	Bárcena 1998: 222–4; Gil et al. 2014: Table 2; Durán et al. 2018: 62
Northern Mendoza	Paso de Paramillos I	Paramillos 12	Top of Level 2	UCTL-318	1470	50	Jagüel	C	Beta-21719	550	60	1420	-50	-9	pass	Bárcena 1998: 220–2
Northern Mendoza	Tambillos	Tambillitos 14. Decorated	G9, H1, upper level	UCTL-323	1555	45	Tambillitos	B	Beta-88786	540	100	1430	-125	-24	pass	Bárcena 1998: 249–55
Northern Mendoza	Ciénaga de Yalguaraz	Yalguaraz 21	Montículo 1, 56–66 cm	UCTL-315	1440	60	Yalgauraz	B	UZ-2526/ETH-5319	540	55	1420	-20	-4	pass	Bárcena 1998: 224–31
Northern Mendoza	Barrio Ramos	Ramos 16	Vessel left as grave good	UCTL-308	1400	60	Tambillos	B	I-16.636	470	80	1490	90	20	pass	Bárcena 1998: 222–4; Gil et al. 2014: Table 2; Durán et al. 2018: 62
Northern Mendoza	Tambillos	Sample 1. Undecorated	G9, H1, lower level	UCTL-787	1440	60	Tambillitos	B	Beta-88787	460	80	1500	60	13	pass	Bárcena 1998: 249–55
Northern Mendoza	Agua Amarga	Red slip	Unit B1, a1	UCTL-1725c	1433	55	average of two methods	B	Beta-621727	450	50	1490	57	12	pass	Ots et al. 2011: 68; Marsh et al. 2017: Table 4
Northern Mendoza	San Francisco	escudilla Viluco	Hearth, Sector Crucero, 234 cm	UCTL-1645	1510	45		B	URU-0279	440	40	1490	-20	-4	pass	Prieto Olavarria and Chiavazza 2010: 808
Northern Mendoza	Ciénaga de Yalguaraz	Yalguaraz 19	Montículo 1, 26–36 cm	UCTL-322	1520	40	Yalgauraz	B	UZ-2527/ETH-5320	420	60	1530	10	2	pass	Bárcena 1998: 224–31
Northern Mendoza	Mendoza town hall	Cabildo 6. White-grey loza	Pit III, Cabildo level, 180 cm	UCTL-329	1750	20	Cabildo 5	B	I-16,683	220	80	1760	10	5	pass	Bárcena 1998: 257–64
Northern Mendoza	Mendoza town hall	Cabildo 7. Glazed interior surface	Pit III, Cabildo level (140–200 cm)	UCTL-331	1610	40	Cabildo 5	B	I-16,683	220	80	1760	150	79	pass	Bárcena 1998: 257–64

Table 2. Paired TL and ^{14}C dates from Argentina and Chile. The 22 Inca-period pairs are shaded. Positive differences between medians indicate luminescence dates underestimate the paired ^{14}C dates. Many 14C dates are available in recent compilations (Campbell and Quiroz 2015; Gayo et al. 2015; Gil et al. 2014). ^{14}C dates were run on charcoal except the three from Arenal I, which were run on chicken bones.

Site	Project code	Material	Context and depth	Depth (cm)	Laboratory code (UCTL)	(AD)	±	Dosimeter used for correction	Degree of association (A–D)	Production date (AD)	Difference between median dates years	%	χ^2 test	Page number (Bárcena 1998)
Guaymallen	Moyano 74	Large vessel (>800 L) with inscribed date	Museum piece with etched date		484	1730	20	Cabildo 2	A	1632	-98	-6	fail	195–98
Tambillos	Tambillos 13	Spanish *mayólica* (Talavera or Puente del Arzobispo)	SI UC R4, stairs, entrance		316	1480	40	Tambillos	A	1550–1650	120	8	fail	235
Paramillo de Las Cuevas	Casucha 17	Floor brick fragment made in Chile	Casa del Rey		309	1490	50	Tambillos, Tambillitos	A	1760–1772	276	16	fail	198–201
Mendoza plaza	Plaza 43	Pearlware made in the USA or England	Fountain, secondary basin	93	431	1715	30	Plaza de Mendoza	A	1790–1840	100	6	fail	319
Mendoza plaza	Plaza de Mendoza 49	Ceramic beer bottle made in Scotland	Slaughterhouse level	100	437	1770	20	Average dose of sherds	A	1850–1918	114	6	fail	203–6
Mendoza	Loza 80	Tea cup made in Holland	Museum or private collection		490	1730	35	None	A	1900–1930	185	10	fail	201–3
San Francisco	San Francisco 65	Spanish *mayólica* (Talavera)	Pit I, level IV	75–105	475	1560	50	Plaza de Mendoza	A	1550–1650	40	3	pass	294–5
San Francisco	San Francisco 69	Spanish *mayólica* (Talavera)	Backfill		479	1590	45	Plaza de Mendoza	A	1550–1650	10	1	pass	295–7
Mendoza town hall	Cabildo 5	Spanish *mayólica* (Talavera)	Damero, A, level 7	180	330	1600	50	Cabildo 5	A	1550–1650	0	0	pass	292–3
Mendoza town hall	Cabildo 4	Ironstone china made in England	Pit IV	110–145	325	1770	20	Cabildo 5	A	1851–1891	101	5	fail	206–9
Mendoza town hall	Cabildo 8	Floor tile	Damero, A5, level 5	87.5–143	307	1540	40	Cabildo 5	B	1749–1861	265	15	fail	299–302
Mendoza town hall	Cabildo 9	Floor tile	Damero, C, level 8	150	332	1610	40	Cabildo 5	B	1749–1861	195	11	fail	302–3
Mendoza town hall	Cabildo 10	Floor tile	Damero, A5, level 5	95–130	305	1345	65	Cabildo 5	B	1749–1861	460	25	fail	303
Mendoza town hall	Cabildo 11	Floor tile or brick	East of Damero, A12, level 5	95–130	333	1650	30	Cabildo 5	B	1749–1861	155	9	fail	303–4
Mendoza town hall	Cabildo 30	Floor tile	Damero, A5, level 5	145	377	1650	35	Cabildo 5	B	1749–1861	155	9	fail	304
Mendoza town hall	Cabildo 31	Floor tile	Matadero	135	378	1580	40	Cabildo 5	B	1749–1861	225	12	fail	304–5
Mendoza town hall	Cabildo 37	Brick	Feria	160	379	1680	35	Cabildo 5	B	1749–1861	125	7	fail	305–6
Mendoza plaza	Plaza 40	Ceramic pipe	Fountain	235	428	1650	20	Plaza de Mendoza	B	1810–1858	184	10	fail	317
Mendoza plaza	Plaza 46	Brick	Fountain, bottom of basin	200	434	1770	20	Plaza de Mendoza	B	1810–1858	64	3	fail	317
Mendoza plaza	Plaza 47	Sherd	Fountain, bottom between bricks	307	435	1650	30	Plaza de Mendoza	B	1810–1858	184	10	fail	318
Mendoza plaza	Plaza 42	Ceramic rim and handle	Fountain, secondary basin	30	430	1675	20	Plaza de Mendoza	B	1810–1858	159	9	fail	318–9
Mendoza plaza	Plaza 33	Ceramic handle	Fountain, secondary basin		381	1550	50	Plaza de Mendoza	B	1810–1858	284	15	fail	319–20
Mendoza plaza	Plaza 36	Brick	Fountain	222	384	1610	30	Plaza de Mendoza	B	1810–1858	224	12	fail	320–1
Mendoza plaza	Plaza 35	Brick	Fountain	170	383	1660	35	Plaza de Mendoza	B	1810–1858	174	9	fail	321
Mendoza plaza	Plaza 34	Brick	Fountain, bottom of inner basin	170	382	1600	40	Plaza de Mendoza	B	1810–1858	234	13	fail	321
Mendoza plaza	Plaza 32	Brick	Fountain, drainage canal	170	380	1540	50	Plaza de Mendoza	B	1810–1858	294	16	fail	321
Mendoza plaza	Plaza 45	Brick	Fountain	150	433	1680	30	Plaza de Mendoza	B	1810–1858	154	8	fail	321–2
Mendoza plaza	Plaza 53	Brick	Fountain, basin	146	441	1700	30	Plaza de Mendoza	B	1810–1858	134	7	fail	322–3

Table 3. Comparisons of 28 historic-period TL dates on floor tiles, bricks, and sherds with known production dates from northern Mendoza, as in Table 2.

Luminescence Laboratory Code	Site	Unit and level	Depth (cm)	Individual luminesence ages (AD, -BC)						Estimated age (OSL or OSL & IRSL)		Degree of association (A–D)	^{14}C Laboratory Code	Unit and level	Age ^{14}C (BP)	±	Calibrated median (AD, -BC)	Difference between medians		
				TL	±	OSL	±	IRSL	±	Age (AD)	±							years	%	χ^2 test
UW-3754	Agua de la Cueva	B-NE, 24	115–120	~~1608~~	~~54~~	816	120	991	211	860	100	B	LP-1627	A-SW, 24	1220	70	860	0	0	pass
UW-3755	Agua de la Cueva	A-SW, 24	115–120			1200	105	776	285	1150	100	B	LP-1627	A-SW, 24	1220	70	860	-290	-27	pass
UW-3756	Las Cuevas 2	B8, 7	30–35			246	149	-66	276	180	130	B	LP-3602	B7-NW, 7	440	40	1490	1310	285	fail
UW-3757	El Manzano Histórico 2	Z1, 3	20–25	~~1429~~	~~96~~	480	105	~~863~~	~~91~~	480	110	B	LP-1637	Z3, 5	1090	90	1000	520	55	fail
UW-3758	Barrancas, B61	B, 3	10–15	~~-192~~	~~258~~	539	112	631	214	560	110	B	LP-2997	E, 8	2100	80	-80	-640	-32	fail
UW-3758	Barrancas, B61	B, 3	10–15	~~-192~~	~~258~~	539	112	631	214	560	110	B	LP-3088	C, 3	2050	50	-10	-570	-29	fail
UW-3759	Paso de Paramillos	2, 22	62–64	~~1157~~	~~100~~	783	89			780	90	B	LP-3629	2, 22	1730	60	350	-430	-27	fail

Table 4. Paired dates from the pilot study in Mendoza. Crossed-out dates were not used by the laboratory to estimate the age. Valid OSL and IRSL dates were combined following Ward and Wilson (1978) to arrive at estimated sherd ages. Inca-period pair is shaded.