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Editorial

Leveraging radiocarbon in the Central Andes: From chronologies to research agendas☆

1. Introduction

Developing chronological schemes was a fundamental goal of early archaeological research in the Central Andes, an area that covers much of modern Peru, Bolivia, and northern Chile. Seminal research was so successful at achieving this goal that the research agenda of Andean archaeology remains structured by its foundational chronological schemas (e.g., Larco Hoyle, 1946; Willey, 1946; Rowe, 1962; Bennett and Bird, 1964; Lumbreras, 1969), although details have been continuously revised. In spite of competing periodization schemes and debate about the theoretical underpinnings of periodization itself, the field still relies on blocks of time defined by diagnostic material culture to order the Andean past. Although this structure itself has been critiqued (Ramón Joffré, 2005; Swenson and Roddick, 2018), discussions of regional chronology rarely go further than revising the boundaries of those blocks of time and/or replacing their labels (e.g., recently, Carmichael, 2019; Tantaleán, 2023; Rowe, 2024, 2025).

Since at least the early 2000s (Silverman, 2004) one response has been to call for replacing divergent periodization schemes with calendar dates, underpinned by the expansion of radiometric dating. However, the schemes are enduring. They persist because they are *useful*: they provide a familiar shorthand that facilitates communication among colleagues, link current scholarship to what has gone before, and enable generalization from focused studies to broader phenomena. Whether they are also *accurate* and *sufficient* descriptions of the prehispanic past is one of the questions addressed by the papers in this Special Issue.

The growing corpus of ^{14}C dates from the region (Contreras, 2022) now provides an expanded and more precise empirical basis for reevaluating regional chronologies. However, in spite of renewed interest in "big data" approaches to the radiocarbon record across South America (e.g., Riris, 2018; Riris and Arroyo-Kalin, 2019; Prates et al., 2020; Prates and Perez, 2021; Becerra-Valdivia, 2025) and more focused efforts at compiling dates (e.g., Michczyński et al., 1995 [recently updated at https://andesc14.pl/en/]; Rademaker et al., 2013; Gayo et al., 2015; Roscoe et al., 2021), the assemblage of Central Andean radiocarbon dates remains an underexploited resource for developing and addressing major archaeological research questions, whether for refining period boundaries or reformulating schema from scratch.

With the goal of assessing the available evidence and enabling further research based on archaeological radiocarbon assemblages from the Central Andes, we invited contributors to explore aspects of the Central Andean radiocarbon record at a symposium at the 87th annual meeting of the Society for American Archaeology in Chicago, Illinois (USA) in 2022. Participants from that symposium, in collaboration with many colleagues, are the contributors to this special issue of *Quaternary International*.

The remit of that session and this Special Issue was to begin a discussion about how to take better advantage of the rapidly expanding radiocarbon record in the Central Andes. Contributors embraced the challenge. The papers included here not only compile radiocarbon dates associated with particular regions, time periods, and phenomena, but also critically evaluate and analyze them. Contributors use assemblages of archaeological radiocarbon dates to productively rework Central Andean chronologies, examining the radiocarbon record in order to make inferences about not only the patterned human behaviour that produced the materials dated, but also the history of research activity that led to analysis of those samples. What these approaches share is a commitment to assessing patterning in available data in order to make inferences about some combination of the prehispanic past and research history, while also identifying data gaps that future research can productively target.

Previous special issues of *Quaternary International* have constructed country-wide databases of archaeological radiocarbon dates from 13,000 to 7000 ^{14}C BP (Vol. 301, Bueno et al., 2013) or analyzed demographic patterns at macro-region or country scale (Vol. 356, Méndez et al., 2015). In this special issue of *QI* (Vol. 703), Rademaker (2024) updates the archaeological radiocarbon database for Peru from the terminal Pleistocene to early Middle Holocene, extending temporal coverage to 20,000 ^{14}C BP. Garvey and colleagues (2024) explore the Peruvian Middle Holocene radiocarbon record for forager sites. The remaining seven papers in this special issue focus on the last three thousand years, when continental populations peaked and complex sociopolitical formations became common. These papers not only compile radiocarbon dates, but also synthesize and critically evaluate them, as well as exploring various analytical strategies for radiocarbon assemblages.

The nine papers in this special issue compile 3707 radiocarbon dates (628 of which appear in multiple papers) from 833 sites, with radiocarbon ages spanning 20200–150 ^{14}C BP, and spread over approximately 3°S to 23°S latitude and 66°W to 81°W longitude (Fig. 1). Of these approximately 3700 dates, contributing authors evaluated and excluded 443 dates from further analysis (Fig. 2). Taking those exclusions into account, dates span 12950–150 ^{14}C BP, covering most of the region's human history.

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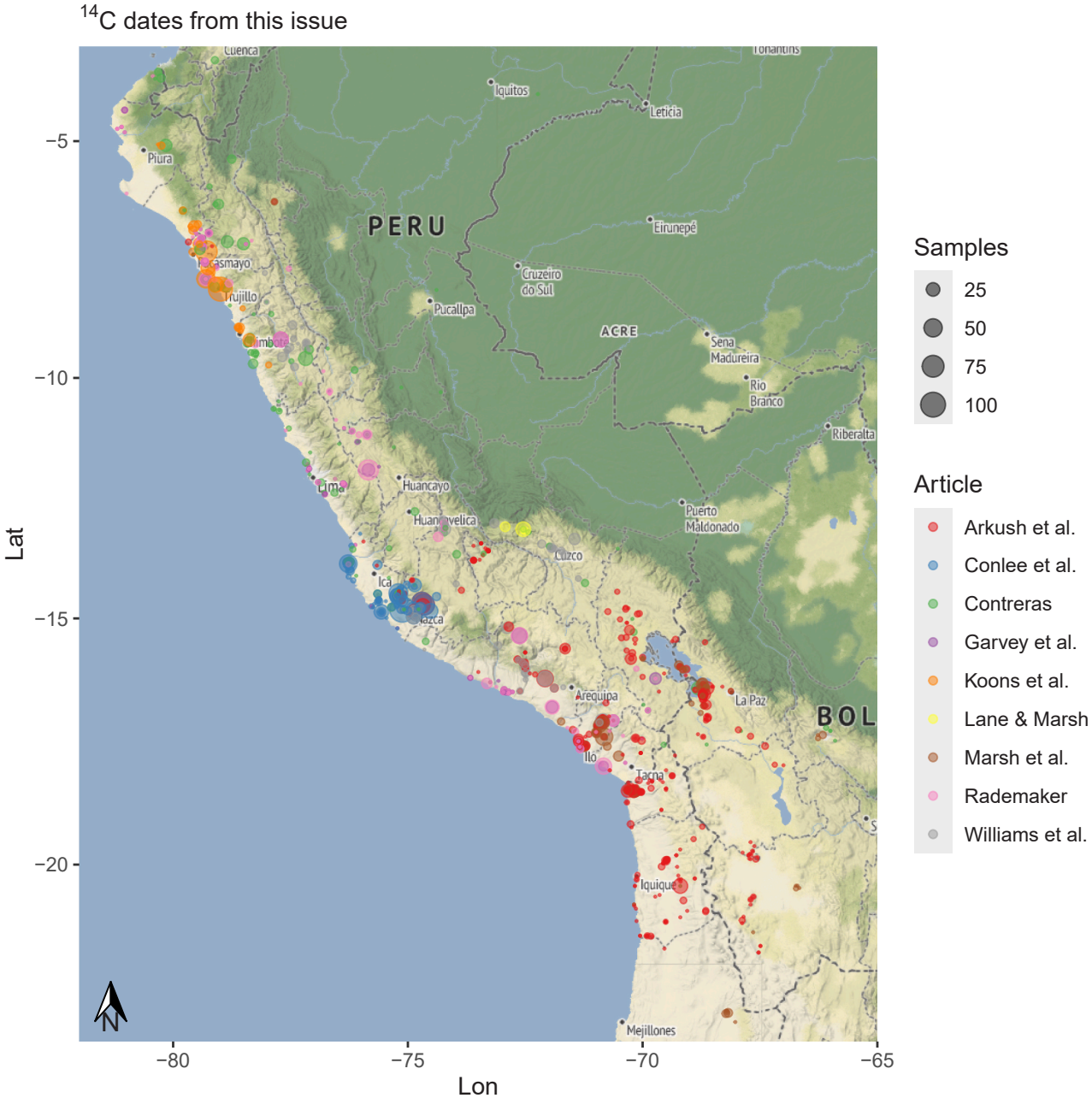

Fig. 1. Spatial distribution of ^{14}C dates included in the papers in this Special Issue. Five ^{14}C dates associated with khipu are of unknown origin and do not appear here. Plotted using the **ggplot2** (Wickham, 2016) and **ggmap** (Kahle and Wickham, 2013) packages in R (R Core Team, 2024).

All participants have shared radiocarbon datasets as supplementary information, and some have archived datasets permanently at Mendeley Data (Koons et al., 2024; Rademaker, 2024) or Open Science Framework (Marsh et al., 2025). Beyond compilation and quality assessment of radiocarbon datasets, many contributors to this special issue model radiocarbon datasets using Bayesian methods, bringing the third radiocarbon revolution to bear on chronologies of the Central Andes. Details on Bayesian model construction and code are also shared to promote future use and refinement of chronological models.

2. Compilation

The initial challenge for contributors was compiling dates. In this all were able to build on previous efforts, which date back almost as far as the employment of radiocarbon dating in the region (beginning with Ravines and Alvarez Sauri, 1967; see review in Contreras, 2022). The proliferation of dates in recent years has made it more difficult to track dates but also potentially more rewarding. Contributors here have been led by particular research foci rather than by attempting to be comprehensive, with the result that the radiocarbon dates that they compile are distinct (though overlapping) in space (Fig. 1) and time (Fig. 3).

3. Critical evaluation

A second challenge, familiar from previous efforts at compilation (see discussion in Ziółkowski, 1994), was chronometric hygiene (Spriggs, 1989) – the evaluation of individual samples to determine their reliability as datapoints. While even inaccurate radiocarbon ages are informative about research history, the inclusion of samples that are not

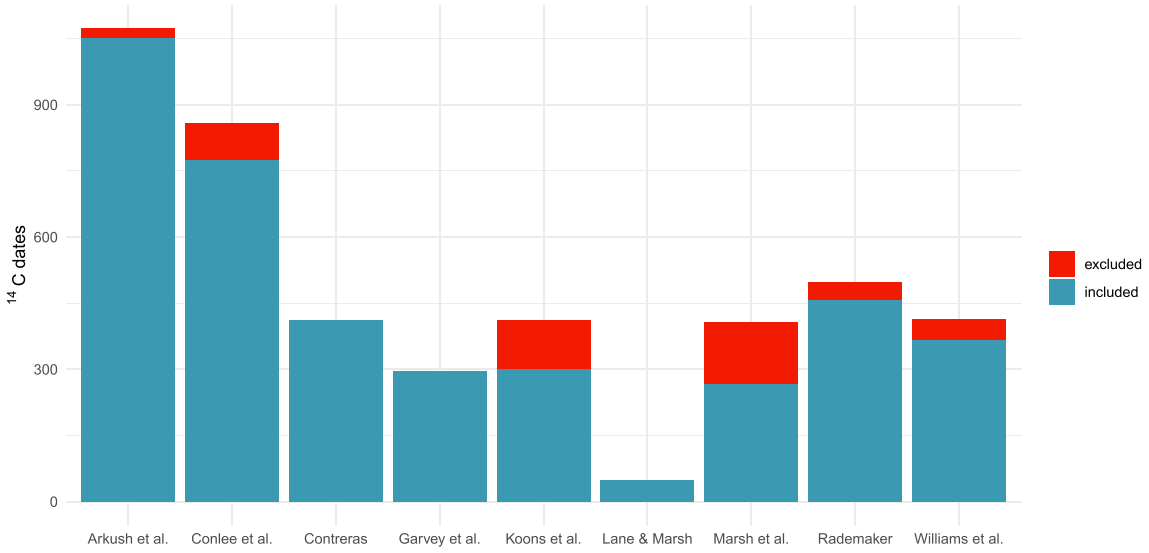

Fig. 2. Chronometric hygiene results in exclusion of varying proportions of ^{14}C dates, depending in specific criteria and original data quality. Note that Contreras, Garvey et al., and Lane & Marsh excluded ^{14}C dates before compilation.

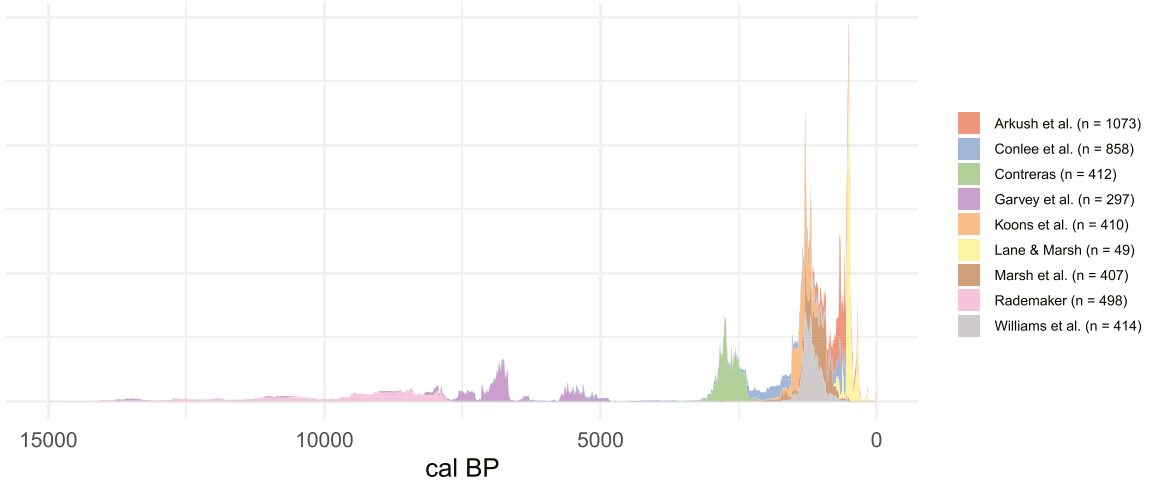

Fig. 3. Summed probability distributions (SPDs) of the ^{14}C dates included in each paper in this Special Issue. All ^{14}C dates calibrated using SHCal20; some dates duplicated across datasets. SPDs are normalized. Plotted using the **c14bazAAR** (Schmid et al., 2019) and **stratigraphr** (Roe, 2020) packages in R (R Core Team, 2024).

clearly associated with the event/material that they purport to date, or whose ages have been inaccurately or too imprecisely determined, can undermine synthetic conclusions. This has been addressed by filtering dates according to more or less explicit criteria (most thoroughly treated in Rademaker, 2024), and either excluding them from compilations entirely or including but flagging samples considered unreliable (Fig. 2). Rademaker (2024) and Koons and colleagues (2024) highlight the risks of continuing to reproduce inaccurate dates, on which misconceptions can continue to be built. One strategy pursued by several contributors, evident in the supplementary material accompanying papers, is the inclusion of information about sample and context in compilations, as well as notes about the rationale for excluding dates. These associated data, as we discuss below, are also important to analytical efforts but often missing from large-scale compilations.

As several contributors note, chronometric hygiene is only the beginning of critical evaluation. In addition to considering the grounds for excluding dates as unreliable – filtering, for example, for dates with large measurement errors (as do, e.g., Garvey et al., 2024; Koons et al., 2024; Rademaker, 2024) or incomplete information about sample material, quality, or pretreatment (see discussions in Koons et al., 2024; Rademaker, 2024) – some contributors also emphasize the importance of assessing purported associations between dated samples and material culture/iconography/architecture (e.g., Conlee et al., 2024; Contreras, 2024; Koons et al., 2024; Williams et al., 2024; Marsh et al., 2025), as well as the relationships between dated events and associated material culture.

4. Analysis

What to *do* with assemblages of radiocarbon dates represents a third challenge. Contributors analyze assemblages of Central Andean ^{14}C dates in three principal ways: as dates, as data, and as metadata. That is, they serve as sources of chronological information, as proxies for past processes, and as indicators of research attention. Contributors 1) revisit the time spans of existing periods, the timing of transitions between periods, and the timespans associated with identifiable suites of material culture (e.g., Conlee et al., 2024; Contreras, 2024; Koons et al., 2024; Marsh et al., 2025; Williams et al., 2024), 2) explore patterning in time and space (all papers), and 3) identify significant and/or intractable problems to be addressed with new dating programs (all papers).

Contributors draw inspiration from the burgeoning ability to describe the relatively deep past with a resolution approaching generations rather than centuries, where radiocarbon dates are abundant and Bayesian modeling widely employed (e.g., Bayliss et al., 2007; Whittle and Bayliss, 2007). Absolute, precise, and high-resolution chronologies enable assessment of relationships between archaeological and paleoenvironmental and paleoclimatic data, examination of the timing/tempo/synchronicity of geographically widespread processes, consideration of time-transgressive nature of some processes (direction, rate of spread), causal inference, assessment of ubiquity of phenomena, escape from tyranny of periodization, and are a necessary component of humanistic approaches to temporality.

For the dates compiled by contributors to this issue to be employed in Bayesian chronological models, however, more than simple compilations of reliable dates are necessary. Vital as compilation and critical evaluation of radiocarbon dates are, contextual data and assessments of the robustness of claimed associations are critical to any modeling of compiled dates. The papers included in this issue distinguish themselves from previous compilations of radiocarbon dates in the region through their commitment to enabling additional analyses. This is in part a recognition of the importance of analyses at multiple spatial and temporal scales, and in part a commitment to build from a sound foundation by returning to the specific excavation context and associated material for each date. Several contributors have gone back to publications in which dates were first reported, original lab reports, and 'lost' excavation details buried in grey literature (e.g., Koons et al., 2024; Marsh et al., 2025). These efforts highlight a tension (discussed in Contreras, 2024) between efficient data harvesting and the importance of reliability and context of each radiocarbon date.

This recognition of the importance of returning to source data to build date compilations that are more than just bare-bones reporting highlights two additional aspects that the papers included here confront. First, the academic politics of data compilation is an often-overlooked aspect of data synthesis. Radiocarbon dates can be important, expensive, and jealously guarded data. A few of these papers have made extensive efforts to include many co-authors, with the goal of including the many unpublished dates as well as the crucial associated information (Koons et al., 2024; Marsh et al., 2025; Williams et al., 2024). Collaborative efforts are especially important as we look for patterns within time periods and/or regions, across various scales of population density and organization, ranging from scattered foragers to complex states and empires. Second, maximizing the utility of compilations of dates calls for not only including contextual data and assessments of reliability, but also for making data available for re-use. Contributors here do so with supplemental files, in some cases hosted in data repositories (Koons et al., 2024; Marsh et al., 2025; Rademaker, 2024). Juxtaposing these contributions has highlighted that more durable and flexible data infrastructure will be a key next step in data synthesis, a point to which we return in the final section.

5. Nine papers, diverse insights

Several major challenges for preceramic periods (pre-4000 cal BP) in the Central Andes include a relative lack of archaeological sites, many poor-quality radiocarbon dates, millennia of landscape taphonomic processes destroying, obscuring, or distorting the available record, and unequal research attention across space and through time. As both Rademaker (2024) and Garvey and colleagues (2024) show, the current body of dated sites is heavily biased in various ways, complicating efforts to scale up the record. Top-down, region-scale treatment of the record in the aggregate runs the risk of burying these granular problems while producing grand but perhaps poorly supported conclusions. What is needed is greater and more consistent archaeological research attention to the early prehistory of the Central Andes, along with a concerted effort to produce high-resolution chronologies based on accurate and precise radiocarbon dates and not merely on supposed diagnostic artifacts, usually projectile points. Fortunately, improvement of this situation is already underway and will pick up speed in the coming decade.

Compilations of dates highlight under-studied areas, such as intermediate elevations from 1000 to 2500 masl (Rademaker, 2024) and areas more distant from modern population centres and roads (Garvey et al., 2024). Gaps in the current record highlight the need for radiocarbon dates from complete stratigraphic sequences at multi-component sites rather than dating only specific components of interest. More even sampling should produce an archaeological radiocarbon record that is more representative of the total occupation history of sites and regions, notwithstanding issues of landscape taphonomy, site visibility, and research intensity. While the majority of early highland chronologies is solid and improving, early coastal chronologies have serious unresolved problems related to marine reservoir and old-wood effects. Early coastal chronologies largely need to be rebuilt by dating terrestrial faunal remains or botanical samples vetted for problems of old wood, marine reservoir, and residence time and modeled accordingly.

Conlee and colleagues (2024) compile and evaluate archaeological radiocarbon data spanning the past 8000 years from three sub-regions of the south coast of Peru (14–15° S), including the Ica Valley where the original master ceramic sequence defining horizons and intermediate periods was developed (Rowe, 1962). This area is also the homeland of the Paracas and subsequent Nasca cultures, with intrusion from the highland-based Wari and Inca states later in time. Examining Kernel Density Estimate (KDE) models of dates associated with ceramic types reveals that the long-proposed ceramic "phases" vary in their temporal distributions across these sub-regions, limiting their utility as temporal markers across the entire area. Conlee and colleagues (2024) identify contemporary production/use/discard of multiple types of pottery, as well as potentially time-transgressive adoption and abandonment of specific ceramic types. Their analysis makes clear that the use of particular ceramic styles to delineate temporal phases is imprecise at best. Ceramic styles are not purely sequential on the south coast and consequently should not be used as chronological markers at regional scale. Moreover, the ceramic phases do not correspond well with the history of hydroclimatic shifts.

Contreras (2024) employs a meso-scale approach to critically examine the concept of the Early Horizon or the "Chavín Phenomenon," a large-scale interaction network recognized by shared ceramics and distinctive iconography among highland and coastal sites in north and central Peru from approximately 3000 to 2500 years ago. Contreras (2024) assembles and models all dates for site contexts with Janabarroid ceramics, sites containing these ceramics but with less certain identifications, and sites lacking these ceramics but with contemporary radiocarbon ages. All KDE plots indicate a relatively brief 400-year window of time, in fact comparable to the time span proposed for the later Middle Horizon, during which iconography and ceramic styles were shared over a large but likely discontinuous area. Moreover, the site of Chavín de Huantar, which has always been central in any definition of the Chavín Phenomenon, clearly dates within this brief period. Gaps and overlaps among the potentially related sites provide specific targets for future dating efforts, which could clarify the temporal and functional relationships among the sites and shed further light on the Chavín Phenomenon.

In their comprehensive update of the Moche radiocarbon chronology and ceramic series, Koons and colleagues (2024) evaluate all published Moche-associated radiocarbon dates, from twice as many sites as a previous effort (Koons and Alex, 2014). Their study reveals significant temporal overlap between ceramic styles, similar to findings for the Nasca region (Conlee et al., 2024). The Moche phenomenon, Koons and colleagues argue, lasted less than five centuries, ca. 350–850 CE – like the Chavín Phenomenon, of shorter duration than previously thought. This new Moche chronology straddles Rowe's (1962) division between the Early Intermediate Period and Middle Horizon, meaning that these two large temporal blocks may not be useful on Peru's North Coast. The

close temporal overlap with Wari and Tiwanaku suggest that Moche may have been connected, especially suggested by Wari influence on Moche ceramics (Williams et al., 2024). This relationship can be teased out by forgoing Periods and Horizons in favour of Bayesian chronologies that track specific stylistic elements.

Williams and colleagues (2024) are explicit about breaking down the 'block' of the Wari polity, dividing the large area with some type of Wari presence or influence into six distinct regions. Within each of these, they distinguish three types of sites and material patterns, spanning a spectrum from Wari state control to absence of Wari influence. Williams and colleagues (2024) apply Bayesian methods to refine this multi-regional sequence of fluorescence and disappearance. Beyond clarifying local sequences and highlighting inter-regional variation, the KDE models make it possible to determine whether state installations preceded or outlasted affiliated sites. Williams and colleagues (2024) also examine the temporal ranges of specific archaeological features, such as mortuary traditions, architectural forms, roadways, and *khipus* (string record-keeping devices). Many of these indeed appear in coeval Wari-affiliated sites in multiple regions, lending support to the idea of linked cultural transformations introduced or at least spread by the Wari culture.

Marsh and colleagues (2025) assemble and analyze a comprehensive dataset of radiocarbon dates to examine the chronology of distinct archaeological artifacts, forms, and features attributed to Wari's contemporary: Tiwanaku. Tiwanaku material culture includes redware ceramics and distinct iconography on textiles, drinking cups, and snuff tablets. Similar to the approach used by Williams and colleagues (2024), Marsh and colleagues (2025) break down Tiwanaku into different geographical areas and construct a series of models for specific sub-regions. Tiwanaku presence or influence in different geographic areas appears time-transgressive rather than simultaneous everywhere. Importantly, KDEs of distinct Tiwanaku material culture types show that these cultural markers do not appear and disappear in lockstep. For dates associated with Tiwanaku material culture, Marsh and colleagues' (2025) results show how horizon-thinking has obscured significant temporal and spatial variability. Breaking down this temporal block facilitates more nuanced perspectives on the people who created and interacted with this enduring and wide-spread material pattern.

Arkush and colleagues (2024) also highlight the insufficiency of inherited chronological frameworks, focusing on what Rowe termed the Late Intermediate Period (LIP). In Peru's south-central highlands, they argue, the LIP was far from monolithic in time or space, and was significant as more than simply a placeholder between periods of Wari and Inca control. Moreover, they find that key archaeological questions – concerning, for instance, Inca expansion – focus on exactly the processes that are obscured by sharp period boundaries (between, e.g., "LIP" and "Inca"). These labels assume the succession of one ceramic style after another, but it is now clear that these styles overlapped in time, and at some sites were never present (e.g., Covey et al., 2025).

Lane and Marsh (2024) use the radiocarbon record to argue that, for the Inca, we need generational-scale chronologies to track multiple waves of interaction, conquest, and reconquest. They argue that although Inca dynastic history has been reconstructed from ethnohistoric sources (Rowe, 1945), these sources do not offer reliable information on absolute dates, and chronologies derived from ethnohistory should be replaced by the growing corpus of radiocarbon evidence (Ogburn, 2012). The implications go beyond revision of the spans of years assigned to various Inca rulers. Based on the radiocarbon evidence, Lane and Marsh argue, our baseline expectation should not be imperial control over a homogenous territory, but dispersed nodes between which Inca leaders leap-frogged. This dynamic helps explain how conquests proceeded very early and very far south into modern Chile (Lane and Marsh, 2024). If this is true of the long arm of the Inca state, it is likely to be at least as true of earlier and more diffuse political entities.

6. Looking forward

One of the results of thinking big, as these papers do, is re-engagement with the raw material of archaeology: patterns in time and space. In consequence, these papers address when and where people were doing or making particular kinds of things in the Central Andes. Questions and scales vary depending on time, subsistence mode, evidentiary basis, and prevailing research questions. Collectively the papers included here cover from the Terminal Pleistocene through the sixteenth century CE in the Central Andes of Peru, Bolivia, and northern Chile (Figs. 1 and 3).

In spite of this diversity of foci and temporal scales, the papers in this Special Issue share a common theme: confronting the realities of the current archaeological radiocarbon record in the Central Andes. Employing chronometric hygiene in compiling radiocarbon data before scaling up in synthetic models forces authors to evaluate the quality of each radiocarbon date and to consider their contexts. Examining geographic and temporal coverages of the compilations highlights where and when radiocarbon dates are dense, sparse, or completely absent. We must then ask what processes and decisions have structured the record in hand. We want to know the cultural dynamics of the past, but what other processes have structured that record? What has been happening on the landscape since dated materials were deposited? How have investigators designed research?

Considering questions like this puts researchers in better positions to a) confront and evaluate the periodization schemes and other constructs that influence archaeological investigation of the Central Andean past, and b) generate interpretations about that past. Explicit grounding in the radiocarbon record may result in significant revision. For instance, one common result of Bayesian modeling is shorter estimated phases (Bayliss et al., 2007), demonstrated by most of the papers in this issue. In addition, a major refinement that appears in most papers is deceptively simple: decorated ceramics overlap in time and are not assumed to be regionally synchronous, calling into question a key assumption of culture history schema that are built on successive ceramic sequences. This simple step forward requires larger sets of dates and Bayesian models that do not take for granted the immediate and complete replacement of one type by another.

Radiocarbon data can address such questions as the timing of colonization of the Central Andean region (and sub-regions) by humans, the rate of occupation of various environments throughout the Holocene, and the density and distribution of foraging populations before and after the beginnings of plant and animal domestication and the spread of food production. They can also be used to confront specific claims about the prehispanic Central Andes. Both Arkush and colleagues and Lane and Marsh argue that even interpretations of the period immediately before the Spanish Conquest, for which ethnohistoric sources are available, should be reevaluated using radiocarbon data. For earlier periods, Conlee and colleagues, Contreras, Koons and colleagues, Marsh and colleagues, and Williams and colleagues all argue that confronting prevailing interpretations with radiocarbon data highlights the ways in which existing frameworks fall short of describing complex realities.

Radiocarbon databases and Bayesian models constructed with care and presented with transparency – like those collected in this *QI* special issue – help increase the resolution at which we can ask and answer questions and formulate ideas about what we need to do next. We hope that the papers in this Special Issue will stimulate and help direct further dating efforts, and provide a framework within which newly published dates can be analyzed. These new ^{14}C dates and compilations of dates (rapidly appearing - e.g., Capriles, 2023; Murphy et al., 2024; Garrido, 2025; Sobczyk et al., 2025) will improve data density and coverage as well as expanding the geographic reach of studies like those in this Special Issue. We look forward to increasingly improved understandings of the Central Andean past.

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