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Coring, profiling, and trenching: Archaeological field strategies for investigating the Pleistocene-Holocene-Anthropocene continuum

Torben C. Rick [a,b,*], Abdullah M. Alsharekh [c], Todd J. Braje [d], Alison Crowther [e,b], Jon M. Erlandson [f], Dorian Q. Fuller [g,b,h], Kristina M. Gill [f], Huw S. Groucutt [b,i,j], Maria Guagnin [b], Richard Helm [k], Courtney A. Hofman [l,a], Mark Horton [m,b], Andrea Kay [b], Ravi Korisettar [n,o], Chantal Radimilahy [p], Leslie Reeder-Myers [q], Ceri Shipton [g], Henry T. Wright [r,s], Michael Petraglia [b,a,e,t], Nicole Boivin [b,a,e,u]

[a] *Department of Anthropology, National Museum of Natural History, Smithsonian Institution, Washington, DC, 20013, USA*
[b] *Department of Archaeology, Max Planck Institute for the Science of Human History, Jena, 07745, Germany*
[c] *Department of Archaeology, King Saud University, Riyadh, Saudi Arabia*
[d] *Department of Anthropology, San Diego State University, San Diego, CA, 92182, USA*
[e] *School of Social Science, University of Queensland, Brisbane, Australia*
[f] *Museum of Natural & Cultural History, University of Oregon, Eugene, OR, 97403, USA*
[g] *Institute of Archaeology, University College London, WC1H 0PY, UK*
[h] *School of Cultural Heritage, Northwest University, Xi`an, Shaanxi, China*
[i] *Extreme Events Research Group, Max Planck Institutes for Chemical Ecology, The Science of Human History, and Biogeochemistry, Jena, 07745, Germany*
[j] *Institute of Prehistoric Archaeology, University of Cologne, Cologne, 50931, Germany*
[k] *Canterbury Archaeological Trust, 92a Broad Street, Canterbury, Kent, CT12LU, UK*
[l] *Laboratories of Molecular Anthropology and Microbiome Research and Department of Anthropology, University of Oklahoma, Norman, OK, 73019, USA*
[m] *Cultural Heritage Institute, Royal Agricultural University, Cirencester, GL7 6JS, UK*
[n] *Indian Council of Historical Research, New Delhi, 110 011, India*
[o] *Robert Bruce Foote Sanganakallu Archaeological Museum, Ballari, Karnataka, 583101, India*
[p] *Institut de Civilisations Musée d'Art et d'Archéologie, Université d'Antananarivo, Antananarivo, 101, Madagascar*
[q] *Department of Anthropology, Temple University, Philadelphia, PA, 19122, USA*
[r] *Museum of Anthropological Archaeology, University of Michigan, Ann Arbor, MI, 48109-1259, USA*
[s] *Santa Fe Institute, 1300 Hyde Park Road, Santa Fe, NM, 87501, USA*
[t] *Australian Research Centre for Human Evolution (ARCHE), Brisbane, Australia*
[u] *Department of Anthropology and Archaeology, University of Calgary, Calgary, Canada*

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ABSTRACT

Archaeologists have long emphasized the importance of large-scale excavations and multi-year or even decades-long projects at a single site or site complex. Here, we highlight archaeological field strategies, termed coring, profiling, and trenching (CPT), that rely on relatively small-scale excavations or the collection of new samples from intact deposits in previously excavated trenches (aka test units or pits). Examples from multiple sites in Africa, Asia, and North America demonstrate that CPT is highly effective for obtaining high-resolution archaeobiological and geoarchaeological samples (e.g., faunal and botanical remains, sediments) and artefacts from areas that have seen limited or no archaeological research, little systematic application of archaeological science methods, or research only on a relatively narrow time period or geographic scale. Designed to complement large-scale excavations at single sites, CPT is ideal for multi-scalar research that works in tandem with remote sensing techniques, providing samples for detailed laboratory analyses and offering a bridge between surface surveys and large-scale excavation. Given the threats facing archaeological sites around the world from climate change and human development, as well as financial, training and infrastructure constraints, and concerns from many Indigenous communities about large excavations, we argue that CPT is an important method for addressing 21st century human-environmental research questions.

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* Corresponding author. Department of Anthropology, National Museum of Natural History, Smithsonian Institution, Washington, DC, 20013, USA.
E-mail address: rickt@si.edu (T.C. Rick).

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1. Introduction

Deciding what to collect and where, when, and how much to excavate are fundamental questions in archaeology. From its inception as a discipline, archaeologists have discussed best practices for excavation, sampling, and other field methods (e.g., Banning, 2021; Biddle and Kjølbye-Biddle, 1969; Binford, 1964; Hole, 1980; Orton, 2000; Roskams, 2010; Scerri et al., 2020). Archaeological field methods are guided by research questions, compliance and development projects, preservation threats (e.g., erosion, looting, or destruction), the views and perspectives of Indigenous communities, curation standards, and myriad other factors. Many projects have focused on large-scale excavations of single sites or site complexes (e.g., Angkor Wat, Çatalhöyük, Gorham's Cave, Pompeii, Teotihuacan). Such large-scale projects became a mainstay of archaeology in its formation as a discipline (Trigger, 2006), and have come to typify traditional perceptions of the field among both archaeologists and the public. These large-scale projects provide temporal and spatial datasets crucial to our understanding of the human past (e.g., Cottier and Wesson, 2014; Cowgill, 2016; Hodder, 2013).

While big excavations remain central to archaeological practice and provide critical insights, they are costly, time-consuming, and require significant long-term commitments by governments, funders, and curation facilities. Consequently, large-scale excavation may not be sustainable in all parts of the world (e.g., nations without adequate resources for curation or politically unstable areas). Moreover, large-scale excavation projects are not necessary for all research questions (e.g., environmental and landscape focused questions discussed below) and may require sub-sampling of excavated constituents to yield manageable sample sizes for some intensive analyses. Under the scenario of a finite and disappearing archaeological record (Surovell et al., 2017), archaeologists also have an ethical responsibility to leave some portion of archaeological deposits intact for future inquiry (Carver, 2015). Large excavations also concentrate resources on particular locations and sites, while smaller excavations can allow for the excavation of more sites and be an effective response to threats like site erosion, looting, and site destruction (Cottier and Wesson, 2014). Large-scale projects are an important approach to understanding the past (Flannery, 1976), but archaeology operates at multiple scales and small-scale sampling projects also play an essential role in investigating the past.

In this paper, we discuss archaeological field strategies that rely on relatively small-scale excavations to obtain high-resolution animal and plant remains, sediments, and artefacts (Fig. 1). We integrate these small-scale strategies under the framework of archaeological coring, profiling, and trenching (CPT), an approach that complements large-scale excavations of single sites/site complexes. Using examples from Africa, Asia, and North America, we emphasize that CPT is effective for compiling datasets in areas that have seen limited archaeological research, where archaeological science has had limited systematic application, or in occupational landscapes where sites are small and ephemeral. While archaeologists have long relied on small-scale test excavation (shovel test pits, small pits/units, column samples, etc.) to help with site identification and evaluation, and to plan for future research (Carver, 2009; Roskams, 2010), the CPT approach unifies and codifies these strategies. Below, we define CPT and provide examples of the approach in action to make the case that CPT is a valuable and comprehensive approach for generating archaeological materials crucial for evaluating human-environmental research questions across the Pleistocene, the Holocene, and the proposed geologic epoch of the Anthropocene (see Zalasiewicz et al., 2017).

2. Defining coring, profiling, and trenching

CPT is a broad strategy for recovering archaeological materials using relatively small-scale testing, including the excavation of test units/pits or small trenches (such as 1 × 1 m and 1 × 2 m trenches/units), the taking of bulk and column samples from excavation sections and other stratigraphic exposures, and the use of auger holes (coring) or small probes (e.g., shovel test pits) (Fig. 2). The small-scale sampling of CPT works in concert with the use of small mesh screens (1 and 3 mm and smaller), flotation, wet-sieving, and other recovery methods. CPT has its roots in the archaeology of the mid-20th century, when researchers began more systematic scientific investigations, implemented ^{14}C dating and other analytical procedures, and meticulously excavated archaeological field sites with comprehensive procedures for recording the details of excavation and providing samples for laboratory analyses (e.g., Binford, 1964).

The CPT approach unifies a variety of small-scale sampling strategies that have proven effective for addressing human-environmental interactions, including microarchaeology (e.g., Barker, 1995; Cannon, 2000; Glassow, 1993, 2015; McKechnie, 2005; Sanchez et al., 2018; Stein, 1986; Weiner, 2010; Wright, 2010; Wright et al., 1984). While CPT is spatially limited compared to larger excavations – at least at the

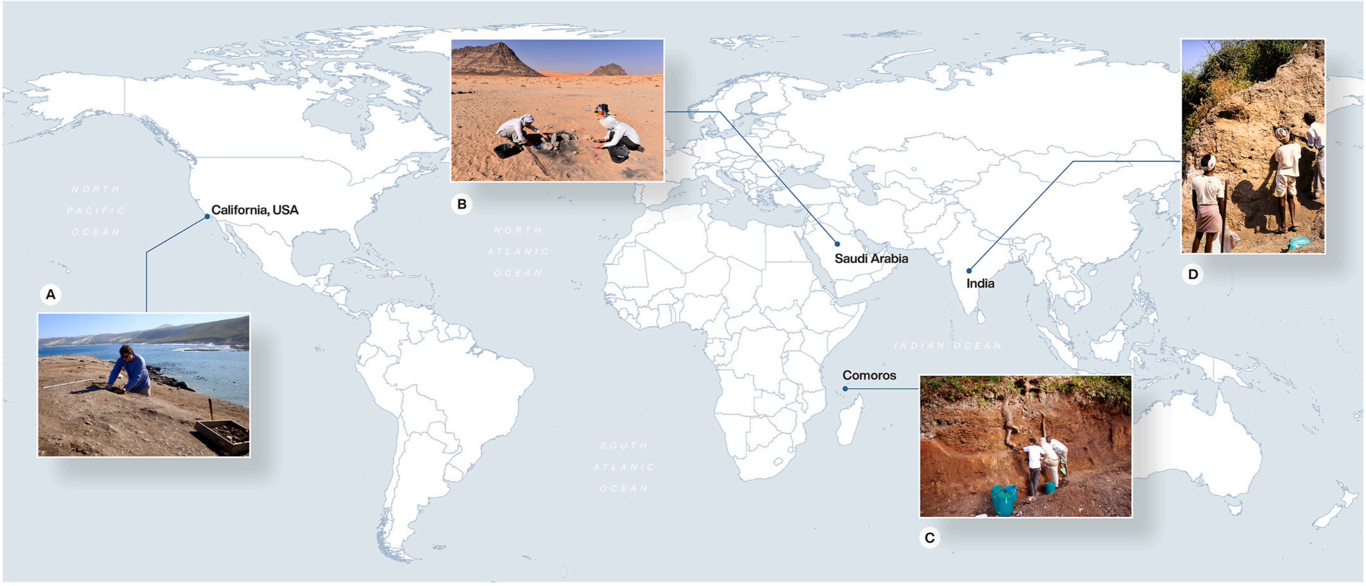

Fig. 1. Location of CPT case studies presented in this paper. A. California Channel Islands. B. Saudi Arabia. C. Comoros, the Western Indian Ocean, and East Africa. D. India and South Asia. Drafted by Michelle O'Reilly, Max Planck Institute for the Science of Human History.

individual site level – it is ideal for collecting specimens for radiocarbon and other chronometric dating methods, archaeobotanical and zooarchaeological study, molecular analyses (ancient DNA, collagen fingerprinting, proteomics, and lipid/metabolite analyses), stable isotope research, sedimentology, micromorphology, and more. CPT allows for investigation of more sites across the landscape, an approach crucial for evaluating human settlement and historical ecology. In addition to archaeological reconnaissance, the approach can be used to re-evaluate earlier large-scale excavations. CPT also provides the initial framework for contiguous test units and trenches that may result in larger excavations (e.g., 4 × 4 m and greater). The CPT approach supplies a means to obtain high-resolution samples that can complement extant museum or legacy collections, which were often collected decades ago using outdated techniques (St. Amand et al., 2020).

The various CPT strategies fall under the umbrella of "low-impact" archaeology approaches that are increasingly employed in numerous places in North America and beyond in collaboration with Indigenous communities (e.g., Cannon, 2018; Erlandson and Moss, 1999; Gonzalez, 2016; Gonzalez et al., 2018; Lightfoot, 2008; Sanchez et al., 2021). Less invasive or "low-impact" methods are, in our experience, preferable to many descendant and local communities and can help gather information efficiently from sites that are in danger of rapid loss due to climate change. They are also often less expensive, easier to implement, and faster to bring to publication. This is especially important for junior scholars and is essential for students who are not connected to existing large-scale projects. While derided as 'telephone booth' archaeology in its earlier form (Flannery, 1976), the modern CPT approach can enable more strategic, responsive, and dynamic ways to study the past, offering material that can enhance traditional large-scale excavation approaches.

The materials gathered through CPT are particularly useful for answering specific research questions, where a particular type of sample or specimen can be targeted through small-scale testing. In this context, CPT is an important field strategy to investigate the deep history of human-environmental interactions around the world, and can address historical ecological questions, contextualize modern ecosystems, and chart effective restoration plans into the future. Through the examples of CPT in action described next, we seek to unify similar small-scale testing programs under the CPT framework, providing a means for archaeologists and interdisciplinary teams to develop field strategies to address cutting edge questions in an ethical (when implemented in collaboration with Indigenous and local communities), efficient, and targeted approach.

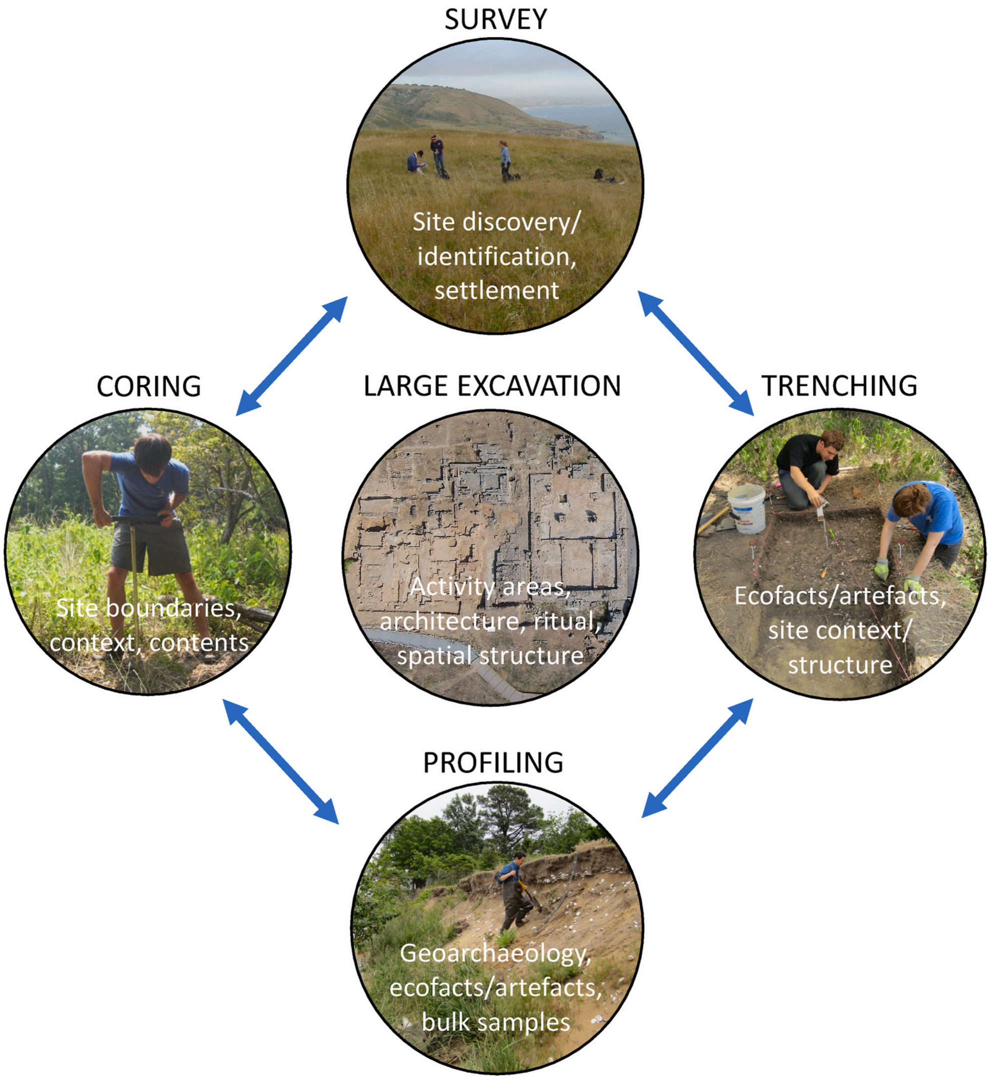

Fig. 2. Relationships between coring, profiling, and trenching, and archaeological survey, showing types of material and/or issues that can be recovered or investigated. Inner core highlights large excavation and some aspects of the past that are more challenging to investigate with CPT/smaller-scale approaches.

3. CPT in practice

3.1. Sealinks Project in eastern Africa

On the coast of eastern Africa and islands in the adjacent Western Indian Ocean, extending from Kenya in the north to Madagascar in the south, Sealinks and other projects have taken a CPT approach to investigate a range of archaeological issues discussed below (Fig. 3). The first introduction of CPT in the region was in the Comoros Archipelago in 1980, where measured volumes of sediment from small excavations and adventitious sections in sites dating to 800–950 CE were sorted with water flotation and fine screens, studied under magnification, and presented quantitatively (Allibert et al., 1990; Wright et al., 1984, 1992). This early use of the CPT approach proved important for understanding settlement chronology, crop use, and site structure, later becoming the focus of a large-scale systematic study of the Sealinks Project beginning in 2008. While the main goal of the Sealinks Project was to examine early Indian Ocean trade and its relationship to biological exchange, a CPT approach offered insights into early dispersals, island colonisations, marine exploitation, and the spread of farming. Since 2010, more than 50 small-scale trenches have been excavated at 22 individual sites across the study region, with the aim of rapidly building a broad temporal and spatial picture of an area that had seen little previous systematic research, with a particular paucity of

Fig. 3. Examples of CPT in action and the materials they generated for Sealinks research in eastern Africa. A. Sampling exposed sections at Old Sima in the Comoros islands to recover faunal remains for zooarchaeological and aDNA analyses. B. Floating sediment samples at Unguja Ukuu in the Zanzibar Archipelago to generate palaeobotanical data relating to early agriculture and food globalisation. C. Reopening and extending an earlier excavation trench at Kuumbi Cave, Zanzibar, to clarify Late Pleistocene and Holocene chronology, human population dynamics and diet from radiocarbon dating, aDNA and isotopes. D. Excavation of Unguja Ukuu, Zanzibar, to recover glass beads and other material culture for provenience analysis.

archaeological science (Boivin et al., 2013). Sealinks research was conducted in collaboration with local communities and curators to define cultural resource management issues and to understand impacts on and threats to archaeological sites.

While trenches were small (1 × 1 m to 3 × 3 m), they were systematically and intensively sampled, with a particular focus on extensive flotation to recover botanical remains and fine-mesh sieving to retrieve all faunal remains and small objects, as well as sampling of sediments and residues. This approach, in particular flotation and wet-sieving, resulted in exceptional and unprecedented rates of recovery of environmental and cultural markers (e.g., charred seeds, glass and shell beads, bead-making waste, bone fragments, and remains of small fauna). Laboratory analyses of samples included Accelerator Mass Spectrometry (AMS) and Optically Stimulated Luminescence (OSL) dating, stable isotope analysis, Zooarchaeology by Mass Spectrometry (ZooMS, collagen fingerprinting), ancient DNA, proteomics, gas chromatography-mass spectrometry (GC-MS), laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), phytolith and starch studies, use-wear analysis, micromorphology, sedimentology, magnetic susceptibility, and micro-CT, among others. A key project finding was that archaeological science methods could yield rich insights into eastern Africa's human and environmental past, despite concerns about preservation (particularly of organics and ancient biomolecules) that previously contributed to an under-application of scientific approaches in the region (Crowther et al., 2018; Prendergast and Sawchuk, 2018).

While the Sealinks Project focused on Holocene archaeology, the occupational histories at a few of the investigated sites extended into the Late Pleistocene, enabling insights into the early human occupation of the eastern African coast (Langley et al., 2016; Shipton et al., 2016, Shipton et al., 2018b), processes of continental island formation across the Late Pleistocene-Holocene boundary (Prendergast et al., 2016), and Late Quaternary landscape evolution (Kourampas et al., 2015). At Kuumbi Cave on Unguja island, CPT investigation placed adjacent to previous large-scale excavations provided stratigraphic control to enable the testing of claims of precociously early occupation and also presence of domestic fauna (Shipton et al., 2016). Notably, Sealinks CPT investigation led to the discovery and analysis of Panga ya Saidi, an extraordinary site with a 78,000-year-long archaeological record. Multidisciplinary investigations at Panga ya Saidi have shed light on early human occupation of tropical forests, early marine resource use, symbolic material culture and burial practice, stone tool technology, and long-term climate and ecosystem change (Blinkhorn and Grove, 2018; Clarkson et al., 2018; d'Errico et al., 2020; Faulkner et al., 2021; Goldstein et al., 2022a; Martinón-Torres et al., 2021; Roberts et al., 2020; Shipton et al., 2018b, 2021).

The CPT approach enabled significant insights into the dispersal of food producers across coastal and island eastern Africa, linked to the large-scale migrations of early Bantu and Austronesian language speakers. The systematic application of flotation and the recovery of botanical remains and molecular analysis of faunal remains shaped our understanding of early foraging and farming economies and produced archaeological evidence for the spread of Austronesian speakers from Island Southeast Asia to the Comoros and Madagascar (Crowther et al., 2016a, 2016b, 2018; Culley et al., 2021a, 2021b; Helm et al., 2012; Ottoni et al., 2017; Prendergast et al., 2017a, 2017b; Shipton et al., 2013). These insights were enriched by the application of ancient DNA analysis to occasional human remains recovered through CPT, which contributed to an overall picture of delayed farmer dispersal to the coast and islands, followed by a long period of forager-farmer cohabitation with limited interaction and admixture, and ultimate swamping of forager ancestry by people from incoming food-producing populations (Crowther et al., 2018; Skoglund et al., 2017; Wang et al., 2020).

The Sealinks Project was interested in reconstructing ancient trade in eastern Africa, and in particular, the region's increasingly globalised connections. While some of this work focused on traditional material culture, such as glass, stone, and metal commodities (Crowther et al., 2022; Horton et al., 2017, 2021; Wood et al., 2017), a key aspect of the project involved reconstruction of less visible aspects of trade, including food globalisation (Boivin et al., 2014), the movement of organic commodities like incense and bitumen (Crowther et al., 2015, 2022), and the biological exchange of species that accompanied novel maritime connections. The CPT approach enabled insights into the maritime introduction into eastern Africa of Asian commensal and invasive species like the black rat (*Rattus rattus*), domestic cat (*Felis catus*), goat (*Capra hircus*), and domestic chicken (*Gallus gallus*), addressing long-term debates about the timing and routes of their arrival (Boivin et al., 2013; Crowther et al., 2022; Culley et al., 2021a; Ottoni et al., 2017 Prendergast et al., 2016).

Finally, the CPT approach has been conducive to reconstructing shifts in biodiversity and land use through time in eastern Africa. Sealinks research on Zanzibar, for example, has revealed patterns of defaunation across the Pleistocene/Holocene transition and into the late Holocene (Prendergast et al., 2016). The project's collections are also contributing to recent collagen fingerprinting research aimed at examining caprine introductions to the eastern African coast and islands (Culley et al., 2021a, 2021b). Patterns of marine exploitation and the historical ecology and sustainability of ancient fishing and foraging activities are a target of ongoing research (Crowther et al., 2014, 2016a; Faulkner et al., 2018, 2019a, 2019b). Sealinks data are also contributing to broader datasets that are helping reconstruct land use patterns at large scales (e.g., Marchant et al., 2018; Stephens et al., 2019), while the CPT methodology is now being applied by a new research program in the southeastern African interior (Goldstein et al., 2021, 2022b; Janzen et al., 2021).

3.2. Domestication in India

A CPT approach, focused on recovering archaeobotanical data, brought to light early farming and plant domestication processes in South India. The presence of wild progenitors of numerous crops in India has long indicated local domestication must have occurred, but most discussions of early farming in India in the 20th century focused on the significance of introduced species from western Asia, China, or Africa (e.g., Harlan, 1992; Hutchinson, 1976; Possehl, 1999). While archaeobotanists working in India recognized the potential for local domestication processes, identification of where and when these might have occurred through regional archaeobotanical datasets and sequences was lacking (e.g., Kajale, 1991; Saraswat, 1992). Since at least the early 1980s, systematic flotation had been used at some excavations focused on Harappan or Ganges urbanization or Chalcolithic cultures in the northern Deccan or Kashmir, but no research was oriented towards the problem of early farming or plant domestication (e.g., Kajale, 1991; Lone et al., 1993; Saraswat, 1992). Southern India, south of Maharashtra was largely *terra incognita* in terms of archaeobotanical data (cf., Kajale and Eksambekar, 1997; Venkatasusbbaiah and Kajale, 1991; Vishnu-Mittre, 1971). This was despite other evidence that this region had developed a Neolithic culture earlier than the northern peninsula and a rapid adoption of pastoralism after 5000 cal BP (Allchin and Allchin, 1982: 352; Korisettar et al., 2001a), and evidence for wild ancestors of Indian millets and pulses in the region (Fuller, 2002). A "regional approach" of "survey archaeobotany" (Fuller, 1999:166) using CPT methodology was devised to address the early farming question on the principle that broad geographical and chronological coverage might better identify Neolithic plant-based subsistence across the region.

Over two field seasons during the winters of 1997 and 1998, 19 Neolithic sites were sampled, representing an east-west transect across northern Karnataka and Andhra Pradesh (S1 and S2 Files; Fuller, 1999, 2008a; Fuller et al., 2001a, 2001b; Korisettar, 2004; Korisettar et al., 2001b). This included the excavation of small test pits at sites identified from previous archaeological survey, cleaning of profiles in sections exposed by erosion or borrow pits, and cleaning of profiles of eroded trenches from previous research excavations that could then be sampled to tie flotation samples directly into previously established stratigraphy, chronology, and material culture (Fig. 4). Several Neolithic sites had been subjected to large research excavations carried out in the 1960s and 1970s, which provided material cultural sequences, and faunal data, but no archaeobotanical evidence (e.g., Allchin, 1963; Ansari and Nagaraja Rao, 1969; Nagaraja Rao, 1971; Nagaraja Rao and Malhotra, 1965; Rami Reddy, 1976). New test pits ranged from 1 × 1 m to 2 × 2 m, and section cleanings were normally 1 m or 2 m wide. Minimum bulk sediment samples of 20 L were taken from all natural stratigraphic units or from arbitrary spits or sub-samples when strata were thicker than 20 cm. This work was timely as many of these sites faced destruction due to agricultural expansion and granite quarrying, processes that had accelerated in the 1990s (Korisettar, 2004). Each site was subjected to archaeological fieldwork for between 1 and 3 days. Flotation took up to an equal number of days, but usually about half as long as excavation, as samples were processed by manual methods of washover bucket flotation (Fig. 4) (Fuller, 2008b; Helbaek, 1969; see Struever, 1968 for an alternative early flotation approach)—a portable, low tech method that is suitable for conditions where samples can be transported to water sources, such as lakes, rivers, or irrigation tanks. While not all sites produced archaeobotanical seed remains, 12 of them did, providing 72 samples and >8700 identified seeds (S2 File). This included evidence for as many as 19 crop species before the end of the Neolithic, with additional CPT sampling at Piklihal (Fuller et al., 2022) and Sanyasula Gavi, and other caves in 2003 (Petraglia et al., 2009). This CPT approach produced substantial returns in terms of archaeobotany with limited expenditure of resources and time. Beyond flotation, the sediments were sieved and produced modest assemblages of animal bones (Korisettar et al., 2001b), ceramics, and other artefacts.

These data provided the first clear evidence for a consistent focus on four native crop species across the wider region (two millets, two pulses) by ca. 4000 cal BP, as well as evidence for the cultivation of introduced species (e.g., wheat and barley) and further agricultural changes between 4000 and 2800 years ago, including the introduction of crops of African origin as well as cotton (Fuller, 2006, 2011; Fuller et al., 2004). This was followed by additional larger-scale sampling and excavation at the Sanganakallu area sites in 2003–2006 (Boivin et al., 2005, 2008, 2018; Roberts et al., 2016). The CPT approach was extended to resampling known Neolithic sites in Uttar Pradesh and Odisha offering insights into regional sequences of early crop adoption (Harvey et al., 2005, 2006; Kingwell-Banham et al., 2018), as well as Iron Age sites in Tamil Nadu (Cooke et al., 2005). The collective South Indian CPT samples supplied seeds for AMS-radiocarbon dating of short-lived samples that more than doubled the chronometric data for the region and significantly refined the regional Holocene chronology (Boivin et al., 2018; Fuller et al., 2007; Roberts et al., 2016). These archaeobotanical data ultimately documented sequences of morphological change in indigenous taxa such as mungbean (*Viga radiata*), horsegram (*Macrotyloma uniflorum*), and pigeonpea (*Cajanus cajan*) (Fuller, 2011; Fuller et al., 2019, 2022; Murphy and Fuller, 2017).

Not all sites tested using the CPT approach produced charred macroremains. These were absent, in particular, where sites were largely on the surface and remains were restricted to the bioturbated topsoil. Indeed, the heavily rooted top soil is rarely productive, so archaeobotany requires stratigraphy that extends below the top soil. The unproductive top soil tends to be thicker in regions with higher rainfall, such as up to 50–60 cm in Odisha or western Karnataka but as thin as ~20 cm in drier parts of northern Karnataka around Ballari. In addition, soils that are rich in clays are prone to reduced charcoal and seed density due to argilliturbation, a major concern among the eastern sites noted

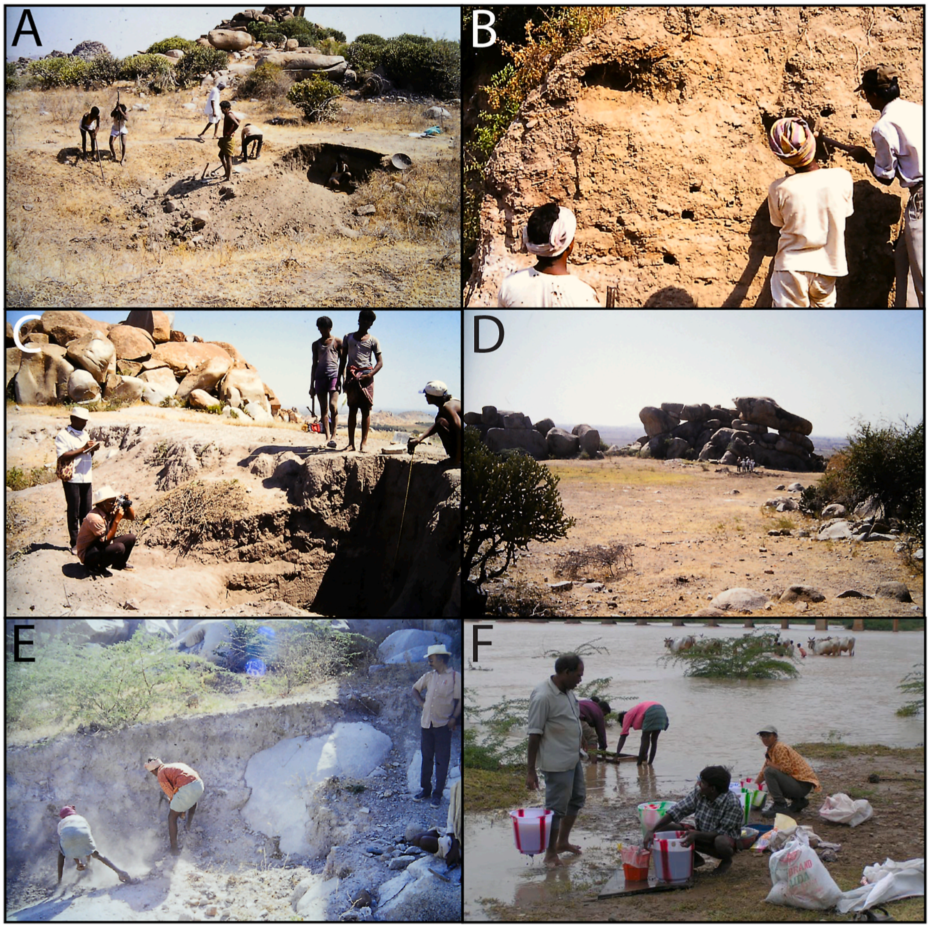

Fig. 4. CPT strategies in action in the Deccan Plateau, southern India. A. Sampling at Tekkalakota in 1998. Remnant of the baulks and partly backfilled trenches from excavations of Nagaraja Rao and Malhotra (1965) were still visible. B. Sampling at Hallur in 1998. The Hallur mound was eroding in part due to the action of the Tungabhadra River, but was also being actively quarried by villagers as fertilizer, so deep exposures could be cleaned and recorded. C. Sanganakallu (Sannarachamma Hill) in 1998. Here, a 1 M wide, ~3 m deep profile was cleaned in the eroded edge of the trench originally excavated by Ansari and Nagaraja Rao (1969). D. Velpumudugu hilltop site, known for its rock art and surface finds had never previously been excavated. E. Kurugodu 1998. This large site has been disturbed by villagers digging it for fertilizer and quarrying of granite boulders. Intact lower layers were sampled in a 1 × 1 m test pit while longer profiles were cleaned from eroding edges. F. Washover bucket flotation of samples from Neolithic sites in 1997 at Peddamudiyam and Singanapalle.

above (in southern Andhra Pradesh). Lastly, the ash mound sites, formed by the accumulation of burned cattle dung, did not produce assemblages, which can be attributed to their formation through higher temperature burning of dung rather than routine waste from human occupation. While the work in South India aimed for ~20 L bulk samples for flotation from each context, a useful guideline for sparse settlement in tropical contexts, the volume needed to attain reasonable sample sizes will vary by region based on site formation and soil condition. For example, archaeobotanical sampling from exposed sections during survey in the Ying Valley in Henan and Sushui Valley in Shanxi, central China, collected samples ranging from 9 to 15 L, based on what was readily collected from sealed layers on exposed profiles. These samples produced sufficient data to explore agricultural change and probable differences in husbandry and crop-processing practices across the region in the Neolithic (Allue et al., 2011; Fuller and Zhang, 2007; Song et al., 2019; Zhang et al., 2010).

The CPT approach has proven very useful for expanding archaeobotanical evidence. In the case of southern India, in what amounted to ~2 months of fieldwork and flotation spread over three seasons, this approach more than doubled the Neolithic/Chalcolithic sites in central Deccan with archaeobotanical evidence (S3 File). Ultimately the CPT approach put South India on the map as a region of independent domestication and contributed to a new multi-regional framework of Neolithic agricultural origins in South Asia (Fuller, 2006, 2011; Fuller et al., 2014).

3.3. Palaeodeserts in Arabia

The Palaeodeserts (or 'Green Arabia') Project is, so far, a twelve-year undertaking with a broad research scope – to investigate climate change and the hominin occupational history of Saudi Arabia from the Middle Pleistocene to the Holocene (Fig. 5). To examine environmental and ecosystem changes and their effect on human populations, a CPT approach was implemented across different geographic areas of the peninsula. In collaboration with Saudi organizations and an international network of interdisciplinary scientists, archaeological teams conducted fieldwork in seven different areas of Saudi Arabia, ranging from the Nefud Desert in the north, to the central uplands in the heart of the peninsula, to the arid zones of the Empty Quarter in the south. Surveys were conducted and small-scale trenches were excavated at a range of archaeological sites to identify stratified and datable sites that would yield high-quality information on spatial and temporal variability in human behaviour and demography across the peninsula.

Trenches placed in Pleistocene archaeological sites were typically small, ranging from 1 × 1 m, 1 × 2 m or 2 × 2 m units (Petraglia et al., 2012). Long and narrow trenches measuring, for example, 2 m × 12 m, were sometimes used on sites to explore variations in stratigraphy and subsurface artefact distributions (Petraglia et al., 2012). Only in exceptional cases were larger block excavations employed to either search for artefacts or to recover abundant finds on buried surfaces (Stimpson et al., 2015). In a few cases, trenches were placed in previously excavated sites (Scerri et al., 2018) or looted sites (Guagnin et al., 2021) to reaffirm or explore subsurface deposits and apply modern scientific methods. This strategy resulted in the discovery and investigation of the first stratified and dated Palaeolithic sites in Saudi Arabia. There was a particular focus on recording the precise location of lithic finds in stratigraphic context, including identifying sampling locations for luminescence dating and sediments for environmental information. For Holocene sites, a similar approach was used, though for some sites well-preserved hearths were evident in surface-subsurface contexts,

Fig. 5. CPT strategies on Pleistocene and Holocene sites from the Palaeodeserts Project, Saudi Arabia. A. MIS 5 site of Mundafan Al-Buhayrah where a series of small excavation units were placed across the landscape to identify the distribution of Middle Palaeolithic artefacts. B. Jebel Qattar-1. Here, trenches were placed to examine fluctuations in wet and dry periods between MIS 5–7. C. Saffaqah where a small trench (left) was placed beside a previously excavated trench (11 × 3 m), obtaining the first chronometric ages for the Acheulean in Arabia. D. Al-Rabyah. Here, a long trench identified the first stratified Epipalaeolithic site in Arabia. E. Jebel Oraf Rockshelter. At this site section trenches were placed beside a looters pit, recovering a stratified Holocene sequence. F. Jebel Oraf-2 where 17 of 170 hearths were sampled, indicating site occupation during two episodes of lake high stands at ca. 6500 BCE and 5300 BCE and material culture connections to the Levant.

resulting in the targeted placement of small excavation units to record their horizontal extent and vertical depth, while also securing samples for environmental and chronological studies. The CPT approach resulted in exceptional new information on the Palaeolithic and Holocene occupations of Arabia, especially from the recovery of environmental proxies (e.g., fauna, freshwater shells, diatoms, mammal fossils) in association with artefacts and cultural remains. Novel information was collected during the CPT program due to the participation of a diverse team of archaeologists, palaeontologists, and earth scientists, along with the application of a wide range of scientific methods.

The Palaeodeserts Project combined the CPT approach with remote sensing techniques that served as a starting point for archaeological investigations. Through the use of satellite imagery and GIS analyses, a network of riverine drainages was mapped and some 10,000 wetlands and palaeolakes were recorded across Arabia. Approximately three-quarters of the dozens of palaeolakes visited for ground-truthing yielded archaeological sites and fossils of different time periods (Breeze et al., 2015).

The CPT approach at the Middle Pleistocene site of Ti's al Ghadah, in the Nefud Desert, provided new information on chronology, habitats, and range expansions of both mammals and early hominins (e.g., Roberts et al., 2018; Stewart et al., 2019). On the basis of the distribution of eroding mammal fossils, it appeared that subsurface fossiliferous deposits extended over 1 km in length. Trenches placed across the landscape produced well-preserved fossils and rare lithic finds in buried contexts, indicating coalescence of fauna and early hominins around a standing body of water.

Surface surveys of igneous dyke landscapes in central Saudi Arabia showed that Acheulean sites were distributed over an area measuring at least 150 × 110 km, one of the most extensive palaeolandscapes of its kind (Jennings et al., 2015). A small excavation was placed at Saffaqah, adjacent to where Whalen et al. (1984) previously excavated a large trench (11 × 3 m), identifying buried Acheulean artefacts. The small trench confirmed the stratified nature of the Acheulean finds, allowing for the first accurate chronometric age estimate for the Acheulean in the region and an understanding of the depositional processes and environmental contexts of the sequence (Scerri et al., 2018; Shipton et al., 2018a).

The Palaeodeserts Project also aimed to understand the relationship between Pleistocene environments and hominin dispersal routes across the peninsula. On the basis of remote sensing analyses, visits were made to palaeolake targets in the Nefud Desert of northern Saudi Arabia, resulting in the identification of a series of Late Pleistocene sites (Scerri et al., 2015). At the Jubbah Oasis, three key Middle Palaeolithic sites were located and CPT strategies revealed differences in stone tool technology and behaviours between them (Groucutt et al., 2015, 2021; Petraglia et al., 2012). At Al Wusta, a fossil *Homo sapiens* finger bone was retrieved on the surface and directly dated to ~88,000 years ago (Groucutt et al., 2018). A series of CPT investigations placed across the Al Wusta site allowed for the application of chronometric dating methods and the retrieval of mammalian fossils and lithics, indicating occupations in association with a lake in a semi-arid grassland habitat. For the first time in Arabia, these data firmly associated *Homo sapiens* with Middle Palaeolithic technology.

Considerable research efforts have been made to understand changes in the context of societal change during the Holocene in Arabia, particularly the transition from hunting and gathering to pastoralism (Guagnin et al., 2015, 2016; Petraglia et al., 2020). Though considerable multi-year efforts have been made to excavate large Holocene settlements in Arabia, such as at the Tayma Oasis (e.g., Hausleiter et al., 2018), the Palaeodeserts Project instead used a CPT approach to examine smaller sites that more commonly dot the desert landscape. At Jebel Oraf in the Jubbah Oasis, 170 hearths were identified across an open-air site surface. Small excavations of 17 of the hearths resulted in AMS dates spanning the Middle to Late Holocene, indicating repeated occupation through time, by small groups who hunted wild game and incorporated domesticated species, such as cattle, into their economies (Guagnin et al., 2021). OSL dating of deposits from a small 1.1 × 0.3 m trench placed in the Jebel Oraf palaeolake deposit and from an excavated hearth allowed a reconstruction of flooding events, indicating partial inundation of the site around 7300 years ago (Guagnin et al., 2020). At the nearby Jebel Oraf rockshelter, the face of stratified deposits that were partially destroyed by looters, was cleaned and excavated in two trenches, measuring 1.1 × 0.5 m and 0.6 × 0.8 m. Testing in the rockshelter produced occupation phases that corresponded well with those at open air sites, while also producing novel archaeological findings, including evidence that people occupied the interior zones during the 'Dark Millennium' (5900–5300 years ago), contrasting with arguments that populations abandoned interior zones as occurred in southeastern Arabia (Petraglia et al., 2020). The Jebel Oraf rockshelter deposits were sieved with 5 mm, 1 mm, and 0.25 mm screens, which allowed the recovery of a range of artefacts, as well as faunal and microbotanical remains and charcoal. Microscopic analysis identified a small piece of gold wire from a deposit radiocarbon dated to 3634-3382 BCE - the oldest gold artefact found thus far on the Arabian Peninsula. Its presence in a location so remote from population centers shows that the populations of northern Arabia during this time were well connected and had access to emerging technologies (Guagnin et al., 2021).

Overall, archaeological explorations across seven project areas in Saudi Arabia, incorporating a CPT approach, provided evidence for human occupation of the peninsula from the Middle Pleistocene to the Holocene. The CPT approach allowed for the assessment of a large number of archaeological sites, providing critical new insights into human expansions across Arabia during periods of environmental amelioration, while also suggesting gaps and regional abandonments, hypothesized to be a consequence of arid and hyper-arid conditions. Moreover, the scale and extent of long-distance contact evident in Early and Middle Holocene sites across northern Arabia would not have been identified had resources been focused on the large-scale excavation of a single site (Crassard et al., 2013; Guagnin et al., 2021; Hilbert et al., 2014; Scerri et al., 2018).

3.4. *Historical ecology of California's Channel Islands*

On California's Northern Channel Islands (NCI), a CPT approach has helped address a variety of archaeological and ecological questions (Fig. 6). Column samples from eroding site exposures, test units (1 × 1 m and 1 × 2 m), soil cores, and bulk samples have helped track the first arrival of humans in the Late Pleistocene, subsequent socio-political changes across the Holocene as human populations densities increased and people adapted to climatic fluctuations, the breakdown of traditional lifeways with the arrival of Spanish colonisers, and a host of ecological issues focused on nearshore marine ecosystems and terrestrial animal and plant communities. Working in consultation with Chumash tribal representatives and within National Park Service, US Navy, and The Nature Conservancy mandates, we have sought to minimize impacts to archaeological sites by focusing on threatened and eroding sites and targeting small-scale testing using fine mesh screen sampling (1–3 mm). To complement legacy collections and refine site chronologies, a CPT approach at previously excavated sites (e.g., Daisy Cave and the village site of CA-SRI-2) increased the sample size of artefacts and archaeobiological materials (Erlandson et al., 1996; Rick, 2011). All CPT research on the NCI is based on a chronology developed by the collection of over 1500 radiocarbon dates from hundreds of archaeological sites over the past few decades, creating a high-resolution picture of the islands' occupational history through time. This chronological framework allows for contextualization and interpretation of a wide variety of cultural and environmental issues despite relatively small sample sizes.

A CPT approach on the NCI has contributed to understanding how and when people first arrived in the Americas, lending support to the coastal migration hypothesis (Braje et al., 2019; Erlandson et al., 2011; Gusick and Erlandson, 2019). Excavation of CPT test units (0.5 × 1 m, 1

Fig. 6. Examples of CPT in action and the materials they generated for specific research projects on California's Channel Islands. A. Excavations at a terminal Pleistocene site on Santa Rosa Island and examples of early technology generated from that research. B. Excavation of buried in situ ~7000 year old red abalone midden and dense shell midden constituents. C. Coring (augering) a Late Holocene site on Anacapa Island that generated important faunal remains for isotopes and aDNA. D. Excavations on Santa Cruz Island that generated important botanical materials to identify a long-term reliance on geophytes and Holocene landscape management activities.

× 1 m, and 1 × 2 m) in eroding Palaeocoastal sites on San Miguel and Santa Rosa islands illuminated the technology and subsistence strategies of people living ~12,000 years ago, providing in situ examples of stemmed projectile points and crescents, and shellfish, fish, bird, and mammal remains (Erlandson et al., 2011). CPT excavations in Early Holocene cave deposits also yielded unique woven cordage artefacts and beads (Connolly et al., 1995; Vellanoweth et al., 2003). Collagen fingerprinting research on mammal remains from Palaeocoastal sites provided species and family identifications on some of the earliest marine mammals hunted by people in the Americas, along with insights into the formation of novel ecosystems and the modern recovery of marine mammal (e.g., elephant seal) populations (Hofman et al., 2018).

Research at NCI shell middens has produced a ~12,000-year record of human interactions with nearshore marine ecosystems (Ainis et al., 2011; Braje et al., 2009; Erlandson et al., 2008, 2009, 2011; Glassow, 1993, 2015; Glassow et al., 2008; Rick et al., 2001). A CPT approach has produced faunal remains from scores of island sites (largely from 0.5 × 1 m, 1 × 1 m, and 1 × 2 m trenches along with 0.25 × 0.25 m column and bulk samples), where systematic radiocarbon dating and faunal analyses provide trans-Holocene perspectives on human-environmental interactions, including human impacts on ancient shellfish populations, fishing intensification, and modern sustainability and management (Braje et al., 2009, 2017, 2021; Erlandson et al., 2008). Many of these CPT projects were specifically designed to collect specimens for stable isotope reconstructions of past foodwebs, human-canid interactions and translocations, and other ongoing genetic and proteomic research (e.g., Braje et al., 2017; Hofman et al., 2016, 2018). Data gathered using similar CPT approaches has explored complex human environmental research questions, including spatial and temporal variability in marine climate conditions and their effects on the distribution and human harvest of red abalone (*Haliotis rufescens*), wavy top turban (*Megastraea undosa*), Pismo clam (*Tivela stultorum*), and a variety of estuarine shellfish (e.g., Erlandson et al., 2019; Glassow, 2015; Glassow et al., 2008; Jazwa et al., 2015; Perry and Hoppa, 2012; Thakar, 2011; Vellanoweth et al., 2006).

CPT research has provided key data on island plant communities and human landscape management through time. Archaeobotanical samples from test units and bulk soil samples (1 × 1 m and 1 × 2 m) have documented distinct strategies for targeting island plant communities. This includes an emphasis on *Brodiaea*-type corms and other geophytes, complemented by smaller amounts of other plants, but very limited evidence for acorns that were heavily used by mainland peoples (Gill, 2016; Gill and Hoppa, 2016). Geophytes were harvested for at least 11, 500 years on the NCI (Gill et al., 2021) and were a key component of complex land use and management strategies, contributing carbohydrates and other nutrients that supplement marine proteins (Gill et al., 2019a). Within this framework, new insights into plant harvesting and ancient economies helped fuel research that challenged the perceived marginality of the Channel Islands, suggesting instead that the islands sustained large populations of Chumash peoples for millennia (Gill et al., 2019b).

Small-scale testing on the Channel Islands has been instrumental in research on Island Chumash hunter-gatherer-fisher sociopolitical systems during the Late Holocene (Arnold, 1992, 2001; Kennett, 2005; Rick, 2007, 2011). Remote sensing and small-scale testing of archaeological house depressions, for instance, provided a low-impact and less invasive approach for investigating the changing social, economic, and political dynamics of Chumash society (Arnold et al., 1997). Isotope analysis, radiocarbon dating, and faunal data obtained from a CPT approach of column samples (0.25 × 0.25 m) and other small units on the NCI established a trans-Holocene perspective on Island Chumash social organization and ecology (Kennett, 2005). These and other projects also used survey, radiocarbon dating, and CPT methods to identify the location of named Chumash villages described in the ethnohistoric record (Arnold, 1990; Johnson, 2001; Kennett, 2005; Kennett et al., 2000; Rick, 2007, 2011). Finally, a CPT approach and extensive archaeological survey were used to build a framework for understanding 19th century Chinese fisheries and settlement on the Channel Islands (Braje, 2016).

Collectively, Channel Islands researchers have used CPT as an effective strategy to investigate a 13,000-year record of coastal hunter-gatherers and environmental change, exploring questions and datasets that would not have been possible if only a single or small number of large-scale excavations had been conducted. Future CPT research will be focused on obtaining archaeobotanical remains for genetic and other analyses, as well as faunal remains and artefacts to help disentangle human-environmental relationships, past and present, contributing to management strategies in an Anthropocene future (Braje et al., 2021).

4. Summary and conclusions

The CPT approach outlined here unifies traditional small-scale archaeological testing methods to develop regional datasets that help address important human-environmental research questions from the Pleistocene to the Anthropocene. As environmental change and threats to archaeological sites accelerate, CPT is an expedient approach that, when coupled with intensive chronology building and fine screen and bulk soil sampling, yields high resolution archaeobiological and geoarchaeological records ripe for further analysis using modern scientific methods. As archaeology continues to diversify and contribute to interdisciplinary analyses, CPT-based approaches are essential tools for broad sampling through space and time. In this context, CPT is an important framework for addressing a variety of significant issues on a rapidly changing planet.

Our examples from four distinct areas demonstrate the ways in which CPT-based approaches offer the potential to address a variety of archaeological and environmental issues. CPT-based approaches enable effective investigation of biodiversity change, species extinctions and extirpations, land use transformation, and climate change, as well as traditional archaeological questions around human social organization, trade and exchange systems, and settlement strategies through time. CPT approaches offer a number of key advantages and are often easier and more rapid to implement than large-scale projects. From a funding perspective, they allow multiple sites to be investigated and tested at a fraction of the cost of larger-scale excavations. They allow rapid testing of landscapes or regions, providing an important bridge between the data collected during surface surveys and large-scale excavation. The collection of novel environmental and cultural information from the areas we describe above would have never been possible with a focus on single sites or site complexes, attesting to the significance of CPT in archaeology and historical ecology. CPT approaches also allow flexible responses to heritage threats, enabling at least partial recording of threatened sites before they disappear (e.g., Davis et al., 2021). For sites that are not threatened, they leave most of the site intact for future study. In the context of a scientific framework in which methods are rapidly changing and developing, this preservation of intact deposits is particularly important.

A growing and important trend in archaeology is collaboration with Indigenous communities, including the co-production of knowledge as we work to disentangle the colonial foundation of archaeology (Douglass et al., 2019; Gonzalez et al., 2018; Marek-Martinez, 2021; McNiven, 2016). As several archaeologists have noted, low-impact archaeology, or the small-scale sampling of a CPT approach, is preferable to many Indigenous communities (Cannon, 2018; Gonzalez et al., 2018; Lightfoot, 2008; Sanchez et al., 2021). Combining CPT with Indigenous communities' values and targeting threatened or eroding sites further emphasizes the utility of the approach for integrating important research questions into an ethical and sustainable framework. Further adding to the support for CPT is using it as a tool to complement extant museum or legacy collections, providing a means to refine site chronologies and obtain high-resolution samples (St. Amand et al., 2020). With the rise of remote sensing techniques in archaeology, CPT also offers an expedient, low-impact strategy to work with even less invasive strategies of archaeological inquiry like ground penetrating radar, Light Detection and Ranging (LiDAR), and magnetometry (Davis and Douglass, 2020; Sanchez et al., 2021; Thompson et al., 2014). Similar to CPT, remote sensing approaches must be implemented in an ethical manner that is conducted in consultation with local and Indigenous communities (Davis and Sanger, 2021; Sanger and Barnett, 2021).

While we have highlighted examples of CPT in Africa, Asia, and North America, a number of archaeologists throughout the world have used field strategies consistent with a CPT program for their research or in cultural resource or heritage management work. For instance, augers, small test units, and other CPT techniques have long been used on the Northwest Coast of North America to examine a variety of coastal archaeological and historical ecological issues, including changes in marine fishing practices through time, ancient and modern plant communities, and the nature and formation of cultural keystone places (Armstrong and Turner, 2018; Cannon, 2000; Lepofsky et al., 2017; McKechnie, 2005; Moss et al., 2016; West et al., 2017). In northern

California, small-scale testing has been used effectively in collaborative archaeological projects focused on colonial encounters, fisheries, and a range of other topics (Gonzalez, 2016; Lightfoot, 2008; Sanchez et al., 2018). In the Chesapeake Bay region of eastern North America, 1 × 1 m and 1 × 2 m test units and column samples (0.25 × 0.25 m) in a number of shell middens have helped understand Late Holocene human oyster harvest and influence on nearshore shellfish communities, as well as sea level rise and other environmental change (Reeder-Myers et al., 2016). Work in Tierra del Fuego, South America is providing key insights into coastal archaeology and maritime adaptations in an important coastal region using small-scale testing at a variety of sites comparable to the CPT approach outlined here (Zangrando, 2010).

Outside of the Americas, small test units were excavated in southwestern Madagascar to characterize Late Holocene coastal lifeways and nearshore marine subsistence, with fish remains later being analysed for aDNA (Douglass et al., 2018; Grealy et al., 2016). Likewise, in the 1990s, at the early port town of Mahilaka in northwestern Madagascar (Radimilahy, 1998), a CPT approach combined coring with remote sensing to assess craft and domestic organization. Extensive trenching and column sampling at 15 shell middens on the Farasan Islands in the Red Sea produced insight into shell midden formation and associated human activities and environmental change (Hausmann et al., 2019). A CPT approach was also used to explore the diversity of agricultural practices and associated chronological issues at Kirinda and Kantharodai, two sites in Sri Lanka (Murphy et al., 2018). In the Wallacean islands between Southeast Asia and Australasia, CPT approaches with fine (<2 mm) mesh wet sieving established Pleistocene to Holocene occupation sequences in single seasons of investigation on archaeologically unexplored remote islands, documenting the earliest pelagic fishing, and use of ochre crayons, shell beads, shell fishhooks, and groundstone axe technology (O'Connor et al., 2011, 2017, 2019; Shipton et al., 2019, 2020a, 2020b). Similarly, a small-scale testing approach is being employed on Yap, Western Caroline Islands, to understand the broader history of human settlement (Napolitano et al., 2019). In Australia, small-scale testing and chronology building were used to investigate 5000 years of coastal settlement and archaeology in Queensland (Ulm, 2006). Archaeologists in Europe have also used a CPT approach, including important projects in the Mediterranean that investigated patterns in regional settlement and land use at a variety of scales (Attema et al., 2020; Barker, 1995). Despite the value of the approach for obtaining archaeological samples for research, including sophisticated scientific analyses, these studies have generally operated independent of one another without a broad recognition of the unified approach. CPT offers the framework to integrate these approaches and help validate the use of small-scale sampling to address a variety of research questions, alongside traditional large-scale excavations.

CPT-based approaches are not a panacea and should be seen as one component of the broad spectrum of approaches available for exploring the past. CPT has limited ability to answer some archaeological questions, including the identification of activity areas, horizontal diversity, structures, agricultural/defensive features, and other key issues relating to intra-site variability, site function, and past human activities (Fig. 2; Cannon, 2018; Flannery, 1976). Depending on how it is implemented, and at what scale, the CPT approach can also lead to shorter-term engagements with local communities, creating missed opportunities for dialogue and outreach, though this can be mediated through efforts on the part of the archaeological team. Also, problematic is that small-scale excavations can lead to small samples that may not produce statistically representative data, or do not yield insights into animal and plant remains or artefacts that are minor constituents or tend to be more widely distributed in sites (Banning, 2021; Fitzhugh et al., 2019; Lepofsky and Lertzman, 2005; Lyman, 2008). Such limitations can also plague large-scale projects, however, and need to be evaluated for each individual research project. Large-scale excavations are fundamental to archaeological research, but CPT offers a critical and complementary strategy in the 21st century archaeological toolbox.

Most scholars now agree that we are living in the Anthropocene, characterized by profound human influence on Earth's ecosystems, landscapes, and climate (Braje, 2015; Crutzen, 2002; Erlandson and Braje, 2013; Zalasiewicz et al., 2017). As the pace of anthropogenic environmental change accelerates, archaeologists are demonstrating widespread human influence on landscapes, biodiversity, and ecosystems spanning millennia, making archaeological data increasingly relevant for addressing contemporary crises and forecasting change (Boivin et al., 2016; Boivin and Crowther, 2021; Ellis et al., 2021; Fitzhugh et al., 2019; Rick and Sandweiss, 2020; Sabloff, 2008; Sandweiss and Kelley, 2012; Stephens et al., 2019). Anthropocene challenges also pose grave threats to archaeological and other heritage sites, with climate change destroying coastal and other sites, and urban sprawl, development, and conflict threatening cultural heritage around the world (Erlandson, 2008; Hanson, 2012; McGovern, 2018). Archaeological sites represent a finite resource (Surovell et al., 2017), with major implications for how we study and record cultural heritage in a rapidly changing world with numerous constraints and challenges. CPT offers an important strategy for investigating these contemporary environmental and other societal challenges and addressing research questions across the Pleistocene-Holocene-Anthropocene continuum.

Data availability

All data for this review article are available in the manuscript, citations, and supporting online information.

CRediT authorship contribution statement

Torben C. Rick: Formal analysis, Writing – original draft, conceived the study, performed research and analysis, wrote the paper, with input from all authors. **Abdullah M. Alsharekh:** Formal analysis, performed research and analysis. **Todd J. Braje:** Formal analysis, Writing – original draft, wrote the paper, with input from all authors, performed research and analysis. **Alison Crowther:** Formal analysis, Writing – original draft, conceived the study, wrote the paper, with input from all authors, performed research and analysis. **Jon M. Erlandson:** Formal analysis, performed research and analysis. **Dorian Q. Fuller:** Formal analysis, Writing – original draft, conceived the study, wrote the paper, with input from all authors, performed research and analysis. **Kristina M. Gill:** Formal analysis, performed research and analysis. **Huw S. Groucutt:** Formal analysis, performed research and analysis. **Maria Guagnin:** Formal analysis, performed research and analysis. **Richard Helm:** Formal analysis, performed research and analysis. **Courtney A. Hofman:** Formal analysis, performed research and analysis. **Mark Horton:** Formal analysis, performed research and analysis. **Andrea Kay:** Formal analysis, performed research and analysis. **Ravi Korisettar:** Formal analysis, performed research and analysis. **Chantal Radimilahy:** Formal analysis, performed research and analysis. **Leslie Reeder-Myers:** Formal analysis, performed research and analysis. **Ceri Shipton:** Formal analysis, performed research and analysis. **Henry T. Wright:** Formal analysis, performed research and analysis. **Michael Petraglia:** Formal analysis, Writing – original draft, conceived the study, wrote the paper, with input from all authors, performed research and analysis. **Nicole Boivin:** Formal analysis, Writing – original draft, conceived the study, performed research and analysis, wrote the paper, with input from all authors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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