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Coastal Prehistory and Submerged Landscapes: Molluscan Resources, Shell-Middens and Underwater Investigations

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Abstract
This Special Issue brings together fourteen articles that present new methods, ideas, and approaches in the study of coastal prehistory with examples drawn from the Americas, Australia, Europe, Saudi Arabia, and South Africa. In this introductory overview, we set out the rationale for combining articles on shell middens and submerged landscapes and the underlying logic of the order in which we have chosen to present the articles. The sequence begins with studies of marine molluscs and moves progressively outwards from small-scale studies of midden composition to large-scale studies of submerged landscapes, and from land to sea. We summarise the contents of each article and highlight connections between them and similarities and contrasts. We conclude with some final comments about the relationship between on-land and underwater investigations and identify the taphonomic, formational and deformational histories of archaeological deposits, materials and landscapes, and the variable impact of sea-level change as unifying themes.

Introduction
This Special Issue originates in two sessions of the UISPP Congress held in Paris in June 2018, one session entitled 'Shell Mounds, Shell Middens and Coastal Resources' the other entitled 'The Archaeology of Submerged Landscapes'. These sessions attracted over 40 papers from across the world including overviews, new sites and materials, new analytical techniques, and new and emerging themes of research. This collection comprises 14 articles, most selected from the original conference presentations and re-written for publication, together with a small number of additional articles specially commissioned to provide additional coverage in key areas. The articles are divided equally between the two overarching topics – coastal shell

middens and submerged landscapes – and represent the variety of approaches and world coverage of the original conference presentations, with contributions here from Australia, Europe, North America, Saudi Arabia, South Africa and South America.

In the past decade, there has been growing interest in both themes, marked by collected papers in special issues of journals or edited volumes. All fall predominantly under one theme or the other, concerned either with shell middens and coastal archaeology above modern sea level (Bailey et al., 2013; Balbo et al., 2011; Bjerck et al., 2016; Gutiérrez-Zugasti et al., 2016; Roksandic et al., 2014), or with the archaeology of submerged landscapes (Bailey et al., 2017, 2020a; Benjamin et al., 2011; Evans et al., 2014; Fischer and Pedersen, 2018; Flemming et al., 2014, 2017; Harff et al., 2016). In combining articles about both themes in one collection, our aim is to bring these two themes into a closer relationship. The aim of this introduction is to articulate the logic of how we have structured the collection, to summarise the key findings of each article, to highlight the interconnections between them, and to identify underlying similarities and contrasts.

At first sight coastal shell middens and submerged landscapes appear to have little in common. The techniques of investigation and the types of archaeological sites and materials discovered under water are very different from those on land. Despite the accelerating pace of submerged landscape archaeology in recent years and many thousands of finds recovered from drowned landscapes in Europe and North America, underwater shell middens are almost unknown, although a small number are now beginning to be discovered (Astrup et al., 2020, 2021; Cook Hale et al., 2018, 2021). Nevertheless, the principles unifying these apparently disparate themes are quite simple and revolve around two facts: the dominating impact of sea-level change throughout human history; and the relative attractions of coastal regions for human settlement and dispersal.

It is now widely recognised that sea levels have been lower than the present for about 95% of the Glacial-Interglacial cycle throughout the Middle and Upper Pleistocene. During the Last Glacial Maximum, sea-level dropped to −120 m 30,000 years ago and persisted at about that level for over 10,000 years, with a shorter episode of maximum lowering to −130 m at 20,000 years ago (Lambeck et al., 2014). The maximum area of land exposed on the continental shelf during this period is estimated at 22 million square kilometres around the world's coastlines (Dobson, 2014), equivalent to twice the area of the current European land mass between the Ural Mountains and the Atlantic Ocean. Between about 17,000 and 6,000 years ago, sea-level rise progressively drowned this vast territory.

It must follow that the limited information we currently have about human interest in coastlines and exploitation of marine resources during periods of lower sea level is a tiny and most likely highly biased fragment of the original pattern. Most of this earlier evidence is in caves and rockshelters on present-day coastlines that were far inland when sea levels were low. It must also follow that the huge increase in the number and size of shell middens from about 6000 years ago onwards reflects the increased visibility of shorelines associated with modern sea-level, rather than some world-wide evolutionary or socio-economic development. Other factors may also have been at work, such as human population growth and intensification in the use of marine resources. But these possibilities cannot be properly evaluated without addressing the overwhelming impact of differential site visibility because of sea-level rise.

The second point about sea-level rise is that it is not only past shorelines that are under

water, but very extensive areas of coastal territory, including low-lying hinterlands extending tens to hundreds of kilometres inland from their nearest coastline. Moreover, much of this land would have been relatively attractive to human settlement and dispersal because of more equable climate conditions, better water supplies, more productive ecological conditions for plants and animals, and easy pathways of movement, with or without the addition of marine foods at the coast edge. Today, around 13% of the world's population lives in coastal regions less than 10 m above sea level and two-thirds of the world's large cities are located within that zone, with an estimated 40% of the world's population within 100 km of the coast (McGranahan et al., 2007; UN, 2017). It is arguable that similar conditions applied to past populations regardless of time period, technology, or mode of subsistence, with the largest concentrations of population and the densest distribution of settlements in coastal regions, regions which before about 6000 years ago are now mostly under water.

It is not only human societies in the distant past and their material remains that were vulnerable to sea-level rise. We have become increasingly aware in the modern world of similar threats posed by global warming both to modern societies and their built environment and to archaeological sites and cultural heritage on the present-day coastline. The density of modern population in coastal zones has long been a cause for concern because of the impact of modern development on the archaeological record. Shell middens are in the frontline both because of their location in the way of road-construction and other building activities and because of the attractions of the shell deposits as raw material for modern uses (e.g., Camara et al., 2017; Ceci, 1984). To the pressure of modern development, we must now add the intensified pressure of sea-level rise and coastal erosion (Anderson et al., 2017). This theme creates an additional link between the investigation and interpretation of the coastal archaeological record above and below modern sea-level. In both cases there is growing awareness of the impact that differential preservation and visibility of deposits can have on interpretation and the need to evaluate what is exposed to discovery and survives, and what is likely to have been destroyed or buried. It is not only sea-level change and marine erosion that are at issue here, but also more subtle differentials such as the differences in visibility and vulnerability of archaeological coastal sites with shells, and those that lack shells. These issues provide a common thread throughout this special issue.

Overall structure

Our papers fall into five groupings and form a logical progression in the scale of investigation, ranging from the analysis of marine molluscs and micro-scale analysis of individual shell-midden deposits to the mapping of submerged landscapes , and moving progressively from dry land to the underwater zone.

The first pair of papers (García-Escárzaga and Gutiérrez-Zugasti, 2021, this volume; Hausmann et al., 2021, this volume) focus on the molluscs themselves, and on the question that is often the first to be posed in any study of shell middens, namely the role and significance of the marine molluscs as sources of food.

These lead on to a second group of five papers that examine shell middens as deposits and as sites in their wider social and environmental setting (Zangrando et al., 2021, this volume; Allely et al., 2021, this volume; Dupont and Marchand, 2021, this volume; Parkington et al., 2021, this volume; Ritchison et al., 2021, this volume). This is our largest grouping and provides

an intermediate link between micro-scale and macro-scale investigations, and between dry land and the offshore environment.

The third group comprises two papers that examine the interface between the onshore and the offshore record, namely the intertidal zone (Klokler et al., 2021, this volume; Hardy et al., 2021, this volume). This boundary zone does not lend itself easily to the standard techniques of pedestrian survey and terrestrial excavation because of limited periods of exposure at low tide, nor to the standard techniques of underwater investigation, many of which do not work well in shallow water. Yet intertidal zones are areas rich in easily collectable resources including food and raw materials for implements and ornaments and are likely to have been intensively used from the earliest period. Their investigation also provides immediate insights into processes of site formation, burial, or destruction as they are happening in real time. It must also be remembered that all sites and deposits on palaeoshorelines would have gone through an intertidal phase before full submergence, while many sites on the present day shoreline are occasionally exposed to marine processes such as storm surges or minor changes of relative sea level, leading to erosion or burial under marine sediment, and occasional mixing or interleaving of marine and terrestrial deposits.

Our fourth group moves fully into the underwater zone and comprises two papers, both of which focus on the investigation of fully submerged underwater sites, the methods used in their investigation and the nature and significance of the evidence they reveal (Momber et al., 2021, this volume; Beck et al., 2021, this volume).

Our fifth and final group includes three papers that examine the investigation of underwater landscapes (Missiaen et al., 2021, this volume; Wiseman et al., 2021, this volume; Tsakanikou et al., 2021, this volume). All three discuss methods of palaeogeographic mapping both as sources of information about the nature of the submerged landscape and environment in their region and its potential for human settlement and dispersal, and also as a means of identifying target areas to focus the search for archaeological sites.

Molluscs

García-Escárzaga and Gutiérrez-Zugasti (2021, this volume) demonstrate the wealth of information and inference about the role of molluscs as a food supply that can be extracted from archaeological shell middens with the benefit of control studies of modern molluscs, in this case measurements over a three-year period of variations in the meat-to-shell-weight ratio and size variation of rocky shore species, principally limpets (*Patella vulgata*, *P. depressa and P. ulyssiponensis*) and topshells (*Phorcus lineatus*). These are the dominant taxa in the archaeological deposits on the north Spanish coastline, a region that hosts some of the earliest and most numerous Mesolithic shell middens in Europe, all in small caves or rockshelters. The region has also been the focus of long-standing differences of opinion about the relative importance of the molluscs as food and the extent to which changes in the size and taxonomic representation of molluscan species are evidence of intensification as opposed to environmental change or changing proximity to the coastline with changes in sea level. The modern measurements combined with analysis of the shell midden in the cave of El Mazo, dating from 9000 to 7500 cal BP, provide new insights. The results demonstrate the tendency to under-represent the relative contribution of molluscs by reliance on MNI estimates of ungulate bone remains rather than NISP values, the distorting effect of using unequal volumes of deposit to

compare quantities of shells and bones, evidence of the effects of cooking on the estimation of meat yields, and the demonstration that the shift over time to molluscs that grow in the lower intertidal zone involved a shift to a less profitable source of food because of lower-meat-to-shell ratios, thus strengthening the case for intensification as a significant variable in the interpretation of time trends in these Spanish shell middens.

Hausmann et al. (2021, this volume) take up the theme of the role of the molluscs in the huge concentration of shell middens on the Farasan Islands of the southern Red Sea, accumulated between 7400 and 4800 cal BP. Here a single gastropod species, *Conomurex fasciatus*, is the dominant taxon. Like the previous paper, interest here is in finding evidence of human impact and possible intensification. Using a large data on variations in shell size from shell mounds in different locations, the authors show that there is no trend to size decrease over time. Rather, there are differences in shell size between different shorelines, which they demonstrate are linked to different ecological conditions for molluscan growth in different areas. Given the very large quantities of this species collected as food over many hundreds of years, the authors conclude that this is a resilient and reliable food resource, and one that would therefore have been of great importance in arid climates and for populations dispersing around the coastlines of the Arabian Peninsula during Pleistocene pulses of human expansion out of Africa.

Shell Middens

The first pair of articles in this group (Zangrando et al., 2021, this volume; Allely et al., 2021, this volume) examine in detail the internal structure, rates of accumulation, and processes of formation and deformation of individual deposits

These two articles have important points in common. Both are interested in unravelling the temporal dimension of shell deposits, that is the detail of how shell deposits accumulate taking account of such variables as re-use of surfaces, periodic cessation of shell deposition, variation in rates of accumulation within a single deposit, input of materials other than shells, and post-depositional degradation or other changes in composition. In short, they both treat shell middens as the composite outcome of a variety of anthropogenic, biogenic and geogenic processes. Both use a sedimentological approach, although they use the terms in slightly different ways. Both highlight rates of shell fragmentation as a significant and informative variable and illustrate different methods of measuring it. Both note the inadequacy of radiocarbon dates to capture these more subtle temporal variations, and the specific problem of using Bayesian analysis of multiple dates, namely that it assumes a linear rate of accumulation, an assumption which is demonstrably inappropriate for the deposits they analyse.

Zangrando et al. (2021, this volume) use what they describe as a tapho-chronometric approach to analyse bulk samples from a shell midden sequence at the site of Heshkaia 35 in Tierra del Fuego with a date range of 653–497 cal BP. They use different degrees of bone weathering as a relative chronological tool, and analysis of particle size (< 1 mm), organic content, and rates of shell fragmentation to unravel variations in rates of accumulation within the deposit. The results demonstrate a significant difference between the lower part of the deposit with a faster rate of accumulation than the upper deposit. As they point out, such variations can skew the quantitative comparison of shells and ungulate bones to estimate relative dietary contributions; a low rate of shell accumulation will bias the comparison in

favour of the ungulates, a high rate of shell accumulation the reverse, regardless of the original pattern. This amplifies issues of dietary analysis discussed by García-Escárzaga and Gutiérrez-Zugasti (2021, this volume).

Allely et al. (2021, this volume) use a similar approach in the comparative analysis of bulk samples from two shell mounds in widely different contexts, one in the Farasan Islands, the same group discussed earlier by Hausmann et al. (2021, this volume), and another in the Weipa group of shell mounds in the Cape York Peninsula of northern Australia. The comparison of such disparate examples is deliberate, intended to focus on the biotic and abiotic processes that influence the formation and deformation of deposits regardless of cultural context. For the authors, the unit of analysis is the individual clast rather than the mound, and involves the identification of all materials in the size range 1 mm to 90 mm The results demonstrate that a large proportion of the midden consists of materials other than shells, and that the rate of shell fragmentation varies through the deposits and between the two most common molluscan species *Marcia hiantina*, and *Tegillarca granosa*, with differential post-depositional movement of different-sized fragments through the stratigraphic column. The authors conclude that mounds are in a state of continuous transformation involving progressive accumulation, transformation and differential vertical movements of individual materials, and post-depositional alterations both during the use of the site and after its abandonment, including progressive degradation, compaction, and long-term shrinkage of the overall deposit.

These sedimentological approaches underline the fact that shell mounds are not fixed entities with variable properties that can be translated directly into variations in the behaviour of the people who created them. Rather, they are deposits subject to a variety of differential and ongoing formation and deformation processes that need to be understood before reliable behavioural and cultural inferences can be made. The limitation of these micro-scale analyses is that they are applied to bulk samples that represent only a tiny proportion of the deposit in an individual mound in areas with hundreds or even thousands of such sites. The time and labour required to apply such an approach to a larger comparative sample of sites and deposits would be considerable. Nevertheless, the taphonomic insights supplied by such micro-scale analyses have important implications for the interpretation of midden deposits and their contents at larger scales of investigation and highlight confounding variables that could compromise cultural and behavioural interpretations of intra-site and inter-site variability.

The second group of articles look at shell-midden deposits in a wider geographical and comparative setting. The first, by Dupont and Marchand (2021, this volume), examines the history of investigations at another of the classic Mesolithic shell-midden groups in Europe, the shell-midden 'necropolises' on the Atlantic coast of Brittany in north-west France. Though there are only 5 sites, and all are relatively small, they are famous for the detailed analyses of the human burials at the sites of Hoedic and Téviec almost a hundred years ago. The authors detail how interpretations have changed during the 20th century as preconceptions about Mesolithic coastal hunter-gatherers and developments in analytical methods and concepts have evolved. Recent excavations at the shell midden of Beg-er-Vil with a comprehensive sieving programme have revealed a large variety of exploited species including mammals, fish, birds, marine molluscs and other intertidal resources including crabs, and shells collected for ornamental purposes, with an emphasis on marine resources, most probably indicating year-round occupation.

The results also highlight some important conclusions about formation processes. The first is that the shell deposits are not a discrete site type but just one of a range of deposits forming a site complex that includes hearths, pits, human burials, and remains of dwelling structures. Another significant fact is that the sites owe their preservation largely to burial under a protective capping of dune sand and that they have been exposed to discovery, and in some cases destroyed, by marine erosion, leading to speculation about how many more sites may have been lost because of erosion of the present shoreline, to say nothing of sites on now-submerged palaeoshorelines. A third point is that some of these shell deposits are in a fragile state of equilibrium because of high levels of acidity, which is causing progressive loss of shell material, a process of 'self-digestion' as the authors put it, which recalls the conclusions of Allely et al. (2021, this volume) about long-term processes of post-depositional alteration and degradation.

Turning to broader comparative studies of shell midden distributions, Parkington et al. (2021, this volume) examine the shell middens on the Cape coast of South Africa, and specifically the phenomenon of 'megamiddens'. Shell middens occur throughout the Holocene period in this region but the megamiddens form a distinctive episode between 3000 and 2000 cal BP. The sites are unusually large, up to 10,000 m^3, and relatively few, dominated by a single mollusc species, the black mussel (*Choromytilus meridionalis*), with a limited content of other cultural or faunal material. Using a transport-distance model that takes account of the high shell-to-meat-weight ratio of live molluscs, the authors interpret the megamiddens as specialised processing sites located on the immediate shoreline to heat the mussels, remove the shells and dry the meat for transportation and consumption elsewhere and at other times. They support this interpretation through comparison of cultural contents with other types of midden deposits from earlier and later periods and stable isotope palaeodietary analysis of human remains. Similar patterns have been identified in other parts of the world, in the Farasan Islands of the Red Sea (Hausmann et al., 2019), and in the Saloum Delta of West Africa (Hardy et al., 2016).

The authors suggest that the limited time depth of the megamiddens may be related to minor changes in relative sea level that created a short-lived 'window of opportunity', exposing unusually extensive intertidal rocky platforms – the preferred habitat of the black mussel – and therefore great potential abundance of mussels that both facilitated and demanded mass processing on the shoreline. Changes in the socio-economic configuration of settlement and land use in response to other factors could also be involved. Others, notably Jerardino (2012), have drawn attention to greater variety in the contents of middens during the 'megamidden millennium' and advocated the alternative hypothesis that the megamiddens are evidence for an episode of human population growth and resource intensification (see also Jerardino (2020), and Parkington et al. (2020), for further comment on these alternatives).

Ritchison et al. (2021, this volume) address similar issues with respect to the differential distribution of shell-ring deposits on the SE Atlantic coastline of Georgia during the Late Archaic period. These are some of the largest and spatially most complex shell-mound deposits in North America. They date between 5000 and 3800 cal BP and represent the earliest villages in the eastern woodlands of the USA, with evidence of year-round occupation associated with communal feasting. However, they appear to have been abandoned after 3800 cal BP, which has been attributed to a minor drop in sea level causing reduction in the supply of oysters (*Crassostrea virginica*), the principal source of mollusc food, though non-shell-bearing sites

persisted into this later period. Using test excavations at a range of sites and the density of ceramics as a proxy for settlement intensity, the authors show that the non-shell-bearing sites, though indicating slightly lower settlement intensity, have similar spatial complexity to the shell-ring sites, and other evidence showing the continuity of ceremonial feasting adapted to the different ecological conditions in this later period.

An interesting point to emerge from this analysis is the tendency for large shell mounds to attract disproportionate interest and socioeconomic significance in interpretation because of their high visibility in the landscape. This underlines the point made by other authors in this section, that shell middens are not necessarily a discrete and distinctive type of deposit or site, but rather one element in a range of deposits that vary in the amount of shells present, a range of variation that does not correlate in any simple manner with cultural or socioeconomic variables. A second point is the potential significance of changes in coastal geomorphology that alter the availability or abundance of the mollusc supply, recalling the situation proposed by Parkington et al. (2021, this volume). An additional variable in the Georgia case is that a subsequent slight rise in sea level may have added an additional confounding variable because of differential erosion or submergence of sites on some stretches of the coastline (see also Cook Hale et al. (2021)).

Intertidal archaeology

Brazil is famous for its *sambaquis*, massive shell mounds located mostly in the south of the country. These include some of the largest shell mounds by height and volume known anywhere in the world and have attracted the greatest archaeological attention (Gaspar et al., 2008). Klokler et al. (2021, this volume) turn attention to the north-east coastline of Brazil where shell middens are fewer and smaller in size, a difference generally attributed to greater levels of site destruction and fewer available molluscs. Their particular focus is a stretch of coastline with coastal sites dating to the 16th and 17th centuries AD. The first is Saco da Pedra, which may also have an earlier 2000-year-old component. It consists partly of an intact shell midden deposit and partly of re-deposited material in the intertidal zone. The second site, Cunhambebe, of similar date, is known only from re-deposited material in the intertidal zone. The erosion of these sites reflects a dynamic coastline undergoing rapid geomorphological change, with erosion exacerbated in the case of Saco da Pedra by nearby building construction.

Despite the evidence of disturbance and destruction, these sites provide important additional data that would not otherwise be available, including ceramics that link these sites to traditions in the Amazonian hinterland and further south along the Brazilian coast and to movements of peoples between these different regions. More dramatically, the substantial erosion of Saco da Pedra has exposed evidence of a ‘workshop’ for producing shell artefacts, the first of its kind in Brazil, with the artefacts made from the goliath conch (*Labaturs goliath*), a large gastropod. Other finds of partially or fully submerged shell-midden deposits have been reported elsewhere along the Brazilian coastline, and the results from the two intertidal sites reported here focus attention on the need to explore more fully the offshore and underwater landscape.

Hardy et al. (2021, this volume) describe work on the shorelines of north-west Scotland, mostly in locations that are offshore islands today. The interaction between isostatic uplift and global sea-level rise has produced a complex and quite localised pattern of variations in relative

sea-level in this region, with some early shorelines of Late Glacial date above present sea level and other shorelines and extensive areas of land now submerged. Existing sites at Lussa Bay, Clachan Harbour and Lub Dubh Aird comprise many hundreds of worked lithics on beaches or in intertidal settings. Many show evidence of water-rolling and disturbance. Nevertheless, some could be of Late Glacial date according to typological criteria and are therefore of great potential importance as evidence for earliest human entry into Scotland, and therefore of earliest human expansion to the north-western limits of continental Europe. Two new discoveries on the Isle of Skye are an assemblage of worked lithics in sharp condition found beneath raised cobble-beach deposits at South Cuidrach, and circular stone structures in the lower intertidal zone at Sconser. Both are scheduled for more detailed investigation.

These finds are mostly the result of chance discoveries, sometimes because of temporary exposure by marine erosion of material previously sealed and protected beneath marine sediment. Projects in the wider region based on predictive modelling of likely underwater locations for preservation of archaeological material using bathymetry and palaeogeographic reconstructions of the submerged landscape have so far failed to discover any sites. The authors suggest that monitoring of beaches and intertidal zones for exposure of lithic artefacts may be a more productive clue to the location of offshore sites in deeper water, since water-rolled artefacts could have been disturbed and washed ashore from more deeply submerged locations nearby.

Both these articles demonstrate the insights that can be gained from intertidal and shore-edge material into what might happen to archaeological deposits exposed to erosion on a shoreline undergoing inundation by sea-level rise, with dispersal and redeposition of some deposits and protection of others. Both show that despite these disturbances and destructive tendencies, the resulting material has the potential to provide new types of evidence. More importantly, these intertidal studies focus on the offshore landscape and the probability of finding more materials from earlier periods and at greater depth. They also highlight the value of pedestrian surveys of shorelines for clues of a similar nature. In many parts of the world, there are thousands of kilometres of shoreline yet to be surveyed with an archaeological eye. Continuous monitoring with repeat visits over a period of years to promising intertidal localities is also likely to be necessary and to prove rewarding, given the episodic nature of burial and exposure of material on the shoreline. Many of the most famous underwater sites in Europe were first brought to the attention of archaeologists because of finds periodically exposed and observed at low tide, thanks to repeated visits over a period of years, notably in Israel (Galili et al., 1993, 2020) and Denmark (Astrup et al., 2021; Bailey et al., 2020b).

Underwater Sites

The two articles in this section move more fully into the underwater zone and to more detailed methods of underwater investigation and the nature of preservation at underwater sites. Momber et al. (2021, this volume) provide an update on the well-known Mesolithic site of Bouldnor Cliff. The site was originally discovered over 20 years ago when divers, following up on stone tools dredged up by a local fisherman, explored the seabed offshore of the Isle of Wight in southern England and noticed artefacts eroding out of an underwater cliff where submarine currents were cutting a channel into a bench of submerged peat. Since then, continued submarine erosion together with underwater excavation by divers has generated a large body

of material 12 m below present sea level and dated to about 8000 cal BP. The finds include flint artefacts and an unusual collection of organic materials including a large assemblage of worked wood, interpreted by the authors as the remains of wooden platform-like structures and perhaps evidence for boat construction, cordage made from twisted plant fibres, and DNA traces of cultivated wheat in a sealed sedimentary context.

Like the famous underwater sites of Denmark and Germany, the Bouldnor finds do not represent a settlement area of domestic activities and dwellings as conventionally understood, but rather the remains of activities carried out at the shore edge where some materials from settlements on dry land have been discarded into adjacent shallow water with soft bottom sediments, and rapidly encased in anaerobic conditions (Bailey et al., 2020b; Joens et al., 2020). The Bouldnor finds push back in time the earliest evidence for wood-working techniques and the presence of cultivated wheat in England to dates over 2000 years earlier than previously recognised. They also indicate seaborne connections along coastlines and waterways with the European mainland before Britain was finally separated from the continent by sea-level rise. The authors also suggest that submerged peat with sections exposed by submarine channels is the type of deposit which might offer the best prospects for the discovery of similar archaeological materials at greater depth and further offshore in the North Sea.

Beck et al. (2021, this volume) re-visit the pioneering work carried out in the 1970s and 1980s in the Bay of Kiladha in southern Greece, offshore of the Franchthi Cave with its well-known sequence of Upper Palaeolithic, Mesolithic, and Neolithic remains. As often, interest in the offshore landscape was originally prompted by remains on the shoreline, in this case remains of stone structures at the foot of the cave. This in its turn stimulated acoustic survey to map the submerged landscape and coring of offshore sediments. The results produced a wealth of information about the topography of the palaeolandscape and the changing configuration of palaeoshorelines and molluscan habitats with rising sea level. The cores revealed evidence of Neolithic cultural and ecofactual remains in several localities, preserved under 1.5–6 m of marine sediment in water depths of 3–10 m a few hundred metres offshore. These investigations were well ahead of their time, and there was no follow up until new work resumed with the present team in 2012.

Using improved remote sensing techniques, gravity cores, percussion-driven piston cores that reached a maximum depth of ca. 6 m below the seabed, and diver-based underwater excavations, the authors have produced a more detailed reconstruction of the submerged topography in the Bay and recovered new evidence of cultural remains from five of the cored localities, indicating at least two new areas of probable underwater Neolithic settlement. They also identified and excavated remains of a substantial walled Bronze Age structure in shallow water close inshore that had not previously been identified. Of particular interest is the amount of cultural material including diagnostic potsherds recovered from narrow-diameter cores and the number of localities where coring revealed such evidence. The new work used high-resolution bathymetry and sub-bottom profiling for improved maps of the seabed and subsurface sediments respectively. An innovative feature was the use of electrical resistivity tomography, capable of providing high resolution imagery of subsurface sediment layers and rectilinear anomalies clearly indicating traces of stone structures. This article introduces techniques of remote sensing more extensively deployed in the final group of articles.

Submerged landscapes

The first article in this group by Missiaen et al. (2021, this volume) discusses new investigations in the North Sea, a region famous for creating the term 'Doggerland', named after the Dogger Bank in the central North Sea basin (Coles, 1998). The North Sea has also witnessed very significant underwater discoveries during the past decade or so, notably reconstructions of late Pleistocene and early Holocene submerged landscapes using 3D seismic data collected by the hydro-carbon industry (Gaffney et al., 2007, 2009), the discovery of underwater Mesolithic sites during expansion of the Port of Rotterdam (Moree and Sier, 2015), and the recovery of Middle Palaeolithic flint artefacts at least 200,000 years old, fauna and palaeoenvironmental data in stratified and dateable sediments, 18–35 m beneath modern sea level at the A240 site, following recovery of a hand axe by commercial gravel extraction (Tizzard et al., 2014, 2015). These projects highlight the results that are possible in collaboration with offshore industries. New work with dedicated research vessels and equipment is now being carried out in the Dogger Bank region (Gaffney et al., 2017; Hepp et al., 2017).

This article examines the Brown Bank, one of several areas in the southern sector of the North Sea that have generated large quantities of Pleistocene fauna, flint artefacts and occasional human remains dredged up by trawler fishing over many decades. Brown Bank is now 85 km offshore of the English coast and some 20 m below sea level. Originally it would have formed a low hill surrounded by alluvial plains and marshes.

The study reported here is a good example of the techniques and technologies involved in the use of fully crewed research vessels suitable for offshore work in deeper water. In this case, the team used different types of acoustic equipment, vibrocorers capable of recovering cores of sediment as much as 4 m long from seabed deposits, and the use of a dredge for grab samples. Abundant evidence of charcoal, wood and unworked flint was recovered from peat layers dating to 9980 cal BP, and actual worked flints were recovered by dredging in an area further to the north. One technical point brought out clearly by this study is the trade-off between depth of penetration and spatial resolution in the use of acoustic signals of different frequencies to probe beneath the seabed surface. The best results with decimetre resolution were achieved with ultra-high-resolution frequencies in the upper few metres of deposits on the seabed, whereas lower resolution frequencies with greater depth penetration are useful for broader-scale survey. Another point emphasised in the results is the attractions of peat deposits as likely targets for recovering cultural material, especially where they have been partially exposed by channel erosion, recalling the context of the Bouldnor finds.

Wiseman et al. (2021, this volume) examine a very different situation in Australia. Unlike Europe, there is no pre-existing body of underwater finds, and no tradition of underwater archaeology apart from the investigation of shipwrecks and other features of the European era. Moreover, large areas of continental shelf, notably in the project region, are sediment-starved, unlike the North Sea, which is a sediment sink because of the large rivers draining into it. Finds on the seabed are therefore likely to be lag deposits with stone artefacts sitting on the surface, posing considerable challenges for dating and reconstruction of palaeoenvironmental context. On the credit side, there are coastal caves on offshore islands in the region with long sequences (Veth et al., 2007, 2017). Like coastal caves in other parts of the world, including the Franchthi Cave discussed earlier, the cultural sequences extend back into the early Holocene and late Pleistocene with clear evidence for the use of the now submerged landscape and a progressive

increase in marine indicators as sea-level rose and the shoreline moved progressively closer.

The approach adopted is based on two lines of enquiry: a qualitative predictive model using archaeological sites on the present-day land surface and their geomorphological associations to create expectations about likely underwater features and preservation conditions; and a multi-scalar approach to the reconstruction of the submerged land surface, using a combination of open-source satellite imagery, LiDAR, local acoustic and bathymetric survey, drop cameras, drone photography, and diver investigation of specific features. The use of bathymetric and topographic LiDAR is a notable innovation, providing a rapid and seamless digital elevation map over large areas across the land-sea boundary to water depths of 10 m.

The result was the discovery of a number of promising features of potential cultural significance, two of which comprised stone tools, one associated with a former freshwater spring at a depth of 14 m below present sea level, the other a large collection of stone artefacts in the shallow subtidal zone. So far, only minimum dates can be assigned, based on the date when the sites were finally covered by sea level rise. The project provides a good example of an integrated approach to landscape mapping and purposeful archaeological site survey, rewarded by the successful discovery of archaeological material. This 'Australian model' as the authors describe it clearly has great promise for future investigations in the project region, for other coastlines in Australia and beyond, and for investigation of more deeply submerged areas.

The final article by Tsakanikou et al. (2021, this volume) moves out onto the largest geographical scale, looking at the Aegean Basin as a whole. This is an important zone for hominin dispersals between Africa, the near East and Europe. It has also been the focus of claims for very early examples of seafaring ability (Ammerman and Davis, 2013, 2014). Today, this is a marine basin dotted with numerous islands. However, the tectonic history of the region has resulted in long-term subsidence, which has amplified the effects of eustatic sea-level rise in drowning very extensive areas of previously exposed territory. In earlier periods of Pleistocene low sea-level, the Aegean Basin was virtually a continuous land mass dotted with lakes and traversed by rivers. As a side effect, it is worth noting that these dramatic changes in palaeogeography would have substantially reduced or removed sea-distances between islands and their nearest continental land mass, with obvious implications for the assessment of early seafaring abilities.

The authors draw attention to the significance of this region as an attractive terrestrial landscape for settlement and offering easy pathways of population dispersal between Asia and Europe, especially during earlier periods of the Pleistocene. Their approach uses broad-scale information on bathymetry and geology, and concepts of complex topography and methods of measuring topographic roughness, to give greater precision to maps that identify potentially attractive regions for large mammals and their human hunters and pathways of dispersal at different periods of the Pleistocene and different stages of the sea-level cycle. A 'suitability model' drawing on these sources is developed with a particular emphasis on water resources and outcrops of volcanic rocks as sources of raw material for stone-tool manufacture. The results suggest at least two trans-Aegean corridors of dispersal as well as more attractive opportunities for settlement and dispersal around the edges of the Basin when more land was exposed than today. By defining potentially attractive target regions, the method provides a first step towards identifying smaller target areas for more focussed investigation with higher resolution methods of survey and landscape reconstruction.

These three articles, together with the work of Beck et al. (2021, this volume) in the previous section, provide a useful illustration of the range of concepts, techniques, and technologies currently in use in underwater investigations. They also illustrate the relationship between the geographical scale of investigation and the resolution of the results. The Brown Bank study covered the smallest area, approximately 100 km^2, and was able to deploy remote sensing methods of very high resolution, resulting in detailed identification of environmental features and their localised distribution and discovery of archaeological material. The Western Australia case study began initially with an area of 1200 km^2, though investigation stepped down to more localised areas as the survey work progressed, ultimately recovering individual artefacts from underwater locations. The Aegean case study is concerned with an area of 200,000 km^2, and discovery of archaeological sites was not expected or realised at this scale. Each of these scales offers different opportunities for investigation, addresses different questions, and requires different approaches and techniques. All are contributing new knowledge about human landscapes that are now submerged, and all have resulted in the discovery of new underwater archaeological sites or provided the framework for future discoveries.

Conclusion

The articles in this Special Issue highlight the range of new methods, issues and ideas that are now being applied to the archaeology of coastlines both above and below modern sea-level. What of the connections between these two realms of investigation?

On the landward side, investigation has the advantage of a long history of study, large numbers of shell middens with all the advantages they offer of easy visibility in the landscape, easy accessibility, and relatively good conditions for the preservation of dateable sequences of cultural and bioarchaeological data. They also offer opportunities for comparative analysis of site locations and contents, including coastal sites that lack shells, and the investigation and interpretation of socioeconomic trends in subsistence and settlement mobility. Underwater investigation is at a much earlier stage of development, and that is obvious both from the smaller number of underwater finds and sites so far discovered, the slower pace of underwater survey and site discovery, and its more elaborate technical requirements. Nevertheless, new underwater sites are now being found through purposeful survey, together with increasingly detailed reconstructions of the wider palaeoenvironmental and palaeolandscape context. The steady accumulation of new discoveries is not only demonstrating human presence on the continental shelf in areas that were previously a blank on the archaeological distribution map. They are also producing new types of evidence, such as organic remains and woodworking techniques of a type not recovered on terrestrial sites or only at later dates. Underwater shell middens, however, are rare or elusive, and underwater investigations more generally have so far yielded relatively little data with which to pursue more detailed questions about subsistence economy, social organisation, or other aspects of cultural life.

We identify two themes that stand out as being of significance across the boundary between on-land and underwater investigations. The first is the question of formation processes and the taphonomic history of archaeological deposits. Since the foundational literature that established these concepts in archaeological discourse (e.g., Schiffer, 1987; Lyman, 1994), investigations have broadened out to embrace all the conditions that determine the differential

accumulation, preservation, degradation, disturbance, visibility or destruction of archaeological sites and their contents. The nature of these conditions and their potential confounding effects on interpretation is a recurrent theme throughout this Special Issue, and the effects can range from changes in individual fragments of shell and sediment particles within midden deposits at the microscopic end of the scale, to changes in the preservation and visibility of archaeological deposits and landscape features in response to large-scale geomorphological changes at the macro-scale. Moreover, these processes typically involve both natural and cultural behaviours that are difficult to disentangle. Shell middens are a good example of this. The dominant physical constituent of the depositional matrix in shell middens is shells, which are natural objects, and their abundance is determined ultimately by ecological conditions. But the reasons why they accumulate in greater numbers and at a faster rate in some places and at some periods than others are a matter of cultural behaviour. A sedimentary matrix consisting of soil particles, typical of so many other types of archaeological deposits, often accumulates more slowly than the deposition of artefacts and food remains, resulting in 'time-averaged' assemblages. In shell middens, we often see the reverse effect, with the shells accumulating more rapidly than the artefacts or the faunal remains, leading to distortions in interpretation that need to be corrected for.

On the question of site visibility and destruction, it is generally assumed that disturbance or destruction is far worse under water than on land. But that is questionable. Sites on dry land are equally vulnerable to disturbance, burial, or erosion by climatically or tectonically induced processes of soil erosion, while the imprint of human land use and industrial development is probably much greater. One only has to think of the number of shell mounds on land that are known to have been destroyed by quarrying, agricultural activity or building construction. Equally, as on land, so under water, erosion is a finely balanced process including effects that may be both beneficial and destructive. On the one hand, erosion produces marine sediments that can bury archaeological deposits and thus remove them from view, but this also protects them. On the other hand, erosion can disturb and destroy, but the process of erosion, at least initially, exposes archaeological material to discovery. It is perhaps more obvious when working under water that a great deal has been disturbed or destroyed, but there are also high spots of unusual organic preservation in waterlogged sediments. These processes need to be investigated and incorporated into survey strategies and interpretations just as much on land as under water.

The second issue is the impact of sea-level change. That impact is, in the first place, the potentially destructive impact on archaeological sites because of marine erosion during and after inundation by sea-level rise. But that impact is increasingly relevant to archaeological material on the present-day coastline because of coastal erosion and renewed sea-level rise that is happening today and projected to continue in the coming century. The other impact of sea-level change is its impact on past populations, and that includes not only the increased pressure on space and resources when sea-level rose and drowned formerly inhabited landscapes, but also the opportunities for expansion into new territory afforded by exposure of new land when sea level retreated. These are questions of fundamental importance and interest to the understanding of the archaeological record and the interpretation of long-term trajectories of socioeconomic and evolutionary change. Answering them will require new information that integrates archaeological investigations both on land and under water.

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