Submarine prehistoric archaeology enables us to discover how early man lived on the continental shelf during the Pleistocene Ice Ages, when the eustatic sea level dropped to more than 100 m lower than now. The archaeologists have found the remains of hominid and modern human occupation, including stone tools, bones, fireplaces, food remains, and cut timbers from 5000 to 1 million years old off the coasts of South Africa, Japan, Australia, North America, and many European countries. The spread of humanity throughout the globe has been influenced by the exploitation of the continental shelf during glacial phases, by the use of coastal food resources, and by the effect of changed migration routes, connected land masses, or channels which were easier to cross. Archaeologists using data from the study of DNA of modern populations have proposed that people crossed the southern Red Sea from Eritrea to the Arabian peninsula about 100,000 years ago, and then spread throughout southern Asia to Australia, migrating most rapidly along the coast, that is, along the now submerged continental shelf. The archaeological evidence to support this theory is very thin. The only way that the theory can be proved or disproved on the ground is if we can find evidence of Anatomically Modern Humans (AMH) on the continental shelf, either on the shelves of the southern Red Sea, or around Yemen and Oman, or the coast of India.

The archaeology and palaeo-anthropology of human evolution during the last four million years has been described by many competent authors, but I will refer here to only one modern textbook\(^1\) which provides a convenient overview in one set of covers. From this magisterial summary of the process we can see that the continental shelf played an acknowledged role in human and hominid expansion in Africa, and onward to Asia and Australia. However, Klein also says, ‘the boats they used probably perished long ago and in any case the sites where remnants might persist are now inaccessible on the drowned continental shelves of Sunda and Sahul\(^2\). This assumption that submerged prehistoric remains were (a) probably destroyed by the forces of the rising post-glacial marine transgression; and (b) even if they survived marine transgression we cannot find them; and (c) even if they were found we could not study them, is prevalent in all textbooks and monographs on prehistoric archaeology. In fact I have never found a standard textbook, which took any other view. This is unfortunate, because students and professionals starting a career in archaeology are being given a false impression of an important aspect of prehistory.

Some major specialist books have addressed marine aspects of human dispersal and the use of the coast\(^3^–^8\). Clottes and Courtin\(^9\) discussed in detail the artistic features of the cave known as the Grotte Cosquer, which can only be entered through a submerged cavern with its entrance at a depth of 40 m below sea level, and shows an exquisite reconstruction of the landscape of the continental shelf outside the cave at low sea level, but curiously do not consider the way of life of the people who were living on the continental shelf at that time. The consistent source of information on the progress of submarine prehistory in the last 30 years is through specialist academic papers and articles, which are scattered throughout the journal literature, and which have not filtered through to the mainstream textbooks.

In this article I will try to summarize very briefly the massive evidence which has been accumulated over the last 30 years, which shows that thousands of prehistoric settlement and occupation sites do exist on the continental shelves all over the world; that it is possible to find and study submerged prehistoric sites as carefully as if they were on land; and finally to look at the key situation of the Indian continental shelf as a component of this new area of research.

The scope of submarine prehistory

The successive glacial cycles of the last one million years have each had a duration of the order of 120,000 years (120 ky), and the associated glacio-eustatic amplitude of sea level change has been of the order\(^9^–^11\) of 100–150 m. Prior to one million years BP the fluctuations were more frequent but with a smaller amplitude.

Throughout the last million years, plants, animals, and people who lived on the coast were living on what we now call the continental shelf, and they migrated slowly towards the edge of the shelf when the sea dropped, and retreated back to the present shoreline at each inter-glacial maximum high sea level. Since this cycle of expansion and retreat took over 100 ky, the people concerned were not in any way conscious of a ‘migration’ within one generation. The duration of the high sea level turning point

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was, in each case, a very few tens of thousands of years. Thus, for the last million years, 80–90% of the evidence for people living on the coast is submerged below present sea level. The archaeological record on land shows almost no trace of early peoples exploiting the sea, collecting shellfish, catching fish, or building boats. The significance of this missing data is discussed by Bailey.\textsuperscript{12} Only occasionally do we find some hints that people were exploiting marine resources, usually in caves on steep coasts where people were bringing their food up the steep slope from the shore which was quite closely in terms of horizontal distance, and then only during the short interglacial still-stands.

The great majority of early shell midden sites showing consumption of shellfish date after 6000 yrs BP, when the sea level was rising rapidly and was already close to present level. Earlier than that the data are lost and yet it has been known since the 1960s that the first human occupants of Australia arrived there at least 30 ky BP, and that they had to cross many sea channels of tens of km width\textsuperscript{11} to reach Australia. Modern dating of Australian sites shows that people were in Australia at least 50–60 ky BP\textsuperscript{1}, and the only way they could have traversed the sea channels was by using sufficiently sophisticated floating craft to carry many tens of people within the space of a few years. A breeding population of the order 100–200 people is needed to ensure a continuous growth in population, which can be stable against the threats of predators, disease, drought, and bad hunting seasons\textsuperscript{14}. If people could make such crossings 50–60 ky BP, then they could probably make smaller crossings of 2–10 km many thousands of years before that.

The extent to which hominin artefacts can survive in sedimentary context on the continental shelf is demonstrated off the coast of Table Bay, South Africa\textsuperscript{15} (Figure 1) where three Acheulean hand axes were found in depths of 7–8 m. The hand axes were embedded in oxidised soil resting on bedrock, and covered by a metre or more of marine sand. This find suggests that hominin artefacts can survive multiple marine transgressions over a timescale of the order of 500 ky. In the southern North Sea fishermen have dredged up bones of early Pleistocene mammal fauna showing that such materials can survive multiple marine transgressions\textsuperscript{16}. These two sites demonstrate that materials related to hominin activity and the animals which formed the food source for early hominids, both existed on the continental shelf, and can survive marine transgression in certain circumstances.

The great majority of submarine finds of palaeontological materials and prehistoric archaeological artefacts are restricted to the last glacial cycle, that is, the last 120 ky. Artefacts \textit{in situ} dating from 45 ky BP have been found at a depth of 20 m off the North coast of France\textsuperscript{17}, and off Corfu, in a depth of 5 m\textsuperscript{18}. The Grotte Cosquer, with an entrance 40 m below sea level, has dates of occupation between 21 ky and 17 ky BP\textsuperscript{7}. For dates younger than this, many hundreds of sites have been found under the sea\textsuperscript{19–22}, and some will be described later.

The usual concept of hominin diffusion (\textit{Homo erectus}, \textit{Homo heidelbergensis}, \textit{Homo neanderthalensis}, and \textit{Homo sapiens}) out of Africa and into Europe and Asia during the last million years implies a land route through the Sinai into the Arabian Peninsula and the Levant. Tool-making hominids had reached Mount Carmel in Israel and Dmanisi in Georgia, close to the Black Sea, more than one million years ago. It is usually assumed that if marine crossings did take place, they were restricted to Anatomically Modern Humans (AMH) during the last few tens of thousands of years (ky). However, the distribution of the Acheulean hand-axe tradition and the east and central Asian tradition of Chopper or Flake- and Chopper traditions (Figure 2) shows the Acheulean tools distributed far north through Spain into France, in Italy, and eastwards into Arabia and India. The Movius line in north India, and the boundary through Eastern Europe, does not look like dispersal exclusively across the Sinai. Rather, it looks as if there has been contact across the Straits of Gibraltar and possibly from Tunisia into Sicily and Italy. Figure 2

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Three Acheulean hand axes found under the sea at a depth of 8 m in Table Bay Cape Town, South Africa. The artefacts are between 300,000 and 1.2 million years old. The artefacts were found by Bruno Werz. See Werz and Flemming\textsuperscript{19}.}
\end{figure}
shows the boundary at roughly 500 ky BP. Another alternative to the localized short bursts of migration through Sinai alone is the possibility of multiple smaller crossings with interfaces and two-way crossings23. While there is no doubt about the major broad implications of the successive out-of-Africa migrations, the details are greatly influenced by the possibility of multiple routes.

This idea was first proposed by Alimen24 who studied the distribution of Acheulean tools, and also examined the detailed bathymetry of the straits of Gibraltar and Sicily to check the feasibility of crossing routes. Many other scholars25–27 expressed similar concepts, but none of these authors considered the possibility of searching for and studying submerged prehistoric sites, which might provide supporting data. Circumstantial data continue to accumulate slowly, such as the recent discovery of Acheulean tools in caves in Gibraltar (Finlayson, pers. commun., 2003), and the discovery of hominid footprints in volcanic ash about 380,000 years old in southern Italy28. A large quantity of supporting evidence has been brought to light from submerged prehistoric sites in Gibraltar, France, Italy, Greece, and Israel29 to show how such material can contribute to the thesis that people lived on the continental shelf at all low sea level periods, and that they were capable of crossing narrow sea straits hundreds of thousands of years ago (Figure 3). The thesis is not yet proven to reliable scientific standards, but several teams of researchers within the UK project ‘Environmental Factors in the Chronology of Human Evolution and Dispersal’ (EFCHED) are studying different components of the problem (Figure 4).

In northern Europe the timescales of interest vary from considereation of the first hominid occupation of Britain at about 700 ky BP, through to the last human diffusion after the last glaciation when tribes skilled in fishing and hunting spread across what is now the floor of the North Sea, and expanded into Scandinavia, Britain and Russia26,21,22,20–33 between 12 and 6 ky BP. Thousands of Mesolithic settlements have been discovered by the archaeologists on the floor of the Baltic, containing hearths, fish weirs, canoes, burials, flint-knapping sites, flint tools, and artefacts of bone, wood, and antlers. The data are sufficiently robust to determine the population and age structure of communities, the family structure of occupants of dwelling huts, aspects of age distribution and diets, and hunting patterns. The main source of food was marine, both fish and marine mammals, with frequent excursions inland along river valleys to establish temporary hunting camps for reindeer and other large mammals34. The amazing ability for people to travel far and live on coastlines at an early date is confirmed by the findings on the Siberian Arctic coast of the Laptev Sea dating back to 27,000 BP, before the last glacial maximum35.

Other sites have been discovered around the North Sea, and fishermen continuously retrieve several tons of Pleistocene mammal bones each year from the sediments of the southern North Sea22. Large numbers of cold climate fauna bones are retrieved, including mammoth, reindeer, ox, wolf, and bear, dating back to 35 ky BP35.

Figure 2. The shaded portions of the map were inhabited in about 500,000 years BP, as well as India, the Middle East, Africa, and western Europe. The different shaded zones show the Acheulean hand axe tradition and the chopper and flake-and-chopper tradition of stone tools. (From Klein10, p. 258). See text for discussion.

Figure 3. The distribution of known submerged prehistoric sites in the Mediterranean is shown in this map. Sites age from 5000 years to 45,000 years old. (From Flemming et al.22).

Figure 4. Potential migration routes for early humans and hominids out of Africa into Europe and Asia.
Before considering the importance of the Indian continental shelf I will refer briefly to submarine prehistoric sites in other parts of the world, to make the case that the evidence is not restricted to the Mediterranean and European seas. Several submarine prehistoric sites were found on the coast of California\textsuperscript{35}, and a few flint tools were discovered at a depth of 50 m using a geological grab\textsuperscript{37} off the coast of British Columbia, Canada. Several submerged sites dating back to 10 ky have been reported on the Gulf coast of the USA\textsuperscript{38-40}. Thousands of square kilometres of land were exposed between the 100 m depth and the present shoreline, and much of this landscape contains karstic sinkholes and underground rivers. These sites have already revealed human artefacts both above and below present sea level\textsuperscript{41,42}. A few other prehistoric sites on the USA shelf have been reported earlier\textsuperscript{43,44}.

In East Asia the only submerged site with prehistoric artefacts more than 5000 years old deposited \textit{in situ} which has been published to my knowledge is the Jomon culture site at a depth of 25 m off the Tokomari River estuary, and dating from 9000 BP\textsuperscript{35}. Palaeolithic flints have been found scattered on several Japanese beaches, but not \textit{in situ}. Other indicators from the region include extensive mammoth fauna trolled by fishermen at a depth of 80 m in the Taiwan Straits (Wu Xinjhi, pers. commun.). Allen et al.\textsuperscript{4} were well aware of the importance of the submerged shelf of Sunda and Sahul, and Flemming\textsuperscript{46} surveyed the shoals and banks between Darwin and Timor in an attempt to find archaeological evidence of people living on the shelf during the earliest migrations into Australia. This survey revealed complex karstic topography, narrow limestone valleys, fossil beach lines, and fossil corals, indicating an attractive indented coastline, which would have been rich in mangroves and shellfish. No archaeological materials were found.

The ‘Southern Route’ and the Indian continental shelf

The southern Red Sea crossing from Africa to Yemen has attracted considerable attention in recent years as the start of the ‘southern route’ of human migration from Africa to Australia\textsuperscript{47-49}. The hypothesis is that in the most recent phase of human dispersal (AMH) from Africa after about 100 ky BP some tribes crossed the southern Red Sea in the neighbourhood of the straits of Bab el Mandab, and that they were coast-dwelling, and migrated eastwards over the course of thousands of years, reaching Indonesia and Australia about 50–60 ky BP. If this happened during the last glacial cycle while the sea level was 50–100 m lower than at present, there would be very little archaeological evidence of the migration on land, and very little genetic trace in modern DNA.

The ‘southern route’ hypothesis depends upon several plausible, but not necessarily correct, guesses or assumptions. The first assumption is that the most favourable route out of Africa is across the southern Red Sea near Bab el Mandab (Figure 5), and that a combination of low sea level and favourable climate on land on both sides coincided to make crossing peculiarly easy\textsuperscript{48}. At the present date, in spite of the evidence of archaeological deposits above present sea level on both sides of the Red Sea, there is no immediate evidence that this is the result of a southern crossing, and not to due a journey northwards through the Sinai and back again on the Saudi shore. At maximum low sea level about 22 ky BP the strait was not completely dry, and a narrow channel connected the Indian Ocean with the Red Sea, rather like the Bosphorus\textsuperscript{50}, but even shallower. This could have been crossed with the simplest use of any flotation device, but the climate was also drier than now at some stages, and it is possible that the land on either side of the strait at lowest sea level was so inhospitable as to reduce the chance of crossing. Careful research is needed to establish the exact climate and vegetation in the coastal lands adjacent to the southern Red Sea at each stage of sea level change to judge the probability of human crossings. This can only be logically concluded by the discovery of archaeological materials on the submerged shelf showing a continuous culture across a very narrow channel (Figure 5 b). This has not yet been done.

Further evidence that eastward migration was close to the coast at low sea level would require a similar effort of research in the region of Oman, and a similar analysis of the potential for crossing the Straits of Hormuz at low sea level\textsuperscript{51}. Again, there is no direct archaeological evidence yet.

At the eastern end of the presumed route, no sites have yet been found submerged on the continental shelf of Indonesia, although the potential is enormous. The northern shelf of Australia is also an attractive research zone, as reported by Flemming\textsuperscript{46} after mapping the detailed terrain of the Cootamundra Shoals.

To demonstrate that a unique group related to Australian aborigines made such a journey would require both the discovery of some submerged sites, plus, if possible, the recovery of some human bones sufficiently well preserved to contain identifiable DNA. This is not as unlikely as it sounds, since even in the tropics the water temperature is sufficiently low to facilitate the possible preservation of DNA (Gregor Larsen, pers. commun.).

This brings us to the task of actually how one would find submerged prehistoric sites on the continental shelf of India. Experience in other parts of the world has shown that the circumstances which determine the original occupation of a site (precipitation, groundwater, vegetation, food supplies, travel routes, hunting radius, shelter, proximity to a river/lake/the sea, safety from predators, availability of firewood) depend upon topographical and climatic factors at the horizontal scale of a few kilometres and less. When the sea rises over a prehistoric site, the probability of erosion or preservation depends upon whether the site has been covered by sediments or soils, and whether the wave and current action is reduced by the local coastal topography during the few hundred
years that the sea water is only a few metres deep over the site. Ideally the site is protected if the coastal topography at the time of inundation protects the site from the maximum wind-wave fetch; if headlands, bays, or offshore islands further reduce wave impact and protect from strong currents; and if the gradient is such that wave action tends to be constructive rather than destructive.

Assuming that a site has survived the initial inundation and we are now searching for it, discovery and the possibility of future submarine research on the site depends upon artefacts or other signifiers being detectable by eye or using acoustic methods, and whether the present wind-wave-current conditions make work possible on the site. On the coast of India the conditions are further complicated by massive river sedimentation, coastal mangrove forests in some areas, and coral reefs in others. These features need to be taken into account when seeking to identify those locations where submarine prehistoric sites may be preserved.

The distribution of prehistoric sites on land is a key indicator. It is important to study the factors, which determine the location of prehistoric sites on the adjacent dry land, and to try to extrapolate these factors across the modern beach into the submerged environment. As experience is gained in shallow water, it becomes possible to modify the model of predicting site occurrence so as to take into account those attributes, which turn out to be unique to the prehistoric coastal living culture.

**Conclusions**

Research on submerged prehistoric sites in the age date range 5000–100,000 years requires a steady effort over decades to produce results. In every part of the world where this kind of work has been conducted using underwater observation by scuba divers, supported by accurate bathymetric mapping, and an understanding of the sediment regime, submerged prehistoric sites have been found. The rate of discovery has been approximately proportional to the date at which scuba diving equipment became widely used both by sports divers and young scientists at the university and in government laboratories, and to the number of people diving. Observations of this kind started in the USA, Canada, and European waters in the mid to late 1950s, and prehistoric sites were being discovered consistently with officially funded research programmes by the late 1970s and early 1980s. Since there is a great deal of diving on the northern Mediterranean coasts and in Israel, sites have been found there. But up till now there has been very little archaeological diving in North Africa, the Red Sea, or on the coasts of Yemen and Oman, and no submerged prehistoric sites have yet been found there, although they must exist.

The potential discovery and mapping of submerged prehistoric sites on the continental shelf of India is of extreme interest, both because of the information it would provide on early phases of exploitation of marine resources in a tropical climate, and because of its possible significance in the proof or disproof of the "southern route" theory.

I am in no position to suggest the best strategy for a submarine prehistory programme in India, since I am not familiar with the nature of the continental shelf in detail, which is required, and have no first hand knowledge of the
environment. The factors, which determine the primary existence of settlement sites, their taphonomy, survival, and discovery, are critical at a horizontal scale of less than 1 km. The submerged landscape therefore needs to be mapped with this resolution in the areas where prehistoric research is to be carried out. Thick layers of sediment and rapid coral reef growth both in their different coastal regimes, make it extremely difficult to find prehistoric sites, and progress on the Indian shelf will therefore depend on first locating broad areas where these two phenomena are absent.

In order to locate the most likely research areas it is necessary to combine the skills and resources of sea bed bathymetric mapping, acoustic sediment studies, geological sampling of the seafloor, an understanding of the oceanographic regime (waves and currents and their stresses on the seafloor), and the conventional skills of prehistoric archaeology. These skills are well developed in India.