Chapter 1

Introduction: Prehistoric Remains on the Continental Shelf — Why do Sites and Landscapes Survive Inundation?

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The Big Question

This book is designed to provide the best partial answer to an apparently clear-cut and uncomplicated question: "Why do some prehistoric sites, settlements, landscapes, and artifacts survive on the sea floor, after inundation by postglacial sea-level rise, when many others are destroyed or scattered by waves and currents?" There are over 2600 known submerged prehistoric sites in European seas (Jöns *et al.* 2016). At the glacial maximum when sea level was at its lowest, at about –130 m, an additional increment of land became available on the European continental shelf estimated at about 40% of the present-day European land area, amounting to an estimated 4 million km^2. The question of what determines the survival or destruction

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of archaeological sites and landscape features is therefore a serious one. We have no information on how many sites have already been destroyed, or how many survive and are yet to be discovered, or how much of the original pre-inundation terrestrial landscape has been destroyed beyond recognition.

There is a corollary question: "If we can understand the oceanographic conditions, geological circumstances, changes through time and topographic geometry that most favor the survival of prehistoric settlements during and after marine transgression, can we turn the argument round, and use knowledge of oceanography, ice-cap chronology, and coastal geomorphology to predict where prehistoric sites existed, and where they will be preserved on the sea floor of the continental shelf?"

When people are told that there are thousands of prehistoric sites on the sea floor, human settlements and places of occupation ranging in age from 5000 to more than 100,000 years old, their first reaction is often incredulity or skepticism (Bailey & Flemming 2008). This reaction is usually the case both for expert archaeologists and members of the general public alike. How can it be true that fragile, unconsolidated deposits of cultural remains, charcoal, food debris, scattered stone tools, débitage from flint knapping, wooden hut posts, and bits of bone or fragments of wooden canoes survive first the process of postglacial rising sea level and transit through the surf zone, and then thousands of years submerged under present oceanic and coastal conditions? How and why do they survive, and how can we discover their most probable locations?

In this book we make a beginning on the answers to those questions. The answers are not simple, and it has taken the work of many people from many different academic professions to piece together the whole story so far. There is rapid progress continuing in many of the component sub-disciplines that contribute to this research, and so the present book can only be a snapshot of the present situation. We try to indicate the ways in which changes are taking place.

The aim of the present volume, therefore, is to review the current state of knowledge concerning the environment of the exposed continental shelf during glacial lowering of sea level, the causes of changes of land and sea level, the processes of inundation, the mechanism of attack by waves and currents on anthropogenic deposits in shallow seas, and the circumstances in which such deposits are most likely to be preserved, or to be destroyed. The primary goal is to use an understanding of these processes to illuminate the reasons for the differential survival or destruction of archaeological sites. Additionally, such an investigation also contributes baseline data for reconstructing the environment as it would have existed on the now-submerged shelf, the sorts of resources of food, water supplies, topography, soils, flora and fauna that would have been available for human exploitation on these extensive tracts of new territory, and ultimately their impact on patterns of site location and human settlement, mobility and dispersal.

Throughout the book we refer to identified and studied archaeological sites only as examples to show how they may have been preserved or partially destroyed by different processes. SPLASHCOS (Submerged Prehistoric Archaeology and Landscapes of the Continental Shelf — www.splashcos.org/) has produced a digital database of over 2600 submerged prehistoric sites (Jöns *et al.* 2016), and a second volume on the archaeological material is currently in preparation. By using practical examples we hope to base the argument on facts in the field, rather than over-reliance on theoretical hypotheses.

The aim of this introductory chapter is to highlight some general issues affecting the survival or destruction of archaeological features, summarize the recent history of collaboration associated with the SPLASHCOS project and its predecessor, the Deukalion Planning Group project, which gave rise to the work underpinning this volume, explain the rationale for the organization of the volume, outline its contents, and set out the conventions and standards used in presenting information.

General Issues

In the early days of Deukalion and SPLASHCOS in 2008–9, the meetings were dominated by archaeologists and prehistorians, and they frequently wanted to know if it was possible to predict the survival and location of seabed prehistoric sites accurately, so that they could do their work more efficiently and at lower cost. This question could not be answered quickly, and always dropped down the agenda. The oceanographers, sedimentologists, climate experts and technologists felt frustrated by the intractability of the problem, and were not only unable to answer it, but even unable to explain why they could not answer it.

Recently published books on individual sites, or conference volumes (e.g. Flemming 2004; Benjamin *et al.* 2011; Evans *et al.* 2014), confine themselves to the study of prehistoric sites which, by definition, have survived. They do not consider the probable or possible distribution of sites which have not survived or have not been found. A few paragraphs at most may be devoted to considering why particular artifacts have survived at the site being studied. And yet, as scholars from many disciplines start to consider the prehistoric continental shelf as an integrated whole, whether European or global, the same questions recur again and again: where should we search for anthropogenic signals from the periods of glacial-maximum low sea levels? Where would searching be pointless? Where were people living on the continental shelf, and why? What conditions favor survival of anthropogenic deposits and signals? Where will archaeological deposits be buried under tens of meters of modern sediments, and hence difficult to find or excavate? Where will deposits have been eroded away? And where will the overburden of protecting sediments have been eroded away by submarine channels to a sufficient extent to expose material without destroying it? Are there predictable patterns of survival of sites? Where are fragile sites now exposed to erosion so that immediate study or preservation are needed? How can we maximize the efficiency of a search strategy? What instrumental techniques will provide useful environmental data? What geophysical and sedimentary data already exist to help us define favorable conditions for survival of deposits?

The subsidiary questions continue: do we know enough accurately about the positions of the sea level and the land surface at different dates? Can we define the positions of ancient shorelines, river valleys, and shallow coastal lagoons and marshes? Do we know where there are submerged caves or rock shelters that people might have lived in? Can we reconstruct the fine gradations of landscapes, vegetation and fauna extending away from the edge of the ice sheet through the areas of tundra and temperate forests to the Mediterranean or to tropical climates and vegetation zones on the continental shelf? When we have identified drowned prehistoric deposits in context, can we reconstruct the immediate landscape, fauna and flora in the adjacent foraging and hunting area?

The questions listed above, which are by no means exhaustive, illustrate the fundamental and potentially exciting aspects of continental shelf prehistoric archaeology. The answers are not themselves directly archaeological in nature, but rather paleoenvironmental. Yet archaeologists need the answers to these questions, and those answers in their turn depend on extensive interdisciplinary collaboration.

The survival and discovery of submerged prehistoric sites on the continental shelf implies two distinct defining issues: firstly the nature of the archaeological sites themselves, their age, function, cultural associations and technology, and the choice by ancient peoples of favored locations for settlements, camp sites or more ephemeral locations where materials were discarded; and secondly the circumstances of abandonment of the material, its burial or exposure while on land, followed by the processes of inundation and possible destruction or survival. The process of burial and preservation of sites, deposits, or single artifacts depends on complex interactions between environmental forces, coastal geodynamics, coastal configuration, geochemical processes, and biological interactions as shown throughout the chapters of this book for a wide range of conditions and circumstances. The process of inundation by rising sea level and the traverse of the surf zone across an archaeological site are likely to be destructive, or lead, at the very least, to a local scattering of artifacts and other materials. This is not always so, since in some cases sea-level rise may be accompanied by extreme wave attenuation caused by local topography and accumulation of sediments that can protect and partially or totally bury the archaeological material. Nevertheless the likelihood of destruction must be assumed in the analysis, and we should expect that survival of intact sites is likely to be the minority occurrence in most regions and most geodynamic situations.

As the argument progresses it becomes clear that the conditions for survival depend not only on regional climatic and oceanographic conditions, but critically upon topographic land forms and seabed morphology on a scale of meters to a few kilometers in the immediate vicinity of the stratified deposit during inundation and in the following few millennia (see, for example, Flemming 1963; Gagliano *et al* 1982; Belknap & Kraft 1981; 1985; Belknap 1983; Flemming 1983; Waters 1992; Flemming 2004; Harff *et al.* 2007; Benjamin 2010; TRC Environmental Corporation 2012; Evans *et al.* 2014). In addition, the exposure to marine forces, waves, currents, erosion, and burial has to be considered. Thus analysis of each situation depends upon quantitative hydrodynamic laws and mechanisms, but is locally site-specific, and success depends on having very accurate topographic data on the paleocoasts and the sea floor throughout the area of the modern continental shelf. This puts a huge demand upon availability of accurate high-resolution seabed data; although much bathymetric data is already available, it is often not adequate for the kind of analysis required. These data problems are reviewed generically in a chapter on the availability of digital data (Chapter 4), and each regional-sea analysis summarizes the available data sources, with a special emphasis on electronically available maps, core data, and displays.

Recent History of Collaboration

The authors and editors of this book have worked for many years on the task of finding and studying submerged prehistoric sites on the continental shelf of Europe (e.g. Flemming 1968; Galili & Weinstein-Evron 1985; Long *et al.* 1986; Galili *et al.* 1993; Antonioli & Ferranti 1994; Fischer 1995; Momber 2000; Harff & Lüth 2007). However, only in the last decade have collaboration and the exchange of information between different research groups resulted in a European-scale collaboration. During the 1980s and 1990s, various regional groups were already combining disciplines and sharing data to integrate knowledge of climate change, sea-level change, sediment movements and the discovery and interpretation of submerged prehistoric settlements. Particularly strong groups developed to study the Danish archipelago and the straits between Denmark and southern Sweden and Norway, Kattegat and Skagerrak (Andersen 1985; Fischer 1995; Pedersen *et al.* 1997), and the German islands of the southern Baltic (Harff & Lüth 2007; 2011). In the southern North Sea the archaeologists in the Netherlands have a long tradition of working with the fishermen who trawl up Pleistocene megafauna bones and occasional human artifacts (Louwe Kooijmans 1970-71; van Kolfschoten & Vervoort-Kerkhof 1985). In 2002, a conference was held in London bringing together prehistorians from both sides of the North Sea, resulting in a volume on the known finds on the seabed, and outlining national and agency policies (Flemming 2004). This conference in turn led to a joint Anglo–Dutch initiative to promote collaboration between the national cultural heritage agencies in the two countries (Peeters *et al.* 2009), and to further discussion of collaborative initiatives at the IKUWA 3 (International Congress on Underwater Archaeology) held in London in 2008 (www.nauticalarchaeologysociety.org/shop/ikuwa-3-beyond-boundaries-3rd-international-congress-underwater-archaeology) and the subsequent establishment of the Deukalion Planning Group and the SPLASHCOS Action to further consolidate plans for international collaboration.

At the meeting of the SPLASHCOS Working Group 2 in York in April 2010 it was suggested that a review was needed of the environmental conditions in each European sea basin, which would provide prehistorians and other scientists collaborating with them with the background information they required to understand the preservation and destruction of submerged prehistoric sites in their region. From this proposal grew the present book.

Outline of this Book

We start with a series of three thematic chapters analyzing different environmental marine and coastal processes as they may affect the original location and then the survival of submerged prehistoric sites. These conclude with a brief summary of data sources and types.

Europe, the Mediterranean, and the Black Sea constitute a geographical area that is subject to many different types of vertical earth movement and relative sea-level change on time and space scales that overlap with prehistoric archaeological events. Chapter 2 therefore starts by addressing geological and tectonic processes that are controlled by plate tectonic movements on timescales of tens of millions of years. Notwithstanding the relatively slow rates of movement, the vertical changes over tens to hundreds of thousands of years have a profound effect on coastlines, topography, and sedimentary basins or depocenters like the North Sea, or the configuration of the Aegean Sea basin. In the Mediterranean region the convergence of Africa and Eurasia leads to both active mountain building and regions of rapid subsidence on archaeological timescales. The overriding climatic events of the last two million years have been the multiple and recurrent glacial ice caps on the northern continents, associated with growth and decay of more local ice accumulations on mountain ranges such as the Pyrenees, Alps, Apennines and Carpathians. Each phase of increasing ice volume on the land created an equivalent drop of global sea level, and exposure of large areas of what is now the continental shelf. For this reason Chapter 2 provides a thorough overview of the regional tectonics of Europe, the mechanisms of ice cap formation, the driving forces that determine the growth and decay of the ice sheets, the calculation of sea-level change, and the response of the Earth's crust to the redistribution of ice and water.

Chapter 3 starts with a definition of the continental shelf, the shallow flooded margin of the continent, beyond which the sea floor plunges into true oceanic depths of thousands of meters. We then consider how the multiple causes of fluctuating sea level affect the evolution of the continental shelf, and its sediment cover. Special attention is given to the process of sea-level rise transgressing across a prehistoric occupied area. Since the majority of known submerged prehistoric sites have been found in sea water shallower than 5 m, and some have survived in this situation for many thousands of years, it is immediately apparent that the destruction of sites is not inevitable, even when they are potentially exposed to wave action. This empirical fact is used to examine the coastal geodynamic circumstances which have protected sites. Wave and current actions have the potential to destroy some sites while preserving others separated by a few kilometers along the coast. The effects of sediment burial and chemical changes in the submerged environment provide the final stages of preservation.

Chapter 4 outlines the present sources of data needed to describe the seabed and its composition and subsurface sedimentary stratigraphy. The data demands for reconstructing the paleoenvironment are extreme, even by modern industrial standards. Prehistoric archaeological sites are constrained by significant topographic features which need to be defined to a resolution of a few meters or less, while the hunting and foraging strategy and seasonal migration patterns of a Paleolithic family group extended over a range of tens or hundreds of kilometers. Thus we need very high-resolution seabed data over a very large geographical range. This is not available for all parts of the European continental shelf. Where data are available at sufficiently high resolution the data volumes are so great that electronic media are essential, and modern data management and data-merging techniques are needed.

Chapters 2–4 provide background data on processes that recur to differing extents at a regional and local scale in later regional chapters, where the authors go into more detail.

In order to investigate oceanographic, paleoclimatic and environmental processes in a consistent way, throughout the varying climatic zones of Europe and the Mediterranean, we break the area down into discrete sea basins each of which is examined in a separate chapter. Within each basin the conditions of tectonics, geomorphology, tide, wind strength, water temperature, occurrence of sea ice, wave height and so on can be analyzed in a holistic way from coast to coast. If the same factors were analyzed, for example, by national zones of jurisdiction, each sea basin would be broken into arbitrary sections by lines through the center. Oceanographic conditions do not respect national boundaries. Our approach also serves to integrate the prehistoric archaeology within coherent environmental conditions across exposed areas of the sea floor that are now flooded.

The core of the book follows with 14 chapters describing the regional sea basins of Europe in terms of their past and present geomorphological and oceanographic processes on the continental shelf, with selected examples of known submerged prehistoric sites. We start with a review of the Baltic Sea and its potential to preserve prehistoric sites (Chapter 5), and then work southwards in a counter-clockwise direction round the Atlantic margins of Europe (Chapters 6–11) through to the Mediterranean (Chapters 12–15) and the Black Sea (Chapters 16–18).

The authors for each regional chapter are usually teams combining earth scientists, marine geoscientists and prehistoric archaeologists. Even with this pooling of skills it is obviously not possible to provide a complete or exhaustive coverage or analysis of the complex forces, local conditions, particular regional changes of climate, etc., which would be needed ideally for each sea basin. The complex of processes, regional expression of glacio-eustatic sea-level change and local isostatic response, the regional expression of wind–wave energy, ocean basin currents and wind-driven currents, wave climate and previous wave climates under different environmental conditions, sediment transport, changing river patterns and so on, create a requirement for a large book for each sea basin, not just a chapter.

We have had to compromise. The solution has been to summarize the processes in a high-level aggregated manner, citing a full reference list of the major published integrating studies, and to combine this with access to electronic sources of archived data. The latter point is fundamental. We are trying to help the reader to understand multiple interacting spatial processes at scales from less than one meter up to hundreds of kilometers. Printing maps on a book page would not help, or is not sufficient. Thus the decision was taken early on in preparing this book to cite electronic sources wherever possible. These URL citations are grouped at the end of each section within a chapter, and refer the reader to maps, archives, sediment core data, ice-cap models, and other large datasets. Most of the citations are to major institutions and governmental or international agencies which are not going to disappear, but some of the more exotic projects and data sources, which are still important for this book, may not be active more than a few years after publication, although all are current as of December 2016. The intention in these chapters is to provide the reader with a rapid guide to the key literature on the major sea basins, and an authoritative summary of up-to-date information, while accepting that it is impossible to go into detail, or consider all nuances.

Conventions and Standards

Each chapter is designed so that it can be accessed electronically as an independent publication. Thus all acronyms are explained within each chapter, and cited references are included at the end of each chapter.

One of the main aims of the chapters on regional sea areas in this volume is to provide the reader with a guide to the sources of data in many different disciplines. Where specimen maps or screen dumps are shown, it is appropriate that they should be shown in their original format. Thus there is considerable variation in the style of graphics.

It may surprise the reader to discover how uncertain some marine geoscience data are regarding different phases of the Late Pleistocene landscape and environment. In attempting to recreate the coastal and continental shelf environment at the human scale we need to consider many different sources of data, geological, glaciological, sedimentary, etc., and combine them. Thus the uncertainty or errors at the end of the research in one discipline become errors in the input to the next stage of integration — they propagate — and the uncertainty may be magnified. Many different consequences may arise if two adjacent ice sheets did or did not actually meet and merge; a large ice lake may or may not have persisted for thousands of years if a particular ridge was eroded or not; a particular river may or may not have been crossable at a particular date, depending on the rate of melting of an upstream ice sheet, and the raft-building technology of the time. There is uncertainty as to the ability of early humans or hominins to adapt to life in a cold climate, and the earliest dates of seafaring and exploitation of marine and coastal resources.

Multiple sources of data can be integrated with some rigor by intensive research at a relatively restricted regional level, as in the SINCOS projects ("Sinking

Coasts: Geosphere, Ecosphere and Anthroposphere of the Holocene Southern Baltic Sea", Harff & Lüth 2007; 2011), but such a combination of professional skills from prehistoric archaeology to mathematical oceanographic modeling is still rare.

So far as it is possible, we have ensured that the authors of different chapters use similar terminology and conventions regarding symbols, assumed sea-level history, gross European climate changes and sources of European-scale data. The described sea areas have slight overlaps, and there should be no major contradictions at the borders. Authors of the chapters on regional sea areas were provided with an agenda or proforma of topics to be covered, but these are definitely not identical in importance from the icy coasts of the Gulf of Bothnia to the palm-fringed shores of the Middle East. Each team of authors has tended to develop or emphasize additional themes which seemed to them important, or for which they had special skills. This gives an added individuality or color to each chapter, which we have not tried to avoid.

The Last Glacial Maximum is referred to frequently as the LGM, often followed by a bracket of dates such as 21 ka BP to 18 ka BP (Before Present). These dates are not always the same, since the same global cause has different responses depending on the latitude or other regional variables and we have not requested authors to standardize unless precisely the same event is referred to more than once in the same chapter. The so-called LGM can be defined variously as the maximum volume of global ice on land, the time or period of maximum reduction in global sea level, the time of the lowest temperature reached in a region, or the maximum extent of continental and shelf ice in a region. These events may have considerable duration, and local terminology describing the Pleistocene may have adopted a conventional date, or bracket of dates, within the maximum range of about 27 ka BP to 17 ka BP. In general, the initiation of final melting and the start of global sea-level rise is usually quoted in the range 21 ka BP to 18 ka BP.

As explained above, many of the specialized fields summarized in this book have large uncertainties in them, sufficient to cause further problems when used as the input for another level of integration or analysis. Thus different authors may have used different ice-limit models, and maps showing these differences occur in different chapters. It is not possible at present to decide which model is correct, or the most nearly correct, and some models will be most accurate in certain characteristics, and less accurate in others. This is not a school textbook in which we present the student with a smooth unruffled picture of the best approximation to modern knowledge. Sources are cited which may give different interpretations of the data, and the reader must draw conclusions as to which is most useful. This applies equally to different interpretations of regional relative sea-level curves and to best estimates of shorelines at different dates, such as in the Black Sea, and to models of ice volumes and directions of ice flow. Models of these parameters are evolving continuously and becoming more accurate.

The terms 'large scale' and 'small scale' should not need explaining, but in recent decades they have become reversed from their original meaning in common parlance in some communities. In this book we use the original meaning as follows. A small scale map is one in which objects and features look small. Thus, a map or chart at a scale of 1:5 million represents 1 km on the ground as 0.2 mm on the map, i.e. very small. It is a small scale map. A local plan at a scale of 1:1,000 represents 1 km on the ground as 1 m on paper, so that features such as houses and roads appear as large recognizable objects with shape and width. It is a large scale map. Notwithstanding this convention, numerical modeling communities describe the process of using the output boundary equations and variables from a small-scale model of a large oceanic area to drive a more local coastal large-scale model with higher resolution as "downscaling" or "downsizing", when in fact the scale at the local level is being enlarged.

Geological and archaeological terminology used in some regions contains localized and not universally used terms, but these are still the correct form and will be found in the regional literature cited for that area. Such terms are defined in context within each chapter where used. In addition, there may be small differences in spelling and word order between names in the text and embedded in images, an inevitable occurrence when examining such a wide and diverse geographical range. Each chapter on regional sea areas also contains an extensive bibliography of local literature, sometimes in languages other than English.

Statements regarding dates appear in several formats. The statement that something occurred so many thousand years ago should be interpreted as an estimate in calendar years before the date of publication and can be expressed using 'ka' (or 'Ma' for millions of years). The terms 'kyr/Myr' on the other hand refer to lengths of time measured in thousands/millions of years. There is no implication as to method of dating or calibration errors. Dates throughout the book are frequently cited as having been determined by radiocarbon ^{14}C measurements. The use of the acronym BP (Before Present) necessarily implies that the method of dating has been radiocarbon, and that the date is measured as time before 1950. Authors have been requested to cite whether radiocarbon dates have been calibrated (signified by the use of 'cal BP') or not, and where possible to include the laboratory reference and standard deviation. This additional information is provided in some cases, but not in most cases. Where there is no information on calibration, it must be assumed that the assessment is uncalibrated, and possibly that there is a margin of uncertainty. The fact that a cited date is uncalibrated is sometimes followed by the statement that this correlates roughly with so many years ago, even when accurate calibration data are not cited. Issues of precision and accuracy are often more critical in archaeological studies than in the more general geomorphological subjects discussed in the present volume, since interpretation can be significantly affected by margins of error in the correlation of separate events or the measurement of their duration. Formal agreements on standards of presentation of ^{14}C data are summarized by Stuiver and Pollach (1977) Reimer *et al.* (2013) and Millard (2014).

Physical oceanographers are concerned about the exact concentration of salinity in sea water since, combined with the temperature, it largely determines the density and thus the stratification of layers of water, as well as what species can easily live in it. Until the late 1970s, the standard expression of measured salinity was parts per thousand (per mill), expressed by the symbol ‰. During that decade oceanographers devised and later adopted the new Practical Salinity Scale, and dispensed with the symbol, on the basis that the salinity was expressed as a pure number in terms of the ratio of weight of salt to the weight of water. The new international standard TEOS-10 (Thermodynamic Equation of Seawater 2010) uses absolute salinity values in g/kg (Millero *et al.* 2008). Although the use of the old salinity symbol ‰ (per mill) has been discouraged since 1978, it has been customary in a large part of the oceanographic and popular literature to use this expression, and readers unaware of the complex theoretical changes in the professional world of marine physics, expect to see such a symbol. The focus on the precise thermodynamic properties of water of different salinities has led to further definitions of different scales based on functions of salinity (Wright *et al.* 2011). For the present work the implications of the different scales and units are not significant, and we have not asked authors to confirm whether they have used one scale convention or another. Where the symbol ‰ appears it is because the authors of that chapter used it, or cited literature that used it. Where salinity is cited purely as a number with no symbol or unit, the same applies.

Conclusion

We hope that the first question, why some sites survive, is answered successfully to a considerable extent by this book. The reverse question, can we predict where the sites are and find them, is much more difficult. The readers of this book should be in a better position to address this question by the time they finish, and future generations of researchers may refine the arguments still further, and achieve more reliable answers. Improvements in technology, and the growth of large accessible archives of digital data, as well as the development of highly sophisticated models, will make it easier to reconstruct accurate paleotopographies, showing drowned river valleys, soil types, vegetation, and coastlines that are at present under the sea. The use of the knowledge in this book enables the prediction of locations of high probability for prehistoric sites, but still usually leaves the researcher with a further stage of detailed field survey and analysis before anthropogenic indicators can be located (e.g. Wessex Archaeology 2011; Weerts *et al.* 2012; Moree & Sier 2014; 2015). This work can be expensive:

hence the incentive to improve the models and their predictive accuracy and reliability.

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