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Coastal and marine palaeo-environments and human dispersal points across the Africa-Eurasia boundary

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Abstract

Submarine prehistoric archaeological sites on Mediterranean coasts contribute to understanding human migrations in the last 2 million years. "Out of Africa", "Multi-regional", and "Trellis" models of human origins and dispersal depend on what environments attracted hominid and modern human occupation, and how temporal and spatial variations in environments facilitated or impeded population dispersal and gene flow. A determining factor for migration routes, and possible two-way dispersal across potential boundaries, was the level of the world ocean, and the degree of obstruction presented by straits, channels, estuaries, and semi-enclosed seas. During the last 2 million years, the recurrent high latitude glaciations caused the sea level to fluctuate between –120m and +10m relative to present sea level, changing the potential crossing points.

During periods of low sea level hominids and anatomically modern humans could probably cross from Morocco to Spain, from Tunisia to Sicily, and from Djibouti/Eritrea to Yemen, as well as by the land route through Sinai. It is probable that at these points, the process was two-way, with communities on opposite shores in regular cultural communication. The down-stream migrations into north-west Europe, Arabia, India, and SE Asia may also have been profoundly affected by episodic exposure of the continental shelf, and changes in climate and intensity of the monsoons.

This paper examines the tectonic changes in the coastal areas, the glacio-eustatic-isostatic factors determining the exposed shelf areas, the regional

climate changes, the natures of the exposed shelf, vegetation, and water supply, in the key crossing zones and transit areas. It presents a programme for finding submerged archaeological evidence for the crossings.

1 Introduction

During the last 50 years successively older prehistoric sites have been discovered and mapped by divers in the Mediterranean, and elsewhere. A selection of the key sites providing the basis for this statement are described by the following documents: Godwin [1]; Blanc [2]; Louwe Kooijmans [3]; Harding *et al.* [4]; Cockrell and Murphy [5]; Wreschner [6,7]; Andersen [8]; Scuvée and Verague [9]; Flemming [10–13]; Prigent *et al.* [14]; Geddes *et al.*, [15]; Stright [16]; Fischer [17]; Galili and Nir [18]; Galili *et al.* [19]; Momber [20, 21]; Hayashida [22]; Clottes and Courtin [23]; Werz and Flemming [24]; Pederson *et al.* [25]; Josenhans *et al.* [26]. These papers describe submerged prehistoric settlement sites and artefacts dating from 3500 to 500,000 years before present (BP), off the coasts of Europe, South Africa, the Middle East, USA, Canada, and Japan.

Many prehistoric submarine sites have been found in the Mediterranean. The evidence that sites can survive at least 45,000 years and possibly 500,000 years under the sea suggests that future discoveries on the continental shelves of the Mediterranean and Red Seas could provide essential clues to understanding human and pre-modern human contacts between Africa and Eurasia. The earliest proven human occupation of Australia dates to about 50,000 BP (50ky) (Jones [27]) requiring crossings of many tens of km, thus it is highly probable that humans and hominids could cross narrow sea channels well before this date. There are multiple lines of research into human dispersal being pursued based on modern genetics, archaeological sites on land, palaeontological data, palaeoanthropology, linguistics, etc., and the importance of the submarine data should not be exaggerated. Nevertheless, if archaeologists ignore the importance of the changed coastline, extra living space, and easier access across straits, at times of lowered sea level during the ice ages, they will tend to obtain misleading or even false explanations for what happened.

This hypothesis has been put forward by previous researchers, especially Blanc [2], Alimen [28] and Shackleton *et al.* [29] but without the benefit of evidence from submerged prehistoric sites, without up to date sea level change histories, and without the new technology provided by modern acoustics and diving systems. The hypotheses were propositions based on circumstantial evidence, but without any field data to prove that people had lived and hunted at sites on the continental shelf, far from the present coastline. The hypotheses remained to be proven.

The purpose of the present paper is to show that knowledge of ice age (Quaternary) glacially controlled sea level change, coastal and regional earth movements (tectonics), surveys of the sediments and rocks of the continental shelf, and evidence from prehistoric sites already discovered under the sea,

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provides the basis for a full understanding of how hominids (pre-humans) and modern humans lived on and exploited the continental shelf, and how this in turn determines or influences the contacts between Africa and Eurasia.

2 Archaeological background

Hominids, the precursors of modern man, have lived on the North African coast, the Red Sea area, and in the Levant since at least 1.0–1.4 million years ago (Klein [30] (p.316–317)), and on the North coast of the Mediterranean since at least 0.9 million years BP. *Homo heidelbergensis* and then *H. neanderthalensis* lived in central and southern Europe after 900ky BP, until *H. neanderthalensis* was replaced by *H. sapiens* over the period about 100ky to 30ky BP. Thus the Mediterranean and Red Seas have been a focal zone, obstacle, or crossing corridor for human migrations and interactions for over 1 million years. Figure 1 shows possible crossing zones in addition to the Sinai dry land route, without any assumption as to which is most probable or possible at different dates.

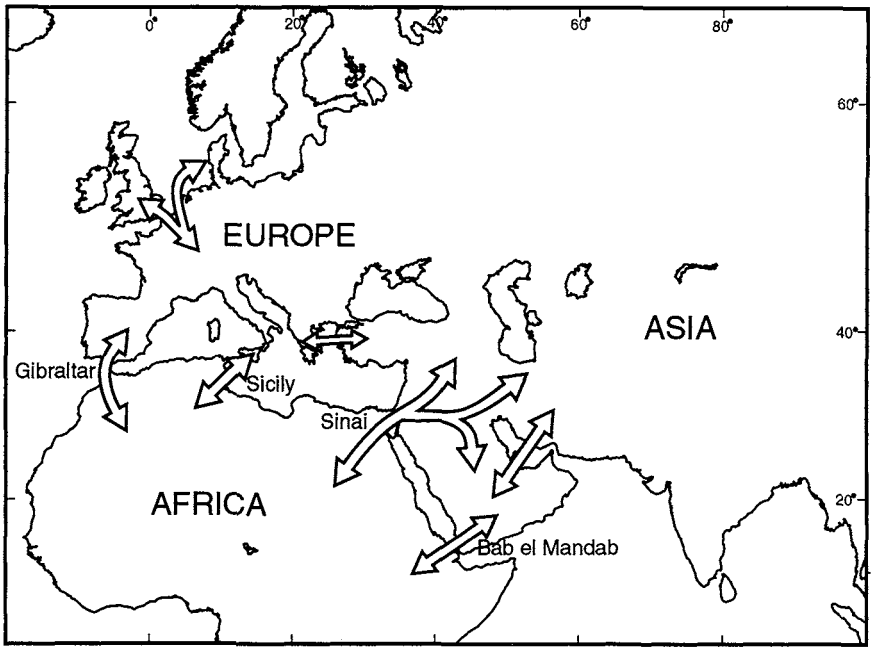

Figure 1. Sketch map showing the potential crossing points for human contact and migration, in addition to the Sinai land route.

The simplest assumption is that all human movements from Africa into the rest of Eurasia, and ultimately to Australia and the Americas, resulted from successive dispersions through the Sinai peninsula, followed by various patterns

of migration, expansion and adaptation to different climates and environments. Klein ([30] p.316) suggests that most dispersals occurred during interglacials. The Sinai, with possible periodic blocking and opening of the restriction during phases of climate change, is consistent with occasional bursts of human expansion from Africa, interspersed with periods of slow change or genetic drift.

A more complex mixture of migrations, gene fluxes, and two-way exchange would be consistent with multiple crossing points, for example at Gibraltar, Sicily-Tunisia, Sinai, and Bab el Mandab, which were favoured by climate fluctuations and sea level change at different times, possibly simultaneously, and possibly at different dates. This geographical interface would be equally compatible with the "trellis" model of dispersal supported by the DNA evidence published by Templeton [31].

Alimen [28] discusses both the Morocco-Gibraltar crossing and the Tunisia Sicily crossing with archaeological data from the south and north coasts to show the likelihood of early Palaeolithic cultural continuity across the straits, rather than diffused contact by the land route round the eastern Mediterranean. Broodbank [32] appreciates the significance of the Cyclades islands being joined during low sea level to provide large land masses and narrow straits in the Aegean, but the enhancement of this crossing, as with the dry Adriatic, does not contribute to the main thesis of this paper, which relates to the African boundary.

The Red Sea crossing was discussed by Faure [33] in 1968, and more recently by Walters *et al.* [34], both of whom found handaxes in uplifted coastal coral. The attractions of coastal zones for early human occupation and dispersal have long been recognised. They facilitate movement and provide more equable climates and diverse terrestrial and marine resources (e.g. Sauer [35]), and see also Bailey & Craighead [36] and Erlandson [37]. Fertile coastlines with abundant and accessible marine resources can provide attractive environments and pathways of movement in otherwise arid regions. This theme, often neglected in global syntheses, has recently gained prominence from the discovery of handaxes associated with alleged evidence of shell gathering on a 125kyr marine terrace on the Eritrean Red Sea coast (Stringer [38], Walters *et al.* [34]). The attractions of tectonically active landscapes for early human occupation have also recently been emphasised (Bailey *et al.* [39]). Since both coastal and tectonic environments occur in close juxtaposition along the Red Sea coast, the hypothesis of a broader pathway of migration between Africa, the Near East and the Indian sub-continent via the Arabian Peninsula gains plausibility. Moreover, there are abundant records of early Palaeolithic archaeology throughout the region (Amirkhanov [40], Whalen & Pease [41], Zarins *et al.* [42]), though these are poorly known, largely undated, and lacking a wider environmental context. The Arabian Peninsula thus offers an ideal setting for examining and refining competing hypotheses of regional dispersal and adaptation to local environments.

The probability of the pattern of crossings at each potential crossing point is controlled by sea level change, tectonic movements of the coasts, the nature of the exposed continental shelf, the extent of vegetation and fresh water on the exposed shelf, the aridity or rainfall in each period, the rate of desalination of the

shelf, and the presence of hominids or people on either side, and the suitability of the environment to support them. In each case there must be a motive for crossing, such as deteriorating resources, or population pressure, and the technical competence for a substantial number of males and females to cross. A breeding population of early humans in isolation has to be of the order of 100–200 people in order to survive set-backs (Jones [43]).

3 Ice age sea level changes and coastal earth movements

A review of climate change and sea level change is provided by Lambeck *et al.* [44], while a more general text-book analysis is given by Siegert [45]. Each glaciation during the last 800ky lasted about 100ky, and locked up about 50 million cubic km of water in continental ice sheets, causing global sea level to fall and rise, with some subsidiary oscillations, through a range of about 130m. Prior to 1 million years ago, the cycles were smaller. Figure 2 shows the curve for the last 150ky with the depth and age of submarine prehistoric archaeological sites in Europe and the Mediterranean superimposed on it.

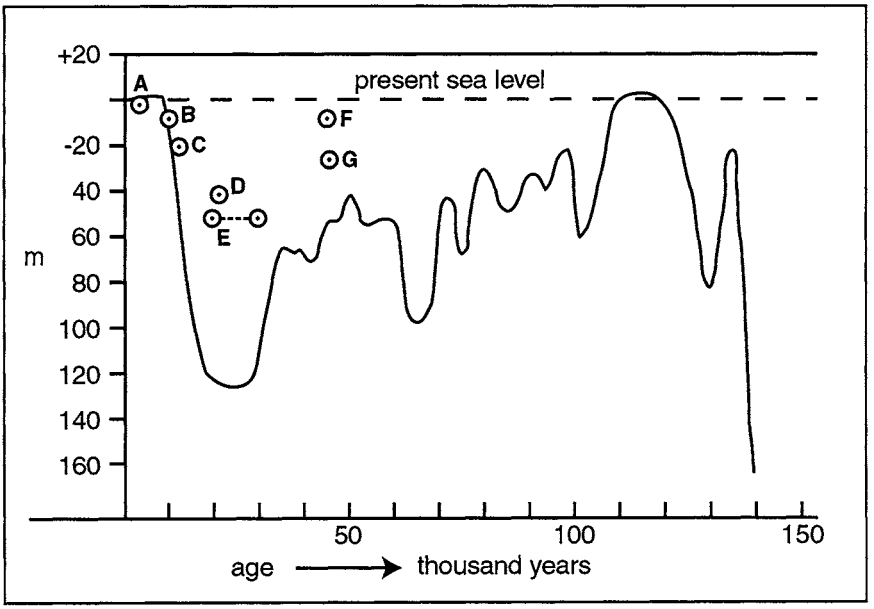

Figure 2. Generalised sea level-time curve, with groups of prehistoric sites shown at depth and age on what was dry land. A = submerged Bronze Age sites due to earth movements, sites 7, 8, and 10 on Fig.3. B = Neolithic sites 3, 5, 9, 11, and 12 on Fig 3. C = Submerged caves at Gibraltar. D = Grotte Cosquer, site 4 on Fig.3. E = Palinuro, 5 on Fig.3. F = Aghios Georghios, 6 on Fig.3. G = Fermanville, northern France, not shown on Fig.3.

On a time scale of one million years the analysis of crossings needs to take account of both glacio-eustatic processes and tectonic vertical movement. The glacio-eustatic contribution is of the order of 120–140 m change with principal time periods of 100ky. Lesser oscillations of ~50m occur on time scales of 20–40ky. Suitable models exist and have been tested against field data in the Persian Gulf (Lambeck 1996) [46]. The same models are applicable for other parts of the Arabian Peninsula and can be developed for other areas. Models are most reliable back to 20ky, but can be extrapolated back to ~120ky (Last Interglacial) with an accuracy of ~ ±10m (Lambeck & Chappell, 2001 [47]). Models for earlier periods become less reliable but we can assume that for the last 800ky (8 glacial cycles) amplitude and periodicities are similar to those of the last cycle. We have good constraint on the timing of the interglacials, and hence a constraint on times of lowstands to within ±10ky.

The plate boundary at Gibraltar does not go directly through the Strait, and tectonic activity is diffuse. Coastal uplift on the Spanish side averages about 10m since the last interglacial 128ky BP (Zazo *et al.* [48]). Both Sicily and Tunisia are tectonically active, and the seismicity and tectonics of the Sicilian-Tunisian platform are described by Max and Colantoni [49].

Earlier work on the East Arabian coast showed relative stability of eastern Saudi Arabia and rapid subsidence (probably in response to collision between Arabia and Iran) at about 8mm/yr in the Musandam area of Oman (Vita-Finzi [50]). The key question in the present context is whether subsidence at Musandam is accompanied by uparching (and therefore coastal uplift) to the southwest. No serious attempt has been made to investigate its response to sea-level change and the tectonic effects of the peninsula's collision with Oman even though there are unconfirmed reports dating from the 1940s of Holocene marine fossils at >100 m above sea level in the Gebel Akhdar. An important component of future work will be to identify locations where topography and bathymetry show that the known sea-level record would have led to significant changes in the resource base. The lack of published information is to some extent outweighed by the computational advantages of an open coast and a relatively simple tectonic setting, with stable Arabia at the rear and a seafloor to the SE which is subject to extension on an azimuth normal to the coast.

The average opening rate of the Red Sea during the Quaternary of 10mm/yr derived from global evidence (De Mets *et al.* [51]) is sufficiently precise for many geophysical analyses, but variations in the rate along the Red Sea and Gulf of Aden in terms of distance from the pole of rotation and over time are crucial to the present enquiry. Has the spreading been gradual or spasmodic? How much coastal uplift accompanied spreading? When was separation finally achieved in the Afar, however defined, and to what degree was the gap reduced during periods of low sea level? How did events at the mouth of the Red Sea influence the salinity and climate of the Red Sea itself? In view of the high level of tectonic activity generated by rift propagation (Hofmann *et al.* [52], Manighetti *et al.* [53]), improved measurement and dating of tectonic activity, aided by new cosmogenic dating techniques, will be central to an understanding of

palaeogeographical changes and their impact on hominid dispersal. Cosmogenic dating will allow dating of events much earlier than the established 40ky limit of ^{14}C.

Tectonic motion on the order of 10mm/yr (in extension, convergence or strike-slip), and sometimes possibly up to 20mm/yr, is characteristic all along the African-Eurasian boundary. Therefore lateral changes of tectonic origin in landscape and topography can occur, in addition to eustatic vertical changes. At the time scale of 100ky, ie. the last glacial cycle, total plate motion is only on the order of 1km and can usually be neglected. But over the time scale of, say, 3 million years (ie. the time of the *Australopithecus afarensis* known as "Lucy"), plate motion may have reached 50km and sometimes more. Coupled with vertical motion due to normal faults, this can be enough to totally change the landscape and geography, in addition to changes of hydrology, vegetation and climate. The landscape that Lucy walked through, and the places where she could cross, are quite distinct from what one would deduce from the present landscape and environment where her remains were found. (eg, Klein [30] p.183; Zarins *et al.* [42]). For the older periods of interest along the Africa-Eurasia boundary, plate tectonics itself must be included in the picture. This is a rare case when the time scales of human evolution and migration on one hand, and continental drift on the other, become comparable, and need to be jointly present in our minds.

4 Critical routes and the submarine archaeological data

4.1 Known submarine prehistoric sites

This section reviews the submerged archaeological sites in the region closest to each crossing area, and which may provide clues to finding other prehistoric sites on the continental shelf. Site locations are shown on Figure 3.

Shackleton *et al.* [29] have described the exposed shelf areas of the West Mediterranean in terms of potential archaeological exploitation, but without submarine prehistoric data, or estimates of site survival.

4.2 Gibraltar

The crossing route at Straits of Gibraltar is flanked by known archaeological sites on the Rock of Gibraltar itself, in southern Spain, and in Morocco. The broad situation is summarised by Alimen [28]. On Governor's Beach Gorham's Cave contains Neanderthal deposits (Klein [30] p.368) and could only have been entered when the sea level was tens of metres lower than at present. Flemming [54, 58] used diving surveys to identify submerged cliffs and caves to the west of Europa Point, with the entrances at –20m, which create a very sheltered environment, and within which prehistoric deposits could be preserved. Finlayson [2002, personal communication] states that divers from the Museum

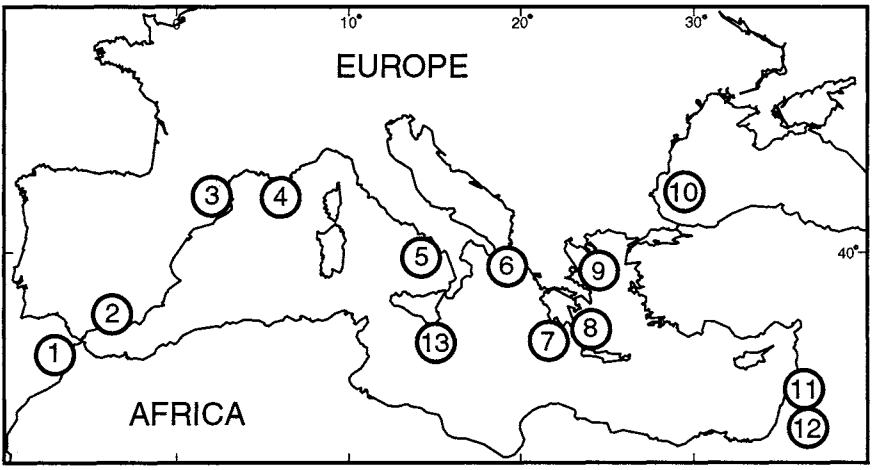

Figure 3. Submerged prehistoric sites, or sites only accessible at lower sea level. 1 = Cave of Hercules, Tangiers. 2 = Gibraltar, Gorham's Cave and sub-merged caves off Europa Pt. 3 = Neolithic site off Leucate. 4 = Grotte Cosquer, Palaeolithic. 5 = Palinuro, Palaeolithic. 6 = Aghios Georghios, Corfu, Palaeolithic. 7 = Methoni, Bronze Age. 8 = Pavlo Petri, Bronze Age. 9 = Aghios Petros, Sporadhes, and Franchthi Cave, Neolithic. 10 = Bulgarian coast, Bronze Age sites. 11 = Atlit, Israel, Neolithic. 12 = Hof Dado and Tel Harez, Israel, Neolithic. 13 = Malta caves. References, see text.

of Gibraltar are continuing to examine these caves. Near Tangier, to the South, there is the famous Cave of Hercules, which opens directly onto the sea.

The Strait is deep and steep sided so that the 12km width does not decrease much at low sea levels, and it did not dry out during the Quaternary. To the west of the narrowest part of the Strait a group of substantial shoals become large islands at glacial low sea level, and these were visible vegetated land masses, completely changing the appearance of the Strait from either shore. The length of the Strait itself was increased, and the archipelago provided a stepping stone and safety net to anyone seeking to cross. The shoals have been surveyed by Giermann [55] and with modern swath acoustics by Sanz *et al.* [56]. Pipeline surveys in the area should be examined to obtain more detail on the sediments and precise topography, including river channels and submerged beaches.

In the western Mediterranean submerged prehistoric sites which should be compared with Gibraltar exist at Leucate (Geddes *et al.* [15]) and near Marseille (Clottes and Courtin [23]). The latter indicates human use of the continental shelf at a depth of –40m at dates around 20ky BP. On the north coast of France the submerged site near Fermanville indicates occupation at a depth of –25m about 45ky BP (Scuvée and Verague [9]).

4.3 Sicily-Tunisia

The crossing route at Cape Bon to Sicily would lead naturally across the Adventure Banks. Again, the archaeological context was set out by Alimen [28]. Colantoni has dived on the banks conducting geological surveys. Gas pipelines have been surveyed and installed to the west of the shallowest routes. Sicily and Malta abound in submerged caves Martineau [57], but very little work has been done on the submarine prehistory of this area. Blanc [2] describes the flooded caves at Palinuro, which have bone breccia cemented onto the walls in places which are now only accessible by boat. Flemming [58], diving in the cave, found rock arches, screes, and stacks, descending to –50m depth, constituting an impressive shelter during periods of low sea level.

4.4 Bab el Mandab

The modern Straits of Bab el Mandab are only 20km wide. A shallow continental shelf at –20 to –30m is penetrated by a deep channel at –137 to –170m, which would have provided sea-water connection from the Red Sea to the Indian Ocean for most of the Quaternary. Rohling *et al* [59] provide analysis of the low sea level stands for the last 500ky, while Naqvi and Fairbanks [60] relate the flow conditions to the monsoon during the last 27ky, and Murray [61] measured the modern stratified flow conditions in order to detect seasonal variations.

When the sea level was of the order of 100–150m lower the narrow sinuous channel through Bab el Mandab would have been only 5 km wide for a length of 150km, and only 10km wide for a further 50km to the north. The topography of this shelf requires intensive analysis by accurate bathymetric surveying, and interpretation of existing surveys. Study of submerged sediments, and location of submerged coral terraces or limestone caves would be significant advance. Many sports diver boats now take tours to this area, and the steep terrain around the Hanish Islands and the Seven Brothers may provide clues to submerged geomorphology and ancient shorelines. No submerged prehistoric sites have been found in the Red Sea, but many sites on the coast, as previously mentioned.

5 Areas of exposed shelf and prehistoric subsistence

At glacial low sea levels large areas of the continental shelf were exposed, and potentially covered in vegetation, river courses, and occupied by fauna. This changes the resources available to early humans. The principal areas are the Golfe du Lyon, The Gulf of Sirte, the Adriatic, large parts of the Aegean, the Nile Delta, and the shores of the southern Red Sea. The human occupation of these areas is important from the point of view of early seafaring, exploitation of fish and shellfish, and early agriculture. This resource base needs to be included in future studies. The climate and vegetation need to be calculated in each case, and international programmes have started to produce the integrated data.

6 Conclusions and recommendations

Submarine prehistoric sites in the Mediterranean show that the continental shelf was occupied by humans to a depth of at least –40m. This is a fact, not a hypothesis. Sites could exist to a depth of –120m, and should exist near potential crossing points. Submerged prehistoric sites are widely distributed, but have not yet been found on the North African coast. A project to understand the function of the potential crossing points and the significance of archaeological prehistoric sites on the continental shelf needs the following components:

. Accurate bathymetry, analysed for drainage patterns and beaches.
. Analysis of sea level changes and tectonics.
. Vegetation, landscape, fauna, precipitation, at each sea level.
. Data on adjacent archaeology on land.
. Evidence from the submarine prehistoric sites.
. Palaeo-Climate data at each glacial maximum and minimum.

International collaboration is needed. The authors of the present paper are collaborating to obtain research funding, based on the broadest interpretation of the objectives. Submarine archaeology is a component of the overall programme, and this paper summarises the role of underwater prehistoric sites.

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