

The Atlantis Hypothesis: Searching for a Lost Land



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Palaeogeographic reconstructions of the Aegean for the past 20,000 years: Was Atlantis on Athens' doorstep?

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ABSTRACT

Sea level has varied spatially through time because of the Earth's response to the glacial cycles on its surface and because of tectonic processes within the Earth. Models describing the physical processes of the glacial response are well known and can be calibrated against the field evidence for sea level change. The tectonic contributions can in many instances be quantified by examining evidence of sea level change over longer cycles. Thus it becomes possible to predict shoreline evolution during a glacial cycle, particularly for the time following the last maximum glaciation. The theory is sketched out and illustrated by a number of examples from areas that have been previously examined in more detail and that have also been variously proposed by other authors as potential Atlantis sites. The case of the Aegean has been examined in greater detail. A common feature of all of these reconstructions is that major inundation of coastal areas occurred during the 'dawn of civilisation'. This raises the question

whether the Atlantis and other flood stories have their origins in the geological past and that preservation of memory is possible over millennia.

1. INTRODUCTION

Sea levels have fluctuated throughout geological and anthropological time, periodically flooding or draining the world's coastal plains. The causes for the changes are varied. The observation of past sea level itself is with respect to the land surface and any change reflects either a shift in the position of the sea surface, of the land or, most usually, of both. Thus tectonic processes that cause uplift or subsidence of the coastal zone will result in an apparent sea level fall or rise. The observations made by Charles Darwin of fossil sea-shells and petrified forest trapped in marine sediments at elevations of hundreds of meters in the Andes of South America are one example of where the sea-land levels have changed because of tectonic processes. Such changes can be large,

of the order of meters in single tectonic episodes or cumulatively a few hundred meters in 100,000 years, but they will be localized. Sea level also changes if the amount of water stored in the oceans is changed. This occurs on the very long geological time scale ($\sim 10^9$ years) due to the outgassing of the planet but this is small on the human time scale. More significant is the cyclic exchange of water between the oceans and the ice sheets and during a glacial cycle, typically some $50\text{--}60 \times 10^6 \text{ km}^3$ of water is exchanged. The sea level response to this is addition or removal of water is global, with an average change of $\sim 130\text{--}140 \text{ m}$ during the glacial oscillations from 140,000 years ago to the present. But they are not uniform and in some parts of the globe they may actually fall during a glacial regression. Nor are the rates of change uniform. On the human time scale this quasi-cyclic exchange of ice and ocean is the most important global and unifying cause of sea-level change. Rates of sea-level rise or fall from this cause have varied through time, reaching extreme values of a few centimetres per year during the past 30,000 years and for some of the flat and low-lying coastal planes have resulted in shoreline movements at rates of hundreds of meters per year (unless otherwise stated, all ages are in calendar years). (See Lambeck & Chappell 2001; Lambeck 2004 for recent reviews) The persistent rise of the sea

that started $\sim 19,000$ years ago with the collapse of the last ice sheets and ended about 7000 years ago will have resulted in major changes within lifetimes and human memory of coastal dwellers and in view of the upheavals that this would have caused from generation to generation it should not be surprising that flood stories permeate early legends.

The sea-level change resulting from the waxing and waning of ice sheets is not everywhere identical. Ocean volumes increase when ice sheets melt but the relative sea-level rise will not be uniform because of the interactions between ice, land and oceans. The geological, geomorphological and archaeological field evidence for the period following the last ice age abundantly demonstrates this spatial variability (Figure 1). But the evidence is usually fragmentary and it is not possible to reconstruct the sea level change through time from empirical evidence alone. To be able to predict the past topography, including the location of past shorelines, we need to understand the processes that lead to the complex patterns observed. Only if these are understood and quantifiable does it become possible to predict the evolution of shorelines and water depths through time. This point has been reached in so far as the important glacially driven processes are concerned and it is possible to make realistic reconstructions of the coastal landscape during the last glacial cycle.

2. SEA LEVEL CHANGE DURING A GLACIAL CYCLE

The reason for the non-uniformity of the sea-level response to the growth and decay of ice sheets comes down to the non-rigidity of the planet and to gravity, two well-understood physical processes. The earth, when subjected to forces, deforms. The forces may be external, such as the gravitational attraction by the Moon and Sun that raises semi-diurnal and longer period tides in the solid part of the planet as well as in the oceans. They may be internal, associated with mantle convection and these operate on time scales of millions of years. Or they take the form of surface loads, a redistribution of sediments, ice and water over the Earth's surface, for example. On the short term, and for small stresses, the response to the forces is primarily elastic. On the long term, including the characteristic time scale of glacial cycles, the response is primarily viscous (a delayed response), the planet continuing to deform after the forces have dissipated. Evidence for the response lies in the geological, geophysical and geodetic observations of the planet and one of the principal aims of geophysics is to understand the processes that determine this response over a wide range of time, length-scale, and stress. The physics is relatively well understood and gravity, naturally, is part of the process but it plays a second role as well. One important source of infor-

mation for deformation is from sea-level data. If meteorological and ocean dynamics are ignored - by time-averaging the record - the ocean surface becomes one of constant gravitational potential. Mass redistribution on the surface of the planet changes the gravitational attraction and hence the shape of the ocean. For example, a large ice sheet will exert a gravitational pull on the adjacent ocean and sea level rises around the ice sheet and falls further away if mass is conserved. When the ice melts, globally the ocean volume increases and globally sea level rises, but, outside the ice, sea level may actually fall because of the change in gravitational attraction. When the Earth deforms under a large ice load the gravitational field is further changed and the sea surface will also reflect this.

A complication is added when one considers the consequence of changing the ocean volumes. Geophysical observations indicate that the Earth deforms under even quite small loads, such as fluctuations in air pressure or the cyclic ocean tidal loading. Thus when the meltwater from the receding ice sheets is added to the oceans the sea floor is loaded and depressed, more in the middle than at the margins, and changing the shape of the ocean basin. The water in the basin has to follow this subsidence and sea level changes by greater or lesser amounts depending on the geometry of the ocean basin. The total

response of sea level to the decay of large ice sheets is therefore a combination of changing ocean volumes, of the response of the crust to the glacial unloading, the response to the water loading of a complex-shaped ocean basin, and to the changes in the gravity field caused by the mass redistribution and deformation.

Typically, beneath a large ice sheet of thickness, say 3000 m, the crustal depression beneath the load will be some 800 m and when the load is removed the rebound of the crust will occur over a period of thousands of years and is still seen in, for example, Scandinavia and Canada. Thus sea level continues to respond, even though the melting may have ceased. Since the last glaciation the large ice sheets of the northern hemisphere and the larger-than-present Antarctic ice sheet added enough water to the oceans to raise the globally averaged levels by 120-140 m. This globally averaged change is often referred to as eustatic sea level change or as the ice-volume equivalent sea-level change (Lambeck et al. 2003). The response of the seafloor in mid ocean to this load, far from the ice sheets, will be some 35-40 m. In between the crustal response will lie between these values depending on the distance from the former ice margins and on the ocean geometry. Beneath the former ice sheets the crustal rebound dominates over the change in ocean volume and the sea-level change

will be primarily one of a falling sea level, as observed in the Gulf of Bothnia and in Hudson Bay (Figure 1). At the edges of the ice sheet the rebound is reduced and the sea level signal will be more complex. At some times the rebound dominates, at other times the eustatic contribution dominates and this produces the signal seen along, for example, the Norway coast.

Within the closed outer shell of the Earth (the lithosphere) mass has to be preserved during the deformation cycle. Thus if the crust is depressed beneath a growing ice sheet, a broad bulge develops beyond the centre of loading. When combined with the changes in gravity, it creates a broad zone around the ice sheets where sea level lies above its average value by some tens of meters. When the ice melts, this bulge subsides and sea levels would appear to rise over and above that due to the changing ocean volumes and when the ocean volumes have stabilised this subsidence will continue because of the planet's viscosity. This broad zone around the former northern European ice sheets extends as far as the Mediterranean such that here sea levels, relative to the crust, continue to rise up to the present. This produces the characteristic signal illustrated in Figure 1 for the south of England.

Further away again, the sea level signal is dominated by the water loading. As the seafloor subsides the ocean sur-

face follows but because this subsidence is greatest in the middle of the ocean basins, water flows away from the continental margins to fill the void and sea levels fall along the coasts. This signal becomes most evident once ocean volumes have stabilized and results in small sea-level highstands peaking at about 7000 years ago. This occurs, for example in the Persian Gulf and along continental margins further away (Figure 1).

Thus the spatial behaviour illustrated in Figure 1 is understood in terms of the interactions between the earth, oceans and ice sheets at times of glacial growth and decay. The physics for the crustal rebound and the sea-level response is well understood and has been tested against a range of geophysical observations (Mitrović et al. 1997; Peltier 1998; Milne et al. 2001) and if the history of the ice sheets is known it is possible to predict the sea level change through time. High-resolution models have been developed with most emphasis being on the period since the start of the last deglaciation although some effort has been made to develop models for the earlier period as well. Then if the bathymetry and topography are known it becomes possible to predict the location of shorelines and water depths into the past.

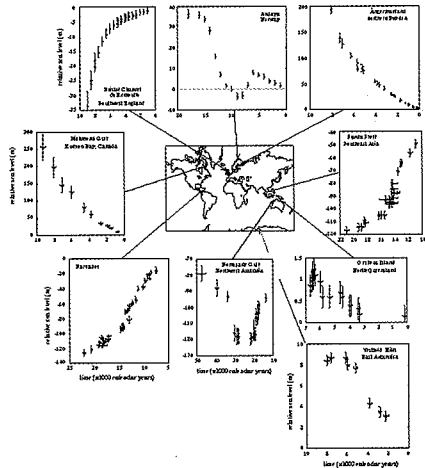


Figure 1. Observed sea levels from different locations around the world (from Lambeck & Chappell 2001). The sea level is expressed relative to the present position. All sites are either tectonically stable or, in the case of Barbados, have been corrected for tectonic uplift. Note the different scales used. Observational uncertainties are shown by the error bars. The Sunda Shelf, Bonaparte Gulf and Barbados results provide approximations of the eustatic change although the isostatic contribution is not negligible. The Richmond Gulf and Ångerman results are typical of sites that were below large ice sheets and the Andøya and Antarctic Vestfold Hills results are representative of a location near but within the ice margin at the time of its maximum extent. The result for Southwest England is representative of locations of a broad zone around the former ice sheets, including the Mediterranean, in which sea levels continued to rise after the end of deglaciation. The Orpheus Island result is representative of continental margins far from the former ice margins.

3. SOME EXAMPLES OF PAST SHORELINE RECONSTRUCTIONS

Examples from many localities have been examined, a number of which coincide with postulated locations for Atlantis (see the cover of the abstract volume of the *Atlantis Hypothesis: Searching for a Lost Land*) or from which there are flood legends. Only four examples are illustrated below, including the Aegean in section 4. Others include the Red Sea and the Gulf of Suez (Lambeck 2004), Africa to Italy (Lambeck et al. 2004), northern Australia (Yokoyama et al. 2001); Southeast Asia (Lambeck 2001) and the Black Sea (Lambeck et al. 2006). In each case the models have been calibrated against local sea level information and the predictions tested against independent data. Thus the methodology is tried and tested and, equally important, for each area it has been possible to identify critical areas from which new data has been collected to test particular aspects of the model.

3.1 Scandinavia

This is a region that has been subject to major glaciation from 20,000 years ago until about 9000 years ago. At the time of maximum glaciation the ice extended onto the northern German plain and across Denmark as far as Jylland and the crust beneath the ice was substantially depressed. As the ice retreated the crust slowly rebounded and land levels rose faster than the sea level such that

across the region sea levels were falling relative to the land. By ~12,000 years ago (10,500 ^{14}C years) the margin had retreated from southern Sweden and the central Baltic and at this time the retreat momentarily halted with the ice pinned on a small mountain range, Mt Billingen (3) between Lake Vänern (1) and Lake Vättern (2). This separated the Atlantic from the Baltic and the latter's level built up about 30 m above coeval sea level with overflow through the Öresund (Björck 1995) (Figure 2). When the ice retreat continued northwards away the ice barrier was removed and the lake drained catastrophically through the Närke Strait. This continued to be the outflow of the Baltic lake until the crustal rebound was sufficient to bring this region above sea level at which point the overflow occurred again through the Danish Straits and as sea-level rose in the open ocean this soon became the access for Atlantic waters. Thus here and further north in the Gulf of Bothnia once the area became ice free, the sea-level change is one of falling levels up to the present time. This is seen in elevated shorelines, in old harbour towns left high and dry, and in folklore (Ekman 1991) and this is one region where there does not appear to be a flood legend. Instead, the whirlpool appears to dominate as an explanation of the falling sea level (e.g. the illustrations in Kirchner (1665), or the explanation by Celsius (1743) of observations of falling sea level in the Gulf of Bothnia).

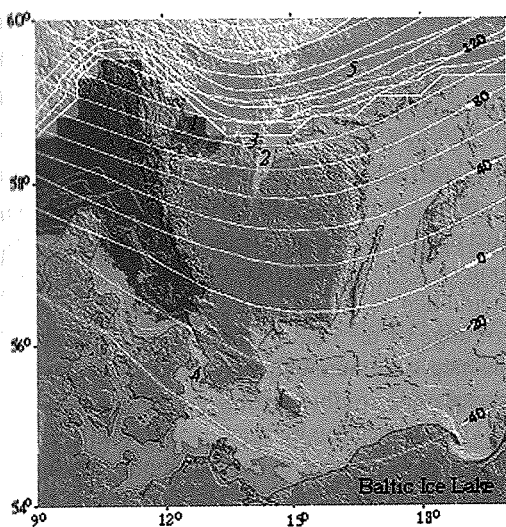


Figure 2. The palaeo reconstruction of the south-western Baltic at $\sim 12,000$ years ago (10,500 ^{14}C years ago). The ice is defined by the white contours giving ice thickness at 200 m interval. The blue areas beneath the ice indicate that the crust is depressed below the sea level of the epoch such that outflow of the Baltic will occur here, the Närke Strait (5), immediately after the ice retreats from the area. At this time the ice sheet was stationary across southern Sweden and the outflow of the Baltic occurred through the Öresund (4) which was above sea level at this time such that the Baltic was isolated from the Atlantic. This formed the Baltic Ice Lake whose surface was some 30 m above sea level (Björk 1995) at this time. The yellow contour indicates areas of uplift (the first contour is the zero value) and correspond to the present elevations of shorelines that may have formed 12,000 years ago. The red contours define sea levels below present.

At the southern margin of the Baltic the crustal rebound was less because the ice was thinner than further north and the rebound was soon overtaken by rising levels that resulted from the melting

of the global icesheets. In consequence, extensive flooding of the German plain occurred throughout the last 10,000 or so years (Figure 2). It is perhaps not surprising that there are proponents for a Baltic Atlantis! Figure 2 illustrates the reconstruction for $\sim 12,000$ years ago and results for other epochs are given in Lambeck (1999).

3.2 North Sea

This is a region of rising sea levels throughout the post-glacial period except for locations in Scotland and the Norway coast where the local crustal rebound following on from the deglaciation exceeds the eustatic change. Much of the North Sea is predicted to have been exposed for a prolonged period in the Lateglacial and Postglacial period (Figure 3). These predictions are consistent with the location of now-submerged shorelines between Shetland and Norway and the site of a Palaeolithic flint discovery, at 143 m water depth 150 km north east of Lerwick (Long et al. 1986) corresponds to the predicted shoreline location up to about 14,000 years ago. Thus extensive sea-faring capability was not required at this time. In these reconstructions the Dover Strait did not open until about ~ 9000 years ago by which time the Dogger Bank also became an island only to vanish below the sea some 1000 years later. Is this an argument for another potential Atlantis site (Erlingsson 2004)? Re-

constructions for other epochs are given in (Lambeck 1995a).

3.3 Persian Gulf

This is region where the sea-level change was initially rapid, reaching its present position about 7000 years ago and reaching a maximum level of about 2 m above present before slowly falling back to its present position.

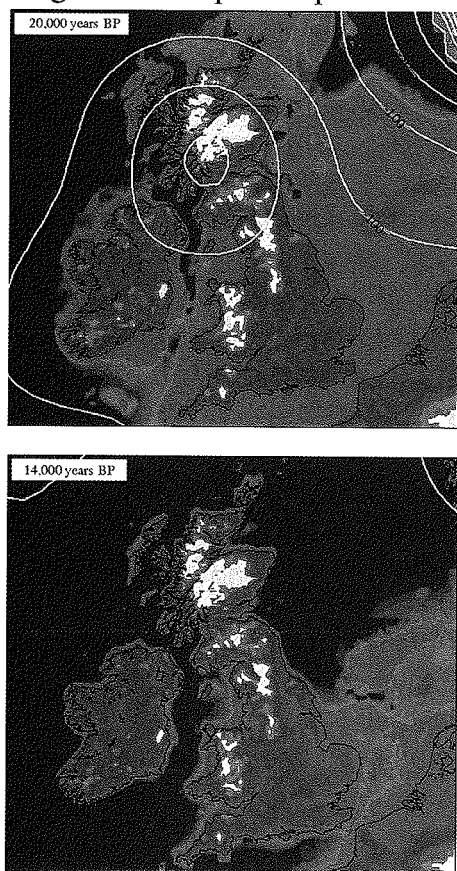


Figure 3. Palaeo reconstructions for the British Isles and the North Sea at 14,000 (top) and 9000 (bottom) years ago. At 14,000 years ago the ice has vanished from Scotland but a small area of uplift, defined by the yellow contour remains.

Red contours indicate areas of subsidence. Because of the combined effects of the rebound due to the deglaciation of both the British Isles and Scandinavia, much of the North Sea is above sea level at this time. Until about this time the Irish Sea was closed between Aberystwyth and Wexford and Bendigeidfran and his host could indeed have waded to Ireland (Mabinogion 1993) if he lived at this time! The flints mentioned in the text were found at the northern edge of the map to the east of Shetland at the map's northern edge. By 9000 years ago the transgression of the North Sea is now significant and the connection between isolation of Britain from the Continent occurs at about this time. The Dogger Bank is also isolated at this time and becomes submerged at ~ 8000 years ago. All ages are calibrated years before present.

The Persian Gulf, being shallow today, was above sea level at the time of glaciation, with the Shatt-al-Arab connecting marshlands and shallow lakes on its meandering way to the open sea at Hormuz (Figure 4). But by about 14,000 years ago sea level had risen sufficiently to breach the sill at Hormuz and to flood the lower Shatt-al-Arab and the next 7000 years was a time of progressive flooding, at times more rapid than others (see Lambeck 1996a; 2004, for other epochs). This continued until ~7000 years ago when the local sea levels ceased their rise at a level a little higher than present such that Hammar Lake formed a shallow extension of the Gulf and the Sumerian sites of Obeid, Ur and Erridu were at the coast, as indeed recorded in the cuneiforms (Jacobsen 1960). These reconstructions prompt a number of questions. Did the now-flooded low-

er Shatt-al-Arab valley form the route travelled from the east by the ancestors of the Sumerians (Roux 1992). As a result of having to constantly move camps on the shores of the gulf lakes are the legends of the Sumerian flood and the struggles with the sea attributable to a collective memory of the prolonged transgression of the sea in palaeolithic time? Has the knowledge of the location of submerged fresh water springs been handed down from the times when the Trucial Coast pearl banks were still above the gulf level about 9000 years ago?

4. THE AEGEAN

The areas discussed above are characterised by (mostly) regional tectonic stability and the changes in relative sea level are mostly attributable to the earth's response to the glacial cycles. Thus these are regions where the rebound and sea-level models can be tested and calibrated with minimal contamination arising from tectonics. But Greece is a region wracked by seismic activity in response to the collision of the African and Eurasian super plates and sea-level change may have a local tectonic component superimposed upon the glacially-induced signal. But the deformation is not uniformly distributed and there are areas where the integrity of the crust appears to be maintained or where deformation is restricted mainly to the

horizontal components.

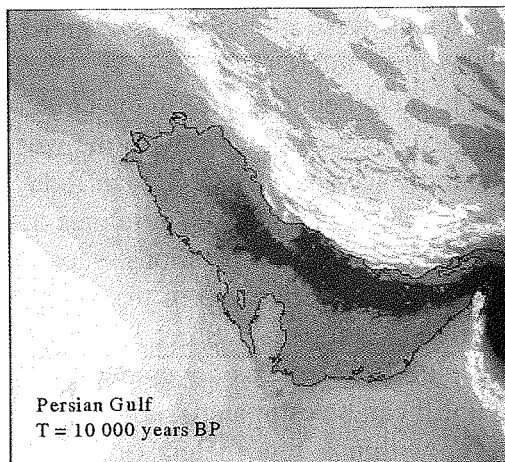
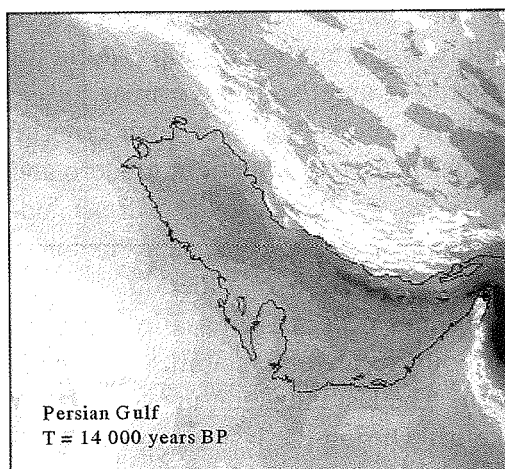


Figure 4. Palaeogeographic reconstructions for the Persian Gulf at 14,000 and 10,000 years ago. Before 14,000 BP the Euphrates-Tigris River system reached the Indian Ocean at the Straits of Hormuz, via a series of low depressions that would have formed lakes or swamps much like the Hamar Lakes before their drainage. By 14,000 years BP the sea level had risen sufficiently to flood the lower valley but isolated fresh-water lakes remain further upstream. The fresh ware lake illustrated here was flooded about 1000 years later and by about 8000 years ago the present Gulf coastline was approached.

Thus to carry out the sea-level analysis for a region subject to tectonics it will be important to develop criteria for separating quiet and active areas.

There are a number of such criteria: an absence of seismicity in modern and historical time, an absence of fresh geomorphological or landscape features, or a preservation of older interglacial shorelines near present sea level would all point to tectonic stability of the region. The last indicator, in particular, is useful. During the last interglacial, between 130,000 and 120,000 years ago, sea levels were globally a few meters higher than today (Stirling et al. 1988) due to there being less ice in the Greenland ice sheet, and possibly in the west Antarctic ice sheet as well, than today. Thus if these interglacial shorelines occur in well-elevated positions, such as along the southern shore of the Gulf of Corinth (Keraudren & Sorel 1987; Collier et al. 1992), rates of average tectonic uplift can be estimated. Where these occur within a few meters of present day sea level, such as in the upper regions of the Gulfs of Messenia, Lakonia and Argolis (Kelletat et al. 1976; van Andel 1987) the vertical tectonic deformation can be assumed to be small. Using these criteria, and considering tectonic indicators, it becomes possible to separate the available sea level data set into categories of tectonically active or passive areas. The latter can then be used to constrain the model for the gla-

cial signal and the former can be used to estimate the tectonic rates.

The field data for sea-level change in the Aegean region are of several types: archaeological evidence that mostly provides estimates of the limits on sea level. A human settlement now submerged at depth $h(t)$ and dated to time t implies that at this time sea level was at least h below present sea level. For example, offshore from Franchthi Cave, near Koilás in the southern Argolis Peninsula, a Neolithic site points to the sea having been at least 11m lower than today between 7610 and 6220 radiocarbon years ago (Jacoben & Farren 1987) and now-submerged Early Bronze Age remains point to sea levels before 5000 radiocarbon years having been at least 5 m lower than today at Saliagos, Andipáros (Morrison 1968). Sometimes the result can be more precisely defined such as when the archaeological feature has a well-defined relationship to sea level at the time of its use (e.g. Fleming 1972; 1978). Examples of this include quay foundations or slipways such as at Matala, Crete, where a slipway of Roman Imperial age has a present elevation that is near to what is expected if it were functional 1900 years ago (Papaioannou 1993). A second type of evidence consists of bio-marine notches that have been lifted above the tidal range by rapid tectonic uplift and these observations are themselves indicators of seismic activity. The age of these fea-

tures is achieved by radiocarbon dating of the borers responsible for the notch in the first place but which died when the tectonic event lifted them above sea level (Pirazzoli et al. 1994). The third type of evidence is sedimentological in nature: a transition from terrestrial to marine sediments would, for example, be indicative of a rising sea level. This evidence comes mainly from the Peloponnesian coast, for Messina, the Argolis plain and Elos and Navarine (Kraft et al., 1975, 1977, 1980). Some of the data points are from back swamps and represent upper limits; others are from shallow marine sediments and indicate lower limits. Together they provide some useful upper and lower limits on relative sea level change in the Aegean.

These observations, along with data from other parts of the Mediterranean, and using the above criteria for distinguishing between tectonically stable and active locations, have been used to validate the predictive models using the data from tectonically stable areas and to estimate rates of vertical land movements for the active regions (Lambeck 1995b; Lambeck & Purcell 2005). Using all available data from the region, irrespective of whether tectonic displacement is important, and compare the predicted change for the times and places of observation with the observed values, we can identify the tectonically active areas as illustrated in Figure 5.

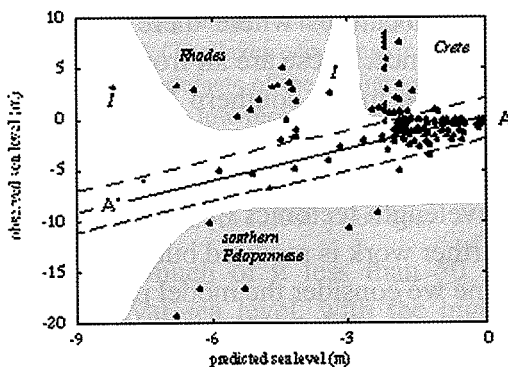


Figure 5. Observed versus predicted sea levels for the times and locations of the observed values for the past 8000 years. In the absence of tectonic movement and perfect observations and predictions, all points should fall on the line AA'. In the presence of observational and predictive uncertainties points that fall within the zone defined by the dashed lines parallel to AA' Points that fall above this limit are indicative of tectonic uplift and points below this zone are indicative of subsidence. The main uplift areas are eastern and western Crete, Ródhos, Kárpáthos, Kíthira and Andikíthira with the highest rates of >4mm/year occurring in southwestern Crete. Other significant uplift occurs along the Gulf of Corinth and the two points marked I are for the Perachóra peninsula.

If both observations and predictions were perfect the points should fall on a straight line and, within the uncertainty estimates of both, a substantial subset of the data meets this condition, including data from Andipáros. But data from an arc extending from Rhodes to Karpathos, Crete and Kithira lie above this line and correspond to sites where there has been tectonic uplift at rates of up to 4 mm/year and more, consistent with subduction tectonics (Jackson 1994). The points below the line in-

dicating localities where there has been subsidence. These are all from scattered locations in the southern Peloponnisos and they do not form a clear geographic pattern and may be indicative of short-wavelength tectonics or data problems. Further work is required but until this is done we consider the model predictions to provide a reliable measure of relative sea level change for the tectonically stable areas, including the Cycladean Islands, and we can map the changes in coastlines, water depths, and inter-island visibility throughout time back to about 20,000 years ago. Results are illustrated in Figure 6 for some selected time steps. The topography is based on a 2.5' digital database and the bathymetry is derived from a digitisation of the nautical charts from across the region. No corrections for sedimentation, erosion or tectonics have been applied and these would clearly be significant for reconstructions of areas such as Thira for times before the last eruption.

The results illustrated in Figure 6 show not only the palaeogeography at the selected epochs but also the contours of relative sea level change since the epoch. At 20,000 years BP, for example, this pattern is one of greater change in the centre of the Aegean than on the mainland coast and differences of 20 m are predicted across the region. This reflects mainly the response of the sea floor to the water that has been added from the global deglaciation at high

latitudes, with the sea floor "sagging" further in mid-sea than at the coast but superimposed on this is a north-south gradient due to the increasing distance from the ice margin. A number of depressions in the topography can be identified that may provide useful targets for testing the model. In the Petalilion Gulf, for example, there is an enclosed basin sediments within which may contain evidence of a marine incursion soon after 20,000 years BP and sediment cores from this site would be important for testing the model (c.f. Yokoyama et al. 2000). Similar depressions are predicted between Míkonos and Náxos or between Síros and Páros, coring of which may yield information on the timing of the transgression, predicted to occur just before 15,000 years BP in former case. Other basins with thresholds near to sea level at this time include the Saroníkos Gulf.

5. WAS ATLANTIS ON THE DOOR-STEP OF ATHENS?

At the time of the last glacial maximum, at ~ 20,000 years ago, the combined effect of the decrease in ocean volume and the associated earth response resulted in the present Cycladean islands forming a large and continuous emerged landscape extending north-south from Ándros to Íos and with an east-west dimension that reached ~100 km. The landscape would have been characterised by a relatively

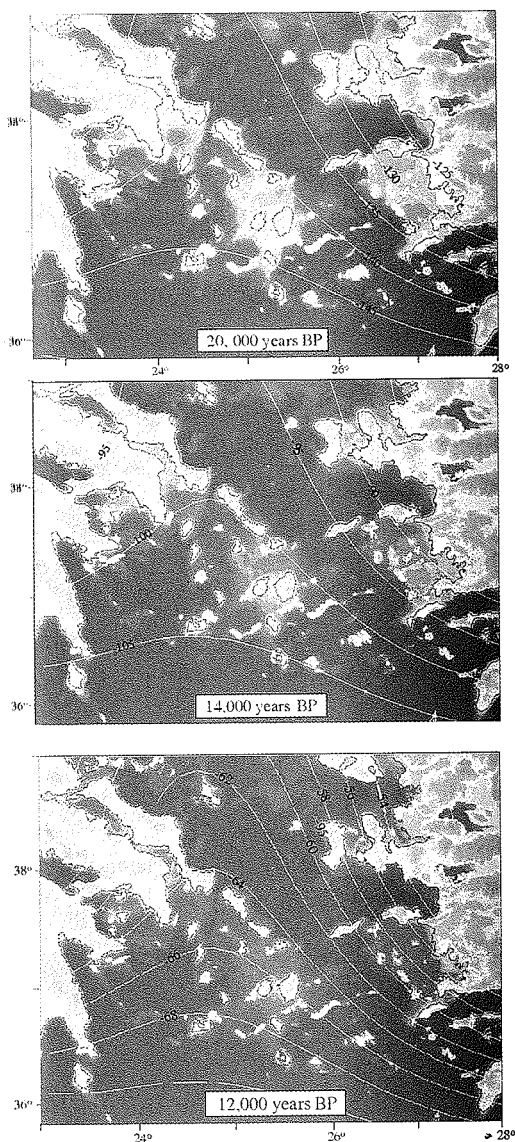


Figure 6. Palaeo reconstructions for the central and southern part of the Aegean. Curves of sea level change, relative to the present, are shown by the red contours. (a) 20,000 years BP, at the time of the glacial maximum. The Cycladean islands form a large plateau separated from Evvoia by a narrow channel. The channels between this platea and Asia Minor are also must restricted such that circulation between the cen-

tral-northern Aegean and the Mediterranean is much reduced. (The lakes occurring on land, as in Turkey are artefacts of the topographic data base used whose low-resolution does not define the river beds when these are narrow.) (b) 14,000 years ago. The Cycladean Plateau is beginning to founder. (c) 12,000 years ago.

low plain, much of it less than 50 m above coeval sea level, with the highest elevations reaching above 1100 m asl. The minimum separation of what I will call the Cycladean plateau from the mainland is ~ 5 km at Ándros and both sides will always be clearly visible during all stages of a water crossing. The separation between the plateau and the western islands are also much reduced at this time and simple intervisibility calculations show that Mílos could be reached via Sífños and Kímolos within loosing sight at any point of the traverse of both departed and aimed-for land (Figure 7). This shoreline geometry initially evolves only slowly but by 15,000 years ago the reduction in size begins to accelerate, mainly in the east-west direction and by 13,000 years ago the Cycladean Plateau founders into two parts with the southern one centred on Páros, Náxos and Íos. At this time the greatest water separation between these fragments and with the mainland is between Náxos and Míkonos, some 20 km shore to shore, but with clear visibility of both sides during any part of a water crossing.

The earliest evidence of movement of people between the Cycladean Islands and the mainland is probably the occurrence

of obsidian from Milos in the Franchthi Cave (Peloponnisos) in strata that date at $10,930 \pm 160$ C14 years or $\sim 12,750$ calendar years before present (Radiocarbon 1976). (It is sometimes quoted as 11th millennium BC (Perles 1979; Cherry et al. 1982) and I adopt the ^{14}C age reduced to calibrated years.) This is about the time of the break-up of the Cycladean Plateau and journeys by the early collectors of the volcanic glass would have involved much less water crossing than in later millennia and could have done so without requiring sophisticated sailing or navigation skills as has sometimes been suggested.

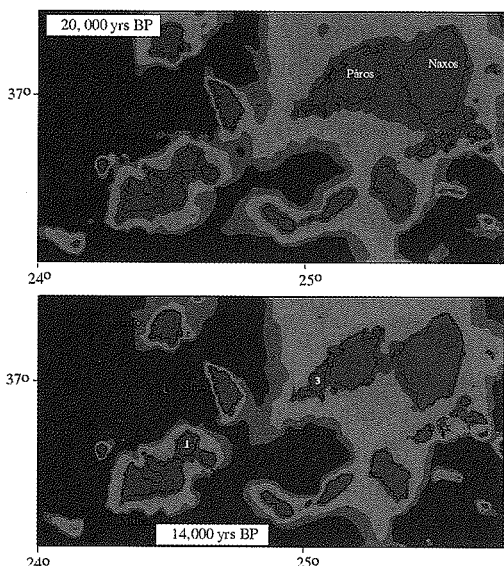


Figure 7. Caption Same as Figure 6 but for the area between Milos and Páros and Naxos at 20,000 and 14,000 years BP. (1. Kímilos, 2. Políaigos, 3. Andipáros.

By $\sim 10,000$ years BP the shoreline configuration was broadly similar to today but locally some important differ-

ences remained. Milos included Kímolos and Políaigos and was considerably more extensive in the past and retained a unity until ~ 6000 years (5300 ^{14}C years) (Lambeck 1996b). Thus possibly much of the evidence for early human activity is now submerged and this may explain the apparent absence of Late Palaeolithic and Early Neolithic settlements on Milos at a time when the obsidian was still being exploited on the mainland (Renfrew 1972).

Whether or not the foundering of the Cycladean Plateau also provides an explanation for the Atlantis myth is not something that I can contribute to in a scholarly way but some speculation may not be inappropriate in the context of some of the other papers presented at the conference. The origins of the Atlantis story lie far back in time and are less securely rooted in ancient Greek tradition than, for example, the Homeric sagas (Luce 1970) and if the Egyptian account to Solon is interpreted at face value, it requires that memories are preserved for a very long time: 'that some dim far-off historical reality lay behind it' (Luce 1970). In so far as flood myths from other regions – whether the Sumerian accounts, the Moses crossing of the Red Sea, the Mabinogion, singing voices from a submerged town in the Baltic, or Australian aboriginal myths – all seem to have geological parallels dating back to the dawn of civilisation. This does require encapsulation of geo-

logical events into short or catastrophic events but other examples of this abound, including the creation of the Earth in five days. It also requires preservation of memory for seemingly impossible long periods but here, perhaps Plato was correct when in his *Phaedrus* Thamos remonstrates against Theuth that the latter's invention of writing will only produce forgetfulness in the minds of those who chose to learn it because they will not practice their memory (Fowler 1996).

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