Destruction of Atlantis by a great earthquake and tsunami? A geological analysis of the Spartel Bank hypothesis

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Destruction of Atlantis by a great earthquake and tsunami? A geological analysis of the Spartel Bank hypothesis

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ABSTRACT

Numerous geographical similarities exist between Plato's descriptions of Atlantis and a paleoisland (Spartel) in the western Straits of Gibraltar. The dialogues recount a catastrophic event that submerged the island ca. 11.6 ka in a single day and night, due to violent earthquakes and floods. This sudden destruction is consistent with a great earthquake (M > 8.5) and tsunami, as in the Gulf of Cadiz region in 1755 when tsunami runup heights reached 10 m. Great earthquakes (M 8–9) and tsunamis occur in the Gulf of Cadiz with a repeat time of 1.5–2 k.y., according to the sedimentary record. An unusually thick turbidite dated as ca. 12 ka may coincide with the destructive event in Plato's account. The detailed morphology of Spartel paleoisland, as determined from recently acquired high-resolution bathymetric data, is reported here. The viability of human habitation on this paleoisland ca. 11.6 ka is discussed on the basis of a new bathymetric map.

Keywords: earthquake, tsunami, Iberia, paleoseismology, geoarcheology.

INTRODUCTION

In recent years several studies have sought to explain the origin of legends and myths deeply rooted in ancient cultures in terms of geological phenomena. Faulting and hydrocarbon gas emissions were demonstrated to have existed at the temple of Apollo in Delphi, Greece, and were reported in ancient documents to have influenced the oracle (Piccardi, 2000; de Boer et al., 2001). The paleogeography of the ancient harbor of Illium (Troy) was investigated using modern sedimentological techniques (Kraft et al., 2003) and was found to correspond closely to the Homeric accounts. The recurrent deluge story (e.g., in the *Epic of Gilgamesh*, Greek mythology, and the Book of Genesis in the Old Testament) has been interpreted in terms of the catastrophic flooding of settlements along the Black Sea as the Bosphorous spillway was breached ca. 5500 B.C. (Ryan and Pitman, 1998; Lericolais, 2001). Several authors have attributed the biblical accounts in Exodus (Old Testament) to the catastrophic eruption of Santorini (Thera), Greece, ca. 1600 B.C., the ash falls of which may have been the source of the ''plague of darkness'' in Egypt (Stanley and Sheng, 1986; Bruins and van der Pflicht, 1996).

Archeological upheavals such as the decline or disappearance of civilizations have been attributed to severe natural disasters (e.g., volcanic eruptions and/or earthquakes). It has been suggested that the abandoning and/or destruction of numerous cities in the eastern Mediterranean ca. 1200 B.C. was partly due to a sequence of destructive earthquakes (M > 6.5) along active plate boundaries (Nur and Cline, 2000). The caldera and island collapse of Thera-Santorini created tremendous ash falls (Stanley and Sheng, 1986) and generated a giant tsunami (McCoy and Heiken, 2000), which has been blamed for the downfall of the Minoan civilization. Some geologists and archeologists believe that this event may have inspired the Atlantis legend (Galanopolous and Bacon, 1969).

Geographical similarities between paleoislands in the western Straits of Gibraltar, which existed during and shortly after the Last Glacial Maximum (LGM), between 20 and 11 ka, have been discussed (Collina-Girard, 2001). It was proposed that their gradual inundation by rising sea levels may have provided the basis for the Atlantis legend (Collina-Girard, 2001), and strong earthquakes (Lisbon, 1755) in the region were also noted (Collina-Girard, 2003, 2004). The purpose of this paper is to examine this Spartel Bank hypothesis in light of new evidence on the tectonics and paleoseismology of the Gulf of Cadiz–Straits of Gibraltar region (Gutscher et al., 2002; Gutscher, 2004). New high-resolution bathymetric data from Spartel paleoisland are presented, and the viability of human habitation on this paleoisland between 14 and 9 ka is examined.

PLATO AND THE GEOGRAPHY AND CHRONOLOGY OF ATLANTIS

The earliest surviving written records describing an ancient Atlantis culture are the di-

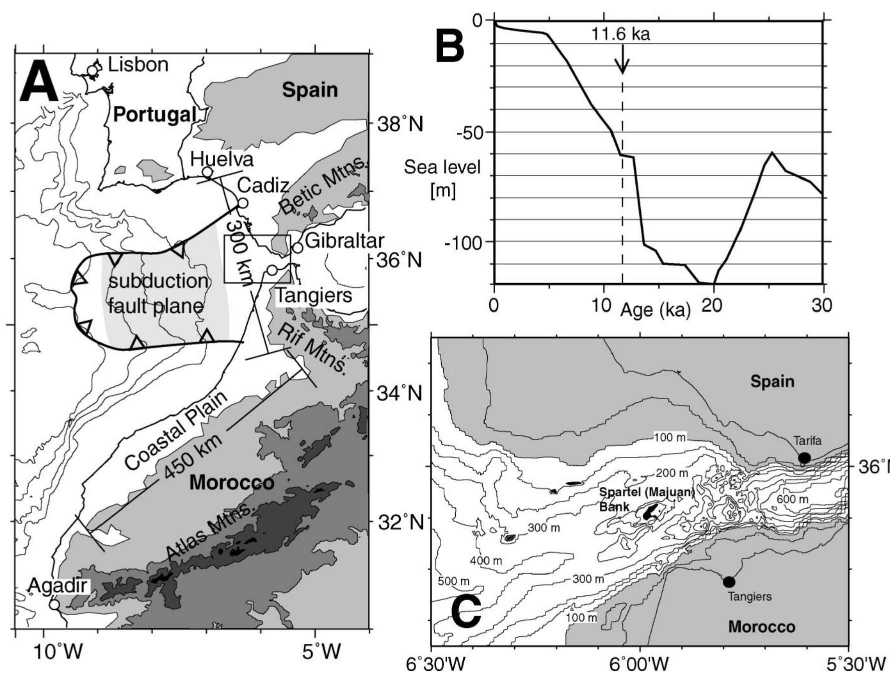

Figure 1. A: Location map of south Iberian–Moroccan region with relief shaded (>200 m light gray, >1000 m medium gray, >2000 m dark gray). Dimensions of coastal plain surrounding Gulf of Cadiz are 450 × 300 km, consistent with Plato's description in *The Critias* (3000 × 2000 stadia). Subduction fault plane (light shading) has been proposed to be source of 1755 earthquake (Gutscher, 2004). B: Eustatic sea-level curve since 30 ka (after Labeyrie et al., 1987; Bard et al., 1996). C: Bathymetric map of western Straits of Gibraltar showing paleoshoreline at 14.5 ka (−100 m contour). Modern shoals rising to <100 m depth (shaded black) represent paleoislands, as pointed out by Collina-Girard (2001, 2003, 2004), and form basis of Spartel Bank hypothesis.

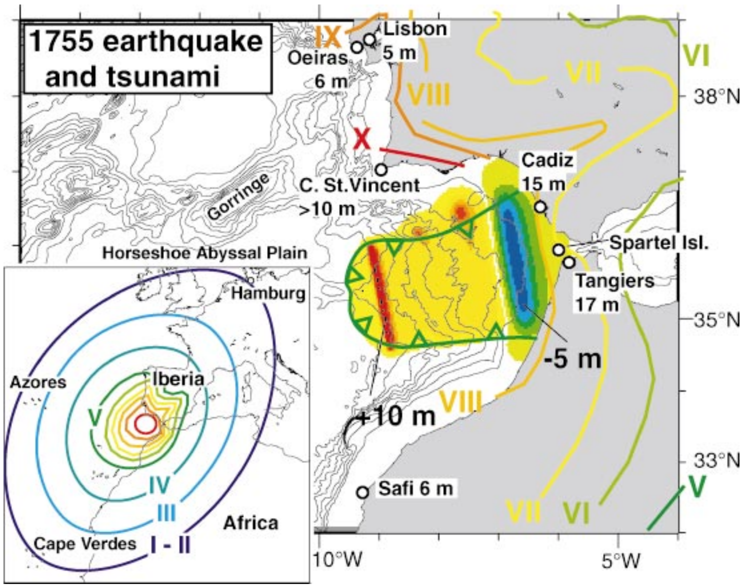

Figure 2. Regional map showing effects of great Lisbon earthquake of 1 November 1755, with isoseismals shown in color (after Martinez-Solares et al., 1979). Historically reported tsunami run-up heights are shown (Baptista et al., 1998). Initial seafloor displacement for east-dipping subduction fault plane is shown (Gutscher et al., 2005). Gorringe Bank has also been proposed as source of 1755 earthquake (Johnston, 1996). Inset shows isoseismals in Europe and Africa (Johnston, 1996).

alogues of Plato, *The Timaeus* and *The Critias* (Plato, 360 B.C.), wherein key details are found concerning the geography and chronology pertinent to the Spartel Bank hypothesis and to the sudden destruction of Atlantis. Only the most important elements are summed here; an extensive discussion of the Spartel Bank hypothesis can be found in Collina-Girard (2001, 2003, 2004).

The chronology given by Plato indicates destruction of Atlantis ca. 11.6 ka, 9 k.y. before Egyptian priests in Sais recounted the tale to Solon. (Solon lived ca. 600 B.C.; Plato lived from 420 to 340 B.C.). A small island is described, located in the Atlantic beyond the Straits of Gibraltar (Fig. 1A), ''This power came forth out of the Atlantic Ocean. . . and there was an island situated in front of the straits which are by you called the Pillars of Heracles.'' The distance to the center of the island is given as 50 stadia, or ~7.5 km (1 stadium = 150 m). In *The Timaeus,* the sudden destruction is described: ''there occurred violent earthquakes and floods; and in a single day and night of misfortune all your warlike men in a body sank into the earth, and the island of Atlantis in like manner disappeared in the depths of the sea. For which reason the sea in those parts is impassable and impenetrable, because there is a shoal of mud in the way; and this was caused by the subsidence of the island.''

SEA-LEVEL CHANGES AND THE SPARTEL BANK HYPOTHESIS

During the LGM (20–15 ka), global eustatic sea level was 130–100 m lower than present and rose to −50 m by 11 ka (Labeyrie et al., 1987; Bard et al., 1996) (Fig. 1B). Sea level remained fairly stationary at ~−65 m from ca. 12.5 ka until 11.5 ka (Bard et al., 1996). These eustatic sea-level changes were due to melting of the ice sheets at the onset of the most recent interglacial period.

In the western Straits of Gibraltar, several shoals rise to within 50 m of sea level and were islands prior to 11 ka (Collina-Girard, 2001). The largest of these paleoislands was ~5–6 km in size, and may be a candidate for a formerly inhabited sunken island (Fig. 1C). Both the effect of lower sea levels on the paleocoastline and the presence of islands in the western Straits of Gibraltar were discussed extensively as being the possible origin of the Atlantis legend (Collina-Girard, 2001, 2003, 2004). The possibility of oral transmission of this inundation event over a period of 6 k.y. (until the advent of written records) was also discussed at length (Collina-Girard 2001, 2003, 2004). The Spartel Bank hypothesis as outlined in these studies emphasized gradual destruction by inundation lasting several centuries (due to a sea-level rise of 4 m per century). However, the sudden destruction described by Plato (in a single day and night) requires a catastrophic event.

REGIONAL TECTONICS AND PALEOSEISMOLOGY

On 1 November 1755, the great Lisbon earthquake (estimated Mw = 8.5–9) struck southwest Iberia and northwest Morocco (Johnston, 1996; Gutscher, 2004) (Fig. 2). Observed intensities from Cadiz (Spain) and Tangiers (Morocco) were I = 7, suggesting similar intensities in the western Straits of Gibraltar (Martinez-Solares et al., 1979; Levret, 1991). The associated tsunami devastated the Gulf of Cadiz region, with reported run-up heights exceeding 5 m for port cities in southwest Iberia and northwest Morocco (Baptista et al., 1998) (Fig. 2).

Recent evidence supports the existence of an active subduction zone beneath the Gulf of Cadiz and Straits of Gibraltar (Gutscher et al., 2002; Gutscher, 2004), that poses a long-term risk of great earthquakes (Fig. 3). The potential seismogenic zone, with mean dimensions estimated as 180 × 210 km, is capable of generating earthquakes of Mw 8.6–8.8 with a periodicity of 1–2 k.y. (Gutscher et al., 2005). Tsunami modeling of a subduction source indicates a strong focusing effect in the eastern Gulf of Cadiz–Straits of Gibraltar area, which amplifies wave heights (Gutscher et al., 2005). This is in agreement with historical reports of extreme wave heights (15 m in Cadiz, 17 m in Tangiers) observed in nearby cities (Baptista et al., 1998).

Two different types of sedimentological data from the Gulf of Cadiz area suggest that great earthquakes and tsunamis occur with a periodicity of 1.5–2 k.y. Coarse-grained tsunami-induced deposits in the lagoon near Cadiz correlate with the 1755 earthquake, and indicate a tsunami height >6 m in order to wash over the barrier of the sand bar (Luque et al., 2001). An older coarse-grained deposit is dated as 200 B.C., thus suggesting a period of 2 k.y. (Luque et al., 2001). Sediment cores from the Horseshoe abyssal plain (Lebreiro et al., 1997) indicate 8 major turbidites since 12 ka, which may be markers of great earthquakes in the past (Fig. 3). The most recent turbidite (H1) is 10–25 cm thick and has been dated as being contemporaneous with the 1755 earthquake (Thomson and Weaver, 1994). If the turbidites record the history of great earthquakes, then a repeat time of ~1.5 k.y. is indicated (Gutscher, 2004). Turbidite H8 has a mean thickness of 50–120 cm and a total estimated volume of 5.8 km^3 (Lebreiro et al., 1997) (Fig. 3). It is the thickest of the postglacial series and has been dated as 12.05 ka (Lebreiro et al., 1997). For comparison, the turbidite associated with the great Lisbon earthquake of 1755 has an estimated volume of ~1 km^3.

NEW BATHYMETRIC DATA FROM SPARTEL PALEOISLAND

In July 2003, high-resolution bathymetric data from Spartel paleoisland were acquired with R/V *Le Suroit* (Fig. 4). At the 130 m depth contour (lowest sea-level stand during the most recent glacial maximum ca. 20 ka),

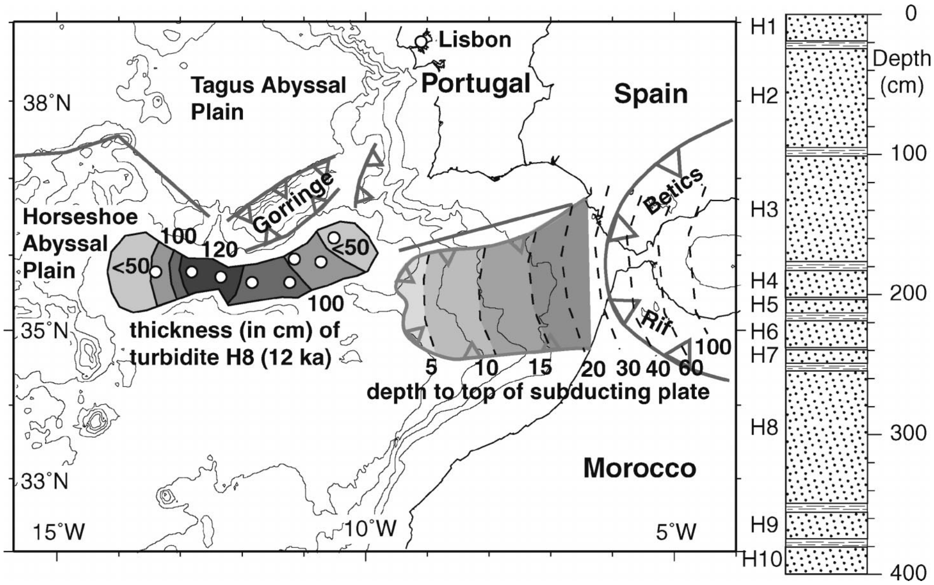

Figure 3. Left: Map of Gulf of Cadiz region; thickness of turbidite H8 in Horseshoe abyssal plain is indicated (after Lebreiro et al., 1997). Core locations are shown by white circles and major faults are shown as thick lines. Estimated depth to top of subducting plate is shown (in kilometers). Right: Schematic stratigraphy based on cores from Horseshoe abyssal plain (after Lebreiro et al., 1997).

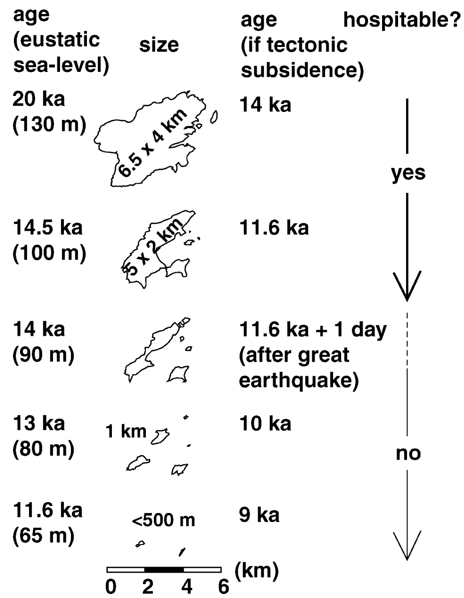

Figure 5. Outline of Spartel paleoisland as function of time and rising sea levels: left—chronology based on eustatic sea-level variations only; right—chronology assuming 40 m of tectonic subsidence since 12 ka.

an island of 6.5 km length (ENE-WSW) and 4 km width was present (Fig. 5). This is much smaller than the 14-km-long paleoisland suggested in earlier studies, on the basis of less accurate hydrographic and navigation maps of the area (Collina-Girard, 2001, 2004).

The western and southern portions of the paleoisland were flattest, and today present the aspect of a paleoterrace at ~120 m water depth that may record a prolonged sea-level lowstand. The backbone of the paleoisland is an ENE-trending ridge at ~60–90 m water depth, with a second morphologic high situated to the SE. These highs are marked by slightly curved parallel bands, likely outcrops of strata, possibly folded sedimentary flysch of the outer Betic and Rif allochthonous units. The 120 m to 100 m depth contours outline a reduced island of ~5 km length, with a sheltered bay, facing east toward the Mediterranean (Figs. 4 and 5). The 90 m and 80 m contours define a scattered archipelago, no wider than a few hundred meters, consisting only of the rocky ridges and not likely to be hospitable to habitation (Fig. 5). Thus, assuming only eustatic sea-level variations, Spartel paleoisland would have been reduced to wave-swept rocky islets by 13 ka at the latest (Fig. 5).

DISCUSSION

One of the most remarkable coincidences is that the type of destruction described by Plato (in a single day and night, by violent earthquakes and floods) is a very accurate description of the sudden (catastrophic) destruction associated with a great (M > 8) earthquake. In 1755, tsunami waves persisted for as long as ~24 h (Baptista et al., 1998) and likewise following the 26 December 2004, tsunami in the Indian Ocean. The occurrence of this type of earthquake and tsunami in the geographic region chosen by Plato for his narrative appears to be more than just fortuitous.

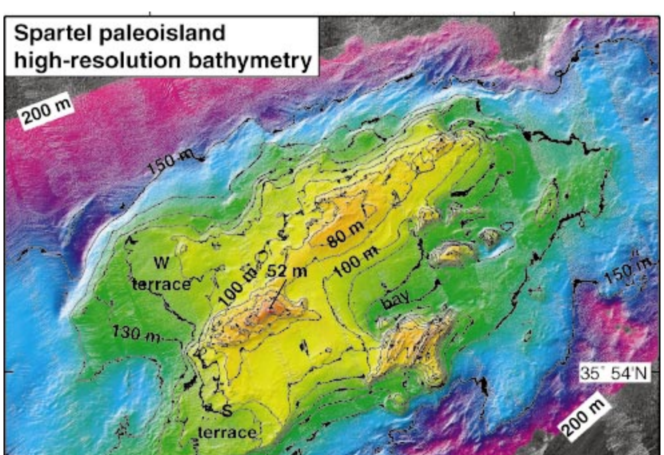

Figure 4. High-resolution bathymetric map (5 m grid spacing) of Spartel paleoisland. Data were acquired by R/V *Le Suroit* (using Simrad EM300 multibeam system) in July 2003 during TV-GIB cruise.

The Gulf of Cadiz–Straits of Gibraltar region is above an east-dipping subduction zone (Gutscher et al., 2002), apparently marked by a wide locked seismogenic zone and a long repeat interval (as much as 2 k.y.) between great earthquakes (Gutscher, 2004). Subduction zones are environments of locally strong uplift and strong subsidence. Coseismic subsidence caused by great earthquakes in the Cascadia forearc are reported to be 0.5–2 m (Clague, 1997), and coseismic subsidence of 1–2 m was observed for the great Alaska earthquake of 1964 (Holdahl and Sauber, 1994). During the great Sumatra earthquake of December 2004, coastlines were significantly changed through the combined effects of the tsunami-induced erosion and local earthquake-induced subsidence. Some low-lying islands were partially submerged. Spartel paleoisland is located in the foreland of the Betic-Rif mountain belt. Land studies of Pliocene–Quaternary marine terraces exposed along the Spanish side of the Straits of Gibraltar suggest continuing active tectonic uplift of the Internal Betic-Rif units at a rate of ~1 mm/yr (Zazo et al., 1999) and subsidence in the foreland region.

Assuming only eustatic sea-level variation, Spartel paleoisland would have been uninhabitable at 11.6 ka (because it would have been reduced to small rocky islets <500 m in size; see Fig. 5). In order for the island to have been inhabitable at the time described in Plato's dialogues, at least 40 m of total tectonic subsidence must have affected the island since then (which represents a mean subsidence rate of 3.5 mm/yr). In such a scenario, the 100 m depth contour line would represent the paleoshoreline ca. 11.6 ka (Fig. 5). Subsidence of 40 m could possibly be explained by ~5 m of coseismic tectonic subsidence during each of the 8 great earthquakes during the past 12 k.y. (the number of earthquakes indicated by the turbidite record). This amount of subsidence is greater than that known for comparable tectonic settings (Cascadia, Alaska). However, the presence of an additional crustal fault may account for the remainder. Rapidly subsiding and tectonically active regions like the Gulf of Corinth, Greece (Armijo et al., 1996), can exhibit modern-day subsidence at rates >5 mm/yr.

If the earthquake ca. 11.6 ka was exceptionally large, as suggested by the great thickness of turbidite H8 found in the Horseshoe abyssal plain (Fig. 3), then perhaps as much as 10 m of coseismic subsidence may have occurred. If one then considers the added impact of a 10-m-high tsunami wave (Fig. 2), then everything within 20 m of the previous sea level would have been obliterated. The remaining rocky islets, after the sudden and irreversible 10 m immersion into the sea, would bear little resemblance to the formerly 5-km-long island with its east-facing bay (Fig. 5). The combined effects of the continuing rise in sea level and additional subsidence due to earthquakes would completely submerge the remnants within a few thousand years.

CONCLUSIONS

The high-resolution bathymetric data acquired on Spartel Bank indicate a significantly smaller island at the 130 m contour (6.5 km × 4 km) than the 15-km-long island reported in previous studies (Collina-Girard, 2001, 2003, 2004). Furthermore, assuming only eustatic sea-level variation, Spartel paleoisland would have been uninhabitable at 11.6 ka (two small rocky islets <500 m in size). Thus, these new bathymetric data, taken alone, do not confirm the Spartel Bank hypothesis; rather, they render it highly unlikely. However, taking into account strong tectonic subsidence due to great earthquakes, and the sudden destruction by a great tsunami, the Spartel Bank hypothesis may be viable. Although the catastrophic destruction described by Plato is consistent with the geological and tectonic history of the Straits of Gibraltar, this does not imply that Atlantis ever existed. It simply means the account is geologically plausible. The question remains, was the paleoisland of Spartel inhabited nearly 12 k.y. ago? In order to obtain an answer, it will be necessary to conduct a detailed survey of the seafloor in this area and search for signs of construction or artifacts.

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