The International Journal of
NAUTICAL ARCHAEOLOGY

The International Journal of Nautical Archaeology (2018) **47**.1: 221–230
doi: 10.1111/1095-9270.12272

Note

2014 Myndos Eastern Harbour Bathymetric Study and First Assessment

Myndos is an important ancient city in the Caria Region of Western Anatolia. In 1837, Thomas Graves created a bathymetric map of the ancient city's harbours (Figs 1 and 2). The project reported here compared data taken from this historic map with bathymetric data recorded in 2014, in order to investigate changes to the main eastern harbour basin over the past 177 years.

Myndos is located in the town of Gümüşlük on the Bodrum Peninsula, in Muğla Province, Turkey. Strabo wrote that the Termerion promontory belonged to the Myndians, and that Myndos was reached via the Astypalai and Zephyrion promontories (Strabo*,* *Geographica,* 14.2.20). The earliest information, though, comes from Herodotus, who mentions that Myndian ships joined the campaign of Naxos in 500 BC under the command of Megabates, the cousin of Darius I (Herodotus, *Histories,* 5.33.1–3). Polybius stated that during the Lade Sea Battle of 494 BC, Rhodian ships that wanted to cross to Kos Island had to anchor overnight in Myndos Harbour (Polybius, *The History*, 16.15.1–8), indicating that Myndos provided a sheltered harbour for warships in the 5th century BC. Moreover, prevailing winds and weather conditions change very quickly on the coasts of the Aegean and the Mediterranean, and sailing ships and galleys have tended to voyage close to the shore (Pryor, 2004: 29–41). Myndos was likely an important port of call for the ships travelling via the Bodrum Peninsula in antiquity.

During underwater research at Myndos in 2013, a second harbour, dated to the Roman period, was discovered in the west of the city. The western harbour is thought to have been used as an exterior harbour, and the eastern one as the main harbour (Dumankaya, 2015: 12–20; Dumankaya and Gündüz, 2016a: 10–3; 2016b: 1–5). The eastern harbour is examined in detail here.

Kocadağ Hill, 484m in height, which forms the western arm of the bay, was joined to the mainland over time at its northern end by a sand tombolo. Such features have commonly been made use of as natural harbours (Frost, 1973: 90; Erol, 1991; Doğaner, 2000; Brückner *et al.*, 2002, Brückner *et al.*, 2004; Ceylan, 2011; 2012), and Myndians likewise made use of this natural topography. However, wave action and alluvial deposits could cause such harbours to silt up. To inhibit siltation and to accelerate water circulation channels were opened in other harbours (see Blackman, 1982: 193–202; 2008: 662–663; Franco, 1996: 115–151; Raban, 2009: 63; Büyüközer, 2013: 11–12). While no such channel has been located at Myndos, the bay's use as a harbour is indicated by a mole (Fig. 3a–c), a fortification wall (Fig. 4a–b) and a harbour wall (Fig. 4c), all dated to the 5th–4th BC and the Mausolus period. These would have prevented undercurrents and siltation. The fortification wall also served to reduce the effects of the *Lodos* wind and connect Asar Island to the mainland (Fig. 1). The mole protected the basin from waves and undercurrents by narrowing the entrance.

The 1837 map

The 1837 map shows the archaeological structural ruins of Myndos observed at that time, and the depths recorded in the harbours. English Imperial units were used; heights given in feet, depths in fathoms (Fig. 2). A graphic scale in yards is included in the legend of the map. For this study, measurements have been digitally converted to metric units.

The 1837 bathymetric map was made using the most suitable technique of the time: a sounding line (also called a lead line). The general accuracy of the 1837 map was assessed by comparing the following fixed points: the 5th–4th BC century mole located at the entrance of the harbour (Dumankaya, 2015: 19, figs 3–4; Dumankaya and Gündüz, 2016a: 13–21); a rocky outcrop in the middle of the harbour, shown on the 1837 map at a depth of 5–6m that was recorded in 2014 at a depth of 5–7m; and the fault line on the north slope of Kocadağ Hill. The correlation of these points reveals the 1837 map to be accurate.

The contour lines and depth points of the 1837 map were transferred to the *ArcMap 10* program and were digitally converted to be compatible with coordinates within UTM and WGS 1984 projections. By using the 'Topo to raster' function, a digital version of the 1837 bathymetric map was created.

The 2014 bathymetric map

Four datum points were established around the harbour, each visible from the other three. Using a Leika TS 06 Total Station, a reflector, RIB, and a depth sounder, the Intersection Method, more commonly used in lakes and reservoirs, was chosen (see Erdi

Published by John Wiley & Sons Ltd. 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.

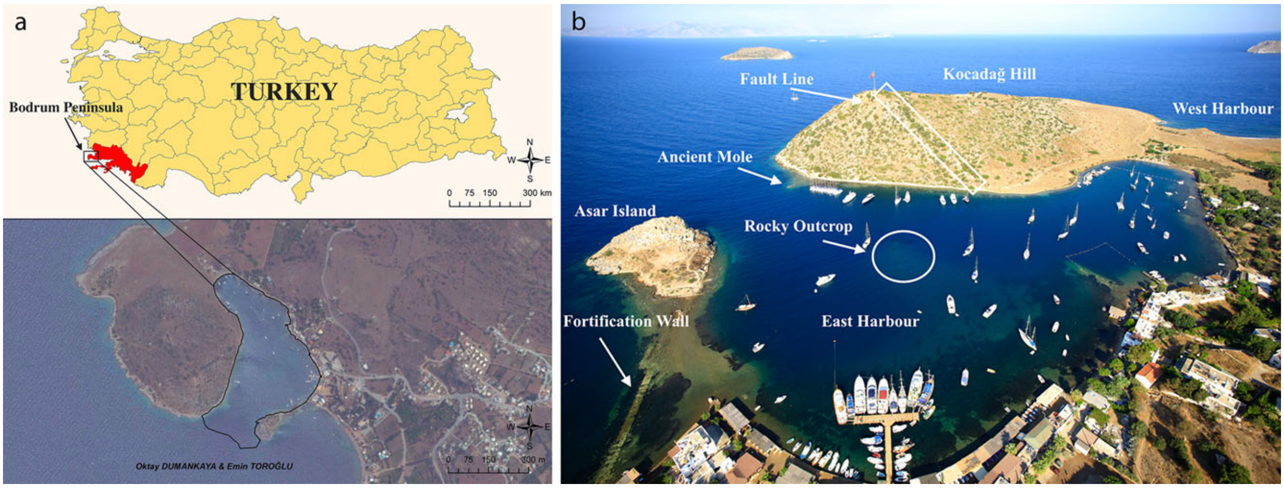

Figure 1. *a)* Location of Myndos ancient city; *b)* view of the remaining structures and the eastern harbour of Myndos (Myndos Excavation Archive).

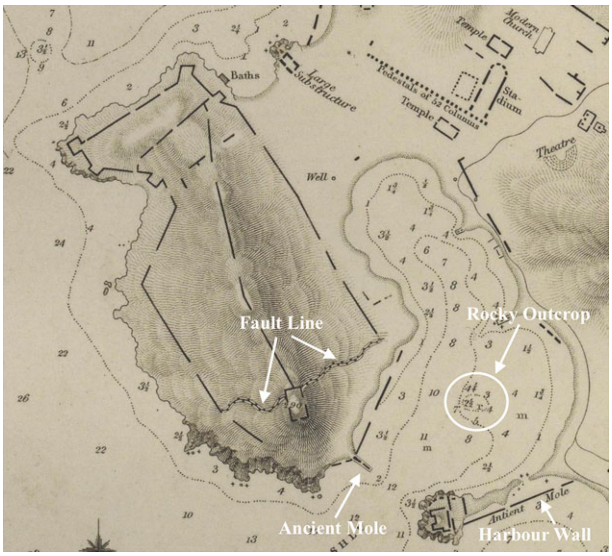

Figure 2. Detail from the Myndos and Bargylia map by Lt Cdr Thomas Graves, 1837 UKHO Chart 1531, published in 1844 (The British Library Board, Maps SEC.5.1531).

et al., 2007; Günok and Pınar, 2009; Ceylan *et al.*, 2010, 2011), and the location and depth data of 520 points at maximum intervals of 10m were recorded. The data obtained was first transferred to Netcad 4.0, and then to ArcMap 10, within which the Triangle Irregular Network (TIN) function and 'TIN to raster' functions were used, resulting in a Digital Elevation Model (DEM) of the harbour.

Error limitations

Three problems were encountered that could have introduced errors into the 2014 map. The first, was the rocking motion caused by waves especially on stormy days, which meant the coordinates obtained from the reflector couldn't be recorded accurately. The second was that the RIB could not get close to the coast in shallows of less than 0.60m. The third was not being able to obtain measurements in certain places as a result of boats and yachts being anchored in the harbour.

In order to reduce the impact of the first, using information obtained from the Meteorological General Directorate of the Turkish Ministry of Forest and Water Affairs, it was determined that August was the period most likely to have the lowest waves. Following the standards published in 2008 by the International Hydrographic Organization (see IHO, 2008: 15, fig. 1), error tolerances were calculated using maximum and minimum depths recorded. The deepest point was determined to be 27.53m, while the shallowest point was 0.69m. As a result, the maximum tolerance for the deepest point was 0.32m and for the shallowest point 0.25m.

Comparison of the 1837 and 2014 maps

To compare the 1837 and 2014 data five different maps were created. A DEM (Fig. 5a–b), DEM difference map (Fig. 5d),block diagrams (Fig. 5c–d), a coastline map for both 1837 and 2014 data (Fig. 6); and a Digital Terrain Model for 2014 data only (Fig. 7).

In the DEM based on the 1837 bathymetric map, the deepest point of the harbour is shown as -22m (Fig. 5a). There is no evident depth difference between the inner harbour and the entrance. In the 2014 DEM, the deepest point of the harbour was -28m. When the 1837 DEM and 2014 DEM maps are compared, a difference of at least 5m depth is noted in the entrance of the harbour (Fig. 5e).

The block diagram shows a rocky outcrop that was in the -9 to -7m depth range in 1837 (Fig. 5c) and in the -7 to -5m range in 2014 (Fig. 5d). The reason for

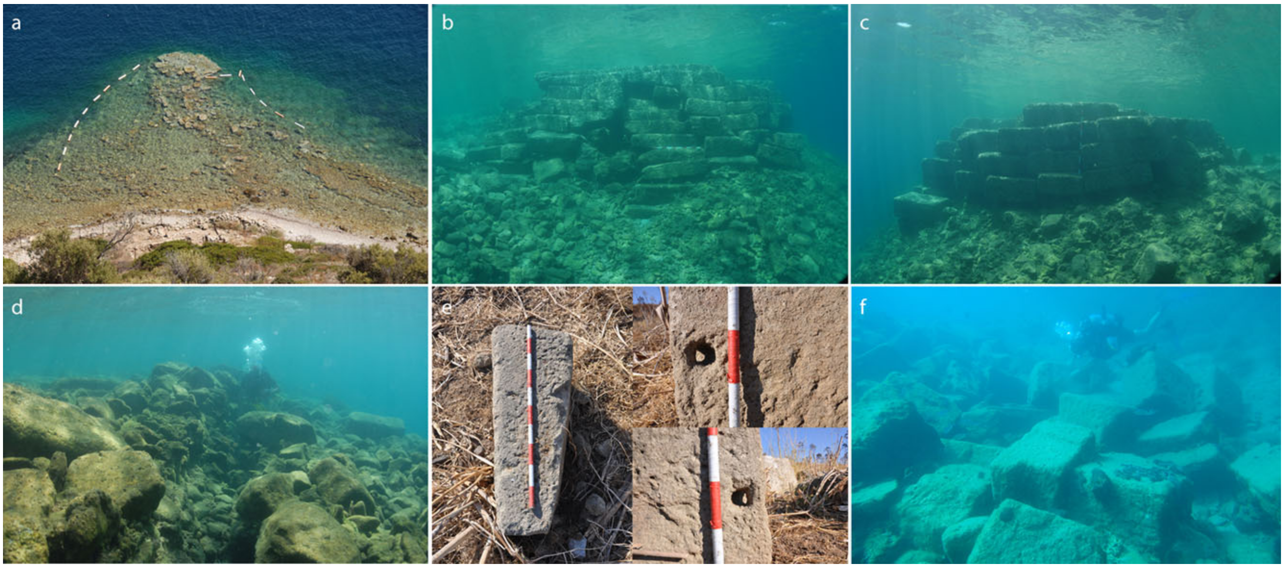

Figure 3. *a)* view of the ancient harbour mole; *b)* harbour mole, south-southwest façade; *c)* harbour mole, south-southeast façade; *d)* a view of fault line (?) extending to north-west; *e)* stone block used as a mooring stone; *f)* detail of the stone blocks and anchors dispersed on the sea-floor (O. Dumankaya).

Figure 4. *a)* and *b)* Harbour and fortification wall; *c)* harbour wall on the south and north of the harbour (Myndos Excavation Archive).

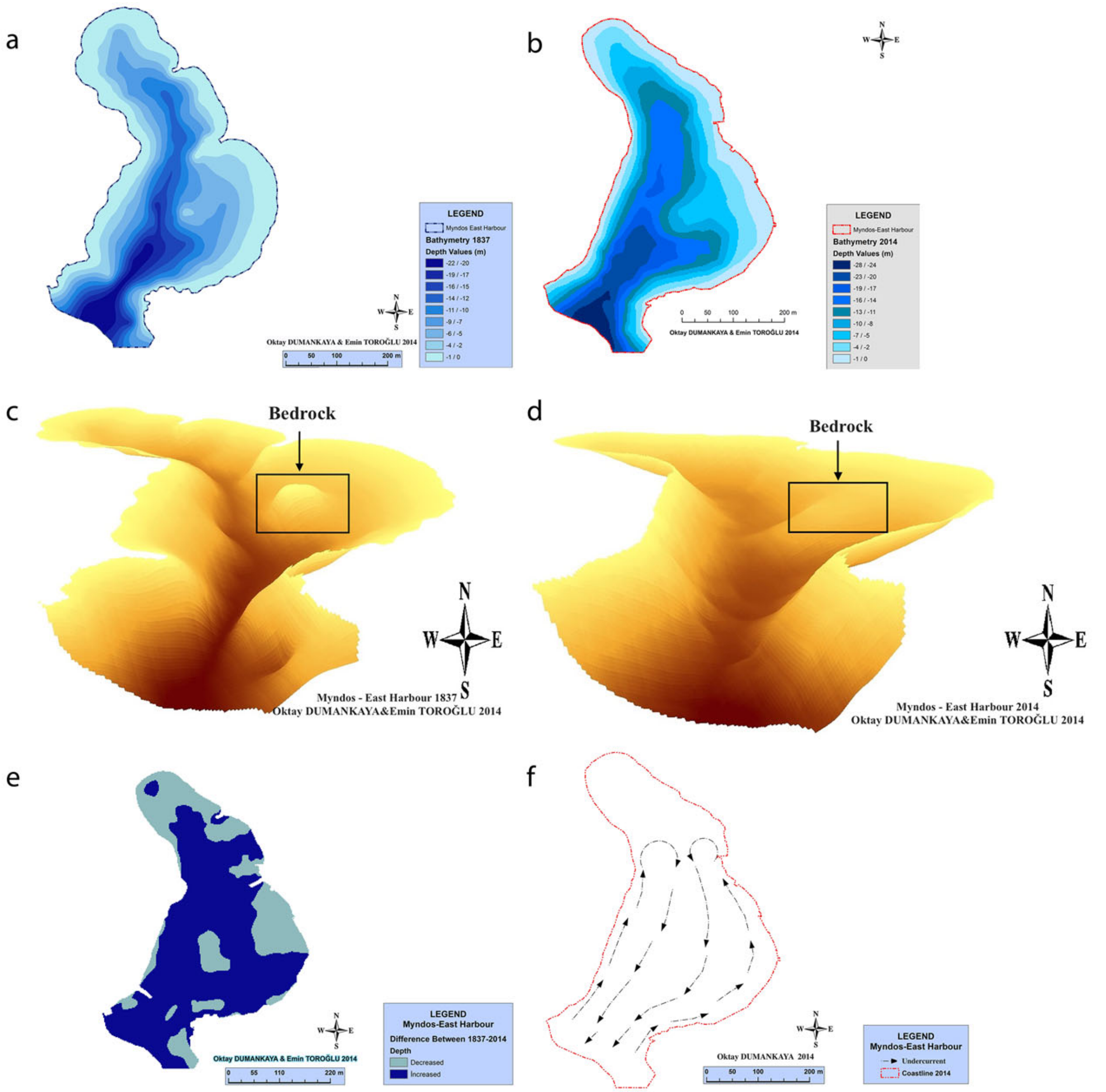

Figure 5. *a)* 1837 DEM; *b)* 2014 DEM; *c)* 1837 block diagram bathymetric map; *d)* 2014 block diagram bathymetric map; *e)* 1837–2014 DEM difference map; *f)* map of undercurrents.

this reduction in depth is the area around the outcrop is filled with sand and clay. On the basis of only this rocky outcrop and its surroundings, it was found that, over the course of 177 years, a 2m-deep layer of material has accumulated in the harbour.

The DEM Difference Map was created by combining the polygon points of the 1837 and 2014 bathymetric maps at the same coordinates (Fig. 5e). In this way, the increase and decrease in depths between 1837 and 2014 can be compared. In the harbour, while one would expect sedimentation to increase over this period, the shallowing of the coasts and deepening of the middle of the harbour and its entrance are noteworthy.

The change in coastline was plotted by overlaying the 1837 and 2014 maps. Depth values were added from 25 different points (Figs 6 and 8). The greatest depth variation can be seen in the areas numbered 11, 12 and 13, where depths have increased because of undercurrents. The least depth variation is seen in the areas numbered 1, 2, 3, 9, 14, 15 and 16, where the water circulates least (Fig. 5f).

Contributing factors

In research carried out on Kocadağ Hill, scattered bands and nodules of chert were observed. These

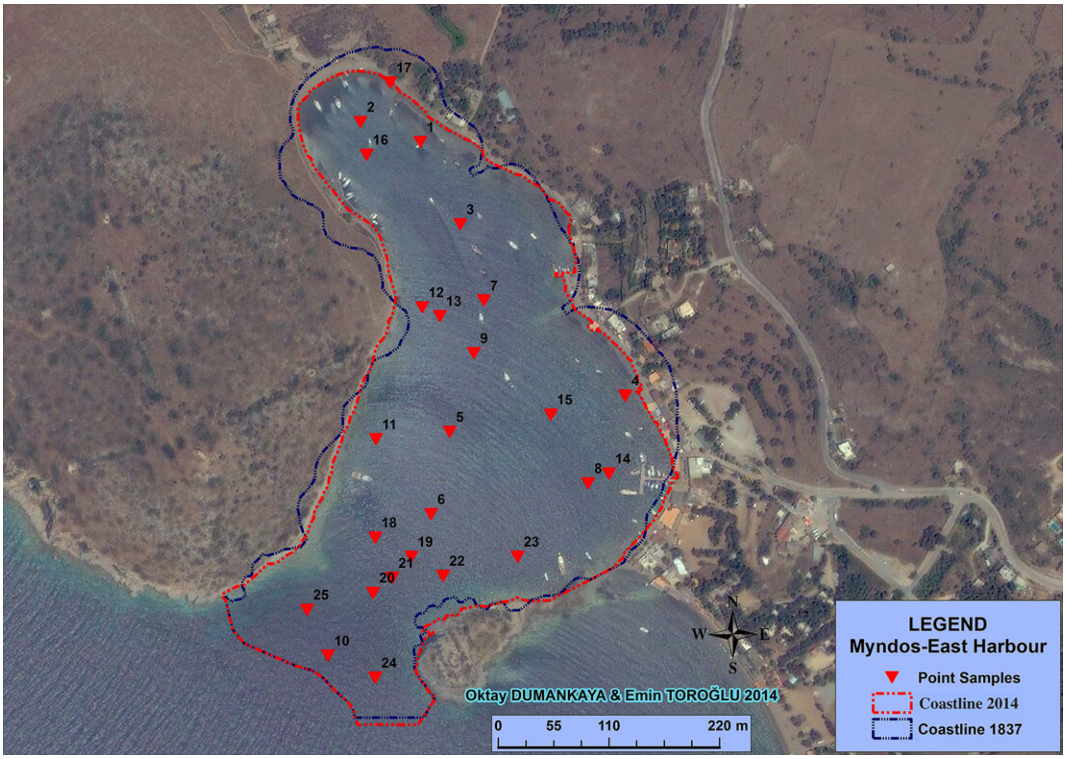

Figure 6. Coastline map for 1837 and 2014 showing measured depth points (see Fig. 8).

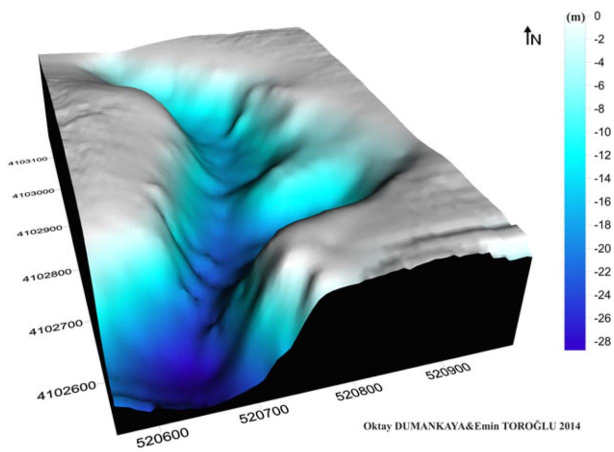

Figure 7. Digital Terrain Model 2014.

contained smooth, grey-coloured fine-medium layers and abundant shell pieces. In similar studies, pelagic limestones, basalt and andesite were also found (Brinkmann 1967: 1–12; Ercan *et al.*, 1981–1982: 24, fig. 1; Ulusoy *et al.*, 2004: 72, fig. 1). This geological structure, known as a Kışladağ formation, is widely dispersed outside the ancient city, too (Bernouilli *et al.*, 1974: 47, 60, 78, fig. 3; Ercan *et al.*, 1981–1982: 24, fig. 1; Ersoy, 1991: 4, fig. 4). The Kışladağ formation generally shows the fractured and fissured structure that is typical of intense tectonic activity. Water feeding this formation, as a result of hydro geo-chemical processes, creates karstic holes and caves. Therefore, the majority of the rain falling on this area is carried into the sea by fault lines and karstic channels.

Alluvial surfaces in this region consist of gravel, sand, silt and mud and extend to the coast, for example the acropolis of Myndos is covered in alluviums (Ulusoy *et al.*, 2004: 72, fig. 1). This formation allows water from seasonal streams to drain down and be carried to the sea (Koç, 2005: 28). Depth variations in the harbour between 1837 and 2014 can be seen at points 1, 2, 4, 5, 15, 16, 17, 20, 22, and 24 as a result of these two processes (Figs 6, 8).

Earthquakes are another factor that has caused the deformation of ancient city structures. One of the fault lines observed around the ancient city is situated on the east of Kocadağ with a displacement of up to 4m (Fig. 1). Another, stretching to the north-west of Kocadağ, which could be an extension of that seen on the east of Kocadağ, was observed under water in the west harbour (Fig. 3d). A third, east-west fault line lies at the acropolis (Ercan *et al.,* 1981–1982: 24, fig. 1). The earliest harbour structures date from 5th century BC (Dumankaya, 2015; Dumankaya and Gündüz, 2016a). Between the 19th and 5th centuries BC more than 100 earthquakes were detected around Rhodes, Kos and Crete, within the Aegean graben region (Ergin *et al.*, 1967; McKenzie, 1972: 115–60, fig. 3.5g; Guidoboni *et al.*, 1994: 408–413; Dirik *et al.*, 2003: 29–30; Kouskouna and Makropoulos, 2004:

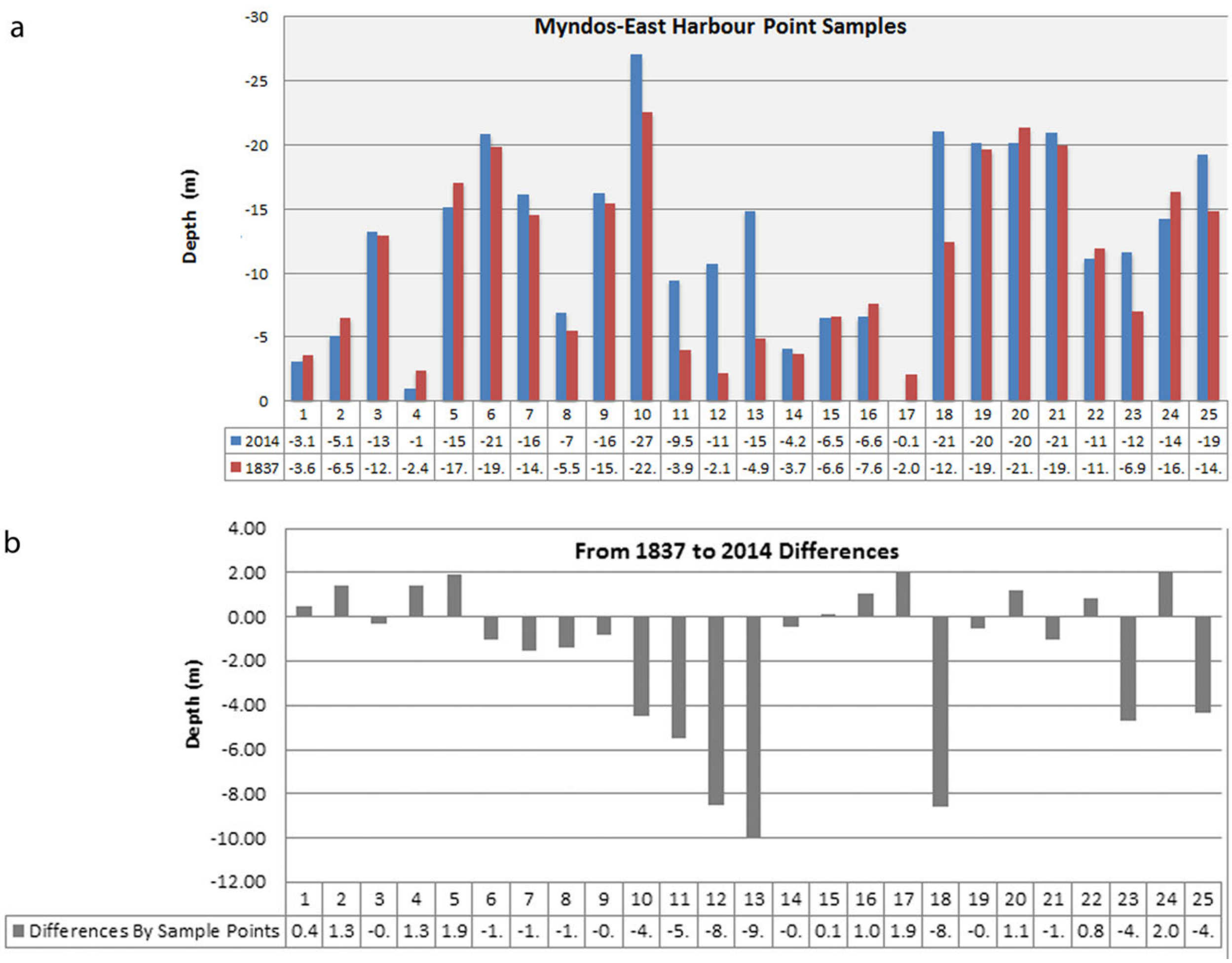

Figure 8. *a)* Depth values for points shown on Figure 6; *b)* depth differences for sample points (O. Dumankaya).

723–731; Altunel, 2004; Ambraseys, 2009: 141–787; Yolsal and Taymaz, 2010: 56), some of which caused tsunamis of up to 3.35m (Yolsal and Taymaz, 2010: 59–60, fig. 4–5).

Research into seismic activities during the so-called Early Byzantine Tectonic Paroxysm covering the coastal areas of Crete, Rhodes, the Aegean, the Mediterranean and the Levant, shows that between the 4th and 6th centuries AD, coastlines were raised 0.5–1.5m (Kelletat and Kayan, 1983; Pirazzoli, 1986; Kayan, 1988: 205–214; 1999: 541–546; Lambeck, 1995: 1022–1039, fig. 9.18; Pirazzoli *et al.*, 1996: 6083–6097, fig. 1; Stiros, 2001: 549–556; Salamon *et al.*, 2007: 1–20; Bekaroğlu, 2008: 1–14; Baika, 2008: 33–48). Using radiocarbon dating, geomorphological-biological and historical resources it has been shown that in the period AD 350–550, coastlines rose approximately 1.5m (Di Vita, 1995: 971–976; Bekaroğlu, 2008: 1–14).

In the Aegean graben region, between 1895 and 2003, 31 powerful earthquakes also occurred (Kouskouna and Makropoulos, 2004: 724, fig. 2; Polat *et al.*, 2008: 593–614).

These earthquakes reveal the effects of active fault lines in the region. The density, intensity and magnitude of these earthquakes inevitably provoked changes to the coastlines of the Aegean and Mediterranean region (see Flemming, 1978).

Coastal variation can also be caused by climate change. Over the past 100 years, a rise in global sea-levels of 0.1 m has been recorded (Flemming and Webb, 1986: 24). The effects of earthquakes and climate change, which brought about major changes to the coastlines of the Aegean and Mediterranean region, can also be seen in Myndos city's structural ruins (Flemming *et al.*, 1973: 42–44), although, at Myndos, the deepening of the seabed in the harbour might also have been caused by wave action, undercurrents and tidal scour. Today, the mole lies 0.30m–1m under water (Fig. 3a–c), which is likely the effect of earthquakes, rising sea-levels (Dumankaya, 2015: 16–45, figs. 4–15; Dumankaya and Gündüz, 2016a: 10–13, figs. 13–22), and it having sunk into the ground over time as a result of its own weight and the effect of undercurrents.

Figure 9. *a)* Engraving titled ‘Remains of Myndus at Gumishlu’, marginal drawing from Chart L1573 by Lt Cdr Thomas Graves in 1837 (UKHO title: Port Gumishlu and the Remains of Ancient Myndus); *b)* recent photograph of the same view (O. Dumankaya).

A second map, drafted by English Admiral Thomas Abel Brimage Spratt in 1847, includes an engraving of the harbour (Fig. 9) that provides evidence of damage by wave erosion. A photograph taken from the same position shows a mound of soil that was on the coastline has now been deposited into the harbour. In the engraving, a small boat can be seen towing a sailing boat towards the shore, while on the coastline blocks of stones that had been removed from the ancient city were being used as moorings. Our research revealed that blocks of stones have been removed from the harbour and used to build a wall on a piece of land approximately 1km away (Fig. 2e). This data is important in terms of showing damage caused by mankind.

In antiquity, a protective wall surrounding the harbour basin was built to decrease the impact of waves and undercurrents and to stop deposits flowing from Kocadağ and the acropolis and filling the harbour (Bernouilli *et al.*, 1974: 47, fig. 3; Ercan *et al.*, 1981–1982: 24, fig. 1, 2; Ulusoy *et al.*, 2004: 72, fig. 1). The walls, which suffered extensive damage due to a combination of human activities, earthquakes, and waves, can be seen now only on the north and south coastlines of the harbour (Fig. 4c).

Conclusion and recommendations

The harbour structures of Myndos may have suffered major damage as a result of earthquakes, undercurrents and wave action. For these reasons, while the inner harbour has silted up, an increase in depth was seen in the entrance. The extent of destruction caused by human activity is also incontrovertible. Over the past century, increasing modern settlement on the coastline has almost covered the whole of the north coast of the harbour, causing the harbour to narrow by becoming shallower. Also in the past century, stone blocks have been removed from the harbour structures for modern construction work. Today, in stormy weather, boats and yachts can only be safely anchored to the east of Kocadağ and Asar Island.

Modern buildings have been constructed very close to the coastline. Therefore, every summer Bodrum municipality pile up sand to create a new beach area and a promenade, which is carried into the harbour each winter: sediment accumulation is increasing rapidly as a result. Measures could be taken to prevent both the accumulation of sand and further damage to the archaeological remains at the harbour. These might include removing modern buildings occupying the harbour basin so that it returns to its ancient extent. Fixed moorings at certain places on the seabed would alleviate damage to fallen blocks and the sea-floor from anchors of the boats and yachts moored inside the harbour. The restoration of the mole and harbour walls would reduce the effects of waves and undercurrents.

As part of this study a map for monitoring future changes in the ancient harbour was created (Fig. 7). This method of comparing historic and modern bathymetric data could be used in other ancient city harbours, enabling changes to be tracked and analysed. The data produced can inform the management of these cultural assets. Additionally, the rate of sediment accumulation can be calculated by geological and geophysical survey of ancient city harbours, which raises the necessity for a multi-disciplinary approach.

Oktay Dumankaya
Kahramanmaraş Sütçü Imam University,
Faculty of Letters, Department of Archaeology,
Avşar Campus, Kahramanmaraş, Turkey,
oktay_dumankaya@hotmail.com

Acknowledgements

My thanks go firstly to the Myndos Excavation Director Prof. Dr Mustafa Şahin for his support, to Sinop University Map and Cadastral Program Teac. Asst. İlke Ekizoğlu, to Uludağ University Archeology Department Research Asist. Dr Serkan Gündüz; to General Directorate of Mineral Research and Exploration Coordinator Dr Özden İleri who provided full support on drawing, and accuracy analysis, to Kahramanmaraş Sütçü İmam University Geography Department Teaching Instructor Associate Prof. Dr Emin Toroğlu and to Research Assistant Ömer Kaya; to David Hemmings who helped with accuracy analysis and with obtaining Thomas Graves' map from the UK Hydrography Office.

References

Altunel, E., 2004, Impacts of Historical Seismicity on Major Ancient Coastal Cities in Southwestern Turkey, in J. Mascle (ed.), *Proceedings of Congress: Human record of Mediterranean and Black Seas recent geological history, held on Santorini, 22–25 October 2003, CIESM Science Series*, 71–76. Monaco.

Ambraseys, N., 2009, *Earthquakes in the Mediterranean and Middle East: A Multidisciplinary Study of Seismicity up to 1900*. New York.

Baika, K., 2008, Archaeological indicators of relative sea-level changes in the Attico Cycladic massif: preliminary result. *Bulletin of the Geological Society of Greece* **47**.2, 33–48.

Bekaroğlu, E., 2008, Doğu Akdeniz'de Geç Holosen'de Yükselmiş Kıyı Çizgileri Üzerine Bir Değerlendirme. *Coğrafi Bilimler Dergisi* **6**.1, 1–21.

Bernouilli, D., de Graciansky, P.C. and Monod, O., 1974, The extension of the Lycian nappes (SW Turkey) into the southeastern Aegean Islands. *Eclogae Geologicae. Helvetiae* **67**.1, 39–90.

Blackman, D.J., 1982, Ancient Harbours in the Mediterranean, Part 2. *IJNA* **11**.3, 185–221.

Blackman, D.J., 2008, Sea Transport, Part 2: Harbors, in J.P. Oleson (ed.), *The Oxford Handbook Engineering and Technology in the Classical World*, 638–670. Oxford.

Brinkmann, R., 1967, Die Südflanke des Menderes-Massivs bei Milas-Bodrum und Ören. *Ege Universitesi Fen Fakultesi İlmi Raporlar Serisi* **43**, 1–12.

Brückner, H., Müllenhoff, M., Handl, M. and Van Der Borg, K. 2002, Holocene landscape evolution of the Büyük Menderes alluvial plain in the environs of Myous and Priene (Western Anatolia, Turkey), in *Zeitschrift für Geomorphologie, Supplementbande* **127**, 47–65.

Brückner, H., Müllenhoff, M., Van Der Borg, K. and Vött, A. 2004, 'Holocene coastal evolution of western Anatolia—the interplay between natural factors and human impact', in J. Mascle (ed.), *Proceedings of Congress: Human record of Mediterranean and Black Seas recent geological history, held on Santorini, 22–25 October 2003*, *CIESM Science Series*, 51–56. Monaco.

Büyüközer, A., 2013 Some thoughts on the military harbour of Knidos, in Y. Morozova and H. Öniz (eds), *Proceedings of 14th Symposium on Mediterranean Archaeology, 23–25 April 2010 (Kiev)*, 11–16. Oxford, BAR International Series 2555.

Ceylan, M.A., 2011, Türkiye Kıyılarında Üzerinde Şehir Yerleşmesi Bulunan Tombololara Genel Bir Bakış. *Marmara Coğrafya Dergisi* **23**, 352–372.

Ceylan, M.A., 2012, General Overview of the Tombolos on Turkey's Coastlines. *World Applied Sciences Journal* **7**.16, 907–914.

Ceylan, A., Kırtıloğlu, O.S., Sarı, F. and Ekizoğlu, İ., 2010, An Analysis of Bathymetric Changes in Sille Dam Reservoir Between 1984 and 2008, in *10. International Multidisciplinary Scientific GeoConference SGEM 2010*, 387–394. Bulgaria.

Ceylan, A., Karabörk, H. and Ekızoğlu, İ., 2011, An Analysis of Bathymetric Changes in Altınapa Reservoir. *Carpathian Journal of Earth and Environmental Sciences* **6**.2, 15–24.

Di Vita, A., 1995, Archaeologists and earthquakes: The case of 365 AD. *Annals of Geophysics* **38**, 971–976.

Dirik, K., Türkmenoğlu, A., Tuna, N. and Dirican, M., 2003, *Datça Yarımadası'nın Neotektoniği, Jeomorfolojisi ve Bunların Eski Medeniyetlerin Yerleşimi ve Gelişimi Üzerindeki Etkisi*, ODTÜ Technical Report AFP-00-07-03-13.

Doğaner, S., 2000, Kıyı Oklarının Doğal Varlıklar Olarak Korunması. *İstanbul Üniversitesi Edebiyat Fakültesi Coğrafya Dergisi* **8**, 1–28. İstanbul.

Dumankaya, O., 2015, East Harbour Mole of Myndos/Myndos Doğu Limanı Mendireği. *Tina Maritime Periodical/Denizcilik Arkeolojisi Dergisi* **3**, 12–45.

Dumankaya, O. and Gündüz, S., 2016a, Myndos Antik Kenti'nin Doğu Limanı ve Yapıları/The Eastern Harbour Myndos Ancient City: Its Structure, in D. Şahin (ed.), *Myndos Araştırmaları I Myndos Studies–I. Myndos Kazı ve Araştırmaları/Myndos Excavations and Researches 2004–2013*, 9–34. Bursa.

Dumankaya, O. and Gündüz, S., 2016b, Myndos Sualtı Araştırmalarında Yeni Bir Keşif: Batı Limanı / A New Discovery in the Myndos Underwater Research: West Harbour, in D. Şahin (ed.), *Myndos Araştırmaları–I/Myndos Studies–I. Myndos Kazı ve Araştırmaları/Myndos Excavations and Researches 2004–2013*, 1–8. Bursa.

Ercan, T., Günay, E. and Türkecan, A., 1981–1982, Bodrum Yarımadasının Jeolojisi. *Maden Tetkik ve Arama Dergisi* **97–98**, 21–32.

Erdi, A., Durduran, S.S. and Uslu, R., 2007, Coğrafi Bilgi Sistemi Yardımıyla Hidrografik Haritaların Oluşturulması: Bayramiç Barajı (Çanakkale) Örneği, in *3. Mühendislik Ölçme Sempozyumu, 24–26 Ekim 2007*, 103–114. Konya.

Ergin, K., Güçlü, U. and Uz, Z. 1967, *A Catalogue of Earthquakes for Turkey and Surrounding Area (11 AD–1964)*. İstanbul Technical University, Faculty of Mines Technical Report 24, İstanbul.

Erol, O., 1991, Türkiye Kıyılarındaki Terkedilmiş Tarihi Limanlar ve Bir Çevre Sorunu Olarak Kıyı Çizgisi Değişimlerinin Önemi. *İstanbul Üniversitesi Deniz Bilimleri ve Coğrafya Enstitüsü Bülteni* **8**, 1–44.

Ersoy, Ş., 1991, Datça (Muğla) Yarımadasının Stratigrafisi ve Tektoniği. *Türkiye Jeoloji Bülteni* **34**, 1–14.

Flemming N.C., Czartoryska, N.M.G. and Hunter P.M., 1973, Eustatic and Tectonic Components of Relative Sea Level Change, in D. Blackman (ed.), *Marine Archaeology: Proceedings of the Twenty Third Symposium of the Colston Research Society*, *held in the University of Bristol, 4–8 April, 1971*, 1–63. London.

Flemming, N.C., 1978, Holocene eustatic changes and coastal tectonics in the northeast Mediterranean: implications for models of crustal consumption. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* **289**.1362, 405–458.

Flemming, N.C. and Webb, C.O., 1986, Tectonic and eustatic coastal changes during the last 10,000 years derived from archaeological data, in *Zeitschrift für Geomorphologie, Supplementbande 62*, 1–29.

Franco, L., 1996, Ancient Mediterranean Harbours: a heritage to preserve. *Journal of Ocean and Coastal Management* **30**.2, 115–151.

Frost, H., 1973, The offshore Island Harbour at Sidon and Other Phoenician Sites in the Light of New Dating Evidence. *IJNA* **2**.1, 75–94.

Guidoboni, E., Comastri, A. and Triana, G., 1994, *Catalogue of Ancient Earthquakes in the Mediterranean Area up to the 10th Century*. Istituto Nazionale di Geofisica, Rome.

Günok, E. and Pınar, A., 2009, Coğrafi Bilgi Sistemi Metodolojisinin Sorgun Çayı Havzası Fiziki Coğrafyasına Uygulanması. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi* **22**, 203–217.

Herod., *Hist*. A. Erhat (trans.), 1983, *Herodot Tarih*. İstanbul.

IHO, 1998, *IHO Standards for Hydrographic Surveys Special Publication 44*. Monaco.

Kayan, İ., 1988, Late Holocene sea-level changes on the Western Anatolian coast. *Palaeogeography, Palaeoclimatology, Palaeoecology* **68**, 2–4, 205–218.

Kayan, İ., 1999, Holocene stratigraphy and geomorphological evolution of the Aegean coastal plains of Anatolia. *Quaternary Science Reviews* **18**, 541–548.

Kelletat, D. and Kayan, İ., 1983, Alanya batısındaki kıyılarda ilk C14 tarihlendirmelerinin ışığında Geç Holosen tektonik hareketleri. *Türkiye Jeoloji Kurumu Bülteni* **26**, 83–87.

Koç, K., 2005, Karaada ve Tavşanburnu (Bodrum) Sıcak ve Mineralli Sularının Hidrojeo Kimyasal İncelemesi. Unpublished master's thesis, Department of Geological Engineering, Hacettepe University, Ankara.

Kouskouna, V. and Makropoulos, K., 2004, Historical Earthquake Investigations in Greece. *Annals of Geophysics* **47**, 2/3, 723–731.

Lambeck, K., 1995, Late Pleistocene and Holocene sea-level changes in Greece and South Western Turkey: a separation of eustatic, isostatic and tectonic contribution. *Geophysical Journal International* **122**, 1022–1044.

McKenzie, D.P., 1972, Active tectonics of the Mediterranean region. *Geophysical Journal, Royal Astronomical Society* **30**, 109–185.

Pirazzoli, P.A., 1986, The early byzantine tectonic paroxysm, in *Zeitschrift für Geomorphologie, Supplementbande* **62**, 31–49.

Pirazzoli, P.A., Laborel, J. and Stiros, S.C., 1996, Earthquake clustering in the Eastern Mediterranean during historical times. *Journal of Geophysical Research* **101**, 6083–6097.

Polat, O., Gök, E. and Yılmaz, D., 2008, Earthquake Hazard of the Aegean Extension Region (West Turkey). *Turkish Journal of Earth Sciences* **17**, 593–614.

Polyb. *Hist. XVI*, E.S. Shuckburg (trans.), 1889, *The Histories*. London.

Pryor, J.H., 2004, *Akdeniz'de Coğrafya, Teknoloji ve Savaş Araplar Bizanslılar Batılılar ve Türkler*, F. Tayanç and T. Tayanç (trans.), İstanbul.
Raban, A. 2009, *The Harbour of Sebastos (Caesarea Maritima), in its Roman Mediterranean Context*, M. Artzy, B. Goodman and Z. Gal (eds), BAR *International Series* 1930, Oxford.
Salamon, A., Rockwell, T., Ward, S.N., Guidoboni, E. and Comastri, A., 2007, Tsunami Hazard Evaluation of the Eastern Mediterranean: Historical Analysis and Selected Modeling. *Bulletin of the Seismological Society of America* **97**.3, 1–20.
Stiros, S.C., 2001, The AD 365 Crete earthquake and possible seismic clustering during the fourth to sixth centuries AD in the Eastern Mediterranean: a review of historical and archaeological data. *Journal of Structural Geology* **23**, 545–562.
Strabo *Geog*., A. Pekman (trans.), 2000, *Antik Anadolu Coğrafyası*. İstanbul.
Ulusoy, I., Cubukcu, E., Aydara, E., Labazuy, P., Gourgaud, A. and Vincent, P.M., 2004, Volcanic and deformation history of the Bodrum resurgent caldera system (southwestern Turkey). *Journal of Volcanology and Geothermal Research* **136**, 71–96.
Yolsal, S. and Taymaz, T., 2010, Gökova Körfezi Depremlerinin Kaynak Parametreleri veRodos-Dalaman Bölgesinde Tsunami Risk. *İtü Dergisi-d Mühendislik* **9**.3, 53–65.

