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Environment, Climate and Society in Roman and Byzantine Butrint

Mario Morellón, Gaia Sinopoli, Adam Izdebski, Laura Sadori, Flavio Anselmetti, Richard Hodges, Eleonora Regattieri, Bernd Wagner, Brunhilda Brushulli and Daniel Ariztegui

Abstract

A multiproxy analysis (sedimentology, geochemistry and pollen) of sediments recovered in the Butrint lagoon (Albania) allows us to reconstruct the environmental changes that occurred in the area during the 1st millennium AD. In this paper, we compare these analytical results with the evidence provided by archaeological investigations carried out at the site of the Roman city of Butrint (surrounded by these lagoon waters) and in the city's hinterlands. From this, we can say that different periods of farming and siltation (AD 400–600 and 700–900) were accompanied by increased run-off and wetter conditions in the region. This coincided with the territorial and economic expansion of the Byzantine empire, suggesting the key role of trade in the profound land use changes experienced in Butrint.

Introduction

Mediterranean coastal areas have a long history of human occupation, extending back to Prehistoric times. From an historical point of view, these zones constituted natural communication links between the main cultural centres of antiquity, and provided essential resources for ancient societies.¹ Coastal landscapes have experienced profound transformations during the last millennia, resulting from the interplay of climate variability and human activities, in the context of sea level rise, river aggradation and significant tectonic activity, mainly manifested through subsidence and earthquakes at centennial to millennial timescales.² Thus, Mediterranean coastal regions, often vulnerable from an ecological point of view, stand out as ideally suited to study the complex interactions between natural climate variability and human activities,³ a key topic for the future management of this region in the context of global climate change.⁴

Coastal lagoon sediments provide continuous natural archives of landscape change extending back for several millennia, and allow a reconstruction of several important environmental variables (sedimentation rates, water budget, run-off, vegetation changes) with the help of multidisciplinary analysis of sediment cores (pollen, sedimentology, geochemistry). A number of sites in the central and eastern Mediterranean region that were investigated in recent years, such as Lake Shkodra in Albania, Amvrakikos Lagoon in Greece, Patria Lagoon in Italy, Larnaca salt lake on Cyprus, and the Syrian coastal plains, provide valuable examples of human versus climate interactions.⁵ However, these records are still scarce compared with palaeoenvironmental reconstructions based on marine cores, located far offshore, and continental sequences recovered in highland areas, characterised by moister or colder climatic conditions and human pressure of a different character.⁶ Thus, more high-resolution records, able to capture high-frequency environmental changes, are required in order to precisely reconstruct the role of human activities and climate on the shaping of coastal landscapes through history, and their spatial-temporal variability within the Mediterranean basin.

Late Antiquity (*ca.* AD 300–650) constitutes a particularly interesting period in the history of the Mediterranean region. On the one hand, it was a time of impressive economic growth and vibrant cultural change, in particular in the East; on the other hand, this period witnessed frequent invasions and political transformation or even collapse, first in the West, and finally, towards the end of the period, also in the East.⁷ Moreover, the climate of the Mediterranean in this period was particularly unstable, with significant shifts between wetter and drier conditions occurring in different regions at variable periods and timescales, and with

1 Marriner *et al.* (2014).

2 Climate variability: Fletcher and Zielhofer (2013); Luterbacher *et al.* (2005). Human activities: Grove and Rackham (2003). Sea level rise: Lambeck and Purcell (2005). Tectonic activity: Völt (2007).

3 Haldon *et al.* (2014); Lavorel *et al.* (1998); Manning (2013); McCormick *et al.* (2012); Roberts *et al.* (2004).

4 Giorgi and Lionello (2008).

5 Lake Shkodra: Sadori *et al.* (2015); Zanchetta *et al.* (2012). Amvrakikos Lagoon: Avramidis *et al.* (2014). Patria Lagoon: Sacchi *et al.* (2014). Larnaca salt lake: Devillers *et al.* (2015). Syrian coastal plains: Di Rita and Magri (2012); Kaniewski *et al.* (2008).

6 Marine cores: Combouieu-Nebout *et al.* (2013); Taricco *et al.* (2009). Continental highland areas: e.g. Lake Ohrid, Albania-Macedonia: Lacey *et al.* (2015); Lake Prespa, Albania-Greece-Macedonia: Leng *et al.* (2013); Lake Dojran, Macedonia: Zhang *et al.* (2014).

7 Cameron *et al.* (2001); Morrisson (2004).

varying severity and abruptness.⁸ Lake Butrint is located in the central part of the western coast of the Balkan Peninsula, which experienced invasions of Germanic, steppic and Slavic groups from the late 4th until the 7th c. AD. However, due to its coastal location, isolated from the interior of the peninsula by high mountain chains, the Butrint area was protected from direct war damage until relatively late, and its harbour gave it easy access to distant markets across the Mediterranean, thus creating opportunities for the export of local agricultural products. Therefore, the Lake Butrint area offers an interesting case study of the interplay between major economic, as well as political, processes, and local climatic and environmental change. Moreover, given the fact that the interaction between Butrint and its countryside achieved unique intensity in the Roman period (including the Late Roman period of *ca.* AD 300–550),⁹ in this specific case the 1st millennium AD offers the greatest potential for synthesising scientific and archaeological evidence.

In this paper we reconstruct environmental changes that occurred around the Butrint lagoon during Late Antiquity and the Early Middle Ages in the context of the Greek / Byzantine history of this area (600 BC to AD 1300). We apply multidisciplinary methods (pollen, sedimentology, geochemistry) to a finely laminated sediment core dated by radiocarbon. Previous research carried out at this site demonstrated the potential of this sequence as an archive of climate variability, human impact and tectonic activity in the region for the last *ca.* 4500 years.¹⁰ A comparison between these results and the archaeological information provided by the outstanding site of Butrint (*Buthrontum*),¹¹ provides us with an insight into the role of human activity and climate in the evolution of the landscape of this region. Archaeological and geoarchaeological investigations carried out over the last few decades in Butrint have provided a vast amount of information about social and economic changes and associated land-use transformations in the lake's catchment area. The combined study of both sources of information (lake sediments and archaeology) allows for a precise reconstruction of variations in sediment input and changes in vegetation, in relation to socio-economic change and climate variability in the central Mediterranean region.

Historical Background: Roman and Early Medieval Butrint

The earliest evidence of human presence in the Lake Butrint area date to the Paleolithic.¹² However, no significant anthropic impact on the local landscape can be seen until the Bronze Age (after *ca.* 2000 BC), when slope-derived 'terra rossa' was deposited in the Konispol Cave (at the headwaters of the Pavllo river, 15 km south-east of Butrint), as a result of incipient grazing, shepherding and deforestation, favoured by warmer conditions.¹³ The Butrint Peninsula (fig. 1b), was only sporadically occupied during the Bronze Age and the Archaic period (8th c. BC), as a hilltop refuge, and, subsequently, as a fortified trading post, which was established by the 6th c. BC.¹⁴ The first major transformation in the area occurred by the 4th c. BC, when Butrint became a Hellenistic port and the peninsular settlement expanded to become a city.¹⁵ During the 1st c. BC, *Buthrotum* was designated as a colony for Roman veterans, and the city flourished, doubling in size and expanding towards the shores of the Vivari Channel. A new aqueduct and a bridge across the channel allowed the city to grow to over 2.5 ha down into the Vrina Plain, located to the south (fig. 1b).¹⁶ Image analysis of historical aerial photographs revealed complex farmland divisions in the Vrina Plain, corresponding to a centuriated pattern, in all probability established in parallel to the foundation of the Roman colony.¹⁷

While the centre of the city, located on the Butrint peninsula, experienced some abandonment during the 3rd c., a number of large houses and villas were built on both sides of the Vivari Channel. One of them was later transformed into a Christian ecclesiastical complex with a large basilica, as the cityscape was Christianised, with a number of churches being built on both sides of the Channel.¹⁸ Later, in the 9th and 10th c., the ruins of the church complex on the Vrina Plain were used for the construction of a Byzantine aristocratic and administrative centre, which pre-dated a significant reconstruction

8 E.g. Izdebski *et al.* (2016); McCormick *et al.* (2012).

9 Hodges *et al.* (2016).

10 Ariztegui *et al.* (2010); Morellón *et al.* (2016).

11 Hansen *et al.* (2013).

12 Schuldenrein (2001).

13 Ellwood *et al.* (1997).

14 Bescoby *et al.* (2004).

15 Hodges (2013).

16 Geenslade and Hodges (forthcoming a); Leppard (2013); Wilson (2013); Bescoby *et al.* (2004).

17 Bescoby (2006); Hodges *et al.* (2016).

18 Hodges and Geenslade (forthcoming b).

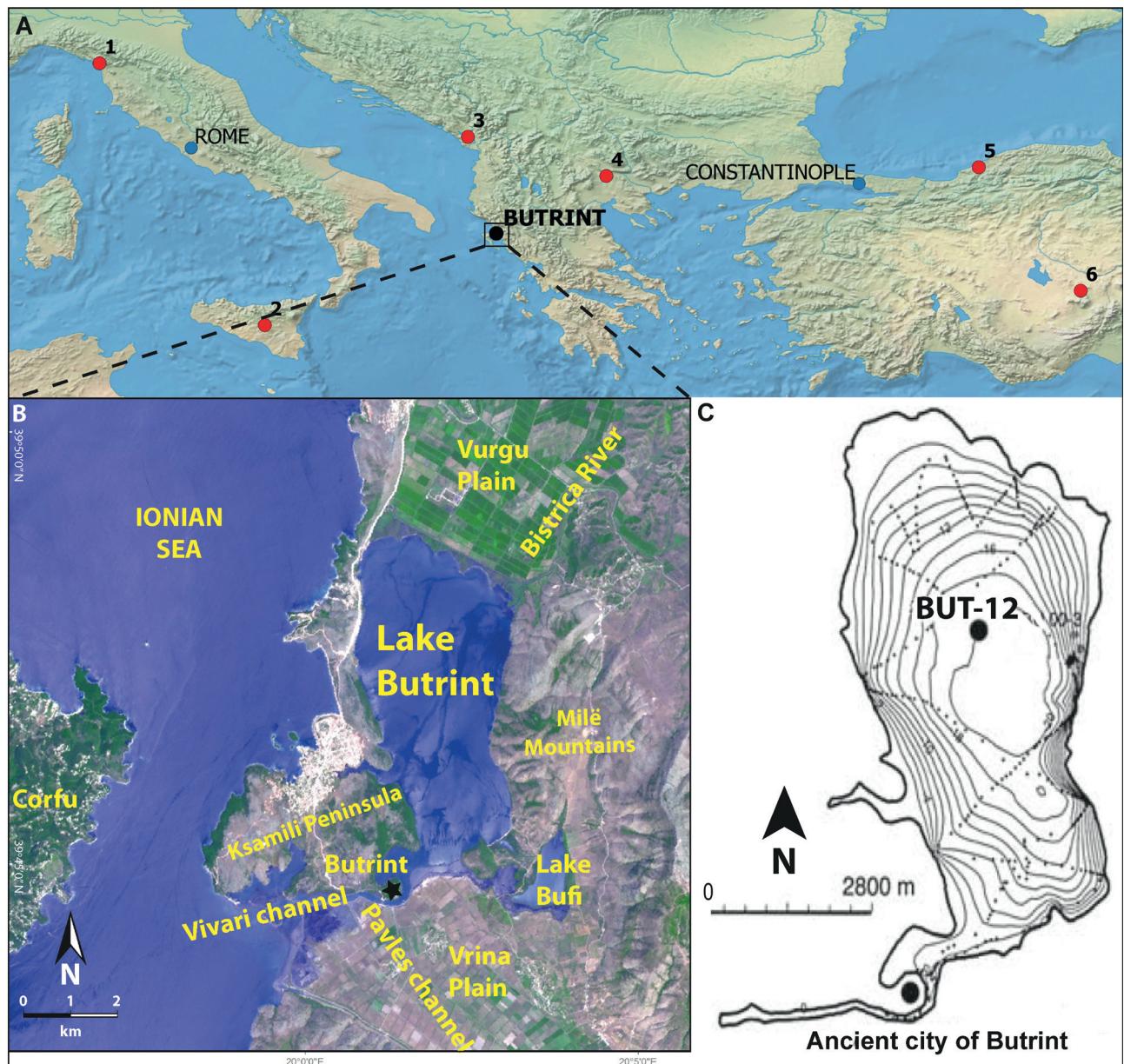


FIGURE 1 a: Location map of Butrint, and other palaeoenvironmental sequences discussed in this paper, within the central Mediterranean region: 1) Corchia Cave, Italy: Regattieri et al. (2014); 2) Lago di Pergusa, Italy: Sadori et al. (2016); 3) Lake Shkodra, Albania-Montenegro: Zanchetta et al. (2012); 4) Lake Dojran, Macedonia-Greece: Zhang et al. (2014); 5) Sofular Cave, Turkey: Fleitmann et al. (2009); Göktürk et al. (2011) and; 6) Lake Nar, Turkey: Jones et al. (2006). b: Close-up of Butrint and adjacent area including the lake and the ancient city (black star). c: Bathymetry of the lake (2 m spacing isolines) with coring location (black dot, BUT-12); modified from Morellón et al. (2016).

of the city on the peninsula, that took place from the late 10th c. onwards.¹⁹

During Late Antiquity, a pronounced economic revival took place in the city of Butrint, despite a major earthquake that destroyed the aqueduct and much of the city in *ca.* AD 360. By this time, maritime trade seems to have been more important than in the early and middle Roman periods, a trade first directed toward

the West, and then, after *ca.* AD 470, toward the East. The city was provided with new walls in the early 6th c., but started to diminish soon afterwards (after *ca.* AD 550), as population numbers decreased significantly. Much of the city must now have become uninhabited, although a Byzantine *kastron* existed in the western defences of the city until *ca.* 800.²⁰

¹⁹ Byzantine centre: Greenslade and Hodges (2013), (forthcoming c). Reconstruction of the city: Hodges (2013).

²⁰ It was sacked by an unknown enemy, probably a local Slavic or post-Roman tribe, *ca.* 800, as attested by rich destruction deposits in two towers: Hodges et al. (2009).

Geographical Setting

Butrint ($39^{\circ}47' N$, $20^{\circ}01' E$) is a coastal lagoon of tectonic origin located in the southern Ionian Sea coast of Albania, in front of the Isle of Corfu and *ca.* 5 km north of the Greek border (figs. 1a and b). The lagoon is surrounded by the Vurgu Plain to the north, the Mile Mountains to the east, the Vrina Plain to the south and the Ksamil Peninsula to the west.²¹ The archaeological site of Butrint is located on a peninsula surrounded by the waters of the lagoon (fig. 1b). The lake's basin bedrock is composed of limestones, of Jurassic-Cretaceous age, and Paleocene flysch.²² The lacustrine basin lies on a N-S extending graben structure formed during the Pleistocene, which has experienced subsidence up until recent times, and was invaded by Mediterranean seawater during the Holocene transgression.²³ This subsidence is responsible for the existence of submerged Roman and post-Roman archaeological remains, which are now below the current water table of the archaeological site.²⁴ Butrint is located near to the boundary between the European plate and the Adriatic microplate, in one of the most tectonically active regions of the Mediterranean basin,²⁵ as indicated by the presence of homogeneous layers within the laminated sediment sequence, interpreted as earthquake-induced mass wasting events.²⁶

Climate and Vegetation

Climate conditions in the area correspond to the Mediterranean type, with relatively wet winter conditions (between November and March) and a dry summer season, averaging a rather high total annual rainfall of *ca.* 1500 mm per year. Mean temperatures range from $9.7^{\circ}C$ in January to $25.1^{\circ}C$ in August. Northerly winds are dominant during spring and summer, whereas southerly winds prevail during winter and autumn.²⁷ Long-term rainfall variability is mostly related to the North Atlantic Oscillation (NAO) and the Eastern Atlantic pattern (EA), as in other areas of the central and eastern Mediterranean basin.²⁸

Natural, semi-natural and artificial habitats are found in the surroundings of Butrint Lake. Vegetation is rather diverse, and consists of a mosaic of Mediterranean, deciduous and hygrophilous and hydrophilous vegetation.

Sclerophillous forests/maquis on the Ksamil peninsula and in the hills to the south-east of the lake, mainly consist of *Quercus coccifera*, and to a lesser degree *Quercus ilex*, *Fraxinus ornus*, *Pistacia lentiscus*, *Phlomis fruticosa*, *Colutea arborescens*, and *Phillyrea media*. Small thickets formed by mainly deciduous trees are found close to Lake Bifi and in the archaeological site of Butrint, and can be considered the remnants of the mesophilous plain forest. They are formed of *Ulmus minor*, *Fraxinus angustifolia*, *Quercus robur*, *Populus alba* and, in some cases, are made up of *Laurus nobilis* and *Quercus ilex*. Differences in lacustrine and perlacustrine environments are due to water availability and saline content; hydrophilous, hygrophilous and aquatic vegetation is fairly well-represented, making Butrint a site included in the Ramsar international convention as a very important humid area. The aquatic macrophytes in the north part of the lake mainly consist of pondweeds, watermilfoil, yellow water-lilies, and the green alga *Chara*. In the freshwater marshes at the northern shore of the lake, common reeds and cattails, as well as clubrushes, grow. The water saline content is very high in the narrow strip along the south shore of the lake, at the mouths of the Vivari channel and River Pavollo, where a vegetation landscape dominated by glassworts, with patches of tamarisks and sea asters, occurs. To the south of Butrint Lake, in the Vrina Plain, the vegetation is dominated by saline tolerant plants, such as glassworts, rushes and tamarisks.²⁹

In order to understand the past vegetation history here, we have to remember that climate changes over the last few thousand years had an impact not only on past natural vegetation, but also on agrarian landscapes.³⁰ Warmer temperatures can in fact provoke faster crop growth, making the growth cycles of some crops (e.g. cereals and grapevine) shorter than at present, possibly causing negative effects on yields. It should also be remembered that the faster development of winter crops may compensate for the negative effect of precipitation decrease, during periods of prolonged summer drought.³¹ Given the high annual rainfall (*ca.* 1500 mm) recorded in the area of Butrint, mostly concentrated during the winter season, we can speculate that, for agriculture, precipitation variability mattered more in terms of erosion and water table levels, than the availability of rain for annual cycles and for the productivity of different crops. It seems to have been more important for local cultivation strategies the extent to which the marshes could be turned into fields.

²¹ Tsabaris *et al.* (2007).

²² Tsabaris *et al.* (2007).

²³ Aliaj *et al.* (2001); Meco and Aliaj (2000).

²⁴ Lane (2004).

²⁵ Meco and Aliaj (2000); Muço (1995).

²⁶ Ariztegui *et al.* (2010).

²⁷ Lane (2004).

²⁸ Lionello *et al.* (2006).

²⁹ ASPBM (2010); Dedej and Bino (2003).

³⁰ Lionello *et al.* (2014).

³¹ Olesen and Bindi (2002).

Butrint Lake's Hydrology and Limnology

Butrint is the southernmost and largest of a series of lagoons situated along the Ionian Sea coast of Albania, and is connected to the sea through the Vivari Channel, a relatively long (3.6 km), narrow (60–100 m) and deep (6 m) natural canal. The Ksamil Peninsula, in the West, separates the lagoon from the sea (fig. 1b). The lake is fed by freshwater, mainly derived from the Bistrica River to its north, and the Pavlo River in the Vurgu and Vrina plains.³² The small creeks and springs located at the Milë Mountains (eastern part of the catchment) and shallow Lake Buçi (2.4 m maximum water depth),³³ also provide small amounts of freshwater.³⁴ Saline waters from the Ionian Sea can occasionally enter into the lake through the Vivari Channel (fig. 1b) during particularly high tide intervals. The area is currently subjected to microtidal influence, with a tidal range of 30 cm.³⁵ Therefore, freshwater (and occasional marine water input and output) and evaporation output, control the variations in the lake's water salinity.

The lagoon has a surface area of 1600 ha, and mean and maximum water depths of 11.4 m and 21.4 m, respectively (fig. 1c); abrupt temperature and salinity gradients in the water column has led to permanent stratification.³⁶ The uppermost *ca.* 8 m have variable temperatures, ranging between 14 and 25°C and are oxic (8–9 mg/l), with salinity varying between 13 and 26 PSU (Practical Salinity Units) and a pH ranging between 6.5 and 9.5. Below *ca.* 8 m, constant temperatures around 17°C and, anoxic/sulfidic conditions, with salinities ranging from 30 to 36 PSU, occur.³⁷ Thus, vertical mixing of the water column is restricted to the epilimnion.

Landscape Evolution During the Last Millennia

The tectonic-origin Butrint Basin was invaded by Mediterranean waters during the post-glacial marine transgression (until *ca.* 7000 cal years BP), and remained open to the Ionian Sea throughout the Mid-Holocene. This formed a large embayment stretching northwards as far as the town of Phoenicë and south towards Mursia, according to archaeological surveys.³⁸ The presence of massive, bioturbated silts with scaphopod shells, also revealed marine conditions in the currently deepest areas of this lagoon (fig. 2a).³⁹ The progressive aggradation

of the Pavlo River delta to the south, which led to the formation of the Vrina Plain (fig. 1b), led to an increasing isolation from the sea, as shown by paleogeographical maps based on dated archaeological sites.⁴⁰ According to the paleoenvironmental reconstruction carried out with sediment cores from the deepest areas of the lake, the transition between marine and the currently restricted lagoon conditions, occurred between 1620 and 1430 BC (fig. 2a).⁴¹ According to archaeological surveys, only the NE and the sw of the Vrina Plain was above sea level prior to the Roman period (fig. 1b).⁴² A series of boreholes along the margins of this plain clearly indicate the environmental evolution of the area, from an open coastal embayment to estuarine wetlands at *ca.* AD 1270–1390, after which it slowly became a river floodplain, its current condition.⁴³ Butrint, an important ancient harbour since the Hellenistic period, progressively declined in importance as it became more isolated from the Ionian Sea.

Materials and Methods

Two overlapping cores (BUT-12-1 AND BUT-12-2) of 12 and 9 m length respectively, were recovered with percussion-coring equipment installed on a floating raft, in the deepest areas of the lake (fig. 1c). A composite sequence of 11.6 m was obtained, based on the lithostratigraphic correlation of these two cores and a previously recovered short-gravity core for the uppermost part (fig. 2a).⁴⁴ The cores were subsequently split into two halves and imaged with a Jai cv L105 3 CCD Colour Line Scan Camera, with a resolution of 140 ppcm (350 dpi). Sedimentary facies were defined after visual and microscopic smear slides observations (fig. 2).⁴⁵ Elemental composition of the sediment core sections was obtained with an AVAATECH XRF core scanner, with a resolution of 1 mm to obtain relative concentration on different chemical elements (Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Rh, Zn, Br, Rb, Sr, Zr, Mo, Pb and Bi) under variable working conditions. The XRF results are expressed in counts per second (cps), and only chemical elements with a mean cps over 1500 were considered to be statistically significant. Only calcium (Ca), strontium (Sr) and the titanium (Ti)/Ca ratio have been selected for this study as

³² ASPBM (2010).

³³ Lane (2004).

³⁴ Negroni (2001).

³⁵ Ariztegui *et al.* (2010); Hounslow and Chepstow-Lusty (2004); Negroni (2001).

³⁶ Negroni (2001).

³⁷ Negroni (2001).

³⁸ Lane (2004).

³⁹ Morellón *et al.* (2016).

⁴⁰ Martin (2004).

⁴¹ Morellón *et al.* (2016).

⁴² Ariztegui *et al.* (2010); Martin (2004).

⁴³ Bescoby *et al.* (2008).

⁴⁴ Ariztegui *et al.* (2010); Morellón *et al.* (2016).

⁴⁵ Morellón *et al.* (2016), applying the methodology described in Schnurrenberger *et al.* (2003).

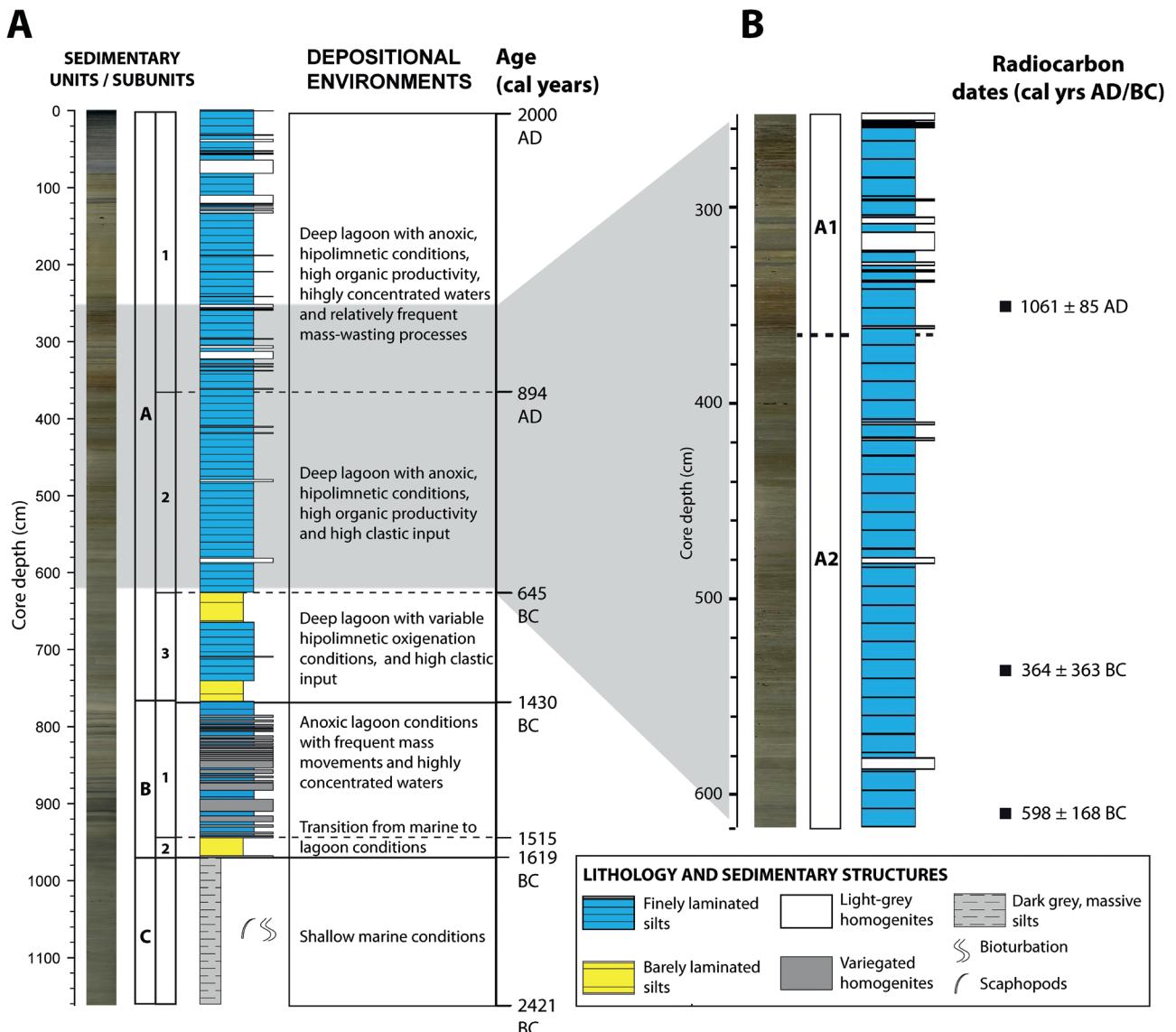


FIGURE 2 *a.* Core image, sedimentary units and sub-units, sedimentological profile and reconstruction of the main depositional environments interpreted from the whole Lake Butrint sediment sequence: modified from Morellón et al. (2016). *b.* Detail of the part of the sequence analysed in this research, including: core image, sedimentary sub-units, sedimentological profile and the three calibrated radiocarbon dates constraining the chronology of this period 600 BC–AD 1300.

they are considered to be the most representative geochemical proxies. Cores were subsampled every 10 cm for pollen, avoiding homogeneous layers.⁴⁶

The chronology of the whole lake sequence is based on: i) ¹³⁷Cs dating of the previously recovered core BUT-00-2 and ii) seven accelerator mass spectrometry (AMS) ¹⁴C dates from terrestrial macro-remains and charcoal, analysed at the ETH Zürich Laboratory of Ion Beam Physics. Radiocarbon dates were converted into calendar years BP with the Calib 6.0 software using the INTCAL13

calibration curve,⁴⁷ selecting the median of the 95.4% distribution (2σ probability interval). The age-depth relationship for the whole sequence was constructed by linear interpolation of calibrated radiocarbon dates using Analyseries. The radiocarbon dates constraining the study period which this research focuses on, can be found in Table 1.

46 A detailed explanation of the analytical techniques used, including pollen and charcoal chemical extraction, can be found in Morellón et al. (2016).

47 Reimer et al. (2013).

TABLE 1 Radiocarbon dates used for the construction of the age model for the selected interval of the Lake Butrint sequence. Dates were calibrated using *Calib 6.0* software and the *INTCAL13* curve: Reimer et al. (2013); and the mid-point of 95.4% (2σ probability interval) was selected: modified from Morellón et al. (2016).

Comp depth (cm)	Sub-unit	Laboratory code	Type of material	AMS radiocarbon age (yr B.P.)	Calibrated age (cal yrs B.P.) (2σ range)
348.6	A1	ETH-48488	charcoal	1012 ± 26	889 ± 85
537.2	A2	ETH-48489	charcoal	2233 ± 99	2314 ± 363
614.2	A2	ETH-48490	charcoal	2468 ± 27	2548 ± 168

Results

The Sedimentary Sequence: Geochronology, Sedimentology and Geochemistry

According to the chronological model we are using,⁴⁸ the study period (600 BC–AD 1300) lies within the composite sediment sequence, between 250 cm and 610 cm core depth. Three radiocarbon dates of 598 ± 168 BC (at 614.2 cm), 364 ± 363 BC (537.2 cm) and AD 1061 ± 85 (348.6 cm) carried out within this interval, provide chronological control for this *ca.* 150 cm long part of the sediment sequence (table 1, fig. 2b).

This sediment section is located in the mid to upper part of the sequence, and comprises the lower part of sedimentary sub-unit A1 and the uppermost part of sub-unit A2 (fig. 2).⁴⁹ Sediments are finely laminated silts formed by the seasonal deposition of yellow (calcite), organic-rich (brown) and clay laminae (grey), with intercalations of homogeneous layers;⁵⁰ they occur at 500 BC, the late 1st c. AD, and between the 11th and 13th c. AD (fig. 2b). Increases in calcium (Ca) and strontium (Sr) from the geochemical dataset,⁵¹ are interpreted as higher water salinity, resulting from reduced run-off and/or higher evaporation (more negative water balances). Conversely, the Ti/Ca ratio reflects detrital input derived from the catchment as a result of higher run-off, due to: i) more abundant and/or intense rainfall; ii) more intense soil erosion caused by deforestation and farming or; iii) a combination of these two factors. Total Organic Carbon (TOC) and Total Nitrogen (TN), both indicative of organic matter concentration, reach maximum values throughout the sequence during this period (1–4%). The contemporaneous increase in the TOC/TN ratio indicates a predominant terrestrial origin for this

organic matter, as plant remains transported from the lake's catchment.⁵²

According to these compositional variations, three main periods can be identified (fig. 3): i) from the 6th to the 1st c. BC, which is characterised by variable but generally high values of Ca and Sr, indicative of more saline waters coinciding with generally low Ti/Ca ratios, which reflected reduced sediment input in the lagoon; ii) from the 1st c. AD to the year AD 800, when Ca and Sr decrease significantly, reflecting fresher and more positive water balances in the context of highly variable Ti/Ca ratios, peaking during the periods AD 400–600 and AD 700–900; and finally, iii) from AD 800 to 1300, when the situation is reversed and Ca and Sr return to relatively high values, coinciding with lower Ti/Ca ratios, indicating more arid conditions characterised by saline waters and reduced sediment input (fig. 2b).

Vegetation Changes

The results of pollen analysis (extraction from sediment cores using a chemical standard procedure and pollen identification and counting at a transmitted light microscope) are presented in a pollen diagram (fig. 3). It aims to represent the floristic and vegetation changes that occurred in our study region during a particular time interval, and it reflects the history of vegetal landscape changes.

Here we present a simplified pollen diagram with selected curves for groups of plants and other indicators. The first curve, AP (arboreal plants) pollen concentration represents the arboreal biomass and the presence of forest canopy (drops in AP values indicate increased erosion in the catchment, mainly due to forest reduction, in particular forest clearing). We also provide percentage curves for cultivated trees, cultivated herbs, weeds and ruderals, microcharcoals and for two NPPS (non pollen palynomorphs), *Pseudoschizaea* and *Glomus* that are found in pollen preparations. Weeds

48 Established by Morellón et al. (2016).

49 As defined by Morellón et al. (2016).

50 Interpreted as earthquake-triggered mass-wasting deposits by Ariztegui et al. (2010).

51 Morellón et al. (2016).

52 Morellón et al. (2016).

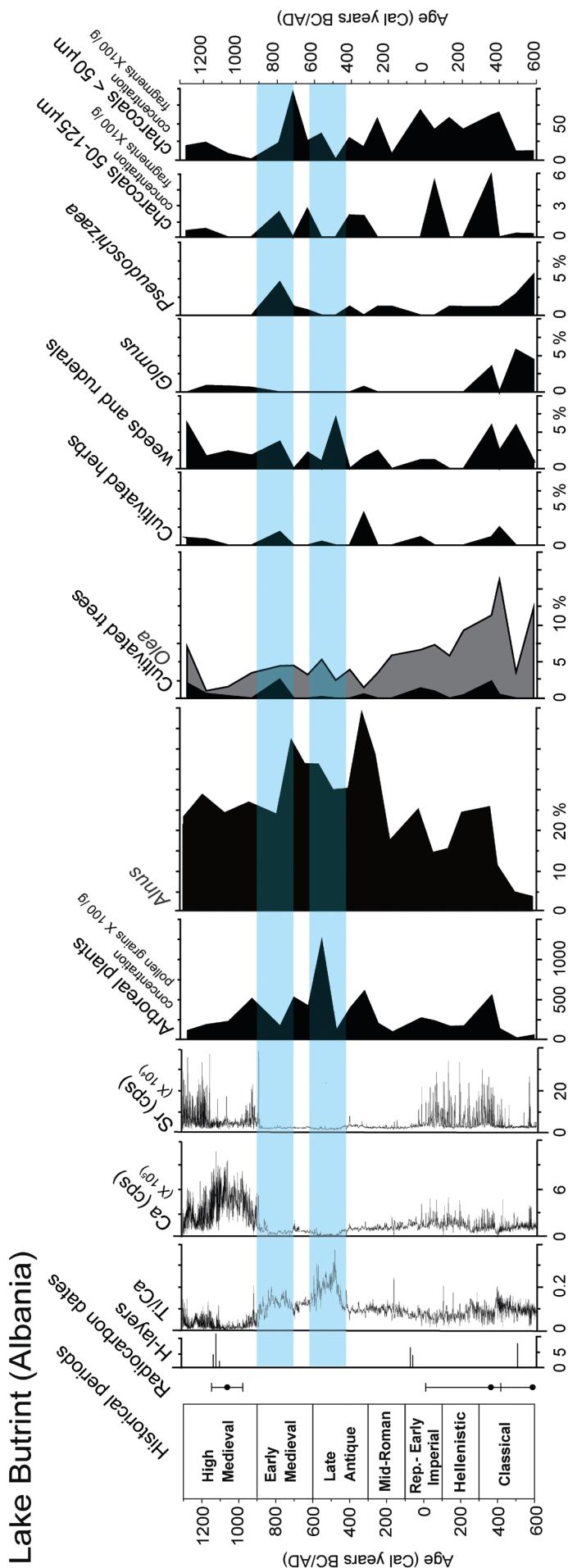


FIGURE 3 Environmental indicators (geochemical proxies and pollen curves) for the Lake Butrint sequence during the period 600 BC–1300 AD. Geochemical proxies are Ti/Ca , Ca and Sr expressed as counts per second (cps). Taxa groups are: arboreal plants, cultivated trees (Castanea – chestnut, Juglans – walnut, Olea – olive, Vitis – grapevine), cultivated herbs (Cannabis – hemp, Cereals, Fabaceae), weeds and ruderals (Centaurea sp., Centaurea cf. nigra – common knapweed, Asphodelus cf. albus – white asphodel, Cichoriaceae, Filipendula, Plantago cf. lanceolata – narrowleaf plantain, Rumex, Urtica sp. – nettle, Urtica cf. dubia – membranous nettle). Blue, shaded bars represent maxima in Ti/Ca interpreted as periods of maximum run-off in the catchment.

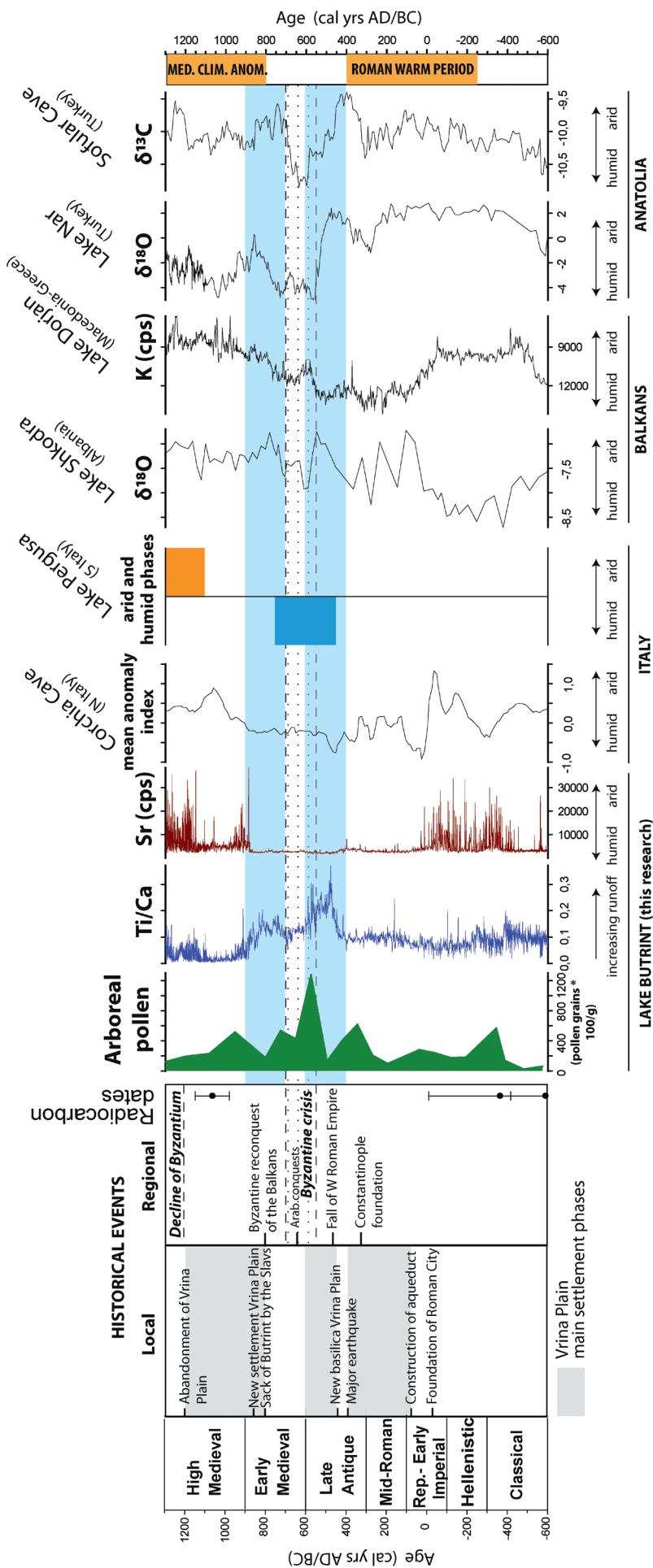


FIGURE 4. Summary of local and regional historical events that occurred in Butrint and the Byzantine empire that potentially affected land use in the study area (left), selected paleoenvironmental indicators analysed in this research (arboreal pollen, titanium/calcium ratio (Ti/Ca) and strontium (Sr , expressed in counts per second) for the Lake Butrint sequence (centre), and other paleoclimatic sequences from the Italic Peninsula (Cochlia Cave: Reggiani et al. (2014), and Lago di Pergusa: Sadori et al. (2016); the Balkans (Lake Shkodra: Zanchetta et al. (2012), and Lake Dojran: Zhang et al. (2014)) and Anatolia (Sofular Cave: Fleitmann et al. (2009), Göktürk et al. (2009), and Lake Nar: Jones et al. (2006)) during the period 600 BC–AD 1300. Grey, shaded bars on the left represent the main periods of intense settlement in the Vrina Plain. Blue, shaded bars represent maxima in Ti/Ca interpreted as periods of maximum run-off in the catchment. Dotted bar represents the 'Byzantine Crisis' also known as the 'Byzantine Dark Ages'; Decker (2016).

and ruderal plants increase when human impact is increasing. Microcharcoals come from ashes dispersed in the atmosphere during a fire (both natural and human-induced), the biggest particles (50–125 micrometres) can have a local origin, the smaller ones (<50 micrometres) can come from the wider region.⁵³ Increases in *Pseudoschizaea* and *Glomus* are taken as evidence of soil erosion.⁵⁴

After a clear human disturbance process that took place throughout the Classical Greek period, the pollen diagram suggests a different land-use pattern during the Hellenistic era (300 BC–100 BC) and earlier Roman times (100 BC–AD 300), with decreased presence of weeds and a still important cultivation of tree crops, especially olive tree. Local and regional fires are quite important from 400 BC to AD 100, but show a temporary decrease in the mid Roman period (ca. AD 100–300). The passage from the mid Roman to late antique periods is marked by many landscape changes: olive is strongly reduced at around AD 300; cultivated herbs (cereals, legumes and hemp) show a peak; and local fires/use of fire increase again. At AD 400 olive trees and weeds increase, while the presence of herb crops markedly decreases. At the end of the late antique period, shortly before AD 600, arboreal pollen concentration points to an increase in forest cover.

The transition (AD 600) from Late Antiquity to the Middle Ages is marked by a reduction in cultivated trees and herbs, while weeds and regional (but also local) fires increase. *Pseudoschizaea* starts to increase soon after AD 700, and peaks at AD 800, matching a decrease of forest biomass, suggesting enhanced erosion soon after intense fire activity.

Discussion: The Record of Human vs Climate Interactions in Butrint

Regional Climate Changes During the First Millennium AD

Relatively wet conditions generally prevailed in the Butrint area from the 1st to the 8th c. AD, as evidenced by low Ca and Sr values, which are both indicative of low water salinity and thus, more positive water balances (figs. 3 and 4). Moreover, relatively high Ti/Ca ratios centred during the period AD 300–800, resulting from increased run-off (caused by higher or more intense rainfall and/or soil erosion) might indicate that most of the late antique and early medieval period (AD 400–900) were notably wetter than the preceding and subsequent

periods. The rising of the water table is also suggested by increases in *Alnus* (alder), that in this period records its highest percentage values for the whole record (fig. 3).⁵⁵ Alders are riparian trees that are fast growing in wet soils fed by fresh water.

Prolonged wetter conditions covering much of Late Antiquity have also been recorded by several other central Mediterranean sites, that also show a major transition to a drier climate in this region between AD 750 and 800.⁵⁶ Lake records from the Balkans also point to more humid conditions during most of the 1st millennium AD (AD 1–800),⁵⁷ with notably wetter conditions after AD 200 (fig. 4). An exception to this pattern occurred in Lake Shkodra (northern Albania), where the timing of short-lived more humid periods seems a bit different. Here they were registered during AD 150–450, AD 500–700 and AD 850–1150.⁵⁸ In particular, in the period between AD 500 and 700 both isotope content and pollen influx indicate wet conditions.⁵⁹ For this basin we have to consider the overlapping of climate and geological changes that led to its evolution from a marsh to a permanent lake in Roman times.⁶⁰ In contrast, the eastern Mediterranean paleoclimate records, such as Lake Nar or the Sofular Cave, recorded a more complex pattern,⁶¹ characterised by very dry climatic conditions during the period AD 300–550, increased moisture from AD 550 to 670/750 and a return to drier conditions from ca. AD 750 to 950.⁶²

A major climatic transition towards drier conditions occurred in Butrint after AD 800, characterised by increasing salinity, marked by higher Ca and Sr, and reduced run-off, as indicated by lower Ti/Ca (fig. 4). Consistently, a significant reduction in arboreal concentration and a decrease in alder was also recorded, indicating a landscape more adapted to arid conditions. This profound hydrological change occurred in the context of the Medieval Climate Anomaly (MCA), characterised by warmer conditions at a global scale, and to generally drier conditions in the western and central Mediterranean regions.⁶³ This pattern can be also found

55 Morellón *et al.* (2016).

56 E.g. Lake Pergusa (ca. AD 300–650); Sadori *et al.* (2016). Corchia Cave (ca. AD 300–500); Regattieri *et al.* (2014).

57 E.g. Ohrid: Lacey *et al.* (2015). Dojran: Francke *et al.* (2013); Zhang *et al.* (2014). Prespa: Leng *et al.* (2013).

58 Zanchetta *et al.* (2012).

59 Sadori *et al.* (2015).

60 Mazzini *et al.* (2016); Mazzini *et al.* (2015).

61 Lake Nar: Jones *et al.* (2006). Sofular Cave: Fleitmann *et al.* (2009); Göktürk *et al.* (2011).

62 Izdebski *et al.* (2016).

63 Global scale: Stine (1994). Western Mediterranean: Moreno *et al.* (2012). Central Mediterranean: Sadori *et al.* (2016).

53 Gardner and Whitlock (2001); Sadori and Giardini (2007).

54 Medeanic *et al.* (2008).

in other lake records from the Balkans,⁶⁴ but an opposite response, with more humid conditions, has been reconstructed in Anatolian sequences, such as Lake Nar,⁶⁵ highlighting the hydroclimatic complexity of this period within the Mediterranean basin.⁶⁶ In fact, mild temperatures and abundant rainfall during the 9th and 10th c. AD in the eastern Mediterranean might have favoured an agricultural and demographical expansion of the Byzantine empire.⁶⁷

In summary, climatic conditions around Butrint remained humid throughout Late Antiquity, in agreement with the other central Mediterranean areas, but at the same time was more stable than in many continental parts of the Balkans or in the eastern Mediterranean, where a number of medium-term relatively abrupt changes in precipitation regimes are recorded for this period. The combination of these two factors (humidity and stability) might have favoured the expansion of agriculture in this area throughout the 1st millennium AD, or at least until AD 800, when there occurred a major environmental transition towards drier conditions. At the same time, the water table rise, that in all probability occurred in Late Antiquity, almost certainly had a negative impact on buildings located on the Vrina Plain and along the Vivari Channel, including a number of large houses and splendid villas.

Land Use Changes in the Hinterland of Butrint and the Local Agricultural Economy

Increases in the Ti/Ca ratio indicate higher sediment delivery to the lake basin, caused by more intense soil erosion, likely favoured by farming activities (involving forest clearances and the expansion of crops) or higher rainfall. Two major peaks in this ratio stand out in the record (AD 400–600 and AD 700–900), in the context of relatively high values on Ti/Ca and low Sr and Ca values, occurring throughout the 1st millennium AD. These two maxima match the low concentration of arboreal pollen and high percentages of weed and ruderal herbs, and can be interpreted in terms of episodes of land use change in the hinterland of Butrint (fig. 3).

The first, and most prominent peak in Ti/Ca, recorded between AD 400 and 600, is preceded by an increase in cultivated herbs and large (50–125 µm) charcoal particles, likely indicative of local fires (AD 300–350), and is followed by a decrease in arboreal taxa (AD 350–400). This situation might indicate the occurrence of forest

clearances for the expansion of crops in the region. The first peak in cultivated herbs (including cereals), was recorded during the 4th c. AD (fig. 4). There is also additional evidence for large-scale deforestation in the Butrint catchment during the 1st millennium AD, coming from the nearby Lake Bufo sediment sequence, where a significant decrease in arboreal pollen (mainly in *Quercus* and *Fagus*), contemporaneous to an increase in charcoal, was reconstructed for the 1st millennium AD.⁶⁸ Unfortunately, the lack of an absolute chronology in this neighbouring sequence makes it impossible to achieve a more precise correlation between these two natural archives.

This first peak in Ti/Ca coincides with the economic revival of both the city of Butrint⁶⁹ and Roman farming on the Vrina Plain up to the nearby hills.⁷⁰ In this first phase of the Late Roman period, *ca.* AD 300–470, the city had strong maritime trading links to the western part of the empire, in particular Italy.⁷¹ It is, therefore, conceivable that the increased interest in cereal farming in the hinterlands of Butrint had to do with the increased demand for grain coming from the city of Rome, no longer provisioned from Egypt on the same scale after the foundation of Constantinople in AD 330. This would resemble a similar process of agricultural expansion and landscape change that occurred in this period in southern Italy.⁷²

A shift towards an increased focus on olive cultivation in local agriculture occurred afterwards (*ca.* AD 400–600, fig. 3) and seems to coincide with the second phase of the Late Roman period in Butrint (after *ca.* AD 470), when the city developed stronger trading connections with the East, it mainly exporting fish products.⁷³ Considering the continuity of rather stable, humid conditions in the region, a climatic change is rather improbable as a potential cause for this transformation. Thus, this increase in olive production must have been a response to the new maritime contacts with the eastern Roman empire, and Constantinople in particular. This increasing focus on olive cultivation, occurring late into the Late Roman period, invites comparisons with a number of regions in the eastern Mediterranean that were also increasingly focusing on olives,⁷⁴ in particular the

68 Lane (2004).

69 Hodges (2013).

70 Yet this was without an increase in rural settlement intensity, that would be comparable to the processes that were occurring in Greece at that time: Hodges *et al.* (2016).

71 Hodges (2013).

72 Saduri *et al.* (2016).

73 Hansen *et al.* (2013).

74 Waliszewski (2014).

64 E.g. Prespa: Leng *et al.* (2013).

65 Jones *et al.* (2006).

66 Haldon *et al.* (2014); Roberts *et al.* (2012).

67 Xoplaki *et al.* (2016).

hinterlands of Miletus, where pollen evidence suggests that this process also started relatively late, at the earliest in the 5th c. AD.⁷⁵ However, in the case of Butrint, there is no evidence of locally made olive oil containers, that would suggest the large-scale import of olive oil from elsewhere.⁷⁶ Thus, in all probability, the increased focus on olive cultivation was linked to the decline in trade with the West, and the need to assure a local supply of olive oil for the otherwise thriving Butrint area.

A return towards relatively low Ti/Ca ratios, indicating reduced soil erosion, was recorded from *ca.* AD 600 to 700. This period coincides with a decrease in cultivated taxa and also with the decline and abandonment of the settlements in the Vrina Plain, and the depopulation of the city.⁷⁷ The desertion of the Vrina Plain settlements might be explained by the failure of the port, as a result of the significant decline of Mediterranean trade during this epoch, in the context of the socio-economic crisis of the Byzantine empire.⁷⁸

A second increase in Ti/Ca (but lower than the first) occurred afterwards, between AD 700 and 900. A parallel increase in large charcoal particles, indicative of local fires and likely forest clearances, was accompanied by a relative increase in cultivated herbs and, in this case, a more marked increase in cultivated trees, particularly *Olea*. This second increase in Ti/Ca occurred in parallel with high values of mid *Pseudoschizaea*, indicative of soil erosion, and was preceded by a significant increase in small charcoal particles (<50 microns), likely resulting from increasing regional fires, pointing to a larger-scale land use transformation. In this case, a more diverse agricultural pattern, including different cultivated trees, apart from *Olea* and herbs, can be interpreted from the pollen spectra (fig. 3). This period approximately coincides with the reduction of Butrint to its smallest settlement footprint since the Bronze Age; it was also experiencing a highly restricted economy at this time. One hypothesis might be that the previous urban nucleation was succeeded in the 7th to 9th c. by small dispersed settlements in the surrounding landscape, although none were identified during field surveys.⁷⁹ A relative maximum in cultivated trees, herbs and *Pseudoschizaea* coincides with this period.

During the mid 9th c., the administrative centre of Butrint moved away from the largely deserted town, and was relocated in the Vrina Plain (fig. 1b). This new

Middle Byzantine settlement included a small residential area, workshops, a cemetery and probably a chapel, and it was characterised by a combination of rural and urban elements.⁸⁰ This new settlement might have caused some renewal of farming, after nearly three centuries of decline, however the town's impact on the environment was highly limited.

A drastic environmental change occurred in Butrint and on the Vrina Plain soon after this *ca.* 900. It appears in the record as increased water salinity and reduced run-off in the lagoon watershed, and was accompanied by a progressive decline in cultivated taxa and charcoal, suggesting a relative decrease in importance of local farming (fig. 4). There are evidences of a rising water table and the expansion of swamps along the edges of the Vrina Plain from the 11th c.⁸¹ As a result, this increasingly marshy terrain was mostly abandoned and only populated by shepherds and fishermen.⁸² In contrast, the old fortified town located on the peninsula experienced a new expansion, involving the reconstruction of wall circuits during the 11th c.⁸³ This suggests that there was a persistence of favourable socio-economic conditions, as occurred in other areas of the Byzantine empire. Thus, this relative decline in cultivars could be interpreted as a response to a local changing environment, rather than broader socio-economic changes. Alternatively, the onset of the Medieval Climate Anomaly, which led to drier conditions in most western and central Mediterranean regions, might have also contributed to the reduction of rainfall and thus, the availability of freshwater in the region, reducing farming productivity during this period.⁸⁴

Conclusions

Late Antiquity and the Early Middle Ages in Butrint were characterised by prolonged and rather stable and wet hydroclimatic conditions. These conditions lasted through the period AD 300–800, as evidenced by lower Ca and Sr values, generally high Ti/Ca ratios and a relatively high proportion of arboreal taxa. This climatically-stable situation is coherent with most central/eastern Mediterranean records (fig. 4), and might have favoured agricultural expansion in the region. The high mean annual precipitation in this region today suggests that

75 Izdebski (2016).

76 Reynolds (2010).

77 Greenslade and Hodges (2013; Hodges *et al.* (2016).

78 Mediterranean trade: Greenslade and Hodges (2013). Socio-economic crisis: Decker (2016).

79 Hodges *et al.* (2016).

80 Greenslade and Hodges (2013), (forthcoming c).

81 Bescoby *et al.* (2008); Bescoby (forthcoming).

82 Greenslade and Hodges (2013); (forthcoming c).

83 Hodges (2013).

84 Medieval Climate Anomaly: Stine (1994). Drier conditions: Moreno *et al.* (2012).

variability in rain distribution and amount was probably never a limiting factor for agriculture. The effect of changes in precipitation amount and regime mattered more in terms of erosion in the catchment and in the level of the water table, which conditioned any change from marshes into fields and vice versa.

Two main periods of maximum run-off and sediment delivery occurred at AD 400–600 and 700–900. Both were characterised by an increase in cultivated taxa at the expense of trees, and were preceded by increases in large charcoal particles, indicative of local fires and thus, forest clearances, presumably for the expansion of crops. The first stage was initiated by an expansion in cultivated herbs (AD 300–350), likely responding to local needs as well as for some exportation, and was followed by an increase in olive trees (AD 400–600). This agricultural change might have been a response to a change in economic strategies, marked by a decreasing demand for cereals in Italy and new trade opportunities associated with the foundation of Constantinople (AD 330).

After a decline in run-off and farming during the 7th c. AD, coinciding with the Eastern Roman empire's major economic and political crisis, a new expansion of cultivated taxa was recorded from 700 to 900, in this case characterised by a higher diversity and a greater relative importance of cultivated trees. This period coincides with the development of a new settlement in the Vrina Plain, and a modest revitalisation of trade with Byzantine southern Italy and the western Balkans, in the context of the reassertion of Byzantine authority in both regions. Finally, a drastic environmental change, characterised by increasing salinity and decreased run-off in the Lake Butrint catchment, occurred after *ca.* 900. This was paralleled by a progressive decline in cultivated taxa and the expansion of marshes, leading to the progressive abandonment of the Vrina Plain, in the context of more arid conditions associated with the Medieval Climate Anomaly.

The sedimentary record of Butrint documents dramatic changes in the landscape associated with climate variability and socio-economic changes. The expansion of agriculture in the region occurred in the context of generally favourable climate conditions, and each time can be associated with the consolidation of (Eastern) Roman power and its economy in the area. This study demonstrates the importance of combining archaeological research with multidisciplinary paleoenvironmental reconstructions in order to understand the changing relationship between ancient societies and their natural environment. Additionally, an adequate understanding of the interplay of climate, environment and human activities in lake catchments is needed to fully explain changes in the sedimentary record of these natural systems.

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