XLIII. International Moor Excursion

Sardinia / Italy

02.-07. September 2019

Excursion Guide

Organizers:

Giorgia Beffa, Erika Gobet, César Morales del Molino & Christoph Schwörer

Institute of Plant Sciences and Oeschger Centre for Climate Change Research, University of Bern

UNIVERSITÄT BERN

OESCHGER CENTRE
CLIMATE CHANGE RESEARCH

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Programme

Monday, 02.09.2019

Afternoon:	Individual arrival in Olbia and checking in at the Hotel Essenza
18:00	Welcome reception on the roof terrace of the Hotel Essenza in Olbia
20:00	Dinner at the Ristorante Frontemare in Olbia

Tuesday, 03.09.2019

8:00	Breakfast at Hotel Essenza, Olbia
9:00	**Departure** to Posada. Meeting in the bus parking lot close to the Hotel Essenza
10.30	**Posada:** Walk to the Castello della Fava
11:00	8000 years of coastal changes in the **Posada** plain (Matteo Vacchi)
12:30	Lunch at the beach
14:00	Departure to Stagno di Sa Curcurica
15:00	**Sa Curcurica:** Vegetation and fire history of coastal north-eastern Sardinia (Italy) under changing Holocene climates and land use (Giorgia Beffa)
17:00	Departure to Nuoro
18:30	Arrival at Hotel Sandalia, Nuoro
20:00	Dinner at Hotel Sandalia, Nuoro

Wednesday, 04.09.2019

8:00	Breakfast at Hotel Sandalia, Nuoro
9:00	**Departure** to Su Gologone
10:00	Hike through *Quercus ilex* forests to the Lanaittu valley (Salvatore Pasta)
11:00	Glacial to Holcoene vegetation at **Grotta di Corbeddu** (Pim van der Knaap)
12:00	Lunch at the natural park of Sorgente di Su Gologone
13:00	Departure to Su Nuraxi di Barumini
16:00	Visit of the UNESCO natural heritage site of **Su Nuraxi di Barumini**
17:30	Departure to Oristano
19:00	Arrival at Agriturismo il Giglio, Oristano
20:00	Dinner at Agriturismo il Giglio, Oristano

Thursday, 05.09.2019

7:30	Breakfast at Agriturismo il Giglio
8:30	**Departure** to Chia
11:00	**Stagno di Chia**: Holocene vegetation dynamics at Chia, southern Sardinia (César Morales)
12:00	Lunch at the beach at Spiaggia di Chia
13:30	Departure to Tharros
16:30	**Laguna di Mistras** Vegetation change and human impact (Erika Gobet & Christoph Schwörer)
17:30	Visit of the archaeological site of the Phoenician town of **Tharros**
18:45	Departure to Oristano
19:30	Arrival at Agriturismo il Giglio, Oristano
20:30	Dinner at Agriturismo il Giglio, Oristano

Friday, 06.09.2019

8:00	Breakfast at Agriturismo il Giglio
9:00	**Departure** to Lago di Baratz
11:30	Holocene fire, vegetation and land use dynamics at **Lago di Baratz** (Erika Gobet & Christoph Schwörer)
13:30	Lunch at Lago di Baratz
14:30	Departure to Capo Caccia
15:30	Hike through coastal maquis with *Chamerops humilis* at **Capo Caccia** (Salvatore Pasta)
17:00	Departure to Castelsardo
19:00	Arrival at Hotel Domus Beach, Castelsardo
20:00	Farewell dinner at Hotel Domus Beach, Castelsardo

Saturday, 07.09.2019

7:30	Breakfast at Hotel Domus Beach
8:30	**Departure** to Monte Limbara
10.00	Upland vegetation dynamics at **Monte Limbara** (Jacqueline van Leeuwen & Pim van der Knaap)
11.00	Departure to Olbia airport
12.30	Planned arrival at Olbia airport

Participants

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Introduction

Natural and cultural history and landscapes of Sardinia: A sketch

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Geography

Sardinia is the second largest island of the Mediterranean. The ancient Greek traders named it 'Ichnousa' (from Ichnos = foot print) and 'Sandalyon' for its shape, which is reminiscent of the form of a sandal.
Located in the middle of the West Mediterranean Sea (Fig. 1), between 38°51' and 41°15' N latitude and between 8°8' and 9°50' E longitude, its surface is approximately 24,000 km^2 with a coastline of about 1900 km and around 140 satellite islands, islets and stacks. The highest mountain is the calcareous-dolomitic Massif of Gennargentu (1834 m a.s.l.) in the central-eastern sector of the island (Fig. 2).

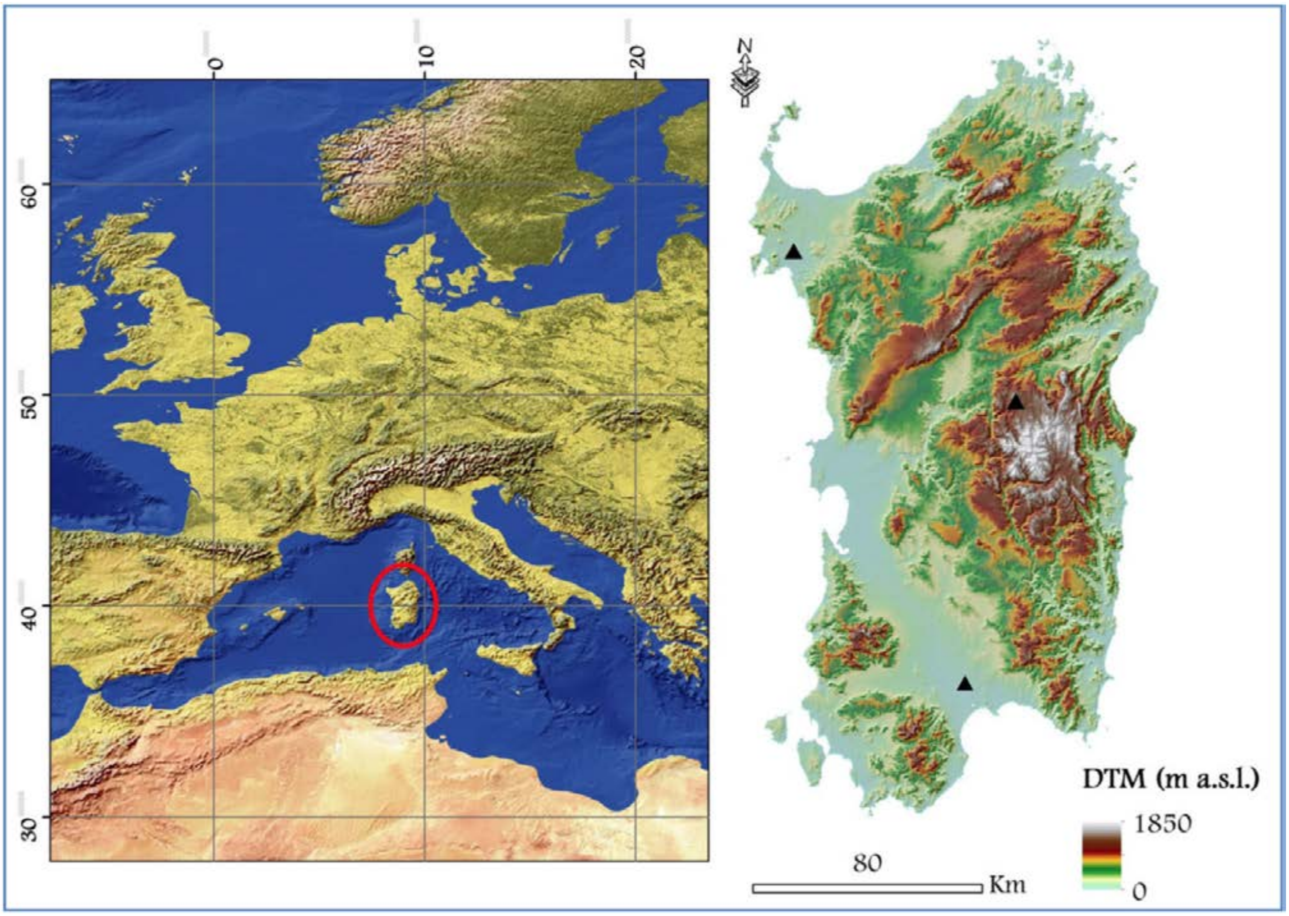


Figure 1: Location and altitudinal pattern of Sardinia (Salis et al., 2015)

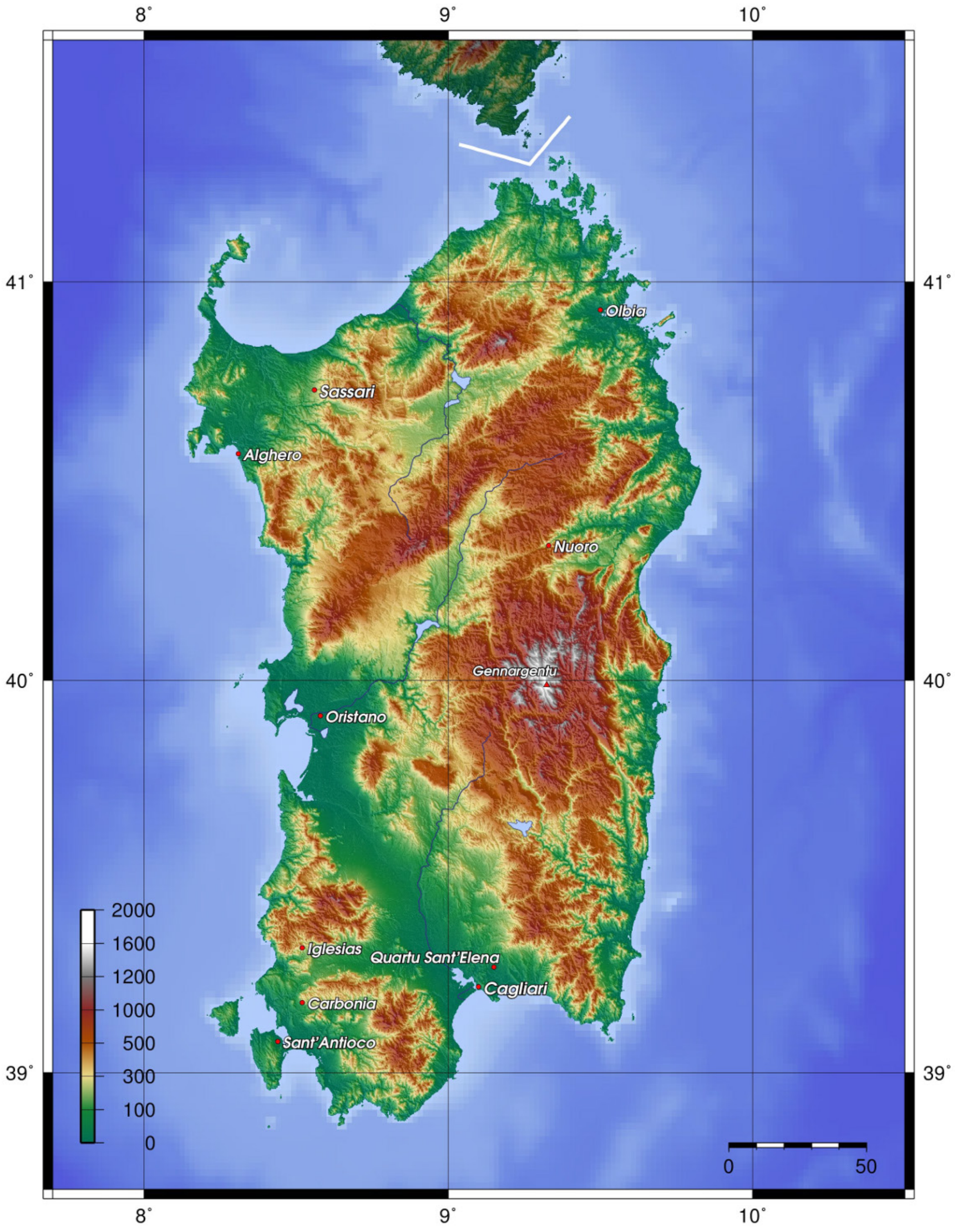


Figure 2. Physical map of Sardinia (source: https://en.wikipedia.org/wiki/Sardinia#/media/File:Sardinia_topo.png)

Five million years of solitude: paleogeography of the Corsican-Sardinian microplate and its biological consequences

The emerged part of Sardinia has a very long and complex history and hosts the oldest rock outcrops of Italy (Carmignani et al., 2016). During the last 40 years an increasing number of specimens (pollen, fossil prints and macroremains: Biondi, 1983; Filigheddu, 1985; Pittau & Del Rio, 2002; Pittau et al., 2008; Scanu et al., 2015) allowed to improve and update the information on the structure and evolution of the past Sardinian plant assemblages since the Carboniferous up to present day. According to the most recent reconstruction of the palaeogeographic evolution of the W Mediterranean area (Advokaat et al., 2014), the Corsican-Sardinian microplate was still connected with the W Alps until 120 Ma (Fig. 3a), and was still close to S France, Spain, Balearic islands and the future S Calabria and NE Sicily until 50 Ma (Fig. 3b). Around 30 Ma it started its rotation counterclockwise and hereinafter remained separated from the other land masses (Figs. 3c-d).

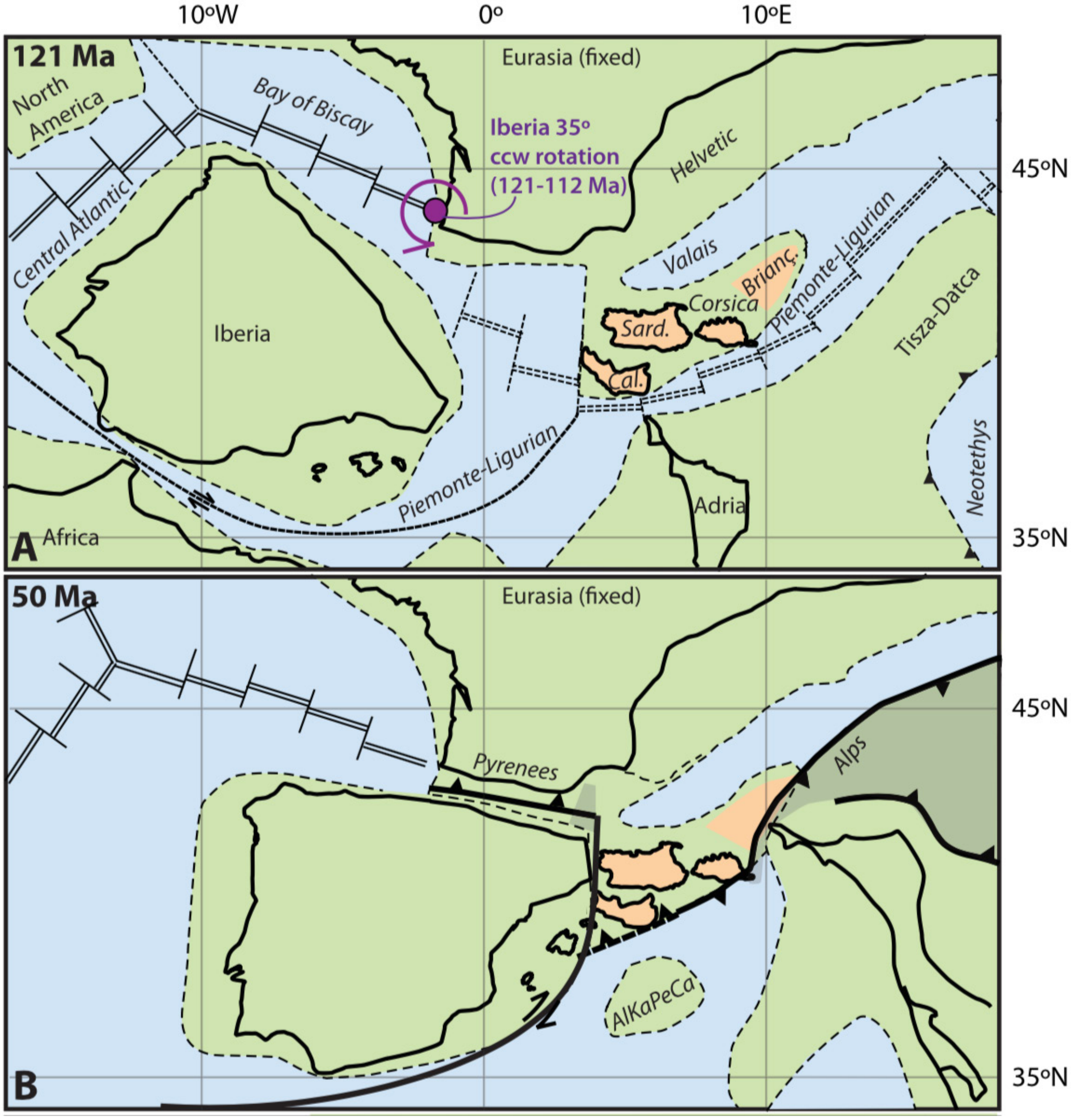


Figure 3: Palinspastic reconstruction (i.e. a 'slow motion film') showing the relative position and the relative shifts of Sardinia and its neighboring areas over last 120 million years (from Advokaat et al., 2014). **A**: 121 Ma, i.e. before the rotation of Iberia; **B**: 50 Ma (Eocene), when Corsica-Sardinia probably started to rotate counterclockwise

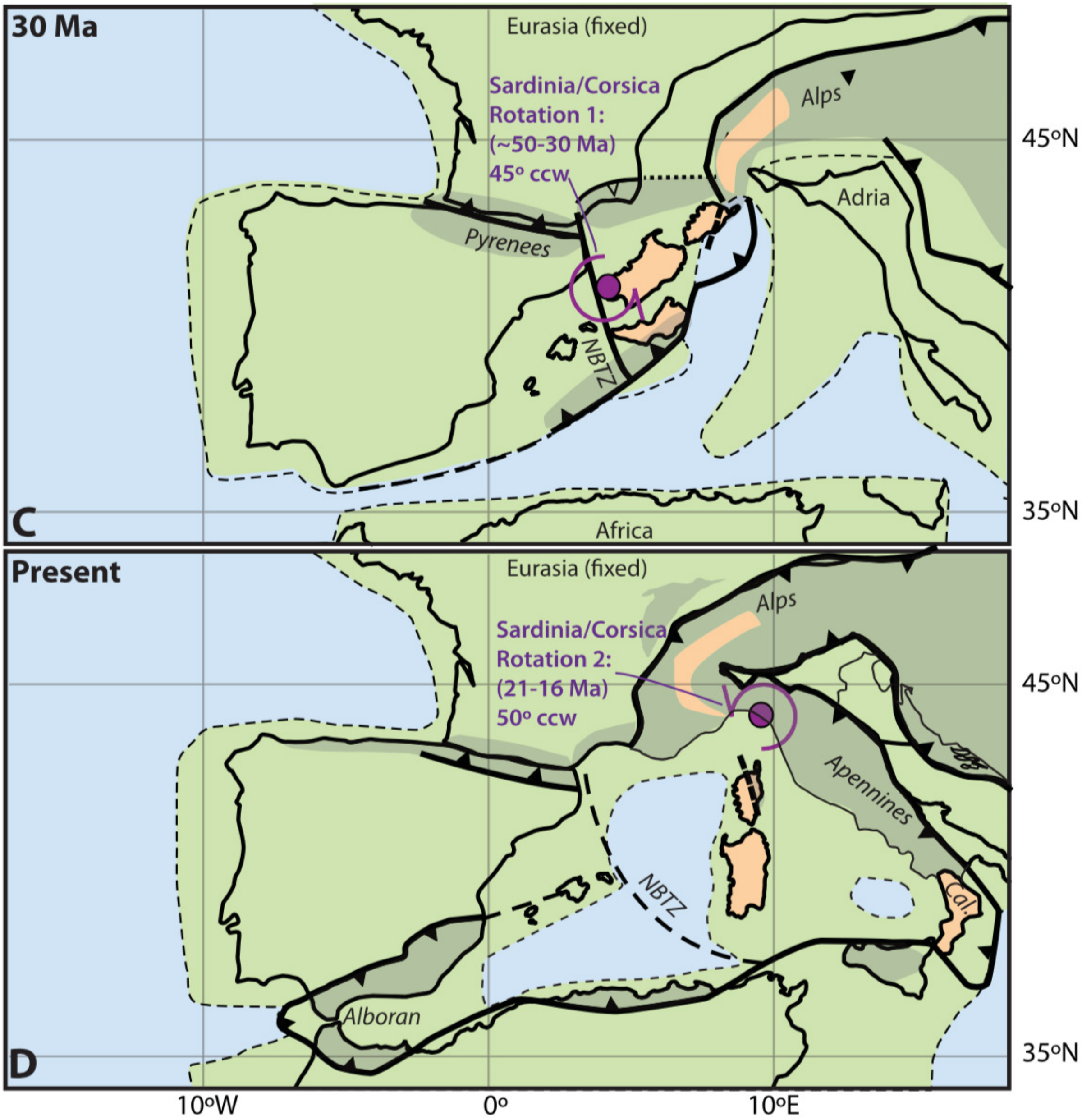


Figure 3 (continued): Palinspastic reconstruction **C**: 30 Ma: onset of opening of the Liguro-Provencal Basin; **D**: present day. **AlKaPeCa** = **Al**borán + **Ka**bylides (Algeria) + **Pe**loritani-**Ca**labrian Arc.

Considering that Sardinia was uninterruptedly emerged and separated from Europe since a long time (c. 5 million years according to Salvo et al., 2010), in agreement with the basic hypotheses of island biogeography the Corsican-Sardinian microplate should have a striking biological originality with respect to the neighboring land masses, and we should expect that the island hosted a remarkable number of endemics, even at genus level. Indeed, the two islands of Sardinia and Corsica host *Morisia monanthos* and *Nananthea perpusilla*, unique species belonging to two monotypic genera, *Morisia* (Brassicaceae) and *Nananthea* (Asteraceae), and give hospitality to many taxonomically distinct and/or phylogenetically isolated and/or relict taxa such as *Bellium crassifolium*, *Centaurea horrida*, *Helichrysum montelinasanum*, *Lamyropsis microcephala*, *Ribes sardoum*, etc. On the other hand, the percentage of species and subspecies endemic to Sardinia is lower than that of Sicily, even though Sicily is only few kilometers apart from the S Italian coast, and was connected many times with Europe during the Pleistocene. Perhaps Sardinia lost a high number of exclusive plants, plant communities and ecosystems due to the long-lasting disturbance performed by men.

From geology to landscape functional units

Sardinia has a very long and articulated geological history. The different age (Fig. 4) and geochemistry (Fig. 5) of its outcropping rocks (Carmignani et al., 2001, 2016) created a complex mosaic of soil assemblages (Madrau et al., 2008; Fig. 6).

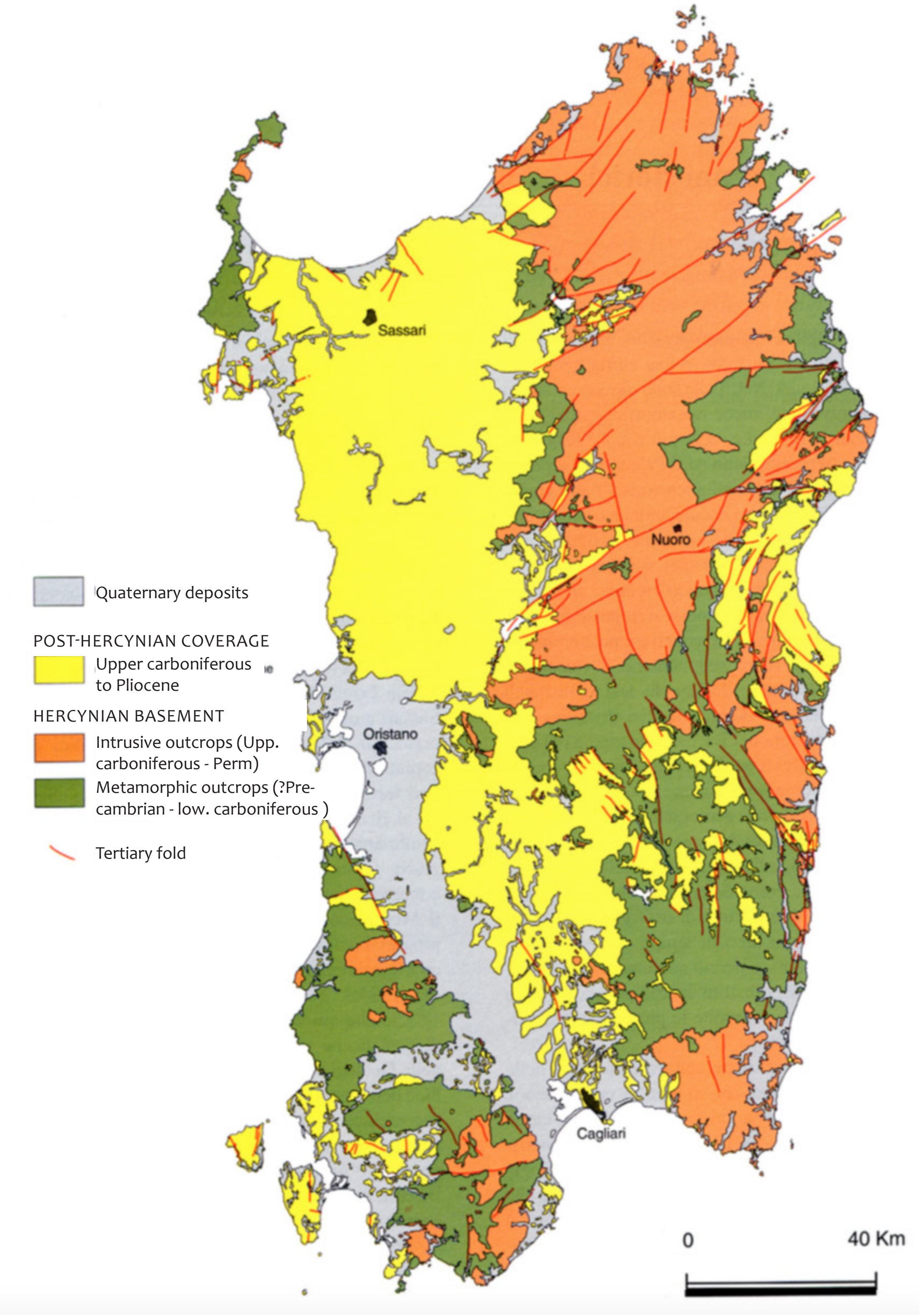


Figure 4: Geochronological sketch of Sardinia (Bacchetta et al., 2009, modified from Carmignani et al., 2001). Grey = Quaternary sediments; Yellow = rock outcrops post-Hercynian orogenesis (Upper Carboniferous to Pliocene); Orange = Permian to Upper Carboniferous; Green = Metamorphic outcrops (Precambrian? to lower Carboniferous)

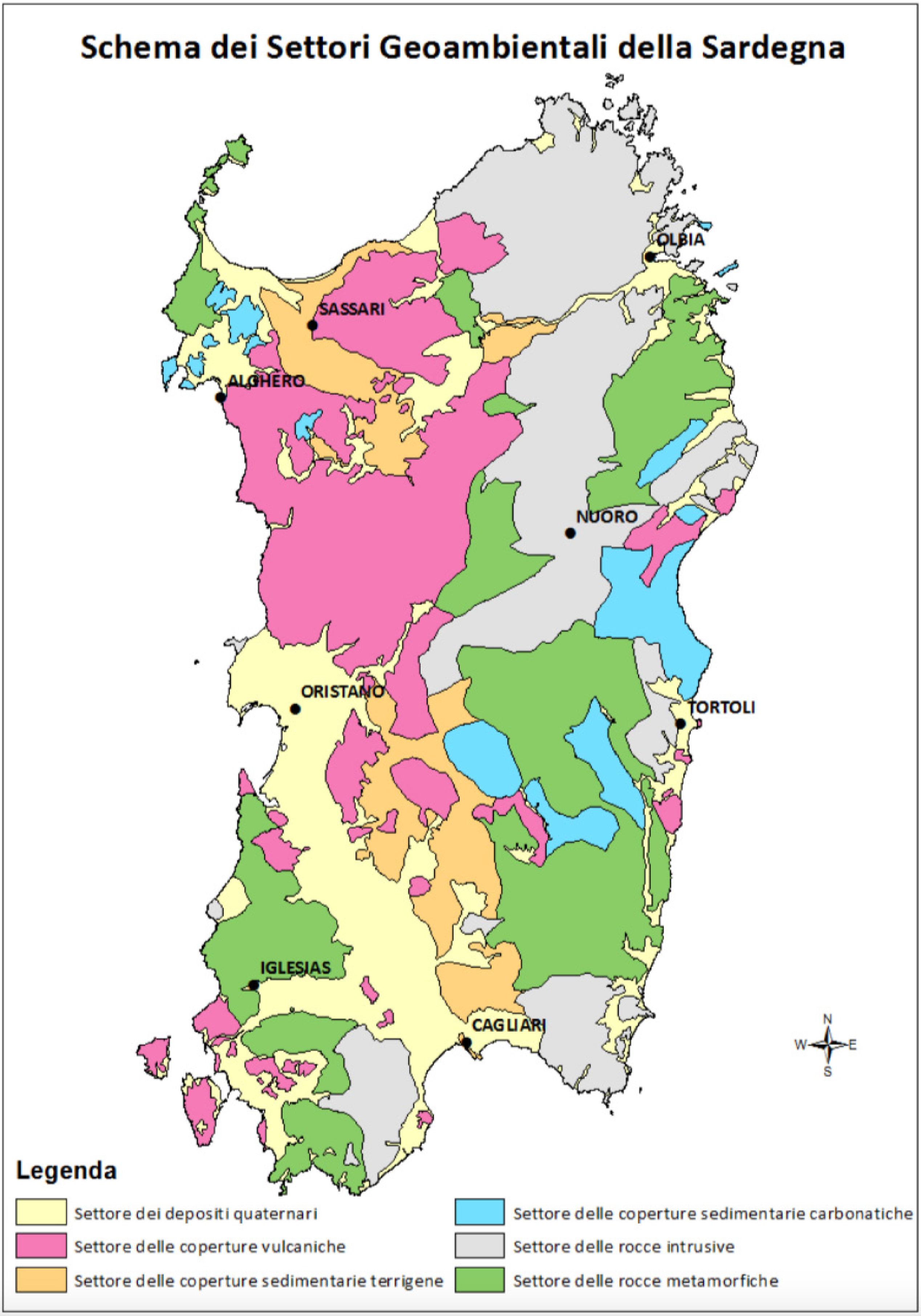


Figure 5:. Map of the geo-environmental sectors of Sardinia (Camarda et al., 2015, modified from Carmignani et al., 2001). Pale yellow: Quaternary deposits; pink: volcanic rock outcrops; pale orange: sedimentary and terrigenous rock outcrops; light blue = calcareous sedimentary rocks ; grey = intrusive/crystalline; green = metamorphic rock outcrops.

The **metamorphic** geo-environmental sector (Fig. 5, green) hosts the oldest outcrops of Sardinia and of Italy (from Precambrian to lower Carboniferous). They formed during and after the Ercynian orogenesis (i.e. between 600 and 300 Ma BP), when the sedimentary, volcanic and metamorphic rocks of Sardinia underwent different levels of metamorphism and deformation. After the orogenesis, local erosion processes gave birth to mostly gently sloping and rounded hills, steeper when harder rock types outcrop. This sector is well represented in the western (Nurra, Sulcis ed Iglesiente) and in the eastern (Baronie, Monti del Gennargentu, Ogliastra, Gerrei) part of the island. The prevalent land cover are silicicolous forests and maquis, garrigues, often of high biological value, whilst cultural landscapes are mostly made of pasturelands or area subject to extensive farming activities. Urbanisation rate is low and represented by small villages. The sector includes the mining districts of Sulcis and Iglesiente.

The **intrusive/crystalline** geo-environmental sector (Fig. 5, grey) is made of the deep magmatic Hercynian basement. It issues from the volcanic activity occurring between the Upper Carboniferous and Permian (320-250 Ma). The most frequent outcrops are granites and granodiorites, secondarily tonalites, sienites and gabbri. These rock types are scattered, being more common in N Sardinia but rather frequent also throughout the central and southern part of the island. The crystalline hills and mountains characterise most of the landscape of NE Sardinia, like the Gallura, the archipelago of La Maddalena, and southwards most of the territory of Nuoro (Goceano, Barbagia di Bitti, Barbagia di Ollolai, Baronie), the district of Sarrabus (from Mt. Sette Fratelli up to Capo Carbonara) and some localities of Sulcis on the western side of the island. The landscape of the coastal areas is among the most typical and renowned of Sardinia (e.g. Costa Smeralda), with smooth shapes and gently sloping hills and small bays shaped by wind erosion. The mountain landscape of this sector is characterised by deeply incised valleys and steep slopes. This sector includes many areas of paramount naturalistic interest. The inner parts are covered with cork- or holm oak forests, while at lower altitudes evergreen sclerophyllous maquis communities do prevail. Many endemic species occur there, especially near to the coast. Urbanisation is low with mostly small villages, except for the city of Nuoro and some important towns like Tempio Pausania and Lanusei.

The outcropping rocks of the **calcareous sedimentary** geo-environmental sector (Fig. 3, blue) are dolomites, limestones and marly limestones deposited between the Upper Trias and Upper Cretaceous (220-80 Ma) over the Hercynian basement during the Mesozoic evolution of the south European margin before the beginning of the Alpine orogenesis. The rocks of this sector occur in NW (Nurra) as well as in E Sardinia (Supramonte, Mt. Albo, Mt. Tuttavista, Gulf of Orosei, Ogliastra) and give birth to breathtaking landmarks such as the impressive cliffs of Orosei and those of Capo Caccia north of Alghero. This sector is shaped by karstic erosion and hosts a very high number of endemic plant and animal species. The landscape of the inner part of this sector is dominated by high and steep mountain ridges (Supramonte, Mt. Albo) separated by very deep canyons (locally called “codule”); elsewhere the main landmark is represented by huge horizontal calcareous banks (“tacchi” d’Ogliastra) which cover the top of the hills made of Paleozoic metamorphic rocks. Most of the sector is covered with *Quercus ilex* forests and evergreen sclerophyllous maquis assemblages. Urbanisation is almost absent.

The **sedimentary and terrigenous** geo-environmental sector (Fig. 3, pale orange) is made of marine and continental deposits issuing from marine ingression and regression events, alternated with transitional and continental phases. These phases took place between the Palaeocene and Pliocene (60-3 Ma) along with the deformation of the S European margin, the Pyrenaean collision and the opening of the Balearic Basin and the Tyrrhenian Sea. The most common outcropping rocks are quartz sandstones, marls, conglomerates, calcarenites, sands, silt, argillites, often rich in marine and terrestrial fossils. These deposits cover a wide surface of Sardinia: they crop out along the eastern margin of the Plane of Campidano from Cagliari up to the north, whilst in N Sardinia they also occur in the inner part of Logudoro near Sassari up to the coast between Castelsardo and Porto Torres. These sediments gave birth to smooth hills and to almost flat surfaces, with steeper morphologies where more compact rocks (limestones, marls, etc.) crop out. Extensive agriculture shaped the landscape of this sector until few decades ago. After recent abandonment, many areas are devoted to pastures or are covered by shrubland communities due to ongoing succession processes. Urbanisation is generally low, with the exception of the city of Sassari and its hinterland, where sparse small villages occur.

The rocks of **volcanic** geo-environmental sector (Fig. 5, pink) includes rocks with different chemistry and different genesis. Several small-sized outcrops of acid rocks (mostly riolites and riodacites) are scattered throughout the island, e.g. in the Ogliastra district (Mt. Ferru di Tertenia, Perdasdefogu, surroundings of Villagrande Strisali and Baunei), in Barbagia (Mt. Perdedu), in SW Sardinia (Punta di Cala Piombo) and N Sardinia (Mt. Littigheddu and Mt. Ruiu). They formed between the Carboniferous and Permian (320-250 Ma) as the aftermath of the post-collisional processes triggering the Hercynian orogenesis (Carmignani et al., 2001). Much more common are the volcanic rocks issuing from two different phases of rifting. The lavas and ignimbrites dating back to the Oligocene-Miocene (30-5 Ma) are mainly calc-alkaline riolites, andesites, and they crop out near the NW and SW corners of the island (i.e. Anglona, Logudoro, Planargia, Sulcis, islands of San Pietro and Sant'Antioco). The volcanic products of the Pliocenic (c. 3.5 Ma) rifting are mainly basaltic lavas whose massive flow gave birth to many vast plateaus (Campeda, Abbasanta, Marmilla, Planu Mannu, Giara di Gesturi, surroundings of Dorgali and Orosei) and to few volcanic cones (Mt. Arci e Montiferro). The landmark of this sector are these flat volcanic surfaces, often interrupted by abrupt cliffs at their borders. The whole sector is characterised by large savanna-like dehesas, yet forest and maquis cover is important. Only medium- to small-sized towns and villages occur there.

The geo-environmental sector of **Quaternary deposits** (Fig. 5, pale yellow) includes alluvial, colluvial and eolian sediments (namely gravel, sand, loam, silt, conglomerates, sandstone and tufa) dating back to the Pleistocene and Holocene, i.e. the last 1.8 Ma. This sector includes the Plain of Campidano, the valleys along the main river courses, the coastline and the neighbouring lowlands. This sector is the stage of an increasingly hard conflict between humans and nature, as it hosts not only vulnerable species and entire ecosystems of extremely high naturalistic interest (sand shores, dunes, brackish lagoons, fluvial habitats), but also represents the main source of economic income for the local population. In fact, the majority of touristic infrastructures exploit the coastal areas, the agricultural activities are concentrated in fertile plains enjoying the regular water availability for intensive agriculture (mainly orchards and irrigated crops). Additionally, this sector is the most urbanized of Sardinia: the main cities, as well as the biggest industries and harbours, are concentrated there.

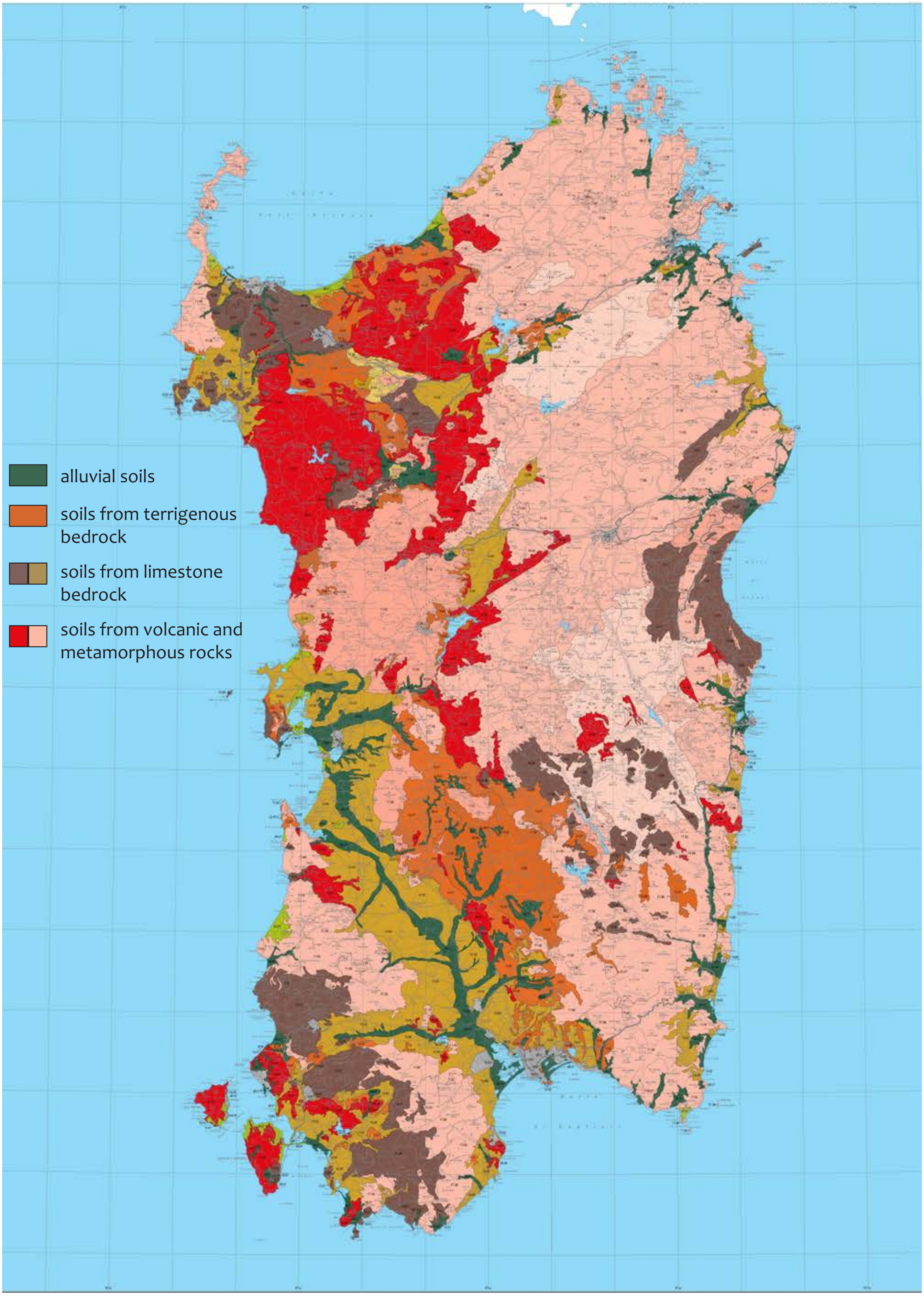


Figure 6:. Eco-pedological map of Sardinia. Dark green: soils from alluvial plains; orange: soils from terrigenous rock outcrops (mainly shales, sandstones and marls); pale to dark brown: soils from limestones; pink to red: soils from volcanic and metamorphic rocks (source: https://esdac.jrc.ec.europa.eu/Library/Data/250000/Italy/Regions/Italy_Map10.jpg)

Bioclimatic features

Sardinia is subject to a typically Mediterranean climate, with dry and hot summers and relatively rainy and mild winters. Rainfall ranges from 411 to more than 1215 mm in the inner mountainous regions. Measured mean annual temperatures range from 11.6 °C to 18.0 °C. By the means of interpolation techniques, Canu et al. (2015) recently published a bioclimatic map of Sardinia based on the data recorded by 203 rain gauges and 68 temperature stations. By adopting the bioclimatic indices proposed by Rivas-Martínez (2011), these authors identified 43 iso-bioclimatic areas (Fig. 7).

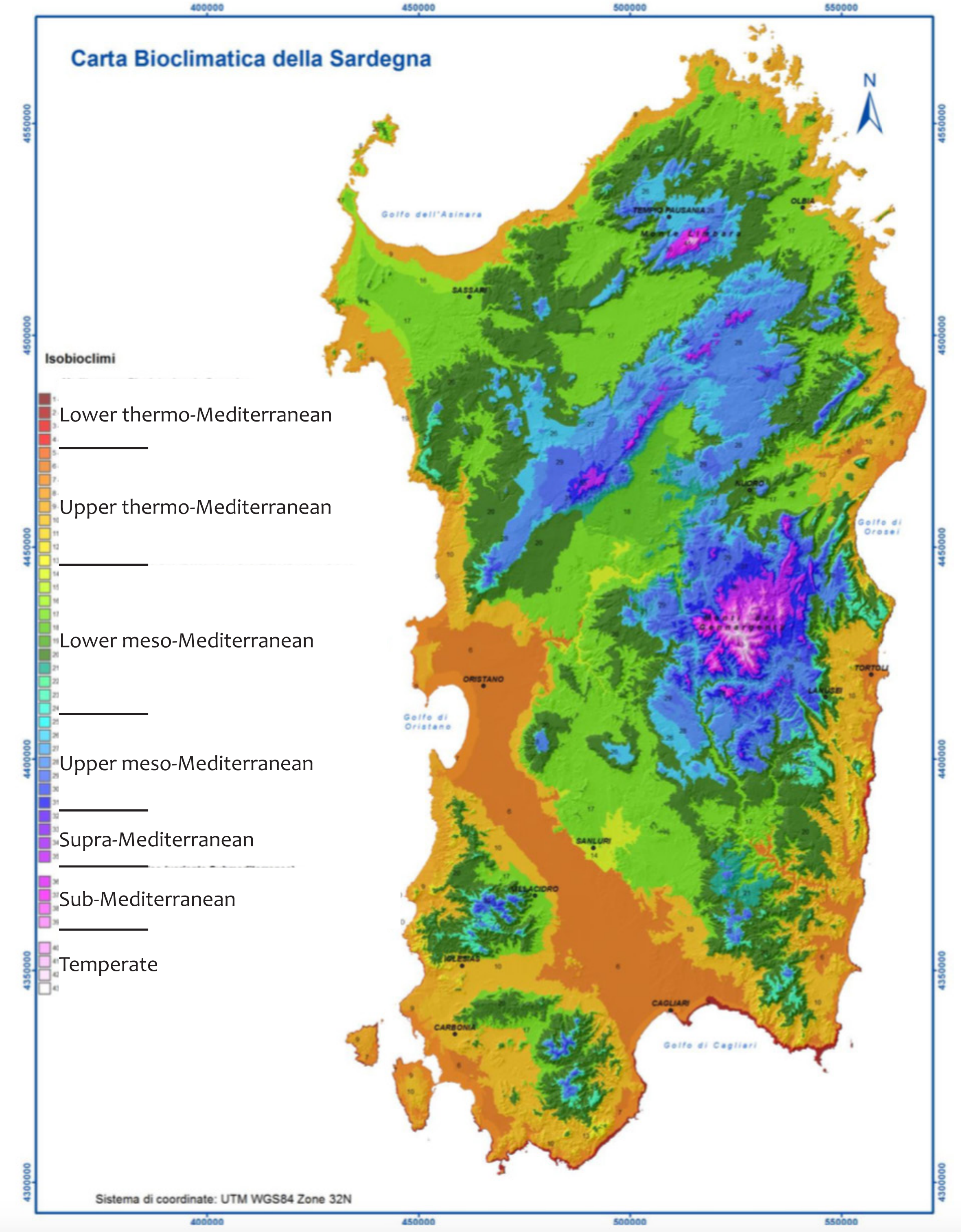


Figure 7: Bioclimatic map of Sardinia (http://www.sar.sardegna.it/pubblicazioni/miscellanea/carta_bioclimatica_sardegna.pdf; source: ARPAS, 2014); red and orange nuances: lower and upper thermo-Mediterranean; green and blue: lower + upper meso-Mediterranean; violet: supra-Mediterranean.

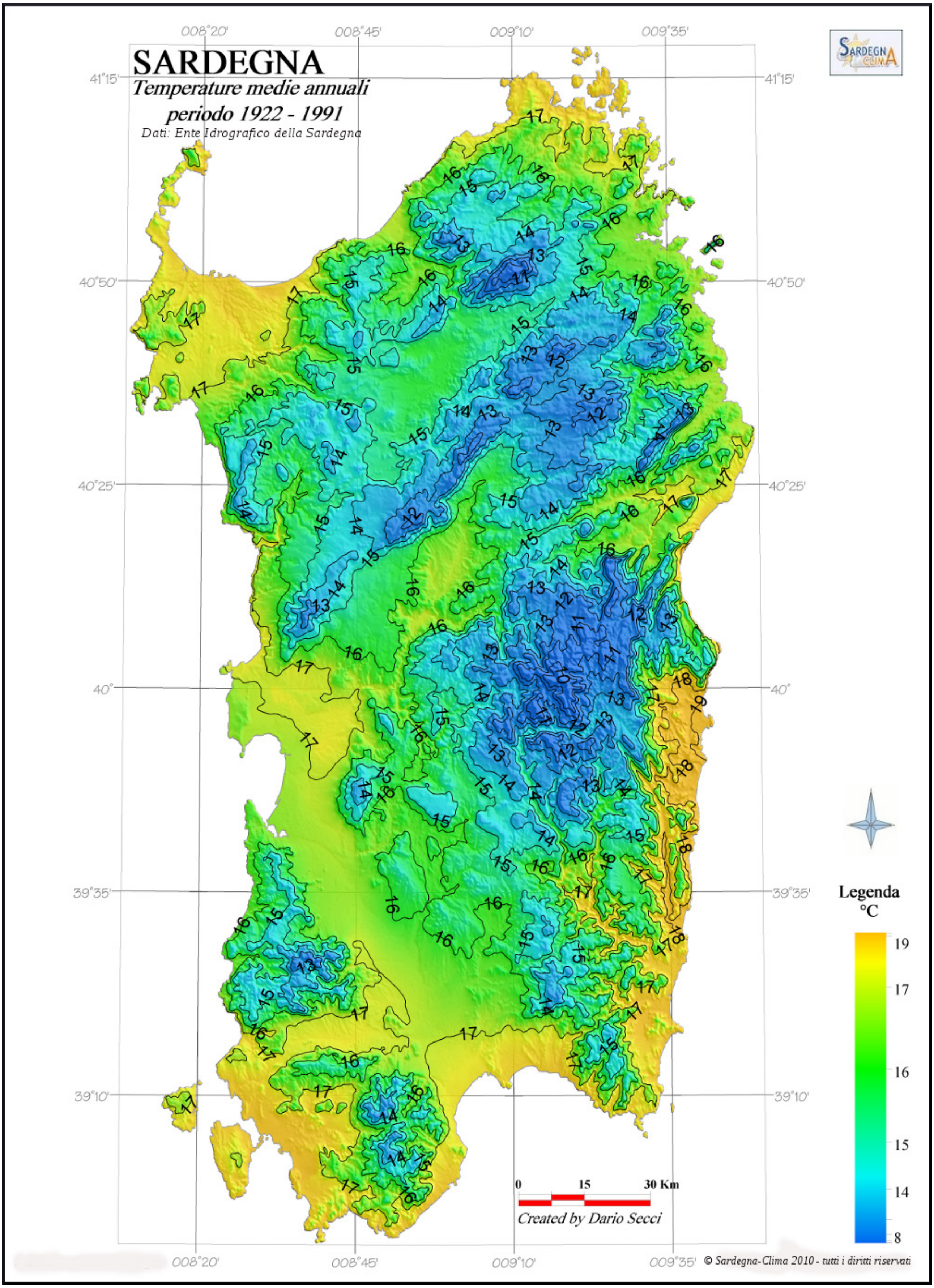


Figure 8: Mean annual temperatures for the period 1922 - 1991 (source: http://www.sardegna-clima.it/index.php/dati-climatici/469-precipitazioni-e-temperature-medie-in-sardegna-analisi-spaziale-e-modelli?showall=&start=1)

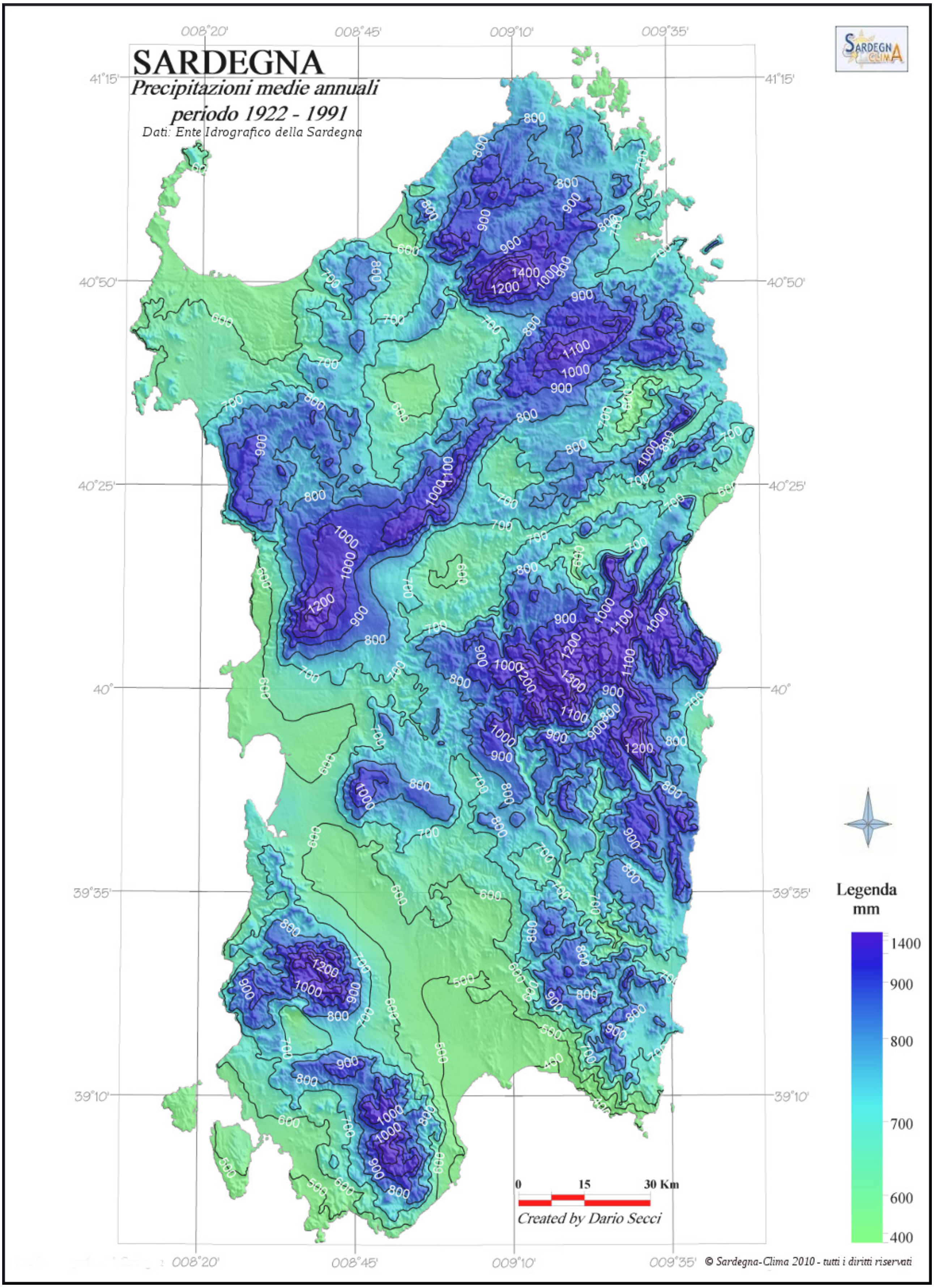
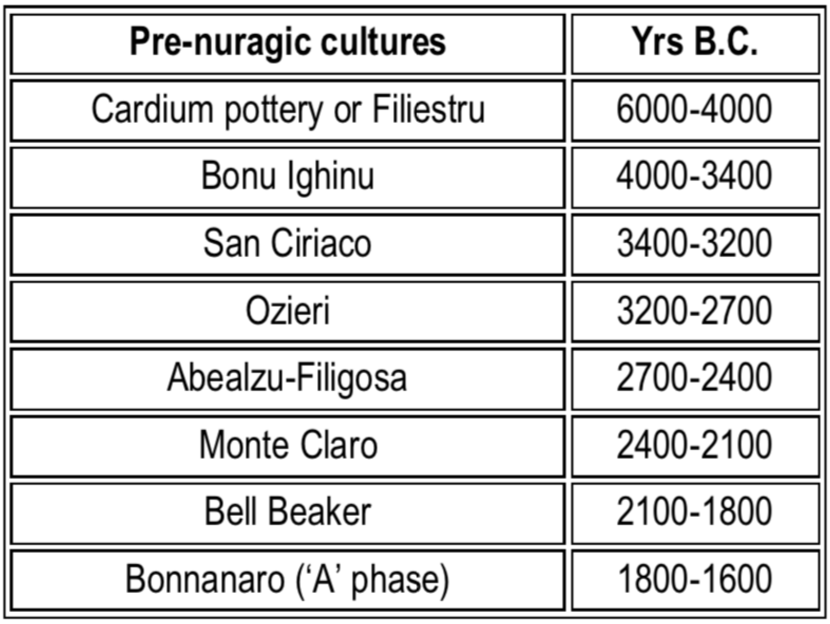


Figure 9: Mean annual precipitation sums for the period 1922 - 1991 (source: http://www.sardegna-clima.it/index.php/dati-climatici/469-precipitazioni-e-temperature-medie-in-sardegna-analisi-spaziale-e-modelli?showall=&limitstart=)

Human history

The earliest traces of anthropomorphic beings in Sardinia date back to c. 8.5 Ma and belong to a primate called *Oreopithecus bambolii*. In 1996 a hominid finger bone dating back to c. 250 Ka was found in a cave in the Logudoro region. Modern humans colonized the island during the Upper Paleolithic (e.g. Corbeddu cave, near Oliena, c. 18 Ka). Mesolithic human remains have been discovered at Su Coloru cave of Laerru but also in the south (Sirri, Arbus). It is worth to be underlined that already in the Stone Age, Monte Arci played an important role as one of the most important sources of obsidian, extracted and worked to produce cutting tools and arrowheads.
The Neolithic began in Sardinia in the 6th millennium BC with the Cardial culture (Tab. 1). Later on, important cultures like the Ozieri culture of the late Neolithic and the Abealzu-Filigosa and Monte Claro culture of the Chalcolithic period, developed in the island accompanied by megalithic manufacts. Up to now dozens of Pre-historic and Pre-nuragic monuments and constructions, called 'Domus de Janas' ('Houses of the Fairies' in Sardinian), as well as menhirs and dolmens, are interspersed in the Sardinian landscapes. By the end of the 3rd millennium BC, the megalithic civilization was substituted by people coming from Western Europe bearing the Bell Beaker culture.



Pre-nuragic cultures	Yrs B.C.
Cardium pottery or Filiestru	6000-4000
Bonu Ighinu	4000-3400
San Ciriaco	3400-3200
Ozieri	3200-2700
Abealzu-Filigosa	2700-2400
Monte Claro	2400-2100
Bell Beaker	2100-1800
Bonnanaro ('A' phase)	1800-1600

Table 1. Overview of the Sardinian pre-nuragic cultures (source: https://en.wikipedia.org/wiki/History_of_Sardinia)

The Bronze Age of Sardinia is characterized by dry stone cylindrical buildings called 'nuraghes'. More than 8,000 of them still occur on the island (Fig. 10). The most famous group of nuraghes is the complex of Barumini in Medio Campidano.

Most of the nuraghes were built between 1800 and 1200 BC. In that time, Sardinians had intense trade and cultural exchanges with many eastern Mediterranean civilizations such as Mycenaeans, Minoans and subsequently Phoenicians. These latter started to settle along the coasts of the island during the VIII century BC, founding several important colonies and strongholds on strategic points along the coasts of S and W Sardinia, mostly on peninsulas or islands near estuaries, easy to defend, such as Tharros, Bithia, Sulci, Nora and Caralis (Cagliari). The mining area of the Iglesiente was important for the metals lead and zinc. The Carthaginians took over the control of the island around 510 BC; they consolidated the previous Phoenician colonies and founded many new ones, such as Olbia, and enhanced cereal crop cultivation.

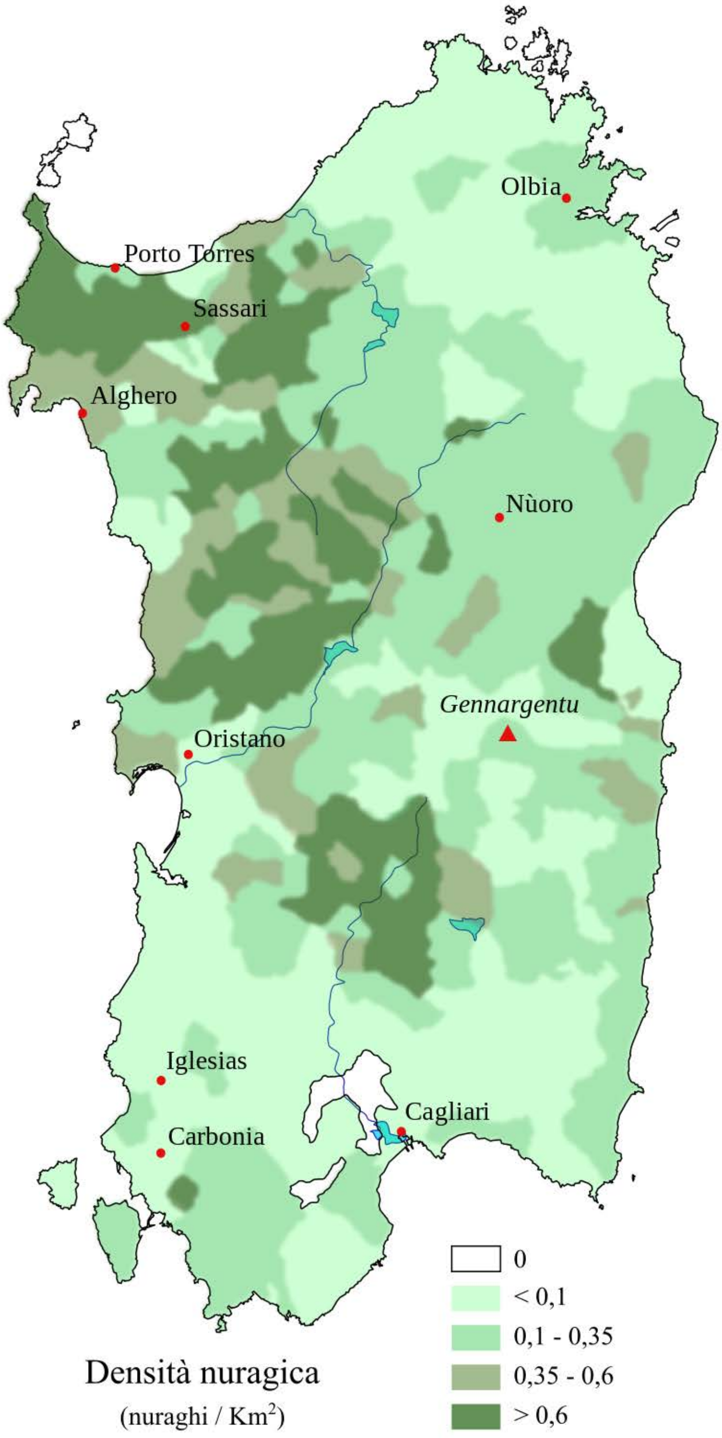


Figure 10: Map showing the distribution pattern and the density (average number / km2) of the Sardinian nuraghes (source: https://en.wikipedia.org/wiki/Nuraghe#/media/File:Sardegna_densit%C3%A0_nuragica.svg)

Conquered by Rome at the end of the First Punic War (238 BC), Sardinia shared the same administrative destiny of Corsica until the 4th century AD. In the early Middle Ages, after barbarian raids, Byzantines ruled the island for a very short time between mid 6th and the end of 7th century. After taking Sicily, Arabs tried to conquer Sardinia too, but all their repeated attempts were unsuccessful. Between the 8th and 9th century AD the regional territory was divided into four sub-regional kingdoms called Judicates (Latin: Judicati; Sardinian: Judicados). In the 11th century, Sardinia fell under papal influence and then was disputed between the two maritime republics of Genoa and Pisa, the Judicates and the Crown of Aragon, which eventually annexed the island in 1324. The Kingdom of Sardinia lasted until 1718, when it was annexed to the House of Savoy. In 1861 the island was framed into the Kingdom of Italy and since 1946 it is part of the Italian Republic.

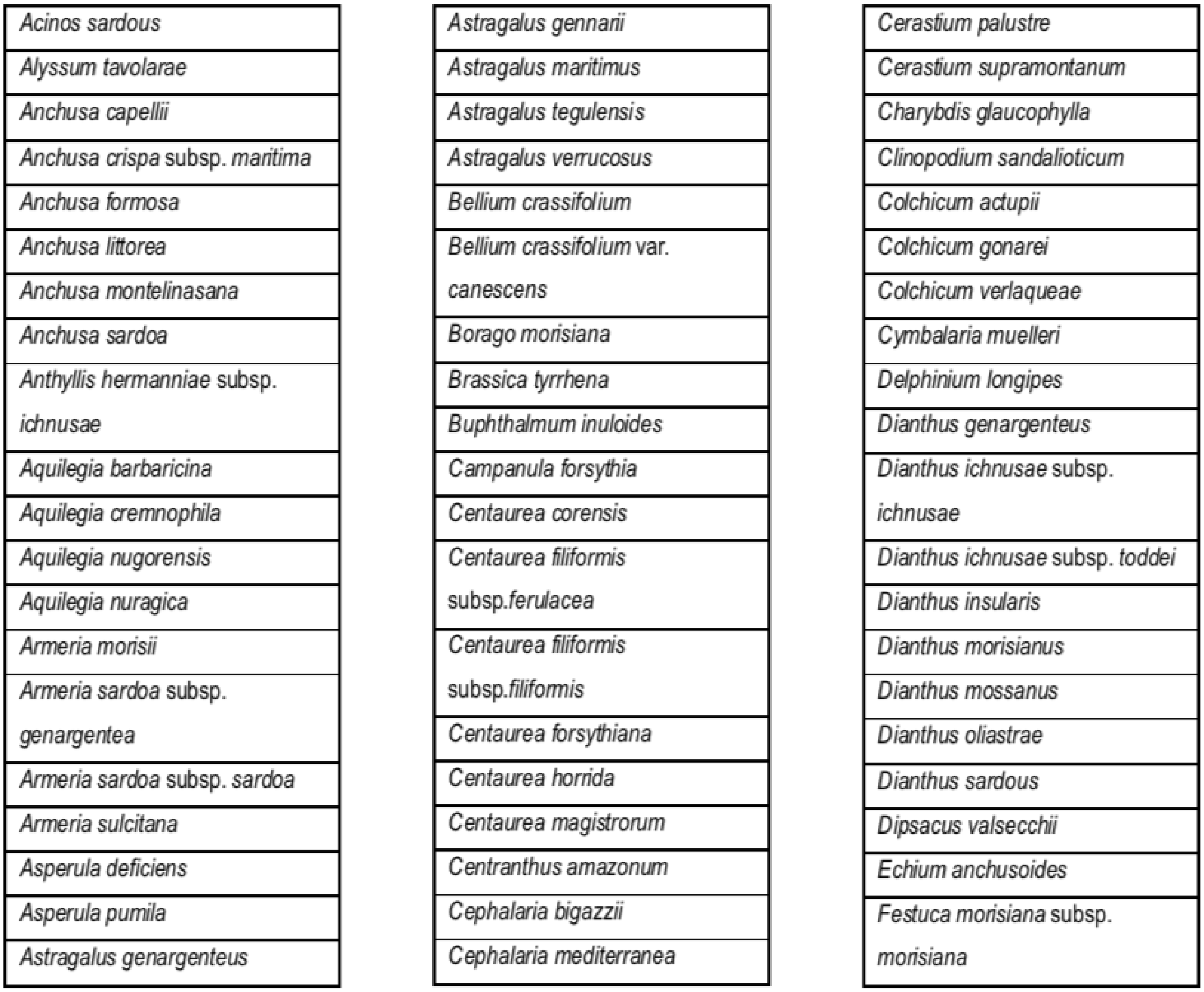
During the last 3000 years the proud Sardinians did not mingle that much with foreigners and preferred to abandon the most fertile inner or coastal plains exposed to the incursions of pirates and more demanded by conquerors. Local people settled the more inhospitable and less productive hilly and mountain areas, creating a complex network of small rural communities, whose survival depended on extensive residential farming and transhumance. This explains why - despite having more or less the same surface - Sardinia hosts less than 1/3 of the people (1.65 vs. 5.03 million) who live in Sicily. As a result of this long-lasting history of low human density and moderately low rate of cultural and genetic admixture, the Sardinian language is so strikingly distinct from Italian to deserve to be considered a language, the most 'relict' romance language of Europe (Ballester, 2011; Putzu, 2012; Fig. 11). The same feature issued from the analysis of the genetic pattern of local human population. In fact, the recent paper of Chiang et al. (2018) attests a low level of genetic admixture. More in detail, up to present day Sardinian people bear many rare traits typical to other distinct or isolated human communities issuing from the early spread of Asian Neolithic farmers.

Figure 11: Map showing the different dialects of Sardinian language (source: https://it.wikipedia.org/wiki/Lingua_sarda#/media/File:Sardinia_Language_Map.png) and the coastal sites and areas influenced by other regional or foreign dialects (Ligurian, Corsican, Catalan, Castilian)

The Sardinian vascular flora: general features, conservation value and biogeographic interest

With the only exception of a few Sardinian plants mentioned by Diodorus Siculus and Pliny the Elder (1st century AD), no botanical information on the island's flora was available until the XVI century AD, when the most skilled plant gatherers and field explorers of that time, i.e. Melchior Wieland (also called Guilandus or Guilandino) from Koenigsberg, the Italian Aloisio Squalermo (also called Anguillara), and the Flemish Joseph Goedenhuyse (also called Benincasa or Casabona) visited Sardinia on behalf of the botanical gardens of Pisa and Padua (the two oldest ones in the world!). At the same time, a first short, second-hand and partially wrong list of plant species growing in Sardinia was compiled by J.F. Fara, but remained unpublished until the beginning of XIX century (Arrigoni, 2006b). The first liable data on the vascular flora of Sardinia where collected by Michele Piazza and published by Allioni (1759), while the first comprehensive flora was published by Moris (1837-1859). Within less than 10 years, Arrigoni (2006a-2014) achieved to publish the 6 volumes of his remarkable 'Flora dell'Isola di Sardegna'. According to his work and to other recent checklists, the Sardinian vascular flora currently includes around 2,400 plant taxa. Among them, c. 350 are (invasive, naturalized or casual) aliens (Podda et al., 2011, 2012; Puddu et al., 2016; Camarda et al. 2016) and more or less the same number (349) are endemics. Nearly half of these latter also occur in Corsica and/or the Balearic Islands, while 170 thrive exclusively in Sardinia (Tab. 2).

Table 2: List of the Sardinian narrow endemics (in alphabetical order, after Bacchetta et al., 2012, updated)



Acinos sardous
Alyssum tavolarae
Anchusa capellii
Anchusa crispa subsp. *maritima*
Anchusa formosa
Anchusa littorea
Anchusa montelinasana
Anchusa sardoa
Anthyllis hermanniae subsp. *ichnusae*
Aquilegia barbaricina
Aquilegia cremnophila
Aquilegia nugorensis
Aquilegia nuragica
Armeria morisii
Armeria sardoa subsp. *genargentea*
Armeria sardoa subsp. *sardoa*
Armeria sulcitana
Asperula deficiens
Asperula pumila
Astragalus genargenteus
Astragalus gennarii
Astragalus maritimus
Astragalus tegulensis
Astragalus verrucosus
Bellium crassifolium
Bellium crassifolium var. *canescens*
Borago morisiana
Brassica tyrrhena
Buphthalmum inuloides
Campanula forsythia
Centaurea corensis
Centaurea filiformis subsp.*ferulacea*
Centaurea filiformis subsp.*filiformis*
Centaurea forsythiana
Centaurea horrida
Centaurea magistrorum
Centranthus amazonum
Cephalaria bigazzii
Cephalaria mediterranea
Cerastium palustre
Cerastium supramontanum
Charybdis glaucophylla
Clinopodium sandalioticum
Colchicum actupii
Colchicum gonarei
Colchicum verlaqueae
Cymbalaria muelleri
Delphinium longipes
Dianthus genargenteus
Dianthus ichnusae subsp. *ichnusae*
Dianthus ichnusae subsp. *toddei*
Dianthus insularis
Dianthus morisianus
Dianthus mossanus
Dianthus oliastrae
Dianthus sardous
Dipsacus valsecchii
Echium anchusoides
Festuca morisiana subsp. *morisiana*

Galium glaucophyllum
Galium schmidii
Genista arbusensis
Genista bocchierii
Genista cadasonensis
Genista insularis subsp. *fodinae*
Genista insularis subsp. *insularis*
Genista morisii
Genista ovata
Genista pichi-sermolliana
Genista sardoa
Genista sulcitana
Genista toluensis
Genista valsecchiae
Helianthemum morisianum
Helichrysum montelinasanum
Helichrysum saxatile subsp. *morisianum*
Helichrysum saxatile subsp. *saxatile*
Hieracium iolai
Hypericum annulatum
Hypericum scruglii
Hypochaeris sardoa
Iberis integerrima
Juncus gussonei
Lactuca longidentata
Lamyropsis microcephala
Lavatera triloba subsp. *pallescens*
Limonium ampuriense
Limonium bosanum
Limonium capitis-eliae
Limonium capitis-marci
Limonium caralitanum
Limonium carisae
Limonium coralliforme
Limonium cornusianum
Limonium cunicularium
Limonium gallurense
Limonium hermaeum
Limonium insulare
Limonium laetum
Limonium lausianum
Limonium malfatanicum
Limonium merxmuelleri
Limonium morisianum
Limonium multifurcatum
Limonium nymphaeum
Limonium oristanum
Limonium protohermaeum
Limonium pseudolaetum
Limonium pulviniforme
Limonium racemosum
Limonium retirameum
Limonium sulcitanum
Limonium tenuifolium
Limonium tharrosianum
Limonium tibulatium
Limonium tigulianum
Limonium tyrrhenicum
Limonium ursanum
Limonium viniolae
Linaria arcusangeli
Linum muelleri
Malva plazzae
Medicago intertexta var. *tuberculata*
Micromeria cordata
Narcissus supramontanus subsp. *cunicularium*
Narcissus supramontanus subsp. *supramontanus*
Nepeta foliosa
Oenanthe lisae
Ophrys chestermanii
Ophrys normanii
Ophrys ortuabis
Ophrys panattensis
Ophrys scolopax subsp. *sardoa*
Ophrys subfusca subsp. *liveranii*
Orobanche australis
Orobanche denudate
Phleum sardoum
Polygala sardoa
Polygala sinisica
Pulicaria vulgaris var. *sardoa*
Quercus ichnusae
Ranunculus cymbalariifolius
Rhamnus persicifolia
Ribes multiflorum subsp. *sandalioticum*
Ribes sardoum
Romulea bocchierii
Rubus arrigonii
Rubus limbarae
Rumex suffocatus
Ruta lamarmorae
Salix arrigonii
Salvia desoleana
Santolina insularis
Scorzonera callosa
Scrophularia morisii
Sedum villosum subsp. *glandulosum*
Senecio sardous
Senecio vulgaris var. *tyrrhenus*
Sesleria insularis subsp.*barbaricina*
Sesleria insularis subsp.*morisiana*
Silene beguinotii
Silene ichnusae
Silene martinolii
Silene mociniana
Silene rosulata subsp. *sanctae-therasiae*
Silene valsecchiae
Thesium italicum
Verbascum plantagineum
Vinca sardoa
Viola corsica subsp. *limbarae*

Many monographs focused on the floristic and phytogeographic features of Sardinian sub-regional territories, such as Iglesiente (Bacchetta & Pontecorvo, 2005), Sulcis (Bacchetta, 2006), Sinis (Fenu & Bacchetta, 2008), Supramontes (Fenu et al., 2010) and Gennargentu (Bacchetta et al., 2013), have been published during last decade. Based on the available data, some recent overviews allowed to identify the driving factors and the distribution patterns of local endemics (Fenu et al., 2014; Cañadas et al., 2014; Fois et al., 2017) and to better address conservation priorities (Bacchetta et al., 2012a-b; Fois et al., 2014).

From the biogeographic point of view, many questions concerning the Sardinian plant assemblages are still unanswered. For example, the ratio 'number of native species / area', one of the most important parameters in insular biogeography, is strikingly lower than the value recorded on the other major Mediterranean islands (e.g. Sicily or Crete). This pattern could depend on the long-lasting geographic isolation: in fact, local plant assemblages had plenty of time to find new equilibria. Another good reason for the realtively low number of species is the absolute predominance of base-poor, acid substrata (Figs. 5-6), a trait that hampers plant species-richness worldwide. According to the basic assumption of insular biogeography, dynamic and steady communities often show lower species-richness values. Another reason for this pattern could be the large average size of the patches of the island that share the same geopedological substrate (Figs. 5-6). An alternative (or complementary) explanation is that wide areas of Sardinia experienced a rather low human impact during historical times. The more homogeneous in time (disturbance regime) and space (stress factors) the ecosystems, the lower is their species-richness. The early isolation of Sardinia has strongly influenced the present composition of its woodlands. For example, as many important habitat-shaping European or Eurasian temperate trees (e.g. *Abies alba, Acer pseudoplatanus, Carpinus betulus, Fagus sylvatica, Pinus laricio, Platanus orientalis, Quercus cerris, Quercus petraea*, etc.) did not reach the island during Quaternary glacial events, local forest assemblages did not experience the intense 'species reset' which probably affected the supra-Mediterranean vegetation belt in Sicily.

Interestingly, the fact that Sardinia shares many endemic plants with Sicily and/or NW Africa (Camarda, 1992; Troia et al., 2012; Pasta, unpubl.), revives some old hypotheses on the past occurrence of a complex network of stepping stones once connecting the Tyrrhenian territories (Guarino & Pasta, 2018).

Potential vegetation and past land use

The knowledge on the vegetation of Sardinia is very good (especially coastal areas, satellite islands and islets, the Massif of Gennargentu, the calcareous massifs of the central-eastern sector of the island, Sulcis and the surroundings Sassari). Bacchetta et al. (2009) provide a comprehensive overview of the Sardinian vegetation units and series, as well as a rich reference list of the most important regional papers on this topic.
Simplifying the scheme proposed by Arrigoni (2006a) and based on the information reported by Bacchetta et al. (2009), we may recognize four 'potential vegetation belts' or 'phytoclimatic areas' which characterize the natural landscape of Sardinia from sea level to the top of the main massifs of the island. These belts are:

1) A **Basal Belt**, typical to the coastal areas and plains subject to thermo-mediterranean climate, characterized by woodland and maquis communities dominated by thermophilous, evergreen shrubs and small trees (e.g. *Chamaerops humilis*, *Juniperus turbinata*, *Olea europaea* var. *sylvestris*, *Quercus coccifera*, *Erica arborea*, *Pistacia lentiscus*, *Phillyrea angustifolia*, etc.) and summer-deciduous and winter-green shrubs like *Anagyris foetida* and *Euphorbia dendroides*. During our field trip we will observe some well-preserved examples of such sclerophyllous vegetation during our excursion at **Capo Caccia**, characterized by thermo-mediterranean scrub (*Chamaeropo humilis-Juniperteum turbinatae*) and maquis (*Prasio majoris-Quercetum ilicis chamaeropetosum humilis*) on base-rich lithosoils, and *Pyro spinosae-Quercetum ilicis* on the siliceous, base-poor soils of **Posada**.
2) A **Hill and Foothill Belt**, almost continuous, with a wide altitudinal range, subject to milder Mediterranean climate and characterized by holm oak (*Quercus ilex*) and downy oak (*Quercus ichnusae*) forests where the above-mentioned thermophilous species still play an important role (e.g. *Viburno tini-Quercetum ilicis*).
3) A **Mountain Belt**, scattered and uneven under sub-mediterranean climate conditions, with an increasing frequency of summer-green deciduous broadleaved trees (e.g. *Fraxinus ornus, Acer* spp.) - sometimes forming almost pure stands (*Quercus congesta* and *Ostrya carpinifolia*), and the occurrence of some evergreen species (i.e. *Taxus baccata , Laurus nobilis, Ilex aquifolium* and *Daphne laureola*) under extremely cool and humid microclimatic conditions. On base-poor siliceous soils these assemblages are well represented by *Asplenio onopteris-Quercetum ilicis*, localized in central-northern Sardinia, or *Galio scabri-Quercetum ilicis* and *Saniculo europaeae-Quercetum ilicis* on **Mt. Limbara**, while on the limestones of the central plateau of Supramonte we mainly observe *Aceri monspessulani-Quercetum ilicis*, rich in calcicolous endemic plants.
4) A **Supra-Mediterranean Belt**, characterized by low-growing subshrubs which form a discontinuous plant cover of thorny cushions on the top of Gennargentu and sporadically occurs elsewhere above 1300-1400 m a.s.l., dominated by *Juniperus communis* subsp. *hemisphaerica, Astragalus genargenteus, Berberis aetnensis, Thymus catharinae, Daphne oleoides*, particularly rich in hemicryptophytes of high biogeographic interest. On **Mt. Limbara** we will admire a typical example of orophilous supramediterranean gorse vegetation referred to *Violo limbarae-Genistetum salzmannii* (Valsecchi, 1994).

The scheme shown above only focuses on potential vegetation. In fact, it emphasizes the role of average annual temperature, decreasing from sea level up to the top of the mountains, but does not take into account neither the main stress factors, such as slope, soil pH and water availability, nor the most important disturbance factors, i.e. the intensity and frequency of farming and breeding activities and man-set fires (Farris et al., 2013). On this purpose, we should never forget that in Sardinia, as well as everywhere in the Mediterranean Basin, the size, the functioning and the species assemblage of many forests has been shaped after centuries of intense exploitation (mostly coppicing) for many purposes (fodder for pigs, wood, charcoal, etc.). Hence, many apparently 'natural' forest types actually are a byproduct of human choices and activities. For example, transhumance and cork exploitation has favored *Quercus suber* on the detriment of other oak species. Similarly, the downy oaks (*Quercus pubescens* s.l.), unable to re-sprout after fires and overbrowsing like most of the evergreen sclerophyllous trees and after coppicing like *Q. ilex*, is now recovering after centuries of destruction as a result of the succession processes following the abandonment of traditional land use practices in inner mountain areas. For the same reason, abandoned chestnut (*Castanea sativa*) and hazelnut (*Corylus avellana*) groves are now evolving towards mixed woods with a rather high degree of naturalness.

Since 3,000 BP Sardinia has played a very important role for mining several precious ores, especially silver, lead and copper, locally and for brief time also iron, zinc and gold (Cauli, 1996). With no doubt this long-lasting industrial activity, together with farming and pastoral activities (Acquaro et al., 2001; Bakels, 2002; Celant, 2010; Depalmas & Melis, 2011; Di Rita & Melis, 2011; Pittau et al., 2012; Beffa et al., 2015; Ucchesu et al., 2015; Melis et al., 2017), played a major role in shaping the regional natural landscape through millennia. Nowadays the Sardinian forest cover appears very discontinuous, with rather small patches interspersed within a matrix of non-forest woody communities. Mantle communities, mostly dominated by thorny Rosaceae and Leguminosae may be framed into the phytosociological class *Rhamno-Prunetea* and the alliance *Pruno-Rubion ulmifolii*, and often result from overbrowsing and frequent burning of wood communities in the hill-foothill and mountain belts. At lower altitudes, the combination of disturbance and seasonal drought stress favor the prevalence of garrigues communities dominated by shrubs and subshrubs, mostly stress and fire-adapted and good re-sprouters (Lamiaceae, Cistaceae, *Erica* spp., etc.). On base-poor soils, we can observe communities referred to the phytosociological class *Cisto-Lavanduletea* and to the alliances *Teucrion mari* and Anthyllidion hermanniae, whilst on base-rich and thin soils plant communities belonging to the class *Rosmarinetea officinalis* and the alliance *Cisto eriocephali-Ericion multiflorae* do prevail.

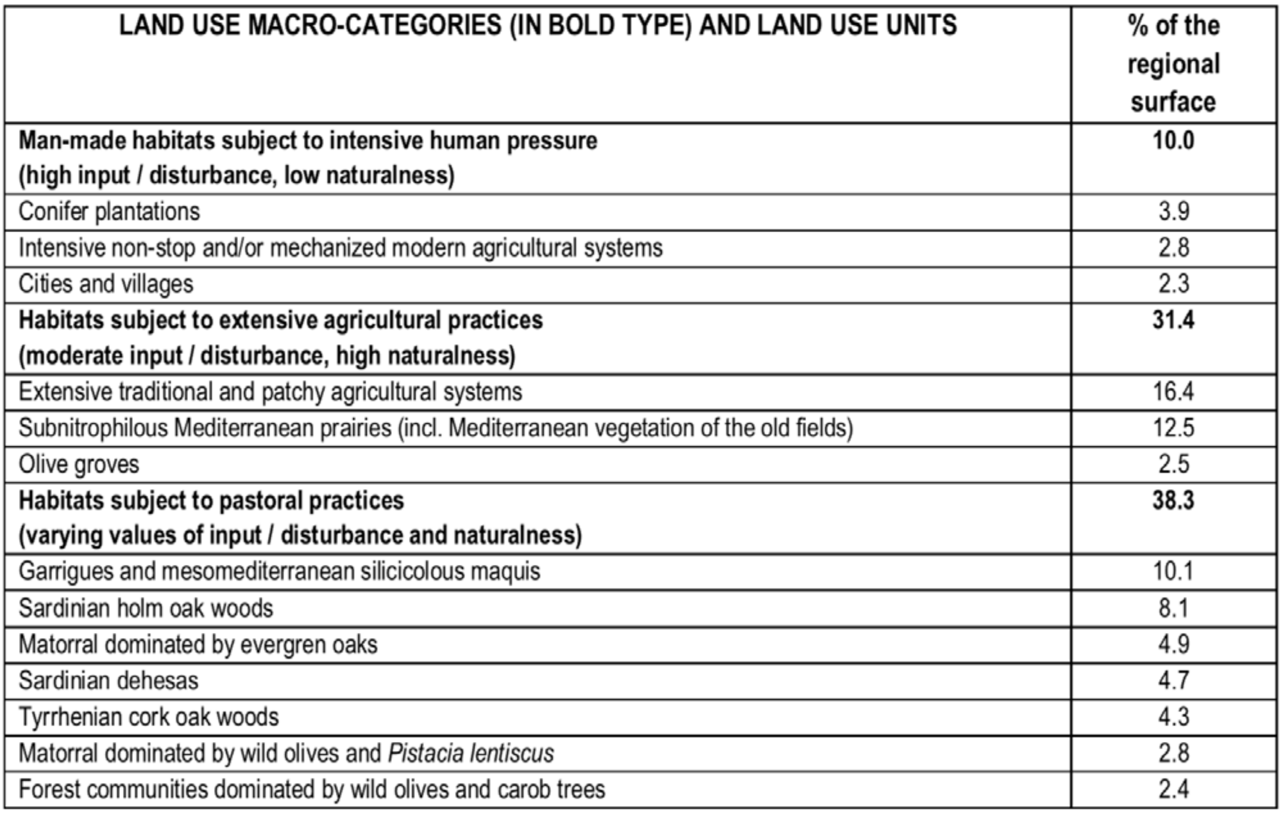
Along watercourses, below 400-500 m a.s.l., the hygrophilous forest vegetation of the riverbeds is characterized by pure or mixed stands of black alders (*Alnus glutinosa*), narrow-leaved ashes (*Fraxinus angustifolia* subsp. *oxycarpa*), willows (*Salix* spp.) and poplars (*Populus* spp.). Along braided streams subject to warmer climate and more intense stress and natural disturbance, forests are substituted by more or less dense hygrophilous thickets dominated by tamarisks (*Tamarix* spp.), oleanders (*Nerium oleander*) and chaste trees (*Vitex agnus-castus*).

After the Second World War up to present day private individuals, municipalities and the regional forest agency often planted fast-growing non-native conifers (*Pinus halepensis, Pinus pinea*, but also *Pinus nigra*, *Cedrus atlantica*) and less frequently other exotic tree species such as *Eucalyptus* spp. and *Acacia saligna*.

Some statistical data on the current patterns of land use in Sardinia

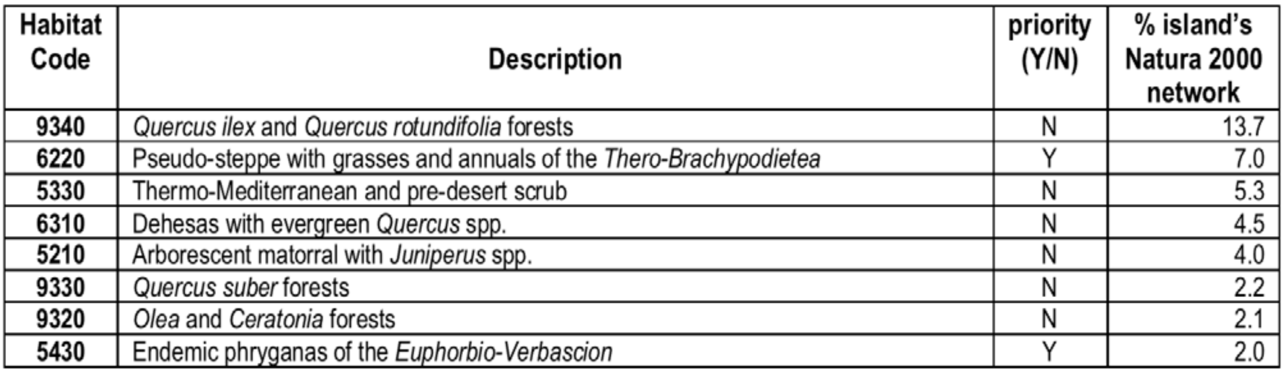
The landscape of Sardinia appears like a mosaic of intensive (mostly near the coasts and the main cities) and extensive (inner part of the island) land use patches (Fig. 12). As much as 93 land use categories (see Tab. 3 for the most common ones) can be recognized and mapped according to Corine Biotopes Classification (Camarda et al., 2015).
Moreover, the island hosts 63 habitats (see Tab. 4 for the most represented ones) as defined by 92/43 EU 'Habitats' Directive which fall within the Sites of Community Interest belonging to the regional network of Natura 2000.

Table 3: The most common land use units of Sardinia (Camarda et al., 2015; source: https://www.sardegnaprogrammazione.it/documenti/35_84_20150917105216.pdf).



LAND USE MACRO-CATEGORIES (IN BOLD TYPE) AND LAND USE UNITS	% of the regional surface
Man-made habitats subject to intensive human pressure (high input / disturbance, low naturalness)	**10.0**
Conifer plantations	3.9
Intensive non-stop and/or mechanized modern agricultural systems	2.8
Cities and villages	2.3
Habitats subject to extensive agricultural practices (moderate input / disturbance, high naturalness)	**31.4**
Extensive traditional and patchy agricultural systems	16.4
Subnitrophilous Mediterranean prairies (incl. Mediterranean vegetation of the old fields)	12.5
Olive groves	2.5
Habitats subject to pastoral practices (varying values of input / disturbance and naturalness)	**38.3**
Garrigues and mesomediterranean silicicolous maquis	10.1
Sardinian holm oak woods	8.1
Matorral dominated by evergren oaks	4.9
Sardinian dehesas	4.7
Tyrrhenian cork oak woods	4.3
Matorral dominated by wild olives and *Pistacia lentiscus*	2.8
Forest communities dominated by wild olives and carob trees	2.4

Table 4. Together with grasslands, the most common forest and pre-forest terrestrial habitats included in the 92/43 EU 'Habitats' Directive account for nearly half of the whole the Sardinian surfaces belonging to the Natura 2000 Network (Camarda et al., 2015; https://www.sardegnaprogrammazione.it/documenti/35_84_20150917105216.pdf).



Habitat Code	Description	priority (Y/N)	% island's Natura 2000 network
9340	*Quercus ilex* and *Quercus rotundifolia* forests	N	13.7
6220	Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	Y	7.0
5330	Thermo-Mediterranean and pre-desert scrub	N	5.3
6310	Dehesas with evergreen *Quercus* spp.	N	4.5
5210	Arborescent matorral with *Juniperus* spp.	N	4.0
9330	*Quercus suber* forests	N	2.2
9320	*Olea* and *Ceratonia* forests	N	2.1
5430	Endemic phryganas of the *Euphorbio-Verbascion*	Y	2.0

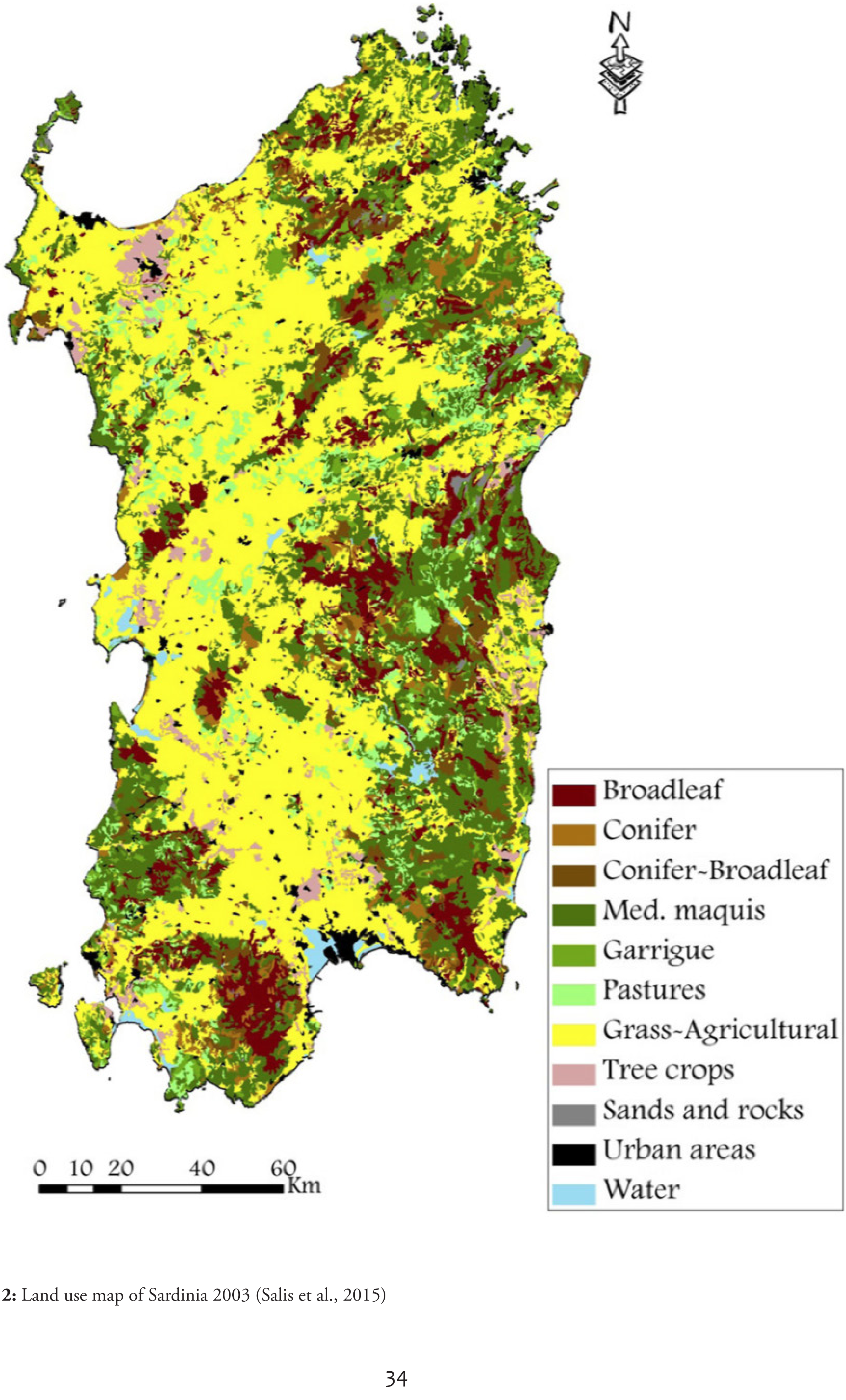


Figure 12: Land use map of Sardinia 2003 (Salis et al., 2015)

A sketch on the main vegetation features that we will observe during the field trips

03.09.2019

Posada Plain - The muddy streamsides of Rio Posada are characterized by pioneer nitro-hygrophilous grass-dominated communities referred to Paspalo-Agrostidion.

Sa Curcurica - The landscape around the pond is shaped by the past and current human activities, as testified by the frequency of cactus pears - *Opuntia ficus-indica* (wild and cultivated). During last decades alien tree species such as *Acacia saligna* and *Eucalyptus camaldulensis* have been used for afforestation together with *Pinus halepensis*. The most common woody species of the undergrowth (i.e. *Olea europaea* var. *sylvestris*, *Pistacia lentiscus, Juniperus turbinata, Chamaerops humilis, Myrtus communis*) suggest that local vegetation may evolve towards thermophilous evergreen sclerophyllous communities referred to *Oleo-Ceratonion*.

05.09.2019

The vegetation surrounding the pond of **Chia** is characterized by *Cistus*-dominated shrublands and evergreen thermophilous maquis assemblages with *Juniperus turbinata, Pistacia lentiscus* and *Myrtus communis.*

The coastal lagoon of **Mistras** consists of several interconnected water basins separated by ancient sand beaches which formed in different period (the inner the older) according to the varying position of sea level. The salty and muddy soils of this area are unsuitable for tree cover, and the main landmark is chenopod scrub, dominated by *Suaeda* spp. and *Salicornia* spp. and framed into *Salicornietea fruticosae*.

06.09.2019

Located in the Nurra of Sassari, **Baratz** is the only natural lake of Sardinia. It hosts several aquatic (mostly framed into *Potamion*) and hygrophilous (*Nerio-Tamaricetea, Juncetalia*) plant communities. The dune habitats nearby host artificial Aleppo pine forests and low maquis rich in evergreen sclerophyllous species such as *Juniperus turbinata, Chamaerops humilis, Olea europaea* var. *sylvestris, Arbutus unedo* and *Pistacia lentiscus*.

Near the coast, the calcareous areas of **Capo Caccia** are characterized by low maquis communities dominated by dwarf palm, *Chamaerops humilis,* together with *Anagyris foetida, Calicotome villosa, Calicotome spinosa, Juniperus turbinata* and *Pistacia lentiscus.* The coastal cliffs exposed to marine salt-spray are dominated by *Anthyllis barba-jovis* and host one of the few extant populations of *Centaurea horrida.*

07.09.2019

There are no peat bogs in Sardinia, with the exception of the fragments we will visit on **Mt. Limbara**. This granitic massif is of particular botanical interest because it is home of several narrow endemics such as *Hieracium limbarae, Rubus limbarae, Viola corsica* subsp. *limbarae*. Moreover, the Limbara Mts hosts several regionally rare species such as *Genista desoleana, Rosa serafinii* and *Populus tremula*. On this massif also occur the only native maritime pine (*Pinus pinaster*) wood patches, often consociated with *Quercus ilex*, whilst some pure stands are localized in the locality of Carracana and represent the last remnant nuclei of a forest type which was widespread until the 1950s. Additionally, the top of the massif hosts the widest heathlands dominated by *Erica scoparia*. This area hosts some remnant nuclei of evergreen mesophilous vegetation with *Ilex aquifolium* and *Taxus baccata*, intermingled with mantle communities dominated by *Crataegus* spp. During the last tens of years the local forest agency planted many forest trees which are not native to Sardinia, such as *Fagus sylvatica, Acer pseudoplatanus, Abies alba, Castanea sativa, Cedrus atlantica, Pseudotsuga menziesii,* etc.

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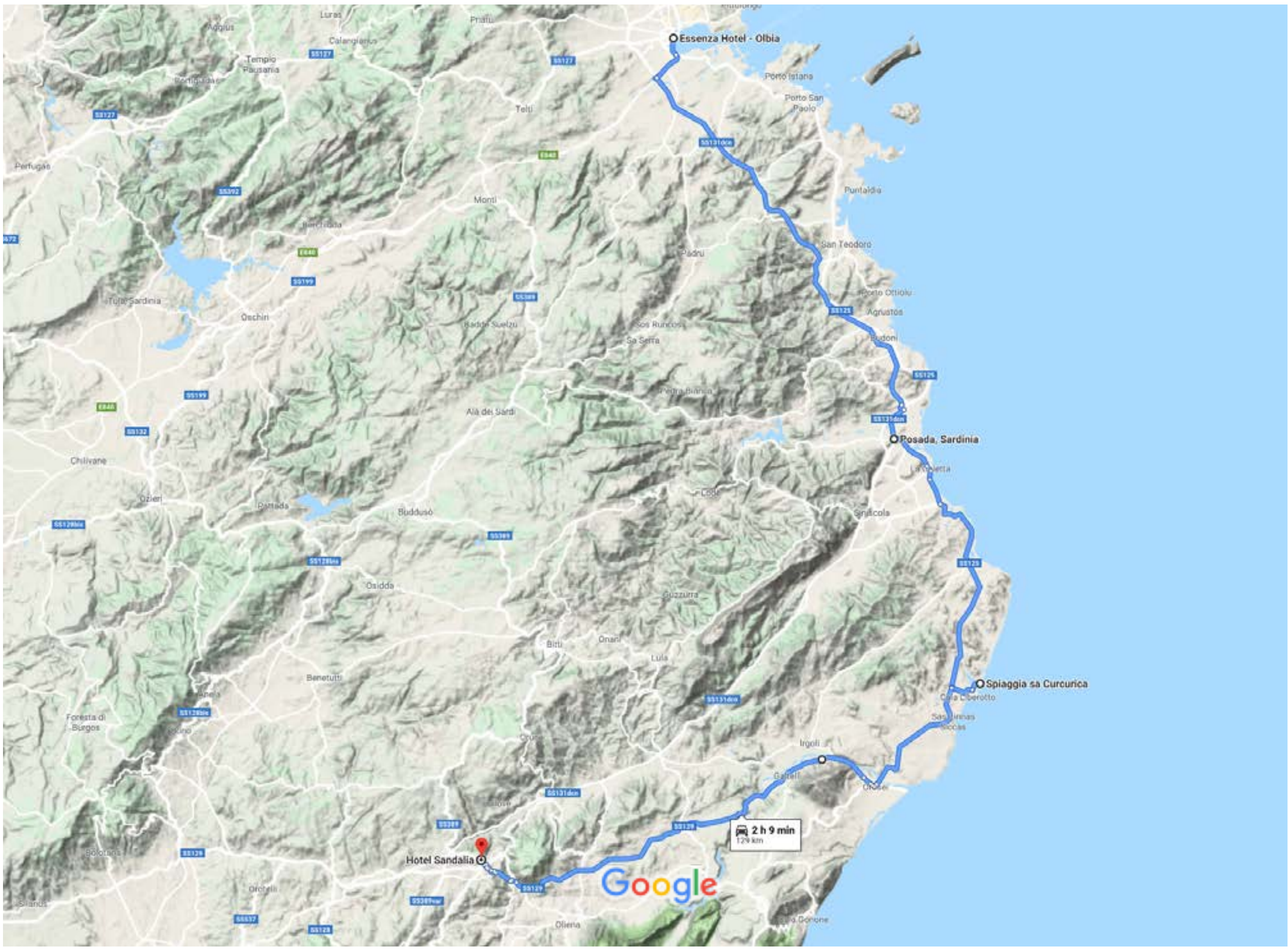
Monday 02.09.2019

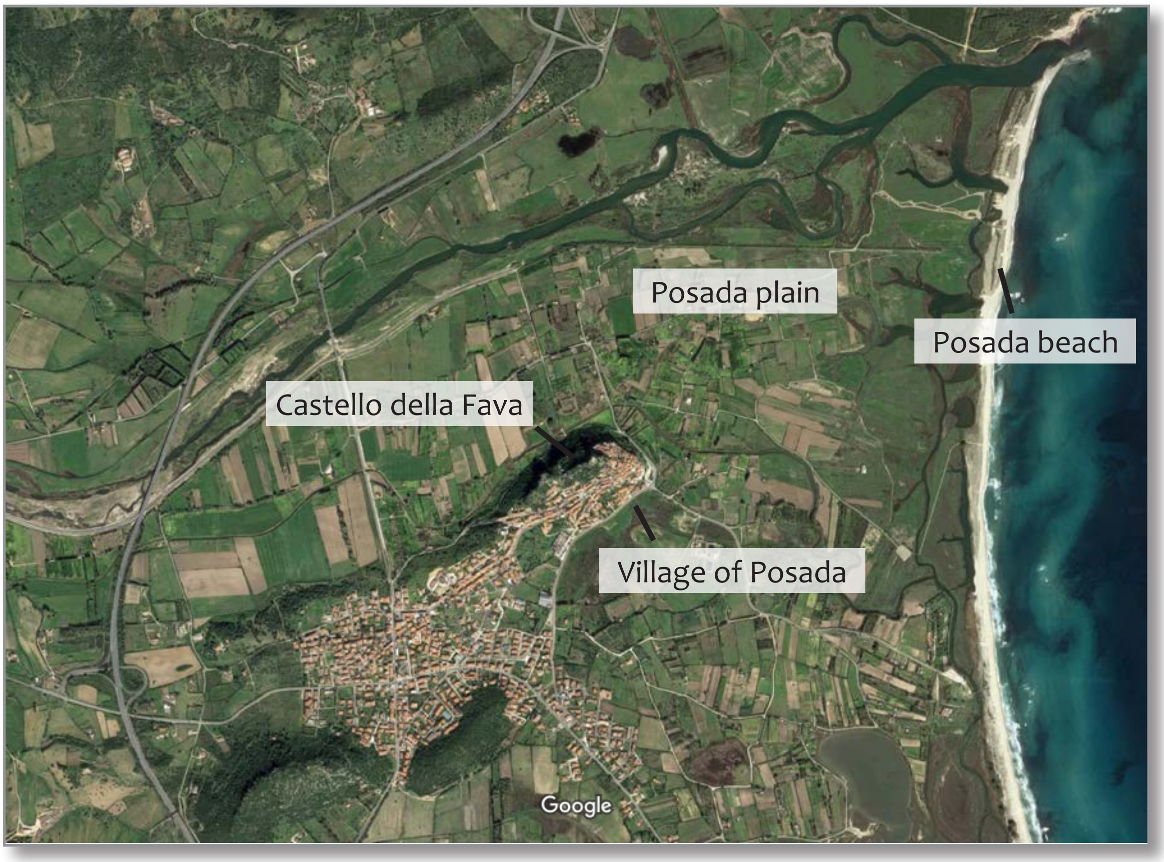
Afternoon:	Individual arrival in Olbia and checking in at the Hotel Essenza
18:00	Welcome reception on the roof terrace of the Hotel Essenza in Olbia
20:00	Dinner at the Ristorante Frontemare in Olbia

Tuesday 03.09.2019

8:00	Breakfast at Hotel Essenza, Olbia
9:00	**Departure** to Posada. Meeting at the bus parking lot behind the Hotel Essenza
10.30	**Posada:** Walk to the Castello della Fava
11:00	8000 years of coastal changes in the **Posada** plain (Dr. Matteo Vacchi)
12:30	Lunch at the beach
14:00	Departure to Stagno di Sa Curcurica
15:00	**Sa Curcurica:** Vegetation and fire history of coastal north-eastern Sardinia (Italy) under changing Holocene climates and land use (Giorgia Beffa)
17:00	Departure to Nuoro
18:30	Arrival at Hotel Sandalia, Nuoro
20:00	Dinner at Hotel Sandalia, Nuoro



The Posada plain



8000 years of coastal changes in the Posada plain

Dr. Matteo Vacchi, University of Pisa, Italy

Coastal plains contain key sedimentary archives to determine environmental change. In the Mediterranean region, such modifications are controlled by both natural processes and human impacts. In fact, coastal plains have always been ideal locations for settlements due to their strategic position in relation to food availability, proximity to hinterland valleys and the sea, and the control of major trading routes. In the last 5 years, a large amount of coastal plains from Corsica and Sardinia were investigated through a multiproxy approach including geomorphologic, bio-sedimentary and palynological analyses. Among the studied coastal plains there is Posada which is the focus of this first stop.

Geomorphological and archaeological setting

The Posada river alluvial plain, filled by Quaternary sediments, lies along a structural E-W depression. The coast is characterized by long sandy beaches between the promontories of Torre S. Giovanni and Mt. Orvili. Sand dunes and relict river channels mainly characterize the backshore area (Fig. 1). The presence of settlements in the area surrounding the Posada coastal plain dates back to at least the Mid-Neolithic but the density of settlements increased during the Bronze Age (Nuragic civilization) notably on the hillsides overlooking the floodplain (Fig. 1). Little is known about the next period of Punic-Roman occupation. Historical sources report the existence of a Roman city, Feronia. In the Middle Ages, Posada reached its maximum development, thanks to its strategic position between the middle of the two large medieval kingdoms of Gallura and Arborea.

Stop 1. Castello della Fava

The multiproxy analysis (sedimentological parameters, micro and macro-fauna and pollen assemblages, figs 2,3) of 5 boreholes document the landscape evolution of the Posada coastal plain, including the main phases of shoreline development during the last 8000 years. The complex interplay between sea-level rise, sediment supply at base level and river progradation resulted in a very dynamic coastal environment during the mid- to late Holocene. This active landscape dynamics played an important role in the long-term settlement patterns of the area (Melis et al., 2018). In fact, the low density and discontinuous nature of human occupation of the plain, from prehistoric to historic periods, was most likely related to the rapid and constant evolution of the coastal landscape (Fig. 4).

Evidence of these changes are documented also in the palynological record (Fig. 5), which furnishes new data on vegetation development on the eastern side of Sardinia. In the sixth to fifth millennia BC, the landscape was dominated by *Erica* evergreen scrub woodland in the hinterland and brackish water lagoonal environments along the river mouth and coastline. The first major change was marked by a change from a brackish to a freshwater environment that had occurred by the middle of the 4th millennium BC. This was coincident with a partial replacement of the *Erica* scrub by evergreen oak scrub woodland (*Quercus ilex*) and *Myrtus* shrub communities, and then an increase in *Juniperus* which is consistent with the accumulation of dune deposits and a rapid increase in *Alnus* pollen testifying to the development of scrubby woodland on the damp riparian margins of the floodplain. As for clear evidence for human impacts, the pollen data suggest only a modest use of the land in the catchment for arable crops during prehistoric times. Instead, the presence of significant frequencies of *Carduus, Asphodelus, Rumex* and other taxa, including species living in meadows exploited by cattle, are mostly consistent with livestock grazing activities, although other corroborative evidence of human activities in the locality is still largely lacking for the Neolithic period. Nonetheless, from the later Neolithic, the aggradation of the alluvial floodplain of the lower Posada valley suggests increasing human impacts in the catchment, with clearance and agricultural activities leading to soil erosion (Melis et al., 2018).

Stop 2. Posada beach

The coupled analysis of boreholes and beachrocks sampled down to -35 m of depth provided fresh data on the postglacial evolution of the relative sea-level (RSL) in Sardinia. The reconstructed sea-level history shows an offset with the model predictions proposed for the area (Fig. 6). Between ~7.5 and ~7.0 ka BP, RSL was at least ~5 m above the position predicted by the model. At ~5.3 BP, a marine limitation demonstrates that RSL was at least ~3 m above the predicted position. Tectonics is not responsible for this offset, as Sardinia is recognized as a very tectonically stable area. These data indicate the partial inadequacy of the widely used geophysical models to predict the RSL evolution in this sector of the Mediterranean (Vacchi et al., 2018).

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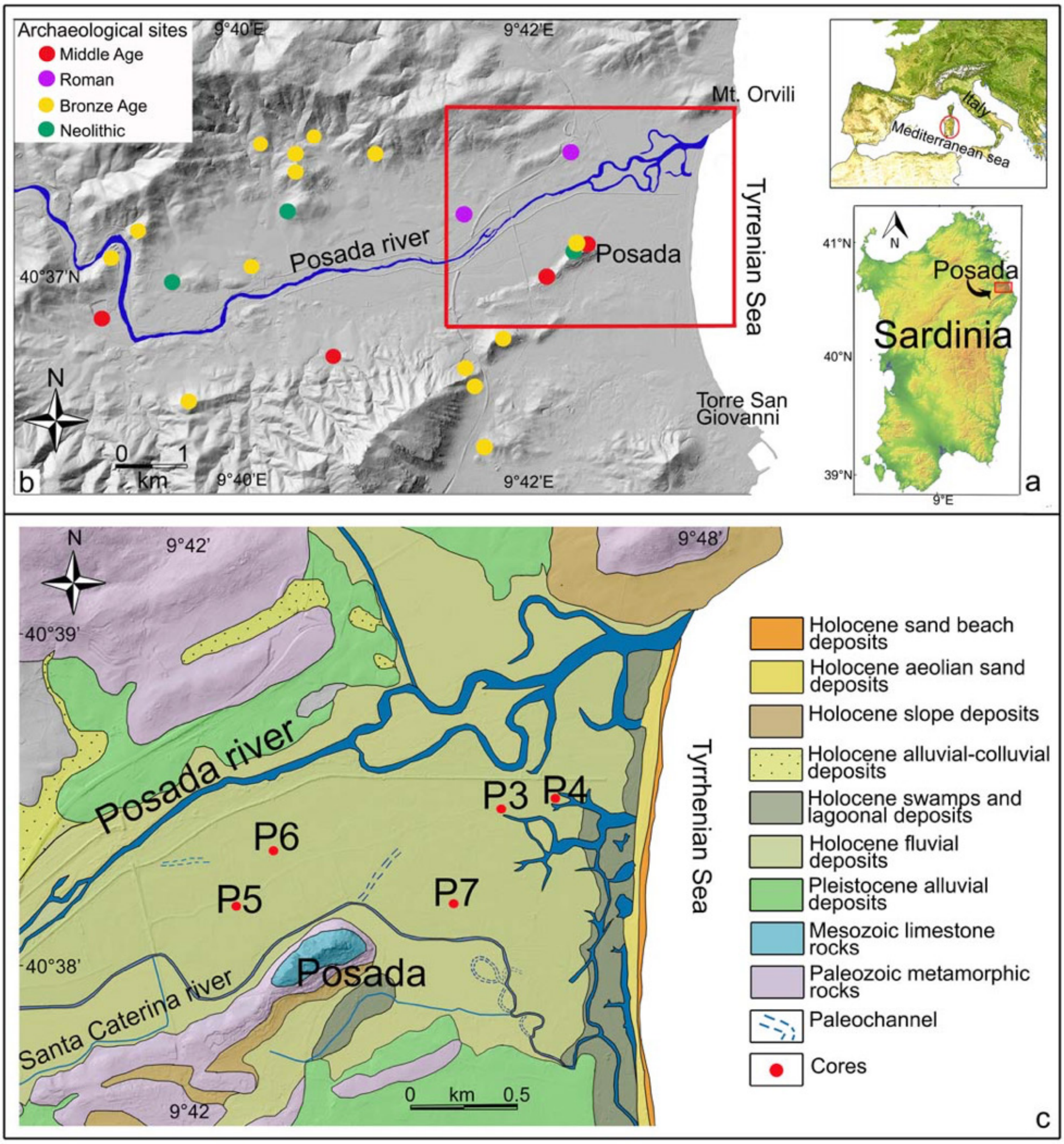

Figure 1 a) Location of the study area on the north-east coast of Sardinia; **b)** distribution of archaeological sites, the box shows the location of the Posada coastal plain; **c)** Schematic geological map (DEM, Regione Sardegna, 2017) and location of the cores

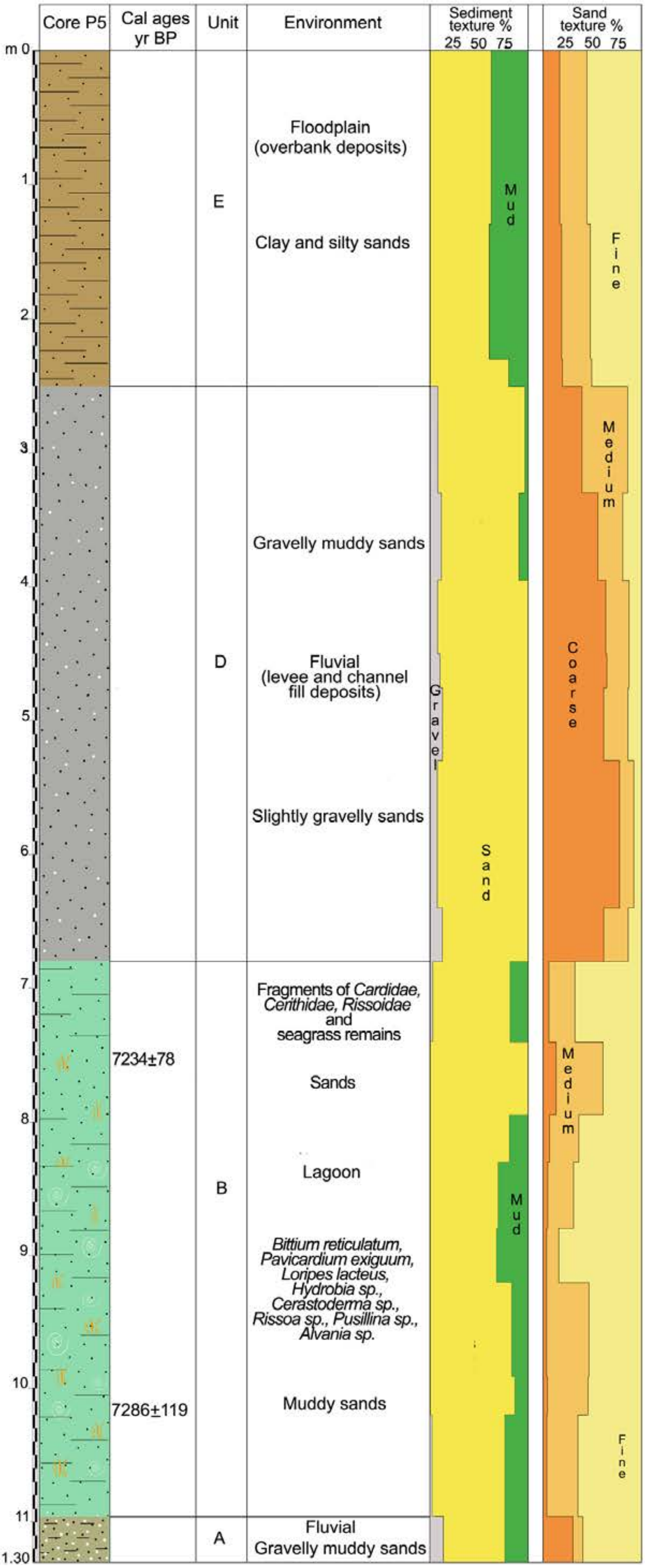

Figure 2a. Log of P5 core

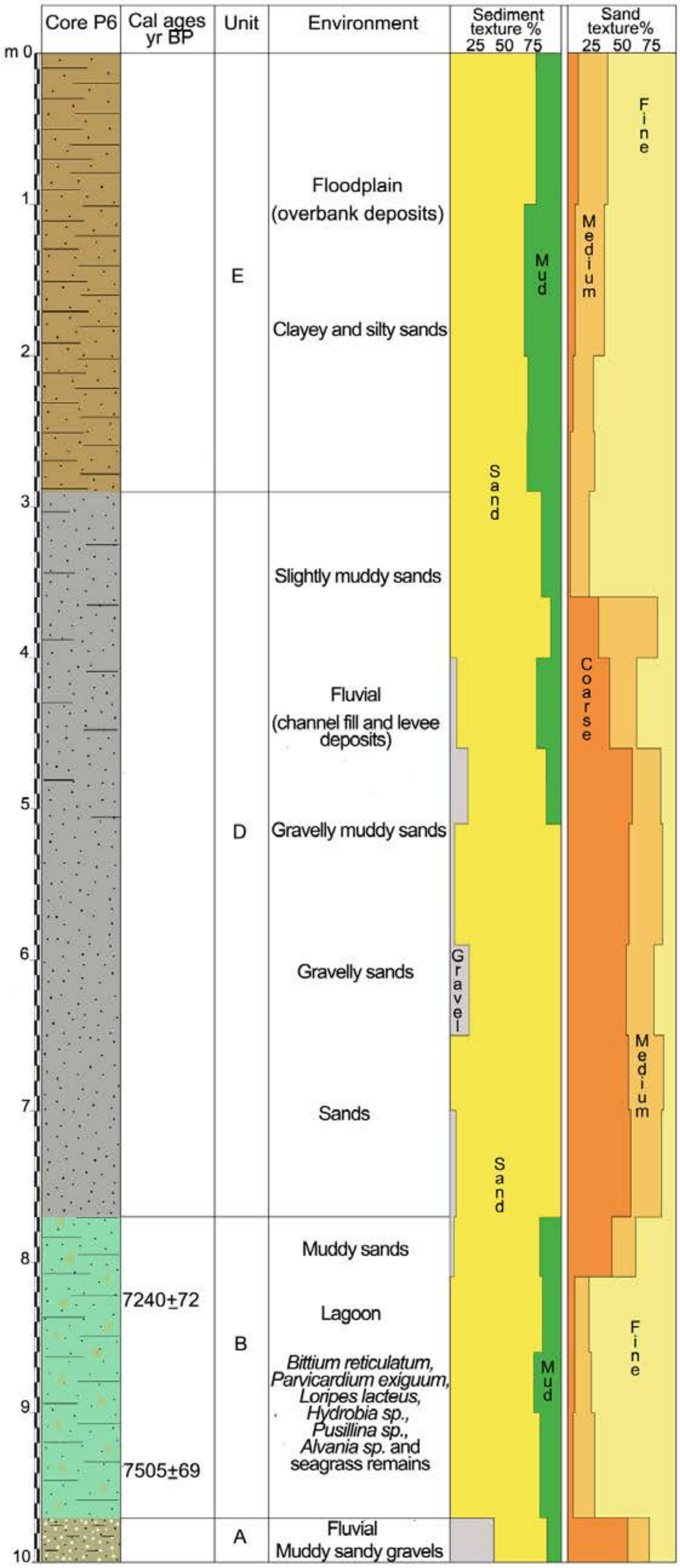

Figure 2b. Log of P6 core

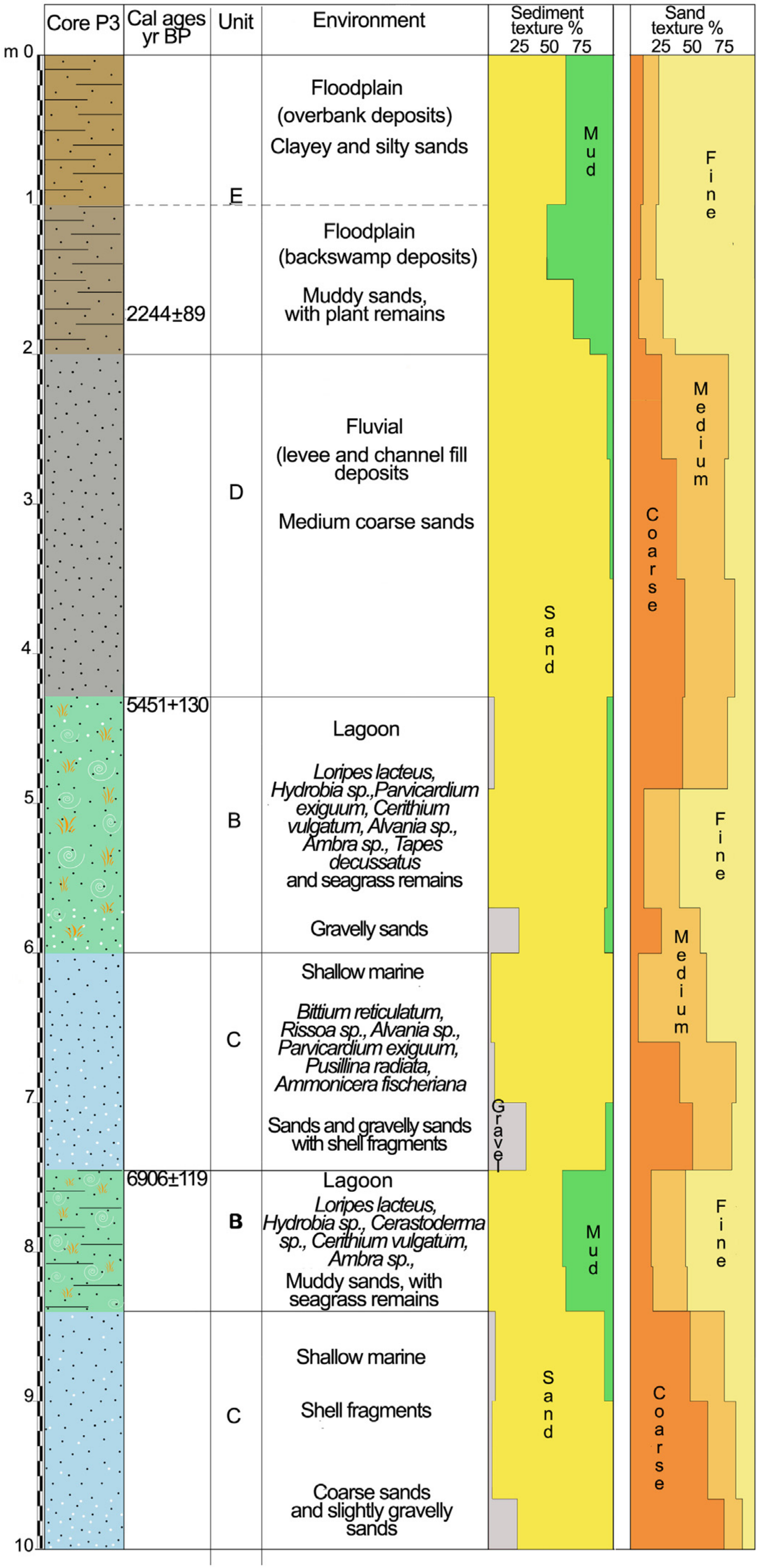

Figure 3a. Log of P3 core.

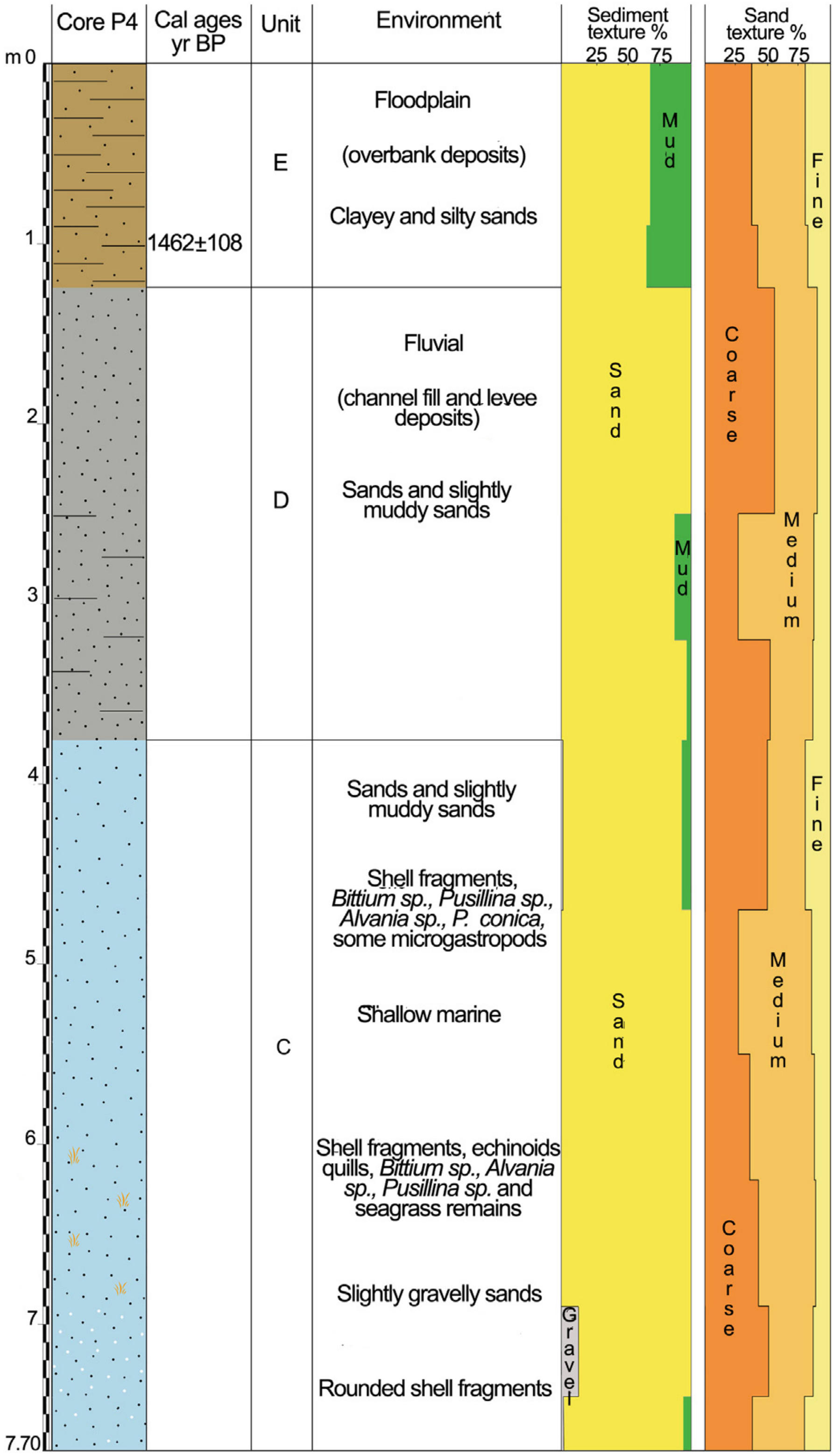

Figure 3b. Log of P4 core.

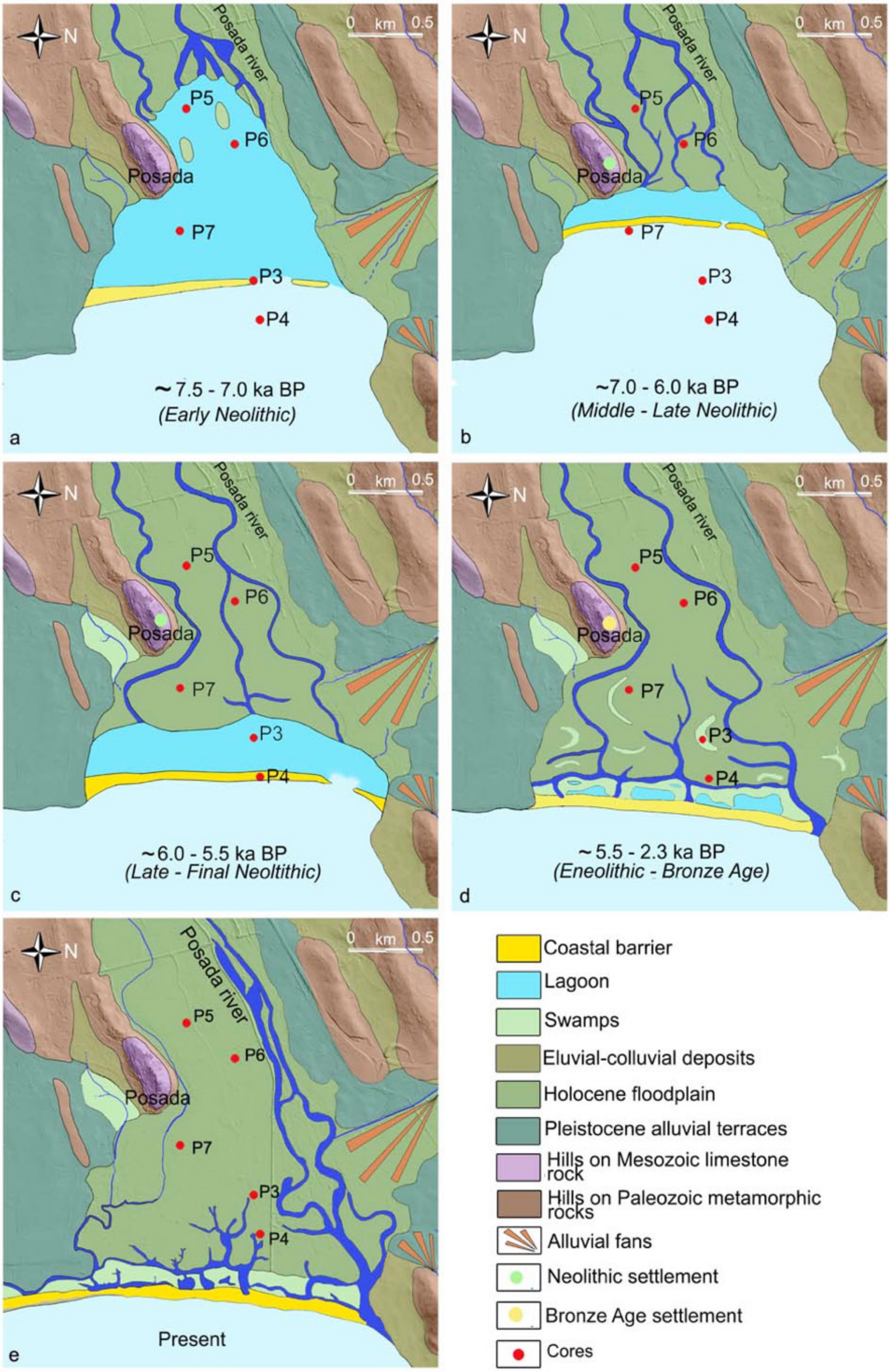

Figure 4. Schematic reconstruction of the main phases of the Posada coastal plain evolution as reconstructed by facies analysis and interpretation.

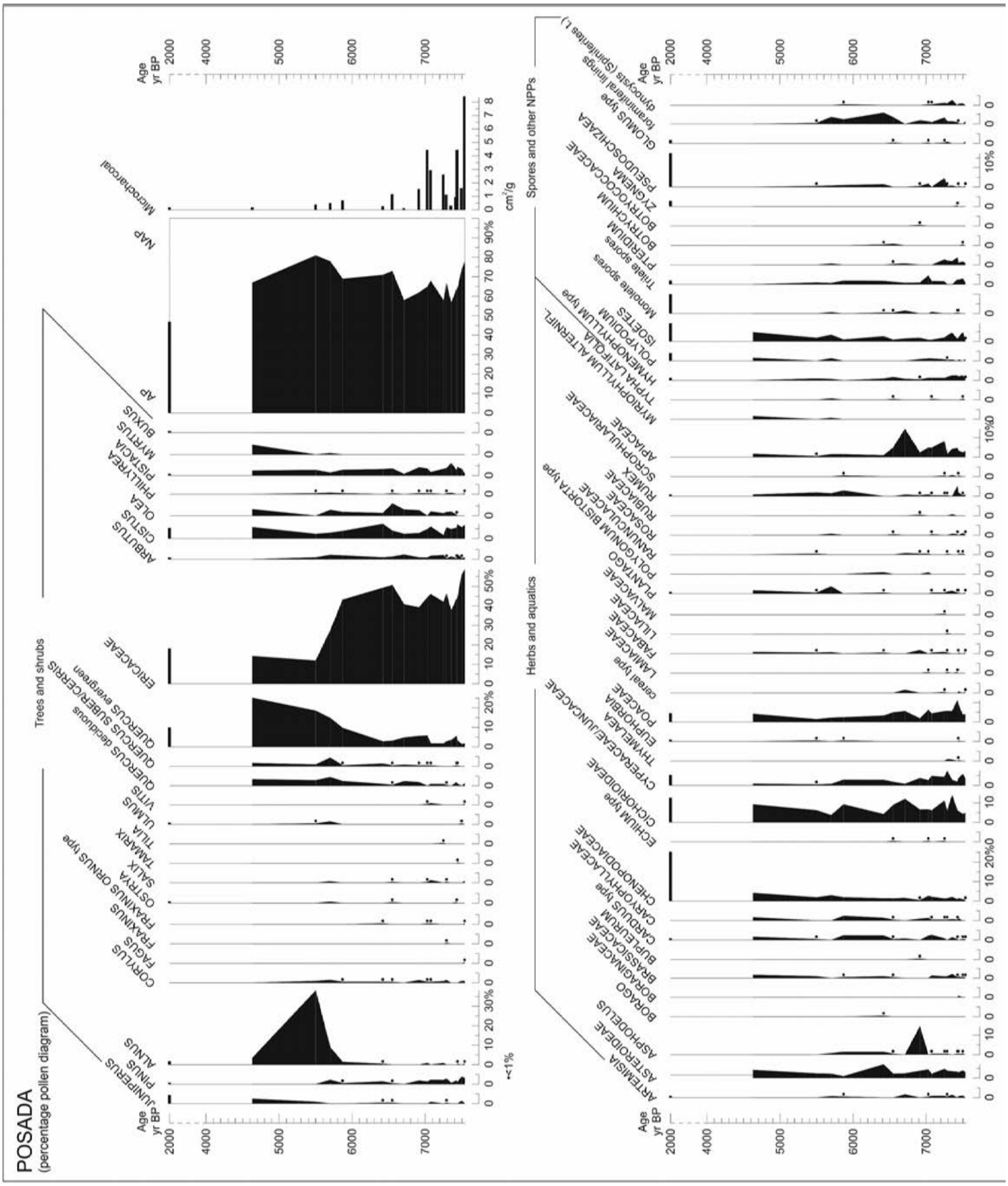

Figure 5. Percentage pollen record of Posada, including almost all the taxa and microcharcoal concentrations plotted against age.

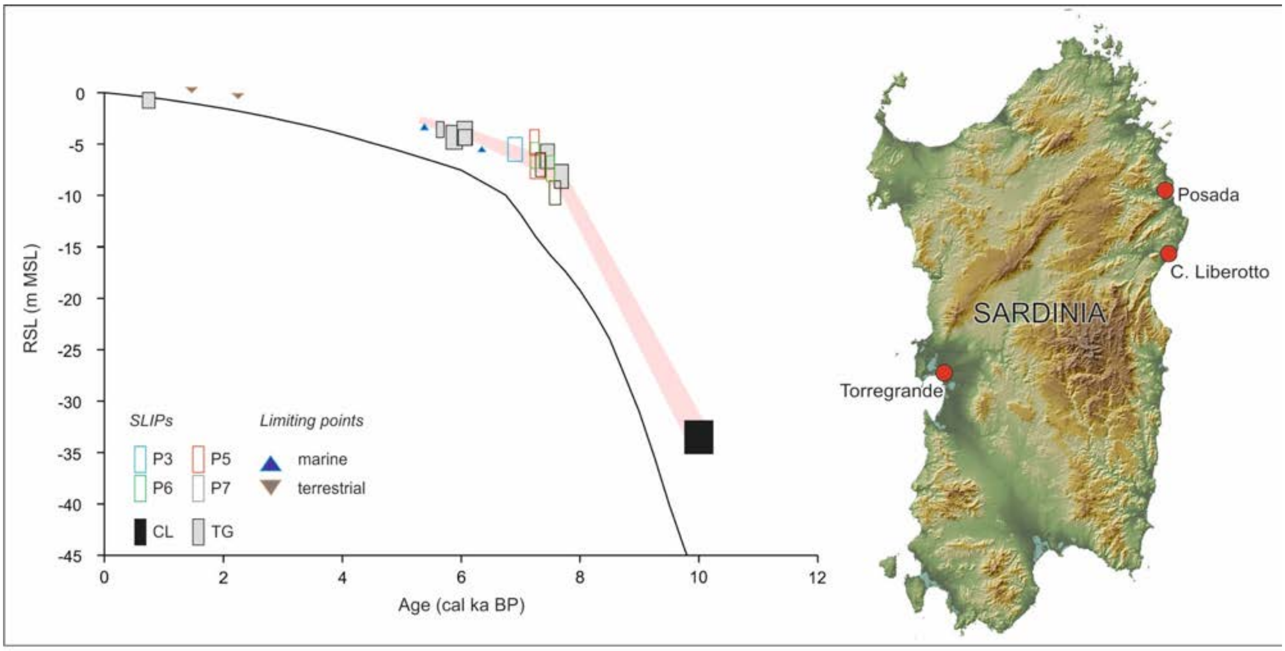

Figure 6. RSL reconstruction of the Posada coastal plains plotted against the predicted RSL curve (Lambeck et al., 2011) for eastern Sardinia. Sea Level Index Points (SLIPs, boxes) are plotted as calibrated age against the change in sea level relative to present. Limiting points are plotted as terrestrial or marine triangles. P3, P5, P5 and P7 are the lagoonal samples from Posada coastal plains, CL is the beachrocks from Cala Liberotto, TG are the Torregrande lagoonal samples (western Sardinia).

Stagno di Sa Curcurica

Veget Hist Archaeobot (2016) 25:271–289
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ORIGINAL ARTICLE

Vegetation and fire history of coastal north-eastern Sardinia (Italy) under changing Holocene climates and land use

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Abstract Little is known about the vegetation and fire history of Sardinia, and especially the long-term history of the thermo-Mediterranean belt that encompasses its entire coastal lowlands. A new sedimentary record from a coastal lake based on pollen, spores, macrofossils and microscopic charcoal analysis is used to reconstruct the vegetation and fire history in north-eastern Sardinia. During the mid-Holocene (c. 8,100–5,300 cal BP), the vegetation around Stagno di Sa Curcurica was characterised by dense *Erica scoparia* and *E. arborea* stands, which were favoured by high fire activity. Fire incidence declined and evergreen broadleaved forests of *Quercus ilex* expanded at the beginning of the late Holocene. We relate the observed vegetation and fire dynamics to climatic change, specifically moister and cooler summers and drier and milder winters after 5,300 cal BP. Agricultural activities occurred since the Neolithic and intensified after c. 7,000 cal BP. Around 2,750 cal BP, a further decline of fire incidence and *Erica* communities occurred, while *Quercus ilex* expanded and open-land communities became more abundant. This vegetation shift coincided with the historically documented beginning of Phoenician period, which was followed by Punic and Roman civilizations in Sardinia. The vegetational change at around 2,750 cal BP was possibly advantaged by a further shift to moister and cooler summers and drier and milder winters. Triggers for climate changes at 5,300 and 2,750 cal BP may have been gradual, orbitally-induced changes in summer and winter insolation, as well as centennial-scale atmospheric reorganizations. Open evergreen broadleaved forests persisted until the twentieth century, when they were partly substituted by widespread artificial pine plantations. Our results imply that highly flammable *Erica* vegetation, as reconstructed for the mid-Holocene, could re-emerge as a dominant vegetation type due to increasing drought and fire, as anticipated under global change conditions.

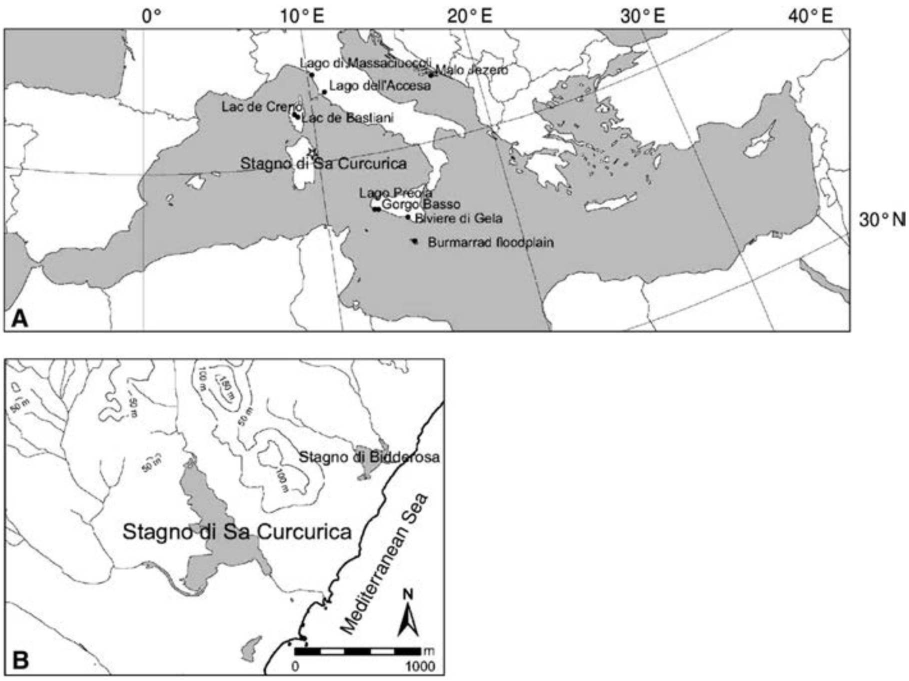


Fig. 1 **a** Map showing the location of important Mediterranean study sites. **b** Topographical map of the area around the study site Stagno di Sa Curcurica. *Source* Sardegnaportale (2014)

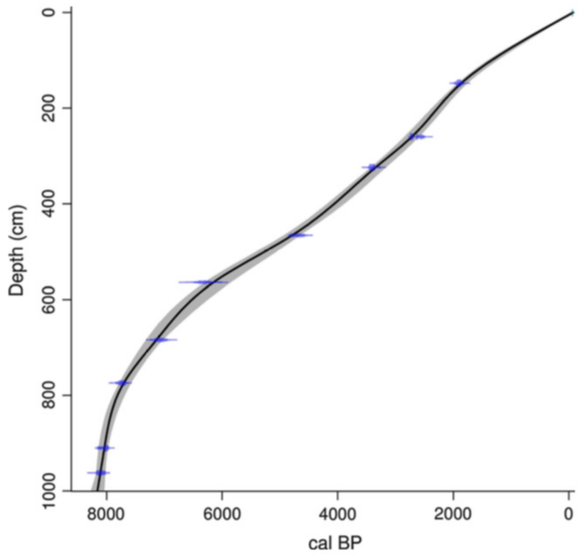


Fig. 2 Age-depth model of Stagno di Sa Curcurica. Points represent 9 calibrated ages on terrestrial macrofossils (Table 2). The model (smooth spline 0.2, *black line*) was developed with the program clam 2.2 (Blaauw 2010), which take into account 2σ-confidence rage of calibrated ages (*grey areas*)

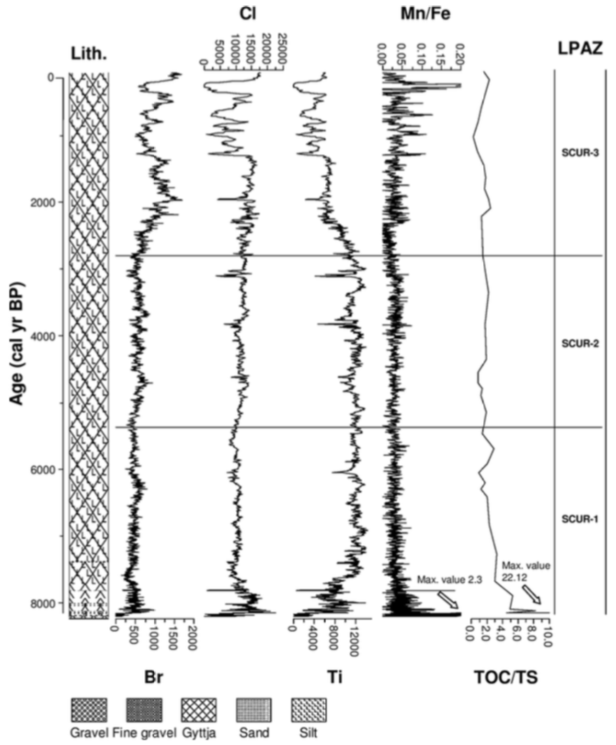


Fig. 3 Comparison of X-ray fluorescence (XRF) data of bromine (Br), chlorine (Cl), titanium (Ti) and manganese over iron (Mn/Fe) ratio and total organic carbon over total sulphur (TOC/TS). Data for Br, Cl and Ti are displayed in counts. The TOC/TS ratio was calculated from percent weight data for both elements. LPAZ: local pollen assemblage zones (analyst: Hendrik Vogel)

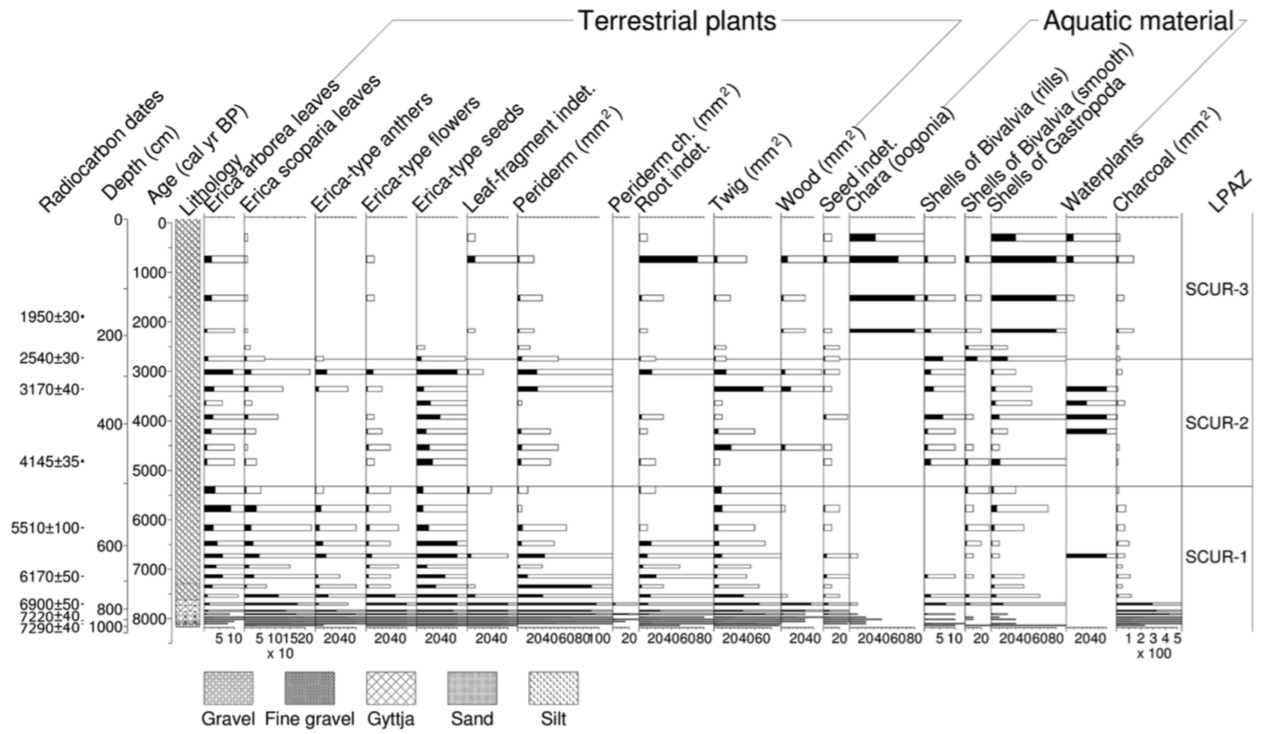


Fig. 4 Plant-macrofossil concentration diagram of Stagno di Sa Curcurica (per 10 cm^3). The *empty bars* are 5× exaggerations. ch.: charred. LPAZ: local pollen assemblage zones (analysts: Pascal Süsstrunk and Giorgia Beffa)

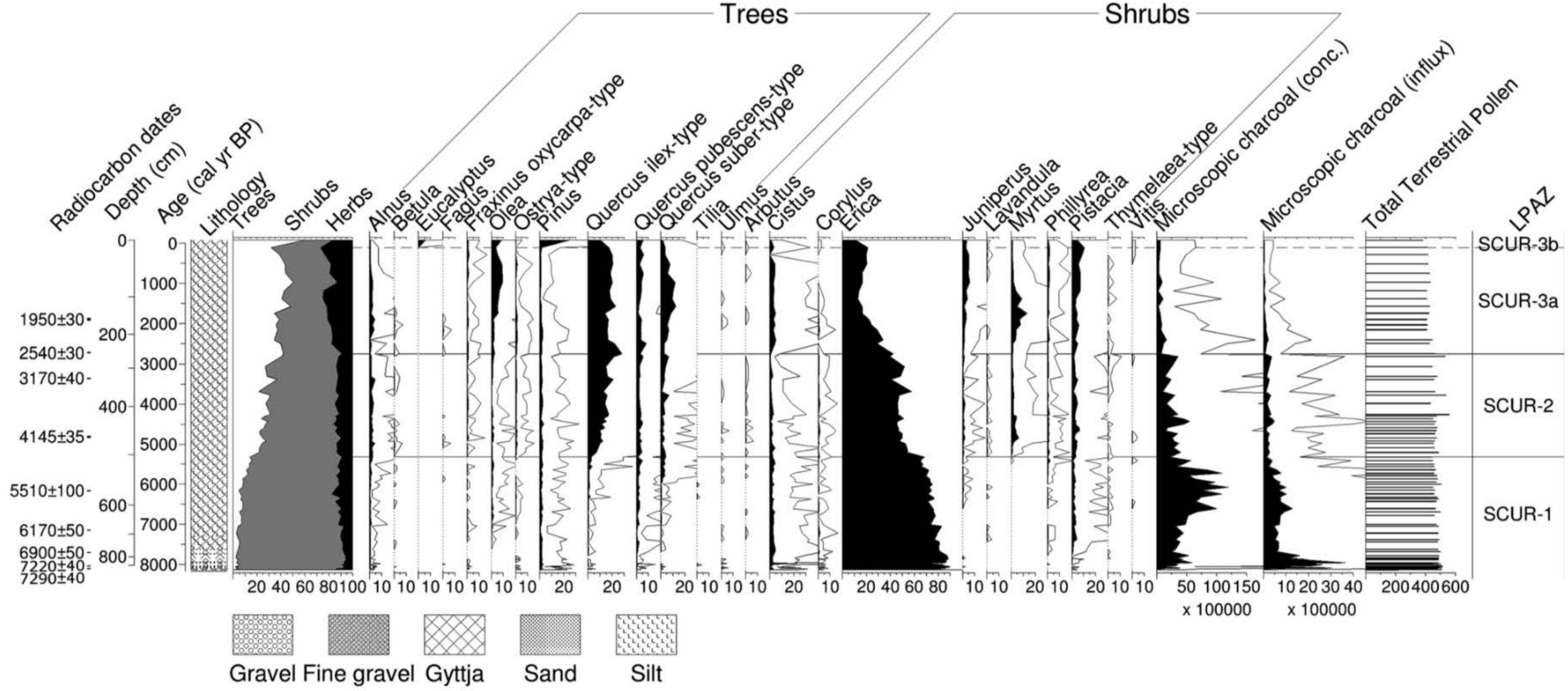


Fig. 6 Arboreal pollen (AP) percentage and microscopic charcoal diagram of Stagno di Sa Curcurica. Only selected taxa shown; for further explanations see Fig. 5 (analyst: Giorgia Beffa)

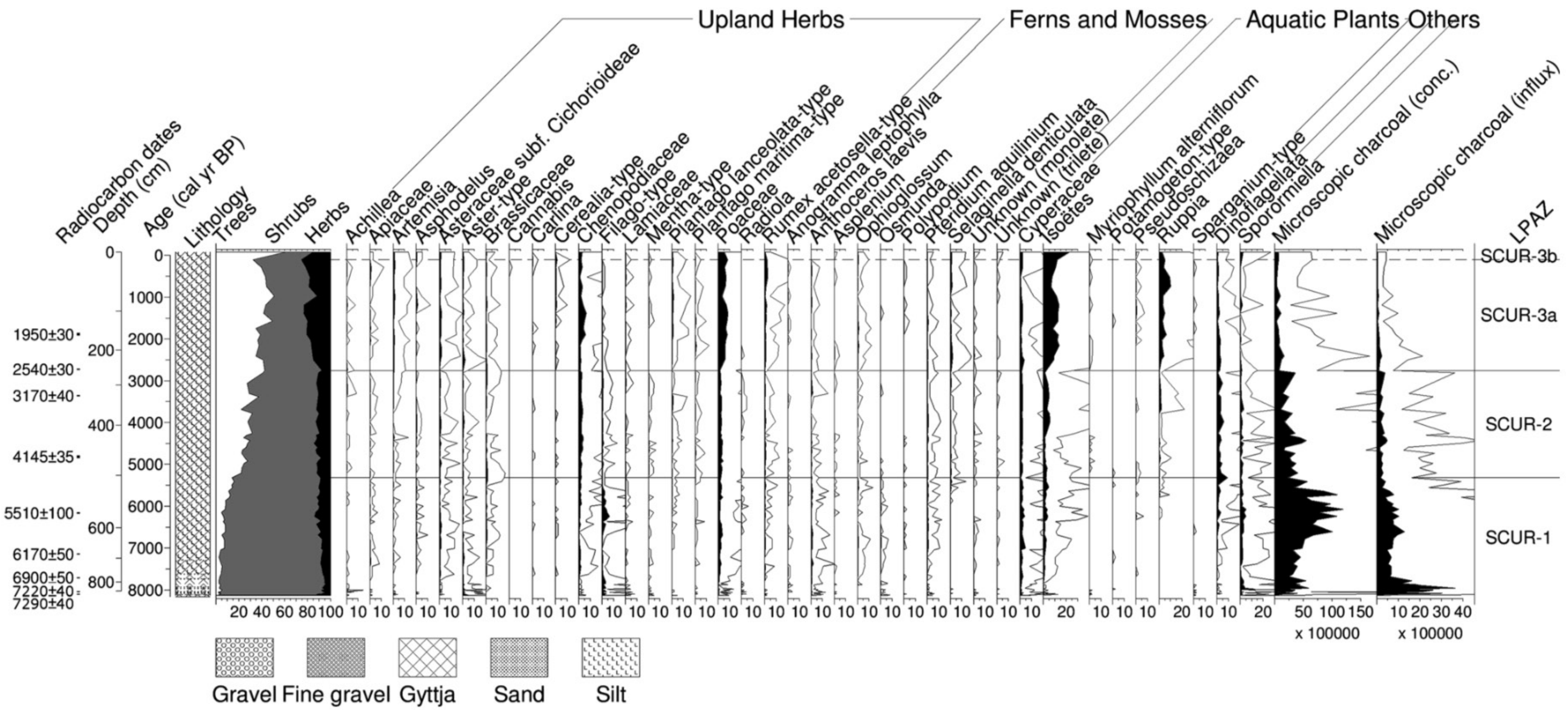


Fig. 7 Non arboreal pollen (NAP) percentage, spores and microscopic charcoal diagram of Stagno di Sa Curcurica. Only selected taxa shown; for further explanations see Fig. 5 (analyst: Giorgia Beffa)

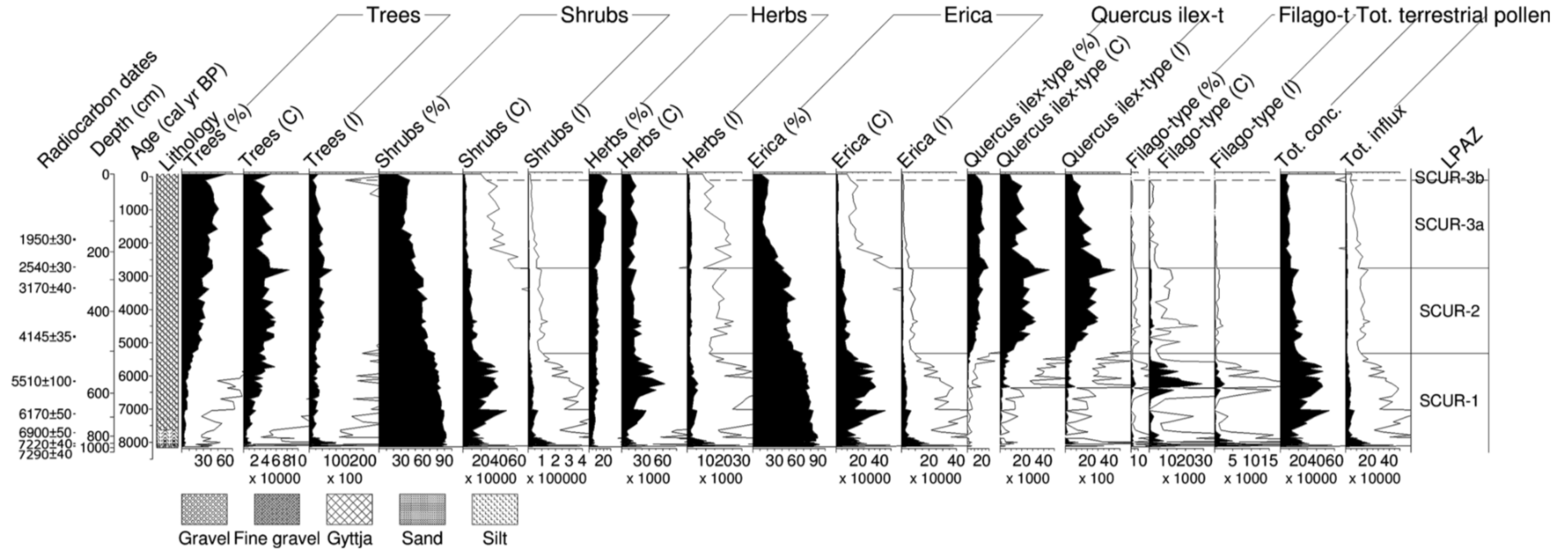


Fig. 5 Comparison between pollen percentages, concentrations and influx of selected pollen sub-sums (trees, shrubs, herbs, *Erica*, *Quercus ilex*-type, *Filago*-type and total terrestrial pollen) of Stagno di Sa Curcurica. Empty curves show 10× exaggerations. LPAZ: local pollen assemblage zones. *Unbroken lines* statistically significant zone limits. *Dashed lines* statistically non-significant zone limits

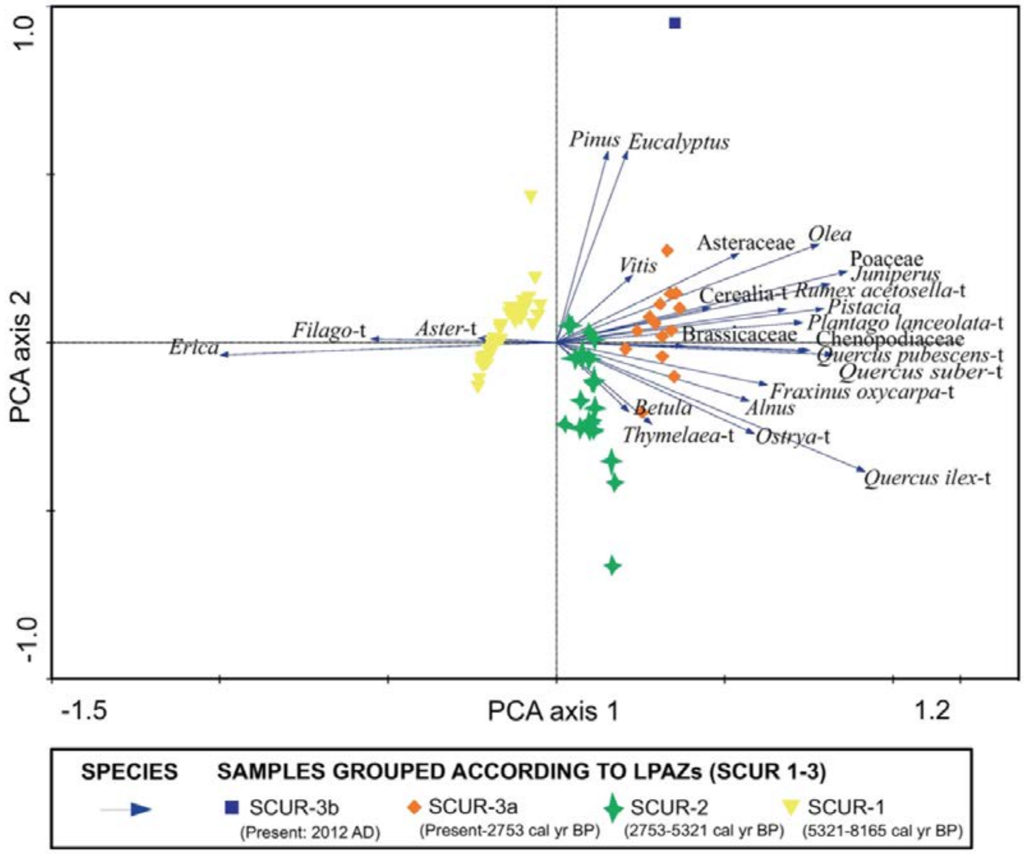


Fig. 8 PCA scatterplot of samples and selected species. The first axis explains 93.6 % of data variance, while the second axis only 2.2 %. Samples are grouped according to the local pollen assemblage zones (SCUR 1-3; see legend of Fig. 7)

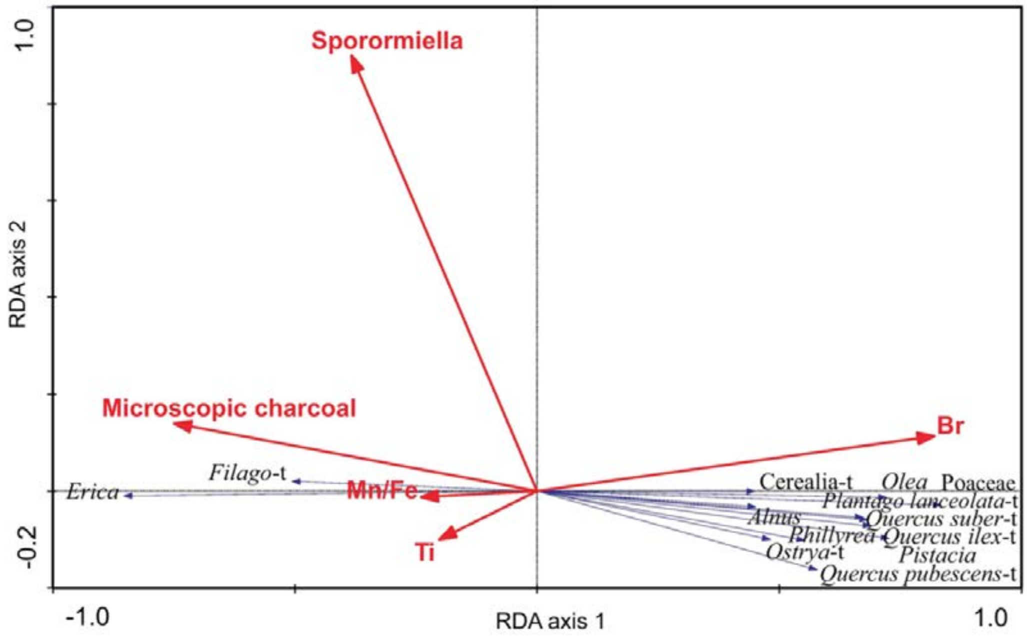


Fig. 9 RDA biplot of selected species and 5 explanatory variables. Microscopic charcoal influx and spores of the dung fungus Sporormiella are used as proxies for fire (which influences 37.9 % of data variance) and "presence of grazing mammals" (which influences 10.5 % of data variance), respectively. Abiotic variables were obtained from the X-ray fluorescence (XRF) analysis. Bromine (Br), titanium (Ti) and manganese over iron (Mn/Fe) were respec- tively chosen as proxies for organic input. Br influences 45.3 % of data variance, while Ti and Mn/Fe are not statistically significant

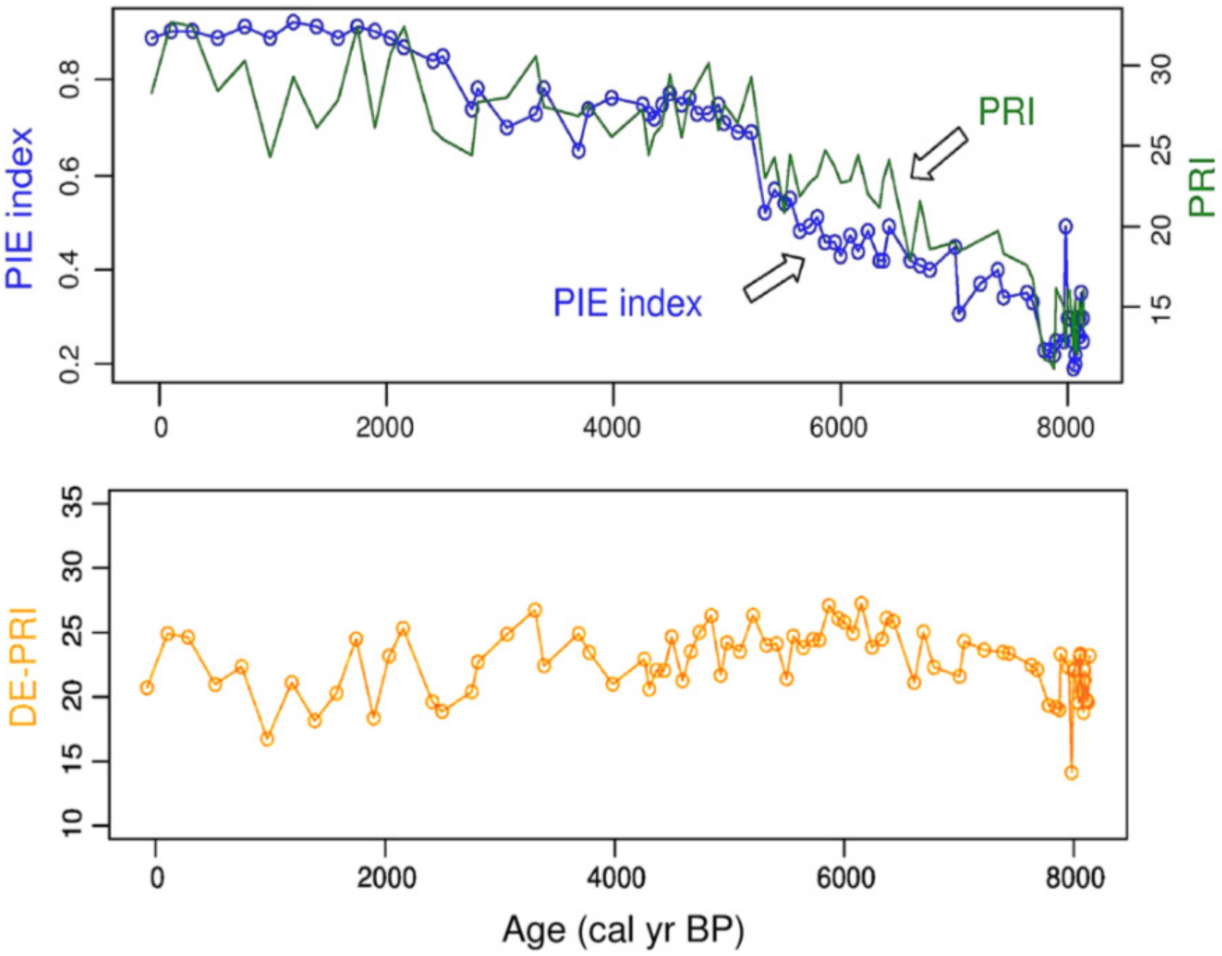
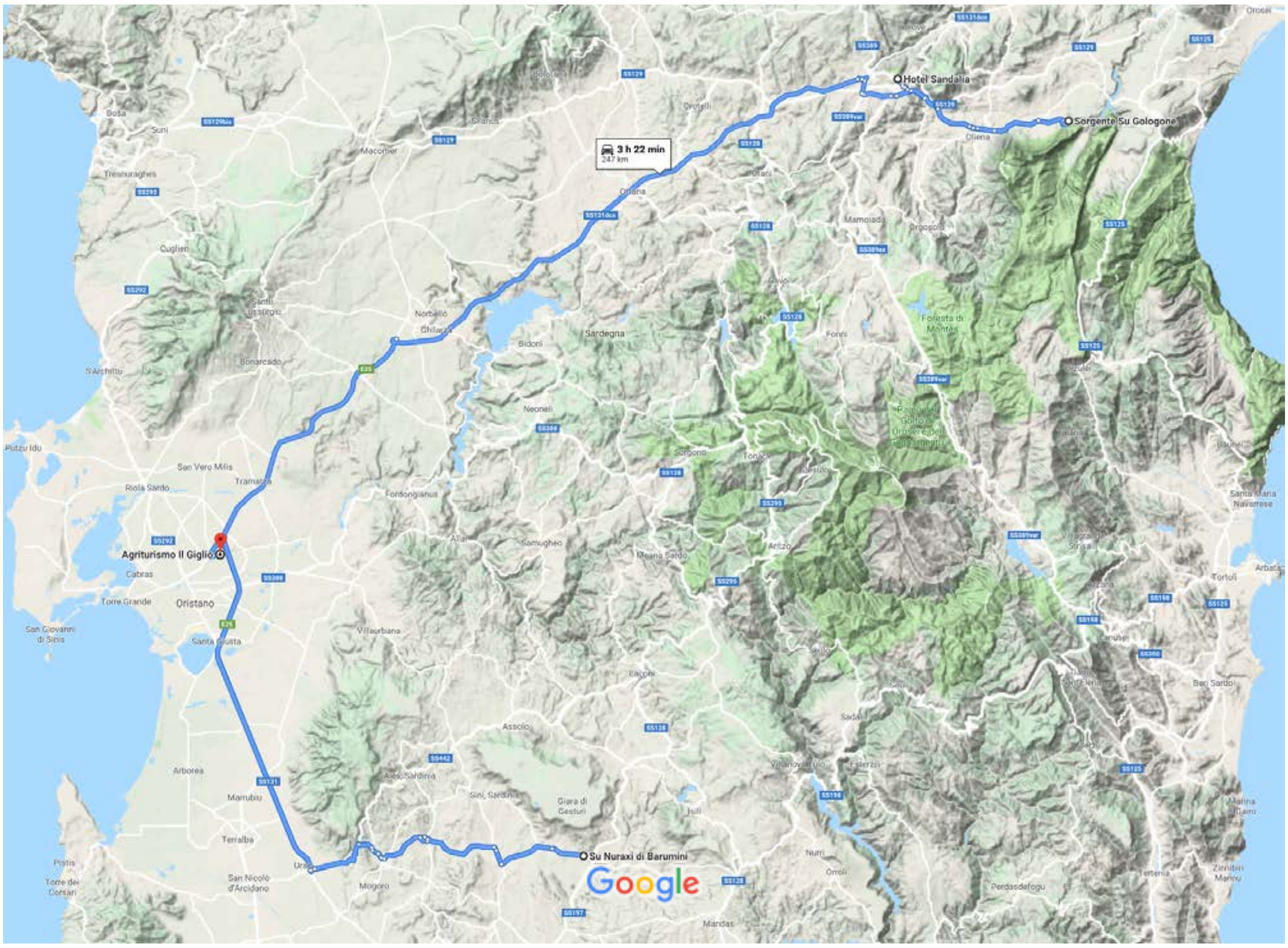


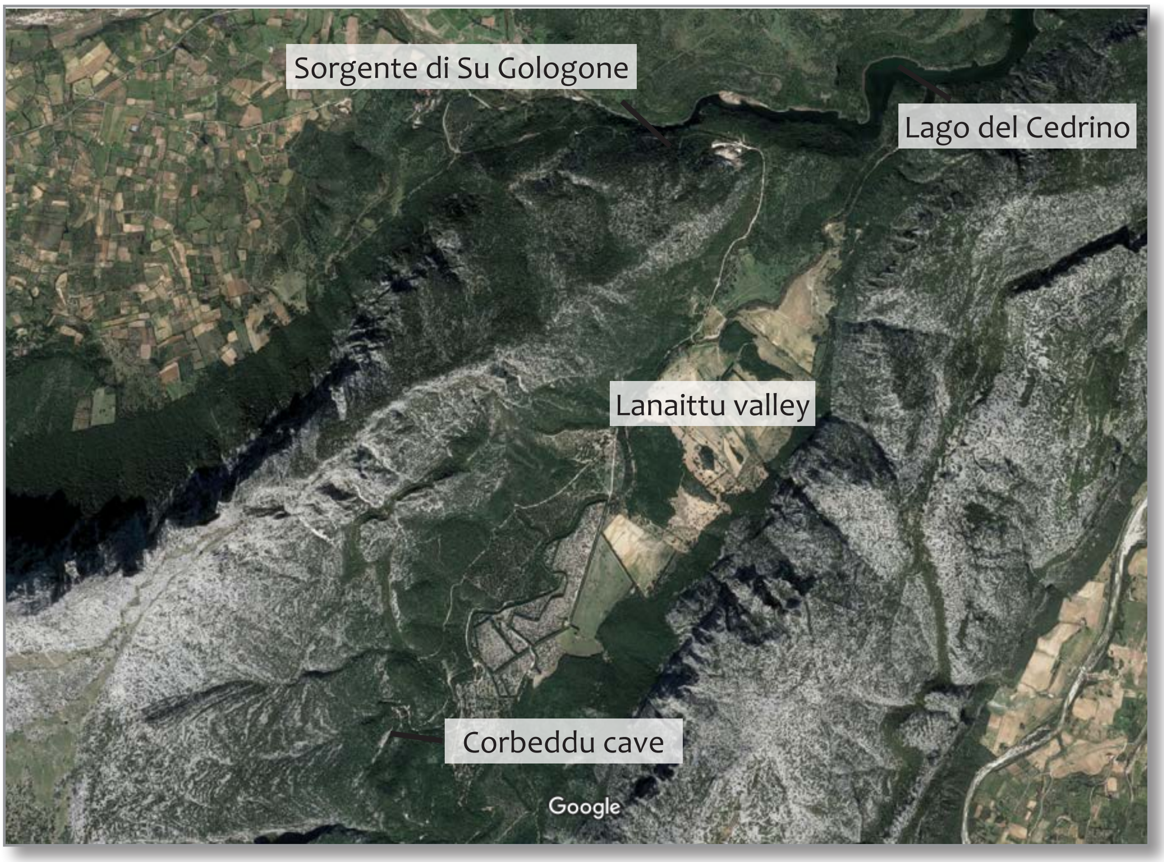
Fig. 10 Top Comparison of palynological richness (PRI, green line) and evenness (PIE, blue line with points) estimated on a constant sum of 216 pollen grains. Bottom Evenness-detrended palynological richness (DE-PRI, orange line)

Wednesday 04.09.2019

8:00	Breakfast at Hotel Sandalia, Nuoro
9:00	**Departure** to Su Gologone
10:00	Hike through *Quercus ilex* forests to the Lanaittu valley
11:00	Glacial to Holcoene vegetation at **Grotta di Corbeddu** (???)
12:00	Lunch at the natural park of Sorgente di Su Gologone
13:00	Departure to Su Nuraxi di Barumini
16:00	Visit of the UNESCO natural heritage site of **Su Nuraxi di Barumini**
17:30	Departure to Oristano
19:00	Arrival at Agriturismo il Giglio, Oristano
20:00	Dinner at Agriturismo il Giglio, Oristano



Sorgente di Su Gologone / Grotta di Corbeddu



Anthracological studies on the early Holocene sediments of the Grotta di Corbeddu (Nuoro, Sardinia)

Arie J. Kalis & Werner Schoch

Abstract – Grotta di Corbeddu is a cave system in the central North East of Sardinia. It is known as an archaeological site for its bone bearing layers, deposited by humans during the Palaeolithic. The cave was not only visited during the Pleistocene, sediments from the Holocene show many traces of human presence too. Members of the Institute of Prehistoric Archaeology of the Goethe-University Frankfurt am Main (Germany) excavated 8 m² of these early and middle Holocene layers. It was shown that the cave was regularly visited by Mesolithic people and intensively used by the Early Neolithic Cardial Impressed Ware and Filiestru groups, and subsequent by the Middle Neolithic Bonu Ighinu group.

In this contribution the results of the archaeobotanical studies are presented, especially of the charcoal analyses. All investigated strata contained charcoal, in a low concentration in the Mesolithic layers, and in (very) high concentration in the Neolithic. Almost all wood types could derive from plant species currently present around the cave. There are, however, two exceptions: *Pinus nigra* and *Paliurus spina-christa*, which both do not belong to the present-day flora of Sardinia, although Corsican pine was present in almost all Mesolithic and Early Neolithic samples. The charcoal spectrum of the Mesolithic reflects undisturbed vegetation near the cave, that of the Early Neolithic, however, a man-induced maquis, of more or less the same species composition as today[1].

Keywords – Sardinia, cave sediments, anthracology, Mesolithic, Early Neolithic

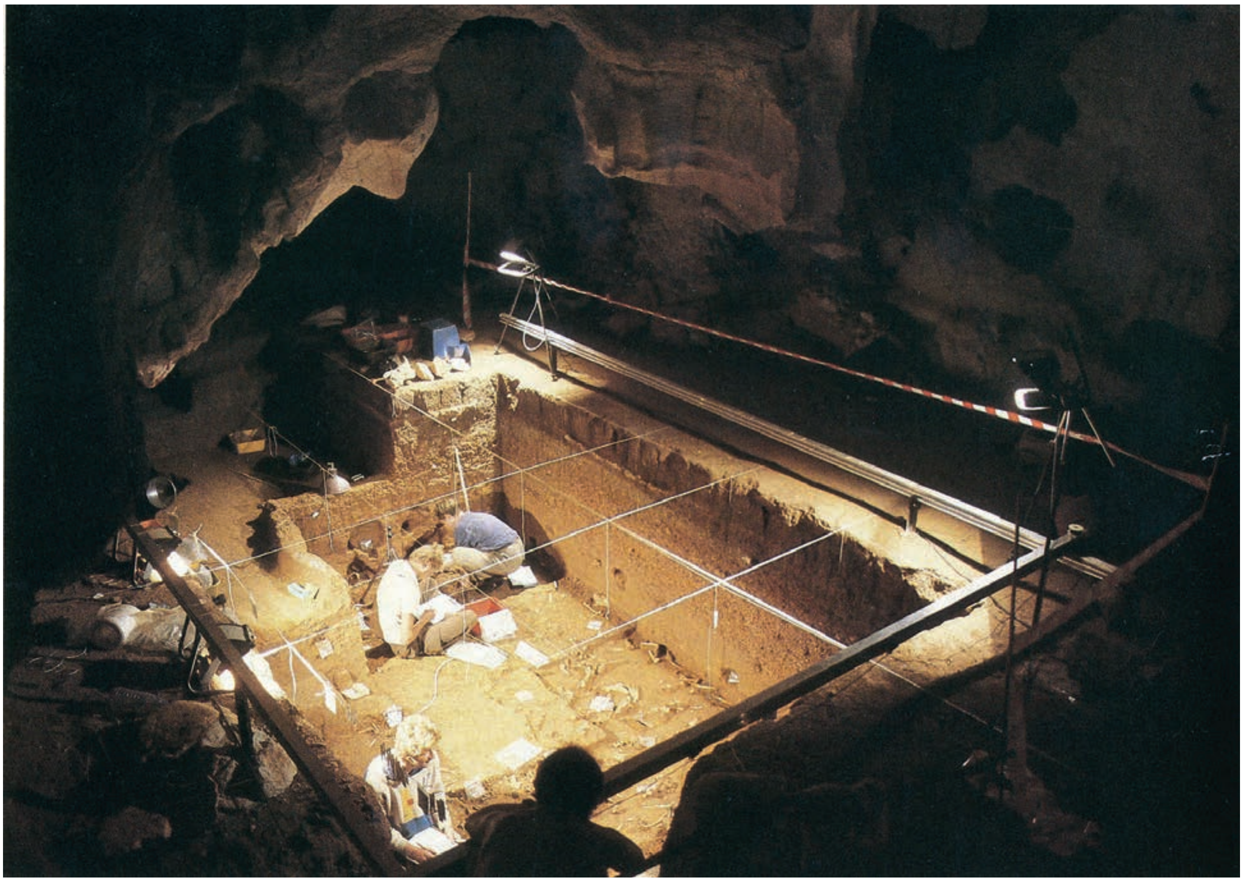
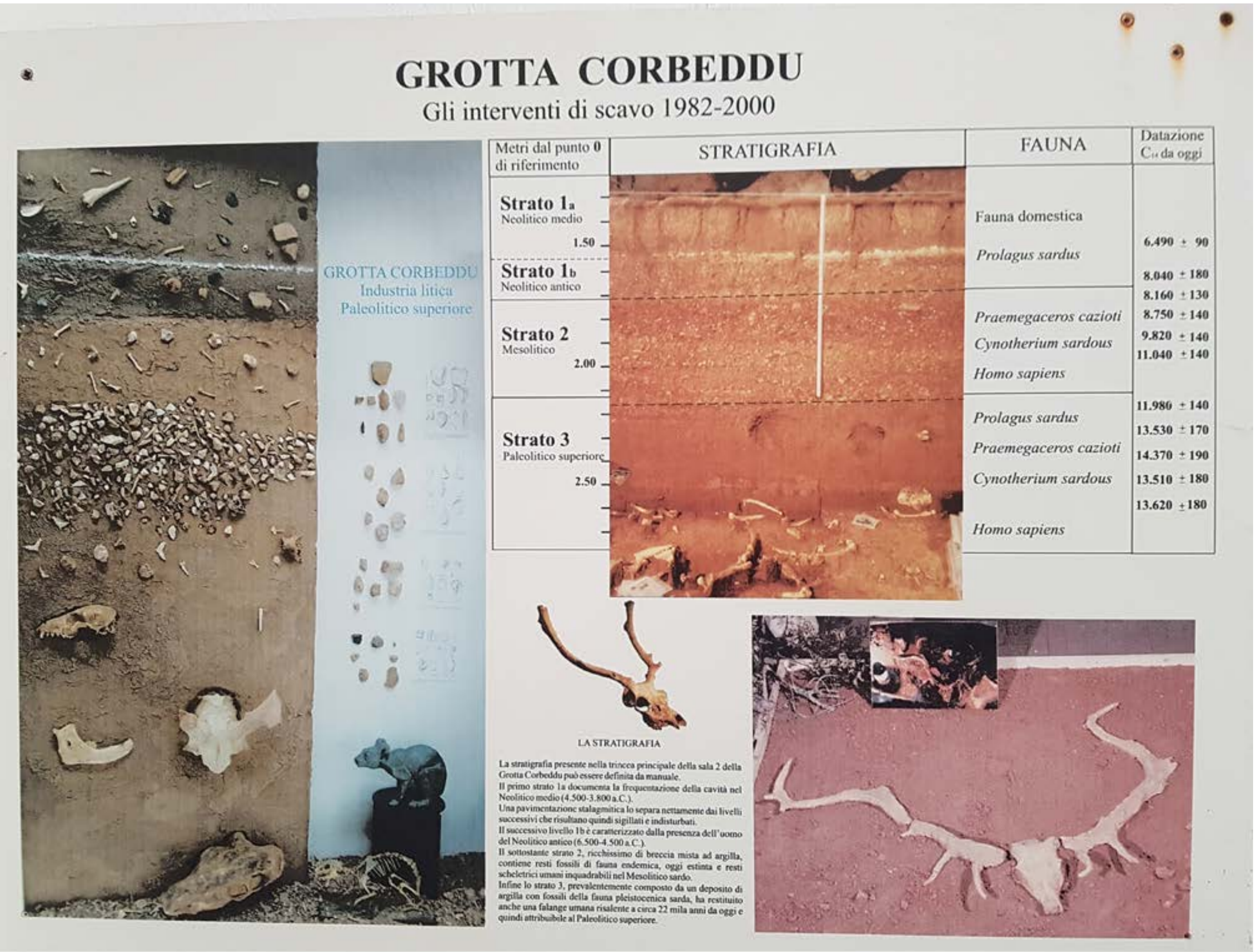


Fig. 1 View in Hall 2 of Corbeddu Cave during the archaeological excavations.



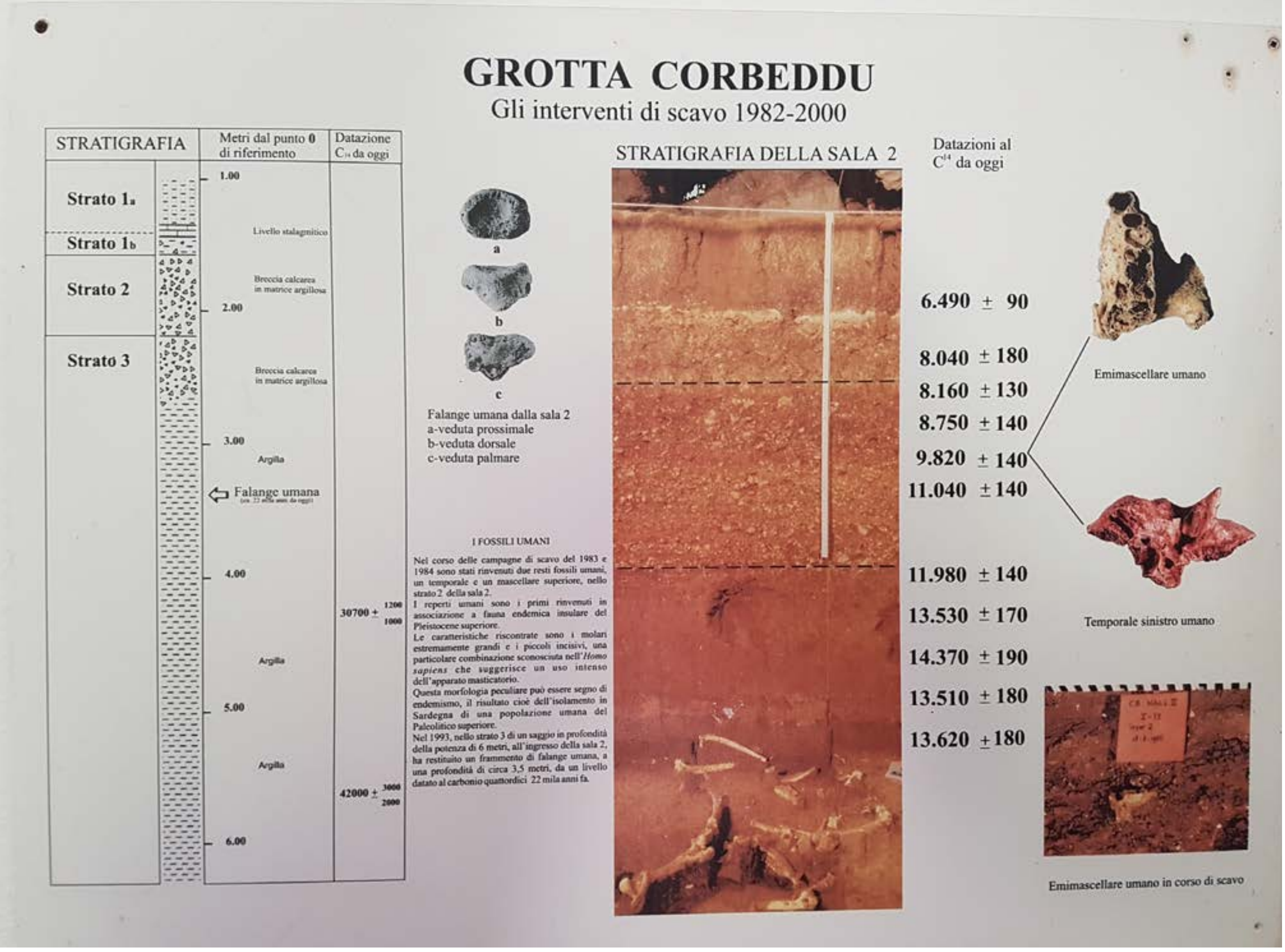
GROTTA CORBEDDU

Gli interventi di scavo 1982-2000

Metri dal punto 0 di riferimento	STRATIGRAFIA	FAUNA	Datazione C_{14} da oggi
Strato 1a Neolitico medio 1.50		Fauna domestica *Prolagus sardus*	6.490 ± 90
Strato 1b Neolitico antico			8.040 ± 180
Strato 2 Mesolitico 2.00		*Praemegaceros cazioti* *Cynotherium sardous* *Homo sapiens*	8.160 ± 130 8.750 ± 140 9.820 ± 140 11.040 ± 140
Strato 3 Paleolitico superiore 2.50		*Prolagus sardus* *Praemegaceros cazioti* *Cynotherium sardous* *Homo sapiens*	11.980 ± 140 13.530 ± 170 14.370 ± 190 13.510 ± 180 13.620 ± 180

LA STRATIGRAFIA

La stratigrafia presente nella trincea principale della sala 2 della Grotta Corbeddu può essere definita da manuale.
Il primo strato 1a documenta la frequentazione della cavità nel Neolitico medio (4.500-3.800 a.C.).
Una pavimentazione stalagmitica lo separa nettamente dai livelli successivi che risultano quindi sigillati e indisturbati.
Il successivo livello 1b è caratterizzato dalla presenza dell'uomo del Neolitico antico (6.500-4.500 a.C.).
Il sottostante strato 2, ricchissimo di breccia mista ad argilla, contiene resti fossili di fauna endemica, oggi estinta e resti scheletrici umani inquadrabili nel Mesolitico sardo.
Infine lo strato 3, prevalentemente composto da un deposito di argilla con fossili della fauna pleistocenica sarda, ha restituito anche una falange umana risalente a circa 22 mila anni da oggi e quindi attribuibile al Paleolitico superiore.



GROTTA CORBEDDU

Gli interventi di scavo 1982-2000

STRATIGRAFIA	Metri dal punto 0 di riferimento	Datazione C_{14} da oggi
Strato 1a	1.00	
Strato 1b	Livello stalagmitico	
Strato 2	Breccia calcarea in matrice argillosa 2.00	
Strato 3	Breccia calcarea in matrice argillosa 3.00 Argilla ⇦ Falange umana (ca. 22 mila anni da oggi) 4.00 Argilla 5.00 Argilla 6.00	30700 ± 1200/1000 42000 ± 3000/2000

Falange umana dalla sala 2
a-veduta prossimale
b-veduta dorsale
c-veduta palmare

I FOSSILI UMANI

Nel corso delle campagne di scavo del 1983 e 1984 sono stati rinvenuti due resti fossili umani, un temporale e un mascellare superiore, nello strato 2 della sala 2.
I reperti umani sono i primi rinvenuti in associazione a fauna endemica insulare del Pleistocene superiore.
Le caratteristiche riscontrate sono i molari estremamente grandi e i piccoli incisivi, una particolare combinazione sconosciuta nell'*Homo sapiens* che suggerisce un uso intenso dell'apparato masticatorio.
Questa morfologia peculiare può essere segno di endemismo, il risultato cioè dell'isolamento in Sardegna di una popolazione umana del Paleolitico superiore.
Nel 1993, nello strato 3 di un saggio in profondità della potenza di 6 metri, all'ingresso della sala 2, ha restituito un frammento di falange umana, a una profondità di circa 3,5 metri, da un livello datato al carbonio quattordici 22 mila anni fa.

STRATIGRAFIA DELLA SALA 2

Datazioni al C^{14} da oggi

6.490 ± 90
8.040 ± 180
8.160 ± 130
8.750 ± 140
9.820 ± 140
11.040 ± 140
11.980 ± 140
13.530 ± 170
14.370 ± 190
13.510 ± 180
13.620 ± 180

Emimascellare umano

Temporale sinistro umano

Emimascellare umano in corso di scavo

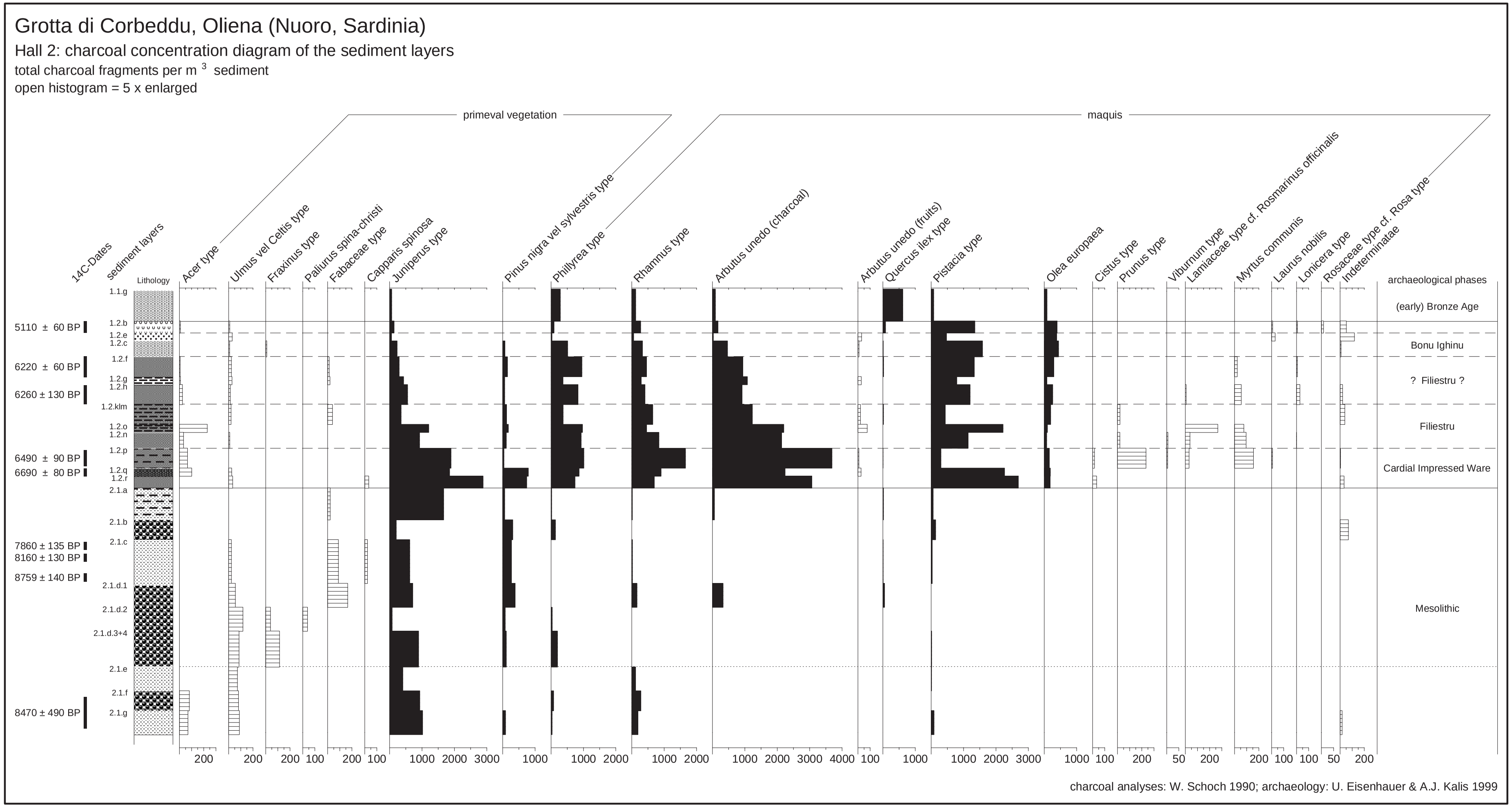


Fig. 2 Diagram of the charcoal concentration per m³ in the Holocene sediments of Hall 2 in Corbeddu Cave.

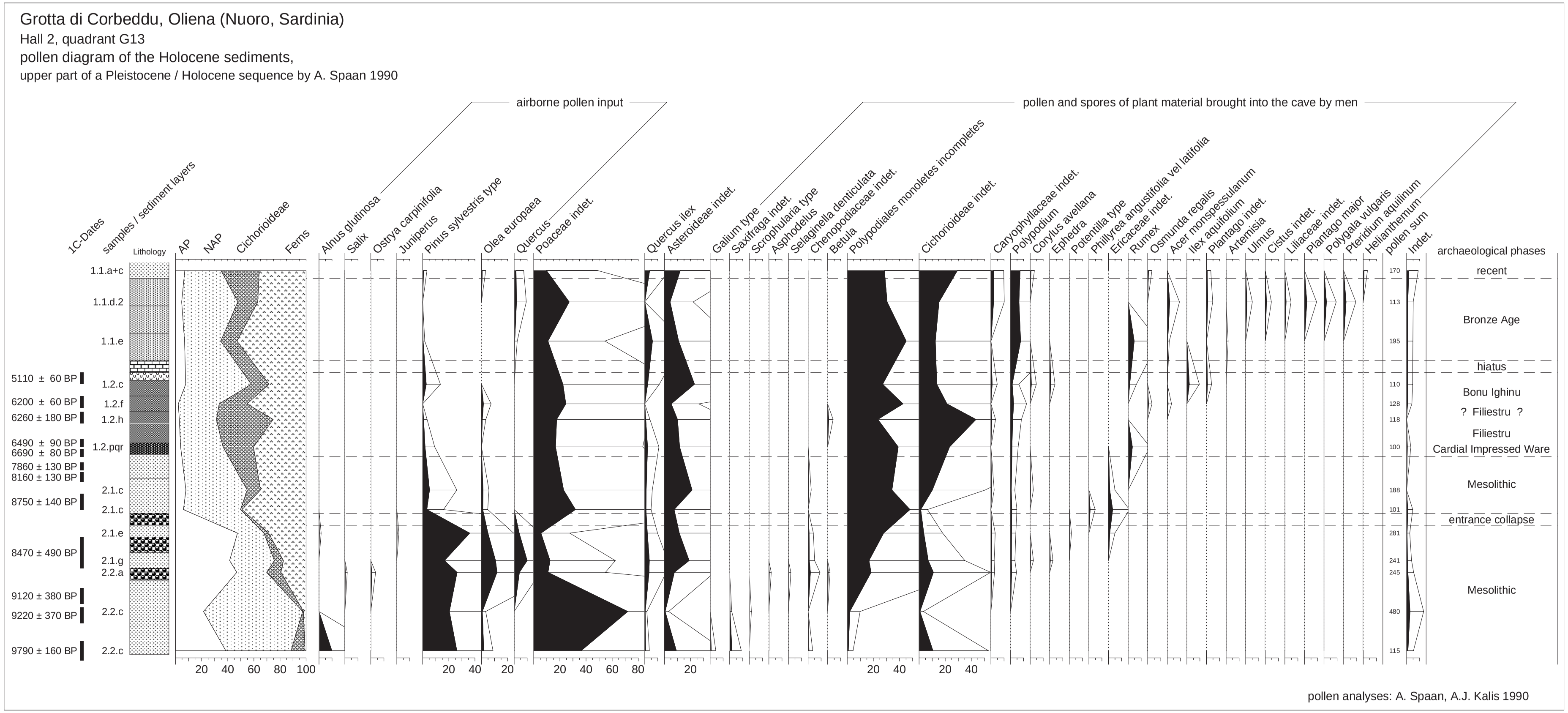
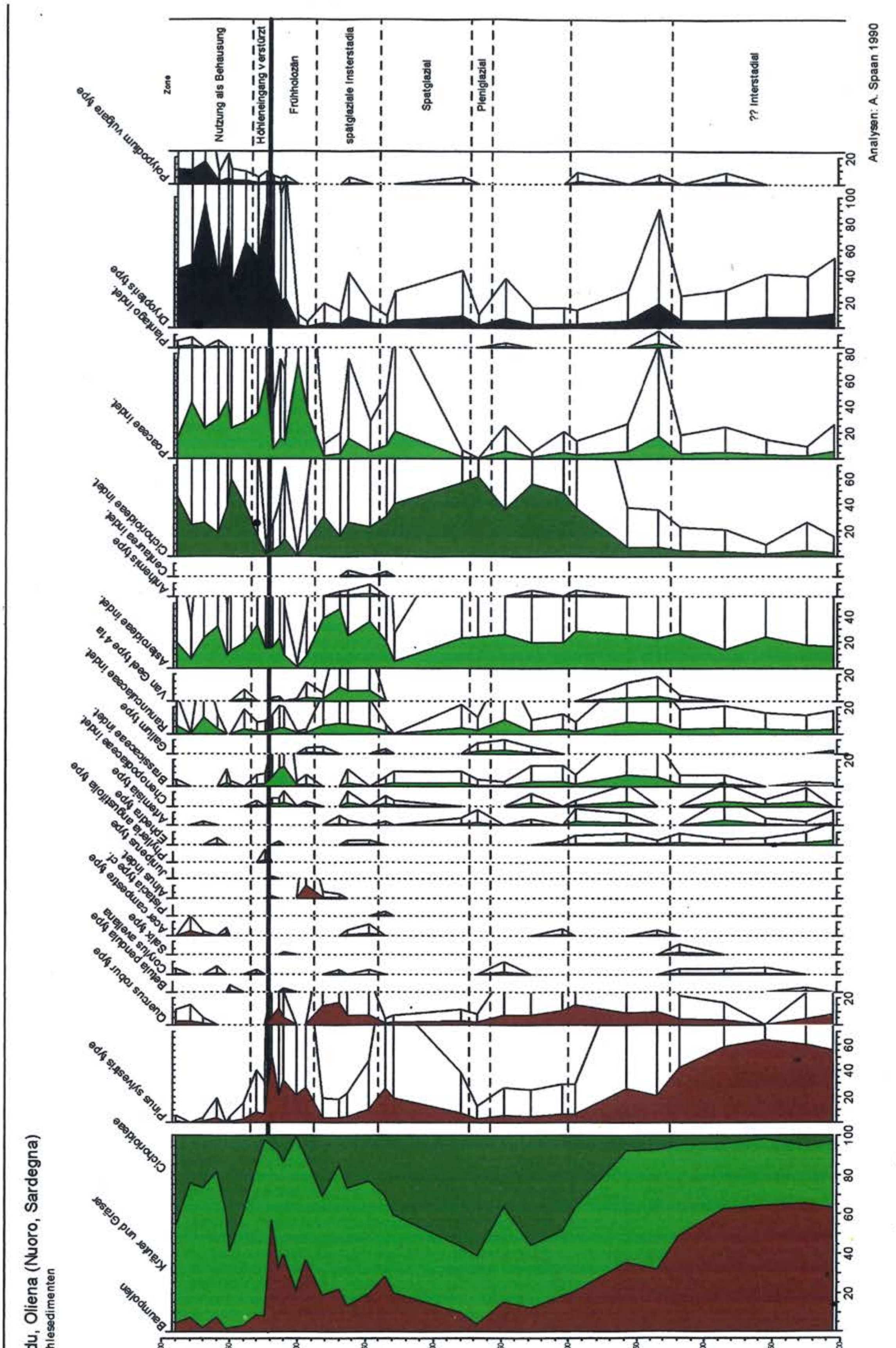
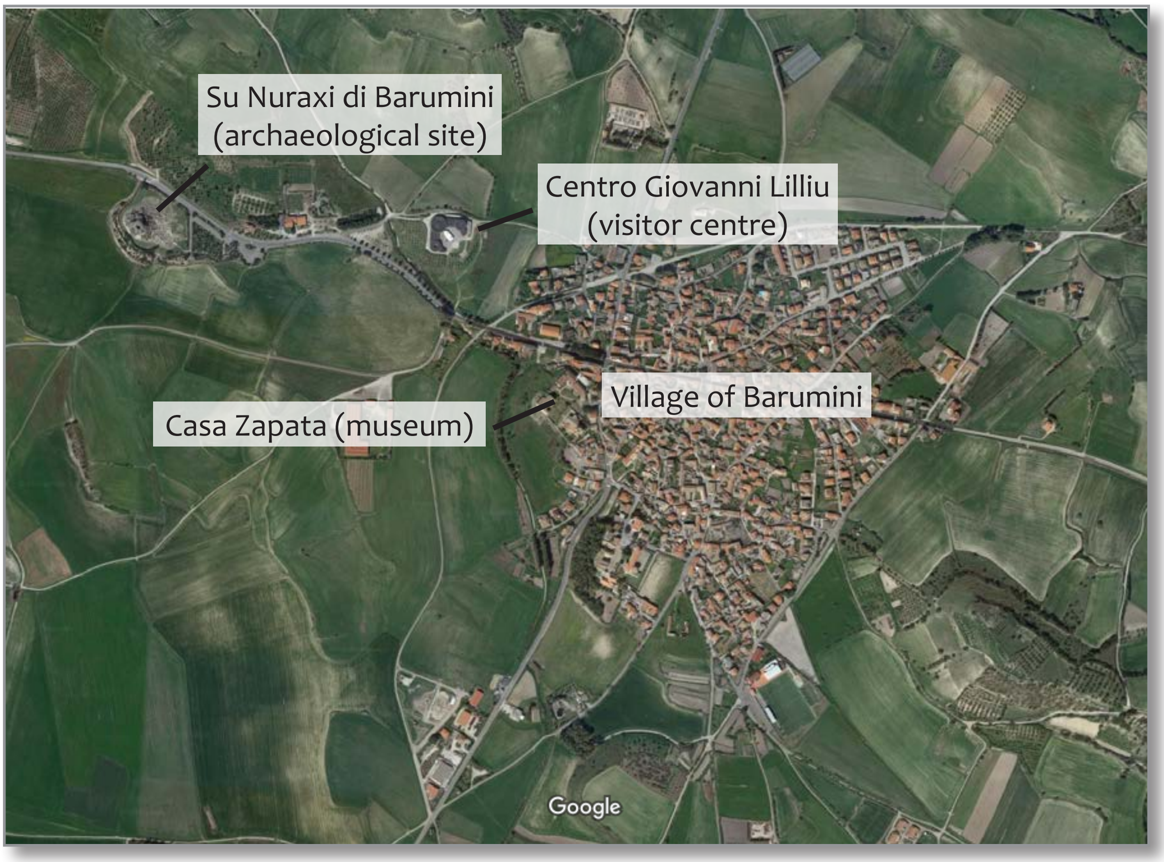


Fig. 22 Pollen diagram of the Holocene sediments of Hall 2 in Corbeddu Cave.

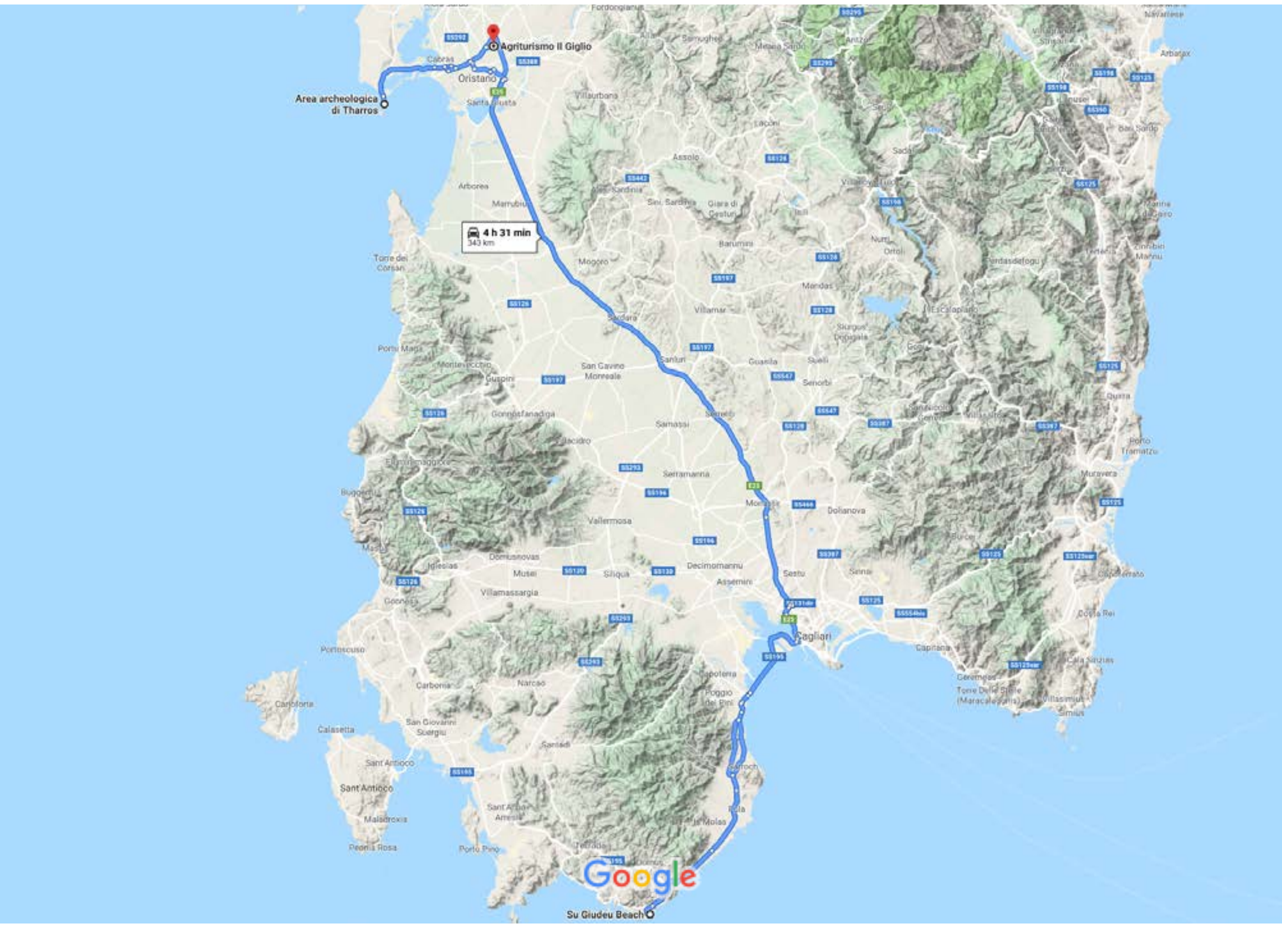

Grotta su Corbeddu, Oliena (Nuoro, Sardegna)
Pollendiagramm der Höhlesedimenten
Ausgewählte Pollentypen
Baumpollen
Kräuter und Gräser
Cichorioideae
Pinus sylvestris type
Quercus robur type
Betula pendula type
Corylus avellana
Salix type
Acer campestre type
Pistacia type cf.
Alnus indet.
Juniperus type
Phillyrea angustifolia type
Ephedra type
Artemisia type
Chenopodiaceae
Brassicaceae indet.
Galium type
Ranunculaceae indet.
Van Geel type 4-1a
Asteroideae indet.
Anthemis type
Centaurea indet.
Cichorioideae indet.
Poaceae indet.
Plantago indet.
Dryopteris type
Polypodium vulgare type
Zone
Nutzung als Behausung
Höhleneingang verstürzt
Frühholozän
spätglaziale Insterstadia
Spätglazial
Pleniglazial
?? Interstadial
Analysen: A. Spaan 1990
Dates
8 750 ± 140 BP
9 790 ± 160 BP
11 980 ± 140 BP
13 530 ± 170 BP
13 620 ± 180 BP
13 510 ± 180 BP
14 370 ± 190 BP
15 700 ± 200 BP
30 700 ± 1200 BP
42000 ± 3000 BP
Depth
100
150
200
250
300
350
400
450
500
550
600
20
40
60
80
100

Su Nuraxi di Barumini



Thursday 05.09.2019

7:30	Breakfast at Agriturismo il Giglio
8:30	**Departure** to Chia
11:00	**Stagno di Chia**: Holocene vegetation dynamics at Chia, southern Sardinia (César Morales del Molino)
12:00	Lunch at the beach at Spiaggia di Chia
13:30	Departure to Tharros
16:30	**Laguna di Mistras** Vegetation change and human impact (Erika Gobet & Christoph Schwörer)
17:30	Visit of the archaeological site of the Phoenician town of **Tharros**
18:45	Departure to Oristano
19:30	Arrival at Agriturismo il Giglio, Oristano
20:30	Dinner at Agriturismo il Giglio, Oristano



Stagno di Chia

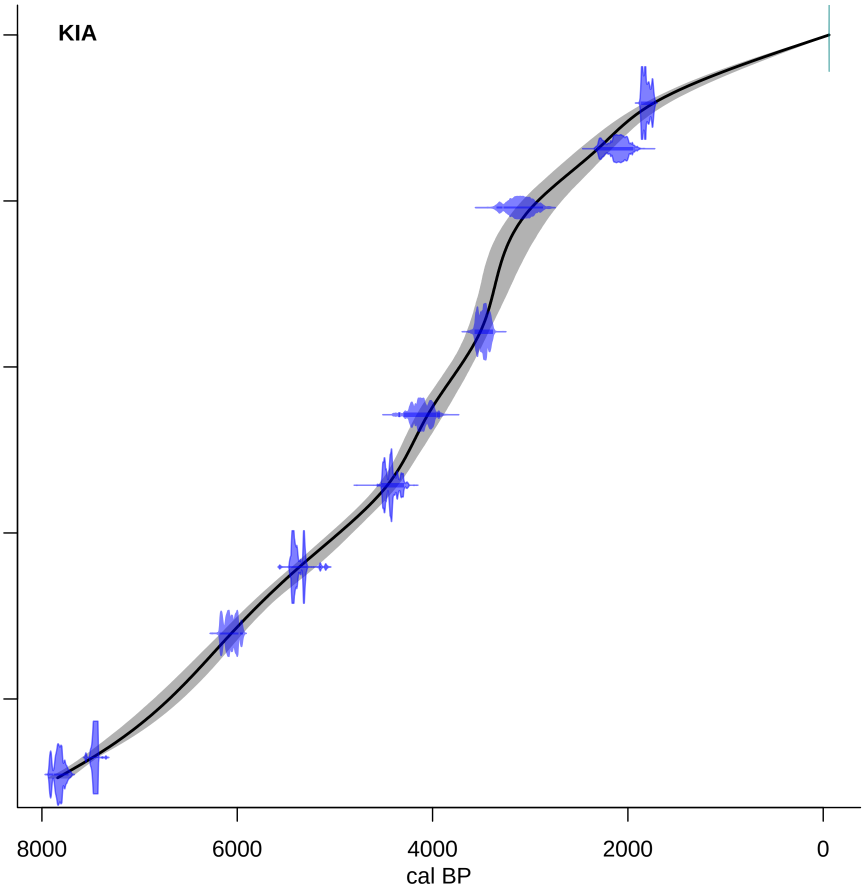


Figure 3. Age-depth model of Stagno di Chia based on 10 radiocarbon dates

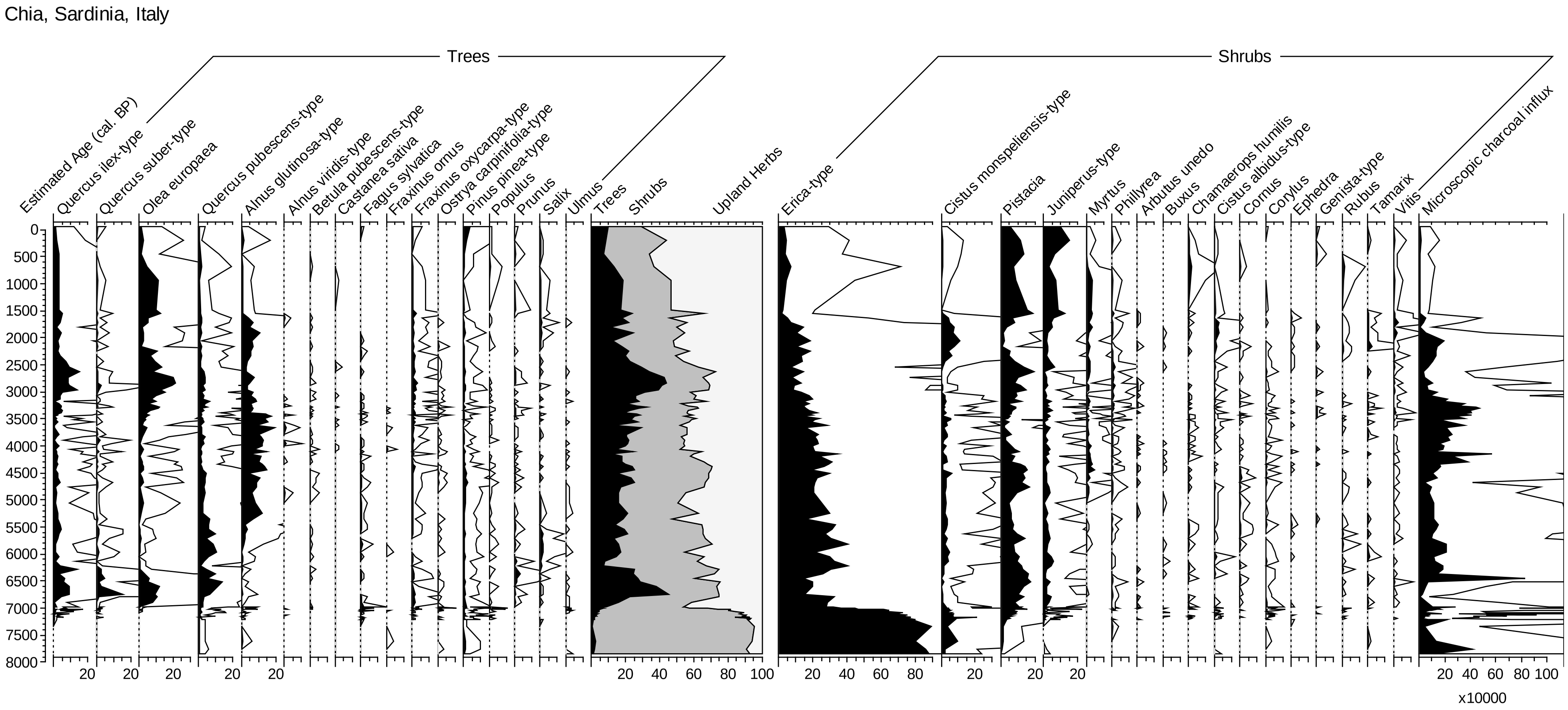


Figure 1. Arboreal pollen percentage diagram of Stagno di Chia, showing selected taxa only. Empty curves show 10x exaggeration.

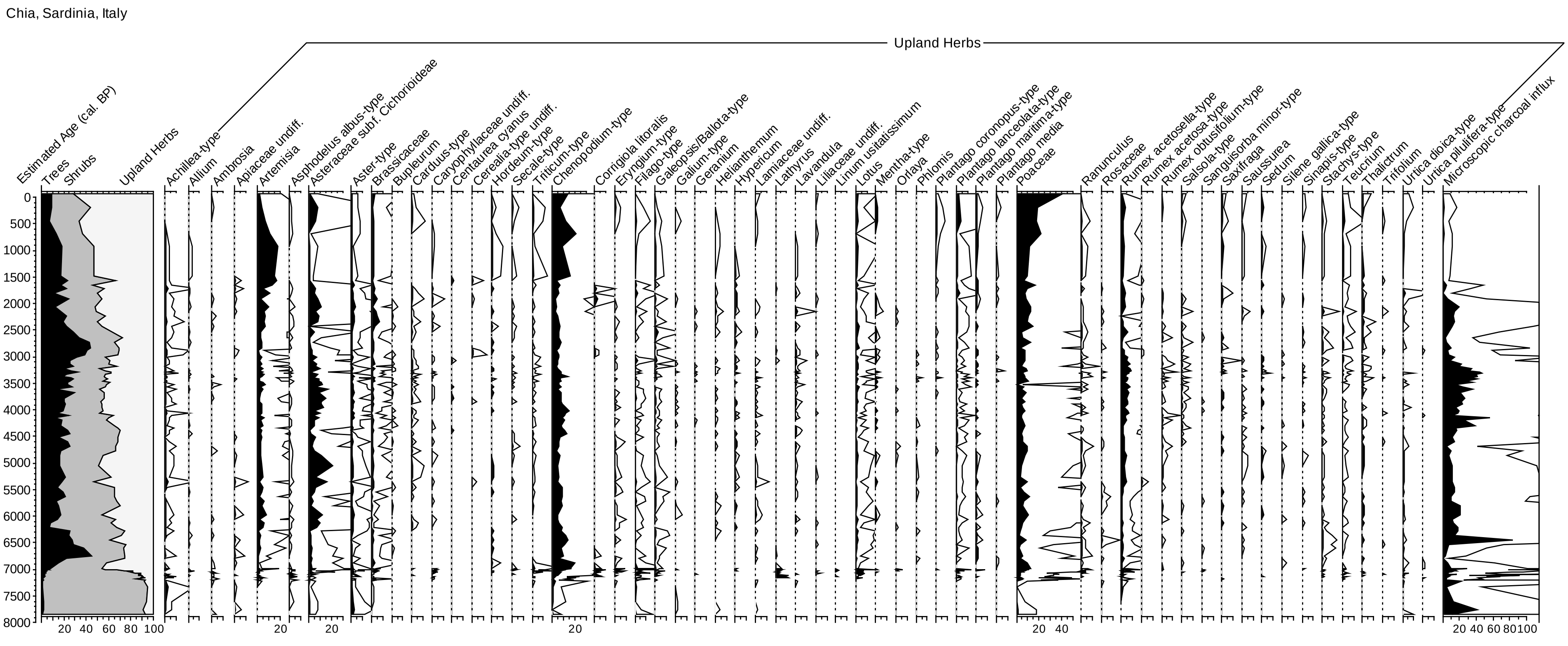


Figure 2. Pollen percentage diagram of Stagno di Chia, showing selected herbaceous taxa, as well as microscopic charcoal influx (particles cm^{-2} yr^{-1}). Empty curves show 10x exaggeration.

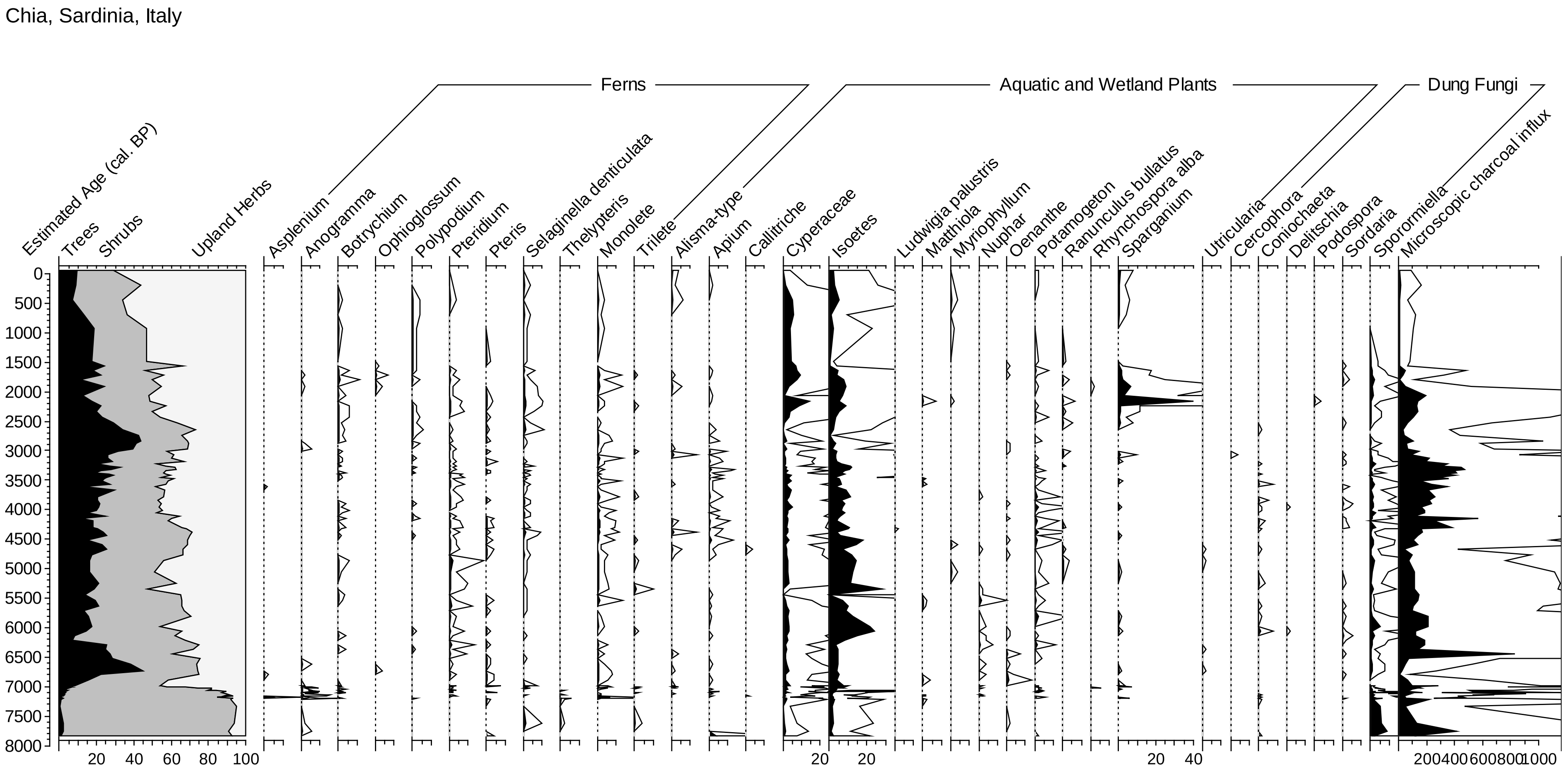


Figure 4. Pollen and spore percentage diagram of Stagno di Chia, showing selected aquatic and wetland taxa as well as ferns, coprophilous fungi and microscopic charcoal influx (particles cm^{-2} yr^{-1}). Empty curves show 10x exaggeration.

Laguna di Mistras / Tharros

Vegetation history in the region of the Mistras Lagoon

Dr. Federico di Rita, La Sapienza, University of Rome, Italy

Mistras Lagoon (Fig. 1) is a hypersaline lagoon of about 50 cm water depth covering a surface of ca. 600 ha. It is located along the north-western side of the Oristano Gulf, in the southern sector of the Sinis peninsula, close to the ancient city of Tharros, one of the most important Phoenician, Punic, and Roman archaeological sites in Sardinia.

The geological setting of this sector of the Sinis peninsula includes a Neogene sequence of volcanic and marine sedimentary rocks (marl, sandstone, and limestone), and Quaternary deposits along the coast (aeolian and marine sandstone), while the Oristano Gulf lies on Pliocene and Quaternary deposits of the Campidano graben.

The genesis of the Mistras Lagoon is linked to geomorphic dynamics that led to a progressive accretion of two littoral spits from Capo San Marco.

The archaeological evidence indicates an intense human presence in the area during the last few millennia. Neolithic settlements were mainly located around the Cabras Lagoon (Fig. 1) from which these communities drew their resources. In the Bronze Age, coinciding with the development of the Nuragic civilization (ca 2300-238 BC), there was a general increase of settlements throughout the territory.

The density of settlements was very high in the Middle Bronze Age (1700-1350 BC). During the time interval from the Final Bronze Age to the Early Iron Age (1200-730 BC) new villages were built near the lagoons and the coast. In the studied area, the Nuragic age ended with the establishment of Phoenician and Punic settlements.

The arrival of the Phoenicians, probably in the 8th century BC, changed the general structure of the territory also in connection with the abandonment of the Sinis peninsula by the Nuragic people. The presence of Phoenicians is attested manly in the city of Tharros, while it is rare inland and elsewhere along the coast. With the conquest by the Carthaginians in 510 BC, there was a new important occupation of the Sinis peninsula and Campidano plain. The Punic diffusion in the Sinis region further increased in the 4th and 3rd centuries BC because of the Carthaginian strategy that encouraged the intensive use of land for agricultural practices. During the Roman occupation, in 238 BC, the territory of Sinis underwent a slow Romanization over several centuries, although starting from the Imperial age a radical change occurred: most of the small rural villages disappeared possibly in favour of an urbanization process. In the Late Antiquity and Middle Ages (4th to 6th century AD) a gradual decline of the city of Tharros and a displacement of the population towards the interior regions occurred. The Sinis area was completely abandoned in the Middle Ages due to barbarian incursions.

The climate of the area is typically Mediterranean, with a marked dry summer season and a mean annual precipitation of around 500 mm. Most of the landscape surrounding the Mistras Lagoon is currently managed for agriculture, with rural environments dominated by cereal cultivations, vineyards and olive groves. The rocky coasts of the western sides of the Sinis peninsula are covered by a dense low evergreen scrubland rich in *Pistacia lentiscus, Cistus monspeliensis*, and *Euphorbia dendroides*. The present vegetation of the lagoon is characterised by marshy plants rich in different species of Amaranthaceae. A few individuals of *Chamaerops humilis* and *Thymelaea hirsuta* occur within the scrubland at the edge of the lagoon.

Pollen analysis was carried out on sediment samples taken at 10 cm interval between 420 and 180 cm depth from a 650 cm long sediment core (MTR1), which was drilled at the end of the central littoral spit of the Mistras Lagoon (Di Rita and Melis, 2013).

The chronology of the MTR1 core is based on four AMS radiocarbon dates carried out on bulk sediment samples at the NSF-Arizona AMS Laboratory. They provided an age of the pollen sequence spanning the interval 5300-1600 cal BP.

From the record, four main phases in the vegetation history can be recognized, marked by four local pollen zones, numbered from the base upwards and prefixed by the site abbreviation MTR-1 (Fig 2).

- Between **5300 and 4650 cal BP** (zone MTR1-1), the landscape surrounding the Mistras Lagoon was characterized by open vegetation consistent with an Amaranthaceae-dominated salt-marsh. The arboreal component, mainly represented by sclerophyllous evergreen taxa, presumably formed different woody vegetation formations, varying from open *Pistacia*-dominated scrublands, mostly located along the coast, to dense oak-dominated woodlands rich in *Erica*, mostly distributed in inland sectors, as also currently observed in the nearby Monti Ferru massif. Deciduous oaks and other deciduous taxa were also present but probably they played a marginal role in the local forest development. In this phase, scattered occurrences of cultivated and synanthropic plants suggest that human populations did not make an intensive use of the land. The relatively low fire frequency is consistent with a sporadic presence of local human settlements, partly caused by a rather unstable coastal environment.
- Between **4650 and 4000 cal BP** the Mistras lagoon area experienced significant environmental changes related to a rapid salt-marsh vegetation decline, caused by local hydrological and sedimentological processes, and a general increase in sclerophyllous communities, especially *Quercus ilex* (holm oaks), paralleled by a decline in both cork and deciduous oaks. The human impact is mainly testified by the occurrence of cereal type pollen.
- Between **4000 and 2050 cal BP**, the landscape kept rather stable vegetation conditions as suggested by the absence of dramatic changes in the AP/NAP diagram. Presumably, extensive open formations of Mediterranean maquis dominated by holm oaks were distributed in the coastal plain surrounding the lagoon. The herbaceous vegetation was mainly represented by salt-marsh plants, especially Amaranthaceae. *Ruppia* communities grew in the brackish water of the site. In this phase there was also remarkable development of synanthropic indicators, which paralleled a clear increase in fire frequency (Fig. 4), pointing to major human activity and land exploitation, favoured by more stable environmental conditions. This coincided with a considerable increase in the number of prehistoric and historic settlements in the whole Sinis peninsula, clearly enhanced by the marine and lagoonal resources and fertile soils in the area. Pollen data along with archaeobotanical evidence suggest a prevailing arable farming economy, devoted to *Vitis* and cereal exploitation, during the Nuragic phase until 2300 cal BP. Then, it was replaced by a prevailing stock rearing economy, testified by the increase in *Asphodelus, Carduus*, and *Plantago*, commonly found in pasturelands (Fig 3). The significant frequencies of *Glomus* in this phase may represent an evidence for soil erosion and downwash possibly induced by stock rearing.
- Between **2050 and 1600 cal BP** (zone MTR1-4), the pollen record of the Mistras Lagoon suggests both forest vegetation dynamics and salt-marsh vegetation changes. The dramatic increase in Amaranthaceae between ca 2050 and 1900 cal BP is consistent with an expansion of the salt-mash, probably related to the transition from a lagoon with mixed marine/fluvial influence to a lagoon with marine influence (Fig 3). This hydrological process was also accompanied by an increase in sand and gravel fractions in the sediments, probably contributing to a drop of pollen concentrations and palynological richness. An increase in *Pistacia*-dominated vegetation was presumably related to a new development of evergreen scrubland along the rocky coastal belt. This phase was also characterized by a clear reduction of anthropogenic indicators and a general decrease in fire frequency, suggesting a less intensive human impact on the landscape. This is consistent with the documented abandonment of the rural villages in favour of a slow urbanization, experienced by the Sinis territory since Imperial times. However, the continuous curve of *Plantago* and the scattered records of *Vitis*, cereals and Cannabaceae point to a possible local presence of farming activities. Particularly in this phase, the increase in *Q. suber*, an important floristic element of the natural sclerophyllous vegetation, may provide evidence of a regional enhancement of the cork oak exploitation since the Romans times.

Reference:

Di Rita, F., Melis, R.T., 2013. The cultural landscape near the ancient city of Tharros (central West Sardinia): vegetation changes and human impact. Journal of Archaeological Science 40:4271–4282.

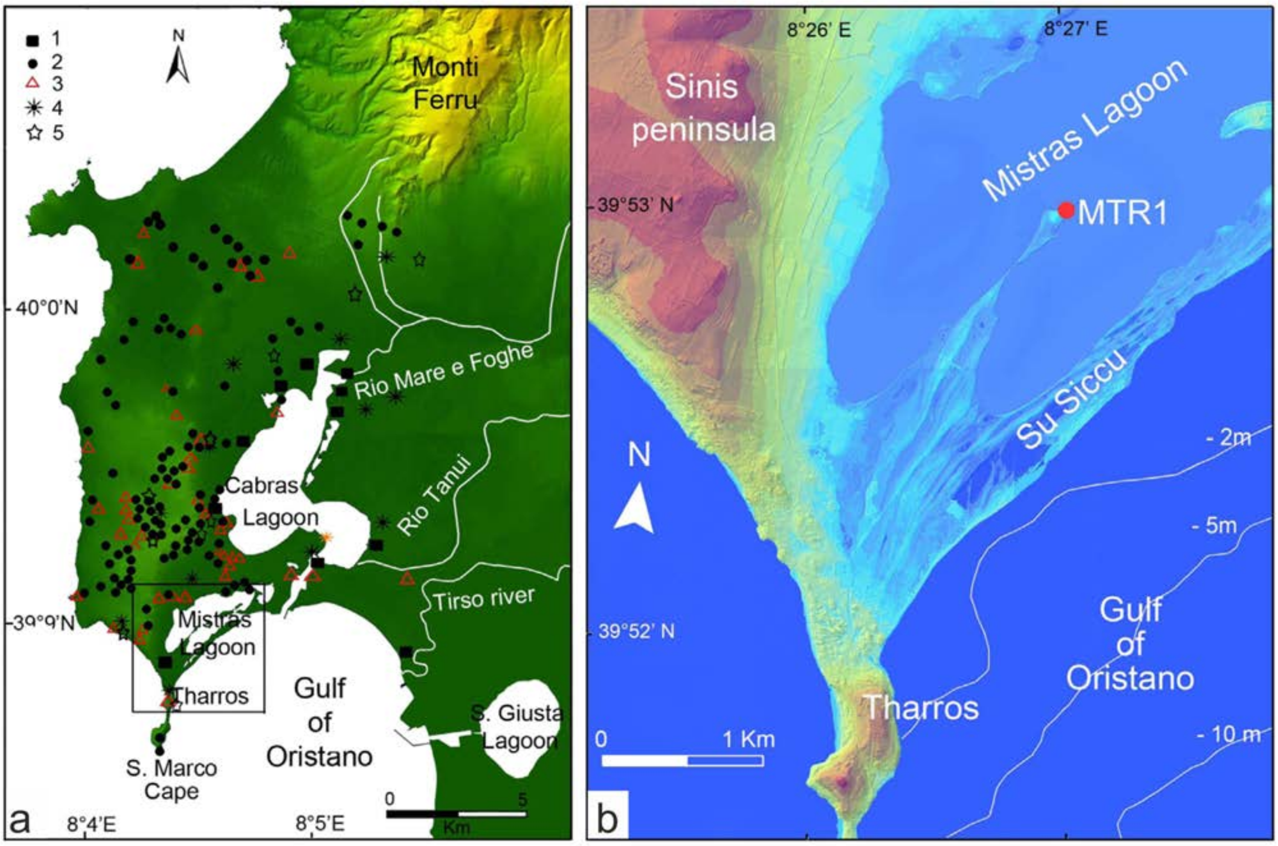


Fig. 1 a) Study area in the Sardinian central west coast and distribution of archaeological sites: 1, Neolithic villages; 2, Nuraghe (Bronze Age); 3, Nuragic villages (Bronze Age); 4, Punic settlements; 5, Roman settlements. Fig. 1 b) Location of the MTR1 core in the Mistras Lagoon.

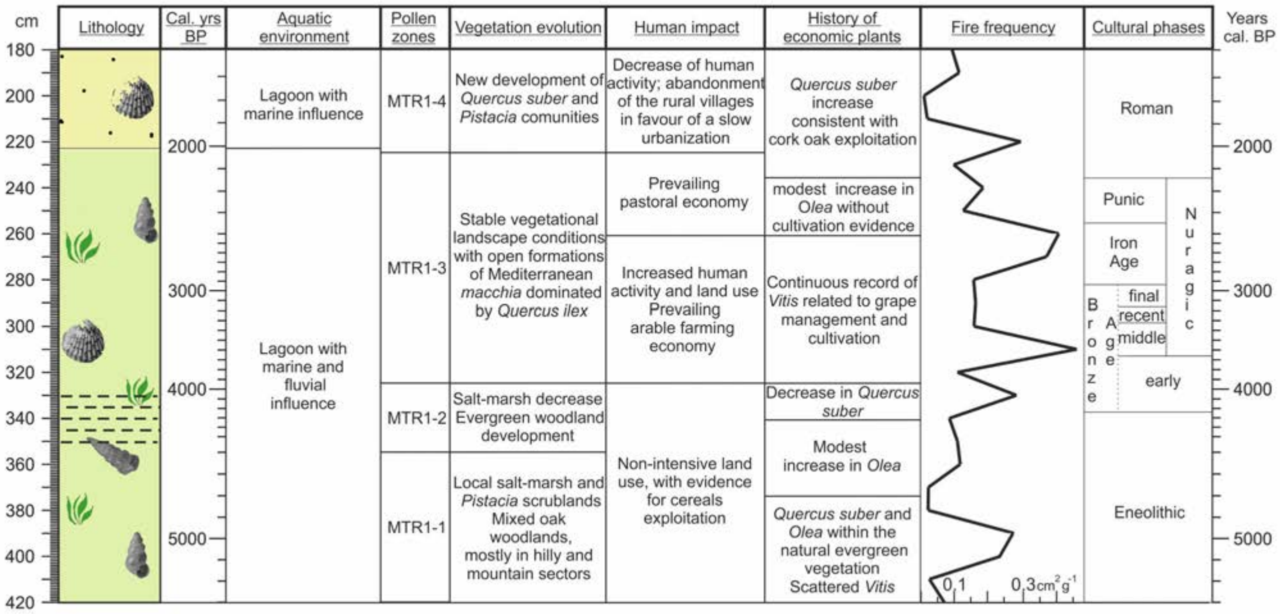


Fig. 3. Synoptic table with timing and nature of key environmental changes reconstructed from the Mistras Lagoon record.

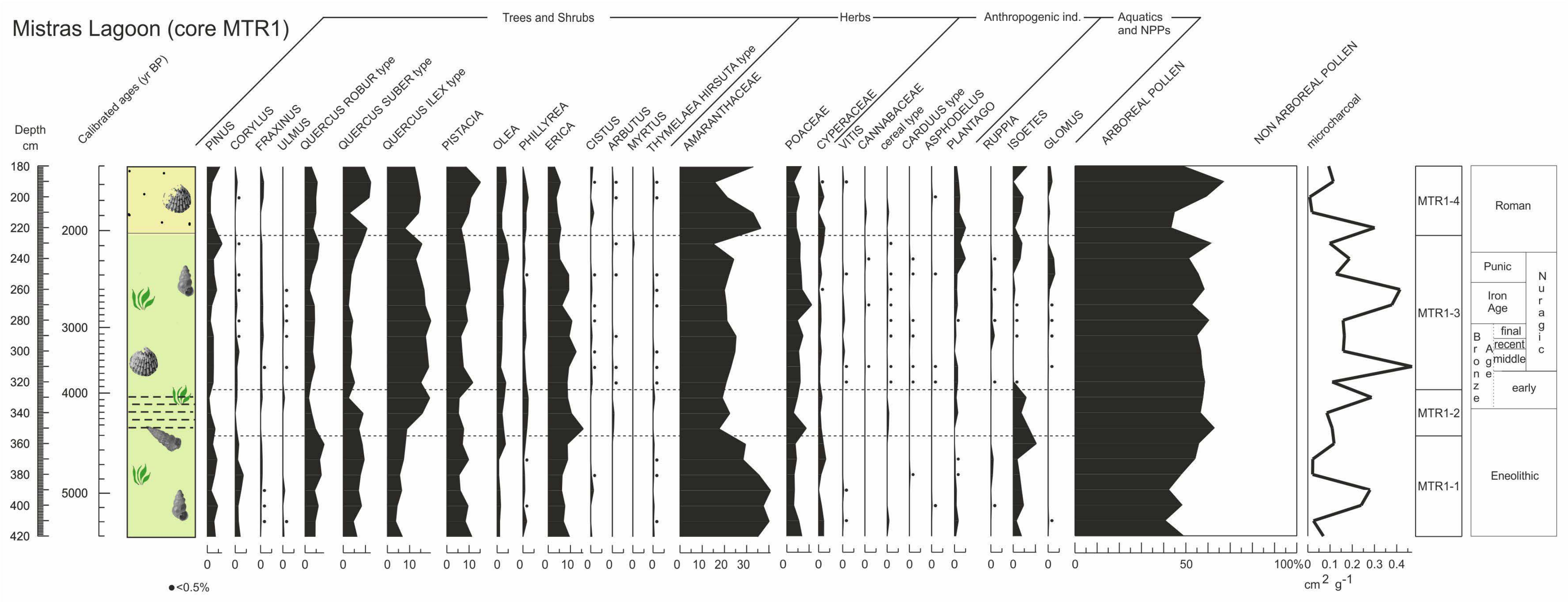
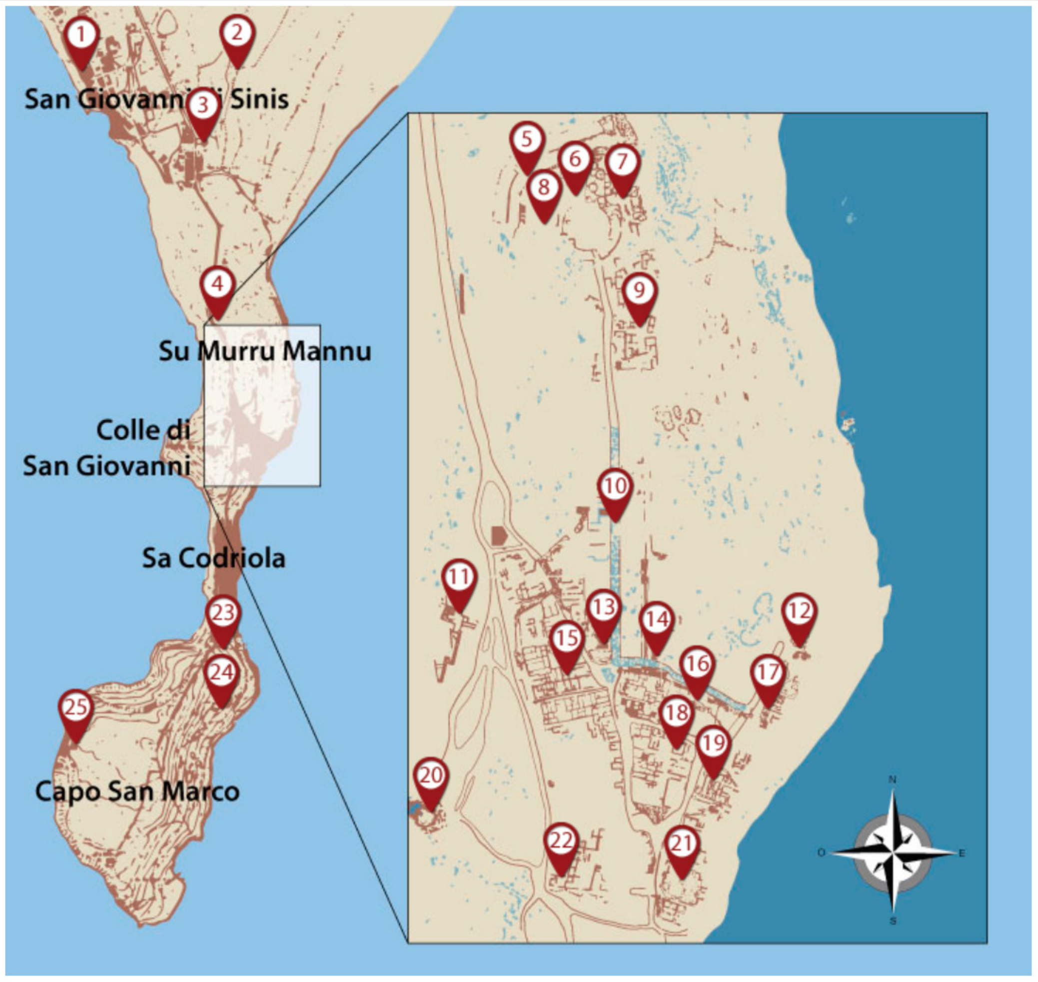


Fig. 2. Pollen percentage diagram of selected taxa and microcharcoal concentrations from the Mistras Lagoon (MTR1). The table at the right hand of the diagram shows the cultural phases.

History of Tharros



The city of Tharros was probably founded by the Phoenicians at the end of the 8th century or possibly in the early 7th century BC in an area already populated during the Nuragic period (n. 7). The main evidence of the Phoenician colony of Tharros is represented by the necropolises and the tophet (n. 6), which was a typical Phoenician and Punic open air sanctuary or sacred burial area, because the settlement itself has not been located yet (it is currently an active archaeological site). The Phoenician necropolises are located in the area of Cape San Marco (n. 23) and the modern village of San Giovanni di Sinis (n. 1). In the necropolises cremated corpses, along with rich burial goods including jewelry, were buried in circular or elongated shaped pits dug into the sand. Since the 7th century BC, thousands of cinerary urns, containing the burnt bones and ashes of children and sacrificed animals, were deposited in the tophets together with hundreds of sandstone stelae, small votive monuments often representing small temples and divine symbols.

During the second half of the 6th century BC, Tharros was conquered by the Carthaginians, who constructed several new buildings, including the monumental temple and the city's defensive wall. During the 5th century BC, a handicraft district (n. 8) that specialized in iron metallurgy was created near the tophet in the west, at a time when the use of the sanctuary was increasing.

During the Punic period, the dead of Tharros were buried in a supine position, along with the typical vessels of the period and other personal objects, into chambers carved in the rock in the same funeral areas used during the Phoenician period.

The time between the Roman conquest of Sardinia (238 BC) and the end of the Roman Imperial age (5th century AD) was the period of greatest transformation for Tharros. During the Republican age

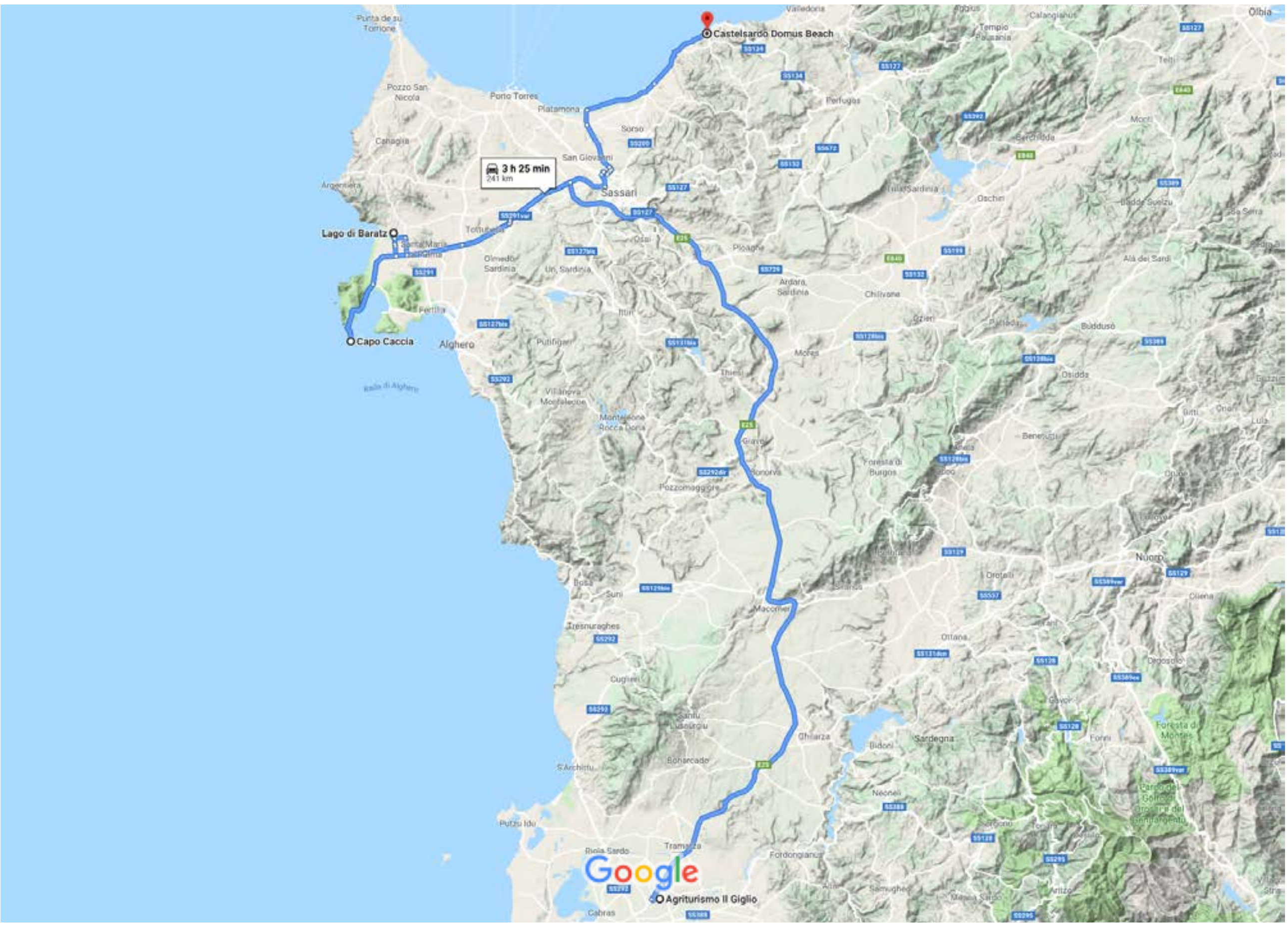
(2nd century BC), the fortifications of Su Murru Mannu (the great defensive wall, n. 5) were renovated and the so-called Temple K (n. 22) was built. By the 2nd century AD, a new urban system had been established with the construction of roads using slabs of basalt, a volcanic stone, and a very sophisticated sewer system that enabled the dumping of waste waters. Numerous large and grand public buildings were also constructed, among which were three thermal bath complexes (public baths: ns 14, 17, 21) and the Castellum Aquae (n. 13), a structure for distributing fresh water brought into the city from the aqueduct (n. 4). In this period, the funeral practices included both incineration and inhumation (burial of the body in a grave) and a variety of different types of tombs were used.

Unfortunately, during the early Christian period and the High Middle Ages, the principal Roman buildings and the thermal baths suffered severe degradation. This was primarily due to exposure to the elements and the destruction of the ancient structures to provide materials for new construction. A long period of decadence and a slow depopulation followed the raids of the Saracens, although Tharros remained the Episcopal see (the official church seat) until 1071, when the bishop transferred the see to Oristano, which marked the end of the ancient city of Tharros.

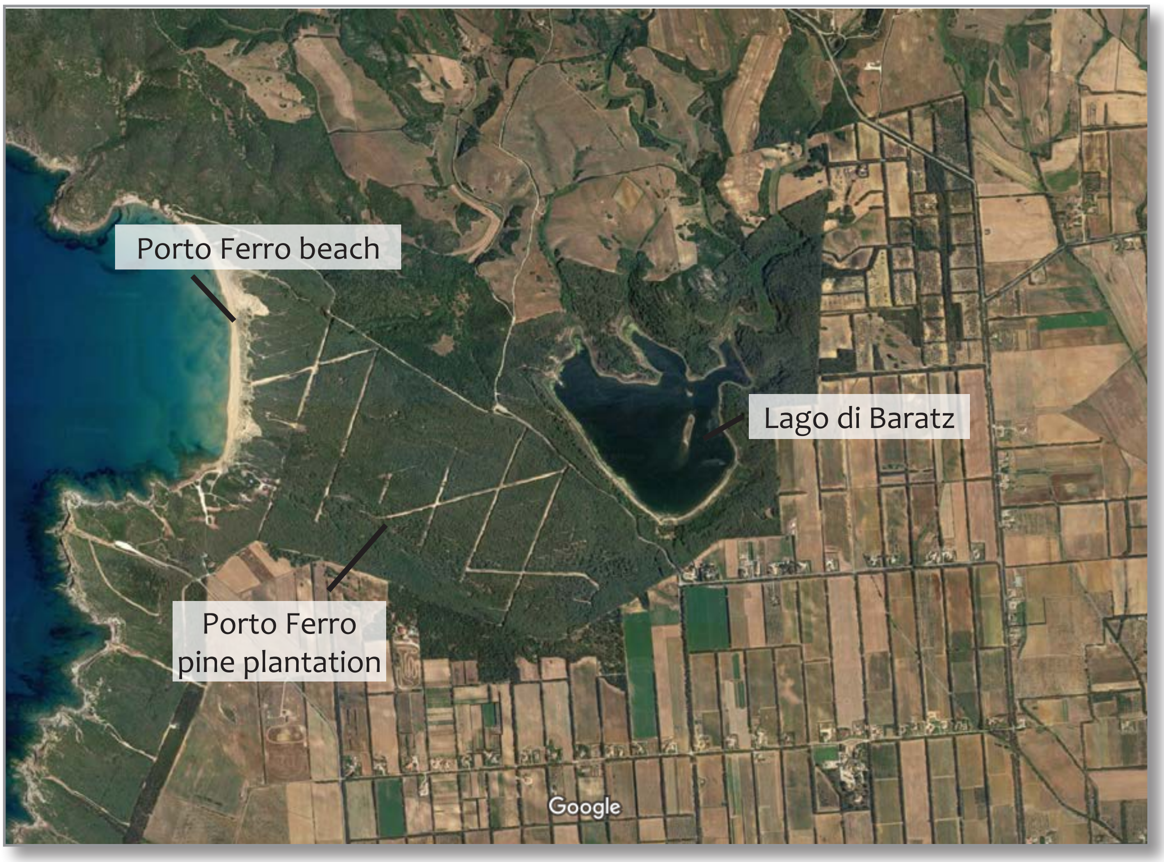
(source: www.tharros.sardegna.it/en/history-of-tharros/)

Friday 06.09.2019

8:00	Breakfast at Agriturismo il Giglio
9:00	**Departure** to Lago di Baratz
11:30	Holocene fire, vegetation and land use dynamics at **Lago di Baratz** (Erika Gobet)
13:00	Lunch at Lago di Baratz
14:00	Departure to Capo Caccia
15:00	Hike through coastal maquis with *Chamerops humilis* at **Capo Caccia**
16.30	Departure to Castelsardo
18.30	Arrival at Hotel Domus Beach, Castelsardo
20:00	Farewell dinner at Hotel Domus Beach, Castelsardo



Lago di Baratz



8000 years of climate, vegetation, fire, and land-use dynamics in the thermo-mediterranean vegetation belt of northern Sardinia (Italy)

Tiziana Pedrotta[1], Erika Gobet[1*], Christoph Schwörer[1*], Hendrik Vogel[2], Jacqueline F. N. van Leeuwen[1], Salvatore Pasta[3], Giorgia Beffa[1], Benjamin Amann[4], Christoph Butz[4], Elias Zwimpfer[1], César Morales-Molino[1], Daniele Colombaroli[1,5] , Paul Henne [1,6], Martin Grosjean[4], Flavio S. Anselmetti[2], Willy Tinner[1]

Abstract

Knowledge about the vegetation history of Mediterranean's second largest island Sardinia is scanty. We present a new 8100 years old sedimentary record from Lago di Baratz, North-West Sardinia. The vegetation and fire history are reconstructed by pollen, spores, macrofossils, charcoal analyses and environmental dynamics by XRF scanning and biogeochemistry. 8100-7500 cal. BP *Erica arborea* and *E. scoparia* woodlands dominated the landscape at the coastline, when fires were frequent. After 7500 cal. BP *Erica* communities were partially replaced by thermo-mediterranean shrubs, e.g. *Pistacia, Cistus,* and *Tamarix*, and to a lesser degree also by evergreen broadleaved trees (e.g. *Quercus ilex*) and fire incidence diminished. Subsequently, evergreen *Quercus* forests expanded in Northern Sardinia after 5500 cal BP. This forest expansion was interrupted around 5000 – 4500 cal. BP by a mass expansion of shrubs such as *Tamarix* and *Pistacia* together with increased fire activity followed by a rapid re-expansion of evergreen-oak forests with admixed olive trees. This coastal thermo-Mediterranean woodlands persisted until ca. 200 cal. BP when agricultural activities and fire disturbance increased. The general vegetation and fire dynamics at this site are very similar to those observed in the east of Sardinia. The vegetation around Lago di Baratz was similarly forested but with a higher share of *Q. ilex* and shrubs such as *Pistacia* and *Tamarix*, if compared to eastern Sardinia. Openland dominated by Poaceae was also more abundant in the west at Lago di Baratz than in eastern Sardinia. These local vegetational differences, were most probably a consequence of salinity and soil differences, in particular water carrying capacities. The mid and late Holocene expansion of thermomediterranean forests observed at several sites in northern Sardinia was likely controlled by increasing moisture availability, while land use led to a moderate increase of cultivated land after 3500 cal BP, when *Q. ilex* forests were anthropogenically reduced.

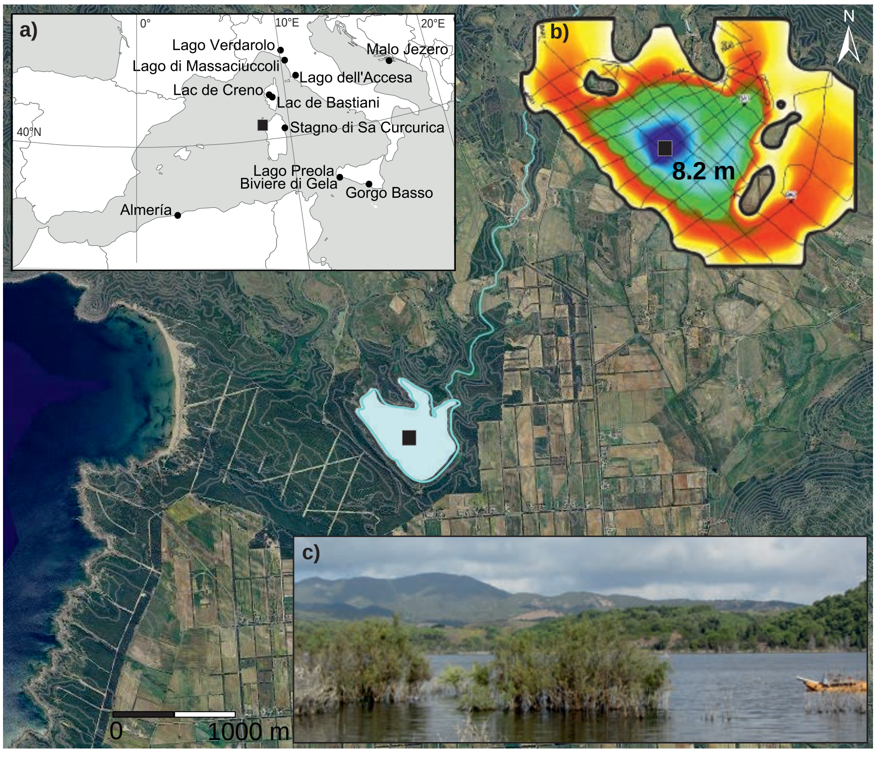


Figure 1. Map of the study area, including (a) overview of important Mediterranean paleoecological survey sites, (b) bathimetric map of Lago di Baratz with coring point (black square) and (c) Lago di Baratz view from the shore.

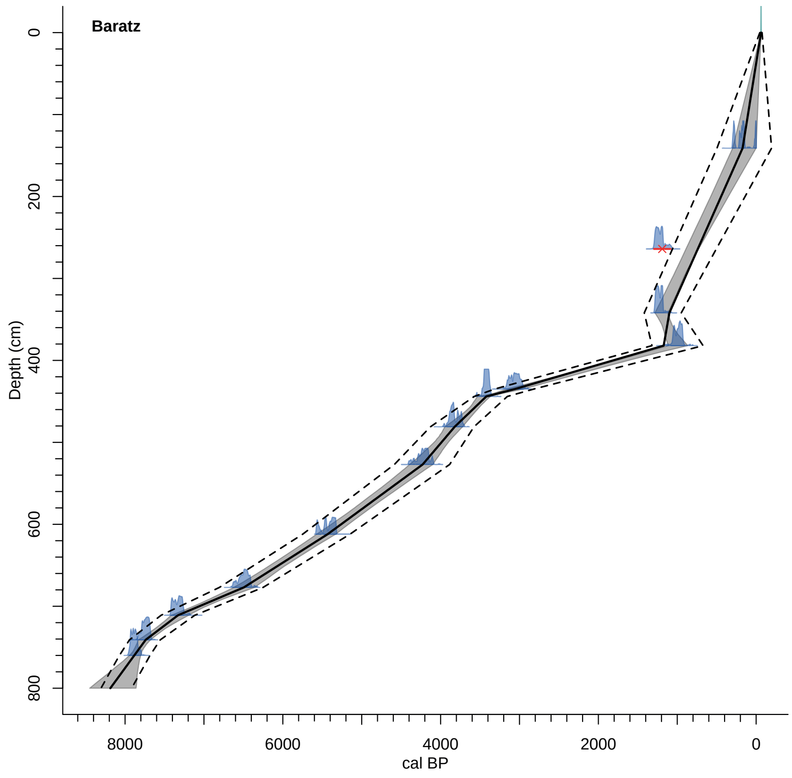


Figure 2. Depth-age model for core BRZ-D of Lago di Baratz (Italy) drawn with Clam 2.2 (Blaauw 2010) based on thirteen terrestrial macrofossil samples. The Model takes into account the 2-sigma confidence range of the calibrated ages (grey area) and the 95% confidence envelope of the generalized mixed effect regression (GAM, dotted lines, Heegaard et al. 2005).

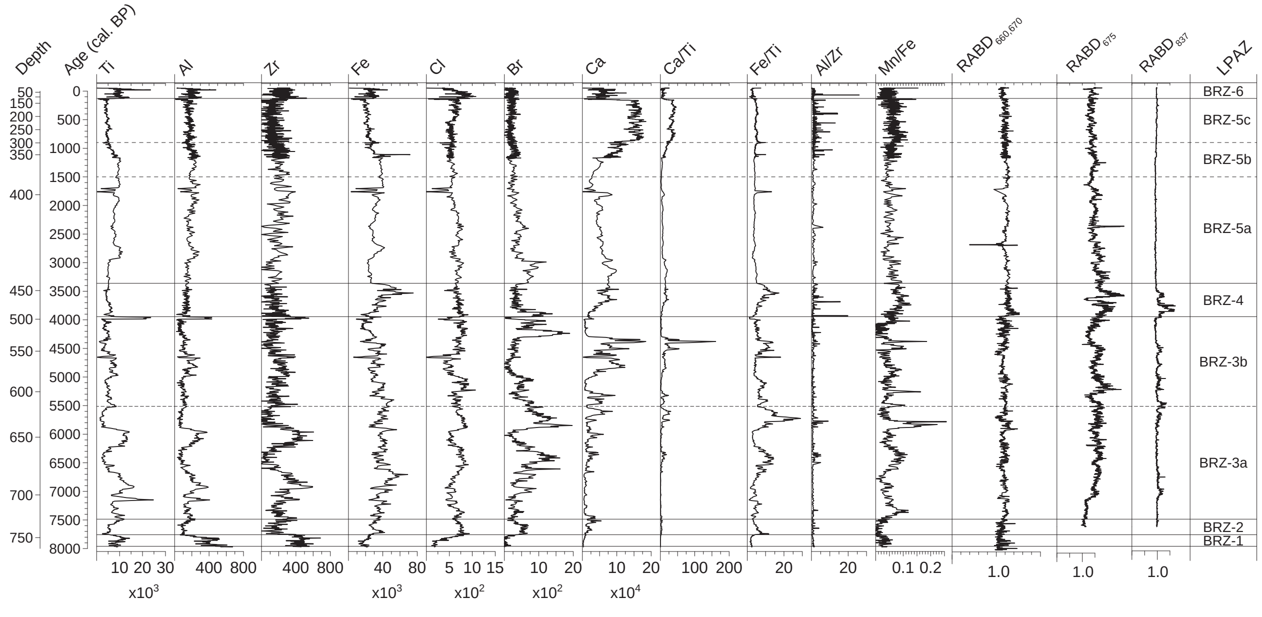


Figure 3. Elemental count data and ratios from X-ray fluorescence (XRF) analysis, chlorins from scanning reflectance spectroscopy (RABD660;670), selected chlorophyll-a and bacteriopheophytin-a spectra from hyperspectral scanning spectrometry (RABD675; RABD837).

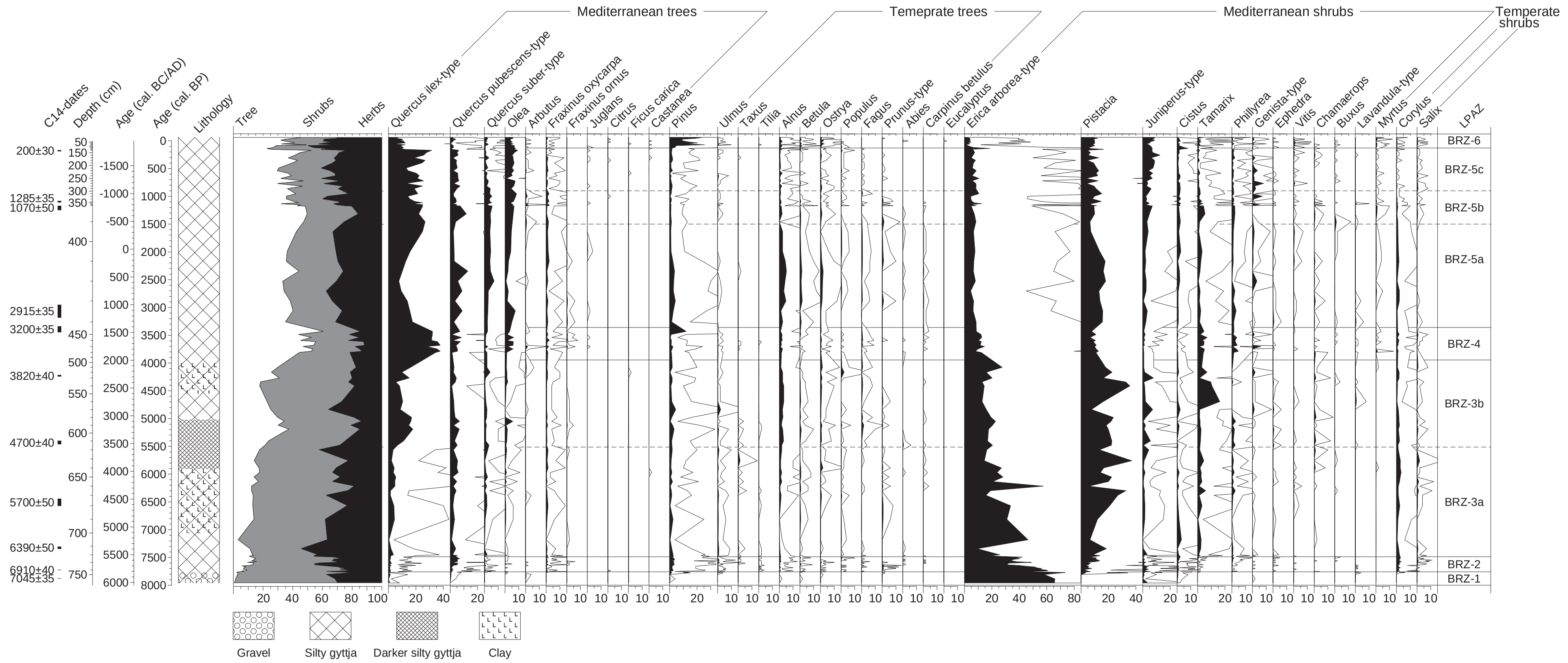


Figure 5. Selected arboreal (AP) and non-arboreal pollen percentages (NAP), microscopic charcoal influx profiles of core BRZ-D from Lago di Baratz (Italy), along with wetland and waterplants, spores and palynological richness (PRI), detrended-richness (DE-PRI), evenness (PIE). Curves show 10 x exaggerations. LPAZ: local pollen assemblage zones. Unbroken lines show statistically significant boundaries. Dashed lines represent ecologically relevant boundaries (not statistically significant).

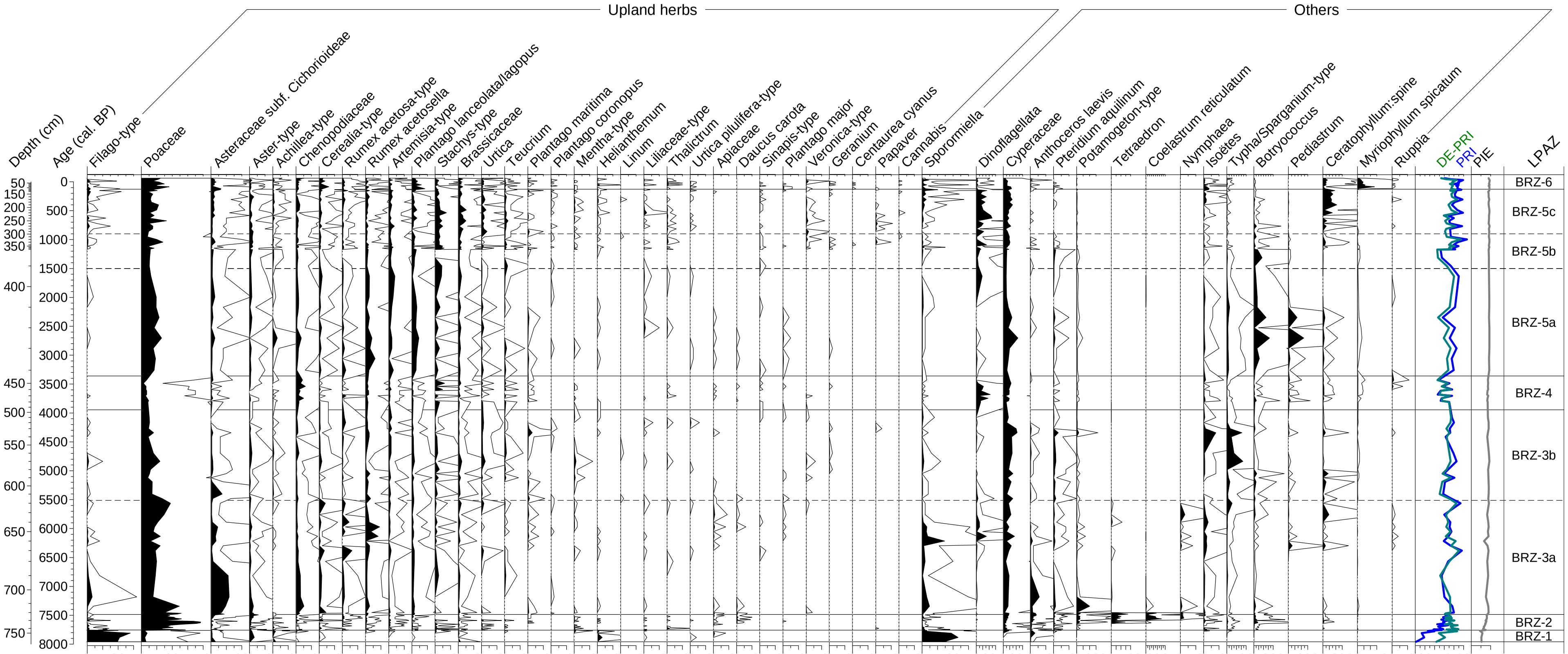


Figure 5. continued

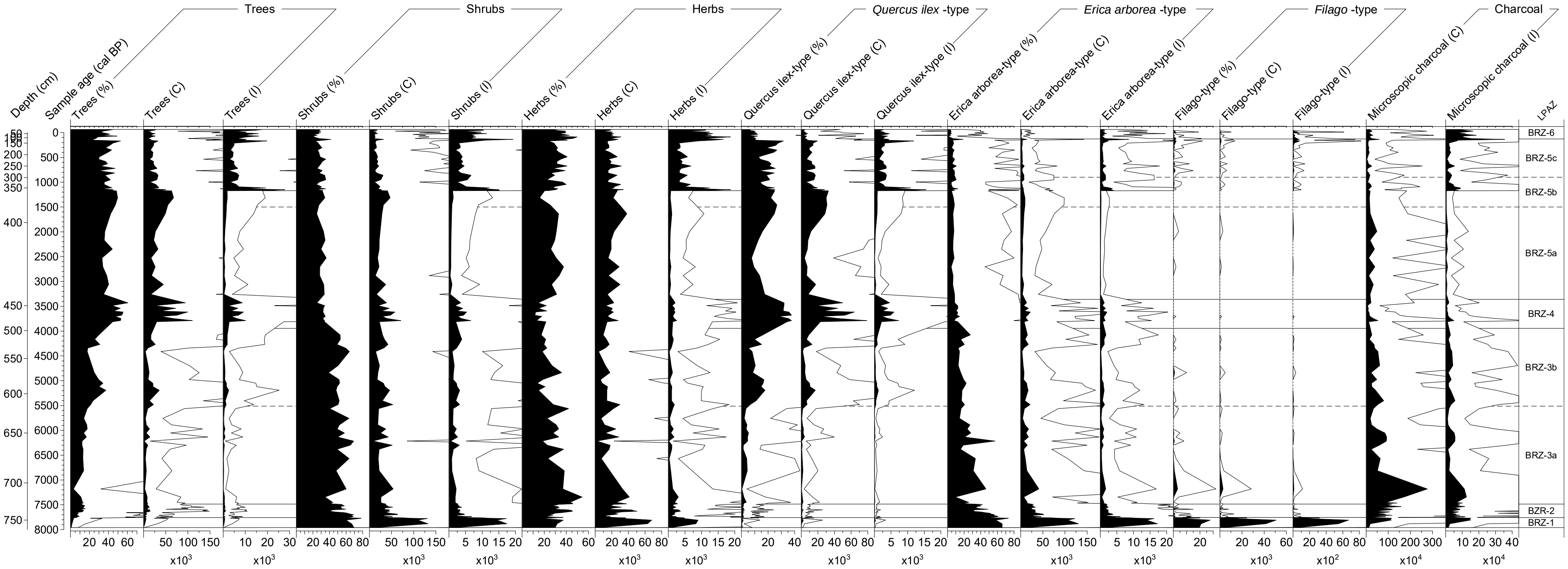


Figure 4. Pollen percentages, concentration and influx of tree, shrub, herbs sum and *Quercus ilex*-t., *Erica arborea*-t. and *Filago*-t. of core BRZ-D from Lago di Baratz (Italy), along with microscopic charcoal concentration and influx profiles. Curves show 10 x exaggerations. LPAZ: local pollen assemblage zones. Unbroken lines show statistically significant boundaries. Dashed lines represent ecologically relevant boundaries (not statistically significant).

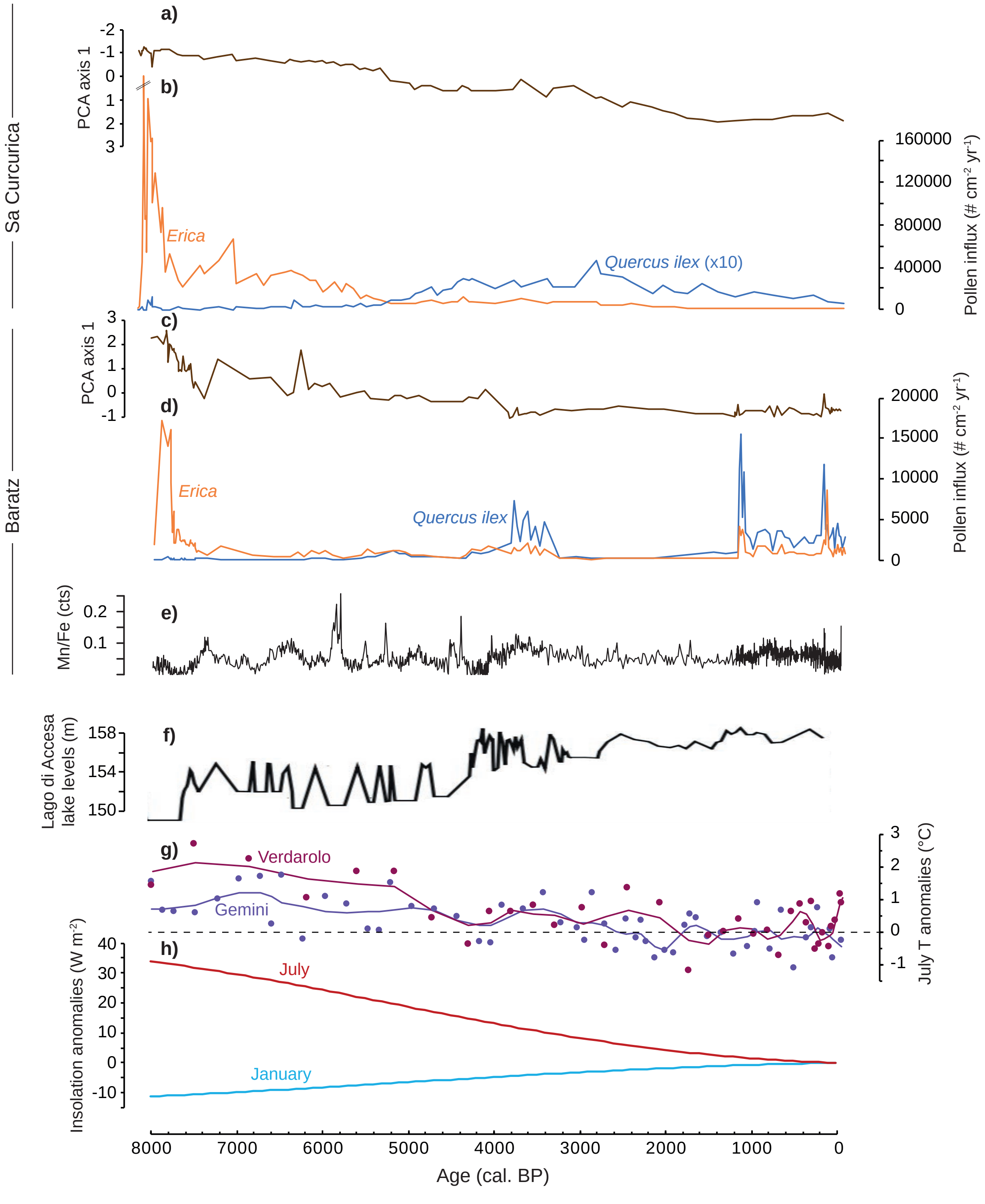


Figure 6. Comparison of ordination analyses, biotic and abiotic proxies from Lago di Baratz and Stagno di Sa Curcurica combined with different climate records: **a)** principal component analysis (PCA) axis 1 sample scores from Sa Curcurica; **b)** pollen influx of *Erica arborea* (orange) and *Quercus ilex* (blue) from Sa Curcurica (Beffa et al., 2015); **c)** principal component analysis (PCA) axis 1 sample scores from Lago di Baratz; **d)** pollen influxes of *Erica arborea* (orange) and *Quercus ilex* (blue) from Lago di Baratz; **e)** Magnesium to Iron ration from the XRF-analysis of Lago di Baratz indicating lake level variability; **f)** Accesa lake level reconstruction after Magny et al. (2007); **g)** chironomid-inferred july temperature reconstructions from Lago di Gemini and Lago di Verdarolo (Samartin et al. 2017); **h)** July and January insulation curves after Laskar et al. (2004).

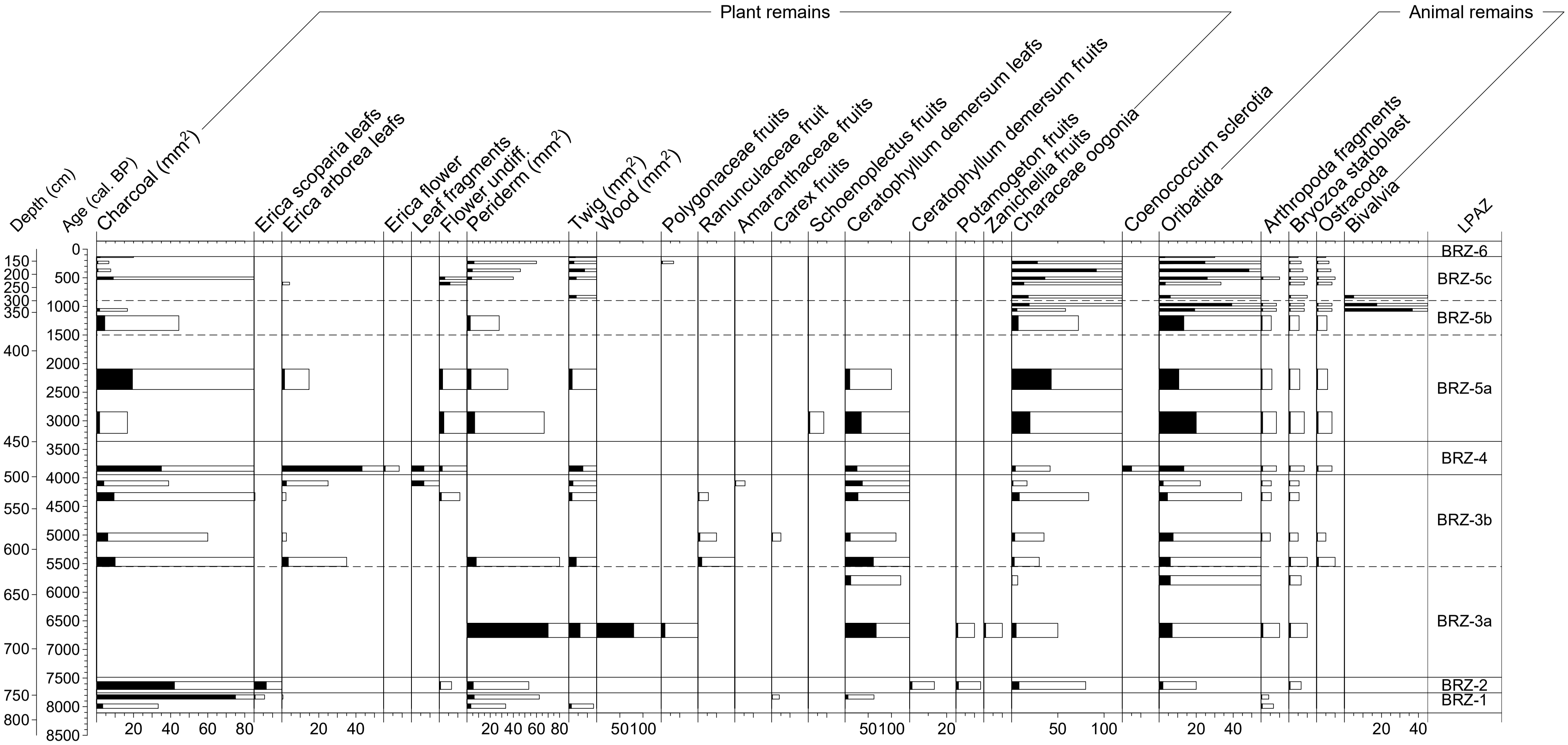


Figure 7. Plant-macrofossil concentration diagram of Lago di Baratz, Italy, including 21 samples (averaged at 10 cm3). Empty bars show 5 x exaggerations, LPAZ: local pollen zones (analysts: Elias Zwimpfer, Giorgia Beffa)

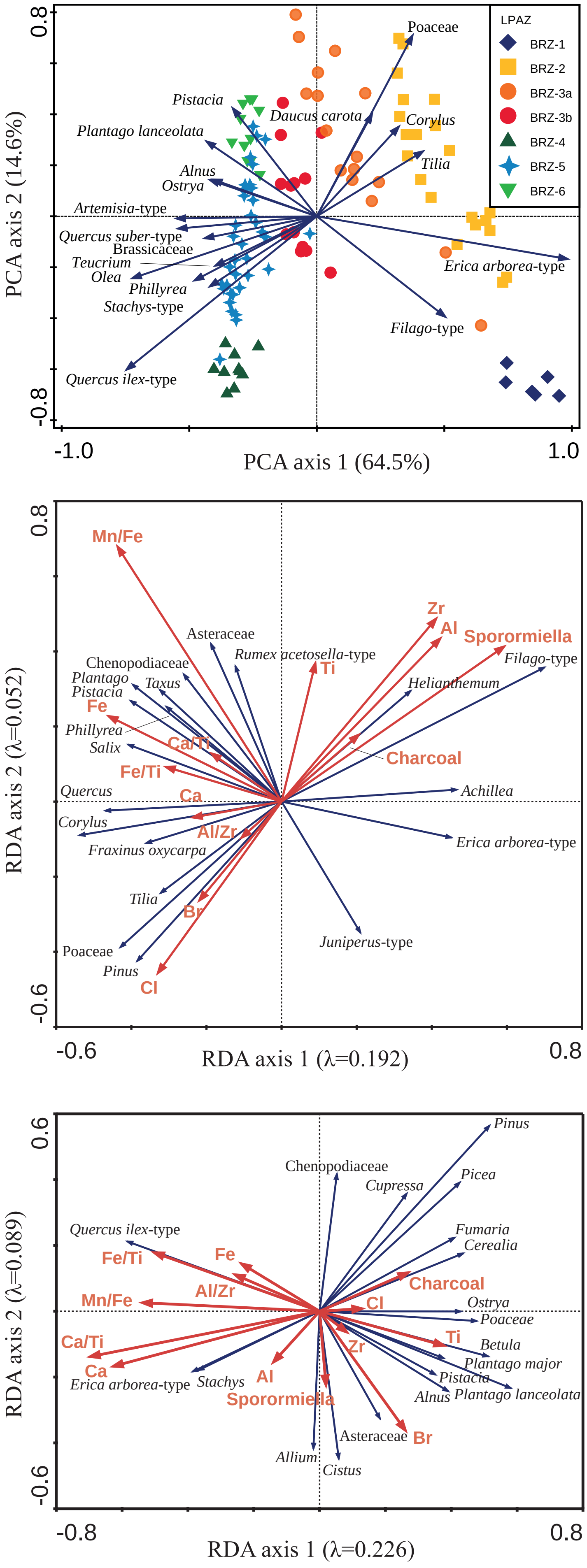


Figure 8. a) PCA scatterplot of samples and selected species from Lago di Baratz, Italy. The first axis explains 64.5 % of data variance, while the second axis explains 14.6 %. Samples are grouped according to the local pollen assemblage zones (BRZ 1-6; see legend in Figure 3); **b)** RDA biplots for 8100-4100 cal. BP and **c)** 4100 cal. BP – present respectively, showing the relationship between selected plant species and a total of ten explanatory variables. The two biotic variables include *Sporormiella* and microscopic charcoal. Eleven abiotic variables were obtained from elemental analyses (XRF, see materials and methods for more details).

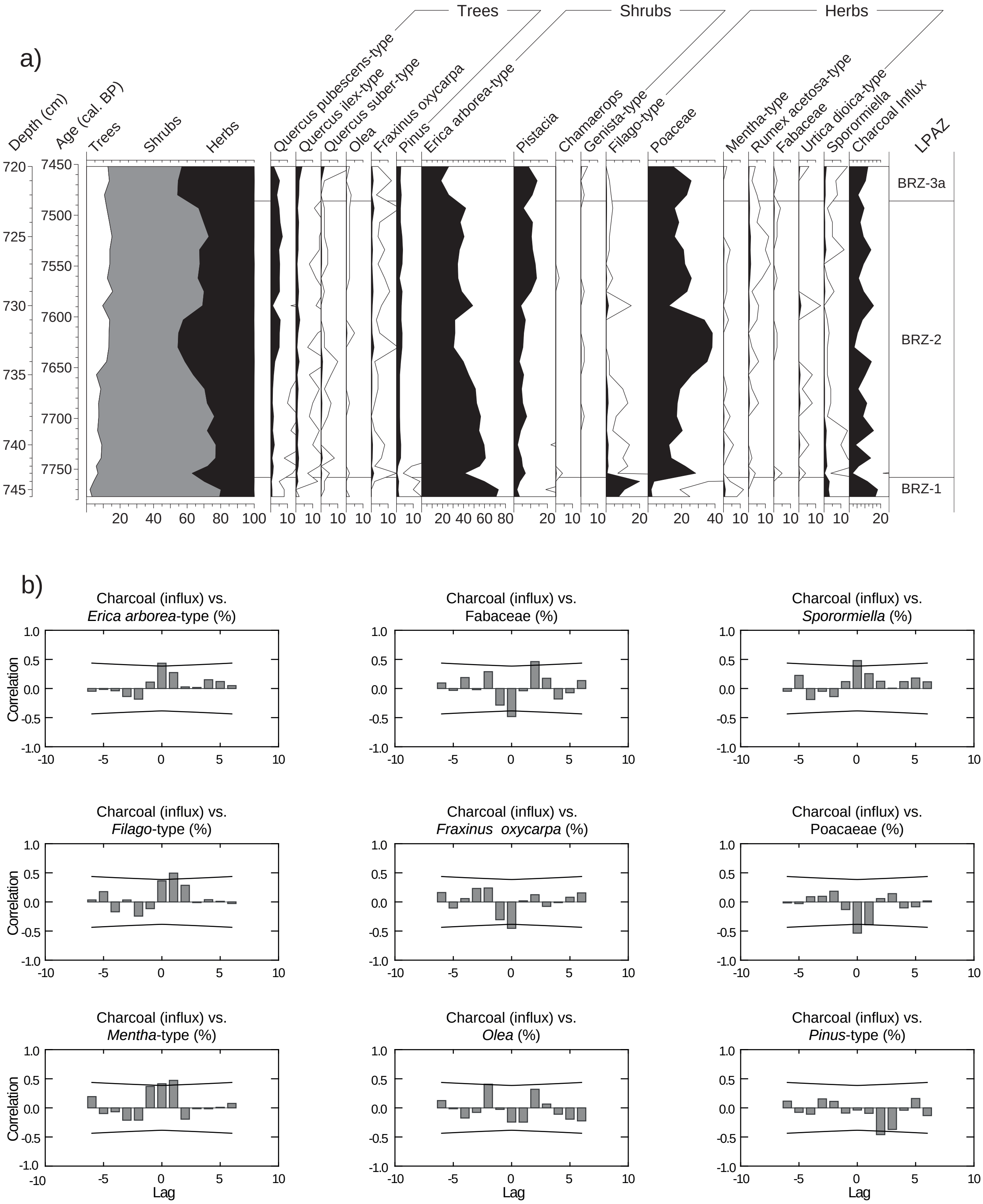


Figure 9. a): selected pollen percentages from the high-resolution section (720-746 cm / 7400-7770 cal. BP) of core BRZ-D from Lago di Baratz (Italy), along with microscopic charcoal influx profiles. Curves show 10 x exaggerations; **b)**: cross-correlation diagrams of selected terrestrial pollen percentages versus microscopic charcoal influx, both detrended. Cross-correlation plots were calculated over contiguous samples, 1 lag corresponds to 14 ± 1 years. The black lines mark the significance level (P=0.05).

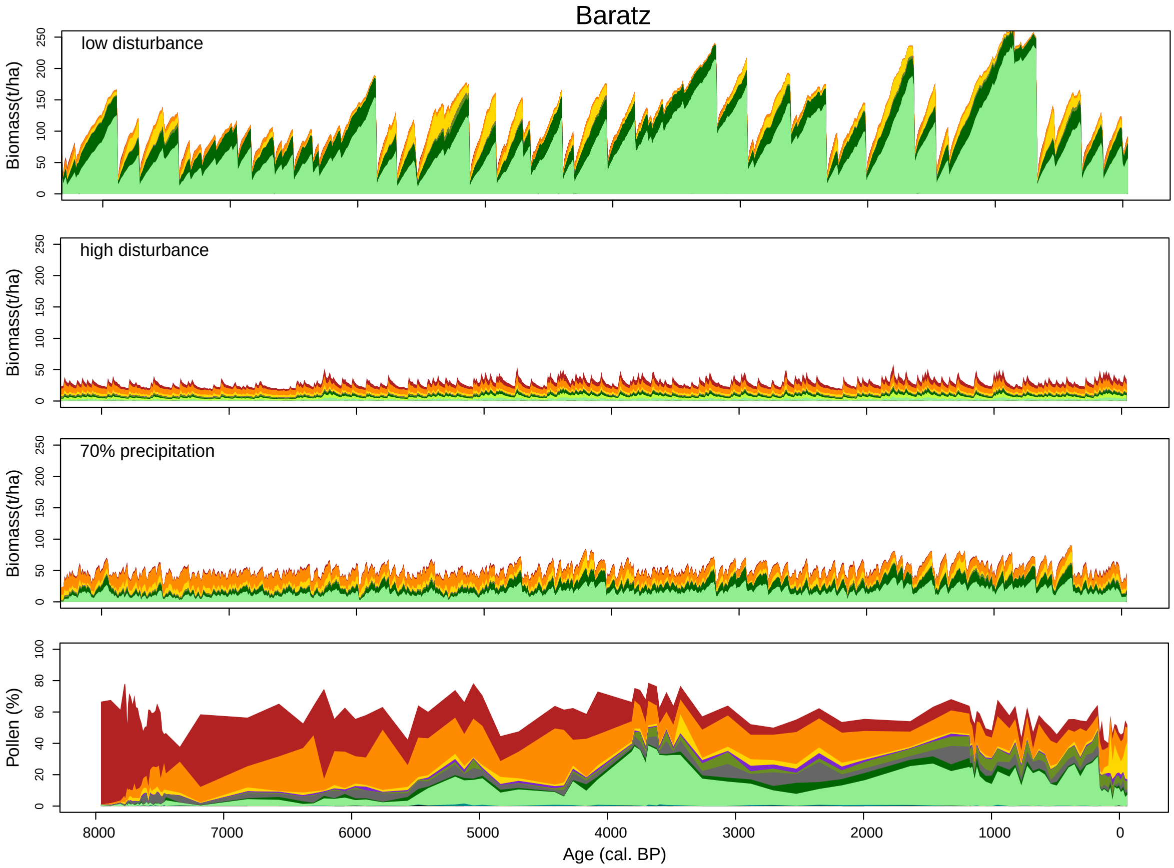


Figure 10. Model-data comparison of different simulation runs using the LandClim dynamic vegetation model with stacked pollen percentage data from Lago di Baratz.

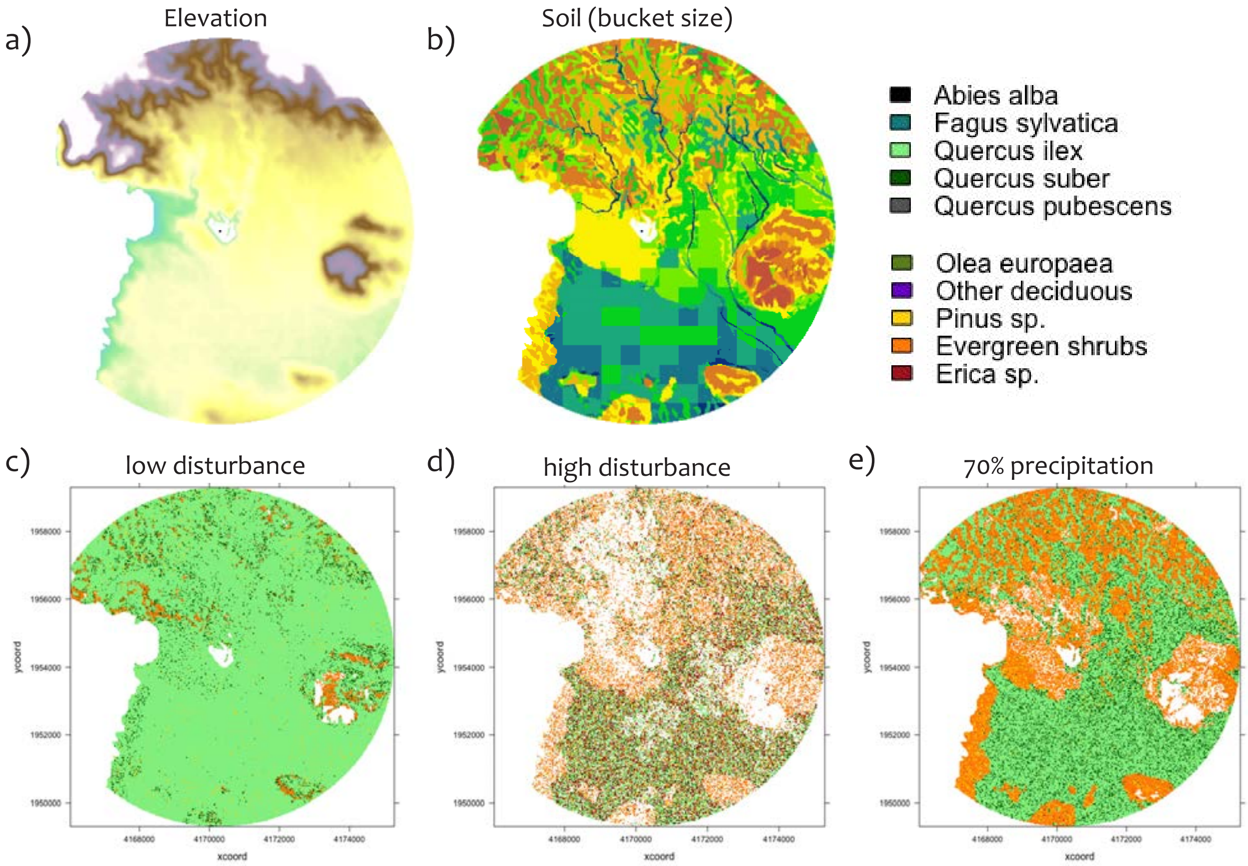


Figure 13. Maps of the simulated landscape around Lago di Baratz showing topographic input features as well as the dominant taxa per gridcell at 8000 cal. BP for different simulation runs. **a)** Digital elevation model going from sea level (green) to 400 m a.s.l. (white); **b)** soil bucket size with deep soils and high water holding capacity in dark blue and shallow soils and low water holding capacity in brown; **c)** LandClim simulation output at 8000 cal. BP for the low disturbance scenario, **d)** the high disturbance scenario and **e)** precipitation reduced to 70% of current values

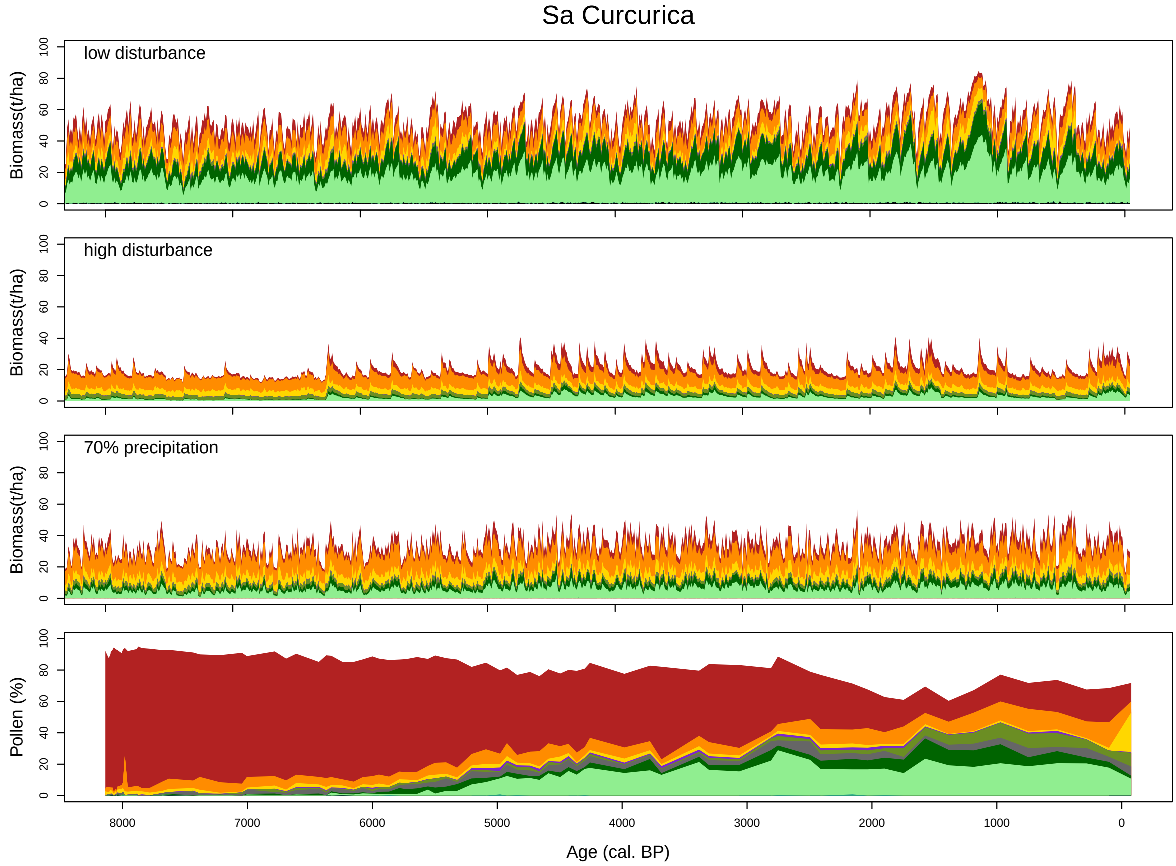


Figure 12. Model-data comparison of different simulation runs using the LandClim dynamic vegetation model with stacked pollen percentage data from Stagno di Sa Curcurica.

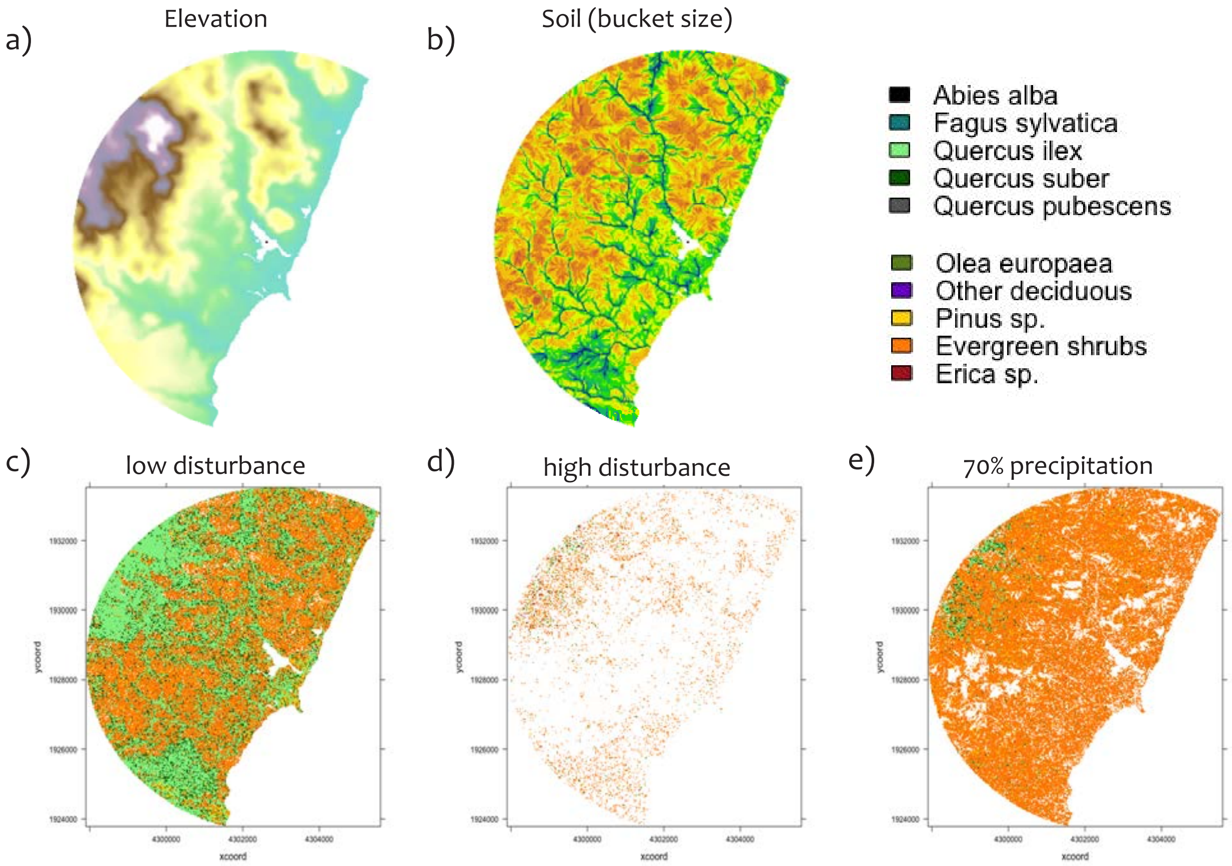
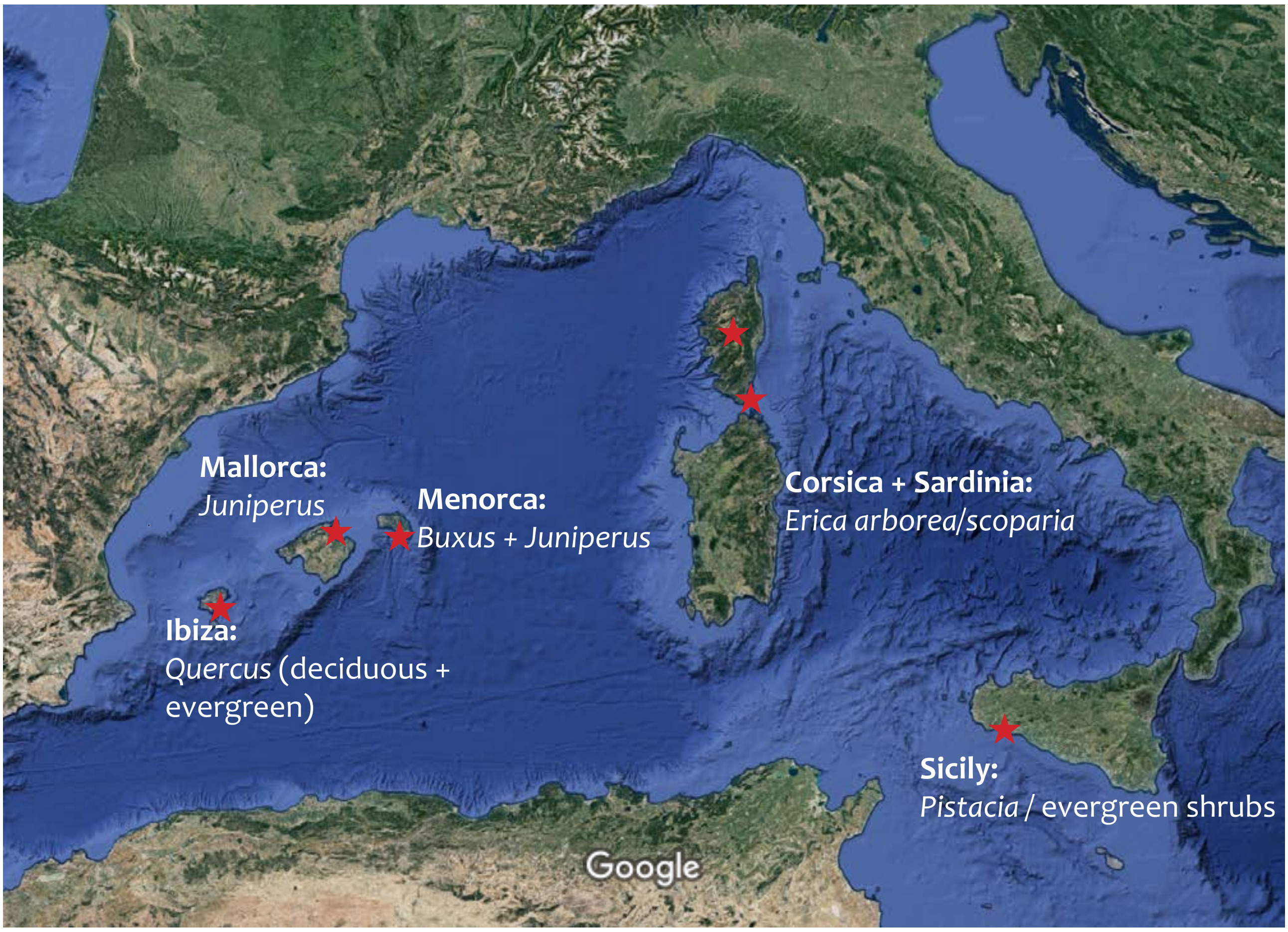


Figure 13. Maps of the simulated landscape around Sa Curcurica showing topographic input features as well as the dominant taxa per gridcell at 8000 cal. BP for different simulation runs. **a)** Digital elevation model going from sea level (green) to 428 m a.s.l. (white); **b)** soil bucket size with deep soils and high water holding capacity in dark blue and shallow soils and low water holding capacity in brown; **c)** LandClim simulation output at 8000 cal. BP for the low disturbance scenario, **d)** the high disturbance scenario and **e)** precipitation reduced to 70% of current values

Early Holocene vegetation dynamics of other Mediterranean islands



Sicily: Gorgo Basso

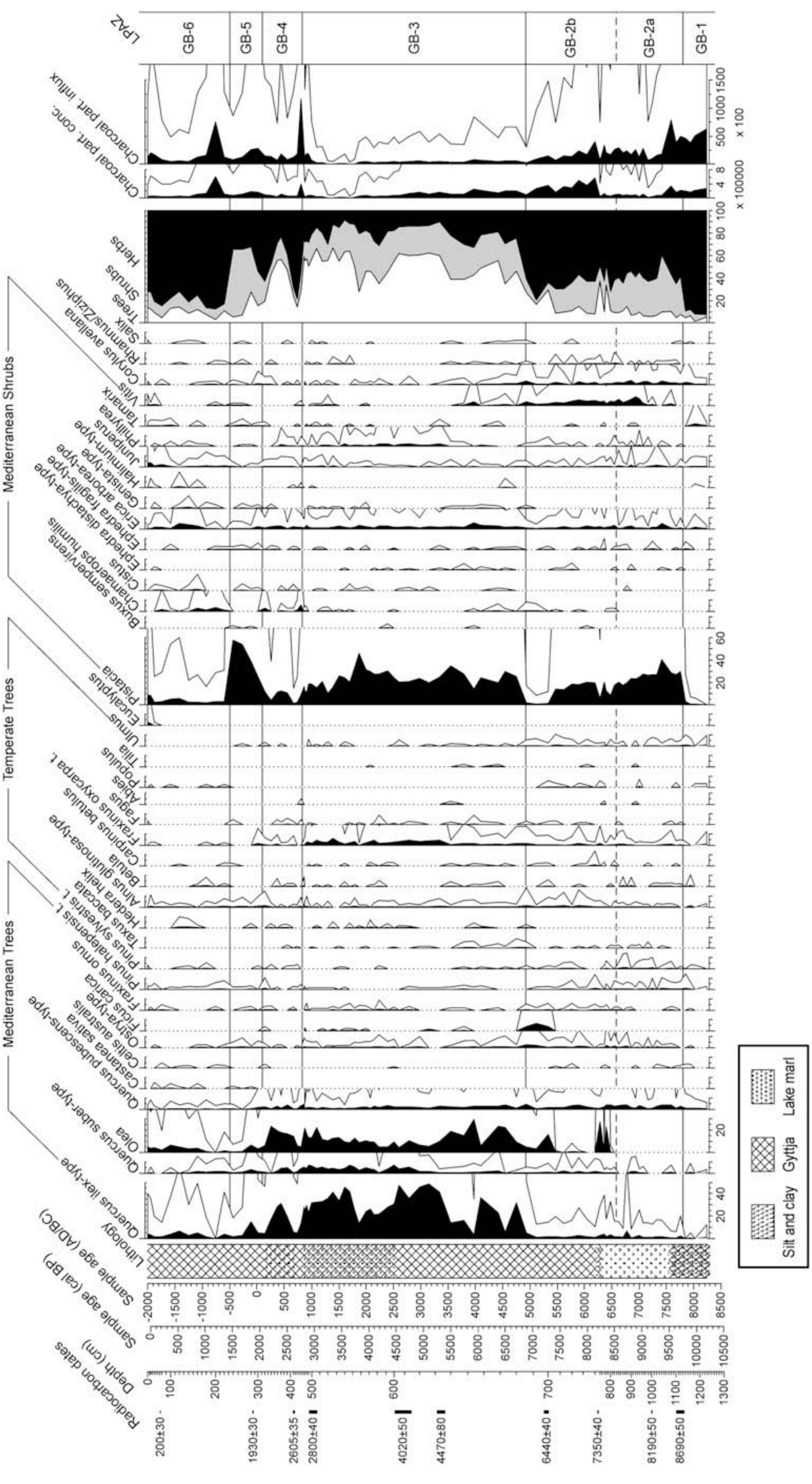


Fig. 4. Arboreal pollen percentage and charcoal influx diagram of Gorgo Basso. Selected pollen types only. Water plants and ferns are excluded from pollen sum. LPAZ = Local Pollen Assemblage Zones. Empty curves show 10× exaggerations. Pollen analyst: J.F.N. van Leeuwen, charcoal analyst: W. Tinner.

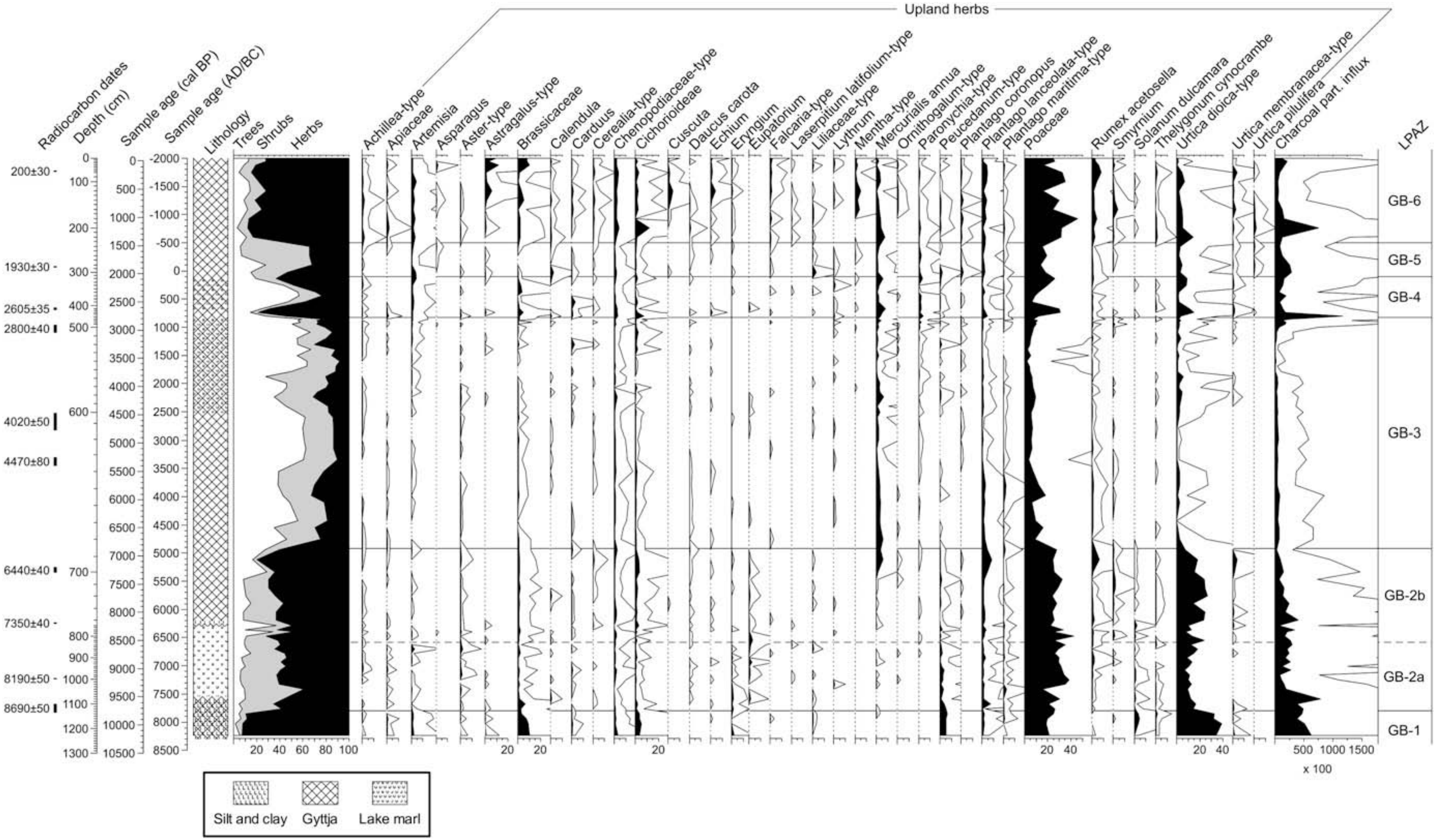


Fig. 5. Non-arboreal pollen percentage and charcoal influx diagram of Gorgo Basso. Selected pollen and spore types only. Upland herbs = non-aquatic and non-wetland herbs. Water plants and ferns are excluded from pollen sum. LPAZ = Local Pollen Assemblage Zones. Empty curves show 10× exaggerations. Pollen analyst: J.F.N. van Leeuwen, charcoal analyst: W. Tinner.

Corsica: Lac de Creno

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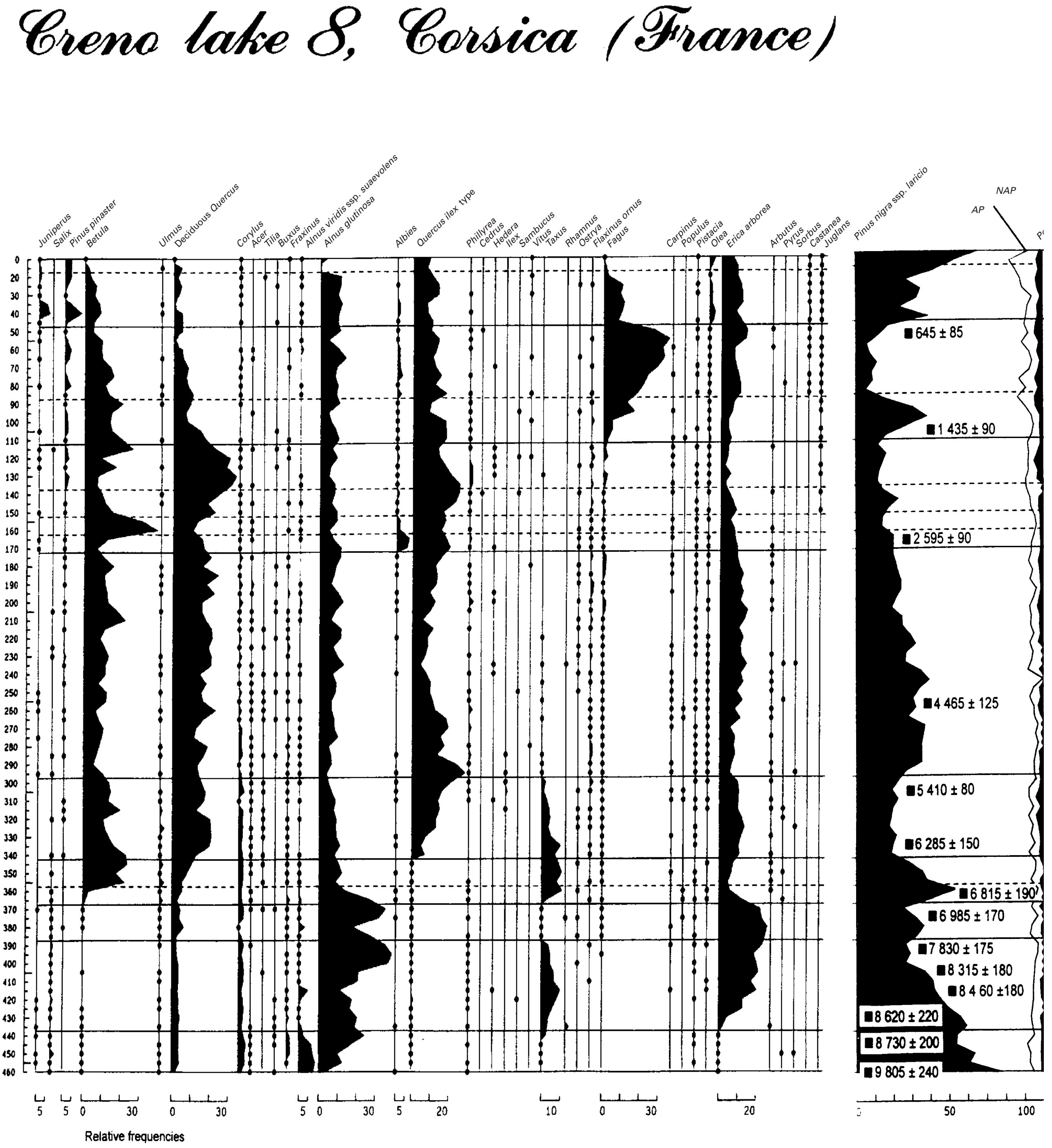


Figure 3. For legend see opposite.

Reille et al. (1999) The Holocene at Lac de Creno, Corsica, France: a key site for the whole island. *New Phytologist* **141** 291-307

Altitude: 1 310 m

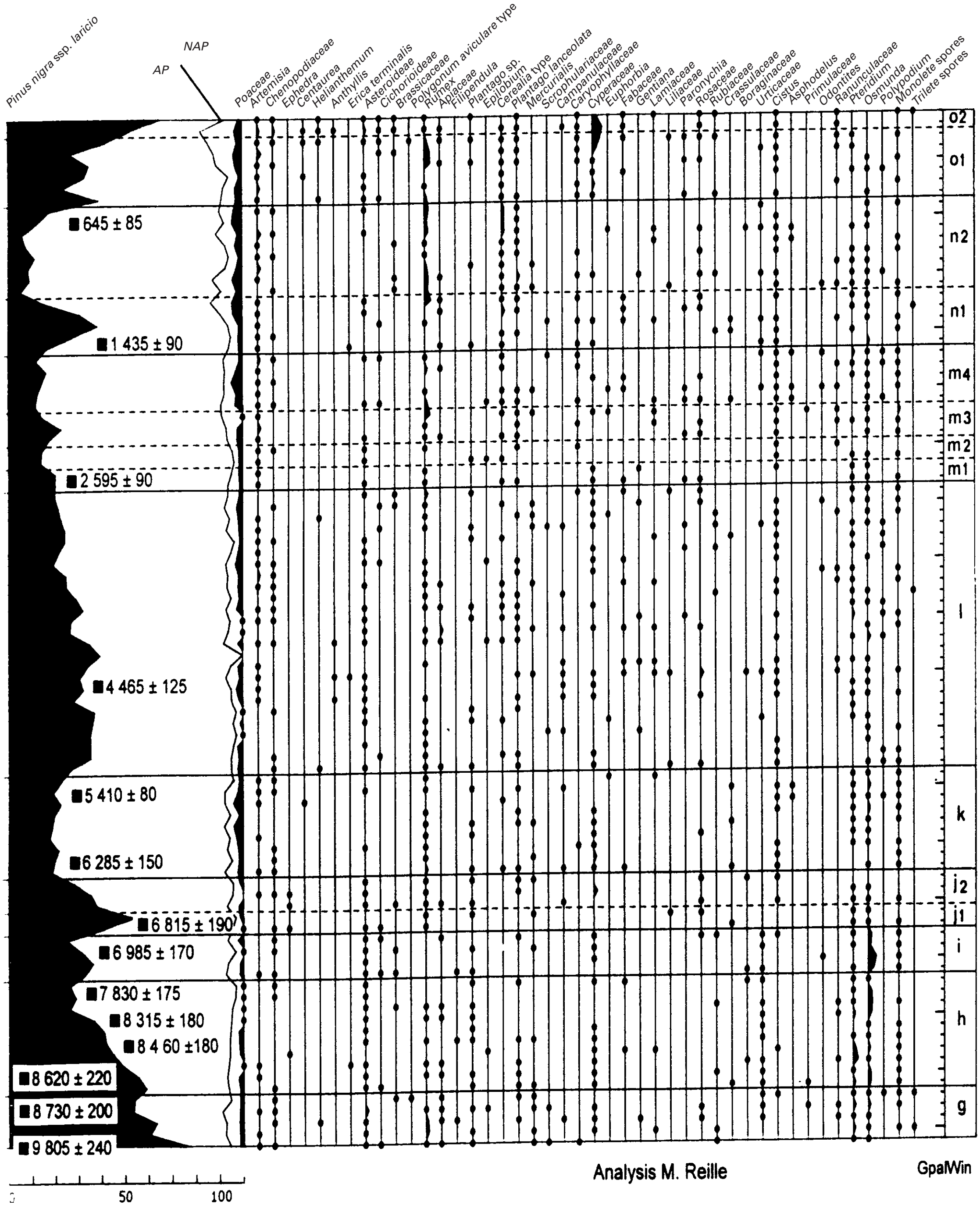
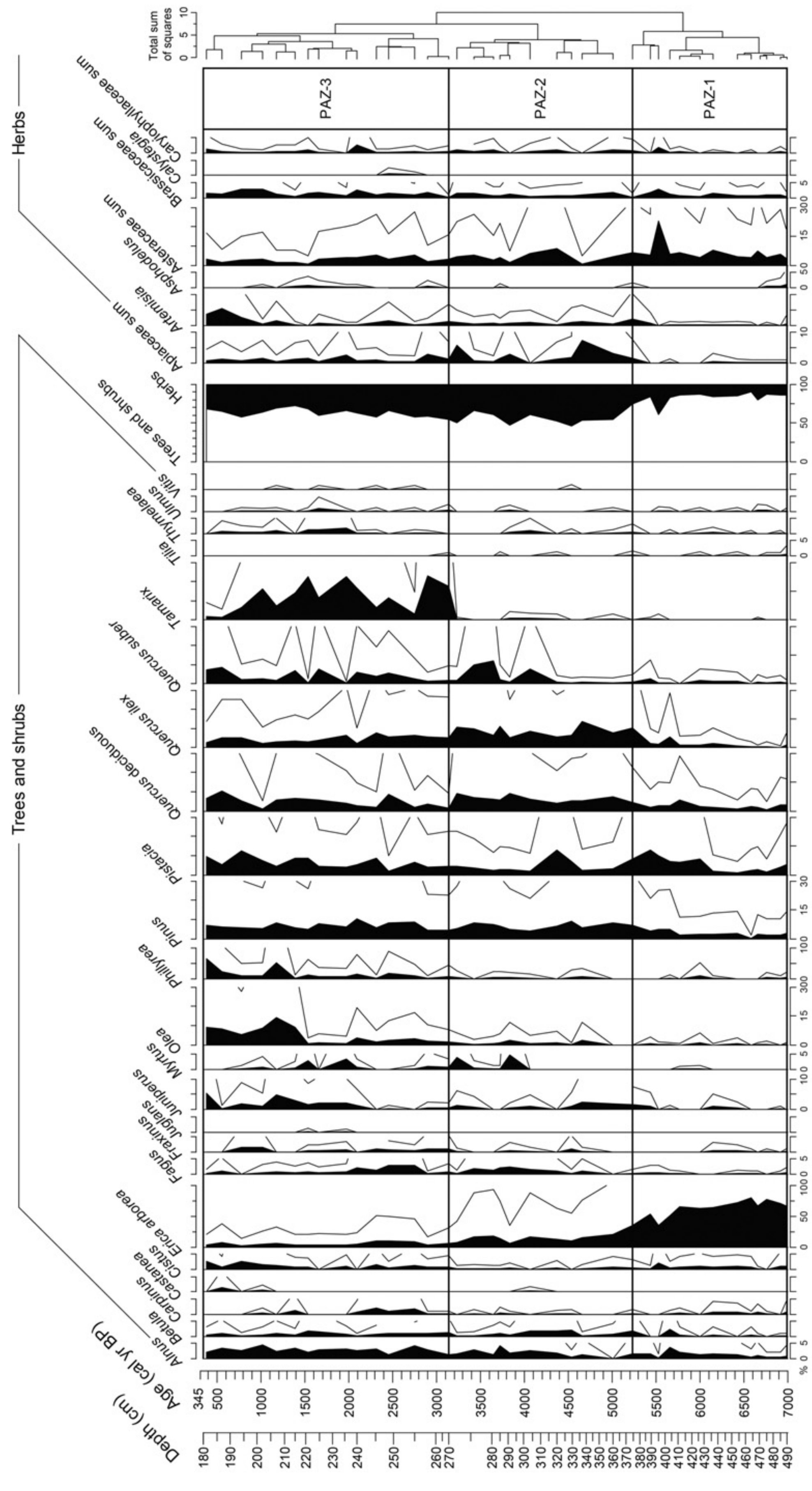


Figure 3. Sequences of Lac de Creno, Corsica, France. Diagram of relative frequencies of pollen in the uppermost 4.7 m of core. Dates are not calibrated (cf. Table 2 in which dates are calibrated).

Corsica: Greco Pond (Ile Cavallo)



Poher et al. (2017) Holocene environmental history of a small Mediterranean island in response to sea-level changes, climate and human impact. *Palaeogeography, Palaeoclimatology, Palaeoecology* **465**, 247-263

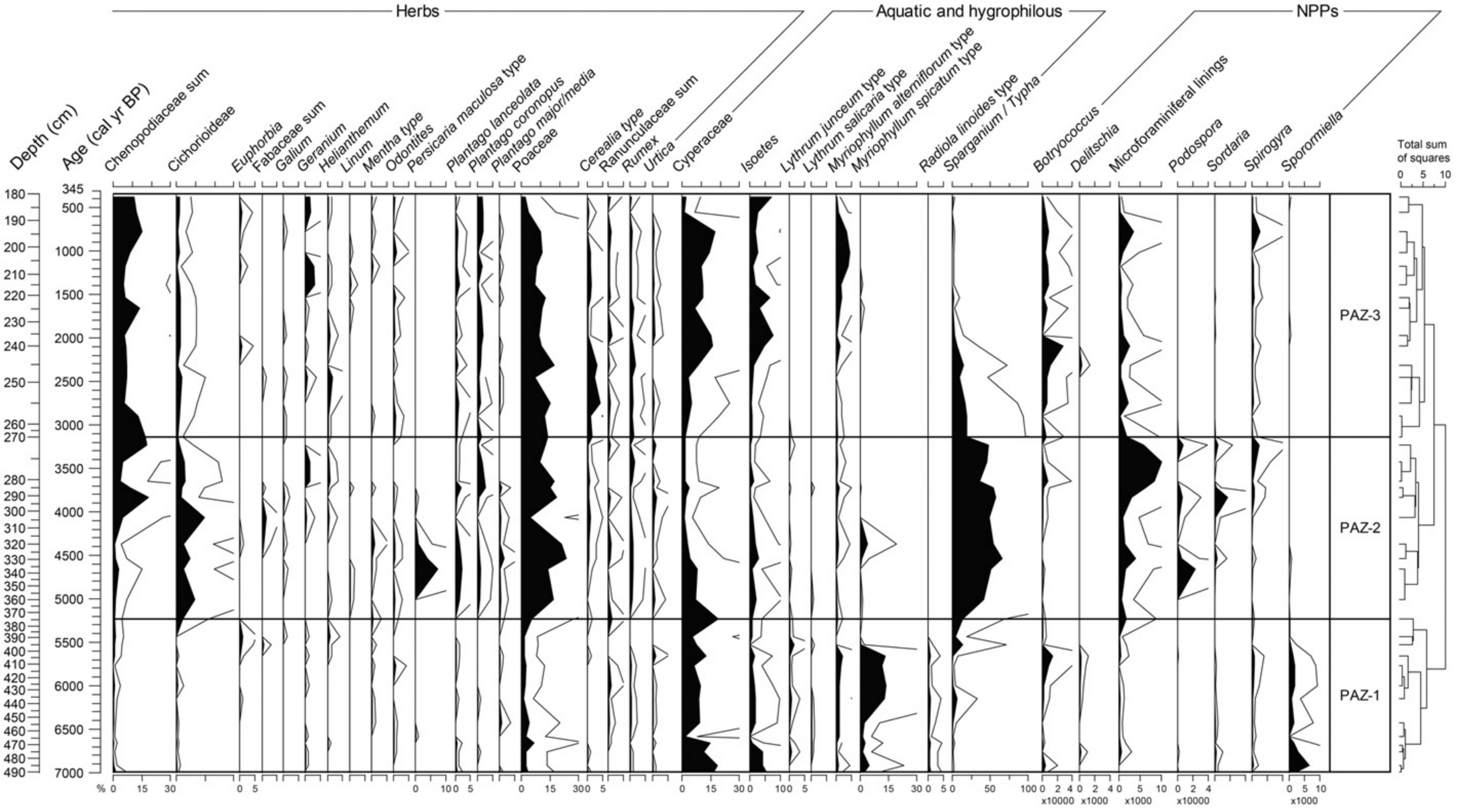


Fig. 4. Simplified pollen and non-pollen palynomorphs diagram from the Greco pond (Cavallo Island). All pollen percentage values are expressed in percentage of total terrestrial pollen sum excluding spores, aquatics plants and non-pollen objects. Empty curves show 5× exaggerations. PAZ, pollen assemblage zones.

Menorca: Cala'n'Porter / Algendar

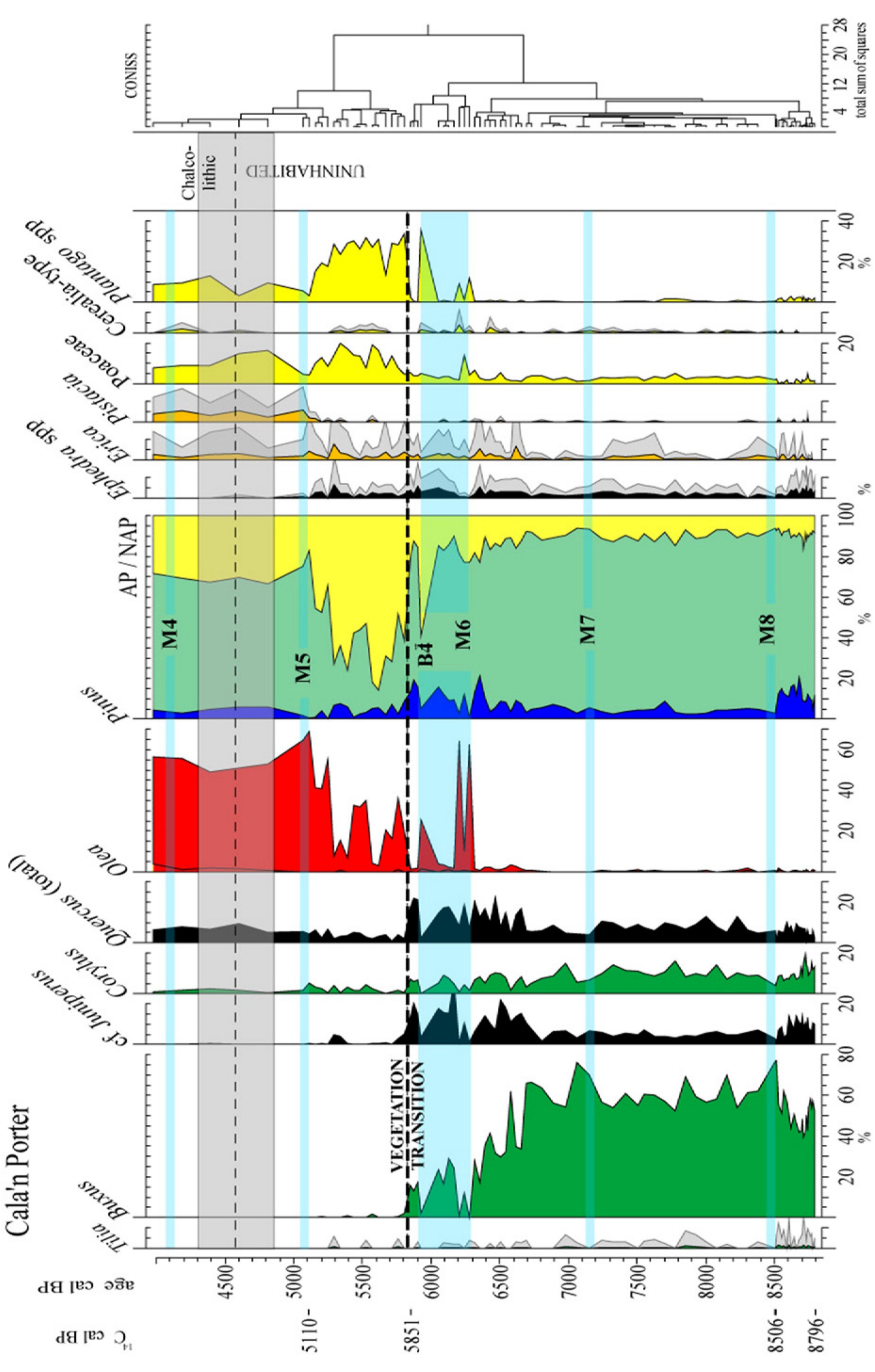


Fig. 2. Pollen diagram of Cala'n Porter (Minorca), selected taxa. Climatic events (M8 to M4) correspond to Minorca events (Frigola et al., 2007), and B4 corresponds to Bond event 4 (Bond et al., 1997). The events are marked with blue bars. The grey bar shows the transition towards the first settlements. The grey double curve in some taxa corresponds to an exaggeration of the real value for better visualization.

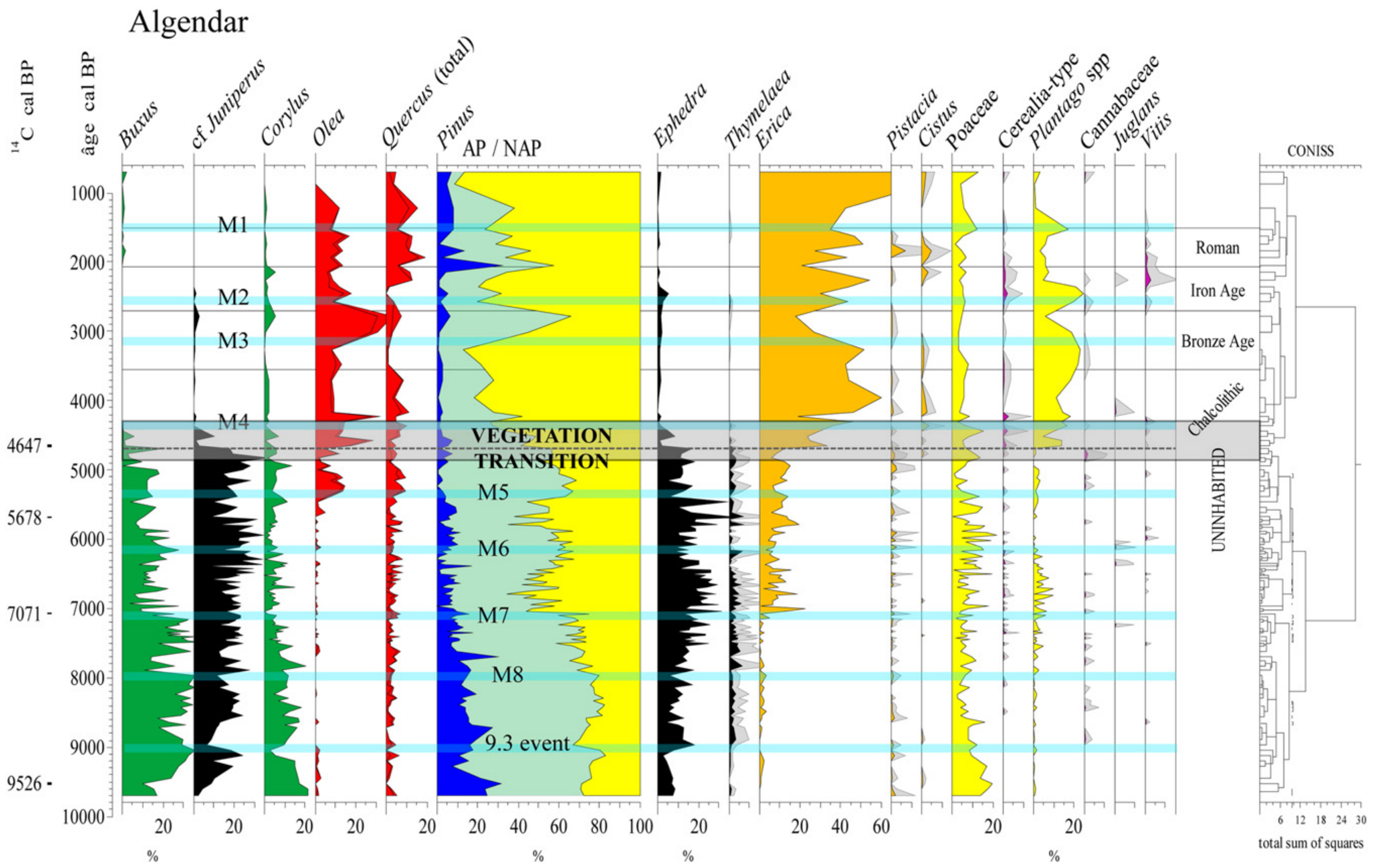


Fig. 3. Pollen diagram of Algendar (Minorca), selected taxa. Climatic events (M8 to M1) correspond to Minorca events (Frigola et al., 2007) and the 9.3 event according to Rasmussen et al. (2014). Events are marked with blue bars. The grey bar shows the transition towards the first settlements. The grey double curve in some taxa corresponds to an exaggeration of the real value for better visualization.

Mallorca: Albufera d'Alcúdia

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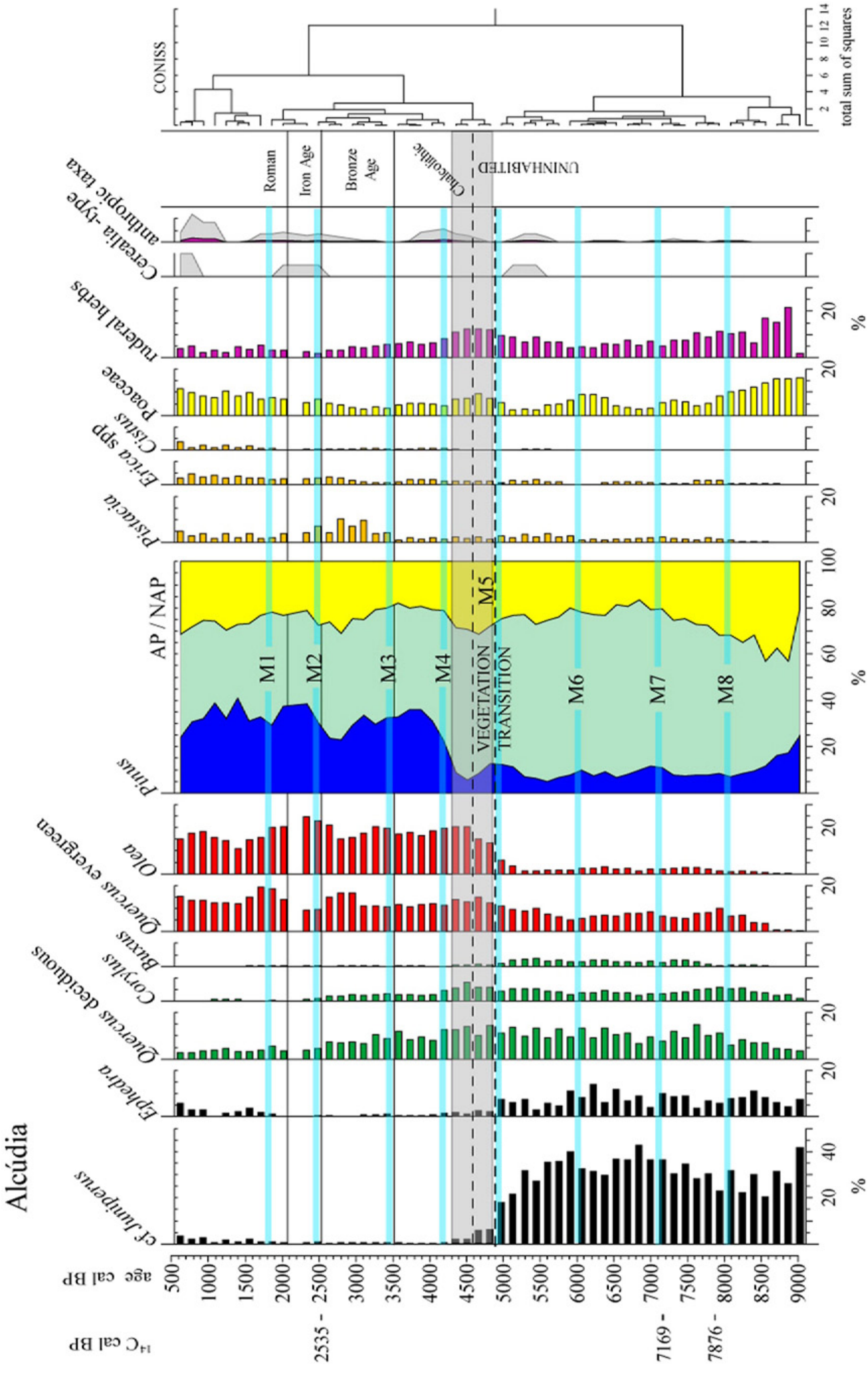


Fig. 5. Pollen diagram of Albufera d'Alcúdia (Majorca), selected taxa. Climatic events (M8 to M1) correspond to Minorca events (Frigola et al., 2007), marked with blue bars. The grey bar shows the transition towards the first settlements. The grey double curve in Cerealia-type and anthropic taxa corresponds to an exaggeration of the real value for better visualization.

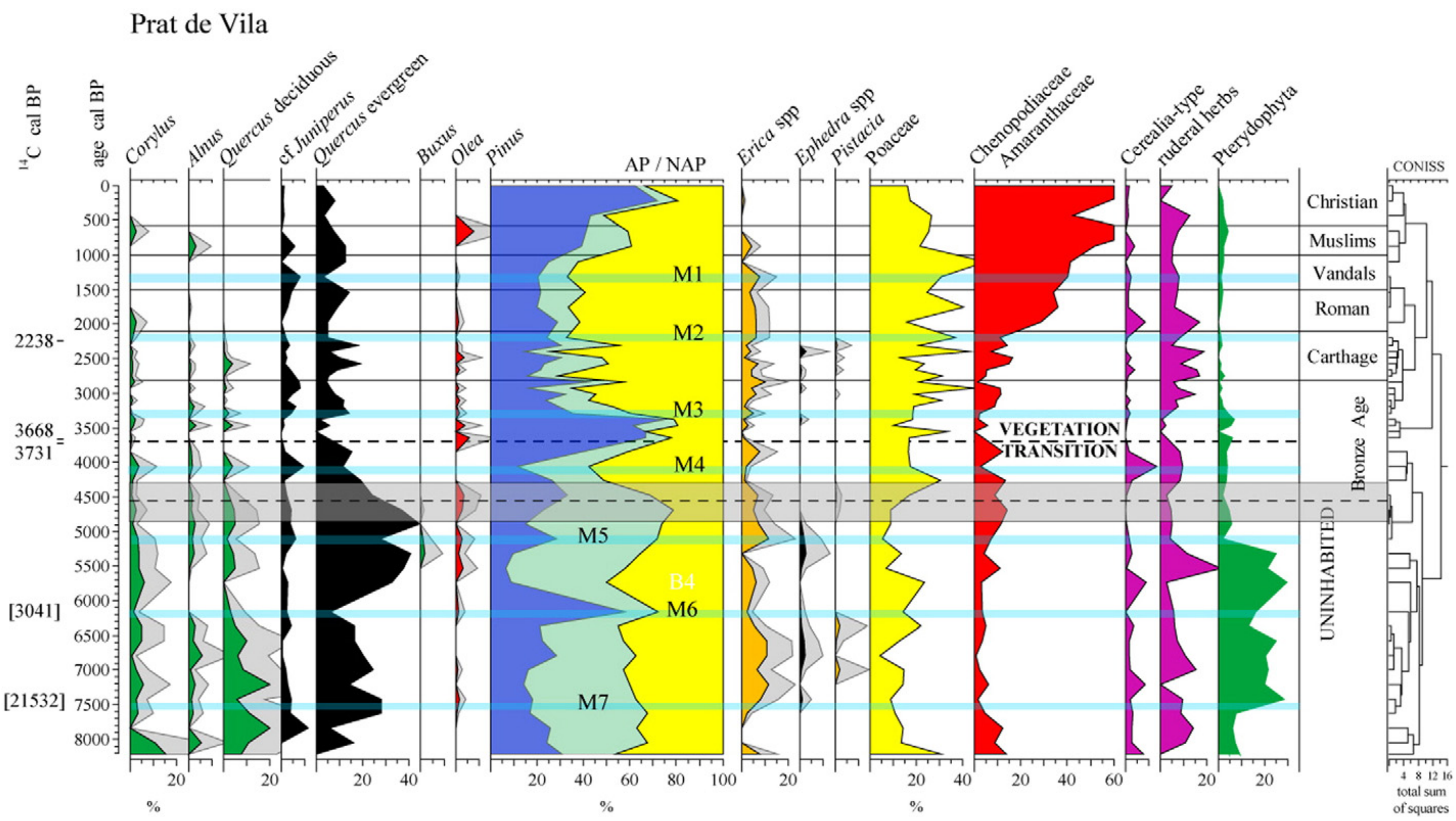
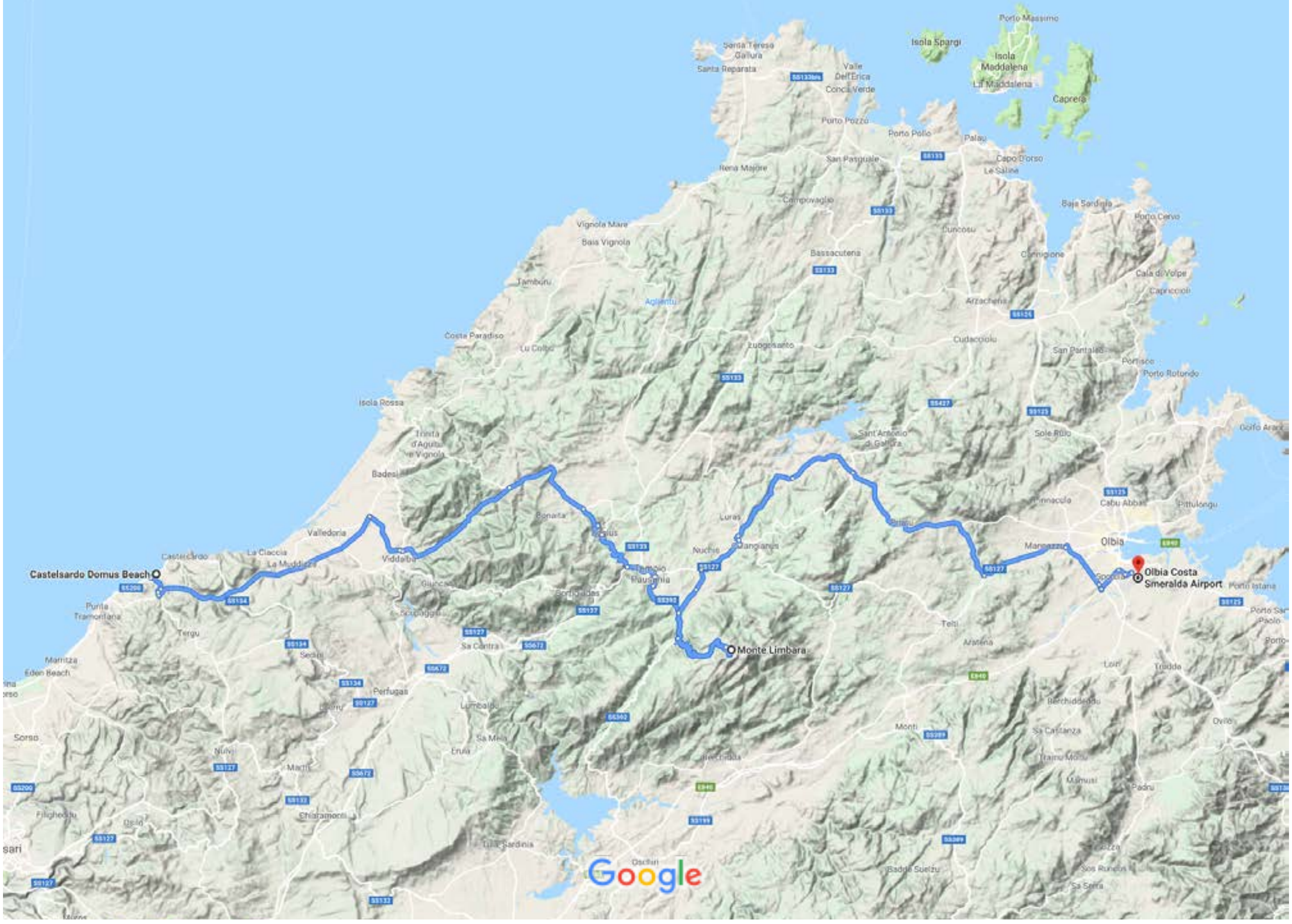


Fig. 6. Pollen diagram of Prat de Vila (Ibiza), selected taxa. Climatic events (M7 to M1) correspond to Minorca events (Frigola et al., 2007), marked with blue bars. The grey bar shows the transition towards the first settlements. The grey double curve in some taxa corresponds to an exaggeration of the real value for better visualization. Chenopodiaceae and Pteridophyta excluded from the total sum. Note that dates in brackets at the bottom of the diagram were not used because they are incoherent.

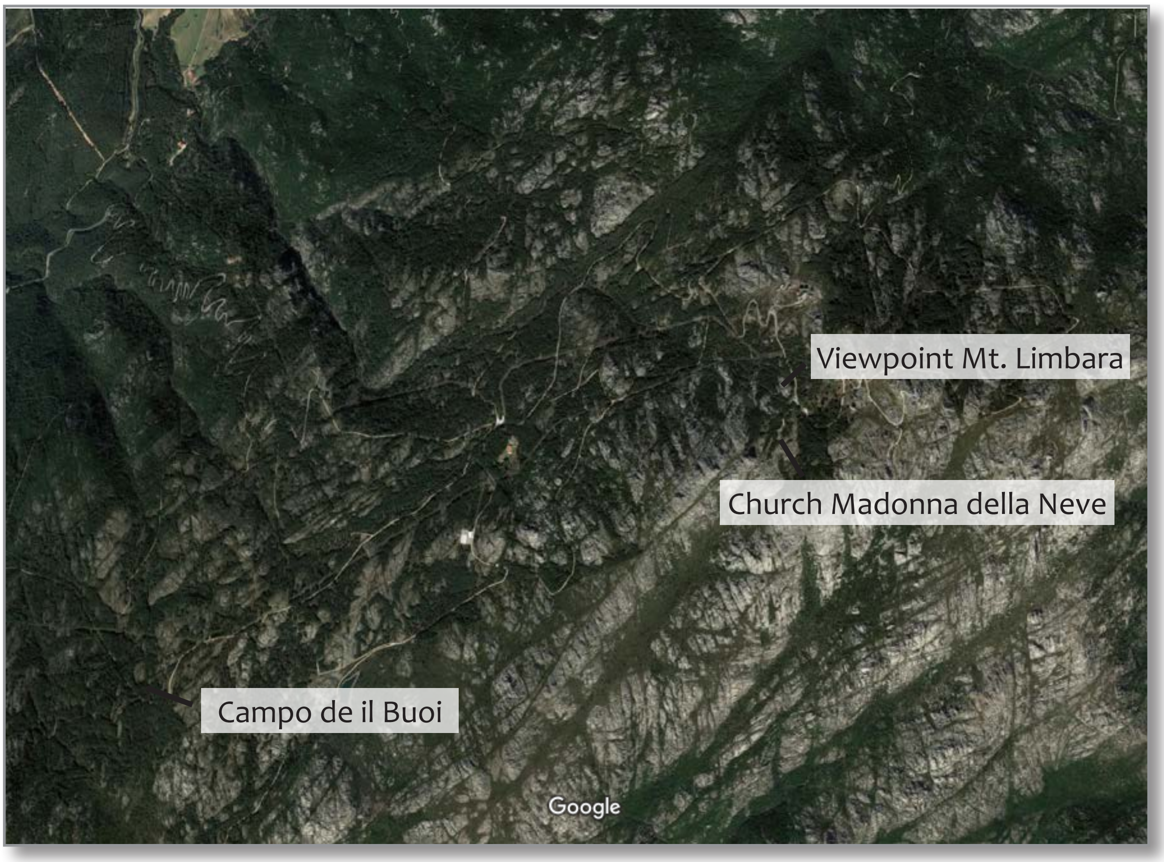
Capo Caccia

Saturday 07.09.2019

7:30	Breakfast at Hotel Domus Beach
8:30	**Departure** to Monte Limbara
10.00	Upland vegetation dynamics at **Monte Limbara** (Jacqueline van Leeuwen & Pim van der Knaap)
11.00	Departure to Olbia airport
12.30	Arrival at Olbia airport



Monte Limbara



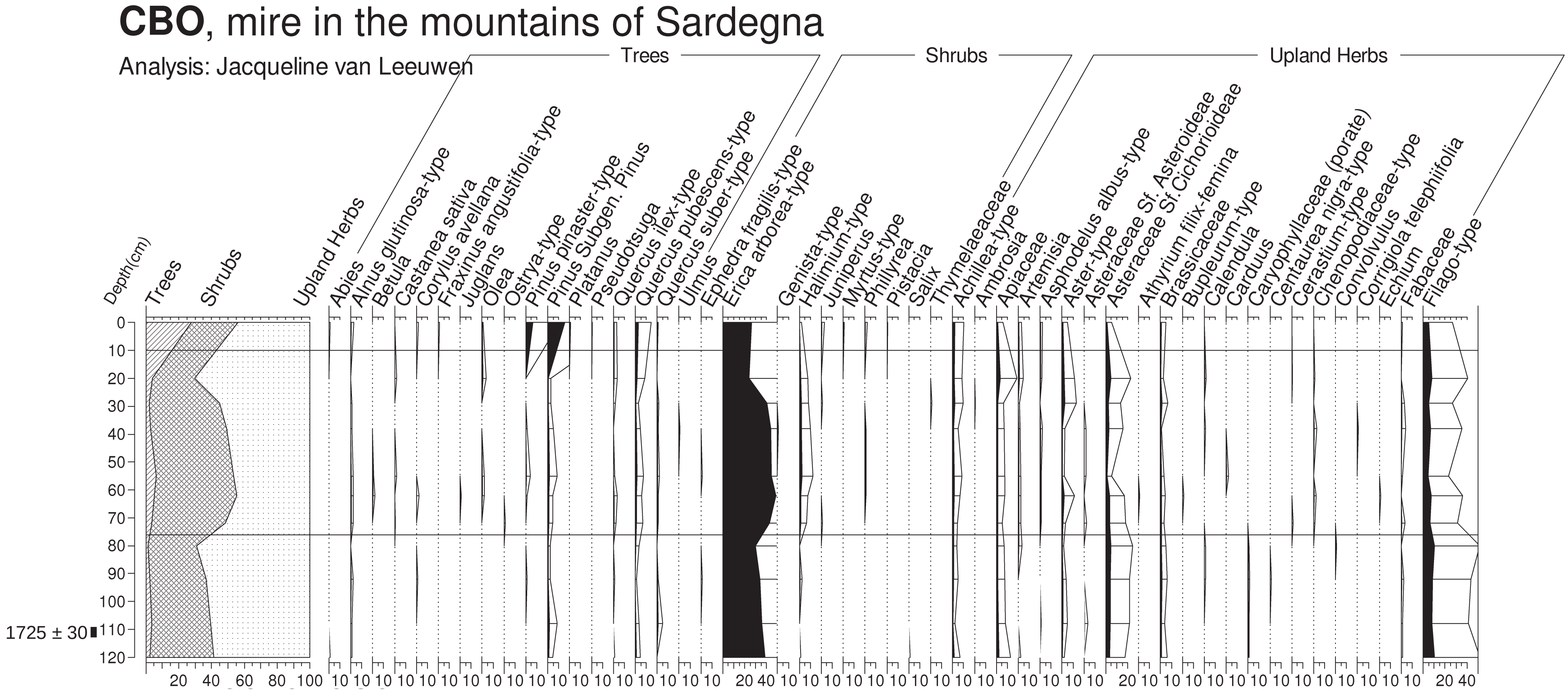


Figure 1. Pollen diagram from the Monte Limbara peat bog

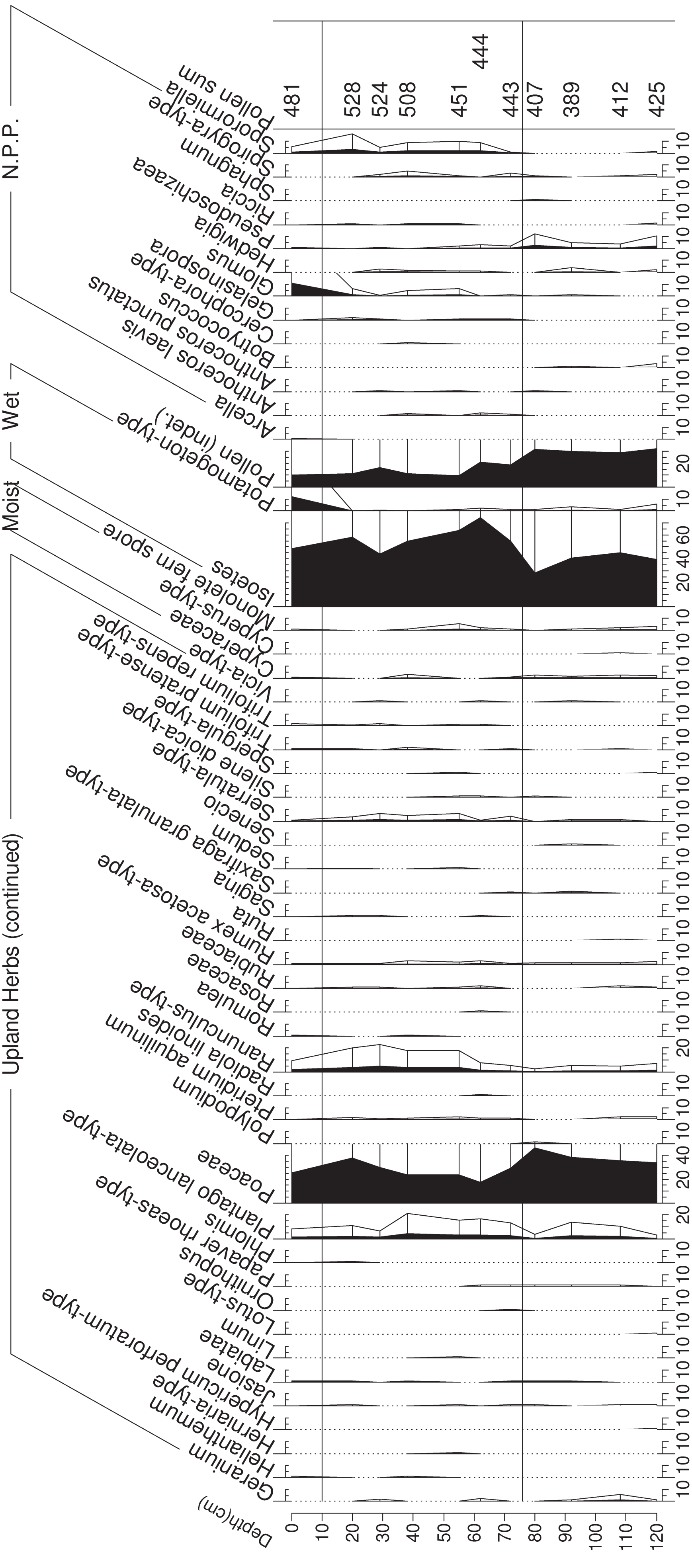


Figure 1.continued