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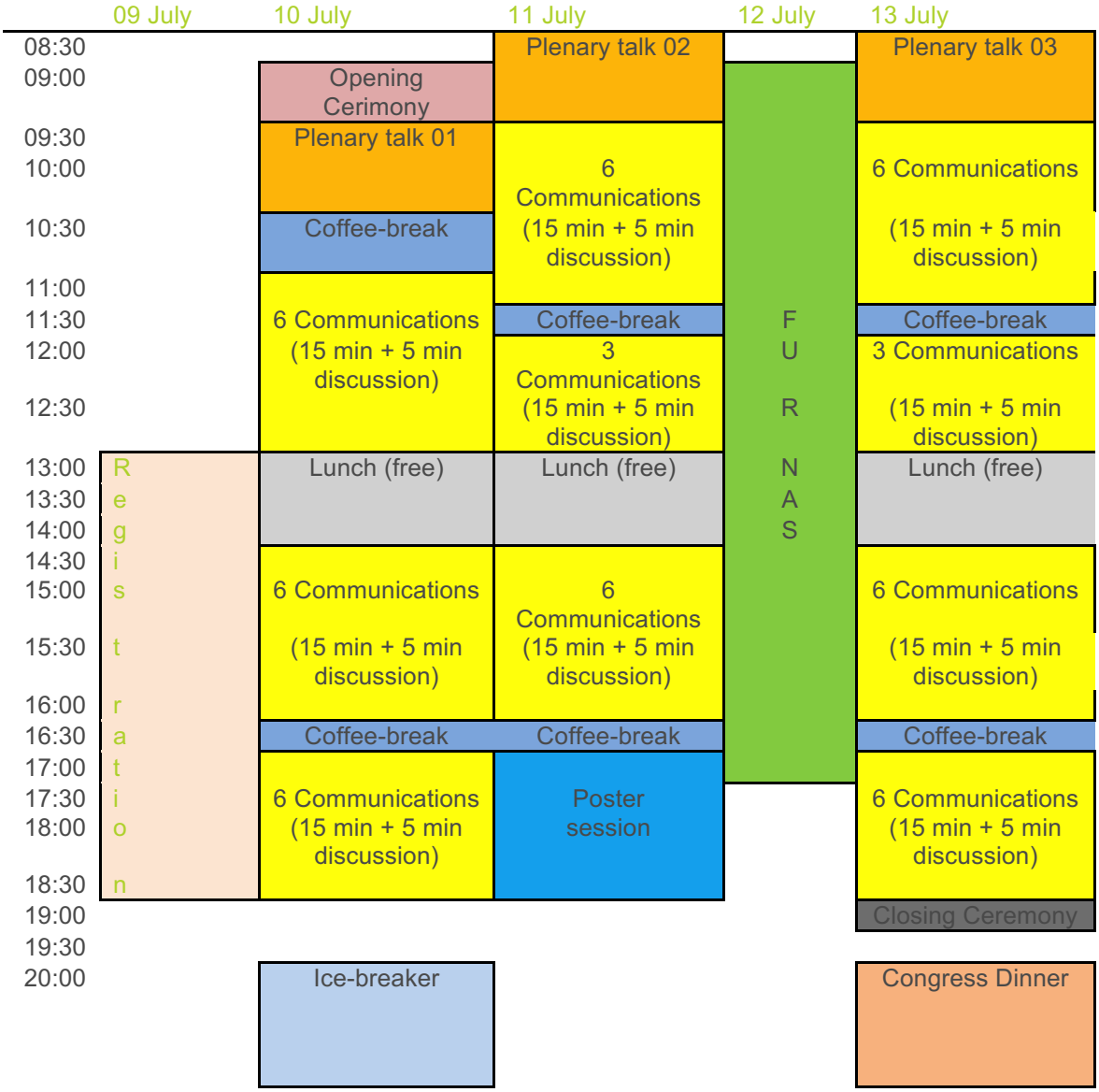
Foreword

Stratigraphy is a key subject area in the geosciences that attracts a high number of researchers and students. This science also has witnessed interest from a growing number of people in society at large, due to its inter-related impacts on the economy, the broader environment, and technology. The Organising Committee welcomes all interested researchers to take part in this exciting event with state-of-the art communications that intends to bring together an international team of experts in a pleasant atmosphere in the middle of the Atlantic Ocean, at the volcanic oceanic Azorean island of São Miguel!

Sérgio P. Ávila

Head of the Organizing Committee of the VI RCANS

Programme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TALKS

GIS and remote sensing applications for the Atlantic Quaternary: case-studies

Potential contributions of Coastal GIS and Remote Sensing based applications for improving the knowledge in the palaeogeography and palaeoecology of the Atlantic margins

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Remote Sensing data and processing techniques have been widely used in Geosciences, namely in Coastal Science, especially in the last two decades. Nevertheless, there is still much potential to discover regarding the use of Remote Sensing data and techniques in Palaeogeography and Palaeoecology case-studies, namely in places located in the Atlantic margins. This oral communication aims at presenting some case-studies using remote sensing data and processing techniques that might be regarded as good models for improving the knowledge in the palaeogeography and palaeoecology of the Atlantic margins.

Keywords: GIS; Remote sensing; coastal areas; management

Overview and Comparative Analysis of the legal instruments at international and national level for the conservation of geological and paleontological heritage in EU

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During the last two decades, the legislation for the conservation of the geological and paleontological heritage made a step forward. Many are the states that promoted new laws for the protection of geologically significant sites. At International level, the UNESCO Geoparks counts 123 designated area around the world. Within the European Union, Spain is the state with the major number of registered Geoparks, while Portugal, even though it has a smaller number, boasts the Açores Archipelago UNESCO Geopark, comprising its 9 islands. Nevertheless, many are the areas of geological and paleontological interest that are not included in this classification but are regulated at regional and local level with laws and strategies. This study aims to highlight the European regulation for the protection of Geoparks or related sites with a comparative analysis of the history of the Geoprotection at national level of the Iberic peninsula for identifying potential gaps in this matter.

Keywords: Geological heritage; EU legislation; Maritime Spatial Planing; UNESCO Geopark

Maritime Spatial Planing and Palaeontology: Santa Maria (Azores) as a case study

Vera Noon, Anthony Mastitski

Methods of evaluation of geosites: Santa Maria Island geosites as a case-study

Vera B. Raposo[1,2*], C. S. Melo[1,2,3], L. Silva[1], P. Madeira[1,2], R. Cordeiro[1,2], A. C. Rebelo[1,2] & S. P. Ávila[1,2,4]

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The quantitative assessment of the geositesis a fundamental step for the application of geoconservation strategies. The improvement of the methodologies used to evaluate the geosites and the revision of previous evaluations must be done on a regular basis. Santa Maria is the oldest island of the Azores Archipelago and is renowned for its geobiodiversity and palaeontological heritage. Furthermore, in terms of geology, it has been under intense study and an important amount of recent scientific papers has been coming out, changing so the geosite evaluation parameter's. This work aims to re-evaluate the fossiliferous geosites of this island, based on a geoconservation methodology comparison. A new evaluation is proposed for the 17 studied geosites. All criteria were calculated independent of each other and considered together for the final result, which is useful for management purposes. The final ranking rated Prainha, Pedreira do Campo, Pedra-que-pica and Ponta do Castelo in the first positions,and Pedrinha da Cré (MIS 5e) and Ponta da Baía de Nossa Senhora in the last position.

Keywords: Assessment; Geoconservation; Geosites; Methodology; Santa Maria

Geological evolution of oceanic islands

Emergence and evolution of Santa Maria Island (Azores)

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The growth and decay of ocean island volcanoes are intrinsically linked to vertical movements. While the causes for subsidence are better understood, uplift mechanisms remain enigmatic. Santa Maria Island in the Azores Archipelago is an ocean island volcano resting on top of young lithosphere, barely 480 km away from the Mid-Atlantic Ridge. Like most other Azorean islands, Santa Maria should be experiencing subsidence. Yet, several features indicate an uplift trend instead. We have reconstructed the evolutionary history of Santa Maria with respect to the timing and magnitude of its vertical movements, using detailed fieldwork and 40Ar/39Ar geochronology. Our investigations revealed a complex evolutionary history spanning ~6 m.y., with subsidence up to ca. 3.5 Ma followed by uplift extending to the present day. The fact that an island located in young lithosphere experienced a pronounced uplift trend is remarkable and raises important questions concerning possible uplift mechanisms. Localized uplift in response to the tectonic regime affecting the southeastern tip of the Azores Plateau is unlikely, since the area is under transtension. Our analysis shows that the only viable mechanism able to explain the uplift is crustal thickening by basal intrusions, suggesting that intrusive processes play a signicant role even on islands standing on young lithosphere, such as in the Azores.

Keywords: ocean island volcanoes; uplift; subsidence; Santa Maria; Azores

The conundrum of ocean island uplift revisited – insights from a stationary plate environment

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Ocean island volcanoes are typically subjected to long-term subsidence, as the linear, age-progressive island chains of the Pacific Ocean clearly exemplify. Mechanisms for subsidence are generally well understood and are consistent with the plate tectonics and isostasy framework. A few island systems (e.g. the Cape Verdes, the Canaries, and Madeira Archipelago), however, fall out of pattern and feature numerous volcanic edifices that have experienced pronounced uplift trends, vertical stability, or complex uplift/subsidence histories. These are mostly concentrated in, but not restricted to, the NE Atlantic, where the Nubian plate moves very slowly or is quasi-stationary with respect to the islands' melting source. Here I analyse and discuss the origins of these vertical movements, using recent uplift/subsidence reconstructions for several islands, and in relation to its geodynamic context. Correlations suggest that, for fast-moving plates relatively to the melting source, uplift episodes are mostly dominated by a flexural mechanism associated to volcanic loading "upstream" the island chain. Conversely, at stationary plate environments, uplift episodes are probably related to either pulses of hotstpot swell growth or more importantly to intrusive processes that jack up the island edifices. In these environments, as magmatism progresses through time, warming and thickening of the deep hot zone inhibits magma ascent to the surface, favouring intrusion processes at crustal levels. Crustal thickening in this context can thus act both as a long-term inhibitor of surface volcanism and a source of uplift. Plate velocity relative to the melting source is thus expected to be a powerful constraint on intrusive vs extrusive processes of island building.

Keywords: ocean island volcanoes; uplift; subsidence; stationary plates

Palaeo-shorelines development on reefless volcanic islands: new insights from high-resolution marine geophysical data from Santa Maria Island (Azores Archipelago)

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Palaeo-shorelines are relict depositional and erosional coastal landforms. On volcanic ocean islands their development is deeply influenced by sea-level changes and the islands' vertical motions. Palaeo-shorelines on insular shelves are the result of erosion during past relative sea-level changes and are now submerged by rising sea level. Although these features are relatively well studied in continental and reef island settings, little is known about their development on reefless volcanic islands. In this study, we intend to increment our knowledge about how these features form and are preserved, using Santa Maria Island shelf as a case study. Santa Maria is the oldest island of the Azores Archipelago in the Atlantic Ocean. Its subaerial geological history is now well constrained (extending to ~6 Ma), with the recognition of a sequence of raised marine terraces varying between 7-11 m and 210-230 m in elevation. In this study we show a sequence of submerged palaeo-shorelines and respective marine terraces located at approximately -40/-50 m, -70/-80 m, -85/-90 m, -100/-110 m and -125/-145 m. The mapping of these palaeo-shorelines was made using ultra-high resolution multibeam bathymetry and closely spaced seismic reflection profiles of the shelf surrounding Santa Maria Island. Based on a dated subaerial terrace (Ramalho et at., 2017), we tried to correlate the other terraces depth with known sea level stands, reported on published sea-level curves. Our study suggests that presently subaerially exposed marine terraces on volcanic islands were formed during sea-level highstands or higher intermediate stillstands, while submerged terraces were probably formed during sea-level lowstands or lower intermediate stillstands. This analysis was made taking into account the complex interplay between glacio-eustatic sea-level fluctuations, the island vertical motion trends, the width of the shelf, and the intensity of marine erosion. The results of this study demonstrate that late Quaternary palaeo-shorelines carved during highstands, lowstands or even stillstands might be well preserved also on slow uplifting/subsiding landmasses. Hence, their study can be used to better constrain the complex history of the vertical movements of volcanic islands.

Keywords: Palaeo-shorelines, sea-level changes, reefless volcanic islands, insular shelves.

Post-eruptive morphological evolution of island volcanoes: Surtsey (Iceland) as a modern case study

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The competition between constructional and destructive processes has the main relevance in the growth and evolution of insular volcanoes. This is particularly important for emergent Surtseyan volcanic edifices made up of tephra/tuff cones very prone to marine erosion, being commonly short-lived or with very rapidly changing morphologies.

Surtsey is a small volcanic island in the Vestmannaeyjar archipelago, off the south coast of Iceland, in the Northern Atlantic. The eruption leading to the island's emersion lasted for 3.5 years (1963-1967) while destructive forces have been active for over 50 years (1963-present-day). Since their formation, Surtsey and its satellite submerged vents have suffered constant, rapid erosion due to strong wave and current activity, causing substantial reduction of its original surface (2.65 km2 in1967, reduced to 1.31 km2 in 2012) especially in the first years after volcanic activity ceased, and the overall reshaping of the island shoreline and shallow-water portions. Combined marine erosive and depositional processes markedly changed the original coastal and submarine morphology at Surtsey, proceeding at extremely high rates in the first decades and markedly slowed down in recent times. Due to the very large documentation acquired since its emergence from the sea in 1963, this small island gave the opportunity to continuously observe and quantify the effects of ongoing wave erosion processes at the half-century time scale in a high-energy marine environment.

Surtsey provides a directly observed, modern analogue for the post-eruptive degradational stage of emergent island volcanoes that might be of help in interpreting older preserved successions. Analogies with the post-eruptive morphological evolution of other recently formed, ephemeral, shallow-marine Surtseyan cones which underwent marine erosion (encompassing different climatic conditions, wave regimes and geological contexts) will be discussed.

References

Romagnoli C., Jakobsson S. P. (2015) Post-eruptive morphological evolution of island volcanoes: Surtsey as a modern case study. Geomorphology, 250, 384-396, 10.1016/j.geomorph.2015.09.016.

Keywords: island volcano, post-eruptive stage, coastal changes, cliff recession rates, submarine morphology

Post-eruptive Submarine Terrace Development of Capelinhos, Azores

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Erosion of the coasts of volcanic islands by waves creates shallow banks, but how erosion proceeds with time to create them and how coastline retreat rate relates to wave climate are unclear. In this study, historical and recent marine geophysical data collected around the Capelinhos promontory (western Faial Island, Azores) offer an unusual opportunity to characterize how a submarine terrace developed after the eruption. The promontory was formed in 1957/58 during a Surtseyan eruption that terminated with extensive lava forming new rocky coastal cliffs. Historical measurements of coastline position are supplemented here with coastlines measured from 2004 and 2014 Google Earth images in order to characterize coastline retreat rate and distance for lava- and tephra-dominated cliffs. Data from swath mapping sonars were used to characterize the submarine geometry of the resulting terrace (terrace edge position, gradient and morphology). Limited photographs are available from a SCUBA dive and drop-down camera deployments to ground truth the submarine geomorphology. The results reveal that coastal retreat rates have decreased rapidly with the time after the eruption, possibly explained by the evolving resistance to erosion of cliff base materials. Surprisingly, coastline retreat rate decreases with the growth of terrace width, and in a simple inverse power law with retreat distance. We explore how wave attenuation over the terrace affects variation, and more widely the implications for the terrace widening relationships to the development of abrasional banks and guyots.

Keywords: submarine terrace; coastal erosion;Surtseyan eruption; wave climate; Capelinhos

Geodynamical evolution of a foreland basin of the Atlas region (Morocco): the Neogene and Quaternary deposits of the northern side of the Atlas of Marrakesh

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From the upper Eocene-Oligocene, which is characterized by a passage from marine strata of the Middle Eocene to continental Oligocene strata (?), the northern Atlas basin functions as a foreland basin. The siliciclastic deposits of the Neogene and Quaternary fill in this basin which is called the Haouz of Marrakesh. The latter is part of a tectonic depression. The basin is not homogeneous: it is made of small units with specific sedimentary dynamics and contents. Thus in each one of these units, the deposits have their own organization (alluvial fans, fluviatile formations, etc.) and their distribution is controlled by the morpho-structural setting.

Keywords: Marrakesh High-Atlas, Neogene, Quaternary, Neotectonics, Alluvial-fan, Alluvial plain, Foreland-basin.

Morpho-structural setting of Terceira offshore revealed by high-resolution multibeam bathymetry and seismic profiles

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High-resolution bathymetric and seismic reflection data, acquired in the framework of the FAIVI EUROFLEET project, around Terceira Island in the Azores archipelago allowed us to unravel the main volcanic, tectonic and mass-wasting features. The island lies at the intersection of four submarine ridges, several tens of kilometres long and oriented along NNW-SSE and WNW-ESE directions. Volcanic features are mostly located on the Western (Serreta) and North-Western ridges, encompassing linear eruptive centers, pointy and flat-topped cones. A relationship has been observed between volcanic morphologies and water depth, likely reflecting the interaction between hydrostatic pressure and crustal thickness. A large number of fault scarps displacing the seafloor have been also mapped, mainly in the Eastern and South-Eastern ridges, and to a lesser extent in the North-Western Ridge. The strike of fault scarps and linear eruptive centers has been used as a tectonic marker for the stress field, revealing two main systems trending WNW-ESE and NNW-SSE. Both systems are consistent with the regional tectonic structures and related to the diffuse dextral transtensional zone. Mass-wasting features are mainly characterized by a few hundred-meters wide superficial landslide scars affecting the edge of the insular shelf, often representing the headwall of submarine channels. Large-scale summit or flank collapses have not been identified in the multibeam bathymetry, while two landslide scars, 1-1.4 km wide, have been imaged on the upper part of Serreta Ridge between -100 and -600 m, where the 1998-2001 submarine eruption occurred. The distribution of volcanic, tectonic and mass-wasting features, with remarkable differences in size and morphology, between the submarine ridges are explained in the framework of the morpho-structural evolution of the Terceira edifice and hypothesized as reflecting successive stages of ridge evolution.

Keywords: volcanic cones, linear eruptive centers; fault scarps, mass-wasting; ridge evolution

Neogene sea-level changes and its record in the Atlantic coasts

Cyclicity and depositional model of Langhian-Serravallian warm-temperate carbonates of the Lagos-Portimão Formation (Algarve, South Portugal)

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Since the pioneer works in the late 1980s, neritic carbonate sedimentation characterized by the heterozoan factory has received increasing attention. Middle Miocene (Langhian-Serravallian) carbonates of the Lagos-Portimão Formation (Pais et al. 2000; Dabrio et al., 2008) deposited in the south Portuguese shelf are a good example of sedimentation in an open shelf dominated by heterozoan carbonates. These deposits are well exposed in the Vau-Rocha cliffs (Portimão, Algarve). Three main facies were recognized: mollusk-rich floatstones (molechfor), skeletal packstones/grainstones (molechfor) and quartz-rich skeletal packstone (bryozoans > planktonic formaminifers >echinoids) that represent, respectively, conditions of inner (above WAD), middle and outer shelf. Skeletal components (foraminifers, molluscs, echinoids, barnacles, bryozoans and serpulids) indicate the domain of the heterozoan factory and oligophotic conditions for the middle and outer shelf.

The vertical distribution of facies and bounding discontinuities of the facies packages allow to recognize three sequences, each with ca. 5 meters thick, within the Langhian-Serravallian succession. The occurrence of Preaorbulina in the lower part of the section, and the presence of Orbulina in the referred sequences, as well as mollusk Sr isotopic ages of 12.2Ma and 11.5Ma in the upper one, define a time span from Langhian to Serravallian. Moreover, in the uppermost part of the studied section, the occurrence of Globigerina apertura, Neogloboquadrina acostaensis and a Sr isotopic age of 10.7Ma indicate the Lower Tortonian.

The sequences have an erosive lower boundary that can be linked to hardground surfaces developed on the underlying shallowest facies (mollusk-rich floatstones); the overlying facies becomes progressively deeper ending with inner shelf facies. They represent transgressive-regressive cycles tentatively related to 3rd order eustatic cycles (Haq et al. 1987). In the upper sequence, recognizable higher order cyclicity (with ca 0.4 m thick) may be linked to orbital forcing (i.e. Milankovitch cycles).

The compositional and textural characteristics and the observed vertical association of facies suggest sedimentation in an open shelf dominated by wave action. The absence of non-skeletal particles (peloids, ooids, and grapestones), carbonate mud precipitates, hermatypic corals and calcareous green algae in the shallow-water deposits suggest cool surface water temperatures (< 20 ºC year-round).

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Keywords: Heterozoan carbonates, Open shelf, Cyclicity, Langhian-Serravallian, Lagos-Portimão Formation

Neogene sea-level changes record at the Canary islands: eustatism and tectonic

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Miocene outcrops from Lanzarote are located between Janubio, to the northwest and Playa Quemada to the southeast, between 10 and 70 m asl. These deposits, which appear in sections, are found on basalt materials of the Ajaches Formation, dated between 14.5 and 13.5 Ma (Carracedo et al., 2002). In Janubio, the fossiliferous outcrops have been covered by another Tías-Janubio Formation, dated 8.9 Ma (Meco et al., 2007).

In Fuerteventura the deposits extend from the Aljibe de la Cueva, to the northwest of the island, to near Tarajalejo to the southeast, at a variable height, ranging from 3-4 m to over 40 m asl in Jandía. In the central zone they are located on a platform carved in the materials of the Basal Complex (Gutiérrez et al., 2006) or on the basaltic rocks of the Initial Dorsal Building (Fernández et al., 2006). In the northwestern part of the island, these deposits cover basaltic castings dated between 17 and 11.8 Ma (Abdel-Monem et al., 1971). In the peninsula of Jandía are located on basaltic materials of the Miocene building of Jandía, dating between 21-14 Ma (Coello et al., 1992). At the same time, the marine deposits located between the Aljibe de la Cueva and Aguas Verdes beaches have been covered by basaltic castings dating to 1.9 Ma, 2.7 Ma, 2.9 Ma and 4.4 Ma (Coello et al. Al., 1992).

In Gran Canaria they are located in the north and northwest of the island, up to 120 m asl, constituting what is known as Detritic Formation Las Palmas (FDLP). FDLP covers trachytes and phonolites dated between 13.3 and 9 Ma (Carracedo et al., 2002), and materials of the Roque Nublo Formation, whose aged is between 4.9 and 2.9 Ma (Guillou et al., 2004), are included among the sedimentary materials. However, a phonolithic wash located between alluvial materials with phonolitic bolulders and marine deposits in Guiniguada has been dated to 9.37 Ma (Meco et al., 2007).

From the stratigraphic point of view, the deposits reveal that the sedimentation sequence always begins with a conglomerate level, located on the Miocene volcanic materials that constitute the insular buildings. This conglomerate basal level establishes a clear correlation between the deposits of Lanzarote and Fuerteventura, a fact that should be confirmed in the case of the Detritic Formation of Las Palmas. In addition, the height at which the different deposits are located indicates tectonic movements of the insular buildings (Fernández et al., 2006).

Keywords: Canary islands; Miocene; sea-level changes

Trace fossils in Neogene sediments of Santa Maria Island (Azores, Portugal)

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Late Neogene sandy calcarenites sandwiched between volcanic rocks of Santa Maria Island contain different trace fossils, foremost burrows and borings. Burrows include the fodinichnia *Asterosoma* isp. and *Dactyloidites ottoi* (Geinitz) produced of ?polychaete, the irregular echinoid pascichnia *Bichordites monastiriensis* Plaziat & Mahmoudi and ?*Scolicia* isp., the crustacean domichnia/fodinichnia *Ophiomorpha nodosa* Lundgren, *Ophiomorpha* isp., *Thalassinoides* isp. and ?*Psilonichnus* isp., the domichnion/fodinichnion *Palaeophycus* isp. produced of ?polychaetes, the repichnion ?*Curvolithus* isp. referred to ? flat worm, the domichnion *Diopatrichnus santamariensis* Uchman et al., which tubes are built of shell debris, produced by a polychaete similar to *Owenia* sp., and the pascichnion *Macaronichnus segregatis* Clifton & Thompson produced by polychaetes. *M. segregatis* is abundant in the Malbusca section, where it shows prevailing vertical orientation controlled by fluctuations of the transition between fresh and marine water in pores of foreshore sediments (Uchman et al., 2016). Moreover, the feeding burrow *Piscichnus* isp. produced by ray fishes is present. These trace fossils include foremost members of the Skolithos and the Cruziana ichnofacies. They have been produced in sediment ranging from foreshore (e.g., abundant *Macaronichnus*) to shoreface (e.g., *Bichordites, Asterosoma*).

In hard substrates, variable borings are present. *Gastrochaenolithes* cf. *torpedo* Kelly & Bromley, produced by *Myophorceps ariestatus* (Dillwyn) occurs in thick shells, sandy calcarenites and weathered basalts. Entobia isp. (boring of clionaid sponges), *Caulostrepsis taeniola* Clarke (boring of spionid polychaetes, mostly *Polydora*), ?*Talpina* isp. (produced by phoronids) and barnacle attachment scars are present in mollusc shells. Regular echinoid borings *Circolites kotoucensis* Mikuláš, *Ericichnus bromleyi* Santos et al. and *Ericichnus asgaardi* Santos et al. occur in sandy calcarenites and locally in basalts. These borings have been produced very shallowly in the intertidal and shallow subtidal zone.

Keywords: Trace fossil; Diopatrichnus santamariensis*; calcarenites; Santa Maria; NE Atlantic*

Neogene high-energy events in the Atlantic

Stratigraphic record of Neogene hurricane deposits on islands in the Macaronesian Realm (NE Atlantic Ocean)

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Oceanic islands attributed to the Macaronesian realm include the Cape Verde, Canary, Madeira, and Azores archipelagos situated between 15° and 40° N latitude in the NE Atlantic.The >30 individual islands from among these groups are all volcanic in origin with as many as half that number retaining Neogene strata represented by limestone and volcaniclastic sandstone.Under present-day conditions, subtropical storms that affect the Atlantic basin (and often spill over into the Caribbean basin) get their start near the Cape Verde islands off Africa's west coast around 15° N latitude.From 1850 onward, detailed records show there have been as many as 891 hurricanes that cover every part of the North Atlantic basin within reach of their collective storm tracks.Based on computer models (i.e Wara et al, 2005 and. Brierley et al, 2009) it has been suggested that the frequency of hurricanes was greater during the Pliocene Warm Period from about 5 Ma and 3 Ma.If so, it should be possible to utilize the network of Macaronesian islands as station outposts to test for the presence and relative magnitude of geological hurricane deposits before and after the Pliocene Warm Period through the entire Neogene.Although a rare phenomenon, massive onshore transport of sediments as a by-product of sea storms is known to occur and such events may be expected to leave a permanent coastal record.The most convincing stratigraphic evidence for a Pliocene hurricane deposit is based on a 5-m thick sandstone bed distinguished by laminae with alternating dark minerals and lighter carbonate grains at Malbusca on the south shores of Santa Maria Island in the Azores.Similar Pleistocene deposits of laminated sandstone are exposed at Prainha, also on the south shores of Santa Maria.An older deposit that dates from the middle Miocene (14-15 Ma) has been suggested as a major storm deposit that left a 2.6-m thick limestone conglomerate formed by rhodoliths (spherical-shaped coralline red algae) trapped among island sea stacks at the Cabeço das Laranjas off Porto Santo in the Madeira islands.Massive berms and other coastal over-wash deposits formed by loose rhodoliths also are known from the exposed windward shores of Sal and Maio in the Cape Verde islands, as well as Fuerteventura in the Canaries.These appear to be Holocene or even historical in age.Much potential territory remains to be explored throughout the Macaronesian area in search of possible hurricane deposits.

Keywords: Hurricane deposits; Pliocene Warm Period; Macaronesian archipelagos; North Atlantic Ocean

Glacial age megatsunami fossil deposits in volcanic oceanic islands: a biological point of view

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The expansion and contraction of geographical range distribution of species (taxon cycles) is a common and well-studied biogeographical process. For terrestrial taxa, both fossil and extant records document poleward shifts, with range expansion of tropical species and range contraction of temperate species. For extant marine species, the geographical range contraction of cold-water taxa to higher latitudes as a result of the current global warming, as well as the range expansion of warm-water species to higher latitudes are also documented. Regarding the fossil record, outcrops on volcanic oceanic islands testify the range expansion of tropical marine species towards higher latitudes during interglacials (Ávila et al., 2015). However, so far, no studies have shown the expected range expansion of cold-water marine species during glacial episodes. This is probably because such deposits are seldom preserved due to erosion by rising sea levels during the subsequent interglacial episode. Thus, tsunami events occurring during glacial times and transporting large amounts of sediments onshore, away from the erosive action of interglacial high sea levels, are probably the only way to have access to glacial fossil assemblages. Here we document and discuss, for the first time, the palaeobiodiversity of the Tarrafal tsunami deposit (Santiago Island, Cape Verde), attributed to a flank collapse of Fogo volcano ~73 ky ago (Paris et al., 2011; Ramalho et al., 2015), which conclusively proves the tropical-ward geographical shift of marine molluscs during the glacial MIS 5a.

Keywords: Tsunami deposits, glacial episodes, MIS 5a, palaeobiogeography, Cape Verde

Depths and shapes of nearshore sandy clinoforms on high wave-energy coasts

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In coasts of high wave energy, sand produced by erosion and biological activity is commonly found deposited in rounded bodies at 20-60 m water depth. These are sandy clinoforms or otherwise called infralittoral prograding wedges. To test whether deposition occurs at water depths where wave oscillations fall below the threshold of motion of the sand, a compilation of such bodies was obtained from the literature and their rollover depths estimated. Wave properties were obtained at each clinoform using 10 years of reanalysis of the ERA-40 models. From the upper 5-percentile of wave properties at each site (representing stormier conditions), we found that the predicted wave-induced bed shear stress at the rollover is indeed quite similar to the threshold of motion predicted independently from grain size. This suggests that we may be able to broaden the analysis to work out which areas of ocean island shelves such as the Azores are likely in the future to be mobilised by climate-related changes in wave properties.

A second interesting property of these sand bodies is their surface morphology, which is commonly smooth and upwards convex. An old argument originally introduced by Bagnold shows that when sand agitated on a gradient (by waves, for example) causes particles to saltate, saltating particles sense gravity so that they tend to migrate downslope. Combined with conservation of mass considerations, this implies that the sediment topography could follow a diffusion equation in which the diffusion parameter varies strongly with the wave oscillation velocity. As wave oscillation declines sharply with depth, the diffusion parameter should also abruptly decline with depth. A forward finite-difference model calculation based on this scheme produced similar upwards-convex sand bodies as found in seismic reflection data. Although the model is incomplete (it does not allow for downwelling current transport, for example), it suggests how variations in stratigraphy might be studied to help interpret, for example, changes in sand input flux or varying wave climate over time.

Keywords: Coastal areas; sand migration; modellation; waves

Palaeogeography and palaeoecology of the Atlantic margins during the Neogene

Gastropod molluscs assemblages from the upper Miocene (Tortonian) of Lanzarote, Fuerteventura and Gran Canaria (Canary Islands, Spain). Chronostratigraphic and paleoenvironmental implications.

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Fossils mollusk association is crucial to know the chronobiostatigraphy of Canary islands Neogene, until now determined in the Mio-Pliocene limit. The fauna of gastropod molluscs of Canarian Neogene is represented by 92 species, ten of which are new species: Patella tintina, P. maxoratensis, P. mahaensis, Jujubinus ajachaensis, Osilinus burgadoi, Gibbula tindayaensis, Cerithium miocanariensis, Tectarius isletaensis, Morula mionigra and Conus fuerteventurensis (Martín-González et al., 2017). In addition, 52 species are cited for the first time for the Canarian Neogene. It is possible to emphasize the high number of archaeogastropods genera, such as Patella, Nerita and Osilinus, very rare in european Neogene deposits. The autoecological study indicates that most of the studied outcrops dominate genera from the rocky littoral environment, indicating the membership of the mesolitoral or tidal reef zonation rocky.
Eastern Canary islands shares 36 taxon with the Atlantic basins (Aquitaine, Loire, southern Portugal, etc); 44 with Mediterranean basins (Piedmont-Liguria, Karaman, etc.); 29 with the Paratethys (Vienna, Korytnica, etc); and 15 species with other Macaronesian archipelagos. Many of the species mentioned have a tropical-subtropical distribution, as evidenced by other accumulations of tropical organisms on the Paratethys coasts (Mandic et al., 2011) associated with coral reefs and mangroves.
In Neogene deposits of the islands, there are 14 species that are extinct before Miocene end: Oxystele rotellaris Michelotti, Gibbula biangulata Eichwald, Nerita martiniana Matheron, Clypeomorus obliquistoma Seguenza, Turritella turris Basterot, Janthina typica Bronn, Alvania rotulata Sacco, Pseudopusula parcicosta Schilder, Semicassis grateloupi (Deshayes), Vexillum indicatus Bellardi, Ancilla glandiformis Lamarck, Olivella longispira Bellardi, Conus eschewegi Da Costa and Subula plicaria Basterot, and two others (Hipponix sulcatus Borson and Ancilla patula Döderlein) extinguish at lower Pliocene. Of these 11 are cited in european basins during the upper Miocene, specifically during the Tortonian. Only four arrive at the Messinian (Conus eschewegi, Oxystele rotellaris, Ancilla patula and Ancilla glandiformis). Thus, the association of identified gastropods indicates that the sites studied belong to the upper Miocene, specifically the Tortonian. However, can not be ruled out that the upper levels of the stratigraphic series of some deposits could belong to Messinian.

Keywords: Canary islands; Miocene; Tortonian; gastropods

Influence of orbitally-controlled climatic changes on planktonic foraminifera of Montemayor-1 (Huelva, Spain) between 5.6 and 5.5Ma

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This study focuses on the planktonic foraminifera of the Montemayor-1 core (Guadalquivir Basin, SW Spain) during the late Messinian (5.6 to 5.5 Ma) and their response to the climatic changes related with the cyclicity of terrestrial astronomical parameters, especially linked to the precession cycle of Earth's axis.

Fluctuations of planktonic foraminifera communities and their abundance in the sediments reflect a gradual increase in water's temperature, evolving from a colder environment to a warm temperate one, and cooling again at the top of the analyzed section.

There is a predominance of cold species like Globigerina bulloides and Neogloboquadrina acostaensis during glacial phases (TG 14 and TG 12.) The maximum abundance of tropical species (Globigerinoides spp.) was observed at 5.56 Ma, 5.54 Ma and 5.52 Ma coincident with precession minimums of the Earth's axis. It was observed that at times of precession minima, corresponding to maximum summer insolation in northern Hemisphere, there is a significant increase of typical species of subtropical waters, indicating rising water temperatures. On the other hand, when the precession is maxima, corresponding to minimum summer insolation in the northern Hemisphere, there is a decline of the subtropical species and an increase of cold water species, indicating the cooling of Atlantic waters.

Moreover, it was possible to characterize alternating warmer and colder periods, which correspond to previously characterized wet and dry periods, respectively, in the Iberian Peninsula (Van der Berg et al., 2015).

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Keywords: Guadalquivir Basin, Messinian, Precession cycles, Climatic changes

Fossil Bryozoa in the Azores – the clash between biogeographic patterns and Neogene ocean circulation in the North Atlantic

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A shallow-water coquina of Pliocene age from Santa Maria, the oldest Azorean island, yielded some 40 cheilostome bryozoan species. As almost all of these bryozoans brood their embryos, and have non-planktotrophic larvae that usually spend only minutes to few hours in the water column prior to settlement, the only means of transport by which the founder populations could have reached these remote islands was by adult colonies rafting on floating objects. Geographic origin of these rafts and founder colonies was thus either the shallow western or eastern Atlantic continental shelves, and/or other (palaeo-)islands in the North Atlantic.

While most bryozoan genera have an ocean-wide to global distribution, some geographically restricted taxa allow an assessment as to the origin of this assemblage. Of the fossil taxa occurring in Santa Maria Island, the (sub-)genera Calvetomavella Reverter-Gil, Berning & Souto, 2015, Glabrilaria Bishop & Household, 1987, Hagiosynodos Bishop & Hayward, 1989, and Saevitella Bobies, 1956 are known only from the eastern Atlantic and Mediterranean Sea in both the fossil record and Recent faunas. Moreover, some of the Azorean fossil morphospecies are clearly sister taxa of, or possibly even identical with, fossil or extant species from the eastern Atlantic, such as Figularia figularis (Johnston, 1847). None of the fossil taxa from the archipelago can, on the other hand, unequivocally be ascribed to a western Atlantic source region.

This biogeographic pattern, which also exists in other marine taxa (e.g. molluscs, crustaceans, sponges), is thus in stark contrast to the prevailing surface currents in the mid-latitude North Atlantic, which are dominated by the eastwards flowing Gulf Stream (i.e. the northern part of North Atlantic Gyre). As palaeoceanographers insist that this surface current system has remained more or less the same and relatively stable throughout the Neogene, the transport of bryozoan colonies from the eastern Atlantic to the central Atlantic Azores Archipelago is difficult to explain.

Keywords: Bryozoa: palaeobiogeography; Pliocene; Azores; North Atlantic Gyre; dispersal

The palaeobiodiversity of the Azores: 15 years of research, from the Pliocene to the Recent

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Santa Maria Island is the oldest and southeasternmost island in the Azores. This island is remarkably rich in exposed marine fossiliferous sediments of Pliocene-Quaternary age. The marine fossils of Santa Maria Island are known since the 16th century. Recent studies herein documented, based on a multidisciplinary approach by an international team of researchers, increased our knowledge on the palaeobiodiversity of the Azores. As a result, several papers covering a wide range of topics were published, e.g., the evolution of marine organisms in oceanic islands, systematics, palaeoecology, palaeobiogeography, geology, geochemistry, sedimentology, ichnology, conservation and sustainable touristic management, educational purposes, geoconservation and historical reviews. Our revised list of species reports 185 taxa from the early Pliocene outcrops of Santa Maria and 126 taxa from the Pleistocene (Last Interglacial). During this talk, a pictorial summary will be done, displaying the most important fossils of the studied marine groups.

Keywords: Pliocene; Pleistocene; Last Interglacial; Invertebrate fossils; Vertebrate fossils

Neogene brachiopods of the North Sea Basin

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Neogene brachiopods of the Atlantic region are rarely studied and not so well-known. Recently, brachiopods of the North Sea Basin were studied in detail, mainly on the basis of Naturalis Biodiversity Center materials (the Netherlands, Belgium, Germany, France and England), and some private collections in the Netherlands. Considering the direct paleobiogeographical connections, the new data maybe also useful for researchers of the Atlantic.

„Inarticulate" brachiopods are represented by phosphatic shelled groups: lingulids and discinids. Genus Lingula is frequently mentioned in the literature, but until now only Glottidia dumortieri is confirmed from the North Sea Basin. Discinids are rather rare; however, at least three different species can be found in the Netherlands: Discinisca fallens, Discradisca multiradiata and Discinidae n. gen. n. sp. (under description). Rhynchonellids are not frequent but represented by three species. Notosaria nysti was rarely mentioned and illustrated in the literature but it is common at some localities. Two species of the very small and very fragile Cryptopora were recognized in the North Sea Basin samples. C. nysti was originally described from Belgium by Davidson, while C. lovisati was recorded for the first time from several washed samples from the Netherlands.

Neogene brachiopod fauna of the North Sea Basin is dominated by large-sized terebratulids which have a long and complex nomenclatural history. Several names were introduced in the literature. It seems that nearly all, or at least most of the Oligocene-Pliocene large terebratulids belong to the genus Pliothyrina described by van Roy, with the type species P. sowerbyana. This name became widely accepted and well-known, and several papers mentioned it. However, Peter Moerdijk in 2016 detailed the nomenclatural problems of Neogene Pliothyrina assemblages and the correct name of the very common and widespread species is under discussion. There is a significantly different form, which was separated by Lacourt and Voskuil („Terebratula" distinguenda). On the basis of some Dutch private collections (Freddie van Nieulande, Peter Mordijk, Harry Raad) this separate taxon with very small pedicle opening really exist, and its internal morphology is also significantly different from Pliothyrina, referring to a separate, new genus. This new taxon will be described in the near future in the framework of the cooperation with the private collectors.

Macandrevia cranium is present in several localities, but with much smaller specimen numbers. Terebratulina retusa, which is a common member of brachiopod faunas in the Mediterranean and the Central Paratethys, is decidedly rare in the North Sea Basin. Members of family Megathiriididae occur with small-sized micromorphic forms (Argyrotheca cistellula, A. cf. plicata, ?Bronnothyris). The presence of some rare species (Gwynia capsula, Glaciarcula spitzbergensis) was also indicated from the North Sea Basin in the literature.

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Keywords: Brachiopoda; Neogene; North Sea Basin; Naturalis

Atlantic rocky and sandy coastlines during the Neogene

Overview on spatial relationships between Neogene to modern rocky and sandy shores in the Macaronesian Realm (NE Atlantic Ocean)

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Oceanic islands attributed to the Macaronesian realm include the Cape Verde, Canary, Madeira, and Azores archipelagos in the NE Atlantic.The >30 individual islands in these groups are volcanic in origin, some with eruptions as recent as 2012 (Hierro in the Canaries) and 2015 (Fogo in the Cape Verdes).The youngest exhibit a sub-circular shoreline around a centralized caldera or a more irregular shape defined by a breached caldera.Basaltic cliffs plunge through a narrow submarine shelf to account for nearly 100% of the coastline on younger islands.Those that date for example to 20 Ma in the Canaries or 16 Ma in the Cape Verdes express a more complex coastal outline influenced by a longer history of development with multiple volcanic centers and late-stage flows that issued from peripheral vents.Typically, these are ovate or even more elongated in shape (i.e. São Nicolau in the Cape Verdes or Fuerteventura in the Canaries) with wider insular shelves due to a longer history of coastal erosion. Depending on geographic orientation, accrual of sedimentary formations through time that include extensive carbonate deposits has been and continues to be shaped by exposure to prevailing NE trade winds, or in the Azores a more westerly flow of atmospheric circulation.Maio in the Cape Verdes provides the model for a N-S ovate shape strongly influenced by the oblique strike of NE trade winds resulting in a windward rocky shore with a narrower shelf on one side and a leeward sandy shore with a wider coastal plain and marine shelf on the other.Distribution of rocky and sandy shores is evenly divided over the 76-km perimeter of that island, but 75% of rocky shores occur on the windward east side and 75% of sandy shores are restricted to the opposite leeward side.The Neogene sedimentary record throughout much of Macaronesia shows a proclivity for limestone deposits contributed by movable rhodoliths (spherical-shaped coralline red algae) impounded against rocky shores on windward coasts, although carbonate sand from abraded rhodoliths may accumulate in the shelter of leeward shores.With its unusual E-W orientation already in evidence during the late Miocene, São Nicolau exemplifies this particular case.In contrast, fossil coral reefs as indicators of high-energy coastal settings are rarely found on Macaronesian islands.Examples of Miocene coral beds in Macaronesia are recorded at Porto Santo (Madeira) as well as the Pleistocene of Gran Canaria (Canaries), and Santiago (Cape Verdes).

Keywords: Basalt shores; carbonate sands; prevailing winds; geomophology; Macaronesian archipelagos

Taphonomic development of shelly and diverse macroid deposits off a high-energy rocky shore: Lower Miocene carbonates from the Lagos area (southern Portugal)

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The middle Miocene Lagos-Portimão Formation features stratigraphic cycles of limestone and sandstone exposed in sea cliffs on the western Algarve coast of southern Portugal.Coastal outcrops can be followed for 45 km from Porto de Mós (in the west) to Albufeira (in the east).Overall, the sequence attains a thickness of around 100 m and spans the upper Burdigalian, the Langhian and lower Serravalian stages deposited during a maximum interval of 3 million years.This study focuses on the basal 5 m of the Lagos-Portimão Formation at Canavial Beach 2 km south of Lagos, where the disconformity with underlying Cretaceous limestone and dolomite is fully exposed. The first half-meter of Miocene strata reflects conditions during the initial marine onlap across a low-relief rocky shore. Coarse-grained carbonate sand forms the matrix around echinoid tests (Echinolampas), gastropods (Turritella, Ficus, and Cypraea), as well as abundant bryoliths. The succeeding half-meter is noteworthy for pectinid and venerid bivalves that underwent a complex taphonomic transformation from living organisms (both epifaunal and infaunal in habit) to post-mortem substrates for selective encrustation of inner-shell surfaces by bryozoans polychaete worms and extensive encrustation of outer-shell surfaces by coralline red algae. Pectinid bivalves occur as disarticulated valves, but the venerid bivalves often are articulated, although the original aragonitic shells were dissolved after being fully encased by a thick coating (>1 cm) of “lumpy” coralline red algae. After exhumation from an infaunal setting, strongly hinged venerid bivalves became the nucleus for rhodoliths up to 6 cm in diameter that rolled around on the shallow seabed under the influence of waves and currents. Thick limestone composed 80% by rhodoliths first appears between 3 m and 4 m above the base of the Miocene succession at Canavial Beach. Taxonomic details identified from thin sections allow rhodoliths from this level to be identified as Phymatolithon calcareum and *Spongites* sp .*Serpulid polycheats* also occur interspersed within algal thalli, but are poorly preserved. Rhodoliths constitute a commonly re-occurring facies throughout the Lagos-Portimão Formation, but this first successful taxonomic treatment is the result of superior preservation at the Canavial locality. Localized occurrences of pebbles and small bioeroded boulders of Cretaceous limestone attest to paleoshore erosion. High-energy conditions close to a low rocky shore are shown by the combination of bryoliths near the bottom of the Miocene sequence, followed immediately by large rhodoliths uniquely nucleated around bivalve shells (both articulated and unarticulated), and the subsequent development of substantial rhodolith banks.

Keywords: Miocene rocky shore; macroids nucleation; rhodoliths; southern Portugal

Rhodoliths and associated sediments around reefless volcanic island shelves (Azores and Madeira Archipelagos, NE Atlantic)

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Rhodoliths – nodules of free-living crustose coralline red algae (Rhodophyta) – are well recognized as amongst the most important carbonate builders worldwide. Their occurrence has been recorded from shallow to relatively deep-water shelf environments from tropical to temperate seas, such as in the Mediterranean, the North and South Atlantic, the Caribbean Sea, and across the Pacific.

In the Macaronesian region (sensu lato), however, the extent and location of rhodolith beds is still unknown, despite growing evidence of their crucial role in supporting island marine habitats. Recent evidence suggests that, in several places, the extension of these beds was larger than expected, especially at water depth tens of metres deep. In particular, the extent of rhodolith beds in the archipelagos of Madeira and the Azores is widely unknown, with only sparse information on some coastal enclaves and a few reports of deeper-water occurrences offshore Pico Island in the Azores, and Porto Santo in Madeira Archipelago. Given this, every opportunity should be used to improve our scientific knowledge of rhodolith beds in these archipelagos, and to map their extent and pristine status. Additionally, these archipelagos feature fossil rhodolith beds interbedded within the islands' volcanic successions, providing the means to gain a unique insight on the evolution of these assemblages, and their relationship with the depositional environment where they thrive.

The mid ocean geography of these volcanic islands makes them prime candidates for the study of present and past coastal biotopes and sedimentary processes, as well as places to gain insights on ancient patterns of wind and ocean currents.

The aim of this study is to improve our understanding of rhodolith ecosystems (habitat protected by European Union legislation) of the Azores and Madeira Archipelagos and associated marine biodiversity along the shelves of reefless volcanic islands, namely their ecology, structure, relationship with bottom and sediment dynamics, and temporal evolution, using both living and fossil rhodolith biotas. Here we present preliminary data concerning rhodolith beds from both the Azores and Madeira Archipelago, and how they compare to the fossil record. Our observations show that the shelf extension and the bathymetric gradient around volcanic islands in the Macaronesian realm are more limiting constraints tied to variations in water turbulence associated with regional wind and wave patterns. Thus with regard to surviving fossil rhodolith deposits in the Macaronesian island groups, there is potential for significant differences between early and middle Miocene deposits as opposed to later Miocene, Pliocene, and Pleistocene deposits. This change may

account for the relative scarcity of rhodoliths around the islands today.

Keywords: Nongeniculate coralline algae; Oceanic islands; Sedimentary dynamics, Macaronesian region

Terrestrial ecosystems in the Atlantic during the Quaternary: palaeoecological and palaeoclimatological reconstructions

The ecological impacts of the climate changes and human colonization on cladocera and chironomid assemblages in oceanic islands – the Holocene Caveiro Lake record (Azores archipelago)

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The Azores constitutes the most remote archipelago of the North Atlantic Ocean. Both human colonization and natural changes (mainly climate and active volcanism) have significantly modified its ecosystems. Cladocera and chironomid assemblages in a 805-cm long sediment core from center and deeper (4 m depth) part of Caveiro Lake in Pico Island was studied to assess the impact of environmental and climate changes over the last 5700 yr. Concordant patterns in composition between two biological groups were found, indicating major past environmental changes such as climate fluctuations (arid vs humid periods), volcanic activity, and anthropogenic intervention. Between 5200 and 5700 cal yr BP, and after a major volcanic eruption, both assemblages were dominated by littoral aquatic macrophyte species indicators, such as Alona intermedia (type) and the Psectrocladius sordinellus group. The ratio of littoral/planktonic (L:P) assemblages was low, indicating shallow lake conditions. Between 2100 and 5200 cal yr BP, an increase of planktonic and profundal chironomid taxa, suggesting lake deeper conditions. This period was also characterized by great volcanic activity on the Caveiro Lake, resulting in increased production of cladoceran resting eggs. Between 1800 and 2100 cal yr BP, coinciding with peat formation in the lake margin, an arid period was identified, reflected by the low abundance of subfossil remains of both assemblages, and the presence of high plant macro rests in the sedimentary sequence. Between 500 and 1800 cal yr BP, large changes in the L:P ratio were recorded, including the appearance of stream indicators taxa, such as Simulium sp., Zavrelimyia sp. and Rheocriotopus fuscipes type all suggesting a period characterized by climate instability. After 500 cal yr BP to nowadays the drastic reduction of total abundance and taxon diversity on both assemblages, which coincides with the establishment of the Portuguese colonizers, reflects forest clearance in lake catchment and the introduction of exotic species (plants, mammals and fishes). These results highlight the interplay that human and climate forces had on the environmental evolution of the islands' ecosystems.

Keywords: Pico island; climate fluctuations; volcanic activity; anthropogenic intervention; multiproxy

Late Holocene environmental reconstruction in Empadadas Norte Lake (Azores archipelago, Portugal) based on diatom assemblages.

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Environmental reconstructions using lacustrine sedimentary sequences are a useful tool to both identify long term changes in lake conditions and correlate these changes with environmental and climate drivers. Here we present a diatom-based environmental reconstruction from a 270-cm long sediment core of Empadadas Norte Lake (São Miguel island, Azores archipelago), corresponding to the last ca. 700 years, integrated with other proxy records.

Diatom assemblages along the Empadadas sequence show changes in species composition and diversity, resulting from climatic and anthropogenic forcings. The lower part of the sequence (ca. 1350 to 1450 AD) is dominated by macrophyte associated species, typical of low nutrient conditions, such as Stauroforma exiguiformis and Encyonema neogracile, indicative of an oligotrophic lake rich in macrophytes. These findings are supported by the high TOC/TN ratios indicative of organic matter (OM) mainly derived from lake macrophytes and external inputs. From 1450 to 1750 AD, a replacement of S. exiguiformis by Encyonema gaeumannii and Brachysira brebissonii, two benthic epipelic species, suggests lower lake levels probably associated with more arid climate conditions. This period also displays the shrink of trees and increase of shrubs and grasslands percentages owing to the increasing of human population in São Miguel island. Lower TOC and TOC/TN values during this phase also suggest a reduction in allochthonous OM inputs to the lake due to vegetation changes and reduced runoff. This stage is followed by a period (1750 to 1980 AD) of significant anthropogenic impact in lake ecosystem (replacement of native vegetation by exotic tree species, fish introductions, water consumption and impermeabilization of the littoral zone) that were reflected in the diatom assemblages with changes in species dominance. The major shift in diatom assemblages is observed from 1980 AD to present, with a drastic reduction of species richness and diversity, due to the high dominance of Staurosira sp., a tychoplanktonic diatom. This drastic shift also coincides with the recent global warming and could be associated to higher water level and productivity resulting from increases in precipitation and temperature.

Keywords: Diatom, Volcanic lakes, Environmental reconstructions, Azores, NE Atlantic

Woody ecosystems in the Galician Rias Baixas (NW Iberia) at the end of the last glacial cycle

Castor Muñoz Sobrino

Palaeobiogeography and palaeoecology of MIS 5e and MIS 11 deposits in the Atlantic coasts

Cutting the Gordian knot: contrasting biogeographic patterns and processes during glacial and interglacial episodes in volcanic oceanic islands

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The study of past climate changes provides important clues for the current global change biology. The effects of glacial and interglacial episodes on the geomorphology of volcanic oceanic islands as well as on the insular shallow-water marine biota are herein explored. A total of 12 Atlantic archipelagos and 4 marine groups (algae, molluscs, echinoderms and fishes) were studied. In most archipelagos, the estimated number for species of the examined groups was lower during the LGM, in comparison with that reported for the present interglacial. The main conclusions are: species richness is strongly correlated with littoral area; the power model is the best model for all marine groups studied but reef fishes; the GDM is not supported by our data. Two reinforcing effects take place during glacial episodes: on one hand, species richness is expected to decrease (in comparison with interglacial periods) due to the local disappearance of sandy/muddy-associated species; on the other hand, because littoral area is minimal during glacial episodes, area per se induces a decrease on species richness (by extirpation/extinction of marine species) as well as on speciation rates; maximum speciation rates are expected to occur in the interglacial periods, whereas immigration rates are expected to be generally higher at the LGM; and finally, sea-level changes are a paramount factor influencing marine biodiversity of animals and plants living in reefless volcanic oceanic islands.

Keywords: Marine organisms, marine species-area relationships, marine endemism patterns, large-scale biogeographic patterns, Pleistocene sea-level changes, island biogeography, volcanic oceanic islands, Atlantic Ocean

Palaeobiogeography of the eastern Atlantic and Mediterranean Neogene molluscs: implications for the Quaternary in the Macaronesian region

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From the study of dispersion patterns, it is possible to know the provenance of the species that we find today in most places. These patterns are not constant over time as they are closely linked to various environmental factors. During Miocene all the islands that make up the Macaronesia were located in a single biostratigraphic province with tropical characteristics (i.e. there was a faunistic continuity – marine realm - among the archipelagos). Over the years, the variation in temperature (i.e. with consequent variation in sea level) has led to an abrupt divergence of the type of fauna present. At the present, the islands that make up the Macaronesia are located in two biostratigraphic provinces (Azores, Madeira and Canary Islands with subtropical characteristics and Cape Verde with tropical characteristics). The data gap between these two-time series makes of outmost importance the improvement of paleobiogeography studies. The fossil deposits formed during the MIS 5e interglacial stage (pleistocene) allow the closing of this gap and thus better understand the variation of the dispersion patterns that have occurred in Macaronesia in the last 6 Ma.

Keywords: MIS 5e; sea level change; miocene; pleistocene; biogeography

Pleistocene echinoids of Santa Maria island (Azores, NE Atlantic)

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Santa Maria, in the easternmost of the Azores, is the only island of the archipelago to have outcropping fossiliferous sediments. The Pleistocene (MIS5e) record of Santa Maria is believed to be represented by a very narrow range of environments, i.e., restricted to deposits associated with an ancient rocky shore. A recent review of the fossil echinoid fauna of this island, revealed three species from the Pleistocene fossil record (MIS5e): Arbacia lixula, Sphaerechinus granularis and Paracentrotus lividus. All species are regarded as the most conspicuous elements of the extant rocky shores of the Azores. We present a fourth new species, Echinocyamus pusillus (O.F. Müller, 1776), an echinoid known to occur in the extant waters of the Mediterranean Sea and Northeast Atlantic, from boreal waters of Scandinavia and Iceland to tropical waters of Cape Verde and Sierra Leone. This species is also considered a common element in today's Azorean coasts. However, unlike the previous identified Pleistocene species, this soft bottom inhabitant is also known from the Pliocene fossil record of Santa Maria. The presence of E. pusillus among hard substrata inhabitants was not entirely surprising given the resilience of Echinocyamus tests to survive transportation. In the Azores, tests are frequently found among the debris in beaches and occasional are also found trapped among algae mats. Additionally, the rather broad geographical distribution in the extant waters of the Northeast Atlantic may be the key to understand the constant presence of this species throughout the history of the archipelago, from Pliocene to present times. In sum, this new record further reinforces the close faunal affinities with the NE Atlantic continental shores, found both in the fossil and extant Azorean coasts.

Keywords: Pleistocene; MIS 5e; Echinoidea; Echinocyamus pusillus; Azores; NE Atlantic

The littoral gastropod fauna of the North-Atlantic Ocean and adjacent Seas: biodiversity and biogeographical analysis

Ricardo Cordeiro

How does paleontological and geological information influence inferences drawn from genetic data?

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In the last decades, molecular markers have been recurrently used to enlighten the evolutionary history of several organisms, allowing to estimate divergence times in phylogenetic trees according to a molecular clock. The inclusion of a timescale in phylogenetic studies helps to link the evolution of certain characters to particular geological, biotic or climatic events, increasing the plausibility of the inferences drawn. Calibration of phylogenetic studies - the process by which relative time is transformed into absolute age (e.g. millions of years) - can be achieved using independent information such as geological events or the fossil record.

Assigning a calibration point to a given node, based on a particular geological event, assumes that the split on the evolutionary history occurred as an immediate consequence of such event. However, most of the geological events occur at a slow, continuous way, and genetic exchanges are likely to continue as new barriers are formed, depending on the dispersal abilities of the organisms involved. A different scenario is assumed for species endemic to volcanic oceanic islands, where the age of the islands is often used as a proxy to the maximum age of the split between the island endemic species and their continental conspecifics. Nevertheless, the dispersal of endemic species can pre-date the age of the current islands if those landmasses are the most recent element of a series of oceanic island formation over time in that region, thus underestimating the age of the split event.

The idea of the fossil record constituting the best calibration source is the most consensual. It uses the age of a fossil as a minimum constraint for the age of the split event. However, several problems are associated with it, namely the incompleteness of the fossil record, erroneous fossil age estimates and the accuracy of the placement of fossils into phylogenies. The integration of slightly different fossil ages to calibrate the same node, estimated taking all these problems into account, can result in significantly different estimates for the other split events on the evolutionary tree. Moreover, the inaccurate placement of fossils into phylogenies often lead to the underestimation or overestimation of the timing of most evolutionary splits on the tree. Attempts to calibrate the phylogenetic tree of the family Rissoidae reflect most of these limitations.

Despite the advantages of calibrating molecular phylogenies based on geological and paleontological data, caution is advised when choosing the most appropriate calibration points to avoid critical errors in estimation and posterior inferences drawn.

Keywords: Calibration; fossils; geology; phylogenetics; incompleteness

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