

PROVENANCE OF MULTICYCLE SEDIMENTS ON THE BAY OF CADIZ AND THE ADJACENT CONTINENTAL SHELF (SW SPAIN) BASED ON SILICICLASTIC GRAINS EXOSCOPY

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Studies on the provenance and sediment transport have been based on the use of accessory minerals to determine assemblages and source areas. These can be supplemented by techniques such as the exoscopy, which provides information on morphology and surface features of grains as well as the differentiation of sedimentary stages.

In the littoral zones and inner continental shelf, recent sea level changes force to coexist relict sediments deposits, formed when sea level was lower than nowadays, with more recent sediments which are in equilibrium with hydrodynamic agents. It is important to consider the sedimentary facies distribution and the characteristics and provenance of the sediments.

The objective of this work is to establish differentiation criteria between present and relict sediments, the determination of depositional environments, source areas and the sedimentation cycles undergone by the recent sediments of the bay of Cadiz and the adjacent continental shelf. This study was based on a multidisciplinary methodology involving the use of sedimentological, mineralogical and morphological analysis of the quartz and heavy minerals grains.

The study area constitutes an example of a siliciclastic sedimentary marine environment and displays several sediment types: inner bay with mud, external bay with sand and muddy-sand, while in the inner shelf predominate sandy-mud to the north and the muddy-sand to the south. The littoral zone is formed by beaches, cliffs, river mouths, and tidal creek and salt marsh edges. The mineralogical analysis shows the predominance of quartz in the sandy fraction. The heavy fraction in the sediments was never more than 5%, the heavy minerals studied are zircon, garnet, tourmaline, epidote and andalousite.

The use of surface feature analysis using SEM gives information about morphological characteristics and separate phases of the sedimentary evolution. The principal mechanical and chemical surface features identified in quartz and heavy minerals grains are: conchoidal features, mechanical V's, curbed grooves, arcuate steps, oriented etch pits, solution pits, chattermark trails, and polished surface. In addition, idiomorphic, subidiomorphic and xenomorphic grains are also observed especially in the group of heavy minerals. These textures (marks) and morphologies are generated as a consequence of sedimentary processes undergone by sediments during different stages and geological cycles of erosion, transport and deposit. The coexistence of different morphological types of siliciclastic grains in these sediments indicates a

high reworking grade, polycyclic character of the sediments and diversification of source area.

The combination of compositional and mineralogical study of modern sediments of the bay of Cadiz and the adjacent continental shelf is of great hydrodynamic and sedimentary processes interest. The application of textural and morphological analysis has allowed the establishment of multicyclic character of the sediments and the stages and cycles undergone by the terrigenous grains during its sedimentological evolution.

UPWELLING VARIATIONS IN CABO FRIO REGION DURING THE HOLOCENE AND ITS RELATION WITH PALEOCLIMATE CHANGES INLAND

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The Cabo Frio region as indicated by its name is a place of low SST due to a local upwelling triggered by the Northeast trade winds, the northward flow of cool South Atlantic Central Water and vortex of the Brazilian current in the upper warm Tropical Water. Paleoceanographic conditions during the last 13,000 years have been reconstructed based on two cores collected on the outer shelf. The studied proxies included mineral and heavy metal quantification, bulk organic matter characteristics and planktonic foraminifera.

A first phase of sedimentation between 13,000 and 7,000 cal BP is characterized by high mineral content probably due to the lower sea level. SST reconstructions indicate cool and highly variable temperatures that were probably not related to upwelling events made difficult by the low sea level but to lower regional SSTs. This is in good agreement with observations of continental climate dryer in southwest Brazil with intense events of precipitation.

A second phase between 7,000 and 3,000 cal BP shows higher SST indicating few occurrences of upwelling. Its may be due to the decrease of South Atlantic Convergence Zone (ZCAS) intensity linked to the lower summer insolation and the reduced monsoonal flux at that time. On the adjacent continent the decrease monsoon is evidenced by low lake levels and poorly developed forests.

The third and last phase, post 3,000 cal BP, is characterized by the onset of upwelling events that may be related to an intensification of the South American Monsoon and of the ZCAS activity leading to an increase of Northeast winds during summer which is typically the upwelling season. On the continent this period was marked by forest development. The transition at 3,000 yrs BP is very late compared to other Holocene record. Paleoclimate model simulations suggest that this later change would be a characteristic of the southern tropics.

LA CASCADE MESSINIENNE DU DETROIT DE GIBRALTAR

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Il est admis qu'au Messinien, la Méditerranée a connu un grand déficit hydrique dont a résulté une accumulation de sels de plusieurs dizaines de mètres dans certains de ses bassins.

En mer d'Alboran, ce type de sédimentation n'existe pas, et le Messinien n'est représenté que par de faibles épaisseurs sédimentaires indiqués par un faciès sismique particulier. Cette période est également marquée par une érosion généralisée revêtant parfois des dimensions spectaculaires dans le prolongement de certains cours d'eau en particulier au droit de oued Kert dans le Rif oriental et oued Laou dans le Rif occidental, mais aussi à la sortie orientale du détroit de Gibraltar. L'importance de cette érosion suggère qu'elle s'est produite à l'air libre, mais surtout que le détroit fonctionnait déjà à la fin du Miocène et non pas au Pliocène comme le soulignent tous les travaux antérieurs.

Avant le Messinien, l'alimentation de la mer Méditerranée par l'eau océanique était assurée par le biais des corridors passant par le sillon Sud-Rifain et par la chaîne bétique. Ces corridors se seraient fermés au Messinien. Pour expliquer la quantité de sel déposé au niveau du bassin Algéro-Baléare, certains auteurs envisageaient une alimentation en eaux salées sans pour autant préciser son origine. La découverte de cette entaille d'érosion messinienne à l'Est du détroit de Gibraltar comble cette lacune. Nous pensons que pendant cette période le détroit était partiellement ouvert et fonctionnait comme une cascade alimentant la Méditerranée en eau océanique avant son effondrement qui a donné lieu aux inondations catastrophiques qui ont mis un terme à la crise de salinité messinienne. Les produits de l'érosion, des marges exondées et entaillées par les cours d'eau, s'accumulent en partie dans des dépressions de la mer d'Alboran comme l'atteste un faciès sismique caractéristique associé à cette période.

L'excédent d'eau ainsi qu'une partie des sédiments alimentaient un cours d'eau qui se déversait dans le bassin algéro-baléare.

THE ESTREMADURA SPUR CONTINENTAL SHELF (WEST IBERIAN MARGIN): GEOLOGY, GEOMORPHOLOGY AND DEPOSITIONAL ARCHITECTURE

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The Estremadura Spur (ES) is a E-W trending submarine promontory (*ca.* 200 x 100 km) off the West-Iberian Margin, which establishes the morphological connection between the Madeira-Tore Rise (MTR) with the Portugal mainland and separates the Iberia Abyssal Plain in the north from the Tagus Abyssal Plain in the south.

The coalescence of the TMR and ES with the onshore mountains of the Portugal mainland that resulted from the Alpine shortening events of Paleogene and Miocene age, as well as alkaline magmatic intrusions of Late Cretaceous age (Miranda *et al.*, 2009) indicates that the history of the formation of the ES is polyphase and underwent different tectonic and magmatic processes.

In order to characterize its continental shelf, namely the morphology, surface structure and depositional architecture the following data set was used: (1) a bathymetric mosaic acquired with single-beam and multi-beam echo sounders; (2) single channel seismic reflection profiles acquired with sparker and chirp sonar systems; and (3) high-frequency side-scan sonar sonographs.

The Digital Terrain Model (DTM) analysis and its derived products (Slope, Aspect, Curvature, Roughness and Fractal Dimension) allowed segmenting the ES continental shelf in three distinct bathymetric and morphological domains: inner, middle and outer shelf. Alternatively, the seismic stratigraphy interpretation calibrated with rock samples dated by Mougenot (1976), allowed the production of a geological map and thus a correlation of morphology with stratigraphy and tectonics. Peaks of Palaeozoic and Mesozoic rocks were uplifted during the Miocene tectonic inversion (Tortonian) and now make up the main relief in the inner and middle shelf. These reliefs delineate and enclose depressions (Ericeira Sea and Lourinhã Basin), which were partially filled during the Aquitanian-Burdigalian transgression.

Ravinements and abrasion platforms of late-Palaeogene age were identified (Lourinhã Monocline) in the outer continental shelf, which was later affected by Aquitanian extensional tectonics. These morphologies are directly covered by Pliocene-Quaternary deposits comprising both with prograding and aggrading internal reflection configurations.

The transition between the continental shelf and the upper continental slope is sharp and uneven. The maximum depths of the shelf edge are -250 m to -440 m, which is unusual for the West-Iberian Margin. The seismic profiles show that the shelf edge is carved on Jurassic - Cretaceous rocks and its irregularity is a result of sharp ravines which took place at the end of Palaeogene. The maximum distance of the shelf edge to the coast is *ca.* 70 km, whilst it generally does not exceed 40 km along the West Portuguese Margin.

The most conspicuous tectonic feature in the study area is the WNW-ESE trending, 68 km long, Estremadura Spur Fault. Along this fault a gorge of approximately 20 km in length was carved – the Ericeira Submarine Valley. Morphologic analysis together with seafloor magnetic data suggests that this fault links the Tore Seamount with Sintra Sub-volcanic massif. This fault was reactivated during Messinian through Pliocene times, with an apparent

extensional drop of 45 m of the northern block. Aligned with this fault were observed, on side-scan sonar sonographs, lineaments that were interpreted as igneous dykes.

The geological map produced in this work reproduces the general pattern of the existent one by Boillot *et al.* (1978) but improves the detail of the cartography regarding the Miocene and Pliocene-Quaternary patches and allowed establishing the control of reliefs of hard-rock outcrops as sediment traps.

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SUBSIDIARITY OF SINGLE-CHANNEL HIGH-RESOLUTION AND MULTICHANNEL SEISMICS IN DEPICTING NEOTECTONICS OF A CONTINENTAL SHELF (TYRRHENIAN SEA, ITALY)

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We run high-resolution reflection seismic profiles exactly on the same survey routes of multi-channel higher penetration / lower resolution seismic lines, ruled out for oil exploration purposes in the late '60s; afterwards we have applied sequence stratigraphy and seismostratigraphy concepts to analyse a thick high-resolution seismic profiles network along the continental shelf of Latium (between Mount Argentario, southern Tuscany, and Capo d'Anzio, central Latium). The deformations within Pleistocene prograding deposits were described and every deformation typology was interpreted, classified and finally compared with the evidences shown by multichannel seismic profiles, for defining a structural model consistent with examined evidences.

The purpose of this study is to test a new effective method for examining the recent tectonic evolution of a continental margin, with a new technique not only integrating high-resolution seismic and multichannel seismic data acquired along the same survey routes in order to determine the agreement of deformation evidences in depositional sequences with deep structures activity, but also allowing us to date such an activity by means of sequence stratigraphy instruments and time-constrained seismic surfaces.

The Quaternary depositional units that make up the continental shelf are made of different deposits formed in contrary eustatic conditions on land and on shore. Chiocci (2000) detected and interpreted unconformity surfaces in marine deposits, as shown by high-resolution reflection seismics, gave them an age estimated by means of direct and indirect methods and related them to eustatic sea-level variation curves.

High-resolution reflection seismic profiles show upper Pleistocene depositional sequences (last 500 kyr) bounded by unconformity surfaces and their correlative conformities surfaces, some dated through the use of borehole data. It has allowed us to subdivide the middle-upper Pleistocene succession in (at least) seven 4th-Order Depositional Sequences.

High-resolution seismic reflection data show detailed deformation history of the upper part of the margin. The main structural elements have been revealed by means of evidences of deformation they produced in the middle-upper Pleistocene deposits. Every deformation typology was interpreted, classified and finally coupled with the geometry of the deep structures of the continental margin (revealed by multi-channel seismic profiles), hence demonstrating that most of the deformation evidences observed in high resolution seismic profiles were caused by faults interpreted from multi-channel seismic profiles.

Deformative elements were further assigned to classes according to the time constrained limit of their activity, as well as highlight by high-resolution seismic interpretation. As a result, this study allowed us to assess the neotectonic behaviour of the Latium continental shelf (Central Eastern Tyrrhenian Sea).

We generally found extensional structural elements with either NW-SE or NE-SW trends, with the only exception of a few compressive / transpressive elements southward of the River Tiber mouth, with a NW-SE trend and maybe connected to the Palmarola Fold System (Marani and Zitellini, 1986). Elements with more recent activity (within the last 450 kyr) were identified in three areas: between Mount Argentario and Montalto di Castro, offshore the River Tiber mouth and offshore Capo d'Anzio. In the two latter areas some deformations reach the seafloor, thus we classified them as active, although only one of them may be connected to seismicity on the continental shelf.

As deformation evidences have given hints on the state-of-activity of faults and folds, the depth of the paleo shelf breaks gives information of the vertical mobility of the continental margin. Such a reconstruction matches similar studies realised on the coastal plain (Bosi *et al.*, 1990; Bordoni and Valensise, 1998; Nisi *et al.*, 2003; Ferranti *et al.*, 2006), but it concerns a wider area and allows to better understand the regional tectonics in the last half million years.

Chiocci (2000) revealed a differential preservation of Pleistocene sequences, due to both subsidence of the outer shelf and coast-parallel tilting of the whole shelf. In fact, in the northern area subsidence allowed deposits to preserve, while from north to south there is a gradual erosion of these deposits on the inner and middle shelf areas during glacial

lowstands, therefore only the correlative conformities are kept intact. In addition, offshore the River Tiber mouth the gullies networks carved by hyperpycnal fluxes during the eustatic sea-level fall and lowstand develop more northwestward at every cycle (Chiocci and Normark, 1992).

Previous studies evidenced that the Pleistocene evolution of the Latium continental margin is strongly characterised by a strict interaction among tectonics, vulcanism and eustatism (Cavinato *et al.*, 1992; Cavinato *et al.*, 1994; Marra *et al.*, 1998; De Rita *et al.*, 2002; Giordano *et al.*, 2003). We performed a detailed analysis of mobility in relation to the depth of the eustatic minimum of 450.000 years ago (Marine Isotopic Stage, MIS, 12). Such depth has been measured along the paleo shelf break and two submerged terraces, formed at the same sub-sea-level depth. During the MIS 12 the sea level was at a height of about 110 m under the actual sea level, but now those elements are at altitudes varying from 110 to 89 metres under that level. We suppose that the subsidence affecting the outer continental shelf has a rate of about 0,24 mm/yr (Fraccascia, 2008). The seismostratigraphy of the shelf shows that the sequence boundaries of MIS 10, 8 and 6 are characterised by lacking unconformities, with only correlative conformities remaining, while more ancient boundaries have both unconformities and correlative conformities (Chiocci, 2000). In consequence we suppose a vertical uplift in the continental margin starting from 450-350.000 ago (corresponding to the main phase of volcanism in most of the Volcanic Districts of Latium), with a rate from 0 up to 0,25 mm/yr.

The actual position of the paleo shelf break and the two submerged terraces formed during the MIS 12 shows two main peaks. The first one (centered to Ladispoli) has been attributed to a regional uplift studied in the continental areas and caused by the activity of the Volcanic Districts of Latium. This uplift is not rigid along the continental margin, but it seems to be a bulge maybe centered on the Sabatini Mounts. The second peak (centered to Torvaianica) has been attributed to a local uplift caused by three anticlines whose end of activity is unknown, because the erosional unconformity formed during the last glacial sea-level lowstand eroded most of the depositional sequences more recent than 450.000 years ago; very high-resolution seismic reflection data reveal deformation evidences at least up to 350.000 years ago. The multichannel profiles in this area show the geometry of such anticlines.

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MARINE GEOHAZARD OF THE ITALIAN CONTINENTAL MARGINS, THE MAGIC PROJECT

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Introduction

Due to its high-density population, the Italian coasts are punctuated by coastal settlement; moreover, the presence of a mountain chain at short distance from the coast causes roads and railways to run close to the coast and along high cliffs for tens or hundreds of km. The presence of infrastructures and settlements in the coastal zones significantly increased after World War II with the increased of exploitation of near-shore and offshore resources. As a consequence, great attention needs to be devoted to coastal and marine natural risk, possibly enhanced by human activity.

The Italian offshore display a large number of active geological processes, reflecting the recent origin of the country within the complex geodynamic setting of the Central Mediterranean area. The continental shelf and slope show diffused erosional scarps, deeply-incised canyon systems and slide scarps and diffuse mass-wasting deposits, indicating frequent destabilizing of the thick and fast growing sedimentary cover lying on the continental margins. Moreover, active volcanic islands and underwater volcanic activity are present in the Tyrrhenian Sea and

Sicily Channel; recently they demonstrated to be able to generate landslide and cause tsunamis (e.g. the Stromboli 2002 event, with max. run-up greater than 10m). Indeed, the coastal regions experienced severe earthquakes and tsunamis in historical times (see Casalbore *et al.*, and Bozzano *et al.*, this volume).

The Italian project MAGIC (Marine Geohazards along the Italian Coasts) has been conceived in order to depict and classify the geohazard-related features of the Italian continental margins.

The project is funded by the National Civil Protection Department and aims at producing the 1:50,000 Map of Geohazard Features of the Italian Seas (consisting of 72 sheets). A GIS-based online archive of the geological, sedimentological, and geomorphic maps derived from existing literature on the Italian seas will be produced as well (*Infor.Mare* database, see Capperucci *et al.*, this volume).

The realisation of the Map of Geohazard Features will be based on high-resolution morpho-bathymetric data derived from multibeam bathymetry. During the 5-year life span (2007-2012) of MAGIC, more than 70,000 nautical miles of multibeam data will be analysed, of which ca. 60,000 will be acquired during the project that will allow identification and comparison of geological features produced by sedimentary and tectonic processes that actively shape continental margins. The project will provide new and relevant information on seafloor morphology and geology of the Italian margins and may have a wide range of application on different management issues.

Structure of the Project

MAGIC Project is a Research Grant given by the National Civil Protection Department to CNR-IGAG (Institute for Environmental Geology and Geo-Engineering), based in Rome. Project manager is F.L. Chiocci, Professor at University of Rome.

The project was conceived since the beginning as a cooperative effort by the entire Italian scientific community working on Marine Geology as it involves three Institutes of the CNR - National Research Council (based in Naples, Rome and Bologna, respectively), the Osservatorio Nazionale di Oceanografia e Geofisica Sperimentale (OGS) in Trieste, and eight universities (Milan, Rome, Cagliari, Sassari, Benevento, Palermo, Genova, Trieste) coordinated by Conisma (Consorzio Interuniversitario per le Scienze del Mare). Also the involvement of the Italian Navy (Istituto Idrografico della Marina) is foreseen, though not realised yet.

A total of 19 research units have been defined, each of them having the complete responsibility of one or several of the 72 sheets of the 1:50,000 Map of Geohazard features of the Italian Seas. The responsible of each research unit plus a few external experts and representatives of Civil Protection Department made up the Scientific Council, that is the leading body of the project. A Group for acquisition and processing (GAE), composed by experts, defines the procedures and standards for multibeam data acquisition and processing.

Results

During the first year of the project, 25 of the 72 sheets of the Map of Geohazard Features of the Italian Seas have been produced (Fig.1). The compilation of these maps was based on existing data gathered by the different Research Institutions and groups involved in the project during their previous scientific activity. This cartographic issue required a huge cooperative effort for the definition of standard interpretative and mapping criteria accounting for the significant differences, in each area, of the submarine geology and morphology.

Through a one-year-long discussion of the Scientific Council of the project, a hierarchical four-level interpretative and mapping procedure has been set up.

- The first level (1:250,000 in scale) defines the main "domains" present in the area by mapping the general geomorphological features.

- The second and third levels made up the 1:50,000 Map of Geohazard Features of the Italian Seas. In particular, the second level defines areas having similar characters or being affected by similar erosional/depositional processes; quantitative geohazard attributes are associated to these areas, to build up a GIS-based database.

- The third level is expressed by lines, symbols and small areas by which the seafloor features are mapped in detail. Second and third levels are jointly represented in the 1:50,000 map as areas in colour (2nd) and vectors (3rd).

- The fourth and final level is a series of highlights (at appropriate scale) on potentially dangerous settings that deserve attention, monitoring and further investigations.

The mapping is realised by a customised mapping software (Global Mapper-Magic Project version) used by all the research groups.

Conclusions

MAGIC is the largest singular project in Marine Geology in Italy since the '80s, as far as amount of data to be acquired, number of institutions and research units involved and coordination are concerned. Moreover, MAGIC project fund a large number (some 80 annuities) of research contracts and fellowships, in order to exploit the maximum possible information from the massive data acquisition and mapping. Such an effort would boost the growth of a new generation of researchers in marine geology in Italy in the meanwhile accomplish the goals that are needed by Civil Protection Department both before and during the emergencies.

TERTIARY TO QUATERNARY EVOLUTION OF SCOTT REEF, AUSTRALIA'S NORTH WEST SHELF

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The Australian North West Shelf is a carbonate ramp which was established in the Cretaceous. Its surface is marked by discontinuously developed coral reef systems, which vary from fringing reefs to isolated reefs rising from deep-ramp settings. The Scott Reef system (at 14°S) is a small carbonate platform which rises from depths of 400-700 m on the distal portion of the carbonate ramp. It is a complex of two large isolated coral reefs: North and South Reef, separated by a deep channel, which overlies a major gas discovery in the Browse Basin. Scott Reef environment is tide-dominated, cyclone influenced and wave-influenced, in a tropical setting. The combination of core data from a range of reef crest and lagoonal settings, shallow seismic and U-series dating has provided a unique opportunity to develop a 3D model for reef growth which is geologically detailed whilst informing biophysical analysis and environmental management.

The Scott Reef seismic architecture resemble a flat-topped platform bounded by platform margin reefs which flank steep marginal slopes, as reflected in the current day surface environments. Seismic profiles reveal a buried Last Interglacial (MIS5, ca. 125,000 year) reef system, in contrast to the regionally emergent reef of similar age along the Ningaloo coast, such that reefs which apparently grew to sea level are now 30m below present sea level, indicating significant subsidence in the Late Quaternary. Earlier distinct cycles of upward platform development are flat and parallel in shape, with cycle boundaries being marked by platform wide seismic discontinuities (R1, R2, and R3). The internal architecture of reef building phases in North Reef and South Reef is similar, with the exception that equivalent horizons are shallower in North Reef. The average Quaternary subsidence rate for South Reef is calculated to be 0.45m/ka whilst North Reef experienced a 0.29m/ka rate of subsidence.

In the 180 m cored interval studied in North and South reef five stacked reef buildup phases, each ca. 35 m thick have been established. Each represents rising sea levels of interglacial meltwater events dated as MIS 1,5,7,9 and 11 (400,000 years of reef growth history), with good correlation with ice core records of global climate cycles. Each reef growth phase has kept pace with rising deglaciation sea levels, demonstrating the resilience of the reef system. During glacial stages the platform was exposed; thin soils and calcrete were formed as hiatuses, which also show karst features in South Reef lagoon. Establishment of fresh water lenses during exposure intervals resulted in diagenesis of parts of the reef limestones. The dominant frame builders are communities of arborescent and domal corals (including *Porites*); established as end member communities. These may occur

in association with *Halimeda*, the latter playing a significant role in some of the accretionary phases of reef growth. There is also a distinctive assemblage of robust branching corals and coralline algae in some cores, representing a high energy association in more exposed reef sites.

The abundance of *Porites* in logged sections enabled detailed Sr/Ca analysis of Early, Mid and Late Holocene sections. This new data shows that Scott Reef experienced a marked cooling event at 8.3 ka, which indicates temperatures as low as 24°C. Supporting $\delta^{18}\text{O}$ data confirms cooling (~2 °C) of SST relative to the Middle and Late Holocene. At 5.8 ka $\delta^{18}\text{O}$ records show another important oceanographic change with surface seawater becoming more saline. These records are currently being further analysed.

Scott Reef has one of the most complete seismic and core data sets available for the Quaternary in the Australian region and will provide sea level, growth history and coral community evolution records in an important tectonic and oceanographic setting.

OCEAN CLIMATE IN THE TROPICAL SOUTH EASTERN PACIFIC DURING THE LAST TWO MILLENNIA

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We present marine Late Holocene proxy records from the Tropical South Eastern Pacific, based on near-laminated sediment cores from the central Peruvian continental margin (12 - 14°S). The climate between 500 and 1350 AD was characterized by cool sea surface temperatures (SST) along the Peruvian coast, stronger nitrate reduction in the water column (related to an intensified Oxygen Minimum Zone), reducing conditions in the sediments and limited terrigenous input associated to arid conditions in the hinterland. This pattern is consistent with the hypothesis that the dry Medieval Climate Anomaly (MCA) in the Eastern Pacific region resembled to modern La Niña conditions. The MCA was followed by wetter conditions, warm coastal SST, increased water column ventilation and milder reducing sediment conditions during the "Little Ice Age" (LIA), from 1400 AD to 1820 AD. Comparison with other records in the Pacific and in Cariaco Basin strongly suggests that meridional latitudinal shifts of the

InterTropical Convergence Zone (ITCZ) position as the key mechanisms explaining these centennial-scale changes. A rapid increase of upwelling and productivity characterizes the ocean conditions since the late nineteenth century, in tune with regional alongshore wind intensification. Since the mid-twentieth century, comparison of proxies with historic and instrumental SST records indicate unprecedented coastal cooling, in parallel with offshore warming, as current hypotheses of global warming impacts on upwelling systems predict.

FORMATION OF MUDDY DEPOCENTERS ON CONTINENTAL SHELVES

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Deposition of fine-grained material on clastic continental shelves takes place under a range of different environmental conditions, a fact which is expressed by a wide variety of resulting types of mud depocenters. A still limited but increasing number of three-dimensional studies of mud bodies on shelves through sediment-acoustic and sediment-coring approaches has gained our knowledge on the architecture and evolution of such deposits over recent years.

Three of our own studies illustrate these individual conditions of mud deposit formation. (1) Off NW Spain, the Galician mud depocenters have formed over the past 5 ka (cal ka BP) by expanding from around two very local nuclei. These initial spots were located far away from the original source of sediment supply. By this development an elongated *mud belt* and a number of independent *mud patches* have formed, as a result of interaction between shelfal currents and local morphology. (2) Off Mauritania, two locally defined *mud wedges* have formed since 9 ka. These centers show internal foresetting and are the result of shelf inundation together with a continuous aeolian sediment input. However, they have in the end formed behind a pronounced step in seafloor morphology. (3) Off Senegal, a bifurcate *mud belt* has formed which extends not only to the South of the river mouth but also to the North which is seemingly against the prevailing current conditions on the shelf. The paradox shaping of this mud body is, according to our studies, related to a stepwise southward shift of the river mouth over the past 5 ka and an associated gradual change in the coastal morphodynamics.

As general observation compiled from published studies, locally defined mud deposition on shelves has initiated around four alternative time intervals related to 1) early outer-shelf drowning, 2) wide inner-shelf inundation, 3) the stage of maximum flooding, or 4) during sub-recent times. The subsequent expansion dynamic might occur a) omni-directional in case of a direct depocentre attachment to the fluvial sediment source, b) in terms of current-parallel or current-normal clinof orm progradation, or c) in

the direction of advective current transport associated with a detachment from such a source.

Nine individual types of shelfal mud depocenters are identified and described on the base of surface appearance, in-depth architecture and their formation history. These defined types are prodelta, subaqueous delta, mud blanket, mud patch, mud belt s.s., mud downdrift, mud entrapment, mud wedge, mud contourite drift. Major sedimentation-forcing parameters are 1) sediment input, 2) morphology and 3) hydrographic conditions. A lateral or stratigraphic transition from one into another type might, however, appear as response to a shift in the balance of these environmental control forces.

Further studies in modern and ancient settings are needed for a better understanding of the formation and preservation of such shelfal mud depocenters. Even of higher importance might be their potential storage capacity for (bio-) chemical compounds and their influence on the benthic system, both yet un-estimated but probably of high impact for the modern ecosystem.

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EARLY HUMANS, CLIMATE CHANGE AND COASTAL REFUGIA

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The period just prior to and during the last glacial cycle (LGC) experienced significant climate change that significantly impacted the development and behaviour of *Homo species*. For instance, Antón *et al.* (2002) suggest that it was during a period of increased aridity and

coincident expansion of African grasslands and reduced primary productivity that changes in hominin diet and foraging behaviour potentially increased *H. erectus*'s reliance on meat and fat and led to increased brain and body size. During periods of less extreme climate change, dispersal barriers for early hominins were reduced, facilitating their ability to follow migrating animals. Although temperature reductions were not as significant during glacial intervals in the tropics as in high latitude regions, the climate of Africa was still impacted. For example, during the last glacial maximum increased desertification appears to have reduced productivity in some regions of interior Africa. Flora, fauna, and human populations likely inhabited the potentially more productive and proximally located African continental shelf exposed by lowered sea levels (Faure *et al.*, 2002; Hetherington *et al.*, 2008). Earlier migrations may have been similarly influenced. Some researchers suggest that earlier modern human dispersals out of Africa may have been related to human exploitation of coastal shellfish resources that provided extensive and valuable nutritional advantages (Crawford *et al.*, 1999; Foley, 2002; R.G. Klein, 1999). Marean *et al.* (2007) have found evidence of the use of marine resources at Pinnacle Point on the south coast of South Africa by ~164 000 (+/- 12 000) years ago. These findings indicate an early coastal adaptation along with bladelet technology, which was more typical of much later periods (Ambrose, 2002; Soriano *et al.*, 2007). During marine isotope stage 6 (MIS6:150,000-135,000 years ago) and later glacial intervals, coastal sites may have acted as refugia, with shellfish becoming critical resources when increased aridity made interior terrestrial resources more depleted. These examples emphasize the importance of changing climate in human development, behaviour, migration and dispersal.

This paper, which focuses on human occupation of the continental shelves of the world, is based on Hetherington and Reid (2010). Geological and climatological data are combined with the results of an equilibrium climate simulation for marine isotope stage 6 (MIS6: 150,000 to 135,000 years ago) and a 122,000-year time-series (MIS5e to present) simulation performed on the UVic Earth System Climate Model to show changing climate and vegetation with particular focus on those regions of the world inhabited by humans. The model is driven by time-dependent changes in atmospheric CO₂ and orbital forcing through the LGC. Land-ice thickness is interpolated from prior ice sheet simulations at 1000-year intervals. Results from the climate simulations indicate changing land and surface air temperatures, land and sea ice extent, precipitation, and coverage and productivity of various vegetation types as the Earth moved through glacial and interglacial cycles. Model results and proxy findings are discussed in light of archaeological data to illuminate connections between climate change and key events in human history and evolution.

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PRODELTAIC UNDULATIONS OFF THE GUADALFEO RIVER, ALBORAN SEA NORTHERN MARGIN: A GEOSTATISTICAL APPROACH

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A geostatistical analysis of multibeam bathymetric data was executed in a significant field of prodeltaic undulations located off the Guadalfeo River, northern margin of the Alboran Sea, western Mediterranean Basin. Our main motivation was to depict with great detail the along- and across-shelf variability of the sea-floor undulations, in order to get useful insights of the involved genetic mechanisms and to ascertain the potential geohazard risk.

Multibeam data were collected with a 300 kHz Simrad EM3000D multibeam echo-sounder, providing complete

coverage for the shelf domain in the study area and beyond. The geostatistical analysis was based on the determination of characteristic parameters and derived relationships (rms (H), azimuth (Θ), characteristic width (L_n) and characteristic length (L_s), as well as the wave or vertical form index (L_n/H) and aspect ratio (L_s/L_n)) that define the Von Kármán covariance function through an inverse process, and involved three steps: a) data sampling; b) grid adaptation; c) data inversion.

Our results support the contention that prodeltaic undulations off the Guadalfeo River should be regarded as sediment waves, mainly generated by strong normal-to-contour sediment flows with a riverine origin, and that the contributions of other wave-forming processes such as bottom currents or sediment deformation, if they exist, must be regarded as secondary. Of the geostatistical parameters, the relationship L_n/H appears to be the most predictable, as it delineates two main depositional axis, apparently related with the present and a previous river mouth. Those two main depositional loci are distinguishable from the geostatistical parameterization; the western field is highly symmetrical, with the higher undulations in an axial position and diminishing the L_n/H relationship both laterally and downslope. In contrast, the eastern field shows lower undulations, and the L_n/H changes are less conspicuous, but in contrast the undulations are more elongated. Those significant differences are considered to be the product of temporal changes that involved significant modifications in the generating sediment flows, with a tendency to more intense flows, with increased proportion of bedload sediment transport. Ultimately, this change could be indicative of an increase in the torrentially and/or seasonality of the river basin.

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A MIDDLE EEMIAN TECTONIC EVENT : OFFSHORE AND ONSHORE EVIDENCES ON THE RHARB AND MARMORA COAST, MOROCCO.

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Sedimentary involutions may record co-seismic activity. From the Rabat region to El Jadida, several beach sections show evidence of Late Interglacial large involutions associated with cliff and shore caves collapse

and megaclast upturning. Bone-bearing and clastic beds include soil fragments that also attest for an abrupt event. Other types of deformations were described in the same area by Plaziat *et al.* (2006). These features are fossilized by intra-eemian lithified dune sands. Similar features are recorded in the same region on the "5 m" platform, buried under tidal muds overlain by dune sands and a continental soil. They show similar facies to those described by Mhammdi *et al.* (2008) and attributed to the Lisbon tsunami. Datings by Barton *et al.* (2009) in the Contrebandiers' cave south of Rabat, allowed us to emplace these events close to 115 ka. North of the Rharb, back barrier sands cropping at ca. 8 m at the level of the Lalla Zahra anticline are truncated by a marine abrasion surface and are fractured before burial by dune sands, in a similar stratigraphic position. The most complete section crops out about 30 km to the North, but without any traces of a major earthquake or a tsunami. Recurrent microseismicity is recorded here from the MIS 5 sl to the end of the dune settlement. In North Africa and southern Portugal, dune activity prevailed up to 80 ka (Mauz *et al.*, 2009). This event seems also to be recorded offshore and seems to be centered on the Bouregreg and Oued Cherrat region.

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MID TO LATE HOLOCENE HYDRODYNAMIC CHANGES ON THE SOUTHEASTERN BRAZILIAN SHELF BASED ON GRAIN SIZE RECORDS

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High-resolution grain size analyses of three AMS ¹⁴C-dated cores, from the Southeastern Brazilian shelf were performed in order to study Mid- to Late Holocene changes related to wind-driven currents variability.

The cores exhibit changes that allow us to recognize a millennial variability which may be associated with shifts in the average latitudinal position of the Inter Tropical Convergence Zone (ITCZ), as observed by Haug *et al.* (2001), for the South American continent. Centennial

variations in the grain-size can be associated with changes in strength of the El Niño phenomena, as observed by several authors. Finally, we recognized a 1100-yr cyclicality which has been reported by Clemens (2005) and which may be one of the first sure indications of solar forcing of this time scale on the climate of the Southwestern Atlantic margin.

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THE SOUTHERN BRAZILIAN SHELF: GENERAL CHARACTERISTICS, SEDIMENT DISTRIBUTION AND QUATERNARY EVOLUTION

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Extending from latitude 34°S to 22°S the Southern Brazilian shelf constitutes the only part of the Brazilian shelf with a subtropical to temperate environment.

The studies on the different geological aspects of the area began in the 1960's and have recently been reassessed after the studies related to the determination of the Economic Exclusive Zone.

In terms of morphology, the Southern Brazilian shelf may be divided into three sectors, the São Paulo Bight, the Florianópolis-Mostardas Sector and the Rio Grande Cone, characterized by conspicuous differences in terms of geological determining factors, bathymetry, declivities and the presence of canyons and channels.

Despite the existence of hundreds of radiocarbon datings the sea level changes curve of southern Brazil during the Last Glacial Cycle is still a matter of debate. A recent controversy on the Middle and late Holocene sea level changes curve raised the question of the amplitude of the oscillations which occurred in the period. Also, a few but relatively consistent radiocarbon datings suggest the occurrence of a high sea level during Isotope Stage 3.

In terms of sedimentary cover the Southern Brazilian shelf exhibits a very strong hydrodynamic control, both latitudinal and bathymetrical. The sector southward from 25°S is characterized by the influence of the plume of water carrying sediments originating from the Río de La Plata. Actually its presence is conspicuous up to 28°S, with the

area between this latitude and 24°S constituting a transitional zone.

In terms of bathymetry the outer shelf is marked by the “floor-polisher” effect of the Brazil Current, which is responsible for the maintenance of a relict facies in areas deeper than 100 meters.

PALEOSEISMICS IN AN UPLIFTED, FORMER SHELF, AREA

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Like exposed land areas, the shelves also suffer the effects of neotectonics and paleoseismics. From present day and historical seismic offshore events we often record disastrous secondary effects like tsunami waves; as was the case at the 1755 Lisbon event and the 2004 Indian Ocean event. Past events (paleoseismics) have to be recorded by stratigraphic means (e.g. Mörner *et al.*, 2008). The structural traces left (faults, fractures, slides, deformations, pock marks, etc.) have to be traced by geophysical recording instruments. Those instruments often allow a good mapping of the structures in question. Off-shore sampling and dating are possible, but do never allow as detailed analyses as do similar studies in exposed land records. All this refers to normal off-shore records of ours shelves, to the progress of which the IGCP 526 group has contributed so much and efficiently.

In a few areas of the world, former shelves have, in postglacial time, been lifted out of the sea, now to constitute large land areas. This is the case with glacial isostatically uplifted areas such as New England, parts of Canada, parts of Scotland and large areas of Fennoscandia.

In Sweden, we have documented 56 high-magnitude paleoseismic events in postglacial time (Mörner, 2003, 2004, 2005). Most of those occurred in sub-aqueous environment and 16 events set up tsunami waves. All the 56 events are documented by multiple criteria and most of them are very precisely dated.

With multiple criteria, I mean the recording of simultaneous events in faults and fractures, in sedimentary deformations, in liquefaction characteristics and spatial distribution, in earth- and rockslides, in height and extension of tsunami waves, in distribution and age of turbidites, etc.

With very precise dating, I mean dating with a resolution as to a single year (sometimes even the season of a year) in the Swedish Varve Chronology (Tröften and Mörner, 1997; Tröften, 2000; Tröften, 2000; Mörner, 2003).

Therefore, studies in those uplifted former shelf areas may help us to understand the mode of offshore deformation and the special characteristics of structures created (e.g. off-shore liquefaction).

Paleoseismically induced turbidites are recorded in association with some of the events in Sweden. In the varve chronology those varves stick out as special “marker varves”, which can be dated with an annual precision (in one case even with a seasonal precision). The turbidite is set up by the sediment masses set in motion by slides, liquefaction and tsunami waves. This implies that they are “seismites” (Mörner, 2003, 2008).

The paleoseismic event occurring in the autumn of varve 10,430 BP set up a turbidite that is recorded over an area of 300x200 km (always in the same varve and at 3 sites 70 km apart in the autumn of this varve).

The paleoseismic event occurring in the varve year 9663 BP set up a turbidite which is recorded in the same varve over a distance of 320x90 km.

The paleoseismic events of 9428 and 9291 varves BP are recorded in the over 60x30 km and 50x40 km, respectively.

Liquefaction and venting of liquefied material are recorded at numerous sites. Their special distribution – 320x100 km for the 10,430 vBP event and 80x40 km for the 9663 vBP event – give evidence of high-magnitude events. At several events, we were able to record multiple phases of liquefaction. At the 9663 vBP event, we recorded 5 successive phases, interpreted in terms of chock and after-chocks. The size and type of liquefaction structures have a bearing on the magnitude. In some cases we have recorded the venting of gravel, even coarse gravel. This calls for magnitudes in the order of $M > 8$.

With magnetic methods (Mörner and Sun, 2008) we were able to prove the liquid stage of the structures observed. The fine, polarity carrying grains were free to move and re-align with respect to the geomagnetic pole.

Methane venting as a function of rapid hydrate/gas transformation was recorded in the varves (at the 9663 vBP event) and as bedrock tectonics (e.g. an event 2000 BP with an associated 20 m tsunami wave).

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STRUCTURE OF THE KASBAH FOLD ZONE (AGADIR BAY, MOROCCO); IMPLICATIONS ON THE CHRONOLOGY OF THE RECENT TECTONICS OF THE WESTERN HIGH ATLAS AND ON THE SEISMIC HAZARD OF THE AGADIR AREA

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Detailed re-interpretation of the north-eastern segment of a profile realized across the Agadir bay along a NE-SW trend and crosscutting the main structures, together with analysis of available isochron maps, allowed us to retrace the geological history of the offshore western High Atlas.

Two tectonostratigraphic sequences were distinguished: Unit II, which displays a simple structure, laying unconformably on Unit I, with a more complex structure dominated by a reverse fault (F1) striking WNW-ESE with a NE dip. Correlation to boreholes Souss-1 and AGM-1 allowed us to assign Unit I to the Triassic – Palaeogene and Unit II to the Miocene – Present.

The NE fault block shows a ramp-flat fault plane (F2) with an overlying SW-vergent fold that can be interpreted as a fault-bend fold.

Three main stages were distinguished: (1) during the Cretaceous, F1 could have been a syndepositional normal fault with the NE block moving downwards; (2) towards the beginning of the Tertiary, the displacement of plane F2 induced the development of a fault-bend fold and erosion of the forelimb and hinge of the fold; displacement along F2 was transferred to fault F1; (3) afterwards, during the Miocene, reverse motion of F1 deformed and tilted the plane F2 and accentuated the folded structure. This evolution is typical for a frontal basin above a fault-related fold. Evaluation of the thickness and bed depth differences shows that the largest growth rate was recorded in Late Miocene times.

Seismic activity recorded in the Agadir bay appears to be clearly related to this fault zone, as inferred from focal mechanisms. Seismic moment evaluation suggests that earthquakes of magnitude $M_w \geq 6$ are likely to occur, but could not be much larger because of the fault segmentation geometry of the High Atlas Front.

PALEOPRODUCTIVITY AND CLIMATIC CHANGES: HOLOCENIC MARINE RECORDS, SW ATLANTIC.

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A multi-proxies approach (sedimentological, geochemical and microfaunal proxies) on two sedimentary cores (core 7606, 26° 59'16"S and 048° 04'33", Itajaí, SC, and core 7620, 22°56'31"S and 41°58'48"W, Cabo Frio, RJ) allowed us to recognize Mid to Late Holocene paleoproductivity and climatic changes in the Southeastern Brazilian continental shelf. Both cores were collected in sites considered to be of high primary productivity, but submitted to different hydrodynamic regimes. In the last 3 kyr, a productivity increase is observed in both areas, shown by organic carbon contents, Ba/Ca and Ba/Al ratios and benthic foraminifera community. In the southernmost area, primary productivity and lateral advection of the La Plata River plume are the main source of organic carbon input. Meanwhile, in the Cabo Frio area, productivity is a result of coastal upwelling process establishment, enhanced by NE winds, which promote continental aridity conditions. Hydrodynamic conditions also changed in the last 3 kyr, as shown by the mud content in the sediments. In the Itajaí area, a decrease of bottom current velocities is observed; while an enhancement of the Brazilian Current flow is suggested for the Cabo Frio area. Higher values of Fe/Ca and Ti/Ca ratios suggest an efficient terrigenous input in the Itajaí in the last 3 kyr, probably related to more humid climatic conditions. Whereas, in Cabo Frio, higher values of Fe/Ca and Ti/Ca ratios are observed prior to 6 kyr cal BP, occurring a decrease in these ratios values towards the Present, which confirms drier climatic conditions in that area. Our data suggest that the Cabo Frio area was in phase with NE Brazil climatic conditions, in light of the climatic model proposed by Cruz *et al.* (2009) that suggests a climatic antiphasing between NE and S Brazil during the Holocene.

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PETROGRAPHIC ANALYSIS OF THE OFFSHORE BEACHROCKS ON THE BRAZILIAN NORTHEASTERN SHELF: RISCA DO ZUMBI, RIO GRANDE DO NORTE, BRAZIL

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The Brazilian continental shelf adjacent to east coast of Rio Grande do Norte state is formed by siliciclasts and bioclasts sediments, and thus is classified as a mixed platform. Previous works has recognized several seafloor features, such as transversal and longitudinal dunes, incised valleys, canyons, coral-reefs and sandstone banks. Little information exist about the sandstone banks, specially in point of petrographic or petrologic view. In order to fill this gap, the aim of this work is to describe and to classify these offshore sandstone banks present on the continental shelf adjacent to Rio Grande do Norte east coast. A sandstone bank located 20 km far from Rio do Fogo district was selected for this investigation. It is named in the nautical charts as Risca do Zumbi. Samples were collected from two stations by *in situ* dive, and taken photos and movies around the studied area. Thin-sections, in a standard size of 3x5 cm, were confectioned without thin-surface and analyzed quality and quantity under conventional petrographic microscope. The quality analysis consists in to identify and determine all of compositional and textural aspects. In the other side, the quantity analysis consists in to quantify the compositional constituents of the rock. To do this, it was used a technique that based in to partition of the thin section. This technique separates the thin section in nine quadrants in a central portion, excluding the borders. And, in each quadrant it was determined the amount of each compositional constituents based on percentage tables models. In the end, the average is reached of all of quadrant values, resulting in trustful percentages value. Oracet B was used to aid in determining and quantifying of porosities. Compositionally, the framework grains (average 70%) are formed essentially by quartz, feldspar and lithic fragments. Bioclasts are rarely presents, which are identified only in a thin section. Quartz (average into framework grains 77,5%) occurs as mono and polycrystalline, which the first one is the most common and where were identified biphasic fluid inclusions. Feldspar (3,8%) are represented by potassium and calc-sodium rich, and frequently exhibits alteration (montmorillonite or illite). Lithic fragments (7,8%) are presents which the most common are derived of crystalline rocks. Nevertheless, lithic fragments of sedimentary origins were recognized in only a thin section. The cement (21%) is typically carbonated, and occurs into four morphologies: isopacous prismatic rims, microcrystalline calcite, equant spar and cryptocrystalline coats. Matrix is founded in only a thin section, and is attributed as primary origin. The porosity founded (2,8%) is mainly secondary, but primary is also present. Now talking about textural aspects, the most important in this study is the packing, which are all opened. The others parameters are too much variables. Based on all of realized descriptions allow us to the follow conclusions: (1) Siliciclasts are the most important grains of the framework of this deposit, where quartz is derived mainly from plutonic rocks. It is corroborated by quantities of monocrystalline quartz on which fluid inclusions are

presents; (2) Carbonate cements indicates marine influence for this rocks; (3) Packing symbolize early cementation that occurred into shallow diagenetic environment, probably eodiagenesis; (4) This rock is classified as sublitharenite (into McBride 1963 compositional classification for sandstones), and as *beachrock* into a genetic approach. This last classification is corroborated by the presence of carbonate cement and compositional parameters.

Référence:

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RECONSTRUCTION OF REGIONAL RADIO-CARBON RESERVOIR EFFECT DURING THE HOLOCENE AND PALEOCEANOGRAPHIC IMPLICATIONS: A CASE-STUDY FROM THE ARID COAST OF NORTHERN CHILE AND SOUTHERN PERU

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Regional radiocarbon reservoir effects are particularly strong in distinct coastal area of the globe, and may significantly alter geochronological analyses if they are not properly recognised and quantified. In coastal regions affected by upwelling conditions these effects may be important and may have changed through time, as a consequence of former wind condition variations or of modifications in the paleoceanographic circulation patterns.

We present the major results of a study aiming to reconstruct the evolution of the radiocarbon reservoir effect (ΔR) along a coastal sector of the Atacama Desert in southern Peru and northern Chile (14-24°S), during the last 11 000 years, and the paleoceanographic inferences that can be drawn from these results.

Major changes in ΔR during the Holocene were inferred from a reappraisal of previous and new ¹⁴C data from associated charcoal and marine shell fragments sampled in archaeological sites along southern Peru and northern Chile, and from a limited number of (pre-bomb) marine shells of known ages (Ortlieb *et al.*, submitted). Dating of 83 pairs of contemporaneous associated marine and terrestrial material, from 19 localities thus provided a consolidated series of ΔR values throughout the whole Holocene period.

The mean ΔR values varied from 511 ± 278 years, in the early Holocene, to 226 ± 98 years in the second half of the Holocene, at least until the last millennium. During the last few centuries, the mean ΔR value increased again to 355 ± 105 years, but showed a higher variability than in the preceding millennia. Additional information obtained from laminated marine sediments from a protected embayment in

northern Chile, and based upon other chronological markers suggested a mean ΔR value of 262 ± 13 years for the eighteenth and nineteenth centuries AD, a higher value than the one which has been generally accepted up to now for modern times (190 ± 40 years, Berger & Taylor & Berger, 1967).

Variation throughout the Holocene of ΔR values apparently reflect combinations of effects from varying upwelling intensity and changes in the circulation of water masses, at different time scales, in the heart of the Humboldt Current system. The variations of amplitude of ΔR values and the mean values of ΔR calculated for these successive Holocene periods are thus interpreted in terms of paleo-circulation dynamics and variations of paleo-wind conditions. Northward advection of subantarctic and antarctic waters, as well as southward advection of subtropical and tropical waters, but also fluctuations in the intensity of the southeastern Pacific anticyclone (SEPSA) and ENSO (El Niño-Southern Oscillation) effects are involved in these phenomena and explain the observed ΔR variations (Toggweiler *et al.*, 1991; Vargas *et al.*, 2006, 2007).

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SHORE DISPLACEMENT OF THE BALTIC SEA AND EARLY HUMAN OCCUPATIONS IN PÄRNU AREA, SOUTHWEST ESTONIA

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Geological, geodetic and archaeological shore displacement evidences were combined to create a time-space water-level change model for southwest Estonian coast of the Baltic Sea. Baltic Sea shoreline database for the Estonian territory was used for modeling containing about 1200 sites from the Baltic Ice Lake, the Ancylus Lake and the Litorina Sea stages (Saarse *et al.*, 2003). This database was combined with a shore displacement curve from Pärnu area and with geodetic relative sea level data for the last century (Vallner *et al.*, 1988). A shore displacement curve was reconstructed on the basis of palaeocoastline elevations and 18 radiocarbon dated peat and soil sequences and ecores from archaeological sites. (Raukas *et al.* 1995; Heinsalu *et al.* 1999; Veski *et al.* 2005; Kriiska and Lõugas 2009). New radiocarbon dates from recently investigated sequence from Tolkuse lagoon, reflecting the water level history in Baltic Sea basin between 8000-4000 cal yrs BP, were also used. Reconstructed curve displays three regressive phases of the past Baltic Sea interrupted by Ancylus Lake (10600-10200 cal yrs BP) and Litorina Sea transgressions (9000-7300 cal yrs BP) with magnitudes 12m and 10m, respectively. Palaeogeographic situations for different Baltic Sea stages were reconstructed by subtracting the water-level change model from the modern digital terrain model in order to examine the relationships between coastline change and displacement of the earliest human occupations in Estonia since at about 10500 cal yrs BP.

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GEOMORPHOLOGY OF EASTERN CONTINENTAL SHELF OF INDIA, BAY OF BENGAL AND IMPACT OF TSUNAMI, 2004

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The continental shelf of Bay of Bengal around Indian peninsula lies off east coast of India and extends from off Point Calimere in the southwest to Ganga delta in the northeast. It further stretches eastward towards Bangladesh and Burma up to Irrawadi river mouth. The Bay of Bengal was created by the initial Paleocene-Eocene collision of India with the subduction zone of the north side of the Tethys Ocean (Alam, Curray, et al, 2003). It is also postulated that the east coast of India came into existence after its separation from Australia and Antarctica (Subramanya, 1994). The eastern continental margin of India is passive and the shelf is shaped partly by sedimentary basins like Cauvery, Pennar-Palar, Krishna-Godavary, Mahanadi, and Bengal. Presence of number of submarine canyons and Bengal fan sediments has impact on the morphology of the eastern shelf. Major contribution of sediments to the shelf is through the river system of Ganga, Mahanadi, Godavari and Krishna. Ganga carries good quantity of sandy sediments; where as input from other four rivers are mostly clay and silt. Last glacial maxima and subsequent rise of sea level and fluctuations had effect on the geomorphology of the seabed and sediment pattern. The eastern shelf of India trends NE-SW from west of Ganga delta to Nizampatnam bay and N-S from Nizampatnam to Point Calimere. It is E-W off Ganga delta. The width of the shelf is relatively narrow (15km to 60km) in compare to western shelf. It is very narrow (15 to 20km) off Krishna-Godavari delta and wider (about 100km) off Ganga delta. The northern part of eastern shelf is having its coast, characterized by the presence of the largest tide dominated Hoogly estuary with numerous channels, creeks and mangroves of Sunderban. This part of the shelf receive huge sediments from Ganga-Brahmaputra- Meghna river system, depositing huge thickness of sediments. There are number of sand bars and deltaic islands. A prominent U to V shaped submarine canyon known as "Swatch of No Ground" accepts a huge sediment load in this part of the shelf. Survey has recorded signatures of neo-tectonic movement on the inner shelf of the western bank of this canyon. S.K. Biswas et al (1992) suggested that the Bengal shelf with its easterly dip probably came into existence in the late early Cretaceous time with the onset of seafloor spreading in the eastern Indian Ocean. In the central sector of the east coast there are rocky (crystalline rocks) coasts with cliffs.

In general terrigenous sands, except the deltaic area occupy the inner shelf and clayey/silty sediments cover the outer shelf. Relict sands are present up to 100/200 isobaths. These palaeosands are delineated within 100m isobath off West Bengal to south of Paradip coast; less than 200m off Tuticorin coast and up to 200m isobath in other sectors. At many places modern sediments (sands and clay/silt) cover

relict sandy zone. The sandy zone (relict) is having occurrences of placers like ilmenite, sillimanite, garnet, zircon, monazite, rutile in a discontinuous fashion. The promising zones are off Orissa and Andhra coasts (Saha, 2005). There exist coralline sands off Chennai and Tuticorin.

Though rare, tsunami waves had hit Indian coast earlier. The historical information tells about earliest tsunami hazard in east coast of India in 500AD in the city of Poompuhar in southern part of India. The 26th December, 2004 tsunami caused unprecedented destruction in the vast area of Indian coast and adjoining southeast Asian countries across the Indian Ocean (Saha et.al, 2005). The southern part of the east coast of India was vastly affected. The impact of tsunami was less north of Godavari delta and was considerably severe from Godavari river mouth to further south. The most affected sector is near Ongle and up to Godavari river mouth (about run-up elevation 1.5-2.00m and 500m distance). In southern most part in Nagapattinam-Karaikkal belt run up level was 3m with distance 250m (Srinivasan et.al, 2007). Along the creeks the run up distance extended up to 1 to 1.5 km. In fact, creeks and rivers joining the sea had dissipated the energy of tsunami waves, resulting rising of water levels in those creeks and rivers. Narrow shelf and shallow water depth nearer to the coast, which are common geomorphic features in some parts of the eastern continental shelf of India was also responsible of higher impact of tsunami waves in some part of the east coast of India. New channels and scours were developed at some places on the seabed and on the coast with dispersal of sediments.

Post tsunami field work In the Karaikkal-Nagapattinam beach estimate about 58% concentration of heavy minerals with 26% ilmenite (Mahapatra, 2006), which appears to be marginally higher than the earlier reported occurrences, This increase is possibly due to selective sorting. Offshore survey in the adjoining seabed during that period did not show any indication of input from offshore due to tsunami of 2004.

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MULTI-DECADAL SCALE CHANGES IN FISH SCALE DEPOSITION FROM MARINE LAMINATED SEDIMENTS OFF PISCO, PERU

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The highly productive upwelling environment off the coast of Peru sustains one of the world's largest fisheries, the Peruvian anchoveta (*Engraulis ringens*), but biomass variability on interannual to decadal timescales results in dramatic variations in catch. As observed in other upwelling ecosystems of the world, a decline in anchovy landings in the Humboldt Upwelling Ecosystem from 1975 to the middle to late 1990s coincided with an increase in sardine (*Sardinops sagax sagax*), and a warm phase of the Pacific Decadal Oscillation (PDO). Fish scales and bones buried in the sediments may be preserved when favorable conditions (hypoxia) exist, and provide a history of pelagic communities which inhabited the area. In order to infer decadal- to centennial-scale pelagic fish population variability prior to the development of the fishery, we quantified variations in fish scale abundance preserved in laminated sediments from three box cores collected in the Oxygen Minimum Zone (OMZ) of the Peruvian margin (off Pisco, central Peru). One box core was dated using sedimentation models derived from excess ²¹⁰Pb activity profiles and from radiocarbon analysis of organic matter, while the other two were stratigraphically correlated to provide a preliminary chronology. In all box cores the fish scales records show similar temporal changes. From ~1500 to approximately ~1820, low abundance of fish scales of all species and higher degradation characterized the records, in association with lower productivity and higher oxygenation of the water column. However, a multi-decadal period, from ~1840 to ~1880, is characterized by the presence of oceanic waters species like sardine (*Sardinops sagax sagax*), jack mackerel (*Trachurus picturatus murphyi*) and mackerel (*Scomber japonicus*) and low anchovy scale fluxes, even as inferred primary productivity is higher. Finally, a centennial-scale increase of anchovy scales, supported by a still greater increase in productivity occurs from ~1880 to the present. Nevertheless the presence of sardine scales near the core top is consistent with the variability of fish landings off Peru in recent decades. The presence of sardine scales, as occurred from ~1975 to the late 1990s, is not a typical feature associated with warm

phases of the PDO, since sardine scales were nearly absent from 1925-1945. Although a relative long period with oceanographic conditions favorable to oceanic species persisted for several decades (~1840-1880), another period of inferred low abundance of anchovy persisted without an increase in sardine (~1500-1820). Thus, various modes of variability can be observed in the Humboldt Current Ecosystem with regards to the relative abundances of anchovy and sardine.

TERRESTRIAL LASER SCANNER TECHNIQUES FOR EVALUATION OF EXTREME WAVES FLOODING IN MADDALENA PENINSULA (SOUTH EASTERN SICILY, ITALY).

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Tsunami impact wreaks havoc on the coastal areas and, with the increasing growth and development of coastal regions, greater loss of life and property damage will occur an even large scale. In order to guarantee the coexistence between this catastrophic phenomena and human activities, it is essential to develop models that provide forecasting, planning, warning and monitoring tools. In fact, the implementation of mathematical models must have real correspondence of the complexity of processes that occur during coastal inundation in order to obtain the run up, the landward limit and destructive forces that could be produced by future tsunami.

Many authors have realized numerical models that simulate the potential of tsunami based on differential equations elaborated with particular boundary conditions that take into account some approximation with respect to local coastal features.

Tsunami propagation across coastal landscape is influenced by topographic irregularities, sloping, the presence of buildings, vegetation textures, etc.

Hills & Mader (1997) have provided an empirical formula that permits to calculate the inland flooding limit of tsunami wave for coastal area characterized by overland flat profile. However often the coastal sector shows sloping overland profile; starting from the cited formula, Pignatelli *et al.* (2009) introduced a factor $\cos \alpha$, where α represents the mean sloping, that take into account the coastal overland profile.

The formula is strongly influenced by Manning's number that represents the hydraulic roughness; it causes resistance to the water flow through creating a retarding force. The Manning number is an empirically derived coefficient, which is dependent on many factors, including

surface roughness and sinuosity; it is calculated by empirical formula for open channel flow, or free-surface flow driven by gravity.

Tsunami flooding, usually, occurs in low-lying region and implies erosion, transport and mixtures of debris/sediment deposit inland; in particular, deposits accumulated by palaeo-tsunami, can be used to recognise past events. Recent studies highlight as tsunami waves are able to detach megaclasts weighting up to hundreds tons from intertidal/adlittoral zone and to transport them onshore at different distances and altitudes above sea level. When boulders are present along the rocky coasts it is possible to evaluate the intensity of past catastrophic waves; in fact, hydrodynamic equations from Nott (2003) optimized by Pignatelli *et al.* (2009) permit to calculate minimum wave height necessary to entrain and transport boulders landward.

The wave heights used to simulate the tsunami flooding are referred to the boulder transported inland; if a boulder is detached from cliff edge (joint bounded scenario) the height of the water column flooding, can be obtained from this relationship:

$$H_{FL} = H_T - \text{Altitude of the cliff} \quad (3)$$

In fact, at the edge of the cliff – where the boulders initially were placed - the tsunami wave height had to be the minimum able to transport the biggest block. The tsunami wave must be not smaller than minimum wave able to move the biggest boulder. Therefore, it is important to obtain good accuracy in the measurement of the boulder parameters: a = the major axis, b = medium axis, c = minor axis corresponding to the height, shape, volume and weight.

The aims of this work is debug and test, in sample areas showing evidence of past extreme waves impact, the Pignatelli *et al.* (2009) method to obtain extreme wave inundation limit with the support of terrestrial laser scanner techniques.

Eastern Sicily is one of the most seismically active areas of the central Mediterranean. Normal faulting accommodates WNW-ESE oriented extension, active along the Siculo-Calabrian rift zone (Monaco & Tortorici, 2000). In eastern Sicily the normal faults are mostly located offshore and controls the Ionian coast from Messina to the eastern lower slope of Mt. Etna, joining southwards to the system of the Malta Escarpment. It is marked by a high level of crustal seismicity producing earthquakes with intensities of up to XI-XII MCS and $M \sim 7$, such as the 1169, 1693 and 1908 events (Postpischl, 1985; Boschi *et al.*, 1995).

Several earthquake-generated tsunamis struck the Ionian coast of south-eastern Sicily in historical times (AD 365, 1169, 1329, 1693, 1818, 1908, 1990; Soloviev *et al.*, 2000; Tinti *et al.*, 2004).

The effects of the 1169, 1693 and 1908 tsunamis are still recognizable in the Siracusa coastal area where boulders up to 182 ton in weight, encrusted by dated marine organisms, were removed and transported inland at a distance of up to 70 m (Scicchitano *et al.*, 2007).

The major boulder accumulation has been found along the north-eastern coast of the Maddalena peninsula, south of the Siracusa natural harbour. The peninsula is a

calcareous semi-horst gently tilted to the ENE, formed by Miocene sediments that along the coast are unconformably covered by Pleistocene calcarenites (unit weight = 2.28 g/cm³). Most boulders are up to 40 t in weight and are scattered at a distance of up to 70 m from the coast on a large terrace located 5 m above sea level, gently sloping towards the sea. The blocks are mostly arranged in isolated elements and have also been found on a flat anthropogenic platform at 1–2 m a.s.l. inside an ancient Greek quarry located along the coast.

Scicchitano *et al.* (2007) used a hydrodynamic approach based on the equations proposed by Nott (2003a) to determine whether tsunami- or storm-generated waves were responsible for coastal boulder deposition in Maddalena peninsula. The analysis suggests that tsunamis would be responsible for the detachment and transport of the largest blocks, which are incompatible with the storm wave regime of the studied area. The analysis also confirms the importance of the pre-transport setting of boulders in determining the height of the wave required for it to be transported, as suggested by Nott (2003), and that diffuse layering and fracturing of shore platform rocks favour the detachment of large blocks from the platform edge, as suggested by Noormets *et al.* (2004). Radiocarbon age determinations on marine organisms encrusting the boulders, compared to historical catalogues, suggest that large tsunamis with local source have washed over the Maddalena peninsula at least two times in the last 1000 years. The first tsunami were probably triggered by the earthquake of January 11, 1693 which destroyed south-eastern Sicily and the second by the strong earthquake which took place in the Strait of Messina on December 28, 1908.

Terrestrial Laser Scanner TLS surveys have been performed along Maddalena peninsula (South eastern Sicily) in order to obtain the 3D reconstruction of four boulders in particular. Three of these boulders were probably detached from the shoreline and transported in land by two different tsunamis occurred on 1693 and 1908, the fourth boulder has been mobilized along the coastline by a severe storm occurred in South eastern Sicily on November 2008. Dimensions, shapes, volumes and positions of each boulder has been measured by using TLS techniques and DGPS measurements to debug and test the Pignatelli *et al.* (2009) method to obtain extreme wave inundation limit.

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ANALOGUE REGIONAL OCEAN CONDITIONS IN THE SOUTH-EASTERN TROPICAL PACIFIC RECORDED DURING THE LATE PLEISTOCENE AND HOLOCENE COLD EVENTS

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Laminated sediments off the central marginal system, which are accumulated under specific oceanographic conditions (intense upwelling, dysoxia, high sedimentation rates), preserve and record different oceanographic and climatic changes during the late Pleistocene. The use of different organic and inorganic proxies result in different temporal and spatial signals linked to productivity, structure of the OMZ, and terrigenous input. Changes in the terrigenous input likely correspond to changes in continental humidity, which affects fluvial transport and is consequently homogenized by oceanic mixing. Sediment cores collected off the central Peruvian coast reveal that the cold period within the late Pleistocene as Younger Dryas is and within the upper Holocene as LIA are marked by the increase of terrigenous input accompanied by increase of water column ventilation. Based on the comparison with other paleoceanographic records, those analogue regional oceanic

and climatic conditions recorded during two different global climatic periods can be explained by the latitudinal shift of the InterTropical Convergence Zone (ITCZ) triggered by solar forcing or by the changes in the thermohaline circulation.

MORPHOLOGICAL CHARACTERIZATION OF THE AMAZON CONTINENTAL SLOPE

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The Amazon shelf is subject to energetic forcing from different sources, including near-resonant semi-diurnal tides, large buoyancy flux from the Amazon River discharge which supplies 20% of world-wide freshwater input to the world ocean, wind stress from the north-easterly trade winds, and strong along-shelf flow associated with the North Brazil Current. Extensive studies have investigated the Amazon River and Shelf, but the Amazon Continental Slope has received little investigation. As part of the PIATAM Ocean Project (UFF-UFPA-Brazilian Navy-PETROBRAS), geophysical and sedimentological studies were developed on the Brazilian Continental slope adjacent to Amazon Mouth (N Brazil) aiming the morphological characterization of this slope. The objective was to record the sedimentological and geometric character of strata preserved in this unknown portion of the Amazon system. The results based mainly on shallow seismic profiling (chirp) and surface sediment samples shown different bottom substrates: flat, wavy, and channels. Outside of the Amazon River influence the continental slope is rocky and steep. While under the Amazon River influence the slope is gentle, due to high sedimentation rates.

VERTICAL MOVEMENTS OF THE EARTH SURFACE ON THE GULF OF GDANSK COAST AS INFERRED FROM PALAEOGEOGRAPHICAL, TIDE-GAUGE AND SATELLITE RADAR INTERFEROMETRY DATA

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The Gulf of Gdansk is located in the southern part of the Baltic Sea, on the periphery of the Eastern Europe Precambrian Platform. There are a several minor fault zones within the platform dividing the coastal zone on separate blocks. During the last deglaciation, the northern Poland and southern Baltic were subjected to glacioisostatic

uplift which have reactivated old fault zones. The blocks' structure started to play the key role in neotectonic movements after ceasing the glacioisostatic uplift about 9000 years ago. According to Liszkowski (1982) the coasts of the Gulf of Gdansk are rather tectonically stable whereas Wyrzykowski (1985) presents the map where the NW coast of the Gulf is stable or a little uplifting in a rate up to 0.5 mm/year, and the SE coast is subsiding in the rate of 1-2.5 mm/year. For solving the problem palaeogeographic data (RSL curves based on ¹⁴C datings and pollen and diatom data), tide-gauges records and satellite radar interferometry data were analysed and compared.

The smoothed RSL curves for the Puck (NW part of the Gulf) and Vistula Lagoons (SE part of the Gulf) shows that the area of Vistula Lagoon has been subsiding in a rate of about 0.1 mm/year during last 5000 years).

Tide-gauge records shows the very similar results; water level rise in Vistula Lagoon is about 0.1 mm/year faster than in Puck Lagoon. This small differences between Puck and Vistula Lagoons seem to be related to the real neotectonic movements.

The rate of water level rise in Gdansk and Gdynia is bigger than in Puck and Tolkmicko (Fig.1). There are potential reasons for that in tectonic features, but more likely the water level rise in Gdansk is accelerated by compaction of the thick layer of deltaic Holocene deposits. This supposition is currently tested by processing the satellite radar interferometry data (PSInSAR method) for Gdansk and Gdynia agglomeration. Application of PSInSAR method should allow to assess if the temporal vertical ground deformation are on local or regional scale.

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RECONSTRUCTION OF THE LAST TWO HUNDRED YEARS OF SARDINE AND ANCHOVY POPULATIONS IN A COASTAL SYSTEM OF NORTHERN CHILE.

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Historical fluctuations in sardine and anchovy stocks in the Humboldt ecosystem where the ENSO mode of climatic variability seems to strongly influence the fish stocks (Bertrand *et al.*, 2004). Past fluctuations of pelagic fish populations conditions can be deduced from analyses of laminated marine sediment sequences when particular physico-chemical conditions are met, particularly in low-oxygen environments (Schwartzlose *et al.*, 1999).

In the north of Chile, Mejillones bay acts as a center of sedimentary deposition for the abundant biological productivity of the zone (annual production of $1070 \text{ g C m}^{-2} \text{ y}^{-1}$), while dissolved oxygen profiles showed that, at depths greater than 50 meters, oxygen is depleted which strongly restricts the presence of benthic macrofauna. These factors have favored the accumulation of diatomaceous organic-rich sediments, in which there is very little bioturbation. These characteristics are ideal for the reconstruction of local paleoceanographic conditions at the scale of the last centuries and millennia.

In this environment, fish scale records were analyzed in a short sediment core (42 cm). Fish scales were identified and counted from the material retained in the 500 micron mesh size sieve. The chronology was established from a CF-CS model based on excess ^{210}Pb profiles and further confirmed by radiocarbon ages corrected by local reservoir effects, yielding an average sedimentation rate of 1,67 mm y⁻¹; the age at the base of the core was estimated at 1740 AD.

It was observed a good preservation of scales in sediments of Mejillones bay, and a dominance of two species; Anchovy and Sardine. However, apparent SDR for records prior to 1820 have probably been influenced by dissolution processes linked to the oxygenation of the bottom environment of Mejillones Bay, as suggested by other proxy records. After 1820, the fluctuations in the relative abundance of sardine and anchovy scales point to alternating warm and cold conditions during about 30 years and then a progressively cooler period. Since ca. 1870, marked fluctuations of SDR of both species are observed, probably as a consequence of the onset of a different oceanographic regime characterized by intensified upwelling, stronger subsurface oxygen deficiency, higher primary productivity, and enhanced “ENSOLike” interdecadal variability. While anchovy SDR fluctuated in periods of 25–40 years, only two peak periods of sardine SDR occurred (late 19th century and late 20th century), suggesting that sardine abundance depends on other ocean-climatic factors.

The historical data of landing of both species show some correspondence with the respective SDR measured in the sedimentary column. This is more evident for anchovy than sardine, probably because there is a longer anchovy landing time series. The strong increase of anchovy SDR in the 1960s coincides with an increase of anchovy catches. After the fall of anchovy catches between 1975 and 80, the anchovy population recovered as shown by increases both in catches and SDR. The parallel sequences of both time

series are striking even if the magnitude of these fluctuations is different. The sedimentary record indicates that in Mejillones Bay there were more anchovy in the 1960s than in the 1990s, however catches were much greater in the 1990s probably due to greater numbers and capacity of fishing ships. The sediment core of this bay can be used with respect to landing statistics for an evaluation of pelagic fish populations, even for the last decades.

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SEISMICALLY-INDUCED SHALE DIAPIRISM: THE MINE D'OR, BETAHON AND TREZ ROUZ SECTIONS, BRITTANY

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The Pénestin section (southern Brittany) presents large regular undulations, commonly interpreted as evidence of periglacial pingos. It is an upper Neogene palaeoestuary of the Vilaine River reactivated during the middle Quaternary (middle terrace). It is incised into a thick kaolinitic saprolite and deformed by saprolite diapirs. Similar deformations exist at Betahon, on the right bank of the Vilaine, in association with fluids escape structures. In Trez Rouz, deformations are associated with an Holstenian peat (Van Vliet-Lanoë *et al.*, 2002). This paper presents the arguments leading to a mechanistic interpretation of the deformations at Pénestin and their extent to the peculiar Trez Rouz section. Neither recent transpressive tectonics nor diagnostic evidence of periglacial pingo have been found despite evidence for a late paleo-permafrost. The major deformational process is shale diapirism, initially triggered by co-seismic water supply, with further loading and lateral spreading on an already deformed and deeply-weathered basement which allowed the shale diapirism to develop (Van Vliet-Lanoë *et al.*, 2009). Deformations are favoured by the liquefaction of the saprolite and a seaward mass movement and recorded, rather distant, effects of an earthquake (c. 280.000 yr. B.P.) resulting from the progressive subsidence of the southern and Western Armorican margin. These deformations triggered by an earthquake are similar to those induced by classical shale diapirism. They are probably common in tectonically-active continental environments with shallow water tables.

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PALEOSEISMOLOGY OF LARGE TSUNAMIGENIC EARTHQUAKES IN THE LAST MILLENNIA FROM SEDIMENTARY RECORDS OFF THE CENTRAL ANDES

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Sedimentary records from northern Chile provide a new view about the occurrence of large earthquakes in the subduction zone off the Central Andes. From detailed geochronology and sedimentary characterization of laminated series accumulated in narrow shelf along the continental margin off northern Chile and central Peru, we observed that anomalous sedimentary structures, as slumps and discontinuities, are associated with large historic earthquakes in the area.

The comparison of the sedimentary records with the historical data suggest that high submarine ground acceleration, with minimal values of 20-30%, and probably greater than 40-50%, is needed to produce slumping or discontinuities. This is the case of the large destructive earthquakes occurred on 1878 off northern Chile and on 1746 off Callao.

The analysis of long (ca. 6 m) sediment cores altogether with high resolution seismic profile data allow us to infer the occurrence of several earthquakes in the last 2000 years in northern Chile, and suggests a non linearity in the recurrence of these events. Ongoing analyses from long sediment cores obtained off Callao, suggest similar implications, concerning the non linearity of the occurrence of large earthquakes along the subduction zone.

PROVENANCE OF SEDIMENTS FROM BRAZILIAN NORTHEAST SHELF USING Nd ISOTOPES AND HEAVY MINERALS

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Heavy minerals and Nd isotopes studies were developed on the Brazilian Continental shelf adjacent to Potiguar Basin (NE Brazil) aiming Provenance of these shelf sediments. Terrigenous sediments from important rivers and shelf were investigated to identify their heavy minerals assemblages and source areas. Additionally, Mesozoic and Cenozoic rocks from the Potiguar Basin, including terrigenous and carbonate sediments have been investigated to identify their isotopic signature and source areas.

The distribution pattern of the principal heavy minerals indicate the major point source of sediment supply onto the shelf and reveal intensive mixing, sorting processes and that an westerly (from east to west) longshore current plays an important role in the sediment dispersal. As a result, the mineral distribution east of the Açu River is rich in stable heavy minerals (mainly zircon and tourmaline) whilst west of the Açu River is rich in unstable ones (mainly hornblende and epidote). A mixing zone occurs in front of the river, where stable and unstable minerals are present. In addition to provenance-induced variability, mineralogical differences between E and W provinces could indicate that environmental processes have contributed to the total variability of the inner continental shelf sediments.

The Sm-Nd isotopic signatures of the rocks yielded model ages (T_{DM}) in the range of 2,19-2,88 Ga, indicating archaic to paleoproterozoic sources from the basement. The terrigenous sediments yielded model ages (T_{DM}) in the range of 2,31-2,26 Ga, from 17,5 to 0 cm depth. Despite the small number of samples, limited variations of provenance ages indicates the homogenization of the sediments, probably due to the strong influence of the basement, as the main source of sediments to the shelf. The Sm-Nd isotopic signatures of the carbonate sediments yielded model ages (T_{DM}) in the range of 2,09-2,61 Ga, indicating archaic to paleoproterozoic sources from the basement. The results also indicate that the shelf sediments are mainly derived from the Açu River or other small rivers from the Setentrional Sector of Rio Grande do Norte State. The littoral drift doesn't seem to contribute with sediments from the Oriental Sector since isotopic signatures from this sector were not detected.

ON THE EVOLUTION OF THE PEARL RIVER DELTA, CHINA, BY STUDYING RELATIVE SEA LEVEL CHANGES AND NEOTECTONICS

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The Pearl River Delta, one of the largest deltas in China, is located at north margin of the South China Sea. The evolution of the delta is subject to both sea level changes and local neotectonic movement. Previous research indicates that the delta has 6 formations representing 2 marine transgression cycles (Huang *et al.*, 1982). Although there has been consensus on the age of the 2nd transgression, which resulted from a postglacial sea level rise, the age of the 1st transgression has been greatly debated. Based primarily on ¹⁴C and TL dating (~ 40 ka BP), the oldest deposits of the 1st cycle was regarded as late Late Pleistocene (i.e., MIS3 equivalent) by Huang *et al.* (1982) and by Feng *et al.* (1990). But according to Qian (1994) MIS3 is actually a sub-interglacial stage of the last glacial period when sea level was about 50 m lower than present in the northern South China Sea, similar to other parts of the world. Present altitudes of the marine deposits of the 1st cycle, i.e. -25m~-10m, in the delta do not match with the sea level of MIS3. This difference probably comes from dating errors resulting from younger carbon contamination of deposits during low sea levels in glacial periods and from errors in TL techniques (Yim, 1999, Feng *et al.*, 1990). Therefore the 1st cycle might be older than MIS3.

We investigated marine terraces, T₀, T₁, T₂, T₃, developed on bedrock of K-E red beds and granites. T₀ was formed during the Holocene high sea level. But there might be several possibilities about ages of T₁ and the 1st transgression cycle, and evolution of the delta considering both sea level changes and local neotectonic movement:

1. T₁ was formed in MIS7 and the 1st transgression occurred in MIS5e. In this case, the area was slowly uplifted before MIS7 and shifted to slow subsiding after MIS7. The high sea level in MIS5e resulted in the 1st transgression, following by regression in MIS4-2 in company with slow tectonic subsidence. In MIS1, the 2nd transgression brought about the mid-Holocene marine deposits.

2. T₁ was formed in MIS5e and the 1st transgression occurred in MIS3. In this case, the area was slowly uplifted before MIS5e and shifted to fast subsiding between MIS5e and MIS3, resulting in 50m lower than present sea level and marine facies deposits in MIS3. From MIS3 to MIS1, the area shifted to fast uplifting but still several meters below present sea level in the Holocene.

3. T₁ and the 1st marine transgression formed at the same time as MIS5e. In this case, the area was slowly uplifted before MIS7 and shifted to slow subsiding after MIS7, followed by MIS5e transgression. Continuous subsidence allowed marine deposition in MIS1 transgression in some places, whereas the MIS5e deposits in other places were elevated, forming MIS5 T₁ terraces.

4. T₁ was formed in MIS3 and the 1st marine transgression occurred in MIS3. In this case, the area was slowly uplifted before MIS5e and shifted to fast subsiding down to >50m below present sea level after MIS5e, resulting in marine facies deposition in MIS3. Since then differential fault-block movement resulted in fast uplift and formation of T₁ in some places and slow uplift in other places, where marine facies were deposited again in MIS1.

We have found some deeply weathered reddish deposits on marine terraces. Comparing these to regional reticulate laterite (approximately in the middle Pleistocene, 0.7-0.4 Ma BP) (Yuan *et al.*, 2008, Yang *et al.*, 2005), to ages of nearby river terraces of the West and North River (Yuan *et al.*, 1990), and to ages of marine terraces in other areas along the northern coast of South China Sea (Kevin Pedroja *et al.*, 2008), the T₁ terrace most likely formed in MIS7. Thus, as a fault-block delta (Huang *et al.*, 1983), some places without faults probably were caused by the 1st possibility, whereas, other places with faults were caused by the 3rd possibility. However, the final solution of whether a place resulted from the 1st or 3rd possibilities will not be resolved until more reliable chronological analyses of the deposits are available.

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POSTER SESSION

RECONNAISSANCE GEOLOGIQUE DES PLATES-FORMES CONTINENTALES DU DETROIT DE GIBRALTAR : CAMPAGNE OCEANOGRAPHIQUE GARCIA DEL CID 2004

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La campagne océanographique Garcia del Cid 2004, dénommée aussi « Campagne géologique des plateformes de la zone du seuil du détroit de Gibraltar » a été réalisée, conjointement par les deux sociétés d'états : la SNED (Maroc) et la SECEG (Espagne) conformément à leur Plan de Travail qui vise l'étude en commun de la faisabilité technico-économique d'un lien fixe à travers le détroit de Gibraltar. Cette campagne, utilisant le bateau océanographique « Garcia del Cid », propriété du Conseil Supérieur des Investigations Scientifiques espagnol (CSIC), a consisté en la reconnaissance géologique des plateformes du Déroit en utilisant les techniques de prospection récemment mises au point dont principalement le Sonar à Balayage Latéral digital.

La zone d'étude couvre les deux plateformes continentales, entre punta Paloma en Espagne et Cap Malabata au Maroc sur une superficie approximative totale de 100 km² (Fig. . Cette zone, d'intérêt pour les études du projet de liaison fixe, a par ailleurs fait l'objet de nombreuses recherches géologiques. A noter que ces plateformes continentales marocaine et espagnole représentent environ 70% de la longueur du tracé sous-marin du projet de la liaison fixe.

Lors de cette campagne océanographique et afin d'obtenir des informations sonographiques de bonne qualité et bien positionnées, un système numérique à double fréquences simultanées et de très haute résolution a été utilisé. Parallèlement aux profils de sonar à balayage latéral, des profils de sismique réflexion, au moyen d'un système géophysique de haute résolution ont également été réalisés. Pour la connaissance de la nature géologique du sous-sol marin de la zone d'étude, des échantillons rocheux ont été prélevés à l'aide d'un carottier gravitaire de roche à des points préalablement sélectionnés sur la base des données obtenues par les images de sonar à balayage latéral.

Les données sonographiques récoltées sont d'une grande importance pour l'étude morphologique des plateformes continentales du détroit de Gibraltar. Les profils de sonar à balayage latéral obtenus au cours de cette campagne sont de bonne qualité et ont permis de fournir des informations sur la couverture sédimentaire superficielle ainsi que sur les changements du relief au niveau du fond marin.

Les profils de sismique réflexion de haute résolution ont fourni des informations sur la structure, la disposition morphologique et l'épaisseur des couches superficielles des remplissages sédimentaires récents ainsi que la profondeur du substrat rocheux basal. Les sédiments meubles sont soit absents soit d'épaisseur très réduite (faible apport sédimentaire de part et d'autre du détroit et actions du régime des courants profonds et superficiels qui produisent un lavage des fonds marins).

De point de vue lithologique, l'observation des échantillons prélevés permet de révéler, selon les zones, soit des flyschs constitués essentiellement de grès gris, de calcarénites, de marnes argileuses, de pélites argileuses soit des formations pliocènes et quaternaires constituées de bioalcalarenites, de graviers et de sables litho-bioclastiques.

ANALYSE DE LA FRACTURATION ISSUE DES DONNÉES SATELLITAIRES OPTIQUES (LANDSAT ETM+ et SPOT XS) et RADAR (ERS-1) DU DOMAINE ATLANTIQUE DE LA PÉNINSULE DE TANGER (TANGER-LARACHE)

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Dans le présent travail, nous avons réalisé une cartographie "multicapteur", en utilisant les données HRV de SPOT, Landsat ETM+ et RSO d'ERS-1 et une série de photographies aériennes pour des précisions locales couplées aux techniques de traitement numérique d'amélioration et de traitement d'image, dans le but d'en extraire l'information géographique concernant la fracturation responsable de la structuration de la façade atlantique de la péninsule de Tanger. La méthodologie d'approche est basée sur le traitement de l'information satellitaire par l'intermédiaire des techniques de traitement d'image, du complément d'information par les données de terrain et ensuite de l'intégration des données géoréférencées dans un Système d'Information Géographique pour des corrélations avec les structures éventuelles en mer

Les images satellitaires ont été mises à notre disposition par l'équipe de recherche GEORISK (Risques Géologiques et Télédétection de la Faculté des Sciences de Rabat). Elles ont été acquises dans le cadre de l'action intégrée AI n° 593/91, AIn° 219/STU et VOLUBILIS MA/08/192 en collaboration avec le Laboratoire de Géologie,

Géomorphologie, Structurale et Télédétection de l'Université Paris VI., et le Laboratoire de Géologie de l'université du Maine à Le Mans France et L'université de Brest.

Dans le domaine atlantique entre Tanger- Larache de la péninsule de Tanger, on observe des failles de taille régionale qui affectent les terrains affleurant dans la région. Ces failles s'expriment sur les images optiques HRV, ETM et sur les images radar ERS par des linéaments structuraux plus ou moins rectilignes qui délimitent ou décalent des zones de texture, de teintes et de contrastes lithologiques différents. L'analyse des linéaments a permis de déceler quatre grandes familles de failles qui, selon leur ordre d'importance sont : NW-SE, N-S, E-W à ENE-WSW et NE-SW. La détermination du sens des jeux et l'évaluation des rejets horizontaux des différentes failles repérées ont été déduits à partir des décalages des structures tectoniques et des limites d'affleurements des différentes lithologies.

- Les failles de direction ENE-WSW à E-W : Parmi les failles les plus importantes, on retrouve celle au nord d'Azilah (Dar Chaoui) de direction E-W qui de la côte atlantique se prolonge vers l'Est dans la topographie par une série d'escarpements à rejet vertical important au niveau de la cluse de Tétouan. L'accident plurikilométrique de Charf El Akab orienté N075 se distingue mieux sur les données optiques que sur les données radar; ceci est expliqué par le fait que l'angle de visée de la pulsion et quasi parallèle au tracé de la faille. D'autres accidents, se dégagent essentiellement sur les données optiques ETM et HRVentre Asilah et Larache, elles prennent naissance de la côte atlantique et se prolongent vers l'Est.

- Les failles de direction NE-SW : Elles s'observent sur aussi bien sur les données optiques que radar. Au niveau de la péninsule de Tanger, cette direction est présente de façon homogène et traverse l'ensemble du secteur depuis la côte méditerranéenne à la côte atlantique. Elles s'expriment mieux et avec une densité importante au nord de la péninsule. Sur l'image radar, la faille de Khouaime se prolonge vers le SW jusqu'au niveau de la région d'Azilah et atteste d'un mouvement en décrochement dextre observé sur les grès numidiens du Jbel Mensar au SW de Sebt Zinet. Plus à l'Ouest, on note la présence de la faille de Dar Chaoui qui affecte nettement les terrains des nappes de flychs. Vers l'Ouest, la faille d'Arbaa Ayacha, se présente sur les images ETM et ERS-1 sous la forme de tronçons alignés selon une direction N050 à travers les terrains numidiens et l'unité du Habt.

- Les failles de direction NW-SE : elles se manifestent le long du domaine atlantique de la péninsule de Tanger. Parmi les failles les plus importantes, on retrouve celles du Cap Spartel-Dar Chaoui qui montre sur l'image RSO un jeu apparent sénestre attesté par la présence de crochons au niveau des terrains numidiens de Jbel Kbir. La faille de Malabata, responsable du chevauchement des nappes de Beni Ider et de Melloussa vers le SW par dessus l'unité de Tanger. L'accident de Charf El Aqab-Tleta des Bni Idder (Jbel Mensar-Jbel Boumassim) formé par un ensemble de failles discontinues sur l'image RSO d'ERS-1. Entre Asilah et Larache le relief étant faible, les données RSO semblent

apporter plus d'information que les données optiques. On distingue alors les linéaments d'Azilah-Arbaa des Ayacha et de Khmis Bni Arous-Tanakoub, les failles affectant les terrains gréseux des nappes numidienne et de Melloussa et la faille de l'Oued Loukkous.

- Les failles de direction N-S : Sur les images optiques HRV et ETM, le réseau de failles de direction méridienne se repartit d'une façon homogène sur le domaine atlantique entre Assilah- Larache et l'Arbaa Aayacha et souk el Kola. Ce réseau, est généralement parallèle aux limites des différentes formations géologiques des principales unités. Sur le terrain, il correspond souvent aux fronts de chevauchement de ces unités les unes sur les autres. En complément aux données optiques, l'analyse de l'image radar a permis de mettre en évidence un réseau de failles subméridien du Domaine Externe. Ces failles mises en évidence grâce à un angle de visée latérale perpendiculaire aux structures, présentent une direction N005-N020. Parmi les plus importantes, citons de l'ouest vers l'est, les failles qui affectent le Numidien de Jbel Kebir, la faille de Tanger traversant les terrains marneux du Fahs de Tanger (Unité de Tanger), l'accident plurikilométrique de Hjar Lasfar-Dar Chaoui délimitant Talaa Lakraa à l'Est et faisant décaler en un jeu sénestre l'unité de Melloussa, les failles d'Azilah-Larache mettant en contact les nappes du Habt et du Prérif par des falaises de direction N020.

Ce travail a été effectué dans le cadre de l'action intégrée VOLUBILIS MA/08/192

CHAMPS DE CONTRANTES NEOGENES ET QUATERNAIRES DANS LE DOMAINE ATLANTIQUE DE LA PENINSULE DE TANGER (TANGER -LARACHE)

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Sur le domaine atlantique situé entre le Détroit de Gibraltar au Nord et Larache (Oued Loukkos) au Sud, affleurent les unités structurales rifaines (Numidien, Melloussa, Prérif, Habt et Tanger externe) et des terrains post-nappes (bassin de Charf l'Aquab, Pliocène d'Asilah, plateau de Khemis Sahel et le Quaternaire des grottes d'Hercule).

L'analyse microtectonique de miroirs de failles (stries mécaniques de glissement visibles, détermination possible du sens de glissement) effectuée à partir d'observations réalisées sur le terrain le long de cette façade atlantique de la péninsule de Tanger, nous a permis le calcul des tenseurs de contraintes depuis l'Oligocène supérieur jusqu'à l'Actuel correspondant à l'orientation des trois axes principaux de contrainte σ_1 , σ_2 et σ_3 et du rapport $\phi = (\sigma_2 - \sigma_3) / (\sigma_1 - \sigma_3)$

Ainsi, 5 périodes tectoniques ont pu être identifiées chacune caractérisée par un champ de contrainte donné.

- Période distensive Oligocène supérieur-Langhienne :

Cette période se caractérise par une tectonique synsédimentaire liée à une extension bidirectionnelle (d'abord N010 ensuite N095) avec une permutation entre σ_3 (contrainte minimale) et σ_2 (contrainte intermédiaire)

- la distension Oligo-aquitaine mise en évidence dans les niveaux inférieurs des grès d'Asilah orientée N-S.

- la distension Langhienne mise en évidence dans les niveaux supérieurs des grès d'Asilah datée du Langhien. Elle est orientée E-W.

- Période compressive Serravalle-tortonienne :

Elle correspond à la succession de deux épisodes compressifs :

- l'épisode compressif N-S responsable de l'écaillage et la structuration de la nappe pré-rifaine et de son charriage vers le Sud.

- l'épisode compressif E-W corréléable avec un déplacement de la nappe pré-rifaine vers l'Est daté du Tortonien.

- Période distensive fini-Miocène, Pliocène inférieur

- Episode distensif bidirectionnelle fini-Miocène: Des failles normales N060-080 liées à une extension orientée N175 s'observent dans les formations post-nappes du Tortonien supérieur de Charf l'Aquab. Une permutation entre σ_3 et σ_2 va donner naissance localement à une extension N065 liée cette fois au jeu de failles normales N160.

- Episode distensif pliocène NW-SE: Des fractures et failles normales N050-070 affectent le Pliocène inférieur dans le bassin de Charf l'Aquab et à Asilah. Bien que la nature lithologique du pliocène (sable fin jaune peu induré) soit un mauvais enregistreur quelques tectoglyphes et des stries ont été conservés.

- Période compressive - Un épisode compressif orientée ENE-WSW responsable du jeu décrochant dextre des failles N000-040 et senestre N090-115, et aussi de failles inverses N150-010. Ces failles inverses ont permis dans la localité de Charf l'Aquab le chevauchement de l'unité du pré-rif interne sur l'ensemble des calcarénites conglomératiques du Tortonien supérieur.

- Période distensive Quaternaire ancien (post-villafranchien) et moyen:

Après l'érosion des reliefs récemment créés par les événements antécédents, l'accumulation de ces matériaux ainsi démantelés constitue le Villafranchien.

- Un épisode distensif subméditerranéen du Quaternaire ancien (post-villafranchien) a été mis en évidence dans les sables rouges à cailloutis du Villafranchien de Khemis Sahel. Il est attesté par le jeu normal des failles N080-125 d'ampleur métriques à parfois kilométriques qui recoupent les formations anté et post-nappes (mio-pliocènes).

- Un épisode distensif Quaternaire moyen (Ouljien) : Les terrains du Quaternaire moyen (Ouljien) du domaine atlantique en l'occurrence les calcarénites bioclastiques des grottes d'Hercule, à l'Ouest de Charf l'Aquab, à Larache dans le plateau de Rmel montre des structures distensives

matérialisées par des failles normales métriques à parfois kilométriques orientées N175-025.

NB : Un épisode compressif matérialisé par des failles décrochantes dextres NW-SE et senestres NE-SW recoupent localement dans les calcarénites bioclastiques des grottes d'Hercule les failles normales orientées N175-025. Le champ de contraintes N-S à NNW-SSE obtenu à partir du jeu de ces failles décrochantes est en accord avec les mécanismes au foyer d'un certain nombre de séismes de la région du Détroit de Gibraltar.

Les résultats de cette étude de part sa situation géographique seront interprétés aussi bien dans le cadre de l'évolution récente structurale et sismique de l'Atlantique central que celle du Détroit de Gibraltar.

Ce travail a été effectué dans le cadre de l'action intégrée VOLUBILIS MA/08/192

RECONSTRUCTING THE WATER MASS STRUCTURE ALONG THE MOROCCAN ATLANTIC MARGIN (~35°N) FROM THE LAST GLACIATION TO THE HOLOCENE

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The Moroccan Atlantic margin gives home to different specific marine ecosystems, as e.g. chemosynthetic seep communities or cold-water coral reefs. Especially the latter are closely related to the prevailing environmental setting mainly in terms of food availability (i.e. productivity) and food supply to these sessile filter feeders. Long-term records of the presence/absence of cold-water corals along the Moroccan Atlantic margin reveal a variable history of these hotspot ecosystems that most likely is caused by changing oceanographic conditions in terms of water mass structure, bottom current velocities, productivity and possibly temperature.

In order to get a comprehensive overview of the long-term oceanographic development of this region (i.e. the long-term forcing for these cold-water coral ecosystems), this study will exploit a set of six sediment cores taken along a depth transect along 35°S. Covering a depth range from 370 m to 1380 m, physical variations in the benthic environment will be reconstructed by means of various paleoceanographic proxies.

In its initial part the focus of this study was on benthic foraminifera. Stable carbon isotopes from benthic foraminifera carbonate tests are used as proxies of paleoproductivity and water masses characteristics. Their stable oxygen isotope composition is used for stratigraphical purposes and for estimating paleotemperatures. Furthermore, X-ray fluorescence (XRF) data have been obtained in order to assess the elemental composition of the sediments.

SEISMO-STRUCTURAL ANALYSIS AND 3D VELOCITY MODELLING OF THE TARFAYA MARGIN (SOUTHERN MOROCCO ATLANTIC MARGIN) FROM THE LOWER CRETACEOUS TO THE PLIO-QUATERNARY USING 2D SEISMIC REFLECTION DATA

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We define in the Tarfaya margin four main tectonostratigraphic stages: the Pre-rift (Precambrian-Palaeozoic) corresponds to the NE-SW Zemmour hercynian thrust faults, the Syn-rift (Late Triassic-Early Jurassic) characterized by grabens and half graben structures which are bounded by NE-SW striking listric normal faults and filled with continentally derived shales, sandstone and evaporites, the Post-rift (Upper Jurassic-Upper Cretaceous) marked by the installation of the carbonate platform of the Upper Jurassic which underwent variable subsidence. With erosional base level lowered, thick sequence of continental to marine-deltaic clastic sediments was deposited at the Early Cretaceous period and marked by two main structural domains which defined an asymmetric basin and are separated by a rollover anticline: 1) thin-skinned extensional listric growth faults resulting from gravity sliding above a salt and/or shale décollement, 2) Compressive domain located downslope and it is marked by a main reverse fault PRF2 dipping landward. The Middle and Upper Cretaceous marked only by a general transgression of eustatic origin and the inversion of the Tertiary expressed by tectonic instability that is linked to the evolution of the Atlas and Rif belts and interferes with glacio-eustaticy starting in the Oligocene with the Antarctic and Arctic glaciations.

We present in this study Three dimensional velocity model for the major interpreted stratigraphic horizons and faults in the Tarfaya margin in order to perform time to depth conversion of the seismic reflection data.

The model is based on a total of 6371 stacking velocity which was generated from the seismic reflections lines.

The result of this modelling shows that the seismic velocities range from very low values in some part of the near surface deposits (500 m/s for the Plio-Quaternary sequence) to more than 2000 m/s for the Tertiary formation, to 4500 m/s or larger for the Mesozoic and more than 6000 m/s for the Precambrian-Paleozoic crystalline basement which represent the highest velocities values linked to the higher percentage of the metamorphic rocks. The velocity values vary in the Tarfaya margin mainly with the lithology (change in the sand and carbonates content) and with the burial depth.

CLIMATE CHANGE AND MODERN HUMAN EVOLUTION

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This poster is based on a new book “*The Climate Connection: Climate Change and Modern Human Evolution*”ⁱ that brings together saltatory evolution and rapid climate change in discussions on human evolution, migration, and behavioural change. Geological and climatological data are combined with the results of an equilibrium climate simulation for marine isotope stage 6 (MIS6: 150,000 to 135,000 years ago) and a 122,000-year time-series (MIS5e to present) simulation performed on the UVic Earth System Climate Model to show changing climate and vegetation with particular focus on those regions of the world inhabited by humans. The model is driven by time-dependent changes in atmospheric CO₂ and orbital forcing through the last glacial cycle. Land-ice thickness is interpolated from prior ice sheet simulations at 1000-year intervals. Results from a 120,000-year time-series climate simulation indicates changing land and surface air temperatures, land and sea ice extent, precipitation, and coverage and productivity of various vegetation types as the Earth moved through glacial and interglacial cycles. Model results and proxy findings are discussed in light of archaeological data to illuminate connections between climate change and key events in human history. These concepts are used to highlight the relevance of saltatory evolution and in ascertaining potential mechanisms for dealing with impending future climate change.

During the last glacial cycle *Homo sapiens* populations experienced both stable and highly variable conditions. Stable conditions would have encouraged conventional behaviours that brought the greatest benefit to the social group. Rapidly changing conditions would have forced early humans to migrate out of deteriorating regions and concentrate in more habitable areas, periodically placing disparate groups in social contact with one another. For humans, the disruption of a stable climate puts a premium on physiological and behavioural adaptability, leading to the application of novel behaviours and new ideas that might have been obstructed as “too revolutionary” or too much against traditional practices in previously stable social groups. Migration from formerly supportive environments to a small number of refugia may result in the intermingling of previously isolated groups that have already developed novel tools and ideas. The combination of *crisis*, *communication*, and *collaboration* is a powerful generator of emergent social novelty and it is here we must look for insights to deal with impending future climate change.

ⁱ Hetherington, R., and Reid, R.G.B. (2010). *The Climate Connection: Climate Change and Modern Human Evolution*. Cambridge: Cambridge University Press.

MORPHOLOGICAL CHARACTERIZATION OF CAP SPARTEL OFFSHORE.

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L'étude de l'interface eau-sédiment, au large de Cap Spartel, a été entreprise grâce à un sonar à balayage latéral (remorqué par le navire océanographique de la Marine Royale « ABOU AL BARAKAT). Les images sonars obtenues (sonogrammes) nous ont permis d'identifier 3 grands types de fond, et préciser leur extension.

Dans la zone d'étude, ces trois faciès sont matérialisés sur les enregistrements sonars par des signatures acoustiques différents. Ils correspondent aux :

- Domaine rocheux : très rétrodiffusant, se caractérise par une teinte très foncée. Souvent, les reliefs forts créent des zones d'ombre (teinte claire)
- Domaine mixte : caractérisé par une grande extension dans notre secteur d'étude. Localisé à la périphérie des barres rocheuses présentant une forte concentration par rapport aux autres sites.
- Domaine sableux : représenté par un faciès acoustique clair pour les sédiments, relativement, fins et faciès sombre pour les sédiments, relativement, grossiers.

Ces mêmes sonogrammes permettent d'identifier les structures sédimentaires transversales au courant (mégarides, vagues de sable) et les structures longitudinales au courant (placages sableux, rubans sableux, traînées sableuses) qui permettent de renseigner sur les conditions hydrodynamiques du secteur.

Les interprétations de ces profils de sonar latéral ont permis de dégager les résultats suivants :

- Stock sableux plus élevé à l'est qu'à l'Ouest
- Dynamique plus forte à l'Est qu'à l'Ouest
- La distribution des structures sédimentaires est assez corrélée avec l'enchaînement de (BELDERSON 1982)
- la morphologie du fond, est marquée par la présence des champs de mégarides, de différentes longueurs d'onde, des vagues de sables de types BARKHANES. Ces dernières, sont souvent tapissées par des mégarides de faible longueur d'onde. On note la présence des figures longitudinales dans l'ensemble du secteur.
- Le transit sédimentaire déduit de la polarité des figures transverses au courant est dirigé vers l'ENE.
- Ces différents corps sableux sont constitués de sable fin à moyen (avec une taille de grains minimale d'ordre 0,17 mm) reposant sur un substrat rocheux.

CAMPAGNE Océanographique IHPT2009-HERM02, DU 9 AU 28 JUIN 2009

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Une campagne océanographique au large des côtes marocaines entre Tanger et Casablanca a pu être réalisée avec succès. Cette campagne, intitulée IHPT2009-HERM02, menée par le bateau "Gago Coutinho" de la marine portugaise était financée par le projet européen 'Hotspot Ecosystem Research and Man's Impact on European Seas – HERMIONE' et l'Institut Hydrographique de Lisbonne et à laquelle le CNRST marocain a été associé. Elle a eu lieu entre le 9 et le 29 juin 2009.

La campagne avait deux objectifs spécifiques, un géophysique intitulée : « Caractérisation des processus de la pente continentale nord-ouest marocaine et ses impacts sur le champ de volcans de boue de Larache », et l'autre concernait la collecte des échantillons et des données en relation directe avec notre projet CNRST /FCT, cette partie de la campagne était intitulée : « Dynamique du plateau continental Nord-ouest marocain, impacts sédimentaires et chimiques et interactions avec les plumes fluviales ».

Cette partie de la campagne visait la caractérisation des régions du plateau continental qui sont sous l'influence de deux des principales plumes fluviales de la côte du Maroc, celles du Loukous et du Sebou. Des observations détaillées étaient conduites dans des domaines encadrant la région d'influence de chacune des deux plumes fluviales. En chacun de ces domaines, des profils de température, salinité, turbidité et fluorométrie ont été recueillis avec une bathysonde CTD, dans une maille de stations avec haute résolution spatiale et entre la surface et le fond (figures 3 et 4 sur le document en annexe détaillant la campagne océanographique). Chaque profil CTD était complété par des prélèvements des échantillons d'eau à des profondeurs sélectionnées. Ces échantillons seront utilisés pour quantifier la matière particulaire en suspension et déterminer sa composition, et aussi pour évaluer les concentrations en sels nutritifs et en métaux lourds. L'ensemble de profils CTD et correspondants échantillons d'eau permettra de caractériser les conditions hydrologiques, sédimentaires et chimiques de la colonne d'eau, dans les régions du plateau nord-ouest marocain où l'influence des plumes fluviales du Loukouss et du Sebou se fait sentir.

Deux étudiants de l'équipe marocaine ont embarqué avec l'équipe portugaise pendant toute la campagne et ont pu ainsi aider et apporter une contribution de la partie marocaine. Aussi cela a permis de les former aux différentes techniques de prélèvements et d'études géophysiques (Capacity building).

Cette campagne IHPT2009-HERM02 était liée avec des campagnes de mesures sur les estuaires du Loukos et du Sebou, qui étaient conduites par l'équipe marocaine dans le cadre du projet de coopération CNRST-Maroc/GRICES-Portugal. Cette articulation des campagnes, au large et sur le continent, permettra de lier les conditions observées dans chaque estuaire avec celles observées sur le plateau continental proche et de construire une image intégrée des interactions entre le système fluvial et le plateau continentale pour identifier les échanges entre les deux régions de cette marge continentale..

Ainsi l'équipe marocaine a menée deux campagnes de prélèvements sur le Loukous (12 juin) et sur le Sebou (le 23 juin). Les dates correspondaient au moment où les prélèvements ont été effectués au large, par bateau, pour une meilleure corrélation.

Des échantillons de sédiments et d'eau à différents niveaux ont été prélevés. Trois points par fleuve ont été choisis (embouchure, 5 et 10 km en amont). Les échantillons ont été préparés au Maroc, filtration, acidification, séchage, congélation... Le Bateau de la campagne a effectué une escale à Casablanca (Voir document en annexe pour les détails) et les échantillons (plusieurs dizaines) ont été acheminés au port de Casablanca et embarqués par le partenaire portugais.

Ces échantillons seront utilisés pour quantifier la matière particulaire en suspension et déterminer sa composition, et aussi pour évaluer les concentrations en sels nutritifs et en métaux lourds polluants. Ces investigations et analyses seront menées en partenariat avec les collègues portugais dans les laboratoires de l'Institut Hydrographique de Lisbonne.

PROTIT AND NOMADS OCEANOGRAPHIC PROGRAMMES (NORTH WESTERN ATLANTIC MOROCCAN MARGIN) PLEISTOCENE DEFORMATIONS OF THE OFFSHORE RHARB FOREDEEP BASIN

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The understanding of the Neogene evolution of the the Atlantic Moroccan continental margin are motivated three new high-resolution (Sparker) seismic surveys Protit1, Protit2 and Nomads, carried out during 2001,2003 and 2007 and conducted by the University of Brest in France and the Sciences Faculty of El Jadida in Morocco. The cruises allowed the record of about 3000 km of seismic lines located between the latitudes of Safi and Tanger and were associated with industrial seismic lines provided by ONHYM, bathymetry data and field observations collected along the coastline.

As a result, it is possible to define a coherent seismic stratigraphy for the Neogene and Quaternary deposits and to characterise the vertical readjustments of the shelf that followed the development of the Prerifaine Nappe during Upper Miocene.

In this poster we will focus on the Pleistocene deformation of the Rharb basin, in particular the active front of the Prerifaine nappe in the area of Lalla Zahra (South of Moulay Bouselham). This coastal basin corresponds to the foredeep basin linked to the Rif Cordillera and extends southwards through the northern Moroccan Meseta that defines the foreland region of the Western Rif (Flinch, 1993). The integrated study allows to better understand the link between the onshore observations across the Western termination of the Rif front (Ait Brahim, 2003 ; Chalouan *et al.*, 2006a) and the multibeam bathymetric data previously collected across the Gulf of Cadiz (Gutscher *et al.* 2008). Seismic interpretation clearly shows evidence of deformations affecting the Pleistocene sedimentary cover. They are mainly located between the Lalla Zahra ridge and the Neogene nappes that outcrop at seabed to the North of Larache. The identified structures delimit the upper proximal part of accretionary wedge described by Gutscher *et al.* (2008) and are assumed to be developed by Pleistocene activation of the major tectonic structures located at the Southern front of the Rif Cordillera. The offshore extension of the Lalla Zahra Ridge is characterised by a E-W trending major folded and faulted corridor and lead to suggests it could corresponds to the western extension of the NE-SW sinistral Jebha fault, forming the southern limit of the internal rifain domain.

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MAPPING GEOLOGICAL ACCIDENTS FROM AIRBORNE AND SATELLITE IMAGERY AND ANALYSIS OF FRACTURES NETWORKS OF THE NORTH-WEST OF THE COSTAL MROCCAN AREA BETWEEN RABAT AND LARACHE

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On geological maps at 1:50,000 or 1:100,000 scale of the Northwest coastal area of Morocco (Western Rif) the only mapped faults correspond to submeridional major tectonic contacts between the main structural units (Aït Brahim 2002, Aït Brahim et al 2003).

The main purpose of this study is to map the fracture networks in the north-west of the coastal Moroccan area between Rabat and Larache using Airborne (aerial photographs) and Satellite imagery (Landsat ETM+), and to characterise them through the statistical and geostatistical methods. Image processing techniques have permitted to improve the structural and linear features contained in the raw satellite images. That permits a better mapping of geological objects. The fracturing map obtained after treatments is very dense and include many lineaments of variable sizes. The validation of these fractures has been made using the existing geological and photo-geological maps and ground observation. The analysis of the fracture networks indicates that fracture length varies, which indicates the heterogeneity of the geological formations and succession of several tectonic events (Chaoui 1999, Sossey Alaoui 2005). The distribution of fracture length follows power law indicating that the fracture networks of our study area have reached its optimal stage. The geostatistical analysis shows that the fractures networks coastal area between Rabat and Larache behaves like a regionalized variable. The omnidirectional rose of the fracture density is characterized by several structures putting in evidence the structuring at different scales and involving the complexity of these fracture networks. Fracture structuring is not identical in all the space directions. The sum of the results contributes to a better knowledge of the fracture networks of the North-West of the coastal Moroccan area.

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THE LARACHE (AL-AARA'ISH) MEGA-BOULDER FIELD (NORTHWESTERN MOROCCO); A NEW EXAMPLE OF THE EFFECTS OF THE 1755 AD LISBON TSUNAMI?

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Along the coastal areas of southwest Iberia and northwest Morocco, large boulders were described from Cabo Trafalgar (Whelan and Kelletat, 2005) in Spain, from the west of Lisbon in Portugal (Scheffers and Kelletat, 2003), and more recently from the Rabat area in Morocco (Mhammdi *et al.*, 2008). These megaclasts are thought to have been emplaced by tsunamis, especially by the major tsunami related to the AD 1755 November, 1st, earthquake (M = 9). North of Rabat, a preliminary exploration of the coastal area south of Larache (Al-Aara'ish) with the help of satellite imagery revealed the existence of possible megaclasts arranged in ridges. we could clearly observe a megaclast ridge along the cliff base. A survey was then carried out in April and June 2009 in order to study the main features of the boulders. This paper exposes the first results of the survey carried out at the cliff beneath the sand extraction site located at 35° 05' 50"N; 6° 12' 33" W.

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LARGE BOULDERS ALONG THE RABAT COAST (MOROCCO) AND POSSIBLE RELATIONSHIP WITH THE NOVEMBER, 1st, 1755 A.D. TSUNAMI

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The northwestern Moroccan coastline is fully exposed to the Gulf of Cadiz, where the boundary of the North African and European plates becomes convergent near the Gorringe Bank (e.g. Buforn *et al.*, 2004; Stich *et al.*, 2005). This zone, probably one of the most dangerous seismic and tsunamigenic areas in the world, is the source of the Lisbon earthquake (M=9.0) on November, 1st, 1755AD, as well as of other historical events (216-209BC, 881AD, 1731AD), that led to partial destruction of some Moroccan and southwestern Iberian coastal cities (Campos, 1991; Elmrbet, 2005). This seismogenic / tsunamigenic area continues to be active, as attested by the occurrence of the large earthquakes of 28 February 1969 (M=7.3), 26 May 1975 (M=7.9), which generated small tsunamis (Baptista *et al.*, 1992; Heinrich *et al.*; 1994), and 12 February 2007 (M=6.3), strongly felt in Morocco. The calculated return period of tsunami generation is of 200 years in some oceanic sectors around 36°N 10°W (El Alami and Tinti, 1991).

One of the most spectacular effects related to the tsunamis of the Gulf of Cadiz is the displacement of boulders of several tons along the shoreline. Such boulders have been observed in southern Spain at cape Trafalgar (Whelan and Kelletat, 2005) and in Portugal, west of Lisbon (Scheffers and Kelletat, 2003). In Morocco, despite detailed studies on the Quaternary coastal deposits (Guilcher and Joly, 1954; Gigout, 1957; Akil, 1980 among others), only Gigout (1957, p. 10-11, plate II, Figs 3-4),

described single boulders in the Rabat coastal area, and interpreted their displacement and overturning as related to storms. On the basis of literature published on Iberia, and within the context of general interest in tsunami research after the December, 26th 2004 catastrophe in the Indian Ocean, we re-visited the coastal area south of Rabat several times during 2007 in order to investigate the existence of comparable tsunami-related boulders.

The rocky coastline south of Rabat (Morocco) shows a large number of boulders lying upon the lithified dune system. The boulders, of 4-100 tons, may be single, in imbricated sets, or forming clusters and ridges. Several boulders were lifted and overturned, thus showing pool apertures downwards. Transport distance is generally decametric because of the surface roughness, but it can reach 300 m in flat areas. All boulders have been detached from their initial position at the fractured front of the active cliff. Quantification with the help wave hydrodynamics and rock displacement mechanics shows that dislodgement and transport of these boulders were accomplished rather by tsunami than by storm waves. Although no dating was attempted, post emplacement bio-erosion by littorinids and the absence of any erosional features below the boulders suggests that they were emplaced during the 1st November 1755 AD Lisbon tsunami.

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SEA-FLOOR CHARACTERIZATION AND IDENTIFICATION OF POCKMARK, MOROCCAN MEDITERRANEAN SEA.

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Pockmarks have been identified on recently collected multibeam bathymetry of Moroccan Mediterranean sea.

In the study area, pockmarks occur in water depths from 300 to 600 m.

Pockmarks are circular to elongate depressions that are associated with fluid expulsion. We document the presence of pockmarks from Moroccan Mediterranean sea.

The average of pockmark size is about varies 300 m in diameter, and morphologies vary from conical to sediment-draped and in-filled. Additionally, we observe that pockmarks may be randomly distributed, clustered, or occur along linear trends. Their elongated shape is linked to the current direction. They occur either as single or as composite features. From seismic sections (it can be seen that they are cut down through the seabed sediments).

NEW EVALUATION OF HEAT FLOW IN MOROCCAN ATLANTIC MARGIN

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The thermal field in sedimentary basins of continental margins is disturbed by subsurface water circulations in onshore area while classical oceanic measurements in

offshore area are disturbed by seasonal fluctuations induced by surface marine currents.

The study aims to propose a new analysis of terrestrial heat flow along the Moroccan continental margin, based on rocks thermal conductivity estimate from the oil wells geophysical logs. This method uses the neurons networks technique which has been tested successfully worldwide in the ODP wells. Bottom Hole Temperatures are corrected by using the cylindrical source models. The geophysical logs data are reduced in order to estimate the heat flow, as well as the in-depth temperatures distribution.

THE MOROCCO MARITIME SURVEY

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The Morocco Maritime Survey is a long-term archaeological, hydrographical, marine geological, biological and ethnographical investigation into the coastal landscapes and riverine environments of the Kingdom of Morocco.

The first phase of the Morocco Maritime Survey focused on the Tanger Peninsula, the southern boundary of the Straits of Gibraltar, in order to identify evidence of near-shore human maritime activity by analysis of the seabed (primarily ancient but also historic shipwrecks and ship-related materials or features). This phase of the project, which took place in 2002-2003, was conducted under the auspices of the Institute of Nautical Archaeology (College Station, Texas, USA) and Institut National des Sciences d'Archéologie et du Patrimoine (Rabat, Morocco).

The project's goals were realised through visual SCUBA diver survey (in waters shallower than 30 metres), test excavations, and terrestrial site reconnaissance. Underwater survey included a very limited recovery of diagnostic artefacts. In 2003, the project's goals were realised through remote sensing (multi-beam sonar), SCUBA diver survey and documentation, video recording, and artefact materials sampling.

In this poster, the general aims of the 2002-2003 field project are presented, with a discussion focused on one of the larger sites identified at Cap Spartel, CSP062.