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of Sardar Formation (Serpukhovian-Bashkirian in age), stratigraphic position of conglomerate and the existence of foraminifera such as *Polysphaerina* bulla and *Umbella* bekovae in the conglomerate pebbles, could be considered Late Visean-pre Serpukhovian age for Sardar conglomerate. Therefore Sardar-Shishtu Formations boundary which is determined with conglomerate, correlated with boundary of Kaskaskia I and Kaskaskia II super cycle that show Visean-Serpukhovian age.

SESSION 26

T34.01 - Sea level during the last interglacial SATURDAY, August 21, 2004 - 9:00
Room: 29 - Cavanigino

Conveners:

Antonoli Fabrizio, Lambeck Kurt

26-1 Key Lecture Lambeck, Kurt

THE MIS 5.5 SHORELINE IN THE MEDITERRANEAN: ISOSTATIC AND TECTONIC CAUSES FOR SPATIAL VARIABILITY IN ITS ELEVATION ABOVE PRESENT SEA LEVEL

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Keywords: Last Interglacial shoreline; Mediterranean; Isostasy

The altitude of MIS 5.5 shoreline are found in Mediterranean between +200 and -120 meters. The spatial variability of sea level for the period following the Last Glacial maximum is well known across the Mediterranean as being the result of glacio-hydro-isostatic adjustment of the earth to the last deglaciation and more localized tectonic movements. That for earlier periods is less well understood but in analogy to the variability that occurs in the west Atlantic, isostatic effects here are also likely to be important and to be dependent on the ice history over Europe from stage 6 to 2. New models for this ice history form the basis for new model predictions across the Mediterranean basin. These are compared with the observed elevations for the MIS 5.5 shorelines in order to calibrate the model parameters and to establish estimates for long-term (105 year) tectonic rates.

26-2 Invited Waelbroeck, Claire

RECONSTRUCTING SEA LEVEL FROM DEEP-SEA CORES

WAELEBROECK Claire¹, LABEYRIE Laurent¹, PARRENIN Frederic², CORTIJO Elsa¹, BASSINOT Franck¹, DUPLESSY Jean-Claude¹, JOUZEL Jean¹
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Keywords: Past sea level; Benthic foraminifera; Marine Isotope Stage 5

The lecture will review the various ways in which continuous records of past sea levels have been derived from deep-sea sediments using benthic oxygen isotopes. These reconstructions will be compared to a recent reconstruction based on planktonic oxygen isotopes from a Red Sea core (Siddall et al., 2003). In each case, uncertainties will be evaluated and discussed. Finally, current developments of Mg/Ca measurements on benthic foraminifera shells will be presented. Paired measurements of $\delta^{18}O$ and Mg/Ca ratio on benthic foraminifera offer the possibility to directly subtract the deep water temperature component from the benthic oxygen isotopic ratio, and hence to compute the change in global ice volume much more precisely than previously. A second advantage of this approach lies in the fact that it provides a measure of the time lag between deep water temperature and sea level changes, thus yielding precious information on the dynamics of climate change.

26-3 Invited Potter, Emma-Kate

MIS-5A AND 5C SEA-LEVEL OBSERVATIONS AND IMPLICATIONS FOR GLOBAL ICE-MELTING HISTORY

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Keywords: Sea level; Caribbean; Ice sheet; Isostasy

The effects of glacio-hydro-isostasy are such that the pursuit of a "global" ice-equivalent sea-level curve requires sea level observations that are not only temporally but also spatially distributed. A clear demonstration of this is apparent in the observation of a south to north gradient of increasing marine isotope substage 5a (~80 ka BP) sea level that has been recorded across the Caribbean and surrounding region. Across this transect MIS-5a sea level, relative to present, ranges from -19 m to more than +3 m between Barbados, Haiti, the Bahamas, Florida, Bermuda and the US Atlantic Coast. In contrast, no gradient in sea level is observed for the last interglacial period MIS-5e (~128-118 ka BP) at tectonically stable localities in the same region, with deposits generally lying several metres above present. The observed gradient in MIS-5a deposits can be used to characterise regional and global earth rheology and is an important indicator of the behaviour of the North American ice sheets during the last glacial cycle. By combining worldwide sea-level observations for this time period we can place further constraints on global ice melting history during the last interglacial period.

26-4 Invited Ferranti, Luigi

ALTITUDE AND SPATIAL DISTRIBUTION OF THE MIS 5.5 HIGHSTAND MARKER IN ITALY: RELATION WITH ACTIVE TECTONIC PROCESSES

FERRANTI Luigi¹, AMOROSI Alessandro², ANTONIOLI Fabrizio³, DAI PRÀ Giuseppe³, LEZZIERO Alberto³, MASTRONUZZI Giuseppe², MAUZ Barbara³, MONACO Carmelo³, ORRU Paolo³, PAPPALARDO Marta³, et al.

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Keywords: relative sea-level changes; vertical displacements; MIS 5.5; active tectonics; Italy

Studies on recent relative sea level changes in Italy have greatly relied on well developed and preserved markers of the sea level highstand occurred during the

Marine Isotope 5.5, which are represented by wave-cut and wave-built terraces and tidal notches along rocky coasts and by beach ridges and lagoon deposits outcropping or encountered in cores in coastal plains. The MIS 5.5 highstand is readily identifiable when represented by marine deposits hosting the warm "Senegalaese Fauna", and particularly the species *Strombus dubonius* L. This warm-water gastropod flourished in the Italian Seas only during the Last Interglacial highstand, and provides a unique marker of the MIS 5.5 horizon (named "Tyrrhenian" in the literature). Extensive radiometric dating of organic and inorganic material associated with the *Strombus* yielded ages clustering around 125 Ka, the age of the main last interglacial highstand. The pattern of vertical displacement emerging from investigation of the MIS 5.5 marker in Italy is one of fast uplift centred in the southernmost part of the country (northeastern Sicily, southern Calabria, Ionian side of Basilicata). The rate of uplift steadily decreases away from these regions and is small in west-south Sicily, and in southern-central Italy. The Northern Tyrrhenian coasts, as well as the coasts of the rocky promontories of the central Tyrrhenian Sea, southern Adriatic Sea, southern Sicily and Sardinia are affected by minor uplift or are stable. Subsidence is identified at the northern coast of the Adriatic Sea, in some Tyrrhenian coastal plains and southern Sicily. In this work, data from several research groups are compiled to give an update summary of the altitude and spatial distribution of the MIS 5.5 highstand in Italy. The vast knowledge acquired in decades of research, integrated with more precise estimates of altitude and age of some sites, will be discussed in light of current geodynamic models for the Italian region.*Et al. Radtke Ulrich (Geographisches Institut University of Koeln), Renda Pietro (Earth Dept., University of Palermo), Romano Paola (Earth Dept., University of Naples), Sansò Paolo (Earth Dept., University of Foggia)

26-5 Oral Hearty, Paul J.

SEA-LEVEL OSCILLATIONS DURING THE LAST INTERGLACIATION (MIS 5E): A GLOBAL PERSPECTIVE

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Keywords: Sea-level; oscillations; last interglaciation

The geomorphology and morphostratigraphy of numerous globally important sites reveal the relative movements of sea level during the peak of the last interglaciation (marine isotope stage (MIS) 5e, ca. 132-118 ka). Because sea level was higher than the present datum, deposits are exposed, emergent, and widespread on most stable coastlines. Correlation with MIS 5e is facilitated by similar morphostratigraphic relationships, a low degree of diagenesis, uranium-thorium (U/Th or U-series) dating and amino acid racemization (AAR) geochronology. This study focuses on sites from tectonically stable areas (Bermuda, Bahamas, Western Australia), and those that have experienced minor uplift (Mediterranean, SE US Coastal Plain, and Hawaii) (<3 m/ka). A composite last interglacial sea-level record is characterized by stable intervals separated by rapid shifts of sea level. These intervals include: 1) post-glacial (from MIS 6) rise to above present previous to 130 ka; 2) stability at +2 to +3 m for initial several thousand years (~130 and ~125 ka) during which fringing reefs were established and terrace morphology imprinted along the coastlines; 3) a brief fall to near or below present datum; 4) a rise again to ~+3-4 m for a few thousand years (~124 to ~120 ka); followed by 5) a distinct period of instability characterized by a rapid rise to between +6 to +9 m during which multiple notches and benches were developed; and 6) an apparently rapid descent of sea level into MIS 5d. On the basis of the succession and relationship among geologic features, ages and duration of these intervals are estimated. Unfortunately, despite increases in measuring precision, it is not possible to distinguish the sea-level intervals by U/Th radioisotopes. One feature common to most all sites is a well-developed terrace, marine deposits, and/or reefs at +2 to +3 m, formed early in the interglacial. Thus, for use in uplift calculations and isotopic conversions of ice volumes, a new benchmark is proposed at +2.5 ± 1 m at 127 ka, in lieu of the former one at +6 m-125 ka. The geological evidence suggests that significant oceanographic and climatic changes occurred during the last interglaciation. Apparently abrupt rises and falls of sea level implies instability Northern Hemisphere and/or West Antarctic ice sheets.

26-6 Oral Araujo, Maria Assuncao

EEMIAN AND FLANDRIAN DEPOSITS ON PORTO (NORTHERN PORTUGAL) LITTORAL PLATFORM: THE INFLUENCE OF RECENT TECTONICS

ARAÚJO Maria Assuncao¹, GOMES António Alberto¹

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Keywords: Eemian; Flandrian; marine deposits; lagunar deposits; neotectonics
 Porto is the second city in Portugal and it lies on the riverside of Douro, which is deeply entrenched on the littoral platform, close to its mouth. This platform contains several outcrops of cenozoic deposits and it is limited to the interior by a step relief (marginal relief) which is probably a fault scarp acting mostly after the earlier deposits had been formed. The higher and older deposits have a fluvial origin and they present several evidences of tectonic movements. After the fluvial deposits formation a new tectonic event produced the subsidence of the narrow fringe (1-2km maximum width, going till 37m high) were the marine deposits are lying. Those deposits can be assigned to at least three levels (around 30m, 20m and from 10 to recent sea level). The existence of these levels can be proven by sedimentary criteria. They are not everywhere at the same altitude, but they are disposed in an irregular up and down pattern, with a general trend indicating a subsidence towards the meso-cenozoic basin that begins at Espinho, 15km south of Porto (Lusitanian basin). We will focus on the sea level variation and regional tectonic framework that created the differences between 2 specific places, one of them at the north and the other at the south of Porto area. The TL datation recently performed on an eolian sandstone lying upon a marine deposit (Labruge beach, 15 km north of Douro river mouth, 5m above mean sea level) gave a result of 84kaBP. This allows us to say that the marine deposit lying under it belongs to Eemian. The same must be said about other iron cemented sandstones covering old marine platforms that can be found at several places in this coastline. At Aguda beach, some 12 km south of Porto this marine sandstone is lying at a lower altitude, 1m above mean sea level. Upon it, we found a lagoon deposit, whose top (around 4-5m above msl) was dated of 8ka BP. So, the lagoon deposits are a testimony of continental conditions during last glaciation and holocene transgression. The lagoon deposit is covered by another marine sandstone, at about 5 m above msl. So, in this area, there are clear evidences of 2 marine sea levels with about 120 ka difference of age lying at quite similar altitudes. At Aguda beach, the superposition of a flandrian marine deposit upon a Eemian one may suggest that the southern area is undergoing some subsidence as attested by the general trend of Eemian deposits.

26-7 Oral Caramanna, Giorgio

A DOUBLE MIS 5.5 MARINE NOTCH ?

CARAMANNA Giorgio¹, KERSHAW S.², FERRANTI Luigi³, ANTONIOLI Fabrizio¹

local rivers with a run-off of 30 to 145 million m³/year. The productivity of the explored and exploited water intakes is 0.5-0.8 m³/sec or 15-25 million m³/year. Due to that the technique of exploration and evaluation of groundwater exploitable reserves was developed insufficiently in those years and in the conditions of that time, and also due insufficient knowledge of the geological structure of the areas under exploration and interaction between the ground and surface water, the real water level lowering appeared to be higher than it was predicted by the exploration results. The groundwater levels at the water intakes correspond to the predicted ones, but with water expenditure twice lower than it has been expected. The run-off from the local rivers are dammed in two water storage reservoirs; on the rivers of Kara-Kengir (with a water volume of 312 million m³) and Djedza (with a volume of 43 million m³). These storage reservoirs do not catch the surface run-off completely. Thus, the idle water discharge through the dam on the Kara-Kengir river to the desert varies from zero (water shortage in the storage reservoir) to 307 million m³ (1972). The average annual idle water discharge through the dam amounted for 38 years of observations to 36 million m³. Due to the conditions formed, the exploiting organization took a decision to build an artificial water replenishment system in order to avoid idle water discharge through the dam on the Djedza river. The increase of exploited groundwater is expected for the first turn to be, on the average, 14 million m³ annually. The quality both of the ground and surface waters satisfy all the acting standards. It is planned to remove the upper 3 m loam cover to open water infiltration to the limestones

98-27 Poster Ortega-Guerrero, Marcos Adrián

AQUIFER-AQUITARD INTERACTION IN THE GROUNDWATER MANAGEMENT STRATEGY FOR MEXICO CITY

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Keywords: aquifer management; aquitard-aquifer interaction; Mexico City

The Metropolitan Area of Mexico City (MAMC) depends mainly on groundwater for supplying its almost 25 million inhabitants and some 30% of the nation's industry. Groundwater is extracted from a regional alluvial-pyroclastic aquifer and from an aquifer in fracture volcanic rocks that underlie a thick sequence (between 50-300 meters) of clayey lacustrine sediments, denominated in hydrogeological terms as a regional aquitard. Most of Mexico City is constructed over this high-compressibility aquitard. At present, approximately 52 m³/s of groundwater is extracted from these aquifers, out of a total of 65 m³/s consumed in the MAMC. The lacustrine aquitard plays a very important role in the overall strategy for groundwater management because its affording the underlying aquifers a natural protection against the numerous contaminants present on the surface and in the transitory response topumping; a process that manifests itself in both the consolidation and sinking and fracturing of the land that affect the urban infrastructure, including the pipe lines of drinking water that causes about 40-50% in losses to the ground. The lacustrine aquitard located in the first 25 m to 40 m of profundity does not represent an impermeable barrier to the contamination of the subjacent aquifer, because it was found to contain different scale fractures. Contribution of water from the aquitard into the groundwater balance is not yet well known; and from the chemical point of view high concentration of solutes in the aquitard have changed from the downward molecular diffusion with a small upward advective flux in geologic time, to an advection-controlled flux induced in modern time by extensive aquifer pumping. These hydrogeologic conditions represent a dilemma for water managers in the inevitable increase in demand and continued major exploitation of the aquifer against the progressive subsidence, damage to urban infrastructure and potential for deterioration of the water quality. Groundwater exploitation from deeper carbonate aquifers represents other problems that should be considered.

98-28 Poster Saayman, Irené

TOWARDS AN INTEGRATED USE AND MANAGEMENT STRATEGY FOR THE CAPE FLATS AQUIFER, SOUTH AFRICA

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Keywords: Groundwater Management; Urbanisation; Cape Flats Aquifer; Land-use Planning

The Cape Flats aquifer (CFA) represents an important potential source of water for the City of Cape Town. The aquifer is predominantly unconfined, consisting of aeolian sands. The CFA overlay a fractured rock aquifer, the Malmesbury Group of rocks, and in some places a granitic aquifer. Unfortunately urban development has taken place over most of the aquifer. Developments that have occurred above the aquifer include numerous waste disposal sites and wastewater treatment works, light industry, a power station and large areas of un-serviced informal settlement. The literature reports on a number of instances of groundwater pollution within the Cape Flats aquifer (Tredoux, 1984, Weaver & Tworeck, 1988, Saayman, 2000, etc.). Water use from the Cape Flats aquifer is presently limited to agricultural irrigation. Growth in urban and agricultural water demand will however necessitate intense use of the Cape Flats aquifer in the near future. This will however only be possible if measures are taken today to mitigate the impact of urban development on water quality in the aquifer. This paper outlines management options that could be considered to enable the optimum use of the aquifer and to protect it against the threat posed by urban development and possible seawater intrusion. Use options are discussed and a methodology is proposed to enable best-option land-use demarcation in different parts of the aquifer. Zones are delineated and the activities that should be restricted in each are listed. This document represents a first attempt at the development of an integrated use and management strategy for the Cape Flats aquifer. Consideration is given to hydraulic properties of the aquifer, current land-use demarcation, urban development needs and the influences of climate change.

98-29 Poster Kusuda, Takashi

HYDROGEOLOGICAL STRUCTURE AND GROUNDWATER QUALITY OF MYOKO AREA, ICHIHARA CITY, CHIBA PREFECTURE, JAPAN

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Keywords: geo-pollution mechanism; groundwater table; confined aquifer; Wurm glacial stage; environmental hormone

Highest concentration of 4-tertiary butylphenol (4TBP), a kind of environmental pseudo-hormone in Japan was found at Asai Bridge in Yorogawa River in Chiba prefecture on 1998. Polluted seepage point to Yorogawa River was investigated and survey was started to clear the geo-pollution mechanism of groundwater and river water. Observation wells were installed to clear the geological structure, to monitor the groundwater pressure of the aquifer pumping up groundwater for domestic use, to monitor the concentration of 4TBP and other pollutants in aquifers. Geological condition: Boso peninsula locates southeast of Tokyo on Kanto Plain. Geology of this area is as follows in ascending order. (1) Kogochi formation, medium sand; (2) Izumiya formation (Lebensspur layer, channel layer, humus layer, shell-bearing layer), silt to fine sand; (3) Jizodo formation, fine sand; (4) Holocene sediments, silt to fine sand and gravel; (5) artificial landfill (waste, silty fine sand). (1) to (3) formations are belong to Pleistocene of Quaternary. In this field, the sickness of east part of Izumiya formation is thinner than other part because it was eroded at Wurm glacial age up to humus layer. The bed dips northwest, toward Tokyo bay area. Hydrogeological structure: The first aquifer formed in waste fill. The second formed on Myoko mud layer, Holocene sediments. The third formed on unconformity of Holocene. This aquifer also includes Jizodo formation, Pleistocene strata. Jizodo formation lay under the Holocene unconformity and has recharge area which spread upward of strata inclination. Jizodo formation formed confined aquifer and supply groundwater to Holocene's bottom strata which formed unconfined aquifer. The groundwater flow of third aquifer is north to northwest. The fourth formed confined aquifer in Kogochi formation, groundwater flow toward southeast in spite of bed dips. It considered the eroded area of Izumiya formation decrease groundwater pressure and pour out groundwater. Groundwater quality: It's well known that according to the groundwater flows gradually increase the concentration anions and cations. Same phenomena observed in observation wells of fourth aquifer, from upward to downward of groundwater gradient. Concentration of 4TBP in fourth aquifer monitoring well which located close to waste fill site is about 100 times of limits of quantities analysis, but no detect in domestic wells.

98-30 Poster Afonso, Maria José

REGIONAL MORPHOTECTONICAL AND HYDROGEOLOGICAL MAPPING FROM THE PORTO-S. JOÃO DA MADEIRA SECTOR (NW PORTUGAL): IMPLICATIONS ON GROUNDWATER RESOURCES

AFONSO Maria José¹, CHAMINÉ Helder I.², MARQUES José Manuel³, GOMES Alberto⁴, ARAÚJO Maria Assunção⁵, FONSECA Paulo E.⁶, CARVALHO José Martins⁷, MARQUES DA SILVA Manuel Augusto⁷, TEIXEIRA José⁷

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Keywords: urban hydrogeology; groundwater; morphostructural mapping; crystalline rocks

More than 50% of the world's population live in urban areas that cause a remarkable impact on the hydrological cycle due to impermeabilization of the land surface, which reduces direct infiltration and increases surface runoff. Hydrogeological data acquisition in urban areas is rather difficult, and so, it is of crucial importance the integration of geotectonical and geomorphological features. The overall aim of this research is to assess the role of the regional structural geology and geomorphology mapping on the sustainable groundwater resources management in Porto-S. João da Madeira region (NW Portugal, near the Atlantic shoreline), where groundwater is an important resource for local water supply. The Porto-S. João da Madeira sector is located in a complex geotectonic domain of the Iberian Massif, between the Porto-Albergaria-a-Velha-Tomar shear zone and the Douro-Beira Carboniferous Trough. Most of the region is characterised by the prevailing Variscan granitic rocks and a substratum of Upper Proterozoic and Palaeozoic metasedimentary rocks. The granitic rocks weathering in this region results in arenization, which may reach depths of more than 100 m. In the geomorphologic framework, the region corresponds to a wide flat area dipping gently to South and West. There are ubiquitous evidences for neotectonic activity, such as: a) abundant faults (mainly reverse) affecting the higher deposits of this littoral platform; b) same marine levels seems to appear at different altitudes, developing an irregular pattern with a general trend dipping from the North to the South. In this study, the regional hydrogeological units are presented as well as an outline of the Porto-S. João da Madeira hydrogeological map, facing their future use as an important tool for the sustainable management of local water resources. The negative impact on the quality of groundwater resources can take considerable time, since the response time of groundwater systems is the longest of all components of the urban hydrological cycle. Then, in these areas, hydrogeological data acquisition namely structural, morphotectonical and geological, is, generally, the key to predict the possible negative impacts of surface water-groundwater interaction. The intensity of the impacts is usually dependent on the pollution vulnerability of underlying aquifers (here characterised through the DRASTIC methodology) and directly connected with the type and stage of urban development.

98-31 Poster Branka, Bracic Zeleznik

WHERE ARE THE LIMITS OF LAND USE AND GROUNDWATER EXPLOITATION ON THE AREA OF LJUBLJANA FIELD AND MARSHLAND AQUIFER?

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Keywords: intergranular aquifer; groundwater exploitation; groundwater pollution; land use

For the central position in the country and the geographical position of the area the gravel plain of Ljubljana Field is where the interests of urbanisation, industry, agriculture and public drinking water supply intersect. Ljubljana had been developed in the last hundred years from a town of twenty thousand inhabitants to a city of almost three hundred thousand inhabitants. The small town situated at the foothill of the Castle hill has been expanded over the great part of the Ljubljana Field and joined with the villages in the vicinity. The aquifers of Ljubljana Field and Marshland are drinking water sources for the city. Today the drinking water supply has been distributed from five water fields, four of them are situated on the Ljubljana Field and one on Ljubljana Marshland. The water fields were in the past situated faraway from the city. Today they are surrounded with intensive urban areas and industrial zones. Anthropogenic activities modify the entire aquifer area, impact the hydrological balance, reduce aquifer recharge, influence groundwater flow characteristics and change the water source availability and restoration. In the present day, the groundwater quality indicates moderate ability to compensate the negative influences of heterogeneous land uses. However, the increasing concentration of some pollutants, indicates a tendency to approach the loading limits that the medium can transfer. If we want to maintain good drinking water quality in the future,