Growth and demise of Bahamian carbonate platforms within changing tectonic settings

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The carbonate platforms of the Bahamian archipelago experienced three different tectonic regimes since their initiation in the Late Jurassic. The platform growth reflects these tectonic changes. During times of tectonic quiescence the platforms expand laterally to form coalesced megabanks, while during times of tectonic change platforms either aggrade, backstep, and in some cases drown.

The Bahamas platforms established on the rifted margin of the opening Atlantic and experienced prolific growth during the drifting stage in the Early Cretaceous when subsidence was governed by passive margin tectonics. High sedimentation rates filled rift grabens and platform progradation welded most platforms together to form a large carbonate province that became known as the “megabank”. At the beginning of the late Cretaceous, the regional stress regime changed as the Caribbean plate started to move into the proto-Caribbean realm. Deep-seated extensional faults were reactivated, causing the break-up of the megabank. The collision of the advancing arch with the North American continent caused over-thrusts and loading of the plate. As a result the megabank disintegrated and partly drowned. The drowning process was not a one-time event but progressed from south to north as the archipelago was transformed into a foreland basin. This progressive drowning that is in lockstep with the evolution of foreland basin indicates that faulting and increased subsidence rates are sufficient for the demise of carbonate platforms. With the opening of the Cayman Trough and the concomitant shift of the plate boundary south of the Cuba the archipelago was largely reversed to a passive margin setting. The platforms also resumed their sea-level controlled lateral expansion.

An exception is Cay Sal Bank, which remains part of Cuban fold and thrust belt. As a consequence, the Bahamian archipelago today has platforms in two tectonic settings. Most platforms are on a passive margin setting, while Cay Sal Bank is in a tectonic active setting. Yet, their morphology is similar. All platforms are flat-topped and steep-sided, although Cay Sal Bank is about five meters deeper than GBB that is 7 – 12 m deep. The difference is mostly in the subsurface. Multi-channel seismic and multi-beam data reveal several structural elements along the eastern side of Cay Sal Bank. Deep-rooted faults with both thrust and wrench fault characteristics separate the platform from the adjacent basin. Two of these faults reach the seafloor, forming 30 km long and 50 m high scars on the seafloor. Anticlines that are dissected by faults display Holocene fold-growth strata. Both these features, together with recent earthquakes, document the neo-tectonic activity in this part of the archipelago. Neo-tectonics does not change the general bank morphology but it is reflected in the slope development. GBB with its 450 km long margin that is nearly perpendicular to the Cuban fold and thrust belt displays the decreasing tectonic influence from south to north. In the proximity of the fold and thrust belt, large margin failures are common. Away from plate boundary only slope failures are observed that are most likely not triggered by tectonic processes.

The evolution of the Bahamian platforms within the changing tectonic settings reveals the competition between tectonic destruction and platform growth. Faulting combined with changes in subsidence rate can potentially disrupt platform growth without other environmental changes.

Characterization of some Quaternary Deposits in Wadi Al kuf (Sector1), Tansolukh Area, Al Jabal Al Akhdar, NE Libya

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The study area sector (1) is located in the northwestern part of Al Jabal Al Akhdar region. The study was conducted in Wadi Al kuf of Tansalukh area. In this region, Quaternary laminated carbonates rich in pebbles and red soil horizons, the focus of the study, overlay Tertiary rocks. The purpose of the present study is to investigate sequence characteristics, position and lithologic features of such occurrences. Stratigraphically, the study area consists of five Formations ranging in age from Middle Eocene to Late Miocene.

The stratigraphic correlation between measured sections (numbered 1 to 5) indicates that the northern sections (3 & 5) are predominantly composed of stratified red soil layers, while the southern sections (1, 2 and 4) are mainly composed of debris-flow deposits underlain by relatively coarse-grained materials of bedrock suggesting deep river incision at this vicinity.

The geologic record preserved in surficial deposits in some localities of Wadi Al Kuf is greatly common between most wadies in Tansolukh area, suggestting that the rivers draining the northwestern slopes of the main escarpments had broad flood plains.

The relatively wide and flat valley floor of Wadi Al Kuf (NW side between escarpments) suggests that the stream level in this Wadi have been stable throughout the Late Quaternary.

The presence of numerous local bedrock exposures along the studied profiles indicates that the river incised much deeper than their present level. Additionally, the local presence of deeply weathered debris-flow deposits at or near the level of present drainage also suggests that the Late Quaternary fluvial down cutting has been modest.

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Phosphate pollution in the Gulf of Gabes (Tunisia): the problem of the phosphogypsum discharge

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Important phosphate deposits are present in Western Tunisia. They are currently exploited in five different mining centers and phosphate minerals are treated in three main industries on the eastern coast (Sfax, Skhira and Gabes).

Phosphate treatment consists of the transformation phosphate ore into phosphoric acid using sulfuric acid. During this process, a large amount of phosphogypsum waste is produced. Phosphogypsum as a waste product is stored into spoil tips along the coasts and near the industries of Sfax and Skhira. It contains a low level of P_2O_5 (around 1 % in wt.), which is partially soluble, thus causing important environmental pollution. Previous environmental studies showed contamination with P_2O_5 by leaching process of spoil tips. Indeed the P_2O_5 content into sea water next these industries exceed the current standard. The situation at Gabes is even worse because the totality of phosphogypsum is discharge directly into the sea.

To assess the P_2O_5 pollution, seven coast stations were sampled (sediments and water) in the Gulf of Gabes between Skhira and the north edge of Djerba Island. One station was also sampled at El Kantaoui located in the Gulf of Hammamet in the northern part of Tunisia to compare the phosphorus content between the northern and southern part of Tunisia. Total phosphorus content was measured on water samples and phosphorus content in the sediment by the sequential SEDEX extraction method.

The phosphorus content in the sediment and in the sea water near the phosphates industries of Gabes shows the higher concentrations, lower concentrations occur between Gabes and the edge of isle of Djerba. However, the phosphorus content in the water does not exceed the phosphorus standard in the Mediterranean Sea (0-0.35mg/L), except near the Gabes industries. Phosphorus contents in the water and the sediments are much higher in the Gulf of Gabes than those recorded in the Mediterranean. For this reason the high concentration at Gabes may be the result of industry discharge of phosphogypsum causing an eutrophication of the marine environment.

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Post depositional evolution of MIS5e encrusting algal rims (Porto Alabe, Sardinia, Italy)

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Late Quaternary marine carbonate deposits and aeolian sand grains crop out extensively in the northwestern coast of Sardinia. Carbonates OSL dated at 125±10 ka "last interglacial deposits (MIS5e)" typify some places. They consist of up to 1 m thick cemented marine shells (*Patella ferruginea*, *Stramonita haemastoma*, *Chelyconus ermineus*, *Glycymeris glycemeris*, *Arca noae*, …) with encrusting red coralline algae, mostly *Lithophyllum byssoides*.

The aim of this work is to define the diagenetic evolution of these encrusted carbonates in Porto Alabe (western coast of Sardinia).

Samples are collected from Porto Alabe and thin-sections for microscopical studies using both optical and scanning electron microscope were performed.

Micrite is the dominant matrix constituent of the studied samples. Carbonate bioclasts, mostly fragmented, with average size ranging from <1 mm to several centimeters have been identified. Two types of coralline algae were found: the non-geniculate crustose corallines *Lithophyllum byssoides* -the most abundant and the geniculate corallines. Bivalve or univalve shells (mollusks, serpulids) or multi-element/multi-plate shells (echinoderms) are dominant. Both planktonic and benthic foraminifera exist. Terrigenous grains are sub-rounded and mostly made of quartz, alkali feldspars, calcic plagioclase and heavy minerals.

Fabric-selective porosity dominates. It is represented by interparticle porosity, which is not high because pores are partially occluded by cement and sediment, and intraparticle porosity. Non-fabric selective porosity is only represented by vuggy porosity.

The results revealed that micritization, dissolution and cementation are the most important elements of the diagenetic process. The partial alteration of some carbonate grains "micritization" with the preservation of relics of the original structure is evident. Secondary porosity is found either as dissolution of carbonate grains or as moldic porosity.

The predictable major types of interparticles cement are: 1) microcrystalline high-Mg calcite equant rims, 2) isopachous crust of aragonite and aragonite fibrous cements. Interparticle and intraparticle equant or granular calcite cement were also identified. Cement morphology and mineralogy suggest that diagenesis occurred in the marine and mixed phreatic environments. We here hypothesize that this may have occurred during MIS5c when sea level was lower than MIS5e but still 2 m higher than the present.

Characteristics of deep sea sediments from the Levantine basin (Israel economic zone) - Preliminary results

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The Levant Basin, situated in the Eastern Mediterranean Sea, is a semi-enclosed intercontinental basin. Previous research in the area focused either on the distribution and sources of clay minerals, or reconstruction of Quaternary paleoclimate (sapropels). These studies indicated that the clays in the basin area are mostly contributed by the Nile River and Saharan dust. However, in terms of sediment characterization, transport mechanism and sedimentation rates, most of this region is still unexplored.
In addition, recent discoveries of gas and oil in the Levant Basin within the economic water of Israel (~28,000 km^2) have led to an accelerated development. In light of this, there is a need to better characterize the surface sediments. The current study was designed to characterize the grain size, chemical and mineralogical composition and microfauna of the sediments. Here we present preliminary results of the grain size analysis along with their geochemistry.
A systematic sampling campaign was carried out by Israel Oceanographic and Limnological Research Institute (R/V Shiqmona) and the Geological Survey of Israel during June-July 2013. Sediments were sampled in 52 locations along the slope and the basin floor area at 200-2000 m water depth. In each location, surface (0-1 cm) and subsurface sediments (9-10 cm) were sampled using a box corer. Samples < 1 mm were pretreated to dissolve salts and carbonate and analyzed for particle size distribution (PSD) using laser diffraction analyzer. Each sample was measured as bulk and after dissolution of carbonates.
Most of the bulk surface samples are composed of fine-silt to clayey grains, with a uni-modal PSD. The PSD mode gradually decreases towards the west from ~8 µm at the slope to ~4 µm at the basin. An additional coarser mode (50-70 µm) is present in some upper slope samples (mostly quartz and biogenic fragments) and also present in the deepest parts of the basin (>1300 m water depth) where it is mostly composed of whole and fragmented planktonic foraminifera and pteropods. Similar to the surface sediments, the subsurface sediments (9-10 cm) exhibit finning trend with depth but the PSD mode is finer (~ 6-3 µm). For most surface and subsurface samples, the carbonate-free fraction exhibits a pronounced uni-modal PSD. In the basin deepest parts, the sand fraction decreases from 12% (bulk) to ~1% (carbonate free), an observation which supports the relative increase of the clay fraction compensating the dissolution of biogenic sand-size component. The mode is still very fine (6-3 µm); however in places the PSD mode of the carbonate free fraction increases to the sortable silt fraction (10-21 µm). The $\%CaCO_3$ in the samples though has a wide range (9 - 65%) shows a good correlation between the $\%CaCO_3$ of the surface sample to the subsurface, suggesting an overall stable depositional environment. The major and trace element compositions of the insoluble residue of these samples show good correlation among K, Ba, Fe, Mg and Cu, Ni and Co. These correlations indicate presence of mica and/or illite, plagioclase and possibly hornblende in the detritus.
In general, the finning trend of the surface PSD follows the bathymetry. The results of the bulk PSD indicate an almost uniform westward fining trend from the slope towards the basin; however the carbonate free fraction suggests that the sorting process is somewhat more complex. Further research will focus on estimation of deposition ages and sedimentation rates, chemical analysis and microfauna characterization.

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First Maps of the Mesozoic and Cenozoic Structural-Sedimentation Floors of the Easternmost Mediterranean and their Relationship with the Deep Geophysical-Geological Zonation

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The easternmost Mediterranean is a tectonically complex region within the Neo-Tethyan collision zone. It is mainly composed of the Mesozoic terrane belt and the adjoining oceanic crust complex of the northern part of the Sinai plate. Despite years of investigation, the geological-geophysical structure of the easternmost Mediterranean is not completely known. The recent discovery of large hydrocarbon deposits has attracted a great deal of attention to this region. The performed investigation is based on the integrated analysis of geological, geophysical, paleodynamical and paleobiogeographical data. For the first time a series of maps (from the Triassic to Neogene-Quaternary stages) reflecting the structural distributions of six structural floors in the easternmost Mediterranean was developed. On one hand, the maps reflect the postaccretional stage of the Triassic and Jurassic structure disposition and their subsequent deformation in recent times. On the other hand, it is known that they are partially associated with terranes formed to the north-east of their modern location and were part of shelf and rift zones of the Ethiopian paleobiogeographic province. The Triassic and Jurassic structural floors exhibit a strongly discordant position related to the tectonic structures within the terrane belt and foreland. The combined geological-geophysical and biogeographical data testify to the fact that the terrane belt and most of the oceanic crust of the easternmost Mediterranean are allochthonous structures transferred along the series of transform faults from the east. The marginal western terranes were transferred probably from the region disposed to the NW from the modern position of the Persian Gulf. For the first time a Kiama paleomagnetic hyperzone of reverse polarity was delineated in the easternmost Mediterranean (to the east of the Eratosthenes). This zone occurs discordantly and returned clockwise at 90^{o}. Revealing this zone confirms the conception of remnant kind of the Earth's crust in the Mediterranean basin. A paleomagnetic map constructed on the basis of magnetic, paleomagnetic, tectonic, petrological, paleobiographical, radiometric and facial data indicates that to west of the Kiama zone situates Jalal zone, and to east – Illawarra, Omolon and Gissar zones. The easternmost part of the oceanic crust is associated with the Middle Triassic-Jurassic according to Carmel's ophiolite investigation. We can suggest that the Kiama zone and the oceanic crust adjacent to it from the east may represent a part of small oceanic basin. Analysis of the satellite derived gravity field pattern and its transformations (spatial derivatives and entropy map), airborne observed magnetic field, seismic data and some thermal characteristics along with the tectonic-structural reconstructions indicate the clear isolation of the Sinai plate from the Arabian and Nubian plates. Within the oceanic Levantine plate, Late Messinian salt plays an important role in forming hydrocarbon reservoirs. The rear depression of the terrane belt adjacent to this basin contains prospective oil and gas collector facies of Late Messinian erosional incisions and delta cones. Obviously the revealed geodynamic zones control the deep influx of hydrocarbons and form structural hydrocarbon traps in different tectonic and sedimentary floors. The geological and geophysical maps and these corresponding tectonic conclusions have considerable importance for the development of future hydrocarbon search strategies and its exploitation in the easternmost Mediterranean.

Lateral and vertical variation of lacustrine travertine shrub layers as possible analogue for the Pre-Salt microbialite reservoirs

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Recent discoveries in the Pre-Salt section, offshore Brazil, revealed continental carbonates which possess very good oil reservoir characteristics. However, unfortunately lacustrine travertines are poorly documented from a sedimentological point of view. Only recently sequence stratigraphy was applied on continental carbonate outcrops, but it is still incipient, especially for travertines.
Travertines from Tivoli possess a shrub-like fabric. The latter are laterally very continuous, and are remarkably similar to the ones described for the Pre-Salt reservoirs. Two quarries were analysed in the Tivoli area (Central Italy), with the aim to document the lateral facies variations and to unravel the stacking patterns and cyclicity in travertine shrubs.
Three sequences, limited by erosive surfaces and covered by paleosols, were recognized and described in detail from an ~11m high and ~100m long wall. The first sequence comprises 2m of a small terrace facies that varies laterally into a lacustrine facies. The small terrace facies is composed of shrub-like fabrics, that occur mainly on rims and in small bumps. The lacustrine facies correspond to a laminated mudstone (possibly microbial mats) locally with reworked intraclastic travertine. The second sequence displays an impressive thickness of 6m with laterally continuous shrub-type layers. The shrub facies were deposited under low energy, very shallow (less than 1m) conditions with very low gradients, typical for alkaline sheet lakes, fed by multiple vents. The shrubs occur intercalated on millimeter to centimeter (0.5 – 5cm) scale with micritic and coated bubble facies. They vary laterally in morphology, size and consequently porosity-permeability characteristics. They present shallowing upward cycles marked by an erosive surface and paleosols on top of the sequences.
The third sequence, approximately 4m in thickness, comprehends very porous reworked reed facies at the bottom with an irregular architecture, followed by flat shrub layers.
The paleosols, indicating fluctuations of the water table, represent stages of reduced accommodation space, and possibly more arid conditions. They correspond to the shallowest part of the described cycles and they pinch out towards the deepest part of the basin.
The contacts between the paleosols and the other facies is marked by an erosional surface and large vugs. The vugs are related to late water percolation and dissolution.
If the couple of shrub and micritic layers comprise cycles of one year (summer-winter) an average of 3mm/yr growth rate can be calculated. In one parasequence with about 2m of thickness, bound by unconformities, they possibly correspond to 3^{th} - 4^{th} order cycles. So, the three main sequences are interpreted as 3^{th} order cycles, and high frequency, meter to centimeter cycles possibly correspond to 5-6^{th} order cycles.
The stacking patterns of these bodies are aggradational, slightly retrogradational, with shallowing-upward cycles.
The study of sequence stratigraphy is extremely important to facies prediction and global events correlation. The Tivoli travertines correspond to an interesting area with regard to this reservoir analogue study, because they are travertines that were deposited in a lacustrine domain. Furthermore they possess similarities with the Pre-Salt facies.

Possible early signature of the Late Paleozoic Ice Age in Early Pennsylvanian paleo-cave deposits, southwestern Colorado, U.S.A.

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Other researchers have shown that Cenozoic cave deposits can be linked to dust or loess (eolian silt) sources, either via direct eolian deposition into the cave or through a process of dust trapping on the overlying land surface and subsequent redeposition in cave passageways by hydrologic events. This study extends these concepts to the geologic record to show that Early Pennsylvanian paleo-cave deposits may represent the earliest terrestrial record of the Late Paleozoic Ice Age (LPIA) in North America. The study utilized stratigraphy, petrography, textural analysis, SEM/EDS analysis, XRD analysis, and zircon thermochronology.

In southwestern Colorado, late Mississippian eustatic sea-level fall created karst features in the Mississippian Leadville Limestone. These features included phreatic tubes, breakout domes, tower karst (kegelkarst), solution valleys (poljes), sinkholes (dolines), solution-enhanced joints (grikes), surficial flutes (rillenkarren), and solution pans (kamenitzas). Autochthonous cave sediments (flowstone, dripstone, and cave pearls) were interbedded with parautochthonous cave sediments (mosaic, crackle, and chaotic breccias) and allochthonous cave sediments.

The overlying Early Pennsylvanian Molas Formation is a loessite (eolian siltstone) composed of angular quartz silt having ferruginous kaolinite clay rims on grains. The U-Pb ages of accessory zircons in the loessite indicate that the source areas for the eolian silt are from the peri-Gondwanan and Grenville provinces of eastern and southern North America, which are approximately 2000 km to the east. There is also a province signature from the rising Ancestral Rocky Mountains. The evidence suggests that, during the Early Pennsylvanian, the dust was trapped on the land surface by a combination of topography (paleokarst landscape), moisture, and vegetation. Weak paleosols in the Molas Formation suggest relatively rapid rates of dust accumulation. It has been observed that in modern loess soils, the high porosity and low bulk density make them susceptible to groundwater piping or sapping. It is hypothesized this mechanism may have facilitated redeposition of the Molas Formation loess into karst passageways. Alternatively, surface run-off may have delivered loess into karst passageways.

The paleo-cave sediments in the Leadville Limestone can be linked to the overlying loess in the Molas Formation by compositional and textural matches. In addition, facies analysis of the paleo-cave sediments documents transport and deposition by episodic hydrologic events, producing flood deposits (inundites) and debris flow deposits (debrites) in paleo-cave passageways. Mudcracked surfaces within the paleo-cave successions indicate intervals between successive hydrologic events. These event deposits are also interbedded with speleothems such as flowstones and dripstones.

In summary, the paleo-cave sediments in the Mississippian Leadville Limestone can be shown to be derived from the overlying Molas Formation loessite. This loessite was derived in part from dust sources in tectonic highlands at least 2000 km to the east. The high preservation potential of the paleo-cave sediments has created a geological archive of what may be the oldest terrestrial evidence of the LPIA.