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ABSTRACT BOOK

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Petroleum Geology II edition
student contest

Shell

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PREFACE

This book collects the abstracts submitted to the 2nd edition of the Petroleum Geology Student Contest, which has been held the October 4th and 5th 2017, in the beautiful town of Calvello (Potenza), in the heart of the woods of the Basilicata Region of southern Italy.

The previous first 2015 edition of the workshop was organized in Matera and after its unexpected positive outcome, as well as the continuous support of the SHELL Italy E&P sponsorship, we were encouraged to schedule the contest for three editions.

The PGSC is an unique event of this type in Italy, aiming at offering the opportunity to young researchers to show the results of their research to an audience of academic and industrial geologists, and discuss and exchange novel research ideas and breakthroughs.

The original research works included in this book deal with several fields of the Earth Sciences, treating different aspect concerning the Petroleum Geology, such as Geodynamics, Regional Geology, Basin Analysis, Sequence Stratigraphy, Applied Sedimentology, Structural Geology, Geophysics, Palaeontology and Geochemistry. These disciplines are used to tackle topics of outcrop analogues, data processing and interpretation, petrophysics and rock physics, reservoir modelling, fluid flow simulation, etc.

In the PGSC of Calvello, 16 abstracts were selected by a Scientific Committee, among those included in the present book. The Committee was composed of colleagues working in a number of Italian and foreigner universities and research centres, who have enthusiastically offered their cooperation to the workshop. The authors of the designated abstracts were thus invited to present their original research at the PGSC which, in this 2nd edition, accounted two separate sessions: one for oral and one for poster presentations, involving PhD and MSc students, respectively. Then, at the end of the conference, a Judging Committee awarded the two best presentations of each session after a final ceremony.

The workshop, open with a keynote lecture presented by Carlos Pirmez, Chief Geologist at Shell Italy E&P, was also in this edition enriched by the presence of researchers, colleagues and students who formed a lively atmosphere and a stimulating setting.

We are grateful to the following friends of the Scientific Committee: Mauro Agate (Università di Palermo), Andrea Bistacchi (Università di Milano Bicocca), Domenico Chiarella (Royal Holloway University, London), Sveva Corrado (Università di Roma 3), Nicola De Paola (University of Durham), David Iacopini (University of Aberdeen), Alessandro Incarbona and Attilio Sulli (Università di Palermo), Rosanna Maniscalco and Giovanni Barreca (Università di Catania), Giovanni Mongelli and Giovanna Rizzo (Università della Basilicata), Francesco Muto and Edoardo Perri (Università della Calabria), Mariano Parente and Stefano Tavani (Università di Napoli "Federico II"), Marco Patacci (University of Leeds), Davide Scrocca (IGAG CNR), Emanuele Tondi (Università di Camerino), Marcello Tropeano and Andrea Brogi (Università di Bari) and Enzo Rizzo (CNR IMAA).

Our gratitude also goes to the components of the Judging Committee: Elisabetta Erba (President of the Italian Geological Society – S.G.I.), Pierluigi Vecchia (ENI, Italy E&P), Massimo Mattei (Università di Roma 3), Marco Brandano (Università di Roma "La Sapienza"), Alessandro Amorosi (Università di Bologna), Stefano Mazzoli (Università di Napoli "Federico II") and Giacomo Prosser (Università della Basilicata).

We are grateful to SHELL Italy E&P, who have enthusiastically believed in the importance that an event like this represents for young researchers who are moving their first steps in the world of the Petroleum Geology.

Finally, we would like to thanks all the students who attended this 2nd edition of the Contest for their fervent participation.

Looking forward to the next edition of the Petroleum Geology Student Contest.

Sergio G. Longhitano & Fabrizio Agosta
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1st SESSION – PhD Student Abstracts

Coupled ecologic and parasitic mollusc-derived trends in Holocene Po coastal plain (Italy): testing a novel approach for refining facies and sequence stratigraphic interpretations

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Keywords: flooding-surfaces, mollusc, parasites.

A 20m-thick core (61 samples) framed in the high-resolved Holocene Po coastal plain (Northern Italy) has been analysed to delineate paleoenvironmental changes based on quantitative information derived from extant, ecologically well-known, mollusc species. At the same time, we assessed stratigraphic variation of parasitic signatures (trematodes traces) and their potential in (sequence) stratigraphic interpretations. Trematodes produce distinctive oval-shaped scars with raised edges on the inner shell surface of their bivalve hosts, and these traces are preserved in the fossil record (Huntley and Scarponi, 2015).

Multivariate paleoenvironmental analyses coupled with quantitative parasite-derived trends across the core reveal distinctive signatures, useful in refining facies associations and supporting previously determined surfaces and intervals of sequence-stratigraphic significance.

Indeed, salinity represents the prominent environmental driver controlling macrofossil turnover along the studied core. Temporal trends of ordination-derived sample scores display multiple orders of cyclicity. At the overall scale of the sedimentary package a strong glacio-eustatic imprint is identifiable. At a higher resolution, the vertical stratigraphic trajectory of ordination scores depicts five major salinity peaks (>22 psu) followed by a gradual return to reduced salinities (i.e., 8-10 psu). The major salinity shifts indicate non-Waltherian facies displacements, interpreted as flooding surfaces, with the overlying deposits recording increased marine influence incompatible with a gradual lateral migration of adjacent environments.

As for parasitic inferences, infestation values (prevalence) were significantly and repeatedly elevated ($p < 0.01$) in samples associated with flooding surfaces, while within the flooding-bracketed deposits (parasequences) these values show a marked decreasing trend. At systems tract level, prevalence of trematode parasites was significantly lower within the highstand systems tract respect to the transgressive systems tract. The results will be of interest to sequence stratigraphers and petroleum geologists who can use coupled parasitic and ecologic signatures to refine facies associations and identifying surfaces and intervals of sequence-stratigraphic significance. These inferences should be applicable to older succession accumulated within comparable depositional contexts.

Reference:

Huntley J.W. & Scarponi D. (2015) - Geographic variation of parasitic and predatory traces on mollusks in the northern Adriatic Sea, Italy: Implications for the stratigraphic paleobiology of biotic interactions. Paleobiology, 41, 134–153.

Application of the 3D seismic analysis on the Neogene Stretava Formation in the East Slovakian Basin

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Keywords: Stretava formation, 3D seismic, Petrel.

The Lower Sarmatian Stretava Formation belonging to the East Slovakian Basin consists of clay-, sand- and gravel- sized deposits with volcanoclastics derived from the volcanic Slanské vrchy Mts. In the western margin of the basin, the formation consists of the coarse-grained deposits named as Košice Gravel, deposited in deltaic and inner shelf environment (Karoli et al. 1989, Vass et al., 2000). The deltaic sediments were also deposited on the northern margin of the basin, where Laborec and Topľa rivers entered the sea (Janočko et al. 2003).

The main aim of the study is to show the geometry of the Lower Sarmatian deposits in the area of Višňov which can be used for both paleogeographical studies and estimation of the hydrocarbon potential of the formation. In Schlumberger's Petrel software the study of 3D Višňov seismic cube is performed.

With the help of geobody interpretation tools the studied horizon has been selected. It is in the debt of 390 to 1050 ms. The horizon is build by discontinuous reflex of low to high amplitude and low frequency. Several arbitrary composite sections have been drawn in the cube to closely examine the seismic signal. The reflex that is building the studied horizon is showing the lateral shifts in the amplitude (from low to high). The same changes could be observed through the whole surface. In the areas with high amplitude the sand fairways active during the sedimentation has been marked. Those sand fairways are built by distributary channels around which the interdistributary area with lower signal amplitude is present. Overall situation with the connection of structural geology features is showing the transport of coarse grained material from north to south on the slope which is bounded by synsedimentary faults. The coarse grained sedimentary material is transported with deltas to the basin margin where the underwater distributary channels are taking leading role in transport furthermore into the basin depocente.

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Hydraulic properties of carbonate fault rocks, insights from an integrated structural, diagenetic and petrophysical investigation

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Keywords: carbonate fault rock, porosity, permeability.

This work is aimed at deciphering the role played by cataclastic and diagenetic processes on both amount and distribution of connected porosity, as well as the cross-fault permeability of carbonate fault zones. Despite the great importance of this knowledge for structural geologists dealing with seismic or working in the hydrocarbon, water, and geothermal industries, the micro-mechanics and petrophysics of carbonate fault cores is still matter of debate. In fact, due to paucity of published data, and the profound effects that diagenetic processes such as cementation, compaction and pressure solution have on the resulting porosity, a great difficulty arises in the comprehension of the control exerted by grain fracturing and grain rolling on pore type, geometry and connectivity of carbonate fault rocks at shallow crustal levels (< 1km).

In order to better understand the relationships among micro-mechanisms, porosity and permeability, the present work focuses on high-angle normal fault zones crosscutting the Lazio-Abruzzi and Campania-Lucania platform carbonates, Italy. In particular, calcite-rich fault rocks exposed along the Fucino, Sulmona and Agri Valley basins, respectively located in central and southern Italy, and dolomite-rich fault rocks cropping out along the Mercure Basin and at the Vietri di Potenza relay ramp zone, southern Italy, are investigated by a combined field and laboratory study. In the field, structural analysis is aimed at deciphering the inner architecture of the exposed fault cores, the main fault rock textures, their spatial distribution, crosscutting relationships and multi-scale dimensional properties. In the laboratory, the representative hand samples collected along each identified structural domain of individual fault zones are studied by mean of X-Ray diffraction, optical microscopy, SEM, Cathodoluminescence and digital image analyses. The goal is to document the composition and texture of the sampled fault rocks, compute the dimensional properties of survivor grains, characterize the nature and timing of cements, as well as the fluid patterns during the exhumation history of the fault zones. The results of this multi-disciplinary work are integrated with those arising from petrophysical analysis (porosity measurements, ultrasonic and permeability test), aimed at deciphering the amount of effective porosity, pore geometry and type, dimension of connected pores, and cross-fault permeability.

Altogether, both structural, diagenetic and petrophysical data are discussed to understand the spatial and temporal evolution of permeability in carbonate lithologies according to fault damage and fault related diagenesis. These processes variably modify the pore systems and hence control the temporal evolution of permeability in the fault zones. Such an understanding can be applied to subsurface reservoirs to improve reservoir quality predictions and to better assess the sealing potential of carbonate fault zones.

Hybrid event bed processes, facies trends and distributions in deep-water turbidite systems

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Keywords: Hybrid event beds, deep-water fans, depositional processes.

Hybrid event beds (HEBs) are a type of deep-water sediment gravity flow deposit comprising a basal clean (clay- poor) and/or banded sandstone overlain by muddier (debritic) sandy facies emplaced during the same transport event. HEBs have recently been increasingly recognised as an important component of many deep-sea fan and sheet systems. From an applied perspective, they are important when present in hydrocarbon reservoirs because they can have a significant negative impact on reservoir performance. This work investigates the character, facies tracts, flow processes, lateral variability, and stratigraphic occurrence of HEBs in a range of outcrop exposed sedimentary basins, with a particular focus on the Cretaceous-Palaeocene Gottero turbidite system, NW of Italy, where extensive new fieldwork has also generated an improved stratigraphic framework. The main findings are: 1) Different types of HEB occur in specific depositional sub-environments: a new classification scheme have been developed using as a main criteria the texture of the intermediate mud-rich division and the size and shape of clasts within it. Thick mudstone-clast rich and raft-bearing HEBs are preferentially found in confined sheet-systems and in lobe initiation settings. Thinner, clay-rich and mudstone clast poor HEBs are mostly observed in fan lobe successions in muddy inter-lobe intervals or lobe fringes. The two types of HEB have specific facies tracts and form by different mechanisms of mud entrainment and ensuing flow fractionation. 2) The process of substrate entrainment have an important impact on HEBs development: turbulent erosion and relatively soft-substrate imply acquisition disaggregated clay promoting hydraulic fraction of low- density clays and other components in flow margins and tails followed by turbulence damping, leading the formation of argillaceous-type HEBs. This type of erosion mostly occur in proximal fan settings as in canyons, channel-lobe transition zones and avulsion sites. Otherwise high-volume and high-concentration flows and cohesive and well-layered substrates promote the detachment mudstone clasts or even large (10s m across) substrate slabs by local delamination producing extensive shallow scours. The entrained material is than disaggregated and mixed with the transported sand in a shearing boundary layer forming mud-clast rich or raft-bearing HEBs. In this case, erosion and entrainment may happens in relatively distal locations in basin-floor or against basin margins where the flow energy is focused by basin confinement. 3) Although generally forming tabular beds, HEBs can show marked lateral variability in bed make-up over short (10s m) length scales, reflecting complex interfingering between the up-dip sandstone-dominated part of the event bed and the down-dip muddier sandstones. This variability is interpreted to occur due to a combination of the patchy nature of flow transformations and internal erosion by the linked debrite that modifies the geometry of the basal and just deposited clean sand. The resulting geometry will affect sweep efficiency during hydrocarbon production involving HEB-prone reservoirs. 4) Despite allogenic factors have been linked to HEBs occurrence, those not seem to be the major control on the studied systems. Otherwise, the HEB formation and distribution at system scale seem influenced by autogenic factors as the pattern of lobe compensation and avulsion, the flow magnitude and the nature of the substrate.

Outcrop characterisation of slope channel architecture: monitoring change from shelf edge to toe-of-slope, Jurassic Neuquen Basin, Argentina

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Keywords: Slope channel architecture, sediment-density-flow transformation.

Slope channels act as leaks and conduits for deep water reservoirs when they are below subsurface resolution, thus outcrop characterization of these elements are vital for petroleum exploration. Here we present a new outcrop study of a coarse-grained system in Neuquen Basin, Argentina, where slope-channel facies and architectural variability are revealed in high resolution in both depositional strike and dip section, along a series of >300m high, northward- prograding clinoforms in the back arc Neuquen Embayment formed during early-middle Jurassic time.

Continuous walkable exposure from fluvial and shelfal to deepwater-slope and basin-floor deposits (Los Molles Fm) reveals slope-channel deposits from shelf edge to toe-of-slope. Two types of slope channels are identified: upper-slope channels in incised canyons, 1-2km wide and up to 100m- thick with conglomerate and coarse-grained sandstone facies showing the characteristics of sandy debrites and high-density turbidites with poor sorting and occasional inverse grading, and lower-slope channels that are one order of magnitude smaller, and are filled with amalgamated, tabular bedded, normally-graded low-density turbidite sandstone. Pebble-sized conglomeratic debrite and coarse-grained high- density turbidite sandstone re-occur in the basin floor fan deposits, and in 'channel-lobe transition zone'.

The distribution of lithofacies and geometry of the outcrops reveals two aspects of the slope-channel systems in this narrow shelf (<40km), medium water depth (<400m) system: the varying geomorphology of the channels and by- passing sediment on the slope and the changing process stratigraphy along the clinoforms. For channel geomorphology, the upper slope channels are likely to be more sinuous than lower slope channels as: 1. more laterally-inclined infill strata are observed in upper slope channels while lower slope channels are mostly filled by vertically aggrading sandstone beds. 2. Coarser grain size of the upper-slope channel fills suggest relatively rapid flow deceleration that hints at flow deceleration due to changes of downslope morphology or slope gradient. 3. conglomerates in upper slope channels and on basin-floor fan lobes but not in lower-slope channels suggests coarse-grain bypass through the lower slope channel.

The high facies resolution on clean outcrops also reveals possible sediment density flow transition down the shelf- margin slope. The debrites and high-density turbidites generated at the shelf edge or outer shelf were derived from a river-delta system across a narrow (<40km) shelf. The turbidite deposits in the lower slope channels have two possible origins: (1) turbidity currents that were coeval with, and evolved from upper slope debrites after accompanying mud- lofting and coarse grained sediment dumping caused by increasing water entrainment, or (2) already deposited, but unconsolidated debrites on the upper slope become incorporated and reworked as turbidite flows and then delivered further downstream into lower slope and basin floor. Either way, the two mechanism for flow transition partitions coarse grains to the upper slope channels and finer grains to the lower slope, but also allows some lesser gravels to come onto the basin floor. Combining with knowledge of fluvial, shelfal and basin floor fan facies in the same S2S depositional system, we suggest significant grain size and facies partitioning along the Jurassic Neuquen Basin margin.

Structural variation in fold thrust belts and implications on exploration targets. A case study from Kohat Potwar fold thrust belt of Pakistan

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Keywords: Detachment, Duplex.

Fold and thrust belts (FTBs) show structural variations along and across strike due to changes in detachments, basement architecture and wedge thickness. Classical models build with analogue or numerical techniques examine the geometry and causes of these structural variations. Analogies between these models and field data based structural models are discussed in order to get a better understanding of the driving factors for such structural variations in FTBs. These models are helpful in understanding structural architecture and targeting hydrocarbon reservoirs.

The Kohat and Potwar fold thrust belts (K-FTB and P-FTB) in Pakistan represent the outermost external zone of the Himalayan fold and thrust system. Main boundary thrust (MBT) mark their northern boundary which shows both are genetically linked to Himalayan orogenic deformation propagated from north to south toward foreland. However it is interesting to observe distinct contrast in their structural style. This contrast becomes even more obvious at the southern P-FTB range front where the active strike-slip Kalabagh fault zone (KFZ) links it to the K-FTB. Previous studies explained the structural evolution for each of these belts separately, disregarding the structural architecture and compatibility of fold and thrusts on surface extending from one to other. This research focuses on a 3D structural model at the contact of the two thrust belts, evaluating similarities and differences in their structural style. The model is constrained by integrating field, seismic and well data. The northern parts of P-FTB and K-FTB are intensely internally deformed above ramps originating in a brittle basal detachment. The southern P-FTB, in contrast, is less internally deformed above a ductile salt detachment. The K-FTB surface structures evolved above an active roof thrust in Eocene evaporites form a secondary detachment. The Ramps which formed duplexes in the K-FTB extend in the P-FTB as blind thrusts tip lines of fault propagation folds. The basement slope changes from flat ($\beta < 1°$) below the K-FTB and northern P-FTB to north dipping ($\beta > 1°$) below the southern P-FTB and Kalabagh reentrant. The KFZ, linking the K- FTB and P-FTB, is interpreted as a complex dextral strike slip rotational fault block. The Precambrian salt, highly mobile within the KFZ had resulted in normal faulting and formation of lobe structures in the western salt range, reshaping its original geometry. Based on the comparison of our model with analogue ones, we suggest that the structural variation in the K-FTB and P-FTB can be attributed to the change of detachment cohesion, change in basement slope, presence/absence of a secondary detachment and salt mobility (expulsion vs accumulation in different zones).The model shows important structures in the boundry zone which are neglected so far due to structural complexity could be possible hydrocarbon targets if drilled in future.

Fault and fracture analysis and investigation of their mineral infill in the Mesozoic carbonates cropping out along the SW section of Monte Alpi, Basilicata region, Italy

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Keywords: Apulian Platform, fracture stratigraphy, DFN modelling.

The proposed work is aimed at investigating the Mesozoic fractured carbonates pertaining to the inner Apulian Platform, and cropping out in the axial zone of the southern Apennine fold-and-thrust belt, Italy. The proposed study area is Monte Alpi (Basilicata, Italy) that represents an unique of the whole Southern Apennines fold-and-thrust belt because a portion of the Apulian Platform crops out. Specifically, along the south-western sector of Monte Alpi, the Jurassic-Lower Cretaceous limestone rocks pertaining to the inner Apulian Platform are crosscut by numerous high- angle faults, which show multiple stages of activity and a variable persistence and offset. In particular the following work is based on a detailed structural analyses of the Apulian carbonates that will shed light on the fracture stratigraphy of the Jurassic-Lower Cretaceous carbonates and on the inner structure of high-angle faults that crosscut them. Furthermore results of both mineralogical and geochemical analyses will unravel the origin of the mineralizing geofluids, and the temperature of mineral precipitation in veins, fault slickensides, and travertines that crop out along the south-western edge of the Monte Alpi.

Results of the proposed project will be therefore helpful to better define the modalities of circulation of geofluids throughout the fractured limestone rocks, as well as used to compute the migration and storage properties of Apulian carbonates, originally buried several kilometres beneath the allochthon tectonic units of the fold-and-thrust belt, which form structural analogues of the reservoir rocks present in the oil fields of Basilicata. In this regard, the work will integrate the knowledge gained in the recent past on the outer sector of the Apulia Platform exposed in central and southern Italy. Such knowledge was used to assess the close correlation between faults, fractures and the petrophysical properties (porosity and permeability) of platform carbonate rocks.

Furthermore, integration of the existing fault and fracture dataset with those expected after the present research work will be used to decipher the multi-scale 3D geometry of the fault and fracture systems by mean of Discrete Fracture Network modelling. DFN modelling, a common prestige which allow synthetic, unconditionally simulated fractures to be stochastically generated in 3D within geocellular volumes representing the study rock masses, is often use in Petroleum and Engineering Geology. Results of such a work will be helpful not only to decipher the migration and storage properties of the study limestone rocks but also to help the oil industry to identify innovative technological solutions designed to optimize the production of hydrocarbons.

Time-space evolution of the Monte Alpi foreland basin system

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Keywords: Apulian Platform, 3D geological modelling, Late Messinian foredeep basin.

The Monte Alpi is the only portion of the Apulian domain cropping along the axial portion of the southern Apennines ftb and can be considered as a structural analogue of the nearby exploited fields of Basilicata. The massif is made up of Mesozoic carbonates of the Inner Apulian Platform topped by an Early to Late Messinian sedimentary succession. This sequence is characterized by a pronounced, angular unconformity between the Early Messinian carbonates and the Late Messinian terrigenous deposits.

By integrating a variety of methods, this work focuses on the role played by extensional faulting on the nucleation and development of the Messinian foreland basin system of the Monte Alpi area.

Field analysis of the exposed Late Messinian sedimentary succession permits to assess its textural, compositional and thickness variations. Differently, 3D geological modelling (Gocad®) of the Monte Alpi massif and surrounding areas is aimed at deciphering attitude, kinematics and dimensional properties of the high-angle faults. Moreover, 3D geological data are computed to reveal the configuration of the Pre-Messinian fault network as well as the throw profiles analysis for the individual, high-angle Early Messinian and Late Messinian to recent fault zones.

As documented after the field and laboratory analyses, both NW-SE and ENE-WSW trending extensional fault sets were active during nucleation of the Messinian foreland basin system, whereas its development was mainly controlled by activity of the former fault sets. In particular, the progressive, foreland-directed migration of the Southern Apennines orogenic wedge caused the development of the back-bulge basin by mean of extensional faulting of the Apulian carbonates, with formation of scattered depozones bounded by the two aforementioned fault sets. In the proposed conceptual model of the Messinian foreland basin system, the marked angular unconformity between Early and Late Messinian deposits is due to the strain accumulated in the forebulge area, which caused uplift, exhumation and tilting of both Mesozoic and Early Messinian carbonates.

The results of this work are coherent with the structural style documented for the foreland flexuring of the Apenninic Platform during Early Miocene times, and hence show evidences of along-foredeep stretching. Moreover, development of the Messinian foreland basin system was likely controlled by the visco-elastic flexure of the overridden Inner Apulian Platform. The results of this study are therefore consistent with a foreland system affected by a rapid migration of the orogenic wedge during Upper Miocene times.

Such a work highlights the evolution of isolated fault segments during the poly-phase tectonic evolution of the Monte Alpi tectonic unit, and provides new data to constrain the Messinian tectonics. Therefore, the acquisition of this new knowledge will allow to characterize the migration paths of geofluids within the buried carbonate reservoir.

3D sedimentological model of a reservoir analogue: an example applied to continental carbonates (the Lapis Tiburtinus travertines, Tivoli, Central Italy)

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Keywords: Pre-Salt, Lapis Tiburtinus, 3D modelling.

The carbonate rocks of Pre-salt reservoir, discovered in 2006 (Lula field) offshore Brazil and then later in Angola, have shown similarities with the travertine bodies. So, continental carbonates may possess good characteristics as reservoir rocks.

Unfortunately the knowledge on these reservoir in general is limited due their lithofacies complexity.

The Lapis tiburtinus (Tivoli, Central Italy) is one of the most famous continental carbonate system, developed in a small sedimentary basin (30 Km2) almost entirely interested by quarry activity. To reconstructs the constraints of the entire sedimentary basin in term of better understanding of the continental carbonate facies distribution, geometries and architecture, nine quarries were visited, performing linedrawing, detailed stratigraphic logs, petrography, geochemical and petrophysical analysis and as well as some boreholes.

Ten different geobodies bounded by unconformities (covered by immature brown paleosoils, erosive, or associated with reworked deposits) and composed of six main lithofacies testifying for subaqueous, lacustrine and slope environment represent the building blocks of the Lapis tiburtinus travertine system.

Such geobodies were modelled with a 3D cad taking in count facies associations, distributions, geometries, depositional environments and the different unit volumes.

Virtual models can be used to gain a better understanding of geobody architecture, to facilitate correlation and to model outcrops in 3D. Modern 3D software provides fundamental tools that allow geologists to reproduce and characterize field data with a high degree of detail. This is especially true in hydrocarbon production, where, inside a 3D virtual space, it is now possible to process a huge amount of data collected in the field to define and to model the architecture and characteristics of potential reservoir analogues.

The Lapis tiburtinus travertines were developed in a system composed by several subsiding depressions, different in dimensions, interconnected each other by slopes especially developed in the central part of the area toward the southern sectors. The main geobody geometries are lenticular, convex and concave in the northern – central part, while tabular in the southern part.

Thanks to the dimension and for the local facies charateristics/distribution, the Lapis Tiburtinus travertines can be considered as a potential Pre-salt reservoir analogue.

2D & 3D Geological and seismic modelling of a carbonate platform-to-basin transition: a case from the Maiella Mountain (Central Apennines, Italy)

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Keywords: Maiella Mountain, Outcrop analogue, Geological and seismic modelling.

Platform-to-slope-to-basin carbonate systems are recently increasingly recognised to play a fundamental role in the oil and gas exploration. However, carbonate slope systems still remain less understood with respect to the siliciclastic settings being the product of complex interacting processes and therefore more studies are needed for their better understanding. This research integrates several data known from the various studies related to the carbonate platform- to-slope-to-basin transition exposed across the Maiella Mt. (central Italy), with new field observation and 2D-3D geological and seismic modelling. This outcrop represents an excellent analogue for the slope plays located along the transitional zone of the Apulian platform in the central and southern Adriatic offshore (Fig. 1a, 1b).

Modelling results offer a novel and interactive geological view and seismic imaging of this base-of-slope carbonate system with modern techniques (Fig. 1c, 1d, 1e, 1f). The 3D geological model built from outcrop data allows a detailed quantitative characterization of the paleoescarpment and related carbonate megabreccia bodies, in terms of lateral extension, thickness, shape, volumes, width and length, which are elements used for conditioning object-based models typically undertaken with a stratigraphic framework that defines the large-scale architecture of the model. Seismic modelling results of this study provide an improved 2D/3D seismic model for the Maiella carbonate system with respect to the previous 2D model realised during the 90s.

The key objective of this synthetic modelling is to translate the outcrop geometries of the paleoescarpment and related resedimented slope deposits into subsurface reflection images providing a useful output which is directly comparable to real world seismic data helping in understanding what extents subsurface and outcrop are alike and how much information from the outcrop can be used for subsurface reservoir characterization. Computation of seismic modelling through the image ray tracing directly delivers zero-offset time-domain migrated seismic sections, permitting a more straightforward comparison with the real migrated industrial marine seismic data (e.g., Adriatic offshore). The output synthetic seismic data still does, similarly to the real seismic data, not have the resolution for detailed reservoir modelling but since the synthetic model is derived from description of outcrop geometries and facies, the outcrop information can serve as a conceptual guide to construct reservoir models starting from core and log data.

The seismic model is a valuable addition to outcrop-based 3D geological models for developing and assessing reservoirs from seismic data. Moreover, this study also shows for the first time a comparison between PSDM synthetic seismic sections derived from individual 2D seismic modelling with those extracted from the 3D synthetic seismic volume. The 3D synthetic seismic modelling, further allows investigating the geometries and the lateral variations of the carbonate system, such as truncation, onlap terminations, pinch out, etc in 3D space, helping in better visualising them in areas with poor or no exposures. In addition, it also potentially represents a synthetic analogue for deriving and quantifying volumes of the geological bodies, hence helping in proposing simple volume-correction rules for hydrocarbon reservoirs directly from the seismic data.

Crustal deformation and active tectonics in the NW Sicily Channel through multi-scale analysis of seismic reflection profiles, well-log and on-land data

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Keywords: compression; active tectonics; Sicily Channel.

The NW Sicily Channel represents the offshore prolongation of the Sicilian fold and thrust belt which formed during Africa-Europe convergence, whose front migrated from NW towards the SE (Roure et al., 2012).

The proposed deformational history of the Channel is based on a multi-scale analysis of seismic reflection profiles from the VIDEPI database, industry and newly acquired high-resolution single-channel sparker (SCS) profiles.

By refining previous view, a thick-skinned deformation style is proposed and an accurate location the actual front of the chain is performed.

Starting from Miocene, contractional deformation affected the Egadi area with deep-seated thrust-ramps (ETF, Egadi Thrust Front). This activity ended ~8 My ago, as evidenced by the high-amplitude reflector associated to the sandy member of Terravecchia formation that apparently seal the deformation. During the Late Miocene, a new thrust front acted along the eastern side of the Adventure Bank also reactivating an inherited Mesozoic crustal boundary which separated the proximal shelf facies (Trapanese domain) from the distal ramp facies (Saccense domain) in the Terravecchia foredeep. During the Plio-Pleistocene, the offshore area between Capo Granitola and Sciacca experienced a transcurrent deformation with either normal or reverse component of motion. Contemporarily, in the Egadi area we assist to a transtensional re-activation of normal faults related to the Early Pliocene rift system and a new generation of distributed back-thrust reverse faults which are traced up to the sea-floor.

The analysis of SCS profiles calibrated with well-log data and outcrop on the coastal belt of the offshore study area was aimed to reconstruct the structural framework of the Pleistocene-Holocene sedimentary cover. The study area was divided in two zones based on different tectonic framework. The offshore area to the west, between Capo Granitola and Capo San Marco is chacterized by deformation expressed by folds of relatively lower amplitude and wavelength and low-medium aspect ratio, associated to slumping and fluid seepages and responsible of Pliocene sediments uplift in the north-western part, which extend for about 9 km from the coast. The folds are responsible of dip changes of Middle- Late Pleistocene strata. Whereas, the area between Capo San Marco and Eraclea Minoa to the east is controlled by high amplitude and high wavelength folds with high aspect ratio extending for about 20 km and producing major deformation of Middle- Late Pleistocene units. They are associated to fluid infiltration along high angle faults that diverge of some degree to the north from the structures of the western area.

The space-temporal distribution of seismic units highlights a major tectonic control on the thickness distribution of the Late Pleistocene-Holocene unit, compared to that of the Middle- Late Pleistocene unit, as it better follows the structure trends. So, it can be inferred that tectonic activity pulsed in the Late Pleistocene-Holocene.

Finally, this analysis confirms and extends in the offshore the deformation belt expressed by gentle folds, which affect Quaternary deposits in the area of Campobello di Mazara and Punta Granitola (Barreca et al., 2014). The transition from the on-land to the offshore domain is marked by an en echelon arrangement.

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Flow behaviour in siliciclastic sedimentary successions of fluvial and aeolian origin

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Keywords: Fluvio-aeolian deposits, Permeability, Heterogeneities.

Fluvial and aeolian sedimentary successions represent porous media that host hydrocarbon resources. Study of their heterogeneities in aquifers provide a better understanding of techniques for enhancing recovery in oil reservoirs. This research investigates the hydraulic properties of a fluvial succession deposited in a continental rift setting: the Triassic St Bees Sandstone Formation, which represents the basal part of the UK Sherwood Sandstone Group in the eastern Irish Sea Basin.

The succession was investigated from plug to field scale by combining a range of sedimentological, structural, petrophyisical and hydro-geophysical techniques. The aim of this research is to characterize the impact of sedimentary and tectonic heterogeneities on flow in the continental deposits of the Sherwood Sandstone aquifer, and to assess the validity of the findings up to reservoir depths.

In the relatively shallow (< ~100-200 m BGL) saturated zone of the St Bees Sandstone aquifer, acidic meteoric waters have enlarged fractures to create karst-like features resulting in very high field-scale hydraulic conductivity ($K \sim 10^{-1}$-10^{0} m/day). A deeper investigation (> 150m depth) demonstrates that the aquifer has not been subjected to rapid groundwater circulation at these depths; hydraulic conductivity is substantially lower, decreasing from $K \sim 10^{-3}$ m/day at 150-400 m BGL, to 10^{-4} m/day down-dip at ~1 km BGL. Pore-scale permeability becomes progressively more dominant with increasing depth. Thus, this sandstone aquifer at ~ 1 km depth approximates the hydraulic properties of analogous hydrocarbon reservoirs which are dominated by intergranular flow. The succession contains a variety of fine- grained and relatively low-permeability units including laterally extensive mudstone layers that occur interbedded with highly permeable sandstone channel deposits. Where present, a higher frequency of occurrence and greater lateral extent of mudstone units impede flow, reducing the field-scale permeability. Zones characterized by higher preservation of mudstone layers also show higher field-scale permeability anisotropy (Kh/Kv) due to a significant reduction of flow perpendicular to these fine-grained heterogeneities. In contrast, normal faults represent preferential flow pathways up to ~1 km depth, due to the presence of highly connective open fractures.

The hydraulic properties of the St Bees Sandstone Formation are compared with those of other formations of both aeolian and fluvial origin within the Sherwood Sandstone Group, and similar siliclastic formations worldwide to achieve a more general understanding of flow behaviour in siliciclastic sedimentary successions of continental origin.

Continental successions in rift settings are also characterized by aeolian deposits in the NW Europe Triassic realm. Aeolian deposits typically possess higher matrix permeability due to a relatively paucity of intergranular clay with respect to fluvial deposits. Thus, reservoir quality rises with increasing content of preserved aeolian sediments due to the dominance of intergranular flow in silicilastic successions buried at depths > ~1 km. Deposits of aeolian-dunes also exhibit contrasting hydraulic behaviour with those of fluvial origin where intersected by fault zones: where normal faults deform aeolian deposits, deformation bands partially impede flow to production wells in analogous hydrocarbon reservoirs.

Sedimentary facies, heterogeneity development and provenance of the sand-rich pre- collisional Bordighera turbidite system

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Keywords: Low-efficiency turbidite system, bed-scale heterogeneity, provenance.

The Upper Cretaceous San Remo Unit of the Western Ligurian subduction flysch complex represents a trench fill that comprises a basal complex (San Bartolomeo Fm.) and two thick turbiditic sequences: A low-efficiency siliciclastic turbidite system (Bordighera Sandstones) which interfingers with a calcareous turbiditic sequence (San Remo Helminthoid Flysch) that becomes increasingly abundant toward the lateral and distal domains. In order to test the outcrop analog potential of the coarse-grained, sand-rich axial fan, the Bordighera Sandstones have been investigated by detailed facies analysis. Main emphasis is being placed on the quantification of inter-sandbody heterogeneity due to hybrid event bed (HEB) development. In the context of complex tectonic deformation and partly limited lateral outcrop exposure, the utilization of sedimentological metrics (e.g. amalgamation ratios, sandstone-mudstone-ratios, grain size distribution trends, facies proportions) provides an effective tool for the determination of depositional environments and subsequent spatial allocation of facies heterogeneity distribution along the sand fairway. Three main depositional domains - marked by strikingly contrasting dominant lithofacies proportions along a downstream transect - can be recognized: (1) Proximal channel-fill successions, (2) a spatially limited transitional zone of ca. 5 km basin-ward expansion defining an abrupt transition to (3) extensive lobate sand sheets. Whereas the channelized proximal domain represents an array of comparably homogeneous sandbodies defined by the presence of mud-poor sand bed types which are distributed in thick, highly amalgamated intervals, the transitional zone records a modest increase of bed types proportions accountable for heterogeneity. By contrast, the more distal sheet-like succession is dominated by mudclast- rich sandstones and HEBs typically intrinsic to amalgamated packages. Remarkably, the widespread occurrence of such bed types within axial zones of the preserved elongated sand fairway contrasts models that predict HEB distribution to be characteristic of outer fan environments. The atypical nature of a low-efficiency (i.e. initially mud-poor) turbidite system being highly prone to HEB-related heterogeneity is interpreted as the result of enhanced availability of cohesive mud due to intercalations of the calcareous Helminthoid Flysch. Sediment provenance analysis of the Bordighera Sandstones provides new insights for understanding the complex pre-collisional paleogeological evolution of the Western Tethys. Modal framework grain analysis characterizes the sandstones as arkosic arenites (average modal composition: Q50F48L2; mean K/P-ratio: 0.68), suggesting that elevated bedrock (granitoid plutons and low-grade metamorphic geobodies) provided the provenance for the sand-rich turbidites. New geochronological data (U-Pb detrital zircon ages) reveal the strong affinity of the clastic detritus to the Paleo-European margin. Ongoing research comprises the integration of geochronological data of the underlying basal complex and the detailed confrontation of detrital age clusters against published datasets of peak magmatism age populations of candidate source areas (i.e., Calabria, Sardinia, Corsica, Dora-Maira Massif), with the aim of clarifying the geodynamic evolution of continental microterranes that constituted the reactivated hyperextended European continental margin.

The ups and downs of modelling extended continental margin evolution

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Keywords: Passive margins, basin analysis, geodynamic modelling.

Continental rifts and extended passive-margin type settings account for a large percentage of the world's largest oil fields. A good understanding, not only of the present-day geometry of sedimentary basins within these settings but also of their deformational history is crucial in the reduction of exploration risks and assessment of play potential. Doing this is only possible if the feedbacks between margin processes occurring across a wide range of temporal and spatial scales are understood in detail.

Plate tectonic models (as well as products derived from them such as seafloor age maps and paleobahymetric/paleogeographic reconstructions) are routinely used by the petroleum industry to provide context to individual basin-scale studies. Geodynamic models can indeed shed light on basin geometries, strain distribution and depositional environments during basin evolution (amongst others). However, their limitations must be recognized and quantified in order to avoid drawing flawed conclusions from tectonic model predictions. These limitations are well illustrated by the fact that, despite the improvement in acquisition techniques, data quality and availability in recent years, different geodynamic models for any particular area of the world fail to converge into a single solution that describes its tectonic history. For example, almost 60 years after the first computer-assisted model describing the opening of the South Atlantic was published, there still is no agreement on the detailed history of the ocean and its margins since South America and Africa started separating sometime in the early Cretaceous.

One of the features frequently identified by petroleum geologists in seismic and potential field data are Continent- Ocean Boundaries (COBs). Although the idea of a simple linear boundary between continental and oceanic crust at extended continental margins is widely recognized as an oversimplification, COBs are often used as markers from which to make heat flow assumptions, maturity predictions and even build paleobathymetric and palinspastic reconstructions. In the South Atlantic, the mean width of an ensemble of 25 published COB interpretations is 207 km. In places, such as the Santos basin, COB interpretations differ by up to 800 km. This in turn means that, whilst a carefully-chosen plate kinematic model may provide a useful context in which to conduct basin-scale studies, assumptions about basin evolution cannot be made on the basis of a plate kinematic model built using COB locations as geographic markers. Even more crucially, the depths portrayed by paleobathymetric reconstructions built from COB- based plate tectonic models may be erroneous by up to several km.

Using the South Atlantic as a case study, I will discuss (1) why are there such a broad variety of published interpretations of the evolution of the ocean and its margins, (2) what factors introduce uncertainty in models and in which way, (3) how these uncertainties can lead to large innacuracies and errors when using poorly-constrained geodynamic models and (4) how can petroleum geologists use tectonic and geodynamic models to their advantage, minimizing errors and misinterpretations.

Reappraising the Numidian system (Miocene, southern Italy): deep-marine sandstone fairways confined by tectonised substrate

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Keywords: Numidian turbidites, basin evolution, syn-orogenic sedimentation.

Many deep-marine sedimentary systems accumulate at active plate boundaries so their ancient record have been tectonically deformed. Understanding the evolution of these systems not only requires the appropriate adoption of structural methods, but also confronting the stratigraphic record of deformed sedimentary successions. Here we accept the challenge of developing better understanding of these deep-marine systems, focusing on an example from the active orogenic system of the Central Mediterranean. Numerous turbidite systems in the region (e.g. Cilento, Gorgoglione, Annot) have yielded important studies of turbidites that are widely used as outcrop analogues for subsurface in modern deep-water settings. Much of this research has targeted little-deformed sections sampling discrete parts of the original turbidite pathways, yet the bulk of these systems are represented by deformed successions which have attracted less modern sedimentological and stratigraphic investigation. One such is the Numidian (Miocene) of Sicily and the southern Apennines. Its turbidites include thick, ultra-mature quartz sandstones sourced from North Africa and deposited in now- deformed and dismembered basins caught up in the Apennine-Maghrebian orogen of the Central Mediterranean. This work present new data based on field mapping, sedimentological/structural fieldwork, and biostratigraphy (foraminifera, nannofossils) that focus on north, central and eastern Sicily. These include the greatest extent of Numidian strata in the Mediterranean. Sandstones form aggradational bed-sets that accumulated in elongate lobes along with local gravels. In general the sandstones show parallel lamination (difficult to identify in clean and well-sorted sand), locally disrupted by post-deposition dewatering. The structureless nature of the Numidian sandstones, generally interpreted as result of rapid sand deposition, has been greatly over-reported. The sedimentology is consistent with large-scale sediment bypass. There is no architectural evidence for major incisional channel systems in the outcrops but common erosional products derived from local substrate incorporation of pre-Numidian strata. Muddy basin-floor substrate can be locally incorporated by erosion from fold crests and rock-falls from the limbs of growing folds characterize mass wasting products from carbonate substrates. While there may have been significant bulk creep of substrate operating in tandem with thrust tectonics, there is only minor evidence for large-scale slumping or debris flows within the Numidian system, which presumably implies rapid deposition compared with tectonic tilt-rates. Fairway margins with 200-300 m thick amalgamated sandstones passing over 1-2 km laterally into fine-grained slope deposits are abrupt, controlled by active thrusts and inherited structures. Although parts of the system become occluded (e.g. by the influx of orogen-sourced immature turbidites such as Reitano), active structures largely serve to separate the distinct fairways. These provide key markers in the restoration of the subsequent tectonics thus yielding better palaeogeographic models. Although classically interpreted as being unconfined, our work demonstrates the system accumulated across active contractional (and inherited largely extensional) structures. These provided tortuous, evolving corridors through which turbidity currents were routed, transporting coarse sand for hundreds of km.

The effect of tides on morphology, stratigraphic architecture and sediment bypass in river-dominated deltas

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Keywords: Tide-influenced deltas, compound clinoforms, Delft3D.

Deltas are dynamic and sensitive systems that undergo changes of morphology, channel network, and stratigraphic architecture in response to variations in coastal processes, e.g., waves and tides. These changes need to be properly understood in order to make reliable subsurface predictions.

Single coastal process dominance has been studied extensively using numerical modeling methods, but the sensitivity of deltas to mixed-process environments has rarely been examined. Therefore reservoir predictions based on such models could be highly misleading when used in mixed-process delta systems, where laterally varying waves and/or tidal processes can rework the deposits of fluvial floods. In this study we investigate the influence of tidal currents on river-dominated deltas in terms of deltaic stratigraphic architecture and sediment partitioning using Delft3D. We conducted 24 modeling runs with different ranges of tidal amplitude and initial sediment composition of the substrate.

The modeling results show that deltas formed under pure river-dominated conditions have a concave delta-front profile while with increasing tidal amplitude the delta front becomes convex and develops a compound clinoform geometry. With no tidal currents, distributary channels avulse and bifurcate frequently, resulting in the complete reworking of deltaic lobes. As a result, coarse sediment is stored in the proximal delta plain. In contrast, the presence of strong tidal currents creates deeper and stable distributary channels. These channels do not rework previously deposited deltaic lobes, but act as an efficient conduit for sediment to bypass across the delta during ebb currents. Furthermore, the analysis of sediment fluxes across the delta shows that ebb tidal currents increase suspended and bedload sediment fluxes by at least 3 times compared to cases without tidal currents. The enhanced sediment flux leads to deposits with net-to-gross ratios higher in tidally-influenced cases than in their river-dominated counterparts.

This study shows how tidal currents, even under river-dominated conditions, have strong effects on delta surface morphology, stratigraphic architecture, and sediment partitioning. In particular, channel overdeepening and compound clinoform geometries are possible important tidal signatures that should be considered when interpreting ancient systems, and sand may be bypassed much farther basinward in tide-influenced than in purely river-dominated deltas. Therefore it is critical when trying to model paralic reservoirs to consider the changes that varying tidal influence may have in reservoir geometry, net-to-gross distribution, and flow path barriers.

Analysis of the Miocene sedimentary sequences of the Sardinian Graben System as possible analogue for the Upper Jurassic Rogn Formation reservoirs of the Norwegian mid-Continental Shelf

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Keywords: Sardinian Graben System, Outcrop analogue, Rogn sandstone.

The Rogn Fm is an Oxfordian to Volgian sand-rich interval represented the main reservoir of some exploratory success in the offshore of the Norwegian mid-Continental Shelf. In its type well the formation is up to 50 m thick and exhibits a coarsening-upward trend. The Rogn sandstone is well-sorted, coarse-grained, made up of sub-angular clasts and shows a diffusely cross lamination. The more accepted interpretation on the genesis of the Rogn Fm is the derivation from the erosion of the uplifted Frøya High, and the subsequent accumulation in sheltered coastal zones and/or in more distal 'shelf' environments, tectonically shaped into narrow-elongate depocenters. The recurrent motif of cross-bedding suggests a greneral control exerted by tractional flows. However, a number of uncertainties related to the sub-seismic depositional architectures or lateral facies changes of the Rogn Fm call for evaluable outcrop-analogue studies.

For this reason, a facies-based study was promoted on two outcrop areas belonging to the Sardinian Graben System (SGS), in the western Mediterranean, aiming to (i) characterise physical attributes of deposits similar to the Rogn sandstone; (ii) interpret depositional processes in sedimentary environments comparable to those inferred for the Rogn Fm; (iii) reconstruct depositional scenarios constraining eventual reservoir modelling.

The SGS was an N-S-striking elongate basin, developed during an extensional phase in a back-arc setting from the Late Oligocene onwards and filled by continental and marine extra-basinal clastics and intra-basinal carbonates during a major marine transgression. The sedimentation and the tectonic evolution of the SGS during the Miocene well matches the geological history of the Norwegian Continental Shelf during the Late Jurassic.

The first study area is ca. 10 km wide and represents the analogue for the first setting (i.e., sheltered coastal zone). The sedimentary succession lapping against the flank of a Palaeozoic basement block. Continental-to-transitional tide- influenced deposits are transgressively overlain by tidal flat heterolithics and, in turn, by beach-barrier sands. The area was interpreted as a coastal embayment where tidal currents were generated because of the peripheral position respect to a larger seaway (i.e., the Sardinian Seaway).

The second study area is a 10-km-wide and 20-km-long half-graben (i.e., the Logudoro Basin) and reveals analogies with the second setting (i.e., laterally confined 'shelf' setting). In this area, the Florinas Sandstone (FS) has been investigated since it exhibits textural features comparable to those observed in the Rogn sandstone. The FS has been interpreted as deposited in a shallow-marine setting, due to the delta-fed sand discharge, associated with minor recycling of older substrate units. The Logudoro Basin is thought to be part of the larger Sardinian Seaway, crossed by alongshore (tidal) currents, capable to rework the delta-fronts of marginal river deltas and forming extensive bedform fields in axial sectors.

The documented outcrop analogues help in constrain depositional settings and major processes of the Rogn Fm, assuming the existenxe of a series of marine seaways across the Norwegian mid-shelf during the Late Jurassic. Besides, the present work supports the existence of the Sardinian Seaway, an N-S-elongated tide-influenced marine passageway, representing an exceptional comparative example for the Upper Jurassic Norwegian mid-shelf.

The role of submarine landslides in deep-water turbidite systems: a subsurface and outcrop investigation of reservoir facies architecture influenced by mass-transport deposits.

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Keywords: Deep-water, MTDs, Turbidites.

Submarine landslides have been documented in many deep-water systems, thanks to advance in seismic resolution. These events have been subject of intense study by the hydrocarbon exploration because of their commonly erosive character, which may result in deep and widely occuring truncation and removal of underlying primary reservoir targets, or in seal breach, with consequent vertical migration of hydrocarbons. Furthermore, mass-wasting processes and the related emplacement of mass-transport deposits (MTDs) may reset the bathymetry of the sea floor through creation of both erosional and depositional relief. The modified seascapes can then influence the dispersal patterns of subsequent sediment gravity flows, deflecting, ponding or changing the flow behaviour over a relatively small length scales (<1 km), inducing heterogeneity in associated deep-water deposits at scales that extend below that of seismic resolution. Because both the geometry and connectivity of producing sandstones may be affected, the characterisation, quantification, or prediction of such heterogeneities is important for the optimisation of oil and gas production. Thus, the principal aim of this work is to better constrain the links between MTD-related seafloor bathymetry and facies variability in subsequent deposits.

Two case studies of MTD-influenced deep-water systems are presented: the subsurface (core-based) Britannia Sandstone Fm (Lower Cretaceous, UK North Sea) and the outcropping Marnoso-arenacea Fm (Miocene, Central Italy). These studies document i) the different scales of seafloor rugosity created by the emplacement of MTDs and ii) the effects of such bathymetry upon sandstone facies distribution and termination geometries. A structural restoration exercise in the Britannia Sandstone formation enabled construction of maps of the palaeobathymetry developed after each of four major mass transport events. Morphological features such as deep troughs (~ 5 km long and < 60 m deep) provide pathways for the emplacement of relatively sandy, high net-to-gross deposits, whereas subtle rugosity (5-10 m relief) produced hybrid event bed-prone deposits with marginal, clay-rich banded facies adjacent to confining slopes. Field data from the Casaglia MTD enable the recognition of three different scales of rugosity on the upper MTD surface (based on vertical and horizontal dimensions, respectively): subtle (1-5 m, 10-25 m), intermediate (5-30 m, 50-100 m) and large-scale (15-30 m, 500-1000 m). The two smallest scales of rugosity effectively represent the inter-well scale in the subsurface. Overlying sandstone deposits show evidence of flow deflection, confinement and ponding, with the latter resulting in the development of thick mud caps and a reduced net-to-gross.

The co-occurrence of MTD and turbiditic deposits in deep-water settings is widely recognised, however, the increase of uncertainty and exploration risk linked to their interplay remain generally understudied. This work emphasises that reservoir heterogeneity in sandstone deposits overlying MTDs is mainly controlled by the shape, depth and size of the morphological features associated with the MTD, together with their elevation above the seafloor bathymetry in relationship to the thickness and direction of the depositing flows. The insights thus gained aid linkage of seismic scale reservoir architecture to reservoir facies distribution, and are likely applicable in other deep-water MTD-influenced settings.

2nd SESSION – MSc Student Abstracts

Finite strain analysis of the Simano Lower Pennine nappes (Central Alps, Switzerland).

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Keywords: Simano unit, finite strain, augengneiss.

In the Central Alps some large nappes Simano show ambiguous relationships. They show a constant regional metamorphism and deformation features but no significant strain gradient nor any evident localization of deformation have been observed between this unit. I want investigate the strain pattern in order to elucidate whether ductile strain shows a relationship to nappe contacts and to shed light on the nature of the sub-horizontal foliation typical of these gneiss nappes of the Central Alps.

To quantify finite strain, I will use the Rf /∏ and Fry techniques (Ramsay 1967; Fry,1979; Ramsay & Huber 1983) on feldspar grains from augengneiss along vertical profiles of the Simano units. The finite strain estimates and 3D strain geometry will be used to calculate the finite-strain ellipsoid, the degree of non-coaxiality and the volume strain. These data will allow to derive the significance of the strain geometries and how they are related to the flat- lying foliation characteristic of the studied nappes as well as if any specific strain localization (mylonites or ultramylonites) occur at the nappe boundaries. We expect to obtain a careful strain characterization of the studied units and thus infer if the deformation was (or was not) more distributed that commonly considered assuming the allochthonous behavior of the Simano nappe during the building of the Alpine orogen.

The objectives of the proposed project need to perform an intense field-work to collect the strain measurements from the augengneiss of the Simano unit. The measurements will be performed along the well exposed gneissic section of several minor rivers flowing in the lateral deep valleys of the Ticino River (Osogna sheet, Swiss National Map n. 1293) in the Swiss Alps. I will analyse feldspar grains from augengneiss along vertical profiles within both units, through two-dimensional strain measurements, which will be made on xy, xz and yz sections (x > y > z, finite-strain axes) to estimate the 3D strain geometry. Feldspars of the augengneiss will be measured both on the field (through basic hand-made measurements of cm-sized grains) and by computerized grain size analysis (using the open source Image SXM software Microsoft Excel and EllipsFitt software) performed on photograms of field outcrops and petrographic thin sections. The results will be than integrated with the geological structure derived from the recent field mapping of the Osogna sheet carried out in the frame of the Swiss Geological Survey (SWISS TOPO). The interpretation and discussion of the data in the frame of the regional geology, will result into a scientific paper describing the deformation evolution of the studied nappes.

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Structural architecture and permeability characterization of an outcropping fault zone: 3-D geological model VS petrophysical laboratory analysis

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Keywords: 3D geological model, petrophysical laboratory analysis, fault permeability.

The purpose of this thesis was to study in detail the structural architecture and the properties of the Candigliano fault zone (Piobbico PU, Italy), and to calculate its permeability by using the classical statistical algorithms of Fault Seal Analysis (FSA) calibrated for siliciclastic sequences, adapted and applied for a single fault (F1) in carbonate and marl rocks succession, such as Marne a Fucoidi.

The presence of subsurface faults can be an important factor in order to delimitate the size of structural traps and compartmentalizing reservoirs; for this reason, oil companies need to be aware of the presence of subsurface faults that may act as a seal or a barrier. Although juxtaposition against tight lithologies (such as shales) will result in the greatest seal effect, the mechanisms by which these processes actually occur and how they create fault seals in three dimensions is not yet fully understood.

This thesis aims at reproducing a 3D geological model of an outcropping fault zone, which can also be used to understand the behavior of buried structures. The goals of this thesis are to estimate the fault permeability prediction, capillary pressure and possible hydrocarbon column height sustainable of the well exposed fault at present day conditions, using empirical approaches (Sperrevik et al. 2002 , Bretan et al. 2003) based on the petrophysical characteristics of the fault zone. Besides, during my post-graduate Research Internship at the University of Leeds, I decided to perform a detailed analysis concerning this research and I had the opportunity to carry out a petrophysical laboratory analysis of the Candigliano core samples. The purpose was to compare the results of fault permeability prediction resulting from the 3D geological model of the thesis, with those of petrophysical laboratory analyses.

Ourcrops are located in the NE limb of Monte Montiego, along the left and right bank of the Candigliano river in Marne a Fucoidi succession (Aptian-Albian), composed of cyclic alternation of shales, marls and marly limestones with intercalation of black shale layers.

In order to build a 3D geological model and to carry out a complete analysis of the seal capability, four main software are used in this thesis: 123DCatch to create a Digital Elevation Model (DEM) of the outcropping area, Move to build the 3D real model, Petrel to perform the 3D synthetic model and to apply the FSA algorithms, and Traptester to evaluate the fault seal potential from a Vshale curve.

The permeability prediction of F1 is based on the modification of the Sperrevik et al. (2002) equation calibrated for clastic rocks. No software tools are at present available to carry out a fault seal analysis in carbonate successions, for this reason, this topic is of great interest for research centers and oil companies which have highlighted some limitations that have to be overcome.

Field work's analysis shows that when F1 was active, it was a good pathway for fluids, whereas, in quiet periods, it is subjected to cementation due to the presence of abundant calcite veins.

In this thesis, we assumed that FSA algorithms and the empirical approaches could be used in carbonate fault rocks in order to see how the results of fault permeability prediction resulting from a 3D geological model differ from those of a laboratory analysis.

The Shale Gouge Ratio (SGR) median values estimated in Petrel, are between 0.35 – 0.4 (totally sealing). SGR values became progressively more homogeneous in an increasing throw. The maximum hydrocarbon column height sustainable at present-day configuration by F1 is 200 m for light oil and 100 m for gas. The median value of the fault permeability prediction calculated in Petrel, is between 10^{-7} - 10^{-8} [mD] (very low permeability). The permeability estimated with this empirical approach is due only to the SGR of our fault (ranges between 0.35 - 0.4) related to the clay content and pore throat size.

Pores system and carbonate deposition and diagenesis: micro- and nanopores of microbialites-dominated dolomitized carbonate platforms (Upper Triassic - Southern Italy)

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Keywords: Microbialite, Dolomite, Nanopores.

Through mercury porosimetry and electron microscopy have been investigated sedimentary facies dominated by microbialites, of two dolomitized upper Triassic carbonate platforms (named Upper and Lower Units), cropping out in southern Italy. Despite their variability, and because the prevalence of microbialites in inner platform-margin settings and homogeneous diagenetic processes, all facies show micro- to nano-pores systems composed of intra- and inter- crystal pore types. Porosity and permeability are generally very low (<3 % and <1 mD in average respectively) and, as the median of pores diameter is <1 μm and the median of the nanopores volume is >60 %, the porosity derived from nanopores is significant in all facies, and particularly in the shallow-water environments. A positive correlation between nanopores volume and porosity is present in the whole Upper Unit and in the shallow-water facies of the Lower Unit. Moreover, different sub-environments of the platforms show separated amount of nanopores and porosity; on the contrary, permeability does not seem to be influenced by the nanopores distribution. Regardless a wide spectrum of fabric and morphologies, microbialitic facies of both units show a confined range of porosity (average: 1,0 % standard deviation: 0,6) and permeability (average: 0,4 % standard deviation: 0,2), most probably because composed of syn- sedimentary microbial dolomite, which presents a high resistance to compaction during the burial history. Finally, despite the complete dolomitization, porosity and permeability ratio varies in function of the main depositional environments, and less of the precursor sedimentary facies, suggesting a control of the final pore-size distribution mainly linked with the presence/absence of the microbial primary dolomitic facies instead of the native fabrics of the other sedimentary facies.

Fracture analysis and DFN modelling of carbonate rocks of Monte Alpi, Basilicata (Italy).

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Keywords: Apulian carbonates, Fractured carbonates, Discrete Fracture Network modelling.

The Monte Alpi is located in the inner portion of the Southern Apennines fold-and-thrust belt; there, Apulian carbonates elsewhere buried beneath the Appennines chain crop out.

The Monte Alpi is a key area to decipher the structural setting of the Southern Apennines fold-and-thrust belt, in particular it is a key area to define the geometry and distribution of the fracture network dissecting the Mesozoic carbonates pertaining to the inner Apulian Platform. The goal of this study is to decipher the dimensional properties of both background and fault-related fracture network by means both qualitative and quantitative structural analyses.

Therefore, the present work is the result of an integrated field and laboratory analysis of the fracture network present within the Mesozoic limestones. First, a qualitative fracture analysis was carried in Lower Cretaceous limestones to decipher the modalities of deformation and the role played by individual fracture sets during ongoing deformation. Then, a quantitative fracture analysis was performed in the Lower Cretaceous limestones cropping out at Monte Alpi to compute the multiscale dimensional parameters of both background, diffuse fracture sets as well as of the fault-related fracture sets. In the field, the fracture network is investigated by means of scanline methodology to document the orientation, intensity, height distribution, mechanical aperture and roughness of individual fractures exposed along outcrops.

The fracture distribution displayed in the field within the Lower Cretaceous limestones suggests a marked stratigraphic and lithologic control on the development of joints, sheared joints and incipient faults within the rock multilayer and form a well-connected network.

Finally, Discrete Fracture Network (DFN) models of representative geocellular volumes are built to compute both fracture porosity and correspondent permeability.

The result of such work can help us to better understand the storage and migration properties within the Lower Cretaceous fractured carbonates, not only at the scale of the single beds but also at the large scale.

Geochemical analysis of oils from Barbados and basin modeling of Paleozoic units in the southern Llanos basin, Colombia

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Keywords: Geochemestry, Basin Modelling.

This study evaluates two areas using different approaches that help improve knowledge regarding their hydrocarbon potential: 1. A frontier region lying between the junction of the Barbados accretionary prism and the Tobago basin; 2. A mature basin such as the southern Llanos basin in Colombia.

Oil production from The Woodbourne field and the presence of migrated petroleum in outcropping rocks onshore Barbados prove the existence of a working petroleum system. Barbados petroleum is suggested to have been generated by facies similar to the Upper Cretaceous carbonate rich La Luna Formation onshore South America, but it has so far not been proved. This study presents organic geochemical observations to investigate heterogeneities in petroleum composition, thermal maturity, and biodegradation, and to investigate the filling history of the Woodbourne field. The results were also compared with published data for other northern South American and Caribbean oils/source rocks.

The geochemical data suggest that the petroleum present in Barbados can be divided into two groups. The petroleum in both groups was derived from Cretaceous shaly source rocks deposited in marine environments. Group A petroleum was expelled at low maturity levels ~0.75%Ro. By contrast, petroleum in group B was expelled at higher maturity levels ~0.90%Ro. These observations indicate the existence of two separate kitchens sourcing the Barbados petroleum.

Organic geochemical data also suggest that reservoirs at the Woodbourne field have received two pulses of oil. The first oil pulse represents a filling event believed to have charged the reservoirs after the Mid-Miocene uplift of the Barbados ridge. The second more recent pulse consists of very light hydrocarbons. Both oils seem to be compositionally similar and to have the same maturity level.

Geochemical comparison of the Barbados sample set with Upper Cretaceous oils/source rocks from northern South America and Caribbean region indicates that Barbados petroleum was not derived from carbonate facies typical of La Luna Formation or its equivalents in eastern Venezuela.

On the other hand, exploration trends in the Llanos basin have focused exclusively on the Cretaceous-Cenozoic plays, and no hydrocarbons sourced by Paleozoic rocks have yet been discovered. Forward 2D basin modeling was performed along a profile to evaluate timing of hydrocarbon generation and expulsion, and hydrocarbon phase from a potential Lower Ordovician source rock. The 2D model of the subsurface was constrained using a published interpretation of an E-W regional 2D seismic line and data from three exploration wells. Modeling results show that by Late Ordovician-Early Silurian a first major phase of transformation (~60%) occurred in the deepest places of the basin. Later, Permian uplift and denudation most probably destroyed any hydrocarbon accumulation existing in the western and central parts of the basin. A second phase of generation begins in the Miocene and continues up to present day within the easternmost extension of the basin. This potential petroleum system has not undergone the degree of uplift, erosion, and destruction of reservoirs in the eastern part of the basin, making preservation of any petroleum accumulation more feasible. Thus, potential for finding an alternative source of hydrocarbons in a mature basin exists in the eastern depocenters, where newly generated hydrocarbons could coexist with older petroleum preserved from the first generation phase.

Hydrogen content in nominally anhydrous minerals from Finero peridotite (Italy)

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Keywords: nominally anhydrous minerals, hydrogen, lithospheric mantle.

Hydrogen is present as a trace element in nominally anhydrous minerals (NAMs) composing the Earth's mantle. Several hydrous point defects are thought to have important consequences on fundamental physical properties such as rheology, seismic attenuation or electrical conductivity. Hydrogen in NAMs generally occurs as hydroxyl groups (OH) associated to vacancies. Although there is a vast literature on hydrogen distribution in NAMs from relatively dry mantle xenoliths there is a remarkable lack of data on NAMs in water-rich environments which makes challenging to address the effect of hydrous melt or aqueous fluids on the water partitioning in NAMs. The present work is aimed to investigate and quantify the water in olivine and pyroxenes from an unique locality where upper mantle peridotites are strongly metasomatised by hydrous melts (Finero Complex, Southern Alps, Italy). This mafic complex might represents a useful, but yet unexplored, key location to investigate the partitioning of hydrogen in NAMs and to link them to a multistage metasomatic event characterized by the enrichment in volatiles, LREE and in radiogenic Sr, Pb but with low HFSE concentrations. Water content in NAMs has been determined by means of infra-red spectroscopy (FTIR), which is the most sensitive technique for measuring trace OH contents in NAMs that provides information on the speciation and orientation of the OH group in the structure. These analyses were made on ten double polished thin sections and on crystals separated covering most representative lithologies and deformation textures from the Finero peridotite (i.e. coarse grained lherzholite, harburgite, dunite and clinopyroxenite veins). The approach of Kovacs et al. (2008) using unpolarized IR light was followed to constrain water contents and compared with measurements using polarized light on randomly oriented grains. Preliminary results show water contents in olivine around 2 ppm wt. (Bell et al. 2003, calibration) with minor variations depending on the lithology and texture. Water contents in orthopyroxene and clinopyroxene are also comparatively low (respectively around 42 and 137 ppm wt.). These values are surprisingly low considering the water-rich nature of the multistage metasomatising event that resulted in the extensive crystallization of amphibole and phologopite (up to 30 % vol.). Interestingly the low water content in olivine is correlated with very low Ti contents (between 5-10 ppm) measured by laser ablation mass spectroscopy (LA-ICP-MS) on the same samples. This might suggest that Ti partitioning in the melt or in the hydrous phases is controlling the storage capacity in olivine (Berry et al., 2005) despite the availability of volatiles in the system.

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Sedimentological and paleoceanographic characterization of the source rock intervals in the West-African Atlantic margin

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Keywords: Source Rock, Paleoceanography, Sedimentology.

Several basins generated during the opening of the South Atlantic Ocean were prone to the deposition and preservation of source rock intervals, during the late Cretaceous epoch.

Through the integration of sedimentological data, biostratigraphy, petrophysics and geochemistry, the fine-grained sedimentary sequences rich in organic matter deposited on a West African basin during the upper Cretaceous has been characterized. Thanks to the experience acquired during the stage at Eni Exploration & Production S.p.a in San Donato Milanese, the multidisciplinary approach used is aimed to built the sedimentological and paleoceanographic scenario of organic-rich horizons deposited during Cenomanian-Turonian, middle Turonian, Coniacian-Santonian and middle Campanian. The correlation of eight well logs allows to describe the late Cretaceous depositional architecture and to study the geochemical characteristics through TOC and Rock-Eval Pyrolysis data, from proximal to pelagic realm. Whereas the source rock maturity follows the normal trend, decreasing upward toward the shallower intervals, the TOC and HI variability are controlled by local depositional features. The kerogen type of the studied organic-rich facies, ranges between type II and III kerogen, oil-gas-prone with some type I samples, purely oil-prone kerogen from the pelagic Coniacian-Santonian interval.

Geochemical inversion techniques show (through molecular biomarkers) that the origin of oils found within Campanian and Cenomanian reservoirs are linked to the Cenomanian-Turonian source rock, which is the unique mature interval across the analyzed sedimentary sequence.

The work focuses on a complete source rock evaluation of the Coniacian-Santonian sedimentary event (OAE 3), passing through the identification of the three independent factors which are recognized as main control variables of organic matter accumulation: Dilution, Production and Preservation. Petrophysical logs, thin sections from cuttings, cores and sedimentation rates show that the dilution phase is composed by six parasequences bounded by seven flooding surface (4th order cycle). The Coniacian-Santonian interval is controlled by one 3rd order flooding surface which divides the sedimentary succession in LST phase characterized by lobes turbidites transported from the proximal upper slope environment and HST phase composed by muddy hyperpycnal and hypopycnal flows (the latter are able to reach pelagic realms). The 4th and 5th order cycles and the short-term climatic fluctuations control the deposition of black shales and organic-lean clay respectively during humid/arid phases. Optical kerogen analysis, TOC and Rock- Eval data show that the continental fraction of organic matter is massed mainly in the proximal areas whereas amorphous organic matter, widely present through the studied interval becomes particularly dominant towards the distal areas. TOC and HI values are influenced by the distance from the paleo-shoreline (which controls the dilution extent and the productivity) and by the climate which is able to trigger eutrophication pulses during humid periods and algal proliferation until pelagic environments. The preservation factor has been studied through the Pristane/Phytane molecular ratio which describes the widespread and prolonged anoxia, in particular during humid climate.

Source Potential Index (SPI) shows fair to good source rock characteristics at the hemipelagic basin and pelagic environment.

Relationship between the petrophysical characteristics and the seismic response of the Bolognano Formation (Majella, Italy). Modeling and analysis of synthetic AVO (Amplitude vs Offset)

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Keywords: Heavy-oil, Seismic modelling, Carbonate rock.

The accurate knowledge of properties such as porosity and oil saturation is crucial in reservoir characterization for oil and gas exploration and the methods to provide and characterize reservoir properties are mainly geophysical, such as reflection seismology. Thus, relate seismic and petrophysical properties is of primary interests in Earth science. However, quantification of the oil and in particular heavy-oil influences on carbonate rock seismic properties is still a challenging task.

In this work, a thorough petrophysical characterization in laboratory was performed by measuring density, porosity, seismic waves velocities, and elastic parameters of a carbonate reservoir rock outcropping in the Majella mountain (Central Italy). Moreover, due to the abundance of the outcropping bitumen-bearing portions, the influence of hydrocarbon content on petrophysical properties was tested and characterized.

The presence of bitumen stiffens the rock and causes an increase of the acoustic impedance (AI) and a strong decrease of the VP/VS ratio respect to brine saturation. Oil and gas, on the contrary, cause a decrease of the AI and a slight decrease of the VP/VS ratio in comparison with a saturation in brine.

Synthetic Amplitude vs Offset (AVO) modelling was then performed starting from the properties of the characterized lithologies, in order to simulate the seismic response. Furthermore, the variations, in the petrophysical properties, induced by different fluid saturation such as oil and gas, were also analyzed in order to simulate and model the presence of a continuous solution of hydrocarbon from low (bitumen) to high API gravities. The results showed that through the AVO analysis, it is possible to recognize the type of pore fluid that characterize the analysed carbonate reservoir rocks. It was also observed that the increasing porosity plays a key role in the AVO response, by decreasing the bulk density and seismic waves velocities and increasing the amount of fluids that saturate the rocks.

Starting from the synthetic AVO we developed inverse synthetic seismic images in order to test the previously derived empirical relationships that link the seismic parameters with the petrophysical properties. The method allows estimating the velocities (VP and VS) and densities of a layer starting from its seismic response. By comparing the trends developed in this work (e.g. saturation degree – VP/VS) with the results derived from the inversion methodology, we have been able to predict the properties of that layer.

The modeled AVOs provide significant keys for the quantitative interpretation, from seismic sections, of the porosity, the fluid type and the level of heavy-oil saturation of the carbonate reservoir.

Study of cements present in carbonate fault rocks outcropping in the Central and Southern Apennines

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Keywords: Fault Core, Structural Diagenesis, Extensional Faults.

This work proposes to characterize the process of cementation and its space-time evolution, within fault cores of extensional fault zones that cut carbonate rocks outcropping in the central and southern Apennines. The cementation process, together with compaction and dissolution, is one of the main diagenetic processes. Structural diagenesis is the study of the interaction between deformation (produced by deformation processes) and physical-chemical changes, produced by diagenetic processes. The comprehension of these interactions has become increasingly important because it has found a wide range of applications, such as studying the path and action of underground fluids or in the field of hydrocarbon extraction from deep reservoirs.

In the light of the above-mentioned reasons, the study carried out the following main objectives: (i) the characterization of the degree of cementation within the Fault Cores analyzed, with reference to the control exercised by the nature (calcareous and dolomitic) of the host rock that are cut from the studied faults; (ii) the analisys of the distribution of cements within the domains (inner and outer) of the carbonate fault cores, with reference to the influence of the internal architecture of the fault zones; (iii) the definition of the environment of documented generation of cements, in the context of the space-time evolution of deformation and, hence, in the context of the phases of exhumation of studied carbonate fault cores.

The study was performed on samples from 5 fault zones; 2 located in the central Apennine (Roccacasale and Venere-Gioia dei Marsi) and 3 located in the southern Apennine (Vietri di Potenza, Marsicovetere and Madonna del Soccorso). After sampling of the fault cores, the following methods of analysis were used: X-ray diffraction on powdered samples (XRD), optical microscopy (OM) and electronic scanning microscopy (SEM) on thin sections of samples.

The main conclusions of the work were: (i) the degree of cementation in carbonate fault cores is predominantly controlled by the availability of limestone rocks along the pathway performed by the cementing fluids, hence by the lithology of the host rock; (ii) the distribution of cements within the fault cores is controlled by the internal architecture of the faults, and in particular by the role of barrier performed by main slip zone and outer fault core, in relation to the path of cementing fluids; (iii) the development of a conceptual model representing the phases of deformation and exhumation of outcropping carbonate fault cores, as part of the various generations of recognized cements and in the context of their precipitation environments.

Tectonic evolution of the Murge area (Apula platform) and control exerted on sedimentation, in the upper Cretaceous

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Keywords: tectonic, evolution, limestones, bauxite, syn-sedimentary, Cretaceous.

The study aims to reconstruct the upper cretaceous tectonics of the Murge area (Apula platform, southern Italy) and to propose an evolutionary model. The study sites are: 1) Cava di Bauxite, Spinazzola (Ba) (late Cenomanian-Early santonian) which outcrops the top of Calcare di Bari fm, a Bauxite deposit and the bottom of Calcare di Altamura fm, 2) Cava Potrelli, Altamura (Ba) (late Santonian) wich outcrops the top pf Calcare di Altamura fm, and 3) Cava di Leo, Altamura (Ba) (middle Santonian), Calcare di Altamura fm..

Starting from structural data provided by Korneva et al., 2014; Laurita et al.,2016 and Panza et al.2016, concerning the Calcaredi Bari fm, and the Calcare di Altamura fm, we conducted a sampling of the breccias filling large opening mode fractures (at Cava di Leo site), a sampling of some brecciated levels belonging to the limestone succession (Cava Potrelli site) to compare the microtextural and mineralogical features, allowing us to date the opening/filling process, whether the samples show similarity.

We then focused on the bauxite deposit (Spinazzola site), wich marks a limestone depositional hiatus and fills a stratigraphic gap of ~10 Ma (late Cenomanian and Turonian) (Mongelli et al, 2014). In order to understand how tectonics acted in this lapse of time, we observe how it influenced the deposition of bauxite and the deposition of the limestones, and how the structures influenced the groundwater ciculation.

Firstly we collected structural data and reconstruct the structural setting of the Spinazzola site area, then we did an accurate sampling in proximity of main structures, to investigate the variations on microtexture and mineralogy.

Microtextural and mineralogical data will be provided by Microstructural observation, SEM and XRD analysis. Stuctural data, coming from both Spinazzola and Altamura sites, will be merged to obtain a wider (but anyhow high resolutive) structural model and, with data coming from laoratory analyses, we will be able to give an interpretation on how the processes interacted along the upper Cretaceous, distinguishing the elder ones from earlier ones, obtaining a multi-step tectonic model enclosed in a relatively narrow lapse of time.

Fracture analysis of a carbonate reservoir analogue, Mt. Faito, Sorrento Peninsula

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Keywords: fracture, carbonate, reservoir.

This study proposes the modelling of a discrete fracture network (DFN) carried out using Move 2016 software. The stochastic distribution of joints has been developed from two surveys performed at two different observation scales: one with the scan line method, for a total length of about 20 meters, analysing six alternating limestone and dolostone beds, and the other one, from Corradetti et al., 2016, with a digital outcrop model obtained by a drone applied to a 250-m- wide by 200-m-thick outcrop. The beds analysed are well exposed on the NW slope of Mt. Faito, in the Sorrento Peninsula, and belong to a Lower Cretaceous portion of carbonate succession of the Apennine Platform unit of the southern Apennines. This succession shows many analogies, in terms of lithology, age, facies, mechanical bed thickness and texture, with the productive beds of the Apulian Platform that represent the reservoir for the petroleum systems of the southern Apennines.

The software Move allows to obtain a stochastic distribution of the discrete fracture network and to analyse the relative connectivity of a fracture system, starting from the joints characteristics recorded on surveys. Fracture systems have been reproduced for each bed, defining the following parameters: region of the "Geo-Cellular Volume" to involve, number of sets, mean length and standard deviation, orientation and "K Fisher value" (Fisher, 1952), aspect ratio and mean aperture. The model obtained shows a well-defined relationship between permeability and porosity with the relative connectivity of the fracture network. The latter is clearly influenced by the length and aperture of the joints, and only to a lesser extent by the fracture intensity of the bed. Furthermore, the surveys performed at two different observation scales defined the occurrence of an arresting surface for throughgoing joints represented by a 43 cm thick bed. Throughgoing joints play a primary role in fluid flow processes, connecting isolated fracture systems through beds and guaranteeing, in this manner, a vertical linkage of a reservoir. The bed itself is a dolostone level, named C2-6, characterized by a pseudo-stratification of about 1-2 cm and has a low relative permeability grade controlled by its background jointing. These features are rendered in a final model in which the C2-6 level represents a permeability barrier that can determine a vertical compartmentalization of the reservoir. The information obtained from the final model could be very important in order to understand the processes of fluid flow in a carbonate reservoir analogue, although the different burial conditions between the Apennine Platform and the Apulian Platform have to be taken into account.

Hydrodynamics and sediment distribution in tidal point bars

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Keywords: point bars, tidal channel, morphodynamics, Venice Lagune, Tremp Basin.

Although the majority of meandering channels along modern coastal environments are tidally influenced, in the fossil record we mainly recognize fluvial channels. This suggests that we are still unable to distinguish between them, and that we need precise depositional models, which can describe the main features of a tidal context.

The present work analyses the characteristic hydrodynamic processes of a tidal meander and their consequences in terms of sediment distribution, reconstructing morphology and depositional architecture of a point bars. To achieve this goal, the work focused on the comparison between a modern study case, represented by a tidal point bar located in the northern Venice Lagune (Italy), and a fossil case, represented by Cretaceous sediments of the Tremp Formation outcropping near Tremp (Spain).

The modern case was studied in terms of morphodynamic development through image analysis, comparing aerial photos to highlight the planimetric evolution of the point bar in a certain interval of time. Afterwards the high resolution facies analysis allowed to reconstruct the spatial architectures of the point bars, and the acquisition of flow rate measurements (Acoustic Doppler Current Profiler) showed sediment transport within the channel both during flood and ebb currents.

The fossil case was described through paleocurrents measurements, to explain hydrodynamic features, and facies analysis. The generation of a three-dimensional model (photogrammetry) allowed tracing boundaries between different deposits, highlighting geometries of the studied bodies through space.

It was possible to notice that, during the flood stage, a direct flow promotes sand deposition in the upper seaward part of the bar, while a secondary helical flow concentrates the sandy deposits at the landward toe of the bar slope. During the ebb stage, the process reverses. The alternation between flood and ebb currents contributes to develop a peculiar grain size distribution along the point bar. In particular, the basal part is characterised by a classical fining upward trend (described also for fluvial point bars), whereas the upper part shows an atypical coarsening upward trend.

The results permits to propose a new depositional model for tidal point bars, which is applicable to a wide range of modern and ancient cases.

Classical facies analysis integrated with digital-photo and laser-scan techniques: an example from the study of a lower Pleistocene tidal sand body in southern Italy

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Keywords: facies analysis, outcrop photomosaic, digital processing, modelling.

Novel digital technologies are becoming even more used in Geology, aiming at integrate the study of outcrop sections with traditional field methods. This combined approach allows substantial improvements in the study of stratigraphic successions exposed in outcrop, often poorly accessible to close-up analyses.

An example of this integrated modern approach has been performed on a lower Pleistocene succession exposed in the Siderno Basin, southern Italy. The study area comprises a series of magnificently exposed elongate sand bodies (3 km long x 100 m wide x 35 m thick, on average), including complex motifs of large-scale cross stratification and a number of minor features indicating a clear tidal signature. These evidences have been attributed to the influence of strong tidal currents flowing on a mobile subaqueous bottom and generating the migration of extensive bedform fields in a general strait setting (Colella & D'Alessandro, 1988; Cavazza et al., 1997; Longhitano et al., 2012; Rossi et al., 2017).

However, detailed studies on the depositional architectures of these sand bodies are virtually absent and no facies schemes or models have been proposed until now to explain the dynamics of these tidal deposits.

The aim of the present study is thus to provide a general facies model, combining traditional facies analysis methods and innovative digital techniques.

One of the best-exposed section has been selected among others. The succession consists of ca. 35-m-thick biocalcarenites, erosionally lying on shelf sandstones and internally exhibiting a series of multiple cross-cutting sets, displaying 'festoon' geometries, tangential foresets and plain-parallel lamination. The description of these features, grouped in a number of facies associations, has been integrated with a LIDAR Scan acquisition and a high-resolution photograph analysis.

The results of this approach indicate that a number of hierarchical elements can be internally detected, forming the bulk of the depositional architecture of the studied sand body. They can be related to different depositional environments which developed adjacently during the migration of extensive tidal dunes, under the dominance of unidirectional tidal currents.

Since a number of recent hydrocarbon discoveries have been found in similar settings, the present study may represent an outcrop-analogue example useful to constrain reservoir modelling on comparable tidal sand bodies.

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Seismic well constrained pore pressure estimation

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Keywords: Pore Pressure Prediction, Seismic velocity analysis.

The safe drilling of wells for hydrocarbon exploration or production requires that the wellbore pressure be maintained between the formation pore pressure and the maximum pressure the formation can withstand without fracturing. This task is made more difficult when drilling in overpressured areas, which require a quantitative pre-drill prediction of pore and fracture gradients. Knowledge and understanding of overpressured zones can be derived from many sources such as formation pressure tests, daily drilling and end of well reports. In addition, a common practice is the interpretation of well log based (sonic) velocity from offset wells and increasingly, seismic interval velocities as a means of predicting pore pressure in shales.

As exploration moves into frontier areas where no wells have been drilled or to deeper targets in an area that has only been explored at shallower depths the reliance on seismic interval velocities for pore pressure prediction becomes increasingly important. The estimation of pore pressures from seismic data uses seismically derived velocities to infer the subsurface formation pore pressure. Concerns arise in that the workflows used to derive these seismic velocities can differ depending on whether improving the image is the requirement, i.e. optimising the stacking process, or whether velocities are to be used for pressure prediction. There are also significant challenges in terms of matching seismic and well velocity due to resolution and frequency differences. There are many different types of seismic velocities, but only those velocities that are dense and accurate and are close to the formation velocity under consideration, will be of interest. Beyond this simple approach to velocity analysis lies a range of more sophisticated techniques including: dense velocity analysis (DVA), spatially continuous velocity analysis (SCVA), horizonkeyed velocity analysis (HVA), geologically consistent velocity analysis (GVA), reflection tomography, pre-stack elastic inversion and so on. These techniques can increase the accuracy of the velocity analysis but require additional processing time and computational power, commonly at higher cost. The question is which technique is appropriate for a given situation. Also important to highlight is that geologic and interpreter input to the velocity analysis is essential to a good pressure prediction. Using seismic data therefore presents some unique challenges. Both wellbased and seismic interval velocities (regardless of how they are processed) are affected by changes in rock properties such as increasing temperatures with increasing depth which may cause diagenetic changes in shales resulting in additional overpressure which is no longer related to effective stress and porosity. Only overpressure generated by compaction disequilibrium can be predicted by using conventional seismic based pore pressure methods. In addition, diagenetic processes can develop a further lamination in the rock which may produce velocity anisotropy whereby the rock has a different velocity depending by the direction of wave propagation, resulting "slower" parallel to the symmetry axis. Dealing with anisotropy means balancing unknown parameters, trying to honour both seismic principles and pressure gradients consistency. If only seismic velocities are available and therefore no calibration is possible, the tendency is that pressure is under-estimated and erroneously depth positioned.

2D seismic interpretation and basin modelling of the Rockall continental margin (offshore Scotland – UK): is it the next North-Sea?

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Keywords: Rockall Trough, seismic interpretation, burial history.

The Rockall continental margin offshore Scotland is a potential target area for hydrocarbon exploration and could be considered the new frontier for the exploration. Exploration interest in this basin has grown during the past few years for two reasons. Firstly, there have been a number of significant petroleum discoveries in the basins of the West Shetlands region, which lie along strike from the eastern part of the Rockall region. Secondly, the growing exploration maturity of the North Sea has resulted in exploration companies looking to other adjacent regions which offer significant petroleum potential. The objective of the project is to reconstruct the geometry and the evolution of the continental margin along part of the Offshore Scotland in order to evaluate the real potentiality of the area.

Since 1999, the Department of Energy and Climate Change (DECC) (formerly the Department of Trade andIndustry) He has Conducted Strategic Environmental Assessments (SEAS) prior to offshore licensing rounds. SEA7 lies Within the Atlantic Margin area, and its assessment was during 2007 completed. SEA7 Incorporates Rockall Basin Quadrants 127-132, 138-142, 147-154, 157-165, 168-171 and 173-174, as well as parts of the adjacent Outer Hebrides Platform and Rockall High, plus parts of the Hatton Basin and Hatton High.

The Rockall Basin is the most prospective area for hydrocarbons within SEA7. The basin is a failed rift-formed by crust extension, mostly in the Hauterivian to Cenomanian (136 to 93 Ma, (Musgrove and Mitchener, 1996). Some authors have suggested that an earlier phase (or phases) of rifting may have occurred (e.g. (Cole and Peachey, 1999); (Nadin et al., 1999); (Smythe, 1989) and if so this increases the basin prospectivity as it may have allowed Jurassic or older source rocks to accumulate, albeit in areas much less extensive than the current basin. However, the idea that Jurassic rocks occur across the whole basin (Naylor and Shannon, 2005) seems unrealistic.

The western margin of the Rockall Basin comprises a series of tilted fault blocks that have been thrown down to the east (Joppen and White, 1990), but the nature of the eastern margin is less certain because it is masked by the early Palaeogene volcanics (65 to 35 Ma) and the direction of throw on the faults is debated. Sediments within the central part of the basin are generally flat-lying. In particular the Cretaceous (140-65 Ma) section here is affected by igneous intrusions. Palaeogene lavas are extensive, especially in the north of the basin and on the margins. Where present, the volcanic layers mask the deeper structures so that the pre-Cenozoic geology is difficult to explore. This is a major hindrance to hydrocarbon exploration of Rockall Basin. Shetland. Many of these are in smaller basins marginal to the Rockall Basin. Lower Cretaceous tilted fault blocks, synchronous fault and basin-floor fan sandstones, and Paleocene to Eocene post-fault fan sands are the most likely play types in the Rockall Basin. The potential for pre-fault Carboniferous to Jurassic plays is highly speculative although the southeastern part of the basin, in UK designated waters, may contain Westphalian, Permo-Triassic and Middle to Upper urassic plays of thistype.

No hydrocarbon source rocks have been drilled in the Rockall Basin. However numerous potential source rocks have been proved on the Atlantic Margin of the British Isles from south west Ireland (Porcupine) to west of Evidence (or implication) that source rocks exist in the Rockall Basin comprises:

1) The Dooish gas condensate discovery by Irish well 12/2-1, probably sourced from Carboniferous shales
2) The Benbecula gas discovery by well 154/1-1 from an, as yet unpublished, source (Carboniferous, Jurassic or Early Cretaceous ?).

Mechanical stratigraphy control on oil first migration: the Triassic shale of Favignana Island (Sicily)

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Keywords: mechanical stratigraphy, first migration, fracture.

Rock fracturing is strictly controlled by variations of mechanical stratigraphy of different layers. This process increases secondary permeability and, as consequence, allows high production rates of oil and gas from rocks characterized by low primary porosity/permeability (e.g. shale). In light of this, the analysis of the interplay between rock fracturing and their properties, such as lithology, texture, facies and diagenetic evolution, may improve the understanding of processes responsible for migration of fluids. In light of this, the integrated analysis of the fracture network and host rock properties (e.g. lithology, texture, facies and diagenesis), may improve the understanding of processes responsible for migration of fluids.

The aim of this study is to improve knowledge on the role of the mechanical stratigraphy on the first migration of oil and gas. To achieve this goal, integrated sedimentological, structural and microstructural analysis has been performed in the Upper Triassic shale of Favignana Island (Aegadian Archipelago). These rocks belong to a succession that crops out in the locality of Punta Faraglione (NW sector of Favignana Island). It consists of meters to centimeters thick beds of yellowish clayey marls and marls that alternate to thick beds of grayish to blackish stromatolitic and loferitic limestones. A pervasive dolomitization affects these rocks that were detected in a limb of a Miocene syncline, with an axis roughly oriented N48E. Dolomitic and stromatolitic well bedded sediments are typical of epeiric sea lagoons characterized by euxinic environments capable of preserving its organic matter. This outcrop allows direct mesoscopic observations on different patterns of fractures and veins that occur in lithologically different layers. An analogue to this succession is exposed in the Marettimo Island (Punta Bassano section), close to the Favignana Island.

Three high-angles and one low-angle (to bedding) opening mode fracture sets were detected in the aforementioned outcrop, in which both joint and calcite filled veins were included; these sets strike roughly N10E, N100E, N50E and N130E. Only a small number of joints (oriented to N100E and N50E) cross the marls layer, since the greatest part of them are strata bounded into the dolomitic/stromatolitic layers. Differently, the greatest part of the veins crosscut multiple layers; furthermore, veins pertinent to the set N10E frequently show macroscopic oil evidence at the vein edges. Analysis of thin section allows recognizing several bed parallel catagenetic micro-fractures. Their genesis was interpreted to be related at the increase of the oil volume, which occurred during organic matter maturation. The syntaxial nature of the calcite crystals inside the veins indicates several opening phases, in which the opening starts at the center of the vein and propagates towards the edges. These recurrent phases are also testified by oil in the central part of a vein related to the set N100E. These suggest that the two sets of fractures were formed during the migration of oil, and were probably reactivated during the folding phase, in which the last two sets were formed.

The new dataset provides the first evidence of fracture sets related at the increase of oil volume, which occurred during organic matter maturation, in the Upper Triassic shale of Favignana Island. Thus, the mechanical stratigraphy of the study sedimentary succession played a key role in the oil first migration in the Aegadian Islands.

Erosional Messinian surface in the northern Piedmont plain

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Keywords: Messinian Salinity Crisis, Base Pliocene Surface, Messinian Erosional Surface.

The salinity crisis of the Mediterranean during Messinian time was one of the most dramatic episodes of oceanic change of the past 20 or so million years, resulting in the erosional events and the deposition of thick evaporitic sequences.

This work aims to the reconstruction of the Messinian incisions in the upper Piedmont plain, in an area between the Sesia and Ticino Rivers, and their comparison with Lombard paleo-valleys of the Adda, Serio and Oglio rivers. The work has been performed through the interpretation of 20 seismic lines (about 330 km), calibrated with Salussola1, Cavaglietto1, Cavaglietto2 and Lisanza1 wells. Data elaboration was conducted in ENI data room, located in S. Donato Milanese (Milan). Working with Move2015 software, I reconstructed the isobath map of the base Pliocene/ Messinian unconformity, that describes the overall trend of paleo-Messinian valleys. The map was further integrated with another regional map, generated by digitalization of available maps of Po Valley. This allowed me to have a complete overview of the trends of the paleo-valleys, caused by the Messinian drop of sea level.

During the Messinian Salinity Crisis (MSC) the level of the Mediterranean lowered by about 900 m. This phenomenon contributed to the emergence of a foothills, several tens of km wide, which was engraved by paleo-rivers on the southern side of the Alps. They were forced to adapt to the conditions imposed by the new baseline, represented by a branch / bay of the Adriatic Sea that occupied the center of the Po Valley. The isobath map of the Messinian unconformity shows that the current hydrographic axes coincide with the incisions generated during the MSC, as already reported by previous authors. In the Piedmont sector, the actual course of the Sesia River coincides almost exactly with the axis of its paleo-Messinian valley. East of the Sesia paleo-valley, the existence of another paleo-valley has been reported, which is located south of Orta Lake and coincident with the current course of the Agogna stream. It is the remain of the Toce paleo-valley, which has therefore been captured from the watershed verbano drainage basin only in post-Messinian age (probably middle-upper Pleistocene). The map also shows the existence of a Messinian incision particularly pronounced, deeper than the others, which outflows from the Maggiore Lake at Ispra in the direction of Varese Lake. It would constitute, according to the data reported in literature, a paleo-valley of the Ticino River.

Incisions like those in the high plains of Piedmont are also present in the high plains of Lombardy. The regional map obtained by the integration of these data with the literature allows me to extend the comparison between the Messinian incisions and the current hydrography from the Piedmont region to Lombardy. The course of the Adda, that nowadays exits from the branch of Lecco of the Como Lake, coincides perfectly with the valley engraved during Messinian. Serio and Oglio Rivers appear only slightly moved east, relative to the axes of the respective paleo-Messinian valleys. The map also confirms the existence of a paleo-valley in the Como branch of Como lake, located just east of the Lambro river. The coincidence of the current hydrographic axes with the axes of the Messinian incisions in the upper Lombardy and Piedmont plains demonstrates the existence, at least from the Miocene, of an Alpine river network on the southern side of the Alps like what we see nowadays.

Dry Well Analysis of Well 10-5 in the Norwegian Sea

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Keywords: Frøya High, Norwegian Sea, hydrocarbon activity, seismic interpretation, fault seal analysis.

The region of investigation is located in the Norwegian Sea, which is an area of high hydrocarbon activity. Many reservoirs have been successfully identified, drilled, and now they are producing in large oil & gas fields. However, the Norwegian Sea has a complex geology as it resulted from Permian to Late Jurassic crustal extension, which created rift basins and several horst and graben structures. Most of the important hydrocarbon reservoirs in the Norwegian Sea are Jurassic. Because of the complex geology, identifying these reservoirs and successfully positioning wells is challenging. The research for this project is conducted on a dry well, 10-5 that was drilled along the western fault bounded Frøya High in the Norwegian Sea. This High is a Triassic paleo-uplift: a NNE-SSW trending horst bounded by the Vingleia and Klakk fault complexes on the eastern side and a major fault on the western side, which separates it from the Froan Basin. A Jurassic rollover anticline developed along the western margin of the Frøya High where the well is located. Since 2015, many fields such as Pil, Bue and Snilehorn, have been discovered in the same geological trend. However, in the study area, the two wells 10-1 and 10-2, only contain hydrocarbon shows, and the newly drilled well 10-5 is dry. This study focuses on identifying the failure reason of the dry well 10-5.

Newly acquired 3D seismic data covering the study area, well reports, log data and geochemical reports of the wells 10- 1 and 10-2 are used for the project. This research provides an understanding of the geological elements of the petroleum system which lead to debate the reasons for failure of the well. Different techniques developed to analyze and improve the understanding of all the petroleum system elements in the Frøya High, Norwegian Sea.

- Seismic interpretation is performed to gain knowledge of the structure, lateral and vertical extent of key formations, providing the insight of the subsurface. Jurassic succession in the hanging wall of the Vingleia fault is observed whereas most of this succession is missing in the footwall.
- As the rollover anticline is a product of faulting, 2D restoration is performed to observe the lithologies across the fault at a certain age and the amount of area growth. These observations are used to analyze the viability of the trap.
- A workflow for seismic attribute analysis is developed to distinct between faults in top seal and noise pattern. It shows that the top seal is heavily faulted but these faults have minor throw and they are not connected. The hydrocarbon generation and burial history study is performed under basin modelling concludes that the local source rock did not expel generated hydrocarbons. Hence the hydrocarbon shows in the studied wells are not from local source rocks.
- Fault seal analysis is carried out by juxtaposition diagrams and shale gouge ratio (SGR), which enhances the understanding of the potential sealing of the fault. The reservoir Rogn Formation in the hanging wall is juxtaposed against the Åre Formation in the footwall that consists of sandstone, shale and coal. The SGR analysis suggests a sealing fault; however, the ratio is so close to the borderline that the fault can also have leaking potential.
- Based on the analysis above, failure of trap is the most likely reason for the dry well 10-5. The Vingleia fault present against the rollover anticline has high chances of leaking which implies that hydrocarbons migrated from the trap into to the Cretaceous strata lying above the Jurassic reservoir rock.

Sedimentological - stratigraphic analysis and distribution of reservoir pressure from subsurface data of the Scaglia Formation (Late Cretaceous – Paleogene) – Central Adriatic Sea

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Keywords: Scaglia Fm., calciturbidites, reservoir.

Several oil and gas reservoirs of the Central Adriatic Sea are located within the Scaglia Formation. It consists of pelagic limestones deposited since the Cenomanian to the Late Eocene, frequently interbedded with carbonates resediments, mostly made by shallow-water components.

This thesis was performed with the great support of Eni s.p.a. In this work, more than 90 wells were examined, mainly located in the Marche-Abruzzo offshore, in order to: reconstruct the type, distribution and thickness of resediments in the Scaglia Fm. and infer the possible source area; define the distribution of mineralizations within the Scaglia Formation; study the changes in pressure regimes and temperature and ascertain the degree of hydraulic separation of the Mesozoic succession, in order to provide useful information for the petroleum play.

The analysis of more than 1400 meters of cores images from different wells showed a greater concentration of resediments in the Upper Senonian-Paleocene interval. These are mainly calciturbidites (in broad sense) and debris flows deposits, with thicknesses varying from few centimeters to over ten meters, containing shallow-water clasts, with wide stratigraphic distribution; these lithofacies have been correlated even using the electrical wireline logs. The major resediments are concentrated within 60 km from the Marche-Abruzzo coast. Stratigraphically the resediments are organized in thickening upward cycles, with different order of magnitude, within a fractal geometry. The correlations between resedimented bodies suggests the presence of lenticular bodies interbedded with pelagic deposits. The regional distribution of the proximal and distal lithofacies suggests the presence of more than one source areas. In particular, the proximal lithofacies present in the southernmost wells could come from an unknown platform area, maybe buried under the Apennine thrust belt.

The main mineralizations are concentrated along the Marche-Abruzzo coast. These are typically heavy oils, whose movement seems to be controlled by the density and salinity of the layer water.

The pressure data show the presence of fields with significant differences in the hydraulic regimes. In some southern and northern fields the overpressure exceeds more than 60 kg the natural hydrostatic trend, while the external areas show near hydrostatic trend. This is indicative of a hydraulic regional separation of some fields. In addition, in most fields, pressure and temperature data testify the absence of hydraulic barriers within the Mesozoic carbonates, allowing to hypothesize a vertical migration of hydrocarbons from the source rock.

Influence of bitumen on the petrophysical properties of the Bolognano Formation: a multidisciplinary approach applied to an area of the northern flank of Majella

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Keywords: Carbonate Reservoir, mechanical properties, 3D Reservoir modelling.

Understanding hydraulic and mechanical processes that acted in reservoir rocks and their effects on the rock properties is of a great interest for both scientific and industry fields.

In this work, we have investigated the role of hydrocarbons (HC) in changing the petrophysical properties of rock by merging laboratory and historical data focusing on the carbonate-bearing Majella reservoir. This reservoir represents an interesting analogue for several oil fields both onshore (Cigno, Vallecupa) and offshore (Ombrina, Rospo) and is known for the presence of variable fractions of bitumen and asphalts, so it can be defined "the Natural Laboratory" for our study of carbonate reservoir properties.

In order to investigate these properties, porosity, density and seismic wave measurement at different confining pressure have been measured on carbonate samples of the Bolognano formation (Chattian-early Messinian in age). Two groups of samples were selected: 1. Clean rocks (without oil) and 2. HC-bearing rocks (with different oil-saturation levels).

The investigated samples show a porosity from 8% to 28% and different grain density values, homogeneous for clean samples (2.7 gr/cm^3) and variable for those HC-bearing (2.48-2.67 gr/cm3), showing an inverse relationship between grain density and HC content due to the lower bitumen density (1.14 gr/cm3) over the total rock density. Therefore, combining grain and bitumen density we have calculated the HC percentage for each sample (from 14% to 3%), confirmed by Point Counting analysis on thin sections. Consequently, HC % has allowed us to calculate the original porosity before HC saturation.

For clean samples, ultrasonic P velocity (Vp) spans from 4.1 to 4.9 km/s at ambient pressure, showing a very good linear-inverse correlation with porosity whilst HC-bearing samples are out by this trend. At 100 MPa of confining pressure, Vp ranges from 4.5 to 5.2 km/s with a pressure independent Vp/Vs ratio (about 1.9). The P-wave velocity hysteresis is higher for clean samples (2.48%) respect to HC-bearing samples (1.13%), suggesting an almost perfectly elastic behaviour for HC-filled rocks.

We then integrated all laboratory measurements with a historical dataset (ALBA company), retrieved from ENI's archives and composed by 44 wells, drilled among Lettomanoppello-Fonte di Papa-Fonticelle in the early 1900. We build a 3D reservoir model (0.9x2.5 km) (Fig.1) using Petrel®, simulating the effect of oil on acoustic behaviour of rocks at larger scale. The developed 3D model highlights the HCs distribution vertically and laterally and how HC presence produces higher Vp, with an average increase about 6%. This suggests that in the presence of HC-bearing rocks a similar complex velocity model should be adopted in order to obtain more appropriate underground images.

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Petrographic characterization of "Testina" travertine, Tivoli (Central Italy)

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Keywords: Continental carbonates, travertine petrology, thermal spring systems.

The Late Pleistocene Tivoli travertines can represent a possible analogue of the pre – salt continental carbonate reservoirs discovered in the Santos and Campos Basins (Brazil offshore), and, more recently, in the Kwanza Basin (Angola offshore). The aim of this study is to provide a detailed petrographic analysis of the Testina Unit, outcropping in the uppermost part of the Acque Albule Basin. The study of this travertine unit allowed a reconstruction of the depositional history, the major factors influencing travertine deposition and the diagenesis impact. Possible limitations to this study can be related to the strong horizontal heterogeneity usually affecting travertine deposits and the limited usefulness of the plugs for petrophysical analyses, due to the locally very uncohesive material composing the Testina travertine. In order to achieve the above mentioned goals, a detailed fieldwork was realized together with petrographical analysis, revealing a complex depositional system. The Testina Unit is mainly composed by sub – horizontal layers related to Marsh – Pool and Flat – Pool facies, occasionally alternated with Smooth Slope facies, either deposited in a Depressional Depositional System, which from the North toward the South, gradually pass from proximal to more distal environments respectively. Subsequently, petrophysical analyses performed on 1 inch plugs, showed very high porosity and permeability values but a strong heterogeneity. Stable Carbon and Oxygen isotopes signatures revealed that the CO2 sources can be related to the hydrolysis of the marine limestone bedrock and a complex interaction between microbial activity, water temperature and groundwater mixing with meteoric water. The 3D model and the depositional history affecting the southernmost area display slightly steeper gradient and the alternance of high and low energy environments. These differences could be related both to fluctuation of the water table and topographic control on travertine deposition. The appearance and the previous studies regarding the Testina unit lead to consider this travertine deposit as spongy and poorly lithoid material, reflecting the scarce diagenesis occurred. Nevertheless, microscopical studies with Cold CathodoLuminescence revealed that these travertines are affected by strong cementation, particularly those deposits located at the northernmost part of the plain, mostly characterized by calcite cement. This difference could be related either to flatter gradient affecting the northernmost deposits and/or higher calcium carbonate precipitation rates characterizing this area. The results of this study give insights into the petrographical, petrophysical and geochemical properties of subsurface hydrocarbon reservoirs in similar depositional settings. The here presented characterization of the Testina travertine can represent the basis for future researches on reservoir analogue and 3D modelling of similar continental carbonate deposits.

Characterization of thermal maturity of Oligocene to Pliocene-Pleistocene sedimentary successions in the Southern Adriatic basin by means of dispersed organic matter petrography and FT-IR spectroscopy: new constraints for thermal modelling

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Keywords: Basin analysis, Thermal modelling, Adriatic Sea.

The hydrocarbon exploration in Italy developed gradually from the second half of the 19th century (Mattavelli et al., 1993). Important gas fields were found in the eastern Po-Plain and in the Adriatic off-shore since the 1950 and these discovers allowed to an acceleration in the exploration of the Adriatic basin (Anelli et al., 1995). Despite the Adriatic basin represents the most hydrocarbon potential area of the Italian peninsula (Anelli et al., 1995) there are very few pieces of information about the thermal maturity of the sedimentary successions, particularly for the Adriatic basin. The Adriatic basin is a foredeep basin bordered by the Apennine chain to the west and the Dinaride chain to the east. Its geodynamic evolution was characterized by several stretching and subsidence phases during the Mesozoic period, which allowed the deposition of shallow and pelagic carbonates in different areas (Anelli et al., 1995). During the Tertiary age the area evolved into a foredeep basin with a wide-spread deposition of clastic sediments due to the major subsidence event during the Neogene age (Anelli et al., 1995).

The goal of this project of MsC thesis was to provide new thermal constraints by the analysis of the dispersed organic matter present in the Oligocene to Pliocene-Pleistocene sedimentary successions drilled in three wells of the Adriatic offshore in order to improve the 1D thermal and burial model calibration.

The organic matter maturity was determined using a multi-method approach in order to reduce the problems related to the absence or low reliability of vitrinite reflectance values. It has been performed a laboratory work concerning the optical analysis of the vitrinite reflectance and FT-IR (Fourier Transform in Infrared Spectroscopy) on concentrated organic matter.

In terms of thermal maturity the Well 1 shows vitrinite reflectance values between 0.43% to 0.49% and Roeq% values calculated from FT-IR parameters between 0.38% to 0.50%. Ro% values measured for the Well 2 range between 0.40% and 0.68% while Roeq% between 0.44% to 0.56%. Finally the Well 3 shows Ro% values comprise between 0.28% and 0.39%. All data indicate mainly the immature stage of hydrocarbon generation for the studied stratigraphic sections and the adopted techniques provide results in quite good agreement.

For the Well 1, results are consistent in terms of thermal maturity state when compared to data published by Caldarelli et al. (2013). Furthermore the best calibration curve for this well was obtained using a constant heat flow of 38 mW/m2. In the Well 2 it has been possible to calibrate the thermal model using a constant heat flow of 70 mW/m2, higher with respect to the values provided by previous authors (Cermak et al 1996; della Vedova et al., 2001; Carminati et al, 2012). The thermal maturity evolution of the Well 3 was determined ex-novo and the model was calibrated using a constant heat flow of 58 mW/m2, in agreement with published data (Cermak et al 1996; della Vedova et al., 2001; Carminati et al, 2012). The higher heat flow values compatible with the wells 2 and 3 modelling could be related to the presence of evaporates at higher depths, which probably caused a rise of the isotherms upward (Anderson et al., 1991).

Chemostratigraphic characterization and clays mineralogy of the Upper Cretaceous fluvial-volcanic Bajo Barreal Formation, Gulf of San Jorge Basin, Argentina

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Keywords: Bajo Barreal Formation, San Jorge Basin, chemostratigraphy.

The Upper Cretaceous Bajo Barreal Formation consists on an aggradation of fluvial-lacustrine sediments, deposited in a thick floodplain during extensive volcanic activity since Late Jurassic. The Bajo Barreal formation, belonging to the Chubut Group, is a large hydrocarbons reservoir located in the Gulf of San Jorge Basin in Argentina. The main objectives of this study are (1) to define the vertical and lateral continuity of reservoirs through the chemostratigraphic characterization of the volcaniclastic deposits and (2) to investigate the inherent diagenetic processes regarding the evolution of volcanic glass products. The techniques of chemostratigraphy and petrography were combined in order to construct the stratigraphical framework of the formation. A total of 132 cuttings and 69 core samples, from 3 wells along 800-1000 meters of section, were analyzed by multidisciplinary petrographic and geochemical techniques in bulk samples and the clay fraction (ICP-MS, QEMSCAN, XRD and SEM-ED). Here, inorganic geochemistry data is key in the identification of discrete chemozones. Chemostratigraphic subdivisions were performed based on the signature variations of major oxides SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MgO, MnO, CaO, Na_2O, K_2O, and P_2O_5. The interwell correlation was made based on the variations of trace elements Th, La, Cr, Co, Zr, Hf, Sn, and provenance indicator ratios such as Al_2O_3/Si_2O, K_2O/Na_2O, Fe_2O+MgO. Up to 17 chemostratigraphic units and sub-units were identified and correlated within the Bajo Barreal Formation. The laterally disjoined units identified by anomalies in the content of discriminant elements (e.g. Fe, Ti, Mn) is linked to the nearby structural faulted blocks striking NW-SE. Furthermore, petrography analysis show the reservoirs are mainly formed by mudstones to fined-to-medium grained sandstones. The mineralogy comprises abundant quartz and feldspars, with a prevalent albitic composition. Mineral data reveal the abundance of zeolites and volcanic glass at the lowermost part of the section, indicating an important volcanic contribution at this level. In addition, the, K-Feldspar and Illite content decrease proportionally with depth, in parallel to the increase of the smectite and chlorite content which is most probably related to minerals transformations during diagenesis. Finally, we discuss about the provenance scenarios during Late Cretaceous with regards to the paleogeographic context.

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