SOCIETY OF PETROLEUM ENGINEERS
SPE
ITALIAN SECTION
TECHNICAL BULLETIN 4/2021

THE NEW OMC,
BY M. SPADA - OMC PRESIDENT

OVERVIEW OF THE OMC 2021
AWARDED PAPERS

THE OMC INNOVATION ROOM,
BY E. DELLAROLE OMC SCIENTIFIC
COMMITTEE CHAIR

SPECIAL ISSUE

OMC 2021

MED ENERGY CONFERENCE & EXHIBITION

SPE International
Italian Section

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Via Cufra 19
43125 Parma (PR) - Italia
Tel. +39 0521 965211
Fax. +39 0521 965252

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For any information concerning advertising on this bulletin you are kindly invited to contact:
Antonio Calleri
Ph: +39 02 98252302
a.calleri@geolog.it

EDITOR G. Giudicati
EDITORIAL COMMITTEE P. Del Bo, A. Di Lullo, F. Marfella

AI - SPE - ASSOCIAZIONE ITALIANA SUPPORTO PROFESSIONISTI ENERGIA
via Montenero 30, c/o Geolog Srl
20098 San Giuliano Milanese (MI)

SECTION PROGRAM

DATE	EVENTS	SPEAKERS	CATEGORY	TYPE OF EVENT	ONLINE/IN PERSON
24-26 Sep-21	Regional Section Officers Meeting (Budapest) 2021	M.G. De Donno, L. Motti	SPE Europe Section	International Event	In person
28-30 Sep-21	OMC 2021 (29/09 Hackaton)	Various speakers	OMC	International Event (Italy)	In person
06-oct-21	Decarbonization Path (4th Event 2020-2021) - H2 and Biofuels	Enrico Mariutti (IsAG), Manuel Miceli (TotalEnergies), Michele Margarone (Eni)	Decarbonisation Path	International Event (Italy)	On-line
14-oct-21	Young Professional Happy Hours	M. Trevisan	YP Social	Italian Event	In person
22-oct-21	Workshop & Golf Challenge	-	Social, Workshop	Italian Event	In Person +Online
26-oct-21	Rate Transient Analysis Introduction and Workflows	Layla Mahmood (IHS Markit)	Technical Workshop	Italian Event	On-line
02-nov-21	Digital Disruption is Essential for the Oil and Gas Industry: The Current State, Challenges and Success Roadmap	Dr. Satyam Priyadarshy	Distinguished Lecture	International Event	On-line
06-13 Nov-21	Young Professional Congress 2021 (Ideathon)	-	YP	International Event	On-line
18-nov-21	Young Professional Happy Hours	M. Trevisan	YP Social	Italian Event	In person
26-nov-21	COVA turnaround 2021	L. Cadei	Webinar	International Event (Italy)	In Person +Online
11-dec-21	Datathon (bootcamp from october 2021)	-	DSEA Europe	International Event	On-line
15- dec-21	SPE Italy End of Year Dinner	-	Social	Italian Event	In Person

WHAT'S NEXT

27-jan	Impact of Climate Issues on Energy Industry Through 2050	Philip Grossweiler	Distinguished Lecture	International Event	Online
25-jan-22	Decarbonization Path (1st Event 2021-2022)	TBD	Decarbonisation Path	International Event (Italy)	On-line
	"Self leadership program (1st Event 2021-2022)"	Savioli Lorenzo	Self Power Events	International Event	On-line (TBC)
	SPE Mentorship Opportunity Program	TBD	MOP	Italian Event	On-line (TBC)
	AperInDesign - Digital Event	TBD	MO Technical Workshop (Digital Event)	Italian Event	On-line (TBC)

THE NEW OMC

Monica Spada
OMC President

THE NEW OMC BY MONICA SPADA

On behalf of OMC it was a great honour for me to have officially opened the 15th OMC MED Energy Conference edition just few months ago. It is still today a great pleasure not only because we have missed the opportunity to meet in the last two years, but also and ESPECIALLY because in this period, OMC has undertaken an important process of transformation which is in line with the changing scenario of the energy sector; together we are committed to reach a sustainable future for the planet and the community. We are living in unprecedented times in the current Covid environment, called to face "old" and "new" challenges, moving from energy access to Climate change: It is our responsibility to help provide electricity to around 700 million people who still have no access as well as clean cooking solutions to more than 2 billion people who lack this facility. And we need to accelerate the energy transition agenda to grow sustainably in the long term. The energy sector is therefore undergoing a dynamic transition: in 2020, notwithstanding the current downturn, more than 500 billion $ have been spent in energy transition technologies, 800 billion if we consider also energy efficiency activities, andby 2050, the energy world will look completely different for sure. Energy efficiency will improve up to 60%, electrification, renewable power -that will quadruple the current capacity up to around 11000 GW-, circular economy , hydrogen that will account for 6- 15% of the energy mix - and CCS and CO_2 reutilization -that will reduce around 6 to 8 $GtCo_2$ -are some of the main drivers of the future development. BUT TRANSITION also calls for major increases in all sources of flexibility and synergy within the energy sector. The Energy sector needs around 100 -150 trillion dollars of investment which will boost gdp and create more than 120 million jobs in the sector by 2050. An increasing number of energy companies have committed to reducing or eliminating emissions in the medium-long term. And to achieve this target they are massively investing in technologies, adopting strategies and new business models that aim at combining economic with environmental and social sustainability. In addition a growing number of countries are aligning short and medium term objectives to fight climate change and overcome economic downturn. In particular, in the Mediterranean, geographically speaking our main area of interest, there are still significant disparities between the Northern and Southern shores in terms of energy access, availability, sustainability and efficient use. To reduce this gap becomes a priority, an achievement we are all urged to work towards to realize a sustainable future. In this new scenario at OMC- Med energy Conference we have been even more committed to offer a wider perspective of the energy industry, expanding the event horizon. Our new mission has been defined leveraging three key main principles: Continuity, Inclusiveness, Cooperation.

CONTINUITY

The OMC event has a long history of success. It is thanks to the insights provided by hundreds of professionals and companies presenting innovative and technological solutions as well products for the oil& gas industry, the authorities from neighboring countries bringing their perspectives, that OMC has grown since its first edition in the early 90ies into the leading event for the upstream sector in the Mediterranean. It is in this important heritage, in this acknowledged capacity to take in, analyze and discuss the emerging issues of the Mediterranean scenario that lie the reasons we/OMC must evolve into a new event that lays its foundation on the past and looks at the future. Finding new holistic perspectives and defining strategic synergies, alliancing amongst the energy stakeholders, can be the accelerating lever on the path towards decarbonization, and OMC will act as a facilitator and be the convening platform in this process.

INCLUSIVENESS

Starting from the event name which becomes “OMC MED ENERGY CONFERENCE” We have enlarged our event scope, opening its traditional boundaries to all forms of energy, because we are strongly convinced that interdependence and partnerships combined with dialogue and exchange of perspectives are the recipe for a concrete energy future. To this respect, it is an honor for me to announce that Energy Authorities and Institutions from Europe and North Africa, Company CEOs, international associations have embraced these new ambitions for OMC, embracing the energy paradigm at 360 degrees in a long-term sustainable development perspective and have joined the OMC advisory board to support the evolution of the conference.

OMC is grateful to the Advisory Committee for its fruitful contribution, and is committed to do its part to provide all participants to the OMC Med Energy Conference new insights as well as plenty of opportunities for opening up new business.

Moreover, we have opened OMC’s doors also to young students, startups and research centers from the Med area, asking for concrete ideas and proposal for the future to be shared.

The involvement of young people will increase public awareness on energy and climate-related topics, placing future generations with an active and leading role in this crucial debate.It will be our “ Youth4Climate event”, to drive ambitions and suggestions for the future of the planet, as the one happening today in Milan. To facilitate and sustain OMC Med Conference evolution, continuous dialogue is needed, so from this edition OMC Med Energy Conference & Exhibition becomes AN ANNUAL APPOINTMENT To carry out a reshape of the industry capable of taking advantage of competences from all segments of the value chain.

COOPERATION

We have worked to become a catalyzer of ideas through multilayer alliances with all stakeholders, institutions, companies, young people, fostering and encouraging a mix of networks leading to a mix of competences, experiences and knowhow. We strongly believe that there is no single solution, but an array of paths that must be explored before tracing the roadmap to a just and inclusive energy transition… For this reason we made alliances with associations, institutions – both national and international - representing different segments of the energy sector (biogas, solar, wind, recycle, CCUS) with the ambition to bring different perspectives, know-how and operation models all around a table **All the aforesaid thoughts and objectives have been translated into this year’s theme: Rethinking Energy together: alliances for a sustainable energy future**.

Rethink and discuss our industry, search for solutions to achieve the targets all together with an holistic and technology neutral approach, which is pivotal in supporting economic and social growth in the Mediterranean, and build a strong “culture of sustainability “ to create value for all. Creating alliances amongst diverse players, working together on common goals Alliances along the entire value chain become strategical to enable companies to produce lower carbon emissions, enhance efficiency, boost performance and remain competitive. Finally let me say that OMC would not be possible without the alliances within OMC itself, so allow me to thank

- OMC founders, Ravenna Chamber of Commerce, Assorisorse and Ravenna Oil and gas and energy contractors association,
- OMC Associated companies and Partner Associations for sharing and supporting this challenging path of evolution,
- the many Sponsors who have accompanied OMC organizers in a not easy situation.

My final and warmest thank goes to the many exhibitors, the speakers, the delegates who have joined this edition and the visitors who will come in the next days because their participation is the engine of our work and the essence of the OMC event. And last but not least to all the people, (stewards, workers, police), who have been working and will continue their job in the next days to allow us to inaugurate today in person a safe OMC 2021. See you all in Ravenna next May for the OMC MED energy conference 2022.

Edoardo Dellarole
Scientific Committee Chair

INTRO BY EDOARDO DELLAROLE

Nowadays the entire world is asking to accelerate on the green path towards a low carbon future, and fortunately the number of countries announcing pledges to achieve net-zero emissions over the coming decades continues to grow. The energy sector is the source of around three-quarters of greenhouse gas emissions today and holds the key to achieve this global goal so averting the worst effects of climate change. But achieving net-zero emissions requires a radical transformation in the way we supply, transform and use energy. This transformation for achieving our energy and climate goals demands on one hand on a dramatic scaling up of clean energy technologies available today, on the other hand we need an extraordinary effort on research, development and deployment of technologies not yet mature. In synthesis the clean energy technologies we will need for our future hinge on innovation and implementation today. However, technologies alone, even the most promising, cannot be enough, it will be necessary to develop new business models, methodologies, collaborations and strategic partnerships that have been so far only marginally explored. New technologies, business innovation and new alliances will be key for evolving energy, pushing forward gas valorization and carbon neutrality practices while developing clean energy sources as an integrated and synergic process to provide clean and affordable energy in a low-emissions future. To empower the dialogue on these important themes the scientific program has been structured following four main pillar: Technologies, Carbon Neutrality, Circular Economy and Operational Excellence. The new structure has been set up to offer a complete perspective on the evolving energy industry while allowing a deep discussion on specific session topics varying from renewables to CCS, from gas valorization to nuclear fusion, The open dialogue and holistic perspective offered by OMC - MED energy conference will contribute to address these global challenges. We hope to see you in Ravenna contributing to reshape energy and definitively our future.

OMC MED ENERGY CONFERENCE & EXHIBITION
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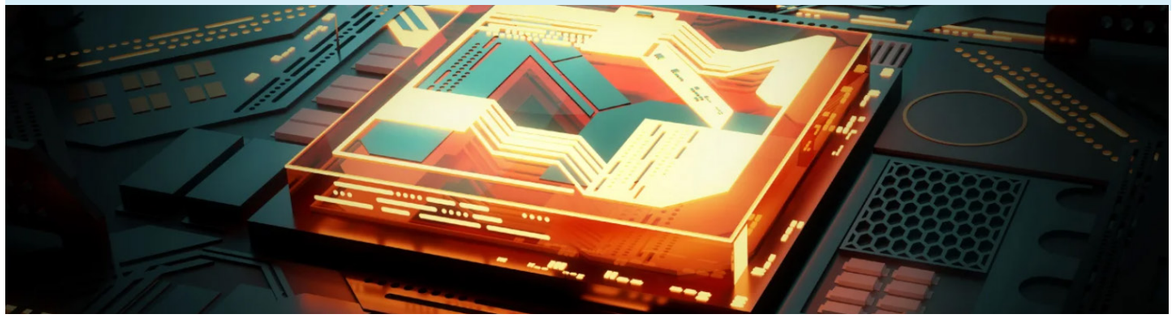
OVERVIEW OF OMC AWARDED PAPERS



A QUANTUM COMPUTING APPROACH TO ANALYSE THE BEHAVIOUR OF OIL & GAS EQUIPMENT

Summary of OMC 2021 paper coauthored by: Marco Piantanida, Eni SpA, Alessia Marruzzo, Eni SpA, Stefano Mangini, Università di Pavia, Dario Gerace, Università di Pavia, Daniele Bajoni, Università di Pavia, Chiara Macchiavello, Università di Pavia

Marco Piantanida
Eni S.p.A.

Introduction

In the last years, data driven approaches have been frequently used to analyze real time data coming from the sensors installed on Oil & Gas plants to detect anomalous behaviors or diagnose potential faults of equipment. However, due to the large amount of installed sensors, it is often required to reduce the number of variables before building machine learning models. With the increased popularity of neural networks, traditional methods used for the reduction of the dimensionality of variables, such as Principal Component Analysis, have been replaced by Neural Autoencoders (NA), which provide the capability to better capture the nonlinear relationships among the variables, and therefore allow to use fewer variables for the analysis of the behavior of the equipment. In this study, we apply the autoencoder as a compression algorithm to data coming from a separator within the Stabilization Unit of an Oil & Gas plant.

We then implement a classification algorithm to the compressed vector to analyze the possibility of predicting the status of the system. We compare a traditional implementation of such approach with an innovative implementation based on Quantum Computing.

Neural Network Implementation

With the usage of Auto-Encoders, see Fig. 1a, two subsystems (one encoder and one decoder) are designed such that the subsequent application of the encoder and the decoder to the input data results in an output that is as close as possible to the input, i.e. the discrepancy between output and input is minimized. With such an approach, the encoder builds a compressed representation of the input data that can be used by the decoder to reconstruct the input.

This means that the compressed representation built by the encoder (often referred to as latent vector) contains the same information of the initial input space (at least, a minimum information is lost). Once the autoencoder has been trained to reconstruct the input, the latent vector can be used as the input space for the classifier.

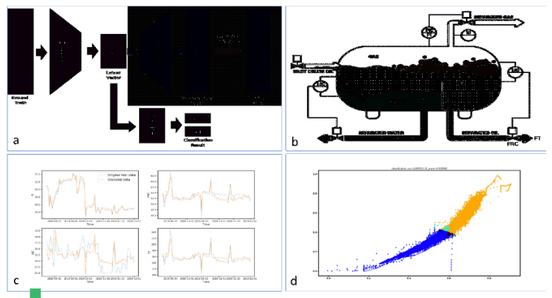


Figure 1

The separator (Fig. 1b) is a vessel receiving a stream of high pressure / high temperature crude oil (left part of the figure, indicated with a black stream), and exploits gravity to separate three output streams:

- Water (the heaviest component), indicated in the figure with a light blue stream;
- Oil (intermediate component), lower part of the figure, indicated with a black stream;
- Gas (lightest component), indicated with a white stream.

The model considers only four variables. This is due to the small size of current quantum devices (i.e., the limited number of connected logical qubits) and their relatively high noise levels, which makes it impossible to run actually relevant and large scale computations. The following variables were selected:

- the oil level (LIC),
- the oil output flow (FT),
- the pressure (PI)
- the opening of the oil output valve (FRC).

The sensors collect the data every 10 seconds.

For the classification problem, we need to define the categorical states to be predicted by the classifier. In order to identify two categorical states, named as “Class A” and “Class B”, we used the initial variables as input to the Kmeans clustering algorithm. Kmeans takes as input the number of clusters, in our case two, and tries to divide the data in groups of equal variances.

To implement the autoencoder, we used neural networks. In our case, the neural network model has four input variables (corresponding to the sensors of the separator) which are compressed by a first neuron layer into two variables. The last neuron layer, the decoder, has four output neurons, with the aim of reconstructing the input.

After the learning phase, the average reconstruction error is around 2%. In Fig. 1c, we show the reconstructed data output of the decoder on top of the original data.

The aim is now to use the two variables of the compressed layer as input for a supervised classification algorithm to predict the class assigned at the beginning through the clustering algorithm. We expect that, if the compressed vector is a suitable representation of the input data, a classification algorithm would be able to achieve very good performances.

In Fig. 1d, we show the results of the classification, using the KNeighborsClassifier algorithm.

In orange and blue we see the points that were correctly classified, while in black we see the points that were wrongly classified as orange and we see in cyan those points that were wrongly classified as blue.

The accuracy scores 90%. Such very high score indicates that the compressed vector can efficiently summarize the information carried by the input data.

Quantum Computing Implementation

Before discussing the actual implementation of a quantum autoencoder and classifier, Fig. 2 introduces some key concepts of Quantum Computing. Fig. 2a introduces the key concept of a quantum bit (Qubit), the fundamental logic unit: when it is read, the result will be either 0 or 1 (as a traditional bit), but during the computations, it behaves as if it can keep any value on the sphere (superposition effect).

Therefore, a single Qubit can be used to represent two complex numbers (α and β, whose squared moduli represent the probabilities of reading 0 or 1 when we read the Qubit).

As far as we proceed in the computations on Qubits without reading them, they bring forward their behavior of having superposed values. A Qubit can be manipulated with an unlimited number of unitary operations (reflections and rotations on the sphere, see Fig. 2b). When more Qubits are taken into account, a fundamental operation involving two Qubits is the CNOT (Controlled NOT) gate. All multiple Qubit logic gates can be composed from CNOT and arbitrary single Qubit rotations.

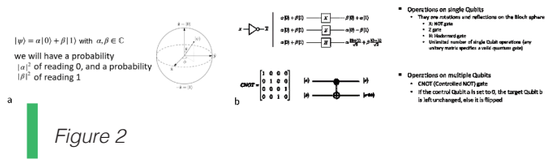


Figure 2

In the following paragraphs, we summarize the quantum implementation of the autoencoder. In order to provide a quantum generalization of a classical autoencoder, it is necessary to introduce the quantum version of a neuron capable of handling continuous variables as inputs. The first step is to write the classical input variables into the state of the quantum hardware. It is possible to define a quantum perceptron model that uses a phase encoding strategy to load continuous classical data onto the state of a quantum system.

A quantum circuit implementing this structure is schematically depicted in Figure 3a. The first operation Ui initializes the Qubit with the values of the input variables. After that, the operation Uw evaluates the product between the input state and the weight vector quantum state, as it happens in traditional neural networks. At last, a multi-controlled CNOT operation targeting an ancillary qubit is used to extract this information which can be retrieved performing a measurement. In particular, the probability of measuring the ancilla qubit in the quantum state 1 is proportional to the desired inner product of the input variables and the weight vector. Such a quantum neuron can perform simple pattern recognitions tasks involving grey-scale images. As shown in the Figure 3b, by encoding the intensities of the pixel on the quantum state, the neuron is capable of recognizing similar images: the quantum neuron yields a higher activation (histograms on the right) when the inputs are very similar to the target fixed weight vector (checkboard pattern on the left). The images showing largest activation, like those labelled by number “9” and “19” are very similar to the target image. Images labelled “7” and “12” are examples of images with low activation.

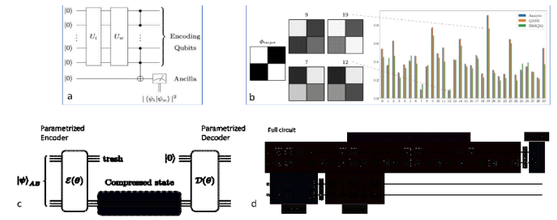


Figure 3

A quantum autoencoder can be created as follows (Fig. 3c): consider two quantum systems denoted as system A and system B; our goal is to compress the state of the system in a lower dimensional representation, for example using only subsystem A to store such information. This can be obtained if the system B is mapped to a reference state, for example the zero state. The aim of the encoder is to find a way to disentangle the two systems in such a way that one of them, called the trash state, goes to the fixed reference state and the other system contains all the original information of the complete state. The full quantum circuit is shown in Fig. 3d. The yellow part is used to initialize the Qubits with the values coming from the sensors; then, the encoder is implemented with a sequence of rotations and CNOT gates; the decoder is the Hermitian (inverse) of the encoder. The quantum states obtained by the trained quantum autoencoder are then passed to a quantum classifier, consisting of a tunable rotation of a single qubit followed by a measurement, whose aim is to recreate the classification in the categorical states “A” and “B”. The quantum circuit has been implemented both with quantum simulation software and on real quantum hardware. With reference to the quantum simulation software, the circuit is written with Qiskit (by IBM). The PennyLane library is then used for the training phase; it provides an interface between the Qiskit-circuit and optimized machine learning libraries (Keras and Tensorflow). The circuit has also been implemented on IBM quantum hardware accessible via cloud through the Quantum Experience platform.

Results

The performances of the quantum autoencoder were evaluated using a test set of 1000 samples: the average reconstruction error was around 5-6%. Results are reported in Figure 4a.

The inner layer of the quantum autoencoder is then used by the quantum classifier. The classification accuracy scores 88% when using the quantum simulator.

The misclassified data are those located near the edge connecting the two classes of data (Fig. 4b).

The tests performed using real hardware from IBM showed remarkably good results. The classification accuracy ranges in ~81%-86% depending on the quantum device used for the execution of the circuit.

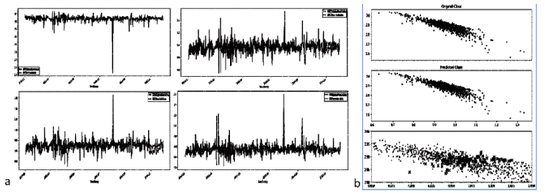


Figure 4

Conclusions

We have presented a direct comparison between quantum and classical implementations of a neural network autoencoder, followed by a classifier algorithm, applied to sample real data coming from one of Eni’s plants, in particular from a separator.

While the achievement of a clear quantum advantage is still out of reach, this work sets a milestone in the field of quantum machine learning, since it is one of the first examples of direct application of quantum computing software and hardware to analyze real data sets from industrial sources.

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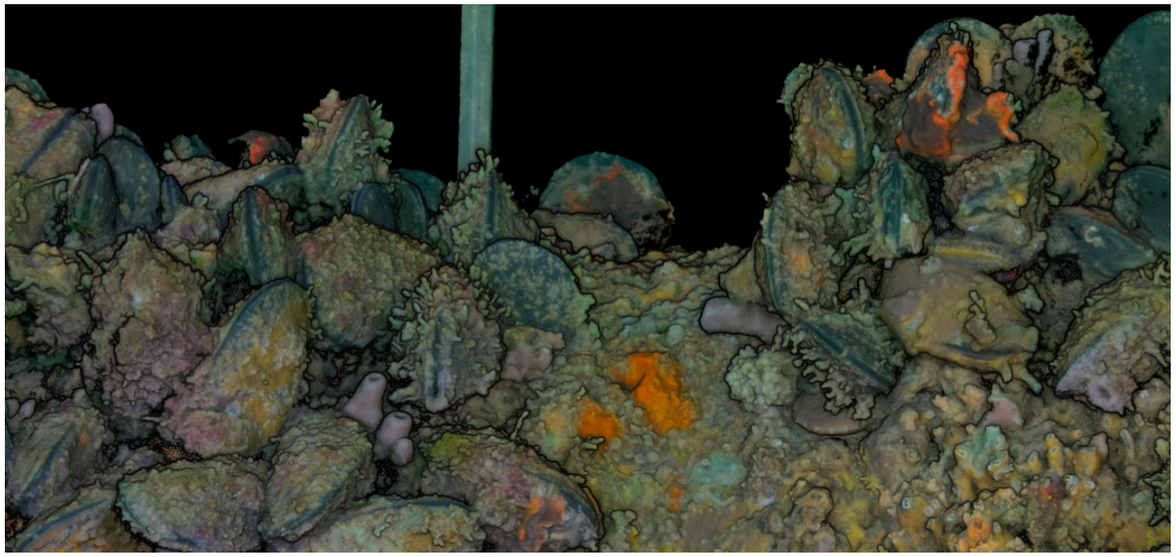
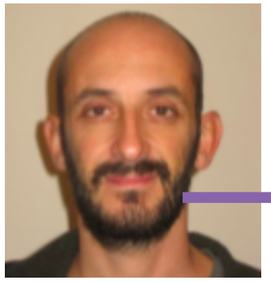
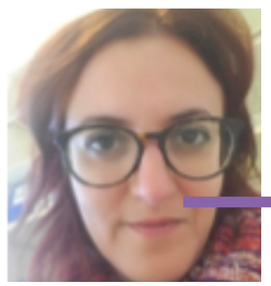


A HOLISTIC APPROACH FOR PROMOTING THE BLUE ECONOMY GROWTH: THE CASE STUDY OF THE PAGURO WRECK



Marco Palma
Ubica srl

Massimiliano Pinat
CNR-IRBIM



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eFrame srl

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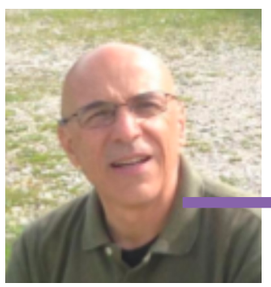


Ennio Ottaviani
On AIR Ltd

Offshore decommissioning and ecological opportunity

The new strategy of the European Commission for sustainable blue economy in the green transaction context, highlights the importance of scientific research and innovation for protecting and restoring marine ecosystems to achieve climate-neutrality by 2050.

Protecting biodiversity and enhancing climate resilience are key factors for assessing the sustainability of marine and maritime industries and driving new business strategies.

In this regard the Oil&Gas sector is at a turning point. The use of fossil fuel as primary source of energy is decreasing while the sector of renewable energy is growing fast. Moreover, most of the platforms deployed at sea are at the end of their production life cycle (approximately 50 years) and will be completely removed following the decommissioning procedures defined by the Protection of the Marine Environment of the North-East Atlantic (OSPAR), which states that disused offshore installations must be considered as dumping sites in accordance with the definition of pollution (OSPAR, 98/3 Decision). However, a large scientific literature supports the ecological role of disused offshore assets. Platforms at sea are considered as artificial reefs representing distinct habitats able to support complex trophic webs based on local biomass production, and the attraction of other species. Benthic communities show to be generally similar to nearby natural reefs but with some variability in species composition, relative abundance and size which is generally larger. The vertical profile of an offshore platform determines a continuum fall of organic material from the top to the bottom of the structure, which in turn supports the detritus community colonising the shell beds. Despite the OSPAR Convention decisions, the Oil&Gas installations placed in the marine environment can have positive impacts on marine ecology, providing hard substrates and habitats to species, increasing the local production and supporting activities based on the blue-economy principles.

The Paguro case study for the Northern Adriatic Sea

In the Mediterranean area, the northern part of the Adriatic Sea has represented an hotspot for natural gas exploitation since the Sixties. The jack-up platform Paguro builded in 1963 was drilling new sites when on the 29th of September 1965 it sank as the consequence of an uncontrolled eruption of underground methane gas. Since then, marine life started colonising the wreck and the site became a natural protected area recognised at the national (DM 21.07.1995 Biological Protection Zone) and European level (Commission Dec. 2012/14/UE SCI code IT4070026, DM 03.04.2019 Special Area of Conservation). Only scientific and recreational scuba diving are allowed at site.

Thanks to its large bathymetric range, the wreck hosts a complex benthic community. The species Mytilus galloprovincialis characterizes the shallower horizon (up to -13 m), and oysters, encrusting sponges, and Epizoanthus arenaceus dominate the wreck between -15 and -23 m. The deeper areas show a less dense community reflecting the water dystrophic conditions near the bottom.

Given the large number of obsolete platforms that will be decommissioned in the next decade, and the European Commission decisions for promoting blue economy growth, the long controversial debate to convert the rigs to reefs is becoming more and more actual, paving the way to consider revising OSPAR Decision (at least partially).

The Interreg Italy-Croatia Adrireef Project

The Adrireef project (CBC Programme Interreg V-A Italy-Croatia) carried out a complex monitoring plan where biological, oceanographics, socio-economic factors were investigated to identify strengths, weaknesses and opportunities for commercial activities pointing at the blue growth principles. The results underline that the Paguro wreck represents a natural and historical heritage supporting local tourism and public awareness.

For the purpose of the Adrireef project, an artificial reef is defined as ensuring “protection, restoration and regeneration of aquatic habitats, and the promotion of research, recreational opportunities, educational use, sustainable fisheries and aquaculture.”. Therefore, within the definition of artificial reefs are included all the accidentally sunk structures and any decommissioned assets intentionally relocated underwater to act as an artificial reef (e.g., rig-to-reefs, sunken ships).

The holistic investigation and monitoring approach tested at the Paguro wreck aimed at:

i) improving marine ecosystems knowledge by monitoring with traditional and innovative methods the water parameters, benthic and fish community at site;

ii) promoting local tourism and the site conservation by engaging scuba divers and the wider public through citizen science based actions and virtual reality immersive experiences;

iii) informing managers on the economic benefits generated by the ecosystem services associated with the alternative use of offshore assets and of decommissioning approaches.

The holistic approach.

The Paguro wreck was studied from July 2019 to July 2021 with a multidisciplinary approach for investigating biotic, abiotic and socio- economic characteristics of the site. A preliminary bathymetric survey with the multibeam echosounder was carried out for planning the underwater sampling of scientific divers. Traditional (i.e. photographic sampling on standard surface, visual census) and new methods (i.e. underwater photogrammetry, stereo videos recording) were applied to characterize the benthic and fish communities. Physical and chemical water parameters were measured regularly as well as the water column currents.

The surveys at the Paguro wreck included the engagement of scuba diver volunteers for mapping the wreck using photogrammetric techniques and to promote the site as a tourist attraction. Data collected during the photogrammetry surveys were processed in different ways and used for different purposes.

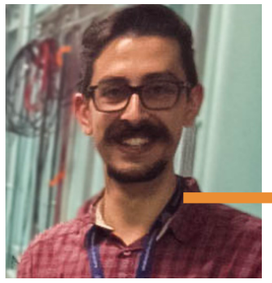
The whole scanned area was processed to generate a scaled and classified point cloud which was then aligned with the bathymetric data collected at site with the multibeam echosounder. The classes were defined to map the benthic communities across accordingly with their species composition. The data were processed and published on a dedicated server based viewer based on WebGL technology (https://adrireef.ubicasrl.com/viewer/Multi) for large public communication.

The high resolution 3D textured models of the scanned areas were optimised and embedded in a 3D seascape scene, and a virtual reality experience simulating a scuba diving around the wreck was delivered for promoting sustainable activities at site to a large public.
Project monitoring results were presented to the large public by using an immersive virtual tour with 360 degree videos and photos collected at site during operations.
Benthos community traditional metrics (i.e. species composition, coverture percentage) were integrated with the fouling volume calculated from the high resolution 3D models of small scanned portions of the wreck (Figure above) and the biomass calculated as weight of the shells component and the weight of the organic component (dry weight).
Innovative visual census methods and technologies were tested at site for characterizing and monitoring the seasonal variation of the fish community. Underwater 360 degree videos were recorded at stationary points and analysed by marine biologists using virtual reality headsets. Underwater stereo video cameras were used to record calibrated videos for the automatic fish identification and size estimation. Deep learning algorithms (RCNN 12, RetinaNet 13, YOLOv3 14) and a user web APIs and interfaces to neural nets were used with annotated datasets to train the networks. The results from traditional and innovative visual census methods were merged to a comprehensive characterization of the fish community living on the wreck.
The economic benefits provided to human activities by ecosystem services at natural and artificial reefs were analysed. Fisheries, aquaculture and shellfish farming, and coastal tourism (recreational scuba diving and boat excursions) were identified as blue economy activities considered in the project. To such activities, it was added scientific research and its application as a further domain to be investigated for assessing the overall benefits provided by ecosystems services also in terms of knowledge development and knowledge-based economy.
For promoting the attitudes of the site, both legal and economic feasibility were assessed. The legal framework for a sustainable exploitation of the reefs was studied with the involvement of the project partners and the criteria for the economic sustainable use of the site were designed.
Stakeholders were identified and their potential benefits in the Paguro wreck exploitation were evaluated according to the assessed capacities of the identified ecosystem services following the CICES classification. A questionnaire for investigating the selected indicators was designed and filled by four identified economic activities (fisheries, aquacultures and shellfish farming, boat excursions and diving centres). rom the gathered data it was possible to estimate the interest related to the reef exploitation and the impact in terms of both revenue and human resources involved.
A second questionnaire for collecting data and investigating the local legal frameworks was designed and filled by project partners and local stakeholders (local authorities responsible for the legal framework).
The questionnaire included 39 multiple choice questions, divided in 5 sections (1 on general characteristics of the legal framework; 4 on the specific characteristics of the legal framework related to the investigated economic activities), with open fields for integrating the choices with specific information and data. From the gathered data it was possible to assess if and how the targeted economic activities are regulated (both permitted and prohibited activities), how the legal framework is impacting on the valorisation of the ecosystems services as well as to provide some recommendations about how to redesign the legal framework to support blue growth development at site with guidelines for reefs' users and recommendations for policy makers and funding agencies.

Conclusion

The Interreg Italy-Croatia Adrireef project represented the unique opportunity to develop a multidisciplinary framework to characterize, monitor and promote the sustainable use of the Paguro rig wreck as natural and cultural heritage.
The presented methods included traditional approaches integrated with innovative technologies, such as deep learning for fish tracking and census and underwater photogrammetry for estimating i) the volume of the fouling community, ii) developing tools for interactive data visualization, iii) creating 3D bionomic maps, iv) producing virtual reality immersive experience and v) engaging scuba diver volunteers to scan the wreck.
The study delves into the opportunity of promoting the ecological and cultural value of the existing offshore assets to support blue growth economy-based activities as suitable alternatives to the complete removal at the end of the production life. Moreover the results coming from the socio-economic analysis highlighted the potential magnitude of the business related to the harvesting of mussels growing on other offshore assets located in nearby areas of the Northern Adriatic Sea.

CARBON STORAGE IN ULTRAMAFIC ROCKS: INNOVATIVE APPROACHES LEARNED FROM NATURAL SYSTEMS



Andrea Rielli
IGG-CNR

To meet COP26 goal of limit global warming to +1.5 ℃ from pre-industrial level, Carbon Capture and Storage (CCS) technologies are required to sequester 100 to 1000 Gt of CO2 over the 21st century. Most of the existing large-scale CCS facilities are based on enhanced oil recovery, where CO2 is trapped, mainly physically, below an impermeable cap rock. An alternative is the permanent storage of CO2 through mineral carbonation. This approach is based on the reaction between CO2 and divalent cations (e.g., Mg2+) resulting in the bonding of CO2 into the structure of newly formed carbonate minerals (e.g., MgCO3), achieving "mineral trapping". This approach has virtually no risk of release, can be applied at the global scale either in-situ, directly injecting CO2 into ultramafic formations, or ex-situ in bespoke reactors, and promises a very large storage capacity (105-108 Gt). In addition, recovery of valuable metals from the feedstock material and commercialization of the carbonate produced as construction material could represent a significant source of revenue. Despite these advantages, to date the large-scale deployment of mineral carbonation is still hindered mainly by slow reaction rates and elevated storage costs. Here we present an innovative approach for the development of alternative carbonation paths in the framework of the Horizon 2020 GECO project (https://geco-h2020.eu). This consists in the study of natural carbonation systems using field geology, petrology, geochemistry and combining the results with batch reactor experiments and geochemical modelling. The aim is to overcome current technological barriers by learning from natural systems which spontaneously sequestered large amount of CO2. The overall goal is to define new cost-effective solutions for the storage of CO2 in ultramafic rocks capable of speeding up the large-scale deployment of CCS so that efficient CO2 storage could be achieved within the timeframe considered by the COP26.

Natural carbonation systems

CO2 storage through mineral carbonation is based on the reaction between CO2 and silicate minerals, such as serpentine, which provide cations, mainly Mg2+, necessary to form carbonate minerals. Even though this reaction is thermodynamically favorable, kinetics is relatively slow, compared to anthropogenic CO2 emission rates, and this is one of the main issues limiting the application of mineral carbonation to the industrial scale. Experimental works have shown that pre-treatments of serpentine, by grinding, thermal activation, acid leaching and the utilisation of high CO2 partial pressures can accelerate carbonation reactions but also significantly increase the storage costs, making mineral carbonation economically unappealing. Another way to implement new carbonation approaches is through the study of natural systems where large amounts of CO2 have been spontaneously sequestered in geologic formations. These systems reach their maximum potential in the genesis of magnesite deposits, where million tons of CO2 have been spontaneously converted into carbonate. These occurrences prove that mineral carbonation can be efficient and that CO2 can be safely stored in carbonate minerals for millions of years. Thus, understanding the genetic processes and boundary conditions of these systems

can bring new insights onto mineral carbonation and help engineer more economic and efficient approaches for the storage of CO2 in ultramafic rocks.

Natural carbonation systems in Tuscany

The peculiar geological setting of Tuscany led the outcrop of significant amounts of ultramafic rocks, mainly represented by serpentinite with minor gabbro and basalt. These rocks host several examples of CO2 mineral sequestration from low temperature (~10-20oC), such as in the Montecastelli Ophiolite Complex (Fig. 1A, Boschi et al 2017; Boschi et al 2020) to high temperature (~100-200oC), such as in the Castiglioncello and Malentrata magnesite deposits (Fig. 1B, Boschi et al., 2009; Rielli et al., submitted). While the first occurrence can be considered a natural analogue for ex-situ CCS where CO2 is sequestered directly from the air (Direct Air Capture), the second example best represents a natural analogue for in-situ CO2 storage, where instead CO2 is injected ad depth in serpentinite at relatively high temperatures.

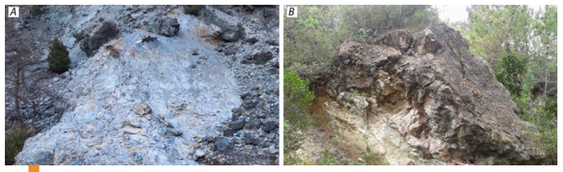
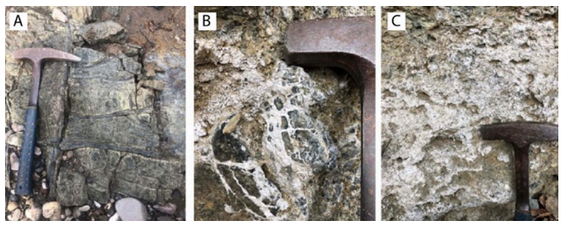


Fig. 1 A) Low-temperature carbonation of a serpentinite outcrop in the Montecastelli Ophiolite Complex. The exposed surfaces are covered by hydrated Mg-carbonate giving it the whitish color; B) Magnesite vein at the Castiglioncello deposit.

Low temperature carbonation is represented by an ongoing process occurring onto rock surfaces exposed to the atmosphere (Fig. 2A to C, Boschi et al., 2020; Boschi et al., 2017) but it is lithologically selective taking place exclusively onto serpentinised dunite outcrops and not onto the more abundant serpentinised harzburgite. Through petrological and geochemical studies, we found that this is due to the presence of brucite, a magnesium hydroxide which formed only during the serpentinisation of dunite and not from harzburgite. Brucite is highly reactive even at low temperatures, releasing the Mg2+ which is required to precipitate hydrous Mg carbonates (hydromagnesite and nesquehonite (Fig. 2) and Mg-Fe layered double hydroxides (coalingite-pyroaurite-LDHs, Fig. 2) which sequester CO2. Even though precise dating of this process is still missing we have document ted that during the fieldwork season newly exposed “fresh” serpentinised dunite becomes coated by hydrous Mg-carbonates in only weeks.



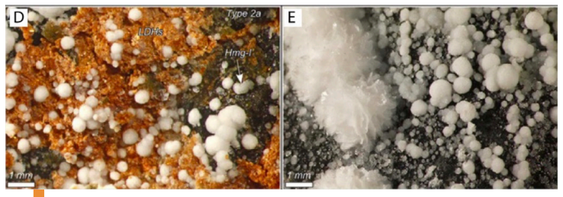


Fig. 2 A to C) Progressive carbonation of dunite in the Montecastelli Ophiolite Complex; D) microphotographs of LDHs dominated assemblage and E) microphotographs of hydromagnesite.

The second natural analogue for mineral carbonation we report here is the formation of magnesite deposit in the Ligurian Ophiolite outcropping in central and southern Tuscany, in particular we will discuss the genesis of the Castiglioncello magnesite deposit (Rielli et al., submitted). This deposit is constituted by veins composed predominantly by magnesite, dolomite and minor silica with a width ranging from few decimetres up to ~10m. On the surface they can be followed up to 1.5km along strike and have been mined down to a depth of at least 100m. These veins are hosted in serpentinised spinel-harzburgite which is unaltered in distal outcrops from the main veins, whereas in the proximity of the mineralised zones the serpentinite has been affected by intense hydrothermal alteration. The magnesite veins that constitute the main ore precipitated in dilatational fault jogs opened onto normal faults (Rielli et al., submitted). These are characterised by early infill of massive cryptocrystalline creamy-white magnesite that has been repeatedly brecciated and cemented by multiple magnesite and dolomite generations. Through a petrologic, geochemical and isotopic study of this deposit we were able to elaborated a genetic model where CO2-rich with temperatures between ~100 and 200oC were concentrated into serpentinite lenses thanks to tectonic activity. Here the CO2-rich fluids became enriched in Mg2+ by incongruent dissolution of serpentine. This process was capable of liberating more than 90% of Mg2+ without saturating the solution in SiO2, that would have happened if complete dissolution of serpentine was achieved. This process avoided the precipitation of silica layers during carbonation and thus helped maintaining a high permeability of the system required for efficient and prolonged CO2 sequestration (Rielli et al., submitted).

Experiments and modelling

Building on the two natural end-member introduced above we have performed laboratory experiment to further constrain the boundary conditions at which these processes take place (Bicocchi et al 2020). We selected as starting material serpentinised brucite-rich dunite and a serpentinised harzburgite and performed different carbonation experiments using a batch reactor type PARR 5500 HP. . The experiments were design to investigate the effect of different chemical and physical parameters, including temperature, time, pressure and gas mixture, on the carbonation of the two selected lithologies. Temperature varied from from 20°C to 110°C, pressure from 10 to 27 bar, experiment time from 6 hours to 45 days. About 3.6 g of powered rocks were used for the experiments together with 18 ml of MilliQ® water and pure CO2 gas or a CO2-H2S mixtures (98-2% by vol). The CO2-H2S mixtures was chosen to reproduce the typical composition of gas from from natural hydrothermal emissions in the study area, and thus test whether the presence of H2S is an important variable for reaching high carbonation efficiency. The results confirmed that the serpentinised dunite rapidly react with CO2 gas at 110°C thanks to the presence of brucite that easily release Mg2+ in solution, with the consequent hydromagnesite precipitation, which turns into magnesite in a few days. At the lower T of ~20° C, the kinetics of carbonation is slower but still efficient. Serpentinised harzburgite reacted sluggishly with the CO2 gas, but significant amount of Mg2+ was released in solution due to serpentine dissolution. However, harzburgite carbonation could have been easily reached by increasing the passive concentration of ions in solution by induced evaporation (Bicocchi et al 2020). An additional kinetic modelling using PHREEQC, based on the experiments results provided a reaction path for the carbonation of serpentinised brucite-rich dunites and serpentinised harzburgites.

Future applications – Upscaling CO2 sequestration

To bridge the gap between experimental work and large-scale deployment of mineral carbonation it is necessary to identify optimal areas for their applications. We have performed a study of the impact of favourable vs. unfavourable parameters both for in-situ and ex-situ CCS applications, including surface and subsurface geological data, temperature at depth, seismic hypocentres, protected natural areas, natural and industrial CO2 degassing. We have used as case study the region Tuscany, but the same approach can be upscaled to larger regions where sub-surface data are available. Collected data have been processed and stored in a GIS geo-database, and used to produce thematic maps. A multi-layered space on which to apply an algorithm for selecting the most suitable areas has finally been generated. Thanks to the developed algorithm we were able to identify ~86 km3 of ultramafic rocks suitable for in-situ¬ CO2 storage which virtually equates to ~70 Gt of CO2 storable only considering the ultramafic rocks in Tuscany.

Conclusions

Here we have showed how the geologic and geochemical study of natural carbonation systems, merged with modelling and experimental work, can lead to a better understanding of mineral carbonation processes. Some of the key aspects highlighted by this study are: i) Serpentinised dunite is the lithology with by far the highest reactivity to CO2 in natural environments favouring spontaneous mineral carbonation at low-temperature.
Therefore, this would be the optimal starting material for ex-situ mineral carbonation and/or as target for in-situ applications. Thus, dunite-rich ophiolite sequences should be favoured in selecting the targets for CO2 mineral sequestration. The abundance of dunite channels in ophiolite sequences depends on the oceanic history of the paleo-ocean from which these complexes were derived, highlighting the importance of understanding the pre-orogenic history of these rocks; ii) The high degrees of serpentinisation also show that serpentine must be considered as main Mg2+ source when thinking about ex- and in-situ mineral sequestration; iii) The preservation of the original argillitic sedimentary cover, together with the embedment of the ophiolite sequence into low-permeability sedimentary formations, due to compressional tectonics during the Apennine orogenesis, makes the studied ultramafic reservoir optimal targeted for CO2 injection because they result well sealed thus minimising the possibility of CO2 escape during the injection stage. iv) carbonation of serpentinised harzburgite is efficient in the formation of magnesite deposits because it proceeds through the incongruent dissolution of serpentine. Experiments based on these natural occurrences showed the potential of this approach in identifying the key conditions for mineral carbonation which can be then tested and further implemented by geological modelling. Once the optimal conditions have been targeted, we have showed that by using GIS based approach is possible to target the most suitable ultramafic bodies for in- and ex-situ CO2 storage through mineral carbonation.

Andrea Rielli is researcher at Institute of Geosciences and Earth Resources (IGG) of the National Research Council of Italy (CNR). His research is focused on the geochemical cycles of carbon and sulfur, mineral carbonation and ore genesis.

Gabriele Bicocchi, Ph.D. in Earth Sciences, is a Science Teacher at High School. He’s also consultant at the DST-UNIFI and collaborates with CNR-IGG in the framework of the H2020 GECO project. Gabriele mainly does research in Fluid Geochemistry (with special emphasis on carbon cycle), Mineralogy, Geothermal, and Soil Mechanics.

Giovanni Ruggieri, Ph.D. in Mineralogy and Petrology, is researcher at Institute of Geosciences and Earth Resources (IGG) of the National Research Council of Italy (CNR). Specialized in fluid inclusions, stable isotopes, hydrothermal mineralogy and their application to geothermal exploration, fluid-rock interaction studies, ore genesis and CO2 mineral sequestration.

Giordano Montegrossi (male), is a geochemical technician working on geothermal system and in modeling water-rock interaction in presence of carbonates/carbon dioxide and sulphur species systems. He has been working on modelling of natural system with application in the fields of CCS and geothermal systems, carrying out a) a basic research work on mineralogy of calcite and sulphides, and thermodynamics of geothermal and volcanic fluid phases with sulphur species and carbon dioxide as main topics, and b) on modelling applications, mainly using PHREEQC and TOUGH2/TOUGHREACT software packages, focused on geochemical

evolution of reservoir and CCS injection feasibility study, and problems related to geothermal fields, like calcite clogging in reservoir, well-scaling by calcite and halite, pipeline encrustation problem in transport of geothermal fluids, geothermal reservoir modelling for geothermal potential estimates.

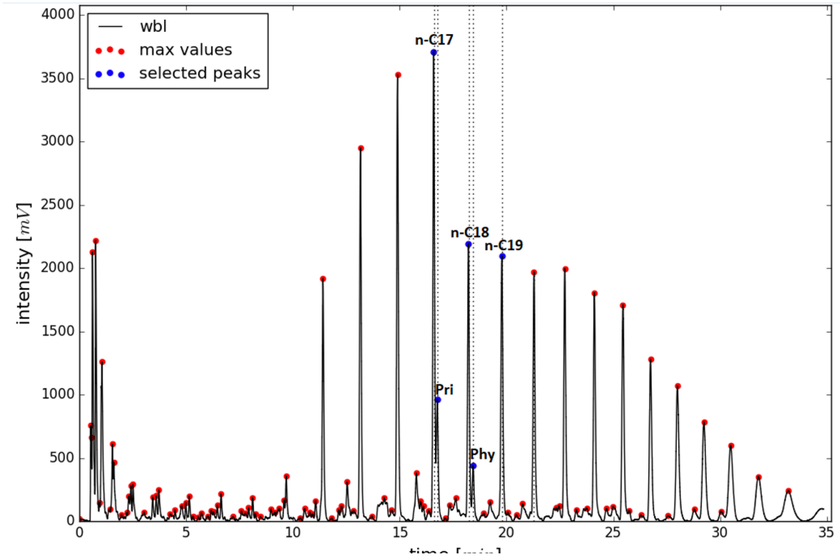
Ilaria Baneschi, Geosciences and Earth Resources-CNR in Pisa, research technologist. PhD in environmental sciences, her research focused on defining the geochemical and biogeochemical proxies to trace and understand carbon and water cycle.

Chiara Boschi, Ph.D. in Earth Sciences, is senior researcher at Institute of Geosciences and Earth Resources (IGG) of the National Research Council of Italy (CNR). She is specialized in mineral CCS, carbonation of ultramafic rocks and serpentinization.

Andrea Dini, Ph.D. in Earth Sciences, is senior researcher at Institute of Geosciences and Earth Resources (IGG) of the National Research Council of Italy (CNR). His main research interest focused on transfer of mass and energy in magmatic-metamorphic-hydrothermal systems.

Andrea Orlando, Institute of Geosciences and Earth Resources, CNR, Firenze (Italy), researcher. PhD in Mineralogy and Petrology, his research is focused on fluid-rock interaction experiments and chemical characterization of solid matrices.

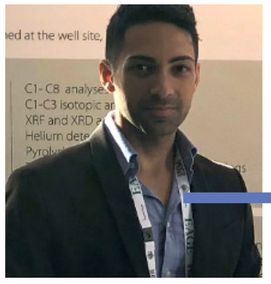
Eugenio Trumpy, Ph.D. in Earth Sciences, is a geologist and works as senior research technologist at Institute of Geosciences and Earth Resources (IGG) of the National Research Council of Italy (CNR). His main research interests include earth sciences digital data management, Geographical Information Systems (GIS), Spatial Data Integration and analysis, 3D geological modelling.



IN SITU EVALUATION OF OIL BIODEGRADATION IN ROCK SAMPLES THROUGH THERMAL EXTRACTION GAS CHROMATOGRAPHY: A CASE STUDY

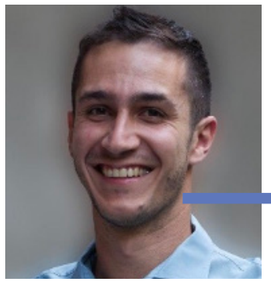
Antonio Bonetti
GEOLOG International

Arjun Tiwari
Cairn Oil & Gas



Placido Franco
GEOLOG Technologies

Kumaran Mahalingam
Cairn Oil & Gas



Luca Mascheroni
GEOLOG Technologies

Gourav Mukhopadhyay

Oil biodegradation determination methods

Early identification during exploration and appraisal of biodegraded oil occurrence and distribution is economically critical: increasing levels of biodegradation strongly impact the quality of oil, lowering API gravity and increasing viscosity with consequent impact on its value and producibility. The required conditions for biodegradation to take place are the presence of microorganisms, substrate (mainly hydrocarbons), nutrients and an oxidizing agent, the timing of hydrocarbon charge and the post-charge temperature history can also have major effects. Optimum conditions often occur at the oil-water contact, but pre-drill predictions are difficult.

The gas-chromatographic fingerprint of oil thermally extracted from reservoir core or cuttings (TE-GC) allows the routine determination of the biodegradation level in as little as two hours from sampling.

Differences in GC peaks distribution can be conveniently correlated to the level of biodegradation, due to the order-of-preference trends in compounds removal as biodegradation progresses. Notably, the straight chain n-alkanes n-C17 and n-C18 are transformed before the branched saturates isoprenoids with similar retention time, i.e., pristane and phytane. The direct measurement of pristane/n-C17 (Pri/n-C17) and phytane/n-C18 (Phy/n-C18) ratios can be used to monitor the degree of biodegradation, as they are low for non-biodegraded oils from most of the depositional environments, and increase in moderate levels of biodegradation. In case of severe biodegradation, the n-alkanes and isoprenoids are equally consumed, so the evaluation relies on the chromatogram shape, with the absence of linear alkanes and an increased unresolved complex mixture (UCM), or on the measurement of multi-ringed biomarker compounds, such as triterpanes and steranes, which tend to be resistant through moderate-to-heavy biodegradation levels.

Geological context

In the Bhagyam Field of the Barmer Basin in Rajasthan, India, the Fatehgarh sandstones have excellent reservoir properties, with porosities of 20-35% and permeabilities reaching 20 Darcy; they produce a medium-gravity waxy crude oil with viscosities of 7-30 cp in the main oil column. The field was developed with waterfloods, but oil productivity was lower than expected, with water-cut rise faster than predicted. The reason could be attributed to adverse mobility ratio, due to the thick biodegraded zone located at the bottom of the oil column (depth below sea level TVDSS 400-448 m), causing a sharp viscosity gradient leading to viscosities over 400 cp near the oil-water contact (OWC).

To better understand Bhagyam productivity performance and provide the operator a tool for prompt decision making in well completion strategies, the characterization of oil quality was pursued in cores and cuttings from several wells, both after drilling and while drilling, with the use of TE-GC.

In situ procedure

Cuttings and core chips were washed with a solution of detergent and water, rinsed with water, dried in oven at 40°C, then ground to obtain a powder with particles of size 125-250 µm. A quartz vial with porous bottom was then filled with the powder (from 50 to 2000 mg, according to different hydrocarbons concentrations) and put into the TE-GC instrument desorber for a 4-min thermal extraction at 330°C in a nitrogen atmosphere; the separation process took then place in the capillary column, with a programmed temperature going from 70°C to 320°C in 35 minutes (Fig. 1). The peaks detected with Flame Ionization Detector (FID) were identified by comparing the retention times with those of analytical standards.

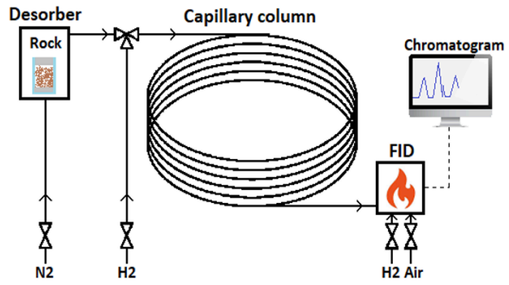


Fig. 1: TE-GC instrumental scheme

The same technology was used to analyze whole oil samples, to compare test oil samples, when available, with the fluid adsorbed on the rock matrix.

After each TE-GC analysis, data post-processing was performed with a proprietary software: chromatograms were baseline-subtracted, signal was normalized with the used sample weight, single peaks were identified, and ratios of interest computed using the height of the peaks (see Fig. above article).

Thanks to the compact size and robustness of the instrument, the described technology could be applied directly at the drilling site, with many advantages: quick decision making regarding well completion; analysis on fresh samples, avoiding alteration due to storage and shipment conditions; overcoming of possible government restrictions in samples export.

A major challenge in the samples analysis was contamination with the drilling fluid: while samples drilled with water-based muds (WBM) did not show the mud signature after the standard washing procedure, the synthetic oil-based muds (SOBM) persistently contaminated the formation oil in the samples. Any removal by organic solvent was not feasible without affecting the target isoprenoids and n-alkanes in the formation oil. In case of an invasive SOBM, with many types of components, including branched alkanes with the same chemical features of pristane and phytane, only the heavier part of the chromatogram, not contaminated, could be assessed, while another SOBM, having a narrow fingerprint, with a few linear alkanes (C14-C18) and no isoprenoids, left room for an evaluation of oil biodegradation: the contaminated n-C17 and n-C18 could be replaced in the ratios with the non-contaminated n-C19 and an approximated biodegradation level could be established.

In order to evaluate the biodegradation degree when no Pri/n-C17 and Phy/n-C18 ratio could be computed due to the severity of biodegradation, the UCM above the blank-level baseline was checked, knowing that, when biodegradation is not heavy, linear alkanes are sharp peaks, while, when biodegradation is heavy, the linear alkanes are low compared to the increased UCM. The ratio between the height of the UCM level and the height of a suitable linear alkane above that level was employed (UCM/n-C19) to translate such a characteristic in a measurable quantity.

Results and conclusion

The biodegradation trend could be assessed with TE-GC in 27 of the 33 wells examined, the exceptions being wells drilled with invasive SOBM without availability of cores, which were less affected by contamination than cuttings. In all the wells, biodegradation was slight or absent in the shallower depths, samples with moderate biodegradation started to appear at 400 m TVDSS and greatly increased in number below 430 m, with the ratio Pri/n-C17 occasionally exceeding 1 and the ratio Phy/n-C18 0.5. All the samples below 445 m showed heavy biodegradation, with the consumption of alkanes as well as isoprenoids, so isoprenoids ratios were not definable (Fig. 2). Around the same depth, oil content in the samples dropped and only few samples had enough oil to determine biodegradation level.

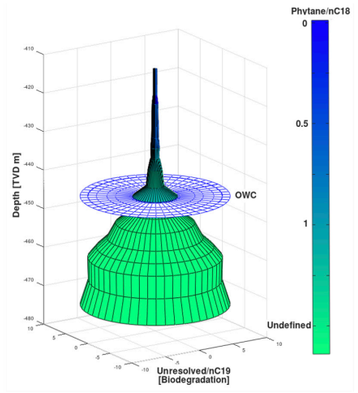


Fig. 2: Biodegradation in the first well of the Bhagyam field, increasing with depth (column width and color code).

The ratio UCM/n-C19 started to be greater than 1 in cores at 442 m TVDSS and all the samples below 445 m had ratios above 1, hinting at the onset of the heavy biodegradation zone.

Pri/Phy ratio stayed in a range between 1.9 and 2.3 throughout the wells and depths, revealing a common depositional environment and paleo-oxygen level for the analyzed samples.

A selection of samples was furtherly analyzed using a laboratory gas chromatography–mass spectrometry (GC-MS) instrumentation, especially samples exhibiting extensive SOBM contamination or severe biodegradation. The measurement of molecular markers that are more resistant to biodegradation and are undetectable through conventional GC-FID techniques, such as triterpanes, allowed to confirm the onsite findings and extend the assessment of biodegradation to more challenging situations.

The ratios made of triterpanes and vicinal n-alkanes, C29-hopane/n-C30 and C30-hopane/n-C31, had a clear correlation with depth, showing an initial slight increase in biodegradation around 410 m TVDSS and an abrupt increase in biodegradation around 440 m.

Overall, the data comparison between the two sets of measurements based on different techniques, TE-GC and GC-MS, showed a good correlation, confirming the suitability and reliability of the TE-GC as fast and cost-effective tool for fluid characterization on-site. Obtained geochemical results were compared also to the viscosity data available from downhole samples of a few wells, confirming the correlation between biodegradation and viscosity.

In conclusion, the Fatehgarh reservoir in the Bhagyam Field exhibited vertical and lateral variations in fluid quality, with significant compositional gradients toward the oil-water contact. Considering the high viscosity of the oil at the bottom of the column and the shallow reservoir in object, it is plausible that mixing between biodegraded and undegraded oil was limited, leaving the deeply altered fluid confined to the close proximities of the oil-water contact.

The changes in fluid quality could be extensive and abrupt; in this context, the TE-GC constitutes an asset, as the assessment of biodegradation can be performed directly at the well site on cuttings, providing quasi-real time information on fluid quality along the whole reservoir profile in a cost-effective manner. This information delivers high value for quick decision making around well completion solutions, enabling intervals showing the onset of heavy biodegradation to be excluded from production and enhancing the planning of future development strategies.

Antonio Bonetti is Domain Expert for organic geochemistry in Geolog International, global operations department. He works on technology validation, analytical instruments performance improvement, adaptation of lab equipment to drilling-site application and data quality check. He holds a MS degree in Energy Engineering from the Politecnico di Milano.

Placido Franco graduated in Organic Chemistry and holds a PhD in Analytical Chemistry, where he specialized in the use of chromatography and mass spectrometry techniques for the analysis and characterization of complex mixtures. He joined Geotech in 2018 with the role of R&D Geochemist, where he is involved in the development of new analytical technologies for field deployment, as well as the application of geochemical methods to reservoir characterization.

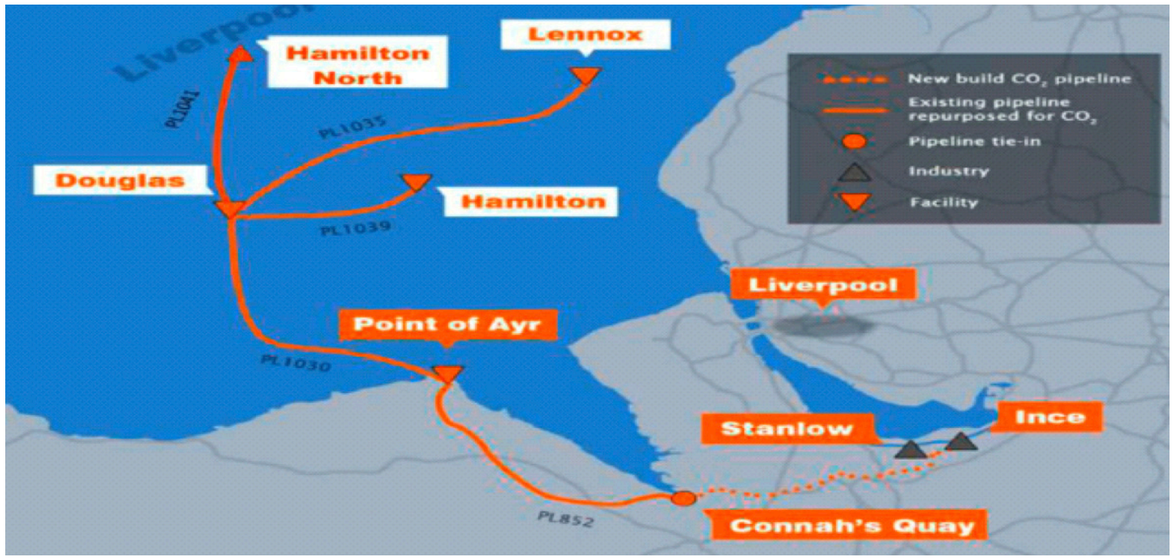
Luca Mascheroni graduated in Material Science at the University of Milano Bicocca. He joined Geolog in 2015 with the role of R&D Chemist and he is currently part of the Geolog Technologies team, where he is involved

in in the development of new analytical technologies for field deployment, as well as the application of geochemical methods to reservoir characterization.

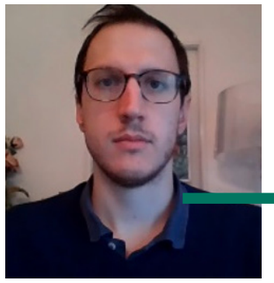
Arjun Tiwari currently working as Lead Geophysicist with Cairn Oil & Gas, Vedanta Ltd. He holds master's degree in Applied Geophysics from IIT (ISM), Dhanbad and working with Cairn since 2011. Having acquired solid technical capabilities his focus area includes Seismic Interpretation, Structural Modeling, Velocity Modeling, Rock Physics, Reservoir Characterization (QI), Seismic Inversion, Well Planning & Drilling.

Kumaran Mahalingam is a graduate in Geology from Presidency College, Chennai, India. He works as Operations Geologist, providing lead to a team of well-site geologists, with responsibility for day-to-day management of drilling activities, formation evaluation plans of drilling campaign and supervision of data acquisition.

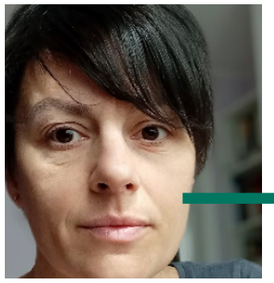
Gourav Mukhopadhyay is a M.Sc. in Applied Geology from IIT-Roorkee and has over 11 years of experience in the Oil & Gas industry. He started his career in Essar Oil and has been associated with Cairn Oil & Gas since 2013. As a technical professional he has expertise in wellsite/operations geology, 2D/3D seismic data interpretation, reservoir characterization and modelling, quantification of subsurface uncertainties, risk mitigation and managing well placement operations. Since 2015, he is working as a Development Geologist and Geomodeller in several development fields of Barmer Basin.



LIVERPOOL BAY AREA CCS PROJECT: INTEGRATED RESERVOIR STUDY FOR A SUCCESSFUL CO2 STORAGE PLANNING



Guglielmo Luigi D. Facchi
Eni S.p.A.



Rosa Altea
Eni S.p.A.

Alberto Di Lullo
Eni S.p.A.

Marco Brignoli
Eni S.p.A.

Stefano Baffi
Eni UK

Ahmed Mohamed Sadek Elgendy
Eni S.p.A.

Introduction

CCS projects have stepped onto the stage in the last decades as one of the most promising technique to contain CO2 atmospheric emission.

The selection of storage candidates has looked for deep saline formation (i.e. aquifer) to secure the storage of high quantities of carbon dioxide due to their large storage capacities (Sleipner). Nevertheless, depleted gas reservoirs have the potential to become a much more viable alternative, albeit a lower storage capacity.

Their strength lies within the major advantages coming, mainly, from their primary exploitation phase: extended geological characterization, knowledge of reservoir dynamics, acquaintance of seal presence and characterization, together with existing infrastructure that can be re-used or re-purposed for CO2 injection. For the assets in the Liverpool Bay Area (LBA) the mass balance evaluation depicts a significant storage capacity.

This, aided by the extensive knowledge coming from 20+ years of production history, has driven all the activity to assess properly the effect of injecting CO2 within three depleted reservoirs.

Reservoir modeling

Developing a reliable predictive tool to assess CO2 plume propagation demands a decent data coverage of the Area of Interest (AOI) running with a proper knowledge of the dynamics of the injected fluid.

Henceforth, three reservoir models have been constructed, each one with its own grid, with higher resolution compared to the standard one deployed for the cultivation phase. In addition, compositional simulation is the most appropriate approach to better track the plume evolution.

The three reservoirs are within the same geological formation (Ormskirk Sandstone, Sherwood Group) characterized by high-quality petrophysical properties (medium-high average porosities, high average permeabilities). The primary seal is provided by the overlaying Mudstone (Ansdell) with a secondary coverage given by Halite layers.

The history matching of the three reservoirs, done in Intersect (IX), had the focus of honoring the main production phase, with the validation of the associated hydrocarbon production and pressure data. Having set the numbers for the capacity evaluation, forecasting the simultaneous injection in three reservoir demands the construction of a coupled model.

Due to the peculiarities of the three fields (low-P and low-T) and the saturating fluid, the construction of the coupled model required an external software to handle the partition of the project injection stream among the three sites.

Eight (8) dedicated injectors, drilled as sidetrack of the existing wells, are capable to accommodate the base case profile, with flowing pressures being below the virgin ones. These results (rates, pressures) provide the basis for a wide range of ancillary activities to evaluate any additional constraint that might arise, due to the selected scenario, generating an update of the coupled model in a closed loop form.

Specialistic Studies

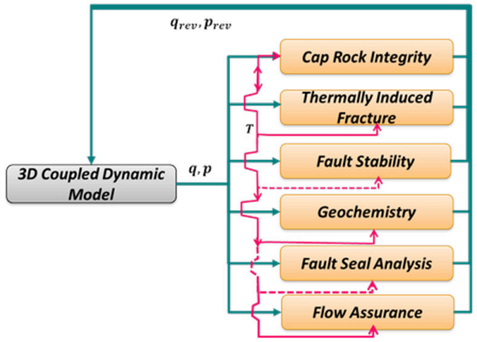


Fig 1. Specialistic Studies Workflow

To ensure the containment during and after the injection operation, having a series of reservoir models is not sufficient. Fig 1 portraits the closed-loop workflow aiming in identifying additional constraints arising from the selected injection scenario.

While dealing with CO2 injection, the mechanical integrity is crucial to ensure that no additional escape route creates due to failure of either the caprock (via Cap-Rock integrity studies) or the formation due to undesired strength loss, either mechanical or thermal (i.e Thermal Induced Fracturing). As injection proceeds, the stability of the fault system is analyzed (via Fault Stability and Fault Seal studies) to determine the state of stress evolution as injection proceeds.

Moreover, being CO2 a highly reactive fluid, geochemical effects on formation properties and integrity are dragged into the loop to quantify the main chemical phenomena (i.e. reaction) and their impact on the formation petrophysical properties. As stated, thermal effects are non-negligible due to the different thermodynamic properties of CO2 compared to the other hydrocarbon Gases, henceforth Temperature dependencies are tackled within a separate loop, as Fig 1 depicts.

This dependence is investigated across the whole ensemble of specialistic studies, with the Flow Assurance playing an important role to ensure the transport from onshore emitters to the storage sites. The specialistic studies took advantage of an extensive experimental characterization, both geomechanical and geochemical.

The first one allowed the determination of the rock-strength parameters, fundamental for the construction of the 1D model for cap-rock integrity, as well as the computation of the failure mode used in the Thermally Induced Fracture (TIF) and Fault Stability modeling.

The experimentally-derived figures, coupled with the usage of state-of-the art simulator, have led to the determination of minimum risk for Cap-Rock Integrity, with reservoir envelope being below the caprock one, and negligible risk of Thermally induced fractures being the hoop effective stress (σ'_ϑ) till positive across the whole project lifespan, with the cooled region extending within the first 100 m around each well.

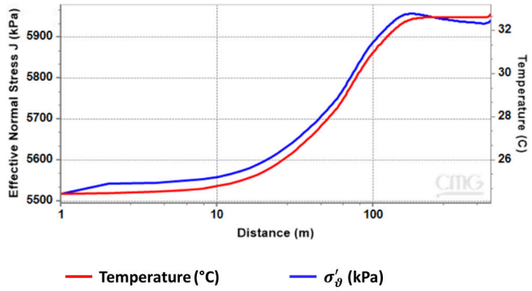


Fig 2. Thermally induced fracture outcome

The Fault Stability study, run on the three reservoir models and across 40+ faults starting from the cultivation phase, has shown that no instabilities occur across the whole project life, deeming the injection scenario feasible being the Slip Tendency (ST) lower than the friction coefficient (μ)

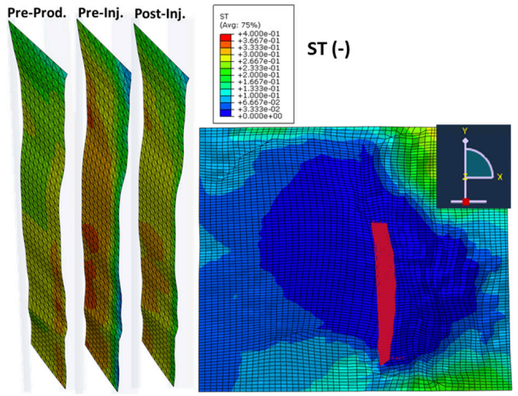


Fig 3. Fault Stability study outcome: Slip Tendency (left), Fault map (right)

Laying a solid geochemistry background helps in understanding how injectivity might evolve with CO2 injection occurring. The Experimental characterization involved several techniques, namely Scanning Electron Microscopy (SEM) with Energy Dispersive System (EDS), X-Ray Diffraction (XRD) and X-Ray Fluorescence (XRF), returned the detailed mineralogical-chemical description of the three reservoir formations. SEM-EDS, the basis of the quantitative mineralogical analysis, permitted the stoichiometry characterization of the site-specific minerals, as well as the determination of their thermo-chemical parameters. With a proprietary-developed workflow, coupling experimental analysis with numerical modeling, highlighted that the overall reactivity of the system is generally low, with Halite Precipitation and Water Vaporization phenomena overrunning the chemical reaction occurring during CO2 injection. Halite precipitation phenomena may alter injectivity leading to a reduction of the overall well efficiency. Using the geochemical data, as well as the formation water characterization, three near-wellbore numerical model have been constructed to evaluate the halite front extension and the impact on the petrophysical properties. Injecting the rate as per project specific, the halite precipitation front extends up to the first 100 m of the well (influenced by rates, temperatures, and initial water salinity), with minimal impact of the petrophysical properties.

The Flow Assurance studies play an essential role in delivering the CO2 designed to the three depleted reservoirs, with a careful design of the necessary equipment. Thermal effects are fully considered across the whole injection network, with computed temperatures used to better constraint the non-isothermal modeling activity. At present day, the whole system can operate in single phase up to a certain reservoir pressure, with multi-phase flow regime being object of a dedicated analysis.

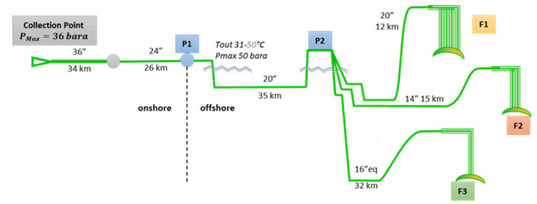


Fig 4 Injection Network Schematic with key nodes (P1, P2)

Conclusions

An integrated methodology has been developed to analyse the CO2 injection dynamics of the three fields involved in the LBA CCS project, breaking down all the elements that act concurrently with the injection dynamics and that may pose obstacles to the well injection and to the storage integrity.

The reservoir simulation provides the base for a closed loop iteration workflow, in which specialistic activities (namely geomechanics, geochemistry and flow assurance) provide their own constraints to the reservoir model. For the base scenario, the specialistic studies highlighted no additional constraint, thus validating in full the base case profile.

Alberto Di Lullo is currently “Senior Knowledge Owner for Advanced Engineering Systems and Troubleshooting” in Eni SpA and is mostly involved in decarbonization efforts, both regarding CCS and Hydrogen projects. He is a Physicist and works in Eni since 1991.

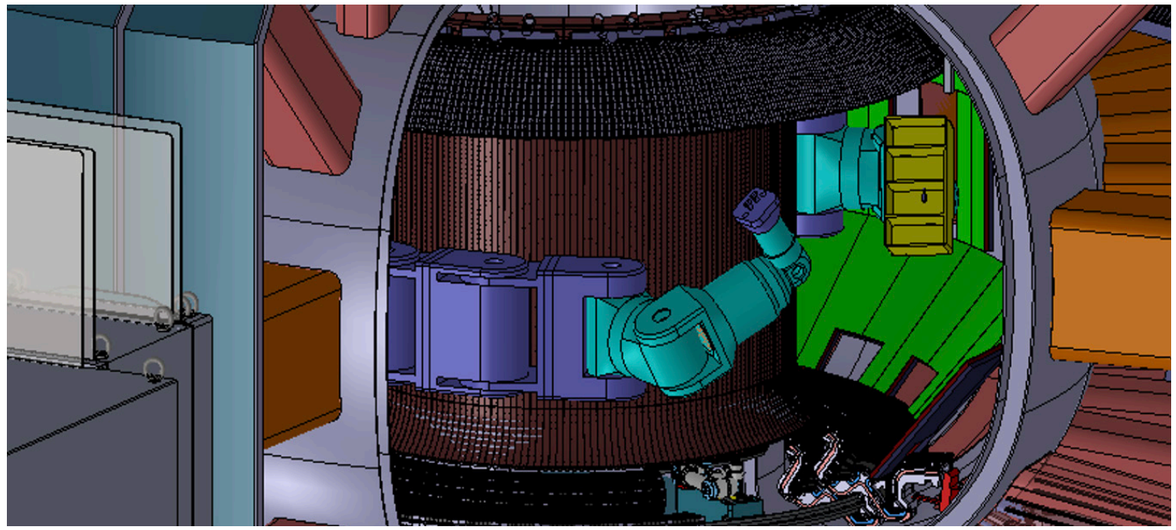
Stefano Baffi degree in Geology and MSc in Geophysics, 22 years’ experience both in exploration and development geosciences. Joined Eni in 2012 as Senior Geoscientist in Eni UK exploration department. Currently working on Carbon storage and transition energy projects.

Rosa Atena is a senior reservoir geologist, working in Eni since 2002. She has been involved in reservoir studies activities in HQ and subsidiaries (USA, Egypt) She also acquired operational knowledge during the working activity in Ravenna Eni Operational District. In the last three years she has been working as coordinator for reservoir activities in CCS projects and tutorship of university students.

Guglielmo Luigi Daniele Facchi is a physicist by background, working in Eni since 2015. He has been involved in reservoir studies activities in HQ (Congo). As Senior Reservoir Engineer, he has been involved in CCS projects from the reservoir and geomechanics standpoint and tutorship of university students.

Marco Brignoli is a physicist by background, currently working in the Eni reservoir department as activity manager for geomechanical characterization and modelling. Always involved in geomechanics issues since joining Eni, his present activity includes support both to traditional geomechanics studies and to the ones related to injection/disposal and CCS projects as well as support to hydrogen and geothermal related activities.

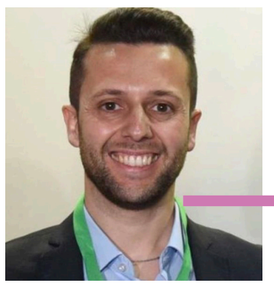
Ahmed Mohamed Sadek Elgendy has a B.Sc. in chemical engineering from Suez university and a Holder of a M.Sc. in petroleum engineering from Politecnico di Torino. He worked for APACHE corporation for 2 years as a production/petroleum engineer. He has joined Eni in October, 2018 and since then he has been working on subsurface modelling of CCUS/UHS processes with a dedicated focus on development of coupling approaches among multi-phase flow, biogeochemical reactions and geomechanics in both thermal and iso-thermal environments.



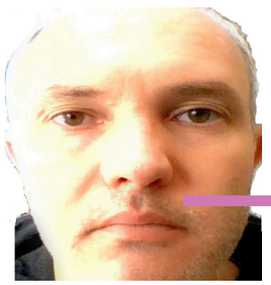
REMOTE HANDLING SYSTEM FOR THE DTT FUSION REACTOR: A SYSTEM ENGINEERING APPROACH FOR PRELIMINARY CONCEPTUAL DESIGN OF THE MAIN ROBOTIC EQUIPMENT

Clemente Lauretti
Eniprogetti S.p.A.

Tiberio Grasso
Eniprogetti S.p.A.

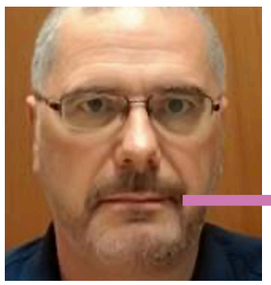


Stanislao Grazioso
Università Federico II Napoli



Dennis Indrigo
Eniprogetti S.p.A.

Eliana De Marchi
Eni SPA

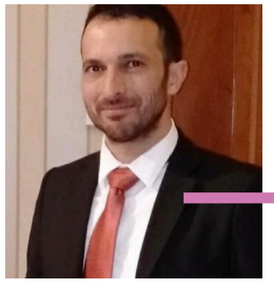


Mauro Favaretto
Eniprogetti S.p.A.

Domenico Marzullo
Università degli Studi di Trieste

Gioacchino Micciché
ENEA

Miriam Parisi
Eni SpA



Andrea Reale
ENEA

Giuseppe Di Gironimo
Università Federico II di Napoli

Introduction

Nuclear fusion has an excellent growth prospect in the field of new energy. Studies on this renewable energy source, which began in the 1950s, involve all the most technologically advanced countries (Europe, Japan, USA, Russia, China, Korea and India). These countries in an international collaboration are concentrating their efforts on a joint program aimed at the realization of the experimental fusion reactor ITER [1] .

ENEA, from Frascati and Brasimone Italy, is actively participating in this project and is contributing to the design of many components that will be used in ITER. It is currently carrying out, together with Eni, CREATE consortium, INFN, RFX consortium, Politecnico di Torino, Università della Tuscia, Università di Milano Bicocca and Università di Roma Tor Vergata, a project called Divertor Tokamak Test (DTT) which has the ambition to try new different configurations and materials for the divertor, in order to optimize the shape of the field lines and facilitate the dissipation of heat [2] . The main objectives of the DTT project can be summarized as: i) testing alternative divertor solutions and ii) improving experimental knowledge in the scientific area of heat discharge for parameter ranges that cannot be addressed by current devices.

The possibility to change divertors plays a critical role in the design and operations of the Tokamak plant and is a key element for demonstrating the long-term feasibility of fusion as an energy source. Moreover, due to erosion of the plasma-facing surfaces of modules, and their refurbishment in a dedicated storage (e.g. a hot room) can be foreseen sometimes during the machine lifetime. Due to the complexity of such replacement operations and the harsh environment conditions in which they are performed (e.g. high radiation levels and thigh spaces), a Remote Handling System (RHS) that addresses all of these remote operations that are not directly feasible for humans is required.

This work builds on previous works which have defined the RHS strategies for the main in-vessel components of DTT [3] . The several design alternatives proposed have been evaluated with respect to multiple criteria by a group of experts involving people from different European Institutions working on RH for nuclear fusion reactors [4] .The current baseline for Divertor RH is based on installation/replacement through four lower lateral ports of DTT machine. While the Outboard and Top First Wall modules are expected to be installed/replaced through four equatorial ports and the Inboard First Wall modules will be installed/replaced through the upper ports.

The scope of this work is to describe the iterative process based on a system engineering approach which is driving the preliminary conceptual design of the main RH equipment for the installation and replacement of Divertor cassettes and Outboard and Top First Wall modules. This approach consists of 5 phases, that are described in detail in the following. They are:

- User needs identification and functional analysis
- Background evaluation and gap analysis
- Logical Architecture definition
- Technical Requirements identification
- Preliminary Conceptual Design

User needs

During the machine operational functioning, in-vessel components, like first wall and divertor cassettes, i) work under extreme environment conditions (i.e. high temperature and radiation levels), ii) directly interact with neutron that get out of the magnetic field control and iii) are continuously subject to high heat fluxes that degrade materials properties.

Therefore, due to erosion of the plasma-facing surfaces, the removal of the in-vessel components and their refurbishment in a dedicated storage (e.g. a hot room) are foreseen a few times during the machine lifetime. Moreover, the possible need for testing different configurations and materials for the divertor cassette (that is the ultimate goal of the DTT project) may even increase the times its replacement is required in the period of the machine running. The replacement of the divertor cassettes as well as the first wall modules are therefore the main activities to be performed during the DTT remote maintenance and, due to environmental constraints imposed by the DTT project, can be achieved only by means of a suitable remote handling system.

Background and gap analysis

To fulfil above mentioned operations, the RH equipment must include subsystems for mobility, manipulation, tooling, sensing, and human-machine interfacing. Since during these maintenance operations, not all the peripheral areas of the reactor, like ports and ducts, are accessible for remote handling systems, RH equipment shall be carried inside the vessel by means of purposely designed transportation systems. In the literature, Remote Handling systems that are used to handle high loads in toroidal reactors, depending on the transportation system they are equipped with, are divided into two main groups. The former, is based on rail transportation systems [5] . The latter is grounded on the use of hyper-redundant articulated robotic arms [6] . Scope of the background evaluation phase and gap analysis was to investigate applicability of these technologies to the DTT RH project. From this analysis emerged that there were the conditions to adapt such approaches to the DTT purposes. Hence, important changes to the design of such devices have been made to comply with strict requirements imposed by DTT project.

RHS Logical Architecture

Therefore, the remote handling system that was conceived to meet user needs and carry out previously mentioned operations, is partly inspired by the literature analysis and is based on a combined use of both hyper-redundant manipulators and rail-based systems.

According to the DTT RHS Logical Architecture coming from the identification of the user needs and the literature analysis, the conceived remote handling system was divided into two main subsystems (a third subsystem concerning the Inboard First Wall modules is not part of this work). They are called in the following Divertor Handling Sub-system and Outboard and Top First Wall Handling Sub-system. The former, includes all the robotic devices for divertor cassette remote handling, namely two components called Cassette Multifunctional Mover (CMM) and the Cassette Toroidal Mover (CTM) [3] . The latter is composed of the main robotic devices to be adopted for Outboard and Top First Wall remote handling, named in the following Hyper Redundant Manipulators (HyRMan) [3] .

Main technical requirements and design concepts of these subsystems are provided in the following.

Technical Requirements

Some of the Functional, Environmental and Operational requirements taken into account for divertor handling preliminary conceptual design, are reported below. These requirements are evolutions of requirements presented in [3] and refer to May 2021 state of DTT project.

1. The system shall be dimensioned to withstand loads of about 400 kg, (i.e. the weight of the heaviest in-vessel component), in its worsen configuration.
2. The system end-effectors shall be able to move, while handling their maximum payload, at a velocity of 2 mm/s, for translation and 1 deg/s for rotation
3. The system shall be dimensioned to fit tokamak ports and not interfere with other in-vessel components, e.g. cooling pipes
4. The system shall be dimensioned such that to guarantee reachability of grip interface placed on in-vessel modules, with adequate dexterity
5. The system shall be dimensioned such as to guarantee adequate reachability and dexterity for performing all the service tasks envisaged in the DTT remote maintenance
6. An accuracy better than ±2 mm for translation and ±1 deg for rotation (in the task space), shall be guaranteed, while handling the maximum payload

Preliminary Conceptual Design

Technical Requirements, partly reported in previous section, have been used to preliminary design concepts of main RHS subsystems, i.e. Divertor Handling System and First Wall Handling System.

a) Divertor Handling Sub-system

The Divertor Handling System has the primary goal of handling divertor cassettes inside the vessel. There are two kinds of cassettes: those visible from the access port, also called Central Cassette (CC), Second Right Cassette (RC) and Second Left Cassette (LC) and those not directly accessible from access port, named Standard cassettes (STDC).

CC, RC and LC will be removed/installed with a robotic platform, included in the Divertor Handling S/S, that is able to move along the port 4 duct namely the Cassette Multifunctional Mover (CMM). Conversely, STDC, being not directly accessible by CMM, make it necessary to use an additional robotic device able to move along the toroidal direction and transport STDC to the access port. This device, named Cassette Toroidal Mover (CTM), makes use of CMM to move to/from VV internal volume. Both the systems are provided with a 6 DoF service manipulation system aimed at performing all the auxiliary operations envisaged in the divertor cassette maintenance mentioned in the previous sections.

b) Outboard and Top First Wall Handling Sub-system

The Outboard and Top First Wall Handling System is a robotic platform whose primary goal is to handle first wall modules inside the vessel. The system preliminary concept is presented in [3], and is composed of two Hyper Redundant Manipulators, named in the following HyRMan 1 and 2. HyRMan2 is provided with a Service Toolbox, namely a box shelf aimed at storing the set of useful tools used by the HyRMan1 to perform envisaged operations like, FW handling, screwing/unscrewing, bolting/unbolting, inspection and auxiliary operations like metrology and

dust removal. From a kinematic point of view, both manipulators are provided with two stand-alone kinematic chains, namely a dexterous end-effector manipulator (aimed at performing the fine manipulation tasks inside the vessel) and a planar arm that has the function of carrying the dexterous end-effector manipulator and tools from the outside to the inside of the vessel and vice versa. The dexterous end-effector manipulator is provided with 7 DoFs (RRRPRRR). At the contrary, the planar manipulator is provided with a prismatic joint (for movements along the port duct) and five rotative joints with parallel axes (for movements in the toroidal direction).

Conclusions

Compliance of the proposed systems with the user and technical requirements, identified in the design process, have been preliminary verified in simulation. In particular, static force analysis has been performed on critical sub-systems of the RH equipment, i.e. the ones that are intended to handle the heavy loads of the in-vessel modules such as the CMM, CTM and HyRMan. This analysis has been carried out in the sub-systems worsen configuration with the maximum payload. The output of the analysis, i.e. torques and forces acting on the subsystem structure at joints level, have been used to perform a market scouting on relevant components of the system, such as actuators, bearings, brakes etc., that meet performance requirements and withstand to the estimated force/torques. Final assessment has been performed on the sub-systems overall encumbrance, by verifying that the system dimension, after integration of commercial and ad-hoc designed components, meet constraints imposed by the vessel geometry. Additionally, the ability of the conceived systems to reach and manipulate objects inside the vessel has been evaluated. This evaluation was done by analysing the system reachable and dexterous workspaces and identifying good and bad regions for manipulation. Future works will be mainly addressed to: i) conduct flexibility analysis of the manipulators; ii) simulate in virtual environment the sequence of operations delegated to the RH System in general, and iii) start the basic and detailed design of the conceived system.

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Clemente Lauretti graduated in Biomedical Engineering at the Campus Bio-Medico University of Rome in October 2015; he obtained the title of PhD in Bio-engineering and Bio-Science in 2019 and currently works in the Robotics and Innovative Automation Systems unit at Eniprogetti SpA, dealing with tele-operated robotics for harsh environments.

Stanislao Grazioso is a researcher at the Department of Industrial Engineering, University of Naples Federico II. His research interests include soft robotics, modeling and control of flexible systems, robotic inspection and maintenance. He is the recipient of the 2019 Georges Giralt PhD Award.

Eliana De Marchi has been appointed as Head the Eni Magnetic Fusion Energy Dept. since its creation in 2018 and as part of the Divertor Tokamak Test Facility Team she is in charge of Innovative Technologies Valorization. She has more than ten years' experience as project manager in R&D and Innovative Project Department. Since she joined Eni group, she has always been deeply involved in novel technology validation, coordinating activities for innovative solution development and deployment, such as robotics for subsea and space application, advanced autonomous control systems up, marine renewable energy systems and their integration in offshore areas.

Tiberio Grasso graduated in Electronic Engineering in 1989 and joined Tecnomare SpA in 1991, where he immediately dealt with advanced robotics for hostile environments, mainly in the underwater field. He became head of the Robotics unit in 2000 and gained experience in underwater, terrestrial and space robotics, on manipulation and sensory systems. From 2007 he coordinates activities dealing with the design and development of robotic systems for Oil & Gas facilities and renewable energy sources.

Dennis Indrigo got the bachelor's degree in mechanical engineering in 2000 at Padua University, , He joined Eniprogetti in 2002 in the Research and development department. He is involved in robotic projects for space applications in collaboration with ESA and ASI, and in deep water autonomous vehicle design as well as in bore diagnostic tool for Oil and Gas industry. He is currently involved in the design of RH system for DTT fusion reactor.

Mauro Favaretto is an engineer with 20+ years' experience in research projects management and development, including remote handling systems for hostile environments, virtual reality systems and innovative tools for O&G operations.

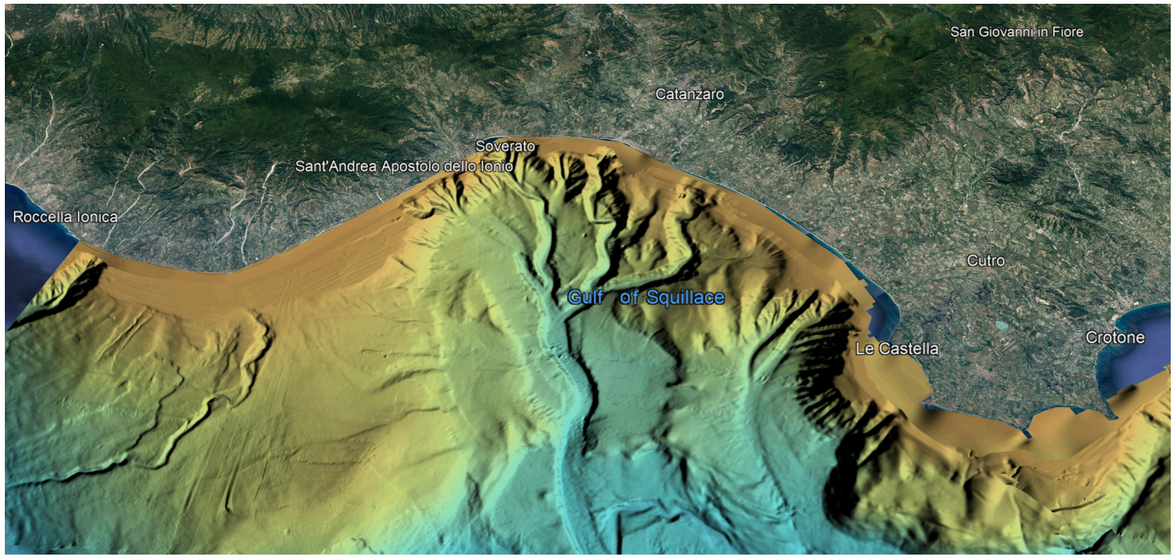
Domenico Marzullo received his master's degree in mechanical engineering (cum laude) from University of Naples Federico II in 2013. During his studies, he worked at the VTT Technical Research Centre of Finland as research trainee. In 2016 he got an Eurofusion Engineering Grant focused on the design and analyses of advanced divertor configurations for nuclear fusion tokamak reactors. Currently, he is Associate Professor at University of Trieste. His research activities focus on fusion technology, in particular on Systems Engineering approach and mechanical design of Tokamak machines (ITER and DEMO).

Gioacchino Micciché got the Diploma in Information Technology and Automation Engineering (University of Bologna 2000) and the bachelor's degree in Information Technology Engineering (University of Bologna2003). Since 2005 he covered the position of deputy of the European system group for the lithium Target Facility of IFMIF and from 2010 the position of European system group leader of the Lithium target facility in the ambit of the Broader Approach agreement. Currently, he is the coordinator of the RH activities for the maintenance of the European Early Neutron Source (ENS) and Project leader of the RH maintenance WPDIV IDTT in EUROFusion

Miriam Parisi received the master's degree in Nuclear Engineering in 2017 from La Sapienza university of Rome. She has two years of consulting experience for ENI (San Donato Milanese and Venice) following R&D drilling project in the first year and R&D Magnetic fusion project in the second one. Hired by ENI in March 2020, she was involved in the Magnetic Fusion research pro jects to deal safety, radioprotection and neutronics aspects in collaboration with ENEA, CNR, and CFS-MIT.

Andrea Reale graduated in Computer Engineering (Programming and Security). From 2002 to 2006 he collaborated with two robotics teams of the University of Rome "Sapienza" SPQR and ALCOR, participating with both in international competitions. He also worked in the aerospace sector for the development of the accelerometer on the Bepicolombo satellite. In 2010 he started working in ENEA, dealing with non-destructive checks on the ITER divertor and remote handling for FTU. He secured two patents as first inventor, one concerning a scanning technique for Divertor, the other concerning a new method of measuring gravitational gradients. Starting from February 2021, I am coordinator of Remote Handling activities in DTT.

Giuseppe Di Gironimo is Head of Mechanical Design Unit at CREATE Consortium, Head of VR Lab "MARTE" and Motion Analysis Lab "ERGOS" at Univ. of Naples Fed II, Responsible for CREATE/University of Naples of several WP in European projects on Fusion Energy (EUROFusion) covering the area of mechanical design and remote maintenance technologies, Head of Mechanical Design Unit and member of the Scientific Board of CREATE Consortium (www.create.unina.it). He was member of the Scientific Board, Responsible for Global Mechanical Integration and Leader of the WP Remote Handling System of the "Divertor Tokamak Test facility" (DTT) (www.dtt-project.enea.it/), co-funded by EUROfusion.



GEOHAZARD-RELATED GEOMORPHIC FEATURES IN THE CROTONE-SPARTIVENTO BASIN (SOUTHERN ITALY): THE EXPRESSION OF CALABRIAN ARC KINEMATICS

Giacomo Mangano, Silvia Ceramicola, Massimo Zecchin, Giuseppe Brancatelli, National Institute of Oceanography and Experimental Geophysics – OGS, Salvatore Critelli, University of Calabria

Giacomo Mangano
Cardiff University (UK)

Giuseppe Brancatelli
OGS

Silvia Ceramicola

Salvatore Critelli
University of Calabria

Massimo Zecchin
OGS

Introduction

A better understanding of geological processes driving marine geohazard-related geomorphic features such as failures, canyon headscarps and mega-mass transport deposits is an important issue that requires particular attention for the safeguard of coastal population and infrastructures. Various studies revealed that compressional tectonics is considered as a predisposing factor for downslope mass-transport processes. The oversteepening resulted from folding and uplift makes tectonically-controlled slopes potential sites for the development of slide scars and canyon incisions (Pratson and Haxby, 1996, Peters and Van Balen, 2007; Casalbore et al., 2019). The Crotone (CS) and Punta Stilo (PSS) swells are two lobate-shaped submerged promontories with steeply-inclined flanks (up to 11°) and are located in the Crotone-Spartivento Basin (CSB) (Calabria region) (Fig. 1a,b,c). The CS corresponds to the downdip compressional domain of a large-scale gravitational collapse that has been involving the N sector of the CSB since Zanclean; it may be seen as a mega-mass-transport deposit and shows signs of activity at present (Fig. 1b) (Minelli et al., 2013; Guerricchio, 2015; Zecchin et al., 2018; Mangano et al., 2020). Conversely, the origin of the PSS, which is marked by slide scars and canyon incisions (Chiocci and Ridente, 2011; Ceramicola et al., 2014a and b; 2015; Candoni, 2018), is still unknown (Fig. 1c). The goal of this work is to investigate the geological processes that may have acted as predisposing factors for the onset of slope instability, expressed in the form of the CS, slide scars and canyon incisions, and that may have driven the evolution of the current seabed morphology along the PSS. In order to achieve this goal, a large dataset consisting of high-resolution multibeam echosounder (HR-MBES), high- and low-resolution 2D multichannel seismic reflection profiles, and well logs has been used. HR-MBES data were interpreted to map seabed morphology and geomorphic features indicative of geohazard, such as slide scars, canyon incisions and mass-transport deposits; high-resolution 2D seismic data were used to assess seismo-stratigraphic units involved by slope instability, whereas the low-resolution 2D seismic data were used to evaluate the deep-buried tectonic structures. Seismic interpretation was based on the recognition of seismic pattern such as seismic terminations, seismic facies and seismic units, and calibrated with well logs. The integration of a dense network of data at different resolution available for this study was key to search for a possible link between tectonics and the observed geohazard-related geomorphic features. This work intends to provide a significant assist to coastal management and safety for the Calabria region, a very active geodynamic area, where seabed instability phenomena have occurred repeatedly (Ceramicola 2014a and b, Candoni, 2018) and are considered to pose a serious threat to marine and coastal infrastructures.

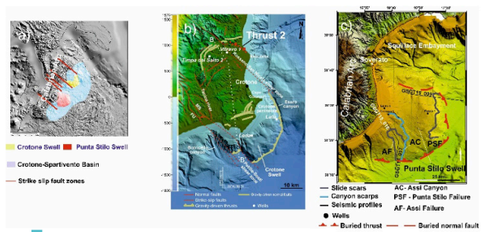


Fig. 1. a) DTM showing the location of the CS and PSS, inside the CSB. b) DTM displaying the area affected by the mega-landslide, resulting in the CS in the offshore sector. c) DTM highlighting the position of geohazard-related geomorphic features along the PSS and position of 2D seismic profiles. DTM from MAGIC Project and Regione Calabria (modified from Ceramicola et al., 2015).

Geological setting

The CSB is a fore-arc depocenter located on the Ionian side of the Calabrian region and was generated in the framework of the SE-ward migration of the Calabrian Arc (CA) (Fig. 1a). Its evolution records phases of extensional/transtensional tectonics, concomitant with the opening of the back-arc sub-basin in the Thyrrenyan Sea, and phases of compressional/transpressional tectonics, associated with a temporary collision between the CA and the adjacent plates. The SE-ward migration of the Calabrian Arc was also accompanied by the development of NW-trending strike-slip faults, namely the Rossano-San Nicola (RSSZ) and Petilia-Sosti (PSSZ) shear zones (Fig.1a). The latter played a key role in the basin evolution (Roda, 1964; Malinvero and Ryan, 1986; Kastens et al., 1988; Patacca and Scandone, 2001; Sartori, 1990; Patacca et al., 1990; Van Dijk, 1990, 1991; Van Dijk and Okkes, 1991;;Mazzoli and Helman, 1994; Van Dijk, 1994; Van Dijk and Scheepers, 1995; Faccenna et al, 2001; Massari et al., 2010; Zecchin et al.; 2012; Massari and Prosser, 2013; Zecchin et al.; 2015; 2020).

The two submerged prominent curve-shaped morphological highs, the so-called CS and PSS, are located just south of the Crotone city and the Squillace Embayment, respectively (Fig. 1a,b,c). The PSS is also marked by two slope failure, that are the Assi Failure (AF) and Punta Stilo Failure (PSF) and by an isolated canyon, known as Assi Canyon, in its both southern and eastern slope setting (Fig. 1c) (Ceramicola et al 2014 a and b; Candoni, 2018).

Results

Current data reveal that the CS is the offshore counterpart of an on-land extensional updip domain, that is made up of a NNE- and E-oriented seaward-dipping listric fault set (Fig. 1c) (Zecchin et al., 2018; Mangano et al., 2020). This fault set is inferred to be the outcropping expression of a buried seaward-immerging listric fault, that is seen to crosscut a N-ward-dipping reverse fault and the concave-down Mid-Pliocene Unconformity (MPCU) (Fig. 2a,b). This buried seaward-immerging listric fault is inferred to be the basal detachment surface of the large-scale gravitational collapse and to connect seawards to the CS. The N-ward-dipping reverse fault is supposed to be a component of a NW-trending thrust, in turn believed to be linked to a NW-tending positive flower structure belonging the RSSZ. The mid-Pliocene Calabrian Arc kinematics-related (Fabbri et al., 1982; Van Dijk, 1991; Van Dijk and Scheepers, 1995; Doglioni et al., 1996; Gueguen et al., 1998; Sartori, 2003; Praeg et al., 2009; Zecchin et al., 2012; 2020; Massari and Prosser, 2013) compressional/transpressional activity of such positive structure is not excluded to have increased the slope gradient and promoted the inception of large scale gravitational collapses, resulting in the CS. The PSS Chiocci and Ridente, 2011; Ceramicola et al., 2014a and b; 2015) shows a prominent lobate morphology and its seismo-stratigraphic succession is composed of various units of Serravallian to Pleistocene age (Fig. 2c,d). Our observations reveal that the PSS is the reflection of the Messinian compressional tectonics. Such tectonic phase is linked to a temporary pause of Calabrian Arc migration and caused the formation of the Upper Messinian Unconformity (UMU) (Massari and Prosser

2013). The UMU is observed to be folded, to truncate the underlying units of older ages and to be sealed by the Plio-Pleistocene succession. The accumulation of the Plio-Pleistocene succession drove the distribution of the present-day seafloor, which seems to show a geometrical trend nearly compatible with that exhibited by the UMU (Fig. 2b,c). The seafloor of the PSS is also characterized by the occurrence of slide scars and canyon incisions in correspondence of the southern and eastern slope setting (Fig. 1a,b,c) (Chiocci and Ridente, 2011; Ceramicola et al., 2014a and b; 2015; Candoni, 2018). Such geomorphic features seem to affect PL2 and PL3 units; no evidence of slope instability events are recorded inside pre-dating mid-Pliocene units (Fig. 3a,b).

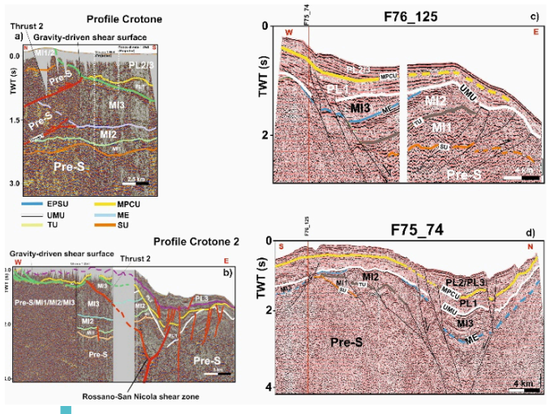


Fig. 2. a) and b) Low-resolution 2D seismics (from ENI and VIDEPI) showing the buried basal detachement surface of the large-scale gravitational collapse, which crosscut a positive flower structure and the MPCU. c) and d) Low-resolution 2D seismic highlighting the deep-buried tectonic structures that conferred the present-day morphology of the PSS.

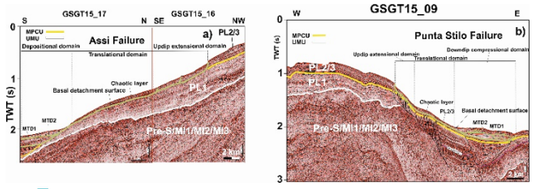


Fig. 3. High-resolution 2D seismics (from RITMARE) showing seismo-stratigraphic units affected by slope failures, the so-called AF (a) and PSF (b).

The compressional Messinian tectonics is likely to have conferred a marked steepness to the swell and let the site prone to slope instability probably since late Pliocene.

Conclusions

In conclusion, we infer that the origin of the morphological highs, namely the CS and PSS, as well as the slide scars and canyon incisions indicative of geohazard inside the CSB, are closely related to the Calabrian Arc kinematics.

The CS is inferred to be the consequence of the mid-Pliocene RSSZ activity-linked compressional/transpressional event. The latter is supposed to have created uplift and promoted the onset of a large-scale slope failure, manifested by the evolution of the swell itself in the offshore area. At a regional-scale, the mid-Pliocene tectonic phase might be related to a temporary pause of the arc migration, due to the convergence between the Calabrian accretionary system and the continental crust of the Apulian margin (Fabbri et al., 1982; Van Dijk, 1991; Van Dijk and Scheepers, 1995; Doglioni et al., 1996; Gueguen et al., 1998; Sartori, 2003; Praeg et al., 2009), concurrently to a temporary spreading interruption or slowdown in the Tyrrenyan back-arc basin (Zecchin et al., 2012; 2020).

Conversely, the PSS is believed to be the effect of the compressional Messinian tectonics. The compressional phase-associated unconformity is supposed to have conditioned the accumulation of the Plio-Pleistocene sedimentary succession and the distribution of the present-day seabed morphologies indicative of geohazard along the PSS. At a regional scale, the Messinian compressional event is likely related to a temporary pause of the Arc migration related to collision and coupling of the NE part of the Calabrian Arc with the Apulian margin (Massari and Prosser, 2013). The resulted marked steepness of the slope setting created favorable conditions for the inception of slope instability, manifested by the presence of slide scars and canyon incisions. However, further detailed studies on the triggering factors that promoted the inception of geohazard-related features are needed in order to provide accurate geomarine-hazard assessment, as the future evolution of canyon and of the instabilities may pose serious threats and security concerns to coastal population infrastructures.

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Giacomo Mangano is a Ph.D. candidate working on the relationships between the structural evolution of the Crotone-Spartivento Basin (S Italy) and the geohazard-related geomorphic features. He is currently based at Cardiff University (UK) and his research interests dealt with the link between tectonics, geo-fluid migration and accumulation, and geo-hazard. He is familiar with the use of Petrel, IHS Kingdom and PetroMod.

Silvia Ceramicola is a Senior Researcher with a PhD in marine geology and over 25 years' experience in studying active processes occurring along active and passive continental margins in several areas of the Mediterranean Basin, with a particular interest in those geological features indicative of marine geohazards such as slope failures, canyon dynamics and mud volcanoes.

Massimo Zecchin is a Senior Researcher at OGS and Editor-in-Chief of Marine and Petroleum Geology. With a Ph.D. in sedimentology and stratigraphy and over 20 years experience in acquisition and interpretation of G&G data, his main research activity deals with sedimentology of marine and continental succession, sequence stratigraphy and relationships between tectonics and sedimentation.

Giuseppe Brancatelli is an Environmental Engineer with a PhD in applied geophysics and over 10 years experience in acquisition, processing and interpretation of geophysical data. As a researcher at OGS, his main research activity deals with seismic processing, velocity modeling and depth imaging.

Salvatore Critelli is Full Professor in Geology at University of Calabria with a Ph.D. in Sedimentary Petrography and over 30 years experience in acquisition and interpretation of geological data. His main research activity deals with geodynamics, basin analysis and provenance of clastic rocks.

OMC 2030 HACKATHON ENERGY VECTORS

THE INNOVATION ROOM

Edoardo Dellarole
Scientific Committee Chair

The OMC Med energy conference– OMC - was launched in 1993, to provide a forum for information exchange and discussion of energy and technology trends, with a particular focus on the Mediterranean region. In over 25 years the OMC conference and Exhibition has grown into the leading event in the Mediterranean region for energy insights with particular emphasis on the upstream sector. In more recent years OMC has started to approach other forms of energy, from renewables, energy efficiency, low carbon economy to circular economy - as shown also by this year Live sessions – with the scope of increasing the awareness about the complementarity of all energy sources. It is a fact, more and more energy companies have committed to reducing or eliminating emissions in the medium-long term to fight climate change. In this new scenario we are even more committed to offer a wider perspective, expanding OMC horizon. Starting from the 15th edition, OMC MED Energy Conference aims to discuss the challenges of the energy transition starting from the path that the oil & gas industry has started in the last decade towards a low carbon energy mix, with a holistic perspective, enlarging the boundaries of its activities, including different sources of energy and with a more diversified energy player selection.

Welcome to OMC Innovation Room.
In the last decades OMC events in Ravenna have attracted a wealth of future professionals. Starting from the 2021 edition MED energy conference organizers attracted young generations to the new arena called Innovation room.
Universities, start-ups, companies and investors were involved in presentations and contests to express the potential of fresh ideas for the energy transition path. The dialogue with the new generation of professionals, researchers and companies starts today with the goal of reshaping together the energy industry.
Starting up Ravenna was held on 28th September when 13 start-ups shared their ideas with a panel formed by company experts. The initiative was organised with the support of Innov-up (the Italian association of innovation centres, star ups, technological and scientific parks) and Joule (ENI's Business School, which aims to encourage the development of new and sustainable start-ups). All initiatives held in the Innovation Room proved successful in terms of participation and audience satisfaction therefore are going to be expanded from 10th to 12th May 2022 when the next OMC Med Energy Conference&Exhibition is taking place in Ravenna. The proposals received cover a wide spectrum of topics from sustainable mobility to renewable energy, from energy storage to the enhancement of biomass.
First prize was won by Bi-rex, a project by Greta Colombo Dugoni and Monica Ferro from Politecnico di Milano. Its objective being the production of tree-free cellulose and chitin from biomass and food industry wastes.
OMC 2030 Energy Hackathon on the second day gathered 55 brilliant minds from the University of Bologna, Pisa, Politecnico di Milano and Politecnico di Torino. Students and researchers between 20 and 30 years old competed with their ideas and solutions to achieve the 7th goal of the UN Agenda 2030 focused on the theme of 'Affordable and clean energy' which encourages universal access to reliable, modern and affordable energy supply services. Awards went to the Best project overall, the Most transformative project, the Most engaged team
This event was possible thanks to the alliance with SPE Italian Section and with the support of Accenture as technical sponsor. Call for ideas for Mediterranean Region universities and researchers from North Africa and the Mediterranean region submitted energy transition projects opportunities. The 10 proposals selected came from Italy, Greece, Morocco and Egypt. They discuss energy transition issues ranging from energy storage with new battery technologies to new hybrid concepts of renewable energy, from circular economy to water recovery enhancement. Unfortunately, the unstable situation due to the pandemic did not allow the presentation of the ideas in person. So the live event had to be postponed to 2022.

See you at OMC 2022!

THE "SPE-THONS" YEAR: YPs COOPERATE AND CHALLENGE THEMSELVES TO GET READY FOR THE NEW ENERGY WORLD

Matteo Trevisan
YP Chair 2021/2022
Prod. Eng at Eni

There's something going on amongst the Society of Petroleum Engineers Young Professionals these days. Maybe you saw it, maybe you didn't – either way, **this stream of energy will get you soon**. I'm talking about the different "-thon" events which are being held nationally and internationally by YPs and for YPs. The most recent ones which saw a deep involvement and dedication of SPE Italian Section have been the OMC2021 Energy Hackathon, the Europe Region GeoHackathon and the global YP Congress Ideathon on Sustainability.

In the month in which governments and world leaders meet in Glasgow for COP26 to debate about climate change and future policies, these SPE initiatives clearly represent the will and the need to be part of the change, recognising **the impact that each professional working in the energy industry has on the topic.**

The terminology of these events comes from a blend of an innovation-related word (e.g. Hack, Idea, Data) and Marathon. In fact, just like in the famous running competition, the participants to a "-thon" event challenge themselves in a short, intensive, workshop-like experience to address some of the most important topics of our time. However, while the Marathon is a challenge between the runner and his very own mind and body, **in these "SPE-thons" the Young Professionals are strongly encouraged to teamwork, interact, cooperate and find a solution all together.** Because, after all, we're a community and each individual's challenge is shared with peers and colleagues.

The **OMC Med Energy Conference 2021 launched the first Energy Vectors 2030 Hackathon took place in Ravenna** in September (the first SPE Italian Section physical event to be held after pandemic struck!) and saw the participation of more than 50 YPs and Students from all over Italy. The initiative has been organised by representatives of the SPE Italian Section Board with the support of Accenture as Technical Sponsor. The teams were invited to conceptualise and focus their attention on Goal 7 – Affordable and Clean Energy – of the UN Sustainable Development Goals, and the outcomes have been amazing!

At an European level, four SPE Sections (Italy, London, Netherlands and Romania) joined forces to deliver the first SPE Europe Energy GeoHackathon, aimed at educating and disseminating knowledge to all the participants on how Data Science applications can support Geothermal Energy Developments and drive the Energy Transition. The organization of the event has been driven by our Digitalisation & Data Science Discipline Leader Luca Motti, Scholarships Officer Gaetano Formato and Web & Social Media Manager Ferdinando Marfella, and sponsored by many international companies such as Geolog, Halliburton and OMV Petrom. The initiative sees the participation of more than 250 members and has been structured in two parts: a Bootcamp with workshops, lectures and technical sessions to understand the basics of Geothermal Energy and Data Analysis, and the Hackathon itself to put in practice what learnt using a real dataset. The motto of the event is: "Our Goal is to move from 'talking' about Energy Transition to 'educating' and 'making it happen' in a datafied and sustainable way". Just another example of how much our Young Members are committed towards building a better future!

Moreover, at an even broader international level, the efforts of many committees such as **Business Management & Leadership (BML), Young Member Engagement Committee, Beyond the Borders, Gaia and Diversity & Inclusion,** co-chaired by our International Relations Officer Maria Giulia De Donno, led to the **first ever global YP Congress Ideathon on Sustainability,** sponsored by Shell.

This one-week initiative saw more than 80 young participants, divided in multicultural teams and mentored by an experienced professional, developing and presenting an innovative project to make the energy industry more sustainable, which has been evaluated by a Jury of experts.

The event included also a YP Bootcamp consisting of live webinars and on-demand videos, all aimed to help YPs in their career and SPE activities.

Furthermore, the Ideathon kick-off session included speeches from top industry leaders, such as 2021 & 2022 SPE Presidents Tom Blasingame and Kamel Bennaceur, which I had the pleasure to introduce and moderate, while the close-out session featured a Sustainability Panel held by senior experts. You could re-live the whole event in each of its part on the official event website: *https://www.spe.org/events/en/2021/symposium/01ypcs/sessions.html*

Are you interested in meeting and collaborating with the multicultural and transversal SPE community?

Get ready for more of these physical and virtual initiatives in the future, because **looking at the feedbacks by participants and partners the "SPE-thons" are here to stay!** Follow the official SPE Italian Section social media to always stay updated!

LinkedIn: www.linkedin.com/company/spe-italian-section
Facebook: www.facebook.com/SPEIta
YouTube: www.youtube.com/c/SPEItalianSection

Matteo Trevisan (matteo.trevisan@eni.com) is currently a Production Engineer at Eni Headquarters in Milan, after an experience as Plant Turnaround Engineer at Centro Olio Val d'Agri in Basilicata in 2021. In SPE, at a national level he served as Liaison Sections 2019-2021, before being nominated as YP Chair for 2021/22, while at an international level he has been elected as Coordinator of the BtB Committee for 2021.

" GUSTAVO SCLOCCHI "
29TH THESES AWARDS 2021

FOR PHILOSOPHY DOCTORS AND UNIVERSITY GRADUATES IN DISCIPLINES RELATED TO THE ENERGY INDUSTRY

1. To reward outstanding university graduates specializing in areas related to the Energy Industry, **SPE Italian Section** (Society of Petroleum Engineers), **EAGE** (European Association of Geoscientists & Engineers) and **Assorisorse (the Italian Sustainable Energy & Resources Industry Association) announce the 29th "Gustavo Sclocchi" Theses Award.**

2. University graduates from Italian universities and Italian nationals graduated abroad who have completed their studies in the period **October 1st 2020 to December 31st 2021 (date reported on graduation certificate)** are entitled to submit their published thesis for the award.

3. The thesis must cover subjects related to Energy:

Exploration, Production and Transport of Hydrocarbons	**Green Refinery Feedstocks**	**Carbon Management and Neutralit**
Geology & Geophysics applied to Geoenergy	**Renewable Sources**	**Energy Economics**
Geothermal Energy	**Energy transition**	**Hydrogen applications**
		Circular Economy
		Health, Safety, Environment

4. Participation instructions are detailed in this announcement and on the SPE Italian Section, EAGE-SEG Italian Section web sites, **http://connect.spe.org/italy/home** and **http://www.eageseg.org**. Questions can be addressed to: **sclocchiaward@gmail.com**. Candidates must fill the registration form **https://bit.ly/sclocchiaward-application2021** complying with the following strict deadlines:

Contact information, abstract and electronic copy of the thesis – strict deadline February 28th, 2022
Graduation certificate – deadline before the Award Ceremony in June 2022

5. The Boards of Directors of the SPE Italian Section, the EAGE-SEG Italian Section, and Assorisorse will jointly appoint the Evaluation Committee. The latter is composed by experts in the above-mentioned areas and will select the theses which will be awarded. The Evaluation Committee decision is final and is not subject to appeal.

6. The theses will be evaluated and awarded according to the following categories:
   A. Master of Science (Laurea Magistrale) theses and Doctor of Philosophy (Dottorato di Ricerca) theses
   B. 2nd Level Master Reports and Bachelor of Science (Laurea di I livello) theses

7. The prize for each thesis under category A will be €2400 (twenty-four hundred Euros) and a Certificate. The prize for each thesis under category B will be €1200 (twelve hundred Euros) and a Certificate. Optional awards for running-up theses will consist of a "special mention" Certificate. Reference to award-winning theses will be published in the **«SPE Bulletin»** of the Italian Section, in the **«EAGE First Break»** journal, and on **Assorisorse website (www.assorisorse.org).** Theses with multiple authors will be reward with single prize or "special mention" Certificate.

8. The total and maximum amount of the prize for both categories is €10800. A maximum of 20 "special mention" Certificates will be provided in total for both categories.

9. The Award ceremony will take place in **June 2022 in the "Aula Magna" of Politecnico di Milano (Piazza Leonardo da Vinci) and via online streaming**. Winners of categories A and B will deliver a short presentation of their theses. Winners will be notified in due time of the date of the ceremony and of the presentation guidelines.

SPE	**Assorisorse**	**EAGE**
Italian Section Chairman	President	President
Paolo Carnevale	**Luigi Ciarrocchi**	**Dirk Orlowsky**

The candidates shall apply **NO LATER THAN FEBRUARY 28th, 2022 (strict deadline)** exclusively by filling the form available on:

https://bit.ly/sclocchiaward-application2021

Only the applications received through the online form will be accepted.

Documents to be submitted

a. Contact information: E-mail address and Telephone number (mobile)

b. Theses Degree (2nd level Master, Bachelor of Science, Master of Science or PhD.) and Title (in English and, if suitable, Italian)

c. Document of the date and place of graduation

d. Abstract of the thesis (in English or Italian strictly following the below reported Guidelines)

e. Reference information of the Dean of the Faculty (full name and e-mail)

f. Reference information of the assisting professor/s (full name and e-mail)

g. Complete electronic copy of the thesis, in English or Italian, (accepted formats: MS Word and PDF Acrobat).
To submit manuscripts larger than 100 MB, it is necessary to use jumbo mail, we-transfer, drop-box or an equivalent system using the email address *sclocchiaward@gmail.com*

BEFORE THE CEREMONY The winners shall provide IBAN, BIC/SWIFT and current address.

Guidelines for the preparation of the Thesis Abstract
The abstract has significant weight on the evaluation process and must contain:
- up to 800 words
- enough information to enable the Evaluation Committee to make a judgment of the content, value, and impact of the thesis.

Abstract shall be structured with the following paragraphs:

1. **Objectives and Scope:** state the objectives of the study sharply and clearly, outline the scope and limitations of your work, and point out aspects that have not been well understood yet, which may require further studies.

2. **Methods, Procedures, Process:** state the approach upon which the thesis is based (e.g., field data, laboratory data, original analysis, or computer work) and how the work has been organized.

3. **Results, Observations, Conclusions**: provide the major results or findings of the study.

4. **Novel/Additive Information:** describe the possible applications or the implications of the knowledge provided in the thesis. State what is new in your study, its importance and list the most important innovations or technical contributions in your thesis.

SPE International
Society of Petroleum Engineers
Italian Section

ASSORISORSE

EAGE
EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

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SPE ITALIAN SECTION BOARD 2021 - 2022

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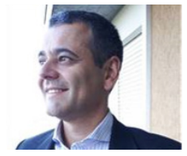

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EniProgetti
fabio.parmigiani@eni.com

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a.calleri@geolog.it

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Vera Rocca
Politecnico Torino
vera.rocca@polito.it

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Filippo Vailati
EniProgetti
Filippo.Vailati@eni.com

Discipline Leader – Digitalization & Data science
Luca Motti
Accenture UK
luca.motti@gmail.com

Discipline Leader – Energy Transformation & New Technologies
Marco Flisi
Eni
Marco.Flisi@eni.com

Rappresentante AI SPE
Alberto di Lullo
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Alberto.DiLullo@eni.com

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paolarobertamaria.delbo@external.eni.com

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uormezzano@tetratec.com

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Eni
matteo.trevisan@eni.com

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Total
manuel.miceli@totalenergies.com

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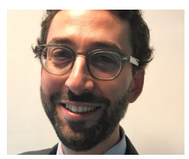
William Palozzo
DG Impianti
william.palozzo@dgimpianti.eu



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Andrea Lamberti
Eni
andrea.luigi.lamberti@eni.com

Discipline Leader – R&D & Innovation
Ettore Carcione
Geolog
e.carcione@geolog.com

Advisor
Maurizio Senese
Indipendent
maurizio.senese@gmail.com

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Paola Del Bo
EniProgetti
paolarobertamaria.delbo@external.eni.com

Web and Social Media
Ferdinando Marfella
Eni
ferdinando.marfella.spe@gmail.com

Bulletin
Gianna Giudicati
Eni
gianna.giudicati@eni.com

Advisor - Marketing
Antonino Gulotta
Wefuture
guloant@alice.it

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Coordinator
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fabio.parmigiani@eni.com

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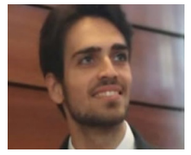
Luca Cadei
Eni
luca.cadei@eni.com



Liaison – Gela Hub
Giacomo D'Alessandro
Eni
giacomo.dalessandro@gmail.com

Diversity & inclusion - UNECE "Women in Resource Management" Ambassador
Cristina Robinson Marras
Saipem
cristina.marras@saipem.com

ASSOCIATIONS COMMITTEE

Coordinator
Ugo Ormezzano
Tetra Technologies
uormezzano@tetratec.com

Liaison – Assoc. Pionieri e Veterani Eni
Giorgio Russo
Eni
gioru91@hotmail.it

SCHOLARSHIP COMMITTEE

Coordinator
Antonio Calleri
Geolog
a.calleri@geolog.it

Scholarship
Gaetano Formato
Eni
gaetano.formato@eni.com

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Coordinator
Matteo Trevisan
Eni
matteo.trevisan@eni.com

Liaison – SPE Internation Relation
Maria Giulia De Donno
Bain
MariaGiulia.DeDonno@Bain.com

ACADEMIC INITIATIVES COMMITTE

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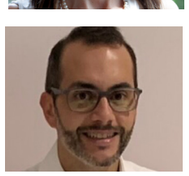
Vera Rocca
Politecnico Torino
vera.rocca@polito.it

Liaison - Faculty
Massimiliano Giamberini
Eni
Massimiliano.Giamberini@eni.com



Thesis Award
Giuseppe Gorla
EniProgetti
Giuseppe.Gorla@eni.com

ITALIAN SECTION DASHBOARD

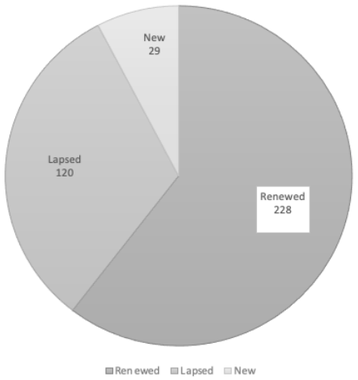
Report as of 11 November 2021

Charts do not include affiliate members.

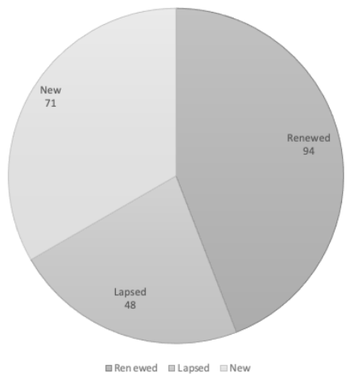
Year to Date
Members: 257
Affiliate Members: 4
Retention: 71.28%
New Member Retention: 67.44%
Growth: -10.45%

Previous Year End
Members: 257
Affiliate Members: 4
Retention: 71.28%
New Member Retention: 67.44%
Growth: -10.45%

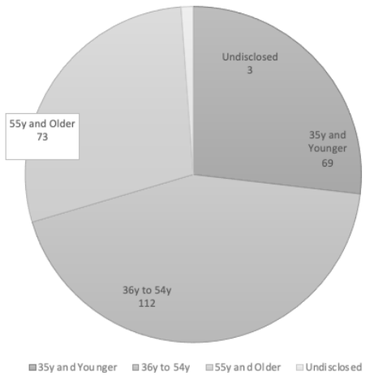
Professional Membership



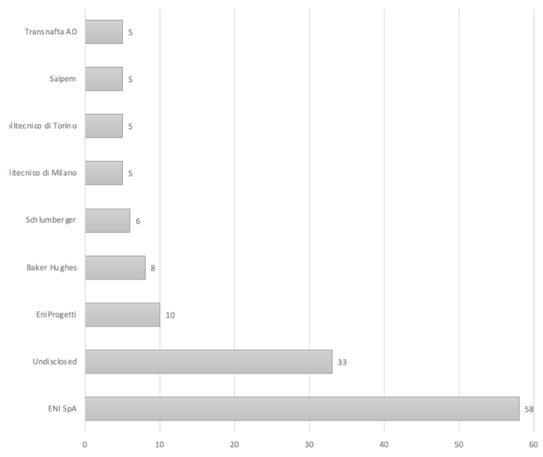
Student Membership



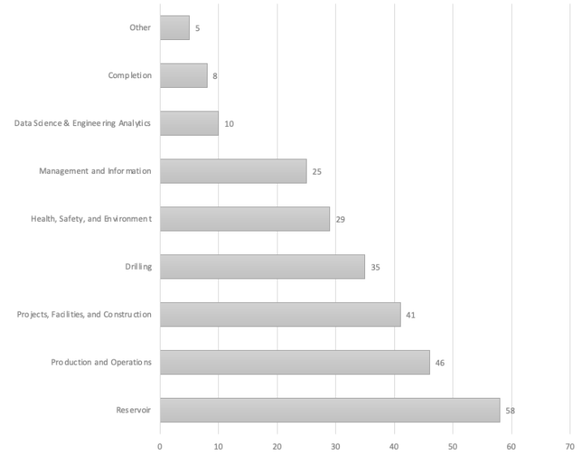
Professional Membership by Age Group



MEMBERSHIP BY EMPLOYER
(Only 9 Shown)



Current Professional Members
by Technical Discipline



SUPPORTER'S PAGE

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SPE President's Open Letter to Members

November 2021

Dear SPE Members, Currently, there are comments circulating on social media concerning SPE costs, value, and integrity. I would like to address these questions and shed some light on how SPE operates and offers the best for its members. I would like to start with clarifying SPE's organizational structure and decision-making processes.

SPE Governance

The SPE Board of Directors is the governing and policy-making body of SPE. The 20 members of the Board care deeply about SPE and its members and volunteer their time to make it a society based on ethics and integrity. Board members serve for terms of three years and represent all of the regions of the world where SPE has members as well as technical disciplines. Board members receive no pay for their service and in many cases the cost of attending SPE functions is paid as a generous contribution by their employers. The Board sets SPE's strategic direction, oversees the finances and retains final authority on all SPE matters. SPE's CEO answers directly to the Board and is responsible for the management of about 250 SPE staff in seven offices around the world. The SPE Board and staff are devoted to fulfilling SPE's mission and meeting the needs of our members.

Availability of Technical Papers

Our conferences benefit not only the attendees, but also others who are able to access the technical papers provided in the OnePetro® online library. All SPE members receive six free paper downloads each year and can purchase additional papers at US $5 per paper. Non-member paper costs are US $25 each. Papers are also accessible to companies and universities through reasonable subscription prices. The fees charged for technical papers in OnePetro are essential to cover the costs associated with the online library as well as to support other SPE programs.

Value of Membership

Our membership dues are among the lowest for professional societies serving our industry. To account for global income disparities, membership fees are determined using the World Bank classification of country income levels. SPE dues have not changed significantly over the past 20 years, but the member benefits have grown every year. For students around the globe we offer free membership with access to many programs that aide in bridging the gap from student to employee. Being an SPE member has benefits even for those members who are unemployed. Since 2015, SPE has offered the Members in Transition program that helps members navigate troubled times through topical discussions and a job board.

Cost Effective Events

The cost of SPE's conferences and other events are partially covered by registration fees, which are typically less expensive than those for commercial organizations producing oil and gas related events. SPE also relies on sponsorships from industry partners to present the most relevant and educational events in the industry. Our SPE members take pride in offering conferences that fulfill our mission and exceed the quality of our commercial competitors. Our authors appreciate the opportunity to present their work knowing that their papers will reach a much broader audience through OnePetro. During the pandemic, the Board and staff worked hard to ensure that quality conferences and other programming (e.g., webinars and workshops) were provided either in a hybrid or fully virtual mode to fulfill our mission during a very difficult time.

SPE Staff

Managing SPE programs and serving our members requires a dedicated professional staff, and it is worth noting that many of our staff are recognized leaders in the association management profession. We have sound compensation policies in place that are benchmarked appropriately on a regular basis and senior executive salaries are set by the Compensation Committee of the Board of Directors. Most of the salaries reported on social media are from US Internal Revenue Service filings that SPE is required to make every year, but some are incorrect and appear to have been inflated by the author of the posts. SPE is a not-for-profit organization in the United States (a 501(c)(3) corporation) and the Board of Directors as well as the Executive Staff are committed to transparency in both our operations and our finances.

The Board of Directors and I state in the strongest possible terms our support for SPE, its staff, and its policies. We are proud to be a globally recognized and respected society that is open and transparent, and we hold ourselves to the highest standards of ethics and process. We are here to serve. If you have questions or concerns about any aspect of the organization, please contact me at *president@spe.org.*

Kamel Ben Naceur, 2022 SPE President

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