Brussels, 30 October 2015

COST 035/15

DECISION

Subject: **Memorandum of Understanding for the implementation of the COST Action "Uncovering the Mediterranean salt giant" (MEDSALT) CA15103**

The COST Member Countries and/or the COST Cooperating State will find attached the Memorandum of Understanding for the COST Action Uncovering the Mediterranean salt giant approved by the Committee of Senior Officials through written procedure on 30 October 2015.

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MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA15103
UNCOVERING THE MEDITERRANEAN SALT GIANT (MEDSALT)

The COST Member Countries and/or the COST Cooperating State, accepting the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action (the Action), referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any new document amending or replacing them:

a. "Rules for Participation in and Implementation of COST Activities" (COST 132/14);
b. "COST Action Proposal Submission, Evaluation, Selection and Approval" (COST 133/14);
c. "COST Action Management, Monitoring and Final Assessment" (COST 134/14);
d. "COST International Cooperation and Specific Organisations Participation" (COST 135/14).

The main aim and objective of the Action is to To determine the causes of:
Timing and emplacement mechanisms of the Mediterranean salt giant
Early salt deformation and fluid flow across the salt
Mechanisms underlying the vertical motions inside the basins
and to explore the possibility that salt giants promote the development of a diverse and active deep biosphere.. This will be achieved through the specific objectives detailed in the Technical Annex.

The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 60 million in 2015.

The MoU will enter into force once at least five (5) COST Member Countries and/or COST Cooperating State have accepted it, and the corresponding Management Committee Members have been appointed, as described in the CSO Decision COST 134/14.

The COST Action will start from the date of the first Management Committee meeting and shall be implemented for a period of four (4) years, unless an extension is approved by the CSO following the procedure described in the CSO Decision COST 134/14.

COST is supported by the EU Framework Programme Horizon 2020

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OVERVIEW

Summary
MEDSALT aims to create a new flexible scientific network that will address the causes, timing, emplacement mechanisms, and consequences at local and planetary scale of the largest and most recent 'salt giant' on Earth: The late Miocene (Messinian) salt layer in the Mediterranean basin. It is a 1.5 km-thick salt layer that covered the bottom of the deep Mediterranean basins about 5.5 million years ago and is preserved beneath the deep ocean floor today. The origin of the Mediterranean salt giant is linked to an extraordinary event in the geological history of the Mediterranean region, commonly referred to as the Messinian Salinity Crisis.

This inter-sectorial and multinational cooperation network will comprise a critical mass of both experienced and early-career researchers from Europe and beyond. The goal will be achieved through capacity building, researchers' mobility, skills development, knowledge exchange and scientific networking.

The study of the unique salt giant is inherently cross-disciplinary, embracing geology, geophysics, geochemistry, microbiology, and paleoclimatology. It is an opportunity for the scientific community to share objectives, data, expertise and tools with industry since there is considerable interest in oil and gas exploration, and consequent hazards, targeting the Mediterranean's deep salt deposits.

The MEDSALT Action proposal has been conceived as a joint initiative coordinating scientific targets from existing research efforts including the European Consortium for Ocean Research Drilling (ECORD), the Japanese and US branches of the International Ocean Discovery Program (IODP), the EU- FP7 ITN MEDGATE, TOPO-EUROPE, and other national and international research programmes focussing on the Mediterranean salt giant.

Areas of Expertise Relevant for the Action	**Keywords**
● Earth and related Environmental sciences: Geological oceanography ● Earth and related Environmental sciences: Paleoclimatology, paleoecology ● Earth and related Environmental sciences: Sedimentology, soil science, palaeontology, earth evolution ● Earth and related Environmental sciences: Biogeochemistry, biogeochemical cycles ● Earth and related Environmental sciences: Thermodynamics, geophysics	● Mediterranean Salt Giant ● Messinian Salinity Crisis ● Deep Biosphere ● Salt deformation and Subsalt fluids ● Deep Earth and surface connections

Specific Objectives
To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination
● Coordinate the construction of a single data base, through critical analysis, of all available digital scientific information on the MSC salt giant and publishing the resulting data in easily accessible, open access synthesis documents and data bases (e.g. seismic atlas, isotope geochemisty data base, etc;
● Integrate sedimentological, geochemical, and biological models to reconstruct the timing and modality of large-scale evaporite deposition and its relationships with small- to large-scale climatic oscillations;
● Coordinate the application of numerical thermo-mechanical models of early multi-layered salt deformation and creep triggered by salt-induced rapid basin subsidence and marginal tilt;
● Evaluate critically matured and complex salt structures as stratigraphic barriers and waste repositories as

stratigraphic barriers and waste repositories;
● Identify microbial communities, pore fluids and evaporite minerals in modern hyper saline systems systems (deep Mediterranean brine lakes, salt mines in Sicily, Red Sea) as modern analogues for the ancient, deep biosphere communities that developed in salt giants;
● Evaluate the drilling hazard represented by microbial gypsum reduction in salt giants producing subsurface accumulations of sour gas (H2S);
● Coordinate the development of coupled tectonic, climatological, oceanographic and geochemical numerical models that investigates the forcing factors and geological and geochemical products of the MSC;
● Identifying national and international research frameworks including industry to promote and coordinate cross-disciplinary and intersectoral scientific activity;
● Increase the training of the next generation of experts focusing on the whole Mediterranean area, including southern and eastern coastal states;
● Provide input to stakeholders (e.g. private enterprises in seismic exploration, oil&gas, insurance, governmental bodies, environmental agencies, research institution and universities) and disseminating of research results to the general public.

Capacity Building
● Fostering knowledge exchange and the development of a joint research agenda around the multi-national, multi-disciplinary initiatives to understand the causes, timing, emplacement mechanisms, and consequences of the Mediterranean salt giant;
● Bridging the fields of geology, geophysics, paleoceanography, microbiology, and climate modelling to achieve breakthroughs results to resolve one of the most enduring controversies in the field of Earth Science: The Mediterranean Salinity Crisis;
● Acting as a trans-national practice community to address the geological exploration of the deep Mediterranean Basin, related risks, and environmental hazard;
● Involving Early Career Investigators, and research teams from the entire Mediterranean area (north-south and east-west transnational cooperation) to create a gender-balanced inclusive research community to enhance knowledge, data acquisition and distribution, and industrial activity on the deep water resources of the Mediterranean region;
● Creating astabe network forums to address students and Early Carreer Investigators field work/ research cruises, and national/international research programs.

DESCRIPTION OF THE COST ACTION

1. S&T EXCELLENCE

1.1. Challenge

1.1.1. Description of the Challenge (Main Aim)

This COST Action aims to create a new flexible scientific network that will address the causes, timing, emplacement mechanisms, and consequences of the largest and most recent salt giant on Earth: the Mediterranean salt giant. It is a 1.5 km-thick salt layer that covered the bottom of the deep Mediterranean basins about 5.5 million years ago and is preserved beneath the deep ocean floor today. The origin of the Mediterranean salt giant is linked to an extraordinary event in the geological history of the Mediterranean region, commonly referred to as the Messinian Salinity Crisis (MSC). Four overarching scientific questions will be addressed through this COST Action network:

1. **What are the causes, timing and emplacement mechanisms of the Mediterranean salt giant?** The salt sequestered in the Mediterranean's geological record represents a minimum estimate of what must actually have precipitated there. Even so, this represents ~5% of the global ocean salt mass. As a result, this event has global climatic consequences through the associated reduction in global ocean salinity and its impact on thermohaline circulation and sea-ice formation. The Mediterranean salt giant lies at the centre of a global-scale system that links monsoonal rainfall from the Indian Ocean to deep water formation in the North Atlantic. The scientific community currently has no coherent, unifying model for how the MSC was triggered and what its consequences were.
2. What are the factors responsible for and the socio-economic consequences of early salt deformation and fluid flow across and out of the halite layer? Most salt giants in the geological record are old and are already intensely deformed. They are of considerable interest to the petroleum industry because of salt's sealing capacity which means it is commonly associated with hydrocarbon traps, including the recent discoveries in the Mediterranean. The mechanical behaviour of salt impacts submarine slope stability and therefore has implications for geohazards such as landslide-induced tsunamis. Understanding the cause and nature of early salt deformation and fluid flow is therefore critical both to industry in terms of mitigating exploration and production risks and to the wider society.
3. **Do salt giants promote the development of a phylogenetically diverse and exceptionally active deep biosphere?** Scientific drilling has shown that microbes are present down to more than 1600 meters below sea floor, taking advantage of thermodynamic disequilibria produced by a number of geochemical processes. Salt deposits comprise a wide range of chemical environments which have the potential to harbour an unprecedented diversity of microbial life. However, because of the difficulty in accessing buried salt, these microbial communities have not been studied and represent a first-order exploration with potential both for unforeseen applications and insight into the environments themselves.
4. **What are the mechanisms underlying the spectacular vertical motions inside basins and their margins?** Besides the industrial interest, salt giants are the sedimentary expression of extreme environmental events of global relevance, often resulting from a combination of deep earth-system dynamics (e.g. mantle convection and the initiation of continental break-up) and climatic forcing (evaporation-precipitation budget at the regional scale). One of the important developments in Earth Science over the past decade has been the recognition of the link between deep Earth dynamic processes and surface geologic processes allowing dynamic topography to develop as a frontier scientific discipline. The rapid deposition of a tabular and up to two kilometers thick salt giant result in almost instantaneous basin subsidence and

margin uplift due to crustal flexure. Yet, the interaction between deep earth and surface processes and their consequences on landscape evolution are little understood.

1.1.2. Relevance and timeliness

The timing is right for this COST Action support in this research field because:

- the technological developments in drilling salt and the possibility that the Integrated Ocean Discovery Program (IODP), the largest and longest-living international research project in Earth Sciences, will bring its platforms to the Mediterranean area, has determined **both scientific and industrial interests in Mediterranean salt and sub-salt geological environment to converge**;
- the recognition that **the Mediterranean-Atlantic gateway is an important driver of global climate** means that the MSC is an ideal case study for understanding the functioning of a past marine gateway;
- the **rising interest in exploring microbial diversity in extreme environments** has focused its attention on high salinity, high pressure, and high H_2S environments most likely to be encountered in the deep sedimentary record of the MSC;

In other words, research is happening, and what the scientific community needs is a network that will help identify the strengths, links and mutual benefits between projects. Perhaps most importantly, **there is a need to target and tackle the gaps in our understanding and knowledge that remain after more than forty years of research by enhancing the interdisciplinarity.**
This COST Action will enable the scientific community to set up and reinforce knowledge exchange and effective mobility throughout our multinational and scientifically diverse network, connecting spatially disparate communities between east and west as well as between north and south in the Mediterranean region. Such characteristics suit well and uniquely the COST Framework.

1.2. Specific Objectives

1.2.1. Research Coordination Objectives

Given the diverse scientific disciplines involved, the scientific objectives are multiple and interrelated among the four disciplines addressing the four overarching questions outlined in Section 1.1.1:

1. to understand salt giant formation and its relationship with local, regional and global environmental change;
2. to investigate salt dynamics and associated fluid flow quantitatively in order to assess geohazards;
3. to understand if salt giants promote the development of metabolically active and phylogenetically diverse deep biosphere communities of microbes and viruses;
4. to model the isostatic response of the lithosphere to extreme and rapid mass transfer and to kilometre-scale differential vertical motions of the Mediterranean margins.

This COST Action will address the following "SMART" research coordination objectives:

1. Coording the construction of a **single data base**, through critical analysis, of all available digital scientific information on the MSC salt giant and publishing the resulting data in easily accessible, open access synthesis documents and data bases (e.g. seismic atlas, isotope geochemisty data base, etc;
2. integrating **sedimentological, geochemical, and biological models** to reconstruct the timing and modality of large-scale evaporite deposition and its relationships with small- to large-scale climatic oscillations;
3. coordinating the **application of numerical thermo-mechanical models** of early multi-layered salt deformation and creep triggered by salt-induced rapid basin subsidence and marginal tilt;
4. leading the **critical evaluation of matured and complex salt structures** as stratigraphic barriers and waste repositories;

5. identification of **microbial communities, pore fluids and evaporite minerals in modern hypersaline systems** (deep Mediterranean brine lakes, salt mines in Sicily, Red Sea) as modern analogues for the ancient, deep biosphere communities that developed in salt giants;
6. evaluating the **drilling hazard** represented by microbial gypsum reduction in salt giants producing subsurface accumulations of sour gas (H_2S);
7. coordinating the development of **coupled tectonic, climatological, oceanographic and geochemical numerical models** that investigates the forcing factors and geological and geochemical products of the MSC;
8. identifying national and international **research frameworks** including industry to promote and coordinate cross-disciplinary and intersectoral scientific activity;
9. Increasing **training of the next generation of experts** focusing on the whole Mediterranean area, including southern and eastern coastal states;
10. providing **input to stakeholders** (e.g. private enterprises in seismic exploration, oil&gas, insurance, governmental bodies, environmental agencies, research institution and universities) and disseminating of research results to the general public.

1.2.2. Capacity-building Objectives

Know-how and the means to perform the planned research (laboratories, equipment, computer power, research vessels) already exist in the institutions of the participating scientists and stakeholders. Man-power will be provided by students, Early Career Investigators (ECI), and senior researchers. **Industry stakeholders and academic partners will be invited to share data otherwise difficult to access outside formal networking**.
Scientific objectives will be achieved by using the opportunity to meet and discuss coordinated strategies for data collection and analysis. Meetings will foster collaborative interpretation of discipline-specific results in the open, multi-disciplinary framework provided by this COST Action network. **Knowledge-transfer and capacity building activities will enhance the opportunity for development of new ideas and concepts, and the planning for future research**.
Specific capacity-building objectives are:

1. Fostering knowledge exchange and the **development of a joint research agenda** around the multi-national, multi-disciplinary initiatives to understand the causes, timing, emplacement mechanisms, and consequences of the Mediterranean salt giant;
2. **bridging the fields of geology, geophysics, paleoceanography, microbiology, and climate modelling** to achieve breakthroughs results to resolve one of the most enduring controversies in the field of Earth Science: The Mediterranean Salinity Crisis;
3. acting as a **trans-national practice community** to address the geological exploration of the deep Mediterranean Basin, related risks, and environmental hazard;
4. **involving Early Career Investigators, and research teams from the entire Mediterranean area** (north-south and east-west transnational cooperation) to create a gender-balanced inclusive research community to enhance knowledge, data acquisition and distribution, and industrial activity on the deep water resources of the Mediterranean region.
5. creating astabe network forums to address students and Early Carreer Investigators field work/ research cruises, and national/international research programs.

1.3. Progress beyond the state-of-the-art and Innovation Potential

1.3.1. Description of the state-of-the-art

Salt-bearing sedimentary basins, preserving kilometre-thick evaporite layers, or 'salt giants', are frontiers for a diverse range of challenging research. Most salt giants in the geological record are old (e.g. Permian Zechstein salt or the Mesozoic salts in the North Atlantic) and have typically experienced intense deformation. They are commonly the **focus of applied research by the petroleum industry** because of the sealing capacity of salt rock, the recurrent association with

structural traps for hydrocarbon fluids, and perturbations to in situ stresses associated with salt bodies.

Besides the industrial interest, **salt giants are the sedimentary expression of extreme environmental events of global relevance**, often resulting from a combination of deep earth-system dynamics (e.g. mantle convection and the initiation of continental break-up) and climatic forcing (evaporation-precipitation budget at the regional scale). Salt deposition impacts the structural, chemical and biological evolution of the sedimentary basins in which it accumulates, and affects global ocean salinity. Because of the variety of chemical environments, salt giants have the potential to harbour an unprecedented diversity of microbial life with exceptional metabolic activity. Being almost free of any overprinting by plate-tectonic processes, young salt structures reflect almost pure salt tectonics caused by differential load and gravitational spread. Finally, quantitative understanding of salt dynamics and associated fluid flow is fundamental to the assessment of submarine geohazards, and exploration or production risks.

Despite their global occurrence and general importance within the global Earth system, **there is currently no complete stratigraphic record through an undeformed salt giant**. Similarly, there is a significant lack of knowledge about the factors controlling salt giants deposition, their early evolution, the impact that thick salt deposition exerts on the isostatic response of continental margins and on sub-salt formations.

About 6 million years ago the Mediterranean Sea became an enormous saline basin where more than one million cubic kilometres of salt (6% of the dissolved oceanic salt) accumulated on the seafloor locally exceeding a thickness of 3 km in the deep basins. This extreme, but geologically brief event (640 ka, 5.97 – 5.33 Ma), changed the chemistry of the global ocean and had a permanent impact on both the terrestrial and marine ecosystems of a huge area surrounding the Mediterranean. Increasing Mediterranean salinity was driven by tectonic restriction of exchange with the Atlantic Ocean and modulated by the impact of climatic precession on surface water salinity. The role of eustatic sea level change in generating the huge volumes of salts remains contentious

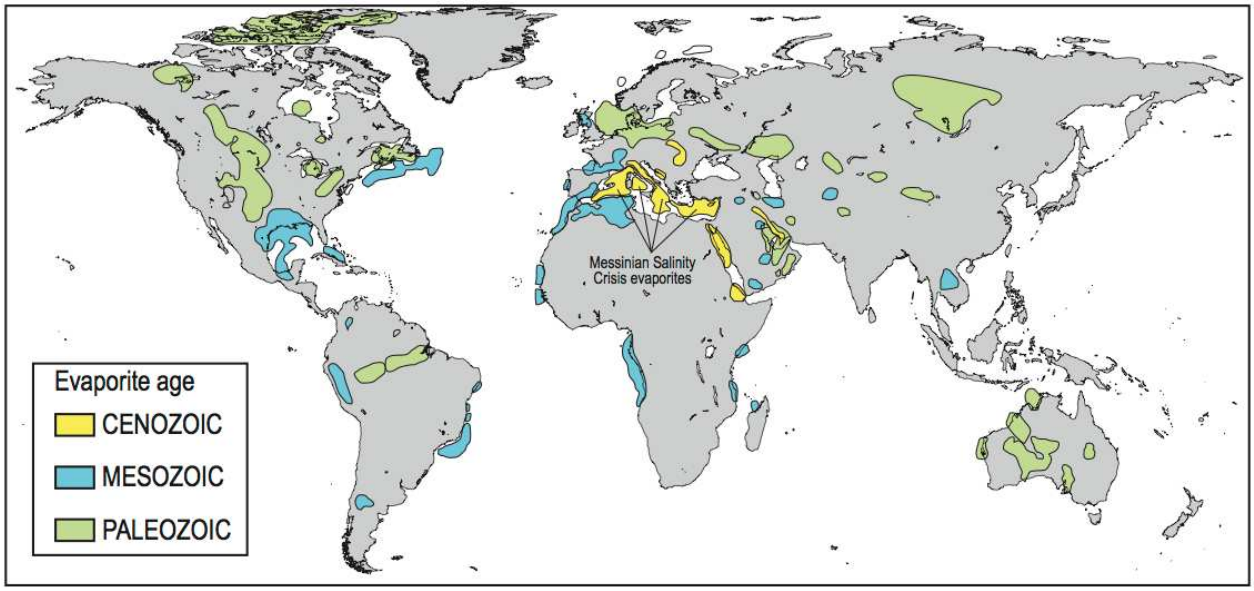

Figure 1. Geographical and temporal distribution of salt giants (modified from Warren, 2010. *Earth-Sci. Rev,* 98, 217-268), among which the Mediterranean salt giant is conspicuously young. Saline giants are found only in the most recent 600 million years of Earth history. The initial salinity of the global ocean is inferred to have been 1.5 to 2 times the modern value. The first great change in oceanic salinity probably occurred during latest Precambrian when huge quantities of salt were sequestered from seawater in giant Neoproterozoic evaporite basins.

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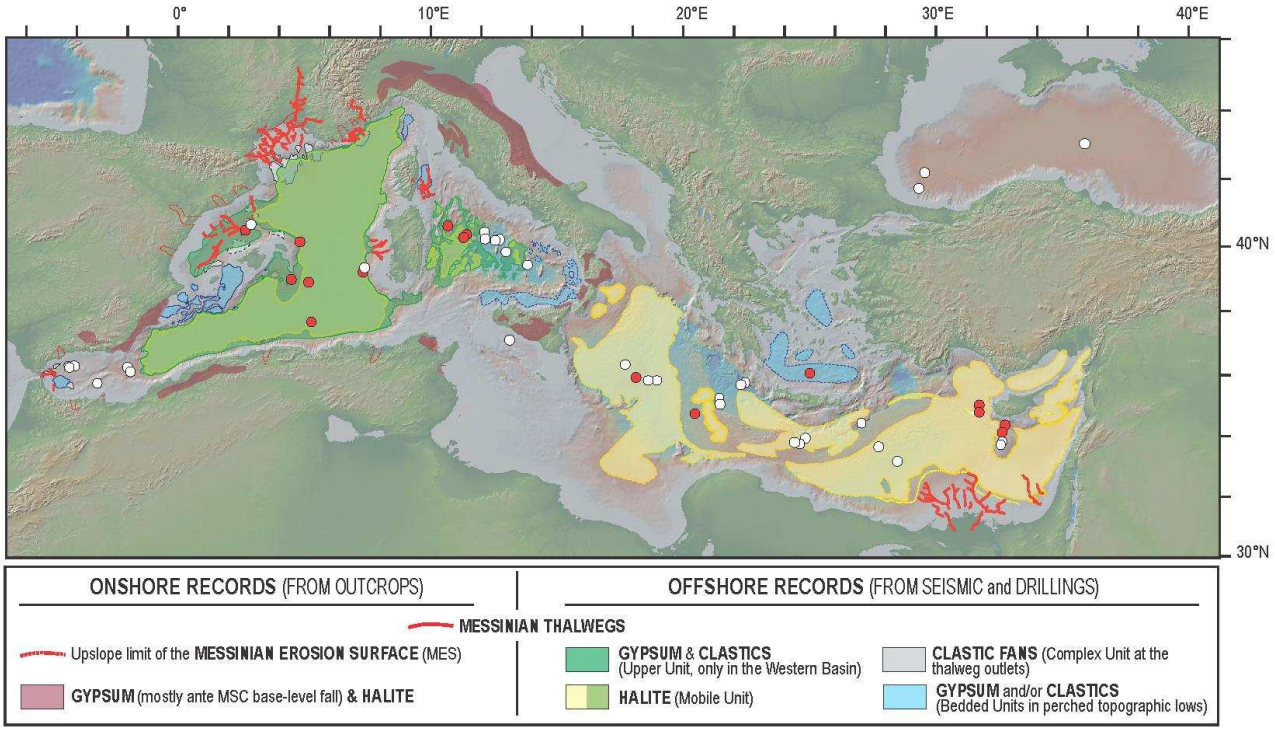

Figure 2. Map of the present-day extent of the MSC evaporites as identified through seismic markers, providing a picture of the areal distribution of the Messinian salt body (Mobile Unit, MU) and other Messinian Evaporites and erosional surfaces in the Mediterranean Basin (Lofi et al., in preparation). Dots in map represent DSDP and ODP drill sites. Red dots refer to drill sites in which Messinian evaporites were recovered.

The first scenario ever put forth to explain the formation of the MSC was generated following the drilling during DSDP Leg 13 in 1970. It envisaged an almost desiccated deep Mediterranean basin with a dramatic 1.5 km drop in sea level. This resulted in the incision of deep river canyons on the continental margins, the deposition of thick evaporites on the Mediterranean's abyssal plains, and a catastrophic flooding event when the Mediterranean-Atlantic connection was re-established through the Gibraltar Strait. This initial hypothesis has been challenged and refined over the years and many different scenarios now populate the scientific literature, illustrating a lack of fundamental understanding, especially for the deepest offshore domains. In spite of 42 years of multi-disciplinary research conducted on the MSC (generating over 1800 peer review papers), the processes, timing, causes, chronology and consequence at local and planetary scale are still not yet fully understood, and the MSC event remains one of the longest-living controversies in Earth Science.

1.3.2. Progress beyond the state-of-the-art

With the recent development of technology able to safely drill evaporites also in deep marine environment, now is the time to overcome this scientific 'impasse' by drawing together existing and new research communities to collaborate on the **planning for acquisition of new material, use available day analogues** (samples taken with previous drilling expeditions, salt mines, outcrops, and deep sea anoxic basins) and look for **solutions with a long-term initiative seeding in this COST Action.**

New emerging fields are addressed in this Action:

Salt tectonics produces some of the most complex low-temperature geological deformation seen on the earth surface, deep within sedimentary basins and on continental margins. However, the influence of buoyancy in driving salt tectonics (diapirism) has long been overestimated. Instead, evaporite deformation has been found to be primarily related to gravitational forces, either causing salt to flow in response to differential sediment loading (*spreading* or *gliding),* as a consequence of basement tilt. Due to its young age and negligible tectonic overprint, the MSC salt giant provides

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unique evidence in seismic data of these conceptual models. **Understanding mechanical behaviour of salt will contribute to the understanding of the causes and recurrence of salt tectonics-induced continental slope mass wasting, and the role of halite layer creep in the generation of submarine slope instability**, which has important implications for the submarine geohazard assessment for industrial activity (exploration or production risks), submarine cables, and the coastal zone management (landslides-induced tsunamis).
Because of the variety of chemical environments it produces, the Mediterranean salt giant has the potential to harbour an **unprecedented diversity of microbial life with exceptional metabolic activity**. The deep biosphere is involved in extensive mineral transformations that both provide oxidative energy for life and are the driving force for the development of microbial diversity. Based on investigations of outcropping evaporitic sulphate deposits – including those formed during the MSC – some of the proponents of this Action have shown that there is the potential for a dynamic deep biosphere community of sulphate reducers to develop based on the reduction of mineral sulphates and the concomitant oxidation of reduced organic carbon (methane, petroleum, organic matter). This process has **implications for sedimentary biogeochemical cycles, the souring of crude oil and the formation of dolomite, one of the long-standing controversies in Earth Sciences.** Furthermore, gypsum and halite crystals contain fluid inclusions that are a micro-habitat in which microbes survive for tens of thousands, to possibly millions, of years. This poses fundamental questions about how/whether cells can devote nearly all of their energy flow to somatic maintenance needs, rather than growth and reproduction, and opens new avenues of research concerning life on other planets. The most ancient known cyanobacterial RNA have been extracted from gypsum solid inclusions of Messinian age. Information of this kind is key in deciphering the complex succession of paleoclimatic and hydrological events that led to the formation of the Mediterranean salt giant.
The Mediterranean salt giant represents a unique case to understand the rheological connections between the deep earth and its surface. The 1.5 km base level drop, the accumulation of up to 3 km of salts, and the rapid refilling of the Mediterranean at the end of the Miocene, are likely to have resulted in kilometre-scale vertical motions of the Mediterranean's margins. **Understanding how the lithosphere and continental erosion react to these dramatic forcings requires an integrated approach to quantify geodynamic, tectonic, and sedimentary processes.**

1.3.3. Innovation in tackling the challenge

This COST Action aims at establishing an original and innovative approach to the long-lasting and emerging issues related to the Mediterranean salt giant which will drive a break-through progression beyond the state-of-the art by:

- Establishing a **new, unprecedented pan-European and pan-Mediterranean scientific network** to coordinate the integration of new and existing data and their interpretation across disciplines relating to the causes and consequences of the deposition of the Mediterranean salt giant;
- **promoting and coordinating additional investigations in the cross-cutting fields of geology**, geophysics, geochemistry and geobiology, taking advantage of existing scientific and technological expertise;
- **steering research traditionally confined to the `fundamental research' sector towards its applications** by identifying research products of interest to industry, private companies, public authorities, and policy makers and all relevant stakeholders involved in the Mediterranean's blue economy;
- assessing the added value expected from this project at national level and across Europe by **supporting cooperation among scientists and researchers**;
- **engaging new communities and existing scientific research projects** within this enterprise to focus scientific initiatives promoting the cross-diciplinary apporach among different research research environments (both national and international), industry, and administrations.

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This COST Action is therefore aimed at European scientific advance as well as at economic and societal needs.

1.4. Added value of networking

1.4.1. In relation to the Challenge

A characteristic of the world-wide research performed so far on the Mediterranean salt giant is that of individual researchers and groups with competing hypotheses and scenarios. Some of the proposed conceptual models for the genesis of the salts are mutually contradictory. The persistence of this debate is linked to the very partial record of the MSC preserved onshore while the only complete record is located offshore in the deepest Mediterranean basins.
Original and innovative aspects of this Action, that have been identified as gaps to be filled are:

- for the first time **an enlarged and inclusive scientific community will share objectives, tools, infrastructures, and research activities** to resolve one of the longest-living controversies in the field of Earth Science: The Messinian Salinity Crisis and the deposition of the Mediterranean Salt giant;
- the outcome of this Action is expected to be a break-through approach that will enable progress in scientific knowledge, planning for co-ordinated long-terms scientific activity, including scientific drilling, broadening of the spectrum of disciplines involved in the research (deep biosphere, oil and gas exploration, geohazards, dynamic topography);
- **stakeholders** (private companies, governmental institutions, environmental organizations) **will have a unique, highly qualified, inclusive scientific counterpart** for addressing scientific, engineering, and environmental issues related to the Mediterranean salt giant;
- **citizens, school teachers, and media will be able to refer to a highly qualified, inclusive scientific counterpart** for correctly addressing the knowledge of the Miocene desiccation theory, alternative hypothesis, and state of the art research. This Action will provide the tools for an effective dissemination process.

1.4.2. In relation to existing efforts at European and/or international level

This COST Action has been conceived as a joint initiative coordinating scientific research of existing international efforts including: The European Consortium of Ocean Research Drilling (ECORD;http://www.ecord.org); the EU- FP7 Marie Curie Initial Training Network, MEDGATE (http://www.eu-medgate.net); the European initiative TOPO-EUROPE: the Geoscience of Coupled Deep Earth – Surface Processes (http://www.topo-europe.eu); the Japanese and US branches of the International Ocean Discovery Program (IODP;www.iodp.org), the International Continental Drilling Program (ICDP;www.icdp-online.de). Each of these projects comprise important elements that relate directly to the central MSC focus of this COST Action and will feed into the network's research objectives. However, individually none of these projects can tackle the breadth of the research questions targeted here which are only achievable through collaborative connectivity.
Additional international research initiatives with whom this Action will link for its activity are:

- ACTIONS MARGES - French Margins Project (http://www.actionsmarges.univ-rennes1.fr/) – Western Mediterranean;
- CIESM – The Mediterranean Science Commission (http://www.ciesm.org);
- EPOS - European Plate Observing System (http://www.epos-eu.org);
- EUROFLEETS (http://www.eurofleets.eu) Salt deformation and fluid circulation in the Algero-Balearic abyssal plain (SALTFLU) Project;
- IMAGE (Investigating Mediterranean-Atlantic gateway exchange)–Magellan Plus Workshop, 2014 (http://www.essac.ecord.org/index.php?mod=workshop&page=upcoming-workshop)
- MERMAID – Mobile Earthquake Recorder in Marine Areas (http://geoweb.princeton.edu/people/simons/MERMAID.html);

- MEDSALC - Messinian Salinity Crisis: the greatest environmental perturbation of the Mediterranean and its repercussions to the biota (http://excellence.minedu.gov.gr/thales/en/thalesprojects/375405), THALIS-NKUA project co-funded by the E.U. and Greek national funds;

The integration and interaction with other research programs will be organized through the circulation of the information about National/International programs will be ensured by a specific item in the Agenda of each Management Committee (MC) Meeting and by a specific Forum in the web site.

2. IMPACT

2.1. Expected Impact

2.1.1. Short-term and long-term scientific, technological, and/or socioeconomic impacts

The expected scientific impact of this COST Action will go beyond the mere understanding of the Mediterranean Salinity Crisis:

1. this COST Action will provide an opportunity to develop further our knowledge of salt rock formation, deformation and its associated hydrocarbon systems. The project will **enable the sharing of knowledge, technology and expertise among the various research groups/communities and with the industry,** now rapidly moving towards deep, sub-salt exploration in the Mediterranean Basin;
2. sampling and analysing samples of the salt giant will allow the investigation of the potential of this geological environment to promote deep-dwelling communities of microbes and viruses. This first order research has a **potential to yield results relevant to industrial applications** like understanding the microbial processes that lead to the formation of sour gas (H_2S), a major hazard for the drilling industry;
3. the study of salt deformation will contribute to the **understanding of submarine geohazards in the Mediterranean region** (earthquakes, submarine landslides, tsunamis, gas emissions).

While performing exciting and novel research, this COST Action will promote participation of young talents and next generation leaders in science and technology, support opportunities for Early Career Investigators, provide gender balance, and foster interdisciplinarity. The experience gained through the management of the Marie Curie-Skłodowska Initial Training Network, MEDGATE will improve the efficacy of our long-term commitment and enhancement of knowledge transfer to younger generations.

The expected socio-economic impact is both in the short- and long-term. In the short term, the Action will improve industrial exploration of deep hydrocarbon resources in the sensitive environment of the Mediterranean Sea. In particular **the Action will allow for a comprehensive and improved perception of risk to the densely populated Mediterranean coastlines** (especially during summer time). In the long term, the development of improved models of rock salt deformation will **help mitigate the risks induced by subsurface salt movement and fluid flow which affect the stability of seafloor and the dry earth surface**. The socio-economic potential of the discoveries in the fields of biology and microbiology are unpredictable, but discoveries with the promise of major practical benefits and applications can be anticipated. Furthermore, understanding the origins and evolutionary history of the deep biosphere will provide insight into the evolution of ancient life on Earth and possibly elsewhere in our solar system.

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2.2. Measures to Maximise Impact

2.2.1. Plan for involving the most relevant stakeholders

In addition to the academic community and higher education institutions, the end-users of the Action include oil and gas industries, public administrations, policy makers (ministries, geological surveys, environmental agencies), and non-governmental agencies. The proponents are aware that engaging such stakeholders formally is challenging. However, seven oil&gas and service companies active in the Mediterranean have expressed in written form their interest in the Action. Several representatives of such companies have attended preparatory meetings, and proponents attend regularly Oil&Gas meetings. The scientific community behind this Action has a formal link with industry through the ECORD (European Consortium for Scientific Ocean Drilling) Industry Liaison Panel (ILP). Some geological surveys and Ministries of Mediterranean countries have also expressed an interest in joining this COST Action.
It has not been possible to identify end users for the deep, extreme biosphere aspect at this stage. However, similar first order exploration of extreme deep sea environments (like black smokers) have yielded high value industrial applications. Bringing in the appropriate communities to develop such products will be kept under review.
An ultimate stakeholder for the output of this COST Action is represented by the general public. The desiccation theory of the Mediterranean Sea offer students and the public in general a fascinating scenario of the magnitude of environmental changes that affected our planet in the recent geological past. Furthermore, the environmental concern of citizens with respect to offshore exploration in the Mediterranean has increased dramatically in the recent years. The dissemination activity of this COST Action will be aimed at presenting an extreme geological event (the Mediterranean Salinity Crisis) as an opportunity for the academic community, the industry, governmental and non-governmental agencies to address in an environmentally sustainable way the economic development of the Mediterranean region.

An artist's impression of the Early Pliocene Gibraltar Strait flooding (©1986 Guy Billout, first published in The Atlantic Monthly).

The strategy to increase the participation of stakeholders in the Action is two-fold: 1) to establish a Cross-Cutting Working Group addressing the organization of knowledge transfer and capacity building via Training Schools involving young scientists, the dissemination of the information and the involvement of stakeholders, and the management of an interactive web-site and digital networking and scientific communication tools; 2) to establish the Steering Group: Industry and public administration liaison (SG IPAL) addressing specifically the relations with Industry and public administration liaison stakeholders.

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Stakeholders representatives will be invited to the project's first Working Groups Scientific Meeting and will be invited to contribute to research and coordination objective 10 of the Action.

2.2.2. Dissemination and/or Exploitation Plan

Dissemination will be targeted to two kinds of audience:
- The research community (universities and research institutions) world-wide;
- stakeholders

Dissemination methods:
For all audience, a web-site will provide a clear and concise outline of the networking activities, outcomes, downloadable key-note presentations, calendar of events. Mailing lists where to send periodic updates of these activities and news and information sharing through social networks.
For the research community a link will be provided with the web site http://web.archive.org/web/20130709230054/http://www.messinianonline.it/ and provide a comprehensive catalogue of initiatives, events, projects and publications about the Mediterranean Salt Giant.
For petroleum companies a list of interested companies will be establish for circulation of regular updates on the project and project highlights, expressions of interest for data access, invitations to participate in this COST Action meetings. In particular a preferential link will be established with the International Ocean Discovery Program (IODP) Industry Liaison Panel.
Governmental institutions like geological surveys and ministries will be informed via e-mail updates, and through invitation to participate at meetings and workshops.
High school teachers and students will be addressed through a dedicated section of the web page containing non-technical articles and digital presentations for the use in the classroom, short videos on a variety of relevant science topics and links with the Geosciences Information of Teachers GIFT Program of the European Geosciences Union (EGU) organized by the EGU Committee on Education.
Media will be addressed by press releases and digital material (images, short descriptions of tasks, highlights of scientific results).

Efficient dissemination and/or exploitation of the results of this Action will be achieved in the following way:
During the kick-off meeting, a detailed plan for collection of available dissemination material to be included on the web site will be defined. This plan will allow the population of the web site addressing all 5 audiences with 'existing material'.
Include a procedure for informing the Web Site Coordinator and the Leaders of the Cross-Cutting Working Group (CcWG) Training and dissemination of any result of the work of the Action that needs to be either on the Web Page, circulated via e-mail or included in a press release. The status of the Dissemination plan will be included in the MC Agenda every meeting.
A documentary will be produced with footage collected by MEDGATE Early-Career Investigators and students interviewing the scientists who formulated the Mediterranean Desiccation Theory in 1973 during the ECORD Magellan+ Workshop in Italy in 2013.
A final **Stakeholders Event** associated to the final meeting will present the results of the projects to industry, and public administrations stakeholders.

2.3. Potential for Innovation versus Risk Level

2.3.1. Potential for scientific, technological and/or socioeconomic innovation breakthroughs

This Action sets the basis for a long-term cooperation. The ultimate goal, extending beyond the life time of the Action is the scientific drilling, for which an umbrella proposal has been endorsed by the

International Ocean Discovery Program (IODP). The first phase of scientific drilling, targeting marginal basins of the Western Mediterranean is envisaged within the life time of the Action. **The achievement of scientific drilling will represent a scientific breakthrough.** It will represent a milestone in the understanding of the evolution of sedimentary basins, climate evolution and more specifically mechanisms of deposition of a salt giant. There is a certain risk that drilling will not happen, as it depends on factors like availability and quality of site survey data, logistics of the infrastructure, environmental restrictions. Such risk cannot be quantified. In this respect the participants consider **the level of uncertainty appropriate to the high potential scientific return**. The establishment of the network will with no doubt lower the risk as it will favour a coordinated effort for planning and performing the drilling.
Socioeconomic innovation breakthrough will happen if the network succeeds in **involving all the stakeholders, and impact on the approach used to explore the deep sea mineral resources of the Mediterranean**. The plan for involving stakeholders has been developed for this purpose. The risk is fluctuation in the oil and gas price, that might dissuade companies for embarking on costly exploration, and public acceptance.

3. IMPLEMENTATION

3.1. Description of the Work Plan

3.1.1. Description of Working Groups

Thematic WG A - Messinian Salinity Crisis, addressing the causes, processes, and timing of the MSC;
Task-specific scientific objectives:
1. To test existing hypotheses for Mediterranean evaporite formation;
2. to develop unifying models for the MSC salt giant;
3. to reconstruct the paleoclimate conditions during the MSC and investigate the impact on global climate.

Task Specific deliverables:
1. Document and publications compiling, with critical analysis, of all available digital scientific information on the MSC salt giant and publish the resulting data in easily accessible, open access synthesis documents and data bases (e.g. seismic atlas, isotope geochemisty data base, etc.);
2. document and publications including the reconstruction of the timing and modality of large scale evaporite deposition and its relationships with small- to large-scale climatic oscillations;

Thematic WG B - Salt Tectonics, fluids and geohazards, addressing the influence of salt deposition in the deep basin in terms of deformation and fluid migration/accumulation;
Task-specific scientific objectives:
1. To investigate syn-sedimentary salt tectonics and halite creep;
2. to constrain post-depositional salt deformation and its consequences on sedimentary mass wasting;
3. to establish the physical and mineralogical conditions that allow fluids to migrate in salt sequences.

Task Specific deliverables:
1. Application of numerical thermo-mechanical models of early multi-layered salt deformation and creep triggered by salt-induced rapid basin subsidence and marginal tilt; publications.
2. Document and publications describing the evaluation of the appropriateness of matured and complex salt structures as stratigraphic barriers and waste repositories;

Thematic WG C - Deep Biosphere, addressing the abundance and diversity of microbial life associated with extreme environments (deep, hyper-saline, possibly high-temperature).
Task-specific scientific objectives:
1. To determine whether evaporitic sulphate minerals are fuelling the Mediterranean's deep biosphere;
2. to establish whether the interaction between limiting factors (pressure, temperature, salinity) and a highly variable chemical environment may produce a diverse and novel deep biosphere community;
3. to use the biomarkers and surviving microbes trapped within brine inclusions to reconstruct the depth, photic and oxic conditions of ancient, hypersaline depositional environments.

Task Specific deliverables:
1. Inventory of the microbial communities, pore fluids and evaporite minerals in modern hypersaline systems (deep Mediterranean brine lakes, salt mines in Sicily, Red Sea) as modern analogues for the ancient, deep biosphere communities that developed in salt giants;
2. published synthesis of the valuation of the potential for microbial gypsum reduction in salt giants to produce subsurface accumulations of sour gas (H_2S) which represent a major drilling hazard;

Thematic WG D - Deep Earth to surface processes interactions, addressing the consequences of base-level change on river behaviour, the erosion, supply, transport of sediment, and landscape-relief and vertical evolution resulting from salt giant deposition.
Task-specific scientific objectives:
1. To quantify the consequences of base-level change on river behaviour, erosion, supply, transport, karstification and landscape-relief evolution;
2. to reconstruct a complete history of basin evolution, with a specific focus on the paleoenvironment, bathymetry and chronology of early sedimentation;
3. to constrain the tectonic mechanisms that contributed to the closure of the gateways before the MSC and the reopening of the connection afterwards.

Task Specific deliverables:
1. Documents and publications including the quantification and modeling (analogical and numerical) of the consequences of inferred baselevel change(s) during salt deposition on river behavior, the erosion, supply, transport of sediment, karstification, landscape-relief and vertical evolution of the basin, based on and comparing the different existing hypothesis.

Cross-cutting WG E - Data management, addressing the technical part of the interdisciplinary DREAM data storage, management, and dissemination in collaboration with all other Working Groups (WGs).
Task Specific deliverables:
1. Web tools for data sharing and management

Cross-cutting WG F - Training and dissemination, addressing the organization of knowledge transfer and capacity building via Training Schools involving young scientists, the dissemination of the information to stakeholders, and the management of an interactive web-site and digital networking and scientific communication tools.

Task Specific deliverables:
1. the identification of research frameworks at a national and international levels, including industry and administrations to promote the cross-disciplinary coordinatation of scientific activity;
2. the training of the next generation of experts focusing on deep sea resources and environmental impact assessment in the whole Mediterranean area, including southern and eastern coastal states.

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Due to the highly inter-disciplinary character of the research, an effort is made to avoid sectorialization of activities. All Working Groups will have to work in a coordinated manner. Therefore, **Milestones are project-specific and consist in: plenary meetings** (including Kick-off Meeting and Final Meeting with an 'Event' for stakeholders), **Training Schools, and international scientific drilling.** Date of drilling is inserted in the GANTT Diagram below only tentatively, as it will depend on the evaluation procedure and logistics of International Ocean Discovery Program (IODP), for which initiatives will be coordinated by all WGs.

3.1.2. GANTT Diagram

	YEAR 1						YEAR 2						YEAR 3						YEAR 4				
TWG-A Messinian Salinity Crisis	M1 Kick-off meeting	X	X	X	X	X	Plenary WG's Scientific Meeting 1	X	M2 Training School 1	X	X	X	Plenary WG's Scientific Meeting 2	X	M3 Training School 2	M4 Training School 3	X	M5 Scientific Drilling (TENTATIVE)	Plenary WG's Scientific Meeting 3	M6 Training School 4	X	X	X	M7 Final Meeting with stakeholders
TWG-B Salt Tectonics, fluids and geohazards				X	X	X		X		X	X	X		X			X				X	X	X	
TWG-C Deep Biosphere				X	X	X		X		X	X	X		X			X				X	X	X	
TWG-D Deep Earth to surface processes Interactions				X	X	X		X		X	X	X		X			X				X	X	X	
CcWG-E Data management		X	X	X	X	X		X		X	X	X		X			X				X	X	X	
CcWG-F Training and dissemination		Web Site set-up		X	X	X		X		X	X	X		X			X				X	X	X	
Steering Group: Industry and public administration liaison			X	X	X	X		X		X	X	X		X			X				X	X	X	
STSM Management			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Project Management	MC mt1	X	X	X	X	X	MC mt2	X	X	X	X	X	MC mt3	X	X	X	X	X	MC mt4	X	X	X	X	MC mt5	

3.1.3. PERT Chart (optional)

No PERT available

3.1.4. Risk and Contingency Plans

Most of the activities of this COST Action are not subject to risk. They are based on on-going program of valorisation of existing seismic data (e.g. the development of the second edition of the Atlas of the Messinian Seismic Markers), examination of samples from existing cores, cuttings from oil industry drilling, outcrop analogues for biological activity, modelling of deep crustal structure, writing and preparation of site survey data for International Ocean Discovery Program (IODP) drilling.
The main risk is represented (as described in Section 2.3.1) by a delay of the first phase of scientific drilling (riserless drilling with the JOIDES Resolution) beyond the lifetime of the project, and fluctuations in the oil and gas price, that might dissuade companies for embarking in costly explorations, and public acceptance.
Should the drilling not happen during the lifetime of the project the activity will remain focussed on preparing for it in a coordinated way, and the drilling will represent an important legacy of the Action. In that case activity will be shifted to Site Survey data acquisition.
Should the interest in this COST Action of oil companies diminish due to negative trends in oil and gas price, the activity will be concentrated towards the remaining stakeholders, and the presentation of the results in oil industry meetings will be increased.

3.2. Management structures and procedures

Structure of this COST Action
- Management Committee (MC)

- Short-Term Scientific Mission (STSM) Manager
- Thematic Working Groups (TWG)
  - A - Messinian Salinity Crisis
  - B - Salt Tectonics, fluids and geohazards
  - C - Deep Biosphere
  - D - Deep Earth to surface processes interactions
- Cross Cutting Working Groups (CcWG)
  - Data management
  - Training and dissemination
  -
- Forums
  - Students and young researchers
  - Field work and Research cruises
  - National/International research programs
- Steering Group: Industry and public administration liaison (SG IPAL)

All participants in this COST Action are working, mostly independently, in teams on individual objectives, and possess the know-how and technical capabilities with respect to the methodologies outlined above.
At the first **Management Committee (MC)** Meeting, the Chair and the Vice-Chair of the Action, the **Working Group** Leaders**, and the STSM Manager** will be elected**.** The Vice-Chair and the -–Vice-WG Leaders will ensure continuity in in the absence of the Chair and the WG Leaders due to participation on the cruises or to field works. . In this process, a particular effort will be made to ensuring an equal distribution of Participating COST Countries in the management of the Action taking into consideration of gender balance. The WG Leaders as well as the Web Site Coordinator will will be elected at the first MC Meeting. The task of the STSM Manager is to coordinate the STSM applications to the MC and their evaluation by MC Members.
All participants in this Action will be actively involved in WGs in line with their expertises. Working Groups and Steering Groups will convene **annually for a joint meeting of the MC and scientific meeting**. Working Group Leaders will also organize **topical meetings** on specific issues according to the Annual plan defined yearly by the MC.
The Early Career Investigators will lead the field work and research cruises **forums**.
In order to ensure a rapid and efficient decision making process outside the MB annual meetings, e-mail consultations will be used for STSMs and other matters using the written procedure '**tacit approval mechanism**' with a two weeks (14 days) response time.
A **web site** will be launched shortly after the start of the Action and maintained until the end of the Action. It will remain accessible on a server of one of the participating institutes after the end of the Action. It will be responsibility of the Web Site Coordinator (within the Training and dissemination WG) to collect input for the web site from WG Leaders. Each MC Meeting will have a web site item on agenda in order to monitor its status and effectiveness.
An essential task of the MC, the WG Leaders, the STSM Manager and the web site Coordinator will be to ensure the coordination of national/international research programs via the feeding of relevant information to the web site Forum in order to stimulate applications to STSMs between laboratories, the establishment of common research teams, participation to conferences and workshops, and the formulation of new research project ideas.
Given the highly interdisciplinary nature of this COST Action, a rule will be established that **all Working Group Meetings will be held in plenary sessions**, in order to avoid sectorialisation of the activity.
Training Schools will be attended not only by trainees specializing in the field of the school theme, but also by trainees coming from different fields of research. The trainers will adapt their training method to this diverse audience.
STSMs will be encouraged to focus on intersectorial aspects of the research.

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3.3. Network as a whole

This COST Action is composed of numerous scientists from universities, research institutions, geological surveys and private companies) scattered all around Europe, the Middle East, North Africa, USA and Japan. It reflects a pan-Mediterranean composition, because the scientific problems addressed are important not only for European countries or northern Mediterranean shore countries.

The relevance of the scientific problems and its societal impacts justifies the need to open this community to the inclusion of both young and experienced researchers, involvement of industries and participation of relevant stakeholders from non-European areas of the Mediterranean region i.e. Middle East and North Africa (MENA region). A special effort has been placed in the involvement of Balkan countries, Middle East countries, and northern Africa countries, linking this COST Action to international cooperation programs such as the Expert Groups of the Western Mediterranean Dialogue (5+5) and the Regional Cooperation in Eastern Mediterranean Sea Research initiatives, of which it is a formal outcome, and the Central European Initiative (CEI) regional intergovernmental forum.

The scientific background of the majority of the partners is in Earth Science.Required expertise varies from geophysics, sedimentology, stratigraphy, paleoclimate, geochemistry biogeochemistry, and paleontology. There are also specialists from the fields of biology and chemistry, as well as engineering. As a consequence this COST Action will contribute to structure a critical mass of expertise, competencies and scientific interests, having the capability to successful achieve the aims of the Network.

Participation of Institutions from Non-COST Countries

The benefits for participants from Non-COST countries from the southern shore of the Mediterranean will be the participation in a highly qualified network from which they will gain in international contacts, opportunities to participate in Short Term Scientific Missions, and in Training Schools.

Because of the tight cooperation with scientists involved in IODP the participation of scientists and engineers from Japan and USA is considered beneficial, and it constitute an added value beyond the strictly scientific input of participants.

In addition, in Japan there is a strong scientific community interested in the Mediterranean Salt Giant, from the sedimentological/stratigraphic the deep biosphere points of view. Japanese scientists participated actively in the previous preparatory meetings held in Italy and France in the years 2013 and 2014.

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