European Cooperation in the field of Scientific and Technical Research
- COST -

Secretariat

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COST 227/08

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action ES0801: The ocean chemistry of bioactive trace elements and paleoclimate proxies

Delegations will find attached the Memorandum of Understanding for COST Action ES0801 as approved by the COST Committee of Senior Officials (CSO) at its 171st meeting on 18-19 June 2008.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action ES0801

THE OCEAN CHEMISTRY OF BIOACTIVE TRACE ELEMENTS AND PALEOCLIMATE PROXIES

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 270/07 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to improve knowledge of the distribution of key trace elements and isotopes in the oceans, and of the processes that control these distributions, so that the past and future response of the ocean biological and carbon system to global change can be more fully understood.

3. 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 12 million in 2007 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

The cycling of key trace elements in the ocean is critical to the functioning of ocean ecosystems, to the carbon cycle, to contamination of the ocean, and to assessment of past climate change. This COST Action seeks to maximize the benefit from research on the marine chemistry of trace elements conducted in a large number of COST countries. National research cruises will use new analytical and modelling techniques to improve understanding of ocean trace-element cycles. This Action will unite these national efforts with Working Groups focused on: i) maximizing the research achieved on nationally-funded cruises through international collaboration; ii) intercalibration and standardisation of analytical measurements across the European research area; and, iii) data management and the production of global data products for a wide range of end-users. A fourth Working Group will co-ordinate significant training and outreach activities, though which the Action will generate an international community of early stage scientists who understand trace-element cycles sufficiently well to contribute to a wide range of future interdisciplinary studies. This Action will liaise closely with international programmes with similar interests, particularly the GEOTRACES programme, and will allow realisation of cross-national goals of that programme within the European research area.

Keywords: Ocean biogeochemistry, Climate paleoproxies, Marine data management, Trace element intercalibration

B. BACKGROUND

B.1 General background

Trace elements and isotopes play a number of critical roles in the ocean. Some are micronutrients which are essential for life, others pollutants which are toxic to life, and others provide powerful tools with which to assess modern and past ocean processes. This COST Action seeks to bring together national research into the marine chemistry of these important trace elements and isotopes (TEIs).

Trace elements as micronutrients:

The oceanic cycles of the major nutrients (PO4, NO3, Si) have been widely studied and are now reasonably well known. Recognition of the importance of certain trace metals as micronutrients is more recent and understanding of the role of such micronutrients is still quite rudimentary. It is well established, however, that the supply of Fe limits total productivity in the high-nutrient, low-chlorophyll (HNLC) regions of the surface ocean. Fe is involved in a wide range of ecosystem processes, and other trace metals are also known to play critical roles in controlling biogeochemical processes in the ocean (Table 1). Cycling of these micronutrients is a key aspect of the ocean system, controlling not only the amount of ocean productivity, but also the nature of the ecosystems and the functions they perform. Micronutrient supply therefore governs critical pathways in the chemical cycles of major elements, including N and C, and is fundamental to the behaviour of life and of carbon in the ocean. This gives them particularly relevance as society seeks to anticipate and plan for future global change including climate warming and ocean acidification. Trace-element cycles influence the biological and carbon-cycle response to these changes, and have even been proposed as a possible route to modify future change.

Understanding of the cycles of these micronutrient elements is, however, incomplete. Analytical developments and key discoveries in recent years have advanced scientific knowledge, but understanding of the distribution of these elements and of the processes that control these distributions is poor. A good example is provided by present attempts to model the Fe cycle. Motivated by recognition of the importance of Fe, several workers have added Fe to ocean models. Such models have to make broad assumptions about the behaviour of Fe in seawater. Accurate knowledge of the chemical processes controlling micronutrient distributions would allow such models to be tested and refined, and similar models to be constructed for other important micronutrients. These models could then be used to improve interpretation of past changes to the carbon cycle (e.g. glacial to interglacial changes in atmospheric CO2), and to improve prediction of the oceans response to future global change.

Biogeochemical process	Important trace elements
Carbon fixation	Fe, Mn
CO2 concentration/acquisition	Zn, Cd, Co
Silica uptake – diatoms	Zn, Cd, Se
Calcifiers – coccolithophores	Co, Zn
N2 fixation	Fe, Mo (?V)
Denitrification	Cu, Fe, Mo
Nitrification	Cu, Fe, Mo
Methane oxidation	Cu
Remineralisation pathways	Zn, Fe
Organic N utilisation	Fe, Cu, Ni
Organic P utilisation	Zn
Formation of volatile species	Fe, Cu, V
Synthesis of photopigments	Fe and others
Toxicity	As (?Cd, Pb)

Table 1: Important biogeochemical processes in the ocean and the trace metals required for their action.

Trace elements and isotopes as paleoproxies:

Trace elements and isotopes also provide some of the most powerful and quantitative proxies with which to reconstruct past climate. Such paleoclimate reconstruction provides the most powerful mechanism with which to test the sensitivity of climate models, and provides significant information about the amplitude and style of climate change that the Earth can undergo (outside the rather narrow range that humans have experienced directly).

A wide variety of geochemical paleoclimate proxies have been proposed and, to varying degrees, calibrated against environmental gradients in the modern ocean. These potentially allow reconstruction of past variables such as sea-surface temperature (e.g. Mg/Ca); nutrient utilization (N isotopes); seawater pH (boron isotopes); and ocean circulation (231Pa/230Th or Nd isotopes). Understanding of many of these proxies is far from complete, however, as is sometimes demonstrated by disagreement between two proxies thought to respond to the same process. Reconciling such disagreements can be achieved through new measurements in the modern ocean to understand the processes controlling the proxies, and the limitations of the proxies. Calibrating such geochemical proxies, understanding their strengths and weaknesses, and establishing new proxies, is a goal of much ongoing research across the COST region and will offer a significant benefit to wider study of the climate system. These goals are critical as researchers, Governments and others seek to predict the complex response of the climate system to future (anthropogenic) changes.

An area of active research at national level:

The importance of trace elements as nutrients and paleoproxies (as well as their role as pollutants and as proxies of modern ocean processes) is generating a large amount of new research at national level across the COST region. This work contributes to a range of international programmes such as IMBER, SOLAS and the newly initiated GEOTRACES. Many COST countries are organizing research cruises under the auspices of these programmes and are collecting significant new datasets of TEI observations on seawater. Such ocean observations are funded and organized at national level and have the potential to revolutionize understanding of the ocean chemistry of TEIs in the coming years, with significant rewards in diverse disciplines.

Why COST?

The scientific rewards of ocean TEI research at national level will be greatly enhanced by international co-ordination of efforts under the auspices of a COST Action. As described further in Section B3, important goals of such international co-ordination include inter-laboratory training of young researchers; maximizing the range of sample collection and measurements on cruises through co-ordinated collaboration; intercalibration of measurement procedures; and organizing of international data management and data products incorporating national efforts. The basic research required to advance understanding of TEI cycles is ongoing at national level across the COST region and is funded at that level. The international co-ordination of this research is not funded at national level, but is well suited to the format of a COST Action and would offer significant rewards in terms of research, training, and data/publication products.

B.2 Current state of knowledge

Previous trace metal research:

In the 1970s, the Geochemical Ocean Sections Study (GEOSECS) produced the first view of the global oceanic distributions of many dissolved chemical species. This knowledge led to fundamental advances in understanding of ocean circulation and biogeochemical cycles, demonstrating the way in which the large-scale distributions of some trace elements and isotopes could allow the rate of ocean processes to be determined.

The development and application of trace-element "clean" techniques, and of improved analytical capabilities in the 1980s revealed, for the first time, consistent distributions of many other trace elements and led to an understanding of the role of trace elements as micronutrients that regulate ocean ecosystems and carbon cycling. This led to recognition of the importance of the global Fe cycle within the whole Earth system. During the 1990s, the key role played by many other trace metals in a wide variety of ecosystem functions also became increasingly clear (Table 1).

Parallel to new understanding of the importance of trace elements to biogeochemistry has been the development of new proxies to improve understanding of paleoceanography. Classic paleoproxies such as O and C isotopes have been augmented by a range of TEI proxies that provide information about a wide range of past environmental variables. These proxies offer greatly enhanced ability to understand feedbacks within the climate system, including those in the carbon cycle, so that the mechanisms driving climate change can be better understood.

To a considerable extent, work on TEI ocean chemistry over the past decades has been performed on single cruises, so assessing the relationships among various tracers, or of the global distributions of many tracers, has been impossible. A more comprehensive understanding of the global biogeochemical cycles of these trace elements is necessary before they can be exploited fully and reliably as tracers of ocean processes; before the sensitivity of marine ecosystems to perturbations of their biogeochemical cycles can be evaluated; before the transport and fate of contaminant species can be assessed; and before their utility as proxies can be realised.

Timely and innovative research:

The time is right for a major advance in understanding of ocean TEI chemistry:

- Advances in sampling techniques now allow efficient collection of clean seawater from all depths in the ocean.
- New analytical approaches now allow rapid ship-board techniques for measurement of key trace elements, and new mass spectrometric techniques allow measurement of isotope ratios.
- These techniques offer newfound ability to collect multi-element datasets from each cruise and are providing a new window into the distribution and cycling of TEIs.
- New understanding of the importance of micronutrients in ocean biogeochemistry and global change drives the need for new observations, at the same time that the ability to make them has increased so dramatically.
- Advances in forward and inverse ocean modelling techniques can now place TEI observations in global context and allow modelling of past and future scenarios.
- Implementation of contemporary ocean research programmes, particularly those assessing responses to future change of biological species and ecosystems in the oceans, will require better information about trace element cycles.
- The need to characterise the baseline distributions of TEIs before further perturbation by anthropogenic inputs.

The International GEOTRACES programme:

Recognition of the importance and timeliness of ocean TEI cycling has led to the establishment of a new international programme GEOTRACES. This programme is sponsored and approved by the Scientific Committee for Ocean Research (SCOR), which contributes to the costs of an international Scientific Steering Committee. The programme has no other direct funding and acts instead as an umbrella organization seeking to co-ordinate and to motivate marine chemical research in countries around the world. The first national cruises within the programme have taken place during the International Polar Year (IPY) in 2007/08 and have involved national research from countries including Germany, Spain, France, The Netherlands, and Sweden. A number of other cruises are funded or are seeking funding and will generate significant new TEI data and understanding in the coming years.

GEOTRACES recognizes the importance of activities that transcend national boundaries and require funding at international level. This COST Action targets these activities, and will set their agenda internationally. There is active nationally-funded ocean-TEI research in at least 14 COST nations. Some of this activity is linked to the international GEOTRACES programme, some to other programme (e.g. IMBER, SOLAS, PAGES, InterRIDGE, LOICZ), and some is unrelated to any international programme. There is no existing effort to co-ordinate this work across Europe. This COST Action will achieve such co-ordination.

B.3 Reasons for the Action

Several issues require international co-ordination if TEI cycles are to be fully understood in the ocean:

i. The diverse equipment and expertise required to sample the oceans and subsequently analyse the samples does not exist in many countries. This requires exchange of information between countries, the training of researchers across national borders, and the exchange of analytical equipment and/or appropriately collected water samples.

ii. National-level research agendas vary so that a ship from one nation might go, for instance to one region to measure Cd, while that from another country goes to a different region to measure Zn. Co-ordination of research efforts in numerous such situations will ensure that a full suite of critical TEIs is analyzed in the maximum number of regions globally.

iii. Many TEI measurements are challenging and have not been well standardized. It is often not clear that measurements of a TEI in one lab can be compared with those made by another lab. This limits the understanding that can be derived from global datasets of trace metals. To overcome this requires the exchange of standards and samples between labs so that the full range of collection and measurement techniques can be intercalibrated.

iv. Data collected during national cruises is archived in a wide variety of settings. These can range from retention by the lead scientist of the cruise, to storage in a national data centre. As datasets grow it becomes increasingly important to harmonize data management systems and to create data products that allow end-users such as ocean and climate modellers to readily access quality controlled sets of data from all nations. The lack of such datasets dramatically decreases the value of the hard-won data from national cruises.

B.4 Complementarity with other research programmes

Work in this COST Action does not overlap with any existing EU or ESF projects. There are no FP7 calls on ocean TEI chemistry and such research within the COST region has been funded only at national level.

One complementary EU activity is a 2008 FP7 call for the accurate inclusion of oceanic biogeochemical cycles in climate models. Such modelling will benefit directly from new observations and co-ordination of TEI data within this COST Action. Similarly, the existing EU Integrated Project, CARBOCEAN, through its focus on CO2 exchange between the ocean and atmosphere, might find some of the results of this Action of relevance, although it does not duplicate any of the scientific goals described here.

The work contributes to international programmes such as SOLAS, IMBER, and particularly GEOTRACES. These SCOR-sponsored programmes represent international umbrella organizations that do not provide funding to conduct research. This COST Action will contribute to these programmes through its training, co-ordination, intercalibration, and data management goals. It represents an explicit contribution to the GEOTRACES programme, by realizing international co-ordination fundamental to realizing the scientific goals of that programme.

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

The main objective of the Action is to improve knowledge of the distribution of key trace elements and isotopes in the oceans, and of the processes that control these distributions, so that the past and future response of the ocean biological and carbon system to global change can be more fully understood.

C.2 Secondary objectives

i. Establish a Europe-wide community of early stage researchers trained in the analytical skills needed for TEI measurements of seawaters, and who understand the processes and significance of TEI cycling sufficiently well to contribute to research in diverse fields that require such understanding.

ii. Co-ordinate measurement of TEIs to ensure maximum use of nationally-funded ship-time for TEI research.

iii. Establish robust intercalibration of analytical techniques for TEI measurements in seawater. This will ensure that data from various laboratories can be readily compared.

iv. Write and publish recommended analytical protocols for collection and analysis of key TEIs to maximize the spread of analytical best-practise, and the quality of resulting TEI data.

v. Establish a quality-controlled data-management system for ocean TEI data so that data from various nations and cruises is accessible through a flexible and easy to use web portal.

vi. Provide versioned data products of global ocean TEI data for end users such as ocean and climate modellers.

vii. Communicate the developing understanding of processes controlling trace element cycling to a wide range of end-user communities.

C.3 How will the objectives be achieved?

The primary objective will be met though significant ongoing research effort across Europe. This research will involve research cruises, laboratory work, and modelling efforts and will involve scientists from a large number of research institutions, including large European marine centres and a wide range of universities and research institutes. At least six nations have run or are expected to run open-ocean research cruises collecting relevant data (France, Germany, Netherlands, Spain, Sweden, UK) and a wide number of other COST nations are actively involved in data collection on returned samples and in interpretation and modelling of data. This data collection effort therefore involves significant manpower, with individual scientists often focused on addressing a quite specific question related to cycling of a particular TEI in a particular oceanographic setting.

The international co-ordination objectives require active communication between representatives of national-level research efforts, and interaction with the rest of the international research community. The co-ordination goals (i.e. the Secondary Goals listed in C2 above) will be achieved through a range of regular meetings, conferences and laboratory exchanges. This will involve significantly less manpower than the collection and analysis of the primary data, although the rewards are nevertheless very significant. Details of the precise mechanisms by which these objectives will be met are given in Section E below.

C.4 Benefits of the Action

This Action will take high quality but largely disconnected research ongoing in a large number of COST nations and co-ordinate it to provide global understanding that cannot be achieved from any one nation efforts alone. It will therefore significantly increase the scientific rewards from ocean-TEI research across the European research area. In particular, it will meet the seven objectives outlined in Section C2, leading to rewards in training; in data-quantity, quality and management; and to understanding of the cycling of TEIs in the ocean.

Such increased understanding will deliver benefits across a spectrum of climate and marine science disciplines, including modelling of ocean biogeochemistry, carbon-cycle studies, ocean ecosystem research, and assessment of ocean contamination. Global datasets of trace element distributions, and understanding of the processes controlling these distributions, will see widespread use, particularly in developing and refining models to assess future global change, informing the development of scientific, economic and social mitigation strategies for future change.

This COST Action will also contribute directly to one of the primary recommendations of the 2006 EC Green Paper, Towards a future Maritime Policy for the Union: A European vision for the oceans and seas. Particular emphases of the Green Paper were on improving marine observation and data management across Europe, both of which form essential parts of the Action.

Research capacity building is also an important aspect of this Action. The outcome will be an international community of young marine scientists who understand the processes regulating trace-element cycles sufficiently well to apply these knowledge in future interdisciplinary studies.

C.5 Target groups/end users

Marine biology research:
Ongoing research has identified the importance of trace elements in a wide variety of biochemical pathways in marine organisms. Study of these processes, particularly when extrapolating laboratory results to the context of the open ocean, relies on knowledge of the concentration, fluxes, and availability of trace elements in the natural environment. This Action, by focusing on the geochemical cycling of these elements, will provide detailed information about the biological availability and cycling of the key trace metals. This information will be of widespread use for study of ocean biology, and will have direct input to programmes such as IMBER. It will also provide important information to understand the role of changing micronutrient availability as the oceans acidify due to increased atmospheric CO2 levels during the 21st century.

Carbon cycle and climate change research:
The influence of trace-metal chemistry on the magnitude and type of ocean productivity gives it an important role in the carbon cycle and hence in climate. Better understanding of the cycling of these trace metals, arising from this Action, will allow inclusion of trace metal cycles, and their biological influence, to be incorporated in models of ocean biogeochemistry and of the global carbon cycle. These models will enable an assessment to be made of the response of the carbon cycle to changes in the cycling of trace metals induced by natural or human environmental change. Such questions include: How will the ocean carbon cycle respond to changes in dust supply caused by increasing desertification? Or to changing ocean circulation as the ocean warms? And how different will such responses be in different emission and mitigation scenarios? Such questions require the understanding of TEI cycles that this Action will provide. Similarly, improved calibration of geochemical proxies for studying past changes will allow rigorous interpretation of existing and new proxy records, and therefore the testing of current understanding of the mechanisms driving climate change.

Oil companies and others with an interest in ocean waste disposal:
Lack of knowledge about the natural cycling of trace metals in the oceans, particularly in the deep sea, means that the impact of additional trace metal inputs from human pollution (either accidental such as acid mine drainage, or intentional such as the aborted sinking of the Brent-Spar oil rig)

cannot be predicted. Knowledge derived from this Action will allow an assessment of the background levels of the trace metals and of the processes controlling trace metal removal, and will therefore inform debate about ocean disposal in the oil, mining, and other industries.

Geoengineers:
Incomplete utilization of major nutrients in the HNLC regions of the worlds oceans allows up welled CO2 to degas to the atmosphere rather than being consumed by biological productivity. Fertilization of the oceans with Fe has been shown, in small and medium scale experiments, to relieve Fe limitation and allow more complete nutrient use, thus increasing productivity and carbon uptake. It has been proposed by some that the same process, but on a larger scale, might be used to draw down CO2 from the atmosphere to counteract the effects of global warming. The consequences of such major Fe fertilization are presently difficult to predict, partly because the cycling of micronutrients such as Fe is poorly understood. The results of this COST Action will be directly relevant to this issue, and will therefore be of interest to both the companies advocating such a geoengineering approach, and to pressure groups arguing against it. The results will allow this debate to be based on a firmer scientific footing so that a rational and appropriate course of action can be followed.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

This subsection focuses on research being conducted and funded at national level. The Work Plan required for co-ordination of this national research is described in the next section (D2) and is the specific task of this COST Action.

The scarcity of TEI data is the major limitation in understanding their cycles. Even for Fe, for which understanding is relatively good, there are only a handful of measured profiles in the deep ocean. Although it is known that ≈90% of Fe supplied to the surface ocean comes from upwelling of deep waters, understanding of the controls of Fe in the deep ocean is consequently very poor. For other trace elements such as Zn, Cd or Co, the situation is still worse. And there is also only very limited observational data in the modern ocean with which to ground-truth important paleoproxies such as 231Pa and Nd isotopes.

A major goal of international research is therefore to constrain the distribution of TEIs in the oceans. This is not just a mapping exercise, however. By measuring TEI distributions along carefully chosen ocean sections that cross major chemical gradients, and sample distinct chemical processes, understanding of the controls on TEI distributions is also achieved. Crossing a major productivity gradient, for instance, provides information about the interaction between biological productivity and trace-metal supply. Other important gradients include dust flux; exchange at ocean margins; riverine inputs; ground-water inputs; and different or ageing water masses in the deep ocean.

Measuring a single TEI across such gradients does not generally provide unambiguous information about controls on that element. It can be difficult, for instance, to unravel the relative importance of inputs and outputs in controlling the concentration of a single trace element. But by measuring a suite of trace elements and isotopes with complementary chemical behaviour, and by augmenting these measurements with other basic oceanographic observations (temperature, salinity, water movement, biological pigments, etc.) it becomes possible to separate such effects. Such separation also comes from modelling TEIs in the ocean (along with significant other information). Attempts to model TEIs in the oceans tests understanding of the important processes controlling their distribution, and constrains the fluxes of TEIs in three dimensions. Understanding the processes controlling TEI distributions will represent a dramatic increase in knowledge of biogeochemical cycles in the ocean, and will be used widely by workers in many fields, including carbon-cycle modellers, ocean biologists, and those interested in human contamination of the environment.

The work required to understand trace element distributions and processes on a global scale is enormous, and cannot be achieved by any one nation. Important work is ongoing at national level, but without international co-ordination, this will not achieve global understanding. Some of this work contributes to international programmes. Amongst the goals of the SOLAS programme, for instance, is the assessment of Fe flux to the surface ocean from the atmosphere. More generally, assessment of the cycling of a large suite of elements in a wide range of ocean environments is the goal of the international GEOTRACES programme. The major research phase of this programme will be completion of about 20 large ocean sections, each measuring a suite of TEIs through the full water column, and each crossing important ocean gradients. These sections will be augmented by process studies to address particular questions that cannot be answered by the section approach.

The range of TEIs that it is important to better map and understand in the oceans includes those crucial to life (Fe, Zn, Mn, Cd, Cu, Co, Ni); those used as tracers of inputs to the ocean and of ocean circulation now and in the past (Al, REEs, Nd, Pb isotopes); those used to assess biological processes (isotopes of C, N, Si, Cd, Zn, etc.); those used to assess the rates of processes in the present and past ocean (the U-series isotopes such as 231Pa, 230Th, 228Ra, 234Th); and those known to be toxic ocean contaminants (Pb, Hg). New collection techniques, such as Ti rosettes mounted on Kevlar cable, now allow clean sampling of all these species. And a wealth of new analytical techniques, including multi-collector ICP mass spectrometry and shipboard flow-injection analysis, allow their measurement at previous unprecedented resolution and precision. Details of the significance of these chemical species, and of the process questions that need to be addressed for each of them, is provided in the Science Plan of the GEOTRACES programme, available to download from www.geotraces.org.

Ocean cruises collecting such TEI data are run by individual countries using national ship facilities, and are funded at national level. For instance, GEOTRACES section cruises are at various stages of planning in several COST nations, including France, Germany, Netherlands, Spain, Sweden, and UK. These will be dedicated cruises with capacity to collect a full range of TEIs. Each host nation is expected to take the lead in the measurement and interpretation campaign on that cruise, as befits cruises funded at national level. In each case, Principal Investigators have justified their cruise to answer a particular question or set of questions related to TEI cycling. But few countries have the analytical expertise or resources to measure the full range of key chemical species. Co-ordination between nations is therefore critical to achieve wider benefit from each cruise and, particularly, if a global map of each trace element is to be achieved. For instance, if a cruise led by one country ran a cruise to an ocean margin to assess the role of submarine groundwater discharges as a source of micronutrient elements to the ocean it would provide important new information about that aspect of TEI cycling. But if researchers on the cruise did not have the capacity to accurately measure the full range of TEIs, the opportunity would be missed to assess the importance of groundwater discharge in influencing proxies, or in transport of pollutants.

Each national cruise will provide important discovery about particular processes and particular chemical species in the quest to fully understand ocean TEI cycles. But to maximize the reward from these cruises and to derive global understanding of the distribution and processes of the full suite of elements requires international co-ordination.

D.2 Scientific work plan – methods and means

To assess the global distribution of key TEIs in the ocean and understand the processes setting these distributions requires co-ordination of national effort in five areas. These represent the Work Plan of this COST Action.

i. Identify synergies between COST nations and ensure maximum reward from national cruises.
This COST Action will bring together scientists during the planning and implementation stages of each nationally-funded cruise. Scientists with diverse expertise will be involved, including those with a wide range of analytical expertise, as well as ocean modellers and end-users. The chief scientists planning each cruise will identify the primary goals and measurements required for that cruise, but discussion within the COST Action will ensure that these primary goals are augmented by secondary goals involving other nations so that a full range of chemical species are measured and maximum benefit is derived from the available ship-time. This co-ordination will involve both senior and younger scientists. Active involvement of young scientists will make them aware of the process involved in planning research cruises, expose them to a wide range of scientific ideas, and help them to create an international network of collaborators. One of the lasting legacies of this COST Action will be that these young scientists, having experienced international co-ordination of research cruise planning across the European research area, are likely to follow similar practices when they plan their own cruises after the lifetime of this Action.

ii. Intercalibration
It is essential that measurements of each trace metal can be accurately compared from one cruise to the next, and from one lab to the next. Many of these measurements are difficult (involving metals present at picomolar concentration, or natural radionuclides with short half-lives), and are prone to contamination during collection or in the lab. An important activity of this COST Action will be to ensure that laboratories involved in TEI analysis are well intercalibrated. A first phase of this activity will build on two US-NSF-funded cruises (in 2008 and 2009). These cruises will collect large numbers of identical samples for the explicit purpose of international intercalibration. Many European laboratories will receive samples from these cruises and will make a diverse range of

measurements. There is no existing funding, however, (outside this COST Action) for explicit intercomparison of these measurements across Europe; for liaison of the European community with the US groups that are leading this effort; or for planning follow up efforts to discuss and correct measurement disagreements. This is an area where research in the European region risks falling behind that in the US. This COST Action will correct this, and will enable Europe to contribute fully to present US intercalibration efforts and to play a full role in planning the next phase of TEI intercalibration. One aspect of intercalibration is the preparation and distribution of standard materials to ensure routine accuracy of measurements. This is an area in which European scientists have significant expertise and will be one area of active discussion and planning during intercalibration co-ordination within this COST Action. Another outcome of this activity will be the preparation of documents (CookBooks) detailing recommended sampling and analytical procedures for each TEI. These will not be prescriptive, but will offer advice to inexpert labs about appropriate protocols. Involvement of young researchers will be an integral part of these intercalibration efforts. It is often young researchers who actually make the measurements and have the most up-to-date awareness of analytical protocols. They are also least likely to be defensive about the measurements protocols they follow, and most willing to be flexible about testing and adopting new approaches. They will therefore play a crucial role in all intercalibration efforts.

iii. Data management

This COST Action will co-ordinate TEI data, establish procedures to assess its quality, and establish a data-management system to ensure storage in a readily useable format. Ocean data management is an activity where Europe has significant expertise, hosting some excellent ocean-data storage facilities, but there is presently no specific archive of TEI data at any data centre in Europe or worldwide. Data storage and management is not cheap and requires dedicated facilities and personnel. Some funding for these activities are in place from a national agency, and other national funding is anticipated during 2008, so the principal infrastructure costs are met. Appropriate data storage requires not just this infrastructure, however, but active discussion between the scientific community and the data storage facilities. Protocols for assessing quality, for metadata content and format, for data format, for reporting of uncertainty, and for output styles and web-interface design all require input from the scientific researchers who create the data and those that use it. This COST Action will bring together data generators and data users with professional data managers to set up, populate, and maintain a new world-centre for TEI data management at a European data centre.

Crucial to this effort will be the construction of an easy-to-use web interface that will be open to all, and will provide sufficient flexibility to allow data to be searched, plotted, and output in diverse ways. Late in the lifetime of the COST Action, this data management activity will also produce global data products. These will be versioned sets of data with global coverage that will be released in several formats (downloadable from web, CDs, etc). Having specific versions of TEI data will ensure that modellers and other end users can readily compare their results, assured that they are working from identical input data. This is a similar in approach to versioned datasets such as the ERA wind fields, and the IntCal radiocarbon calibration datasets.

iv. Modelling of data and end-user interaction

Scientific rewards will arise from discussion between ocean chemists, striving to understand TEI cycles, and ocean modellers. Modellers represent a key group of end-users of TEI data as they strive to model biogeochemical processes sufficiently well that they can predict future scenarios. This COST Action will hold meetings that bring together modellers and observationalists. Modellers will request data types and formats, while learning about the latest discoveries derived from new observations. Observationalists will pose problems to the modellers, and will gain insight from the models about issues such as the fluxes of TEIs, and about regions where models predict gradients in TEI concentrations that have not yet been observed. Modellers will include those with expertise in ocean physics, ocean biology and the global carbon cycle. Meetings will also involve representatives of other end user groups. For instance, groups interested in the perturbation of the natural environment by humans, either accidentally or deliberately. Oil companies, for instance, have sometimes sought to dispose of oil platforms and other structures in the deep ocean and have been prevented by ignorance of TEI cycling in that setting. This COST Action will seek to involve representatives of companies and NGOs with interests in such questions. Again, involvement of young researchers in these activities is crucial to their success and will be fully pursued. It is these young researchers who will be able to explore the new interdisciplinary interfaces discovered during this work.

v. Training of researchers and capacity building

The analysis of TEIs has significantly advanced in recent years and continues to progress. Transfer of measurement procedures from labs that pioneer them to other labs is often slow. Publication of protocols helps, but there is no substitute for talking to those that make the measurements and, ideally, seeing and making the measurements oneself. An important feature of this COST Action will be the training of researchers in new measurement approaches through laboratory visits and though meetings with analytical foci. This activity will involve researchers at all levels those with many years of analytical experience, and those who are just preparing to make their first TEI measurements on seawater. This activity will ensure that best analytical practice is spread amongst the COST nations, and will help in the development and testing of new analytical approaches, opening the door to ongoing European collaboration, to new research directions, and possibly to new commercial analytical products. A particular focus of these activities will be to train researchers in nations without existing measurement capabilities.

E. ORGANISATION

E.1 Coordination and organisation

This COST Action will use a range of approaches to achieve the objectives:

i. Management Committee

The MC will contain at least one member from all participating nations and will meet biannually. It will supervise the formation and activities of WGs and receive reports from them. It will oversee all WG tasks, playing a particularly important role in WG1 (Cruise Planning) which will have a frequently changing membership. It will also liaise with international programmes, particularly the International GEOTRACES programme.

The MC will oversee outreach (including the website) and organize reviewing and approval of publications. The MC will also oversee organization of Workshops and the Conference. The MC will be responsible for the administration of financial arrangements within the COST Action.

Critical early milestones of the MC are to establish membership of WGs (Month 1) and to organize the first workshop (Month 9).

ii. - Workshops and Conference

Workshops will bring together scientists to discuss and plan research. Two workshops will be held. Provisional workshop foci are:

Trace metal chemistry of the high-latitude oceans

There are significant European research interests in the Arctic and Southern Oceans, and these are critical regions for future climate. This workshop will discuss the state of knowledge of these regions following the International Polar Year, will identify new research priorities, and will initiate planning for new high-latitude cruises.

Combining models and observations of ocean chemistry

As data streams increase, interaction between data collectors and modellers becomes critical. This workshop will bring together ocean modellers to learn about new results from observationalists, and to explore productive collaborations.

In the final year of the Action a large high-profile conference will be organized and widely advertised. It will attract a diverse audience including ocean chemists, climate and carbon-cycle modellers, ocean biologists, NGOs, industry, and the media and will be a flagship for TEI research across Europe.

Meeting milestones include holding the first workshop (15 months), the second workshop (30 months); and the conference (45 months).

iii. Training Schools

Two Training Schools (TS) will be held to introduce graduate students and new post-doctoral workers to the latest TEI analytical techniques, and to interpretation of results. They will feature lectures from leaders in the field and practical experience supervised by active practitioners. Provisionally, the focus of the first TS will be measurement and interpretation of bioactive trace metals, and the second will concentrate on paleoproxies and their interpretation.

TS milestones include holding the first TS (12 months) and the second TS (24 months)

iv. Short Term Scientific Missions

STSMs will allow young researchers to spend up to two weeks at an institute specializing in a particular type of measurement. This work will ensure capacity building and comprehensive training of the next generation of scientists. Two issues will form the focus of STSMs:

- where intercalibration efforts point to discrepancies between labs, an STSM will allow comparison of measurement techniques to eliminate the cause of the discrepancy

- where an analytical ability is required on a cruise and insufficient expertise is available, an STSM will rapidly and effectively train a new practitioner.

STSMs will be co-ordinated by WG4 (Capacity Building) who will identify the milestones of this activity based on the needs of the research community.

v. Action specific website

An Action specific website will be set up and regularly updated. It will contain overview material about the Action, and act as a portal from which to enter information about all aspects of the Action. This will include links to intercalibration results and documents, training information, and to the Data Website.

E.2 Working Groups

Four WGs will deliver the Actions objectives:

i. Research Cruise Planning

This WG will ensure that maximum use is made of nationally funded ship-time for TEI research. The group will meet approximately one year before each cruise. Membership of this group will change according to the needs of particular cruises; some permanent members staying on the WG to ensure transfer of knowledge from one cruise to the next. Rotating members will be those with relevant interests to the cruise in question, such as regional expertise, knowledge of key processes, or complementary analytical expertise. The WG will ensure that a full range of TEI measurements are made during each cruise, and that all opportunities for complementary research are explored. Membership of this group will feature a significant number of young scientists. This WG will also survey opportunities for TEI measurements on other cruises, and ensure that links between research in the COST region and other countries are strengthened.

ii. Intercalibration

This WG will collate and compare intercalibration results, solve intercalibration problems, and organize future intercalibration work. The WG will contain experts in the measurement of each class of TEIs. Early meetings will analyse results from the 2008 Intercalibration cruise, and plan for the 2009 cruise. These meetings will identify suitable STSMs, and will identify and commission the production of suitable standards to ensure continued analytical accuracy. The WG will also produce CookBooks providing details of suggested protocols for accurate measurement of each TEI. This WG will interact with existing intercalibration efforts in the US, and will engage countries with developing analytical expertise for TEIs (e.g. China, India) to efficiently propagate best practise.

iii. Data Management

This WG will co-ordinate the scientific aspects of data management, and the production of data products. It will liaise with funded data managers at a major data-management centre, providing the scientific expertise to establish a global database for TEI data. The WG will establish protocols for assessment of data quality, for metadata information, and for data format. The WG will also oversee the design of a website allowing easy access to the data, including suitable software to produce graphs and maps. Towards the end of the Action, this WG will produce and publish versioned datasets for TEIs. This WG will consist of analysts making the measurements who understand the nature of the data; ocean modellers and other end users who need the data; and professional data managers experienced in database building and maintenance. This range of expertise is not normally brought together, so this WG will provide an unusual forum, well placed to build a world-leading new database service.

iv. Training and capacity building

This WG will oversee training and capacity building. It will meet less frequently, generally adjacent to a MC meeting to reduce costs. Its remit will be to ensure that young researchers are adequately trained, and that information about TEI measurement and interpretation is spread to nations were such expertise is lacking. This WG will organize some STSMs, and both the TSs.

E.3 Liaison and interaction with other research programmes

Liaison with International GEOTRACES will be important since this Action shares many goals with that programme. This Action does not seek to replicate any international co-ordination conducted by GEOTRACES but will achieve goals important to GEOTRACES within the European context. A complementary relationship with the GEOTRACES programme will be ensured by having, at all times, a minimum of three people on the Action MC who are also members of the GEOTRACES SSC. Representatives of GEOTRACES from other non-COST nations (e.g. US, Japan, India, and China) will be invited to appropriate Action meetings to ensure their international scope, and to propagate knowledge of new European research results.

Interaction with other international programmes which are complementary to this Action such as SOLAS, IMBER, CLIVAR, and PAGES will also occur. Data products and intercalibration protocols from this Action will take the needs of these programmes into account to maximize the benefit of new TEI measurements to these diverse research communities.

This Action will also interact in a minor way with Action 735 which may feature some effort to assess the flux of limited TEIs to the surface of the ocean from the atmosphere. Duplication of goals is not anticipated, but will be assured against by inclusion of a representative from Action 735 in the MC of this Action.

E.4 Gender balance and involvement of early-stage researchers

This Action will respect an appropriate gender balance in all its activities and the MC will place this as a standard item on all its MC agendas. The Action will also be committed to involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

Early stage researchers will play an important role in meeting the scientific goals of this Action as outlined in Section D2. Their involvement will be particularly important in the co-ordination of cruise planning, in intercalibration, and in modelling. There will also be significant opportunity for training of early stage researchers within the programme. Training is the specific remit of WG4 and forms a significant component of the Action through the TSs and STSMs (Section E1).

Every effort will be made to ensure gender balance on the MC. Some early stage scientists are likely be appointed to the MC, but it is not expected that the MC will contain a large number of them. The MC will, however, take responsibility for ensuring that early stage scientists are fully integrated in all other activities of this Action.

F. TIMETABLE

This COST Action will last for four years. While TEI measurements in the ocean will obviously continue beyond this period, four years is the time required to achieve the specific goals outlined in this COST Action. Specific Action goals for each of the four years of its duration include:

Year 1:

- Convene Management Committee (MC)
- First MC meeting to establish Working Group members and initiate Action
- Action website launched
- First Action Training School (Bioactive metal measurement and interpretation)
- 3 STSMs conducted
- At least one meeting of all four WGs
- Second MC meeting to solve any early teething problems and review early work of WGs

Year 2:

- First Action workshop - Trace metal chemistry of the high-latitude oceans
- Two annual MC meetings to review progress, plan for the future.
- Second Action Training School (Proxy measurement and interpretation)
- 3 STSMs conducted
- WG meetings

Year 3:

- Two annual MC meetings to review progress, and prepare publications
- Second Action workshop - Combining models and observations of ocean chemistry
- 2 STSMs conducted
- WG meetings

Year 4:

- Two annual MC meeting to review progress, and prepare publications
- Final Action flagship conference at prestigious venue
- Versioned global dataset of TEI data published and widely released

- TEI Cookbooks collated and published as a single report (in paper and electronic formats)

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BE, CY, FI, FR, DE, IS, IT, NL, NO, PT, ES, SE, CH, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at EUR 12 million for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

As identified in Section C5, the four main groups of end users will be those investigating marine biology; those investigating the global carbon cycle and climate change; those assessing contamination of the oceans; and those assessing the possibility of geoengineering of the ocean carbon cycle. Within these areas, the background of end-users is diverse. It includes scientific researchers in universities and government institutes; government representatives with an environmental remit; the marine, fossil-fuel extraction and power-generation industries, particularly in aspects with interest in marine disposal of waste; and NGOs with interests in the environmental management of the oceans. These groups will be interested in the analytical advances from this Action, in understanding of the processes responsible for TEI cycling, and in the global datasets.

H.2 What?

Several forms of dissemination will be used within this COST Action:

i. Workshop reports

Workshop reports will be produced outlining the discussion and findings of the two scheduled workshops. These will act as a summary of the workshops and will serve as a starting point for further discussion, and for communication of the workshop findings to a wider audience. These will be provided online on the COST Action website and elsewhere (e.g. on websites of international programmes such as GEOTRACES) as PDF documents, although hard copies will be produced and circulated if there is demand.

ii. Analytical CookBooks

During intercalibration, CookBooks will be produced containing suggesting analytical protocols for each TEI. These will be made available on the COST Action website and elsewhere (e.g. on websites of international programmes such as GEOTRACES). They will initially be living documents being updated (with clear version dates) as intercalibration identifies and refines best practice. Towards the end of the COST Action, these will be collated and published together in hard and soft format as a single report, describing recipes for all relevant TEIs. This will be a unique resource for future ocean TEI geochemists as these measurements become increasingly routine in future years.

iii. COST Action website

This will be hosted by a member of the MC. It will contain basic overview material about the Action, and act as a portal from which to enter detailed information about all aspects of the Action. This will include links to intercalibration information and documents, information about training opportunities, and links to the Data Website.

iv. Data website

The data website will be hosted at a European data management centre, but will be branded with the COST logo and linked in both directions to the COST Action website. It will be an open-access source of TEI data to the international community, providing full metadata to describe available data, and an easy-to-use plotting facility to enable individuals to produce graphs, maps and sections of interest.

v. Data products

Towards the end of the Action, data from the database will be prepared for release as a versioned global dataset of TEI data. This will be released both online and as CD format with appropriate DOI numbers. A booklet will be produced that accompanies this dataset to summarize the collection protocols use for the data, the format of data and metadata, and to indicate appropriate tools for manipulation of the data. This booklet will also contain text and images summarizing the main distributions and findings of the last four years of TEI work. This data-product and the findings it leads to will be widely advertised though articles in appropriate magazines and presentations at international conferences.

vi. Articles in academic literature

Individual sciences and national science groups will produce a wealth of publications on this subject in the coming years. References to these will be collated on the COST website (with links to PDF files of the articles where copyright allows it). In addition, the COST Action will co-ordinate the writing of appropriate summary articles for the peer-reviewed literature which will outline new TEI findings to the wider community.

vii. Final conference

The flagship conference at the end of the COST Action will communicate the results of new ocean TEI science to the widest possible range of interested parties, including scientist in the field, end-user scientists industry, government, NGOs, and the media. The meeting will includes sessions focused on the scientific findings for a more scientific audience, as well as summary sessions for a wider audience, and sessions by possible en-users identifying the uses of the data and possible directions for future important research that leads from new TEI understanding. The conference will be accompanied by a published abstract volume and will form the basis of a special volume in a scientific journal.

H.3 How?

The MC will take responsibility for Workshop reports, for the COST Action website, for collating peer-reviewed articles, for writing or commissioning summary peer-reviewed articles, and for all the dissemination associated with the final conference. They will also have an overview role on other dissemination conducted at WG level. The Intercalibration WG will lead production and publication of the analytical cookbooks, while the Data Management WG will lead organization of the Data Website and of the versioned data-products. The Training WG will organize dissemination through training activities, as described in Section E1 above.

Throughout the lifetime of the COST Action, all MC meetings will feature dissemination of results as an agenda item, and will discuss the success of the dissemination plan. The plan will be modified to ensure that all opportunities are taken for capacity building, training, communication within the scientific community, and outreach to other end-users and interested parties.