Proposal for a SCOR Working Group on
Modern Planktic Foraminifera and Ocean Changes

Abstract

Planktic foraminifera are arguably the most important carriers of paleoclimate information available to scientists. Our ability to reconstruct past climate states and to predict the impact of the functioning of foraminifera under changing oceanic conditions in the future depends on a complete understanding of their ecology, biology, physiology and the mechanisms by which they incorporate geochemical tracers for reconstructing oceanic temperature, pH and salinity. The last synthesis of the state-of-the-art on planktic foraminifer was published 20 years ago (Hemleben et al., 1989). Since then, a suite of new technologies and experimental methods have been applied to living and fossil foraminifera that have resulted in new biological and ecological insights on this group. The result has been an expanded context and a wealth of novel ways to data mine the thousands of publications that exist in the literature. The here proposed synthesis of knowledge and techniques will be a 21st century keystone that both articulates and focuses future research needs and potentials. The WG will disseminate the current knowledge of this field to active researchers, students, specialists and other users of foraminiferal data, from the fields of the marine carbon cycle, through paleoclimate reconstructions to model predictions of future climate change.

Rationale

Planktic foraminifera are the major source of proxy information for reconstructing past changes in ocean biological, chemical and physical parameters. Species assemblages and the geochemical composition of shell calcite provide much of the primary paleoenvironmental information used to reconstruct past oceanic temperature, salinity, productivity and changes in the atmospheric hydrological system. These proxies are commonly based on observed correlations between an environmental parameter in the modern ocean and the geochemical or assemblage distribution data from recent ocean sediments. However, understanding such empirical relationships at the bio-physico-chemical level, and quantification of the relevant ecological components influencing a signal are generally not sufficient for an optimal application of the parameter-proxy relationships. An integrated understanding of these processes is necessary for correctly quantifying past ocean physico-chemistry and determining the effect of ongoing ocean change in terms of thermohaline circulation and ocean acidification on the calcification of these organisms.

Given the large amount of recent research, the lack of any synthetic work for two decades and the upcoming significant generation shift, we believe it is time to integrate the broad knowledge from different (bio-physico-chemical) disciplines, which relate to modern planktic foraminifera. They include 1) their spatial and temporal distribution in the world ocean, 2) their calcification mechanisms, 3) the biological and chemical controls on their shell chemistry and 4) their eco-phenotypical and genotypical variability. Experts on plankic foraminiferal ecology, biology and chemistry often work on an individual basis and interact and collaborate

occasionally, but have not yet fully integrated to address the fundamental issues in this research area in a coordinated way. The proposed working group would provide a mechanism to make this happen as well as to provide a platform to involve young scientists as well as researchers from developing countries.

Results from this working group should stimulate active scientific networking, especially for engaging younger scientists, as well as produce future research proposals and projects. The WG will profit from national and international research programmes (e.g. the EU FP7) and the projects of its members and in turn will provide an umbrella for international research efforts that include the sharing of novel ideas and research tools for future planktic foraminiferal analyses and data interpretation. Cooperation with IGBP PAGES has been initiated to establish a joint SCOR/IGBP WG. The WG will also be open for, and actively stimulate cooperation with, related international scientific initiatives in which the proposed members of the group are actively involved.

Scientific Background

Below, we summarize the primary issues that have prompted the involved scientists to propose this WG.

The usefulness of planktic foraminifera for reconstructions of the ocean's climate were recognized in the late 1940's with Urey's seminal papers (Urey, 1947; Urey, 1948) on oxygen isotopes in nature, and subsequent publications by his student, Cesare Emiliani, (Emiliani, 1954; Emiliani, 1955a; Emiliani, 1955b) on planktic foraminifera geochemistry and Pleistocene Temperatures. Following the recognition of their potential as providers of information on the state of past oceans and climate, the species concept for living planktic foraminifera has been standardised in the 1960's (Parker, 1962), allowing detailed mapping of species abundances in the plankton and surface sediments of the ocean. This work has led to descriptions of the physico-chemical properties of the habitat of individual species and their specific ecological demands governing the geographical distribution of the various species and their abundance (Bé and Hamlin, 1967; Bé 1977) and facilitated their first large-scale applications in the reconstruction of the ocean's temperatures during the last glacial period (CLIMAP 1976).

Since then, foraminifera are used as a primary carrier of geochemical information on past environments and their fossils from marine sediment archives have been used to quantify past ocean conditions related to oceanic temperature, salinity, ocean stratification, atmospheric CO_2 concentration and biological productivity back to about ~120 million years ago. Detailed studies of the modern spatial and seasonal distribution of foraminifera in the world's oceans (Bé, 1977; Bé et al., 1973; Bé et al., 1971; Deuser, 1987; Deuser et al., 1981; Tolderlund and Bé, 1971) and early culture studies followed (Anderson and Bé, 1976; Bé, 1980; Bé et al., 1977; Hemleben, 1982; Spindler et al., 1978; Spindler et al., 1979), which provided fundamental information ranging from the ecological preferences of species to the individual's life cycle and calcification. Since the comprehensive review of Hemleben et al. (1989), a vast and diverse amount of new data has been collected, highlighted by more than 10000 papers in the Web of Knowledge with 'foraminifer' in the title or abstract. This

information has not been synthesized to date and hence is not available to non-specialist scientists in an accessible form.

Today, the quantification of past ocean properties is based on either the distribution of species and their abundances or the geochemical (trace elemental and stable isotope) composition of the calcareous shells. Although in recent years, multiple geochemical tools have been combined to reconstruct parameters such as ocean salinity (Lea et al., 2000; Schmidt et al., 2004; Schmidt et al., 2006), uncertainties in the physical, chemical and biological controls on these proxies place limits on their applicability to paleoclimatic problems (Rohling, 2000). Furthermore, cryptic speciation (Kucera and Darling, 2002), morphological variability (; Kennett, J.P., 1976, Steinke, S., et al, 2005)), diagenetic overprinting (Groeneveld et al., 2008) and incomplete knowledge of the timing and cellular mechanisms controlling shell calcification across the different species-specific habitat depths introduce poorly constrained uncertainties in paleoceanograhic reconstructions.

It is also important to broaden our knowledge of uncommonly used foraminifera species (i.e. deep-dwelling forms, specialists for certain ecological niches, rare species), which have not been studied in detail nor used in paleoceanographic studies, as these species might provide novel information about the ocean's interior processes. The first modeling experiments to predict the global distribution of planktic foraminifera and their seasonal distribution and productivity (Fraile et al., 2009a,b, Lombard et al., 2009) represent a promising avenue of research to understand the relationship between the tolerance ranges of species and the highly inter-related environmental parameters of their oceanic niches (Schiebel and Hemleben, 2005). Although the physiological basis for calcification in foraminifera is being revealed in a number of recent papers (Erez, 2003; Bentov and Erez, 2005; De Nooijer et al., 2009), most of these studies have been conducted with benthic species. Translation of approaches, methods and models to planktic species has the potential to quantify the biological effects on trace elemental incorporation and isotope fractionation (the so-called 'vital effect'). Investigations of molecular genetic diversity in planktic foraminifera continue to reveal fascinating insights into the cryptic diversity in this group (Darling et al., 2007), its relationship to morphological variability (Morard et al., 2009) and the possible underlying biological processes (Aurahs et al., 2009).

To fill the gaps in our knowledge and understanding of these organisms is an important and urgent challenge in the light of ongoing ocean acidification and ocean warming. There is evidence for reduced calcification since the start of the industrialization (Moy et al., 2009, de Moel et al., 2009) by about 30% and clear shifts in assemblage composition have been observed in pace with the warming trends of the last 150 years (Field et al., 2006). Will these organisms go extinct as a result of increasing ocean acidification and how will their distribution change as a result of temperature changes?

Until now, individual lines of research have been pursued largely independently and a coordinated action, summarizing the consequences of this knowledge for the further applications, is missing. This is most unfortunate as the paleoclimate community increasingly appreciates the potential of climate reconstructions based on these organisms (Ivanova, 2009) to further improve climate models. The situation is further aggravated by the multitude of disciplines involved in the studies of these organisms,

and it is a prerequisite that the various communities “speak the same language” to facilitate future cooperation. The proposed working group will therefore contribute not only to a synthesis of knowledge on planktic foraminifera, but it will set standards and benchmarks in their taxonomy and ecology, in an accessible way for a range of disciplines.

Terms of Reference

The main goal of the proposed WG is to synthesize the existing knowledge of modern planktic foraminifera, to build on this knowledge for identifying priority research and to transfer expertise to the generation of young researchers.

The proposed working group will:

1. Synthesize the state of the science of modern planktic foraminifera, from pioneering to ongoing research including
   - their spatial and temporal distribution in the world ocean
   - their calcification mechanisms and shell chemistry
   - and their eco-phenotypical and genotypical variability

as a peer-reviewed publication in an open-access journal (**deliverable 1**).
2. Provide guidelines (cookbooks) in terms of species identification, experimental setup for culture studies, laboratory treatment prior to geochemical analysis (**deliverable 2**) and identify existing gaps in the available knowledge in order to direct future research.
3. Establish an active Web-based network in cooperation with ongoing (inter)national research programmes and projects to guarantee an open-access world-wide dissemination of results, data and research plans (**deliverable 3**).
4. Document the work of the group in a special issue of an open-access journal (**deliverable 5**) in connection with a specialized symposium with emphasis on modern ocean change i.e. thermohaline circulation and ocean acidification, during one of the AGU or EGU conferences, ideally held at the joint EGU/AGU meeting (envisaged for 2013 or 2014, **deliverable 4**).

Full Members:

1. Co-chair: Gerald Ganssen (proxies), The Netherlands
2. Co-chair: Michal Kucera (ecology and diversity), Germany
3. Jelle Bijma (ecology), Germany
4. Jonathan Erez (calcification), Israel
5. Richard Zeebe (bio-physico-chemistry), USA
6. Howard Spero (bio-geochem-paleo- experiments and culturing), USA
7. Dirk Kroon (micropaleontology), UK
8. Divakar Naidu (assemblages), India
9. Daniela Schmidt (microstructure), UK
10. Elena Ivanova (paleo applications), Russia

Associate Members:

1. Frank Peeters (spatio-temporal distribution), The Netherlands
2. Stefan Mulitza (proxies), Germany
3. Michael Schulz (ecological modeling), Germany
4. Thorsten Kiefer (PAGES), Switzerland
5. Caroline Cleroux (deep dwelling species), USA/France, **Y**
6. Ralf Schiebel (size/weight), France
7. Lennart de Nooijer (calcification), The Netherlands, **Y**
8. Steve Eggins (microgeochemistry), Australia
9. Kate Darling (genotypes), UK
10. Baerbel Hoenisch (bio-chemico-physics), USA, **Y**
11. Zhimin Jian (micropaleontology), China

Y= younger than about 35 years and at the postdoc level

Working Group Activities

If approved, the working group will organize its kick-off (**Meeting 1**) in early to mid 2011, potentially as a splinter meeting of a large international conference. Alternatively it can be connected to a foraminifera culturing workshop at the Wrigley Institute of Marine Sciences on Catalina Island in late July/early August 2011 held by Howard Spero. This would include a hands-on one week culture training course for a select group of grad students/post-docs prior to the workshop.
During this meeting WG group members will

- present their expertise with short presentations
- set up the roadmap for science activities within the WG in detail following the terms of reference, assigning different WG members to lead on each term of reference
- define and distribute tasks for the writing of the overview publications with topics and deadlines for submission to the lead author(s)
- initiate and set up the Web-based networking and Web page (including an "electronic" atlas with photographs and detailed description of modern species)

Meeting 2 would be held in late 2012 or early 2013 to

- finalize the overview publication for submission during or shortly after the meeting
- finalize and make the Website available to the community and activate network
- launch network into its active phase
- conduct planning of the specialized symposium for 2014.

Meeting 3 would be envisaged for spring 2014 in conjunction with (potentially) the EGU/AGU joint spring meeting
During this session, the latest results of the WG members and associates will be presented. The meeting will be open, inviting contributions from non-members and closely related research with special emphasis on 'ocean acidification'. A contribution to the special issues of the open-access journal *Biogeosciences* (preferably) is obligatory for members and invited for other participants of the symposium.

The overarching philosophy of the WG is the active knowledge transfer from highly experienced experts to the younger scientists, supported by modern communication media.

Additional funding will be requested from organisations like AGU, EGU and (indirectly) from active research programmes. The work of the WG has strong affiliation with ongoing global ocean programmes like GEOTRACES, the FP7 program EPOCA and others and links with such programs will ensure dissemination of the activities and results via links to these activities.

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