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☑ **Workshop** ☐ **Preliminary** ☐ **Full** ◉ ***New*** ☐ ***Revised*** ☐ ***Addendum***

Please tick or fill out information in all gray boxes

Title:	Oman Ophiolite Drilling Project, Workshop Proposal
Proponent(s):	Peter Kelemen, Ali Al Rajhi, Shoji Arai, Donna Blackman, Georges Ceuleneer, Laurence Coogan, Margot Godard, Steve Goldstein, Philiipe Gouze, Greg Hirth, Al
Keywords: *(5 or less)*	mantle, crust, hydrothermal alteration, carbon capture
Location:	drilling in

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Permission to post abstract on ICDP Web site: ☒ Yes ☐ No

Abstract: *(400 words or less)*

Here we propose an ICDP sponsored workshop to develop a full proposal for drilling in the Samail ophiolite in the Sultanate of Oman. The Samail ophiolite is composed of igneous crust and upper mantle formed at a submarine spreading center, via processes very similar to those at mid-ocean ridges today. Drilling will provide key data on the processes of melt extraction from the mantle, igneous accretion of oceanic crust, and hydrothermal modification of that crust. Drilling will also investigate present day alteration processes, their relationship to the deep biosphere, and their potential for acceleration to achieve carbon capture and storage via in situ mineral carbonation.

Igneous accretion and fluid alteration of oceanic plates at spreading centers are the simplest chemical differentiation processes in the solid Earth. yielding a “Rosetta Stone” for interpreting processes in more complex tectonic settings. Because mantle peridotites are very far from equilibrium with the atmosphere and surface waters, exposure of mantle peridotites on the Earth’s surface, during tectonic extension at ridges and via emplacement of ophiolites on land, yields a chemical potential gradient that is unmatched in magnitude and extent, driving mass transfer that continues off axis and during surficial weathering. Together, these processes create a fertile environment for the subsurface biosphere, and control mass transfer between the hydrosphere and the mantle over two thirds of the Earth’s surface.

Understanding these processes is of increasing societal relevance. For example, ancient and ongoing mineral carbonation processes in the mafic and ultramafic rocks of the Oman ophiolite form a natural laboratory in which we can discover natural reaction pathways and experiment on accelerating these processes for carbon capture and storage. Overall, understanding mass transfer in crustal genesis and evolution provides a template for regulating a variety of environmental fluxes. Such studies build “human capital”, preparing a new generation for a future in which efforts to offset negative human impacts will be increasingly important. Collaboration will involve an international palette of research scientists, and will provide a clear, positive role model for young people, in which science transcends national borders and offers an opportunity for constructive, direct action to address global problems. Finally, there is no geoscience topic with more potential for lasting, philosophical impact than understanding the scientific basis for the origin of life, and there is no geochemical process more conducive to abiotic hydrocarbon synthesis on Earth today than peridotite alteration on the seafloor and in ophiolites.

Scientific Objectives: (*250 words or less*)

We propose a diamond drilling program in two phases; all drill holes will be 500 to 600 m deep because this is the maximum capability of available equipment in Oman, which we plan to use to maximize the impact of limited funding. In Phase I, we will use diamond coring techniques that are standard in the mineral exploration industry, we will drill preliminary holes in three settings: (a) a hole sited to sample the deeper parts of the reaction zone in the ongoing alteration of mantle peridotite, (b) a hole sampling the dike/gabbro transition in the upper part of the crustal section, and (c) a hole sampling the crust/mantle transition at the base of the crustal section. Pending successful results from these three holes, In Phase II we will drill a series holes that together comprise a full crustal section through the ophiolite. Additional sites will be drilled to evaluate spatial variability along strike in crucial horizons. Downhole logging of geophysical properties will provide a key element in linking micron to centimeter scale observations of samples from drill core to 100 m to 10 km scale geophysical observations of active ocean ridges. Similarly, downhole measurements of fracture spacing, permeability, fluid flow, and fluid composition (via CTD and gas-tight samplers), will be combined with core observations of primary lithology, extent and nature of alteration, and small scale permeability to yield a multi-scale understanding of reactive fluid flow. Pressure-tight biological sampling will be an important part of our investigation.

Summary of Support Requested from ICDP

Requested ICDP funds: *(in US$)*	US$ 50,000	Estimated Total Project Budget *(ICDP funds plus other sources)*:	US$ 188,000
Planned Start:	Workshop in 2011 or early 2012	Estimated Duration in Month *(On-site operations only)*:	

Requested Operational Support:	Drill Engineering *(Please contact ICDPs Operational Support Group if required)*	
	Downhole Logging *(Please contact ICDPs OSG if required)*	
	Field Lab Equipment *(Please contact ICDPs OSG if required)*	
	Training Course *(Please contact ICDPs OSG if required)*	

Details such as a Budget Plan, Management Plan, and Drilling Plan to be provided as attachment to the Proposal. OSG contact: U. Harms (ulrich@gfz-potsdam.de), Phone: +49 331 288 1085

Oman Ophiolite Drilling Project
Workshop Proposal

Proponents:

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Introduction

Here we propose an ICDP sponsored workshop to develop a full proposal for drilling in the Samail ophiolite in the Sultanate of Oman. The Samail ophiolite is composed of igneous crust and upper mantle formed at a submarine spreading center, via processes very similar to those at mid-ocean ridges today. Drilling will provide key data on the processes of melt extraction from the mantle, igneous accretion of oceanic crust, and hydrothermal modification of that crust. Drilling will also investigate present day alteration processes, their relationship to the deep biosphere, and their potential for acceleration to achieve carbon capture and storage via in situ mineral carbonation.

Igneous accretion and fluid alteration of oceanic plates at mid-ocean ridge spreading centers are the simplest chemical differentiation processes in the solid Earth. yielding a "Rosetta Stone" for interpreting processes in more complex tectonic settings. Furthermore, because mantle peridotites are very far from equilibrium with the atmosphere and surface waters, exposure of mantle peridotites on the Earth's surface, during tectonic extension at ridges and via emplacement of ophiolites on land, yields a chemical potential gradient that is unmatched in magnitude and extent, driving mass transfer that continues off axis and during surficial weathering. Together, these processes create a fertile environment for the subsurface biosphere, and control mass transfer between the hydrosphere and the mantle over two thirds of the Earth's surface.

Understanding these processes is of increasing societal relevance. For example, ancient and ongoing mineral carbonation processes in the mafic and ultramafic rocks of the Oman ophiolite form a natural laboratory in which we can discover natural reaction pathways and experiment on accelerating these processes for carbon capture and storage. An international workshop on the general topic of mineral carbonation has just been completed in Oman, with three days of discussion followed by two days of field trips. It was held in Oman because of the exceptional extent of the ongoing peridotite carbonation process there. The workshop was sponsored by the ICDP, IODP, European Science Foundation, US NSF, InterRidge, UK IODP (NERC), and Sultan Qaboos University, and included more than 75 participants from 14 countries: Australia, Canada, China (PRC), France, Germany, Holland, Hungary, Iceland, Italy, Japan, Norway, Oman, Switzerland, the UK and the US.

More generally, understanding the processes of mass transfer in the formation and evolution of oceanic crust provides a template for understanding and potentially regulating a variety of environmental fluxes. These studies will build "human capital", training a new generation of petrologists, geochemists and geophysicists as we prepare for a future in which CO2 capture and other geoengineering efforts to offset negative human impacts will be increasingly important. Collaboration will involve the international palette of research scientists working on the Oman ophiolite, and will provide a clear, positive role model for young people worldwide, in which science transcends national borders and offers an opportunity for constructive, direct action to address global problems. Finally, there is no geoscience topic with more potential for lasting, philosophical impact than understanding the scientific basis for the origin of life, and there is no geochemical process more conducive to abiotic hydrocarbon synthesis on Earth today than peridotite alteration on the seafloor and in ophiolites.

hydration and carbonation, geochemical cycles, the deep biosphere, chemosynthetic pathways, and abiotic hydrocarbon synthesis. In the 21st century, it will become essential to understand many of these processes better, in order to learn how to counteract negative, global scale human impacts on the Earth. Study of the Oman ophiolite has played and will play an integral role in this scientific evolution. After landmark research by an international group in the late 1970's (e.g., summaries by Coleman & Hopson JGR 1981; Lippard et al. The Ophiolite of Northern Oman 1986; Nicolas Structures of Ophiolites and Dynamics of Oceanic Lithosphere 1989), recent work has provided vital, first order results on **mechanisms of melt extraction from the mantle beneath ridges** (e.g., Nicolas J. Petrol. 1986; Ceuleneer & Rabinowicz AGU Monograph 1992; Nicolas et al. Nature 1994; Kelemen et al. Nature 1995, Kelemen et al. Phil Trans Roy Soc London 1997; Ceuleneer et al. Nature 1996; Godard et al. EPSL 2000; Braun & Kelemen G-cubed 2002**;** Takazawa et al. G-cubed 2003; Tamura & Arai EPSL 2006; Hanghøj et al J Petrol 2010), on **the geometry and nature of mantle upwelling** (e.g., Rabinowicz et al. EPSL 1984; Ceuleneer et al. Tectonophys 1988; Ceuleneer et al. Nature 1996), on the kinematics and processes of **igneous accretion of the Moho transition zone and oceanic crust** (e.g., Nicolas et al., 1988; Boudier & Nicolas J Petrol 1995; Boudier et al. EPSL 1996; Kelemen et al. EPSL 1997; Korenaga & Kelemen JGR 1997 Korenaga & Kelemen JGR,1998; Garrido et al. G-cubed 2001; Adachi & Miyashita G-cubed 2003; Coogan et al. EPSL 2004; VanTongeren et al. EPSL 2008; Koepke et al G-cubed 2009; Nicolas et al. EPSL 2009), on the nature of the **transition between upper gabbros and overlying, sheeted dikes** (e.g., Nicolas & Boudier JGR 1991; MacLeod & Rothery Geol Soc London Spec Pub 1992; Nicolas et al. G-cubed 2008), on hydrothermal circulation and alteration of newly formed igneous oceanic crust (e.g., Gregory & Taylor JGR 1981; Bosch et al. J Petrol 2004), and on ongoing, low temperature hydration and carbonation processes (e.g., Neal & Stanger The Chemistry of Weathering (Drever ed.) 1985; Kelemen & Matter PNAS 2008; Kelemen et al. Ann Rev Earth Planet Sci 2011 in press).

Although some of these results are uncertain and are the topic of continuing discussion and debate, there can be no doubt that work based in Oman has played a vital role in developing crucial paradigms, and for catalyzing continued research on both active ridges and ophiolites. Hypotheses based on field observations in Oman, and discrepancies between these hypotheses, have clearly delineated the need for additional data to resolve some fundamental problems. The additional data that are required may be separated into three complementary types.

(1) Characterization of rock properties such as the variation of alteration and related fluid composition with depth, the relation of permeability to alteration, and the nature and function of biota in the modern weathering environment.

Measurements to be made on core will be characterization of bulk composition, mineral parageneses and compositions, permeability, fracture density and orientation, and nature and density of microbial organisms. These measurements will be integrated with downhole logging including packer tests to measure permeability on a variety of scales larger than the core diameter, push-pull experiments to evaluate the nature of fluid flow and reaction rates, repeated CTD logs over an extended time to determine temperature and salinity, and constrain the geotherm, gas tight fluid sampling, caliper and borehole televiewer runs to collect additional data on fracture spacing and orientation and evaluate the state of stress, and a variety of remote proxies for geochemical characteristics.

(2) Systematic study of complete sections of the ophiolite, with emphasis on crucial boundaries at the dike/gabbro and crust/mantle interfaces, are required to provide statistically sound characterization of features including the proportions of rock types and the orientation of specific structural indicators.

Measurements to be made on core would be technically similar to those made in the field and on speciments recovered from outcrop. However, emphasis would be on obtaining a large number of analyses from a nearly continuous sample, in order to determine size/frequency characteristics, average values, and variances, on many length scales. Also, it is likely that mantle samples recovered from below the weathering horizon will be much less altered than those available from outcrops.

(3) Characterization of physical properties of the same sections of the ophiolite is needed to refine techniques used in the modern oceans, especially those used to infer the nature of seismic reflectors.

While the physical properties of rocks exposed within 600 m of the surface in the ophiolite may be quite different from the properties of similar rock types at greater depth in the modern oceans, drilling and geophysical logging can nonetheless provide quantitative constraints on magnetic properties, seismic response, density, and conductivity of appropriate rock types with known crack density, alteration, and

depth. Geophysical drillhole logs also provide a vital link between micron to cm scale measurements on core samples, and 100 m to 10 km scale geophysical observations at sea.

Research methods

We propose a multi-disciplinary, diamond drilling program in two phases; all drill holes will be 500 to 600 m deep because this is the maximum capability of available equipment in Oman, which we plan to use to maximize the impact of limited funding. If ICDP wishes to provide more capable equipment, then some holes could be deeper. In any case, we will will optimize the depth of each hole in terms of cost per meter and scientific goals. In general, shorter holes do not provide an optimal cost/benefit ratio because of the large, fixed costs of setting up a diamond drill rig at a specific site.

In Phase I, we will use diamond coring techniques that are standard in the mineral exploration industry, we will drill preliminary holes in three settings: (a) a hole sited to sample the deeper parts of the reaction zone in the ongoing alteration of mantle peridotite, (b) a hole sampling the dike/gabbro transition in the upper part of the crustal section, and (c) a hole sampling the crust/mantle transition at the base of the crustal section. Note that (a) and (c) will provide complementary information, since both will yield data on the composition and structure of the mantle section, and the variation of alteration with depth. Pending successful results from these three holes, In Phase II we will drill a series holes that together comprise a full crustal section through the ophiolite. Additional sites will be drilled to evaluate spatial variability along strike in crucial horizons.

An international consortium of scientists will analyze the core and conduct downhole geophysical experiments to investigate permeability, fracture distribution, state of stress, and the magnetic, seismic and resistivity properties of the lithologic types in the ophiolite. We anticipate that this project will be very attractive to a wide range of geoscientists. Funding for analyses of core will be provided from national and regional funding agencies.

Downhole logging will provide a key element in linking micron to centimeter scale observations of samples from drill core to 100 m to 10 km scale geophysical observations of active ocean ridges. Some important properties to be measured by downhole logging are acoustic velocities (Vp and Vs), for comparison to seismic velocity measurements on samples of drill core, and seismic studies of the ocean crust. Such measurements are recorded in boreholes at acoustic frequencies (a few tens of kHz), then compared to differential transit times from vertical seismic profiles. Electrical resistivity, neutron porosity and density, and acoustic images are also key measurements for the determination of bulk crustal properties. For example, we hope to use petrographic study of the core to learn how geophysical logs record information on igneous layering in gabbroic rocks, yielding a continuous record of layer spacing from the geophysical logs even where core is not recovered. Similarly, downhole measurements of fracture spacing, permeability, fluid flow, and fluid composition (via CTD and gas-tight samplers), will be combined with core observations of primary lithology, extent and nature of alteration, and small scale permeability to yield a multi-scale understanding of reactive fluid flow. Caliper and borehole televiewer logs will be used to image fractures, breakouts, and borehole deformation in order to measure the present-day state of stress. Pressure-tight biological sampling will be an important part of our investigation, but we will not ultra-clean drilling techniques, at least in Phase I, in order to control costs.

Because the holes will be as narrow as 100 mm, downhole measurements will be done using slimline sensors. Except for FMS-like electrical images and geochemical measurements from neutron activation, all standard measurements are available from sensors with diameters between 50 and 75 mm (2 and 3"). For example, this "slimline" equipment is available at the Université de Montpellier II, maintained and operated by PI's Phillipe Pézard and Phillipe Gouze. The main objectives of the downhole measurement program will be to evaluate the relationship between alteration and permeability, measure the state of stress, calibrate geophysical methods (seismic, magnetic, conductivity), provide continuous quantitative measurements and images in order to perform structural and lithological studies, and to obtain measurements of standard physical properties. To detect altered horizons, or to analyze variations in magma composition, spectral analyses of the natural radioactivity of the rock (yielding continuous profiles of K, Th, and U), and magnetic susceptibility measurements (for the detection of titanium and iron-rich oxides) will also be important. At a larger scale (m to 10's of m), downhole seismic experiments or ground penetrating radar measurements, for example, might be made to evaluate the lateral continuity of features identified in the core and from logging. Surface to borehole methods may then be used to link the borehole data to the surrounding geology, and to integrate downhole measurements at seismic scale.

Scientific funding will be sought concurrently with ICDP funding for drilling (e.g., from the US National Science Foundation, the European Science Foundation, and the French Centre Nationale de Récherche

Scientifique). In addition to downhole geophysical logs that are collected during the drilling process, it will be essential to make a very large number of chemical and structural measurements on drill core. This analytical program will be carried out as a service integral with drilling, perhaps in part by commercial labs, to provide a set of basic data similar to that collected by the Shipboard party during IODP drilling programs. One intriguing option would be to use the logging and analytical facilities onboard the Joides Resolution, the IODP standard drill ship, which will be idle for four months per year in the current funding environment. In addition, the Geology Department at Sultan Qaboos University now has extensive analytical facilities (XRF, XRD, SEM, optical microscropy) which could be available for extended periods. In this way, the proposed project will be different from typical geochemical or structural studies where measurements are made to address specific research objectives. Basic data gathering will be essential to the success of the project, and must be supported by special grants.

To ensure long term availability of core to an international group of research scientists, drill core will be archived permanently in a new facility, which will be built in Oman. Once the core has been logged and archived, the international scientific community will be encouraged to develop specific research projects to study it. Interested scientists will apply, and the sample distribution policy will be to provide material, for the cost of shipment, upon approval by a scientific steering committee for the first 5 years after the core is obtained. Where possible, core will be cut lengthwise into quarters to provide sub-samples for shipment. However, it is understood that many tasks, particularly various kinds of petrographic analyses, will require samples extending across the entire core diameter. The steering committee will make a good faith effort to balance immediate requests with the need to retain representative sections of the core on a semi-permanent basis. More than 5 years after the core is obtained, we hope that the Geological Survey of Oman and/or Sultan Qaboos University will take on the task of processing and responding to sample requests.

Similarly, we anticipate that many groups will wish to conduct experiments in the boreholes, e.g. biological incubation, repeated measurements of temperature to delineate the geotherm, long term geochemical tracer studies using push-pull techniques, and hydraulic fracture experiments. Overlapping proposals for use of the boreholes will be considered and balanced by the scientific steering committee for the first five years, and then by an official entity in Oman.

In practical terms, we envision an international drilling effort led by European, American, Omani, and Japanese investigators, and supported by a combination of the International Drilling Program, national science foundations, and industry sources. We have obtained estimates of cost from Lalbuksh Volta LLC, a well known diamond driller in Oman. We worked out the following procedure: drill to 150 meters, log the resulting hole (3.5 inches in diameter), case, and then drill to 600 meters, followed by logging the rest of the hole (2.75 inches in diameter). The cost for this operation is estimated to be US$126,000, including standard site preparation. Note that 600 meters is the maximum depth to which Lalbuksh routinely drills. In Phase II, it may become cost effective to work with Laklbuksh to obtain a drill rig with a larger derrick, capable of drilling to 1.5 km or more.

The Lalbuksh estimate of US$126,000 for a 600 meter hole was made assuming that the drillers would use local ground water or seawater for their lubrication fluid, both of which are standard procedure for mineral exploration drilling in Oman. However, scientific drilling will have more public prominence than exploration drilling, and in any case should conform to high standards for minimum environmental impact. Thus, we anticipate that concerns about water availability downslope and about contamination will dictate use of fresh water trucked to the site. There is infrastructure in Oman for fresh water delivery, in daily use in many regions. However, we can anticipate that this will add to the cost. Thus, we consider conservatively that drilling each 600 meter hole will cost US$200,000. We estimate that the downhole logging program will have a maximum cost of an additional US$200,000 per hole, for an upper bound estimate of US$400,000 for drilling and logging each hole. This effort should be funded by the ICDP plus any additional contributors to the drilling effort. Analysis of drill core will be funded by granting institutions in the home countries or regions of the individual investigators, not by the ICDP.

In the long run, we propose to drill about 15 holes in order to address specific questions and obtain a full crustal section. However, given the cost for each hole, we realize that such a large project cannot be undertaken by the ICDP in a single step. Instead, we anticipate that the project would be conducted in two or more phases, each designed for maximum scientific benefit in its own right. Successively, these phases will gradually prove the utility of the technique and the ability of the investigators to provide important scientific results. Therefore, in our first full proposal to the ICDP, we would request funding for three drill

holes, one in actively altering mantle peridotite, one through the transition from igneous crust to residual mantle peridotites, and one through the transition from sheeted dikes to gabbros.

We will site our drill holes near a recent geophysical traverse of the Oman mountains (Al Lazki et al. GeoArabia 2002). This choice of location is also justified because the southern, Samail and Wadi Tayin massifs are among the best studied in the ophiolite, because they are close to the Muscat metropolitan area, including the Seeb International Airport and the port of Muttrah. Geochemically, the lavas, gabbros and peridotites in thse massifs are the most similar to the same lithologies sampled along typical mid-ocean ridges, and because they have ideal drill sites that are tens of km from towns.

Outreach, education and societal value

A collaborative international team will undertake this project. The group of PI's, scientists from 9 countries, includes Dr. Ali Al Rajhi, Director of the Geological Survey of Oman, and Prof. Sobhi Nasir, Head of the Dept. of Geology at Sultan Qaboos University (SQU) in Oman. Several journalists at the recent mineral carbonation workshop in Oman emphasized to us the importance of public perception of Arab scientists working with others from the US and EU. Undergraduates and graduate students from SQU will play a central role in core logging and analysis, working together with research scientists and graduate students from the international community. Omani student participation will be coordinated by PI Prof. Nasir. A large part of the motivation for this drilling project comes from our interest in studying natural systems to learn the best pathways for engineered mineral carbonation for carbon capture and storage. Checking the rise of atmospheric CO2 is one of the primary scientific and societal challenges of this century. Another important motivation for this project is studying an ideal site for abiotic hydrocarbon synthesis, with implications for the origin of life.. Scientific understanding of the origin of life would be the most important contribution that earth science can make to philosophical understanding of our place in the universe.

Scientific rationale - some examples

Some fundamental issues regarding peridotite alteration and mid-ocean ridge processes are now very well posed, based on two decades of intensive research, and now await definitive solutions. An Oman drilling program, coupled with continued international emphasis on drilling and sampling active ridges, could provide such solutions within the next ten years. In what follows, we give a few specific examples, considering processes in order of shallowest to deepest.

(1) Fluid flow during mineral hydration and carbonation: Retrograde metamorphism – hydration, carbonation and oxidation of igneous and metamorphic rocks – is an essential process in Earth dynamics. Mineral hydration of igneous, oceanic crust and mantle, followed by subduction, supplies huge volumes of water to drive arc volcanism, and maintains or even increases the hydrogen content of the Earth's mantle over time. And, retrograde processes are a vital mechanism in chemical weathering, which is as important as magmatism and plate tectonics in shaping the continents.

The best-known and most common retrograde metamorphic rocks are altered peridotites. Almost everyone has seen them – whether they know it or not – as a popular ornamental stone used for building facades and kitchen counters, in soapstone amulets and monumental statues. Mineral parageneses in peridotite comprise part of the canon of metamorphic petrology. However, unlike most iconic metamorphic processes, which occur in obscurity, deep in the Earth, peridotite alteration is ongoing and accessible, occurring at appreciable rates near the surface. For example, in their classic paper Barnes & O'Neil (GSA Bulletin 1969) estimated that dissolved Ca in one alkaline spring was extracted from 10^3 to 10^4 tons/yr of peridotite.

And no wonder. In the upper crust, say at 2 kb, mantle peridotite is unstable in the presence of water below ~ 700°C. It is unstable in the presence of CO2-rich fluids below ~ 500°C, and it is unstable at any temperature in the high oxygen fugacity that prevails near the Earth's surface. Where plate tectonics, coupled with erosion, exposes fresh peridotite on the surface, this creates a chemical potential gradient that is unparalleled on Earth in magnitude and extent, like a giant battery, which then proceeds to burn itself out.

The energy spinning off from this chemical dynamo drives many of the fundamental processes that shape the Earth. Peridotite alteration controls the rheology of oceanic plates and subduction zones, causes forearc uplift, fluxes arc magmatism, and lubricates the mantle. It is essential in the geochemical water and carbon cycles. It produces some of the most reduced fluids on the surface of the Earth, and generates steep compositional gradients that are exploited by chemosynthetic organisms. It has been invoked as an essential ingredient in the origin of life, and in any case it creates ideal conditions (low Eh, FeNi metal catalysts) for abiotic synthesis of organic compounds. Enhanced peridotite carbonation could play a significant role in CO2 storage, or even a practical and inexpensive route to geological CO2 capture.

Alteration of peridotite is commonplace. It is fundamentally important. And yet, from a geodynamical point of view, we don't understand peridotite alteration at all. In particular, we don't understand the feedbacks between fluid flow and metamorphic reactions that – under some circumstances – allow the retrograde process to proceed. This is crucial. It is low water/rock ratios, due to limited fluid supply, that create the reduced, alkaline conditions conducive to organic synthesis. And yet, synthesis cannot proceed without a supply of reactants from continued fluid flow. Retrograde processes are thought to be uncommon because they are self-limited, via a variety of negative feedbacks described below. And yet, we call upon nearly complete hydration to explain the properties of the seismically slow, buoyant "cold nose" in the mantle wedge above subduction zones, worldwide.

What's the problem? Consider this. In igneous and metamorphic rocks, fluid porosity and permeability may be negligibly small, so retrograde processes are supply limited. Furthermore, fluids enhance diffusion and so act as catalysts for recystallization. Prograde reactions produce fluids, in a positive feedback, while retrograde reactions may consume all available fluid long before recrystallization is complete. Finally, in an initially open system, retrograde reactions may increase the solid volume. This may fill porosity, destroy permeable flow networks, and armor reactive surfaces, limiting fluid supply and slowing reaction rates. Thus, rocks overcome by these limitations often contain a hodge-podge of disequilibrium mineral assemblages formed by incipient, but arrested, retrograde metamorphism. Often, peridotites in outcrop are 10 to 60% hydrated, with abundant relicts of the original, mantle minerals.

However, 100% hydrated peridotites, known as serpentinites, are common. Less familiar, but of increasing scientific interest, are "listwanites", 100% carbonated peridotites composed of, magnesite + quartz. How do these form, when retrogression is self-limiting? Two end-member explanations have been offered. Many metamorphic petrologists consider that such reactions occur at constant volume, in which expansion due to decreasing solid density is balanced by dissolution and export of chemical components in a fluid. However, with notable exceptions, most studies of serpentinites, and our work on listwanites in Oman, suggest that alteration was nearly isochemical except for addition of H_2O and/or CO_2.

Alternatively, MacDonald & Fyfe (Tectonophys 1985) proposed that increasing stress due to volume expansion in an elastically confined volume causes fractures, which in turn increase or at least maintain permeability and reactive surface area, in a positive feedback mechanism that allows retrograde reactions to proceed to completion. This, and other similar processes involving regulation of permeability via (bio) chemical feedbacks, forms the primary hypothesis motivating our proposed project. It has been the topic of recent theoretical work, for example by Jamtveit and colleagues, and Kelemen and co-workers. So far, theory is only qualitatively linked to observations.

Our simplest, testable hypotheses are straightforward. As Kelemen, Matter and their colleagues have found for carbonate veins exposed by erosion (Kelemen & Matter PNAS 2008; Kelemen et al. Ann Rev Earth Planet Sci 2011 in press), we expect that veins in core will have measurable 14C ages (< 50,000 years), with age decreasing with depth, and will record crystallization temperatures ~ 30 to 60°C, documenting formation in an active, near surface system. We expect careful studies will reveal a range in serpentine-magnetite temperatures, indicative of polygenetic formation extending to the present, while – again, based on our preliminary data from surface sampling – $^{87}Sr/^{86}Sr$ in carbonates and leachates from serpentinites will be close to modern seawater and substantially more radiogenic than Cretaceous to Eocene seawater, indicating relatively recent fluid-rock interaction.

Based on theoretical considerations, we expect a positive correlation between the extent of peridotite alteration, fracture density, and permeability, resulting from cracking in response to stress generated by metamorphic increases in the solid volume. We expect the rocks more than 100 m below the surface to be in nearly isotropic compression, driven by metamorphic volume increases, with the least compressive stress nearly vertical. Deeper, we expect the proportion of carbonate alteration to decrease and, yet deeper, the proportion of hydrous alteration to decrease as well. So far, these hypotheses – in our work and in other scientific literature – are supported mainly by qualitative arguments and analogy to more thoroughly understood, similar processes such as salt weathering.

Based on ongoing observations of ground water and alkaline spring water in peridotite catchments in Oman by Shock, Matter and their colleagues, and on geochemical modeling of peridotite alteration, we expect pH, dissolved organic carbon, and the abundance of H_2, CH_4 and other organic compounds to increase abruptly down hole, from pH of 8 to 9 near the surface, to almost 12 at depth. We expect Eh and dissolved inorganic carbon to be negatively correlated with pH. We don't know whether our observation of high dissolved

organic carbon in high pH, alkaline spring waters reflects extensive biological activity at depth, or vigorous abiotic organic synthesis, but either outcome would be fundamentally important.

(2) Engineered, enhanced mineral carbonation for carbon capture and storage: Buiding upon previous work on "ex situ" production of Mg-carbonates from olivine, Kelemen, Matter and their colleagues (Kelemen & Matter PNAS 2008; Matter & Kelemen Nature Geosci 2009; Kelemen et al. Ann Rev Earth Planet Sci 2011 in press) proposed methods for "in situ" carbonation of peridotite for carbon capture and storage. These processes have the potential to make a large contribution, storing gigatons of CO2 per year in inert, stable, non-toxic carbonate minerals. In the context of this drilling proposal, it is important to learn from natural systems what are the spontaneous mechanisms for natural mineral carbonation, which can then be emulated and enhanced in order to achieve rapid reaction with minimal additional energy input.

The processes described in item (1), above, are key to successful in situ mineral carbonation. Because carbonation and hydration reactions involve "condensation" of CO2 and H2O from a gas or fluid to form solid minerals, they are exothermic. Kelemen & Matter calculated that the exothermic heat production due to these reactions can offset cooling due to advection of fluid injected at surface temperature, and due to diffusion to surrounding, colder rocks, maintaining the optical temperature for mineral carbonation. Overlying rocks provide a natural "pressure vessel" maintaining fluids at a high partial pressure of CO2. Experiments demonstrate that the combination of high temperature and high PCO2 yields reaction rates that are millions of times faster than in the subaerial weathering environment near the surface, up to 50% per hour in 70 micron powders and perhaps 50% per year in fractured rocks, ~ 1 ton per cubic meter per year.

The largest cost for ex situ mineral carbonation techniques is quarrying, transporting and grinding rock reagents to ~ 10 micron grain size. If the process of reaction driven cracking described in item (1) above can be activated, this avoids the cost of quarrying and grinding reagents, offering a substantial energy and cost savings. In order to design techniques that take advantage of reaction driven cracking, it is essential to understand the conditions driving this process in natural systems.

In situ mineral carbonation will probably involve drilling and stimulation of a reactive volume via engineered hydraulic fracture. At this point, specific methods for hydraulic fracture of partially altered peridotite have not been developed. It will be essential to study natural fracture patterns and the present-day state of stress in peridotite boreholes. Furthermore, we can anticipate that researchers will wish to use ICDP boreholes for hydraulic fracture experiments, once logging and sampling operations are complete. In turn, the large fluid fluxes during hydraulic fracture offer the opportunity to conduct push-pull geochemical tests over large length scales in newly exposed, fractured rock.

(3) Subsurface biosphere and/or abiotic hydrocarbon synthesis:

As originally described by Barnes & O'Neil (GSA Bull 1969),modeled by Bruni et al. (App Geochem 2002), and observed in Oman (e..g., Neal & Stanger The Chemistry of Weathering (Drever ed.) 1985), reaction of ground water with peridotite at low temperatures forms pH 8, Mg-HCO3 rich, oxidized fluids near the surface. These continue to react with peridotite away from the surface – out of equilibrium with the atmosphere – to produce pH 12, Ca-OH rich, highly reduced fluids with no dissolved C or Mg. The reaction process precipitates large volumes of serpentine and Mg-carbonate minerals in the subsurface, and travertines composed of calcite on the surface. Reduced fluids at depth become saturated with FeNi alloy, awaruite. Thus, the active peridotite alteration system in Oman today produces oxygen fugacity gradients ranging from bars to nanobars, and pH gradients from 6 to 12. The length scales over which these gradients are present could be as small as centimeters, for example in wall rock around a crack filled with flowing surface water. The presence of these gradients has important consequences for the subsurface biosphere and possibly for the origin of life.

Chemosynthetic organisms thrive in geochemical gradients, where they can catalyze spontaneous reactions resulting from disequilibrium, and make a metabolic "profit". In this way, the peridotite alteration environment could be one of the best places on Earth for chemosynthetic organisms. This could provide analogs for subsurface life on other planets, where chemical differentiation has not progressed as far as on Earth and surface rocks retain a near chondritic composition.

Speculatively, maybe we will find that biological activity modulates fluid flow and the extent of reaction. Chemosynthetic organisms should prosper within geochemical gradients created by flow of oxidized surface water into reduced, altered peridotite, and complementary flow of reduced fluid toward the surface. Their growth would be inhibited by decreased fluid flow – for example if they became so abundant that

they filled pore space – and by enhanced fluid flow that overwhelms the buffer capacity of the rock. So, maybe, microbe abundance modulates porosity and permeability.

Alternatively, we may find that there is very little life in the subsurface peridotite alteration environment. High pH conditions are inhospitable to most organisms. In any case, biology or no biology, maybe we will encounter elevated partial pressures of H2, CH4, and more complex hydrocarbons, that counteract the lithostatic load and maintain fracture permeability. Again, this could lead to a self-regulating steady state. Too much flow, no low Eh solid reactants, no gas; too little flow, no oxidized fluid reactant, no gas.

McCollom et al. (GCA 2010) recently demonstrated that an ideal recipe for abiotic synthesis of alkanes and alkenes is the combination of aqueous fluid with reduced carbon species such as CO or CH4, and FeNi alloy as a catalyst. These are, in fact, the fluid and rock compositions produced by peridotite alteration, and it is very likely that these processes are occurring in the active alteration system in Oman.

If the subsurface in actively altering peridotite is a "desert", this could enhance our ability to detect abiotic hydrocarbon synthesis. In most terrestrial environments, abiotic hydrocarbons look tasty to microbial organisms, and are quickly consumed. If the subsurface in actively altering peridotite in Oman is a "desert", this could enhance our ability to detect abiotic hydrocarbon synthesis.

(4) Igneous composition, and hydrothermal metasomatism: Although it remains uncertain to what extent the Oman ophiolite represents a truly typical sample of crust formed at a mid-ocean ridge, it did form at a submarine spreading ridge and is the most best exposed example of such crust on land. Systematic geochemical study of a representative section will provide valuable insight into such outstanding problems as the bulk composition of the oceanic lower crust, and the depth and extent of chemical changes due to high temperature hydrothermal alteration. These data, together with analyses of samples from active ridges, will be of fundamental importance in determining geochemical fluxes at spreading ridges and where oceanic crust is returned to the mantle in subduction zones. In turn, these fluxes are a vital link in ongoing programs that seek to characterize Earth system science.

(5) Correlation of crustal lithostratigraphy and seismic structure: For the past 30 years, the seismic, density, and magnetic structure of oceanic crust inferred from marine experiments has been correlated with a crustal lithostratigraphy which has largely been derived from ophiolite investigations. In particular, seismic layer 2 has been associated with extrusive basalts and sheeted dikes, while seismic layer 3 has been identified with the gabbroic section in ophiolites. Similarly, the seismic Moho has been interpreted as the boundary marking the transition from lower crustal to upper mantle rocks. However, there is increasing evidence that in some localities the seismic properties of the oceanic crust are primarily controlled by its bulk porosity and state of chemical alteration rather by igneous rock type. Thus, it has been suggested that the seismic layer 2/3 boundary does not mark the boundary between sheeted dikes and gabbro, but may be a porosity boundary within the sheeted dike section, while the Moho, at least in some settings, may correspond to an alteration boundary between serpentinized and unaltered ultramafics, rather than the base of the igneous crust.

Attempts to address these problems in the modern oceans by correlating core samples and logging results from drill holes with large-scale seismic structure have been frustrated by poor core recovery and depth limitations. While fracturing and alteration of the Oman ophiolite may differ from that of in situ oceanic crust, it should nevertheless be possible to examine the importance of factors such as igneous rock type, bulk porosity, and alteration on the seismic response using in situ physical properties, determined by logging and measurements on core samples, and larger scale borehole seismic and conventional refraction/reflection profiling. For example, is the downhole variation in crustal bulk porosity or lithostratigraphy more important in controlling the seismic response at the dike/gabbro boundary? Does the layering of gabbros in the lower crust in Oman yield a distinctive signature at seismic wavelengths of 100s of meters that might be identifiable in marine refraction data? What is the seismic signature of the Moho transition zone and how is it affected by alteration, such as may be common at slow spreading ridges where the crust is quite thin. A pilot seismic experiment, to examine some of these questions, will be conducted in Oman in early 1998. Thus, studies of core, downhole logging, and borehole and conventional seismic studies, together will provide quantitative constraints on the the relationship between seismic structure and igneous stratigraphy of oceanic crust.

(6) Lower crustal accretion: Two different hypotheses for the formation of the crust are clearly delineated. In one, the "conveyor belt" hypothesis, all of the plutonic rocks in the oceanic crust undergo ~90% of their crystallization in a shallow magma chamber, and then ductiley flow downward and outward to form the lower crust. In the other, the "sheeted sill" hypothesis, plutonic rocks are emplaced at a variety of depths

within the crust forming at a spreading ridge, with later compaction but little or no vertical transport by ductile flow. Both of these end members clearly play a role in forming the crust, but their relative importance is important and unknown.

One key element in addressing this question will be investigations of geochemical variation in lower crustal gabbros. It is already known that they exhibit extensive, non-systematic variation as a function of height above the crust/mantle transition zone (Figure 2). Because of this, 100's of samples along a representative transect must be analyzed to determine whether there is any general variation, or whether the data are consistent with formation of some of the rocks - regardless of vertical position in the crust - in a single, shallow magma chamber.

Furthermore, irregular, vertical variation in mineral compositions can be used to constrain magma migration processes. The data of Figure 2 have been used to show that, after initial crystallization of the igneous minerals, large volumes of melt cannot have migrated through the crust by diffuse porous flow over length scales larger than the sample spacing (ca. 50 meters). This in turn implies that there was not an interconnected network of melt in the crust on those length scales, which places limits on the bulk viscosity and tensile strength of the solid+melt aggregate in the lower crust beneath oceanic spreading ridges. The bulk viscosity must be high, and most of the melt that forms dikes and lavas in the upper oceanic crust must migrate in conduits of focused flow - probably in cracks.

Another striking thing about Figure 2 is that almost every sample represents an inflection point in plots of composition vs crustal depth. The actual wavelength of chemical variation with height is unknown. Determination of the scale of systematic compositional variation with height (centimeters to meters in gabbros near the crust/mantle transition; Korenaga & Kelemen JGR 1997) provides important constraints on the porosity of the plutonic rocks after initial formation of "cumulate" crystals, and on the mode of melt migration through the lower crust to feed dikes and lava flows.

(7) Size/frequency distribution of melt extraction conduits, dikes, and veins: Two different paradigms, porous flow and melt extraction in fractures, have been proposed to explain the extraction of mid-ocean ridge basalt from its mantle source. While both of these processes certainly operate in some times and places, their relative importance is uncertain. Both produce a distinctive rock type, called "dunite". A key feature of dunite conduits is their size/frequency distribution. The number of large conduits determines the extent to which melt can migrate through the mantle without equilibrating with the surrounding solids, and the slope of the size/frequency distribution may be diagnostic of the nature of the melt migration process. we have recently completed detailed mapping of dunite distribution in a single outcrop of mantle peridotite in the western US, and found that the dunite distribution shows a power law (fractal) relationship between size and frequency. Similar studies in Oman would be very difficult. Observations of dunites in Oman are hampered by the presence of extensive, near-surface alteration of mantle lithologies, and by "desert varnish" - a black oxide coating that obscures the outcrop surface. Furthermore, in any locality, because of the irregular, discontinuous nature of outcrop exposures, it is difficult to collect size/frequency data on the distribution of dunites over areas larger than a single outcrop. Drilling will facilitate collection of a less altered, representative sample suite. Similar studies could be conducted on drill core throughout the Oman crustal section, to determine distribution of basaltic and gabbroic dikes, ductile shear zones, alteration veins, and brittle cracks.

(8) Lower crustal deformation: In considering the igneous and kinematic processes of oceanic crustal accretion, it is vital to quantify the strength of rock fabrics along a representative transect. In the "conveyor belt" hypothesis, rocks formed in a shallow magma chamber and transported downward and outward should show increasingly intense deformation fabrics with increasing depth in the crust. However, the possible presence of plutonic sills intruded into the conveyor belt complicates this test, and requires systematic study of a representative transect rather than surface sampling. One consequence of large strains would be thinning of pre-existing igneous layering. Thus, the conveyor belt hypothesis predicts that on average igneous layers should be thinnest near the base of the crust. Observations of drill core can be linked to downhole geophysical logs to provide a continuous, high resolution determination of layer thickness as a function of depth.

(9) Mantle flow: For a broad segment of our community, the most important issue for understanding ocean ridge processes is the geometry of mantle flow below the Moho. Investigators working in Oman have identified a series of diapiric structures in the peridotite which have been interpreted as frozen, ridge axis diapirs, and therefore as indicative of a three dimensional upwelling geometry for the partially melting mantle beneath oceanic spreading ridges. Although this hypothesis has achieved wide acceptance in some

circles, other investigators question the importance of this process at fast-spreading ridges, and still others note that the scale of the Oman mantle diapirs is much smaller than the spacing of gravity lows, interpreted as diapirs, along the slow-spreading Mid-Atlantic Ridge. Further complications have arisen with recent hypotheses that some of the diapirs disrupt older mantle and crustal structures, and represent the unusual effects of plate boundary re-orientation in the initial stages of ophiolite obduction, off-axis seamounts, and/or the leading ends of propagating ridges.

A crucial element in reconstructing the kinematics of diapirism is to investigate the structure in the area of corner flow; whereas steep and shallow mantle structures have been observed, the transition from one to the other has remained elusive. Drilling, with the potential to gather representative sections of unaltered rock, and the potential for statistical characterization of systematic variations in fabric strength and orientation, can greatly help in addressing this problem. Cross sections based on field observation and interpretation identify many areas in the Sumail massif of the Oman ophiolite where peridotite with vertical lineation at depth is overlain by peridotite with horizontal lineation immediately beneath the crust mantle boundary (Figure 3). Between the two, if the diapir interpretation is correct, there must be a zone of inclined lineations where flowlines "turn the corner".

Furthermore, because the transition from steep to horizontal lineations is very shallow, it has been proposed that a huge volume of upwelling peridotite passes rapidly through a very narrow vertical interval beneath the crust. This is thought to form a kind of shear zone within the crust/mantle transition zone, because in that narrow region the mantle peridotite must have horizontal velocities many times greater than the crustal spreading rate. Within this shear zone, there must be an inversion in the shear sense (Figure 4). Although some preliminary field data support this hypothesis, drilling will test the generality of this result and quantify the magnitude and history of strain.

Tentative identification of drill sites

The following is a prioritized list of potential drill sites, in order of priority. This list is preliminary, and is offered as an example of what drill sites are practically available in the Sumail and Wadi Tayin massifs of the Oman ophiolite. For locations, see Figures 1, 5, 6 and 8.

1. Drill hole near alkaline springs, into actively altering mantle peridotite, near the village of Falaij in the southern part of the Wadi Tayin massif (Figure 5), to study the nature of alteration, fluid composition and permeability as a function of depth and lithology. This is one of the largest actively depositing travertines we have found in Oman, and it is readily accessible from a paved highway. Data on this locality are reported by Neal & Stanger (Chemistry of Weathering, Drever ed., 1985), Kelemen & Matter (PNAS 2008) and Kelemen et al. (Ann Rev Earth Planet Sci 2011 in press).

2. Drill hole through lower crustal gabbros and the crust/mantle transition zone, Wadi Gideah section of the Wadi Tayin massif. This hole would eventually be the deepest in a full transect of the Wadi Gideah crustal section. The section in this area was studied by John Pallister, USGS geologists led by Robert Coleman, and Pallister's advisor Cliff Hopson, and later by the Tectonophysics group at the Université de Montpellier. It was shown to be 5 to 7 km thick, similar to "normal" oceanic crust, and to have gabbro and dike chemistry consistent with crystallization from magmas very similar to mid-ocean ridge basalt. This drill site would require transport of a drill for one to three km beyond the end of the passable road. However, all other proposed drill sites in Wadi Gideah would be accessable by road. Note that data from this hole, as well as holes 1, 3, 6 and 7, will provide information complementary to that for site 1, in addition to the specific objectives outlined here.

3. Drill hole from sheeted dikes into upper gabbros, Wadi Gideah section of the Wadi Tayin massif.

4. Drill hole into peridotite underlying Eocene limestone along the northeast coast, to determine the physical properties and extent of alteration in subseafloor peridotite, which would be the best site for a future, engineered mineral carbonation experiment in Oman.

5. Drill hole through lower gabbros and the crust/mantle transition zone, Wadi Kurah section of the Sumail massif. This hole would penetrate the lower half of a crustal section which is much thinner than in the nearby Wadi Tayin massif (Nicolas et al., 1996), to examine the extent of lateral variability along a key horizon at the base of oceanic crust.

6,7. Two mantle peridotite drill holes in (a) vertically lineated peridotite in the center of the "Maqsad diapir" structure in the Sumail massif, and (b) horizontally transposed peridotite along the periphery of the Maqsad structure.

8,9,10,11,12, …. Offset drill holes linking the sections sampled by holes 2 and 3, to obtain a full lower crustal sample from the Wadi Gideah section of the Wadi Tayin massif.

Four important questions, and our response

We anticipate three important, critical questions about this proposal, and address them here.

- The Oman ophiolite is well exposed, in a desert region with deeply dissected canyons, so why is drilling necessary? In fact, the ophiolite is deeply weathered; oxide coatings obscure contact relationships, particularly in the mantle and Moho transition zone, and alteration associated with shallow circulation of ground water impedes geophysical, petrographic and geochemical measurements. Also, because the canyons are deeply incised, meandering, and joined by innumerable branches, it is impossible to collect representative vertical sample sections. Extensive mapping already completed, and mountainous exposures, do provide an unparalleled opportunity for choosing drill sites, and for correlating "stratigraphy" from one hole to another.
- Ophiolites are not necessarily representative of normal mid-ocean ridges, so why study them? It is plain that ophiolite research has provided fundamentally important insights to those studying active, submarine spreading systems, in a productive, ongoing dialogue. While the Oman ophiolite may not be typical of a "normal" mid-ocean ridge in every respect, the presence of pillow basalts underlain by a continuous layer of sheeted dikes establishes beyond doubt that it formed at a submarine spreading center. The processes that formed the igneous crust in Oman were similar to those at mid-ocean ridges. Geochronological and geological data, including the presence of a continuous gabbroic layer between dikes and mantle peridotite and the general absence of large fracture zones (e.g. Tilton et al. JGR 1981; Nicolas & Boudier JGR 1995), suggest that the ophiolite formed at a fast spreading ridge. Thus study of the ophiolite can provide important insight into processes at fast spreading ridges. Drilling in Oman will be complementary to the continuing efforts of the Ocean Drilling Program. Results from Oman cannot be correctly interpreted without complementary results from modern mid-ocean ridge systems.
- Given the existing results and core from the Cyprus Crustal Study Project, why conduct a drilling program in another ophiolite? Drilling in Oman will be complementary to previous drilling in Cyprus. First, we can anticipate from the Cyprus results that the core recovery will be excellent, much better than for drill holes from the Joides Resolution at sea. This presents a great opportunity, since downhole logging of ophiolite holes combined with good core recovery can be used to calibrate the logging techniques for use by ODP in holes with poor recovery. Unfortunately, in Cyprus there was no geophysical logging of the holes; this is one of the chief motivations of our drilling proposal for the Oman ophiolite. Second, the Cyprus drilling did not obtain a full crustal section, and in particular lacked core from the crust/mantle transition zone and the upper mantle. Third, it will be much easier to place Oman drill holes in geological context, because of the exceptional outcrop exposures . Finally, because the Oman ophiolite is one of the largest in the world, it will be easier to choose drill sites that are representative of typical crustal sections over 350 km along strike.
- Why study peridotite alteration in Oman? Why not California? To our knowledge, the peridotite alteration system in Oman is the largest, most active system exposed on land. We have visited the original locality in the Cedars peridotite studied by Barnes & O'Neil, and many other peridotite outcrops in the California Coast Ranges, the Klamaths and the Cascades, as well as in New England, and we have never seen anything comparable. Furthermore, seismic and gravity studies show that in many places the peridotite in Oman is several kilometers thick, so we can confidently plan to drill 500 meter holes entirely in peridotite. By contrast, in many US West Coast localities where alkaline springs and other indicators of active alteration are present, one would risk drilling through peridotite into underlying host rocks within a few hundred meters of the surface.

History of this workshop proposal

An earlier version of this workshop proposal was sent to the International Continental Scientific Drilling Program in January, 1998. It received approval by the ICDP in 2000, and we were offered funding for a planning workshop to be held in Oman. However, then came September 11, 2001. Later, frankly, the proponents were too busy with other projects to do this one justice (in Kelemen's case, ODP Leg 209 and the Talkeetna Arc Continental Dynamics Project), and so we have postponed it until now. Perhaps this has been for the best. The evolving interests of the community have added very important topics to this new proposal, especially study of the deep biosphere and ongoing, active alteration of mantle peridotite in the Oman ophiolite, with relevance to carbon capture and storage.

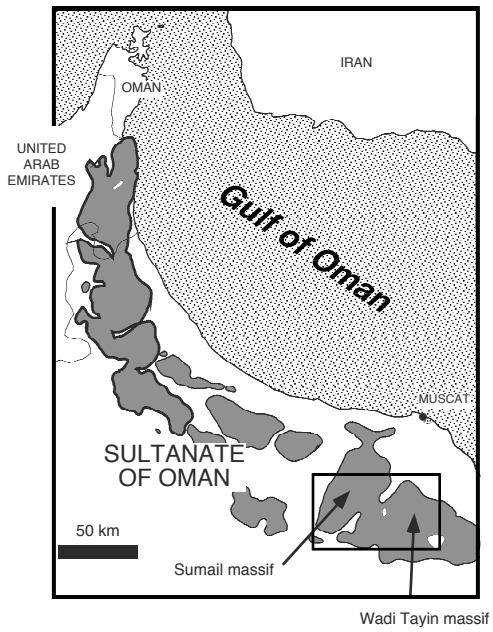

Figure 1 (above): Outcrop area of the Oman ophiolite (grey), redrawn after Lippard et al., 1986. Rectangle indicates approximate location of geologic map in Figure 5.

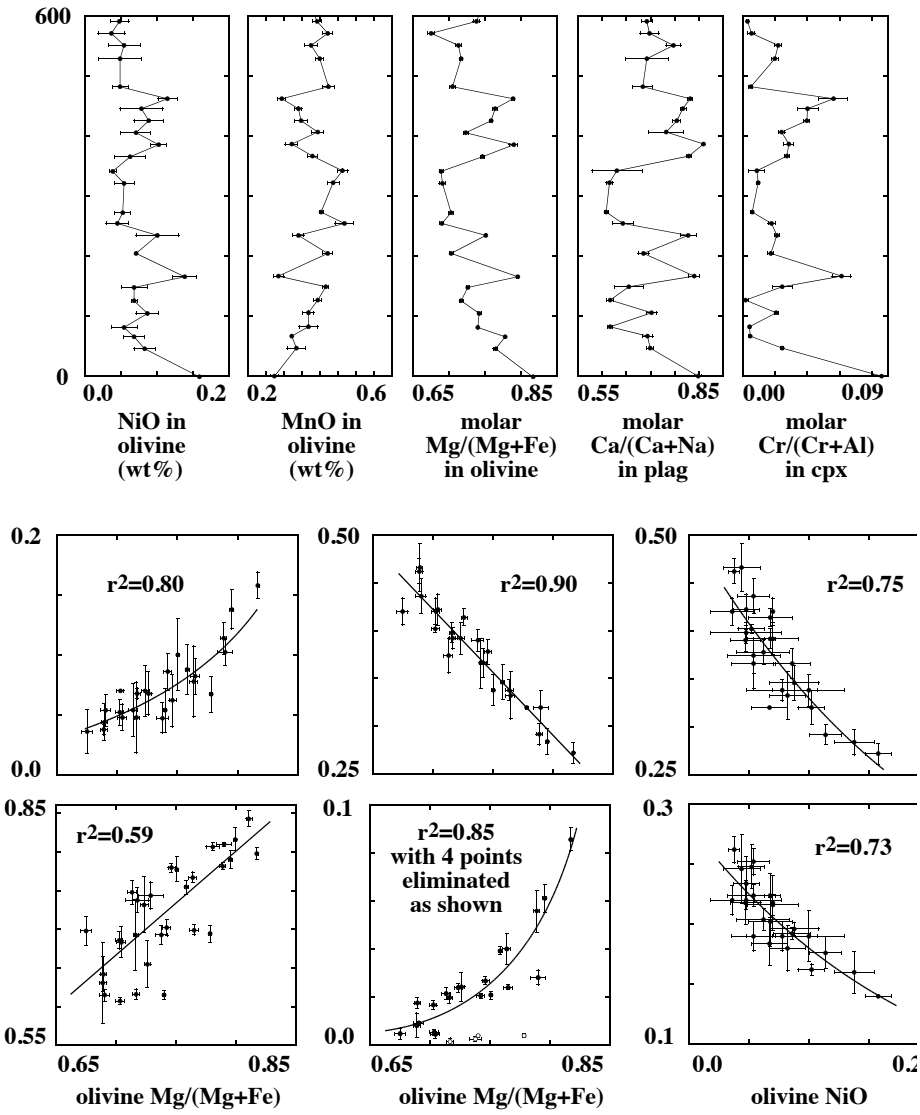

Figure 2 (right): Variation of mineral chemistry in lower crustal gabbro from the Oman ophiolite, compiled by Korenaga & Kelemen (1998) from the PhD thesis of Paul Browning (1982) at the Open University. Mineral compositions show no regular variation with height above the Moho, but are strongly correlated with each other. Korenaga & Kelemen (1998) argued that this precludes substantial migration of melt by diffuse porous flow through the lower crust after crystallization of the igneous minerals. Note that almost every sample constitutes an inflection point in plots of height vs. mineral composition, so that the actual length scale of chemical variation is unknown. Analyses of drill core will provide detailed measurements on a nearly continuous section.

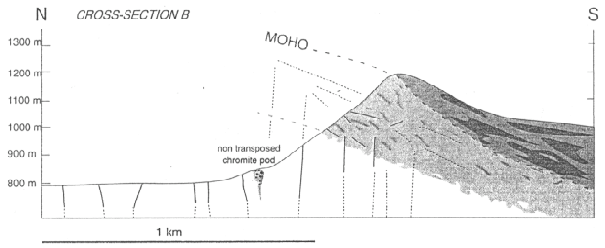

Figure 3 (left): Cross section in residual mantle harzburgites, plus dunites (grey) and gabbro (dark) along the crust/mantle transition near Wadi Kurah (figures 5 and 6) in the Sumail massif of the Oman ophiolite, from the PhD work of David Jousselin with the Tectonophysics group at the Université de Montpellier (paper submitted to Journal of Geophysical Research, 1997). Straight lines indicate dip of lineation, and show how near veritical lineation extends to within one or two hundred meters of the Moho, and is directly overlain by peridotite with nearly horizontal lineation. If the structure in this area was formed by diapiric mantle flow, upward at depth and then outward just beneath the Moho, then drilling should sample the transition between vertical and sub-horizontal mantle flow regimes. Alternatively, if the vertically lineated mantle was "intruded" into pre-existing oceanic lithosphere, for example due to ridge propagation, then an "angular unconformity" should be observed.

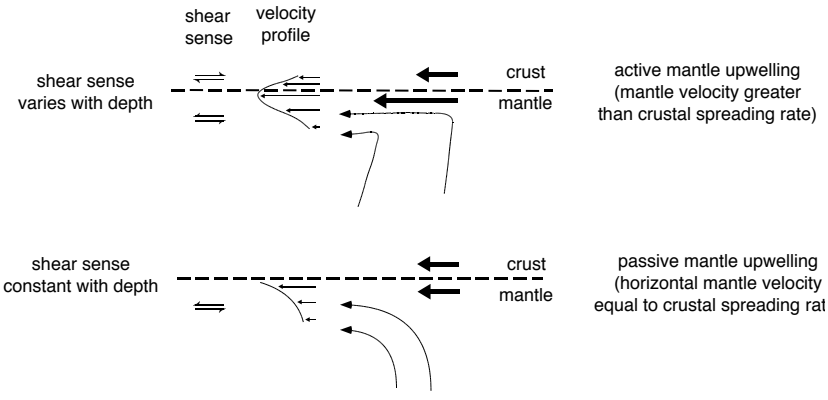

Figure 4 (right): Schematic illustration of the predicted inversion in the shear sense near the crust/mantle transition zone, for oceacic crust and uppermost mantle formed as a result of active mantle upwelling, contrasted with consistent shear sense predicted for passive mantle upweling, drawn after Nicolas et al., 1994. Drilling should provide statistically robust indications of the presence and strength of variation in shear sense with depth.

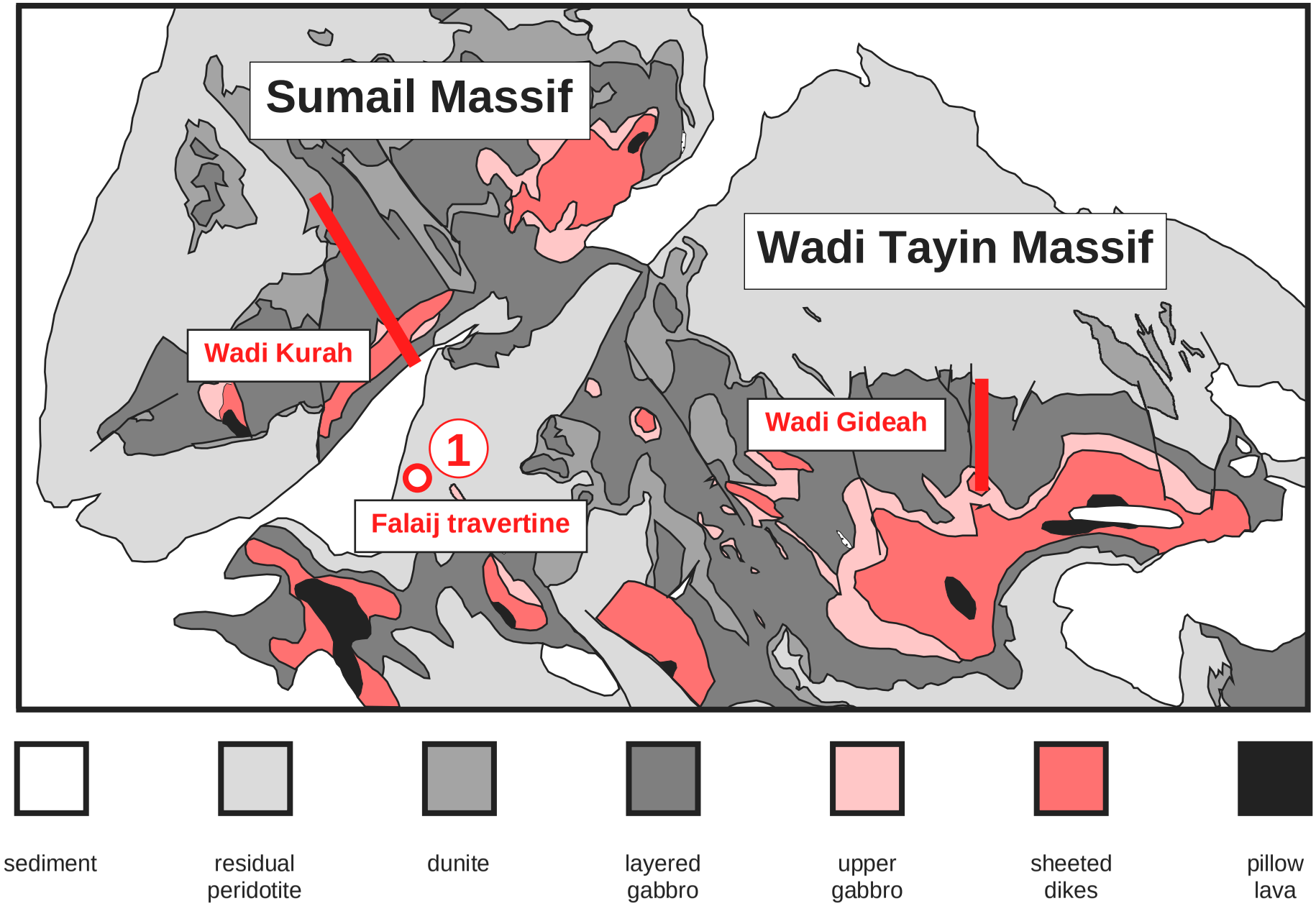

Figure 5: Geologic map of Wadi Tayin and Sumail massifs, showing location of cross-sections in Figure 6. Redrawn from unpublished map compiled by the Tectonophysics Group, University of Montpellier, ca. 1995.

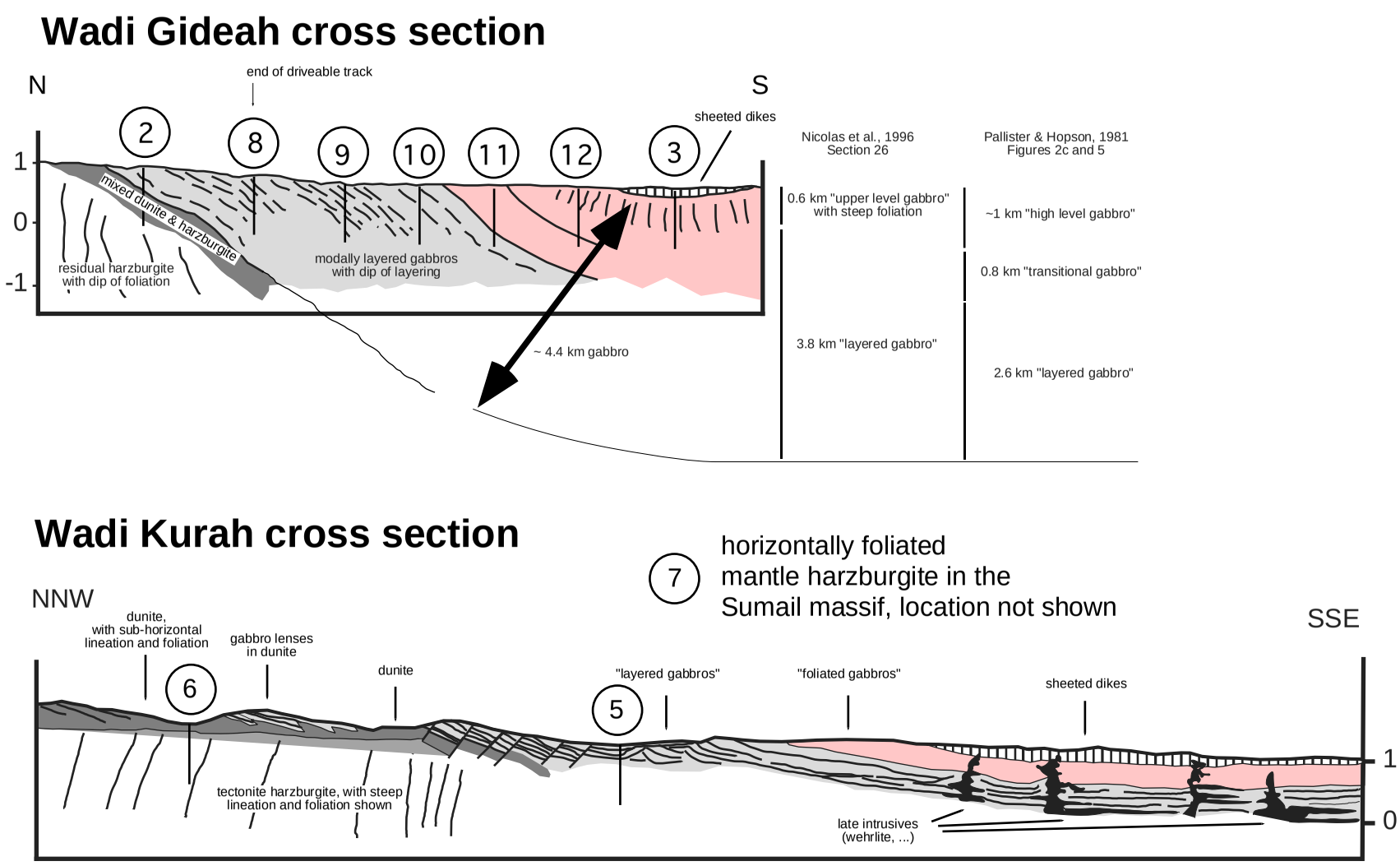

Figure 6: Cross sections of parts of the Wadi Tayin and Wadi Sumail massifs, as indicated in Figure 5, with proposed drill sites marked with vertical lines 1 km long, and numbered in order of priority. Data for Wadi Gideah cross section from Pallister & Hopson (1981) and Nicolas et al. (1996). Data for Wadi Kurah cross-section from Françoise Boudier (personal communication, 1998). Both sections are at the same scale, with no vertical exageration, and elevations in kilometers.

Figure 7: Alkaline spring in travertine near the village of Falaij, left, and carbonate veins in peridotite, right, from the active peridotite carbonation system in Oman. Samples from both photos yield 14C ages of less than 30,000 years. See Kelemen & Matter (2008) and Kelemen et al. (2011) for more information.

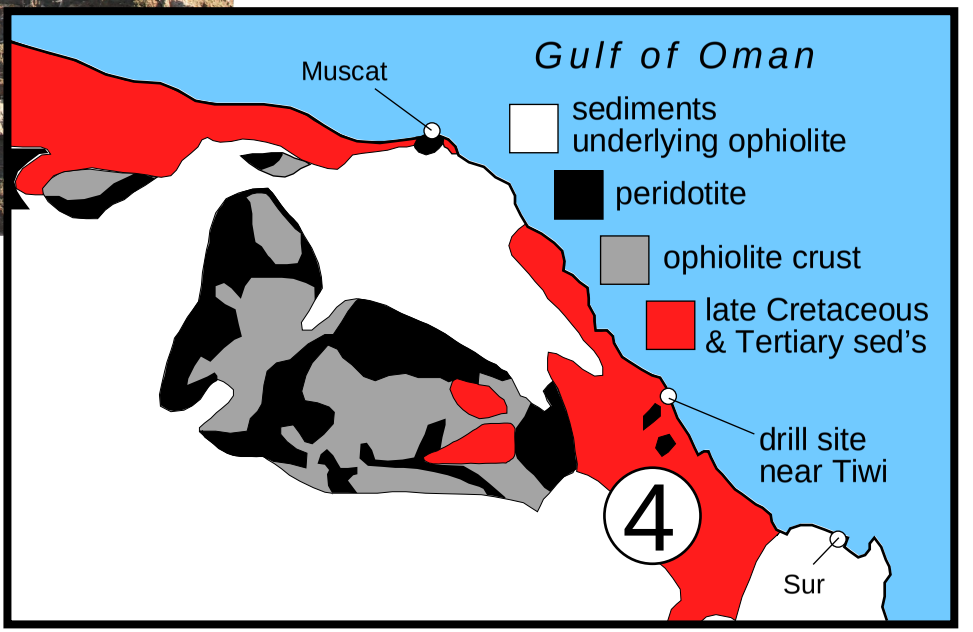

Figure 8: Simplified geologic map of the Wadi Tayin and Samail massifs, Samail ophiolite, Oman. Mantle and crustal rocks of the ophiolite were thrust over Mesozoic and Cretaceous sediments, and are unconformably overlain by late Cretaceous and Tertiary sediments. Open circle: location of prospective drill site along the NE coast. Map width ~ 400 km, top to north.

Informal budget

Informal budget for planning workshop, to be held at the Dolce Palisades Hotel and IBM Conference Center, Palisades NY, USA, near Columbia University's Lamont Doherty Earth Observatory

Air transportation, per person average	US$ 1000
Ground transportation, per person	US$ 200
Lodging, meals and conference facilities for four days	US$ 1200
Total cost per person	US$ 2400
Total cost for 70 people	US$ 168,000
Cost for support personnel at Lamont Doherty	US$ 20,000
Total cost of Workshop	US$188,000
Proposed ICDP contribution	US$ 50,000

Balance to be provided by individual grant funding available to participants and by contributions from national and regional funding agencies. Full funding will be offered to keynote speakers, key personnel, and to Omani government personnel from the Ministry of Commerce & Industry (Geological Survey), the Ministry of Environment, and the Ministry of Water Resources. Decisions on allocation of travel support will be made by the PI's on this proposal.

A New York venue was the consensus choice among attendees of the recent Workshop on Geological Carbon Capture & Storage in Mafic and Ultramafic Rocks: The Role of Oceanic and Continental Scientific Drilling, held at Sultan Qaboos University, Muscat, Oman from January 8-12, 2011. The attendees included many of the PI's on this proposal.

An Oman venue would also be possible at similar cost, but would "compete" with the upcoming international conference on the geology of Oman, to be held in January, 2012. Certainly, however, "field trips" to drill sites could be held during the international conference.

CVURRICULM VITAE

Personal Information

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Academic Packground

Degree	Major	School	Degree Date
PhD Degree	3D Modeling of Sur Tertiay Basin, eastern Oman	JVRCCS Sultan Qaboos University, Oman	2008
MSc Degree	Sedimentology	Bern University (Switzerland)	1998
Bachelors Degree	Earth Science	Sultan Qaboos University (OMAN)	1991

Further Training

Course Title/Vendor	Completed Date	Number of Days	Comments
Middle East and North Africa Mining Congress	10/2010	3	United Arab Emirates, Dubai
Symposum of Using the Coal to generate electercity in Oman	1/2010	2	Sultanate of Oman, Muscat
Leadership and Orginizational Management	4/2009	22	Kualalumbor, Malaysia
Geological Parameters for Environmental Protection.	3/2002	3	Sultan Qaboos University, Muscat.
How to start a small business.	4/2001	5	Gulf organization for Industrial consulting (Muscat).
International Fair for Marble.	6/2000	6	Carrara, Italy
Minning Development and Minerals exploration.	3/2000	30	JICA, Japan
UN Scholarship Award in Canada, Related to Al-Kamil Coal development project.	2/1993	120	Gemcom, Vancouver; Geol. Survey of Canada, Calgary

Professinal Experience

Start. Date	End. Date	Company, Location	Title	Responsibilities
10/2009	Crt.	Ministry of Commerce and Industry (MOCI)	Asistant Director General of Minerals	Replacement of the director general in his absence. Supervising various work activities of the departments. Contribution to future plans and stratigies of the Directorate. Conduction of reseach. Supervising mineral agreement with local and international companies, organisation and universities. Giving advice concerning mineral permits.

4/2007	10/2009	Ministry of Commerce and Industry (MOCI)	Director of Research and Geological Survey	Supervising activities of the geological survey and georesearch in the Sultanate. Supervising the production of geological maps and updating old ones at different scales. Making available data base for geosciences through the GIS department for investor in mieral sector. Preparing technical specifications for geological projects to be implimented by forigen and local companies. Coordinating with other government departments concerning siesmic activities, natural hazards, dams and other construction projects.
9/2006	4/2007	Ministry of Commerce and Industry (MOCI)	Head of non-metalic minerals exploration department	Studying available geological data such as geological maps and reports. Evaluating rocks and industrial minerals. Studying non-metalic mineral concession areas and issuing prospecting permits and exploration licenses for minerals investors.
9/2002	9/2006	Joint Virtual Reality Center for Carbonate Studies (JVRCCS) Sultan Qaboos University, Oman & Bordeaux University, France	PhD candidate	"3D modeling of Sur Tertiary basin, eastern Oman".
1/2000	9/2002	Ministry of Commerce and Industry (MOCI)	Head of non metalic minerals exploration department	Evaluating industrial rocks and minerals. Responsible for issuing prospecting and exploration permits.
6/1998	12/1999	Ministry of Commerce and Industry (MOCI)	Geologist	Carried out geological work, prospected for metalic and non-metalic minerals areas. Worked as a counter-part with JICA group for Exploration methodology and the discovery of massive sulphide deposites in the Batinah Coastal area.
4/1996	5/1998	(Bern University) Switzerland	MSc candidate	Studied the Lithostratigraphy of the Tertiary Formations in the Batain Plain,Sur region. Mapping of Sur sheet at the scale of 1:100,000.
12/1991	3/1996	Ministry of Petrol. & Mineral (MPM) Oman	Geologist	Carried out geological work (mapping, sampling ... etc) and studies for the following: - Al Kamil Coal fields Development project. - Ghabah Gypsum Project. –Hatat Lead and Zinc Project.

Additional Responsibilities

- Member of the Energy and Indusries Sector in the Reaseach Council.
- Member of the Oman Geological Society.

Publications:

2001 PETERS, TJ., AL BATTASHY, M., BLÄSI, R., HAUSER, M., IMMENHAUSER, A**.**, MOSER, L. AND **AL RAJHI**, A. Geological map of Sur and Al Ashkharah – Explanatory Notes to Sheet **NF 40-8F** and Sheet **40-12C**. Directorate General of Minerals, Oman Ministry of Commerce and Industry.

Shoji Arai

PERSONAL INFORMATION
Date of Birth: OCTOBER 27, 1948
Position: PROFESSOR OF EARTH SCIENCES, KANAZAWA UNIVERSITY

EDUCATION
B.S. in Geology, University of Tokyo, Tokyo, Japan: March 1971.
M.S. in Geology, University of Tokyo, Tokyo, Japan: March 1973.
DSc. in Geology, University of Tokyo, Tokyo, Japan: March 1976.

EMPLOYMENT HISTORY
April 1976-March 1977: Research Associate, University of Tokyo, Japan
April 1977-April 1979: Research Associate, Shizuoka University, Japan
May 1979-March 1981: Associate Professor, Shizuoka University, Japan
April 1981-November 1985: Associate Professor, University of Tsukuba, Japan
December 1985-March 1989: Assistant Professor, University of Tsukuba, Japan
April 1989-present: Professor, Kanazawa University

SOCIAL ACITIVITY
Member of IODP Planning Committee of Japan (2002-2005)
Member of IODP Science Planning Committee of Japan (2003-2006)
Chairman of Committee of Earth's Interior of Japanese Drilling Earth Science Consortium (2003-2006)
Co-chair of Science Steering and Evaluation Panel of IODP (2003-2005)
Member of ICDP SAG (Science Advisory Group) (2007-2009)
Member of IODP SASEC (Science Advisory Structure Executive Committee) (2010-present)
President of Japanese Association for Petrologists, Mineralogists and Economic Geologists (2002-2004)

RESEARCH INTEREST (SEE BELOW)
I have been working on petrology of deep-seated rocks (mainly peridotite and related rocks) from the ocean floor, the island arc and continent. I have also been interested in the geological aspects of emplacement of mantle materials.

List of Publication (selected from 233 peer-reviewed papers)

Arai, S. and Ishimaru, S. (2010) Zincian chromite inclusions in diamond: a possible deep recycling origin. Journal of Mineralogical and Petrological Sciences (accepted)

Arai, S., Okamura, H., Kadoshima, K., Tanaka, C., Suzuki, K. and Ishimaru, S. (2010) Chemical characteristics of chromian spinel in plutonic rocks: implications for deep magma processes and discrimination of tectonic setting. Island Arc (in press)

Ishimaru, S. and Arai, S. (2010) Peculiar Ca-Mg-Si metasomatism along a shear zone within the mantle wedge: inference from fine-grained xenoliths from Avacha volcano, Kamchatka. Contributions to Mineralogy and Petrology (in press)

Khedr, M. Z., Arai, S., Tamura, A. and Morishita, T. (2010) Clinopyroxenes in high-P metaperidotites from Happo-O'ne, central Japan: implication for wedge-transversal chemical change of slab-derived fluids. Lithos, 119 439-456.

Santosh, M., Rajesh, V.J., Tsunogae, T. and Arai, S. (2010) Diopsidites from a Neoproterozoic-Cambrian suture in southern India. Geological Magazine, 147, 777-788.

Akbulut, M., Pişkin, Ö., Arai, S., Özgenç, İ and Minareci, F. (2010) Base Metal (BM) and

Platinum-Group Element (PGE) Mineralogy and geochemistry of Elmaslar Chromite Deposit (Denizli, SW Turkey): Implications for a local BM and PGE enrichment. Ofioliti, 35, 1-20.

Rajesh, V.J., Arai, S., Santosh, M. and Tamura, A. (2010) LREE-rich hibonite in ultrapotassic rocks in southern India. Lithos, 115, 40-50.

Khedr, M.Z. and Arai, S. (2010) Hydrous peridotites with Ti-rich chromian spinel as a low-temperature forearc mantle facies; evidence from the Happo-O'ne metaperidotites (Japan). Contributions to Mineralogy and Petrology, 159, 137-157.

Arai, S. (2010) Possible recycled origin for ultrahigh-pressure chromitites in ophiolites. Journal of Mineralogical and Petrological Sciences, 105, 280-285.

Payot, B.D., Arai,, S., Tamayo, R.A., Jr. and Yumul, G.P., Jr. (2009) What underlies the Philippine Island Arc?: Clues from the Calaton Hill, Tablas Island, Romblon (central Philippines). Jour. Asian Earth Sci., 36, 371-389.

Ishimaru, S., Arai, S. and Shukuno, H. (2009) Metal-saturated peridotite in the mantle wedge inferred from metal-bearing peridotite xenoliths from Avacha volcano, Kamchatka. Earth and Planetary Science Letters, 284, 352-360.

Arai, S. and Ishimaru, S. (2008) Insights into petrological characteristics of the lithosphere of mantle wedge beneath arcs through peridotite xenoliths: A review. Jour. Petrol., 49 (D.H. Green vol.), 665-695.

Tamura, A., Arai, S., Ishimaru, S. and Andal, E.S. (2008) Petrology and geochemistry of peridotites from IODP Site U1309 at Atlantis Massif, MAR 30oN: micro- and macro-scale melt penetrations into peridotites. Contrib. Mineral. Petrol., 155, 491-509. (doi: 10.1007/s00410-007-0254-0)

Arai, S., and Y. Takemoto (2007) Mantle wehrlite from Hess Deep as a crystal cumulate from an ultra-depleted primary melt in East Pacific Rise, Geophys. Res. Lett., 34, L08302, doi:10.1029/2006GL029198.

Python, M., Ceuleneer, G., Ishida, Y., Barrat, J.-A. and Arai, S. (2007) Oman diopsidites: a new lithology diagnostic of very high temperature hydrothermal circulation in mantle peridotite below oceanic spreading centres. Earth Planet. Sci. Lett., 255, 289-305.

Ishimaru, S., Arai, S., Ishida, Y., Shirasaka, M., and Okrugin, V.M. (2007) Melting and multi-stage metasomatism in the mantle wedge beneath a frontal arc inferred from highly depleted peridotite xenoliths from the Avacha volcano, southern Kamchatka. Jour. Petrol., 48, 395-433.

Arai, S. (1994) Characterization of spinel peridotites by olivine-spinel compositional relationships: Review and interpretation. Chem. Geol., 113, 191-204.

Arai, S. and Yurimoto, H. (1994) Podiform chromitites of the Tari-Misaka ultramafic complex, southwestern Japan, as mantle-melt interaction products. Econ. Geol., 89, 1279-1288.

Arai, S. (1992) Chemistry of chromian spinel in volcanic rocks as a potential guide to magma chemistry. Mineral. Mag., 56, 173-184.

Arai, S. and Hirai, H. (1985) Relics of H_2O fluid inclusions in mantle-derived olivine. Nature, 318, 276-277.

Arai, S. (1975) Contact metamorphosed dunite-harzburgite complex in the Chugoku district, western Japan. Contrib. Mineral. Petrol., 52, 1-16.

Biographical Sketch of Wolfgang Bach

Contact Information
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Professional Preparation

Undergraduate Education:		
University of Giessen	Mineralogy	Diploma (~M.S.) 1991
Graduate Education:		
University of Giessen	Geochemistry	Ph.D. 1996
Postdoctoral Institutions:		
Woods Hole Oceanographic Inst.	Dept. of Geology and Geophysics	10/1996-05/1999

Appointments

Full Professor (W3)	University of Bremen (since 10/2005)
Associate Scientist	Woods Hole Oceanographic Inst. (05/2003-09/2005)
Assistant Scientist	Woods Hole Oceanographic Inst. (05/1999-05/2003)

Selected Publications:

Bach W, and Früh-Green GL (2010) Alteration of the Oceanic Lithosphere and Implications for Seafloor Processes. *Elements* 6: 173-178.

Bach, W., and Klein, F. 2009. Petrology of rodingites: Insights from geochemical reaction path modeling, *Lithos* 112: 103-117

Bach, W. and Edwards, K.J. 2003. Iron and sulfide oxidation within the basaltic ocean crust: implications for chemolithoautotrophic microbial biomass production. *Geochimica et Cosmochimica Acta*, 67, 3871-3887.

Bach, W., Humphris, S.E., and Fisher, A.T. 2004. Fluid Flow and Fluid-Rock Interaction Within the Oceanic Crust: Reconciling Geological, Geochemical and Geophysical Observations. In Wilcock, W., DeLong, E., Kelley, D., Baross, J., Cary, C. (Eds.) The Subseafloor Biosphere at Mid-Ocean Ridges. Geophysical Monograph, 144, 99-117, American Geophysical Union

Bach, W., Paulick, H., Garrido, C.J., Ildefonse, B., Meurer, W.P., and Humphris, S.E. 2006. Unraveling the sequence of serpentinization reactions: petrography, mineral chemistry, and petrophysics of serpentinites from MAR 15ºN (ODP Leg 209, Site 1274), Geophysical Research Letters, 33, L13306, doi:10.1029/2006GL025681

Bach, W., Peucker-Ehrenbrink, B., Hart, S.R., and Blusztajn, J.S. 2004. Geochemistry of hydrothermally altered oceanic crust: Hole 504B – Implications for seawater-crust exchange budgets and Sr- and Pb-isotopic evolution of the mantle. *Geochemistry, Geophysics, Geosystems*, 4(3), 10.1029/2002GC000419

Barnes, J.D., Paulick, H., Sharp, Z.D., Bach, W., and Beaudoin, G. (2009) Stable isotope ($\delta^{18}O$, δD, $\delta^{37}Cl$) evidence for multiple fluid histories in mid-Atlantic abyssal peridotites (ODP Leg 209) *Lithos* 110: 83-94

Eickmann, B., Bach, W., and Peckmann, J. 2009. Authigenesis of carbonate minerals in ocean-floor hard rocks: modern and Devonian examples. *Journal of Geology* 117: 307-323.

Eickmann, B., Bach, W., Peckmann, J. 2009. Geochemical constraints on the modes of carbonate precipitation in peridotites from the Logatchev Hydrothermal Vent Field and Gakkel Ridge. *Chemical Geology* 268: 97-106

Hinrichs, K.-U., Hayes, J.M., Bach, W., Spivack, A., Holm, N.G., Hmelo, L., Johnson, C.G., and Sylva, S. 2006. Biological formation of ethane and propane in the deep marine subsurface, *Proceedings of the National Academy of Science*, 103, 14684-14689

Jöns, N., Bach, W., and Schroeder, T. (2009) Formation and alteration of plagiogranites in an ultramafic-hosted detachment fault at the Mid-Atlantic Ridge (ODP Leg 209), *Contribution to Mineralogy and Petrology* 157: 625-639

Klein, F., Bach, W., Jöns, N., McCollom, T.M., Moskovitz, B., Berquo, T. 2009. Iron partitioning and hydrogen generation during serpentinization of abyssal peridotites from 15°N on the Mid-

Atlantic Ridge *Geochimica et Cosmochimica Acta 73(22) 6868-6893,* doi:10.1016/j.gca.2009.08.021

Klein, F., and Bach, W. 2009. Fe-Ni-Co-O-S phase relations in peridotite-seawater interactions, Journal of Petrology, 50, 37-59

McCollom, T.M., and Bach, W. 2009 Thermodynamic constraints on hydrogen generation during serpentinization of ultramafic rocks, Geochimica et Cosmochimica Acta, 73, 856-879

Peckmann, J., Bach, W., Behrens, K., and Reitner, J. 2008 Cryptoendolithic life in Devonian pillow basalts, Rheinisches Schiefergebirge, Germany. Geobiology, 6, 125-135

Perner, M., Bach, W., Hentscher, M., Koschinsky, A., Garbe-Schönberg, D., Strauss, H., and Streit, W.R. 2009. Short-term microbial and physico-chemical variability in low-temperature hydrothermal fluids near 5°S on the Mid-Atlantic Ridge, *Environmental Microbiology* 11 (10): 2526-254

Santelli, C.M., Banerjee, N., Bach, W., Edwards, K.J. 2010. Tapping the subsurface ocean crust biosphere: low biomass and drilling-related contamination calls for improved quality controls and novel approaches for the future of subseafloor research. *Geomicrobiology Journal* 27:158–169

Santelli, C.M., Edgcomb, V., Bach, W., and Edwards, K.J. 2009. The diversity and abundance of bacteria inhabiting seafloor lavas positively correlate with rock alteration. Environmental Microbiology, 11, 86-98

Santelli, C.M., Orcutt, B.N., Banning, E., Bach, W., Moyer, C.L., Sogin, M.L., Staudigel, H., and Edwards, K.J. 2008. Abundance and diversity of microbial life in ocean crust, Nature 453: 653 - 656

Synergistic Activities

- Co-chair and co-organizer of the IODP INVEST meeting in Bremen, Sept. 2009
- Co-convener of the ECORD Summer School “Geodynamics of Mid-Ocean Ridges”, Sept. 2009
- Member of IODP Science Steering and Evaluation Panel (2003-2005)
- Presentations on Deep-Sea Hydrothermal Systems in elementary schools
- Lectures in ECORD, RIDGE and InterRidge short courses and summer schools

Collaborators & Other Affiliations

Collaborators and Co-Editors:

Jeff Alt (U Mich), Jaime Barnes (U New Mexico), Henry Dick (WHOI), Carlos Garrido (U Granada), Susan Humphris (WHOI), Benoit Ildefonse (U Montpellier), Adam Kent (Oregon State U), Hidenori Kumagai (JAMSTEC), Graham Layne (U St.John), Kentaro Nakamura (U Tokyo), Yaoling Niu (U Durham), Jörn Peckmann (U Bremen), Bernhard Peucker-Ehrenbrink (WHOI), Jeff Seewald (WHOI), Pat Shanks (USGS), Zach Sharp (U New Mexico), Damon Teagle (NOC Southampton), Meg Tivey (WHOI), Heiner Villinger (U Bremen)

Graduate and Postdoctoral Advisors:

Graduate Advisor: Jörg Erzinger
Postdoctoral Advisor: Susan Humphris

Thesis Advisor and Postgraduate-Scholar Sponsor:

Current Postdoctorals: Niels Jöns (10/2007-), Eoghan Reeves (4/2010-)
Former Postdoctorals: Neil Banerjee (U Edmonton), Martin Rosner (BAM)
Current PhD Students: Michael Hentscher, Dominik Niedermeier, Svenja Rausch, Liping Shu,
Former Graduate Students: Cara Santelli (Ph.D. MIT/WHOI, 05/2007), Paul Craddock (Ph.D. MIT/WHOI, 09/2008), Peter Canovas (M.S., MIT/WHOI, 03/2006), Frieder Klein (Ph.D., U Bremen, 05/2009)

Donna K. Blackman
Research Geophysicist
Scripps Institution of Oceanography
La Jolla CA 92093-0225
dblackman@ucsd.edu http://www.igpp.ucsd.edu/~dkb/

Education

	Major	Degree	Yr
Semester at Sea, University of Colorado, Boulder CO	Humanities		1977
Pasadena City College, Pasadena CA	Geology	A.A.	1979
University of California, Santa Cruz CA	Earth Science	B.S.	1982
Massachusetts Institute of Technology, Cambridge MA	Marine Geophysics	M. Sc.	1986
Brown University, Providence, RI	Marine Geophysics	PhD.	1991

Graduate Advisor: Donald Forsyth, Brown University
PostDoctoral Advisors: John Orcutt, Jason Phipps Morgan, Scripps Institution of Oceanography

Positions Held

1/07-3/10	Senior lecturer, UCSD, La Jolla CA
7/03-present	Research Geophysicist, Scripps Institution Oceanography, La Jolla CA
7/99-6/03	Associate Research Geophysicist, Scripps Institution Oceanography, La Jolla CA
9/96-4/03	Lecturer, SIO/UCSD, grad/undergrad courses, Geophysics/Earth & Environ. Sciences
8/95-6/99	Assistant Research Geophysicist, Scripps Inst. of Oceanography
8/95-7/96	Lecturer, Dept Earth Sciences, University of Leeds, Leeds, UK
5/92-6/95	Postgraduate Researcher, Scripps Inst. of Oceanography
1/92-4/92	Acting Assistant Professor, School of Oceanography, Univ. of WA, Seattle WA
3/91-12/91	RIDGE Office admin., & research postdoc, University of Washington
10/86-12/86	Visualization Programming, Deep Submergence Lab, WHOI, Woods Hole MA
8/80-8/83	Field/Lab Assistant, USGS, Pacific Marine Geology Branch, Menlo Park CA
11/78-6/79	Lab Assistant, Jet Propulsion Laboratory, Pasadena CA

Shipboard Experience

Participation in geophysical/geological data acquisition during 21 research cruises since 1981, 3-6 wks each throughout the worlds oceans. Led/designed acquisition and sailed as chief scientist on 5 of these.

Professional & Synergistic Activities

Marine Geosciences Leadership Symposium, Speaker March 2009
IODP Science Planning Committee, Nov 2008-present; SSEP 2001-2004
IODP Distinguished Lecturer 2006/2007 Academic year
Ridge 2000, Chair 2005-2008, Steering Committee 2002-2005

Teaching

1992 Marine Geology, graduate level, University of Washington
1996 Geodynamics, graduate, SIO
1997 co-instructor Continuum Mechanics, graduate, SIO
1999 co-instructor ERTH101, undergraduate UCSD
2001-2003, 2006-2009 co-instructor ESYS Solid & Fluid Earth, undergraduate UCSD
2006-2009 co-lead for Geophysics Research Discussion, graduate SIO

Selected Publications

Blackman, D.K. and J.A. Collins (2010) Lower Crustal Variability and the Crust/Mantle Transition at the Atlantis Massif Oceanic Core Complex, Geophys. Res. Lett. 37, L24303, doi:10.1029/2010GL045165.

Harmon, N. and D.K. Blackman, Effects of plate boundary geometry and kinematics on mantle melting beneath the back-arc spreading centers along the Lau Basin, Earth Planet. Sci. Lett. (2010), doi: 10.1016/j.epsl.2010.08.004

Donna K. Blackman, J. Pablo Canales and Alistair Harding, Geophysical signatures of oceanic core complexes, Geophys. J. Int. (2009) 178, 593–613, doi: 10.1111/j.1365-246X.2009.04184.x.

Castelnau, O., D. K. Blackman, T.W. Becker, Numerical simulations of texture development and associated rheological anisotropy in regions of complex mantle flow, Geophys. Res. Letter, 36, L12304, doi:10.1029/2009GL038027, 2009.

Collins, J.A., D.K. Blackman, A. Harris, R.L. Carlson, Seismic and drilling constraints on velocity structure and reflectivity near IODP Hole U1309D on the central dome of Atlantis Massif, Mid-Atlantic Ridge 30°N, G^3 10, doi:10.1029/2008GC002121, 2009

Blackman, D.K., R.C. Searle, G.D. Karner, 3-D structure of oceanic core complexes: effects on gravity signature and ridge flank morphology, MAR 30N, GCubed, doi:10.1029/2008GC001951 2008.

Ildefonse, B., D.K. Blackman, B.E. John, Y. Ohara, D.J. Miller, C.J. MacLeod, IODP Expeditions 304/305 Science Party, Oceanic core complexes and crustal accretion at slow-spreading ridges, Geology 35, 623-626, doi: 10.1130/G23531A.1, 2007.

Blackman, D.K., Use of mineral physics, with geodynamic modeling and seismology, to investigate flow in the Earth's mantle, Reports on Progress in Physics 70, 659-689, 2007.

Blackman, D.K., de Groot-Hedlin, C., Harben, P., Sauter, A., Orcutt, J.A., Testing low/very low frequency acoustic sources for basin-wide propagation in the Indian Ocean. J. Acoust. Soc. Amer. 116, , doi: 10.1121/1.1786711, 2004.

Blackman, D.K., H-R. Wenk, J-M. Kendall, Seismic anisotropy in the upper mantle: 1. Factors that affect mineral texture and effective elastic properties, G-Cubed 10.1029/2001GC000248, 2002.

Blackman, D.K. and J-M. Kendall, Seismic anisotropy in the upper mantle: 2. Predictions for current plate boundary flow models, G-Cubed 10.1029/2001GC000247, 2002.

Kelley, D.S., J.A. Karson, D.K. Blackman, G.L. Fruh-Green, D.A. Butterfield, M.D. Liley, E.J. Olson, M.O. Schrenk, K.K. Roe, G.T. Lebon, P. Rivizzigno and AT3-60 Shipboard Party, An off-axis hydrothermal vent field discovered near the Mid-Atlantic Ridge at 30°N, Nature 412, 145-149, 2001.

Blackman, D.K., C.E. Nishimura, J.A. Orcutt, Seismoacoustic recordings of a spreading episode on the Mohns Ridge, J. Geophys. Res. 105, 10,961-10,973, 2000.

Cann, J.R., D.K. Blackman, D.K. Smith, E. McAllister, B. Janssen, S. Mello, E. Avgerinos, A.R. Pascoe, J. Escartin, Corrugated slip surfaces formed at ridge-transform intersections on the Mid-Atlantic Ridge, Nature 385, 329-332, 1997.

Blackman, DK, Variation in lithospheric stress along ridge-transform plate boundaries, Geophys. Res. Lett. 24, 461-464 1997.

Blackman, DK, JA Orcutt, DW Forsyth, J-M Kendall, Seismic anisotropy in the mantle beneath an oceanic spreading center, Nature 366, 675-677, 1993.

Curriculum Vitae
(mars 2010)

Georges CEULENEER
Né le 10/12/59 à Bruxelles - Marié, 3 enfants.
UMR 5562 « Dynamique Terrestre et Planétaire »
Université Paul Sabatier – Observatoire Midi-Pyrénées - 14 av. E. Belin, 31400 Toulouse
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***Fonction actuelle** :*
Directeur de l'UMR5562

***Parcours professionnel** :*
1977-81: Maîtrise de Géologie à l'Université Libre de Bruxelles.
1981-82: DEA de Géophysique - Géologie Structurale à l'Université de Paris XI, Orsay.
1982-85: Thèse en géologie structurale au Laboratoire de Tectonophysique de Nantes.
1985-86: Service National dans la force navale belge.
1987-88: Post-Doc ESA au CNES (Toulouse) (Géophysique théorique).
1988: Chargé de Recherche CNRS.
1998: Habilitation à Diriger des Recherches (UPS, Toulouse).
1999: Promotion dans le corps des Directeurs de Recherche.

***Domaine de recherche** :*

Spécialité :
. Pétrologie magmatique, géochimie.
. Etudes de terrain dans les ophiolites.
. Campagnes d'échantillonnage en mer.

Thématiques scientifiques :
. Genèse et migration des magmas dans le manteau terrestre.
. Construction de la croûte océanique et des croûtes planétaires.
. Interactions magmas/roches/fluides.

Chantiers principaux :
Ophiolites : Oman (~ 1 campagne/an depuis 1983), Californie, Venezuela, Europe.
Dorsales : Plongées en submersible (*Nautile, Shinkai-6500*) et forages (*Joides Resolution*).

***Administration – Animation – Evaluation de la Recherche** :*

International :
. Membre du Science Steering and Evaluation Pannel « Earth's Interior » d'ODP (1997-1999).
. Membre de Comités de Bilan et Prospective ODP et I-ODP (en 2002 et en 2008).
. Reviewer de projets européens (NERC, etc …).
. Rapporteur de PhD étrangers (UK et Australie).
. Reviewer d'une demi-douzaine d'articles par an (pour Nature, JPetrol, G3, CMP, Lithos, etc…).

National :
. Chargé de Mission au Ministère de la Recherche (MSTP – DS3) (2006-2007).
. Commission Nationale « Flotte et Engins - Evaluation » depuis (depuis 2007).
. Comité « Géosciences Marines » (IFREMER-CNRS-IRD-BRGM) (2002-2007).
. Comité Scientifique des programmes DyETI et SEDIT (INSU) (2005-2007).
. Membre et puis animateur du groupe ad hoc OCEAN (INSU) (1997-2003).
. Commissions de spécialistes de l'UBO (35ième et 36 ième section du CNU) (2004-2008).
. Comité de Gestion de la Microsonde Ouest (UBO-CNRS-IFREMER) (depuis 2009).
. Membre et/ou président de Comités de Visite pour l'évaluation et/ou la création d'UMR.
. Rapporteur d'une vingtaine de thèses et d'HDR.

Local:
. Direction de l'UMR 5562 (depuis janvier 2009)
. Direction adjointe de l'UMR 5562 (2007-2008).
. Responsable de thématique dans le cadre de la création d'une future UMR « Geosciences-Environnement ».
. Responsable de l'équipe Petrologie et Modélisation de l'UMR 5562 (2003-2007).
. Conseil Scientifique de l'Observatoire Midi-Pyrénées (membre du bureau) (2005-2007).
. Conseil de l'Ecole Doctorale SU2E de l'Univsersité Paul Sabatier (Toulouse) (depuis 2006).
. Comité d'attribution des bourses de l'ED SU2E (depuis 2006).
. Commissions de spécialistes de l'UPS (35ième section du CNU) (2004-2008).
. Collège Scientifique BEST (Biologie, Environnement, Sci. De la Terre) de l'UPS (depuis 2008).
. Conseil d'Administration de l'OMP (1992-1996).
. Responsable scientifique de l'atelier roches de l'OMP (1997–2007).

Diffusion de la connaissance :

. Initiateur et animateur de l'Action Nationale de Formation scientifique « FORSTERITE » (depuis 2007).
. Responsable de sessions de formation pour professeurs du secondaire, organisé par l'IUFM (2004-2006).
. Nombreuses conférences grand public (Fêtes de la Science, Clubs de minéralogistes et géologues amateurs, Université du Temps Libre, Université des Savoirs Populaires, Museum de Toulouse, Prison de Muret, …) .
. Organisation d'excursions géologiques dans l'ophiolite d'Oman dans le cadre de congrès internationaux et de formation permanente pour professeurs du secondaire.
. Rédaction d'articles de vulgarisation, interviews pour la presse nationale et internationale ....
. Cours de pétrologie magmatique en Master (une quinzaine d'heures par an).

Encadrement de thèses :

5 thèses soutenues et 2 en cours, portant sur l'ophiolite d'Oman.
Mes anciens thésards poursuivent tous des activités de recherche :
. Isma Amri, dont j'ai encadré la thèse française (1995) et la Thèse d'Etat marocaine (2007), est professeur à l'Université de Tétouan.
. Mathieu Benoit (thèse soutenue en 1997) est chercheur au CNRS et a rejoint Toulouse après 8 ans passés à l'IUEM (Brest).
. Marie Python (thèse soutenue en 2002) a commencé en 2008 un mandat de 3 ans de professeur à l'Université de Kyoto, après 3 ans de post-doc et CDD au Japon et 1 an de post-doc à Toulouse.
. Harold Clénet (thèse soutenue en 2009) a débuté un post-doc CNRS à Lyon.

Publications : 50 articles dans des revues à comité de lecture. Citations WoS : ~ 1.000 ; H : 17.
En incluant les articles non pris en compte par le WoS pour ce calcul (ODP,…) : Citations ~ 1.200; H : 20.

Distinction :

Prix Furon (géologie endogène) de la Société Géologique de France (2003).

CURRICULUM VITAE

LAURENCE A. COOGAN

School of Earth and Ocean Sciences
University of Victoria
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Canada

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Professional Preparation:

University of Leicester (UK) PhD (1998) University of Liverpool (UK) BSc. (1993)

Appointments:

2008-present: Associate Prof. (University of Victoria)
2004-2008: Assistant Prof. (University of Victoria)
2002-2004: NERC Post-doctoral Research Fellow (Leicester University)
1998-2002: Post-doctoral Researcher (Cardiff University)

Awards:

2007: Mineralogical Association of Canada Young Scientist Award.
2002 NERC Fellowship

Five publications relevant to this proposal:

Coogan, L.A., (2007), The lower oceanic crust, *in* Turekian, K., and Holland, H.D., eds., Treatise on Geochemistry, Elsevier. (Revised version in review for forthcoming edition).

Perk, N., Coogan, L.A., Karson, J.A., Klein, E.M. and Hanna, H., 2007. Primitive cumulates from the upper crust formed at the East Pacific Rise. Contributions to Mineral Petrology: DOI:10.1007/s00410-007-0210-z.

Coogan, L.A., Howard, K.A., Gillis, K.M., Bickle, M.J., Chapman, H.J., Boyce, A.J., Jenkin, G.R.T., and Wilson, R.N., (2006), Chemical and thermal constraints on focused fluid flow in the lower oceanic crust: American Journal of Science.

Coogan, L.A., Jenkin, G.R.T. and Wilson, R.N., 2007. Contrasting cooling rates in the oceanic lithosphere at fast- and slow-spreading mid-ocean ridges derived from geospeedometry. Journal of Petrology, 48: 2211-2231.

Coogan, L.A., 2008. Reconciling temperatures of metamorphism, fluid fluxes and heat transport in the upper crust at intermediate- to fast-spreading mid-ocean ridges. Geochemistry Geophysics Geosystems.

Five other significant research publications:

Coogan, L.A. and Hinton, R.H., 2006. Do the trace element compositions of detrital zircons require Hadean continental crust? Geology, 34(8): 633-636.

Coogan, L.A., Kasemann, S., and Chakraborty, S., 2005, Rates of hydrothermal cooling of new oceanic upper crust derived from Li-geospeedometry: Earth Planet. Sci. Lett., v. 240, p. 415-424.
Coogan, L.A., 2003, Contamination of the lower oceanic crust in the Oman ophiolite: Geology, v. 31, p. 1065-1068.
Coogan, L.A., Banks, G.J., Gillis, K.M., MacLeod, C.J., and Pearce, J.A., 2002, Hidden melting signatures recorded in the Troodos ophiolite plutonic suite: evidence for widespread generation of depleted melts and intra-crustal melt aggregation: Contrib. Mineral. Petrol., p. DOI 10.1007/s00410-002-0413-2.
Coogan, L.A., Kempton, P.D., Saunders, A.D., and Norry, M.J., 2000, Evidence from plagioclase and clinopyroxene major and trace element compositions for melt aggregation within the crust beneath the Mid-Atlantic Ridge: Earth Planet. Sci. Lett., v. 176, p. 245-257.

Collaborators and co-authors:

G. Banks (Cardiff), A. Barker (Upsala), T. Barry (Open Uni.), M. Bickle (Cambridge), A. Boyce (SUURC), D. Canil (UVic), S. Chakraborty (U. Bochum), H. Chapman (Cambridge), M. Chaussidon (Nancy), M. Cheadle (Wyoming), F. Costa (Singapore), H. Dick (WHOI), R. Dohmen (U. Bochum), N. Hayman (Texas), K. Gillis (UVic), M. Godard (Montpelier), R. Hekinian (Infremer), E. Hellebrand (Mainz), R. Hinton (Edinburgh), A. Hosford Scheirer (USGS), K. Howard (Leicester), G. Jenkin (Leicester), J. Karson (U. Syracuse), S. Kasemann (Edinburgh), A. Kavassnes (Bremen), A. Khan (Leicester), P. Kempton (NERC), E. Klien (Duke), C. MacLeod (Cardiff), P. Maguire (Leicester), C. Manning (UCLA), G. McKenzie (Leicester), N. Mitchell (Cardiff), J. Natland (Miami), Y. Niu (Durham), M. Norry (Leicester), M. O'Hara (Cardiff), J. Pearce (Cardiff), R. Pedersen (Bergen), N. Perk, P. Robinson (Dalhousie), A. Saunders (Leicester), G. Thompson (Hong Kong), D. Weis (UBC), R. Wilson (Leicester)

Graduate Students supervised:

Kathi Faak (PhD – in progress, U. Bochum); Archana Shejwalkar, (PhD – in progress, UVic); Brock Anderson (MSc – in progress, UVic); Casey Brant (PhD – in progress, UVic), Simon Jowitt (PhD, Leicester), Graham Banks (PhD, Cardiff), Richard Thomas (PhD, Cardiff), Zhihuan Wan (MSc, UVic.), Lisa Worrell (PhD, Liverpool)

Field experience:

Numerous field seasons in both the Oman and Troodos ophiolites. Seagoing experience with submersible, ROV, portable rock-drills and dredging.

Synergistic Activities:

2007-present: member of the editorial board of LITHOS

Marguerite Godard
Géosciences Montpellier
UMR CNRS-UM2 5243
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Place Eugene Bataillon
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Senior Researcher CNRS
Geochemistry

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Tel : + (0) 467 14 36 03
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RESEARCH INTERESTS:

Origin and evolution of the oceanic lithosphere: Quantification of melt-rock interactions associated to magma transport in partially molten upper mantle, and of their feedback effects on physical properties of the oceanic lithosphere; Characterization of chemical and hydrodynamic processes associated to the alteration of (ultra-)mafic rocks on the ocean floor and of their possible environmental impact; Application for CO_2 sequestration and H_2 production.

Methodological developments: Trace element analyses in highly depleted (ultra-)mafic rocks (ICP-MS and HR-ICP-MS coupled to Laser Ablation); Numerical modeling of liquid/solid chemical interactions in porous media; Development of percolation-reaction experimental protocols for simulating the (induced or natural) hydration and carbonation of (ultra-)mafic rocks by hydrothermal fluids in the oceanic lithosphere (T up to 400°C; P ~ 40 MPa; variable pCO2).

EMPLOYMENT

- 1990-1993: Fellowship from the French Ministry of Research and Technology.
- 02/1994-10/1994: Associate Researcher, Water ResourceS Research Unit (director: R. MacKay), Dept. of Civil Engineering, University of Newcastle (United Kingdom)
- 1994-…: Researcher – CNRS-University of Montpellier

CURSUS

- 1990: DEA « Tectonique, Géophysique, Géochimie, Hydrogéologie » *(Master)*, Université Montpellier 2. « Seuils de percolation et rhéologie des magmas en cours de cristallisation : approche analogique ». *(Percolation threshold and rheology of crystallizing magmas: An analogical approach*) . Supervisor: A. Vauchez & A. Nicolas.
- 13/09/1993 : Thèse de Doctorat « Physique et chimie de la Terre » (*PhD*), Université Montpellier 2. "Modélisation des interactions chimiques liquide/solide: application à la circulation des magmas mantelliques" *(Modeling liquid/solid chemical interactions: applications to melt transport in mantle rocks)*. Supervisor: G. Vasseur.

FIELD WORK AND SCIENTIFIC CRUISES

• June 1992: MASCAFLUX – Heat flow measurements - (Marion Dufresne, Chief scientist: A. Bonneville)
• 1997, 2001, 2007: Field work & sampling in the Oman ophiolite
• Sept.-Nov. 2000: ODP Leg 192 Ontong Java Plateau – Igneous petrology - (JOIDES Resolution, Chief scientists: G. Fitton & J. Mahoney)
• May-Jul. 2003: ODP Leg 209 MAR 15°20N FZ – Geochemistry - (JOIDES Resolution, Chief scientists: P. Kelemen & E. Kikawa)
• Nov. 2004-Jan. 2005: IODP X304 MAR Atlantis Massif – Geochemistry - (JOIDES Resolution, Chief scientists: B. John & D. Blackman)

TEACHING AND ADMINISTRATION OF RESEARCH

- *Supervision of PhD projects :*

L. Gerbert-Gaillard (2002) "*Geochemical characterization of the Oman ophiolite peridotites; Magmatic processes at the asthenosphere/lithosphere transition*" (with F. Boudier)
M. Drouin (2008) "*Accretion of the oceanic lithosphere at slow spreading ridges: A petrophysical and geochemical study of gabbros and associated ultramafic rocks at the Mid-Atlantic Ridge"* (with B. Ildefonse).

- *Supervision of 10 Master (DEA) research projects – Université Montpellier 2 – from 1998 to today.*
- Co-direction of the Master of Geology at Université Montpellier 2 (2003 –-2007)

SELECTED PROFESSIONAL ACTIVITIES AND SERVICES:

Reviewer of INSU & NSF research proposals; Reviewer of manuscripts submitted to *Earth and Planetary Science Letters, Geochimica et Cosmochimica Acta, Swiss Journal of Geosciences, G-cubed, Terra Nova, Journal of Petrology, Journal of Asian Earth Sciences.*

PUBLICATIONS 2008-2010:

Godard, M., Lagabrielle, Y., Alard, O. and Harvey, J., **2008**, Geochemistry of the highly depleted peridotites drilled at ODP Sites 1272 and 1274 (Fifteen-Twenty Fracture Zone, Mid-Atlantic Ridge): Implications for mantle dynamics beneath a slow spreading ridge. Earth Planet. Sci. Lett., 267(3-4): 410-425, doi:10.1016/j.epsl.2007.11.058.

Andreani, M., Luquot, L., Gouze, P., **Godard, M.**, Hoise, E. and Gibert, B., **2009**. Experimental study of carbon sequestration reactions controlled by the percolation of CO2-rich brine through peridotites. Environ. Sci. Technol., 43(4): 1226-1231; doi: 10.1021/es8018429.

Drouin, M., **Godard, M.**, Ildefonse, B., Bruguier, O. and Garrido, C., **2009**. In situ geochemistry of olivine-rich troctolites (IODP Hole U1309D, Atlantis Massif, Mid-Atlantic Ridge, 30°N): a record of magmatic impregnation in the lower oceanic lithosphere. Chem. Geol., 264: 71-88, doi:10.1016/j.chemgeo.2009.02.013.

Godard, M., Awaji, S., Hansen, H.-E., Hellebrand, E., Brunelli, D., Johnson, K.T.M., Yamasaki, T., Maeda, J., Abratis, M., Christie, D., Kato, Y., Mariet, C. and Rosner, M., **2009**. Geochemistry of a long in-situ section of intrusive slow-spread lithosphere: Results from IODP Site U1309 (Atlantis Massif, 30°N Mid-Atlantic-Ridge). Earth Planet. Sci. Lett., 279: 110-122, doi:10.1016/j.epsl.2008.12.034.

Lorand, J.-P., Alard, O. and **Godard, M.**, **2009**. Platinum-group element signature of the Primitive Mantle rejuvenated by melt-rock reactions : evidence from Sumail peridotites (Oman Ophiolite). Terra Nova, 21(1): 35-40, doi: 10.1111/j.1365-3121.2008.00850.x.

Marchesi, C., Garrido, C., **Godard, M.**, Belley, F. and Ferré, E., **2009**. Migration and accumulation of ultra-depleted subduction-related melts in the Massif du Sud ophiolite (New Caledonia). Chem. Geol., 266: 180–195. doi:10.1016/j.chemgeo.2009.06.004.

Miller, D.J., Abratis, M., Christie, D., Drouin, M., **Godard, M.**, Ildefonse, B., Maeda, J., Weinsteiger, A., Yamasaki, T., Suzuki, Y., Niino, A., Sato, Y. and Takeda, F., **2009**. Data Report: Microprobe analyses of primary mineral phases (plagioclase, pyroxene, olivine, and spinel) from Site U1309, Atlantis Massif, Integrated Ocean Drilling Program Expedition 304/305. In: D.K. Blackman et al. (Editors), Proc. IODP, 304/305: College Station TX (Integrated Ocean Drilling Program Management International, Inc.). doi:10.2204/iodp.proc.304305.202.2009.

Deschamps, F., Guillot, S., **Godard, M.**, Chauvel, C., Andreani, M. and Hattori, K., **2010**. In situ characterization of serpentinites from forearc mantle wedges: Timing of serpentinization and behaviour of fluid-mobile elements in subduction zones. Chem. Geol., 269(3-4): 262-277; doi:10.1016/j.chemgeo.2009.10.002.

Drouin, M., Ildefonse, B. and **Godard, M.**, **2010**. A microstructural imprint of melt impregnation in slow-spread lithosphere: olivine-rich troctolites from the Atlantis Massif (Mid-Atlantic Ridge 30°N, IODP Hole U1309D). Geochem. Geophys. Geosyst., 11: Q06003, doi:10.1029/2009GC002995.

Hanghoj, K., Kelemen, P., Hassler, D. and **Godard, M.**, **2010**. Composition and genesis of depleted mantle peridotites from the Wadi Tayin massif, Oman ophiolite. Major and trace element geochemistry, and Os isotope and PGE systematics. J. Petrol, 51(1&2), 201-227, doi:10.1093/petrology/egp077.

Total number of publications: 30 (http://www.researcherid.com/rid/A-7127-2008)

Meetings: 84

BIOGRAPHICAL SKETCH

STEVEN L. GOLDSTEIN

LAMONT-DOHERTY EARTH OBSERVATORY OF COLUMBIA UNIVERSITY, 61 Rt. 9W, PALISADES, NY 10964; Phone: 845-365-8787, Fax: 845-365-8155, Email: steveg@ldeo.columbia.edu

(A) Professional Preparation:

BA	Columbia University, New York, NY	Chemistry	1976.
MA	Harvard University, Cambridge, MA	Geological Sciences	1978.
PhD	Columbia University, New York, NY	Geological Sciences	1986.

(B) Appointments:

2005- present	Professor, Department of Earth and Environmental Sciences, Columbia University, Palisades, NY 10964.
1998- 2005	Associate Professor, Columbia University
1996-98	Assistant Professor, Columbia University
1985-96	Staff Scientist, Max-Planck-Institut für Chemie, Geochemistry Division, Mainz, Germany.

(C) Publications

(i) Five Relevant Publications to the Proposed Project

Stein, M. and Goldstein, S.L. "U-Th and Radiocarbon Chronologies of Late Quaternary Lacustrine Records of the Dead Sea Basin: Methods and Applications", in New Frontiers in Dead Sea Paleoenvironmental Research, ed. By Y. Enzel, A. Agnon, and M. Stein, GSA Special Paper 401, 141-154, 2006.

Haase-Schramm, A., Goldstein, S.L., and Stein, M. "U-Th dating of Lake Lisan aragonite (late Pleistocene Dead Sea) and implications for glacial East Mediterranean climate change", Geochimica et Cosmochimica Acta 68 (5), 985-1005, 2004.

Bartov, Y., Goldstein, S.L., Stein, M., and Enzel, Y., "Catastrophic arid episodes in the Eastern Mediterranean linked with the North Atlantic Heinrich events", Geology 31, 439-442, 2003.

Machlus, M., Enzel, Y., Goldstein, S.L., Marco, S., Stein, M., "Reconstruction of low levels in Lake Lisan by correlating fan-delta and lacustrine deposits", Quaternary International 73/74 137-144, 2000.

Schramm, A., Stein, M., Goldstein, S.L., "Calibration of the ^{14}C time scale to >40 kyr by ^{234}U-^{230}Th dating of sediments from Lake Lisan (last Glacial Dead Sea)", Earth and Planetary Science Letters 175, 27-40, 2000.

(ii) Five Other Publications

Straub, S,M., Goldstein, S.L., Class, C., and Schmidt, A., "Mid-ocean ridge basalt of Indian type in the northwest Pacific Ocean basin", Nature Geoscience, 2, 286-289, 2009.

Goldstein, S.L., Soffer, G., Langmuir, C.H., Lehnert, K.A., Graham, D.W., and Michael, P.J., "Origin of a 'Southern Hemisphere' geochemical signature in the Arctic upper mantle", Nature 453, 89-93, 2008.

Pahnke, K., Goldstein, S.L., and Hemming, S.R. Abrupt changes in Antarctic Intermediate Water circulation over the past 25,000 years, Nature Geoscience, 1, 870-874, 2008.

Thompson, W.G. and Goldstein, S.L. "Open system coral ages reveal persistent suborbital sea-level cycles", Science, 308, 401-404, 2005.

Piotrowski, A.M., Goldstein, S.L., Hemming, S.R., and Fairbanks, R.G., "Temporal relationships between ocean circulation and carbon cycling during glacial-interglacial transitions", Science 307, 1933-1938, 2005.

(D) Synergistic Activities:

Journals: Chemical Geology, Editorial Advisory Board (1990-2002); Earth and Planetary Science Letters, Editorial Advisory Board (1991-present); Journal of Geophysical Research-Solid Earth, Associate Editor (1995-1997), Geochimica et Cosmochimica Acta, Associate Editor (2000-2002), Chemical Geology, Editor-in-Chief (2002-2008).

Professional Service: AGU Hess Medal Committee (1998-1999); Co-Organizer, ICDP Workshop on a Deep Drill Hole in the Dead Sea, 2002; NSF Workshop on the CyberInfrastructure for the Integrated Solid Earth Sciences (ISES-CI), 2003; Co-Organizer, Workshop on Curation of Terrestrial Scientific Cores, Samples, and Collections, Houston TX, May 2004; Co-Organizer, Workshop on Linking Information Systems in Marine and Terrestrial Geosciences: Sediment Geochemistry, Washington, D.C., June 2004, Co-Organizer '*SESAR: Designing Interoperability for Sample-based Data Management via the International Geo Sample Number IGSN*'), San Diego, January 2005. Co-Organizer, GERM Workshop, Columbia University, May 2006.

Teacher Education: Goldstein, S.L. "Hawaii and hotspots; a window to the deep mantle" a Chapter in "Earth; Inside and Out", ed. by E. Mathez, New Press. New York, NY, p. 93-99; essays on the Earth for K-12 teachers; 2001. Lecturer, Earth2Class Program for K-12 teachers.

Undergraduate Research: Advisor for LDEO Summer Intern Program, and Columbia undergraduates (1996-present); Faculty Advisor to (undergraduate) Rabi Scholar Program, Columbia University (2002-2008).

Public Outreach: Lamont-Doherty Earth Observatory Annual Open House (1996-present), public lectures laboratory tours and demonstrations; geological field trips for Boy Scouts; Columbia University Alumni Association Lectures, Lamont-Doherty Earth Observatory Public Lecture Series, Public School Lectures on Earth Science, Science Clubs in Retirement Communities, lecturer in Earth2Class Program middle and high school teachers.

(E) Collaborators and Other Affiliations:

(i) Collaborators Over the Past Four *Years*: *M. Dungan (U Geneva), D. Graham (OSU), A. Gómez-Tuena, (UNAM), I. Hall (U of Cardiff), C. Langmuir (Harvard), P. Michael (U Tulsa), K. Pahnke (U. Hawaii), M. Stein (Geol. Survey of Israel), T. van de Flierdt (Imperial, Lond.), R. Zahn (U Barcelona).*

(ii) Graduate Advisors: *R.K. O'Nions (UK Science Council), A. Zindler, C. Langmuir (Harvard).*

(iii) Primary thesis advisor to the following students:

At MPI: *C. Class (LDEO), K. Haase (U of Erlangen), G. Loock; A. Haase-Schramm (U of Erlangen), (3 women, 1 man).*

At Columbia: *Y. Cai (Columbia Science Fellow), C. Doherty, K. Jones (Exxon-Mobil), J. Jweda, A. Hartman, A. LaGatta (Jorgensen Associates); A. Piotrowski (Cambridge U), R. Rutberg (CUNY), K. Simons (U of Miami), W. Thompson (WHOI). (6 women, 4 men).*

Dr. Philippe Gouze	
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Philippe Gouze, born 1964, French, is research scientist at the CNRS-INSU (French National Centre for Scientific Research – Earth and Planetary Sciences Institute) in the Geosciences Research Unit, University of Montpellier, France. He received his Ph.D. degree (modeling transport in porous media) from the University of Paris VI (1993) working in Professors Ghislain de Marsily (University of Paris VI) and Guy Vasseur (University of Montpellier) groups. He jointed the Water Resource Systems Research Unit, Department of Civil Engineering, University of Newcastle upon Tyne, UK, for a post-doc position in 1993-1994 (Dr. Ray Mackay group) and joint the CNRS and the University of Montpellier in 1995 to form a group for borehole geophysics and hydrodynamics research (LGHF). He has been the deputy director of the Tectonophysic research unit from 2004 to 2007. In 2000, he created the Experimental Resources Laboratory ICARE for investigating transport-reaction processes, from subsurface (ex: salt intrusion) to geothermal environments, and coordinated several projects focusing on underground storage of CO_2 and hydrothermal/geothermal studies. He is now heading of the Transport in Porous Media Group of the Géosciences research unit.

His research covers the areas of flow and transport in aquifers and sedimentary reservoirs, underground storage and geothermal processes. Specifically:

1. **Groundwater hydrology.** This includes conceptual, mathematical and numerical modeling of groundwater flow and contaminant transport in heterogeneous aquifers, sea water intrusion into coastal aquifers, pumping tests to determine aquifer coefficients, (non-Fickian) dispersion measurements from laboratory to borehole scale, flow and transport in fractures, and borehole geophysics for application to hydrogeology.

2. **Fluid-rock mass transfer in reservoir.** This research focuses on experimental characterization and modeling hydrodynamical properties (porosity, permeability, reaction surface area) changes induced by dissolution-precipitation processes in the course of reservoir diagenesis and underground CO_2 storage, with emphasis on carbonation processes.

3. **Geothermal energy & hydrothermal processes in low enthalpy environments.** This includes laboratory scale experimental characterization and modeling of flow, transport and fluid-rock-gas reactions associated with natural hydrothermal cycles at the mid-ocean ridges and forced borehole extraction of heat in geothermal areas (ex: Iceland).

4. **Diffusion in low permeability media,** for applications to nuclear waste disposal in claystones. This research concerns for example the measure of diffusion coefficient and sorption of the radioelements (iodine) in natural conditions.

5. **Microstructure and macroscopic properties of heterogeneous materials**. This research focuses on the development of numerical tools for deterministic and statistical characterization of the heterogeneity from X-ray micro-tomography imagery.

Dr. Gouze research projects are almost equally funded by governmental subsidies (ex: National Agency for Research projects and CNRS-INSU), by the European Commission, by collaborative projects with national R&D institutes such as the Atomic Energy Commissariat (CEA) and the Research Institute for Radioprotection (IRSN) and by contracts with international companies (ex: TOTAL, LAFARGE, ...).

His work has been summarized in over 50 papers in scientific journals and published research reports (http://www.researcherid.com/rid/A-3929-2010)

2008-2010 bibliography:

Andreani M., P. Gouze, L. Luquot, P. Jouanna (2008), Changes in seal capacity of fractured claystone caprocks induced by dissolved and gaseous CO2 seepage, Geophys. Res. Lett., 35, L14404, doi:10.1029/2008GL034467.

Andreani M., L. Luquot, P. Gouze, M. Godard, E. Hoisé, B. Gibert (2009) Experimental study of carbon sequestration reactions controlled by the pe;rcolation of CO2-rich brine through peridotites, Environ. Sci. Technol., 43 (4), pp 1226–1231

Dentz M., Ph. Gouze and R. Carrera (in press) Effective Non-Local Reaction Kinetics for Transport in Physically and Chemically Heterogeneous Media, J. Cont. Hydro, doi:10.1016/ j.jconhyd.2010.06.002.

Dupraz S., B. Ménez, P. Gouze, R. Leprovost, P. Bénézeth, O. Pokrovsky, F. Guyot, (2009) Experimental approach of CO2 biomineralization in deep saline aquifers, Chemical Geol., doi:10.1016/j.chemgeo.2008.12.012.

Gouze P., T. Le Borgne, R. Leprovost, G. Lods, T. Poidras, P. Pezard (2008), Non-Fickian dispersion in porous media: 1. Multiscale measurements using single-well injection withdrawal tracer tests, Water Resour. Res., 44, W06426, doi:10.1029/2007WR006278.

Gouze P., Y. Melean, T. Le Borgne, M. Dentz, J. Carrera (2008), Non-Fickian dispersion in porous media explained by heterogeneous microscale matrix diffusion, Water Resour. Res., 44, W11416, doi:10.1029/2007WR006690.

Gouze P., Leprovost R., Poidras T., Le Borgne T., Lods G., Pezard P. (2009), CoFIS and TELog: New downhole tools for characterizing dispersion processes in aquifers by single-well injection-withdrawal tracer tests, C. R. Geoscience 341 (2009) 965–975.

Gouze P. and L. Luquot (in press), X-ray microtomography characterization of porosity, permeablity and reactive surface changes during dissolution, J. Cont. Hydro, doi:10.1016/j.jconhyd.2010.07.004.

Jouanna P., G. Pèpe, J. Dweik, P. Gouze (in press) Atomic modelling of crystal/complex fluid/crystal contacts – Part I. The Genetic Iterative Multi Species (GIMS) approach. Case of kaolinite/brine/kaolinite, J. of Crystal Growth.

Le Borgne T., P. Gouze (2008), Non-Fickian dispersion in porous media: 2. Model validation from measurements at different scales, Water Resour. Res., 44, W06427, doi:10.1029/2007WR006279.

Lods G., P. Gouze (2008), A generalized solution for transient radial flow in hierarchical multifractal fractured aquifers, Water Resour. Res., 44, W12405, doi:10.1029/2008WR007125.

Luquot L., P. Gouze, Experimental determination of porosity and permeability changes induced by massive injection of CO_2 into carbonate reservoirs, Chemical Geology 265 (2009) 148–159, doi:10.1016/j.chemgeo.2009.03.028.

Noiriel C., L. Luquot, B. Madé, L. Raimbault , P. Gouze, J. Van Der Lee (2009) Changes in reactive surface area during dissolution process: an experimental and modelling study, Chemical Geol., doi:10.1016/j.chemgeo.2009.01.032.

Pèpe G., J. Dweik, P. Jouanna, P. Gouze, M. Andreani, L. Luquot (in press) Atomic modelling of crystal/complex fluid/crystal contacts – Part II. Simulating AFM tests via the GenMol code for investigating the impact of CO2 storage on kaolinite/brine/kaolinite adhesion, J. of Crystal Growth.

Wittebroodt C., S. Savoye, P. Gouze (2008), Influence of initial iodide concentration on the iodide uptake by the argillite of Tournemire, Physics and Chemistry of the Earth, doi:10.1016/j.pce.2008.05.020.

GREG HIRTH

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Brown University
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Experience:

2010-present	Professor, Dept. Geological Sciences
2007-2009	Associate Professor
2002-2007	Adjunct Associate Professor Brown University
Spring 2007	Visiting Scientist, Laboratoire de Tectonophysique University of Montpellier
1998-2007	Associate Scientist (Tenured in 2001)
1994-1998	Assistant Scientist
1993	Postdoctoral Scholar Department of Geology and Geophysics Woods Hole Oceanographic Institution
1993-2007	Research Affiliate, Department of EAPS Massachusetts Institute of Technology
Fall 1999	Visiting Professor of Geophysics, Div. GPS California Institute of Technology
1991-1992	Postdoctoral Research Associate Dept. of Geology and Geophysics University of Minnesota

Education:

Ph.D. Geological Sciences, Brown University, 1991
Sc., M. Geological Sciences, Brown University, 1987
B.S. Geological Sciences, Indiana University, 1985

Professional: & Synergistic Activities

Fellow MSA (2006) and AGU (2008)
Panelist, NSF MARGINS panel (OCE), 2000
Member, NSF-MARGINS steering committee, 2000-2004
Co-convener, MARGINS Workshop on Interpreting Mantle Images, 2006
President-Elect, Tectonophysics Section, AGU, 2010-present

Five publications relevant to proposed research

Warren, J., G. Hirth, P. Kelemen, Evolution of olivine lattice preferred orientation during simple shear in the mantle, *Earth Planet Sci. Lett.*, 272, 501-512, 2008.

Behn, M.D., G. Hirth and J.R. Elsenbeck II, Implications of grain-size evolution on the seismic structure of the oceanic upper mantle, *Earth Planet. Sci. Lett.*, 282, 178-189, doi:10.1016/j.epsl.2009.03.014, 2009.

Mehl, L., B.R. Hacker, G. Hirth, and P. Kelemen, Arc-parallel flow within the mantle wedge: Evidence from the accreted Talkeetna arc, South Central Alaska, *J. Geophys. Res.*, 108, B8, 2375, doi:10.1029/2002JB002233, 2003.

Renner, J., K. Viskupic, G. Hirth, and B. Evans, Melt extraction from partially molten peridotite, *Geochemistry, Geophysics, and Geosystems*, DOI number 10.1029/2002GC000369, 2003.

Evans, R.L., G. Hirth, *K. Baba, D. Forsyth, A. Chave and R. Mackie, Compositional controls on oceanic plates: geophysical evidence from the MELT Area, *Nature*, 437, 249-252, 2005.

Five other recent publications

Sundberg, *M.*, G. Hirth, and P.B. Kelemen, Trapped Melt in the Josephine Peridotite: Implications for Permeability and Melt-Extraction in the Upper Mantle, *J. Petrology*, 51, 185-200, doi:10.1093/petrology/egp089, 2010.

Billen, M., and G. Hirth, Rheologic controls on slab dynamics, *Geochemistry, Geophysics, and Geosystems (G-cubed)*, 8, doi:10.1029/2007GC001597, ISSN: 1525-2027, 2007.

Mehl, L., and G. Hirth, Plagioclase recrystallization and preferred orientation in layered mylonites: Evaluation of flow laws for the lower crust, *J. Geophys. Res.*, 113, B05202, doi:10.1029/2007JB005075, 2008.

Behn, M.D., G. Hirth and P. Kelemen, Lower crustal foundering as a mechanism for trench parallel seismic anisotropy below volcanic arcs, *Science*, 317, 108-111, 2007.

Hirth, G., and D. Kohlstedt, Rheology of the Upper Mantle and the Mantle Wedge: A View From the Experimentalists, in *Inside the Subduction Factory*, ed. by J. Eiler, Geophysical Monograph 138, 83-105, American Geophysical Union, Washington, D.C., 2003.

Graduate Advisor: Jan Tullis, Brown University

Postdoctoral Advisor: David Kohlstedt, University of Minnesota

Students, Post-docs and recent non-Brown/WHOI collaborators: M. Andreani, K. Baba, M. Billen, M. Boettcher, M. Braun, L. Chernak, B. deMartin, J. Escartin, B. Evans, J. Gaherty, C. Garrido, A. Getsinger, B. Hacker, B. Hager, M. Handy, J. Homburg, J. Hustoft, G. Jaroslow, B. John, P. Kelemen, A. Kohli, D. Kohlstedt, D. Lizarralde, L. Mehl, P. Molnar, J. Renner, E. Roland, A. Sheehan, P Skemer, M. Sundberg, K. Viskupic, J. Warren, R. Wenk, A. Yoshinobu, W. Zhu.

Curriculum Vitae

Albrecht Werner Hofmann

Date of birth: 11 March 1939 in Zeitz (Germany)

Marital status: Married, 2 children

Citizenship: German

Education:

Elementary:	1945-46	Schlitz (Germany)
	1946-49	Stuttgart
Secondary:	1949-52	Stuttgart
	1952-58	Ravensburg
University:	1958-59	Duke University, Durham, North Carolina, USA
	1959-62	Universität Freiburg i.Br., Germany
	1962-68	Brown University, Providence, R.I., USA
	1965	M.Sc.
	1968	Ph.D. Major: Geochemistry, minors mineralogy and thermodynamics (advisor B.J. Giletti).

Professional Career:

1968-70	Assistant, Laboratorium für Geochronologie, Heidelberg
1970-72	Postdoctoral Fellow, Geophysical Laboratory, Carnegie Institution of Washington
1972-80	Scientific Staff Member, Department of Terrestrial Magnetism, Carnegie Institution of Washington
1980-2007	Director, Geochemistry Division, Max-Planck-Institut für Chemie, Mainz
1987-	Adjunct professor at the University of Mainz
1989-91; 98-2000	Managing Director of the Max-Planck-Institut für Chemie.
Since 04/07	Max Planck Emeritus
	Visiting Senior Research Scientist at Lamont-Doherty Earth Observatory, Columbia University, New York.
	Adjunct Professor at the University of Nanjing, China.

Honors:

1987	Jaeger-Hales Lectureship at the Australian National University;
1994	Fellow of the American Geophysical Union;
1994	Chevalier de l'Ordre des Palmes Académiques;
1995	Sherman-Fairchild Scholarship at California Institute of Technology;
1996	MESR/Humboldt Award of the Ministère de l'Enseignement Supérieur et de la Recherche and the Alexander-von-Humboldt-Foundation;
1996	V.M. Goldschmidt Medal of the Geochemical Society;
1996	Geochemistry Fellow of the European Association of Geochemistry and the Geochemical Society.
1999	Foreign Associate of the U.S. National Academy of Sciences
1999	Fellow of the Geological Society of America

2001	Harry H. Hess Medal of the American Geophysical Union
2003	ISI "Highly Cited Researcher" in Geoscience

Editing (at various times):

Chemical Geology, Editor;
Geochimica et Cosmochimica Acta, Associate Editor;
Contributions to Mineralogy and Petrology, Associate Editor.
Editor of "Frontiers Section" of Earth & Planetary Science Letters (2008-09)

Memberships and Offices in scientific organizations:

Max-Planck-Gesellschaft, Member;
European Union of Geosciences , Founding Council Member, President 1997-99;
European Association of Geochemistry, President 1999-2000;
Geochemical Society, Member, Member of Board of Directors 1998-2001;
American Geophysical Union, Member;
Geological Society of America, Member;
Deutsche Mineralogische Gesellschaft, former Council Member;
Geologische Vereinigung, former Council Member
Forschungskollegium Geochemie e.V., Founder and Member;
Forschungskollegium Mineralogie, Member;
Comité Scientifique, France (Member 1989-1993).

CV

Bjørn Jamtveit,
Physcis of Geological Processes, University of Oslo,
PO Box 1048 Blindern, N-0316 Oslo

Born 21.09.60 in Notodden, Norway. Married. 4 children.
PhD (September 1990) Department of Geology, University of Oslo (supervisor Prof. Kurt Bucher, now at Univ of Freiburg, Germany),
MSc (March 1986), Mineralogical.Geological Museum, University of Oslo (supervisor Prof. William L. Griffin, now at Maquarie University)

Employment

2006-:	Director of PGP, a Norwegian Center of Excellence hosted by the University of Oslo
2003-2006:	Co-director of PGP
2000-2001:	Group leader at Center for Advanced Studies, Norwegian Academy of Science
1993- :	Professor of Petrology, University of Oslo
1991-1993:	Odd Hassel research grant from the Norwegian Research Council to stay at University of Bristol, UK
1990-1991:	Post-Doc grant from the Norwegian Research Council, University of Oslo
1987-1990:	Personal PhD grant from the Norwegian Research Council, University of Oslo
1985-1987:	Scientific Assistant, University of Oslo

Awards and Major Grants

2010	The Fritjof Nansen Prize from the Norwegian Academy of Science and Letters
2003-	Director & Co-director of the PGP Center, a Norwegian Center of Excellence at the University of Oslo (annual budget ca. 5 MEUR)
2001	Elected member of the Royal Society of Norway
2000	Elected group leader at the Center of Advanced Studies at the Norwegian Academy of Science and Letters
1997-2001	Leader of the Strategic University Program 'Fluid Rock Interactions' (total budget ca. 1.6 MEUR)
1996	Elected member of the Norwegian Academy of Science and Letters
1993	The Reusch Medal from the Norwegian Geological Society
1991-1993	The Odd Hassel stipend from the Norwegian Research Council (max 2 grants per year awarded within Science and Mathematics in Norway)
1982	Student grant from petroleum companies to the 10 best students at the Dept of Geology, Univ of Oslo (EUR 1200)

Main research interests include: pattern formation in geo-systems, fluid migration in the Earth's crust, metamorphic processes, and mineral growth-dissolution.

Scientific production

2 edited books, guest editor of the June 2010 issue of *'Elements'*, **87** peer reviewed articles. **57** invited talks, **51** regular conference presentations, and **55** appearances / popular presentations in radio, TV, newspapers and magazines since 2002. **262** ISI-citations in 2010; a total of **2015** ISI-citations; h-index= **24**,

Conference and special session organization (2004-)

Co-convenor, Goldschmidt 2011, Prague. Session: "Interplay between Plastic Rock Deformation and Mineral Reactions". With Rainer Abart and John Wheeler.

Convenor, AGU Fall meeting 2010, San Francisco. Session: "Carbon Dioxide Sequestration via Mineral Carbonation: Insights from Field Observations, Experiments and Modeling" (with Andreas Beinlich and Peter Kelemen).

Co-convenor, Goldschmidt 2010, Knoxville, Tennessee. Session: "Metamorphism over multiple length and time scales" (with Barb Dutrow)

Convenor, Goldschmidt 2009, Davos, Switzerland. Session: "Patterns formation through growth, dissolution or replacement processes" (with Paul Meakin and Carl Steefel)

Organiser of the annual cross-disciplinary Kongsberg seminar series (1994-2010)

Co-convenor, AGU 2007, San Francisco. Session: "Fragmentation processes in the Earth" (with Karen Mair and Charles Sammis).

Co-organizer Goldschmidt conference 2004 (main organiser: Susan Stipp), Copenhagen

Committees, Board member-, Consultant and other activities (2000-)

Member of the board of VISTA (a research cooperation between the Norwegian Academy of Science and Letters Letters and StatoilHydro) (2009-).

7 talks on the organization of research units and scientific leadership for various research organizations (2005-2011)

Organiser of the annual cross-disciplinary Kongsberg seminar series (1994-2010).

On the editorial board of Geofluids (Blackwell) (2002-) and The Norwegian Journal of Geology (2000-).

Member of the board of 'Volcanic Basin and Petroleum research' - a research and consulting company in Oslo (2000-2005).

Member of the Board, European Association of Geochemistry (2000-2004).

Co-developer of the commerical SILL00 and SILL01 reports marketed by VBPR (Volcanic Basin and Petroleum Research) (1999-2001).

External consultant for the Norwegian Geological Survey (1998-2003).

Member of the Urey medal committee – European Association of Geochemistry (2003 and 2004).

Member of the Roebling medal committee –Mineralogical Society of America (1999 and 2000).

Review activities

Member of review panels for the Deutche Forschungsgemeinschaft (2006)

Member of international panel to evaluate the Institute of Earth Sciences in Reykjavik, Iceland (May 2006)

Reviewer for numerous grant applications to the Norwegian Research Council & NSF-USA

Reviewer for most major ISI-journals in Geoscience

Member of several committees evaluating applicants for academic positions in Norway and Sweden.

Teaching

Teaching General geology, Mineralogy, Petrology, and Geochemistry at all levels since 1993 (except during the period as PGP director)

Curriculum Vitae – Peter B. Kelemen
Arthur D. Storke Memorial Professor
Lamont Doherty Earth Observatory,
Columbia University, Palisades NY 10964
Telephone: 845 365 8728
E-mail: peterk@ldeo.columbia.edu

PROFESSIONAL PREPARATION:

1980 A.B, Dartmouth College, Cum Laude, Honors in Earth Science.
1985 M.Sc., University of Washington, Department of Geological Sciences
1987 Ph.D., University of Washington, Department of Geological Sciences

APPOINTMENTS, 2004-2010:

2008 MARGINS Distinguished Lecturer
2007 Hallimond Lecturer, Mineralogical Society
2006– present Fellow, Mineralogical Society of America
2004– present Arthur D. Storke Memorial Professor, Dept. of Earth & Environmental Sciences, Columbia University and Lamont Doherty Earth Observatory; Associate Research Scientist, Dept. of Earth and Planetary Sciences, American Museum of Natural History; Adjunct Scientist, Woods Hole Oceanographic Inst.
2004– present Fellow, American Geophysical Union
2001-04 Charlies Francis Adams Chair, Woods Hole Oceanographic Institution
2001-04 Tenured Senior Scientist, Woods Hole Oceanographic Institution.

5 publications most closely related to this proposal, 2008-2010*:*

Kelemen, P.B. and J. **Matter**, In situ mineral carbonation in peridotite for CO2 storage, Proc. National Acad. Sci. 105, 17,295-17,300, 2008.

Kelemen, P.B. and 10 others, White Paper for IODP Decadal Science Planning Meeting, INVEST, *In situ* mineral carbonation in peridotite and basalt for CO_2 capture and storage, available online, 2009.

Kelemen, P.B., J. Matter, L. Streit, J. Rudge, W. Curry, J. Blusztajn, Rates and mechanisms of mineral carbonation in peridotite, in press, Annual Reviews of Earth & Planetary Sciences, 2010.

Matter, J. and P.B. **Kelemen**, Geochemical controls on permanent CO_2 storage in geologic reservoirs, invited paper for Nature Geoscience 2, 837-841, 2009.

Rudge, J.F., P.B. **Kelemen**, and M. Spiegelman, A simple model of reaction induced cracking applied to serpentinization and carbonation of peridotite. Earth Planet. Sci. Lett. 291, 215-227, 2010

5 other Oman- and peridotite-related publications, 2010*:*

Hanghøj, K., P.B. **Kelemen**, D. Hassler & M. Godard, Composition and genesis of depleted mantle peridotites from the Wadi Tayin massif, Oman ophiolite: Major and trace element geochemistry, and Os isotope and PGE systematics. J. Petrol. 51, 206-227, 2010.

Homburg, J., G. Hirth, and P.B. **Kelemen**, Investigation of the strength contrast at the Moho: A case study from the Oman Ophiolite, Geology 38, 679-682 2010.

Skemer, P., J.M. Warren, P.B. **Kelemen** & G. Hirth , Microstructural and rheological evolution of a mantle shear zone. J. Petrol. 51, 43-53, 2010

Sundberg, M., G. Hirth, and P.B. **Kelemen**, Trapped melt in the Josephine peridotite: Implications for permeability and melt extraction in the upper mantle. J. Petrol. 51, 185-200, 2010

SYNERGISTIC ACTIVITIES 2005-10

1. COURSES, COLUMBIA UNIV: Intro. to Earth Sciences fall, undergrad non-majors, Petrology spring, majors & grad students, Field Petrology every other fall, Seminars (2004-present); 9 month/yr geodynamics seminar; new "Mineral Resources and Sustainable Development" course fall starting 2010

2. OUTREACH PUBLICATIONS & PRESENTATIONS including K-12 EDUCATION:

Farragut Middle School, Hillside Elementary School, 05-10, Earth2Class Workshop for Teachers, NY 07, Riverdale Country School, NY 08, 09; MARGINS Distinguished Lecturer 07-08; Lamont Advisory Board 06, 09; JP Morgan Private Bank 09; Alliance Bernstein 10; Columbia University Trustees 10, Popular Mechanics 09 Huffington Post 09, Oceanus 98, Oceanus 04, Scientific American 09, **Press coverage** of Kelemen & Matter, Proc National Acad Sci 2008 paper included The Economist, Christian Science Monitor, Popular Mechanics, OnEarth (NRDC), NPR Earth & Sky, BBC Naked Scientists, MSNBC, ABC Online, Der Spiegel, Times of India, Times of Oman, Shanghai Daily, China Post, Frankfurter Allgemeine Zeitung, El Mundo, El Pais, Technology Review, Physics Today, Nature Reports

3. SCIENCE PLANNING: 9/10: keynote speaker, Carnegie Institution of Washington Deep Carbon Observatory & IODP Workshop: Reaching the Mantle Frontier – Moho and Beyond; **9/09:** keynote speaker, IODP INVEST Meeting, Bremen, GE; **7/09:** keynote speaker, InterRidge-IODP Workshop, Southampton, UK; **6/09**: rapporteur, air capture of CO2, National Academy of Sciences Workshop on Geoengineering; **3/09**: invited participant, American Physical Society CO2 Air Capture Meeting, Princeton University; **3/09**: presentation at Coalition for National Science Funding Exhibition and Reception for the US Congress; **2/09**: invited speaker, British Petroleum CO2 Capture from Air Symposium, New York; **08-present:** member CO2 Sub-Committee, Society of Exploration Geophysicists Research Committee; **11/07**: Keynote speaker MARGINS Izu-Bonin-Marianas Workshop; **3/07** Lead Proponent (1 of 5), Mission Moho Proposal, IODP; **9/06**: Keynote speaker, IODP Mission Moho Workshop

4. MEETING AND SHORT COURSE CONVENOR: September 2008 Chapman Conference / 5th Int'l Workshop on Orogenic Lherzolites, Mt Shasta, CA; July 2006 Penrose Conference on Arc Crustal Genesis and Evolution, Valdez, Alaska; December 2005 AGU Special Session on Results from Talkeetna Arc Continental Dynamics Project; June 2005 ODP Leg 209 Scientific Meeting, Samani, Japan

COLLABORATORS: 2006: Ahmed Hassan Ahmed, Helwan U, Cairo; Shoji Arai, Kanazawa U; C Kent Brooks, retired; Susan DeBari, W Washington U; Steve Goldstein, Columbia U; Andrew Greene, UBC; Stan Hart, WHOI; David Scholl, Moss Landing; Brad Singer, U Wisconsin; **2007**; Natsue Abe, JAMSTEC; Jeff Amato, New Mexico State U; Stefan Bernstein, Avanna Resources; Sam Bowring, MIT; Jack Casey, U Houson; Peter Clift, U Aberdeen; Amy Draut, USGS; Craig Grimes, Mississippi State U; Benoit Ildefonse, U Montpellier; Barbara John, U Wyoming; Eiichi Kikawa, JAMSTEC; Hidei Kumagai, IFREE; Frank Mazdab, U Arizona; Jay Miller, IODP TAMU; Terry Pavlis, U W Texas; Tim Schroeder, E Connecticut State U; John Valley, U Wisconsin; Doug Wilson, UCSC; Jay Wooden, Stanford U; Gene Yogodzinski, U S Carolina; 2008: William (Bill) Carlson, U Texas Austin; Shan Gao, Wuhan U; Cin-Ty Lee, Rice U; Yan Liang, Brown U; Yongsheng Liu, Wuhan U; Peter Luffi, Rice U; Luc Mehl, Anchorage AK; Zachary Morgan, don't know current address; Holger Paulick, U Bonn; J Schwartz, was at U Wyoming; Donna Shillington, LDEO; Sergei Silantyev, Vernadsky Inst; Guenter Suhr, U Köln; W Xu, Wuhan U; KQ Zong, Wuhan U; 2009: Alissa Park, Columbia U; Suzanne Straub, Columbia U; **2010**: Kay Achenbach, U Wyoming; Mark Behn, WHOI; Jerzy Blusztajn, WHOI; Jean-Louis Bodinier, U Montpellier; Francoise Boudier, U Montpellier,; Mike Braun, ExxonMobil; Amandine Cagnioncle, ExxonMobil; Mike Cheadle, U Wyoming; Martin Collier, ExxonMobile; Jamie Connolly, ETH-Zurich; William (Bill) Curry, WHOI; Henry Dick, WHOI; Uli Faul, Boston U; Marguerite Godard, U Montpellier; George Gehrels, U Arizona; Tim Grove, MIT; Brad Hacker, UCSB; Karen Hanghøj, Avanna Resources; Deborah Hassler, ExxonMobil; Greg Hirth, Brown U; Janelle Homburg, Columbia U; Bjørn Jamtveit, University of Oslo; Craig Manning, UCLA; Edmond Mathez, American Museum of Natural History; Hans Massonne, U Stuttgart; Jürg Matter, LDEO; Jim Mattinson, UCSB; Martin Menzies, Royal Holloway U; Marc Parmentier, Brown U; David Prior, U Liverpool; Matt Rioux, MIT; John Rudge, U Cambridge; Alberto Saal, Brown U; George Scherer, Princeton; Barbara Sherwood Lollar, University of Toronto; Everett Shock, Arizona State U; Phil Skemer, Washington U; Marc Spiegelman, Columbia U; Marshall Sundberg, U Minn; Susan Swapp, U Wyoming; Eiichi Takazawa, Niigata U; Damon Teagle, Southampton; Andrea Tommassi, U Montpellier; Jill VanTongeren, Columbia U; Jessica Warren, Stanford; Wenlu Zhu, University of Maryland

KELEMEN'S ADVISORS: MSc., PhD: Bernard Evans, U Washington (emeritus); Postdoctoral Scholarship: H.J.B. Dick, WHOI

ADVISOR: MIT/WHOI PhD: Einat Aharonov, Hebrew University (95), Jun Korenaga, Yale University (00), Mike Braun, ExxonMobil (03); **Columbia PhD:** Martin Collier, ExxonMobil (co-advised w Marc Spiegelman, 10); Jill van Tongeren, Columbia U (11); Janelle Homburg, Columbia U (11); Meghan Crowley, Columbia U (12); Lisa Streit, Columbia U (12) **WHOI postdocs:** Carlos Garrido, U Granada (95-98); Matthew Jull, now an architecht in the Netherlands (98-00); Othmar Müntener, U Lausanne (98-99); Karen Hanghøj, Avanna Resources (99-00); Laurent Montesi, U Maryland (01- 03); Magali Billen, UC Davis (02-03); **LDEO postdocs:** Ben Holtzman, Columbia U (04-07); Taber Hersum, ExxonMobil (05-07); John Rudge, U Cambridge (08)

Prof. Dr. Jürgen Koepke
Institut für Mineralogie
Leibniz Universität Hannover
Callinstrasse 3 · D-30167 Hannover

Telephone: +49-(0)511-762 4084
Fax: +49-(0)511-762 3045
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Curriculum Vitae

Hannover, January, 12, 2011

Personal

Institut für Mineralogie, Leibniz Universität Hannover, Callinstrasse 3, 30167, Germany
koepke@mineralogie.uni-hannover.de; 0049511 7624084 (phone); 0049511 7623045 (fax)
Born in Braunschweig, Germany, on Oct. 28, 1955
2 daughters; Jenny Koepke, born Dec. 29. 1983 & Nina Koepke, born Jan. 25, 1989
Private: Tonstrasse 3, 30449 Hannover, 0049511 9215153 (phone)

Education

M.Sc. (1981) Mineralogy, Technical University Braunschweig, Germany: "Petrology of the Upper Cretaceous crystalline complex of Leda (Uppermost unit, Asterousia Mountains, Crete)"
PhD (1986) Mineralogy, Technical University Braunschweig, Germany: "Ophiolites of the Southern Aegean Islands: Petrology and Geochronology"

Professional Experience

1982-1985: Scientific assistant, Inst. for Mineralogy, Technical University Braunschweig
1082-1985: Commercial mineral separation
1985-1994: Scientific assistant, Inst. for Physical Chemistry, Leibniz University of Hannover; head of the microanalytical lab
1994: Scientific assistant, Inst. for Mineralogy, Leibniz University of Hannover; head of the electron microprobe lab
2004: Postdoctoral lecture qualification (Habilitation), Inst. for Mineralogy, Leibniz University of Hannover: "Experimental investigations in hydrous basic systems: Differentiation of MORB, partial melting and trace element diffusion in melts"
2004: Appointment to "Privatdozent" at the Inst. for Mineralogy, Leibniz University of Hannover
2010: Appointment to "Professor" at the Inst. for Mineralogy, Leibniz University of Hannover

Research Interests

Petrology and geodynamics of ocean ridges; magmatic processes at the interface between igneous and hydrothermal processes; role of water during construction of the ocean crust
Experimental petrology of basalts and gabbros, especially the role of aH_2O and fO_2 on phase equilibria and the evolution of SiO_2-rich melts within basaltic systems
Development and application of microprobe techniques
Experimental geochemistry on properties of silicate melts and magmas

Important Funded Projects

Deutsche Forschungsgemeinschaft (DFG), Project Leader: 12 projects (see http://gepris.dfg.de)
Deutsche Forschungsgemeinschaft (DFG), Co-Project Leader: 10 projects (see http://gepris.dfg.de)
Person in charge of a Joint Research Project with Russian Federation funded by DFG (co-operation partner: Sergei Silantyev, Vernadsky Institute, Moscow)

Person in charge of a DAAD PROCOPE Exchange Program with the University of Montpellier, France (co-operation partner: B. Ildefonse)

Person in charge of a DAAD PROCOPE Exchange Program with the University of Montpellier, France (co-operation partner: F. Boudier, A. Nicolas)

Person in charge of 7 projects on the development of synchrotron microprobe techniques and application to silicate melt properties at HASYLAB, Deutsches Elektronen-Synchrotron DESY, Hamburg

German supervisor in a joint doctorate funded by the "Cotutuelle" Program within the Deutsch-Französische Hochschule; based on an agreement between the Universities of Hannover and Montpellier, France (co-operation partner: B. Ildefonse)

German supervisor in a joint doctorate funded by the "Cotutuelle" program; based on an agreement between the Universities of Hannover and Toulouse, France (co-operation partner: G. Ceuleneer)

Co-Proponent for the IODP Drilling Proposal "Superfast-Spreading Crust IV" (522-Full4; scheduled to drill in April/May 2011)

Co-Proponent for the IODP Mission Proposal "Mission Moho", submitted at March, 2007

Supervisor Activity

MSc and BSc supervisor for: A. Tegge-Schüring, S.T. Feig, S. Graßmann, A. Schimroscyk, M. Johannson, T. Attia, V. Petrov, S. Schönborn, J. Stichnothe, K. Ziaja, J. Blume, D. Penner, W. Dziony, A. Matthias, M. Pump, T. Stampehl, E. Wolff, M. Albrecht, D. Kosanke, P. Nasemann, N. Götze, K. Voges, J. Wiencke

MSc and BSc co-supervisor for: M. Freise, K. Klimm, M. Haack, O. Beermann, S. Cichy, F. Rohlfs, A. Stechern, J. Probst, L. Kuschel, C. Bonnecke, A. Fiege, C. Kirchner, J. Probst, M. Oeser, M. Tiedke, M. Singer, S. Wilke, C. Klahn, R. Brodehl

PhD supervisor for: J. Berndt, S.T. Feig, W. Dziony, C. Kirchner, E. Wolff

PhD co-supervisor for: A. Tegge-Schüring; M. Hahn, R. Almeev, L. France (in the framework of a joint doctorate with the University of Montpellier, France), B. Abily (in the framework of a joint doctorate with the University of Toulouse, France)

Post-doctoral co-supervisor for: R. Botcharnikov; R. Almeev

Long-term responsibilities in the Administration of the Leibniz University Hannover

Program coordinator BSc, MSc "Earth Sciences" at Leibniz University of Hannover

Member of the audit committee "Earth Sciences" at Leibniz University of Hannover

International program coordinator "Earth Sciences" within the Natural Science Faculty

Member of the selection committee for MSc "Earth Sciences" at Leibniz University of Hannover

5 selected Publications

Koepke, J., Schoenborn, S., Oelze, M., Wittmann, H., Feig, S., Hellebrand, E., Boudier, F., Schoenberg, R. (2009): Petrogenesis of crustal wehrlites in the Oman ophiolite: Experiments and natural rocks. 10, doi:10.1029/2009GC002488.

Koepke, J., Berndt, J., Feig, S.T., Holtz, F. (2007): The formation of SiO_2-rich melts within the deep oceanic crust by hydrous partial melting of gabbros. Contrib. Mineral. Petrol. 153, 67–84.

Koepke, J., Feig, S.T., Snow, J. (2005): Late-stage magmatic evolution of oceanic gabbros as a result of hydrous partial melting: Evidence from the ODP Leg 153 drilling at the Mid-Atlantic Ridge. Geochem. Geophys. Geosyst. 6, 2004GC000805, pp. 1-27.

Koepke, J., Feig, S.T., Snow, J., Freise, M. (2004): Petrogenesis of oceanic plagiogranites by partial melting of gabbros: An experimental study. Contrib. Mineral. Petrol. 146, 414-432.

Koepke, J., Behrens, H. (2001): Trace element diffusion in andesitic melts: An application of synchrotron X-ray fluorescence analysis. Geochim. Cosmochim. Acta 65, 1481-1498.

Dr. CHARLES H. LANGMUIR

HARVARD UNIVERSITY, DEPARTMENT OF EARTH AND PLANETARY SCIENCES
20 OXFORD ST, CAMBRIDGE, MA 02138 OFFICE: 617-384-9948 LANGMUIR@EPS.HARVARD.EDU

PROFESSIONAL PREPARATION:

1973	:	B.A. with honors - Harvard University - History of Science and Geology
1977	:	M.S. - SUNY, Stony Brook, New York
1980	:	Ph.D. - SUNY, Stony Brook

FELLOWSHIPS AND AWARDS:

2011:	:	Christensen Fellow, Oxford University
2010	:	Leverhulme Fellowship
2010	:	Urey Medal, European Association of Geochemistry
2009	:	Astor Lectureship, Oxford University
2006	:	National Academy of Sciences
2003	:	Arthur Holmes Medal, European Union of Geosciences
1998	:	Fellow, Geochemical Society and European Geochem. Soc.
1998	:	Daly Lecturer, American Geophysical Union
1997	:	Fellow, American Academy of Arts and Sciences
1996	:	N. L. Bowen Award, American Geophysical Union
1993	:	Fellow, American Geophysical Union
1983 - 1985	:	Alfred Sloan Research Fellow

PROFESSIONAL ACTIVITIES:

2009	:	Medals Committee, VGP-AGU
2008	:	Program Committee, AAAS
2002 - 2005	:	Ridge 2000 Steering Committee
2000 - 2002	:	AGU Nominations Committee
1998 - 2000	:	Co-founder, *Geochemistry, Geophysics, Geosystems*

APPOINTMENTS:

2008 -	:	Director, Harvard University Mineralogical Museum
2006 -	:	Higgins Professor of Geochemistry, Harvard University
2002 - 2006	:	Professor of Geochemistry, Harvard University
1989 - 2002	:	Arthur D. Storke Memorial Professor, Lamont-Doherty
1988 - 2002	:	Professor, Lamont-Doherty Geol. Obs.
1986 - 1988	:	Associate Professor, Lamont-Doherty Earth Obs.
1981 - 1988	:	Assistant Professor, Lamont-Doherty Earth Obs., of Columbia University, Palisades, New York 10964

SEAGOING EXPERIENCE:

15 cruises, 8 as chief scientist or co-chief scientist

FIVE RELEVANT AND FIVE OTHER PUBLICATIONS:

Langmuir, C. H., Klein, E. M., and Plank, T., 1992, Petrological Systematics of Mid-Ocean Ridge Basalts: Constraints on Melt Generation Beneath Ocean Ridges, *AGU Monograph, 71*, 183-280.

Tomascak, P., Langmuir, C., le Roux, P., Shirey, S. (2008). Lithium isotopes in global mid-ocean ridge basalts. *Geochimica et Cosmochimica Acta*, 72, I 6, 1626-1637, doi:10.1016/j.gca.2007.12.021.

Langmuir, C. H, Bezos, A., Escrig, S., Parman, S., 2006, Chemical systematics and hydrous melting of the mantle in Back-Arc Basins. *AGU Geophysical Monograph* Vol.166, 87.

Cottrell, E., Spiegelman, M., Langmuir, C.H. (2002). Consequences of diffusive reequilibration

for the interpretation of melt inclusions. *Geochem. Geophys. Geosyst.*, 3 (5), 1026, doi:10.1029/2001GC000205.

Michael, P. J., Langmuir, C.H., Dick, H. J. B., Snow, J. E., Goldstein, S. L., Graham, D. W., Lehnert, K., Kurras, G., Jokat, W., Mühe, R., Edmonds, H. N., 2003, Magmatic and amagmatic seafloor generation at the ultraslow-spreading Gakkel ridge, Arctic Ocean *Nature* 423, 956.

Huybers, P., and Langmuir, C. (2009). Feedback between deglaciation and volcanic emissions of CO_2.

Earth Planet. Sci. Lett. 286, 479–491, doi:10.1016/j.epsl.2009.07.014.

Donnelly, K. E., Goldstein, S. L, Langmuir, C. H., et al., 2004, Origin of enriched ocean ridge basalts and implications for mantle dynamics *Earth Planet. Sci. Letters* 226: 347-366.

J. Escartín, D.K. Smith, H. Schouten, C.H. Langmuir, S. Escrig, , 2008, Central role of detachment faults in accretion of slow spreading oceanic lithosphere, Nature 455, 790-794.

Class, C., Miller, D., Goldstein, S., Langmuir, C. (2000). Distinguishing melt and fluid subduction components in Umnak volcanics, Aleutian Arc. *Geochem. Geophys. Geosyst.*, 1, Paper # 1999GC000010.

Plank, T. and Langmuir, C. (1998). The chemical composition of subducting sediment and its consequences for the crust and mantle. *Chem. Geol.*, 145, 325-394.

SYNERGISTIC ACTIVITIES

1. Weaver and Langmuir (1991) presented a widely used program for modeling the differentiation of basaltic magmas.
2. We have developed the ocean ridge petrology database (PetDB) served over the world wide web, that both integrates and transfers knowledge to investigators and students. This work has been expanded to become integrated with other database efforts.
3. I served as an editor of Earth and Planetary Science Letters for 10 years, and was one of the founders of G-cubed, published by AGU and the Geochemical Society.
4. In 2004 I was a distinguished lecturer for the RIDGE 2000 program, and gave four talks to small undergraduate colleges around the country.
5. I am Director of the Harvard University Mineralogical Museum that educates thousands of people every year about the Earth.

GRADUATE STUDENTS ADVISED: Emily Klein, Carl Agee, Youxue Zhang, Jeff Ryan, Dan Miller, Jennifer Reynolds, Terry Plank, Miranda Fram, Niraj Kumar, Jennifer Monteith, Katherine Donnelly, Alexandra Lagatta, Elizabeth Gier, Yong Jun Su, Kyla Simons, Dana Himmel, Gad Soffer, Gang Yu, Allison Gale, Stephen Turner.

POST-DOCTORAL FELLOWS: Terry Plank, Kathleen Donnelly, Elizabeth Gier, Dave Christie, Yao Ling Niu, Dana Desonie, Paul Asimow, Antoine Bézos, Stéphane Escrig, Steve Parman, Jeff Standish, Muriel Laubier, Daniel Selles, Alberto Saal.

Collaborators and Co-Editors:

Advisor: Gilbert Hanson (Stony Brook)

P. Asimow, Caltech, E. Baker, NOAA PMEL, H. Dick, J. Dixon, Miami, H. Edmonds, Texas, D. Fornari, WHOI , S. C. German, Southampton, K. Lehnert, Lamont, P. Michael, U. Tulsa, S. Parman, Brown., Colleen Dalton, Boston University, Antoine Bezos, University of Nantes, Richard Katz, Oxford University, Suzanne Carbotte, Jerry McManus, Columbia University

Curriculum vitae – Christopher John MacLeod

School of Earth & Ocean Sciences, Cardiff University, Cardiff CF10 3YE, Wales, UK

Tel: *+44 29 20874332;* ***Fax****: +44 29 20874326;* ***E-mail:*** *macleod@cardiff.ac.uk*

Nationality: *British* ***Date of birth:*** *8th August 1964*

Employment history:

2009	Professor, School of Earth & Ocean Sciences, Cardiff University
2002-2009	Senior Lecturer in Marine Geology, Cardiff University
2005-2007	Chair, ESSAC (Science Support & Advisory Committee of the European Consortium for Ocean Research Drilling), and Director of the ESSAC Office
1995-2002	Lecturer in Marine Geology, Cardiff University
1993-1995	NERC Fellow, Inst. Oceanographic Sciences/University of Leicester: *'Application of borehole imaging techniques to structural geological studies with the Ocean Drilling Program: structure of the lower oceanic crust in Hess Deep'*
1991-1993	NERC PDRA, Inst. Oceanographic Sciences: *'Tectonic evolution of the Lau Basin, SW Pacific, from structural studies of ODP core and geophysical well logs'*
1990-1991	Open University Research Fellow *'Geological evolution of the Southern Troodos Transform Fault Zone, Cyprus'*
1988-1989	Royal Society European Exchange Fellow, Université de Montpellier 2, France *'Oceanic spreading axis segmentation in the Oman ophiolite'*

Qualifications:

Ph.D. (Open University, 1988): *'Tectonic Evolution of the Eastern Limassol Forest Complex Troodos Ophiolite, Cyprus'* (supervisor: Professor I.G. Gass, F.R.S., now deceased)

B.Sc. (Hons.) Geology, Upper Second Class (University of Durham, 1984)

Research background:

My principal scientific interests centre on the processes of formation and deformation of ocean lithosphere at mid-ocean ridges. I conduct observation-based, multi-disciplinary, meso-scale geological investigations both of modern ocean floor and of ophiolite complexes. My work on the Troodos and Oman ophiolites was initially concentrated on tectonic and magmatic processes at ridge axial discontinuities, but later broadened to include crustal accretion mechanisms, focusing on the physical and chemical processes in magma chambers that lead to generation of the lower crust at fast-spreading ridges. In all of these I have applied fine-scale mapping, structural geology, rock magnetics/palaeomagnetism, petrology and geochemistry to address geological problems. In the marine realm I have attempted to develop the methodologies that allow us to conduct structural geological/tectonic studies comparable to those I have applied on land. With ODP I was the first to develop and apply core-log integration techniques to reorientate cores, and I was a prime mover behind the development of the BGS remotely-operated seabed rock drill that, uniquely, collects oriented cores from hard-rock seafloor. I have subsequently used seabed drills in combination with other marine geophysical techniques (e.g. sidescan sonar, swath mapping) to further our understanding of detachment fault mechanisms and the relationship between tectonism and magmatism at slow-spreading ridges. Most recently I led the site survey cruise to Hess Deep, in support of our IODP drilling proposal, during which we used an ROV not only to characterise drill sites but to sample the East Pacific Rise lower crustal section in detail and decipher its tectonic disruption.

Relevant research cruise/field experience:

- Semail ophiolite, Sultanate of Oman/UAE 8 months field experience since 1989
- Troodos ophiolite, Cyprus ~24 months field experience since 1985
- Chief Scientist, RRS James Cook cruise JC021, Hess Deep (2008)
- Co-Chief Scientist, RRS James Cook cruise JC007, Mid-Atlantic Ridge 13°N (2007)
- Chief Scientist, RRS James Clark Ross cruise JR63, Mid-Atlantic Ridge 15°45'N (2001)
- Co-Chief Scientist, RRS James Clark Ross cruise JR31, Atlantis Bank (1998)
- ODP Leg 147, Hess Deep (1992-93) *Structural geologist + JOIDES logging scientist*
- ODP Leg 135, Lau Basin (1990-91) *Structural geologist + JOIDES logging scientist*
- participant in four further research cruises in Atlantic, Indian & Pacific oceans (1992-2010)

Professional appointments and memberships:

- Chair, ESSAC (ECORD Science Support & Advisory Committee), 2005-2007
- Vice-Chair, ESSAC, 2003-2005, 2007-2008; UK representative ESSAC, 2003-2008
- ECORD Representative, IODP Science Planning Committee (SPC), 2003-2007
- IODP INVEST Session Chair 'Variability in ocean crust composition and structure', Sept 2009
- IODP Thematic Review Committee 'Oceanic Crustal Structure and Formation', 2008-2009
- IODP Science Advisory Structure Executive Committee Permanent Alternate, 2007-09
- InterRidge Deep Earth Sampling Working Group member, 2004-2009
- NERC UK ODP & IODP Strategy Group and Grants Committee member, 1995-2008
- UK representative, ODP (JOIDES) Science Committee (SCICOM), 2001-2003
- UK representative, ODP Scientific Measurements Panel, 1997-1999
- ODP Curatorial Advisory Board member, 1997-2000
- UK representative, ODP Information Handling Panel, 1995-1997

Selected research grants

- *NERC grant IP1193-1110 (2011-2013; £33,000) *'Geodynamics of the Oman/UAE ophiolite: spatial and temporal variability in lithospheric accretion at the onset of intraoceanic subduction'*
- *NERC grant NE/C509023/1 (2008-2011; £332,992) *'Accretion of the lower oceanic crust at fast-spreading ridges: a rock drill and near-bottom seafloor survey at Hess Deep'*
- *NERC grant NE/B500058/1 (2007-2010; £147,575) '*Geological and Geophysical Studies of the Mid-Atlantic Ridge, 12°30'N to 14°30'N'*
- NERC grant NE/E003079/1 (2007-2009; £18,446) *'Spatial and temporal scales of crustal accretion in slow-spreading rate oceanic crust (IODP Site U1309)*
- *NERC + ECORD Managing Agency (2005-2007, £295,240) *Management of the ESSAC Office and ECORD education & outreach activities*
- *NERC grant GR3/11767 (1999-2004, £155,234) *'A low-angle detachment fault on the MAR'*
- *NERC grants GR3/10791+ GST/02/2293 (1997-2001, £169,699) *'Plutonic foundation of the oceanic crust: portable rock drilling on the SW Indian Ridge'*
- NERC grant GST/02/1166 (1996-1998, £56,549) *'Sea trials of the oriented hard-rock corer'*
- NERC grant GST/02/996 (1995-1996, £82,265) *'A seafloor drill for oriented rock cores'*

[= first-named Principal Investigator];* + in-kind contributions (shiptime, ROV hire, NERC facilities use): £2,799,540*;* + 10 further grants from miscellaneous other sources: £882, 721

Selected relevant publications:

MacLeod CJ, et al., 2009. Life cycle of oceanic core complexes. *Earth Planet. Sci. Lett.*, **287**, 333-344.

Morris A, Gee JS, Pressling N, John BE, **MacLeod CJ**, Grimes CB & Searle RC, 2009. Footwall rotation in an oceanic core complex quantified using reoriented Integrated Ocean Drilling Program core samples. *Earth Planet. Sci. Lett.*, **287**, 217-228.

MacLeod CJ, Escartín J, et al., 2002. Direct geological evidence for oceanic detachment faulting: the Mid-Atlantic Ridge, 15°45'N. *Geology*, **30**, 879–882.

Coogan LA, Thompson G & **MacLeod CJ**, 2002. A textural and geochemical investigation of high level gabbros from the Oman ophiolite. *Lithos*, **63**, 67-82.

MacLeod CJ & Yaouancq G, 2000. A fossil melt lens in the Oman ophiolite: implications for magma chamber processes at fast-spreading ridges. *Earth Planet. Sci. Lett.*, **176**, 357-373.

Manning CE, **MacLeod CJ** & Weston PE, 2000. Lower-crustal cracking front at fast-spreading ridges: evidence from the East Pacific Rise and the Oman ophiolite. *Geol. Soc. Am. Spec. Pap.*, **349**, 261-272.

Yaouancq G. & **MacLeod CJ**, 2000. The use of the anisotropy of magnetic susceptibility in petrofabric investigation of gabbros from the Oman ophiolite. *Mar. Geophys. Res.*, **21**, 289-305.

MacLeod CJ, Célérier B & Harvey PK, 1995. Further techniques for core reorientation by core-log integration: application to structural studies of lower oceanic crust in Hess Deep, Eastern Pacific. *Scientific Drilling*, **5**, 77-86.

Gass IG, **MacLeod CJ**, et al., 1994. *The Geological Evolution of the Southern Troodos Transform Fault Zone*. Cyprus Geological Survey Memoir, **9**, Geol. Surv. Dept., Nicosia, Cyprus, 218pp.

MacLeod CJ & Rothery DA, 1992. Ridge axial segmentation in the Oman ophiolite: evidence from along-strike variations in the sheeted dyke complex. *Spec. Publ. Geol. Soc. London,* **60**, 39-63.

MacLeod CJ, Allerton S, Gass IG & Xenophontos C, 1990. Structure of a fossil ridge-transform intersection in the Troodos ophiolite. *Nature*, **348**, 717-720.

MacLeod CJ, et al., 1992. Identification of tectonic rotations in boreholes by the integration of core information with Formation MicroScanner and Borehole Televiewer images. *Spec. Publ. Geol. Soc. London* **65**, 235-246.

Biographical Sketch – Craig E. Manning

Professional Preparation

University of Vermont	Geology	BA, 1982
Stanford University	Geology	MS, 1986
Stanford University	Geology	Ph.D, 1989
U.S. Geological Survey	Geochemistry	Postdoctoral Scientist, 1989-90

Appointments

2010-	Affiliate Member, UCLA Insitute of the Environment
2008-	Chairman, Dept. of Earth and Space Sciences, UCLA
2002-2008	Vice-Chairman, Dept. of Earth and Space Sciences, UCLA
2008-	Humboldt Fellow, Bayerisches Geoinstitut, Bayreuth, Germany
2007,2008	Visiting Scientist, École Normale Supérieur de Lyon, France
2006	Visiting Scientist, GeoForschungsZentrum, Potsdam, Germany
2002-	Professor of Geology and Geochemistry, UCLA
2000	Visiting Professor, Swiss Federal Institute of Technology (ETH Zürich)
1996-2002	Associate Professor of Geology and Geochemistry, UCLA
1990-1996	Assistant Professor of Geology and Geochemistry, UCLA
1989-1990	Postdoctoral Scientist, U.S. Geological Survey, Menlo Park, Ca.
1983	Geological Field Assistant, U.S. Geological Survey, Menlo Park, Ca.
1981-1982	Field Geologist, Wagner, Heindel and Noyes, Consulting Hydrologists, Burlington, Vt.

Relevant Publications

Dolejs D., and Manning, C. E., 2010, Thermodynamic model for mineral solubility in aqueous fluids: theory, calibration, and application to model fluid-flow systems. Geofluids, v. 10, p. 20-40.

Manning, C. E., Antignano, A., Lin, H. A., 2010, Premelting polymerization of crustal and mantle fluids, as indicated by solubility of albite + paragonite + quartz in H_2O at 1 GPa and 350-620°C. Earth and Planetary Science Letters, v. 292, p. 325-336.

Ingebritsen, S. E., and Manning, C. E., 2010, Permeability of the continental crust: Dynamic variations inferred from seismicity and metamorphism. Geofluids, v. 10, p. 193-205.

Manning, C. E., MacLeod, C., and Weston, P. E., 2000, Lower-crustal cracking front at fast-spreading ridges: evidence from the East Pacific Rise and the Oman ophiolite. In Dilek, Y., Moores, E., Elthon, D., and Nicolas, A., eds., Ophiolites and Ocean Crust: New Insights From Field Studies and Ocean Drilling Program, Geological Society of America Special Paper 349, p. 261-272.

Manning, C. E., Weston, P. E., and Mahon, K. I., 1996, Rapid high-temperature metamorphism of East Pacific Rise gabbros from Hess Deep: Earth and Planetary Science Letters, v. 144, p. 123-132.

Five Other Publications

Manning, C. E., and Ingebritsen, S. E., 1999, Permeability of the continental crust: constraints from heat flow models and metamorphic systems. Reviews in Geophysics, v. 37, p. 127-150.

Manning, C. E., 1997, Coupled reaction and flow in subductions zones: Si metasomatism in the mantle wedge. In: Jamtveit, B., and Yardley, B. W. D., eds., Fluid Flow and Transport in Rocks, Chapman Hall, p. 139-148.

Manning, C. E., 1994, The solubility of quartz in H_2O in the lower crust and upper mantle. Geochimica et Cosmochimica Acta, v. 58, p. 4831-4839.

Newton, R. C., and Manning, C. E., 2002, Solubility of silica in equilibrium with enstatite, forsterite, and H_2O at deep crust/upper mantle pressures and temperatures and an activity-concentration model for polymerization of aqueous silica. Geochimica et Cosmochimica Acta, v. 66, p. 4165-4176.

Manning, C. E., and MacLeod, C. J., 1996, Fracture-controlled metamorphism of Hess Deep Gabbros, Site 894: Constraints on the root zones of mid-ocean ridge hydrothermal systems at fast spreading centers. In: Mével, C., Gillis, K. M., Allan, J. F., and Meyer, P. S., eds., Proceedings of the Ocean Drilling Program, Scientific Results, v. 147, College Station, TX (Ocean Drilling Program), p. 189-209.

Five Synergistic Activities

2006-08 Secretary, American Geophysical Union VGP section
2000- Associate Editor, "American Journal of Science"
2003-05 Panelist, National Science Foundation, Petrology and Geochemistry Program
2001-03 Councilor, Mineralogical Society of America
1997-2000 Panelist, Ocean Drilling Program Scientific Steering and Evaluation Panel

Collaborators and Other Affiliations

Collaborators (last 4 years)

J. Boyce (UCLA)
E. Cowgill (UC Davis)
I. Daniel (ENS Lyon, France)
D. Dolejs (U Bayreuth, Germany)
J. Hanchar (Memorial U)
M. Harrison (UCLA)
D. Hirsch (Western Washington U)
S. Ingebritsen (USGS Menlo Park)
E. Johnson (James Madison U)
P. Kapp (U Arizona)
A. Kavner (UCLA)
H. Keppler (U Bayreuth, Germany)
J. Mavrogenes (ANU Canberra, Australia)
T. McCollum (U Colorado)
S. Mojzsis (U Colorado)
R. Newton (UCLA)
T. Plank (Columbia U)
E. Schauble (UCLA)
C. Schmidt (GeoForschungsZentrum, Potstdam, Germany)
D. Sverjensky (Johns Hopkins U)
A. Thompson (ETH Zürich)
P. Tropper (U Innsbruck)
M. Wilke (GeoForschungsZentrum, Potstdam, Germany)
A. Yin (UCLA)
E. Young (UCLA)

Graduate and Postdoctoral Advisors

D. Bird (Stanford U)
S. Bohlen (Joint Oceanographic Inst.)
R. Coleman (Stanford U)
J. Liou (Stanford U)

PhD students[§], MS students[‖] and Postdoctoral Scientists[†] mentored in last 5 years

A. Antignano[§] (Exxon Research)
S. Briggs[§] (William Lettis & Associates)
C. Colasanti[‖] (PhD cand., U Munich)
M. Cruz[‖] (PhD cand., Stanford U)
C. Donahue[§#] (Exxon Research)
L. Hayden[†] (Researcher, U Michigan)
Michael Huh[‖*]
J. Hunt[§*]
G. Lazar[§] (Postdoc, Geophysical Lab)
C. Macris[§*]
C. Menold[§] (Asst Prof, Albion College)
A. Shahar[§] (Staff Scientist, Geophysical Lab)
R. Thomas[‖*]
A. Wohlers[†] (Researcher, GFZ Potsdam)
J. Wykes[‖§##] (PhD cand., ANU Canberra)

[*]Current graduate student or postdoctoral scientist at UCLA
[#]U Michigan student who did experimental part of dissertation work at UCLA
[##]Australian National U student who did experimental part of MS work at UCLA; in residence at UCLA in 2010-11 as a Fulbright Fellow
Total students = 13; total postdoctoral scientists = 2

CURRICULUM VITAE – Juerg M. Matter

Doherty Associate Research Scientist
Lamont-Doherty Earth Observatory
Columbia University, Palisades NY 10964
Telephone: 845 365 8543
E-mail: jmatter@ldeo.columbia.edu

(I) PROFESSIONAL PREPARATION

Swiss Federal School of Technology	Earth Sciences	Diploma (M.S.), 1997
Swiss Federal School of Technology	Earth Sciences	Ph.D., 2001
Lamont-Doherty Earth Observatory	Geochemistry	2001 – Date

(II) APPOINTMENTS

2005-Date	Doherty Associate Research Scientist, Geochemistry Division, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY
2001-2004	Postdoctoral Research Scientist, Geochemistry Division, Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY
2001	Ph.D., Swiss Federal Institute of Technology, Earth Sciences, Zurich, Switzerland
1997-2001	Research Assistant, Swiss Federal Institute of Technology, Earth Sciences, Zurich, Switzerland
1997	M.S. Swiss Federal Institute of Technology, Earth Sciences, Zurich Switzerland

(III) PUBLICATIONS related to this proposal

Matter, J.M., T. Takahashi, and D. Goldberg (2006). Experimental evaluation of in situ CO_2-water-rock reactions during CO_2 injection in basaltic rocks: implications for permanent CO_2 sequestration. (in press G^3)

Matter, J.M., N. Assayag, and D. Goldberg (2006). Basaltic rocks and their potential to permanently sequester industrial carbon dioxide emissions. GHGT-8, June 19-22, 2006, Trondheim, Norway (https://events.adm.ntnu.no/ei/viewpdf.esp?id=24&file=d%3A%5CAmlink%5CE VENTWIN%5Cdocs%5Cpdf%5C950Final00411%2Epdf)

Assayag, N., J. M. Matter, M. Ader, and P. Agrinier (2006). Water chemistry and isotope characteristics to monitor fluid-rock interaction following a small scale CO_2 injection. GHGT-8, June 19-22, 2006, Trondheim, Norway (https://events.adm.ntnu.no/ei/viewpdf.esp?id=24&file=d%3A%5CAmlink%5CE VENTWIN%5Cdocs%5Cpdf%5C950Final00354%2Epdf)

Matter, J.M., D.S. Goldberg, R.H. Morin, and M. Stute (2005). Contact zone permeability at intrusion boundaries: New results from hydraulic testing and geophysical logging in the Newark Rift Basin. Hydrogeology Journal (2006) 14: 689-699.

Matter, J.M., N.H. Waber, S. Loew, and A. Matter (2005). Recharge areas and geochemical evolution of groundwater in a shallow alluvial aquifer system in the Sultanate of Oman. Hydrogeology Journal (2006) 14(1-2): 203-224.

(IV) **SYNERGISTIC ACTIVITIES**

(1) **Teaching:** Lamont-Doherty Earth Observatory, Columbia University, Lecturer, Summer reading group seminar on Geological and Mineral Carbon Sequestration (2005).
Montclair State University, Lecturer, Weston Science Scholar Program, Introduction to Global Warming and Carbon Sequestration (2006)
(3) **Educational Outreach:** Public Lecturer at the Lamont-Doherty Earth Observatory Public Lecture Series, Spring 2006. Served as a Judge of the "Best Student Presentation" at the AGU Fall Meeting, San Francisco, 1999, 2005. Public Lecturer at the Ministry of Water Resources, Sultanate of Oman, 1999, 2000.
(4) **Scientific and Engineering Community Service:** Representative for the Big Sky Carbon Sequestration Partnership (one of the seven U.S. Department of Energy regional partnerships). Reviewer for Chemical Geology, Hydrogeology Journal and Geochimica et Cosmochimica Acta (GCA).
(5) **Meeting and Co-convenor, Session Chair:** GHGT-8 (8^{th} International Conference on Greenhouse Gas Control Technologies, 19-22 June 2006, Trondheim, Norway.

(V) COLLABORATORS AND OTHER AFFILIATIONS

M. Ader, Physical chemistry of geological fluids laboratory, Institute de Physique du Globe de Paris, France. **P. Agrinier**, Physical chemistry of geological fluids laboratory, Institute de Physique du Globe de Paris, France. **A. Bonneville**, Research Center for CO_2 geological storage, Total-Schlumberger, IPG-Paris, Institute de Physique du Globe de Paris, France. **W. Broecker**, Lamont-Doherty Earth Observatory of Columbia University **S. Capalbo**, Department of Agricultural Economics, Montana State University. **S. R. Gislason**, Science Institute, University of Iceland, Iceland. **D. Goldberg**, Lamont-Doherty Earth Observatory of Columbia University. **K. Lackner**, Earth Engineering Center, Columbia University **P. McGrail**, Batelle Pacific Northwest Laboratory. **T. McLing**, Geoscience Research Group, Idaho National Laboratory. **R. H. Morin**, U.S. Geological Survey, Denver. **E. Oelkers**, Laboratoire des Mécanismes et Transferts en Géologie, University of Toulouse, France. **T. S. Ramakrishnan**, Schlumberger-Doll Research Laboratory, Connecticut. **D. Schrag**, Earth and Planetary Sciences, Harvard University. **P. Schlosser**, Lamont-Doherty Earth Observatory of Columbia University. **R. Smith**, Biological and Agricultural Engineering Department, University of Idaho at Idaho Falls. **M. Stute,** Lamont-Doherty Earth Observatory of Columbia University. **T. Takahashi**, Lamont-Doherty Earth Observatory of Columbia University. **H. N. Waber**, Institute of Geological Sciences, University of Bern, Switzerland. **P. Zuddas**, Center for CO_2 geological storage, Total-Schlumberger, IPG-Paris, Institute de Physique du Globe de Paris, France.

(b) Graduate and Post Doctoral Advisors:

Graduate: S. Loew, Earth Sciences, Swiss Federal Institute of Technology (ETH) Zurich, Switzerland; W. Kinzelbach, Institute of Hydromechanics and Water Resources Management, Swiss Federal Institute of Technology Zurich, Switzerland
Postdoctoral: T. Takahashi, Lamont-Doherty Earth Observatory of Columbia University; D. Goldberg, Lamont-Doherty Earth Observatory of Columbia University
A**DVISING: Columbia Ph.D. advisor to:** Jonathan Levine (DEEE 10); Samuel Krevor (DEEE 09); Anna Wall (DEES 10) Ph.D. committee member: Oliver Lopez (Institute de Physique du Globe de Paris, France 06); Nelly Assayag (Institute de Physique du Globe de Paris, France 07).

Curriculum Vitae (C. V.) (Updated on 26 September, 2010)

Above Mariana Trench
24th September, 2010

Katsuyoshi Michibayashi, Ph. D

Associate Professor

Personal

Nationality: Japanese

Date and place of birth: 27 June, **1965**, Shizuoka, Japan

Permanent address: Institute of Geosciences, Shizuoka University, Shizuoka, 422-8529, JAPAN

Mailing address: Institute of Geosciences, Shizuoka University, Shizuoka, 422-8529, JAPAN

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Tel: +81-54-238-4788

Education

1. Bachelor of Science

   Geology, Shizuoka University, Japan, **1988**

2. Master of Science

   Structural Geology, Shizuoka University, Japan, **1990**

   Microstructural development of quartz and feldspar during plastic deformation: a study of naturally and experimentally deformed granites

3. Doctor of Philosophy

   Structural Geology, James Cook University of North Queensland, Australia, **1994**

   Microstructural processes and deformation history within shear zones: the Kashio shear zone, Japan and the Hemlo shear zone, Ontario, Canada

Work Experience

1. April **2002** – **present**

   Associate Professor at Shizuoka University, Japan

2. October **1994** – March **2002**

   Assistant Professor at Shizuoka University, Japan

3. August **1997** – August **1999**

JSPS Postdoctoral Fellow at Université Montpellier II, France

4. April **1994** – September **1994**

JSPS Postdoctoral Fellow at the University of Tokyo, Japan

Publications

1. Muramoto, M., **Michibayashi, K.**, Ando, J. and Kagi, H., **2010**. Rheological contrast between garnet and clinopyroxene in the mantle wedge: an example from Higashi-akaishi peridotite mass, SW Japan. ***Physics of the Earth and Planetary Interiors***, in press.
2. Satsukawa, T., **Michibayashi, K.**, Raye, U., Anthony, E. Y., Pulliam, J. and Stern, R. J., **2010**. Uppermost mantle anisotropy beneath the southern Laurentian margin: Evidence from Knippa peridotite xenoliths, Texas. ***Geophysical Research Letters***, in press.
3. Hirauchi, K., **Michibayashi, K.**, Ueda, H and Katayama, I., **2010**. Spatial variations in antigorite fabric across a serpentine subduction channel: Insight from the Ohmachi Seamount, Izu-Bonin frontal arc. ***Earth and Planetary Science Letters***, in press.
4. Harigane, Y., **Michibayashi, K.** and Ohara, Y., **2010**. Amphibolitization within the lower crust in the termination area of the Godzilla Megamullion, an oceanic core complex in the Parece Vela Basin, ***Island Arc***, in press.
5. Okudaira, T., Ogawa, D. and **Michibayashi, K.**, **2010**. Grain-size-sensitive deformation of upper greenschist- to lower amphibolite-facies metacherts, ***Tectonophysics***, doi: 10.1016/j.tecto.2010.06.002.
6. Mizouchi, J., Satish-Kumar, M., Motoyoshi, Y. and **Michibayashi, K.**, **2010**. Exsolution of dolomite and application of calcite-dolomite solvus geothermometry in high-grade marbles: An example from Skallevikshalsen, East Antarctica. ***Journal of Metamorphic Geology***, **28**, 509-526.
7. Kamei, A., Obata, M., **Michibayashi, K.**, Hirajima, T. and Svojtka, M., **2010**. Two contrasting fabric patterns of olivine observed in garnet- and spinel-peridotite from a mantle-derived ultramafic mass enclosed in felsic granulite, the Moldanubian Zone, Czech Republic. ***Journal of Petrology***, **51**, 101-123, doi:10.1093/petrology/egp092.
8. Ohuchi, T., Nakamura, M. and **Michibayashi, K.**, **2010**. Effect of grain growth on cation exchange between dunite and fluid: implications for chemical homogenization in the upper mantle. ***Contribution to Mineralogy and Petrology***, **160**, 339-357, doi:10.1007/s00410-00900481-7.
9. Katayama, I., **Michibayashi, K.**, Terao, R., Ando, J. and Komiya, T., **2010**. Water content of the mantle xenoliths from Kimberley and implications for explaining textural variations in cratonic roots. ***Geological Journal***, doi: 10.1002/gj.
10. Katayama, I., Hirauchi, K. **Michibayashi, K.** and Ando, J., **2009**. Trench-parallel anisotropy produced by serpentine deformation in the hydrated mantle wedge. ***Nature***, **461**, 1114-1117, doi:10.1038/nature08513.
11. Satsukawa, T. and **Michibayashi, K.**, **2009**. Determination of slip system in olivine based on crystallographic

BARBARA SHERWOOD LOLLAR

Dept. of Geology, University of Toronto, Toronto, ON M5S 3B1
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1. Professional Preparation

B.A. Geological Sciences, Harvard University, 1985.
Ph.D. Earth Sciences, University of Waterloo, 1990.

2. Appointments

NSERC Postdoctoral Fellow, University of Cambridge	1990-92
Faculty, Dept. of Geology and Director, Stable Isotope Laboratory	1992-present
Canada Research Chair (Isotope Geochemistry)	2007-2014

Awards and Fellowships

Distinguished University Professor, University of Toronto	2010
Canada Council Killam Research Fellowship, University of Toronto	2004-2006
TIME Magazine – profiled as one of "Leaders for 21st Century"	2000
Darcy Lecturer (U.S. National Ground Water Association)	1998

3. Publications, 5 most relevant

1. Gilfillan, S.M.V., Sherwood Lollar, B., Holland, G., Blagburn, D., Stevens, S., Schoell, M., Cassidy, M., Ding, Z. Lacrampe-Couloume, G., Zhou, Z. and Ballentine, C.J. (2009) Solublity trapping in formation water as dominant CO_2 sink in natural gas fields. **Nature** 458:614-618. **Cover story**
2. Sherwood Lollar, B. and McCollom, T.M. (2006) Biosignatures and abiotic constraints on early life. (2006) **Nature** 444:E18. Dec. 14, 2006.
3. Lin, L.-H., Wang, P.-L., Rumble, D., Lippmann-Pipke, J., Boice, E., Pratt, L., Sherwood Lollar, B., Brodie, E. Hazen, T., Andersen, G., Moser, D.P., Kershaw, D. and Onstott, T.C. (2006) Long-term sustainability of a high energy, low diversity crustal biotome. **Science** 314:479-482.
4. Sherwood Lollar, B., Lacrampe-Couloume, G., Slater, G.F., Ward, J., Moser, D.P., Gihring, T.M., Lin, L.-H. and T.C. Onstott. (2006) Unravelling abiogenic and biogenic sources of methane in the Earth's deep subsurface. **Chemical Geology** Vol. 226:328-339.
5. Sherwood Lollar, B., Westgate, T., Ward, J., Slater, G.F., and Lacrampe-Couloume, G. (2002) Abiogenic formation of alkanes in the Earth's crust as a minor source for global hydrocarbon reservoirs. **Nature** Vol. 416:522-524.

4. Publications, 5 other significant

1. Sherwood Lollar, B., Voglesonger, K., Lin, L.-H., Lacrampe-Couloume, G., Telling, J., Abrajano, T.A., Onstott, T.C. and Pratt, L.M. (2007) Hydrogeologic controls on episodic H_2 release from Precambrian fractured rocks - Energy for deep subsurface life on Earth and Mars. **Astrobiology** 7:971-986.
2. Fu, Q., Sherwood Lollar, B., Horita, J., Lacrampe-Couloume, G., Seyfried Jr., W.E. (2007) Abiotic formation of hydrocarbons under hydrothermal conditions: Constraints from chemical and isotope data. **Geochimica Cosmochimica Acta** Vol.71:1982-1998.
3. Allen, M., Sherwood Lollar, B., Runnegar, B., Oehler, D.Z., Lyons, J.R., Manning, C.E., Summers, M.E. (2006) Is Mars Alive? **EOS Transactions,** American Geophysical Union. 87 (41): 433, 439.
4. Lin, L.-H., Slater, G.F., Sherwood Lollar, B., Lacrampe-Couloume, G., and T .C. Onstott. (2005) The yield and isotopic composition of radiolytic H_2, a potential energy source for the deep subsurface biosphere. **Geochimica Cosmochimica Acta** Vol. 69(4):893-903.
5. Ballentine, C.J., Marty, B., Sherwood Lollar, B. and Cassidy, M. (2005) The Ne isotopic ratio of the convecting mantle and the origin of volatiles in the Earth. **Nature** Vol. 433:33-38.

Plus 93 additional papers

5. Synergistic Activities (up to 5 examples)

1. Member of National Research Council National Academies of Sciences Committee on the Origin and Evolution of Life (Space Studies / Life Sciences Board). As a member of a sub-committee of this group, co-authored the 2007 Astrobiology Strategy for the Exploration of Mars (ISBN 978-0-309-10851-5).
2. Member of MEPAG sub-committee developing the White paper on design of the Mid-Range Rover mission for Mars. NASA Mid-Range Rover Science Analysis Group member (MRR-SAG 2009)
3. Was an international collaborator with the NAI Indiana-Princeton-Tennessee team (co-PIs Pratt and Onstott) (2003-2008) and while on that team participated in the NAI Distributed Workshop "Methane on Mars' hosted by the NASA Goddard Space Flight Center. With Mark Allen of JPL co-authored the EOS summary paper on the proceedings of this workshop entitle "Is Mars Alive?" EOS Transactions AGU 87(41):433-439.
4. Executive Program Committee Co-Chair, Goldschmidt 2008, Vancouver, Canada; Organizing Committee, AbSciCon 2010; Geochemical Society Treibs Medal Selection Panel (2007-2010).
5. Co-PI on $1.6 million NSERC Canadian Astrobiology Training grant to McGill-Toronto-Western Ontario-McMaster to fund international student and postdoctoral fellow research in astrobiology. International partners include NASA Ames (McKay; Stoker, Rothschild), JPL (Mielke), Cornell (Bell), SETI (Anderson), the OU (Cockell) and Princeton (Onstott).

6. Thesis advisor and post-graduate scholar sponsor, last 5 years

Penny Morrill (Memorial University), Sarah Hirschorn (NWMO), Silvia Mancini (Golder Associates), Jennifer Gray McKelvie (NWMO), Michelle Chartrand (University of Ottawa), Martin Elsner (Helmholtz Zentrum Munich), Jon Telling (University of Bristol), Ken Voglesonger (Northeastern Illinois University), Iffat Jabeen (University of Toronto). Current are L. Douglas (PhD), C. Chan (MSc), S.Mundle (PDF), L.Li (PDF), X. Liang (PDF).
Total number of graduate students advised is 21. Total number of postdoctoral scholars sponsored is10.

7. Collaborators

E. Edwards (University of Toronto), B. Sleep (University of Toronto), G. Slater (McMaster University), M. Simpson (University of Toronto), S. Mabury (University of Toronto), J. Brenan (University of Toronto), D. Muir (CCIW), N. Roulet (McGill University), L. Whyte (McGill University), C. McKay (NASA Ames), M. Allen (NASA JPL), T.C. Onstott (Princeton), J. Gossett (Cornell University), J. Spain (Georgia Tech), K.K. Lehmann (University of Virginia), P. Mahaffy (NASA Goddard), L. Pratt (Indiana University), S. Pfiffner (University of Tennessee), T. Phelps (ORNL), F. Brockman (PNNL), T. Kieft (NMIMT), T. Hazen (LBNL), S. Clifford (LPI), W. Pollard (McGill University), N. Perreault (McGill University), D. Anderson (SETI), J.K. Fredrickson (PNNL), K. Pederson (Goteborg University), C.J. Ballentine (University of Manchester), G. Southam (University of Western Ontario), G. R. Osinski (University of Western Ontario), N. Banerjee (University of Western Ontario), D. Moser (DRI), T. McCollom (LASP), J. Seewald (WHOI),

8. Consultation / advising to government bodies, etc.

Served as Sub-panel Chair for NAI Review Panel Can-4 (2005).
NASA Mid-Range Rover Science Analysis Group member (MRR-SAG 2009)
NASA E2E SAG Advisory member (Sept. 2010- June 2011)
National Aacademies of Sciencxes Space Stduies Board COEL committee (2005-2011)
Executive Committee Carnegie Institution of Washington Deep Carbon Observatory (2011-2012)
In Canada serve on Council (Advisory Board) for our national research funding organization (NSERC) and on the Space Exploration Advisory Council to the Canadian Space Agency.

Biographical Sketch for Everett L. Shock
School of Earth & Space Exploration, and Dept. of Chemistry & Biochemistry
Arizona State University, Tempe, AZ, 85287

Professional Preparation

Undergraduate: Univ. of California, Santa Cruz	Earth Sciences	B.S. 1978
Graduate: Univ. of California, Berkeley	Geology	Ph.D. 1987

Appointments

Professor, School of Earth & Space Exploration and Department of Chemistry & Biochemistry, Arizona State University (since July 2002).

Director, W.M. Keck Foundation Laboratory for Environmental Biogeochemistry, Arizona State University (since July 2002).

Director, Environmental Studies Program, Washington University, St. Louis, MO, USA (1993-2001).

Professor, Associate Professor, and Assistant Professor, Department of Earth and Planetary Sciences, Washington University, St. Louis, MO, USA: (1987-2002).

Research Assistant, U.C. Berkeley: theoretical research in high-pressure/temperature inorganic and organic aqueous solution chemistry, chemical interaction of minerals and organic compounds with aqueous solutions in geochemical processes (six years).

Teaching Assistant, U.C. Berkeley: structural geology, introductory geology, theoretical geochemistry (one year).

Five Recent Publications Most Closely Related

Havig, J.R., Raymond, J., Meyer-Dombard, D., Zolotova, N., and Shock, E.L. (2011) Merging isotopes and community genomics in a siliceous sinter-depositing hot spring. *Journal of Geophysical Research* (in press).

Meyer-Dombard, D.R., Swingley, W., Raymond, J., Havig, J., Shock, E.L., and Summons, R.E., (2011) Hydrothermal ecotones and streamer biofilm communities in the Lower Geyser Basin, Yellowstone National Park. *Environmental Microbiology* (in press).

Shock, E.L. (2009) Minerals as energy sources for microorganisms. *Economic Geology* **104**, 1235-1248.

Shock, E.L. and Canovas P.C. (2010) The potential for abiotic organic synthesis and biosynthesis at seafloor hydrothermal systems. *Geofluids* **10**, 161-192.

Shock E.L., Holland, M.E., Meyer-Dombard, D.R., Amend, J.P., Osburn, G.R., and Fischer, T. (2010) Quantifying inorganic sources of geochemical energy in hydrothermal ecosystems, Yellowstone National Park, USA. *Geochim. Cosmochim. Acta* **74**, 4005-4043.

Five Additional Publications of Relevance to this Proposal

Bradley, A.S., Dibbell, A., Meyer-Dombard, D.R., Fredricks, H.F., Shock, E.L., Hinrichs, K.-U., and Summons, R.E. (2011) The lipid and isotopic compositions of streamer biofilm communities in the Lower Geyser Basin of Yellowstone National Park. *Environmental Microbiology* (submitted).

McCollom, T.M. and Shock, E.L. (1997) Geochemical constraints on chemolithoautotrophic metabolism by microorganisms in seafloor hydrothermal systems. *Geochim. Cosmochim. Acta* **61**, 4375-4391.

McCollom, T.M., and Shock, E.L. (1998) Fluid-rock interactions in the lower oceanic crust: Thermodynamic models of hydrothermal alteration. *Jour. Geophys. Res.* **103**, 547-575.

Vick T.J., Dodsworth J.A., Costa K.C., Shock E.L., and Hedlund B.P. (2010) Microbiology and geochemistry of Little Hot Creek, a hot spring environment in Long Valley Caldera. *Geobiology* **8**, 140-154.

Wetzel, L.R. and Shock, E.L. (2000) Distinguishing ultramafic- from basalt-hosted submarine hydrothermal systems by comparing calculated vent fluid compositions. *Jour. Geophys. Res.* **105**, 8319-8340.

Synergistic Activities

- Development of thermodynamic databases for aqueous organic and inorganic species that are freely distributed over the internet, and used around the world.
- Application of High-Resolution Inductively-Coupled Plasma Mass Spectrometry (HR-ICP-MS) to trace element studies of natural and human-impacted water resources, hydrothermal fluids, petroleum, and soils.
- Director of field research on hydrothermal ecosystems at Yellowstone National Park involving scientists from Arizona State University, Washington University, University of New Mexico, Yale, Stanford, MIT, University of Colorado, Carleton College, University of Waikato, McMaster University, Lawrence Livermore National Lab, Woods Hole Oceanographic Institution, University of North Carolina, University of Nevada-Las Vegas, NASA-Ames, University of Illinois-Chicago, Montana State University, University of Oslo, and Universidad Nacional Autónoma de México.
- Editorial Board of *Geofluids* (1999-2003), *Earth and Planetary Science Letters* (2001-2007) and *Geochemistry, Geophysics, Geosystems* (1999 - 2005).
- Collection Editor, AGU's *Biogeoscience Editor's Choice* journal (2002-2005).

Collaborators & Other Affiliations

Jan Amend (Wash. U.), Ariel Anbar (ASU), Steve Desch (ASU), Jeremy Dodsworth (UNLV), Katrina Edwards (USC), James Elser (ASU), Tobias Fischer (U. New Mexico), Ian Gould (ASU), Nancy Grimm (ASU), Hilairy Hartnett (ASU), Brian Hedlund (UNLV), Melanie Holland (Geotek), John Holloway (ASU), D'Arcy Meyer-Dombard (U. Ill. Chicago), John Moreau (U. Melbourne), Sandra Pizzarello (ASU), Panjai Prapaipong (ASU), Jason Raymond (UC Merced/ASU), Paul Westerhoff (ASU), Lynda Williams (ASU), Hongyu Yu (ASU), Chuanlun Zhang (U Georgia), Natalya Zolotova (ASU).

PhD Advisor: Harold C. Helgeson (UC Berkeley; deceased) *Postdoctoral Advisor:* none

Graduate Advisees: David Sassani (PhD, 1992, Golder Associates); Marc Willis (MS, 1993, Fullerton College); Tom McCollom (PhD, 1996, U. Colorado); Laura Wetzel (PhD, 1997, Eckerd College); Mitch Schulte (PhD, 1997, U. Missouri); Laura Griffith (PhD, 1998, US Navy); Panjai Prapaipong (PhD, 2001; ASU); Samantha Fernandes (MS, 2002; consulting); D'Arcy Meyer-Dombard (PhD, 2004, U. Ill. Chicago); Jennifer Smith (MS, 2006, Dugway Data Services Team); Brandon McLean (MS, 2007, HydroSystems, Inc.); Jeff Havig (PhD, 2009, ASU); Todd Windman (PhD, 2010, ASU); Tracy Lund (MS, 2010, SESE); Xiaoding Zhuo (PhD, 2010, C&B); Chris Glein (PhD, current, SESE); Peter Canovas (PhD, current, SESE); Ziming Yang (PhD, current, C&B); Kris Fecteau (PhD, current, C&B); Brian St. Clair (PhD, current, ELS); Grayson Boyer (PhD, current, C&B); Kirt Robinson (PhD, current, C&B); Kristin Johnson (PhD, current, C&B).

Post-doctoral Advisees: David Sassani (Golder Associates), Johnson Haas (U. Western Michigan), Jan Amend (Washington University), Mikhail Zolotov (ASU), Andrey Plyasunov, Melanie Holland (Geotek), Natalya Plyasunova, Jenny Cox, Florian Schwandner (Colorado State University), Jeffrey Dick (ASU), Jeff Havig (ASU).

Totals: Masters: 5; PhD: 18; Post-docs: 11.

ERIC L. SONNENTHAL, Ph.D.

Professional Preparation

Pennsylvania State University	B.S. Geosciences, Geochemistry option, 1982
University of Oregon	Ph.D. Geological Sciences, 1990
Indiana University	Postdoctoral Fellow, Geochemistry, 1990-1993
French Institute of Petroleum	Postdoctoral Scientist, Geochemistry, 1993-1994

Appointments

Associate Researcher, University of California at Berkeley, Earth and Planetary Science, 2009-present.

Staff Geological Scientist**,** Lawrence Berkeley National Laboratory, Earth Sciences Division, 2004–present.

Geological Scientist**,** Lawrence Berkeley National Laboratory, Earth Sciences Division, 1996-2004.

Visiting Instructor, Department of Geological Sciences, University of Oregon, 1995.

Publications (Five Most Closely Related)

Mukhopadhyay, S., E.L. Sonnenthal, and N. Spycher, 2009. *Modeling of coupled heat transfer and reactive transport processes in porous medium: Application to seepage studies at Yucca Mountain, Nevada*. Journal of Porous Media 12:725-748.

Xu, T., E. Sonnenthal, N. Spycher, and K. Pruess, 2006. *TOUGHREACT: A simulation program for non-isothermal multiphase reactive geochemical transport in variably saturated geologic media: Applications to geothermal injectivity and CO_2 geological sequestration.* Computers & Geosciences. 32:145-156.

Sonnenthal, E., A. Ito, N. Spycher, M. Yui, J. Apps, Y. Sugita, M. Conrad, and S. Kawakami, 2005. *Approaches to modeling coupled thermal, hydrological, and chemical processes in the Drift Scale Heater Test at Yucca Mountain*. International Journal of Rock Mechanics and Mining Sciences, 42:698-719.

Sonnenthal, E.L. and A.R. McBirney, 1998. *The Skaergaard Layered Series. Part IV. Reaction-transport simulations of foundered blocks*. Journal of Petrology, 39(4): 633-661.

Sonnenthal, E.L., 1992. *Geochemistry of dendritic anorthosites and associated pegmatites in the Skaergaard Intrusion, East Greenland: Evidence for metasomatism by a chlorine-rich fluid*. Journal of Volcanology and Geothermal Research, 52: 209-230.

Publications (Five Other Significant)

Hazen T.C., E.A. Dubinsky, T.Z. DeSantis, G.L. Andersen, Y.M. Piceno, N. Singh, J.R. Jansson, A. Probst, S.E. Borglin, J. L. Fortney, W. T. Stringfellow, M. Bill, M.S. Conrad, L.M. Tom, K.L. Chavarria, T.R. Alusi, R. Lamendella, D.C. Joyner, C. Spier, J. Baelum, M. Auer, M. L. Zemla, R. Chakraborty, E.L. Sonnenthal, P. D'haeseleer, H-Y. N. Holman, S. Osman, Z. Lu, J.D. Van Nostrand, Y. Deng, J. Zhou, and O.U. Mason**,** 2010**.** *Deep-sea oil plume enriches indigenous oil-degrading bacteria.* Science [DOI: 10.1126/science.1195979].

Zhang, G., N. Spycher, E. Sonnenthal, C. Steefel, and T. Xu, 2008. *Modeling reactive multiphase flow and transport of concentrated solutions*. Nuclear Technology, 164:180-195.

Spycher, N., E. Sonnenthal, and J. Apps, 2003. *Prediction of fluid flow and reactive transport around potential nuclear waste emplacement tunnels at Yucca Mountain, Nevada*. Journal of Contaminant Hydrology, 62-63: 653-673.

Xu, T., E. Sonnenthal, N. Spycher, K. Pruess, G. Brimhall, and J.A. Apps, 2001. *Modeling multiphase fluid flow and reactive geochemical transport in variably saturated fractured rocks: 2. Applications to supergene copper enrichment and hydrothermal flows*. American Journal of Science, 301: 34-59.

Sonnenthal, E.L. and G.S. Bodvarsson, 1999. *Constraints on the hydrology of the unsaturated zone and infiltration at Yucca Mountain, Nevada from three-dimensional*

models of chloride and strontium geochemistry, Journal of Contaminant Hydrology, 38: 107-156.

Synergistic Activities

Lead PI for NSF Project "Collaborative Research: Coupled Thermal-Hydrological-Mechanical-Chemical-Biological Experimental Facility at DUSEL Homestake". 2009-2012.

PI for DOE geothermal projects to develop and apply coupled THMC codes. 2009-2012

TOUGHREACT Training courses (2007, 2008, 2009).

TOUGHREACT Reaction-transport code co-developer (Xu, T., E. Sonnenthal, N. Spycher, and K. Pruess). Second most requested code in Dept. of Energy Software Center, and widely used internationally in universities, national laboratories, and industry.

Working Group Leader – Deep Underground Science and Science and Engineering Laboratory Induced Flow, Transport, and Activity, (2004-2006, 2008)

International DECOVALEX-THMC Project: Coupled Thermal-Hydrological-Mechanical-Chemical processes, Lead for THC tasks, 2005-2007.

Collaborators & Other Affiliations

Collaborators and Co-authors: A.S. Almgren (LBNL), T.R. Alusi (LBNL), C. Anderson (Black Hills State), G.L. Andersen (LBNL), E.S.P. Aradottir (U. Iceland/Reykjavik Energy), M. Auer (LBNL), J. Baelum (LBNL), S. Bang (SDSM&T), J.B. Bell (LBNL), H. Beller (LBNL), M. Bill (LBNL), J. Birkholzer (LBNL), G. Bjornsson, S.E. Borglin (LBNL), D.F Boutt (U. Mass), E. Brodie (LBNL), S. Brown (LBNL), R. Chakraborty (LBNL), K.L. Chavarria (LBNL), J. Christensen (LBNL), M. Conrad (LBNL), P. Cushman (U. Minn), Y. Deng (U. Oklahoma), D. DePaolo (UC Berkeley/LBNL), P. D'haeseleer, T.Z. DeSantis (LBNL), P. Dobson (LBNL), C. Doughty (LBNL), E.A. Dubinsky (LBNL), J. Druhan (UC Berkeley), S. Elliot (LANL), D. Elsworth (Penn State Univ.), C. Fairhurst (U. Minn), B. Faybishenko (LBNL), S. Finsterle (LBNL), J.L. Fortney (LBNL), B.M. Freifeld (LBNL), L. Germanovich (Georgia Tech), S.D. Glaser (UC Berkeley), E. Gunnlaugsson (Reykjavik Energy), I. Gupta (Chevron), H-Y. N. Holman (LBNL), S. Hubbard (LBNL), J.R. Jansson (LBNL), G. Jones (Chevron), H. Jonsson (U. Iceland), D.C. Joyner (LBNL), M. Kennedy (LBNL), T. Kieft (New Mexico Tech) R. Lamendella (LBNL), D. Leitner (LBNL), K. Lesko (UC Berkeley), M.J. Lijewski (LBNL), P. Long (PNNL), H.H. Liu (LBNL), R.P. Lowell (Virginia Tech), Z. Lu (U. Oklahoma), A.R. McBirney (Univ. of Oregon), K. Maher (Stanford), B.J. Mailloux (Barnard), O. Mason (LBNL), G. Moridis (LBNL), S. Mukhopadhyay (LBNL), L.C. Murdoch (Clemson), S. Nakagawa (LBNL), T.C. Onstott (Princeton), S. Osman (LBNL), G.S.H. Pau (LBNL), C.A. Peters (Princeton), Y.M. Piceno (LBNL), A. Probst (LBNL), K. Pruess (LBNL), W. Roggenthen (SDSM&T), J. Rutqvist (LBNL), N. Singh (LBNL), H. Sobel (UC Irvine), C. Spier (U. Pacific), N. Spycher (LBNL), C. Steefel (LBNL), L.D. Stetler (SDSM&T), W. Stringfellow (U. Pacific/LBNL), J. Taron (Leipzig), L. Tom (LBNL), N. Uzunlar (SDSM&T), J.D. Van Nostrand (U. Oklahoma), T. Xu (LBNL), H.F. Wang (U. Wisconsin), J.S. Wang (LBNL), K.H. Williams (LBNL), M.L. Zemla (LBNL), G. Zhang (Shell Research), L. Zheng (LBNL), J. Zhou (LBNL/U. Oklahoma)

Graduate Advisors and Postdoctoral Sponsors:
Ph.D. advisor: A.R. McBirney, Univ. of Oregon
Postdoctoral Sponsor: E. Brosse, French Institute of Petroleum.
Postdoctoral Sponsor: P. Ortoleva, Indiana Univ.

Thesis Advisor (1) and Postgraduate Sponsor (1)
Edda Arradottir, 2007-present. Ph.D. student. University of Iceland.
Jihoon Kim, 2010-present. Postdoctoral Fellow, Lawrence Berkeley National Laboratory.

BIOGRAPHICAL SKETCH

DAMON A.H. TEAGLE

CURRENT POSITION: (since September, 2007)

Professor of Geochemistry, School of Ocean and Earth Science,
National Oceanography Centre Southampton, University of Southampton, SO14-3ZH, UK.

POSTS HELD:

2006-2009 Co-Chair NOCS Geochemistry Research Group
2004-2007 University Reader, University of Southampton
1999-2004 University Lecturer, University of Southampton
1997-1999 Assistant Research Scientist, Dept. Geological Sciences, Univ. Michigan
1993-1997 Post-doctoral Research Fellow, Dept. Geological Sciences, Univ. Michigan

DEGREES:

1993: Ph.D., Earth Sciences, University of Cambridge, UK.
1987: M.Sc. (with Distinction), Geology, University of Otago, New Zealand
1985: B.Sc. (Hons.), Geology, University of Otago, New Zealand

PHD EXAMINER:

University of Southampton, University of Cambridge, University of Leicester, CRPG-Nancy

SHIPBOARD/OCEAN DRILLING EXPERIENCE AND SERVICE; OTHER EXPEDITIONS

Co-Chief Scientist, IODP Expedition 335 – Superfast 4 (Apl-Jun, 2010)
Member – Scientific Ocean Drilling renewal – Science Plan Working Committee.
Theme Co-Chair, IODP-INVEST Meeting Bremen, Sept, 2009. "Earth System Dynamics, Reservoirs and Fluxes"
Lecturer – ECORD Summer School on "Slow Spreading Ridges", Bremen, Sept 2009
Convener: InterRIDGE-IODP Workshop – Melting, Magma, Fluids, Life, July 2009
Co-Chair: Science Working Group 2b "Beyond 2013 - the Future of European Scientific Drilling Research" – ECORD/ESSAC Workshop, Vienna, Apr 2009
Convener: Special Session, "Formation & Evolution of Ocean Crust", AGU, San Francisco, Dec, 08
Co-I RRS *James Cook* JC021 – Hess Deep Site Survey, Jan-Feb, 2008
Co-I RRS *James Cook* JC018 – Monserrat – Ash-Seawater Interactions, Dec, 2007
Petrologist, IODP Expedition 312, Superfast 3
Co-chief Scientist on IODP Expedition 309, Superfast 2
2004-2009: Editor: G-Cubed Special Theme – "Formation & Evolution of the Ocean Crust"
2003 Leader – Australian Antarctic Division Project #2327 "Hydrothermal alteration of Macquarie Island", 55th Australian National Antarctic Research Expedition
Co-chief Scientist on ODP Leg 206 Superfast Spreading Rate Crust
2000 – 2006: UK representative on ODP/IODP Science Steering Evaluation Panel
2000 – 2006: UK-ODP/IODP Steering and Peer-review Committee
Petrologist: ODP Leg 183, Kerguelen Plateau, 169, Sedimented Ridges II, 163, SE Greenland Margin, 148, Costa Rica Rift.

PROFESSIONAL SOCIETIES:

American Geophysical Union, Geoscience Society of New Zealand, Member of the Royal Society of New Zealand (MRSNZ).

RESEARCH INTERESTS:

Hydrothermal alteration in mid-ocean ridges and ophiolites; Modeling of fluid-rock tracer exchange; Global chemical cycles; Radiogenic isotope and trace element analysis; Active analogs of ore mineralization; Metamorphogenic gold deposits.

AWARDS, PRIZES AND SCHOLARSHIPS:

2009 Excellence in Reviewing Citation – AGU – G-cubed, Tarduno, Ed., EOS 90(28) 14 July
2008 Roy. Soc. NZ: International Science & Technology (ISAT) Linkages Exchange.
1995 Sokol Postdoctoral Fellowship, University of Michigan.
1991 Cambridge Philosophical Society Research Studentship.
1988 William Georgetti Scholarship for Social, Cultural & Economic Development of NZ
1988 Commonwealth Scholarship (Cambridge).
1987 Kendall Postgraduate Bursary of Science, Churchill College, Cambridge.
1987 Cambridge Commonwealth Trust Overseas Student Bursary.
1986 James Park Scholarship in Economic Geology (University of Otago).

SELECTED RECENT PUBLICATIONS

Bickle, M.J., Pälike, H., and **Teagle**, D.A.H., Continued collaboration in scientific ocean drilling is an essential component of UK Earth and environmental research (and a proven investment) Nature Geoscience, *In review*

Teagle, D.A.H, Ildefonse, B., and Blum, P., 2010. Superfast spreading rate crust 4. *IODP Sci. Prosp.,* 335. doi:10.2204/iodp.sp.335.2010

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Research Papers 2011 to 1990

Tominaga, M. and Umino, S., 2010. Lava deposition history in ODP Hole 1256D: Insights from log-based volcanostratigraphy. *Geochem. Geophys. Geosyst*, Q05003, doi: 10.1029/2009GC002933. (2010.5.11)
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Umino, S. and Kushiro, I., 1989. Experimental studies on boninite petrogenesis. *In* A. Crawford (ed.), *Boninites and Related Rocks*, 89 - 111.

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Education

Carnegie Institution of Washington	Postdoctoral Research, Geochemistry	2008-2010
MIT/WHOI Joint Program	Ph.D., Geochemistry and Geophysics	2007
University of Cambridge	M.A., Natural Sciences	2003
University of Cambridge	M.Sci., Earth Sciences	2000
University of Cambridge	B.A., Natural Sciences	1999

Academic Appointments

2010-present	*Assistant Professor*, Stanford University
2008-present	*Guest Investigator*, Woods Hole Oceanographic Institution
2008-2010	*Postdoctoral Fellow*, Carnegie Institution of Washington
2007	*Postdoctoral Investigator*, Woods Hole Oceanographic Institution
2005-2006	*COE-21 Collaborative Researcher*, Okayama University at Misasa
2001-2007	*Graduate Research Assistant*, MIT/WHOI Joint Program

Five Publications Related to Proposed Research:

Warren, J. M. and N. Shimizu (2010). Cryptic Variations in Abyssal Peridotite Composition: Evidence for Recent Melt-Rock Reaction at the Ridge, Journal of Petrology, 51(1-2), 395-423.

Dick, H. J. B., C. J. Lissenberg and J. M. Warren (2010). Mantle Melting, Melt Transport, and Delivery Beneath a Slow-Spreading Ridge: The Paleo-MAR from 23°15'N to 23°N, Journal of Petrology, 51(1-2), 425-467.

Warren, J.M., N. Shimizu, C. Sakaguchi, H.J.B. Dick, and E. Nakamura (2009). An assessment of upper mantle heterogeneity based on abyssal peridotite isotopic compositions, Journal of Geophysical Research, J. Geophys. Res., 114, B12203, doi:10.1029/2008JB006186.

Warren, J.M., N. Shimizu and H.J.B. Dick, 2009. Causes and Consequences of Mantle Heterogeneity From Observations of Abyssal Peridotites, Eos Trans. AGU, 89(53), Fall Meet. Suppl., V43B-2162.

Dantas, C., G. Ceuleneer, M. Gregoire, M. Python, R. Freydier, J.M. Warren, and H.J.B. Dick, 2007. Pyroxenites from the Southwest Indian Ridge, 9-16°E: Cumulates from Incremental Melt Fractions Produced at the Top of a Cold Melting Regime, Journal of Petrology, 48(4), 647-660.

Five Additional Publications

Skemer, P., J. M. Warren, P. B. Kelemen, and G. Hirth (2010). Microstructural and rheological evolution of a mantle shear zone, Journal of Petrology, in press.

Kurz, M. D., J. M. Warren and J. Curtice (2009). Mantle deformation and noble gases: helium and neon in oceanic mylonites, Chemical Geology, 266, 10-18.

Warren, J.M., G. Hirth and P. B. Kelemen (2008). Evolution of olivine lattice preferred orientation during simple shear in the mantle, Earth and Planetary Science Letters, 272, 501-512.

Courtier, A. M., M. G. Jackson, J. F. Lawrence, Z. Wang, C.-T. A. Lee, R. Halama, J. M. Warren, R. Workman, W. Xu, M. M. Hirschmann, A. M. Larson, S. R. Hart, C. Lithgow-Bertelloni, L. Stixrude, W.-P. Chen (2007). Correlation of seismic and petrologic

thermometers suggests deep thermal anomalies beneath hotspots, Earth and Planetary Science Letters, 264, 308-316.

Warren, J.M. and G. Hirth (2006). Grain Size Sensitive Deformation Mechanisms in Naturally Deformed Peridotites, Earth and Planetary Science Letters 248, 423-435.

Synergistic Activities:
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MIT/WHOI Joint Program, Teaching Asst. for *Intro. to Marine Geology and Geophysics*, 2004;
MIT, Department of Earth, Atmospheric and Planetary Sciences, Mentor, *EAPS Graduate Student Mentoring program*, 2004-2006;
Special Exhibit Curator, *Volcano Watch: Maurice and Katia Krafft and the Smithsonian*, National Museum of Natural History, 1997.
(ii) Service:
Council member for the Geological Society of Washington, 2009;
Representative to the Carnegie Institution of Washington Library Committee, 2009;
MIT/WHOI Joint Program Representative to the Educational Assembly, 2003-2004.
(iii) Reviewer:
Proposal reviewer for the National Science Foundation and InterRidge, 2008-present;
Manuscript reviewer for *Nature, Nature Geoscience, Contributions to Mineralogy and Petrology*, *Earth and Planetary Science Letters*, *Journal of Petrology*, 2002-present.
(iv) American Geophysical Union:
Co-convener, VGP Special Session, *Using Small-Scale Observations to Answer Big Questions in Earth Sciences: Advances From 30 Years of Ion Microprobe Analysis*, 2009 Fall Meeting;
Co-convenor, VGP Special Session, *Origin and Evolution of Continents: Lithospheric and Asthenospheric Perspectives*, 2007 Fall Meeting.
(v) Workshops:
DCO Workshop on Reaching the Mantle Frontier, 2010;
MARGINS Theoretical and Experimental Institute: Volatiles in the Subduction Factory, 2009;
CIDER Community Workshop, 2009; Marine Geoscience Leadership Symposium, 2009;
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- Woods Hole Oceanographic Institution, Marine Geophysics, Postdoc 1998

Appointments

- **Assistant Professor**
  University of Maryland College Park 2007-present
- **Assistant and Associate Scientist**
  Woods Hole Oceanographic Institution 1999-2007
- **Research Affiliate**
  Massachusetts Institute of Technology 1997-present
- **Research Affiliate**
  State University of New York at Stony Brook 2005-2008

Honors and Fellowships

- **Best Research Paper in Basic Research in Rock Mechanics**
  American Rock Mechanics Association (ARMA) 2007
- **Claudia S. Heyman Fellow**
  Deep Ocean Exploration Institute, WHOI 2006
- **J. Sewald Johnson Postdoctoral Fellowship**
  Woods Hole Oceanographic Institution 1997
- **Outstanding Student Award**
  Mineral and Rock Physics, American Geophysical Union 1997
- **Best Teaching Assistant Award**
  Department of Earth and Space Sciences, SUNY at Stony Brook 1992

Five Most Relevant Publications

Zhu, W., Gaetani, G., Fusseis, F., Montesi, L. and De Carlo, F. (2010), Microtomography of partially molten rocks: three-dimensional melt distribution in mantle peridotite, in review, Science.

Walsh, J. and Zhu, W. (2010) On the stability of frictional sliding: A view from viscoelastic energy dissipation, in revision, Geophysical Journal International.

Chen, T.-m., Zhu, W., Wong, T.-f. and Song, S. (2009) Laboratory Characterization of Permeability and Its Anisotropy of Chelungpu Fault Rocks. Pure and Applied Geophysics, DOI 10.1007/s00024-009-0497-y.

Zhu, W., Montési, L. and Wong, T.-f. (2007) A probabilistic damage model of stress-induced permeability anisotropy during cataclastic flow, Journal of Geophysical Research, 112, B10207, doi:10.1029/2006JB004456.

Tembe, S., Vajdova, V., Baud, P., Zhu, W. and Wong, T.-f. (2007) Compactive yield behavior of two porous sandstones under undrained condition, Mechanics of Materials, 39, 513-523.

Five Other Publications

Schouten, H., Smith, D.K., Zhu, W., Montési, L. and Klein, E.M. (2008) Cracking of lithosphere north of the Galapagos triple junction. Geology, 36, 339-342.

Zhu, W., Tivey, M.K., Gittings, H. and Craddock, P.R. (2007) Permeability-porosity relationships in seafloor vent deposits: Dependence on pore evolution processes, Journal of Geophysical Research, 112, B05208, doi:10.1029/2006JB004716.

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Zhu, W. and Hirth, G. (2003) A network model for permeability in partially molten rocks, *Earth Planetary Science Letters*, 212, 407-416.

Synergistic & Educational Activities

- Associate Editor, Journal of Geophysical Research--Solid Earth, 2008-2011
- Visiting Professor, Universite of Cergy-Pontoise, France, 2009
- WHOI's Summer Student Fellowship Program Committee, 2005-2007
- Featured Scientist at http://www.womenoceanographers.org, an education website to engage the public and school children in the day-to-day lives of women working in marine science, 2000

Collaborators and Other Affliations

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