

*Deep Carbon Cycle Conference
Beijing, China, April 22-24, 2010*

The Deep Carbon Observatory



Connie Bertka

Program Director

Deep Carbon Observatory Secretariat

Geophysical Laboratory, CIW



- Achieving transformational understanding of carbon's chemical and biological roles in Earth's interior
- Multi-disciplinary, international decade long effort
 - stable funding provided by Sloan Foundation
- Example of proposed scope
 - Census of Marine Life

DCO - *History*



➔ Alfred P. Sloan Foundation – March 2007



↪ The Deep Carbon Cycle: A Proposal for
Interdisciplinary Study – July 2007

↪ Deep Carbon Cycle Workshop – May 2008
Broad Branch Road Campus, CIW

↪ The Deep Carbon Observatory – July 2009
3 years , \$4 million

↪ DCO Secretariat – Sept. 2009
Geophysical Laboratory, CIW

DCO - *Secretariat*



Robert M. Hazen, *Principal Investigator*

Russell J. Hemley, *Co-Principal Investigator*

Constance M. Bertka, *Program Director*

Lauren Cryan, *Program Assistant*



Carnegie Institution of
Washington

Geophysical Laboratory

DCO *Founders Committee*



John Baross, University of Washington, USA

Taras Bryndzia, Shell Oil Company, USA

Rixiang Zhu, Chinese Academy of Science, China (Yingwei Fei, CIW, USA)

Vincent Courtillot, Institut de Physique du Globe de Paris, France (Claude Jaupart)

Adrian Jones, University College London, UK

Barbara Sherwood Lollar, University of Toronto, Canada

Eiji Ohtani, Tohoku University, Japan

Sergei Stishov, Russian Academy of Sciences, Russia



*Front Row - Adrian Jones, Connie Bertka, Taras Bryndzia, Barbara Sherwood Lollar, Robert Hazen
Back Row - John Baross, Sergei Stishov, Russell Hemley, Eiji Ohtani, Yingwei Fei, Claude Jaupart*

DCO *Organization*



Executive Committee



Science Directorates



Deep Carbon
Reservoirs and
Fluxes



Deep Life



Energy,
Environment and
Climate



Science Teams

Decadal Questions

Show me the Carbon



Carbonaceous Chondrites
Range in the Earth

3.2 wt%

0.1 to 1.5 wt%



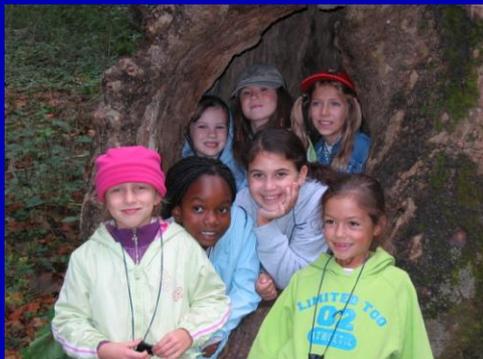
Crust 200 ppm



Atmosphere CO₂
380 ppm
Vegetation



Ocean 50x atmosphere
Oil and Gas 10x atmosphere



Deep Carbon Reservoirs and Fluxes

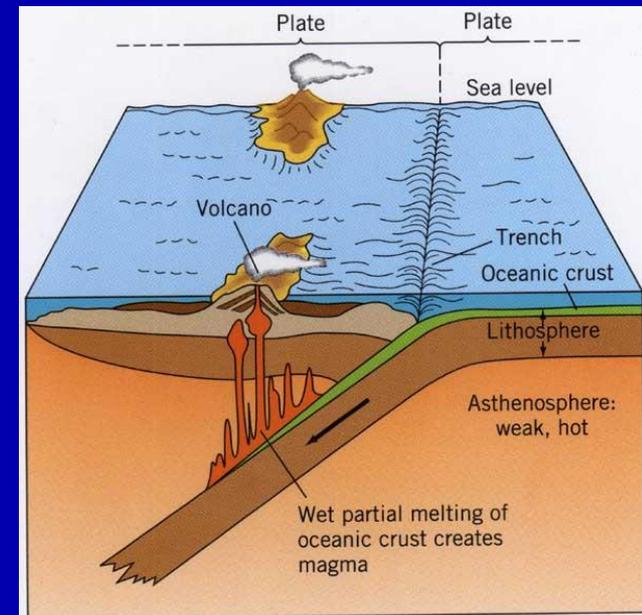


Workshop - AGU December 13, 2009

Co-chairs - Erik Hauri (Carnegie) and Bernard Marty (Centre de Recherches Petrographiques et Geochimiques)

Goal: To advance understanding of the deep-Earth cycling of abiotic carbon from atomic to global scales

- (1) What are the pathways of carbon exchange between the surface and deep Earth, and what are the fluxes along those pathways?
- (2) What is the chemical form of carbon in the deep Earth?
- (3) How variable is the carbon abundance of the Earth's interior?
- (4) How rapidly does carbon exchange between the surface, mantle and core – and how are the surficial and deep carbon cycles linked?
- (5) What are the interactions between the deep carbon cycle and the dynamics of the Earth's interior?
- (6) What is the ultimate origin of Earth's carbon?





Path Forward

(1) Coordinated, field based, global sampling effort to observe Earth's deep carbon

- **acquire global data for sediment thickness and the carbon content of subducting sediment and ocean crust**
- **carbon data on existing drill cores and more drilling**
- **ground-based measurement of carbon fluxes through the crust and from volcanoes**
- **analyze existing volcanic glasses from mid-ocean ridge system and collect and analyze magmatic melt inclusions in volcanic rocks**
- **routine measurement of geochemical proxies for carbon**
- **study ancient subduction environments and volcanic systems over a range of geologic ages**



Path Forward

(2) Dedicated program of laboratory experiments and targeted analytical methodology to understand behavior of deep carbon

- **determine P-T stability limits of carbon-bearing compounds in equilibrium with deep Earth minerals, the molten iron of the Earth's outer core, and the solid iron of the inner core**
- **explore speciation and solubility of carbon in common mantle minerals, fluids and melts**
- **determine effects of carbonaceous phases and carbonate melts on the rheology of mantle rocks**
- **analyze isotopic composition of carbon in mantle derived samples in conjunction with complementary stable isotope and noble gas measurements**



Path Forward

(3) Build a coherent interdisciplinary community of researchers

- **field-based studies and sampling efforts linked with physical chemistry and materials efforts**
- **encourage linkage of deep-Earth and shallow carbon research through meetings and workshops**



Deep Life

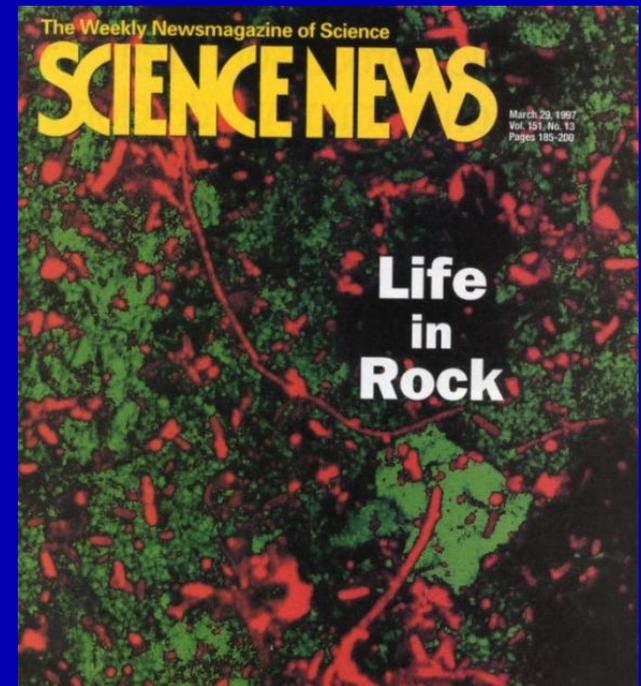
Workshop – Catalina CA, March 16-17, 2010



Co-chairs – Mitchell Sogin (Woods Hole), Katrina Edwards (University of Southern California) and Steve D'Hondt (University of Rhode Island)

Goal: To advance understanding of the inner limits of our planet's life process and the role of deep life in controlling biogeochemical processes and climate on the surface

- (1) How does life grow, persist and evolve in the deep subsurface?
- (2) How can increased understanding of subsurface microbial cell biology and genetics advance large scale questions of ecology, evolution, diversity, biogeography, biogeochemical cycles and climate?
- (3) How does microbial activity in subsurface environments play a role in the cycling of carbon and other elements between deep and shallow environments on Earth?





Path Forward

(1) Locate and characterize diverse subsurface communities in a range of globally distributed geological settings

- **begin with substantial collections of existing continental and marine subsurface samples for meta-analyses of microbial population structures**
- **select new field sites based on opportunities to sample key locations identified in a global survey of pertinent locations**



Path Forward

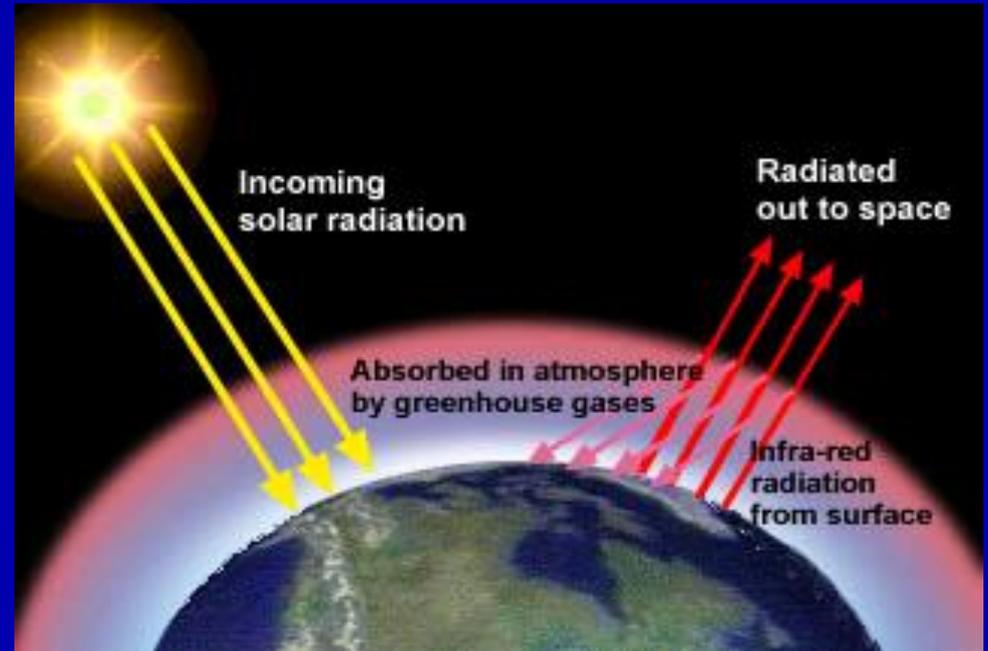
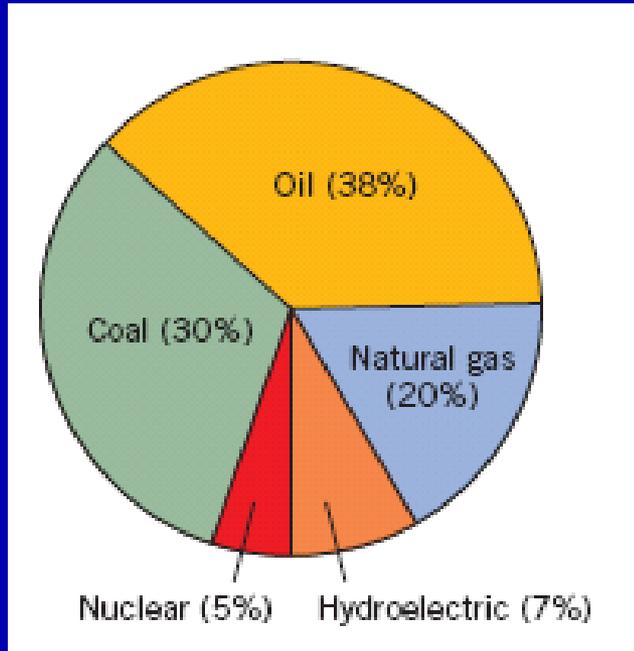
(2) Organize and coordinate field sampling campaigns insitu measurements and experiments with complementary laboratory experiments

- **integrate cultivation-independent, genomic approaches with physiological and biochemical studies made possible through the isolation and growth of microorganisms in the laboratory**
- **develop technology to obtain high-quality clean samples for laboratory investigations and cultivation attempts; to characterize in situ chemical and physical conditions; to detect low density populations and low rates of activities**



(3) Invest in detailed chemical and isotopic characterization of subsurface environments. Constrain the response of physiological diversity and community structure to variations in carbon, nutrients, and transition metals, composition and flux.

- **focus research efforts towards understanding the full range of elements and chemical speciation necessary to support life in the deep subsurface, their availability, and the processes that regulate their abundance**
- **characterize chemical context of subsurface environments and assess operant metabolic strategies that may take advantage of available energy sources**
- **identify and characterize the biotic fringe (limit of life in subsurface)**
- **identify fluxes of both thermogenically and biologically mediated carbon compounds within the deep biosphere**



How does the deep carbon cycle interact with the near surface carbon cycle?

Energy, Environment and Climate



Workshop - Houston, TX July 2010

*Co-chairs – Detlef Hohl (Shell Global Solutions (US), Inc.) and
Christian Mailhot (Lawrence Livermore National Lab)*

Focus on deep chemistry and physics

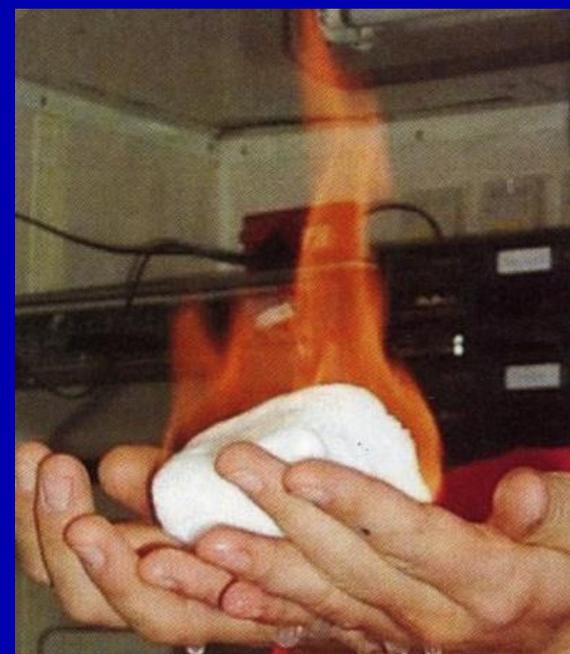
-Materials modeling

- C/H Isotope signatures

**- High P/T experimental facilities and
instrumentation**

-Deep organic synthesis

-Abiogenic hydrocarbons



Methane Clathrates

Numerous Workshops, Conferences and Symposia have taken place or are planned



- Deep Carbon Cycle Conference, Carnegie Institution (CI) (May 2008)*
- Ultra-Carbon Microscope Workshop (Sept. 2008)*
- Next Generation Tandem Mass Spectrometer Workshop (Sept. 2008)*
- Deep Earth Carbon Interface with Microbial Activity Limits, CI (Oct. 2008)*
- Deep Earth Carbon Abundance and Distribution Experiment CI (Oct.2008)*
- Carbon Day - Shell Oil, CIW (Nov. 2009)*
- Origin of Life Gordon Conference, Deep Carbon Cycle (Jan. 2010)*
- Integrated Ocean Drilling Program, Science Advisory Meeting (Jan. 2010)*
- Geochemistry Group Meeting, Carbon System Science, London (March, 2010)*
- Deep Carbon Cycle International Conference, Beijing, China (April 2010)*
- European Geophysical Union, New Insights into the Deep Earth (May 2010)*
- Japan Geoscience Union Meeting, Deep Carbon Cycle, (May 2010)*
- Goldschmidt, Fluid-Mineral Interactions in the Deep Crust and Mantle (June 2010)*
- Organic Geochemistry Gordon Conference, Deep Life (Aug. 2010)*
- Reaching the Mantle Frontier: MOHO and Beyond, IODP-DCO (Sept. 2010)*



Deep Carbon Observatory Website

<http://dco.ciw.edu>

