The History of Deep Carbon Science

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November 21, 2022

Abstract

Deep carbon is terrestrial carbon that is not in the atmosphere or oceans or on the surface. We have a great deal of knowledge about the properties of near surface carbon, but relatively little is known about the deep carbon cycle. The Deep Carbon Observatory, was founded in 2009, to address major questions about deep carbon. Where are the reservoirs of carbon? Is there significant carbon flux between the deep interior and the surface? What is deep microbial life? Did deep organic chemistry have a role in the origin of life? This project is directed toward documenting and describing of the history of deep carbon science. The narrative begins in 1601, when William Gilbert suggested that Earth's interior behaves like a giant bar magnet. We trace across three centuries the slow evolution of thought that led to the establishment of the interdisciplinary field of Earth System Science. The concept and then development of the deep carbon cycle of burial and exhumation dates back at least two hundred years. We identify and document the key discoveries of deep carbon science, and assess the impact of this new knowledge on geochemistry, geodynamics, and geobiology. A History of Deep Carbon Science is in preparation for publication by Cambridge University Press in 2019. Its illuminating narrative highlights the engaging human stories of many remarkable researchers who have discovered the complexity and dynamics of Earth's interior.

The History of Deep Carbon Science

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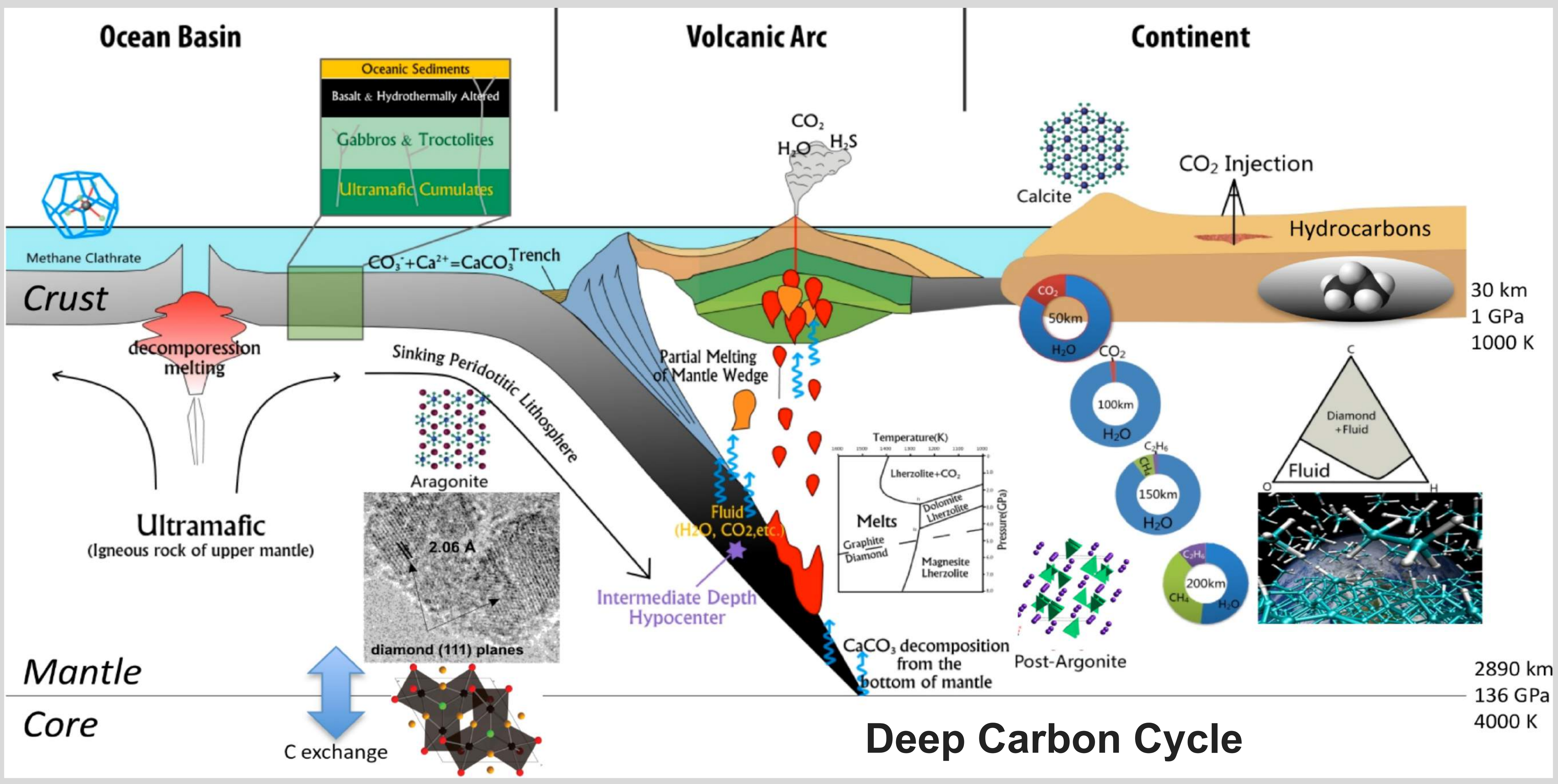
DEEP CARBON OBSERVATORY

What Did We Know Before 2009?

Carbon is the fourth most abundant element in the universe, the result of the explosive finale of the evolution of stars. We are stardust. We are organic life. We exist. Carbon is the basis of all life on this Earth. Carbon underpins the health and sustainability of that life.

Deep carbon is the terrestrial carbon that is not in the atmosphere, oceans, or on the surface. This book project is directed toward documenting and describing the history of deep carbon science. We trace across four centuries, discovering the slow evolution of Earth system science that helped lead to the the recognition of carbon as a key element. Key discoveries are identified, and the impact of this new knowledge on geochemistry, geodynamics, and geobiology is assessed.

The History of Deep Carbon Science will be published by Cambridge University Press in 2019. Its 300 pages of engaging narrative and many illustrations will highlight the human stories of remarkable researchers who have delved into the complexity and dynamics of Earth's interior and its carbon content.



The Deep Carbon Observatory (DCO)

"Carbon plays an unparalleled role in our lives. It is the element providing the chemical backbone for all essential biomolecules. Carbon-based fuels supply most of our energy, while small carbon-containing molecules in Earth's atmosphere play a major role in our variable and uncertain climate. Yet in spite of carbon's importance we remain largely ignorant of the physical, chemical, and biological behavior of the carbon-bearing systems more than a few hundred metres beneath our feet."- Robert Hazen, Director of the DCO, 2009

In short, our knowledge of deep carbon is seriously incomplete. To address this the Carnegie Institution of Washington, with funding from the Alfred P. Sloan Foundation, boldly launched a decade-long program, the Deep Carbon Observatory. The transformative science of this global research program has engaged a large community of scientists, biologists and physicists, geoscientists and chemists, and many others. Together they tackle four main themes:

Reservoirs & Fluxes

By identifying the deep reservoirs and their fluxes we can unlock many of the secrets of the deep carbon cycle. Research from authors such as McKenzie, Barnes, and Giggenbach has allowed for links between carbon emissions and volcanic and tectonic activity to be made, as well as giving insights into important cycling processes such as mantle convection. Deep Carbon Observatory aims to produce quantitative models of global carbon cycling at the planetary, tectonic and reservoir scales, as well as assessing the evolution of the cycle over time.

Extreme Physics & Chemistry

Deep Carbon is stored at extremely high temperatures and pressures, in planetary mantles and cores. Bridgman pioneered the application of high pressure physics to mineralogy, paving the way for investigations into the physical and chemical behaviour of different elements and compounds in extreme conditions. Using both theoretical and experimental approaches the Deep Carbon Observatory has been developing databases and simulations of deep carbon material properties and seeking new carbon bearing minerals.

Deep Life

Deep Life exerts a vital influence on Earth's elemental fluxes and reservoirs. This was recognised by pioneers such as Claude ZoBell the 'Father of Marine Microbiology' credited with discovering biofilms. The Deep Carbon Observatory continues to assess the abundance and diversity of the subsurface realm, The *Census of Deep Life* developed through DCO will help us find the environmental limits to deep life.

Deep Energy

Carbon-based fuels supply most of society's energy, whilst atmospheric carbon dioxide is the primary cause of climate change. We must understand more about these deep sources of energy if we are to continue to exploit them. Thomas Gold daringly proposed the deep gas hypothesis, suggesting fossil fuel formation via abiogenic processes and tectonic driven migration. The Deep Carbon Observatory uses observation and experimentation to quantify the environmental conditions and processes that control the origins, forms, quantities and movements of carbon, abiogenic hydrocarbons and organic compounds in the deep earth over geologic time.

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1. Who wrote (1542) the first textbooks on mineralogy and physical geology?

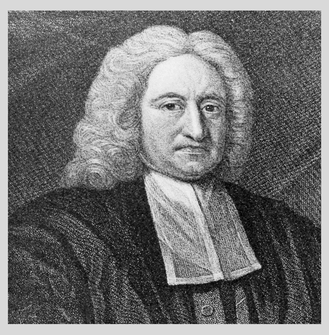
2. Who (1687) funded publication of *Principia Mathematica* when the Royal Society was close to bankruptcy?

3. Who was awarded both the Nobel Prize for Physics (1903) and the Nobel Prize for Chemistry (1911)?

4. Who was rescued (1908) in Greenland by a clergyman after having just eaten their last pony and dog?

5. Whose book (1913) begins: "It is perhaps a little indelicate to ask of our Mother Earth her age"?

6. Who fed numerous quarters into a stamp machine to send their paper (1967) on plate tectonics to Nature after finding the post office was closed?



7. Whose suggestion (1952) that the Mid Atlantic Ridge has a rift valley was "discounted as girl talk"?

8. Who was banned (1954) from the Mount Wilson Observatory, where the all-male dormitory was known as the monastery?

9. Who described (1964) the Vine-Matthews hypothesis as "a fruitful idea"?

10. Who suggested (1992) that microbial life is widespread in Earth's porous crust?

(1) Georgius Agricola (2) Edmond Halley (3) Marie Curie (4) Alfred Wegener (5) Arthur Holmes (6) Maurice Ewing (7) Marie Tharpe (8) Margaret Burbidge (9) Harry Hess (10) Thomas Gold

Acknowledgements

The generous support of the Alfred P Sloan Foundation through its Public Understanding of Science book program is gratefully acknowledged. Members of the DCO Synthesis Group 2019 are warmly thanked for their advice and encouragement. Simon Mitton thanks Marie Edmonds for initiating this project and providing direction on its fulfillment.