Endolithic anaerobic methane oxidation at cold seeps

JEFFREY J. MARLOW*, JOSHUA STEELE AND VICTORIA J. ORPHAN

California Institute of Technology, MC 100-23, 1200 E. California Blvd., Pasadena, CA 91125 (*correspondence: jjmarlow@caltech.edu)

The anaerobic oxidation of methane (AOM) at deep sea cold seeps has been the target of much work over the last decade, as researchers have sought to characterize complicated syntrophic relationships [1], identify metabolically relevant chemical species [2], and understand the role of AOM in the broader carbon cycle [3]. However, much of this work has focused on cold seep sediments, and comparatively little is known about the associated authigenic carbonates that are formed as a product of AOM. If biologically active, these rocks would contribute significantly to AOM processes in the global deep ocean environment.

Here we describe a unique microscopy and molecular study of cold seep endolithic environments that compares sediments, protolithic carbonate nodules, carbonate rocks associated with active methane seepage ('active'), and carbonate rocks from dormant seep areas ('inactive'). Image analysis and cell staining with DAPI and domain-specific CARD-FISH probes showed abundant cell aggregates in all environments including the interiors of the 'inactive' carbonates. Carbonate rocks from active seep habitats contained the largest and most abundant cell aggregates, with average diameters around 10 um. 16s rRNA gene sequences and T-RFLP analyses revealed syntrophic methane oxidizing archaea and sulfate reducing bacteria, in keeping with previous studies. X-ray diffraction exposed mineralogical differences between samples; a relative abundance of metal-based minerals in rock interiors could expose cells to additional electron acceptors and accommodate larger, more abundant aggregates.

A quantitative model of methane uptake based on aggregate density, theoretical enzyme kinetics, measured methane concentrations, and carbonate rock porosity will be presented to demonstrate the role of carbonate pavements in overall methane consumption. The finding of active endolithic AOM consortia expands our understanding of where and how AOM occurs, suggesting that a significant – possibly dominant – component of AOM activity in cold seep habitats may occur within lithified carbonates at and within the seabed.

[1] Orphan *et al*. (2002) *PNAS* **99**, 7663–7668. [2] Beal, E.J. *et al*. (2009) *Science* **325**, 184–187. [3] Reeburgh, W.S. (2007) *Chemical Reviews* **107**, 486–513.

Elastic properties of nano-crystalline MgO to high pressures by Brillouin scattering

HAUKE MARQUARDT[1], ARIANNA GLEASON[2], KATHARINA MARQUARDT[1], SERGIO SPEZIALE[1], LOWELL MIYAGI[3], GREGOR NEUSSER[4], HANS-RUDOLF WENK[2] AND RAYMOND JEANLOZ[2]

[1]German Research Center for Geosciences (GFZ), Telegrafenberg, 14473 Potsdam, (hama@gfz-potsdam.de)
[2]Department of Earth and Planetary Science, University of California, Berkeley, CA 94720
[3]Geology and Geophysics Department, Yale University, P.O. Box 208109, New Haven, CT 06520
[4]Institute for Geological Sciences, Freie Universität Berlin, 12249 Berlin, Germany

Recent Brillouin scattering results on the sound wave velocities of MgO powder compressed under non-hydrostatic conditions show velocities that are around 20% lower than expected from single-crystal data [1]. These results question the reliability of Brillouin scattering of polycrystalline materials and they illustrate that several poorly understood processes might affect the derived sound wave velocities, including a preferred orientation of the crystallites (texturing), non-hydrostatic conditions in the diamond-anvil cell, and grain size effects.

Here, we report the elastic properties of nano-crystalline MgO powder determined by Brillouin scattering to pressures above 30 GPa. We find the acoustic velocities to be significantly lower than reported data on single-crystal MgO. A careful characterization of the crystallite sizes in our sample material by synchrotron x-ray diffraction and high-resolution scanning and transmission electron microscopy shows that the average crystallite size stabilizes at about 7 nm at high pressures. The small crystallite size has a profound effect on the elastic properties and is responsible for the observed low velocities in MgO. We show that this effect prevails at high pressures.

Based on our first data analysis, zero-pressure bulk and shear moduli of the intercrystalline material (mostly grain boundaries) are reduced by about 70 % and 80 %, respectively, as compared to the crystalline material. The effect of grain size on the measured velocities is by far exceeding any effects of non-hydrostaticity and texturing. Our findings imply that a thorough characterisation of the crystallite size distribution is crucial for the interpretation of Brillouin scattering results from polycrystalline materials.

[1] Gleason *et al*. (2011) *GRL* **38**, L03304.