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Attention Turns to Naturally Occurring Methane Seepage

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Methane is the most abundant organic compound in the Earth’s atmosphere. As a powerful greenhouse gas, it has implications for global climate change. Sources of methane to the atmosphere are varied. Depending on the source, methane can contain either modern or ancient carbon. Methane exiting from swamps and wetlands contains modern carbon, whereas methane leaking from petroleum reservoirs contains ancient carbon. The total annual source of methane to the atmosphere has been constrained to about 540 teragrams (Tg) per year [Cicerone and Oremland, 1988]. Notably absent from any identified sources is the contribution of geologically sourced methane from naturally occurring seepage.

Natural gas seeps, ranging from micro-seepages to macro-seepages, commonly occur in both terrestrial and marine settings and include natural exhalations of methane from exposed outcrops of black shales, coal beds, organic-rich melanges, and oil shale. Rates of methane seepage from natural sources are difficult to assess, however, because gas seeps are usually episodic, ephemeral, and often difficult to observe.

A U.S. Geological Survey-sponsored workshop was recently held to assess this unaccounted-for methane in the current global inventory of atmospheric sources. The workshop participants made preliminary estimates of natural methane seepage rates, synthesized existing data, evaluated the role of methane oxidation and dissolution as constraints on methane seepage, and discussed future research needs.

Estimates of Methane Seepage

The workshop participants developed two approaches to making global estimates of geological methane seepage rates. The first was to compile existing information on the local, regional, and global seepage rates that have already been estimated and reported. This kind of information is currently scattered in the scientific literature, but consensus estimates were obtained by synthesis of data in hand. Based on this approach, it was estimated that about 50 Tg/yr of methane seeps from the seabed and about 30 Tg/yr of methane reaches the atmosphere.

A second approach involved broad assumptions based on considerations of the availability of methane for seepage from all global geological sources through geologic time. The methods used in this approach were extrapolated for natural gas from two earlier research studies dealing with crude oil [Kvenvolden and Harbaugh, 1983; Miller, 1992]. Preliminary assumptions were made that need further refinement. The total geologic reservoir of methane was estimated to be between 10^8 and 10^9 Tg, while the half-life of the total geologic methane reservoir was set at 10^7 yr. With these and other assumptions concerning the length of time for reservoir depletion (10^8–10^9 yr), the flux of methane was estimated to be about 30 Tg/yr from the seabed and about 10 Tg/yr into the atmosphere. Thus, the results from this theoretical approach and the observational approach were similar within a factor of three.

If the atmospheric input of geologically sourced methane is about 20 Tg/yr—the average of the observational and theoretical approaches—then the magnitude of the estimate is significant and should be included in the inventory of annual methane release rates from identified sources [Cicerone and Oremland, 1988]. The participants recognize that these global estimates are first approximations to be refined as more information is obtained.

Constraints on Methane Seepage Estimates

The workshop participants discussed factors that limit the amount of methane that reaches the ocean/atmosphere and land/atmosphere systems. Two important processes are methane oxidation and dissolution. Microbial methane oxidation, both anaerobic and aerobic, is estimated to consume over half of the total methane produced on Earth. In fact, microbially mediated methane oxidation in ocean waters and sediments is so effective that it prevents the ocean from being a major methane source in the global budget [Reeburgh et al., 1993]. Anaerobic methane oxidation is a nearly quantitative sink for methane diffusing or advecting from anoxic ocean sediments. Neither the mechanism nor the organism responsible for anaerobic methane oxidation is known, but recent biomarker and molecular genetic studies suggest that it is mediated by archaea under low hydrogen partial pressures maintained by actively growing sulfate-reducing bacteria. Aerobic oxidation rates have been measured in ocean waters by observing decreases in methane [Scranton and Brewer, 1978] and by direct tracer studies [Reeburgh et al., 1991; Valentine et al., 2001]. Water column methane oxidation rates are highly dependent on concentrations of methane. Methane turnover times (concentration/oxygenation rate) ranged from about 1 year, where methane concentrations are high, to decades, where methane concentrations are low. The workshop participants concluded that the difference in the global estimates of seepage rates of 20 Tg/yr between the sea floor and the atmosphere, as discussed above, is due mainly to methane oxidation in the water column.

A second factor considered in the workshop is the process of methane dissolution during transport through water. Gas bubbles rising from great depth (500–1000 m) contain much greater amounts of methane than similar sized bubbles at shallower depths due to greater pressure (50–100 atm versus 2–10 atm). Frequently, these bubbles are coated with an opaque or frosty layer that is presumed to be clathrate hydrate, which forms at the interface between the gas bubbles and the surrounding seawater. Because of the presumed slower diffusion of methane through the hydrate layer, it is assumed that the rate of gas dissolution from these bubbles will be slower and that the bubbles will survive much longer in the water column than would be expected if they lacked the hydrate coating. Recent experiments in Monterey Bay confirm that this process does occur. Hydrate formation delays the dissolution of bubbles. When bubbles are coated with oil, the effect may be similar. These processes tend to concentrate methane in surface ocean layers above 500 m, where it has a much higher probability of venting directly to the atmosphere rather than being biodegraded in the water column. The participants agreed that bubble transport is an important mechanism in the transfer of methane, which helps determine the amount of methane that ultimately reaches the atmosphere.

Future Research Needs

One of the most significant hurdles to estimating the role of methane seepage in the global methane budget lies in determining the extent of seep occurrences and the flux of methane from these various sources. To this end, the workshop participants identified tools and methodologies that could be used to examine this problem. Methods for estimation of methane seepage will rely on geophysical and geochemical mapping of seep occurrences and the direct measurement of seepage rates by new instrumentation. Other methods of measuring fluxes include geophysical measurements linked to imaging gas in the water column, gas near the seabed, and gas trapped as gas hydrate. Because water column methane concentrations tend to vary highly both spatially and temporally over seep areas, better tools and methods for methane sensing are needed. Key tools include a reliable rapid-response methane sensor suitable for eddy covariance studies and improved acoustic methods for bubble flux quantification.

Growing Interest in Natural Methane Seepage

Interest in methane seepage and the role of methane from natural seepages is growing throughout the world, as evidenced by the increasing number of publications on the subject. The development of the European Program on Sea Floor Advection of Methane (FLAME) addresses the question of sea floor carbon fluxes via methane as a contribution to the estimation of the global carbon budget. Two recent international meetings addressed the issue; methane seepage symposia were held at the April meeting of the European Union of Geosciences, and a European Science Foundation workshop in August considered natural hydrocarbon seeps, global tectonics, and greenhouse gas emissions. A NATO conference on gas seeps, planned in

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conjunction with the biennial international meeting of the Shallow Gas Group, is scheduled for 2002 in Baku, Azerbaijan, where spectacular methane seeps are present. Now is the time to focus on the role of natural methane seepage on global processes.

The workshop, informally named the Gaia’s Breath Working Group, was held May 2–4, 2001, and was hosted by the U.S. Geological Survey Water Resources Division District Office in Portland, Oregon.

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Tectonophysics

Fluid flow, reaction and permeability change in porous media: Experimental results, Eric A. Tenthorey, Columbia University, Christopher Scholz, January 2001.

Honors

The Association for Women Geoscientists (AWG) awarded 2001 Chrysalis Scholarships to Gwyneth Jones, an AGU member since 1997 (Volcanology Geochemistry Petrology), and to Josette Stanley, an AGU member since 1995 (Volcanology Geochemistry Petrology). This financial aid is given to exemplary women graduate students in the geosciences who have experienced an interruption at some time in their formal education and are in the final stages of writing their theses.

Appointments

David Farmer holds a new position as dean at the Graduate School of Oceanography at the University of Rhode Island. He was formerly senior scientist and head of the Acoustical Oceanography Group of the Institute of Ocean Sciences in British Columbia. He has been a member since 1984 (Ocean Sciences).