He added that some undersea volcanic systems also are known to concentrate precious metals, and that this could be another finding after further analysis. "If I were a betting man, I'd bet we will end up with some very interesting mineralogical findings," he said.

(Any findings concerning minerals and other economically valuable resources found in submerged lands in the area will be of interest to the U.S. as well as to the Commonwealth of the Northern Mariana Islands, a self-governing territory of the U.S.)

Robert Embley, the mission's chief scientist and an oceanographer with NOAA's Pacific Marine Environmental Laboratory, noted that most people do not understand that about 60% of the Earth's volcanism is on the ocean floor, and that the only way to monitor the vast majority of these volcanoes is to visit individual sites and look at plumes and other possible clues.

Embley, who has been studying the ocean for nearly 4 decades, ranked this expedition as perhaps his most exciting. "Every day, it was a joyful thing to wake up and see what was new on the sea floor."

The expedition, which involved 34 scientists spanning a broad range of disciplines from the U.S., Canada, Japan, and New Zealand, was sponsored by NOAA and the Engineering Research Council of Canada. The expedition was a follow-on to a 2003 mission that mapped the area and discovered 10 hydrothermally active volcanoes.

For more information, visit the Web site: http://www.oceanexplorer.noaa.gov.

—RANDY SHOWSTACK, Staff Writer

U.S. Quaternary Fault and Fold Database Released

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A comprehensive online compilation of Quaternary-age faults and folds throughout the United States was recently released by the U.S. Geological Survey, with cooperation from state geological surveys, academia, and the private sector. The Web site (http://Qfaults.cr.usgs.gov/) contains searchable databases and related geo-spatial data that characterize earthquake-related structures that could be potential seismic sources for large-magnitude ($M > 6$) earthquakes.

This is the first nationwide compilation to provide current, comprehensive, geologically based information on known or suspected active faults. The Web site features a visual depiction of spatial and temporal patterns of faulting at local, regional, and national scales. Comprehensive written descriptions based on published data are presented in a uniform format for nearly 2000 faults nationwide. The database will be of interest to the seismological, geodetic, paleoseismic, and the ever-growing seismic hazard assessment communities, as well as emergency managers, the insurance industry, earthquake engineers, public officials, and developers. The Web site features a user-friendly interface and supports user-defined, downloadable geographic information system (GIS) data.

The data compilation for the first release is complete for the lower 48 states, with the exception of parts of California and Idaho. Ongoing efforts to complete those states, as well as Alaska, Hawaii, and the U.S. territories, will proceed into 2005. The database will be periodically updated so it will remain the latest authoritative tool for fault characterization and seismic hazard analysis.

A more extensive description of these USGS searchable databases and related geo-spatial data can be found on the *Eos* Electronic Supplement at http://www.agu.org/eos_elec/000655e.html.

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MEETINGS

Issues and Recent Advances in Soil Respiration

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The terrestrial carbon cycle is intrinsically tied to climate, hydrology, nutrient cycles, and the production of biomass through photosynthesis. Over two-thirds of terrestrial carbon is stored below ground in soils, and a significant amount of atmospheric CO_2 is processed by soils every year. Thus, soil respiration is a key process that underlies our understanding of the carbon cycle. Soil CO_2 fluxes are the sum of root (autotrophic) and microbial (heterotrophic) respiration. Several factors contribute to soil respiration, including photosynthetic supply to roots, substrate quality and availability, temperature, and moisture. The extent to which these factors contribute to soil respiration and associated uncertainties in soil CO_2 measurements limit our understanding of the role of soils in regional and global carbon budgets.

A one-day soil respiration workshop with 78 participants was held last fall to address the following issues:

- Potential biases and uncertainties in measuring CO_2 effluxes and how these biases vary with environment, soils, and vegetation;
- Effect of transient events that influence soil CO_2 pore space (rain, wind, pressure) and measured fluxes;
- Recommendations for sampling, measurement, and reporting protocols; and
- Recommendations for model development and experimentation to understand mechanisms controlling fluxes.

Biology and Soil Respiration Measurements

Measurements of soil respiration are often made by placing a chamber over a PVC collar inserted into the soil surface to measure the changes in CO_2 concentrations over time (closed or non-steady state) or stable CO_2 concentrations resulting from the continuous flow of ambient air through the system (open or steady state). Non-steady state chambers may be static, using either chemical absorption of CO_2 (alkali technique) or manually collecting gas samples over time for analysis of CO_2 concentrations in the laboratory. Most systems are dynamic—air is circulated inside the chamber—and use infrared gas analysers (IRGAs) in the field to measure CO_2 concentrations.

Biological contributions to respired soil fluxes include the role and function of plants and microbial communities. Environmental conditions, such as temperature and moisture, interact with substrate availability and pool size, phenological processes, nutrient cycles, and changes in growing season length to control the rates of soil CO_2 efflux.

Roots and the rhizosphere can contribute up to 50% of total respired fluxes; however, allocation patterns of carbon to these components can vary seasonally, hence influencing rates of respired CO_2. In addition to variable plant allocation, drought can alter root respiration by reducing photosynthesis and root growth, lowering maintenance respiration, and reducing respiratory requirements for metabolic-ion uptake and synthesis. Plant age, density, and growth rates are also important and may lead to uncertain and unidentified ecosystem feedbacks, for example, between photosynthesis and root/mycorrhizal respiration and soil temperature. Nutrient deposition and fertilization can also alter plant allocation patterns to rooting systems, with consequences to both root metabolism and decomposition rates.

Short-lived CO_2 pulses associated with wetting result primarily from microbial response, particularly following intermittent drought or periods of dry-down. Both temperature and water content of soils affect soil respiration, but their combined effects are difficult to determine. Experiments that exclude water to determine moisture effects on respiration may cause mortality and stress, whereas adding water reduces the stress and increases activity during drought.

Pressure pumping or fluctuations in atmospheric pressure influence the fluxes and movement of CO_2 through soils and snow pack. The physical exchange of soil CO_2 with the atmosphere during rainfall is affected by the complex route that CO_2 must take, for example, through fissures, cracks, and channels. With regard to measurements, chambers do not create distorting pressure gradients, however, measurement biases are influenced by the surface disturbance during chamber placement as well as horizontal and vertical variation of soil properties. Chamber impacts on soil moisture and temperature are unknown.

Scaling Chamber Measurements: Recognizing Bias and Uncertainties

Biases associated with chamber measurements can result from pressure differences, turbulence, soil disturbance, soil/atmosphere disturbance, and altered pathways of diffusion. Measurements in media of controlled porosity, confirmed with evidence from field studies, have shown that closed chambers may underestimate fluxes in highly porous materials. Additional studies suggest that this under-estimation is linearly related to the ratio of total soil air volume to chamber volume. To minimize chamber bias, recommendations include reducing the sample duration, inserting the chamber deeper to retard radial (lateral) diffusion, increasing chamber height relative to volume, documenting soil porosity and soil moisture, accounting for possible underestimation of fluxes in deep, porous soils and deep litter layers, and using properly calibrated open chamber systems.

Timing of measurements (the portion of the diel cycle sampled), the season of measurement, and measurement under non-equilibrium soil conditions—for example, during rain—can bias scaled estimates if factors that influence fluxes are not also measured at the relevant scales for use in models. For example, if carbohydrate supply to roots and mycorrhizal communities are greater when photosynthesis is active, extrapolations from measurements made only during daytime may overestimate diel fluxes. Avoiding winter measurements or assuming that fluxes are near or close to zero under snow may also bias estimates. To properly obtain representative spatial rates of ecosystem respiration, all sources and sinks must be accounted for, such as stems and coarse woody debris, as well as structural components that may inhibit soil CO_2 exchange; for example, surface rocks, sub-surface ledge, or parent materials.

Several techniques to reduce spatial, temporal, and environmental factors influencing respiration measurements were suggested. Spatial variability can be reduced by obtaining measurements with larger chambers, for example, >25 cm diameter. The use of permanent collars for chamber placement separate environmental factors from spatial variability. Uncertainty when interpolating fluxes increases with sampling interval, which is important if periodic measurements are used to estimate annual soil respiration. The choice of sample unit—within-plots versus among-plots—influences the overall variance, and variance among plots is substantially lower than variance within plots. Potential uncertainties in scaling from chambers to site include increased variability in the measured fluxes caused by abiotic factors such as rain, wind, and pressure that can be greater than fluxes caused by biological activity in any given measurement period.

Measurement and Modeling Approaches in Estimating Soil CO_2 Fluxes

Process models simulate carbon pools and dynamics regulating their changes. Input data requirements for process models are extensive, and information on rooting dynamics, allocation, turnover rates, and phenology are sparse and difficult to measure. If inputs are adequately represented, however, process models can often reasonably estimate soil respiration and assist in the development of field sampling designs and hypothesis testing. Regression models contain explicit functions of temperature and/or water content with parameter constants that depend on autotrophic and heterotrophic respiration.

Regression models are easy to parameterize, but uncertainties arise when parameter constants vary and are not properly quantified because of seasonal changes in substrate, lack of process level information, and use of same temperature and water functions for both heterotrophic and autotrophic respiration.

Complementary measurement and modeling studies can assist in evaluating environmental influences, seasonality, and phenology effects on soil respiration. Methodologies need to reconcile the differential controls on autotrophic versus heterotrophic respiration and better quantify active and slow carbon pools. Experiments should reflect site uniquenesses, such as seasonality, and site legacy of disturbance or management history.

Workshop Recommendations

Several approaches were suggested to assess potential biases and uncertainties, including development of site- and depth-specific sampling strategies to characterize and evaluate bias from the location and timing of measurements. For instance, sub-canopy eddy covariance measurements could be compared with arrays of continuous soil respiration measurements to evaluate biases introduced by generalizing local characteristics that vary widely, such as climate, soil carbon pools, etc., to larger and inaccessible regions.

The effects of pulse, or transient events, should be investigated with depth-specific analyses of root/rhizosphere and heterotrophic contributions to respired soil fluxes. Evaluation of biological contributions linked to measured active and "protected" pool sizes, litter, woody debris decomposition, and fine root turnover rates would be useful. Experimental designs should be sensitive and appropriate to sampling intervals for scaling respiration measurements to seasonal or annual estimates.

Physiological responses and changes in microbial function should be quantified during and after episodic events, and control for other factors should be accounted for in continuous measurements. It was strongly recommended that whenever possible, a combination of continuous and manual chamber measurements be made to assess both temporal and spatial variability, for example, partitioning eddy fluxes into component sources.

Workshop participants agreed that standardization of measurements and reporting protocols is necessary to facilitate data synthesis for cross-site or regional comparisons. Recommendations also included standardization of statistical treatments and the development of a common data structure that would enable innovative utilization of the data, including the use of variograms or probability density functions to assess spatial variability and auto correlation.

Finally, to understand and quantify soil respiration and its associated processes and feedbacks, model development and experimental design activities should be jointly developed. To accomplish this, a standardized suite of state variables for site comparisons and model data initialization and evaluation variables should be developed in tandem with data protocol and standardization activities. An experiment was proposed, perhaps at flux towers, where unique and important site-level characteristics were linked with exclusion experiments (light/water/nutrients), isotopic studies, and model evaluation activities. The NIGEC Workshop on Measurement and Analysis of Soil CO_2 Fluxes was held 13 October 2003, in Boulder, Colorado.

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