# Construction of a Multi-Purpose Vacuum Line Laboratory for Stable Isotope BioGeoChemistry

A collaborative research proposal submitted to the Keene State College Faculty Development Fund

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**Abstract**

The natural abundance of stable isotopes can be used to trace water movement through the hydrologic cycle and water uptake patterns of plants. We propose to build a multi-purpose high vacuum line for the extraction and preparation of water samples for stable isotope analysis. We also propose to determine the annual variability of stable isotope composition of precipitation in the Keene Region. This will provide critical background information for our research programs in ecosystems ecology (Gebauer) and subsurface hydrology (Allen).

**A. Description of the proposed project**

The elements Hydrogen (H), Carbon (C), and Oxygen (O) are the building blocks for water, organisms, and some rocks. An understanding of the biogeochemical cycling of these elements provides insight into important eco- and earth-system processes. Each of these elements has several isotopes; atoms with the same numbers of protons and electrons, but with different numbers of neutrons. Therefore isotopes of elements differ in mass and are often fractionated from one another by biological, physical, or chemical processes. For example, evaporation of water favors water molecules with light oxygen ($^{16}O$) and light hydrogen ($^{1}H$ or just H) over those with heavy oxygen ($^{18}O$) or deuterium ($^{2}H$ or D). Hence water vapor is enriched in the lighter isotopes $^{16}O$ and H relative to the liquid water left behind. There is great variation in the stable isotope composition of precipitation with increasing latitude or altitude due to differences in local temperatures and evaporation rates (Craig, 1961). At any given location the isotopic composition varies temporally between seasons (Fig. 1) and from storm to storm, as well as spatially within the soil profile. This natural variation in stable isotope composition of precipitation and/or soil water allows us to trace the movement of water through the hydrologic cycle (Clark and Fritz, 1997), to determine the water sources and/or rooting depths of different plant species (Dawson and Ehleringer, 1992; Gebauer and Ehleringer, 2000), and even to trace the migration patterns of birds (Chamberlain et al., 1997).

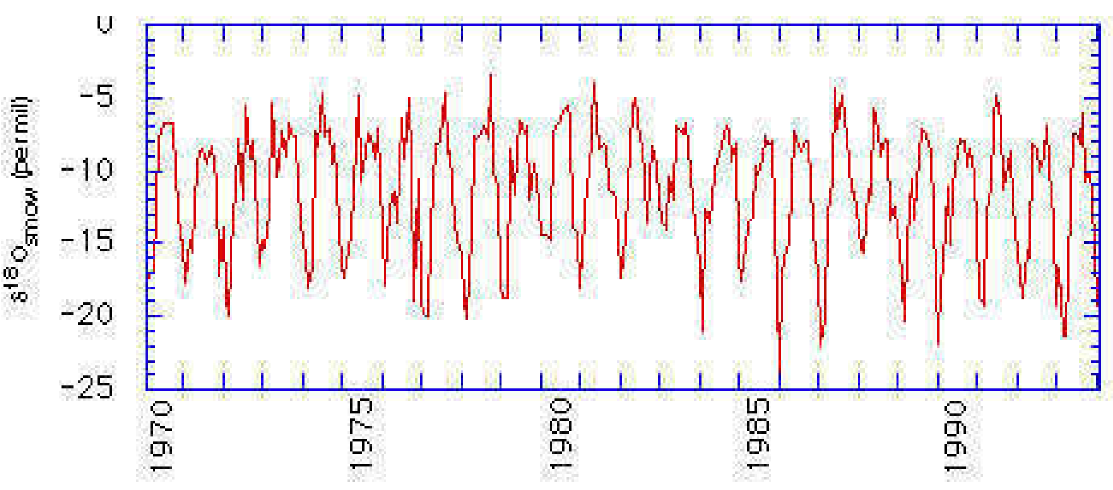


Figure 1: The oxygen isotope composition of monthly precipitation at Ottawa, Ontario between January 1970 and December 1993 (http://www.iaea.or.at/programs/ri/gnip/gnipmain.htm). Although Ottawa is the closest GNIP (Global Network for Isotopes in Precipitation) station to Keene, it is still too far away to be representative of local conditions.

We propose here to build a multi-purpose high vacuum line (Fig. 2) and laboratory for the extraction and preparation of water samples for stable isotope ratio analysis (Socki et al., 1992; Coleman et al., 1982; Cook et. al., 1997). Vacuum lines are not stock items, rather they are custom built and assembled from component parts. We have designed our line to serve several uses, accomplished by changing components attached to the manifold. Initially, planned components include (a) vessels, T's, and collection tubes for extracting water from plant and soil samples (Fig. 2); and (b) modified Gastight syringes for working with Vacutainers to prepare water samples for analysis of their O isotope composition through controlled $H_2O$-$CO_2$ isotopic exchange (Fig. 2). The resulting $CO_2$ gas sample is moved through the line and separated from water vapor with cyrogenics (liquid nitrogen and dry-ice), and then sealed in a glass sample tube. The O isotope composition of this $CO_2$ sample reflects that of the original water sample. To measure the isotopic composition of this gas requires a Stable Isotope Ratio Mass Spectrometer, available at other institutions.

While we could send water samples to a commercial laboratory for isotopic analysis, we would still need the vacuum line and peripherals to extract the water samples from plants and soils, a process that must be carefully controlled and is best done in-house. In addition to ensuring quality-control, it will be more cost-effective and time-efficient for us to prepare the $CO_2$ from water samples ourselves. Furthermore, students in our upper level laboratory classes and independent study projects will greatly benefit from gaining experience with this state-of-the-art technique.

Once the line is operational, we propose to characterize the temporal variability of the stable isotope composition of precipitation in the Keene region. As New England is located at the convergence of several distinct storm tracks (http://www.mountwashington.org/mtw_mtn.htm), we expect to find clear differences in isotopic composition among seasons and potentially among different rain storm events (Fig. 1). We will also do preliminary sampling of soil water profiles in order to establish relationships with the precipitation signal. This necessary background will facilitate further studies of plant rooting patterns (Gebauer) and ground-water recharge dynamics (Allen).

**B. Professional impact and development:**

**Gebauer**: During her postdoctoral work at the Stable Isotope Ratio Facility for Environmental Research at the University of Utah, and in a project funded by the Southwestern National Park

Association, Gebauer conducted conceptually similar projects in a cold desert ecosystem (Gebauer and Ehleringer, 2000) and California's oak woodland (Gebauer and Tiszler, 2000). The construction of the proposed laboratory will allow Gebauer to continue this research in stable isotope ecology in the very different ecosystems of the New England area. In the near future, Gebauer plans to submit proposals to funding agencies such as NSF or USDA to provide further funding for her research. Having the basic capabilities to extract and prepare samples for stable isotope analysis here at Keene State will greatly increase the likelihood of getting funded by these agencies.

**Allen:** With prior experience using stable isotopes to study metamorphic rocks (Allen, 1996), Allen received partial support from the Faculty Development Fund in 1994 for a "Preliminary Investigation of Stable Isotope Fractionation as a Means of Quantifying Groundwater Recharge Rates." The results showed that the partitioning of precipitation between evapotranspiration, surface run-off, and ground-water recharge does not cause measurable isotopic fractionation. However, preliminary analyses of ground-water samples suggested that the isotopic composition of ground water may vary in time. Since 1994 Allen has gained more experience in hydrology and applications of stable isotopes through short-courses, research projects (O'Rourke et al., 1998), and grant writing (Allen, 1997). The construction of the proposed laboratory will allow use of stable isotopes for testing hypotheses about sub-surface hydrologic dynamics.

**C. Project outcome sharing**

We will create a web-page describing the laboratory facilities and the database of the isotopic composition of precipitation in the Keene area. The web-page will be linked to the ISOGEOCHEM web-page (http://geology.uvm.edu/geowww/isogeochem.html), which provides a directory of stable isotope laboratories from around the world. In addition, we intend to present results at scientific meetings (Ecological Society of America, Geologic Society of America) and to submit at least one manuscript to a peer-reviewed scientific journal.

**D. Potential for Continuation**

Once established, this stable isotope vacuum line laboratory will greatly facilitate continued research using stable isotope systems by both Gebauer and Allen, enhancing our ability to obtain external funding. It will also enhance opportunities for student involvement in research. In the future, we plan to add components to the vacuum line for preparing water samples for H isotopic analysis and for extracting $CO_2$ from carbonate rock and mineral samples for both C and O isotopic analysis (Fig. 2).

**E. Workplan and timeline**

As soon as funds are released, we will have the vacuum line (Fig. 2) built by a professional scientific glassblower, and will purchase other required components, assembling them in laboratory space available to Allen (SCI 205 B). Ideally, the line will be tested and operational by the end of summer 2000. We will then develop operating protocols, establish the isotopic composition of laboratory standards, and create a training program for laboratory assistants (students). We will begin collecting precipitation and preliminary soil moisture and ground water samples in Spring 2000, which we expect to finish analyzing in Spring 2001. Gebauer will serve as budget manager for the project.

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Figure 2: Stable Isotope Vacuum Line