IN-SITU MASS SPECTROMETER MEASUREMENTS OF CAVE ATMOSPHERES AS AN ANALOGUE TO FUTURE PLANETARY CAVE MISSIONS. K. E. Mandt1,2, E. L. Patrick1, J. E. Mitchell1, C. Seifert3, J. N. Mitchell1, M. Libardoni1 and K. N. Younkin4, 1Southwest Research Institute, 6220 Culebra Rd., San Antonio, TX 78238 kmandt@swri.org, 2University of Texas at San Antonio, One UTSA Blvd., San Antonio, TX 78249, 3St. Mary’s University, One Camino Santa Maria, San Antonio, TX 78228, 4Harford Community College, 401 Thomas Run Road, Bel Air, MD 21015.

Introduction: Caves on the Moon and Mars have become an emerging area of interest for future planetary missions. The First International Planetary Cave Workshop identified specific focus areas for planetary cave research, including: geologic processes, surficial and atmospheric processes, astrobiology and human utilization [1]. The atmospheres of caves on Mars and the Moon could provide a record of current geologic processes and present biological activity.

Caves present many physical challenges for access and instrument operation. Terrestrial caves are a useful analogue for addressing engineering challenges for future instrumentation. We have initiated a program to survey the meteorology and composition of several local cave atmospheres with two objectives. The primary objective is to build and test the operability of a basic portable mass spectrometer in the harsh atmospheric conditions common to caves and where power supplies are limited. The secondary objective was to apply the data obtained with this instrument to current Earth science issues in the fields of geology and biology. We have successfully achieved both objectives and are in the process of developing a second generation instrument for further terrestrial analogue studies and eventual planetary mission deployment.

Technical approach: For the first generation in-situ mass spectrometer, we looked to the heritage in mass spectrometer operation for planetary missions – quadrupole mass spectrometry. Numerous planetary missions have successfully employed quadrupole mass spectrometers for in-situ atmospheric measurements, including the Cassini mission to Titan. However, this type of mass spectrometer has limited mass resolution and cannot separate multiple components in a single mass channel. This limitation does not allow us to make isotope ratio measurements with the precision necessary for Earth science applications.

For instrument development, ConFlat® hardware provided the basic structure and a residual gas analyzer (RGA) was used for mass analysis. The instrument pressure was controlled and monitored with a small turbopump, a diaphragm pump and an ion guauge. Ambient atmosphere was allowed into the instrument through a leak valve system with an inlet filter to protect the hardware from the high levels of humidity common to local cave atmospheres. The RGA is connected to a laptop computer that operates the instrument and records all data output for later analysis. PTFE tubing was added to the inlet system to draw air from a local well for compositional surveys. Figure 1 illustrates the setup for the prototype instrument. Figure 2 shows the instrument being operated at one of the field locations. The mass spectrometer was powered by a generator located outside of the cave entrance.

The mass spectrometer provides a survey of the atmospheric composition between 1 and 200 amu with a detection limit of a few tens of parts per million. We simultaneously measured the temperature, barometric pressure, relative humidity, airflow velocity and CO2 levels at each location. At each site, the mass spectrometer was pumped down to a pressure of 10⁻⁷ torr and background scans were taken. Scans of the outside air composition were then taken as a baseline prior to entering the cave. Within the cave environment, after initial background scans, the mass spectrometer took measurements of the cave atmosphere for up to two hours followed by final background scans. At the well locations the same approach was used, taking measurements of the ambient air next to the wells and the air within the well.

Sites selected as environmental analogues: Four local caves and two wells were chosen for measurement locations.

Robber Baron Cave. Robber Baron Cave (RBC) is a “maze cave” located in the Austin Chalk formation. This cave exhibits significant airflow and often has very high levels of CO2. The source of this CO2 is not currently known and is under investigation [2]. A key component in this investigation is the isotope ratios in CO2, which can serve as tracers of the source. The biological activity in RBC is largely arthropods, two of which are identified as endangered species.

Wurzbach Bat Cave. Wurzbach Bat Cave (WBC), in spite of its name, is home to only a handful of bats.

![Figure 1 - Schematic for the first cave atmospheres in-situ mass spectrometer prototype.](Image)
It is also located in the Austin Chalk and exhibits very high levels of \( \text{CO}_2 \), especially in the lower levels where supplemental \( \text{O}_2 \) is required for exploration. Extensive deposits of organics and fungal growth are observed along the passages of WBC.

**Natural Bridge Caverns.** Natural Bridge Caverns (NBC) is located in the Edwards Limestone of the Kainer Formation and is a large, heavily visited commercial cave. Airflow in the cave is restricted by closed doors and the highly humid atmosphere is known to be corrosive.

**Bracken Bat Cave.** Bracken Bat Cave is a large volume, single passage cave that is home to the largest bat colony in the world. In the summer, up to 40 million bats use Bracken as a maternity roost. The cave atmosphere contains toxic levels of ammonia and the floor is covered with up to 40 feet of guano. Protective gear (illustrated in Figure 2) is required when entering Bracken for measurements.

![Figure 2 - Instrument setup in Bracken Bat Cave.](image)

In this extreme harsh environment, full tyvek suits and respirators are required.

**Well locations.** The first well bore penetrates the Edwards limestone, has a diameter of four inches and a depth of 302 feet to the water level. High levels of airflow were observed coming from this well. The second well is located 22 feet from the first well, penetrates into the lower lying Glenrose limestone, has a diameter of 10.5 inches, a depth of 435 feet to the water level and exhibited very little airflow.

**Preliminary Results:** The survey of the atmospheric composition within each cave provided a spectrum that resembled the general composition of the Earth’s atmosphere, as illustrated in Figure 3 where the signal in each mass is normalized to the mass 28 signal, which is \( \text{N}_2 \). Measurements taken in the laboratory (black line), where \( \text{N}_2 \) gas is being released by other experiments, and the mass spectrum of the air outside of Bracken (red line) are compared to the signal measured inside Bracken (blue circles). Oxygen, shown at mass 32, is depressed in the laboratory and appears to be present at higher levels inside the cave. This will be confirmed with a statistical analysis of instrument calibration data. The \( \text{CO}_2 \) level, observed at mass 44, also has increased and correlation of the time-variation of the \( \text{CO}_2 \) signal and the independent \( \text{CO}_2 \) measurements is ongoing.

![Figure 3 - Mass spectra taken in a laboratory setting (black line), outside of Bracken Bat Cave (red line) and inside Bracken (blue circles).](image)

The data from the first well, with a diameter of four inches is illustrated in Figure 4. The two wellside spectra (black and green lines) are compared with the measurement inside the well (blue circles). The \( \text{CO}_2 \) signal inside the well is higher than the wellside air and a factor of two increase in the mass 15 signal provides a tentative detection of methane.

![Figure 4 - Mass spectra taken beside the two wells (black and green lines) and inside the narrow well (blue circles).](image)