Distinguishing Signal from Noise in the Near Surface Using Simple Soil-Gas Measurements: Lessons from Natural and Industrial Analogs

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IT’S NOT ABOUT CONCENTRATION... IT’S ABOUT PROCESS!

Introduction and Problem Statement

**Question:** How can a CO₂ release from a storage formation be identified in the near surface, where CO₂ is naturally abundant, temporally and spatially variable, and difficult to quantify?

**Current Approach:** Measure natural “background” CO₂ concentrations over 1 year to explain range of seasonal CO₂ variation. Anything different signals a release.

**Problem:**
- 1 year cannot capture the full magnitude of variation in natural CO₂ concentrations.
- Background measurements are time, cost, and labor intensive.
- Background concentrations cannot be measured everywhere.
- Concentration variations cannot be used to detect a release in the early stages.

**Answer:** Focus on process to identify the origin of CO₂. The various processes that produce and consume CO₂ also affect O₂, CH₄, and N₂ in predictable ways. Chemical ratios can identify whether a signal is natural background noise or a leakage signal.

**NO BACKGROUND MEASUREMENTS REQUIRED!**

Methods and Materials

1. Semipermanent Soil-Gas Wells
   - Provide depth profiles that show subsurface gas distribution.
   - Provide soil cores for analysis.
   - Allow for repeat sampling.
   - Require a driller (S).
   - Require a targeted approach with limited spatial coverage.

2. On-Site Analysis
   - SIR portable gas chromatograph.
   - Dual column (molecular sieve and porapak Q) splits the sample.
   - FIG and TCD measures CO₂, N₂, O₂, Ar, CH₄ in one 6-minute run.
   - Methanizer allows for low CO₂ detection limits.
   - Real-time results.

CO₂ Cycling in the Vadose Zone

3. Processes:
   - Root respiration
   - Methanogenesis
   - Methane oxidation
   - Evapotranspiration
   - Dissolution and reaction with soil carbonate
   - Atmospheric mixing/tranlation

   - Gas concentrations are measured in percent (volume or mole), so any nonreactive addition or subtraction of a gas is a measurement bias, e.g., by definition, dilute or concentration, respectively, all other gases in similar proportion.
   - Assume starting composition is an (78% N₂, 21% O₂, 0.003% CO₂, 17 ppm CH₄).

   - Schematic of CO₂ cycling processes in natural and industrial settings.

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4. Playa Lake
   - Location: Southern High Plains, West Texas, USA.
   - Plays are broad, gently sloping, circular basins that perched surface runoff before infiltration.
   - Systematic variations in environmental factors among geomorphic zones (figs. 4 and 5) provide an opportunity to study the effects of environmental variability on soil-gas gas chemistry.

5. Results
   - Slope and most annulus samples are consistent with biologic respiration and/or oxidation of methane to CO₂ and CH₄ and fall between the lines representing these processes (fig. 7).
   - Floor samples show CO₂ less than expected for their O₂ compositions, indicating a CO₂ sink.

   - The same samples show N₂ > atmosphere (78%) and correlate with CO₂ (fig. 8). Nitrogen isotopes indicate that identification is not responsible for high N₂ concentrations.

6. Playa Conclusions
   - Relationships among CO₂, O₂, and N₂ can be used to distinguish among the processes of biogenic CO₂ production, CH₄ oxidation, and dissolution of soil carbonate. Identification of these processes is independent of concentration. We can use this approach to separate CO₂ releases from natural background.

7. Cranfield Oilfield
   - Oil production from 1944 through 1967
   - P4 plugged and abandoned wells.
   - Field reentered in 2008 for CO₂ EOR.

8. P-Site
   - Targeted area to test soil gas at an engineered site (fig. 10).
   - 13 gas stations with 27 gas wells.
   - Monitored since September 2008, before injected CO₂ reached the area.

   - CO₂ and CH₄ anomalies correlate at well 103 (fig. 11).
   - Isotopes indicate that CH₄ is exogenous from the oil and gas reservoir and CO₂ oxidation of methane.

9. Conclusions
   - Relationships among simple soil-gas parameters can identify carbon-cycling processes.
   - Process can distinguish between background noise and leakage signal.
   - Identifying process may eliminate the need for background measurements at carbon storage sites.
   - More sites are needed to validate this approach, especially controlled release sites.

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