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## PROBLEM STATEMENT

Methanogens/Archaea produce methane. They are often the dominant microbes in reduced environments. Methanogenesis is a requisite component of conventional anaerobic bioremediation.

If Archaea are not controlled, then *in situ* remedial actions employing conventional (*i.e.*, no active control of Archaea) ERD amendments such as [emulsified] oils/lecithins, lactates/sugars, simple hydrogen release compounds or conventional ISCR reagents can generate excessive amounts of methane. At several sites where these conventional ERD/ISCR remedial amendments have been applied excessive methanogenesis (some yielding effervescent samples as shown below) has been observed, sometimes for many months - even years - after the amendments were applied.



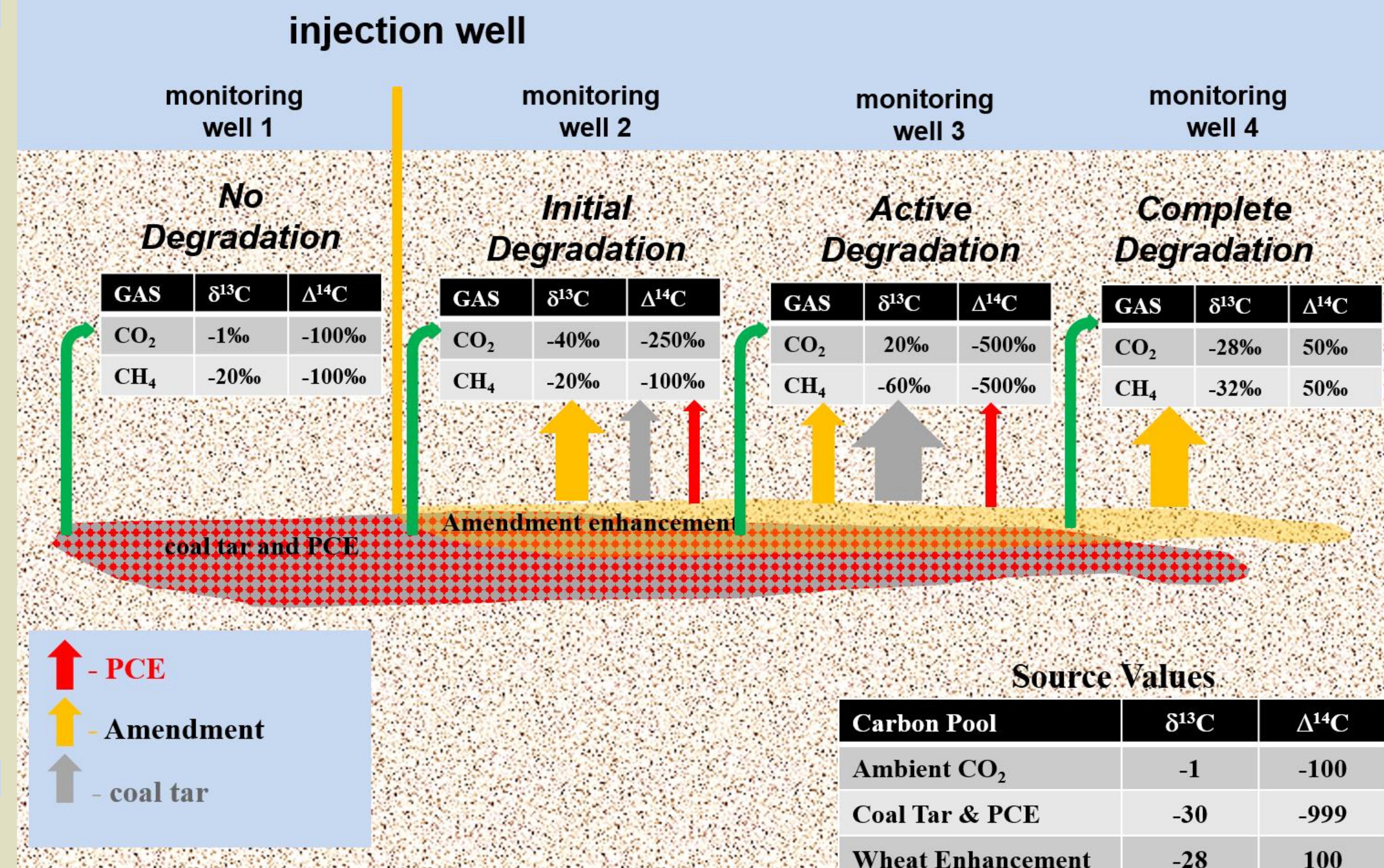
CH<sub>4</sub> production >12 months Post EVO  
(Newman Zone®) Application  
Source US DOD 2017

## WHERE DID ALL THIS METHANE COME FROM?

This question can be answered conclusively using carbon isotope analyses - radiocarbon ( $\Delta^{14}\text{C}$ ) and stable carbon ( $\delta^{13}\text{C}$ ). When coupled with methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) data from groundwater samples the origin of the respired carbon is often clearly determined.

For water CO<sub>2</sub>, dissolved inorganic carbon can be converted to CO<sub>2</sub> and concentrations determined with a coulometer. For water CH<sub>4</sub>, the concentration is measured via GC-FID. This combination of both gasses provides an estimate of total degradation by assuming microbial degradation to CO<sub>2</sub> and, when there is active anaerobic degradation, CO<sub>2</sub> is further reduced to CH<sub>4</sub>.

- Methane in ecosystems can originate:
- Thermogenically from regions of petroleum formation deep within the earth
  - Via microbial fermentation of indigenous organic carbon and subsequent microbial reduction of carbon dioxide
  - Via fermentation of an added carbon source, and /or
  - Via catabolism of contaminant carbon
- Hence, the origin of methane is not always clear.



## Isotope Data Interpretation

- Contaminant Degradation (CO<sub>2</sub> source) =  $\Delta^{14}\text{C}_{\text{well}1} - \Delta^{14}\text{C}_{\text{well}2-4}$
- PCE vs Coal Tar Contribution (CO<sub>2</sub> source) = (Chlorine/PCE) ( $\Delta^{14}\text{C}_{\text{well}1} - \Delta^{14}\text{C}_{\text{well}2-4} / \Delta^{14}\text{C}_{\text{well}1}$ )
- Stable carbon isotope analysis is used to calibrate and confirm radiocarbon

For Technical Support and Proposals

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