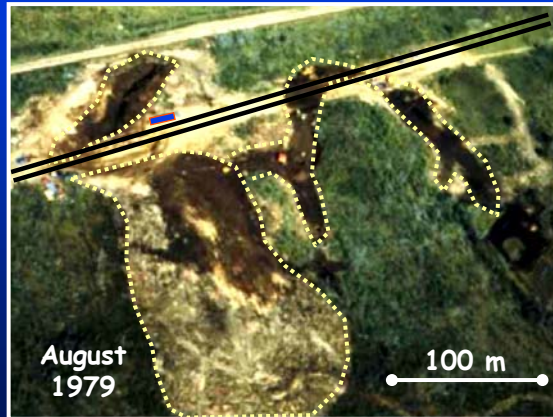


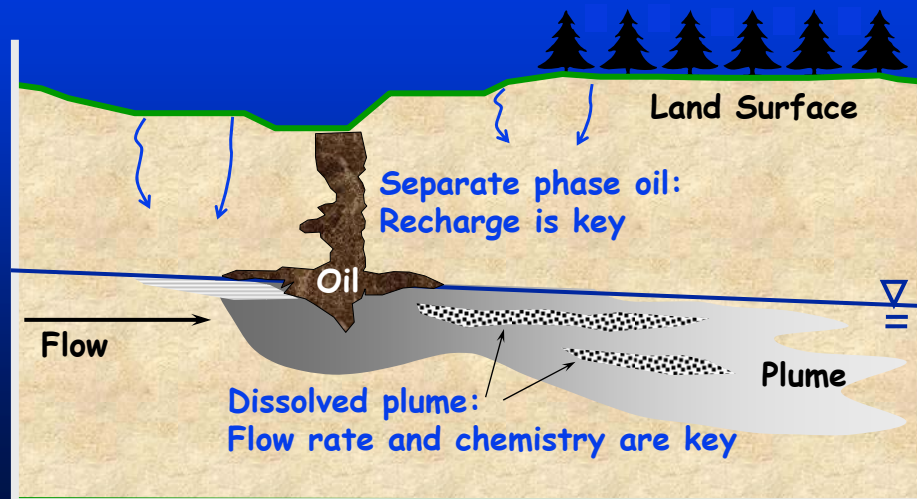
## Selected Slides from 2004 Birdsall-Dreiss Lecture

### The Influence of Hydrogeology on 25 Years of Natural Attenuation at a Crude Oil Spill Site

Barbara Bekins  
U. S. Geological Survey

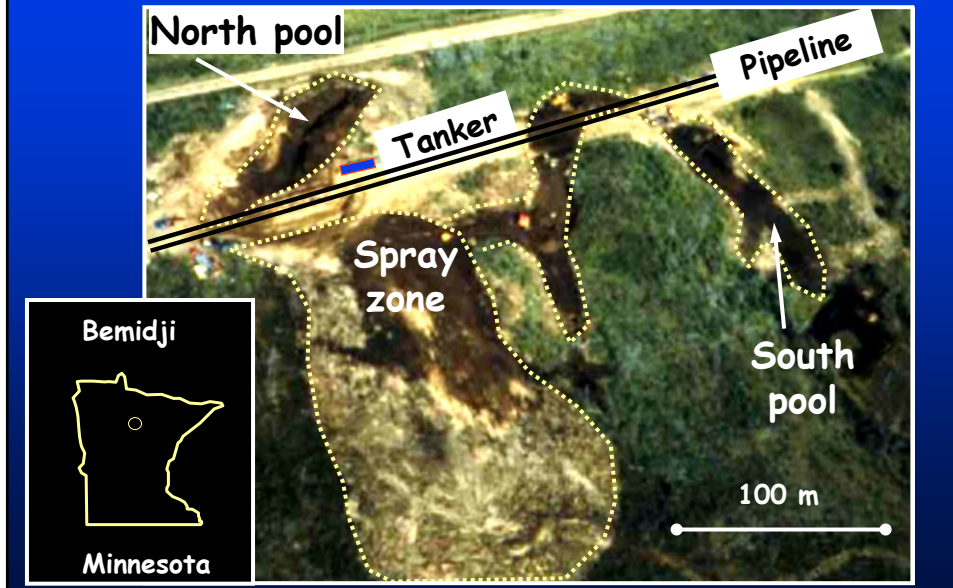


### Hydrology profoundly affects biodegradation processes

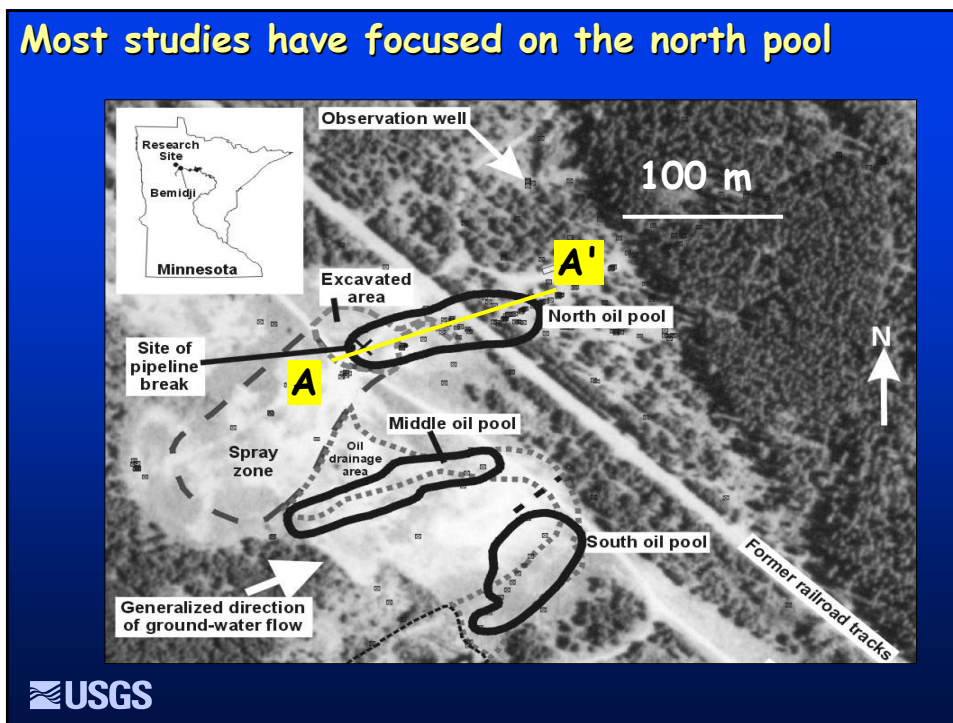


Barbara Bekins, U.S. Geological Survey, [mms://video.wr.usgs.gov/wrd/20may2004.wmv](https://video.wr.usgs.gov/wrd/20may2004.wmv)  
(Menlo Park, CA: 20 May 2004).

A 1979 pipeline break spilled  $1.7 \times 10^6$  liters of crude oil

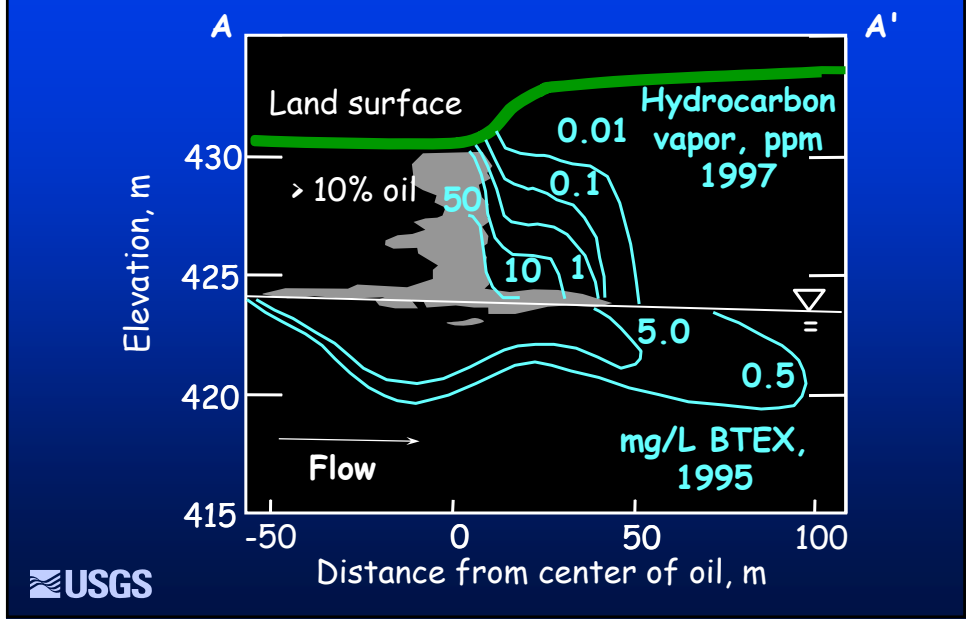


Most studies have focused on the north pool

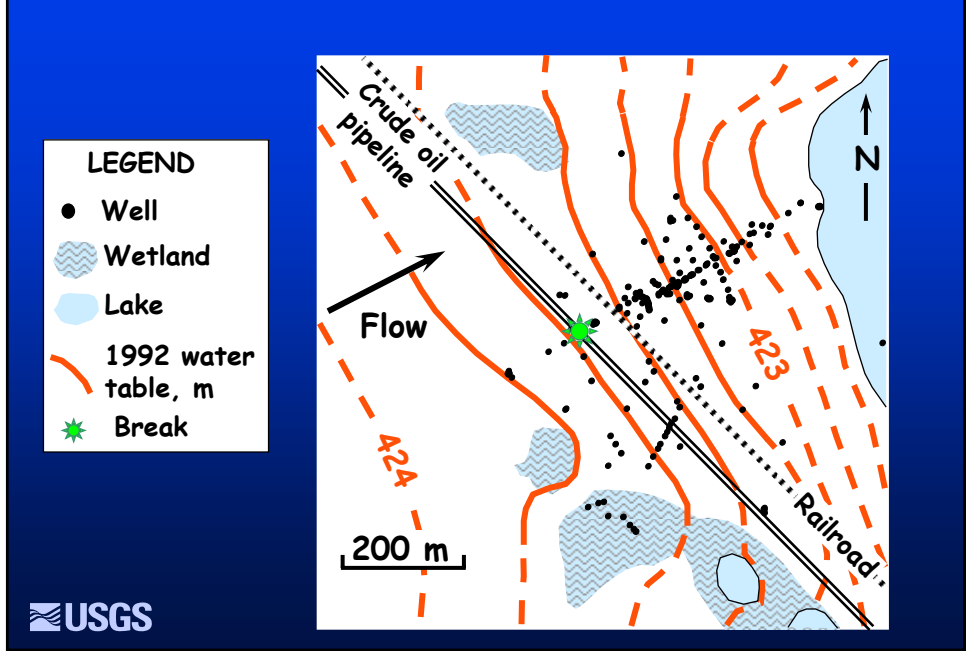


Barbara Bekins, U.S. Geological Survey, [mms://video.wr.usgs.gov/wrd/20may2004.wmv](https://video.wr.usgs.gov/wrd/20may2004.wmv)  
(Menlo Park, CA: 20 May 2004).

**Both the vadose and saturated zone are contaminated**

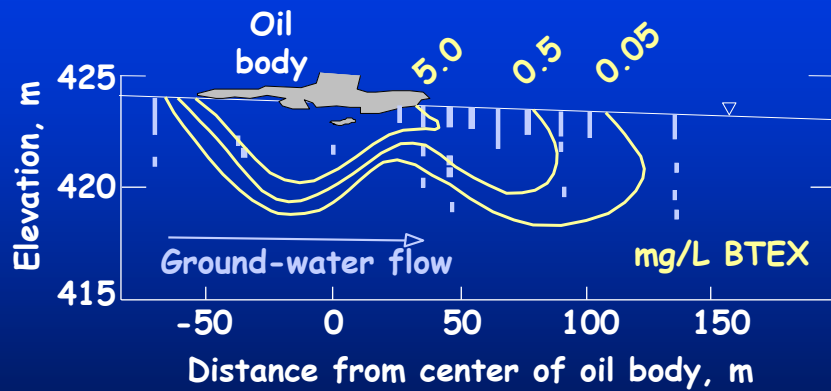


**The flow is about 18 meters per year**



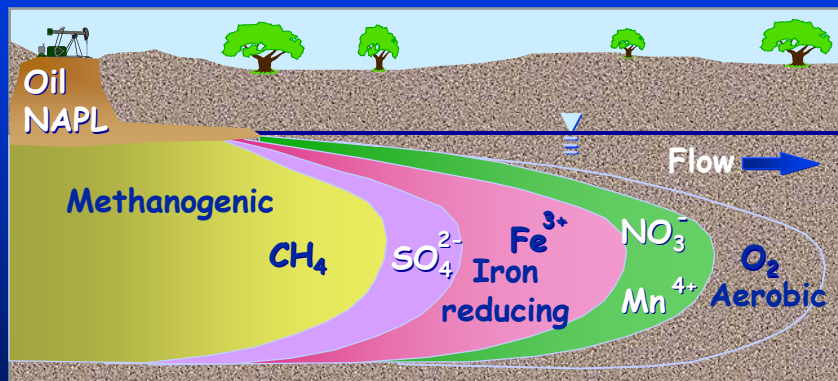
Barbara Bekins, U.S. Geological Survey, [mms://video.wr.usgs.gov/wrd/20may2004.wmv](https://video.wr.usgs.gov/wrd/20may2004.wmv) (Menlo Park, CA: 20 May 2004).

In 1992, the plume appeared to be at steady state or shrinking

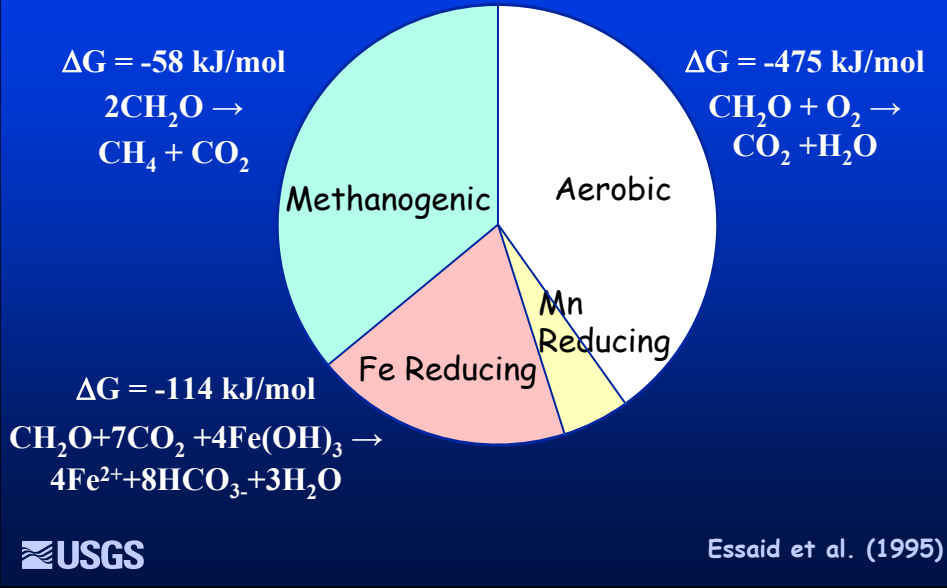


Baedecker et al. (1993)

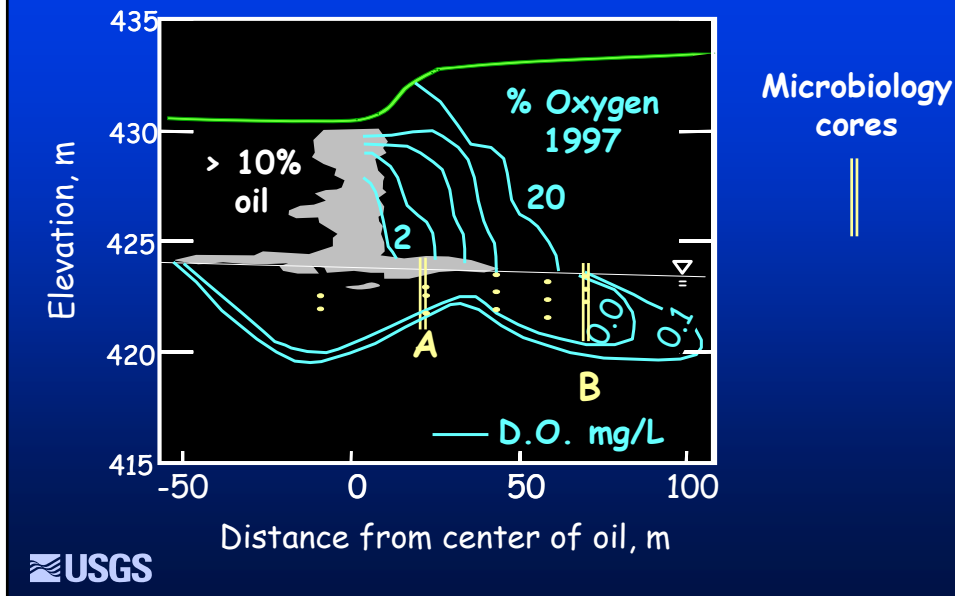
A succession of electron acceptors occurs when an aquifer becomes contaminated with petroleum



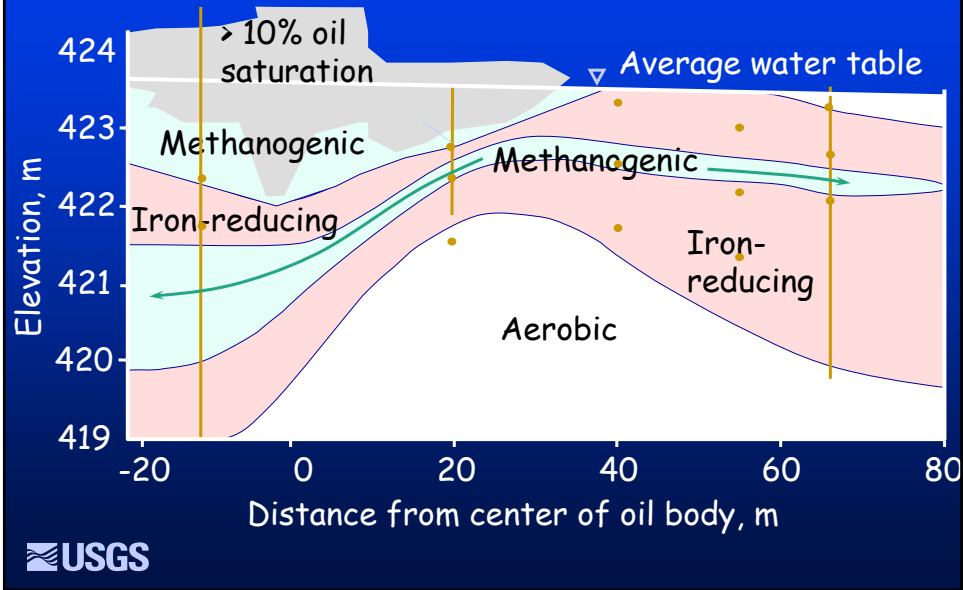
**Chemical data and modeling quantify the relative importance of electron acceptors**



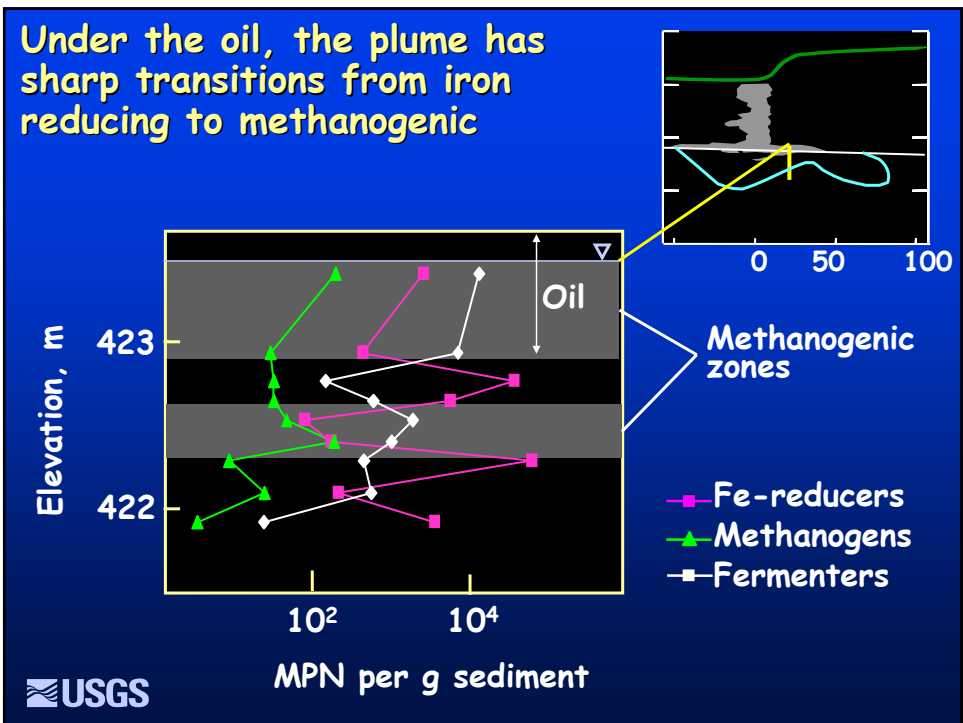
**Cores were collected to identify the microbial populations in the anoxic zone**



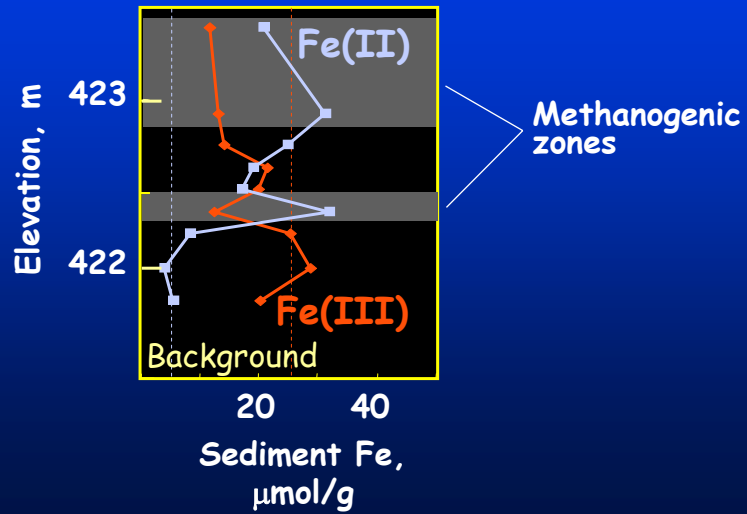
**Methanogenic conditions occur in two areas:  
(1) oil body and (2) center of plume**



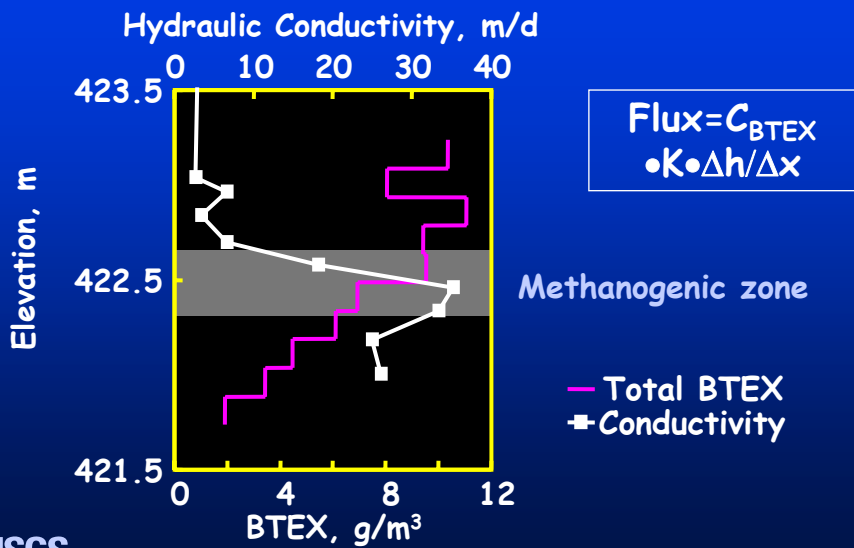
**Under the oil, the plume has sharp transitions from iron reducing to methanogenic**



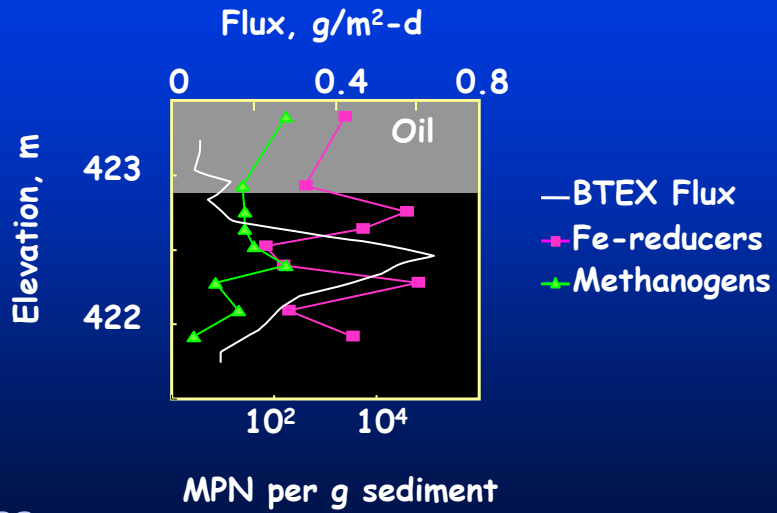
**Methanogenic zones have depleted Fe(III) and high Fe(II) values**



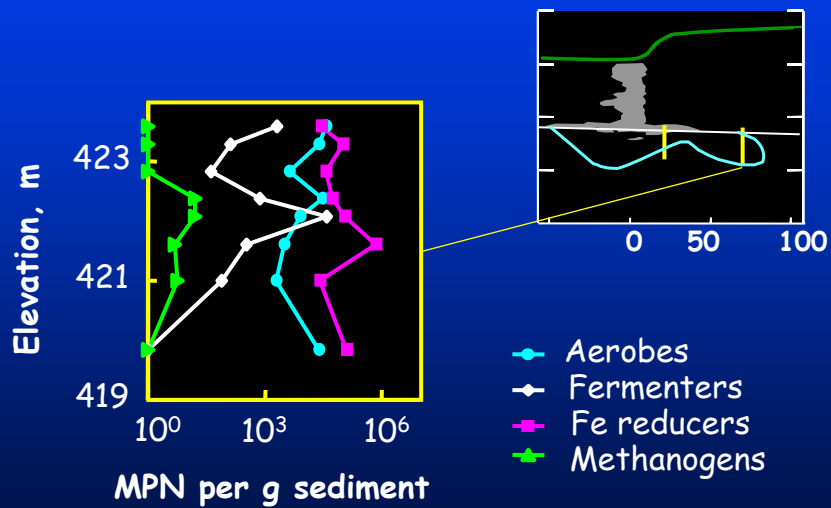
**Methanogenic conditions are related to conductivity and BTEX concentration**



Methanogens are established first where there is maximum BTEX flux

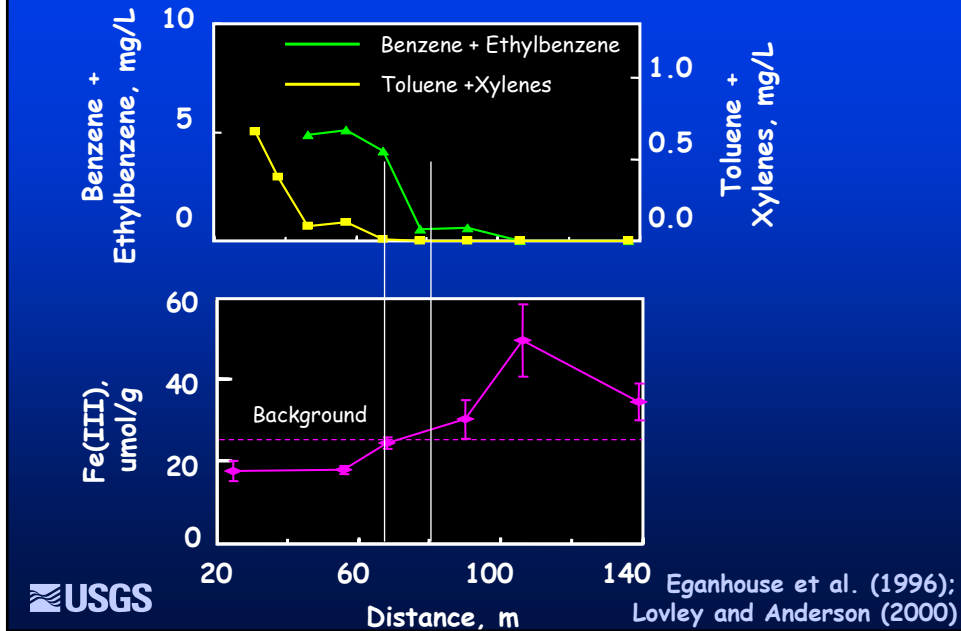


Near the edge of the anoxic zone, methanogens are less well established

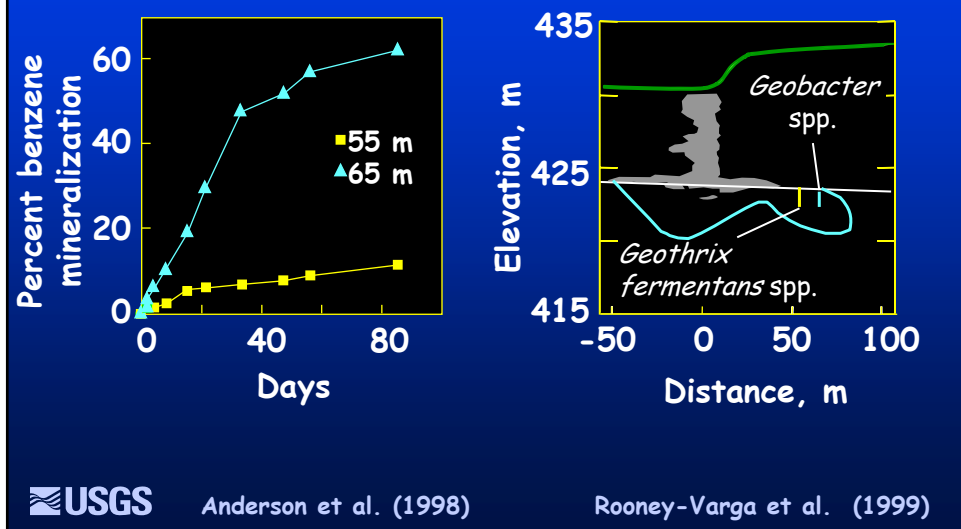




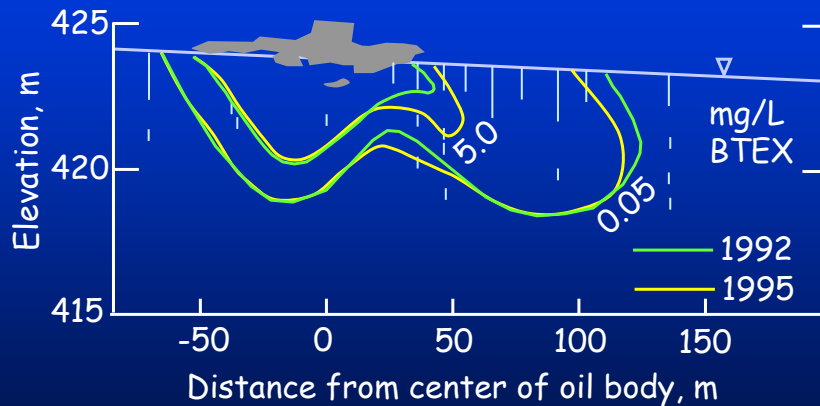
### Benzene degrades where Fe(III) is still high



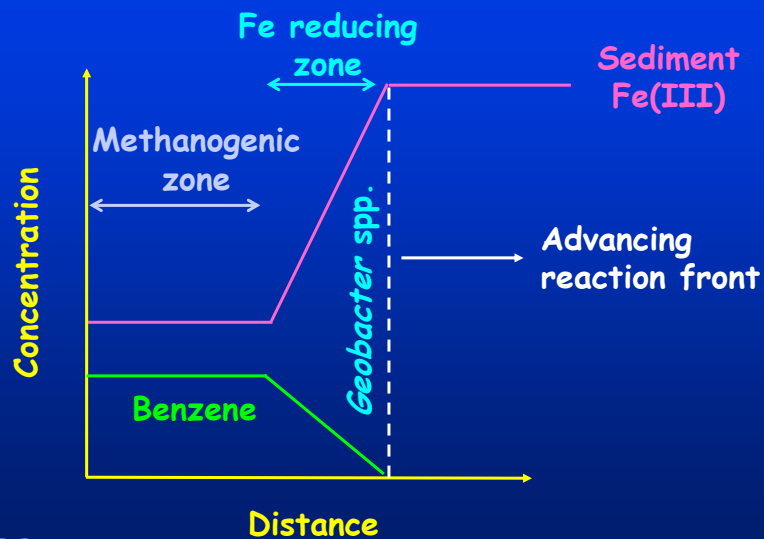
### Benzene degradation occurs only where *Geobacter* spp. are present in the aquifer



The 5 mg/L BTEX contour expands at about 2.5 m/yr as Fe(III) is depleted



The Fe reducing zone and benzene front advance down gradient together



**In the oil body, recharge controls degradation rates via microbial growth**



Supplies nitrogen from the surface

Increases dissolution of soluble fraction

Carries away microbial waste products



**A comparison of adjacent samples shows significant degradation from 1983 to 1999**

