Does crustal seismicity enhance subsurface microbial activity and growth?

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The geochemical, isotopic and microbial attributes of over 100 water and gas samples taken from the deep mines in South Africa from 0.8 to 3.3 km below the surface (kmbls.), temperatures up to 60°C and over a 40,000 km² area have been analyzed. Almost all of these analyses are for fresh intersections of fluid filled fractures, some of which are associated with dykes. Our research group does not know whether these fracture systems are seismically active, but it merits examination. Results from these samples indicate the following:

1. Estimates of the subsurface residence time or the groundwater range from 30 kyr for low salinity water to ca. 400 Myr for saline water.
2. The concentrations of microbial cells ranged from <5x10³ (detection limit) to 5x10⁵ cells/ml.
3. Methane and hydrocarbons from depths >2 kmbls. appear to originate by abiogenic reduction of CO₂ and oxidation of H₂.
4. Methane from depths < 2 kmbls. appear to represent a mixture of methanogenic and thermogenic or abiogenic methane.
5. Copious amounts of H₂ appear to be created by radiolysis of water. Radiolysis may also be responsible for the high concentrations of sulfate encountered at depths > 1.5 kmbls.
6. At depths >1.5 kmbls, indigenous bacterial populations are composed of SRB’s including meso/thermophilic Desulfotomaculum-like gram positives and several novel, deeply branching bacterial lineages. The predominant archaeal clone type from the highest temperature water (60°C) was 99% similar to Pyrococcus abyssi.
7. At depths < 1.5 kmbls, methanogens such as Methanosarcina or Methanosaeta are common.
8. Microbial sulfate reduction appears to be the dominant electron accepting process at depths >1.5 kmbls; whereas, methanogenesis appears to be more abundant at depths <1.5 kmbls.
9. The microbial abundance is far less than expected based upon the availability of electron donors and acceptors for depths > 1.5 kmbls. implying some other limitation upon microbial growth.

More recently in situ experiments have been performed within boreholes to relate metabolic processes to specific microorganisms. In these experiments several different types of nutrient and substrate cartridges are placed at varying depths within a flowing borehole, which is subsequently sealed. Each cartridge is connected to the borehole outlet with tubing that permits monitoring of the gas and water chemistry and isotope composition, temperature and the microbial communities as in situ microbial growth occurs within each cartridge. Underground coring is also in progress to identify the rates of gas and aqueous nutrient migration from the rock matrix into the fracture zone, the presence of any microbial communities in the rock matrix proximal to the fractures and biomineralization on the fracture surfaces. The cores are also analyzed for noble gases that enable the determination of the geological age of the fracture.

H₂ generation has been reported for seismically active faults and is attributed to water-rock interactions. If true then we would hypothesize that the gas compositions and possibly their isotopic signatures for seismically active faults will be distinct from that of less active fracture systems. As H₂ is an important energy source for subsurface microbial communities, the biomass and community structure and the water chemistry associated with seismically active fault systems could be drastically different from more tectonically benign fractures. Fluid and gas transport may also be more rapid in seismically active faults than in inactive fractures and temporal changes in gas and water chemistry and microbial community composition may be associated with seismic events. These nascent hypotheses can be addressed by installing gas and water, sampling ports in the same bore hole used for in situ strain measurements at varying distances across an active fracture zone. Characterization of the physical, geochemical and microbial properties of the core collected from the same borehole would be used to identify target depths for the sampling ports. Analyses of the pore water and gas composition of the core could be utilized to
ascertain how fracturing of the rock during seismic activity alters the ground water and formation gas composition.

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