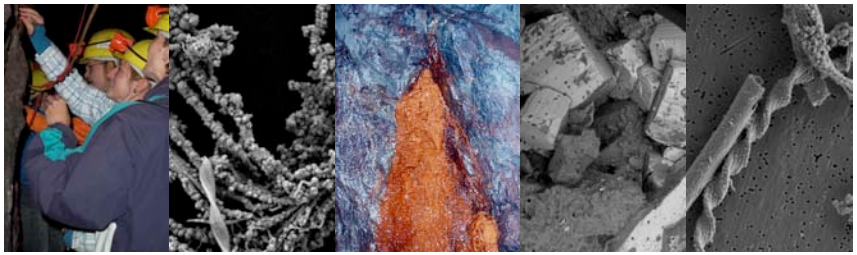
Geomicrobiology and hydrogeochemistry in cold water mineral springs of the Lower Engadine Window

Field trip to geomicrobiologically and geochemically interesting ecosystems in the Swiss Alps
for participants of the Geomicrobiology Course at the ETH Zürich and guests
Wednesday, April 29, 2009

Microbially mediated Fe, S and C cycling and carbonate precipitation in low temperature mineral springs of the „Lower Engadine Window“ and the Albula valley region /GR, Switzerland

Guided by Kurt Hanselmann and Chris Vasconcelos, Geology Institute, ETH Zürich

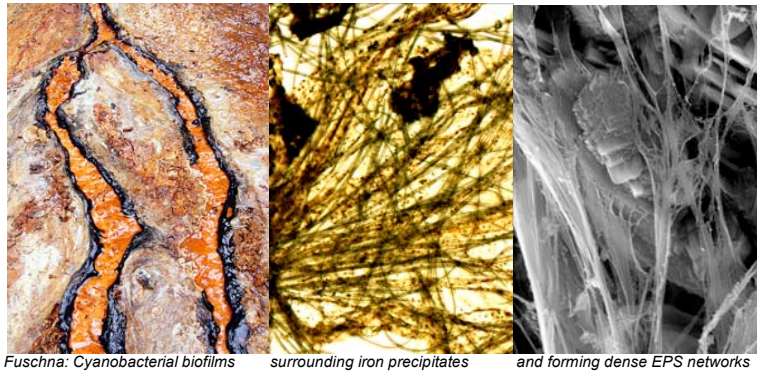


During this geomicrobiological field trip we will learn how to evaluate concepts of microbial ecology as they appear to us in nature and as they apply to the geosciences. We will be confronted with a few hydrochemical essentials, which we will relate to basic chemical knowledge, and to the mineralogy and the geology of the areas visited.

Tarasp-Scuol-Ftan: subsurface geo-hydro-microbiology in the „Lower Engadin Window“, Trias evaporites, Bündner shale, mineral dissolution, CO_2 outgassing and „carbonate ice“ precipitation, deep subsurface chemical interactions and biological processes, surface reactivities of sedimentary rocks.

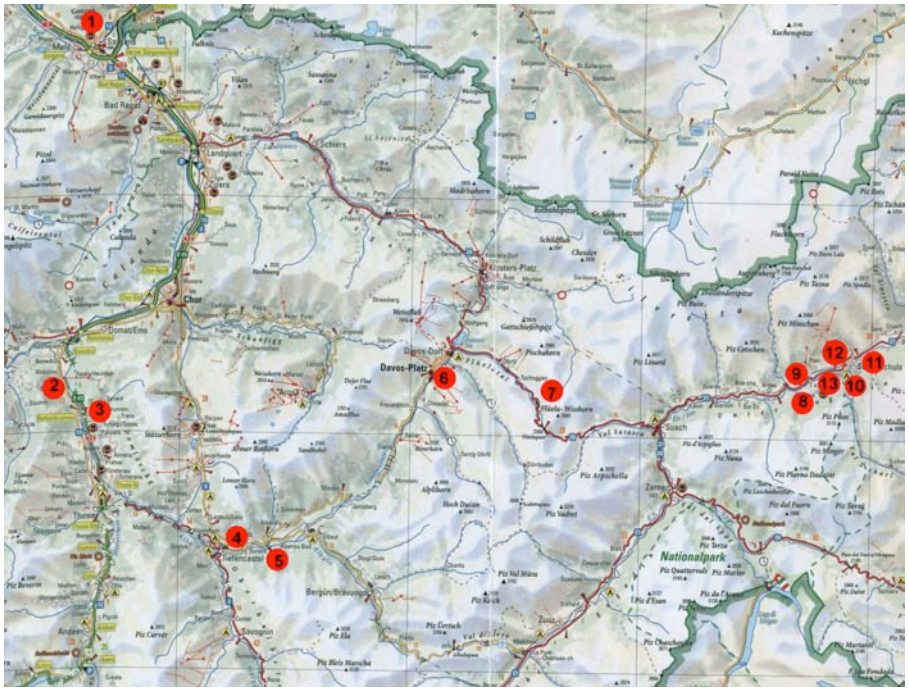
Alvaneu: Competing S- and Fe-chemolithotrophy, biosphere-hydrosphere-lithosphere interactions.

Rothenbrunnen: microbial involvement in iron transformation processes.



Fuschna: Cyanobacterial biofilms *surrounding iron precipitates* *and forming dense EPS networks*

Field trip stops (field sites visited might change depending on weather and time)
8.-12. Mineral springs and travertine formation (Lower Engadine, Scuol-Tarasp-Ftan), –
4 & 5. Sulfur and iron springs (Alvaneu), – 3. Iron fountain (Rothenbrunnen)



Objectives

Geomicrobiology: Often the solutes present in spring water not only represent the water soluble mineral components of the rocks, they also carry a signature of microbiological processes which have taken place in the subsurface. The presence of certain reduced chemicals can be due to the activity of anaerobic chemoorganotrophic bacteria and archaea in the deep subsurface. Aerobic chemolithotrophs at the spring mouth can make a living by oxidizing these reduced compounds.

Bio-geo-chemical cycles: We will see surface phenomena which relate to underground and surface geochemical cycles of iron, manganese, sulfur, carbon and phosphorus (Scuol-Tarasp-Ftan, Rothenbrunnen, Alvaneu). Often ferrous iron and sulfide oxidizing bacteria develop in masses at the anoxic-oxic transition zone. We will study the conditions that must prevail to select specifically for the kind of bacteria, which are present in these aquatic habitats.

Hydrobiochemistry: We will illustrate the quality of the water when it arrives as rain or snow in the Alps: how does it get stored, how is it transported, and how does its chemical composition change while it percolates through different rock formations (Rauwacke, Gypsum, Bündnerschiefer). These topics will be illustrated at different locations in the upper catchment of the Rhine and Inn rivers (Rothenbrunnen, Alvaneu, Scuol-Tarasp). We will focus on the chemical composition of a variety of spring waters and follow how this can create a diversity of ecosystems for microorganisms.

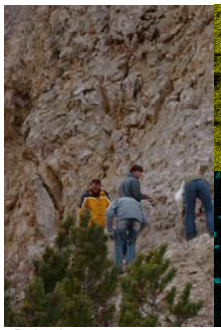
Tectonics: The Lower Engadine Window (LEW) is a large tectonic opening into penninic sediments that originated in a former oceanic basin. The slightly metamorphic pelagic sediment layers are visible as large Bündner shale outcrops in the area of Scuol-Tarasp-Vulpera-Ftan. South of the Inn river the deformed Bündner shales are overlayed by gneiss and serpentinite and by dolomitic sedimentary rocks, which form a permeable karst aquifer. The highly mineralized waters that emerge from these aquifers in numerous low temperature springs are oversaturated with regard to calcium carbonate. They contain high concentrations of hydrogen-carbonate and dissolved CO_2 as well as variable concentrations of sulfate, calcium, magnesium and a number of other dissolved anions and cations. Some contain dissolved ferrous iron, others sulfide, both of which can promote microbial growth and mineral precipitation at the mouth of the springs.
During the field trip we will study the geological and geochemical settings and corresponding microbial life strategies in a number of cold mineral water springs.

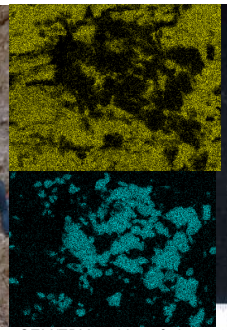
Key topics at stops

8.-13. Mineral springs, Scoul-Tarasp-Vulpera-Ftan: Spring water composition reflects the mirror image of the underground geology and is dependent on the contact time between water and the bedrock. At the mouth of the springs the waters contain the dissolved solutes from the rock minerals. Dangerously large amounts of gaseous CO_2 are formed in enclosed areas underground. When the carbonic acid / bicarbonate saturated aqueous solution reaches the surface the dissolved H_2CO_3 equilibrates with the CO_2 of the atmosphere. This can lead to the formation of carbonate ice and small travertine terracettes. Dense films of microorganisms develop whenever the water contains oxidizable and nutrient components.

4 & 5. Sulfur and iron springs, Alvaneu: The „rust“ in the outflow of the iron spring consists of badly soluble iron(III)-oxides and iron(III)-hydroxides which dominate the habitats of ferrous iron oxidizing bacteria. The sulfur in the springs and fountains is formed by hydrogensulfide oxidizing chemolithotrophs, mostly *Thiothrix spp.* with intracellular sulfur deposits, which are highly enriched under the sulfidic conditions. Competition between biotic and abiotic processes for Fe(II+) and S(II-) oxidation.

3. Iron fountain Rothenbrunnen: The water from the iron-rich Rothenbrunnen spring is processed into marketable drinking water by oxidizing the ferrous iron and subsequent removal of the ferric iron precipitates by filtration. Bacteria which colonize the fountain can catalyze the ferrous iron oxidation (e.g. *Gallionella ferruginea*). They protect themselves from being completely encapsulated with „rust“ by forming an extracellular sheath from which the cells can „escape“ as soon as exchanging metabolites by diffusion becomes limiting.


Dolomite outcrop


SEM/EDX probing of elemental distribution


Bündner shale, former sediments

Discussion topics (depending on interest):

- How mineral waters get formed
- How mineral water composition can be altered by microbes
- How nutrients are cycled in cold aquatic ecosystems
- What is the role of the iron cycle for nutrient accumulation?
- How microbes adapt to extreme environments: psychrophilic lifestyles
- How microbial mats and biofilms are formed in nutrient poor flowing and stagnant waters
- What is the composition of the chemolithotrophic microbiota in mineral springs?
- How subsurface mineral weathering is mediated by chemical and microbial processes
- How “carbonate ice” and travertine are formed at mineral springs

Research Participants are invited to choose one from the following research focus topics that are offered for this field trip.

1. Rothenbrunnen, iron fountain: ferrous iron chemolithotrophs
2. Alvaneu, sulfur springs: hydrogensulfide chemolithotrophs
3. Alvaneu, iron-sulfur springs: iron-sulfide chemolithotrophs
4. Mineral springs Fuschna and Bonifacius: Cyanobacteria and “carbonate ice” communities
5. Mineral springs in the Lower Engadine Window: Origin and geohydrologic system

You may collect samples, conserve them at the collection site and investigated them further at your home laboratory. Please document precisely the conditions at the site from which the samples are collected.
For each site visited investigate the following five aspects:

1. Which microorganisms are present?
2. Describe the site as a habitat (bedrock, hydrology, exposure to atmosphere etc.)
3. Define the living conditions (pH, T, conductivity, sulfide- and ferrous iron concentrations).
4. Discuss the microbial life styles that are possible in the ecosystem.
5. Address the questions, which relate to “your” research topic.
   Aspect 1 should be carried out in the laboratory after the field trip, 2 and 3 are based on your observations and the discussions at the location in the field and 4 and 5 need to be supplemented with background information from the literature and from the field trip comments.

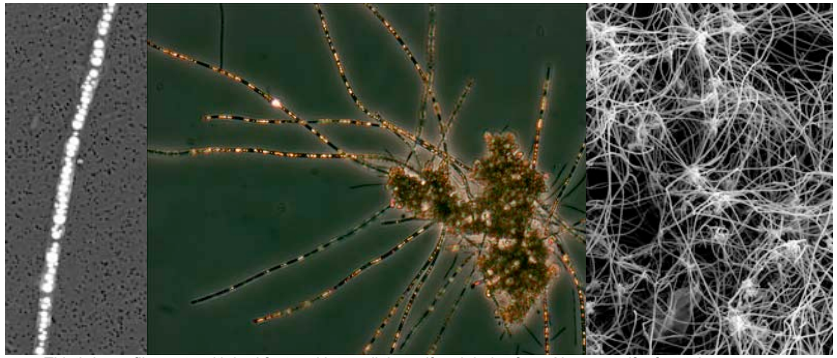
Reporting Each participant will choose scientifically related topics for investigation from the ones offered above, search for background information and summarize and present the findings at the site.

Field trip program

April 29 (Wednesday)

07:00 Departure at Geology ETH, Sonneggstreet 5 by bus
Travel via Klosters – Vereina tunnel - Scuol-Tarasp

10.00 Bonifazius: Travertine formation at spring outflow into the Inn river (stop 8)
10.45 Carola, Luzius, Emerita, „Geysir“, Sfondraz, high mineralization, CO_2 formation and escape. (stop 13)
11.30 Clozza drinking fountain, formation of travertine terracetts at Clüs (stop 11)
12.15 Lischana: High magnesium water (stop 12)
12.45 Fuschna, cyanobacterial mats, CO_2 outgassing and carbonate ice formation (stop 9)
13.30 Travel via St.Moritz – Julier – Tiefenkastel
15.00 Bündner shale outcrop near Tiefenkastel, stop 4
15.30 Alvaneu Bad, walk along the Albula river to the iron and sulfur springs, which are rich in chemolithotrophic microbes. The use of the sulfidic waters for medical purposes, stop 5
16.30 Rothenbrunnen iron fountain, de-ironing of water to make bottled mineral water, stop 3
17.00 Begin travel home via Chur – Sargans - Zürich
19.00 Arrival at Zürich, ETH, Sonneggstrasse



Thiothrix sp. filaments with hod fast and intracellular sulfur globules from Alvaneu sulfur fountain

Clothing etc. The planned excursion can take place regardless of the weather forecast if you are equiped accordingly. But we might decide on the spot to change the program in case the weather or the conditions should demand it. If the weather allows, we will have opportunities to enjoy some beautiful landscapes with great views of the Alps. Don't forget your camera!

Sturty walking shoes are a must since we will traverse rough montainous terraine. Be prepared for snow. Backpack for provisions and samples. Have a drinking cup with you. We will taste different mineral waters along the way.

The weather can change abruptly in the mountains. Please be equiped with sun glasses and UV protective lotion, a hat as well as rain gear.

Please take collecting vials for bacteria and bags for rock samples with you. Bring a note book and record the information given in the field, and a camera if you intend to take pictures of the sites which we will visit.

Fitness In the mountains we will walk on well marked paths; the walks will not be strenuous.

Travel By private mini-bus

Route Zürich – Sargans – Klosters (Vereina tunnel) – Scuol-Tarasp-Ftan – Tiefenkastel – Alvaneu – Rothenbrunnen – Zürich

Costs There is no fee for enrolled ETH students. Backpack lunches are the particpants' responsibility.

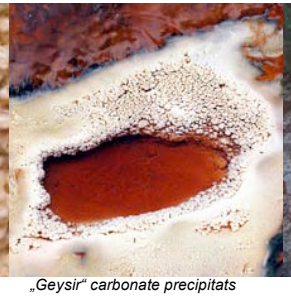
Insurance is the responsibility of the participant. The tour guides cannot be held liable for damages or lost items. You may not leave the group on the walks since you might get lost or get yourself into danger. Please make sure that your accident insurance policy covers mountain rescue operations by helicopter (REGA in Switzerland, www.rega.ch, tel. ++41 (0)844 834 844 or equivalent).

Signing up There are 10 places available in the bus. Please sign up **before April 6**.

Information Application and trip: Chris Vasconcelos cris.vasconcelos@erdw.ethz.ch
Field sites: Kurt Hanselmann, kurt.hanselmann@hispeed.ch

We are looking forward to having interested students and guests on this geomicrobiology excursion. It will be an eye-opener for those who are interested in seeing natural microbiological and geochemical features. You may investigate the samples collected from the sites during the following weeks at your home lab.

Clüs: Travertine terracetts



„Geysir“ carbonate precipitats

Fuschna, „carbonate ice“