Extremophile geomicrobiology in high mountain habitats and in cold water mineral springs

Field trip to geomicrobiologically and geochemically interesting ecosystems in the Swiss Alps
for participants of the Geosciences Program at the Eberhard-Karls-University Tübingen and guests
Wednesday, September 10 to Friday, September 12, 2008

Topics: Fe, S and C geomicrobiology and geochemistry in the Jöri lake catchment and in the mineral springs of the Lower Engadine and the Albula valley region

Guided by Kurt Hanselmann, U. of Zürich and Andreas Kappler, Eberhard-Karls-University, Tübingen

Jöri catchment

Locations with Topics

During this geomicrobiological field trip we will learn how to evaluate concepts of microbial ecology as they appear to us in nature. We will also 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.

Rothenbrunnen: microbial involvement in iron transformation processes,

Alvaneu: chemolithotrophy, biosphere-hydrosphere-lithosphere interactions,

Jöri: alpine microbial habitats, low-nutrient life strategies, cold-adapted microorganisms, microbially mediated geochemical cycling of P, Fe, Mn, relations to alpine geology, alpine water cycle.

Tarasp-Scuol: subsurface geo-hydro-microbiology in the „Lower Engadin Window“, Trias evaporites, Bündnerschiefer, mineral dissolution, CO_2 outgassing and „carbonate ice“ precipitation, surface reactivities of sedimentary rocks.

Alp Weissenstein: endolithic biofilms in gypsum containing dolomite.

Clüs: Travertine terracetts

„Geysir“ carbonate precipitats

Fuschna, „carbonate ice“

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 (Alvaneu, Jöri). 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.

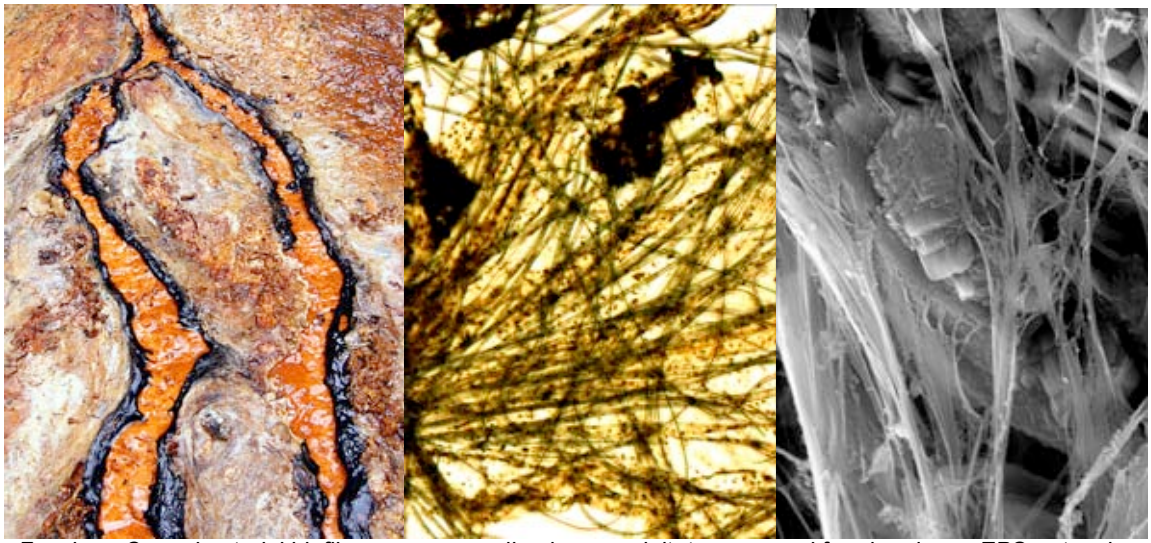
Hydrobiochemistry: We will illustrate the quality of the water when it arrives as rain or snow in the Alps: how does it get stored, how is it transported, and how does its chemical composition change while it percolates through different rock formations (Rauwacke, Gypsum, Bündnerschiefer). These topics 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.

High altitude research: At the High Mountain Research Station we will study how microorganisms respond and adapt physiologically to the complex interactions between extreme and extremely variable chemical, geological and atmospheric determinants in the Jöri lakes, in snow and on ice. The studies here are aimed at understanding evolutionary processes in ecosystems research and the microbial diversity in cold-extreme environments.

Hydrology: The terrestrial hydrological cycle, which begins in the central European Alps distributes water by 4 major river systems across much of the continent. We will cross the divide between the Rhine and and the Danube catchments. Millions of people in Europe depend on water, which originates in these alpine regions for drinking water, power generation, transport, industrial purposes and recreation.

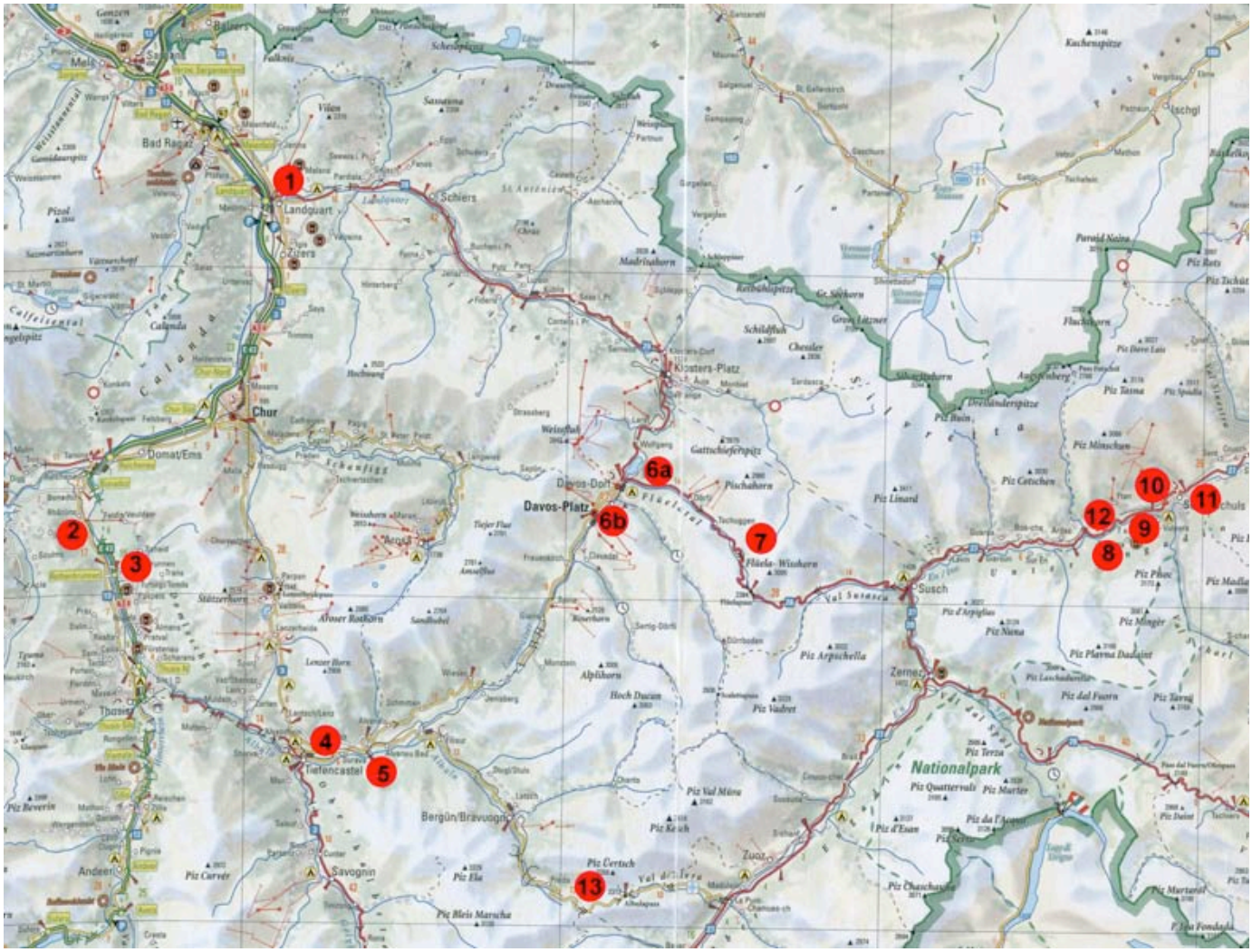
Field trip stops

(might change depending on weather and time)
1. Train station Landquart (pick up K.Ha.) 2. Rhäzünser Mineralwater processing plant (Rhäzüns) 3. Iron fountain (Rothenbrunnen) – 4 & 5. Sulfur and iron springs (Alvaneu) – 6. Davos (TimeOut, SLF) 7. High alpine Jöri lakes (Klosters / Davos) – 8-12. Mineral springs and travertine formation (Lower Engadine, Scuol-Tarasp) – 13. Gypsum containing dolomitic outcrop (Alp Weissenstein, Albula) and carbonate-lake Palpuogna (Preda / Bergün).



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

Key topics at stops



DAY 1 / stops

2. Mineral water for human consumption: Visit at the Rhäzünser mineral water processing plant. For centuries highly mineralized spring waters were used for healing purposes; today they are mostly bottled and marketed as mineral enriched drinking water. As an introduction to the excursion we will be informed about the hygenic requirements and the technology used to process natural spring water into bottled drinking water

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.

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.

DAY 2 / stops

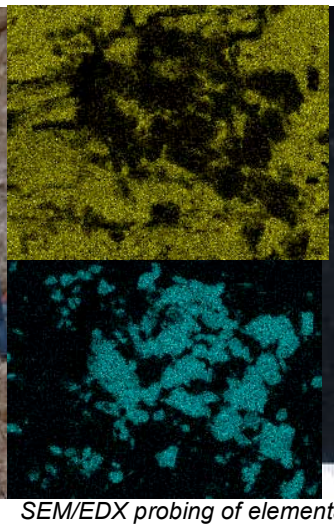
7. High alpine Jöri lakes, Klosters / Davos: Research topics which are addressed at the High Mountain Research Station at Jöri Lake XIII, in the upper Vereina valley/GR are „Microbial life strategies under harsh environmental conditions" and "Geochemical nutrient scavenging in nutrient-poor environments". High mountain lakes, snow and glacial ice offer ideal conditions for the study of adaptations of organisms to a variety of environmental extremes: water temperatures are often near freezing, darkness under snow and ice lasts for many months, UV radiation is strong during the summer months and nutrients are scarce. One wonders how life has adapted to these challenges over time and yet is constantly amazed at the strategies microbes have developed to cope with these extreme conditions.

DAY 3 / stops

8-12. Mineral springs, Scoul Tarasp Vulpera: 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.

13. Gypsum containing dolomitic outcrop, Alp Weissenstein: At Igls Plans (2044 m asl) a gypsum containing dolomitic outcrop offers a window into what is buried in the subsurface on most other locations. They are evaporitic rocks, which are easily eroded and dissolved. Endolithic phototrophic communities find habitats in near surface rock layers.
Carbonate-enriched Lac da Palpuogna, Preda: This and other lakes, which are located just below a dolomitic outcrop reflect the consequences of elevated concentrations of dissolved minerals on algal growth and primary productivity.

Dolomite outcrop



SEM/EDX probing of elemental distribution

Bündner shale, former sediments

Discussion topics include aspects to (depending on interest):

- How mineral waters are formed
- How mineral water composition can be altered by microbes
- How nutrients are cycled in cryosphere ecosystems
- What is the role of the iron cycle for nutrient accumulation
- How nutrients are scavened in oligotrophic high-mountain lakes
- Is self-trophication a phenomenon of specialized low nutrient environments
- How organisms adapt to low temperatures, intensive solar radiation and long periods of
- darkness

- How community diversity is regulated by changing habitat conditions
- How microbes adapt to extreme environments: psychrophilic lifestyles
- How microbial mats and biofilms are formed in nutrient poor flowing and stagnant
- mountain waters
- How sedimentary bio-laminations are built in glacial fluvial deposits
- 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
- How similar are alpine and polar microbial ecosystems
- How microbes live and survive in snow and ice

Research Participants are invited to choose from 8 research focus topics, which are offered for this field trip. There are research topics, which can accommodate 1 student and those, which are suitable for a group of maximally 2 students. Please organize yourself.
Samples for course work may be collected at the following sites:

1. Rothenbrunnen, iron fountain: ferrous iron chemolithotrophs
2. Alvaneu, sulfur springs: hydrogensulfide chemolithotrophs
3. Alvaneu, iron-sulfur springs: iron-sulfide chemolithotrophs
4. Jöri lake XIII, microbial communities in the water column
5. Jöri lake XIII, bloom degradation communities, if bloom has happened
6. Jöri lake I or XIX, biofilms and laminated sedimentary deposits
7. Mineral springs Fuschna and Bonifacius: Cyanobacteria and “carbonate ice” communities
8. Outcrop Weissenstein: endolithic microbes

The samples will be conserved at the collection site and will be investigated at your home laboratory. Please document precisely the conditions at the site from which the samples are collected.

For each ecosystem (site visited) investigate the following five aspects:

1. Which microorganisms are present?
2. Describe the site as a habitat (bed rock, hydrology, exposure to atmosphere etc.)
3. Define the living conditions (pH, T, conductivity, sulfide- and ferrous iron concentrations).
4. Discuss the microbial life styles, which 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 lectures.

Reporting Each participant will choose scientifically related topics for investigation from the ones offered, search for background information and summarize and present the findings together with the on-site experiences in the form of a well documented and illustrated written report. Reports will be made available to all participants.

Field trip program

September 10 (Wednesday)

09.30 Railroad station Landquart. Kurt Hanselmann will join the group, stop 1
10.15 Rhäzünser Mineralsprings, AG, processing plant, Rhäzüns. How natural mineral waters are treated, hygenically checked and bottled (Mr. Niels Jacobi), stop 2
12.00 Rothenbrunnen iron fountain, de-ironing of water to make bottled mineral water, stop 3
13.30 Bündner shale outcrop near Tiefenkastel, stop 4
14.00 Alvaneu, 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
16.00 Arrival at Davos, ev. Presentation of Research Projects at the Swiss Institute for Snow and Avalanche Research (ev. N.N.) shopping for next day's lunch, stop 6a
18.00 Dinner and overnight stay at „Time Out", Davos Platz (Tel. +41-81- 415 36 72), stop 6b
19.00 Presentation and discussion about topics of the following day

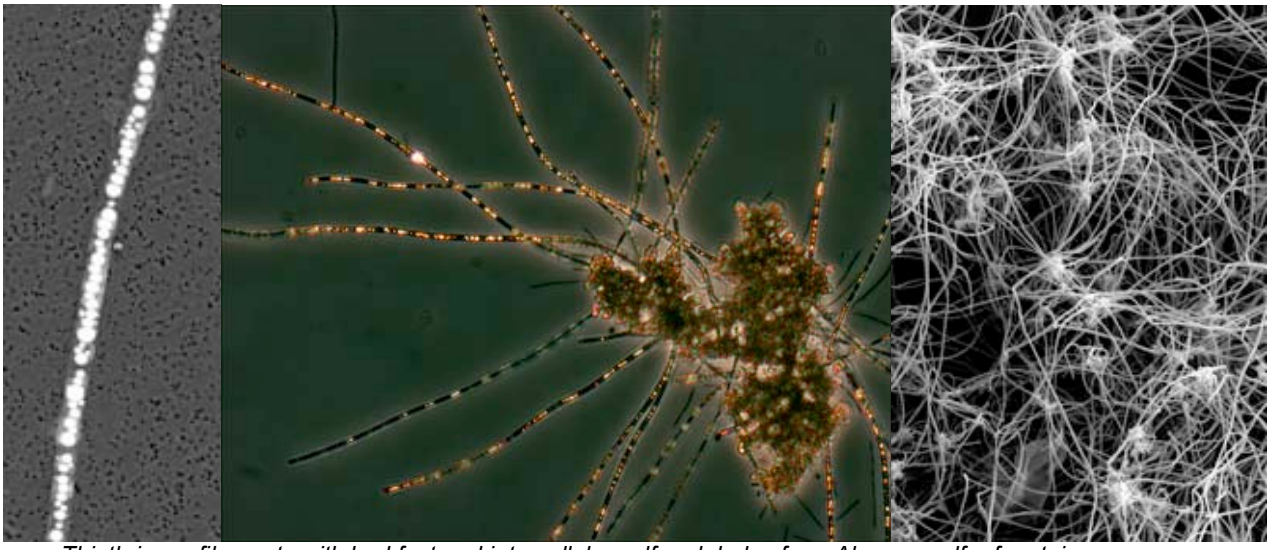
September 11 (Thusday)

07.00 Breakfast at „Time Out". (You may leave your luggage in the room and take only what you need for the day trip)
07.30 Depart from Davos
08.15 Wägerhus, begin climb to Jöri lakes, stop 7
10.30 Arrival at Research station lake XIII: geochemical Fe-, Mn-, P-cycles
12.30 Lake I: highly turbid lake, role of suspended nanoparticles
13.30 Lake II: iron rich swamp and moraine spring with *Hydrurus sp.*
14.30 Lake XIV: Glacial sedimentation field, fractionation of erosion particles
15.30 Glacial lakes XVI – XXII
16.30 Cryoconite holes on Jöri glacier, depends on snow cover
17.00 Winterlücke, begin descent
18.00 Depart Wägerhus, stop 7
18.30 Arrival Davos, shopping for next day's lunch.
19.00 Dinner and overnight stay at „Time Out", Davos Platz (Tel. +41-81- 415 36 72), stop 6b
20.00 Presentation and discussion about topics of the following day

September 12 (Friday)

07.30 Breakfast at „Time Out". (We will take all luggage with us)
08.15 Depart from Davos to the mineral springs at Scuol-Tarasp-Vulpera, Have a drinking cup with you. We will taste different mineral waters along the way.
09.30 Bonifazius: Travertine formation at spring outflow into the Inn river, stop 8
10.15 Carola, Luzius, Emerita, „Geysir", Sfondraz, high mineralization, CO_2 formation and escape. stop 9
11.00 Clozza drinking fountain, formation of travertine terracetts at Clüs, stop 10
11.30 Lischana: High magnesium water, stop 11
12.30 Fuschna, cyanobacterial mats, CO_2 outgassing and carbonate ice formation, stop 12

13.00 Travel via Albula Pass to Alp Weissenstein
14.00 Alp Weissenstein, dolomitic outcrop, endolithic microbial habitats, stop 13
15.00 Summary of field trip, discussion of project questions
15.30 Begin travel home
15.45 Carbonate-rich Lake Palpuogna close to Albulapass road, view from road



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

Clothing etc. Most of the planned excursions 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 the 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 and glacial ice. Be prepared for snow. Backpack for provisions and samples; bag for overnight utensils. Please bring your own shower towels, „Time Out" does not supply them.

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 and have extra dry cloths with you.

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, a drinking cup for tasting the mineral waters 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 highest elevation that we will reach is 2800 m asl, the maximum altitude difference will be 600m but the walks will not be strenuous.

Travel By private cars and mini-buses (large buses are not possible on the narrow mountain roads). Gasoline is availble along the route.

Route

Day 1: Tübingen – Landquart – Rhäzüns – Rothenbrunnen – Alvaneu – Davos.
Day 2: Davos – Wägerhus – Joeri – Davos.
Day 3: Davos – Scoul Tarasp Vulpera – La Punt – Albulapass – Alp Weissenstein – Thusis – Chur – Landquart – Tübingen

Costs € 85 - € 90 for the full 3-days field trip (2 overnight stays) per person. Included are lodging at the base camp in Davos (room and board, includes breakfast and dinner, occupancy 4 persons per room, shower towels but no sleeping bags required).
The costs for transportation by private cars are not included. Backpack lunches are the particpants' responsibility. The housing costs had to be paid in advance at the time the reservations were made. The fees will be colleced during the trip.

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 mountain 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 20 places available. Please sign up before August 10. For the housing at the „Time Out“ in Davos and for the mine visit we had to make reservations far in advance. Once you have signed up and if you are prevented from participating, please let us know as soon as possible. Fees can only be paid back to you if they are reimbursed by the institutions or if you can find a person who will take your place.

Information Application and trip: Andreas Kappler, Eberhard-Karls-University Tuebingen, andreas.kappler@uni-tuebingen.de, phone ++49 70 71 - 29 74 992.
Field sites: Kurt Hanselmann, phone ++41 44 381 40 87, kurt.hanselmann@hispeed.ch

Participants We are looking forward to having interested students and guests on this geomicrobiology excursion to the beautiful Jöri Lakes and the mineral springs in the Canton of Graubünden. It will be an eye-opener for those who are interested in seeing natural microbiological and geochemical features and you will learn a lot. You may investigate the samples collected from the sites during the following weeks at your home lab.