Geomicrobiology and hydrogeochemistry 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 and Geoecology Program at the Eberhard-Karls-University Tübingen and guests
Tuesday, September 1 to Thursday, September 3, 2009

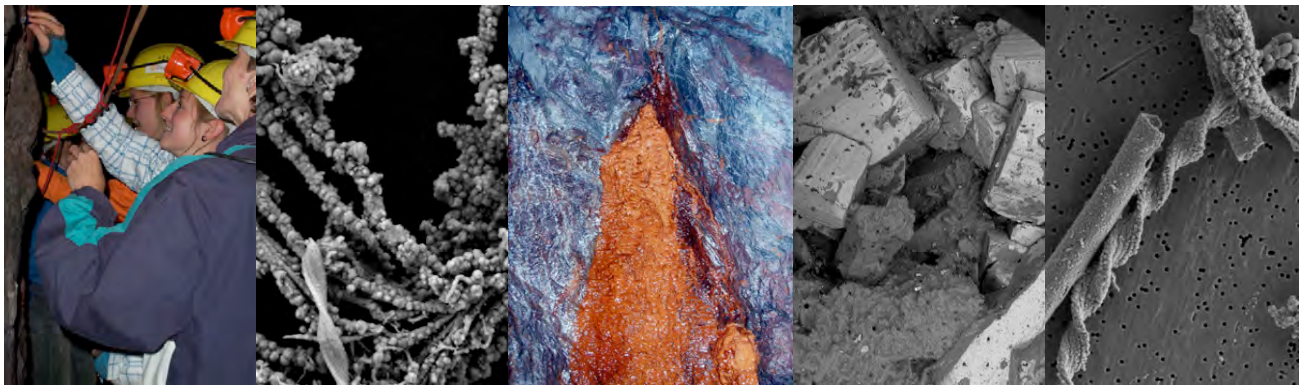
Fe geomicrobiology in the former iron mine Gonzen, Fe, S and C cycling in the Jöri lake catchment and low temperature geochemistry in the mineral springs of the „Lower Engadine Window“, the Albula valley and the Domleschg region /GR, Switzerland

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

Jöri catchment

Locations and Topics

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.
Gonzen: How iron deposits near former hydrothermal seeps became rocks and how these were uplifted.
Rothenbrunnen: microbial involvement in iron transformation processes and iron-removal
Alvaneu: Competing S- and Fe-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 local geology and the alpine water cycle.
Tarasp-Scuol-Ftan: Subsurface geo-hydro-microbiology in the „Lower Engadin Window“, Trias evaporites, Bündnerschiefer, mineral dissolution, CO_2 outgassing and „carbonate ice“ precipitation, deep subsurface chemical interactions and biological processes, surface reactivities of sedimentary rocks.



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.

Geology: At the former iron mine Gonzen we will have an opportunity to go inside an „iron mountain“. Geologists will study the layering, the uplifiting and fracturing of former sedimentary structures; microbiologists will concentrate on the large number of remains of chemolithotrophic bacteria, which are able to make use of the energy released during the oxidation of ferrous (Fe-II) to ferric (Fe-III) iron. Large volumes of biological “rust“ around bacterial sheaths can be seen at the surface of a water filled former mine shaft.

Bio-geo-chemical cycles: We will see surface phenomena which relate to underground and surface geochemical cycles of iron, manganese, sulfur, carbon and phosphorus (Gonzen, Rothenbrunnen, Alvaneu, Jöri, Engadin). 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.

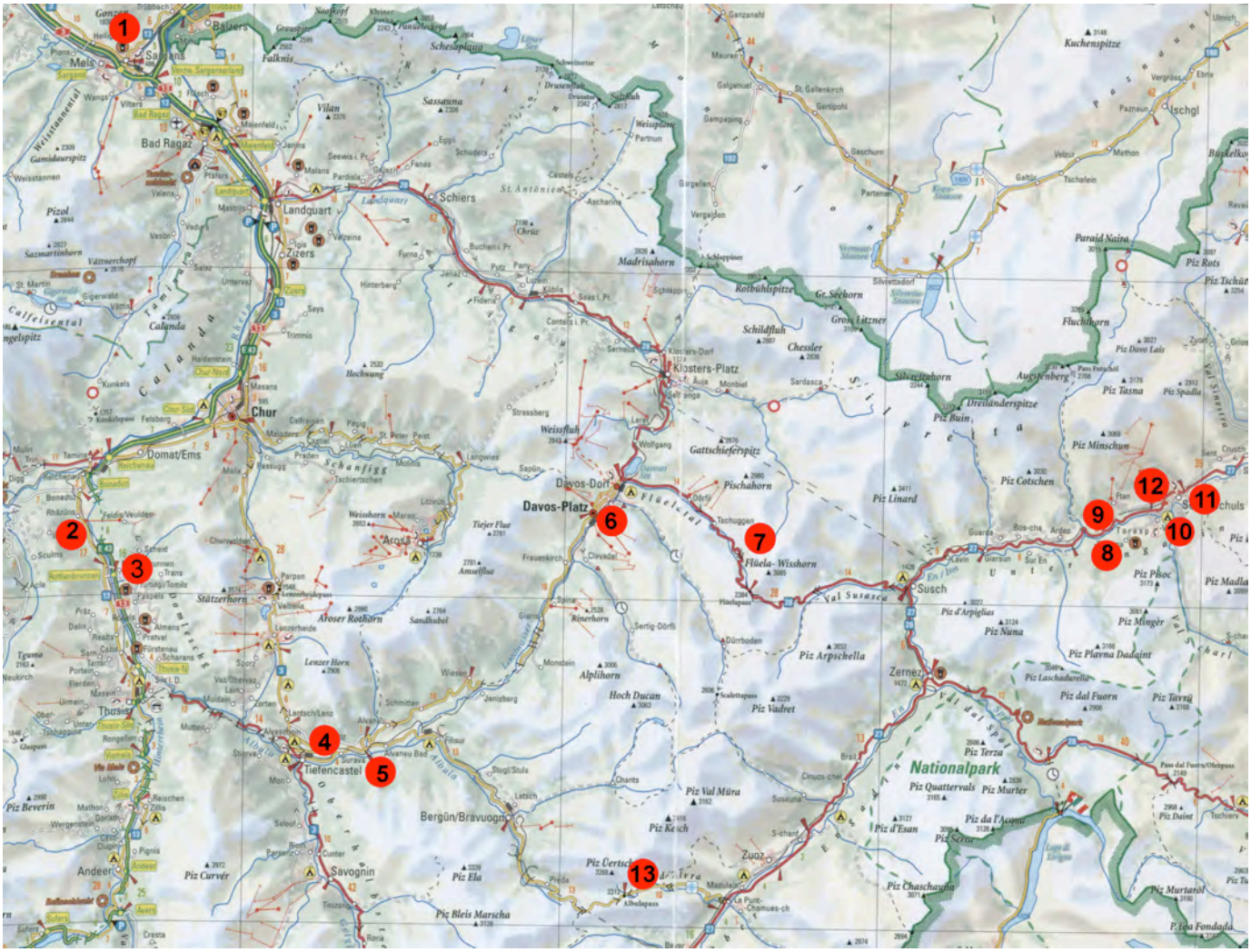
Hydrobiochemistry: We will illustrate the quality of the water when it arrives as rain or snow in the Alps: how does it get stored, how is it transported, and how does its chemical composition change while it percolates through different rock formations (Rauwacke, Gypsum, Bündnerschiefer). These topics will be illustrated at different locations in the upper catchment of the Rhine and Inn rivers (Rothenbrunnen, Alvaneu, Scuol-Tarasp). Here 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: High mountain lakes are ideal for studying the adaptations of organisms to a variety of environmental extremes: nutrients are scarce, water temperatures are often near freezing, darkness under snow and ice lasts for many months and UV radiation is strong during the summer months. We wonder how life has adapted to these challenges over time and yet are constantly amazed at the strategies microbes have developed to cope with these extreme conditions. The water in the 22 Jöri Lakes originates exclusively from rain, snow and ice-melt, which makes them interesting aquatic ecosystems for studying the role of erosion particles as nutrient scavengers and in soil formation, the quantitative contribution of airborne natural components and pollutants to the chemical composition of the water and the early colonization of lakes as the glaciers retreat.

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.

Tectonics: The Lower Engadine Window (LEW) is a large tectonic opening into penninic sediments that originated in a former oceanic basin of the Alpine Tethys. 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.

Field trip stops (might change depending on weather and time)
1. Gonzen, Sargans, former iron mine 2. Rhäzünser Mineralwater processing plant (Rhäzüns) 3. Iron fountain (Rothenbrunnen) – 4. Bündner shale outcrop (Tiefenkastel) - 5. Sulfur and iron springs (Alvaneu) – 6. Davos 7. High alpine Jöri lakes (Klosters / Davos) 8.-12. Mineral springs and travertine formation (Lower Engadine, Scuol-Tarasp-Ftan) 13. (as time allows) Carbonates and Julier granites on Albula pass (2315 m)



Gonzen, the „iron mountain“ near Sargans, a former iron mine (stop 1)

Key topics at stops

DAY 1 / stops

1. Gonzen, former iron mine: With a short movie about the geology of the Gonzen iron mountain and the former mining oprations we will be introduced to the 3 hour walk inside the mountain. Train ride from the Visitors' Center to the central hall of the mine and walk through some of the former mine shafts. Various iron bearing minerals (Magnetite, Hematite, Calcite, Pyrite, Ferrihydrite, Manganite) and mass development of aerobic chemolithotrophic ferro-iron oxidizing bacteria, e.g. *Leptothrix spp*..

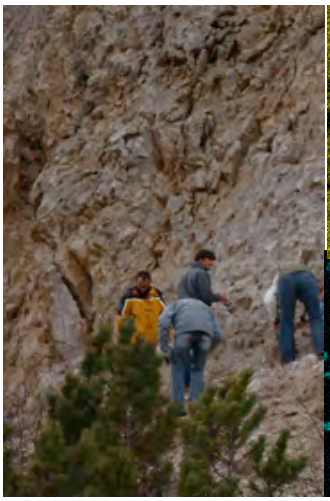
2. Mineral water for human consumption: Visit at the Rhäzünser mineral water processing plant. For centuries highly mineralized spring waters were used for healing purposes; today they are mostly bottled and marketed as mineral enriched drinking water. As an introduction to the haydrochemical excursion topic 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.

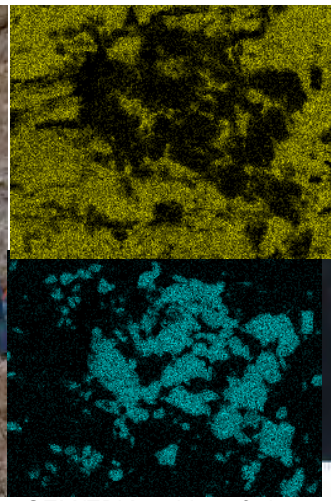
4. Bündner shale outcrop near Tiefenkastel: An instrucitve site that illustrates the finely laminated, not perturbed former sediment layers that were deposited in abyssal plains of the Alpine Tethys. Uplifting, folding and organic carbon content point to the secondary and primary processes during the times of sedimentation in Triassic and Jurassic times.

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. The organisms are highly enriched under the sulfidic conditions. Competition between biotic and abiotic processes for Fe(II+) and S(II-) oxidation.

Overnight stay Davos, Youthpalace



Dolomite outcrop



SEM/EDX probing of elemental distribution

Bündner shale, former sediments

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 extreme and extremely variable conditions.

Overnight stay Davos, Youthpalace.

Geomorphological features

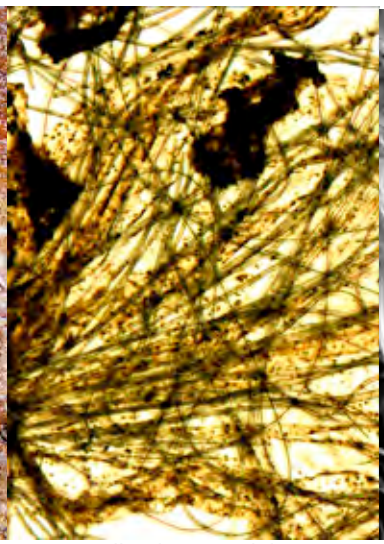
lakes with and without glacial melt water

enormous glacier retreat in 50 years

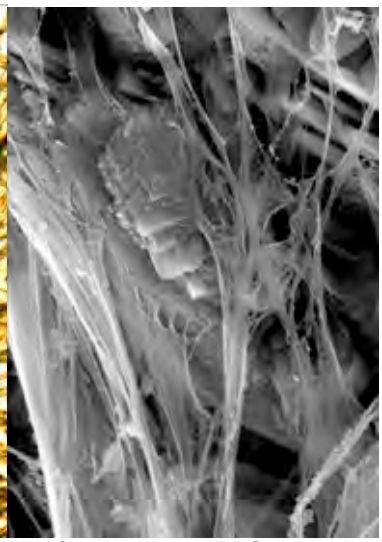
DAY 3 / stops

8.-12. 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. A several fold oversaturation for $CaCO_3$ 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.

Fuschna: Cyanobacterial biofilms



surrounding iron precipitates



and forming dense EPS networks

13. Geology and Geomorphology at Albula pass: The region is the contact zone between Trias dolomite in the east and Julier granite in the west. A number of moraines and block glaciers allow one to reconstruct events of the last ice age.

Albula pass: Meeting zone of carbonates with Albula granite

Discussion topics include aspects to (depending on interest):

- How mineral waters get formed
- How mineral water composition can be altered by microbes
- Where the rocks of Gonzen, the Bündner shales, the Silvretta nappe and the Albula carbonates originate and how they got where they are today

- How nutrients are cycled in cryosphere ecosystems
- What is the role of the iron cycle for nutrient accumulation?
- How nutrients are scavenged in oligotrophic environments, e.g. high-mountain lakes
- Is self-trophication a phenomenon of specialized low nutrient environments?

- How microbes adapt to extreme environments: to low temperatures (psychrophilic lifestyles), intensive solar radiation and long periods of darkness
- How community diversity is regulated by changing habitat conditions
- How similar are alpine and polar microbial ecosystems?
- How microbes live and survive in snow and ice

- How microbial mats and biofilms are formed in nutrient poor flowing and stagnant waters
- How sedimentary bio-laminations are built in glacial fluvial deposits

- What is the composition of the chemolithotrophic microbiota in mineral springs?
- Chemolithotrophic lifestyles in the waters of Gonzen, Rothenbrunnen, Alvaneu and Fuschna

- How Bündner shale, carbonate- and gypsum containing rocks were formed originally
- How subsurface and above surface mineral weathering of Bündner shale, carbonate- and gypsum containing rocks is mediated by chemical and microbial processes
- How “carbonate ice” and travertine are formed in mineral springs
- Why high mountain lakes in the Silvretta nappe are not in danger of becoming acidified.
- How silica containing rocks are weathered

- etc.

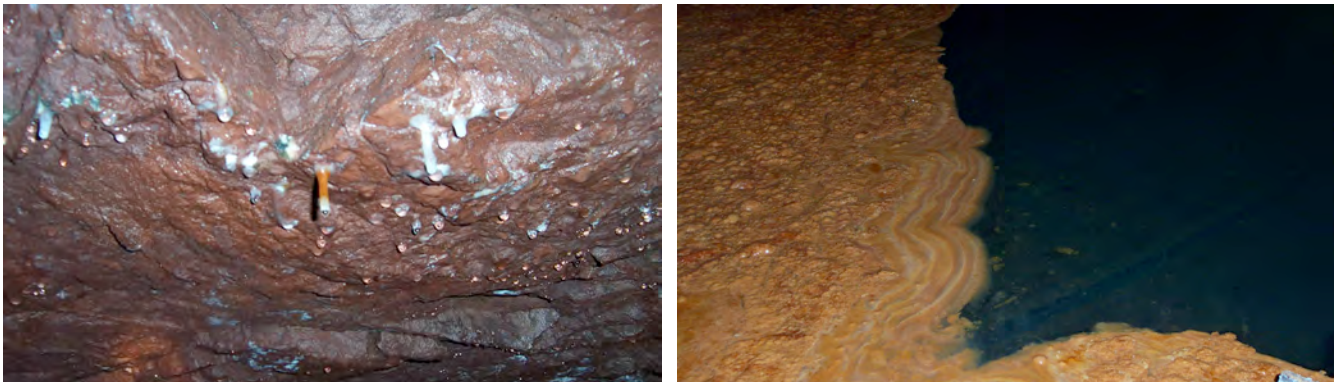
Research Participants are invited to choose one from the research focus topics that are offered for this field trip or create their own. There are research topics, which can accommodate 1 student and those, which are suitable for a group of 2 students. Please organize yourself.

1. Gonzen iron mine: origin and tectonic of the Gonzen rock layers and their mineralogy
2. Rhäzüns mineral water bottling plant: how drinkable water is made from ferric spring water
3. Rothenbrunnen and Gonzen, iron fountain and springs: ferrous iron chemolithotrophs, their life style. Where are the ferric iron reducers and how is ferrous iron produced in the subsurface?
4. Alvaneu, sulfur fountain: hydrogensulfide chemolithotrophs. Where does the hydrogensulfide come from?
5. Alvaneu, Arvadi iron-sulfur springs: Are iron-sulfide chemolithotrophs in competition with ferrotrophs?
6. Jöri lake XIII: Microbial planktonic communities. How is diversity regulated?
7. Jöri lake XIII: Microbial blooms, how do they appear and how are they degraded (if bloom has happened)
8. Jöri lake I or XIX, biofilms and laminated sedimentary deposits
9. Mineral springs Fuschna and Bonifacius: Cyanobacteria and “carbonate ice” communities
10. Mineral springs in the Lower Engadine Window: Origin and hydrologic 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 / minerals / dissolved chemicals are present?
2. Describe the site as a habitat / as a chemical system (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 / chemical equilibria 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 lectures.

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

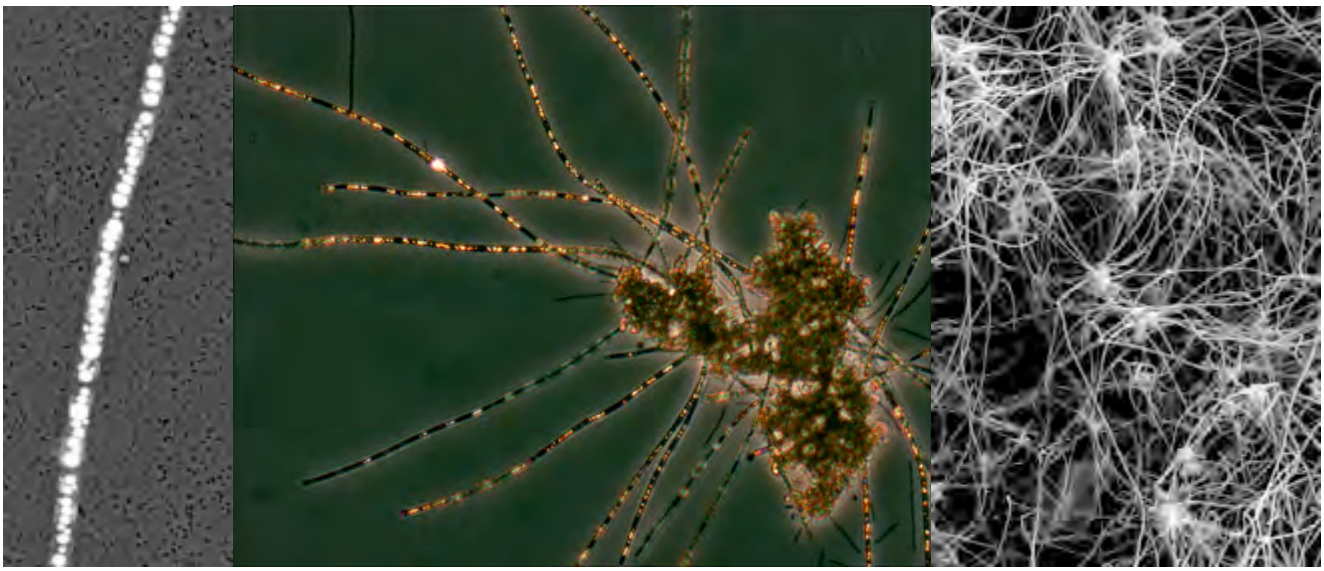


Gonzen iron mountain: carbonate stalaktites and sequentially growing ferrous iron oxidizing bacteria

Field trip program

September 1 (Tuesday)

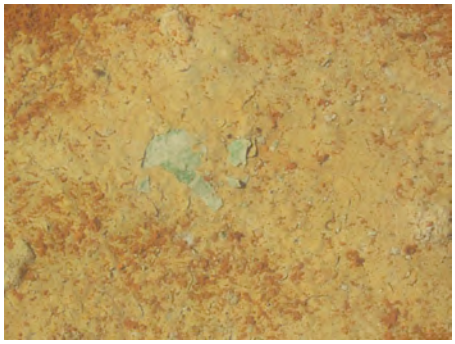
06:00	Departure Tübingen
09.30	Meet at Sargans, Gonzen mine (stop 1: take exit Sargans and follow signs to Bergwerk Gonzen). Short movie about the geology of Gonzen iron mountain and the former mining operations.
10.00	Train ride from the Visitors' Center to the central hall of the mine and walk through some of the former mine shafts.
13.30	Depart from Gonzen
14.00	Rhäzünser Mineralsprings, AG, processing plant, Rhäzüns. How natural mineral waters are treated, hygenically checked and bottled (Mr. Niels Jacobi), stop 2
15.00	Rothenbrunnen iron fountain, de-ironing of water to make bottled mineral water, stop 3
16.00	Bündner shale outcrop near Tiefenkastel, stop 4
16.30	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 wellness purposes, stop 5
18.00	Arrival at Davos, (stop 6), shopping for next day's lunch
18.15	Dinner and overnight stay at the „Youthpalace", Davos Dorf (Tel. +41 (0) 81 410 1920)
19.30	Discussion about field trip topics of the following day



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

September 2 (Wednesday)

07.00	Breakfast at „Youthpalace“. (You may leave your luggage in the room and take only what you need for the day trip)
07.45	Depart from Davos
08.00	Wägerhus (stop 7), begin climb to Jöri lakes.
10.30	Arrival at Research Station, lake XIII: geochemical Fe-, Mn-, P-cycles. Student field presentations.
12.30	Lake I: highly turbid lake, role of suspended nanoparticles. Sediment fractionation in former glacial flood delta.
13.30	Lake II: iron rich swamp and moraine spring with *Hydrurus sp.*: Nutrient scavenging by particles with high ion exchange capacity.
14.30	Lake XIV: Glacial sedimentation field, fractionation of erosion particles.
15.30	Glacial lakes XVI – XXII: Deposits and formation of bio-laminations
16.30	Cryoconite holes on Jöri glacier (depends on snow cover)
17.00	Winterlücke, begin descent
18.00	Depart Wägerhus
18.30	Arrival Davos, shopping for next day’s lunch.
19.00	Dinner and overnight stay at „Youthpalace“, Davos Dorf
20.00	Discussion about topics of the following day



Cyanobacteria in iron mats

Differential oxidation of Fe and Mn

Diatom mats on top of glacial varves

September 3 (Thursday)

07.00	Breakfast at „Youthpalace“. (We will take all luggage with us)
07.30	Depart from Davos to the mineral springs at Scuol-Tarasp-Vulpera-Ftan. Have a drinking cup with you. We will taste different mineral waters along the way.
09.00	Bonifazius: Travertine formation at spring outflow into the Inn river (stop 8)
09.45	Fuschna, cyanobacterial mats, CO_2 outgassing and carbonate ice formation (stop 9)
11.00	Tarasp-Vulpera, most highly mineralized waters. Carola, Luzius, Emerita, „Geysir“, Sfondraz, high mineralization, CO_2 formation and escape (stop 10)
12.15	Clozza drinking fountain, Clozza reservoir, CO_2 accumulation, formation of travertine terracetts at Clüs (stop 11)
13.00	Lischana: High magnesium water (stop 12). Ftan Baraglia: Statigraphic overview
14.30	Albula carbonates (stop 13). Summary of field trip, discussion of project questions
16.00	Begin travel home via Tiefenkastel, Thusis, Chur, Tübingen

Clüs: Travertine terracetts

„Geysir“ carbonate precipitats

Fuschna, „carbonate ice“

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 (e.g. in case of snow). 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. (Sneakers are absolutely not appropriate). Be prepared for snow. Backpack for provisions and samples; bag for overnight utensils.

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.

If you like you may 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 We will be in the field for about 9 hours daily, walking on well marked paths and stopping frequently. 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 mini-buses (large buses are not possible on some narrow mountain roads). Gasoline is availble along the route.

Route
Day 1: Tübingen – Sargans – Rhäzüns – Rothenbrunnen – Tiefenkastel – Alvaneu – Davos.
Day 2: Davos – Wägerhus – Joeri – Davos.
Day 3: Davos – Scoul Tarasp Vulpera Ftan – Albula – Thusis – Tübingen

Costs 168 CHF for students (payable in CHF or in € at the exchange rate of the excursion day) for the full 3-day field trip (2 overnight stays) per person. Included are lodging at the base camp in Davos (room, (WC shower) and board, which includes breakfast and dinner (self-service, buffet, vegetarian meals on request), occupancy 3-4 persons per room, no sleeping bag required), tourist tax, entrance fee to Gonzen.
The costs for transportation by private cars are not included. 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 in the mine and 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 25 places available. Please sign up **before June 15**. Once you have signed up and you are prevented from participating, please let us know as soon as possible (andreas.kappler@uni-tuebingen.de). For cancellations before July 20th the costs amount to 30% of the total price of the arrangement; for cancellations until August 10 50% and for later cancellations, no-show and earlier departure 100%. Paid 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 transportation: 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

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, geological 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.