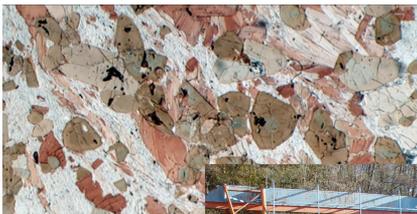


Annual Report 2005





Mineralogisch-Geochemisches Institut

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Director: Kurt Bucher



Back row, left to right: *Kurt Bucher, Hiltrud Müller-Sigmund, Jurgis Klaudius, Joachim Tibi, Juraj Majzlan, Tobias Weisenberger, Simon Spürgin*

Middle row, left to right: *Susanne Schuble, Isolde Schmidt, Sonia Ackermann, Dagmar Flemming, Phillip Mittelstädt, Karin Eckmann, Slavica Drndelic*

Front row, left to right: *Ulrike Seelig, Sigrid Hirth-Walther, Wibke Kowalski, Duy Anh Dao, Christine Höher, Jörg Keller*

Missing: *Melanie Katt, Rune Selbekk, Reto Gieré*

Report editors: Juraj Majzlan and Rune S. Selbekk

Cover photographs:

Upper: An As EXAFS spectrum of a Fe-As precipitate from Pezinok, Slovakia. See page 42 for details.

Middle: A thin section of a tourmaline metapelite from Alpe Sponda, Switzerland. See pages 33-34 for details.

Lower: Our first-year students at the quarry in Kuhbach (Schwarzwald), on their first field trip. See page 10 for details.

Director's Statement

With the winter semester 5/6 a new era commenced at the University of Freiburg. The first 70 bachelor students enrolled for our new program “geosciences”. It is the first curriculum in the new B.Sc. format in natural sciences in Freiburg. It is a true milestone in the history of the geosciences in Freiburg. After about 150 years of two separate curricula, one for geology and one for mineralogy, the geosciences unified the closely related subjects to a single subject “Geosciences”. The students and instructors alike received the new B.Sc. format with enthusiasm and passion. The overwhelming success of the B.Sc. Geosciences will require a great deal of new, presently unavailable, resources for labs, excursions and field camps. Certainly a problem that needs to be solved before the beginning of the excursion season 2006.



*Institute Director
Professor Kurt Bucher*

The only change in staff was the leaving of Prof. Dr. Rodney Grapes at the end of September. He spent four very productive and exciting years with us. We unsuccessfully attempted to extend his non-tenured position. The rigid rules set by the University Administration unfortunately removed this excellent scientist from our University. Rodney published a series of excellent research papers mostly in cooperation with other staff members and students of the institute. He also wrote a monograph on pyrometamorphism during his stay. The book will appear next year in Springer Verlag. Rodney was a dedicated teacher and led several outstanding excursions. We will all remember the excursion to New Zealand, his home country, in the spring 2005. Rodney moved to the Department of Earth Sciences at the Zhongshan University in Guangzhou, China and the cooperation with him will continue. The Zhongshan University is now the fourth university in China with which we maintain regular scientific contacts and project cooperation. We filled his vacant position with two new PhD students working on projects in the fields of environmental geochemistry and hydrogeology (fluid-rock reactions).

We officially opened the “mineral museum” June 24 with a grand opening celebration. Mineral collectors, strahler, science journalists, mineral experts were our guests and we enjoyed a series of lectures and the associated festivities. The collections now represent a “museum” open to the public.

After two years intermission, we revived our works outing with a two day trip to the Oeschinen Lake above Kandersteg in the Berner Oberland. The day (and night) activities included rowing on the lake, picnicking, hiking and a campfire of 5 hours duration.

A short-course “hydrogeology of hardrock aquifers” of the hydrogeology subsection of the German Geological Society was run at MGI in March. The short course was organized, managed and convened by Prof. Dr. Ingrid Stober our external hydrogeology partner from the Geological Survey. Ingrid Stober, Kurt Bucher and 4 external speakers lectured on several topics in the hydrogeology of fractured bedrock aquifers. The short course was booked out early and the 60 participants were very positive about the quality of the course.

Kurt Bucher

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Teaching and Student Affairs

Bachelor and Master programs

A new era began in Freiburg with the first BSc program in natural sciences. Yes, we were the first out with the BSc in Geosciences. The new format still needs a great deal of work and planning for all of us. While the Bachelor of Geosciences started this year, the four Master programs are still in the stage of planning. The plans and the proposals will be submitted to the University Administration for approval early next year. The Bachelor of Geoscience program started with the winter semester 2005-2006 for the first time. The new BSc in Geosciences replaces the Diploma in Mineralogy and the Diploma in Geology. Both Diplomas were detached with the beginning of the BSc Programs.

Student Recruitment

A total of 72 BSc Geosciences majors enrolled for the winter semester 2005/06. This is a tremendous success, which we clearly relate to our efforts to reach potential students at various public activities. Together with the large group of students we already have from the two years before the student recruitment is excellent. The teaching commitments of the staff of our institute includes: BSc. Geosciences, Diploma Geology and Mineralogy, lab practical courses for chemistry majors, teaching for hydrology and geography students. Our teaching unit officially runs at more than 130 % of its formal capacity. This has the consequence that also 2005 little time is left for research during the regular working hours of the staff. We find the time for research during late night working and at the weekends. Still it is remarkable that the staff produces high caliber and internationally recognized research.

Guest Lectures Presented at MGI in 2005

Peter Stille, *CNRS, Strasbourg, France.*

Austausch- und Fraktionierungsprozesse an der Schnittstelle Atmosphäre-Pflanze-Boden-Wasser (Pb-, Nd-, Sr-, Ca-Isotope; Seltene Erden). January 10, 2005

Terry Seward, *ETH Zürich, Switzerland.*

Molecular approaches to the study of aqueous fluids in the Earth's crust. January 31, 2005

Angelika Kalt, *Uni Neuchâtel, Switzerland.*

Xenolithe im Kenia-Rift. January 24, 2005

Christian Scheffzuek, *GeoForschungsZentrum Potsdam, Germany.*

Intrakristalline Last- und Restspannungsmessungen an geologischen Proben mittels Neutronenbeugung. February 4, 2005

Douglas Rumble, *Carnegie Institution, Washington, USA.*

Geochemical and mineralogical evidence of atmospheric photochemistry. November 7, 2005

Karel Schulmann, *EOST Strasbourg, France.*

Deformation microstructures and melt topology of partially molten felsic crust - implications for the rheology of orogenic lower crust. November 14, 2005

Thomas Kohl, *Geowatt AG, Zürich, Switzerland.*

Möglichkeiten der Bewertung geothermischer Reservoirs und Perspektiven im nördlichen Alpenraum. November 21, 2005

Nikolaus Froitzheim, *Universität Bonn, Germany.*

Ozeane in den Alpen: Wie sie entstanden, wie sie verschwanden. November 28, 2005

Wilhelm Heinrich, *GeoForschungsZentrum Potsdam, Germany.*

Stickstoff, Bor, Lithium: Leichte Elemente und ihre Isotope bei metamorphen Prozessen. December 5, 2005

Jan Behrmann, *Geologisches Institut, Universität Freiburg, Germany.*

Wie dicht ist dicht? Zur Ablagerung, Verfestigung und Geohydraulik von jungen Sedimenten am Kontinentalabhang vor Texas und Louisiana (Golf von Mexico). December 12, 2005

Invited Lectures Presented by the MGI Staff

University Frankfurt, 01/05 **Jörg Keller**

Seminar, The Natural History Museum, Department of Mineralogy, London, UK 01/05, **Reto Gieré**

Comenius University, Bratislava, 03/05, **Juraj Majzlan**

Festkolloquium, Mineralogisch-Petrographisches Institut, Universität Basel, Switzerland 03/05, **Reto Gieré**

Keynote Lecture at General Assembly of the European Geosciences Union, Vienna, Austria, 04/05, **Reto Gieré**

Keynote Lecture, 3rd International Conference on Materials for Advanced Technologies, Singapore: 06/05, **Reto Gieré**

Chinese University of Geosciences, China, 08/05, **Kurt Bucher**

Beijing University, China, 08/05, **Kurt Bucher** (2 lectures)

Geological museum, University of Oslo, Norway. 9/05, **Rune S. Selbekk**

Fossheim Steinsenter, Lom, Norway, 9/05, **Rune S. Selbekk**

Seminar, ETH Zürich (Department of Earth Sciences), Switzerland 10/05, **Reto Gieré**

Geowissenschaftliches Kolloquium, (Geologisches Institut), Universität Bonn, Germany, 11/05, **Reto Gieré**

University Neuchâtel, Suisse, 11/05, **Jörg Keller**

Ruhr-Universität Bochum, Germany, 12/05, **Juraj Majzlan**

Keynote Lecture at the Workshop PERALK Tübingen, **Jörg Keller**

Services to the Earth Science Community

Editorial Responsibilities

Kurt Bucher is on the advisory board of *Journal of Petrology* and associate editor of *Geofluids*.

Reto Gieré is the Editor of *Schweizerische Mineralogisch-Petrographische Mitteilungen*, and member of the Editorial Board of the *Journal of Petrology*. He has also been Editor of a Special Issue of the Journal: *Geochemistry: Exploration, Environment, Analysis*, On the topic: *Natural Analogs for Nuclear Waste Disposal*.

Jörg Keller is a member of the Editorial Boards of the *Journal of Volcanology and Geothermal Research*, *Acta Vulcanologica*, *Periodico di Mineralogia* and *GeoActa*.

Peer-review Activities

Journals

Faculty of the MGI have performed reviews for the following journals:

American Journal of Science, American Mineralogist, Applied Geochemistry, Canadian Mineralogist, Geochemistry, Geochimica et Cosmochimica Acta, Chemistry of Materials, European Journal of Mineralogy, Geofluids, Journal of Metamorphic Geology, Journal of Petrology, Journal of Volcanology and Geothermal Research, Lithos, Mineralia Slovaca, Mineralogical Magazine, Physics and Chemistry of Minerals, Quaternary International, Swiss Bulletin of Mineralogy and Petrology, Thermochimica Acta and others.

Grant-awarding Bodies

Assessment of grant proposals for the U.S. NSF, FNSNF, NFR, DFG, INGV-DPC Italy and other granting agencies worldwide have been written by the experts of MGI.

Offices held on administrative and scientific boards

Kurt Bucher served as Vice-Dean of the Faculty of Chemistry, Pharmacy and Geosciences until October 2006.

Jörg Keller is on the board of the *Stiftung Vulkaninstitut Friedlaender, ETH Zürich*, and the *Scientific Council for VULCANIA, Parc Européen du Volcanisme, Auvergne*. He is a member of the *Medal and Awards Commissions of IAVCEI, DMG*. He is also member of the International Evaluation Committee for the 2005/2006 Research Programme of Italian Istituto Nazionale di Geofisica e Vulcanologia/Dipartimento della Protezione Civile.

Reto Gieré is a Society Book Advisor for the *Geological Society, London*, and a member of the *Deutsche Mineralogische Gesellschaft, Mitglied Sektion Angewandte Mineralogie in Technik und Umwelt; www.amitu.de*. He is also a member of the *International Mineralogical Association, Mitglied Subcommittee for the Epidote Group, Commission on New Minerals and Mineral Names*.

Public Outreach Activities

In 2005 the MGI was involved in a variety of public outreach activities. Our interviews with journalists of newspapers and radio and TV stations contributed to the popularisation of geo-science issues in the public.

Dagmar Fleming and **Rune Selbekk** coordinated the presence at the *Mineralien & Fossilientage Freiburg* (Mineral and Fossil Day) where printed information about the new bachelor study and the new mineralogical museum was distributed in addition to exhibiting rocks and minerals.

In late November the general public was hosted during the *Tag der offenen Tür* with lectures and laboratory tours for high-school students by **Kurt Bucher** and **Reto Gieré**.

Awards

Reto Gieré: Elected Fellow, Mineralogical Society of America

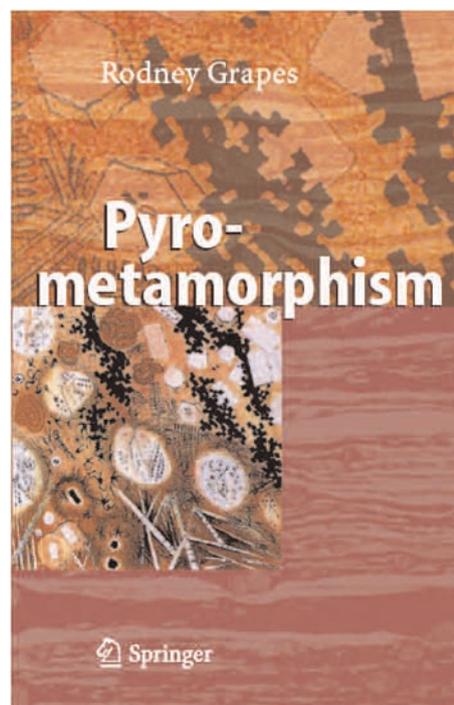
Reto Gieré: New Hot Paper in the Field of Geosciences, ISI Essential Science Indicators (http://www.esi-topics.com/nhp/2005/march-05-Giere_Sorensen.html)

Kurt Bucher: Honorary guest professor at Chinese University of Geoscience, Beijing, China

Published Books

Rodney Grapes: *Pyrometamorphism*. Springer Verlag.

Pyrometamorphism is a type of thermal metamorphism involving very high temperatures often to the point of causing fusion in suitable lithologies at very low pressures. The high temperatures are provided by flow of mafic magma through conduits, by way of spontaneous combustion of coal, carbonaceous sediments, oil and gas, and through the action of lightning strikes. These conditions characterise the sanidinite facies of contact metamorphism. Although pyrometamorphic effects related to igneous activity are usually restricted to very narrow aureoles and xenoliths and to the point of impact in lightning strikes, pyrometamorphic rocks may be exposed over a surface area of hundreds to thousands of square kilometres in the case of combustion of gently dipping coal seams. In all these instances, temperature gradients are extreme, varying by several hundred degrees over a few metres or even centimetres. Relatively short periods of heating create an environment dominated by metastable melting and rapid mineral reaction rates driven by significant temperature overstepping of equilibrium conditions. This results in the formation of a large variety of high temperature minerals, many of which are metastable, are only found in pyrometamorphic rocks and are analogous to those crystallising from dry melts in laboratory quenching experiments at atmospheric pressure.



Compared with other types of metamorphic rocks, pyrometamorphic rocks are comparatively rare and volumetrically insignificant and this is probably the main reason why pyrometamorphism and sanidinite facies mineral assemblages have received scant attention in many modern petrology text books. However, in recent years, a number of papers have appeared in international Earth Science journals detailing field relations, microtextures, mineralogy and geochemistry of pyrometamorphic rocks and related phenomena and this book provides a timely review/synthesis of the subject. It is not a textbook but essentially a compilation of available data relating to some 76 terrestrial occurrences of igneous, combustion and lightning strike pyrometamorphism of quartzofeldspathic, calc-silicate, evaporite and mafic rock/sediment compositions. Examples of anthropogenic pyrometamorphism such as brick manufacture, slag production, waste incineration, drilling and ritual burning are also given for comparison. The last chapter deals with aspects of high temperature disequilibrium reactions and melting of some common silicate minerals.

The manuscript was submitted to Springer in fall 2005, and the book is expected to appear in the academic bookstores in early 2006.

Research at the Institute of Mineralogy and Geochemistry

The staff produced 14 research papers and book chapters in 2005 (see list of publications page 12). The research of the MGI is focused on two fields: a) Geothermal Energy research and b) Environmental Geochemistry research.

Geothermal Energy: This field evolved during 2005 to the main research focus of the Geosciences in Freiburg. It involves projects developed by Prof. Bucher and Prof. Gieré (MGI), Prof. Henk (GI) and Prof. Stober (GI & LGRB). It is planned to develop Geothermal Energy research jointly to our main effort. In this context the Geosciences Freiburg plan to bundle research and teaching in this field to a Center of Geothermal Energy. It will play a central role in the plans of the University of Freiburg to establish a Center of Renewable Energy. This later center is planned to be established in 2007 in connection with the 550 Years celebration of the University of Freiburg. The Center of Geothermal Energy is presently in its active phase of planning and development of project funding applications. Several Diploma Projects and two Ph.D. projects started this year in the field of Geothermal Energy research. 2 papers were related to Geothermal Energy and Hydrogeology research. One of them was the most accessed paper in the journal "Geofluids" in 2005 (ranked #7 journal in the geology category).

Environmental Geochemistry: This second field of research has been very successful in 2005 and produced six research articles mostly in high caliber international journals.

Other published research was related to projects in the fields of metamorphic geology and mineralogy (a total of 5 papers). Also this research appeared in international high-rank journals. We will continue to research in these fields also in the future despite the declared focus in the applied geosciences. We strongly feel that our university research institute has a commitment to support cognition oriented research also for the reason that world class teaching can only be achieved by teachers who are actively involved in high-caliber research.

IMC-4400 is an isothermal calorimeter, an instrument designed to measure heats of reactions. Specific reactions of interest to us are dissolution reactions of minerals in acids. By measuring heats of these reactions, we can derive fundamental thermodynamic properties of the studied minerals, especially their heats of formation. The accuracy, precision, and sensitivity of the instrument allows us to perform measurements on a wide variety of samples, many of whose were not amenable to such experiments in the past. We are aiming at investigating thermodynamic properties of minerals that either form as a result of pollution, or may be used to remediate an existing pollution source. The data obtained will be used to model and predict the performance of remediation strategies.

Research Collaborators

The following are people who have collaborated with IMPG faculty during 2005, or who are active long-term collaborators:

Christian de Capitani, Universität Basel, Switzerland.
 Ronald Frost, University of Wyoming, USA.
 Rodney Grapes, Department of Earth Sciences, Zhongshan University, Guangzhou, China
 Karin Högdal Department of Geology, Lund University Sweden
 Paul Hoskin, Department of Geological Sciences, Central Washington University, Ellensburg WA, USA
 Hanu Huma, Geological Survey of Finland, Finland.
 Erik Jonsson Department of Geology and Geochemistry, Stockholm University, Sweden
 Michael Kraml Bundesanstalt für Geowissenschaften und Rohstoffe (Hannover), Germany
 Xuping Li, Peking University, China
 Mattias Lundmark, University of Oslo, Norway
 Meinert Rahn, PSI, Switzerland
 Ingrid Stober, Geological Survey of Baden-Württemberg, Germany
 Anatoly Zaitsev St. Petersburg State University, Russia and NHM London.

Completed MGI Diploma Theses (undergraduate senior theses)

- Bratzdrum, C.** 2005: Relationships between lamprophyres and granites in the Shanqi-Xiaqi granite complex, China. (Advisors: Rodney Grapes & Reto Gieré)
- Eichinger, F.** 2005: Mineralogy and Geochemistry of antimony in soils from shooting ranges. (Advisors: Reto Gieré & Annette Johnson (EAWAG))
- Finkenbein, T.** 2005: Petrologie und Vulkanologie der Riftflanke und des Sekenge Kraters Engare Sero, East African Rift (Tanzania). (Advisors: Jörg Keller & Rodney Grapes)
- Klemm, O.** 2005: Metamorphe Entwicklung der metabasischen und metasedimentären Anteile der Zermatter Ophiolithe im Bereich Lichenbretter - Oberer Theodulgletscher, Wallis, Schweiz. (Advisors: Kurt Bucher & Regina Freiburger)
- Maurer, R.E.** 2005: Geologische Kartierung im Gebiet des Berdalen W-Jotunheimen, S-Norwegen. (diploma mapping) (Advisors: Rune S. Selbekk, Kurt Bucher & Jan Behrmann)
- Weisenberger, T.** 2005: Zeolite facies mineralisation in the Hvalfjörður area, Iceland. (Advisors: Rune S. Selbekk, Kurt Bucher & John C. Tipper)

MGI 2005 Publication List

Peer-reviewed Journal Articles, Books, and Book Chapters

- Bucher, K.** (2005) Metamorphic rocks, facies and zones. In: Selley, R.C., Cocks, L.R.M. and Plimer, I.R. (editors), *Encyclopedia of Geology*, Volume 3, 402-409, Elsevier Academic Press, Amsterdam.
- Bucher, K.**, de Capitani, Ch. and **Grapes, R.** (2005) The development of a margarite-corundum blackwall by metasomatic alteration of a slice of mica schist in ultramafic rock, Lake Kvesjöen, Norwegian Caledonides. *The Canadian Mineralogist*, 43, 129-156.
- Bucher, K.**, Fazis, Y., de Capitani, Ch. and **Grapes, R.** (2005) Blueschists, eclogites and decompression assemblages of the Zermatt-Saas ophiolite: high-pressure metamorphism of subducted Tethys lithosphere. *American Mineralogist*, 90, 821-835.
- Gieré R.**, Li H., Smith, K.L., and Blackford M. (2005): Particulate emissions from combustion of a coal+tire blend. *World of Coal Ash, 2005 Proceedings*, ISBN 0-9674971-6-7, woca2005:papers:15gie.pdf, p. 1-12
- Gieré R.**, Li H., Smith K., and Blackford M. (2005): SEM and TEM Characterization of Particulates Emitted during Coal and Tire Combustion. In: White T.J., Ferraris C., Yu L., Halada K., and Umezawa O. (eds): *Advances in Ecomaterials*, Stallion Press, Singapore, Volume 1, p. 209-215
- Grapes, R.**, **Bucher, K.** and Hoskin, P.W.O. 2005, Monazite-epidote reaction in amphibolite grade blackwall rocks. *European Journal of Mineralogy*, 17, 553-566.
- Grevel, K.-D., Kahl, W.-A., **Majzlan, J.**, Navrotsky, A. and Lathe, C. (2005) Thermodynamic data of magnesiochloritoid. *European Journal of Mineralogy* 17, 587-598.
- Hetherington, C.J., Mullis, J., Graeser, S. and **Gieré, R.** (2005): Formation of armenite in the Berisal Complex, Simplon Region, Switzerland. *Schweizerische Mineralogische und Petrographische Mitteilungen* 83, 243-259
- Majzlan, J.**, Navrotsky, A., Stevens, R., Donaldson, M., Woodfield, B.F. and Boerio-Goates, J. (2005) Thermodynamics of monoclinic $\text{Fe}_2(\text{SO}_4)_3$. *Journal of Chemical Thermodynamics* 37, 802-809.
- Majzlan, J.**, Botez, C. and Stephens, P.W. (2005) The crystal structures of synthetic $\text{Fe}_2(\text{SO}_4)_3(\text{H}_2\text{O})_5$ and the type specimen of lausenite. *American Mineralogist* 90, 411-416.
- Majzlan, J.** and Myneni, S.C.B. (2005) Speciation of iron and sulfate in acid waters: Aqueous clusters to mineral precipitates. *Environmental Science and Technology* 39, 188-194.
- Stober, I. and **Bucher, K.** (2005) Deep-fluids: Neptune meets Pluto. In: C. Voss (Ed.) *The Future of Hydrogeology. Hydrogeology Journal*, 13, 112-115.
- Stober, I. and **Bucher, K.** (2005) The upper continental crust, an aquifer and its fluid: Hydraulic and chemical data from 4 km depth in fractured crystalline basement rocks at the KTB test site. *Geofluids*, 5, 8-19.
- Stober, I. and **Bucher, K.** (2005) Corrigendum, *Geofluids*, 5, 151.
- Twining J., McGlenn P., Loi E., Smith K.L., and **Gieré R.** (2005) Risk ranking of bioaccessible metals from fly ash dissolved in simulated lung and gut fluids. *Environmental Science & Technology* 39, 7749-7756

Field-guides, Reviews, Reports and Theses

Eldjarn, K. Kvamsdal, L.O. **Selbekk R. S.** and **Müller-Sigmund, H.** (2005) Norske vesuvianer og vesuvianforekomster. *Norsk Bergverksmuseum*, skrift 30, ISBN 82-91337-36-5, 30-40.

Abstracts

Alpers, C.N., **Majzlan, J.**, McCleskey, R.B., Nordstrom, D.K. and Navrotsky, A. (2005) Thermodynamic data for hydrated ferric sulfates and application to secondary minerals at Iron Mountain, California. *15th Goldschmidt conference*, Moscow, Idaho, USA, May 2005.

Botez, C., **Majzlan, J.** and Stephens, P.W. (2005) Structural studies of double-hydrogen-bonded superprotonic fuel cell electrolytes. *NSLS Annual Users' meeting*, Upton, New York, USA, May 2005.

Bucher, K. and Stober, I. (2005) Large scale chemical stratification of groundwater in the crust, data from the geothermal research site "Urach3" germany. *GSA Abstracts with Programs*, 37, A228-3, ISSN 0016-7592, *Geological Society of America*, Boulder, CO, USA

Eichinger F., **Gieré R.** and Johnson A. (2005) Geochemistry and Mineralogy of Antimony in Soils of Shooting Ranges. *1st International Workshop on Antimony in the Environment*. University of Heidelberg. Program with Abstracts, p. 50

Gieré R., Smith K. and Blackford M. (2005) Particulate emissions from tire combustion. *3rd International Conference on Materials for Advanced Technologies*, Singapore, Abstract Volume, p.1

Gieré R., Smith K.L. and Blackford M.G. (2005) Particulate emissions from combustion of a coal+tire mixture. *World of Coal Ash*, Lexington, KY. Program with Abstracts, p. 159

Gieré R., Smith, K.L., Li H. and Blackford M. (2005) Reducing coal consumption by burning tires: environmental impacts. *Berichte der Deutschen Mineralogischen Gesellschaft*, Beihefte zum European Journal of Mineralogy, Vol. 17/1, 47

Gieré R. and Sorensen, S.S. (2005) Petrologic significance of allanite and related minerals: a review. *Geophysical Research Abstracts*, Vol. 7, 06539

Halama, R., McDonough, W.F., Rudnick, R.L., Ash, R.D., **Keller, J. Klaudius, J.** and Trumbull, R. 2005. Lithium concentrations and Li isotopic compositions of carbonatitic complexes. Abstract *AGU* 2005.

Keller, J. (2005) Evolution of Peralkalinity at Oldoinyo Lengai, Tanzania. *Workshop PERALK* Tübingen (invited), Extended Abstracts 41-43.

Klaudius, J. and **Keller, J.** (2005) Natrocarbonatitic activity in the north crater of Oldoinyo Lengai (Tanzania). *Workshop PERALK* Tübingen 04.-06.03.05, Extended Abstracts p. 44.

Keller, J. and **Klaudius, J.** (2005) Historical Activity and Volcanic Hazard at Oldoinyo Lengai, Tanzania. Abstract *Cities on Volcanoes* 4, Quito, Ecuador January 2006.

Kervyn, M., **Klaudius, J.**, Kervyn, F., Scoys, J., **Keller, J.**, Mbede, E., Pirard, E., Ernst, G.G.J. (2005) Remote sensing evidence for sector collapses and debris avalanches at Oldoinyo Lengai Volcano, Tanzania. *Remote Sensing and Photogrammetry Society* annual conference 2005: "Measuring, Mapping and Managing a Hazardous World" Portsmouth University (6-9 Sep 2005).

Majzlan, J., Chovan, M., Jurkovic, L., Lalinská, B. and Milovská, S. (2005) Local structure of Fe and As in X-ray amorphous ochres from Pezinok, Slovakia. ANKA users' meeting,

- Karlsruhe, Germany, October 2005.
- Majzlan, J.** and Kiefer, B. (2005) Crystal structure of ferricopiapite. *Deutsche Mineralogische Gesellschaft Tagung*, Aachen, Germany, September 2005.
- Nielsen, U.G., **Majzlan, J.** and Grey, C.P. (2005) Multi-nuclear solid-state NMR investigations of jarosites, iron soil minerals, and their aluminium analogues, alunites. *EUROMAR, European Magnetic Resonance Community conference*, Veldhoven, the Netherlands, July 2005.
- Majzlan, J.**, Nielsen, U.G. and Grey, C. (2005) The existence and mobility of hydrogen in the structure of jarosite. *15th Goldschmidt conference*, Moscow, Idaho, USA, May 2005.
- Majzlan, J.**, Phillips, B.L. and Myneni, S.C.B. (2005) Aluminum and iron speciation in acidic, sulfate-rich waters. *Geochemistry 2005; Jahrestagung der Sektion Geochemie der Deutschen Mineralogischen Gesellschaft*, Bremen, Germany, May 2005.
- Majzlan, J.**, Speziale, S. and Duffy, T.S. (2005) Elastic constants of alunite. *European Geosciences Union conference*, Vienna, Austria, April 2005.
- Müller-Sigmund, H.** and Schneider, F. (2005): Neolithic pottery from Marocco – petrographic constraints on sources and production. - *Ber. Dt. Miner. Ges., Beih. z. Eur. J. Mineral.* Vol. 17, No. 1, 94.
- Myneni, S.C.B., Hay, M.B. and **Majzlan, J.** (2005) Coordination environments of hydroxyl and organic complexes of aluminum in aqueous solutions and in amorphous precipitates. *American Chemical Society conference*, Washington, D.C., USA, December 2005.
- Selbekk R. S.**, Huhuma, H. and Rosa Diaz, J.D.L. (2005) Hydrous anorthosite generated by partial melting of a mafic crust: REE, Rb/Sr and Sm/Nd isotope evidence from the Skattøra migmatite complex, Norway. *Journée magmatique 2005*, UNI-Lausanne, 24.
- Smith K.L., Blackford M.G., Siegele R., **Gieré R.**, Li H., Vogt S. and Harland C. (2005) Investigation of Fly Ash Particulates Using SEM, TEM and Synchrotron Microprobe Techniques. *Microscopy and Microanalysis '05 Conference*, July 31st - August 4th 2005, Honolulu, Hawaii, USA. *Microscopy and Microanalysis* 11 (Suppl. 2), 1686-1687
- Smith K.L., Blackford M.G., **Gieré R.**, Twining J., Siegele R., Li H., McGlinn P.J. and Loi E. (2005) Fly ash characterisation and leach testing. In: Glenn M., MacRae C.M., Pigram P., and Wilson NC. (eds): *Extended Abstracts. Australian Microprobe Analysis Society, 8th Biennial Symposium*, Melbourne, p. 92-93
- Stober, I. and **Bucher, K.** (2005) Hydraulic and hydrochemical signals from two ultra-deep boreholes at the KTB test site, Germany. *GSA Abstracts with Programs*, 37, A228-13, ISSN 0016-7592, *Geological Society of America*, Boulder, CO, USA
- Zaitsev, A.N. and **Keller, J.** (2005) Calcite carbonatites from Oldoinyo Lengai - magmatic or subsolidus? A continuation of the Dawson - Harmer-Gittins discussion. *Workshop PERALK Tübingen* (invited), *Extended Abstracts* 123-125.

Popular Science

- Mittelstädt, P.** and **Selbekk, R. S.** (2005) "Islands verherendste Naturkatastrophe – Zeugen der Spalteneruption am Laki 1783. *Der Aufschluss* 56, 172-176.
- Weisenberger, T.** (2005) "Zeolithe in Island"; Island; *Zeitschrift der Deutsch-Isländischen Gesellschaft e.V. Köln und der Gesellschaft der Freunde Island e.V. Hamburg*, Heft 1, April 2005, 40-45

Research Abstracts

Geothermal energy research

Ingrid Stober & Kurt Bucher (2005) The upper continental crust, an aquifer and its fluid: Hydraulic and chemical data from 4 km depth in fractured crystalline basement rocks at the KTB test site. *Geofluids*, 5, 8-19.

This was the most accessed paper 2005 in *Geofluids* (ranked 7 journal in the geology category).

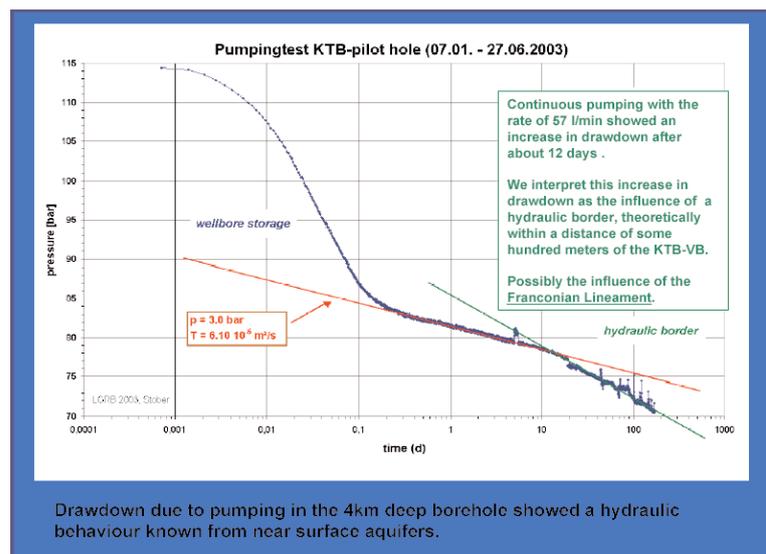
The research was presented at the Annual Meeting of the Geological Society of America 2005 in Salt Lake City: Stober, Ingrid & Bucher, Kurt, 2005. Hydraulic and hydrochemical signals from two ultra-deep boreholes at the KTB test site, Germany. *GSA Abstracts with Programs*, 37, A228-13, ISSN 0016-7592, Geological Society of America, Boulder, CO, USA

This research has been carried out in the context of the DFG-Schwerpunktprogramm: Internationales Kontinentales Tiefbohrprogramm (ICDP) (SPP1006): "Hydrochemical and hydraulic properties of the continental upper crust at the KTB site" granted to Ingrid Stober, LGRB.

The upper continental crust, an aquifer and its fluid: Hydraulic and chemical data from 4 km depth in fractured crystalline basement rocks at the KTB test site

Ingrid Stober, Kurt Bucher

Detailed information on the hydrogeologic and hydraulic properties of the deeper parts of the upper continental crust is scarce. The pilot hole of the deep research drillhole (KTB) in crystalline basement of central Germany provided access to the crust for an exceptional pumping experiment of one-year duration. The hydraulic properties of fractured crystalline rocks at 4 km depth were derived from the well test and a total of 23100 m³ of saline fluid was pumped from the crustal reservoir. The experiment shows that the water-saturated fracture pore space of the brittle upper crust is highly connected, hence, the continental upper crust is an aquifer. The pressure-time data from the well tests showed three distinct flow periods: the first period relates to wellbore storage and skin effects, the second flow period shows the typical characteristics of the homogeneous isotropic basement rock aquifer and the third flow period relates to the influence of a distant hydraulic border,



Hydraulic analysis of one-year pumping test at the KTB pilot hole

probably an effect of the Franconian lineament, a steep dipping major thrust fault known from surface geology. The data analysis provided a transmissivity of the pumped aquifer $T = 6.1 \cdot 10^{-6} \text{ m}^2 \text{ s}^{-1}$, the corresponding hydraulic conductivity (permeability) is $K = 4.07 \cdot 10^{-8} \text{ m s}^{-1}$ and the computed storage coefficient (storativity) of the aquifer of about $S = 5 \cdot 10^{-6}$. This unexpected high permeability of the continental upper crust is well within the conditions of possible advective flow. The average flow poros-

ity of the fractured basement aquifer is 0.6 - 0.7 % and this range can be taken as a representative and characteristic values for the continental upper crust in general.

The chemical composition of the pumped fluid was nearly constant during the one-year test. The total of dissolved solids amounts to 62 g l⁻¹ and comprise mainly a mixture of CaCl₂ and NaCl; all other dissolved components amount to about 2 g l⁻¹. The cation proportions of the fluid ($X_{Ca} \sim$

0.6) reflects the mineralogical composition of the reservoir rock and the high salinity results from desiccation (H₂O-loss) due to the formation of abundant hydrate minerals during water-rock interaction. The constant fluid composition suggests that the fluid has been pumped from a rather homogeneous reservoir lithology dominated by metagabbros and amphibolites containing abundant Ca-rich plagioclase.

The following essay on deep fluids appeared in February 2005 in a special volume on the future developments in hydrogeology in the *Hydrogeology Journal*: Stober, I. and Bucher, K. 2005, Deep-fluids: Neptune meets Pluto. In: C. Voss (Ed.) *The Future of Hydrogeology*. *Hydrogeology Journal*, 13, 112-115. Below, the introduction to the essay is reproduced.

Deep-fluids: Neptune meets Pluto

Ingrid Stober, **Kurt Bucher**

Keywords deep-fluids, fractured basement rocks, hydrochemistry, hydraulic properties, geothermics

Groundwater in fractured crystalline rocks such as granite and gneiss has a remarkable compositional variability and the crystalline hard rock aquifers show a wide range of hydrogeological properties (Gustavson and Krasny 1993; Stober and Bucher 1999a). With increasing depth both the total load of dissolved solids (TDS) and the temperature of groundwater in the crystalline basement increases. Groundwater gradually changes into a hot saline brine that is better termed a crustal deep-fluid. The hydrochemistry of deep-fluid has been recently reviewed by Frappe et al. (2004) and their data compilation shows that at depth greater than about 500 m almost all deep waters are essentially binary NaCl-CaCl₂ mixtures. Few data on fluid composition and in situ hydraulic properties are available from below a depth of 3 km in the continen-

tal crystalline crust. Such “ultra” deep-fluids have been reported from research boreholes and from wells drilled for geothermal energy (Stober and Bucher 2004). At 4-5 km depth, the temperature of these deep-fluids ranges from about 100 to 200°C. The two deep wells, 12.5 km Kola, Russia (Kozlovsky 1984) and 9.1 km KTB, Germany (Möller et al. 1997) had bottom hole temperatures of 240° and 270°C. At still greater depth there is gradual and continuous transition to so-called hydrothermal fluids (Barnes 1995). The depth-range of some hundreds to thousands of meters is truly the venue where Neptune, the god of the waters and the sea, meets Pluto, the god of the underworld, heat and fire; this is the world of hot saline deep-fluids.

This essay first briefly summarizes the hydrogeology of deep-fluids, their chemical composition and the hydraulic properties of the reservoir rocks. Future developments in the hydrogeology of deep-fluids are contemplated from the present meager data and understanding, as well as from the needs of applied science, technology and industry.

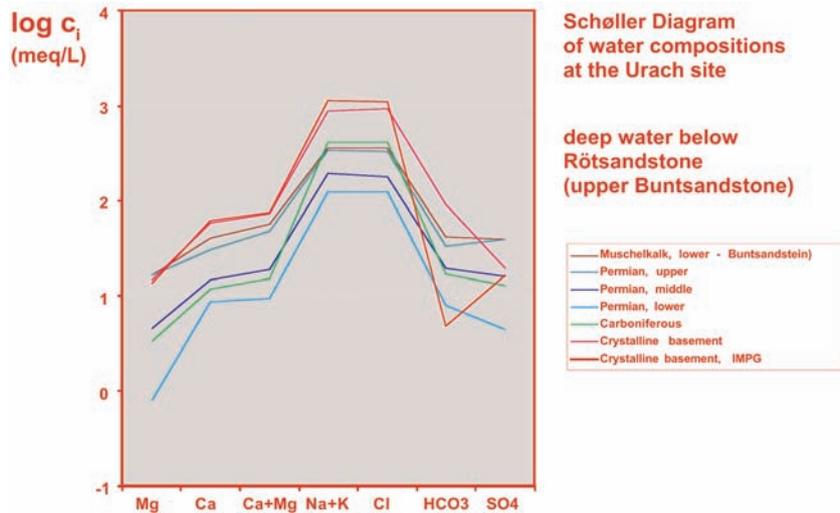
Research at the geothermal well Urach4 goes on!

Kurt Bucher, Ingrid Stober

The research was presented at the Annual Meeting of the Geological Society of America 2005 in Salt Lake City. Bucher, Kurt and Stober, Ingrid, 2005. Large scale chemical stratification of groundwater in the crust, data from the geothermal research site "Urach3" Germany. GSA Abstracts with Programs, 37, A228-3, ISSN 0016-7592, Geological Society of America, Boulder, CO, USA

Our research at the geothermal research site Bad Urach continues. It shifted its focus from the

hydraulic properties of the continental crust to the chemistry of deep fluids. The latest research results were presented at GSA 05. A figure from this research presentation is shown below.



Composition of the deep fluid from the Urach3 geothermal well. All water samples below lower Triassic beds.

The following review article on deep groundwater has been accepted for publication in the Hydrogeology Journal and is, unfortunately, still under revision (due to lack of research time). It summarizes an invited lecture given by Ingrid Stober at the IHS meeting on hydrogeology of crystalline rocks in Prague 2004.

Deep groundwater in igneous and metamorphic rocks

Ingrid Stober, Kurt Bucher

For details please refer to annual report 2004.

A new research project related to the Geothermal Energy focus of the Geosciences in Freiburg has been launched in the fall 2005:

Hydrochemical evolution of deep groundwater in fractured basement aquifers

Kurt Bucher, Ingrid Stober, Ulrike Seelig

A grant application to the DFG has been submitted and is pending.

Co-worker of the project is Ulrike Seelig, who started a PhD program in October 2005.

The project has access to an absolutely unique set of water samples from the world longest railroad tunnel currently under construction between Erstfeld and Bodio in Switzerland (NEAT Alptransit, Gotthard). Currently more than 50 water samples from

water producing fissures from the tunnel are analyzed in our laboratories. The data will be unique in a world-wide context. The water and rock temperatures are currently more than 43°C. The Schöller Diagram (right) shows the first two water analyses and underlines the very special chemical character of these thermal waters in the crystalline basement. The NEAT Gotthard tunnel project will be our central research effort in the field of water and geothermal energy research in the next 3 to 4 years.



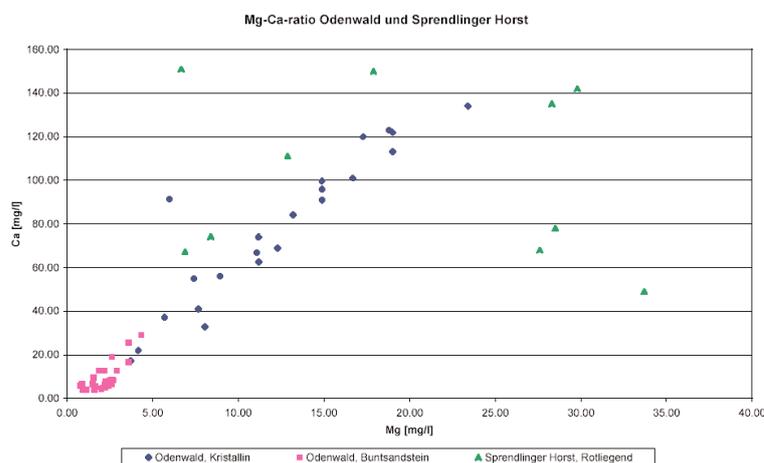
Schöller-Diagram showing the composition (in meq/l) of two water samples at km 16195 from N. Water temperature is about 42°C and the pH~9.8.

Regional variation of groundwater composition in Hessen and its relation to the aquifer geology

Kurt Bucher, Ingrid Stober,
Florian Ludwig

The responsible investigator at HLUG is Dr. Leßmann. Florian Ludwig is co-worker in the project and will use the results of the investigation for a PhD project under the guidance of Kurt Bucher and Ingrid Stober.

The project will produce more than 1000 new full analyses of groundwater including data for a large number of trace elements. The first series of data have been produced for wells in basement rocks and buntsandstein in the south of Hessen. The data show a number of interesting and partially surprising features. An example plot of some data is shown above.



Environmental geochemistry

The results of this study have been published by “Environmental Science and Technology”. The study is a collaboration between our Institute and the Australian Nuclear Science and Technology Organisation in Sydney

Risk Ranking of Bioaccessible Metals from Fly Ash Dissolved in Simulated Lung and Gut Fluids

Reto Gieré, John Twining¹, Peter MgGlenn¹,
Elaine Loi¹, Katherine Smith¹

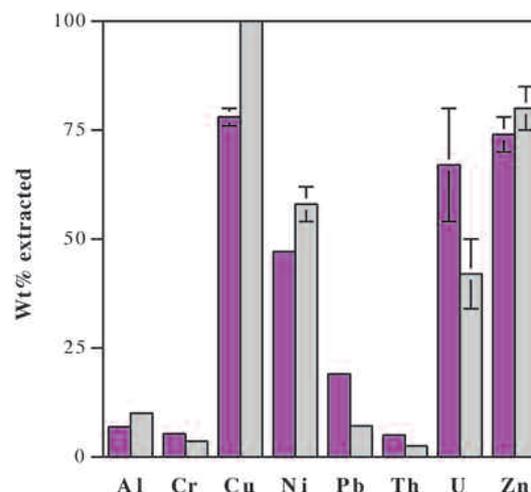
Power plant fly ash from two fuels, coal and a mixture of 95 wt% + 5 wt% shredded

automobile tires, were evaluated for trace metal solubility in simulated human lung and gut fluids to estimate bioaccessibility. The simulated lung fluid was used to mimic inhalation risks, whereas the simulated gut

fluid was used to mimic risks through ingestion.

The proportion of bioaccessible to total metal ranged widely: from 0% (V) to 80% (Zn) for coal-derived ash in simulated lung fluid, and from 2% (Th) to 100% (Cu) for ash from the coal+tire mixture. The tire-derived ash was much richer in Zn, because the tires contain approximately 1 wt% Zn, added during the vulcanization process. However, Zn ranked only 5th of the various toxic metals in simulated gut fluid compared with international regulations for ingestion. On the basis of total concentrations, the metals closest to exceeding limits based on international regulations for inhalation were Cr, Pb, and Al. On dissolution in simulated lung fluid, the most limiting metals were Pb, Cu, and Zn. For metals exposed to simulated gut fluid there was no relative change in the top metal (Al) before and after dissolution but the second-ranked metal shifted from Pb to Ni. In most cases only a proportion of the total metal concentrations in either fly ash was soluble, and thus bioaccessible, in either biofluid.

An important result of this study is that, when considering the regulatory limits for inhalation of particulates, none of the metal concentrations measured were as hazardous



Solubility of various metals in simulated gut fluid. Values show percentage of a given metal extracted from the total amount of the metal present in the ash. Purple: ash from pure coal; Grey: ash from coal+tire mixture

as the fly ash particulates themselves. However, on the basis of the international ingestion regulations for Al, the maximum mass of fly ash that could be ingested is only 1 mg per day. It is possible that such a small mass could be consumed by exposed individuals or groups, particularly if they do not wear face masks.

¹Australian Nuclear Science and Technology Organisation, Sydney (Australia)

This topic was studied within the framework of a Diploma thesis carried out at our Institute and in collaboration with Dr. Annette C. Johnson (EAWAG, Dübendorf). A manuscript is currently in preparation.

Geochemistry and Mineralogy of Antimony in Soils of Shooting Ranges

Florian Eichinger, Reto Gieré, Annette Johnson¹

Antimony (Sb) and Lead (Pb) contamination of soils from shooting ranges is a severe problem in countries with their own defense systems. The aim of this project was to gain better knowledge about the behavior of Sb, which is released from the bullets during weathering. Soils from two Swiss shooting ranges have been studied: at Losone

(Ticino), an acidic (pH = 3.7), organic-rich natural forest soil, sampled behind the stop butt, features Sb concentrations of 93 ppm (0-12.5 cm) and 3.6 ppm (12.5 – 25cm); at Eschenbach (St. Gallen), the samples have been taken from the stop butt, where the upper layer (0 - 12.5 cm) is an intermediate (pH = 6.6), CaCO₃-buffered soil with an Sb concentration of 5,870 ppm, whereas the lower layer (12.5 – 25 cm) shows a concentration of 1,310 ppm.

To obtain an understanding of the weathering of the bullets and the release of Pb and Sb, weathered bullets have been collected at the shooting ranges, sawed, polished, and analyzed by electron probe microanalysis (EPMA). The bullets consist of three parts: a Pb-Sb core, an interlayer of Cu and Ni, and a mantle of Fe. The core of new, unused bullets is not a homogeneous Pb-Sb alloy, but consists rather of Sb grains (1-2 μm across) embedded in a Pb matrix. Where mantle and core have been damaged upon impact, formation of Fe-, Pb- and Sb-rich phases can be observed to enclose soil particles. During this process, especially in the acidic soil at Losone, the elemental Pb is oxidized, but the grains of native Sb in the core are virtually unaffected by oxidation. Where the bullets are not damaged upon impact, the Fe-mantles are oxidized during weathering, thus generating Fe phases (ferrihydrite, goethite, hematite). These Fe phases, however, do not incorporate Sb, because the Sb contained in the core of the bullet is not exposed.

The studied soils have also been separated magnetically and gravitationally. Grain mounts have been prepared from the separated soil fractions, which have been analyzed by EPMA. In the acidic soil from Losone only one Sb-bearing phase has been observed: Sb is present in its elemental form in weathered core fragments. The soil from Eschenbach, in contrast, features three different Sb-bearing phases: most Sb is also present as elemental Sb in core fragments, but Sb could further be found in Fe and Pb-



Polished section through a damaged bullet showing the Fe-rich crusts (brown), which form around the bullets in the soil. Bullet is ~ 3 cm long.

rich crusts around soil particles as well as in individual conglomeratic grains consisting of an Fe-, Pb- and Sb-rich matrix that incorporates soil particles and core fragments.

Single H_2O and oxalate extractions, which have been performed on one grain size fraction (75 – 200 μm) of the separated soil from Eschenbach, demonstrate that 5.1% of the total Sb can be extracted by H_2O , and only 3.6 % can be dissolved by oxalate. These results lead us to conclude that the majority of the Sb is bound in crystalline phases and hence is rather immobile. The applied separation processes have been successful, because it has been possible to concentrate the main Sb-bearing phases in distinct fractions.

¹EAWAG, Dübendorf (Switzerland)

Ph.D. thesis project of Sonia Ackermann (started October 2005).

Funded by: a research proposal has been submitted to the DFG.

Mineralogy of Soils Contaminated by Antimony

Sonia Ackermann, Reto Gieré

Pollution of soils by heavy metals and other toxic elements has become a serious problem to today's society. Immisions by road traffic, landfills and industrial sites are

a few examples among many different sources of contamination.

Understanding the geochemical cycle of these contaminants is essential to predict long-term behavior of these substances in our environment. The results of geochemi-

cal studies are fundamental in answering questions about the future development of contaminated sites and their implications to the humans and the biosphere.

Shooting ranges are characterized by highly polluted soils around the stop butts. The contamination is caused by the bullets, which primarily contain lead, iron and antimony. Antimony is an additive to harden the lead core of the bullets. The annual deposition of these elements by shooting activities in Switzerland is estimated to be around 400-500 tons for lead and 10-25 tons for antimony. In the last few years, the toxicity of antimony to humans has been reliably documented. Since the toxicity is strongly

dependent on the chemical form of Sb, a basic knowledge of the composition and mineralogy of the contaminated sites is necessary.

The aim of this study is to assess the conditions under which antimony forms mobile species in soils. Therefore, the study is focusing on the different mineral phases in these polluted areas. Of special interest are minerals which immobilize antimony either by formation of solid solutions or by adsorption of Sb species on their surfaces. The stability and behavior of these substances under surface conditions can be investigated by identifying these phases and by studying their thermodynamic properties.

The following text summarizes our research within a frame of a large remediation project at the Pezinok deposit in Slovakia. The results of the research were presented at the ANKA (Angstromquelle Karlsruhe) users' meeting and are being prepared for a publication in *Geochimica et Cosmochimica Acta*.

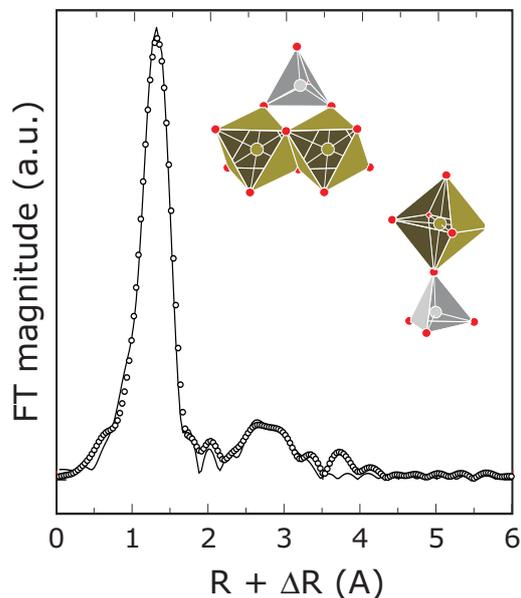
Local structure of Fe and As in X-ray amorphous precipitates in Pezinok, Slovakia

Juraj Majzlan, Martin Chovan¹, Lubomir Jurkovic¹, Brona Lalinska¹, Stanislava Milovska²

We have studied X-ray amorphous precipitates that are discharged from a tailing impoundment at a former Sb deposit Pezinok in Slovakia. The mining activity ceased in 1992, but the environmental impact persisted until today. The primary ores consisted mostly of stibnite (Sb_2S_3), berthierite (FeSb_2S_4), and gudmundite (FeSbS), with abundant pyrite (FeS_2) and arsenopyrite (FeAsS). Gangue minerals were quartz and carbonates.

Weathering of these finely ground minerals in the tailing impoundments produces acidic waters which are quickly neutralized by abundant carbonates. Therefore, the discharges have circumneutral pH and carry most of their metal load in colloidal form. The final weathering product are X-ray amorphous ochres, the subject of this study.

The ochres are rich in As and Sb, with local values reaching 13 wt% As and 2 wt%



An EXAFS spectrum (at the As K edge) of an X-ray amorphous sample from Pezinok in Slovakia. The complexes shown are the most likely building blocks of the nanoparticles in the studied sample

Sb. They are essentially X-ray diffraction (XRD) amorphous.

We have used X-ray absorption spectroscopy (XAS) to determine the local struc-

ture around the Fe and As atoms. X-ray absorption near-edge structure (XANES) spectroscopy has shown that both elements are fully oxidized, i.e., Fe in its +3 state and As in its +5 state. Extended X-ray absorption fine structure (EXAFS) spectra showed that Fe is octahedrally coordinated, with a small number of Fe near neighbors at a distance of 3.0 Å. Such arrangement is characteristic for highly depolymerized nanoparticles, in which only edge-shared octahedra can be found. As EXAFS spectra showed that As is tetrahedrally coordinated. In the

second coordination shell, ~3 Fe atoms are found. These results indicate that the arsenate anion forms a mixture of mononuclear and bidentate binuclear inner-sphere complexes. The arsenate anion probably inhibits the growth and transformation of the nanoparticles into a more stable phase. The results are important for the evaluation of capturing and long-term stability of the As-rich ochres.

¹Comenius University, Bratislava, Slovakia

²Slovak Academy of Sciences, Banská Bystrica, Slovakia

The research summarized here was presented at the annual meeting of the Geochemical section of the DMG. At the moment, we are in a process of collecting and interpreting XAS data on Al K edge in aqueous solutions at the synchrotron in Berkeley. Once those data are available, a publication will be written.

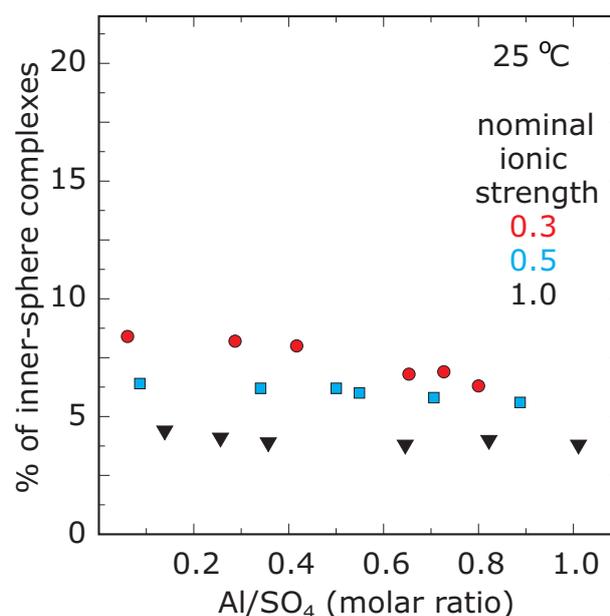
Aluminum speciation in Al-SO₄ solutions

J. Majzlan, S.C.B. Myneni¹, B.L. Phillips²

Acid mine waters, produced at innumerable places around the world, are a product of pyrite weathering. The most abundant ions in these waters are Fe^{II}, Fe^{III}, Al^{III}, and SO₄²⁻. In our previous work (Majzlan and Myneni 2005), we have studied interaction of Fe^{II} and Fe^{III} with sulfate in acidic waters. In this study, we have turned our attention to the aluminum-sulfate interactions in acidic aqueous fluids.

Fourier transform infrared (FTIR) spectroscopy showed that the sulfate tetrahedron is not distorted in the presence of variable amount of Al at variable pH values. These observations suggest that the amount of inner-sphere complexes is rather low, at least with respect to the sensitivity of FTIR spectroscopy. These observations are also in sharp contrast with the Fe^{III}-SO₄²⁻ system, where the presence of Fe^{III} in the solution caused significant distortion of the sulfate molecule.

Nuclear magnetic resonance (NMR)



The fraction of inner-sphere complexes Al(SO₄)⁺, as determined from the NMR measurements

spectroscopy on ²⁷Al allowed quantification of the inner-sphere complexes at 25 and 50 °C. At 25 °C, the inner-sphere complexes represent only <10 % of the total aluminum in solution. The fraction of inner-sphere complexes is a function of the ionic strength and the Al/SO₄ ratio in the solution. At elevated temperatures, the fraction of the inner-sphere complexes rap-

idly increases. Analogous trends have been observed also by Raman spectroscopy (Rudolph and Mason 2002) and potentiometric studies (Xiao et al. 2002). Increasing fraction of the inner-sphere complexes in hot Al-SO₄ solutions is very likely for the precipitation of alunite at higher temperatures, such as in epithermal systems related to volcanic fields. Our results also provide explanation as to why alunite does not precipitate at low temperatures, and Al and SO₄

remain in solution.

Majzlan, J., Myneni, S.C.B., 2005: Environ. Sci. Technol. 39, 188-194.

Rudolph, W.W., Mason, R., 2002: Z. Physik. Chemie 216, 1061-1083.

Xiao, C., Wesolowski, D.J., Palmer, D.A., 2002: Environ. Sci. Technol. 36, 166-173.

¹Princeton University, USA

²State University of New York at Stony Brook, USA

Mineralogy, archaeometry, economic geology

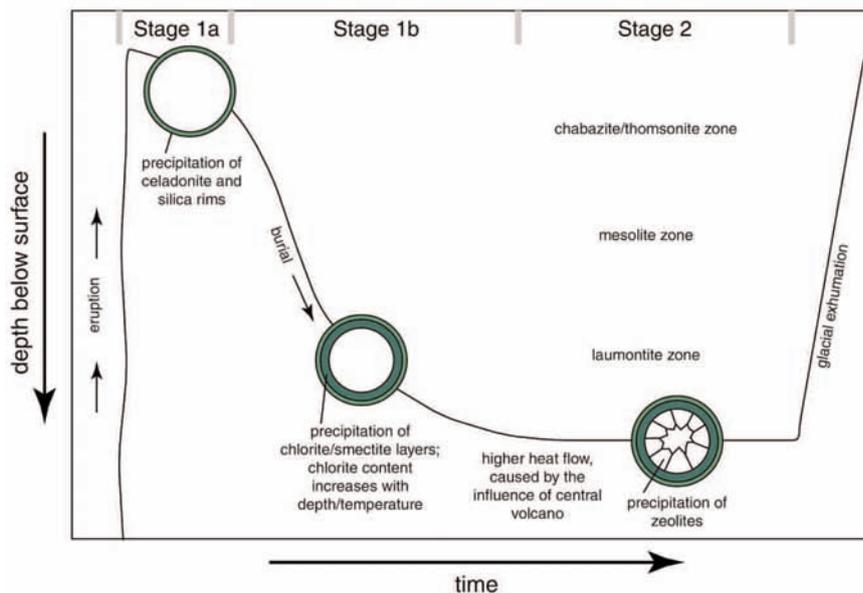
This project is T. Weisenberger's diploma work.

Zeolite facies mineralisation in the Hvalfjörður area, Iceland

Tobias Weisenberger, Rune S. Selbekk

The Hvalfjörður area, 30 km north of Iceland's capital Reykjavik, belongs to the sequence of late Tertiary to early Quaternary flood basalts with minor interlayer of hyaloclastites and rhyolites. (RUTTEN 1958). The basalts are affected by a low temperature zeolite facies metamorphism, caused by

the burial of the lava succession and higher heat flow influenced by the Laxárvogur and the Hvalfjörður central volcano. Low-grade zeolite facies metamorphism of basaltic lavas in the Hvalfjörður field area results in two distinct mineral paragenesis that can be correlated to events in the burial and hydrothermal history of the lava pile. Stage 1a marks near surface alteration in which



Spatial and temporal development of pore-filling mineral assemblages in the Hvalfjörður area. The vertical axis depicts depth below land surface at the time of each event depicted in the figure. Time elapsed after eruption increases to the right. No scales are implied on the axis.

celadonite and silica were precipitated along primary pores. During burial, hydrolysis of olivine and glass led to the formation of mixed layers chlorite/smectite clays. The chlorite content of stage 1b precipitation increases with increasing burial depth and temperature. Stage 2 occurred after burial and is marked by the zeolite mineralisation, caused by higher heat flow, from the Laxárvogur central volcano. Altogether twelve different zeolites were found in the Hvalfjörður area: analcime, chabazite, epistilbite, garronite, heulandite, laumontite, levyne, mesolite, stilbite, stellerite, thomsonite and yugawaralite. Based on the work done by WALKER (1960), zeolites were grouped into zeolite zone. In total three separate depth and temperature-controlled “zeolite zones” are described in the Hvalfjörður area: the upper chabazite/thomsonite zone, the middle mesolite zone and the lowest laumontite zone. The mineralisation temperature for zeolites increases from

the upper chabazite/thomsonite zone to the lower laumontite zone. Correlation between the depth distribution and temperatures for the formation of zeolite zone in the geothermal system, give a geothermal gradient of 133 °C/km. This high temperature gradient is usual for central volcanoes, and together with the geochemistry and tectonic features in the Hvalfjörður area, we suggest the existence of a second central volcano, the Laxárvogur central volcano.

RUTTEN M.G., 1958. Geological reconnaissance of the Esja-Hvalfell-Armannsfell area, southwestern Iceland. *Verhandelingen van het Koninklijk Nederlands Geologisch-Mijnbouwkundig Genootschap, Geologische Seris XVII*, 219-298

WALKER G.P.L., 1960. Zeolite zones and dike distribution in relation to the structure of the basalts of eastern Iceland. *Journal of Geology* 68, 515-528

This review article is printed in the Geological society of Iceland’s international magazine *Jökull*, 2005. 55, 49-52.

Stellerite from the Hvalfjörður area, Iceland

Rune S. Selbekk, Tobias Weisenberger

Stellerite (a zeolite) occurs as tabular crystals up to 1.5 cm on veins in the Hvammsvík area, Hvalfjörður, together with yugawaralite and laumontite. The stellerite have space group *Fmmm*, and lattice parameters for this sample are: $a = 13.5961$, $b = 18.2114$, $c = 17.8615$ Å. The average composition of 5 analyses calculated on the basis of 72 oxygen atoms is: $(\text{Ca}_{3.88}\text{Na}_{0.05}\text{K}_{0.03}\text{Sr}_{0.01})_{\Sigma=3.97}\text{Al}_{7.95}\text{Si}_{28.07}\text{O}_{72} \cdot 28\text{H}_2\text{O}$. The chemistry, calculated space group and the lattice parameters are in agreements with the criteria for the mineral species stellerite. Stellerite (*sensu stricto*) has not been documented from Iceland before.



Stellerite crystals from the Hvalfjörður area, Iceland

A grant application to the DFG has been submitted and is pending.

Co-worker of the project is Tobias Weisenberger, who will start a PhD program in January 2006.

Zeolites in fissures of crystalline basement rocks

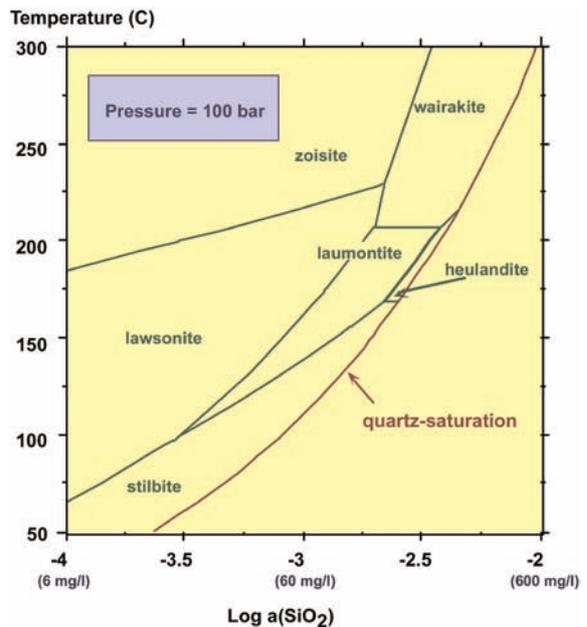
Kurt Bucher, Tobias Weisenberger

The NEAT Gotthard tunnel offers the unique opportunity to relate the composition of the thermal waters to the fissure mineralogy. One of the latest minerals that precipitates from the hot waters in the fissures and cavities opened by the tunnel construction works is laumontite. Other species of zeolite occur as well. Zeolites from fissures in granitic gneisses have been found in the Gotthard road tunnel during construction in the 1980's. Zeolites also occur sporadically in surface outcrops. Due to the fragile nature of some zeolites, they were only found in tunnel fissures. The widespread occurrence of late zeolite minerals in the Gotthard basement can be directly related to the water



NEAT Gotthard: Laumontite needles (about 10 mm long) cover a fissure wall in granite

chemistry and the chemical evolution of hot water along flow paths through the basement rocks. The sample material and the documentation and description of the finds will be used to model the so-called desiccation process. The process has been postulated in several of the Bucher & Stober and Stober & Bucher research papers (see bibliography on our web site) as a viable mechanism for "deep hot water" to evolve to highly concentrated brines.



Computed phase-diagram for Ca-zeolites (thermodynamic data and software by courtesy of Christian de Capitani, Basel)

The following essay is part of a broader study of fulgurite phenomena on country rock surfaces. A short note publication on the magnetic patterns induced by lightning impact is in preparation for *Mitteilungen d. Deutschen Geophysikalischen Gesellschaft*.

Centimeter-scale magnetic structures caused by lightning impact

Wolfhard Wimmenauer, Werner Mehlhorn¹,
Hiltrud Müller-Sigmund

The melilite basalt of Grieslen (Hegau)

displays a strong and locally confined magnetic anomaly attributed to a lightning impact (Mäussnest 1964). A rock sample with some fulgurite glass coating was taken

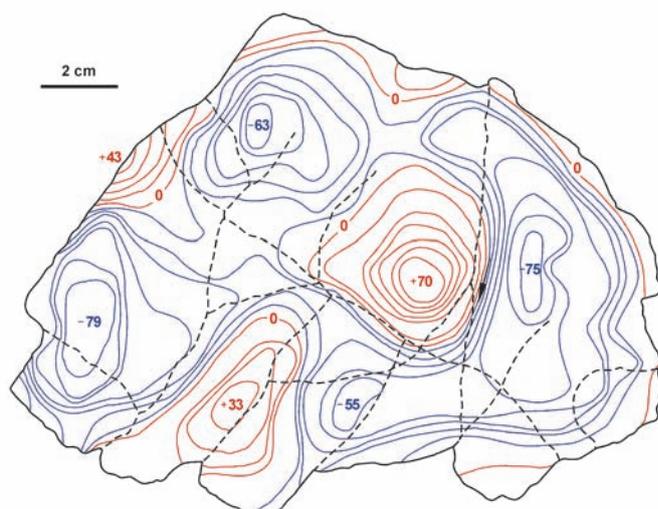


Fig. 1. Centimeter scale magnetic anomalies on a cut slab (vertical intensity in microtesla); the sketch displays rock fractures (dashed lines), positive (red) and negative (blue) magnetic isolines.

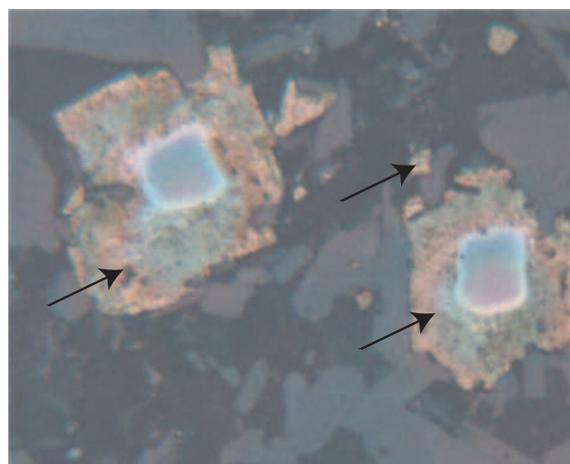
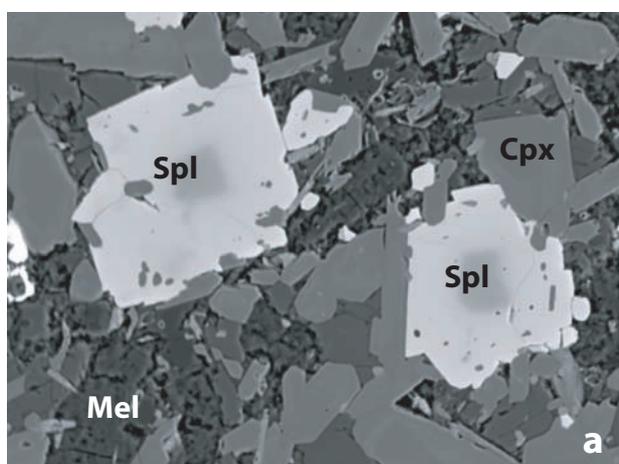


Fig. 2. Polished section, (a) backscattered electron image, long edge 170 mm; Spl spinel (grey) with magnetite rim (white), Cpx Ti-augite. Mel melilite; (b) reflected light optical image, long edge 170 mm, specimen coated with Ferrofluid adhering to spinel rims and groundmass magnetite (arrows, brownish tint)

from the outcrop for closer investigation. The magnetic properties of the natural rough surface were measured within a pair of Helmholtz coils, using a Fluxmaster Teslameter probe (S. Mayer, Münster/Westf.). There appeared quite different directions and intensities of the magnetic field within short distances. In a second step, the magnetic structure on a sawed section of the specimen was studied with a Mag03, MC magnetic probe (Barrington Instruments, Oxford, U.K.) which allowed a more precise structure of the field lines and its strength. The results, expressed as vertical intensities, are shown in fig. 1. The pattern shows a more or less clear relation to fissures in the rock, which acted as conductive leaders of the lightning's current. Thus

the pathway of the discharge in a three-dimensional, branched system within the rock body is clearly visualized.

Investigations of a polished section in reflected light and with the electron microprobe show that the basalt contains about 4.5 vol.-% of magnetite. Magnetite occurs as rim on up to 0.2 mm large, zoned spinel grains and as much smaller ($< 200 \mu\text{m}$) homogeneous grains. In order to visualize the distribution of carriers of induced magnetism in the rock we used Ferrofluid EMG308 from FerroTec, a water based suspension of 10nm sized magnetite particles with a saturation magnetisation of 6 mT (fig. 2). Ferrofluid adheres only to the small groundmass magnetite grains and to the bright rims of spinel crystals (brownish tint

in fig. 2b). The core composition of these larger spinel crystals is $[Al_{1.01}Cr_{0.66}Fe^{3+}_{0.30}Ti_{0.03}][Mg_{0.64}Fe_{0.36}]O_4$, while the outer rim consists of aluminian titanomagnetite $[Al_{0.34}Ti_{0.32}Cr_{0.04}Fe^{3+}_{0.98}Mg_{0.50}Fe^{2+}_{0.80}Mn_{0.02}]O_4$. There is only a narrow transition zone of 6 to 8 μm width in which the change of composition takes place. The small matrix grains have the same titanomagnetitic composition as the rims. The zone of induced magnetism does not fully coincide with the bright rims

in reflected light images but is confined to the outer, mostly homogenous titanomagnetitic part of the grains.

Mäussnest, O. (1964): Feld- und gesteinsmagnetische Arbeiten im Gebiet der Hegauvulkane. Jber. u. Mitt. Oberrhein. Geol. Ver., N.F. 46, 23-33, Stuttgart..

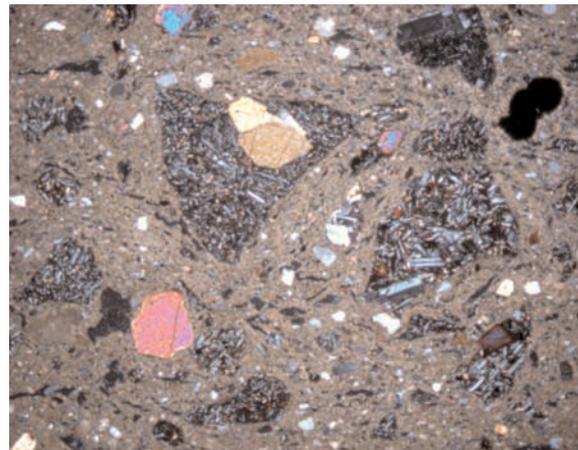
¹Institut für Physik, Freiburg

First results of a newly started joint research topic on mineralogical aspects of Neolithic pottery and lithic artifacts together with the Institut für Ur- und Frühgeschichte, Universität Köln, were presented at the DMG meeting 2005 in Aachen. These promising first results initiated a further cooperation starting with a joint field campaign in April 2006 and will lead to an extension of the existing KAAK research program “Early history of the eastern Rif Mountains, Morocco: The Maghreb as contact zone between Africa and Europe”.

Neolithic pottery from Morocco – petrographic constraints on sources and production

Hiltrud Müller-Sigmund, Jörg Linstädter¹, Florian Schneider²

Neolithic pottery from Morocco is investigated within a joint archaeological project of KAAK (Commission on Archaeology of extra-European Cultures, Bonn) and INSAP (Inst. National des Sciences de l'Archéologie et du Patrimoine, Maroc) on “Early history of the eastern Rif Mountains, Morocco: The Maghreb as contact zone between Africa and Europe”. The undecorated pottery fragments from the excavation at Hassi Ouenzga, NE Morocco, Province of Taza, were found in soil layers dated between 5300 and 6700 BC. Deciphering the development of a settling and producing economy in the Maghreb is crucial for the classification of changes from Epipalaeolithic to Neolithic societies. Pottery characteristics like clay type, filler material, homogeneity, grain sizes, relative amount of filler particles give hints to local versus traded ware as well as to production methods. Thin section microscopy reveals different filler materials (mostly granitic, basaltic and carbonaceous rock and mineral fragments), varying clay to



Thin section light optical image of pottery fragment 291 (long edge 5.5 mm, age ~5500 BC) displaying rock and mineral fragments of olivine basaltic origin

filler ratio and varying filler grain sizes. Filler grains are in most cases homogeneously worked into the clay. While the local rocks consist of limestone, which is relatively scarcely present as filler material, the closest possible sources for basaltic and granitic material are at distances of 10 and 30 km, respectively from the excavation. Chemically identical basaltic fragments occur in pottery from layers of different age data, while fragments from the same layer often differ in filler material. This suggests a

continuous use of raw materials through time and at the same time usage of pottery from different sources and manufacturers.

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²*Institut für Ur- und Frühgeschichte, Freiburg*

This project is Mittelstädt's diploma work. There are more than 50 localities in Norway with "thulite" but more or less none of them has been mineralogically investigated.

The origin of "thulite" in Lom and other localities in Norway

Philip Mittelstädt, Rune S. Selbekk

Manganoan zoisite is commonly referred to as "thulite", and is often mistaken for piemontite which has monoclinic symmetry and represents a manganoan member of the epidote group minerals. The thulite locality near Lom lies within a paragneiss in the south-eastern corner of the Western Gneiss Region. The heterogeneous paragneiss surrounding the thulite locality consists of several layers of amphibolites in which muscovite- and quartz-rich lenses are intercalated. Within a quartz-rich lens an approximately 250 m long and up to 3 m wide pink coloured band with abundant piemontite and thulite forms the investigated mineralization. The intensity of the pink colour increases from the edges of the quartzite to the centre of the mineralization. Primary sedimentary structures such as grading and cross-bedding within this quartz rich lens suggest a possible metasedimentary origin of the thulites. Although thulite occurrences are reported from more than 50 localities in Norway (e.g. Lom, Sauland, Leksvike, Tafjord, Oppdal) no detailed geochemical analyses of the thulites exist and therefore no detailed implications for the formation of thulites can be inferred. Further it is not clear if the reported thulites have not been mistaken for piemontites due to nomenclatorial difficulties (see Abrecht 1981, Reinecke 1986).

During this study several (possible) thulite bearing samples from Norway will be analyzed with respect to their mineral content and petrogenesis. The field relationships of some of the samples suggest a meta-



Thulite from Lom, Norway (field of view is 6 cm wide)

sedimentary origin whereas other samples could be related to hydrothermal activity, skarn or alteration process. Further, textural and geochemical relationships of natural occurring thulite and coexisting piemontite will be described.

Abrecht, J. 1981: Pink zoisite from the Aar massif, Switzerland. *Miner. Mag.* 44, 45-49.

Reinecke, T. 1986: Crystal chemistry and reaction relations of piemontites and thulites from highly oxidized low grade metamorphic rocks at Vitali, Andros Island, Greece. *Contrib. Mineral. Petrol.* 93, 56-76.

Collaboration of our Institute and the Mineral Processing Department, Institute of Material Sciences, Hanoi.

Funded by: Vietnam Academy of Science and Technology

Manganese ores from northeastern Vietnam: mineralogy and processing technology for recovery of high-purity MnO₂

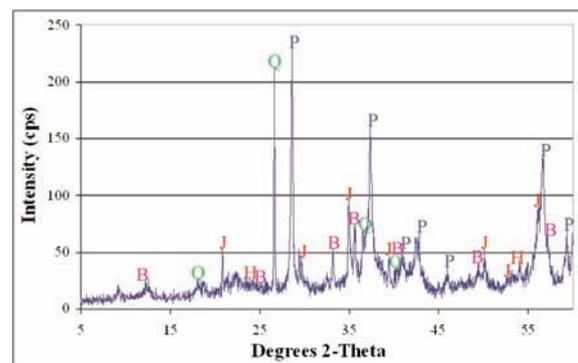
Duy Anh Dao, Reto Gieré

This project is an initiative of the Vietnam Academy of Science and Technology, which is interested in the development of a protocol for improving the grade of manganese ores. Vietnam has a great potential for mining of extensive manganese ore deposits and currently is operating 34 mines. Most of the Vietnamese Mn ore deposits are of sedimentary origin, but supergene processes may have been an important additional mechanism responsible for Mn enrichment. More than ten million tons of raw Mn ore have been estimated to occur.

Exploitation of the deposits and processing of the raw ores is in many cases still performed by hand, but some modern processing plants have been installed recently. These plants apply various methods to improve the ore grade, including crushing, grinding, and gravity separation. Using these techniques, the processed ore can be upgraded to a Mn content of 30-35 wt%. This grade is satisfactory for the production of ferromanganese materials, but is insufficient as a raw material for the production of batteries and other materials, where high-purity MnO₂ is required [e.g., electronic manganese dioxide (EMD) and chemical manganese dioxide (CMD)].

During the first stage of this project, Mn ores from a large deposit in northeastern Vietnam, the Toc Tat manganese deposit, located in the Tra Linh district, Cao Bang

province, will be characterized chemically as well as mineralogically. First results reveal that the ores contain primarily pyrolusite [MnO₂], jacobsonite [Mn²⁺(Mn³⁺,Fe³⁺)₂O₄], birnessite [Na₄Mn₁₄O₂₇•9H₂O], hematite [Fe₂O₃], and quartz. The detailed knowledge of the mineralogy of the ores will help in understanding the most important ore-forming processes. These investigations will form the basis for the subsequent quest for a methodology to separate the Mn-rich minerals from gangue materials. During the last stages of the project, it will be attempted to design a processing protocol that will allow upgrading the economic value of these Mn ores. This study will ultimately help in generating a domestic industry for high-purity MnO₂, a goal of the Vietnamese government. This goal is important for the country, because currently all raw materials for high-purity Mn have to be imported.



XRD-pattern of a typical Mn ore from the studied Mn deposit in northeastern Vietnam. Abbreviations: B = birnessite; J = jacobsonite; P = pyrolusite; Q = quartz.

This project is a re-investigation of a classical locality in the Bohemian massif. The locality is known since 1804 but still hasn't been described in detail. The results are ready to be submitted in the Bulletin of the Czech National Museum in Prague.

Minerals from the exocontact of a pegmatite in serpentinites near Hermanov (Bohemia)

Juraj Majzlan, Rodney Grapes¹

Pegmatite bodies in the Bohemian massif are most commonly developed within or nearby the source granitoid plutons. In many cases, however, the pegmatites penetrated into rocks of a significantly different chemical composition, such as marbles, skarns, or ultrabasic rocks. Contacts of the pegmatites with such rocks generate unusual mineral assemblages, either within the pegmatite or between the pegmatite and the country rocks.

One of such pegmatites occurs near Hermanov (Czech Republic). The pegmatite was emplaced into a fracture in a body of serpentinitized ultrabasic rocks. Remarkable mineral assemblage developed in a “black-wall” between the pegmatite and the serpentinites drew the attention of mineralogists long ago; the first one to describe this occurrence was probably Andre (1804). Minerals in this exocontact are organized in peculiar spherules of approximately identical dimensions with clearly and sharply defined three zones. Brezina (1874) analyzed the minerals and determined the presence of phlogopite and anthophyllite as the major minerals. Since then, no other analytical work has been done, and the pegmatite in Hermanov has become a well-known classical locality for anthophyllite in the Czech Republic.

We have analyzed the minerals of the spherules by electron microprobe analysis and X-ray diffraction patterns. The amphibole in the external zone is a member of the tremolite-actinolite solid solution. Anthophyllite, if present, may be forming only very thin exsolution lamellae in the tremolite-actinolite matrix. The central part of the spherules consists of phlogopite with minor amounts of graphite and chromite. The thin zone between the amphibole and



The mica-amphibole nodules from Hermanov

mica is composed mostly of talc.

The spherules formed by an interaction between the intruding pegmatite body and the serpentinitized ultrabasic rock. Since both of these rocks are rich in H₂O, the fluid phase played probably a significant role in the formation of the spherules. The ultrabasic rocks must have received major influx of K, Ca, and Si from the pegmatite. A number of unanswered questions remain, among them 1) why are the spherules enriched in K and Ca (likely from the feldspars in the pegmatite), but not Na, and 2) what was the mechanism that controlled the almost uniform size of the spherules. We may address these questions if a more variable set of samples becomes available. Because the site is located in a flat, swampy area, collection of more samples will require significant effort and the use of large equipment.

Andre, C.C., 1804: *Anleitung zum Studium der Mineralogie*. Camesimanische Buchhandlung Wien.

Brezina, A., 1874: *Anthophyllit von Hermannschlag*. *Mineral. Mittheil*, 247.

¹Zhongshan University, Guangzhou, China

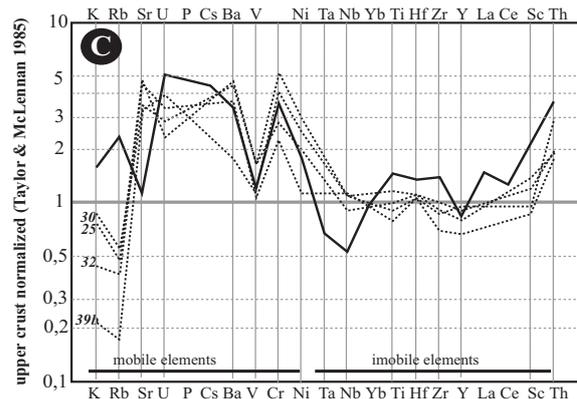
The following essay on provenance analyses of Paleozoic sediments from Southern Vosges and Schwarzwald is part of the PhD thesis of Marc Krecher. Within this project, basin dynamical processes in the context of the Variscan orogeny are investigated by combined analyses of facies, tectonic, stratigraphy and provenance. The paper is conceived for publication in Bulletin de la Société Géologique de la France.

Turbidite sandstones in the Southern Vosges (Markstein Group, France): sedimentary deposition in a Devonian – Carboniferous accretionary foreland basin and its impact on provenance interpretation

Marc Krecher¹, Hiltrud Müller-Sigmund

Turbidite sandstones are exposed in the Markstein Group of the Southern Vosges Mountains (NE-France). Sedimentary facies and their stacking patterns provide evidence for a classical foreland basin evolution. The basin infill started with a fine grained and coarsening upward succession of lower fan turbidites. A proximality trend is recorded between the older and the younger complexes from the Upper Devonian to the late Lower Carboniferous. Paleocurrent data argue for a troughlike basinal setting. Medium to coarse grained sandstones are the dominating lithology with fine grained divisions inbetween and coarse conglomerates in the uppermost complex.

The sandstone composition is of meta-granodioritic and volcanic origin. Petrographic data reflect an increasingly dissected environment of a mature active margin, developing to more quartz and feldspar rich compositions with high contents of polycrystalline quartz grains. Trace element patterns confirm a deposition in a subduction related setting. Provenance analytical results conform to those of related early Lower Carboniferous sandstones in the southern Schwarzwald (SW Germany), which formerly were interpreted as trench turbidites. However, in the Viséan turbidites volcanically active stratigraphic levels alternate with inactive stages and despite of petrographic differences, the inactive stages do still show the same trace element pattern as is observed in the Upper Devonian and the Tournaisian sandstones. Incompatible trace elements of the volcanically active stages



Dacites and rhyodacites of the BLZ
(Middle Viséan, average from Göldempennig 1997)

Central Markstein Complex (Middle Viséan,
volcanically active levels)

Dacite of the eastern volcano-plutonic
provinces in the W-USA (Ewart 1979)

Multi-element spider diagram showing enrichment of immobile and mobile elements ratioed to average upper continental crust. Data from the Badenweiler-Lenzkirch zone (BLZ, Schwarzwald) compare well with data from the Central Markstein complex.

point to detrital material related to an over-thickened mature active margin or a collisional belt. By comparing sedimentary and provenance data we can show that sediment cannibalistic processes are responsible for inherited active margin signatures in the turbidite sandstones and that deposition of the Markstein Group took place in a collisional retro-arc environment. These results demonstrate that the plate tectonic and crustal evolution of the Variscan Schwarzwald and Vosges basement is more readily understood when integrating results from deep crustal and supracrustal investigations.

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Petrogenesis of magmatic rocks

This manuscript is submitted to Contribution to Mineralogy and Petrology.

REE, Sr-Rb and Sm-Nd -isotopes for the hydrous anatectic anorthosites in the Skattøra migmatite complex, Norway

Rune S. Selbekk, Jesus D. De La Rosa Diaz¹, Hannu Huhma²

The 456±4 Ma Skattøra migmatite complex, Tromsø, in the north Norwegian Caledonides consists of migmatitic nepheline-normative metagabbros and amphibolites that are net-veined by numerous nepheline-normative anorthositic and leucodioritic dykes. Plagioclase (An₂₀₋₅₀) is the dominant mineral (85-100%) in the dykes and the leucosome, but amphibole is generally present in amounts up to 15%. The following observations strongly suggest formation of anorthositic magma by anatexis of gabbro in the presence of a H₂O-bearing fluid phase: 1) The migmatites consist of plagioclase-rich (anorthositic) leucosomes and amphibole-rich restites; 2) crystallisation of amphibole in anorthositic and leucodioritic dykes suggest elevated H₂O-activity; 3) the presence of coarse-grained to pegmatitic dykes and miarolitic cavities indicates a fluid-rich magma; 4) hydration zones that surround many anorthosite dykes suggest that the magma probably expelled H₂O-rich fluids during crystallisation. Water saturated melting experiments indicate that the Skattøra anorthosites dykes was produced at 1.0 GPa and 900-950 °C, by melting of a metagabbro.

REE data from the anorthosites give essentially flat patterns with normalised



Dykes of hydrous anorthosite cutting amphibolite

rock/chondrite values in the range from 0.3 to 3. Metagabbro exhibit a LREE up to 70x rock/chondrite but only in the range of 1 to 10 for the HREE's, indicating a continental rift related environment for the protolith. Hydrous anatectic anorthosites with flat to slightly positive Eu anomalies indicating relatively pure plagioclase melting, and a different origin than "normal" anorthosites. ϵ_{Nd} -values ranging from -3.1 to -5.8, together with Sr isotopes strongly indicate a continental source for the hydrous anorthosites in the Skattøra Migmatite Complex.

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This manuscript is ready to be re-submitted to *Geologiska Föreningens Förer* (GFF)

Geological relations and U-Pb geochronology of Hyttsjö granites in the Långban-Nordmark area, western Bergslagen, Sweden

Karin Högdahl, Erik Jonsson, Rune S. Selbekk

The Hyttsjö granites occur in the exten-

sively mineralised Långban-Nordmark area in the westernmost part of the Bergslagen ore province. They have been classified as

late Svecokarelian granites due to their homogeneous and generally isotropic appearance in addition to a WR Rb/Sr age dating. Moreover, as such they have been considered as possible candidates for supplying essential metals to epigenetic mineralisation in this classic district. New U-Pb zircon data yield ages of 1791 ± 2 and $1790 + 8 / - 5$ Ma, respectively, from two Hyttsjö granites, which is similar to the adjacent 1.78-1.80 Ga granitic rocks of the Transscandinavian Igneous Belt (TIB). Mafic rocks occur quite abundantly associated with the Filipstad-type granite (*sensu lato*) and various types of mafic magmatic enclaves as well as hybrid rocks are present, suggesting a co-magmatic origin. Mafic intrusives are also exposed in the vicinity of almost all known Hyttsjö-type plutons. Not least our observations that the former exhib-

it back-veining by granitic melts suggest intimate causal and temporal relationships between these two rock types.

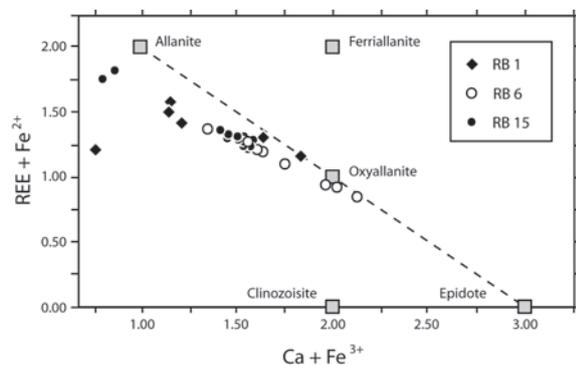
Biotite-rich restitic enclaves and the presence of garnet combined with the overall geochemical character of the studied Hyttsjö granites indicate that their source was a partially melted rock of predominantly metasedimentary affinity. These melts were probably generated by the intrusion of hot, mafic TIB magmas. Thus, the present observations and data suggest that the Hyttsjö granites are intimately related to, if not strictly part of, the TIB magmatism. Furthermore, we do not find any support for the hypothesis that the Hyttsjö granites represent a separate intrusive episode, discernibly responsible for specific mineralisation in this area.

This project is a part of Spürgin's diploma work, together with Lundmark's Ph.D. work in the Jotunheimen.

Rare-earth pegmatites at Berdalsbandet, Jotunheimen (Norway), and their relationship to the surrounding rocks

Simon Spürgin, Rune S. Selbekk, Mattias Lundmark¹

The field area at Berdalsbandet, Jotunheimen (Norway), is located close to the basal thrust zone of the Jotun Nappe Complex (Middle Allochthon) of the Norwegian Caledonides. The rocks are



Prominent exchange reaction incorporating REE into allanite.

mainly of gabbroic composition or can be regarded as their ultrabasic-basic derivatives. A Grenvillian (Sveconorwegian) metamorphic event, related to local anatexis melting (c. 955 Ma), transformed the rocks to medium-pressure Px-granulites, spinel peridotites and other associated lithologies. Simultaneous deformation produced gneissic and mylonitic textures, and subsequent retrogression to upper amphibolite facies can be observed in most samples. Caledonian upper greenschist- to lower amphibolite facies overprint strongly affects the mylonitized rocks in the western field area, whereas the rigid central-eastern block is only caledonized along brittle cracks. Subgreenschist minerals grow in open joints and cavities.

The zoned peraluminous rare-earth pegmatites at Berdalsbandet intruded the metagabbros and amphibolites shortly after

Grenvillian peak metamorphism and migmatitization (949 ± 1.3 Ma). In total, 27 minerals have been identified in the pegmatites, including beryl, REE-phosphates and thorite. Semi-metamict allanite-(Ce), a rare-earth epidote group mineral, is the main phase after quartz and feldspars. REE are incorporated into the epidote structure by exchanging $\text{Ca}^{2+} + \text{Fe}^{3+}$ with $\text{REE}^{3+} + \text{Fe}^{2+}$ (Gieré & Sorensen 2004). Allanite-(Ce) is hydrothermally altered along cracks to oxyallanite-(Ce), with increasing $\text{FeOx} = \text{Fe}^{3+} / (\text{Fe}^{2+} + \text{Fe}^{3+})$ and decreasing REE content. Oxidation in fresh allanite is buffered by biotite to $\text{FeOx} = 0.4$ (Petrík et al. 1995). The pegmatites are cut by a

mylonitic, N-S trending shear zone. Evidence of syn-crystallizing deformation is shown by broken pegmatitic minerals (zircon, beryl) that were healed with later pegmatitic phases (Fe-Ti-oxides, quartz).

Gieré R., Sorensen S.S., 2004: Allanite and other REE-rich Epidote-group minerals. In: Liebscher A. and Franz G. (eds.): *Epidotes. Reviews in Mineralogy & Geochemistry* 56, 431-493.

Petrík I., Broska I, Lipka J, Šiman P., 1995: Granitoid allanite-(Ce): substitution relations, redox conditions and REE distributions (on an example of I-type granitoids, western Carpathians, Slovakia). *Geologica Carpathica* 46, 79-95.

¹*University of Oslo*

Bucher, K. and Frost, R., Fayalite syenites in the Thor Range, Antarctica. *Journal of Petrology*

The status of this paper is: accepted for publication in *Journal of Petrology* (in press).

Fluid recycling in high grade metamorphic terrains intruded by anorogenic granites: the Thor Range, Antarctica

Kurt Bucher, B. Ronald Frost

A composite intrusive igneous complex in the Central Thor Range of Queen Maud Land, Antarctica, displays characteristic features of anorogenic granites. A suite of massive intrusives and various sets of dykes and satellite intrusions are ferroan, alkalic to alkali-calcic, and weakly peraluminous. An early set of plutons consists of charnockitic alkali-granites, a later group of plutons comprises fayalite quartz-syenites. Coarse mesoperthite is the dominant mineral in all rocks, quartz is abundant, plagioclase is a minor mineral. Olivine (fayalite) is the characteristic mafic mineral but subcalcic augite and occasionally pigeonite or orthopyroxene are present. In most samples amphibole is the dominant mafic mineral and its composition is close to endmember hastingsite. It contains high concentrations of F and Cl. Some samples contain igneous fluorite. Primary igneous biotite contains high Ti and halogen contents.



Banded fayalite-granite at Stålstuten (2700m), Mühlig-Hofmann Fjella, Queen Maud Land, East Antarctic Shield. The glacier in the foreground is at 1400m

Thermobarometry calculations suggest a temperature of $900 \pm 25^\circ\text{C}$ and a pressure of 0.4 ± 0.1 GPa for the crystallization conditions of the pyroxene-olivine assemblages. The solidus temperature of $800 - 850^\circ\text{C}$ for both suites of plutonic rocks is typical of water-deficient melts. The estimated low water activity of 0.3 at solidus conditions is consistent with the high halogen content of the bulk rocks and their constituent minerals. In the absence of an aqueous fluid, the halogens remained in the minerals at the solidus. Oxygen fugacity remained below QFM in all igneous rocks above solidus. This is typical of melts derived from partial melting of basaltic source rocks. Retrograde

magnetite formed at subsolidus conditions.

Subsolidus hydration locally modified the igneous rocks and transformed pyroxene- and fayalite-bearing granites to biotite-granites in which all evidence of former high-T history was erased. The hydration event occurred at amphibolite-facies conditions near the wet solidus of granite. It also reset high-grade assemblages of metapelitic rocks that occur as rafts in the plutons and in the envelope. The source of the water for the hydration process is probably locally derived from dehydration of metapelitic gneisses either locally or farther away in the envelope.

This is the result of a Diploma thesis carried out at our Institute.

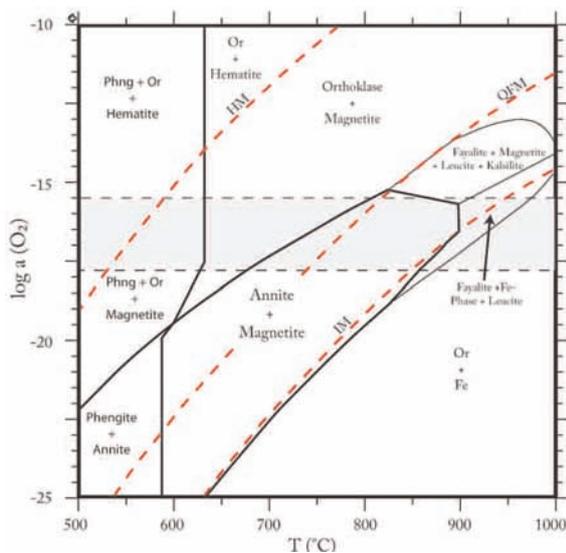
Relations between lamprophyres and granites of the Shanqi-Xiaqi granite complex, Guangdong Province, China: Hydrothermal alteration

Christian Bratzdrum, Rodney Grapes, Reto Gieré, Guoneng Chen¹

During the Mesozoic, due to subduction of the Paleo-Pacific Plate (Kula-Plate), a wide range of tectonic and magmatic events

occurred in Southern China. The Shanqi-Xiaqi granite complex near the city of Luoyang belongs to the third Yanshanian period (138 Ma) and is surrounded by migmatites. The alkali-feldspars in these granites show mesoperthitic unmixing as a result of low partial water pressures. Fluorite and rounded zircon with zoned overgrowth are accessory minerals. Three generations of calc-alkaline lamprophyres, intruded along NNW-SSE striking faults formed in extensional regime, range from coarse-grained, hornblende-dominated spessartites to fine-grained kersantite dykes with late-stage hydrothermal alteration.

In the granites the SiO_2 -content is >76 wt.%, in the lamprophyres it varies between 51.33-59.95 wt.%. All rocks are rich in alkalis and show shoshonitic affinity. The granites can be classified as A-type granitoids, molten by a high geothermal gradient due to underplating of ultramafic magma, which was generated by dehydration of the oceanic Kula-Plate. The descent of the ultramafic lamprophyres was favoured by subduction slab-rollback. They show very high Cr-, Ni,



Stability of analyzed annite $\text{Si}(5.5)\text{Al}(3)\text{Fe}(5.5)\text{K}(2)\text{O}(24.5)\text{H}(4)$ as function of oxygen-fugacity and temperature (2 kbar); shaded area represents estimated crystallization conditions for the granites

as well as high Ba- and Sr-contents. Ba is preferentially incorporated in the Ti-rich biotites. The micas in the granites are Fe-rich annite and Al-rich Fe-phengite. The pargasites of the spessartites also show a high Ti-content, and they are altered to chlorite, epidote (Sr-rich) and titanite. Besides the deuteric alteration of biotite and feldspar, olivine in the lamprophyres is completely transformed into pilitite, a mineral assemblage of clays, chlorite, talk, amphibole, and Fe-minerals, as well as calcite and quartz. The lamprophyres are almost identical in composition, they only differ in their modal mineral content; this special feature is

called heteromorphism.

Petrological calculations of annite stability with THERIAK-DOMINO and geothermobarometry allowed an estimation of the conditions during crystallization. The Al-content of the pargasites gave a depth estimate of $17.42 (\pm 1.31)$ km, i.e. $4.98 (\pm 0.37)$ kbar. The granites were formed under a pressure of at least 4 kbar, a temperature of 950°C - 850°C and $\log f(\text{O}_2)$ between -17.8 to -15.5 .

¹*Department of Earth Sciences, Zhongshan (Sun Yat-Sen) University, Guangzhou 510275, P.R. China*

Petrogenesis and geochemistry of metamorphic rocks

Bucher, K., de Capitani, Ch. and **Grapes, R.**, 2005, The development of a margarite-corundum blackwall by metasomatic alteration of a slice of mica schist in ultramafic rock, Lake Kvesjöen, Norwegian Caledonides. *The Canadian Mineralogist*, 43, 129-156.

The status of this paper is: published 2005 - For details see annual report 2004

Li, Xuping, Rahn, Meinert, and **Bucher, Kurt**, 2004, Serpentinites of the Zermatt-Saas Ophiolite, Central. *Journal of metamorphic Geology*. This paper was published in 2004.

P.S. : This serpentinite paper was one of the three top accessed papers 2004 in Journal of metamorphic Geology (ranked # 2 journal in the geology category).

A cooperative project with scientists from CUG and BU, Beijing, PR China

UHP and HP ophiolites in the Alps and in Tian Shan

Kurt Bucher

Research cooperation with chinese scientists continued also in 2005. A new cooperative project has been initiated by Prof. Dr. Xuping Li from the Chinese University of Geosciences in Beijing. It also involves Prof. Dr. Lifei Zhang from the Beijing University. We visited China in the summer 2005 for a joint field project in the mountain range of Tian Shan. In the Tian Shan range in Xinjiang close to the Kazakhstan border we studied ultra high pressure ophiolites. The group also involved 3 PhD students



Glaucophanites and coesite eclogites from UHP ophiolites of the Tian Shan range (field work 2005)



Field team of the 2005 field work on UHP ophiolites from the Tian Shan range. At the end of the “road” drivable with 4WD vehicles, the horse provided access to the next 20-30 km of the valleys. The “rest” was climbing and hiking.

from Beijing, 2 drivers in addition to the two petrologists from Beijing. Also on this trip was hydrogeology Prof. Dr. Ingrid Stober from Freiburg. We collect water samples from hot springs in a reconnaissance project

on thermal waters from Xinjiang. The more than 50°C hot springs have been analyzed in our laboratories and the results are very promising for the continuation of this hot water, geothermal project.

Collaboration between our institute and the Natural History Museum London.
Funded by: SYNTHESYS program of the EU.

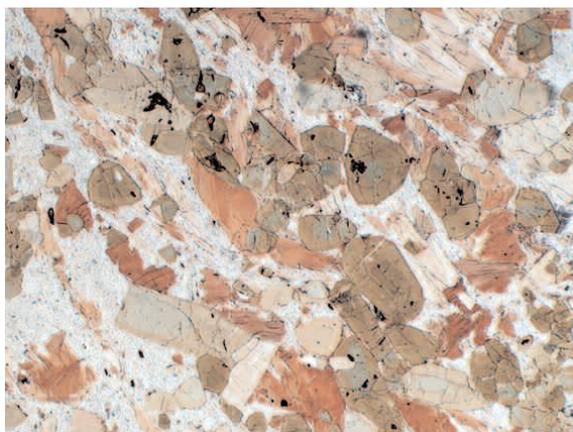
Partitioning of Be and other trace elements in tourmaline-rich schists

Reto Gieré, Teresa Jeffries¹, Terry Williams¹

This project, funded through the SYNTHESYS program, attempts to determine the contents of Be, Li, B and other trace elements in all rock-forming minerals in a tourmaline-rich metasedimentary rock from the Central Alps. The main objectives are to 1) determine the beryllium content of cordierite, thus improving the understanding of Be incorporation; 2) determine the distribution of trace elements, including Li, Be, and B, amongst the various phases; and 3) gain insights into the poorly known geochemical cycles of these elements.

Metapelites containing an unusual abundance of large, euhedral tourmaline crystals occur near Alpe Sponda, Switzerland, and belong geologically to the Penninic Simano

nappe in the Lepontine Alps. In addition to zoned tourmaline, these rocks contain garnet, kyanite, plagioclase, and cordierite, as well as muscovite, biotite, paragonite, and chlorite. There is an ample amount of rutile occurring as inclusions within other minerals, but no quartz has been observed. Quantitative electron microprobe data for major and minor elements have been collected previously for all rock-forming minerals (Patterson & Gieré 2001). Based on the mineral assemblage, it can be concluded that these rocks were metamorphosed under amphibolite-facies conditions (625 °C, 600 MPa), which prevailed during the main Alpine metamorphism in the Tertiary. To find a possible explanation for the unusual abundance of tourmaline and paragonite, the whole-rock chemical composition of these



Photomicrograph of tourmaline-rich metapelite from Alpe Sponda. The green tourmalines are very abundant and exhibit color zoning, which reflects chemical zoning. Other minerals visible in this view are paragonite and muscovite (white), biotite (brown), and some opaque minerals. Image is ~6 mm across.

rocks has been analyzed, and the trace element content is consistent with an evaporite-type depositional environment of the protolith (Macy et al. 2003).

Trace element concentrations have been analyzed by laser-ablation inductively-coupled plasma mass-spectrometry, an in-situ technique that allows for accurate and precise analysis of minerals in thin section. The facility used is located at the Department of Mineralogy at the Natural History Museum in London. More than 250 trace element analyses of the minerals present in the studied rocks have been collected. The results have shown that: 1) cordierite contains about 3700 ppm Be (~ 1 wt% BeO), in very good agreement with the estimated value based on the electron microprobe data, which added to about 97 wt% only (water-free basis). The 1 wt% BeO corresponds to

~ 0.2 Be atoms per formula unit, indicating that $Al+Be = 4$ (i.e., stoichiometric). The cordierite is therefore unusually Be-rich; 2) tourmaline and biotite do not contain detectable Be, whereas the element is always present in paragonite (~10 ppm). Biotite contains ~ 200 ppm Li, paragonite only ~ 100 ppm; and 3) none of the major minerals contains large quantities of REE. Most of these minerals are, in fact, devoid of any REE. There are only two exceptions: garnet, which has a typical heavy-REE dominated pattern, and tourmaline (light-REE enrichment). In addition, tourmaline is strongly zoned (growth zoning) with respect to both major and trace elements, including the REE.

In summary, the results obtained are in good agreement with a previous study on other rocks from a similar metamorphic grade. The results reveal that there are systematic trace element distribution patterns at a specific metamorphic grade. The data for cordierite are of importance for the crystal chemistry of this mineral.

Macy L., Bodanza P., and Gieré R. (2003): Deciphering paleo-depositional environments of the Simano Nappe in the Central Alps. Geological Society of America, Fall meeting. gsa.confex.com/gsa/2003AM/finalprogram/abstract_59108.htm

Patterson L., and Gieré R. (2001): Tourmaline-rich paragonite schists in the Central Alps as paleogeographic indicators? Geological Society of America, Abstracts with Programs 33/6, p. A-382

¹*Department of Mineralogy, The Natural History Museum, London*

Products and consequences of volcanism

Re-Submitted to Geostandards and Geoanalytical Research

A new multi-mineral age reference material for $^{40}\text{Ar}/^{39}\text{Ar}$, (U-Th)/He and FT dating methods: the Limberg t3 tuff

Michael Kraml, Raphael Pik, Meinert Rahn, **Rune Selbekk**, Jean Carignan, **Jörg Keller**

The phonolitic Limberg t3 tephra (Kaiserstuhl Volcanic Complex, Germany) was previously dated by conventional K/Ar method yielding inconsistent results. We have re-dated this tephra layer with three independent methods. Fission Track (FT) external detector analyses on single apatite crystals (16.8 ± 1.3 Ma, 2σ) and (U-Th)/He measures on titanite and apatite (16.5 ± 1.0 Ma, 2σ and 16.8 ± 1.0 Ma, 2σ , respectively) are in close agreement with laser Ar/Ar dates on incrementally heated single crystals

of sanidine (16.3 ± 0.4 Ma, 2σ). Due to very rapid cooling, the He, FT and Ar thermochronometers provide one single age representing the eruption event. The different minerals are characterised by favourable properties with respect to their chemical composition, grain size and shape. In particular for the t3 sanidine, homogeneity has been demonstrated by electron microprobe analysis and on a grain to grain and grain internal scale by single crystal incremental laser heating. Based on the concordance of the ages and the mineral yield of this unit the Limberg t3 tephra is proposed as multi-method age reference material for single grain laser Ar/Ar, FT and (U-Th)/He dating.

Laboratories of the Institute of Mineralogy and Geochemistry

Thin Section Preparation Laboratory

Report by *Melanie Katt*

From December 2004 until the end of November 2005, we handled a total of 1144 samples in our laboratory.

We have prepared:

- 268 polished hand specimens
- 251 polished thin sections
- 242 covered thin sections
- 95 polished mounts
- 77 polished grain mounts
- 6 covered grain mounts
- 22 covered “dry“ sections
- 9 polished “dry“ sections
- 1 double-side polished section

We have also repolished or finished preparation of:

- 165 ore mounts
- 8 soil samples

Of all these, external orders accounted to 45.8 %. Inquiries came from other Institutes of the Freiburg University, from other universities (e.g., University of Bristol, England and Universidad National del Sur, Argentina), civil engineering companies, and private persons.

We tested new polishing materials and improved the quality of the sections manufactured in our lab. The sections produced now have a smaller relief and are finished in a shorter time.

This year, we received 264 Roman marble tiles from the Department of Roman Archaeology at the Freiburg University. We cleaned and polished all these tiles. Originally, these variably colored tiles built a Roman floor mosaic. Once the tiles were repolished, this mosaic was re-assembled in an “Imperium Romanum“ exhibition in Stuttgart. The exhibition is open to the public until January 2006.

Mineral Separation Laboratory

Report by *Dagmar Flemming*

Since the beginning of 2005, our separation lab has been also used by the Institute of Geology. The Institute of Geology used the separation lab about a third of the time, the remainder then being used by our Institute. The facility is currently available to the students of both Institutes.

A total of 287 samples were prepared from December 2004 to November 2005. The processing of rock samples in the separation lab followed two principal goals: 1) Rocks were pulverized and prepared for a subsequent chemical analysis, or 2) rocks were crushed in order to separate specific mineral/minerals. The number of samples processed is listed in the following table:

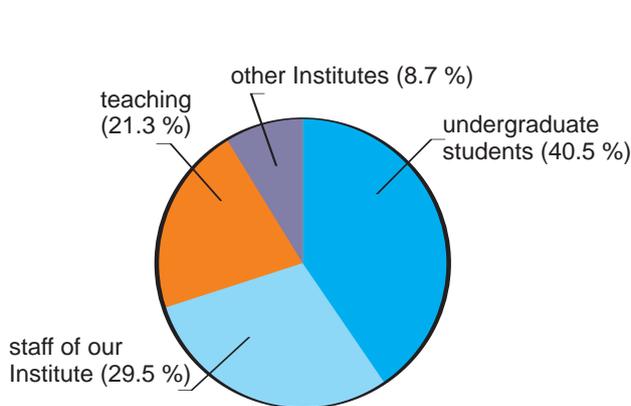
	Institute of Mineralogy and Geochemistry	Institute of Geology
powders for analyses	60	93
separation of minerals	67	67
total	127	160

We handled a few unusual samples and completed a few exciting projects this year. One of these was the processing of soils with abundant organic matter contaminated with heavy metals. Our task and a challenge was the separation of minerals with fairly similar physical and chemical properties. We also refined and optimized the procedures used in our laboratory.

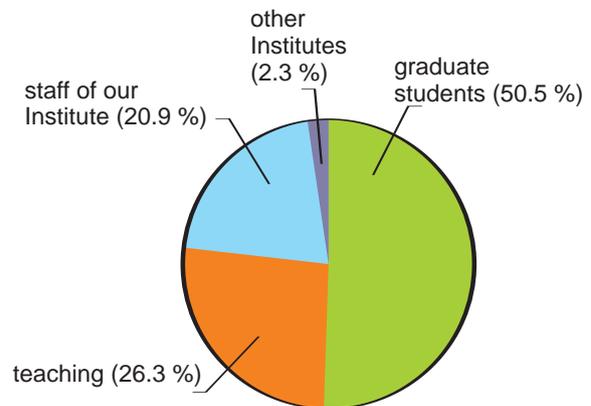
Hydrogeochemical laboratory Report by Sigrid Hirth-Walther

An integral part of our Institute is a modern and well equipped aqueous-geochemistry laboratory. The following instruments are available:

- atomic absorption spectrometer (flame and graphite furnace)
- UV/vis spectrometer
- Titration unit
- Microwave digester
- C/H analyzer
- C/S analyzer
- ion chromatograph



The usage of the flame atomic absorption spectrometer (vario 6) between January and November 2005. A total of 1086 analyses were completed.



The usage of the ion chromatograph (DX 120) between January and November 2005. A total of 220 analyses were completed.

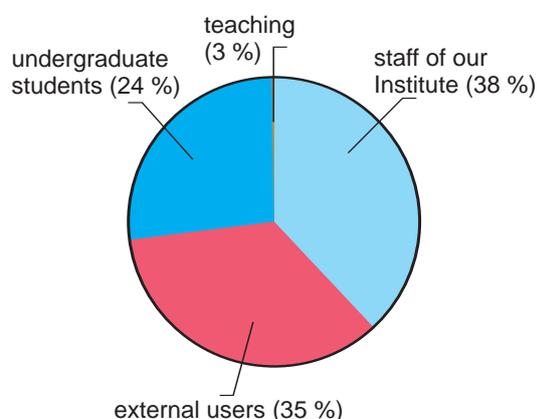
The principal users of the laboratory are our undergraduate and graduate students during their research projects. An example of their work is the comparison of various digestion methods for the analysis of selected elements in a complex matrix. One of the experimental challenges we are facing is the analysis of waters from deep crustal sources owing to their high concentration of ions and the presence of multiple ions, both cations and anions. Beside the routine analytical work, we are capable of addressing difficult analytical problems for aqueous solutions of unusual compositions. When requested, we also analyze aqueous samples for other Institutes at the Freiburg University.

Another task of our laboratory, closely related to the analytical work, is the supervision and guidance of undergraduate students. Students who are majoring in mineralogy, geology, and chemistry, have regular classes in analytical chemistry and analytical methods. The instruction during these classes, demonstration of the instruments, and explanation of the principles of operation are largely the responsibility of our staff.

X-ray laboratory; report for January – November 2005

Report by Isolde Schmidt

A total of 312 samples were analyzed with the X-ray fluorescence spectrometer in the time between January and November 2005. Of those, 210 samples were melted with lithium borate and 102 samples were pressed into tablets and analyzed with no further preparation.



The usage of the X-ray diffractometer between January and November 2005. A total of 252 analyses were completed.

Our Institute participates regularly in an inter-laboratory quality test organized by the International Association of Geoanalyst (IAG). Within the framework of this test, we have analyzed the sample GEOPT17/OU-8 in June 2005 and the sample GEOPT18/KPT-1 in November 2005.

We have encountered problems with analyses of metal-rich samples, investigated by our undergraduate student F. Eichinger. The XRF analytical results did not agree with results obtained by other (wet chemical) techniques. Therefore, we are planning to test a new software IQ+ (written by PANalytical) which offers the possibility of a standardless analysis.

If the results for metal-rich soils, silicate rocks, and sulfide ore samples will appear to be satisfactory, we will consider purchasing the software.

A total of 252 samples were analyzed with the X-ray powder diffractometer. The diffractometer serves for the research conducted in our Institute, for teaching, and for external users.

Electron Microprobe Laboratory

Report by H. Müller-Sigmund

Between January 1 and November 30 the electron microprobe Cameca sx100 was used during 1100 hours, with 40 % of the time spent for customers outside the Institute, 55 % for research purposes within the institute, and 5 % for student education. In January, the EDS software and computer equipment was upgraded to Link Isis 3.35 under Windows NT©. In addition, Virtual WDS by J. Reed was installed and improves preliminary investigations on analysis settings a lot. The machine was only down for two days due to a spectrometer damage.

Student field-trips

Student Field Trips

Iceland Excursion

August 18-31, 2005

Report by Tobias Weisenberger

This excursion exposed twelve undergraduate students to the phenomena and products of volcanism in Iceland. The excursion provided students the opportunity to study minerals, volcanic rocks and volcanological features that were previously learnt about in class. Many outcrops and geological localities in Iceland are “classical” and are known worldwide. The unique island, an exposure of the Mid-Atlantic ridge, is one of the best localities to study volcanoes and their interaction with ice.

The excursion was lead by Rune Selbekk and Tobias Weisenberger.

The Excursion started in Iceland’s capital Reykjavik. Local scientists from the Nordic Volcanological Institute in Reykjavik and the geological survey on Iceland (ISOR) invited the excursion group to visit their facilities and informed about research projects on Iceland. “Monitoring volcanoes and introduction of magma-ice interaction” was the topic of the talk by Erik Sturkell. Peter Danielsen presented the talk “Geothermal energy, their exploration and utilisation in Iceland.”

On the second day the excursion group started the trip around Iceland. The first day was spent on the Snaefellsnes peninsula, where we studied off-rift volcanism, huge columnar jointed basalts, and CO₂ degassing. Continuing to the north, we reached the Myvatn area in Northern Iceland. Famous localities, like the pseudocrater in Skutustadir, the lava formations of Dimmuborgir and the Krafla caldera with products of the last larger volcanic eruption on Iceland, the “Krafla-Fires” (1975-1984) were studied.

Herdurbreid, a wonderful example of a subglacial table mountain, and the large Askja caldera were visited on the next day. The following two days were spent in Eastern Iceland. The fjordlands of Eastern Iceland form a part of the deeply eroded Tertiary lava pile. During burial metamorphism and the influence of central volcanoes, zeolites and secondary minerals were formed. The famous “Iceland spar” mine in Helgustadir and the world-famous zeolite locality Teigarhorn were explored. Magma mingling processes were observed on the Austurhorn intrusion body.

The excursion continued to the south, were the famous Laki fissure with the largest lava field in historical time was visited. The next stop was Landmannalaugar, in the southern highlands. Landmannalaugar forms the northern rim of the Torfajökull caldera and consists of several rhyolitic lava flows. The long day in Landmannalaugar ended with an unforgettable bath in the hot pool.

The last days were spent in the southern part of Iceland. Pillow-basalts and feeder dikes were observed on the Reykjanes peninsula. Last but not least the great Geysir was visited and marks one of the highlights before the excursion ended with the visit of the geothermal power station Nesjavellir.



The excursion group at the Namafjall high temperature geothermal area (Myvatn area)

Campolungo Field Trip

June 25-26, 2005

Report by Wibke Kowalski

Heading for a two-day excursion in Campolungo in Ticino, situated in the Italian-speaking part of Switzerland, a group of five mineralogy students, ten geology students and one hydrology student together with professor Reto Gieré left Freiburg on Saturday, June 25th 2005.

Heavy weather conditions on the St. Gotthard pass, which represents the border between the cantons Uri and Ticino, led to the first stop on our way. There we visited the national museum to learn more about the geological and mineralogical details and the history of this famous pass. Another break slightly beyond it provided the opportunity to discover beautiful radial hornblende as well as garnets.



Students examining one of the outcrops at Campolungo

Our next stop already found us at the village of Rodi in Ticino. From there we took the sky tram which led us halfway towards our overnight accommodation, the Capanna Leit hut, situated 2257 meters above sea level. The remaining distance was covered by a hike during which we received an extensive introduction into the geology of the Swiss Alps. On our way we further visited an outcrop of white sugar-like dolomite layers where we could find our first tremolites, as well as rutile.

The next day started with an introduction into regional geological details given by professor Gieré, with emphasis on the different deformation stages of the impressive fold of some white dolomite. The measuring of the orientation of some metamorphic structures at the upper reservoir called "Lago Leit" then represented our first practical task for this day, before we started to search for various minerals (garnet, staurolite, kyanite (alumosilicates), boron-bearing tourmaline) in metapelitic rocks.

Subsequently we climbed to the Campolungo pass to find some especially well formed tremolites, something Campolungo is world-famous for. (Partly the tremolites were transformed into talc). It furthermore is well-known for being the only place in the Swiss Alps where ruby can be found in dolomite; unfortunately, we could not discover any of those.

During our final descent to Rodi we still passed by a fluorite deposit where, however, we again were not rewarded by any findings. Our excursion nevertheless had been proven very successful such that Sunday evening found us arriving back in Freiburg in a tired but content manner.

Val Malenco – Bergell – Oberengadin Excursion

September 4-10, 2005

Report by Anja Oehler and Bernadette Prömse

This excursion, led by Prof. Reto Gieré offered ten students of mineralogy, geology and hydrology the opportunity to gain an insight of the formation and structure of the Alps.

At the beginning of the excursion the group was introduced into the history and significance of the Viamala gorge. We stopped in Zillis where we visited the church St. Martin, built in 1130. The famous Bündnerschiefer gave a first assumption of the development of the Tethys. Further the existence of the Tethys was confirmed by the ophiolites near Chiavenna.

South of the Helveticum and N-Penninic Ocean, also called Walliser Ocean, the granites, gneisses and granodiorites, which are exposed near Chiavenna, represent the paleogeographic area of the Briançonnais. Strongly deformed K-feldspars could be observed in Truzzo granodiorite, which is a characteristic part of the Tambo nappe. Southward close to Pratta we discovered the border between ultramafites and granites. In those metapelitic rocks the spinel and garnets were accompanied by the aluminium-rich sapphirine.

The border between the European and Apulian plate, called the Insubric Line, was visited near Livo.

After passing Chiesa, the group travelled North through Val Malenco. This valley is characterized by many quarries where the decorative serpentinite is excavated.

For the following three days the group stayed in Chiareggio to investigate the contact metamorphism in the Malenco-serpentinite and the Bergell Intrusion with its aplites and intrusives.

A special highlight was the Bergell pegmatite where some of the students found the really pretty variety of beryl - aquamarine (Refugio del Grande).

In Val Ventina we examined well-exposed ophicarbonates, which were formed by hydrothermal activity. Having climbed onto the Munt Pers (3200 m), the group enjoyed a wonderful view over the Bernina massive. Here the topic was focused on the morphology of glaciers. A glacier trail next to the Munt Pers showed us the retreat of the Morteratsch glacier. Opposite of Bernina-Diavolezza Piz Alv has a dolomitic top upon carbonate-rich breccias.

On our last day we were informed about protective barriers against mudflows caused by the melting of permafrost in Pontresina and a floodwater project in Samedan. We finished our excursion with a hiking tour next to the Malojapass, the watershed between the Mediterranean, the Rhine river and the Black Sea.



The participants in front of the Morteratsch glacier

Mapping course at Brändö, Åland

July 22-31, 2005

Report by Sebastian Lindauer

On Friday, 22.07.05, a group of thirteen geology students led by Rune Selbekk and Meinert Rahn went via Stockholm to Åland, an autonomous Finnish province in the Baltic Sea. Our mapping area was in the eastern part of Åland in the commune Brändö, which consists of several islands, connected by roads.

On the first day we visited several outcrops on the island Björnholma in order to get a general overview of the geology of Brändö and to get familiar with the lithologies we were going to map the following days. We found different kinds of granite, granodiorite-gneisses, biotite-

gneisses, amphibolite-gneisses and migmatites.

On the second day we were split into six groups (2-3 students per group) and went out into the field to map the different areas. Every group had at least one complete island with several lithologies. The islands have numerous large outcrops, but it was quite difficult to get samples, since the surface was formed by glaciations during the last ice age. Locally, some parts of the islands vegetation is so dense, that machetes would have been much more helpful than hammers.



At the field trip

In the afternoon of the third day Dr. Karl Ehlers from the University of Åbo, Finland visited us and showed us several outcrops with various dykes of dark and fine-grained material (diabase). The dykes are just a few centimetres to decimetres thick and mainly semi-concordant. We have seen a 400 m thick dyke at the island Korsö. The material of the dyke consisted mostly of plagioclase. He also showed us pillow structures of monzonite intrusions with granitic fillings in between.

By Friday almost every group managed to make a complete geological map of their area and therefore could enjoy a beer, Finnish sauna and bathing in the sea during the evening.

On Saturday we left Brändö for Mariehamn where we stayed for the night and wrote our mapping reports. In the evening we had a barbecue which marked the end of a great mapping course with superb weather conditions.

Kinzigtal (Schwarzwald) excursion

November 26, 2005

Report by Juraj Majzlan

On a cold and brisk morning, we headed out for the northern part of the Black Forest (Schwarzwald) mountains. This was the first field trip for the first-year undergraduate students. These students are enrolled in the new Bachelor/Master program. Forty-eight students and six members of our staff (Sonia Ackermann, Kurt Bucher, Reto Gieré, Juro Majzlan, Rune Selbekk, Tobias Weisenberger) participated in this one-day introductory field-trip. Each member of the staff drove a minivan and supervised his or her eight students.



Students investigating sandstones at Kuhbach

For most of the field trip, we had a chance to see the crystalline rocks that build the Black Forest. The first stop at Hechtsberg fea-

tured paragneisses, relatively coarse-grained rocks with abundant biotite. Many students had a first opportunity of their lives to take a closer and a more critical look at the rocks, use a rock hammer, and attempt to describe their observations in scientific terms. The outcrops, provided by the quarry wall at Hechtsberg, allowed us to observe larger-scale features, such as extensive fracturing of the rocks.

At the second stop at Artenberg, we saw a different type of gneiss. Fine-grained, more homogeneous rocks lent themselves to discussions about the various origins of the rocks of a similar appearance, chemical and mineral composition. A glance into the geological map of the Black Forest suggested that the observed rocks are orthogneisses.

A small quarry at Paulischänzle offered a varied assemblage of rocks to observe. Most of these rocks are not local, but were brought into the old quarry from construction activities in the wider area. The students had a chance to observe the Triberg granite, a nice, coarse-grained igneous rock. In lesser quantities were present also volcanic rocks with large phenocrysts of feldspars and fine-grained matrix (Permian rhyolites). The quarry itself was opened in strongly crushed gneisses and granite porphyres.

The last stop of the day, at Kuhbach, was in a small sandstone quarry. The sandstones (Buntsandstein) cover the crystalline rocks of the Black Forest, but were eroded from most of the elevated areas. The sandstones provided abundant sedimentation features to observe and discuss. This stop concluded the field trip which gave the students a chance to examine, compare, and describe igneous, metamorphic, and sedimentary rocks in an area nearby Freiburg.

New Zealand field trip

March 10-23, 2005

Report by Benjamin Herr, Stephan Steuer, and Jochen Wittge

The participants of the excursion met in the morning on the 10th of March in Christchurch where the journey started. On the way to the west coast of the southern island we traversed Arthur's pass where a major transform fault was observable. Unfortunately we missed an outcrop with greenstones but a souvenir shop displaying nephrites served as an adequate substitute.

The Franz Josef Glacier was of main interest the next day. By studying the deposits in front of the glacier a big variety of different kinds of schists and greywackes were observed and described.

On the following day, traveling time to the Fox Glacier and the Alpine Fault was shortened by using helicopters as a mean of transportation. The fault zone which marks the boundary between the Pacific and the Australian plate was clearly marked by mylonites and ultramylonites. This structural feature is the only evidence for this major tectonic event. While studying the strongly deformed material a reddish colored outcrop on the other side of the valley gained attention. Even after a long discussion a satisfying explanation for this rather unexpected and peculiar observation was still missing. The next day students therefore had the chance to choose between two different programs.



A view from a helicopter during our trip in the New Zealand Alps

Either try to unravel the mystery about the reddish stones or follow the planned program.

The offer to take a trip to Robert Track with Mr. Sigmund was accepted by most students. Only the three of us decided to find out about the unexplained occurrence of the reddish outcrop. Prof. Grapes, Juraj Majzlan and Hiltrud Müller-Sigmund guided us on that day. We tried to access the outcrop from the northern valley part, but after two hours of fighting through the native forest our attempt ended on a vertical wall. Our second try after the lunch break wasn't successful either, even though we tried to find our way starting from the other side of the valley. Even a well known locality with granitic stones could not be found due to the strong vegetation.

On the fifth day, we travelled to the Golden Bay where we spent the next few days on a remote geological field station.

In this very isolated area mining is one of the most important industrial branches. Gold and silver ores are the most important constituents of the mined material. Unfortunately we did not find any valuable ore but instead found an intensively by iron oxide red colored stream. Visiting an iron mine and a cement-producing factory deepened our knowledge about the different mining techniques.

Another very interesting fault system, Cretaceous dike swarms and associated volcanic rocks of the nland Kzikoura Range were investigated before we spent the entire following day with traveling to the northern island.

The eleventh day was the most exciting one for those geologist in our group interested in geophysics and faults. The biggest horizontal displacement on earth was astonishing and surprising to all of us. The combination of a horizontal and vertical component of the movement displaced a river bed in such a way that it now ends on a wall.

The last few days of the excursion were spent around the city of Rotorua. The buildings are constructed in the middle of a volcanically still active zone. Therefore the city's air is perfumed with the smell of rotten eggs. The excursion ended with a wonderful BBQ in the evening. We had a wonderful and very interesting time and would like to thank Prof. Rodney Grapes, Juraj Majzlan, Hiltrud Müller-Sigmund and Jörg Sigmund for the wonderful trip to New Zealand.

Other Field Trips

Zermatt, Switzerland, July 2005.

Leader: Kurt Bucher.

1 day excursion to Southern Schwarzwald for Geography students

Leader: Hiltrud Müller-Sigmund.

1 day excursion to the former mine Suggental (April 16, 2005).

Leader: Hiltrud Müller-Sigmund. (July 1, 2005)