Institute of Earth and Environmental Sciences
University of Freiburg

Program guidebook
M.Sc. Geology

with focus areas
Geomaterials and Processes
Rock Mechanics and Geodynamics
Geohazards

Freiburg, April 20, 2018

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1. General Information

This module guide provides information about the M.Sc. program *Geology*. The program offers an individual specialization to one of the focus areas, *Geomaterials and Processes*, *Rock Mechanics and Geodynamics* and *Geohazards*. The Master of Science (M.Sc.) is an internationally recognized degree, which can be completed within two years (four semesters) of study. Together with the M.Sc. program "*Sustainable Materials / Crystalline Materials*" it reflects the main areas of geoscience research in Freiburg. English is the official language of instruction and communication of both programs. This guide book aims at presenting the vision, structure, and course of the masters program and provides necessary details of the individual modules and courses.

1.1 University of Freiburg Geosciences: Why to complete M.Sc. studies in Freiburg?

The Institute of Earth and Environmental Sciences belongs to the Faculty of Environment and Natural Resources as part of one of Germany's leading universities. In recent years the University of Freiburg has been ranked atop in research quality in Germany. The research and teaching interests of the Geoscience Department cover a wide range of exciting topics in Earth sciences including petrology, sedimentology, structural geology, planetary geology and impact crater research, geochemistry, mineral resources, fluid-rock interaction, as well as structure of crystalline materials and crystal synthesis. The following pages provide a detailed overview of the areas of Geoscience research at the University of Freiburg.

1.1.1 Sedimentary Geology and Quaternary Reserach

The youngest part of the gelogical history, the Quaternary period i.e. the last 2.6 Ma, was characterised by rapid environmental developments caused by naturally occuring climate change. Furthermore, humans increasingly had an impact on processes on the Earth surface. In the terrestrial realm, these changes have been recorded in a variety of archives such as peat deposits and lakes as well as by sediments deposited by rivers, ice or wind. Investigating these archives helps to decipher natural climate variabilty and its impact on sedimentary systems. In collaboration with archaeological sciences, it also helps to understand how the human race developed and adopted to changing environments in the past.

1.1.2 Structural Geology and Tectonics

Structural Geology and Tectonics are core subjects in geology. Methodology used in our institute ranges from classical field mapping in the Alps to quantitative modeling and from remote sensing to nano-scale investigations. Our specific field of research is to compare standard brittle deformation with fast, rate-dependent dynamic deformation. For this, we are running a 3000 kN triaxial loading frame and a Split-Hopkinson-Pressure Bar to determine the mechanical properties under quasi-static and dynamic loading conditions.

1.1.3 Impact Crater Research and Planetary Geology

Impact crater research is a young discipline in geosciences. At Freiburg we explore terrestrial impact craters by means of field surveying, drilling campaigns, and microstructural analysis of shocked rocks. Our interdisciplinary research is devoted to understand the dynamics of impact cratering and also includes remote sensing of craters on Earth and other planetary bodies and the application of a variety of experimental techniques. In this respect a close collaboration exists to the Fraunhofer Ernst-Mach-Institut (EMI) Freiburg. Impact crater research is closely linked to planetology. Our knowledge on the solar system currently increases rapidly due to the technological development of space exploration techniques. Planetological research at the institute focuses on crater formation, landscape evolution and the tectonics on Mars and the Moon. The implementation of impact geology and planetary dynamics is a unique selling point of Freiburg´s Master Geology program in Germany.

1.1.4 Data analysis and numerical modeling

Modeling of geo-processes has become a major field in geosciences in the previous decades. Our research in this field focuses on long and short-term processes at the Earth's surface, mainly erosion in combination with tectonic processes and mass movements. Concepts of nonlinear dynamics in the context of geohazards also play a major part in our research. As a third subdomain, there has been active research in developing new methods of data analysis.

1.1.5 Near-surface geophysics

The exploration of the shallow subsurface with particular regard to sedimentary environments, mass movements and hydrogeology is actually built up at Freiburg. Focus will be on nonseismic methods (resistivity methods, ground-penetrating radar, and other electromagnetic methods).

1.1.6 Petrology and Evolution of the Lithosphere

The mineral assemblages and structures of rocks ultimately result from large-scale geological processes reflecting dynamics of the Planet Earth. Geodynamic processes include the building of mountain ranges such as the Himalayas and the Alps, the evolution of island arc systems, and the formation of ocean floor along mid-ocean spreading ridges. The dynamic building of mountain belts and motions of lithospheric plate move rock complexes along specific pressure-temperature-time paths. In numerous geological settings, partial melting occurs, magmas segregate and migrate, and contribute to the chemical differentiation of the oceanic and continental crust. The wide range and continually changing pressure and temperature conditions cause chemical reactions in rocks that change their mineral associations and textures. Deciphering this rock record is the principal tool for reconstructing the past and present processes on our planet. The most important insight into the deeper lithosphere come not only from exhumed metamorphic and igneous rocks, but also from modern exploration programs such as oceanic drilling and dredging onboard marine research vessels. Our research includes a variety of subjects such as melt generation and migration, kinetics of crystallization, and implications of melt-crystal interaction for the dynamics of natural magma chambers and growth of the continental crust.

1.1.7 Mineral Resources

Enrichment and accumulation of metals in the Earth's oceanic and continental crust can form economically important mineral resources that provide basis four our society and its modern technologies. The ore deposits occur in diverse geological settings, ranging from mid-ocean spreading ridges through magmatic arc systems to stable cratons. In addition, the formation of ore deposits has been taking place for the entire Earth's geological history. In many element cycles and natural enrichment processes, the interaction of fluids and melts with rocks plays a fundamental role. Understanding magmatic and hydrothermal processes such as magma fractionation, release and mixing of fluids of various composition spanning high-temperature magmatic to low-temperature hydrothermal systems are of critical importance. Furthermore, a variety of geochemical, microanalytical and imaging techniques has become increasingly essential for characterization of host rocks and ores, mineral distribution, optimization of processing and extraction techniques. The combination of these methods often provides vital information to unravel the patterns of metal enrichment in space and time as well as to facilitate the use of these non-renewable resources.

1.1.8 Geochemistry of Water, Crustal Fluids and Water-Rock Interaction

The chemical interaction of water and rock is one of the most universal, multifaceted and fascinating processes in geology. The composition of surface and ground water is largely controlled by the reaction of water with rocks and minerals. At elevated temperatures, the intensity and rates of these interactions are even greater and they lead to diverse economically important products – hydrothermal ore deposits and geothermal energy reservoirs. These systems are now exploited for sequestration and deposition of greenhouse gases. In magmatic systems, volatiles are also ubiquitous constituents and significantly affect the physical and chemical properties of magmas and have substantial impact on volcanic eruption styles, associated risks as well as effect on the Earth's atmosphere and climate. Understanding water-rock interaction is thus of great importance to applied geology and geochemistry, particularly in areas such as geothermal energy, applied hydrogeology and nuclear waste disposal.

1.1.9 Classical Growth of Semiconductor Crystals

Semiconductor materials like silicon, lead iodide, and cadmium telluride are of high importance in a number of industries like the computer industry. Relevant physical properties of such materials are often only achieved if the required semiconducting building blocks are cut from large single crystals of the corresponding chemical element or compound. We optimize conditions for the growth of such crystals, a growth which usually takes place at high temperatures in special furnaces. Close collaborations exist with the Fraunhofer Institut für Solare Energiesysteme (ISE), Institut für Angewandte Festkörperphysik (IAF) and Institut für Physikalische Messtechnik (IPM).

1.1.10 Crystal Growth in External Fields

To improve the quality of our application-relevant semiconductor crystals with respect to purity and position-independent structural uniformity, we investigate crystal growth also in external fields. These may be stationary or rotating magnetic fields or "Gravity fields" like under microgravity. In the latter case experiments are undertaken in space in special (manned) planes, (unmanned) rockets or (in the future) in the ISS (international space station).

Apart from working in close collaboration with the University of Freiburg Division of Chemistry, the institute has close connections to the Freiburg Center for Materials Research (FMF), the Fraunhofer Institute for High-Speed Dynamics (Ernst-Mach-Institut EMI), the Fraunhofer Institute for Solar Energy Systems (ISE), the Fraunhofer Institute for Applied Solid State Physics (IAF), as well as the Fraunhofer Institute for Physical Measurement Techniques (IPM). All these institutions and facilities can be accessed within walking distance.

The Institute of Earth and Environmental Sciences is housed in recently renovated buildings. The "state of the art" analytical infrastructure has been fully renovated and substantial office space for graduate students was created. In combination with a modern and up-to-date library it provides excellent conditions for individual study and research. Computer rooms and library study facilities are easily accessible. A student cafeteria and the university IT services are located within the immediate vicinity of the institute. The institute is conveniently situated only a few minutes away from the city center and the central train station.

1.2 Analytical Facilities for Modern Quantitative Geosciences

The institute hosts advanced analytical facilities for research and teaching in the geosciences. Besides a sample preparation laboratory for crushing and sieving as well as mineral separation and preparation of high-quality polished thin sections from geological or synthetic materials, the institute runs a 3000 kN triaxial loading frame for determination of mechanical properties of solid rocks. The deformation behavior of rocks and the kinematics of gravity-driven mass movements are studied in an analogue laboratory equipped with particle image velocimetry and stereo cameras. Also available are geophysical devices for field surveys (geo-electric, seismic, georadar).

For the structural and chemical characterization of natural rocks and synthetic products two scanning electron microscopes equipped with EDX and an electron backscattered detector (EBSD), an electron microprobe, a WD-X-ray fluorescence spectrometer, and several optical microscopes are used. White-light interferometry is applied for the characterization of surface topographies. Atomic absorption spectroscopy, ion chromatography, and UV-VIS spectrometry are used for the analysis of fluids.

The structure of crystals – from the millimeter down to the picometer scale – can most effectively be investigated using X-ray methods. We use these methods to detect imperfections or inhomogeneities in a crystal (X-ray topography), to measure with highest precision the so-called lattice parameters (high-resolution X-ray diffractometry), to determine accurately the arrangement of the atoms in the crystal (X-ray single crystal diffractometry), or to identify the components of a crystal powder, e.g. a mineral powder (X-ray powder diffractometry). Trace element concentrations in natural waters, soils, and other materials can be analyzed with our atomic absorption spectrometry (Flame AAS and Graphite Furnace AAS) and other equipment (UV-VIS, IC, CSH_2O-Determinators).

With our equipment for differential thermal analysis and differential scanning calorimetry we are able to study phase transitions, for instance melting or solidification, or the transition of a certain atomic arrangement in the crystals of a compound into a different arrangement (polymorphic transition) with respect to transition temperatures or transition enthalpies. Thermogravimetry is used to monitor quantitatively weight changes, which are, e.g., caused by thermal decomposition processes leading to new chemical compounds.

1.3 Application to the M.Sc. Program Geology

The application procedure for the graduate program is available online (http://portal.uni-freiburg.de/master-geo/prospectivestudents/application). Documents can be uploaded during the application process, but must also be sent via postal mail. The annual application deadline is May 15. Students can register for the fall semester only (starting mid´ October). The M.Sc. Geology program is accessible to all students, who have acquired a B.Sc. in Geology, Geosciences, Earth Science, or Mineralogy from a German university, or from other universities and colleges worldwide (in accordance with certain quality control criteria). Students holding a B.Sc. degree in other natural or physical sciences (Chemistry, Physics, Biology, Environmental Science) may also be granted admission to the program. In the latter case, the choice of a focus area may be determined from the student's educational background. Applicants must have English-language skills that meet or exceed level B2 of the Common European Framework of Reference for Languages (see the application form for details).

Questions concerning the general application and admission procedure to the M.Sc. Geology program should be addressed to the Application and Admission Coordinator Ms. Kathleen Robinson and/or to the Academic Advisory Officer, Dr. Heike Ulmer. For organizational enquires concerning the course of study the Geoscience Program Coordinator, Ms. Wibke Kowalski is contact person (see 1.4).

1.4 Advising and contact points

If you have any questions regarding the content of your studies or application, the Academic Advisory Officer or the Head of the Geology Program will be happy to help you with advice and ideas. Consultation hours are arranged on a personal basis:

- **Student Advisory Support**
  Dr. Heike Ulmer, Albertstr. 23-B, 2nd floor, room 02 014
  Tel. +49 (0)761/203-6480; ulmer@uni-freiburg.de

- **Head of the Geology Program**
  Prof. Dr. Stefan Hergarten, Albertstr. 23-B, 1st floor, room 01 011
  Tel. +49 (0)761/203- 6471; stefan.hergarten@geologie.uni-freiburg.de

Questions concerning the general application and admission procedure should be addressed to the Application and Admission Coordinator:

- **Application and Admission Coordinator**
  Ms. Kathleen Robinson, Albertstr. 23-B, 1st floor, room 01 020
  Tel. +49 (0)761/203-6398; kathleen.robinson@geologie.uni-freiburg.de

If you have any questions about the course of studies, please contact the Program Coordinator available during the opening hours and also by appointment:

- **Geology Program Coordinator:**
  Ms. Wibke Kowalski, Albertstr. 23-B, 1st floor, room 01 020
  Tel. +49 (0)761/203-6398; wibke.kowalski@minpet.uni-freiburg.de

The study office provides information on field trip days achieved and the excursion modules posted on the transcript:

- **Excursion Module Coordinator Geosciences:**
  Ms. Kathleen Robinson, Albertstr. 23-B, 1st floor, room 01 020
  Tel. +49 (0)761/203-6398; kathleen.robinson@geologie.uni-freiburg.de

Questions about registration for examinations and Transcripts of Records should be addressed to the Examination Office:

- **Examination Office**
  Ms. Ursula Striegel, Albert-Ludwigs-Universität, Prüfungsamt der Fakultät für Umwelt und Natürliche Ressourcen, D-79085 Freiburg im Breisgau, Germany

Tel. +49 (0)761 203-3605; ursula.striegel@unr.uni-freiburg.de

The Credit Recognition Officer will answer questions regarding the recognition of achievements from abroad, other courses of study or other universities. Questions about the possibilities of a semester abroad are answered by the Study Abroad Coordinator of the geosciences:

- **Credit Recognition Officer Geosciences:**
  Prof. Dr. Stefan Hergarten, Albertstr. 23-B, 1st floor, room 01 011
  Tel. +49 (0)761/203- 6471; stefan.hergarten@geologie.uni-freiburg.de
- **Study Abroad Coordinator Geosciences:**
  Prof. Dr. David Dolejš, Albertstr. 23-B, 1st floor, room 01 016
  Tel. 0761/203-6395; david.dolejs@minpet.uni-freiburg.de

1.5 Structure of the M.Sc. Program Geology

The M.Sc. program Geology (see Fig. 1) includes 120 ECTS[1] points and is offered in English. To ensure high standards of teaching in an international academic setting, the program has been certified by the Language Teaching Institution of the University of Freiburg ("Sprachlehrinstitut") in 2016 with the EMI (English Medium Instruction) quality certificate (http://www.studium.uni-freiburg.de/studieninteressierte-en/english_bachelor_and_master-en/emi).

The M.Sc. course curriculum consists of six compulsory modules (30 ECTS points), six specialization modules (30 ECTS points), six elective modules (30 ECTS points), and a masters thesis (30 ECTS points). Each module has a total of 5 ECTS credits and forms a closed teaching unit with defined objectives, contents and examinations. A maximum of three elective modules, that is, 15 ECTS points may be taken from other areas such as other natural sciences and / or languages. A list of the modules and the module coordinators, including the ECTS points to be acquired, the type of event and the recommended semester are listed in the tables in Sect. 2.1 and 2.2.

The grade of a module is derived from the module examination. The final module examination usually consists of a written or oral examination, in field-oriented courses and practical courses it often consisting of a graded protocol, report or paper. Some modules also include portfolio examinations that combine different types of examinations. The different examination parts of a portfolio examination do not have to be passed individually, but only

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[1] „*ECTS*" stands for "European Credit Transfer and Accumulation System" and is a uniform European system for the evaluation of academic achievements, which credits the amount of work done (30 hours per point) in the form of points (credits).

in sum. The weighting of the individual examination parts is specified in this module manual or will be announced at the beginning of the respective module. Within the modules, ungraded academic achievements may also be required, which are the prerequisites for the successful completion of a module.

The modules use a combination of different forms of teaching and learning, such as small group work, scientific discussions, practical laboratory trails, theoretical exercises as homework, etc. The program is characterized by a balanced combination of theoretical basics, laboratory courses, practical training and field work.

The Master's thesis covers the handling of a scientific topic, as well as the presentation of the results and interpretation within the scientific framework. The Master's thesis aims to show that the students are able to familiarize themselves with a current geoscientific topic within the given period of six months, to use the methods and concepts learned and to present the results in an understandable form.

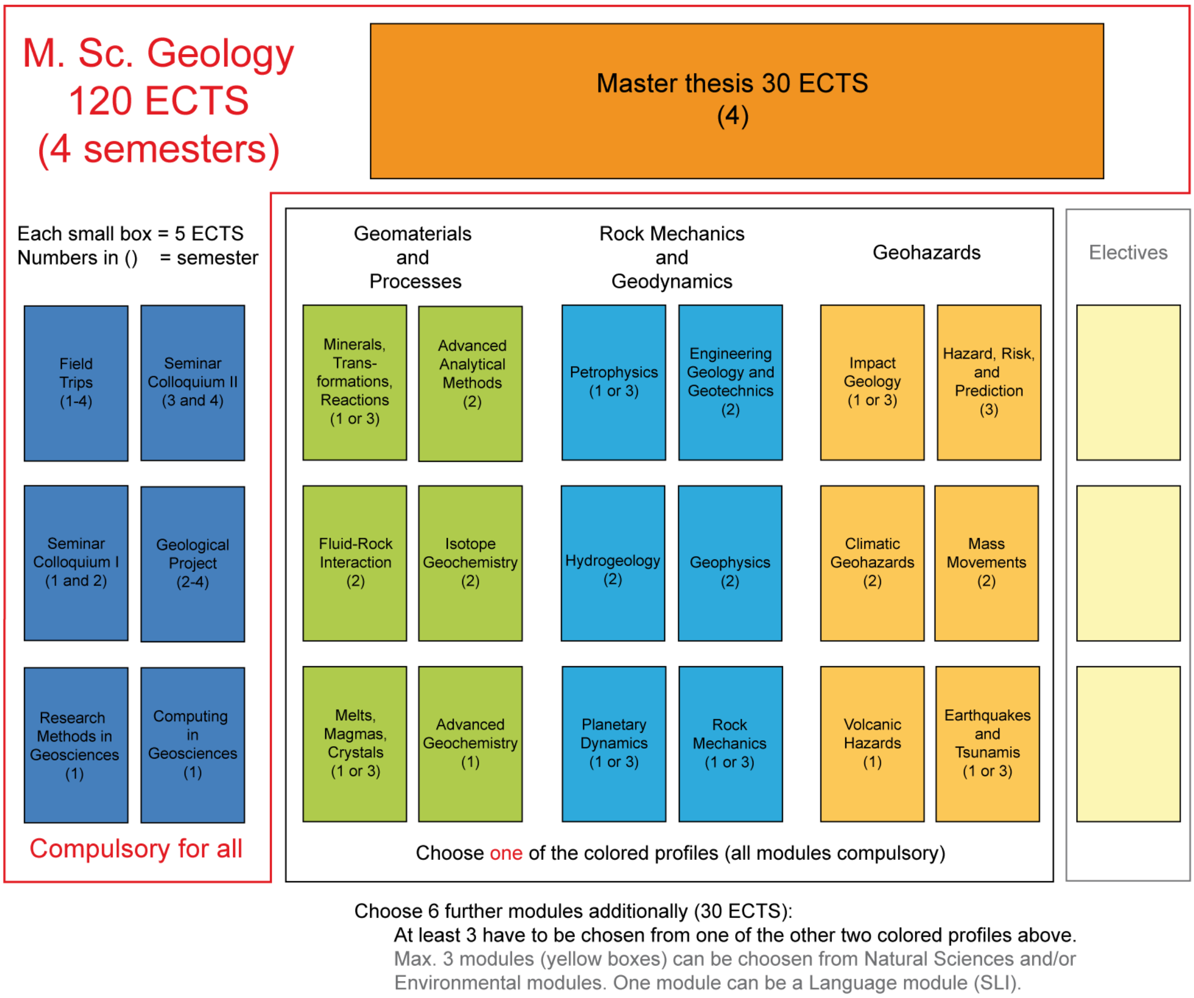

Fig. 1: Structure of the M.Sc. Program Geology

1.5.1 M.Sc. Geology – Focus area *Geomaterials and Processes*

The focus area *Geomaterials and Processes* offers education and research training in petrology, geochemistry, mineralogy and mineral resources. The course curriculum is designed to extend foundations of petrology (metamorphic and magmatic processes, mineral transformations, properties of silicate magmas) and geochemistry (planetary differentiation, processes in the Earth's interior, oceans and surface). These foundations are followed by advanced courses leading to the formation of mineral resources, ore deposits as well as fluid-rock interaction in deep, geothermal and near-surface environments. The curriculum is complemented by practical modules that develop competence in laboratory analytical and experimental methods. Thesis projects are designed to acquire deeper understanding of geological processes through field observations, interpretation of mineral assemblages or experimental studies in laboratory. These approaches, together with phase equilibria and thermodynamic modeling, are used to interpret various metamorphic, magmatic or hydrothermal processes occurring on the Planet Earth as well as those leading to the formation of economic mineral resources. The compulsory specialization modules are highlighted in green in the following chart (Fig. 2). Notice that for "*Seminars*" and "*Research Methods in Geosciences"* only the specific courses from mineralogy and geochemistry qualify for this specialization. The specialization *Geomaterials and Processes* offers a sound education in analyzing, modeling, and understanding of geologic materials and processes, bridging the gap towards material sciences, and opening a wide field of career options in research and applied industries.

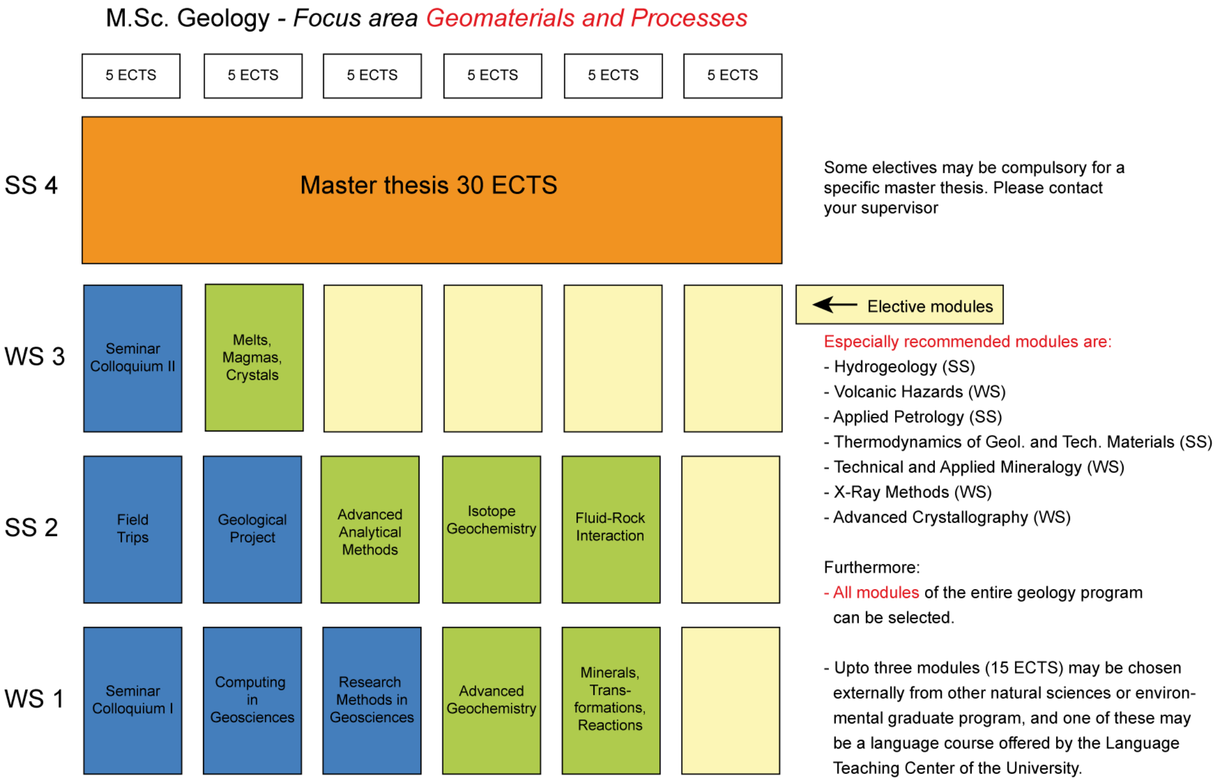

Fig. 2: Compulsory modules of focus area *Geomaterials and Processes*

1.5.2 M.Sc. Geology – Focus area *Rock Mechanics and Geodynamics*

The focus area *Rock Mechanics and Geodynamics* consists of the six specialization modules highlighted in lighter blue in the following chart (Fig. 3). The specialization provides the student with a sound theoretical as well as practical knowledge in the respective fields and the gained qualifications offer a wide spectrum of career choices. Practical expertise includes work in the rock mechanics laboratory that hosts a triaxial loading frame, Split-Hopkinson Pressure Bar, Analogue Laboratory. Geophysical and petrophysical equipment comprise of a He-pycnometer, laser-sizer, white light-interferometer, optical and electron microscopy, and devices for seismic and geoelectric analyses. Note that the modules *Rock Mechanics* and *Petrophysics* are offered biannually alternating in the winter term. The same holds for the modules *Planetary Dynamics* and *Impact Geology*.

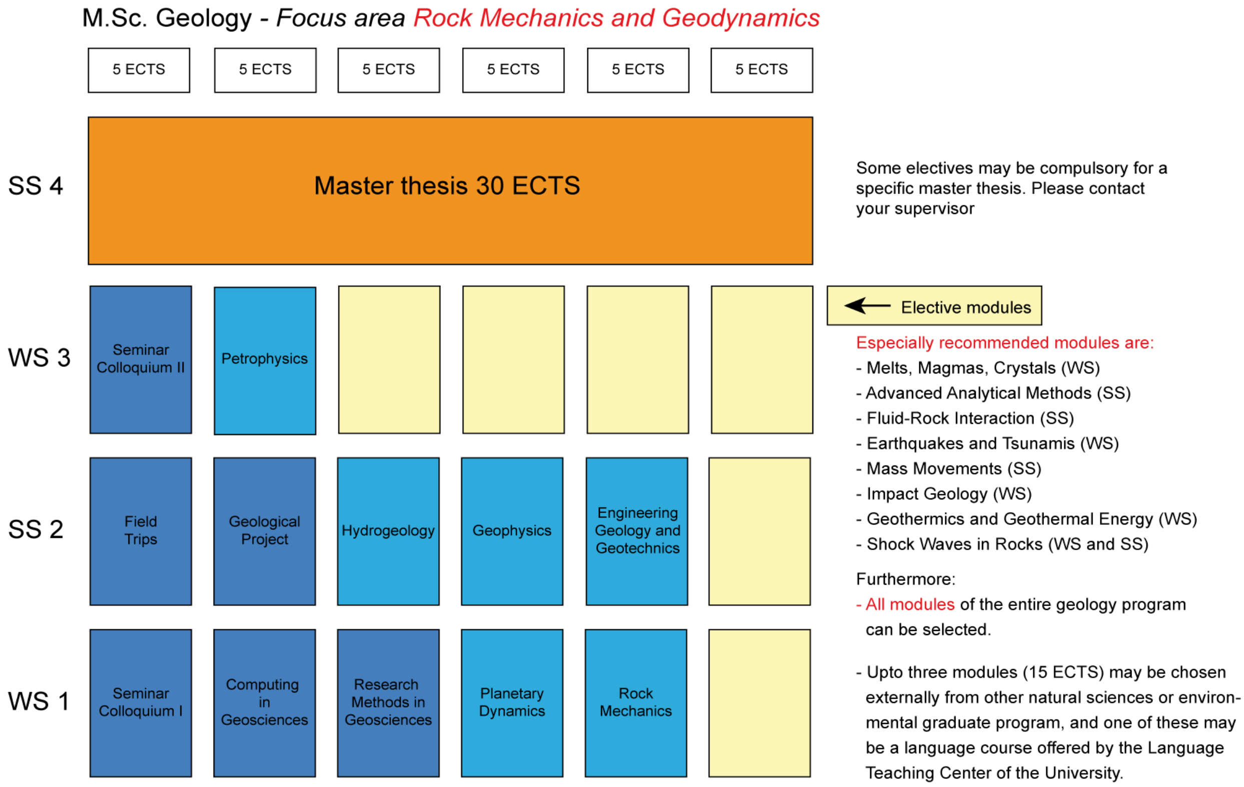

Fig. 3: Compulsory modules of focus area *Rock Mechanics and Geodynamics*

1.5.3 M.Sc. Geology – Focus area *Geohazards*

Quantification and prediction of geohazards has become a major field of both research in geoscience as well as of professional activity of geoscientists. The geohazards line of the M.Sc. program Geology provides a comprehensive coverage of the most relevant geohazards including the underlying physical processes, their relationship to geology, assessment of hazard and risk, as well of concepts of prediction. The specific geohazards considered in this line comprise those with a close relationship to geology (volcanism, earthquakes, tsunamis, landslides, meteorite impact) as well as hazards receiving an increasing interest due to their potential relationship to climate change (e.g., storms, floods and various types of mass movements). As modeling has become an essential part in hazard assessment, numerical modeling approaches are also considered. The focus area *Geohazards* consists of the six specialization modules highlighted in orange in the following chart (Fig. 4).

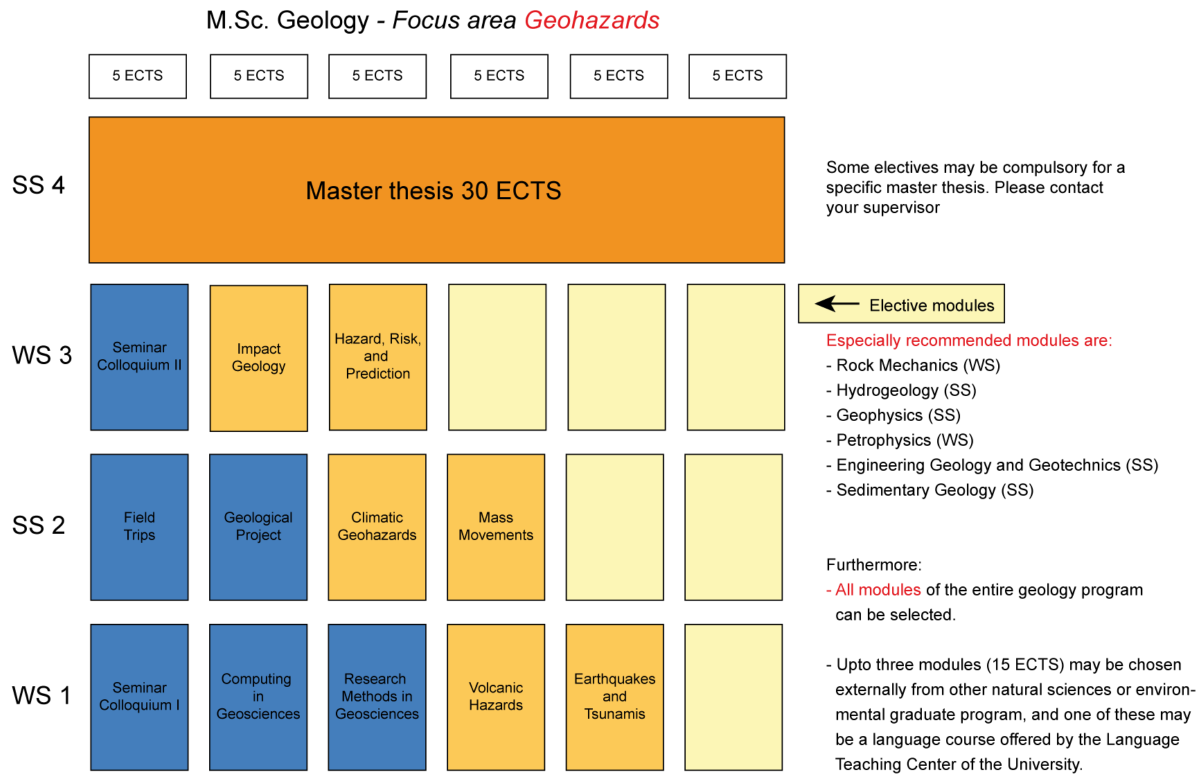

Fig. 4: Compulsory modules of focus area *Geohazards*

2. Module Overview

2.1 General Compulsory Modules (30 ECTS)

Module	Coordinator	Courses	Type	ECTS points	Sem.
Research Methods in Geosciences	Preusser	Laboratory Methods in Geomaterials (Geomaterials & Processes)	L + P	5	1
		Remote Sensing and GIS (Rock Mechanics & Geodynamics or Geohazards)	L + P	2.5	1
		Soft Skills in Geology (Rock Mechanics & Geodynamics or Geohazards)	L + P	2.5	
Computing in Geosciences	Hergarten	Computing in Geosciences	L + P	5	1
Seminar and Colloquium I	Poelchau	Research Seminar	S	3	1 + 2
		Geoscience Colloquium	C	2	
Field Trips	Ulmer	Field Trips and Visits to Industrial Facilities	F	5	1 to 4
Geological Project	Preusser	Geological Project	P	5	2, 3 or 4
Seminar and Colloquium II	Poelchau	Research Seminar	S	3	3 + 4
		Geoscience Colloquium	C	2	

Semester numbers indicate recommended semester, modules marked by “1 or 3” may be offered on biannual schedule only
Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

2.2 Specialized compulsory modules (30 ECTS)

2.2.1 M.Sc. Geology –Focus area *Geomaterials and Processes*

Module	Coordinator	Courses	Type	ECTS points	Sem.
Advanced Geochemistry	Siebel	Geochemical Evolution of the Mantle and the Crust	L + P	3	1
		Marine Geochemistry	L + P	2	

Melts, Magmas, Crystals	Dolejš	Melts, Magmas, Crystals	L + P	5	1 or 3
Minerals, Transformations, Reactions	Dolejš	Minerals, Transformations, Reactions	L + P	5	1 or 3
Advanced Analytical Methods	Müller-Sigmund	Advanced Analytical Methods	L + P	2	2
		High-Resolution Spectroscopy	L + P	3	
Fluid-Rock Interaction	Dolejš	Fluid-Rock Interaction	L + P	5	2
Isotope Geochemistry	Siebel	Isotope Geochemistry	L + P	5	2

Semester numbers indicate recommended semester, modules marked by "1 or 3" may be offered on biannual schedule only

Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

2.2.2 M.Sc. Geology –Focus area *Rock Mechanics and Geodynamics*

Module	Coordinator	Courses	Type	ECTS points	Sem.
Planetary Dynamics	Kenkmann	Planetary Dynamics	L + P	5	1 or 3
Rock Mechanics	Poelchau	Stress and Strain	L + P	2.5	1 or 3
		Brittle Rock Deformation	L + P	2.5	
Hydrogeology	Dolejš	Advanced Hydrogeology	L + P	2.5	2
		Aqueous Geochemistry	L + P	2.5	
Geophysics	Hergarten	Near-Surface Geophysics	L + P	5	2
Petrophysics	Kenkmann	Petrophysics	L + P	2.5	1 or 3
		Rheology and Textures	L + P	2.5	

Engineering Geology and Geotechnics	Preusser	Introduction to Engineering Geology	L + P	2.5	2
		Geotechnical Projects	L + S	2.5	

Semester numbers indicate recommended semester, modules marked by "1 or 3" may be offered on biannual schedule only

Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

2.2.3 M.Sc. Geology –Focus area *Geohazards*

Module	Coordinator	Courses	Type	ECTS points	Sem.
Volcanic Hazards	Preusser	Volcanology and Volcanic Hazards	L	2	1
		Volcanic Hazards Case Studis	S	3	
Earthquakes and Tsunamis	Hergarten	Seismology and Seismic Hazard	L + P	4	1 or 3
		Tsunamis	L + P	1	
Climatic Geohazards	Rambeau	Introduction to Climatic Geohazards	L + P + S	2.5	2
		Climatic Geohazards Case Studies	P	2.5	
Mass Movements	Hergarten	Mass Movements	L + P	5	2
Impact Geology	Kenkmann	Impact Geology	L + P	5	1 or 3
Hazard, Risk and Prediction	Hergarten	Hazard, Risk and Prediction	L + P	5	3

Semester numbers indicate recommended semester, modules marked by "1 or 3" may be offered on biannual schedule only

Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

2.3 Elective modules (30 ECTS)

Students choose a total of six elective modules (30 ECTS) according to their own interest. The elective modules can be selected from the entire geoscience M.Sc. curriculum (any module). Up to three modules (15 ECTS) may be chosen externally from other natural science or environmental graduate programs, and one of these (5 ECTS) may be a language course offered by the Language Teaching Center of the University (SLI). For details please see section 3.29.

Additional elective modules offered by geosciences beyond the focus areas are:

Module	Coordinator	Courses	Type	ECTS points	Semester
Applied Petrology	Dolejš	Experimental Petrology	L + P	2.5	2
		Ore-Forming Processes	L + P	2.5	
Thermodynamics of Geological and Technical Materials	Dolejš	Thermodynamics of Geological and Technical Materials	L + P	5	2
Technical and Applied Mineralogy*	Sorgenfrei	Modern Ceramics, Cements, and Glasses	L + P	TBA	3
		Thermal Analysis	P	TBA	
X-Ray Methods*	Danilewsky	Structure Analysis by X-Ray Diffraction	L + P	TBA	3
		Defect Analysis by Diffraction	L + P	TBA	
Advanced Crystallography*	Danilewsky	Crystallographic Methodology	L + P	TBA	1
		Space Groups and Crystal Structures	L + P	TBA	
Sedimentary Geology	Preusser	Sedimentary Environments	L + S	3	2
		Logging Sediments	P + F	2	
Quaternary Research	Preusser	Reconstructing Past Environments	L + S	2.5	2
		Quaternary Research Practical Studies	P + F	2.5	
Geothermics and Geothermal Energy	Hergarten	Geothermics and Geothermal Energy	L+P	5	3

Shock Waves in Rocks	Kenkmann	Shock Waves in Rocks I	L+P	3	1 or 3
		Shock Waves in Rocks II	L+P	2	2 or 4

Semester numbers indicate recommended semester, “1 or 3” indicates a biannually offered course, “3 + 4” indicates courses comprising more than one semester

Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

* If you want to participate in one of these modules please contact the module coordinator

3. Module descriptions

3.1 Computing in Geosciences

Module Coordinator		Lecturer			
Prof. Dr. S. Hergarten		Prof. Dr. S. Hergarten			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geomat. and Processes C Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	WS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Computing in Geosciences		3 wh / 45 h	105 h		16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Numerical data analysis, visualization, and process modeling have become essential parts of quantitative geosciences. Deepening the knowledge on data analysis and visualization and introducing methods of process modeling, this course provides the basics of quantitative methods used in several other courses. Going beyond technical aspects of computing, data analysis, and visualization, the students learn how to transfer conceptual models into equations and implement solutions in a high-level programming language (MATLAB) using the widespread Finite Difference Methods. As a major qualification, the students shall be able to assess which method is suitable for a given problem and be aware of potential pitfalls.

Syllabus

The class starts with an introduction to process modeling using simple population models based on ordinary differential equations und their implementation using explicit and implicit Euler schemes. The following main part of the module comprises the basic equations behind the models widely used for modeling mass and heat transport processes, solid mechanics, groundwater flow, and landform evolution based on partial differential equations. After discussing the respective equations, the underlying principles, and their mathematical properties, the simplest numerical techniques in the field of partial differential equations (finite differences, upstream schemes) are discussed. Theory is accompanied by a step-by-step introduction to the MATLAB programming environment and exercises focusing on implementing the models in MATLAB and analyzing the results.

Teaching form

Lecture combined with practical exercises and homework

Examination form

Achievement of learning goals (unmarked): ---

Examination: Portfolio Examination: homework to be solved during the semester (65%), exercises to be solved in the class (10%) and a short written test at the end of the semester (25%).

Prerequisites for attending

Basic knowledge in mathematics and computing, e.g., on the level of "Modellierung und Datenanalyse" from the B.Sc. Geowissenschaften

Usage of the module in other programs

Elective module in the Master program Sustainable Materials / Crystalline Materials

Recommended reading

Gerya, T. (2009): Introduction to Numerical Geodynamic Modelling. Cambridge University Press, Cambridge, 358.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.2 Research Methods in Geosciences					
Module Coordinator Prof. Dr. F. Preusser		**Lecturer(s)** a) Dr. H. Müller-Sigmund; Prof. Dr. A. Danilewsky; NN b) Dr. G. Wulf c) Prof. Dr. F. Preusser; Prof. Dr. S. Hergarten; Dr. C. Rambeau			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geomat. and Processes (only a) C Rock Mech. and Geodyn. (only b + c) C Geohazards (only b + c)	150 h	5 ECTS	WS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Laboratory Methods in Geomaterials b) Remote Sensing and GIS c) Soft Skills in Geology		a) 4 wh / 60 h b) 2 wh / 30 h c) 2 wh / 30 h	a) 90 h b) 45 h c) 45 h		a) 15 b) 20 c) 20

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

This module introduces advanced scientific working skills and methods. By this, it forms the basis of the entire curriculum.

a) This interdisciplinary module combines the physical, chemical and crystallographic methods for the full characterization of any material samples. In relation to the overall profile this module provides profound knowledge for all analytical working courses: Aqueous Geochemistry, Advanced Hydrogeology, Isotope Geochemistry, Special Analytical Procedures in Mineralogy. The student gains key competences concerning quantitative material analysis by the use of state-of the-art equipment. The individual qualifications and skills of the module are specified below:

In the course of this practical module students acquaint themselves with a wide variety of physical and chemical analytical techniques available at the institute. Firstly, they identify which technique is the appropriate tool for a given geoscientific problem. Secondly, they memorize the theoretical background of the technique, identify possible sources of error, and prepare the geological material for the subsequent analysis. Thirdly, they measure the samples, thereby collecting own practical experience. Fourthly, they undertake a critical data interpretation and evaluation.

b) The fields of application of remote sensing show a strong multidisciplinary character including Earth Sciences. The increasing quality, resolution and availability of remote sensing data, especially over the last years, permit unprecedented opportunities for geological and geomorphological analyses with a high measure of precision. Consequently, the use and application of such data has become indispensable in modern geosciences. The students should gain both a theoretical and practical understanding of remote sensing data and appropriate software applications.

c) Students will learn how scientific research and applied studies are initiated, funded and carried out. After this module they will understand how scientific articles and reports are structured. They will know about different publication platforms. Approaches how to organise and perform own communications will be trained.

Syllabus

a) This course is designed to introduce the theory, applications, and operation of modern instrumental methods for chemical and physical analyses in environmental, Earth and materials science. Students are introduced to the spectrum of instrumental techniques, which are standard in research as well as in industry, and gain an understanding of the analytical approach to problem solving and data evaluation. To the extent feasible, students get hands-on experience with the machinery in the course of lab exercises, concentrating on concrete small analytical projects.

b) Students learn the theoretical background and practical experience that is necessary to understand the application of geographic information system (GIS) and remotely sensed data in geological sciences. It introduces them to basic principles of remote sensing as well as key concepts of data acquisition and storage, data visualization and processing, and data interpretation. In the course of this process, suitable software packages for quantitative analysis, such as ArcGIS by ESRI, will be used in addition to pure qualitative methods with special focus on visual image interpretation.

c) The course is dedicated to the basic understanding of the scientific world and communication.

Teaching form

a) Lecture + Practice, multimedia introduction into the basics of the methods, hands-on experience with different machinery in small groups (3-4 students), oral presentation of data and critical data discussion within groups

b) Lecture and practical work

c) Lecture and seminar

Examination form

Achievement of learning goals (unmarked): a) Participation at the exercises; b) Regular attendance; c) Regular attendance

Examination: a) One marked written report; b) + c) Portfolio Examination: Oral presentation, written exam and project report

Prerequisites for attending

a) Basic understanding of geological materials, B.Sc. level "Geochemical Methods" or equivalent knowledge

b) and c) ---

Usage of the module in other programs

Laboratory Methods in Geomaterials is a compulsory Module within the M.Sc. Sustainable Materials – Crystalline Materials program (Physical and Chemical Analytical Procedures)

Recommended reading

a) Dinnebier, R.E. & Billinge, S.J.L. (eds.) (2008): Powder Diffraction: Theory and Practice. Royal Society of Chemistry, Cambridge, 604.

   Gill, R. (ed.) (1997): Modern Analytical Geochemistry: An Introduction to Quantitative Chemical Analysis for Earth, Environmental and Material Scientists. Routledge, New York, 344.

   Reed, S.J.B. (2005): Electron microprobe analysis and scanning electron microscopy in geology. Cambridge University Press, Cambridge, 206.

   Reimer, L. (2010): Scanning Electron Microscopy: physics of image formation and microanalysis. Springer, Heidelberg/Berlin, 511.

b) Lillesand, T.M., Kiefer, R.W. & Chipman, J. (2015): Remote Sensing and Image Interpretation. John Wiley & Sons, Toronto, 768.

c) ---

Lecture notes

https://ilias.uni-freiburg.de/login.php

## 3.3 Seminar and Colloquium I					
Module Coordinator Dr. M. Poelchau		**Lecturers** a) Institute internal speakers b) Invited external speakers			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geomat. and Processes C Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	WS/SS	annual	2 terms
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Research Seminar b) Geoscience Colloquium		a) 2 wh / 60 h b) 2 wh / 60 h (30 h each term)	a) 30 h b) 0 h		a) 30 b) 30

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

In-house seminars provide a platform for further geoscientific conversation and for gaining insight in up-to-date geologic research.

The individual qualifications and skills of the module are specified below:

a) The students participating in the research seminar improve their abilities of presenting scientific topics. They defend their results in scientific discussions. They identify possible flaws, misinterpretations or inconsistencies in their own work and in those of other lecturers. Students critically dispute scientific topics and use the correct geological terminology.

b) The geosciences colloquium of the institute is held weakly and is regarded as the "*Window to the world of geosciences*" for students. Internationally renowned researchers covering a wide spectrum of different research and applied geo-topics are invited and give high-level talks. The participating students identify up-to-date research topics, improve their state of knowledge, become inspired by convincing forms of presentation and contribute to scientific discussions. Finally, they recognize possible fields of work for their future professional life and are able to establish contacts to the researchers.

Syllabus

a) The research seminar is a platform for presenting current in-house research topics. It is expected that students present results of their B.Sc. thesis, M.Sc. thesis or results of other recent research of general interest. On a regular basis doctorate students report on their current state of their Ph.D projects. Likewise staff scientists contribute to the research seminar by presenting conference talks, etc. The research seminar is aimed at inspiring scientific debates between students and staff scientists. A further objective is to inform students about the research topics that are addressed in the institute.

b) Presentations on up-to-date research topics, presented by invited and often internationally renowned speakers. The scientific spectrum comprises research topics of the institute (e.g. impact, planetology, structural geology, earth history, mineral, ore and oil deposits, geohazards, geothermal energy, environmental mineralogy, hydrology, geochemistry, crystal growth) and other branches of geosciences. To enhance the practical aspect of the curriculum speakers from companies and industries are specifically welcome.

Teaching form

a) Seminar with occasion for discussion

b) Seminar with occasion for discussion

Examination form

Achievement of learning goals (unmarked): a) Regular attendance, own presentations; b) Regular attendance

Examination: ---

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Pending on the topic of the seminar/colloquium, resp.

Lecture notes

https://ilias.uni-freiburg.de/login.php

<table>
<tr><td colspan="6">3.4 Field Trips</td></tr>
<tr><td colspan="2">Module Coordinator
Dr. H. Ulmer</td><td colspan="4">Lecturers
Academic staff</td></tr>
<tr><td>Type
C Geomat. and Processes
C Rock Mech. and Geodyn.
C Geohazards</td><td>Workload
150 h</td><td>Credits
5 ECTS</td><td>Term
WS/SS</td><td>Cycle
-</td><td>Duration
4 terms</td></tr>
<tr><td colspan="2">Course / Course Name
Field Trips and Visits to Industrial Facilities</td><td>Presence
10 days /100 h</td><td colspan="2">Private study
50 h</td><td>Participants
20</td></tr>
</table>

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

In this module the core expertise of geoscientists – field work – is trained more extensive than it was possible in the B.Sc. program. Excursions are aimed at testing, applying and accompanying the theoretical knowledge acquired in the lectures and are ideal occasions for exchange between students and lecturer. Field trips are grouped together with in-house seminars, because the latter provide another platform for further geoscientific conversation and to gain up-to-date informations.

The individual qualifications and skills of the module are specified below:

Upon participation at field trips the students refine their power of observation. Students write concise reports. They enhance higher-order cognitive skills, and inquiry skills, and understand geological processes in time and space. Students improve in geo-literacy and in knowledge of the regional geology. Visiting at industrial facilities students gain hands-on experience in manufacturing processes, application of geosciences in energy and materials' development and production, working life, and career prospects.

Syllabus

Field trips to rock outcrops play a fundamental role in understanding geological concepts. They are an essential part of the geological learning process in complementing classroom and lab teaching of science concepts. They also provide visual images that are needed to work with more abstract contents of modeling, remote sensing etc. Field trips involve elements of both instructor-lead explanation and student centered exploration / discovery.

Reviewing the trip afterwards is an important activity for cementing observations and interpretations into a comprehensive sense of conceptual understanding. Field trips range from day trips to field campaigns or residential courses of up to 2 weeks. Thematically they cover a wide variety of topics from understanding the regional geology of an area to studying specific geological phenomena like sedimentation, volcanism, metamorphism or environmental aspects. “Classical” geological areas are visited like the Alps, Iceland, Aeolian Islands, Eifel, Bohemian Massif, to name a few. Visits at industrial facilities play an important role linking scientific research and application centered industrial development in geosciences and material sciences. A wide variety of companies and research institutes is visited, ranging from energy generation to waste handling and from raw material production to high-tech material design.

Teaching form

Field trip/Visit at industrial facility, practical training in the field including data acquisition: (GPS, fabric, sampling strategies, drilling, etc.)

Examination form

Achievement of learning goals (unmarked): reports

Examination: ---

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Pending on the topic of the field trip

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.5 Geological Project					
Module Coordinator Prof. Dr. F. Preusser		**Lecturers** Academic staff			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geomat. and Processes C Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	WS	each semester	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Geological Project		project-specific	project-specific		project-specific

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Independent geological projects are aimed at bridging the gap between teaching and research. Students directly get involved in research specific methods. They develop skills in design and execution of an independent research project, in project management, report writing and time management are trained.

Syllabus

The topics offered introduce theoretical and methodological approaches to the investigation and interpretation of geological, or geophysical, or sedimentological or mineralogical-petrological, or geochemical research by practical and/or laboratory-based programs. They commonly involve the hands-on use of available equipment to conduct a practical field or laboratory-based investigation of one of the topics named above, allowing you to test the theories/practices encountered during lectures.

These studies are undertaken under the supervision of members of the Freiburg geosciences staff.

Teaching form

Project-specific; initial project outline and monitoring of progress through regular meetings with the supervisor who also offers suitable advice on library search and review of appropriate literature, data analysis, interpretation and presentation; otherwise mainly free time management.

Examination form

Achievement of learning goals (unmarked): project-specific

Examination: marked report

Prerequisites for attending

project-specific

Usage of the module in other programs

project-specific

Recommended reading

project-specific

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.6 Seminar and Colloquium II					
Module Coordinator Dr. M. Poelchau		**Lecturers** a) Institute internal speakers b) invited external speakers			
Type C Geomat. and Processes C Rock Mech. and Geodyn. C Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS/SS	**Cycle** annual	**Duration** 2 terms
Course / Course Name a) Research Seminar b) Geoscience Colloquium		**Presence** a) 2 wh / 60 h b) 2 wh / 60 h (30 h each term)	**Private study** a) 30 h b) 0 h		**Participants** a) 30 b) 30

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

In-house seminars provide a platform for further geoscientific conversation and for gaining insight in up-to-date geologic research.

The individual qualifications and skills of the module are specified below:

a) The students participating in the research seminar improve their abilities of presenting scientific topics. They defend their results in scientific discussions. They identify possible flaws, misinterpretations or inconsistencies in their own work and in those of other lecturers. Students critically dispute scientific topics and use the correct geological terminology.

b) The geosciences colloquium of the institute is held weakly and is regarded as the "*Window to the world of geosciences*" for students. Internationally renowned researchers covering a wide spectrum of different research and applied geo-topics are invited and give high-level talks. The participating students identify up-to-date research topics, improve their state of knowledge, become inspired by convincing forms of presentation and contribute to scientific discussions. Finally, they recognize possible fields of work for their future professional life and are able to establish contacts to the researchers.

Syllabus

a) The research seminar is a platform for presenting current in-house research topics. It is expected that students present results of their B.Sc. thesis, M.Sc. thesis or results of other recent research of general interest. On a regular basis doctorate students report on their current state of their Ph.D projects. Likewise staff scientists contribute to the research seminar by presenting conference talks, etc. The research seminar is aimed at inspiring scientific debates between students and staff scientists. A further objective is to inform students about the research topics that are addressed in the institute.

b) Presentations on up-to-date research topics, presented by invited and often internationally renowned speakers. The scientific spectrum comprises research topics of the institute (e.g. impact, planetology, structural geology, earth history, mineral, ore and oil deposits, geohazards, geothermal energy, environmental mineralogy, hydrology, geochemistry, crystal growth) and other branches of geosciences. To enhance the practical aspect of the curriculum speakers from companies and industries are specifically welcome.

Teaching form

a) Seminar with occasion for discussion

b) Seminar with occasion for discussion

Examination form

Achievement of learning goals (unmarked): a) Regular attendance, own presentations; b) Regular attendance

Examination: ---

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Pending on the topic of the seminar/colloquium, resp.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.7 Advanced Geochemistry

Module Coordinator	Lecturer
Prof. Dr. W. Siebel	a) Prof. Dr. W. Siebel b) Prof. Dr. W. Siebel

Type	Workload	Credits	Term	Cycle	Duration
C Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	WS	annual	1 term

Course / Course Name	Presence	Private study	Participants
a) Geochemical Evolution of the Earth's Mantle and Crust b) Marine Geochemistry	a) 2.4 wh / 36 h b) 1.6 wh / 24 h	a) 54 h b) 36 h	a) 25 b) 25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

The module contains two courses. Course a) gives insight into the composition and evolution of the Earth's mantle and crust. Course b) covers the key aspects of marine geochemistry and provides the student with the basic oceanographic concepts. The individual qualifications and skills of the module are specified below:

a) The silicate Earth encompasses the crust and mantle. On successful completion of the course students should be able to know how these two major reservoirs were created and modified over geological time and about the magmatic processes which lead to their present composition. Basaltic rocks from mid-ocean ridges and intraplate volcanoes place constraints on the composition of the underlying mantle the presence of small- or large-scale heterogeneities. Subduction zone volcanism causes the large earthquakes and volcanic hazard but it also helps to understand the processes which lead to the formation and composition of the continental crust.

b) In this course students will develop skills for understanding the basic principles and theories associated with the geochemical processes occurring in the oceans. The student will be familiar with sources and sinks of chemical elements or compounds, their distributions and their variability in the oceanic system and also gather an understanding of how marine and coastal environments are impacted by natural climate variability or human activities.

Syllabus

a) The course provides essential insight into magmatic processes associated with plate boundary environments (mid-ocean ridges and subduction zones) and within plate regions (ocean islands and volcanic plateaus). The geochemical and isotopic composition of the different mantle reservoirs will be discussed and magmatic and tectonic processes along subduction zones will be explored. The lecture also focusses on fundamental processes that gave rise to the characteristic geochemical features of the continental crust and the different mantle reservoirs. These topics provide the basis for homework questions and student reports.

b) This course provides an introduction to the concepts, the methods and the applications of marine geochemistry. Teaching topics include basic oceanographic principles operating in the marine realm, ocean basin bathymetry, the chemical properties of seawater, trace elements and isotopes and their distribution in the water column, the marine carbon cycle, ocean circulation, hydrothermal processes and life on the sea floor, as well as formation and distribution of marine sediments. Marine mineral resources and environmental issues will also be covered.

Teaching form

a) Lecture

b) Lecture

Examination form

Achievement of learning goals (unmarked): a) + b) Regular attendance

Examination: One marked written examination

Prerequisites for attending

Usage of the module in other programs

Recommended reading

a) Allègre, J.C. (2008): Isotope Geology. Cambridge University Press, Cambridge, 512.

White, M.W. (2013): Geochemistry. Wiley-Blackwell, New York, 637.

White, M.W. (2015): Isotope Geochemistry. Wiley-Blackwell, New York, 496.

b) Roy-Barman, M. & Jeandel, C. (2016): Marine Geochemistry. Oxford University Press, Oxford, 432.

Chester R. & Jickells T.D. (2012): Marine Geochemistry. Wiley-Blackwell, Chichester, 411.

Lecture notes

https://homepages.uni-tuebingen.de/wolfgang.siebel/

3.8 Melts, Magmas, Crystals					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturers** Prof. Dr. D. Dolejš			
Type C Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannual (2017)	**Duration** 1 term
Course / Course Name Melts, Magmas, Crystals		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

The principal objectives of this course are quantitative description of atomistic structure of silicate melts, equilibrium and transport properties of silicate melts, use of liquidus phase diagrams, kinetics of silicate melts related to crystal nucleation and growth, and interpretation of main processes of magma differentiation based on mass balance of major and trace elements. The students learn how to processes analytical geochemical data from igneous rocks and identify geological settings of magma formation, and they obtain versatile knowledge of magmatic rock-forming properties in the Earth's crust and mantle.

Syllabus

1. Methods of experimental petrology
2. Structure of silicate melts
3. Physical properties of melts and magmas
4. Melt generation in the Earth
5. Magma differentiation: crystal-melt equilibria
6. Phase equilibrium modeling of magmatic systems: MELTS software
7. Geothermobarometry of igneous rocks
8. Crystal nucleation and growth
9. Crystallization, crystal size distribution and rheological thresholds
10. Magma differentiation: mechanical dynamics
11. Volatiles in silicate magmas, fluid exsolution and degassing
12. Dynamics of volcanic eruptions

13. Magma fragmentation and pyroclastic products

Teaching form

Lecture (2 wh), Practical sessions and software modeling (2 wh)

Examination form

Achievement of learning goals (unmarked): homework assignments and projects

Examination: one marked written examination

Prerequisites for attending

Usage of the module in other programs

Elective module in the Master program Sustainable Materials / Crystalline Materials

Recommended reading

Winter, J.D. (2009): Principles of Igneous and Metamorphic Petrology. Prentice Hall, New York, 702.

Philpotts, A. & Ague, J.J. (2009): Principles of Igneous and Metamorphic Petrology. Cambridge University Press, Cambridge, 684.

Best, M.G. (2002): Igneous and Metamorphic Petrology. Blackwell, Malden/Mass, 752.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.9 Minerals, Transformations, Reactions					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturer** Prof. Dr. D. Dolejš			
Type C Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannual (2018)	**Duration** 1 term
Course / Course Name Minerals, Transformations, Reactions		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

The students acquire ability to identify solid-state reactions for a wide pressure-temperature range of regional and contact metamorphic conditions, and perform chemographic analysis of mineral assemblages. They learn principles of mineral thermodynamics, inverse modeling and geothermobarometry including working knowledge of software packages Thermocalc, Theriak and Perplex. Attention will be paid to deformation mechanisms in natural rocks and interpretation of deformation and recrystallization textures in the polarization microscope. Students will be able to interpret metamorphic conditions associated with diverse tectonic settings in the lithosphere.

Syllabus

1. Crystal chemistry of rock-forming minerals
2. Thermodynamics of minerals and geological fluids
3. Activity-composition relations of silicates, oxides and carbonates
4. Formulation of thermodynamic models for rock-forming minerals
5. Inverse equilibrium modeling: session with Thermocalc
6. Metamorphic phase diagrams: session with Perplex/Theriak
7. Chemical potentials and reaction affinity as driving forces for phase transformations
8. Reaction kinetics and diffusion
9. Plastic deformation, deformation laws and paleopiezometry
10. Rheology of polycrystalline rocks and aggregates

11. Metamorphic devolatilization and open systems
12. Interpretation of fluid fluxes using reaction progress 13. Continental tectonics and metamorphism

Teaching form

Lecture (2 wh), Practical session, individual projects and software modeling (2 wh)

Examination form

Achievement of learning goals (unmarked): homework assignments and projects

Examination: written examination

Prerequisites for attending

Usage of the module in other programs

Elective module in the Master programs Sustainable Materials-Crystalline Materials, Chemistry-Inorganic Chemistry / Physical Chemistry

Recommended reading

Winter, J.D. (2009): Principles of Igneous and Metamorphic Petrology. Prentice Hall, New York, 702.

Philpotts, A. & Ague, J.J. (2009): Principles of Igneous and Metamorphic Petrology. Cambridge University Press, Cambridge, 684.

Vernon, R.H. & Clarke G.L. (2009): Principles of Metamorphic Petrology. Cambridge University Press, Cambridge, 446.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.10 Advanced Analytical Methods

Module Coordinator		Lecturers			
Dr. H. Müller-Sigmund		a) Dr. H. Müller-Sigmund; Dr. M. Junge b) PD Dr. A. Danilewsky; Dr. L. Kirste			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term

Course / Course Name	Presence	Private study	Participants
a) Advanced Analytical Methods b) High-Resolution Spectroscopy	a) 3 wh / 45 h b) 2 wh / 30 h	a) 15 h b) 60 h	a) 9 b) 15

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

This module provides practical and theoretical skills in advanced analytical methods important for geological materials. Individual qualifications and skills obtained within this module are specified below:

a) Students are able to prepare rocks and minerals for specific analytical applications. They employ techniques like cathode luminescence, heating-freezing stage for fluid inclusion studies, or reflected light microscopy on various sample materials. They amplify their knowledge in X-ray techniques and are able to deduce on the composition and formation conditions of these samples.
b) For course information please see the current M.Sc. Sustainable Materials – Crystalline Materials guide book at:

http://www.cup.uni-freiburg.de/chemie/studium/msc_Crystalline%20Materials/Studium

Syllabus

a) The emphasis of this course is on important mineralogical techniques used in ore geology, petrology, geomaterials, soil science, and environmental science. Students explore various methods, e.g. cathodoluminescence, fluid inclusions on heating-freezing stage, reflected light microscopy, clay mineral preparation techniques, confocal laser scanning microscopy, both in theory and in the laboratory, where hands-on experience is an essential part of the course.

b) For course information please see the current M.Sc. Sustainable Materials – Crystalline Materials guide book at:

http://www.cup.uni-freiburg.de/chemie/studium/msc_Crystalline%20Materials/Studium

Teaching form

a) Lecture + laboratory sessions (small groups of 2-3 students)
b) For course information please see the current M.Sc. Sustainable Materials – Crystalline Materials guide book at:

http://www.cup.uni-freiburg.de/chemie/studium/msc_Crystalline%20Materials/Studium

Examination form

Achievement of learning goals (unmarked): a) presence; b) Analysis of experimental data

Examination: Portfolio Examination: Written reports on a) and written test on b)

Prerequisites for attending

Research Methods in Geosciences – Laboratory Methods in Geomaterials

Usage of the module in other programs

Recommended reading

a) Craig, J.R. & Vaughan, J.R. (1994): Ore microscopy and ore petrography. Wiley, New York, 434.

Moore, D.M. & Reynolds, R.C. (1995): X-ray diffraction and the identification and analysis of clay minerals. Oxford University Press, Oxford, 378.

Pagel, M., Barbin, V., Blanc, P. & Ohnenstetter, D. (2000): Cathodoluminescence in geosciences. Springer, Berlin, 517.

Shepherd, T.J., Rankin, A.H. & Allldertons, D.H.M. (1985): A practical guide to fluid inclusion studies. Blackie, Glasgow, 239.

b) For course information please see the current M.Sc. Sustainable Materials – Crystalline Materials guide book at:

http://www.cup.uni-freiburg.de/chemie/studium/msc_Crystalline%20Materials/Studium

Lecture notes

https://ilias.uni-freiburg.de/login.php, http://www.krist.uni-freiburg.de/service/edv.php

3.11 Fluid-Rock Interaction

Module Coordinator		Lecturer			
Prof. Dr. D. Dolejš		Prof. Dr. D. Dolejš			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Fluid-Rock Interaction		4 wh / 60 h	90 h		15

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Aqueous fluids, from the Earth's surface to the deep lithosphere, are among the most important mass and energy transport agents on Earth. The processes of interaction of rocks with water and other aqueous fluids from groundwater systems to geothermal and hydrothermal conditions are subject of this module. The individual qualifications and skills of the module are as follows:

Students acquire detailed knowledge of global cycle of water and aqueous fluids in the lithosphere. They learn how to express and process geochemical data from natural and hydrothermal waters, calculate and interpret their speciation at ambient and elevated temperatures and pressures. They are able to relate mineral solubilities to water composition through predominance and activity diagrams and to quantitatively interpret weathering reactions and mass fluxes. They learn how mineral solubilities change with temperature, pressure and presence of complexing ligands, which underlies rock alteration along fluid flow pathways. They acquire working knowledge of mass balancing in altered and metasomatic rocks and can quantitatively evaluate mass changes and element transport in hydrothermal and ore-forming systems.

Syllabus

1. Global water cycle and fluid reservoirs
2. Principles of chemical equilibria in aqueous systems
3. Stability of ions in aqueous solutions
4. Speciation in aqueous carbonate, oxide and silicate systems

5. Activity-activity diagrams
6. Chemistry of surface waters and mass balance of weathering
7. Thermodynamics of aqueous species in hydrothermal systems
8. Ligands, complexes and speciation in high-temperature solutions
9. Mineral-fluid reactions in temperature-pressure gradients
10. Mechanisms of fluid migration and reactive fluid flow in rock environment
11. Geochemistry of altered rocks and mass changes

Teaching form

Lecture (2 wh), practical session (2 wh)

Examination form

Achievement of learning goals (unmarked): practical assignments

Examination: portfolio examination, consisting of homework assignment and written exam

Prerequisites for attending

Usage of the module in other programs

M.Sc. Environmental Sciences, Hydrology and Renewable Energy Management

Recommended reading

Drever, T. (1998): The Geochemistry of Natural Waters. Prentice Hall, Upper Saddle River, 440 p.

Langmuir, D. (1997): Aqueous Environmental Geochemistry. Prentice Hall, Upper Saddle River, 600 p.

Stumm, W., Morgan, J. J. (1996): Aquatic chemistry. Wiley, New York, 1022 p.

Anderson, G.M. (2005): Thermodynamics of Natural Systems. Cambridge University Press, Cambridge, 648 p.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.12 Isotope Geochemistry					
Module Coordinator Prof. Dr. W. Siebel		**Lecturer** Prof. Dr. W. Siebel			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Isotope Geochemistry		4 wh / 60 h	90 h		16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

The individual qualifications and skills of the module courses are specified as follows:

Students learn about the principles of stable and radiogenic isotopes. They realize that isotopes are indispensable tools for reconstructing various Earth processes, palaeo-environmental conditions and for radiometric dating. They examine a variety of isotope systems and dating techniques, and become familiar with possible sources of error. Several lectures include classroom exercises on the same topic. At the end of the course the students will be familiar with the fundamentals of isotope geochemistry and know which isotopic system is suitable to solve a certain geological problem. She/he will also be able to interpret isotope data and understand Earth processes through isotope geochemistry.

Syllabus

The focus is on stable and radiogenic isotope systems and their principles and applications in geology and environmental science. Topics and systems include:

Principles of the K-Ar, Ar-Ar, U-Th-Pb, Rb-Sr and Sm-Nd dating methods, Uranium-series geochemistry; isotopes as tracers of sources and processes; presentation of case studies, isotopes and their measurement techniques, fractionation of stable isotopes and its applications

Teaching form

Lecture and exercises

Examination form

Achievement of learning goals (unmarked): regular attendance

Examination: one marked written examination

Prerequisites for attending

Recommended: basic knowledge in geochemistry at the level to B.Sc. course “Geochemistry”

Usage of the module in other programs

Recommended reading

Allègre, J.C. (2008): Isotope Geology, Cambridge University Press, Cambridge, 512.

Bourdon, B., Henderson, G.M., Lundstrom, C.C. & Turner, S.P. (Eds.) (2003): Uranium-series geochemistry. Geochemical Society, Washington D.C., 656.

Faure, G. & Mensing, T.M. (2005): Isotopes: Principles and Applications. Wiley, New York, 896.

Dickin, A.P. (2005): Radiogenic isotope geology: Cambridge University Press, Cambridge, 492.

Hoefs, J. (2004): Stable isotope geochemistry. Springer, Berlin/Heidelberg/New York, 244.

Sharp, Z.D. (2006): Principles of stable isotope geochemistry. Pearson, Prentice Hall, Upper Saddle River NJ, 360.

Lecture notes

https://homepages.uni-tuebingen.de/wolfgang.siebel/

https://ilias.uni-freiburg.de/login.php

3.13 Petrophysics					
Module Coordinator Prof. Dr. T. Kenkmann		**Lecturers** a) Prof. Dr. T. Kenkmann; Dr. M. Poelchau b) Dr. M. Poelchau			
Type E Geomat. and Processes C Rock Mech. and Geodyn. E Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannual (alternating with "Rock Mechanics")	**Duration** 1 term
Course / Course Name a) Petrophysics b) Rheology and Textures		**Presence** a) 2 wh / 30 h b) 2 wh / 30 h	**Private study** a) 45 h b) 45 h		**Participants** 40 40

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

a) The successful student is getting acquainted with the petrophysical properties of the most important rock types. They quantitatively determine and measure porosities, mineral constituents, fabric of rocks etc. and correlate them with petrophysical data. Students are enabled to interpret petrophysical borehole data with respect to lithology, porosity, structure, and economic potential.

b) Students will describe rock fabrics and mineral constituents of metamorphic and igneous rocks making use of polarizing microscopes. They will identify and describe shape-preferred orientations as well as crystallographic preferred orientations. They will recall and apply techniques to measure rock textures and interpret pole figures and orientation distribution functions. Based on rock textures and fabric analysis the successful students are able to decipher deformation mechanisms and associated flow laws of natural rocks and estimate the conditions during deformation (pressure, temperature, strain, strain rate).

Syllabus

a) Petrophysics is the study of the physical properties of rocks. Its objective is to explain why rocks have the properties they do. In particular how the relative amounts and arrangements of the minerals that comprise them determine their physical properties. Petrophysics is key in numerous applications of geosciences and various fields of rock engineering and well logging. The course program comprise of the following sections: (i)Rock classifications, (ii) Density, (iii) Porosity & Permeability, (iv) Radioactive Properties, (v) Geomechanical Properties (vi) Electrical properties, (vii) Magnetic properties, (viii) Well-logging.

b) Rheology is the study of the flow of matter. In Earth Sciences the focus of rheology is on the ductile flow of mid- and lower crustal rocks in response to applied forces at elevated temperatures. This course is designed to introduce the theory of plasticity and presents various flow laws (Newtonian, power law, etc.) of rocks and how these were determined. The flow behavior is compared with deformation mechanisms operating in the ductile field (diffusion creep, dislocation creep, dislocation glide, etc.). A major goal of the course is to gain practice in interpreting deformation features observed in rock thin sections under the polarizing microscope. A crucial role in deciphering deformation mechanisms is the analysis of shape- and crystallographic preferred orientations of deformed polycrystalline aggregates. Techniques are presented how rock textures can be measured and interpreted.

Teaching form

a) Lecture + Exercises/Homework

b) Lecture and practical work at the polarizing microscope

Examination form

Achievement of learning goals (unmarked): a) Regular attendance and completion of exercises; b) Regular attendance, project work

Examination: Portfolio Examination: the marks are derived by combining the scores achieved in the written test at the end of the semester part (a) (70%), and the presentation the project work (b) (30%).

Prerequisites for attending

Experience in polarized light microscopy is beneficial.

Usage of the module in other programs

Recommended reading

a) Schön, J.H. (2015): Physical Properties of Rocks—Fundamentals and Principles of Petrophysics. Elsevier, Amsterdam, 496.

Schön, J.H. (2015): Basic well logging and formation evaluation. 179. Bookboon e-book (free download)

Cannon, S. (2016): Petrophysics: A Practical Guide. Wiley-Blackwell, Chichester, 204.

Zoback, M.D. (2010): Reservoir Geomechanics. Cambridge University Press, Cambridge, 448.

b) Passchier, C.W. & Trouw, R.A.J. (1996): Microtectonics. Springer, Berlin, 289.

Fossen, H. (2016): Structural Geology. Cambridge University Press, Cambridge, 510.

Urai, J.L., Means, W.D., & Lister, G.S. (1986): Dynamic recrystallization of minerals. Mineral and rock deformation: laboratory studies: The Paterson volume, American Geophysical Union, Washington, D. C., 161-199.

Lecture notes

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3.14 Planetary Dynamics					
Module Coordinator Prof. Dr. T. Kenkmann		**Lecturers** Prof. Dr. T. Kenkmann; Dr. G. Wulf			
Type E Geomat. and Processes C Rock Mech. and Geodyn. E Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannual (alternating with "Impact Geology")	**Duration** 1 term
Course / Course Name Planetary Dynamics		**Presence** 3 wh / 45 h	**Private study** 105 h		**Participants** 25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

The rapid technological development in remote sensing and the substantial progress in space exploration deliver geoscientists with a vast amount of new geological information on the great number of planets, moons, dwarf planets, asteroids and comets of our solar system. The implementation of planetary geology is a unique selling point of Freiburg´s Master Geology program in Germany.

The individual qualifications and skills of the module are specified below:

Why is the Solar System the way it is? Students attending the course successfully know why. The students describe the planetary bodies by means of their physical, chemical, and astronomical boundary conditions. They can interpret surface features and conclude on dynamic interior and exterior geological processes that are dominant on and within these bodies. The students apply remote sensing techniques in combination with geo-information systems (GIS) to unravel the history of planets. Students understand that the evolution of the Earth and life to its present state is a consequence of a specific set of planetary boundary conditions. Students recapitulate the strategies, boundary conditions, requirements and major findings of various space missions.

Syllabus

Understanding Earth requires a planetological perspective. The course starts with a grand tour through our solar system. The formation (accretion, differentiation) of the solar system and the planetological boundary conditions and physical properties of planetary bodies are given. Our knowledge on the solar system is closely linked with the technological development of space craft and exploration techniques.. The practical course deals with remote sensing methods and imagery. Students shall interpret planetary surfaces by means of active geological processes. Volcanic eruptions and tectonic activities of terrestrial planets are linked with the interior structure of these bodies. Planetary surface processes (fluvial, aeolian, impact) and atmospheres are further topics that are compared between different planetary bodies. Minor bodies in the Solar system of the asteroid belt, the Kuiper belt and the Oort cloud are investigated as well. The giant planets of the outer solar system and their satellites complete the introduction to the solar system.

Teaching form

Lecture with audio-visual demonstrations, numerical simulations and high speed videos of experiments. Practical part partly at the polarizing microscope. Investigation of impactite rocks and meteorites. Exercises. Each participant presents a space mission in an oral and written contribution.

Examination form

Achievement of learning goals (unmarked): completion of exercises, oral presentation and report

Examination: Portfolio Examination: Written examination (70 %), and excercises (30%)

Prerequisites for attending

Standard knowledge in computational geosciences

Usage of the module in other programs

Recommended reading

McBride, N. & Gilmour, I. (eds.) (2003): An introduction to the solar system. Open University, Cambridge University Press, Cambridge, 412.

McSween, H.Y. (1999): Meteorites and their parent planets. Cambridge University Press, Cambridge, 309.

Beatty, J.K. & Chaikin, A. (eds.) (1990): The new solar system. Cambridge University Press, Cambridge, 326.

Taylor, S.R. (1993): Solar System Evolution. A new perspective. Cambridge University Press, Cambridge, 307.

Watters, T.R. (Ed.) (2010): Planetary Tectonics. Cambridge University Press, Cambridge, 518.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.15 Rock Mechanics					
Module Coordinator Dr. M. Poelchau		**Lecturers** a) Prof. Dr.T. Kenkmann; Dr. J. Wilk b) Dr. M. Poelchau; Prof. Dr. T. Kenkmann			
Type E Geomat. and Processes C Rock Mech. and Geodyn. E Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannual (alternating with "Petro-physics)	**Duration** 1 term
Course / Course Name a) Stress and Strain b) Brittle Rock Deformation		**Presence** a) 2 wh / 30 h b) 2 wh / 30 h	**Private study** a) 45 h b) 45 h		**Participants** a) 25 b) 25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

The individual qualifications and skills of the module are specified below:

a) The successful student is getting acquainted with matrix calculations to calculate principal stress and strain states in rocks and to determine orientation of the principal axis of stress and strain. Students use graphical techniques to determine normal and shear stresses. Students become familiar with various methods of paleo-stress measurement and the measurement of recent stress fields in the crust. The quantification of strain accumulated in rocks is trained as well. Students get familiar with connecting stress and strain is linear isotropic elastic materials.

b) Students become familiar with the concepts of rock deformation and know how to derive rock mechanical characteristics such as the tensile strength, uniaxial compressive strength, Mohr-Coulomb strength, dynamic and static friction, Poisson ratio, Young Modulus, Tangent Modulus, and the dynamic increase factor.

Syllabus

a) Forces which are responsible for the deformations of the earth's crust act instantaneously and cannot be stored in rocks through time. Deformations of rocks are persistant and all the studied deformations are old, but the related stresses are not visible any more. Furthermore it is impossible to measure stress directly and only very special fabrics allow to describe state and direction of stresses. Nevertheless, one of the major goals of the lecture is to understand the distribution of forces in the earth and how those forces act to produce the different structures. There are lots of practical reasons to do this: earthquakes, oil well blowouts, motor of plate tectonics, landslides etc. The deals with stress acting on a plane and stress at a point leading to the concept of principle and deviatoric stresses, which mathematically are described by stress tensor and 3x3 stress matrix. Different states of stresses and stress fields are introduced and presented methods of measurements include fault-slip analysis, stylolites, wellbore break-out, etc. The strain concept is mathematically based on continuous deformation thus strain is a branch continuum mechanics. In nature deformation is much more complex and far beyond being continuous. In this lecture all different aspects of a deforming rock system are introduced i.e. homogeneous vs. heterogeneous strain, progressive strain, infinitesimal vs. finite strain. We introduce to various quantitative strain measurement techniques including Fry and Rf-phi.

b) Brittle rock deformation is concerned with evaluating, through controlled laboratory experiments, the effects of environmental and material factors on the deformational behavior of rocks. The course deals with rock elasticity, friction, various modes of brittle failure, brittle-to-ductile transition, plastic deformation, and dynamic deformation. The course consists of a theoretical part and a practical part.

Teaching form

a) Lecture + Exercises, calculation the state of stress by means of tensor calculations

b) Lecture, exercises and laboratory work

Examination form

Achievement of learning goals (unmarked): a) Homework; b) Report of the experimental analyses

Examination: Portfolio Examination: Written examination about a) (60 %) + b) (30%) and lab report about b) (10 %)

Prerequisites for attending

Computing in Geosciences

Usage of the module in other programs

Recommended reading

a) Bayly, B. (1991): Mechanics in structural geology. Springer, New York, 253.

Means, W.D. (1976): Stress and Strain. Springer, New York, 339.

Nelson, R.A. (2001): Geologic analysis of naturally fractured reservoirs. Gulf Publishing Company, Houston, 352.

Pollard, D.D. & Fletcher, R.C. (2005): Fundamentals of Structural Geology. Cambridge University Press, Cambridge, 512.

Fossen, H. (2010): Structural Geology. Cambridge University Press, Cambridge, 463.

Ramsay, J.G. & Huber, M.I. (1983): The techniques of modern structural geology Vol 1: Strain Analysis. Academic Press, London, 307.

Ramsay, J.G. & Lisle, R.J. (2000): The techniques of modern structural geology Vol 3: Applications of continuum mechanics in structural geology. Academic Press, London, 360.

b) Paterson, M.S. & Wong, T.-F. (2005): Experimental Rock Deformation: The Brittle Field. Springer, Berlin, 347.

Jaeger, J.C., Cook, N.G.W. & Zimmerman, R.W. (2011): Fundamentals of Rock Mechanics. Blackwell Publications, Malden MA, 175.

Lecture notes

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3.16 Engineering Geology and Geotechnics

Module Coordinator		Lecturers			
Prof. Dr. F. Preusser		a) Dr. J. Miocic b) Dr. J. Miocic; Prof. Dr. F. Preusser			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes C Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Introduction to Engineering Geology b) Geotechnical Projects		a) 2 wh / 30 h b) 2 wh /30 h	a) 45 h b) 45 h		a) 16 b) 16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Many students will find work in the field of engineering and environmental geology. This course aims at providing the necessary basic background in this field. Attendees will be familiar with the basic concepts, nomenclature and problems of applied geology and hence should be able to communicate about and approach applied aspects in geosciences.

Syllabus

a) The course will introduce basic concepts, nomenclature and problems of applied geology with a focus on physical properties of unconsolidated sediments (soils). This will be combined with some practical work on basic methods and approaches.

b) Students will put together an oral presentation on a selected geotechnical projects and will present and discus this in class.

Teaching form

a) Lecture mixed with practical exercises

b) Seminar

Examination form

Achievement of learning goals (unmarked): a) Active participation in the exercises; b) Attendance of the seminar

Examination: Portfolio Examination: Written or oral examination about a) (60 %), lab report about a) (10 %) and oral presentation about b) (30 %)

Prerequisites for attending

Basic knowledge in Earth Sciences

Usage of the module in other programs

Recommended reading

Bell, F.G. (1995): Engineering Geology, Blackwell Science, Oxford, 359.

Lecture notes

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3.17 Geophysics					
Module Coordinator Prof. Dr. S. Hergarten		**Lecturers** Prof. Dr. S. Hergarten, NN			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes C Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Near-Surface Geophysics		3 wh / 45 h	105 h		25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Geophysical methods of subsurface exploration have received a growing interest in many fields of geosciences during the previous decades. The module provides a basic understanding of the geophysical methods most relevant for the exploration of the shallow subsurface. The students learn which of the techniques is most appropriate under given conditions, to analyze the respective field data, and how to use the available instruments.

Syllabus

The module focuses on the methods most relevent for the exploration of the shallow subsurface:

- seismics
- resistivity methods
- geomagnetics
- ground-penetrating radar

Both the theory behind the methods and the respective techniques of data analysis are considered. Understanding is deepened by exercises in the class, homework, and experiments in field.

Teaching form

Lecture accompanied by homework and field experiments.

Examination form

Achievement of learning goals (unmarked): ---

Examination: Portfolio Examination: Homework to be solved during the semester including reports of the field work (60%), and a short written test at the end of the semester (40%).

Prerequisites for attending

Basic knowledge in programming (MATLAB) at the level of the module 3.1 "Computing in Geosciences".

Usage of the module in other programs

Recommended reading

Telford, W.M., Geldard, L.P. & Sheriff, R.E. (1991): Applied Geophysics. Cambridge University Press, Cambridge, 792.

Burger, H.R., Sheehan, A.F. & Jones, C.H. (2006): Introduction to Applied Geophysics: Exploring the Shallow Subsurface. W.W. Norton & Company, New York, 554.

Lecture notes

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<table>
<tr><td colspan="6">3.18 Hydrogeology</td></tr>
<tr><td colspan="2">Module Coordinator
Prof. Dr. David Dolejš</td><td colspan="4">Lecturers
a) Prof. Dr. Ingrid Stober
b) Prof. Dr. David Dolejš</td></tr>
<tr><td>Type
E Geomat. and Processes
C Rock Mech. and Geodyn.
E Geohazards</td><td>Workload
150 h</td><td>Credits
5 ECTS</td><td>Term
SS</td><td>Cycle
annual</td><td>Duration
1 term</td></tr>
<tr><td colspan="2">Course / Course Name
a) Advanced Hydrogeology
b) Aqueous Geochemistry</td><td>Presence
a) 2 wh / 30 h
b) 2 wh / 30 h</td><td colspan="2">Private study
a) 60 h
b) 60 h</td><td>Participants
a) 25
b) 25</td></tr>
</table>

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Water is a ubiquitous component and resource on the Planet Earth. Its diverse physical and chemical roles are best seen in its reservoir properties, flow dynamics, geothermal systems or ore formation by hydrothermal processes. This module concentrates on processes of interaction between rocks and water and other aqueous fluids near the Earth's surface. In this module students acquire detailed knowledge of hydrochemical cycle of water and aqueous fluids in the lithosphere. They will understand hydraulic principles, which govern flow in permeable rocks and control available water supplies. They learn and interpret hydraulic and hydrochemical properties of diverse rock formations, ranging from sedimentary cover to crystalline basement, with examples from southwestern Germany and applications to geothermal energy systems. The students will be able to process geochemical data from natural waters, calculate and interpret their speciation and to derive and evaluate fundamental equilibrium and kinetic processes, which govern the composition of natural waters by weathering, dissolution and precipitation reactions.

Syllabus

a) This course Advanced Hydrogeology covers advanced aspects of hydrogeology and fluid flow in the lithosphere. It focuses on reservoir properties, dynamics of groundwater flow in permeable and fractured rocks, water supply, hydraulic and hydrochemical properties of various rock formations, and applications to geothermal systems. The latter topics provide links to exploitation of geothermal energy or environmental geochemistry.

b) The course Aqueous Geochemistry focuses on chemical aspects of interaction between water and rock environment. Students are introduced to global hydrogeological cycle, types of water and other fluids in the lithosphere and their chemical composition, speciation of dissolved substances and chemical equilibria in aqueous solutions as well as interaction of water with silicate, oxide and carbonate minerals. The course closes with composition of surface and groundwater and origin of their solutes during weathering and alteration processes in nature.

Teaching form

a) lecture and seminar, discussion of results

b) lecture and practical session

Examination form

Achievement of learning goals (unmarked): in-class and homework assignments

Examination: marked written exam

Prerequisites for attending

Usage of the module in other programs

Recommended reading

a) Bear, J. (1979): Hydraulics of Groundwater. McGraw-Hill, New York, 567.

b) Drever, J.I. (1998): The Geochemistry of Natural Waters. Prentice Hall, Upper Saddle River, 436 p.

Langmuir D. (1997): Aqueous Environmental Geochemistry. Prentice Hall, Upper Saddle River, 600 p.

Lecture notes

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3.19 Volcanic Hazards

Module Coordinator		Lecturers			
Prof. F. Preusser		a) Dr. V. May b) Prof. F. Preusser; Dr. J. Miocic			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	WS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Volcanology and Volcanic Hazards b) Volcanic Hazards Case Studies		a) 2 wh / 30 h (as a block course) b) 2 wh / 30 h (as a block course)	a) 30 h b) 60 h		a) 25 b) 25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

The subject is divided into two main blocks one concentrating on volcanology and volcanic hazards (theoretical background) and the second focusing on the current state of research on volcanic hazards (seminar series).

a) This part of the module is designed in a source to surface structure; from the essential processes occurring in the magmatic chamber to how magma erupts and the diversity of volcanic structures on the Earth's surface. During the first half of the semester the students will learn; basic concepts in volcanology, magmatic chamber zonation, lava rheology and its relationship with gases and chemical composition, as well as different types of volcanic eruptions, deposits and structures.

   The second half of the semester links, the volcanic aspects learned during the first half, with the effects of volcanic products on the civilization. During this part, direct and indirect volcanic hazards, as well as the implications of large volcanic eruptions will be learn. In addition, key concepts in in volcano monitoring and volcano risk assessment will be discussed.

   The students should develop a good understanding of volcanic processes, forms, deposits and hazards. Also, they will develop poster presentation skills.

b) The volcanic hazards seminar series, aims to provide a solid overview of the current research on volcanic hazards as well as to aid in developing critical thinking. In addition, the volcanic hazards case studies seminar provides the students with the opportunity to conduct their own research project. The students should develop in-depth knowledge of an aspect of volcanic hazards research.

Syllabus

a) The first part focuses on basic concepts in volcanology from melting to volcanic edifices and sediments. During the second half several aspects of volcanic hazards will be discussed.

b) During the seminar, open discussion on an aspect of volcanic hazards will be conducted. Each student will have the opportunity to research on the hazards of a particular volcano.

Teaching form

a) Lecture

b) Seminar and presentation

Examination form

Achievement of learning goals (unmarked): Regular attendance

Examination: Portfolio Examination: Written exam about a) (40 %), Presentation about b) (30 %) and final report about b) (30%)

Prerequisites for attending

Usage of the module in other programs

Recommended reading

a) Parfitt, E.A., & Wilson, L. (2009): Fundamentals of physical volcanology. Blackwell, Maldem, Mass., 230.

b) Lockwood, J.P., & Hazlett, R. W. (2010). Volcanoes: Global Perspectives. Wiley-Blackwell, Chichester, 539.

Lecture notes

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3.20 Earthquakes and Tsunamis

Module Coordinator		Lecturer			
Prof. Dr. S. Hergarten		Prof. Dr. S. Hergarten			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	WS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Seismology and Seismic Hazard b) Tsunamis		a) 2 wh / 30 h b) 1 wh / 15 h	a) 90 h b) 15 h		a) 25 b) 25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Earthquakes and tsunamis are among the most important natural hazards on Earth. However, the respective theory is extensive and rather complicated, and information on earthquakes and tsunamis propagated in the media is often incorrect. The module attempts to provide an understanding of those parts of the theory with particular relevance for understanding earthquakes and tsunamis as geohazards. The successful students shall be able to understand und interpret scientific results on historical and recent events as well as hazard assessments provided in the literature in a realistic way.

Syllabus

a) The class combines the classical theory of seismology (wave propagation) with geological and statistical aspects comprising the following topics:
  - Types of elastic waves and theory of wave propagation
  - Focal mechanisms; seismic moment tensor
  - Localization of earthquakes
  - Earthquake intensity and magnitude; different definitions of magnitude and their relevance

  The presented theory is accompanied by exercises.

b) The lecture covers the basic princples of tsunami generation and propagation in the ocean:
  - Types of waves in water and their fundamental properties

- Seismic and nonseismic tsunami sources
- Velocity of propagation; wave height; interaction with the coast
- Registration and warning systems

Teaching form

a) Lecture with additional assignments deepening the understanding of the theoretical concepts.

b) Lecture

Examination form

Achievement of learning goals (unmarked): ---

Examination: Portfolio Examination: Homework to be solved during the semester (a, 60%) and a written test at the end of the semester (a+b. 40%).

Prerequisites for attending

Basic knowledge in mathematics and computing, e.g., on the level of "Modellierung und Datenanalyse" from the B.Sc. Geowissenschaften Curriculum.

Usage of the module in other programs

Recommended reading

a) Lay, T. & Wallace, T.C. (1995): Modern Global Seismology. Academic Press, San Diego, 521.

Shearer, P.M. (2009): Introduction to Seismology. Cambridge University Press, Cambridge, 412.

b) Levin, B. & Nosov, M. (2016): Physics of Tsunamis. Springer, Dordrecht, 388.

Kusky, T.M. (2008): Tsunamis - Giant Waves from the Sea. Facts on File, New York, 134.

Lecture notes

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3.21 Impact Geology					
Module Coordinator Prof. Dr. T. Kenkmann		**Lecturers** Prof. Dr. T. Kenkmann, Dr. M. Poelchau			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	WS	biannual (alternating with “Planetary Dynamics”)	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Impact Geology		4 wh / 60 h	90 h		40

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Students will be able to estimate the statistical risk and threat of impact events and know the basics of Near Earth Asteroids and NEO-monitoring. The successful student can recapitulate the short-term geological and physical processes that occur during an impact. Students will deduce impact energies from crater morphologies and are able to determine the age of a planetary surface by measuring the size-frequency distribution of impact craters on it. They will be able to correctly describe impact lithologies, impact-induced microstructures, and impact structures. These skills will enable them to become competent in discovering new impact structures on Earth using remote sensing techniques, where they will be responsible for planning and conducting their own project (Project “Screening Earth”). Here, they will improve their skills in scientific presentations and defend their ideas in scientific debates. They will learn to prepare the logistics for a scientific expedition. The project helps to complete the terrestrial impact record.

Syllabus

The collision of solid bodies is one of the most fundamental geological processes in our solar system forming and reshaping planetary surfaces. The size-frequency distribution of impact craters on planetary surfaces and the current cratering rate and impact probability are presented including mitigation strategies. Composition and provenance of asteroids, comets and meteorites and their importance as possible impacting projectiles are highlighted. Special emphasis is drawn on Near Earth Asteroids and NEO monitoring. The physics of impact crater formation including contact- and compression, excavation, and modification provide the base for understanding geological phenomena in terrestrial and planetary craters. The principles of the progressive shock metamorphism as well as impact petrography are taught in practical exercises. The course gives introductions to the morphology, structural geology, geophysical characteristics of impact craters, and their environmental effects on the hydrosphere and atmosphere. Modern techniques to investigate impact structures including remote sensing, computational simulation, and experimental methods are shown. Within the "Screening Earth" project, the participants undertake a crater search survey on earth utilizing Google Earth© imagery. Promising structures will be investigated in greater detail using geological maps, geophysical data, and further remote sensing resources. In an oral presentation the students introduce to their projects and assess the likelihood of the discovered structures being impact craters. Students will plan a scientific expedition to their discovered structures.

Teaching form

Lecture, exercises, Screening Earth project with presentation

Examination form

Achievement of learning goals (unmarked): Regular attendance, project

Examination: Portfolio Examination: The marks are derived by combining the scores achieved in the exercises, the presentation of the Screening Earth project, and written test at the end of the semester covering all parts of the module.

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Melosh, H.J. (1989): Impact cratering: a geologic process. Oxford University Press, New York, 245.

French, B.T (1998): Traces of Catastrophe: a handbook of shock-metamorphic effects in terrestrial meteorite impact structures. Lunar and Planetary Institute, Houston, Texas, 120.

McSween, H.Y. (1999): Meteorites and their parent planets. Cambridge University Press, Cambridge, 237.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.22 Climatic Geohazards

Module Coordinator		Lecturers			
Dr. C. Rambeau		a) Dr. C. Rambeau; Dr. J. Miocic b) Dr. C. Rambeau			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Introduction to Climatic Geohazards b) Climatic Geohazards Case Studies		a) 2 wh / 30 h b) 1 wh / 15 h	a) 45 h b) 60 h		a) 24 b) 24

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

This course is divided into two main parts: the first block (a) provides the participants with an introduction to the Earth's climate system and to climate-induced environmental changes, providing a theoretical background to the topic; the second block (b) focuses on case studies and aims to give the participants the opportunity to learn more about specific geohazards through critical literature discussion.

a) This part of the module aims to 1) present briefly the Earth's climate system, 2) present examples of past environmental changes connected to climate variations and 3) focus on natural hazards which can be linked with a changing climate (e.g., fire frequencies, floods and droughts, etc.). This block is composed of a series of lectures giving the participants background information into the topic.

b) Critically reviewing and discussing literature about case studies of past climate geohazards. This course will provide the participants with the bases to understand how climate change can induce geohazards, and how such hazards can be assessed by examining environmental archives. The participants will also develop their skills in critically evaluating scientific publications and presenting in front of an audience.

Syllabus

a) Introduction to Climatic Geohazards: basic concepts of Earth's climate, environmental changes in link with climate variation, and associated geohazards. Introduction to the current state of research, including a critical review of the literature.

b) Case studies: analyzing case studies reported in the literature.

Teaching form

a) Lecture

b) Seminar

Examination form

Achievement of learning goals (unmarked): Regular attendance to courses is compulsory

Examination: Portfolio Examination: Literature review and written report on geohazards (a) (50 %) and Seminar presentation (b) (25 %) and critical paper discussion (b) (25 %)

Prerequisites for attending

Attendance to WS Course "Research Methods in Geosciences"

Usage of the module in other programs

Recommended reading

Ruddiman, W.F. (2014): Earth's climate: Past and Future. W.H. Freeman, New York, 445.

Roberts, N. (2014): The Holocene: An Environmental History. Wiley-Blackwell, Chichester, 364.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.23 Mass Movements					
Module Coordinator Prof. Dr. S. Hergarten		**Lecturer** Prof. Dr. S. Hergarten			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Mass Movements		3 wh / 45 h	105 h		16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Mass movements are the most important type of geohazards in mountainous regions. Assessing hazard and risk related to the various types of mass movements (shallow and deep-seated landslides, rockslides, rockfalls, rock avalanches, debris flows, and snow avalanches) is one of the biggest fields of professional activity in the context of geohazards. The module provides a basic understanding of the respective processes, their representation by differential equations and their implementation in numerical models. The students learn how to implement the simplest versions of the models in own computer codes (MATLAB), to assess which type of model is suitable for a given situation, and where the limitations in application to real-world scenarios are.

Syllabus

The class starts with an overview over the various processes of mass movements and their characteristic properties. Afterwards the basic models of slope stability are discussed (method of slices, Bishop's method). The main part of the module concerns the different types of rapid mass movements (sliding, falling, avalanching) and their quantitative description. Understanding is deepened by exercises covering the range from implementation of simple models to hazard assessment.

Teaching form

Lecture mixed with practical exercises and homework.

Examination form

Achievement of learning goals (unmarked): ---

Examination: Portfolio Examination: homework to be solved during the semester

Prerequisites for attending

Basic knowledge in programming (MATLAB) on the level of the module 3.1 “Computing in Geosciences”.

Usage of the module in other programs

Recommended reading

Bromhead, E. (1992): The Stability of Slopes. Taylor & Francis, London, 411.

de Blasio, F.V. (2011): Introduction to the Physics of Landslides. Springer, Dordrecht/Heidelberg, 408.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.24 Hazard, Risk and Prediction

Module Coordinator		Lecturer			
Prof. Dr. S. Hergarten		Prof. Dr. S. Hergarten			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. C Geohazards	150 h	5 ECTS	WS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Hazard, Risk and Prediction		3 wh / 45 h	105 h		16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Assessing hazard and risk is one of the major fields of professional work in the context of geohazards. This module provides a synthesis of the specific modules of the focus area "Geohazards". The students learn about the concept of frequency-magnitude relations, how to derive hazard maps and how to transfer hazard to risk. Beyond this, the students learn about concepts of prediction and contemporary theoretical concepts unifying different types of geohazards.

Syllabus

The main topics of the module are:

- Hazard and risk
- Event-size distributions and frequency-magnitude relations; general concepts and distributions for different geohazards
- Recurrence times
- Temporal correlations
- Assessment of predictions
- Self-organized criticality

Teaching form

Lecture combined with practical exercises and homework.

Examination form

Achievement of learning goals (unmarked): ---

Examination: Portfolio Examination: homework to be solved during the semester

Prerequisites for attending

Basic knowledge in programming (MATLAB) on the level of the module 3.1 "Computing in Geosciences" is required. Beyond this, it is recommended to have finished the majority of the other modules of the focus area Geohazards (3.19--3.23).

Usage of the module in other programs

Recommended reading

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.25 Applied Petrology					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturers** a) Dr. L. Fischer b) Dr. M. Junge			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Experimental Petrology b) Introduction to Ore-Forming Processes		a) 2 wh / 30 h b) 2 wh / 30 h	a) 45 h b) 45 h		a) 15 b) 15

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

This module consists of two courses: (a) Experimental petrology provides insights into experimental approaches to simulate magmatic and hydrothermal processes and its application to petrogenetic problems, and (b) Ore-forming processes gives an overview of the mechanisms of formation of mineral deposits and the mobility of metals in melts and fluids. The module is designed for master students in mineralogy, petrology and geochemistry, and the attendees will acquire state-of-the-art knowledge of petrogenetic and mineral-forming processes and will be able to evaluate and interpret origin of igneous rocks and ore mineralization using microanalytical and experimental methods.

a) The knowledge of the prevailing conditions, such as pressure, temperature and oxygen fugacity as well as phase equilibria during magmatic and hydrothermal processes are crucial for understanding the evolution and formation of igneous rocks in the Earth's interior and at its surface. In this course students will learn about experimental techniques, which can be applied to simulate the processes that are essential for the formation of igneous rocks such as partial melting, fractional crystallization, immiscibility or degassing. In this context different parameters in experimental and natural systems, including phase stabilities, solubilities or partition coefficients will be considered. Case studies will be presented with special focus on the genesis of ore deposits. In addition, functionality and applicability of petrological modeling programs will be discussed. Practical exercises will include evaluation and interpretation of experimental data, and application of modeling programs and geothermobarometry. After attending the course, the students should be able to understand different experimental approaches and their applications within the field, and to apply modeling software and common geothermobarometers to specific petrological questions.

b) Understanding of the processes of ore genesis is essential for the exploration of raw materials and the formation of mineral deposits in general. In this course students will learn both theoretically about the different ore deposit types and their origin as well as practically using hand specimen observations and ore microscopy. The range of different processes that are responsible for the formation of ore deposits in magmatic, hydrothermal and supergene environments will be treated during this course. A particular focus will be the mobility and complexing of metals in fluids and melts which is an essential ore-forming process. Mineralogical and geochemical methods applied to ore deposits geology such as stable and radiogenic isotope and fluid inclusion studies will be discussed as well.

Syllabus

a) 1. Introduction into magmatic and hydrothermal processes and overview of experimental techniques
2. High pressure, high temperature: multi anvil, piston cylinder, mantle melting, crystallization, partition coefficients, phase stabilities
3. Fluids and immiscibility: internally heated pressure vessel, decompression and degassing, solubility, H_2O-CO_2 in melts, sulphide melts, H_2O-NaCl
4. Hydrothermal systems: cold-seal pressure vessel, fluid-rock interaction, dissolution-precipitation processes
5. One atmosphere apparatus: gas mixing furnace, oxygen fugacity, application to processes at elevated pressures
6. Functionality and application of petrological modeling programs and geothermobarometer

b) 1. Introduction and definition of ore deposit geology
2. Magmatic ore systems: differentiation of silicate melts, silicate-sulfide immiscibility and ore formation
3. Magmatic-hydrothermal systems: mobility of metals in fluids, fluid inclusion analytics
4. Hydrothermal systems in sedimentary environments
5. Supergene processes and element transport
6. Case studies and methods applied in ore geology

Teaching form

a) Lecture and practical session

b) Lecture and practical session

Examination form

Achievement of learning goals (unmarked): regular attendance

Examination: written examination

Prerequisites for attending

Usage of the module in other programs

Recommended reading

a) Edgar, A.D. (1973): Experimental Petrology: Basic Principles and Techniques. Clarendon Press, Oxford, 230.

Holloway, J.R., Wood, B.J. (1988): Simulating the Earth: Experimental Geochemistry. Springer Netherlands, 208.

Ulmer, G.G. & Barnes, H.L. (1987): Hydrothermal Experimental Techniques. John Wiley & Sons, 523.

Winter, J.D. (2009): Principles of Igneous and Metamorphic Petrology. Prentice Hall, New York, 702.

b) Evans, A.M. (1993): Ore Geology and Industrial Minerals. Blackwell, Oxford, 390.

Ridley, J. (2013): Ore Deposit Geology. Cambridge University Press, 410.

Robb, L. (2005): Introduction to Ore-Forming Processes. Blackwell, Malden, 373.

Pohl, W.L. (2011): Economic Geology – Principles and Practice. Wiley-Blackwell, Chichester, 663.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.26 Thermodynamics of Geological and Technical Materials					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturer** Prof. Dr. D. Dolejš			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Thermodynamics of Geological and Technical Materials		2 wh / 30 h	120 h		25

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

This module concentrates on physico-chemical principles that underlie structure-property relations of inorganic matter. These relations include feedback between occurrence and stability of minerals, silicate melts, aqueous fluids, their synthetic analogues including inorganic materials and atomic structure and its changes with temperature and pressure. Thermodynamic modeling of phase equilibria, construction of phase diagrams and prediction of element partitioning is a backbone of interpretation of pressure-temperature paths of metamorphic rocks, differentiation mechanisms of magmas as well as design and optimization of numerous technological processes such as crystallization, smelting, combustion, fluid extraction etc. Syntheses of inorganic materials and inovative material properties are increasingly predicted and designed with the aid of thermodynamic and phase equilibrium calculations.

The students are expected to develop a solid understanding of geological and materials thermodynamics, to become familiar with structure and use of thermodynamic datasets and are able to design solutions to phase equilibrium problems in petrology, crystallography, materials science or inorganic and physical chemistry.

Syllabus

The course builds on basic physical chemistry, introduces equations of state for solid and liquid materials, proceeds from simple phases to multicomponent mixtures, and closes with a review of predictive methods: atomistic simulations of thermodynamic properties and numerical algorithms for computation of phase diagrams.

1. Thermodynamic laws, mechanical and thermal processes
2. Thermodynamic state functions and stability criteria
3. Equations of state for gas and other fluids
3. Equations of state for condensed phases
4. Thermodynamics of mixing, partial properties of solutions
5. Link between thermodynamic properties and phase diagrams
6. Calculation and construction of phase diagrams

Teaching form

Lecture combined with practical assignments (2 hr), individual project

Examination form

Achievement of learning goals (unmarked): attendance of lectures, completion of assignments

Examination: Portfolio Examination: written exam (30 %), written project report (40 %) and seminar presentation of the project (30 %)

Prerequisites for attending

Usage of the module in other programs

Elective Module in the Master programs Sustainable Materials-Crystalline Materials, Chemistry-Inorganic Chemistry / Physical Chemistry

Recommended reading

Stølen, S. & Grande, T. (2008): Chemical Thermodynamics of Materials: Macroscopic and Microscopic Aspects. Wiley, Chichester, 395.

Fegley, B. (2013): Practical Chemical Thermodynamics for Geoscientists. Elsevier, Amsterdam, 674.

Ganguly, J. (2008): Thermodynamics in the Earth and Planetary Sciences. Springer, Berlin/Heidelberg, 490.

Patiño Douce, A.E. (2011): Thermodynamics of the Earth and Planets. Cambridge University Press, Cambridge, 722.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.27 Sedimentary Geology

Module Coordinator		**Lecturers**			
Prof. Dr. F. Preusser		a) Prof. Dr. F. Preusser; Dr. C. Rambeau; N.N. b) Dr. C. Rambeau; Prof. Dr. F. Preusser; N.N.			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Sedimentary environments b) Logging sediments		a) 2 wh / 30 h b) 5 days / 40 h	a) 60 h b) 20 h		a) 16 b) 16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Students who successfully complete this module will have developed an understanding of modern sedimentology. The module is subdivided into two courses, one focusing on the theoretical background and the other on practical issues of describing sediments.

Syllabus

a) This course concentrates on the sedimentary dynamics and archives found such as in glacial, fluvial, shallow marine (carbonate) settings. After this course students will understand these sedimentary systems in detail, will be able to describe and interpret sedimentary sequences, and put these observations into a local, regional and global context.
b) Student will learn how to describe (log) sediments in outcrops and cores.

Teaching form

a) Lecture

b) Practical work

Examination form

Achievement of learning goals (unmarked): Regular attendance

Examination: Portfolio Examination: Written exam (a) (60 %) and project report (b) (40 %)

Prerequisites for attending

Basic understanding of geology and sedimentology

Usage of the module in other programs

Recommended reading

a) Benn, D.I. & Evans, D.J.A. (2013): Glaciers & Glaciation. Routledge, London, 802.

Charlton, R. (2008): Fundamentals of fluvial Geomorphology, Routledge, New York, 234.

b) Benn, D.I. & Evans, D.J.A. (2015): A practical guide to the study of glacial sediments. Routledge Taylor & Francis Group, London/New York, 266.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.28 Quaternary Research					
Module Coordinator Prof. Dr. F. Preusser		**Lecturers** a) Prof. Dr. F. Preusser; Dr. C. Rambeau b) Dr. C. Rambeau; Prof. Dr. F. Preusser			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	SS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Reconstructing Past Environments b) Quaternary Research Practical Studies		a) 2 wh / 30 h b) 2 wh / 30 h	a) 45 h b) 45 h		a) 16 b) 16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Students who successfully complete this module will have developed an understanding of how environmental conditions in the recent past are reconstructed. The module is subdivided into two courses, one focusing on the theoretical background and the other on practical issues.

Syllabus

a) This course concentrates on 1) an introduction to the main proxies used for environmental/climatic reconstruction, 2) an introduction to the dating methods most commonly used in Quaternary research, and 3) an overview of the history of main environmental and climatic changes that occurred during the Quaternary. After this course students will gain a comprehensive picture of Quaternary research, and will be able to design projects related to the multi-proxy analysis of climate/environmental change in various contexts.
b) Students will learn how to study and interpret the evolution of selected environmental proxies.

Teaching form

a) Lecture

b) Practical work in the field and in the laboratory

Examination form

Achievement of learning goals (unmarked): Regular attendance

Examination: Portfolio Examination: (a) Written exam (50 %) and (b) project report (50 %).

Prerequisites for attending

Basic understanding of geology and sedimentology

Usage of the module in other programs

Recommended reading

a) and b):

Lowe, J. & Walker, M.J.C. (2015): Reconstructing Quaternary Environments. Routledge, Taylor and Francis, London, 538.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.29 Geothermics and Geothermal Energy

Module Coordinator		Lecturer			
Prof. Dr. S. Hergarten		Prof. Dr. S. Hergarten			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	WS	annual	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Geothermics and Geothermal Energy		3 wh / 45 h	105 h		16

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

Despite its great potential, geothermal energy is slowly growing compared to other sources of renewable energy and still poses challenges concerning geology and engineering. In this module the students mainly learn how to

- assess the geothermal potential at a given location and to
- design geothermal systems for different purposes (electricity, heating) with focus on feasibility, economic efficiency and sustainability.

Syllabus

- Basics of heat transport (conduction, advection)
- Earth's thermal field; global and local geothermal potential
- Shallow geothermal systems (downhole heat exchangers, heat collectors)
- Closed deep geothermal systems and their potential for direct heating
- Hydrothermal systems
- Petrothermal systems

Teaching form

Lecture mixed with practical exercises and homework.

Examination form

Achievement of learning goals (unmarked): ---

Examination: Portfolio Examination: homework to be solved during the semester

Prerequisites for attending

Basic knowledge in programming (MATLAB) on the level of the module 3.1 “Computing in Geosciences”.

Usage of the module in other programs

Recommended reading

Clauser, C. (2006): Geothermal Energy. In: Heinloth, K. (Ed): Landolt-Börnstein, Group VIII, Vol. 3C: Energy Technologies - Renewable Energy. Springer, Heidelberg, 493-595.

Stober, I. & Bucher, K. (2013): Geothermal Energy **-** From Theoretical Models to Exploration and Development. Springer, Heidelberg/Berlin, 291.

Lecture notes

https://ilias.uni-freiburg.de/login.php

3.30 External Modules					
Module Coordinator Various		**Lecturers** Various Lecturers			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. And Geodyn. E Geohazards	150h / 300 h / 450 h	5, 10 or 15 ECTS	WS / SS	variable	1 term
Course / Course Name		**Presence**	**Private study**		**Participants**
Elective modules up to 15 credits may be chosen from other natural sciences or environmental graduate programs. A maximum of 5 credits may be taken from language courses offered by the Language Teaching Center of the University (SLI).		variable	variable		variable

Abbreviations: C – compulsory, E – elective, wh – week hours

Note:

Modules are restricted to a size of 5 credits. If an external module accounts for more credits only 5 will be credited. If an external module accounts for less than 5 credits several modules have to be bundled. In this latter case the student has to consult the student advisor (Dr. Heike Ulmer: ulmer@uni-freiburg.de) in advance and strict regulations apply.

3.31 Technical and Applied Mineralogy

This module combines two courses from the M.Sc. Sustainable Materials – Crystalline Materials curriculum: “Modern Ceramics, Cements, and Glasses” and “Thermal Analysis”. For further course information please see the current M.Sc. Sustainable Materials – Crystalline Materials guide book at:

http://www.cup.uni-freiburg.de/chemie/studium/msc_Crystalline%20Materials/Studium

If you are interested to participate in this module please contact the module coordinator.

3.32 X-Ray Methods

This module combines two courses from the M.Sc. Sustainable Materials – Crystalline Materials curriculum: “Structure Analysis by Diffraction” and “Defect Analysis by Diffraction”. For further course information please see the current M.Sc. Sustainable Materials – Crystalline Materials guide book at:

http://www.cup.uni-freiburg.de/chemie/studium/msc_Crystalline%20Materials/Studium

If you are interested to participate in this module please contact the module coordinator.

3.33 Advanced Crystallography

This module combines two courses from the M.Sc. Sustainable Materials – Crystalline Materials curriculum: "Crystallographic Methodology" and "Space Groups and Crystal Structures". For further course information please see the current M.Sc. Sustainable Materials – Crystalline Materials guide book at:

http://www.cup.uni-freiburg.de/chemie/studium/msc_Crystalline%20Materials/Studium

If you are interested to participate in this module please contact the module coordinator.

3.34 Shock Waves in Rocks					
Module Coordinator Prof. Dr. Thomas Kenkmann		**Lecturer** Prof. Dr. Frank Schäfer			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomat. and Processes E Rock Mech. and Geodyn. E Geohazards	150 h	5 ECTS	WS + SS	annual	2 terms a) one term b) one term or as a block coure
Course / Course Name		**Presence**	**Private study**		**Participants**
a) Shock Waves in Rocks I b) Shock Waves in Rocks II		a) 2 wh / 30 h b) 2 wh / 30 h	a) 60 h b) 30 h		a) 30 b) 30

Abbreviations: C – compulsory, E – elective, wh – week hours

Learning goals and qualifications

a) Collisions of planetary bodies are amongst the most fundamental processes in solar system. During such impact processes, the materials of the involved bodies are subject to extreme dynamical loads that are always associated with the generation and propagation of shock waves. The Lecture “Shock Waves in Rocks I” aims at teaching the fundamentals of shock wave physics, the applications of shock waves, and the mathematical description of shock waves in one dimension. To this purpose, the conservation equations for shock wave physics are derived from first principles and the concept of equation of state for solids is explained. The shock wave theory shall be used for computing the pressure levels reached during crater formation. The second goal of this lecture is to provide an overview of the experimental methods that are used to investigate the material behaviour under shock loads. Here, methods are discussed that are used for generation of Hugoniot data in the laboratory as well as accelerator technology for performing cratering research in the lab at small scales.

b) As a consequence of the shock wave propagation, the material undergoes a transient and irreversible change in its physical state, leading to shock compression and thermodynamic heating of the material. At a later stage of the impact process, the material is released again from the shock state. The Lecture “Shock Waves in Rocks II” aims at teaching the thermodynamic processes during impact and aims at computing the thermodynamic state of materials after release from the shock state.

Syllabus

a) The lecture starts with an introduction into shock waves, where they occur, and what they are applied for. A mathematical description of shock waves in one dimension is then given, starting from first principles. Also, the concept of equation of state for solids is introduced, and how to use them for shock wave computations. The lecture includes a number of exercises, also including computations with spreadsheets.

b) The lecture starts with an introduction in to thermodynamic theory. Then, the principles of the shock- and release processes are taught, followed by computations of the thermodynamic heating of materials following a shockwave passage. The lecture includes a number of exercises, using spreadsheets.

Teaching form

a) Alternating lectures and exercises

b) Workshop: alternating lectures and exercises

Examination form

Achievement of learning goals (unmarked): attendance

Examination: one marked written exam (60 % about (a) and 40 % about (b))

Prerequisites for attending

Usage of the module in other programs

Recommended reading

a) + b)

Melosh, H.J. (1989): Impact cratering. A geologic process. Oxford University Press, New York, 245.

French, B.M. (1998): Traces of catastrophe. A handbook of shock-metamorphic effects in terrestrial meteorite impact structures. LPI-Contribution, Houston, Texas, 120.

Hiermaier, S.J. (2008): Structures under crash and impact: continuum mechanics, discretization and experimental characterization. Springer, New York, 410.

Kenkmann, T. (2009): Asteroid and Comet Impacts throughout Earth´s history. Zeitschrift für Geologische Wissenschaften 37, 293-318.

Lecture notes

https://ilias.uni-freiburg.de/login.php