Institute of Earth and Environmental Sciences
Albert Ludwig University of Freiburg

Program guidebook
M.Sc. Geology

with Elective Tracks
Mineralogy and Geochemistry
Geomechanics and Tectonics
Geohazards
Applied Quaternary Geology

(Examination Regulations 2019)

Freiburg, April 8, 2020

UNI FREIBURG

Table of Contents

1. General Information

This module guide provides information about the M.Sc. program *Geology*. The program offers an individual specialization to one of the four elective tracks, *Mineralogy and Geochemistry*, *Geomechanics and Tectonics, Geohazards*, and *Applied Quaternary Geology*. 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 This guidebook aims at presenting the vision, structure, and content of the M.Sc. program and provides necessary details of the individual modules and courses.

1.1 Overall Profile

Following the development of Geosciences over the last decades, the education in the M.Sc. program Geology focuses first on contemporary methods more than on providing specific knowledge. It provides competences in the critical assessment of scientific literature, scientific writing, techniques of presentation and data handling. These rather general qualifications are not only essential for a scientific career but have also become increasingly important in many fields of professional activity.

Beyond these rather general aspects, the M.Sc. program takes into account the ongoing specialization in all fields of science by offering four distinct elective tracks of topical specialization. These are *Mineralogy and Geochemistry*, *Geomechanics and Tectonics, Geohazards*, and *Applied Quaternary Geology*. Beyond focusing on a specific field of Geosciences, these elective tracks also extend the competences of the students in direction of either laboratory-oriented work, field work, theory or modeling and data analysis. The elective tracks reflect the research areas of the involved groups to some extent, so that components of research can be integrated into teaching, and a high quality can be achieved.

1.2 University of Freiburg Geosciences: Why to Complete M.Sc. Studies at 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 groups contributing to the M.Sc. program cover a wide range of exciting topics in geosciences. The following sections provide an overview of the areas of geoscience research at the University of Freiburg.

1.2.1 Sedimentary Geology and Quaternary Research

The youngest part of the geological history, the Quaternary period, i.e., the last 2.6 Ma, was characterized by rapid environmental developments caused by naturally occurring 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 water, ice or wind. Investigating these archives helps to decipher natural climate variability 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.

1.2.2 Structural Geology and Tectonics

Structural Geology and Tectonics are core subjects in geology. Methodology used at Freiburg 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.

1.2.3 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-Institute (EMI) Freiburg.

1.2.4 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.

1.2.5 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. As seismic methods are a main subject of the Karlsruhe Institute of Technology (KIT) as a partner in the

EUCOR network, our focus is on nonseismic methods (resistivity methods, ground-penetrating radar, and other electromagnetic methods).

1.2.6 Petrology and Evolution of the Lithosphere

Mineral assemblages and structures of rocks ultimately result from large-scale geological processes reflecting dynamics of the Earth. These processes include formation of ocean floor along mid-ocean spreading ridges, evolution of island arc systems and continental margins with their volcanic systems, or building of mountain ranges such as the Himalayas and the Alps. The wide range and continually changing pressure and temperature conditions cause chemical reactions in rocks that change their mineral associations, textures or produce partial melts. Our research includes a variety of subjects such as pressure-temperature conditions, magma production, differentiation and crystallization as principal tools to reconstruct the past and present processes occurring on Earth.

1.2.7 Mineral Resources

Enrichment and accumulation of metals in the Earth's crust is a prerequisite for economically important mineral resources. These metal reserves are basis for the needs of our society and modern technologies. The mineral deposits occur in diverse geological settings, ranging from mid-ocean spreading ridges through magmatic arcs to stable cratons, and have been forming throughout the Earth's geological history. Mineral exploration and geological interpretation employ a variety of microanalytical and imaging techniques that becomes increasingly essential tools in ore processing and metal extraction. Our research focuses on diverse magmatic and hydrothermal mineral deposit types, formation of their mineral associations and metal endowment including high-tech and critical metals.

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

The chemical interaction of water and rock is one of the most universal, yet complex 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 systems – hydrothermal ore deposits, geothermal energy reservoirs or sites for sequestration and deposition of greenhouse gases. Understanding water-rock interaction is thus of great importance to applied geology and geochemistry, particularly in areas such as geothermal energy, applied hydrogeology, water chemistry or nuclear waste disposal.

1.2.9 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 Institute for Solar Energy Systems (ISE), the Fraunhofer Institutes for Applied Solid State Physics (IAF) and for Physical Measurement Techniques (IPM).

1.2.10 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 department 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.

1.3 Analytical Facilities for Modern Quantitative Geosciences

The institute hosts advanced analytical facilities for research and teaching in the geosciences for both laboratory and field work. 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 static mechanical properties of solid rocks and a Split-Hopkinson bar for analyzing the behavior at rapid deformation. The kinematics of gravity-driven mass movements are studied in an analogue laboratory equipped with particle image velocimetry and stereo cameras.

The Quaternary research group operates a fully equipped laboratory for luminescence dating. Available geophysical devices include geoelectrics and ground-penetrating radar.

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.

1.4 Application for 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 the elective track 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. Kathleen Robinson is contact person.

1.5 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 schedules of lectures, practicals and exams, please contact the Program Coordinator available during the opening hours and also by appointment:

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

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

- **Examination Office**
  http://www.unr.uni-freiburg.de/fakultaet/pruefungsamt;
  Albert-Ludwigs-Universität, Prüfungsamt der Fakultät für Umwelt und natürliche Ressourcen, Tennenbacherstr. 4, D-79085 Freiburg

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

1.6 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.

The M.Sc. curriculum comprises six compulsory modules contributing 30 ECTS points compulsory for all elective tracks (blue in Fig. 1, for details see Sect. 2.1), while the remaining 90 ECTS points can be acquired according to the specific interests of the students to some degree. In order to achieve a specific, but balanced portfolio of qualifications, each student must select one out of the following four elective tracks:

- Mineralogy and Geochemistry
- Geomechanics and Tectonics
- Geohazards
- Applied Quaternary Geology

Each of these elective tracks comprises three compulsory modules (15 ECTS points, see Sect. 2.2). Beyond these compulsory modules, several specific electives are offered within each elective track (see. Sect. 2.3).

A total of 45 ECTS points is contributed by elective modules. In general, each module of this program can be used as an elective, except for those modules that are compulsory either for the overall program or for the selected elective track. The following further rules apply to the choice of electives:

---

[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).

- At least three modules must be taken from the catalog of modules explicitly assigned to the selected elective track (see Sect. 2.2, also marked with an E in the module description).
- Modules with a total amount of up to 15 ECTS points may be taken from other programs of the Albert-Ludwigs-University and its partner universities in the EUCOR network. These modules must be graded and considered as appropriate in the context of the M.Sc. program Geology, so that students must apply for such electives before starting the module. It is recommended to ask the Credit Recognition Officer/Head of Geology Program for assistance.
- Up to 5 out of the 15 ECTS points mentioned in the previous point can be covered by language courses offered by the Language Teaching Center of the University (SLI). In contrast to all other electives, these are unmarked.

The grade of a module is derived from the module examination. This module examination may be a single written or oral examination at a given time, but the majority of the modules uses more specific formats to test whether the required qualifications have been achieved. These examinations may consist of several components (e.g., regular homework and a seminar presentation) but are graded as a whole (by adding scores of the individual parts), so that the students are in principle free to choose how much effort they spend for each part. Details about the weighting are provided in the module descriptions (Sect. 3). Within some of the modules, ungraded academic achievements may also be required, which are the prerequisites for the successful completion of a module.

In analogy to cheating in written or oral exams, copying another student's work, copying from literature or web sources without reference or using illicit materials is considered as academic misconduct in all components of exams (homework, reports, etc.). It leads to the loss of the entire score for the respective component of the module examination.

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. It contributes 30 ECTS points.

1.6.1 Elective Track *Mineralogy and Geochemistry*

The elective track *Mineralogy and Geochemistry* offers education and research training in mineralogy, petrology, geochemistry, 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. 1). The elective track *Mineralogy and Geochemistry* 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.

1.6.2 Elective Track *Geomechanics and Tectonics*

The elective track *Geomechanics and Tectonics* provides the student with a sound theoretical as well as practical knowledge in the respective fields of rock mechanics, petrophysics, geophysics, tectonics and the gained qualifications offer a wide spectrum of career choices, e.g. in the mining industry, subsurface investigations, geological surveys. Practical expertise includes work in the rock mechanics laboratory that hosts a triaxial loading frame, Split-Hopkinson Pressure Bar, and Analogue Laboratory. Geophysical and petrophysical equipment comprise of a He-pycnometer, laser-sizer, white light-interferometer, optical and electron microscopy, and devices for seismic, ground-penetrating radar, and geoelectric analyses. Note that the modules *Rock Mechanics* and *Petrophysics* are offered biannually alternating in the winter term. The elective track also offers a planetary focus direction with the modules *Planetary Dynamics* and *Impact Geology* that are also offered biannually.

1.6.3 Elective Track *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 elective track *Geohazards* 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 track 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 an essential component of the program. The elective track *Geohazards* consists of the compulsory and elective modules are marked by a light orange color in Fig. 1.

1.6.4 Elective Track *Applied Quaternary Geology*

Wide parts of the Earth surface are covered by Quaternary deposits, in particular the densely populated areas along rivers, coasts and on most plains. As a consequence, a large number of projects in applied geology are linked to Quaternary deposits. However, since most Quaternary deposits are unconsolidated, they differ significantly with regard to their properties and distribution compared to hard rock. The applied fields covered in the elective track *Applied Quaternary Geology* include hydrogeology, engineering geology, geotechnics, rock properties, environmental geosciences as well as the recognition of and the protection against natural hazards. To some extent, regulatory frameworks and economic aspects will be discussed during the courses. These topics are complemented by two modules focusing on how sediments are formed and on the environmental context during the Quaternary, a time that is characterized by massive and abrupt changes in climate. The elective track *Applied Quaternary Geology* consists of the compulsory and elective modules are marked by a dark orange color in Fig. 1.

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

2. Module Overview

2.1 General Compulsory Modules

Module	Coordinator	Courses	Type	ECTS points	Sem.
Research Methods in Geosciences	Preusser	Research Methods in Geosciences	L + P + S	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
Geographic Information Systems	Wulf	Geographic Information Systems	L + P	5	2
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	
Master Module	Hergarten		MT	30	4

Semester numbers indicate recommended semester
Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course, MT Master Thesis

2.2 Compulsory Modules of the Elective Tracks

2.2.1 Compulsory Modules *Mineralogy and Geochemistry*

Module	Coordinator	Courses	Type	ECTS points	Sem.
Analytical Methods I	Müller-Sigmund	Analytical Methods I	L + P	5	1
Low Temperature Geochemistry	Siebel	Marine Geochemistry	L + P	2.5	2
		Isotope Geochemistry	L + P	2.5	2
Ore-Forming Processes	Dolejš	Ore-forming Processes	L + P	5	2

Semester numbers indicate recommended semester
Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

2.2.2 Compulsory Modules *Geomechanics and Tectonics*

Module	Coordinator	Courses	Type	ECTS points	Sem.
Computing in Geosciences	Hergarten	Computing in Geosciences	L + P	5	1
Tectonics	Kenkmann	Tectonics	L + P + S	5	2
Near-Surface Geophysics	Wilk	Near-Surface Geophysics	L + P	5	2

Semester numbers indicate recommended semester
Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

2.2.3 Compulsory Modules *Geohazards*

Module	Coordinator	Courses	Type	ECTS points	Sem.
Computing in Geosciences	Hergarten	Computing in Geosciences	L + P	5	1
Earthquakes and Tsunamis	Hergarten	Earthquakes and Tsunamis	L + P	5	2
Hazard, Risk, and Prediction	Hergarten	Hazard, Risk, and Prediction	L + P	5	3

Semester numbers indicate recommended semester
Abbreviations: L = Lecture, S = Seminar, C = Colloquium, P = Practical Course, F = Field Course

2.2.4 Compulsory Modules *Applied Quaternary Geology*

Module	Coordinator	Courses	Type	ECTS points	Sem.
Engineering Geology and Geotechnics	Miocic	Introduction to Engineering Geology	L	2.5	2
		Geotechnical Projects	S	2.5	
Sedimentary Geology	Preusser	Sedimentary Environments	L	3	2
		Logging Sediments	P	2	
Earth Management	Preusser	Earth Management	L + S + F	5	3

Semester numbers indicate recommended semester

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

2.3 Elective Modules Assigned to the Elective Tracks

2.3.1 Elective Modules *Mineralogy and Geochemistry*

Module	Coordinator	Courses	Type	ECTS points	Semester
Igneous Processes	Dolejš	Igneous Processes	L + P	5	1 or 3
Metamorphic Processes	Dolejš	Metamorphic Processes	L + P	5	1 or 3
High Temperature Geochemistry	Siebel	Geochemical Evolution of the Mantle and the Crust	L + P	2.5	1 or 3
		High-Temperature Geochronology	L + P	2.5	
Analytical Methods II	Müller-Sigmund	Special Methods in Mineralogy	L + P	2	2
		High Resolution Spectroscopy	L + P	3	

Semester numbers indicate recommended semester; modules marked with “1 or 3” may be offered only biannually

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

2.3.2 Elective Modules *Geomechanics and Tectonics*

Module	Coordinator	Courses	Type	ECTS points	Semester
Petrophysics	Kenkmann	Petrophysics	L + P	2.5	1 or 3
		Rheology and Textures	L + P	2.5	
Rock Mechanics	Poelchau	Stress and Strain	L + P	2.5	1 or 3
		Brittle Rock Deformation	L + P	2.5	
Planetary Dynamics	Kenkmann	Planetary Dynamics	L + P	5	1 or 3
Impact Geology	Kenkmann	Impact Geology	L + P	5	1 or 3
Shock Waves in Rocks	Kenkmann	Shock Waves in Rocks I	L + P	3	1
		Shock Waves in Rocks II	L + P	2	2
Remote Sensing	Wulf	Remote Sensing	L + P	5	3
Engineering Geology and Geotechnics	Miocic	Introduction to Engineering Geology	L	2,5	2
		Geotechnical Projects	S	2,5	

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

2.3.3 Elective Modules *Geohazards*

Module	Coordinator	Courses	Type	ECTS points	Semester
Mass Movements	Hergarten	Mass Movements	L + P	5	2
Volcanic Hazards	Preusser	Volcanology and Volcanic Hazards	L + S	2	See module description
		Volcanic Hazards Case Studies	P + F	3	
Climatic Geohazards	Rambeau	Introduction to Climatic Geohazards	L + S	3	1 or 3
		Climatic Geohazards Case Studies	S	2	
Impact Geology	Kenkmann	Impact Geology	L + P	5	1 or 3
Engineering Geology and Geotechnics	Miocic	Introduction to Engineering Geology	L	2,5	2
		Geotechnical Projects	S	2,5	

Semester numbers indicate recommended semester ; modules marked with “1 or 3” may be offered only biannually

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

2.3.4 Elective Modules *Applied Quaternary Geology*

Module	Coordinator	Courses	Type	ECTS points	Semester
Climatic Geohazards	Rambeau	Introduction to Climatic Geohazards	L + S	3	1 or 3
		Climatic Geohazards Case Studies	P + F	2	
Quaternary Research	Rambeau	Quaternary Research	L + S + P	5	1 or 3
Hydrogeology	Dolejš	Advanced Hydrogeology	L + P	2.5	2
		Aqueous Geochemistry	L + P	2.5	2
Computing in Geosciences	Hergarten	Computing in Geosciences	L + P	5	1
Petrophysics	Kenkmann	Petrophysics	L +P	2.5	1 or 3
		Rheology and Textures	L +P	2.5	
Rock Mechanics	Poelchau	Stress and Strain	L + P	2.5	1 or 3
		Brittle Rock Deformation	L + P	2.5	

Semester numbers indicate recommended semester; modules marked with "1 or 3" may be offered only biannually

2.4 Further Elective Modules

Module	Coordinator	Courses	Type	ECTS points	Semester
Experimental Petrology	Dolejš	Experimental Methods	L + P	2.5	2
		Thermodynamics of Geological and Technical Materials	L + P	2.5	
Geothermics and Geothermal Energy	Hergarten	Geothermics and Geothermal Energy	L + P	5	3
Technical and Applied Mineralogy	See module guide book M.Sc. *Sustainable Materials – Crystalline Materials*				
X-Ray Methods	See module guide book M.Sc. *Sustainable Materials – Crystalline Materials*				
Advanced Crystallography	See module guide book M.Sc. *Sustainable Materials – Crystalline Materials*				

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

3. Module Descriptions

Remarks on examinations in the module descriptions

Oral examinations, such as "oral presentations", "poster presentations", have a duration of at least 10 minutes and a maximum of 30 minutes per candidate according to the applicable framework examination regulations. If specifications that are more concrete have been made, these are stated in the individual module descriptions.

The duration of written exams is at least 60 minutes and maximum 240 minutes according to the applicable framework examination regulations. If specifications that are more concrete have been made, these are stated in the individual module descriptions. The dates for exams as well as the valid aids will be announced to the students in a timely manner.

3.1 General Compulsory Modules

3.1.1 Research Methods in Geosciences

Module Coordinator		**Lecturer(s)**			
Prof. Dr. F. Preusser		Prof. Dr. F. Preusser, Prof. Dr. D. Dolejs, Dr. C. Rambeau, Dr. M. Junge, Dr. J. Miocic, Dr. L. Fischer			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C	150 h	5 ECTS	WS	annual	1 term
Course		**Presence**	**Private study**		**Participants**
Research Methods in Geosciences		4 wh / 60 h	90 h		20

Abbreviations: C – compulsory, wh – week hours

The foundation of scientific work are skills and methods such as the correct way to work with scientific resources and databases, the analysis and critical review of the work of others, the analysis and interpretation of data, and the presentation of data and scientific results. In this module advanced scientific working skills and methods are introduced. By this, it forms the basis of the entire curriculum.

After this module, the students 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

Students will learn how scientific research and applied studies are initiated, funded and carried out. They will be trained in the usage of general scientific databases as well as specific geological databases, and how different publications can be accessed. Students will be instructed in the three essentials of scientific knowledge sharing: scientific papers, scientific posters and scientific presentations. Moreover, the critical analysis and review of papers and presentations is a key learning outcome. Additionally, students will become familiar with how scientific data should be processed and statistically analyzed and how the results of such analyses are presented in the form of scientific graphs. Finally, students are instructed on how to write a thesis.

Teaching form

Lecture, seminar, and practical

Examination form

Achievement of learning goals (unmarked): Regular attendance in the seminar and in the practical part

Examination: Written exam (30 %, 45 minutes), oral presentation (10 %), and project reports (60 %)

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Variable, depending on the seminar topics

Lecture notes

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

3.1.2 Seminar and Colloquium I					
Module Coordinator Dr. M. Poelchau		**Lecturers** ---			
Type C	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS/SS	**Cycle** annual	**Duration** 2 terms
Course 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) 40 b) 40

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

In-house seminars provide a platform for scientific conversation and for gaining insight in up-to-date research. The seminar and colloquium modules are a major component of the scientific education concerning both presentation and scientific discussion. The students improve their presentation skills by giving an own presentation and by discussing the presented topic with the audience. Moreover, they are trained in discussing topics at different scientific levels from presentations by their classmates, by the scientific staff, and by invited external speakers. In addition, the students get the chance to establish contacts to external 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. On a regular basis doctorate students report on their current state of their Ph.D projects. Members of the academic staff also 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 discussion

b) Seminar with 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

3.1.3 Field Trips					
Module Coordinator Dr. H. Ulmer		**Lecturers**			
Type C	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS/SS	**Cycle** -	**Duration** 4 terms
Course Field Trips and Visits to Industrial Facilities		**Presence** 10 days /90 h	**Private study** 60 h		**Participants** variable

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

In this module the core expertise of geoscientists – field work – is trained more extensively 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 opportunities for exchange between students and lecturer. Upon participation at field trips the students refine their power of observation. Students learn to 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-led 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

3.1.4 Geographic Information Systems					
Module Coordinator Dr. G. Wulf		**Lecturer** Dr. G. Wulf			
Type C	**Workload** 150 h	**Credits** 5 ECTS	**Term** SS	**Cycle** annual	**Duration** 1 term
Course Geographic Information Systems		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 20

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

Geographic Information System (GIS) technology has broad applications in natural and social sciences and has become an essential part of geosciences. This module introduces the theory and practice of GIS showing the spectrum of potential GIS applications. The students should gain both a theoretical and practical understanding of spatial data and GIS applications, including the key concepts and skills required to manage, handle, manipulate, analyze and display spatial data.

Syllabus

The course combines lecture-based teaching with linked practical exercises. It introduces the students to basic principles of GIS as well as key concepts of data acquisition and storage, data visualization and processing. The focus of the course lies on extensive practice in data handling and the usage of GIS applications for geoscientific issues. In the process, the students carry out practice-oriented case studies using a suitable GIS software package. The module assumes no prior knowledge or experience of GIS.

Teaching form

Lecture and practical work

Examination form

Achievement of learning goals (unmarked):

Examination: Homework (GIS-bas mapping and data analysis) to be solved during the semester (60%) and a written project report at the end of the semester (40%).

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Bolstad, P. (2016): GIS Fundamentals: A First Text on Geographic Information Systems, Fifth Edition. XanEdu Publishing Inc.

Lecture notes

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

3.1.5 Geological Project					
Module Coordinator Prof. Dr. F. Preusser		**Lecturers**			
Type C	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS/SS	**Cycle** each semester	**Duration** 1 term
Course Geological Project		**Presence** ---	**Private study** 150 h		**Participants** ---

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

Individual 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, and 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): discussions with the supervisor (informal)

Examination: marked report

Prerequisites for attending

project-specific

Usage of the module in other programs

project-specific

Recommended reading

project-specific

Lecture notes

## 3.1.6 Seminar and Colloquium II					
Module Coordinator Dr. M. Poelchau		**Lecturers**			
Type C	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS/SS	**Cycle** annual	**Duration** 2 terms
Course 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) 40 b) 40

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

In-house seminars provide a platform for scientific conversation and for gaining insight in up-to-date research. The seminar and colloquium modules are a major component of the scientific education concerning both presentation and scientific discussion. The students improve their presentation skills by giving an own presentation and by discussing the presented topic with the audience. Moreover, they are trained in discussing topics at different scientific levels from presentations by their classmates, by the scientific staff, and by invited external speakers. In addition, the students get the chance to establish contacts to external 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. Members of the academic staff also 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 discussion

b) Seminar with 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

3.1.7 Master Module

Module Coordinator		Lecturer(s)			
Prof. Dr. S. Hergarten					
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C	900 h	30 ECTS	--	--	6 months
Course		**Presence**	**Private study**		**Participants**
---		---	900 h		---

Abbreviations: C – compulsory

Learning goals and qualifications

The Master thesis asserts that the student is able to perform a scientific study in depth based on the competences acquired during the M.Sc. program.

Syllabus

In the Master thesis, a scientific topic related to the selected Elective Track is considered in depth. The student is guided thematically, methodically, and concerning the written thesis by two supervisors. The supervisors will also act as referees of the submitted thesis. At least one of the two referees must be full-time lecturer at the Faculty of Environment and Natural Resources.

Teaching form

Examination form

Achievement of learning goals (unmarked): discussions with the supervisors (informal)

Examination: written thesis

Prerequisites for attending

A minimum of 60 ECTS must have been achieved for registration.

Usage of the module in other programs

Recommended reading

Lecture notes

3.2 Compulsory Modules of the Elective Tracks

3.2.1 Compulsory Modules *Mineralogy and Geochemistry*

3.2.1.1 Analytical Methods I

Module Coordinator		**Lecturer**			
Dr. H. Müller-Sigmund		---			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Mineralogy and Geochemistry	150 h	5 ECTS	WS	annual	1 term
Course		**Presence**	**Private study**		**Participants**
Analytical Methods I		4 wh / 60 h	90 h		16

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

Students are introduced into the theoretical background of major analytical methods and machinery in modern mineralogy, geochemistry, and crystallography. They learn to decide upon the appropriate method and analytical settings for a given analytical problem. They perform all steps from sample preparation to analysis at the machine, evaluate result quality and are able to plot and interpret these results in their relevant context. Students are thus introduced to a spectrum of standard instrumental techniques, which are widespread in research as well as in industry.

Syllabus

In this course the theory, application, and operation of modern instrumental methods (SEM, EMPA, XRD, XRF, AAS) for chemical and physical analyses in environmental, Earth and materials science is introduced. Analytical advantages and limits are discussed. To the extent feasible, students get hands-on experience with the machinery in the course of lab exercises, concentrating on concrete small analytical projects, and learn how to present, evaluate, and interpret their data.

Teaching form

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.

Examination form

Achievement of learning goals (unmarked): presence in the practical part, homework

Examination: written reports (80 %) and a short written test (20 %, 30 minutes)

Prerequisites for attending

Usage of the module in other programs

M.Sc. Sustainable Materials / Crystalline Materials: Module "Physical and Chemical Analytical Procedures"

Recommended reading

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 micro-analysis. Springer, Heidelberg/Berlin, 511.

Lecture notes

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

3.2.1.2 Low Temperature Geochemistry

Module Coordinator		Lecturer			
Prof. Dr. W. Siebel		Prof. Dr. W. Siebel			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Mineralogy and Geochemistry	150 h	5 ECTS	SS	annual	1 term
Course		**Presence**	**Private study**		**Participants**
a) Marine Geochemistry b) Isotope Geochemistry		a) 2 wh / 30 h b) 2 wh / 30 h	a) 45 h b) 45 h		a) 20 b) 20

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

The module covers the key aspects of marine geochemistry and methods in environmental and low-temperature isotope geochemistry and provides the student with an introduction to fundamental concepts of oceanography and isotope geology. The individual qualifications and skills of the module are specified below:

a) In the course "Marine Geochemistry", 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 gather an understanding of how marine and coastal environments are impacted by natural climate variability or human activities.

b) In the course "Isotope Geochemistry", students learn about the principles of low-temperature radiogenic and stable isotope methods. 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

Course a) introduces 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 water 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.
The focus of course b) is on radiogenic and stable isotope systems and their principles and applications in low-temperature environments. Topics and systems include:

- K-Ar and Ar-Ar methods and the meaning of cooling ages
- Fundamentals of stable isotope geochemistry, including definitions, terminology, basic principles and standards
- U-series disequilibrium dating
- Sr and Nd isotopic variations of sea water
- Principles of fission-track-dating
- Cosmogenic isotope analysis and geomorphology

Teaching form

a) Lecture

b) Lecture and exercises

Examination form

Achievement of learning goals (unmarked): --

Examination: written test (120 minutes)

Prerequisites for attending

Basic knowledge in geochemistry at the level of B.Sc. course “Geochemistry”

Usage of the module in other programs

Recommended reading

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

Chester R. (2012) & Jickells T.D. (2012) Marine Geochemistry, Blackwell Scientific Ltd., Oxford, 420.

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

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

Lecture notes

https://ilias.uni-freiburg.de/, https://homepages.uni-tuebingen.de/wolfgang.siebel/

3.2.1.3 Ore-Forming Processes					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturers** Dr. Malte Junge ; Prof. Dr. D. Dolejš			
Type C Mineralogy and Geochemistry	**Workload** 150 h	**Credits** 5 ECTS	**Term** SS	**Cycle** annual	**Duration** 1 term
Course Ore-Forming Processes		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 15

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

This course is devoted to processes of metal distribution, transport and enrichment in Earth's lithosphere. We use process-oriented approach from mantle-derived mafic magmas and their metal budget through silicic magmas, their volatiles, exsolution and fractionation of metals towards a large group of hydrothermal processes and fluid-rock interaction. The course concludes with fluids generated during crustal metamorphism and in sedimentary basins, and ore-forming processes in near-surface environments (weathering and supergene mobility).

Syllabus

- Metals and sulfur in ultramafic and mafic systems
- Sulfide and oxide ore assemblages
- Magmatic fluid phase
- Mineral equilibria in hydrothermal fluids
- Hydrothermal transport of metals
- Thermodynamic models of reactive fluid flow
- Alteration geochemistry
- Fluid flow in the Earth's crust
- Metamorphic and sedimentary ore-forming fluids
- Supergene processes
- Surface processes
- Metamorphism of ore deposits (MJ)

Teaching form

Lecture and practical session

Examination form

Achievement of learning goals (unmarked): ---

Examination: Homework (data interpretation and calculations)

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Barnes H.L. (ed., 1997): Geochemistry of Hydrothermal Ore Deposits. Wiley, 972.
Richards J.P., Larson P.B. (eds., 1998): Techniques in Hydrothermal Ore Deposits Geology. Reviews in Economic Geology 10, 256.
Ridley J. (2013): Ore Deposit Geology. Cambridge University Press, 409.
Robb L. (2015): Introduction to Ore-Forming Processes (2^{nd} edition). Wiley, 373.

Lecture notes

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

3.2.2 Compulsory Modules *Geomechanics and Tectonics*

<table>
<tr><td colspan="7">3.2.2.1 Computing in Geosciences</td></tr>
<tr><td colspan="2">Module Coordinator
Prof. Dr. S. Hergarten</td><td colspan="5">Lecturers
Prof. Dr. S. Hergarten</td></tr>
<tr><td>Type
C Geomechanics and Tectonics
C Geohazards
E Applied Quaternary Geology</td><td>Workload
150 h</td><td>Credits
5 ECTS</td><td>Term
WS</td><td>Cycle
annual</td><td colspan="2">Duration
1 term</td></tr>
<tr><td colspan="2">Course
Computing in Geosciences</td><td>Presence
4 wh / 60 h</td><td colspan="2">Private study
90 h</td><td colspan="2">Participants
16</td></tr>
</table>

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

Numerical data analysis, visualization, and process modeling have become essential parts of quantitative geosciences. The successful students are able to describe simple processes in terms of differential equations and are able to implement fundamental schemes (finite difference methods) for the numerical solution in a high-level programming language (MATLAB). Beyond this, 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: marked homework to be solved during the semester (software development and mathematical considerations, 85%) and online exercises to be solved in the class (15%).

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

Recommended reading

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

Lecture notes

http://jura.geologie.uni-freiburg.de

3.2.2.2 Tectonics					
Module Coordinator Prof. Dr. T. Kenkmann		**Lecturers** Prof. Dr. T. Kenkmann Dr. M. Poelchau			
Type C Geomechanics and Tectonics	**Workload** 150 h	**Credits** 5 ECTS	**Term** SS	**Cycle** annual	**Duration** 1 term
Course Tectonics		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 20

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

This module deals with various plate tectonic scenarios. The students allocate structural characteristics and physical boundary conditions to these plate tectonic settings. The module provides a basic understanding of the geodynamics of the tectonic environments, e.g. the state of stress in the lithosphere. The presentation of case studies by the students familiarize them with various tectonic and geophysical techniques of crust-scale analyses.

Syllabus

A variety of plate tectonic scenarios is reviewed and their physical boundary conditions and associated geological phenomena are addressed. Case studies for each of the chapters are presented by the participants. The course also considers tectonic structures on other planets and satellites. The agenda of the module is:

Divergent motion:

- Continental graben tectonics
- Passive continental margins and basin formation
- Basin & Range tectonics

Transcurrent motion:

- Continental transform faults
- Inversion tectonics

Convergent motion:

- Accretionary wedges
- Andean style orogeny

- Cordillera style orogeny
- Alpine style orogeny
- Wrinkle ridges and lobate scarps

Radial Motion:

- Volcano and plume tectonics

Salt diapirism

Teaching form

Lecture and seminar

Examination form

Achievement of learning goals (unmarked): Homework (data interpretation and calculations)

Examination: written examination (60 %, 90 minutes) and oral presentation (40 %)

Prerequisites for attending

Basic knowledge in tectonics and structural geology on the level of "Strukturgeologie und Tektonik" from the B.Sc. Geowissenschaften

Usage of the module in other programs

Recommended reading

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

Frisch, W., Meschede, M., Blakey, A. (2011): Plate Tectonics. Continental Drift and Mountain Building. Springer, 212.

Moores, E.M., Twiss, R.J. (1995). Tectonics. Freeman & Co., 415.

Turcotte, D.L., Schubert, G. (2014). Geodynamics (3rd edition). Cambridge Univ. Press, 456.

Lecture notes

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

3.2.2.3 Near-Surface Geophysics					
Module Coordinator Dr. J. Wilk		**Lecturer** Dr. J. Wilk			
Type C Geomechanics and Tectonics	**Workload** 150 h	**Credits** 5 ECTS	**Term** SS	**Cycle** annual	**Duration** 1 term
Course Near-Surface Geophysics		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 16

Abbreviations: C – compulsory, 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 focuses on the most important geophysical methods used in hydrogeology, environmental geology and engineering geology suitable for the exploration of the shallow subsurface. The module provides a basic understanding of these methods and expands on their application. 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 for the investigation of shallow geological structures.

Syllabus

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

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

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): regular attendance in the field measurements

Examination: Homework (calculations and computer-based data analysis) to be solved during the semester including reports of the field work

Prerequisites for attending

The module "Computing in Geosciences" must have been completed.

Usage of the module in other programs

Recommended reading

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.

Reynolds, J.M. (2011): An Introduction to Applied and Environmental Geophysics. 2nd Ed, Wiley-Blackwell.

Telford, W.M., Geldard, L.P. & Sheriff, R.E. (2010): Applied Geophysics. 2nd Ed Cambridge University Press, Cambridge, 792.

Lecture notes

http://jura.geologie.uni-freiburg.de/teaching.php

3.2.3 Compulsory Modules *Geohazards*

3.2.3.1 Computing in Geosciences – see 3.2.2.1

3.2.3.2 Earthquakes and Tsunamis

Module Coordinator		**Lecturers**			
Prof. Dr. S. Hergarten		Prof. Dr. S. Hergarten			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Geohazards	150 h	5 ECTS	WS	annual	1 term
Course		**Presence**	**Private study**		**Participants**
Earthquakes and Tsunamis		4 wh / 60 h	90 h		16

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

Earthquakes and tsunamis are among the most important natural hazards on Earth and thus a major fields of professional activity in the context of geohazards. As a main qualification, the successful students are able bring the rather extensive and complicated theory of seismology and tsunami propagation into the context of geohazards and include their theoretical knowledge in hazard assessment. Beyond this, they are able to understand und interpret scientific results on historical and recent events as well as hazard assessment provided in the literature in a realistic way.

Syllabus

The first part of the module focusing on seismology and seismic hazard combines the classical theory of 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

In the second part, the theoretical concepts of wave propagation and the concepts of intensity and magnitude are transferred to the propagation of tsunami waves.

Teaching form

Lecture with discussion and additional exercises.

Examination form

Achievement of learning goals (unmarked): ---

Examination: Homework (analytical and computer-based calculations) to be solved during the semester.

Prerequisites for attending

The module "Computing in Geosciences" must have been completed.

Usage of the module in other programs

Recommended reading

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.

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

http://jura.geologie.uni-freiburg.de

3.2.3.3 Hazard, Risk, and Prediction					
Module Coordinator Prof. Dr. S. Hergarten		**Lecturers** Prof. Dr. S. Hergarten			
Type C Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** annual	**Duration** 1 term
Course Hazard, Risk, and Prediction		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 16

Abbreviations: C – compulsory, 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 Elective Track Geohazards. The successful students are able to apply theoretical concepts from statistics to hazard assessment, to derive hazard maps and can distinguish between the terms hazard and risk. Beyond this, the students achieve basic knowledge about concepts of prediction and about contemporary theoretical concepts unifying different types of geohazards and improve their abilities in analyzing data quantitatively.

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 discussion, practical exercises and homework.

Examination form

Achievement of learning goals (unmarked): ---

Examination: homework (analytical and computer-based calculations and interpretation of data) to be solved during the semester.

Prerequisites for attending

The module "Computing in Geosciences" must have been completed. Beyond this, it is helpful to have attended as many of the other modules of the elective track *Geohazards*.

Usage of the module in other programs

Recommended reading

Lecture notes

http://jura.geologie.uni-freiburg.de

3.2.4 Compulsory Modules *Applied Quaternary Geology*

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

Abbreviations: C – compulsory, 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 project 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: Written examination about (a) (60 %, 90 minutes), lab report about (a) (10 %) and oral presentation in (b) (30 %)

Prerequisites for attending

Usage of the module in other programs

Recommended reading

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

Lecture notes

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

3.2.4.2 Sedimentary Geology

Module Coordinator		Lecturers			
Prof. Dr. F. Preusser		a) Prof. Dr. F. Preusser; Dr. C. Rambeau b) Dr. J. Miocic, Dr. C. Rambeau; Prof. Dr. F. Preusser			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
C Applied Quaternary Geology	150 h	5 ECTS	SS	annual	1 term
Course		**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, 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, aeolian, and coastal 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) Students 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 in the practical part (b)

Examination: Written tests during the term (a) (60 %) and project report (b) (40 %)

Prerequisites for attending

Usage of the module in other programs

Recommended reading

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

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

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

3.2.4.3 Earth Management					
Module Coordinator Prof. Dr. F. Preusser		**Lecturers** Prof. Dr. Frank Preusser, N.N.			
Type C Applied Quaternary Geology	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** annual, first time in WS 2020/21	**Duration** 1 term
Course Earth Management		**Presence** 2 wh / 60 h	**Private study** 90 h		**Participants** 16

Abbreviations: C – compulsory, wh – week hours

Learning goals and qualifications

Students who successfully complete this module will have developed an understanding of how the Earth surface is modified and what kind of hazards are introduced by humans. This will include the presentation of the legal framework, regulations, procedures as well as economic aspects related to the wider field of geosciences.

Syllabus

This course introduces the following topical fields:

- Methods of protection against geohazards (floods, mass movements)
- Soil erosion, causes and countermeasures
- Concepts of landscape sculpturing such river regulation
- Hazardous substances (natural and artificial chemicals, dust, hydrate)
- Geo-engineering

Teaching form

Lecture, seminar, field trip and practical work

Examination form

Achievement of learning goals (unmarked): Regular attendance in the seminar, field trip and practical part; practical and field trip report.

Examination: Written tests during the term (40 %), oral presentation (30%) and project report (30 %).

Prerequisites for attending

Usage of the module in other programs

Recommended reading

Lecture notes

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

3.3 Elective Modules Assigned to the Elective Tracks

3.3.1 Elective Modules *Mineralogy and Geochemistry*

3.3.1.1 Igneous Processes					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturers** Prof. Dr. D. Dolejš, Dr. L. Fischer			
Type E Mineralogy and Geochemistry	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannually WS 2019/20 WS 2021/22	**Duration** 1 term
Course Igneous Processes		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 25

Abbreviations: E – elective, wh – week hours

Learning goals and qualifications

The principal objectives of this course are understanding of atomistic structure of silicate melts, physical properties of silicate magmas, use of phase diagrams, crystallization kinetics (nucleation, growth, crystal size distribution), magma rheology, internal dynamics of magma chambers, formation of crystal fabric, volatiles in silicate magmas, eruptive styles and pyroclastic deposits. The students obtain versatile knowledge of formation, evolution and behavior of magmas in the Earth's crust and mantle.

Syllabus

- Structure of silicate melts
- Physical properties of melts and magmas
- Melt generation in the Earth
- Magma differentiation: crystal-melt equilibria
- Phase equilibrium modeling of magmatic systems: MELTS software
- Geothermobarometry of igneous rocks
- Crystal nucleation and growth
- Crystallization, crystal size distribution and rheological thresholds
- Magma differentiation: mechanical dynamics
- Volatiles in silicate magmas, fluid exsolution and degassing
- Dynamics of volcanic eruptions

Teaching form

Lecture (2 wh) and practical session (2 wh)

Examination form

Achievement of learning goals (unmarked): ---

Examination: Homework (data interpretation and calculations)

Prerequisites for attending

Knowledge of petrology at the bachelor level

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

3.3.1.2 Metamorphic Processes					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturers** Prof. Dr. D. Dolejš			
Type E Mineralogy and Geochemistry	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannually WS 2020/21 WS 2022/23	**Duration** 1 term
Course Metamorphic Processes		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 25

Abbreviations: E – elective, wh – week hours

Learning goals and qualifications

The students acquire ability to interpret metamorphic processes and conditions using mineral-fluid equilibria and kinetics. The learning goals include temperature ranges 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

- Crystal chemistry of rock-forming minerals
- Composition space and thermodynamics of minerals
- Equilibrium concept of metamorphism
- Construction of metamorphic phase diagrams: Theriak software
- Local and partial equilibria
- Inverse equilibrium models: Thermocalc software
- Metamorphic crystallization and local mass transport
- Chemical potentials and reaction affinity as driving forces for phase transformations
- Deformation laws and paleopiezometry
- Rheology of polymineralic and partially molten rocks
- Metamorphic fluids, internal and external buffering

Teaching form

Lecture (2 wh) and practical session (2 wh)

Examination form

Achievement of learning goals (unmarked): ---

Examination: Homework (data interpretation and calculations)

Prerequisites for attending

Knowledge of petrology at the bachelor level

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

3.3.1.3 High-Temperature Geochemistry					
Module Coordinator Prof. Dr. W. Siebel		**Lecturers** Prof. Dr. W. Siebel			
Type E Mineralogy and Geochemistry	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** annual	**Duration** 1 term
Course a) Geochemical evolution of the Earth's mantle and crust b) High-Temperature Geochronology		**Presence** a) 2 wh / 30 h b) 2 wh / 30 h	**Private study** a) 45 h b) 45 h		**Participants** a) 20 b) 20

Abbreviations: 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 high-temperature radiometric dating and tracing methods. The individual qualifications and skills of the module are specified as follows:

a) The silicate Earth encompasses the crust and mantle. On successful completion of course a), students should be able to know how these two major reservoirs were created and modified over geological time and about the magmatic processes that 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 learn about the principles of high-temperature radiogenic isotope methods. They realize that isotopes are indispensable tools for reconstructing various Earth processes, palaeo-environmental conditions and for radiometric dating. 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

Course (a) 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.

The focus of courses b) is on radiogenic isotope systems and their principles and applications in high-temperature geology. Topics and systems include:

- Principles of the Rb-Sr, U-Th-Pb, Sm-Nd and Lu-Hf dating and tracing methods
- Isotopes as tracers of sources and processes; presentation of case studies
- Radionuclides and their measurement techniques

Teaching form

a) Lecture

b) Lecture and exercises

Examination form

Achievement of learning goals (unmarked): exercises

Examination: written test (120 minutes)

Prerequisites for attending

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, 512.

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

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

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

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

Lecture notes

https://ilias.uni-freiburg.de/login.php, https://homepages.uni-tuebingen.de/wolfgang.siebel/

3.3.1.4 Analytical Methods II

Module Coordinator		**Lecturers**			
Dr. H. Müller-Sigmund		a) Dr. H. Müller-Sigmund; Dr. M. Junge; Dr. Katarina Schlöglova b) Prof. Dr. A. Danilewsky; Dr. L. Kirste			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Mineralogy and Geochemistry	150 h	5 ECTS	SS	annual	1 term
Course		**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: E – elective, wh – week hours

Learning goals and qualifications

This module provides practical and theoretical skills in advanced analytical methods important for geological materials.

a) Students learn to prepare rocks and minerals for specific analytical applications and apply these methods. They amplify their knowledge in X-ray techniques and are able to deduce on the composition and formation conditions of these samples.
b) This course is primarily assigned to the M.Sc. program *Sustainable Materials – Crystalline Materials.* Details are given in the module guide book of this program.

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 etc. both in theory and in the laboratory, where hands-on experience is an essential part of the course.

b) See module guide book of the M.Sc. program *Sustainable Materials – Crystalline Materials.*

Teaching form

a) Lecture + laboratory sessions (small groups of 2-3 students)
b) See module guide book of the M.Sc. program *Sustainable Materials – Crystalline*

Materials.

Examination form

Achievement of learning goals (unmarked): a) presence in the practical part; b) Analysis of experimental data

Examination: Marked written reports on a) (40 %) and written test on b) (60 %).

Prerequisites for attending

The module *Analytical Methods I* must have been completed.

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. & Alllderton, D.H.M. (1985): A practical guide to fluid inclusion studies. Blackie, Glasgow, 239.

b) See module guide book of the M.Sc. program *Sustainable Materials – Crystalline Materials*

Lecture notes

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

3.3.2 Elective Modules *Geomechanics and Tectonics*

3.3.2.1 Petrophysics

Module Coordinator		**Lecturers**			
Prof. Dr. T. Kenkmann		a) Prof. Dr. T. Kenkmann; Dr. M. Poelchau b) Dr. M. Poelchau			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomechanics and Tectonics E Applied Quaternary Geology	150 h	5 ECTS	WS	biannual WS 2019/20 WS 2021/22	1 term
Course		**Presence**	**Private study**		**Participants**
a) Petrophysics		a) 2 wh / 30 h	a) 45 h		40
b) Rheology and Textures		b) 2 wh / 30 h	b) 45 h		40

Abbreviations: 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 comprises 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): Regular attendance in the practical parts of (a) and (b), completion of exercises (a)

Examination: written test (60 %, 90 minutes), and presentation the project work in oral and written form (b) (40%).

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.

Lecture notes

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

<table>
<tr><td colspan="6">3.3.2.2 Rock Mechanics</td></tr>
<tr><td colspan="2">Module Coordinator
Dr. M. Poelchau</td><td colspan="4">Lecturers
a) Prof. Dr. T. Kenkmann; Dr. M. Poelchau
b) Dr. M. Poelchau; Prof. Dr. T. Kenkmann</td></tr>
<tr><td>Type
E Geomechanics and Tectonics
E Applied Quaternary Geology</td><td>Workload
150 h</td><td>Credits
5 ECTS</td><td>Term
WS</td><td>Cycle
biannual
WS 2020/21
WS 2022/23</td><td>Duration
1 term</td></tr>
<tr><td colspan="2">Course
a) Stress and Strain
b) Brittle Rock Deformation</td><td>Presence
a) 2 wh / 30 h
b) 2 wh / 30 h</td><td colspan="2">Private study
a) 45 h
b) 45 h</td><td>Participants
a) 25
b) 25</td></tr>
</table>

Abbreviations: E – elective, wh – week hours

Learning goals and qualifications

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 in 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

b) Lecture, exercises and laboratory work

Examination form

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

Examination: Written examination (a+b, 90 %) and lab report about b) (10 %)

Prerequisites for attending

The module *Computing in Geosciences* should be either completed or attended in the same semester.

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

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

3.3.2.3 Planetary Dynamics					
Module Coordinator Prof. Dr. T. Kenkmann		**Lecturers** Prof. Dr. T. Kenkmann; Dr. M. Poelchau			
Type E Geomechanics and Tectonics	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** biannual WS 2020/21 WS 2022/23	**Duration** 1 term
Course Planetary Dynamics		**Presence** 3 wh / 45 h	**Private study** 105 h		**Participants** 25

Abbreviations: E – elective, wh – week hours

Learning goals and qualifications

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: Written examination (70 %), and exercises (30%, calculations)

Prerequisites for attending

The module *Computing in Geosciences* should be either completed or attended in the same semester.

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

3.3.2.4 Impact Geology					
Module Coordinator Prof. Dr. T. Kenkmann		**Lecturers** Prof. Dr. T. Kenkmann; Dr. M. Poelchau			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomechanics and Tectonics E Geohazards	150 h	5 ECTS	WS	biannual WS 2019/20 WS 2021/22	1 term
Course		**Presence**	**Private study**		**Participants**
Impact Geology		4 wh / 60 h	90 h		40

Abbreviations: 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.

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, project *Screening Earth* with presentation

Examination form

Achievement of learning goals (unmarked): Regular attendance in the project part, consideration of the project

Examination: Written test (70 %, 90 minutes), homework (calculations, 15 %), and oral presentation (15 %)

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

3.3.2.5 Shock Waves in Rocks

Module Coordinator		Lecturer			
Prof. Dr. Thomas Kenkmann		Prof. Dr. Frank Schäfer			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Geomechanics and Tectonics	150 h	5 ECTS	WS + SS	annual	2 terms a) one term b) one term or as a block course
Course		**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: E – elective, wh – week hours

Learning goals and qualifications

Collisions of planetary bodies are among 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 students achieve a basic understanding of the fundamentals of shock wave physics, applications of shock waves, the mathematical description of shock waves in one dimension, and the thermodynamic processes relevant for meteorite impact. They are able to draw conclusions from the respective mathematical equations and develop simple implementation in computer codes

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): ---

Examination: homework (analytical and computer-based calculations, 50 %) and written exam (50 %)

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.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

3.3.2.6 Remote Sensing					
Module Coordinator Dr. G. Wulf		**Lecturer** Dr. G. Wulf			
Type E Geomechanics and Tectonics	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** annual	**Duration** 1 term
Course Remote Sensing		**Presence** 4 wh / 60 h	**Private study** 90 h		**Participants** 20

Abbreviations: E – elective, wh – week hours

Learning goals and qualifications

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. The applications of remote sensing analyses show a strong multidisciplinary character and consequently, the use, handling and analysis of such data has become indispensable in modern geosciences. The students should gain both a theoretical and practical understanding of remote sensing data and the ability to work independently using appropriate software applications for geoscientific issues.

Syllabus

The course gives students a thorough understanding of digital remote sensing and analysis techniques and applications. The module explores basic principles of remote sensing and the use of suitable software packages for quantitative analysis, e.g. GIS. In addition, the students will be trained to perform qualitative analyses with special focus on visual image interpretation. The course combines lecture-based teaching with linked practical exercises and includes case studies from the focus areas of the M.Sc. Geology program.

Teaching form

Lecture and practical work

Examination form

Achievement of learning goals (unmarked): ---

Examination: Homework (computer-based data analysis) to be solved during the semester

(60%) and a written project report at the end of the semester (40%).

Prerequisites for attending

The module *Geographic Information Systems* must have been completed.

Usage of the module in other programs

Recommended reading

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

Lecture notes

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

3.3.2.7 Engineering Geology and Geotechnics – see 3.2.4.1

3.3.3 Elective Modules *Geohazards*

3.3.3.1 Mass Movements					
Module Coordinator Prof. Dr. S. Hergarten		**Lecturer** Prof. Dr. S. Hergarten			
Type E Geomechanics and Tectonics E Geohazards	**Workload** 150 h	**Credits** 5 ECTS	**Term** SS	**Cycle** annual	**Duration** 1 term
Course Mass Movements		**Presence** 3 wh / 45 h	**Private study** 105 h		**Participants** 16

Abbreviations: 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: Homework (computer-based calculations) to be solved during the semester

Prerequisites for attending

The module *Computing in Geosciences* must have been completed.

Usage of the module in other programs

Recommended reading

Highland, L. M. & Bobrowsky, P. (2008): The Landslide Handbook – a Guide to Understanding Landslides. USGS Circular 1325, Reston, Virginia, 129.

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

http://jura.geologie.uni-freiburg.de

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

Abbreviations: E – elective, wh – week hours

*The module will probably be offered once in SS 2020 and later in winter semesters on a regular biannual basis starting from WS 2021/22.

Learning goals and qualifications

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 taught. 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 aims at providing 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 in the seminar part (b)

Examination: Written exam about a) (40 %, 60 minutes), presentation in 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

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

3.3.3.3 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 Geohazards E Applied Quaternary Geology	150 h	5 ECTS	WS	biannual WS 2020/21 WS 2022/23	1 term
Course		**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: E – elective, wh – week hours

Learning goals and qualifications

The students who successfully completed the module will have gained understanding of Earth's climate system and on natural hazards which can be linked to a changing climate, such as droughts, floods, wildfires, etc. The students will also learn about specific climatic geohazards in various regions worldwide. The participants will also improve their skills in critically evaluating scientific publications and debate press releases, synthetizing data, and presenting in front of an audience.

Syllabus

a) This course is composed of 1) a series of lectures giving the participants background information into the topic, including the Earth system and its sensitivity to climate, as well as climate-related geohazards on both short or long-term perspectives; and 2) a synthesis and presentation of chosen climatic geohazards in specific regions, undertaken by the students.

b) This part consists of a critical analysis of current research papers presenting case studies related to various climatic geohazards, in which the students will take an active part. It comprises choosing appropriate papers to discuss, participating in an open debate, and writing a short synthesis of the paper and associated discussion..

Teaching form

a) Lecture and seminar

b) Seminar

Examination form

Achievement of learning goals (unmarked): Regular attendance of the seminar parts

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

Prerequisites for attending

The module *Research Methods in Geosciences* must have been completed or attended in the same semester.

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

3.3.3.4 Impact Geology – see 3.3.2.4

3.3.3.5 Engineering Geology and Geotechnics – see 3.2.4.1

3.3.4 Elective Modules *Applied Quaternary Geology*

3.3.4.1 Quaternary Research

Module Coordinator		**Lecturers**			
Dr. C. Rambeau		Dr. C. Rambeau; Prof. Dr. F. Preusser			
Type	**Workload**	**Credits**	**Term**	**Cycle**	**Duration**
E Applied Quaternary Geology	150 h	5 ECTS	WS	biannual WS 2019/20 WS 2021/22	1 term
Course		**Presence**	**Private study**		**Participants**
Quaternary Research		4 wh / 60 h	90 h		16

Abbreviations: 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 and on how the Earth changed during the Quaternary. They will also know about the structure of Quaternary deposits in key regions of our planet.

Syllabus

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. They will themselves present the regional Quaternary geology of selected regions such as the Upper Rhine Graben, the northern Alpine Foreland or Northern Germany.

Teaching form

Lecture, seminar and practical work

Examination form

Achievement of learning goals (unmarked): Regular attendance in the practical part and seminar

Examination: Written exam (50 %, 75 minutes), oral presentation (30%) and project report (20 %).

Prerequisites for attending

Basic understanding of geology and sedimentology

Usage of the module in other programs

Recommended reading:

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

3.3.4.2 Hydrogeology					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturers** a) Prof. Dr. I. Stober b) Prof. Dr. D. Dolejš			
Type E Applied Quaternary Geology	**Workload** 150 h	**Credits** 5 ECTS	**Term** SS	**Cycle** annual	**Duration** 1 term
Course a) Advanced Hydrogeology b) Aqueous Geochemistry		**Presence** a) 2 wh / 30 h b) 2 wh / 30 h	**Private study** a) 60 h b) 60 h		**Participants** a) 25 b) 25

Abbreviations: E – elective, wh – week hours

Learning goals and qualifications

Water is an 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. 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 exercises

Examination: written exam (120 minutes)

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

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

3.3.4.3 Climatic Geohazards – see 3.3.3.3

3.3.4.4 Computing in Geosciences – see 3.2.2.1

3.3.4.5 Petrophysics – see 3.3.2.1

3.3.4.6 Rock Mechanics – see 3.3.2.2

3.4 Further Elective Modules

3.4.1 Experimental Petrology					
Module Coordinator Prof. Dr. D. Dolejš		**Lecturers** Dr. L. Fischer, Prof. Dr. D. Dolejš			
Type E Mineralogy and Geochemistry	**Workload** 150 h	**Credits** 5 ECTS	**Term** SS	**Cycle** annually	**Duration** 1 term
Course a) Experimental Methods b) Thermodynamics of Geological and Technical Materials		**Presence** a) 2 wh / 30 h b) 2 wh / 30 h	**Private study** a) 45 h b) 45 h		**Participants** a) 15 b) 15

Abbreviations: E – elective, wh – week hours

Learning goals and qualifications

The module consists of two courses:

a) “Experimental Methods” provides insights into experimental approaches to simulate magmatic and hydrothermal processes and its application to petrogenetic problems. 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. 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 evaluation and processing of experimentally obtained data.

b) “Thermodynamics of Geological and Technical Materials” focuses on thermodynamic properties of solid, liquid and gaseous phases that govern their stability and phase equilibria. We will discuss models for solids, melts and fluids, equations of state for high temperatures and pressures, thermodynamic datasets and prediction of phase equilibria and phase diagrams. Thermodynamic modeling of phase equilibria, construction of phase diagrams and prediction of chemical partitioning form basis for interpretation of pressure-temperature paths of metamorphic rocks, differentiation mechanisms of magmas as well as design and optimization of numerous technological processes such as material synthesis, crystallization, smelting, combustion, fluid extraction etc.

Syllabus

a)

- Introduction into magmatic and hydrothermal processes and overview of experimental techniques
- One atmosphere experiments and preparation of experimental samples: one-atmosphere furnace, starting materials
- High-pressure and high-temperature methods: multianvil, piston cylinder, mantle melting, crystallization, partition coefficients, phase stabilities
- Volatile constituents (fluids): internally heated pressure vessel, decompression and degassing, solubility, H_2O-CO_2 in melts, sulphide melts, H_2O-NaCl
- Hydrothermal systems: cold-seal pressure vessel, fluid-rock interaction, dissolution-precipitation processes
- Effect and control of oxygen fugacity in experiments: gas mixing furnace, buffer systems, H_2 membrane
- Evaluation, processing and interpretation of experimental data: graphical presentation of experimental results, image processing software

b)

- Energy: modes, distribution, entropy, spontaneity, stability
- Thermodynamic functions, processes and phase transformations
- Thermal properties of substances
- Pressure-temperature-volume equations of state
- Partial properties and mixing
- Multicomponent, reciprocal and ordered mixtures
- Thermodynamic origin of phase diagrams
- Mathematical methods for calculation of phase diagrams
- Dynamic simulation of thermodynamic data

Teaching form

a) Lecture and practical session

b) Lecture and exercises

Examination form

Achievement of learning goals (unmarked): regular participation in the practical parts, exercises

Examination: Homework (data interpretation and calculations)

Prerequisites for attending

Usage of the module in other programs

M.Sc. Sustainable Materials, M.Sc. Chemistry, M.Sc. Physics

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) 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

3.4.2 Geothermics and Geothermal Energy					
Module Coordinator Prof. Dr. S. Hergarten		**Lecturer** Prof. Dr. S. Hergarten			
Type	**Workload** 150 h	**Credits** 5 ECTS	**Term** WS	**Cycle** annual	**Duration** 1 term
Course Geothermics and Geothermal Energy		**Presence** 3 wh / 45 h	**Private study** 105 h		**Participants** 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: homework (computer-based calculations) to be solved during the semester

Prerequisites for attending

The module *Computing in Geosciences* must have been completed.

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

http://jura.geologie.uni-freiburg.de

3.4.3 Technical and Applied Mineralogy

This module is primarily assigned to the M.Sc. program *Sustainable Materials – Crystalline Materials.* Details are given in the module guide book of this program.

3.4.4 X-Ray Methods

This module is primarily assigned to the M.Sc. program *Sustainable Materials – Crystalline Materials.* Details are given in the module guide book of this program.

3.4.5 Advanced Crystallography

This module is primarily assigned to the M.Sc. program *Sustainable Materials – Crystalline Materials.* Details are given in the module guide book of this program.