



Module Handbook

For the study program

Master of Science Geosciences

Institute of Geology, Mineralogy und Geophysics

1. Introduction to the Handbook.....	3
1.1. Advice (<i>Beratung</i>)	5
1.2. Plan of studies (<i>Studienplan</i>)	5
2. Module descriptions	7
Applied geophysics I.....	8
Applied geophysics II.....	9
Geophysical methods.....	11
Geophysical practical.....	13
Physics of the solid Earth I.....	14
Physics of the solid Earth II.....	15
Applied hydrogeology.....	17
Applied geothermal energy.....	18
Groundwater hydraulics	19
Hydrochemistry	21
Hydrogeochemical methods I	22
Hydrogeochemical methods II.....	23
Scientific project in Hydrogeochemistry/Hydrogeology.....	24
Instrumental environmental analysis	25
Drilling engineering 1 – Geotechnical and near-surface drilling	26
Field courses in applied geology.....	27
Hydrogeological field methods (ab SS 2024)	29
Siedlungswasserwirtschaft.....	31
Earthquake processes	32
Earthquake seminar and data analysis	34
Geology and geohazards in an active subduction zone	36
Seismotectonics and Seismic Hazard	38
Measuring Earth surface motions with InSAR and GNSS	40
Grundlagen des Geoingenieurwesens.....	42
Rock mass and stress field	44
Grundbau und Bodenmechanik.....	46
Rock mass mechanics and rock engineering (Felsmechanik und Felsbau)	48
Baugrundkundung- und Dokumentation	50
Rock mass characterisation (Baugrundcharakterisierung Fels)	51
Baugrundcharakterisierung Boden.....	53
Geomechanik.....	55

Geologie des Pleisto-, Holo- und Anthropozäns	57
Geological Engineering for Subsurface Energy Systems (from '24)	59
Kristallchemie	60
Kristallisation	62
Kristallphysik	64
Festkörperspektroskopie	66
Crystal structure analysis	68
Analytical methods in rock analysis	70
Electron beam microanalysis	72
Igneous petrology	74
Kinetics	76
Metamorphic petrology	78
Thermodynamics	80
Mantle petrology	82
High-temperature geochemistry	84
Field course in tectonics and resources	86
Economic geology II	87
Geochemical analyses by laser ablation-ICP-mass spectrometry	88
Economic geology I	90
Sedimentary geochemistry	93
Structural geology	95
Mineralization in geothermal systems	97

1. Introduction to the Handbook

This module handbook provides an overview of the MSc Geosciences curriculum at the Institut für Geologie, Mineralogie und Geophysik of the Ruhr Universität Bochum. It outlines the modular structure of the program and offers guidance for planning and throughout your studies. The central focus is on descriptions of the currently available modules.

1.1. Advice (Beratung)

Advisor (Fachberater): Prior to commencing your studies, you are required to arrange an advisory meeting with either a preferred professor or the study counselor at the *Institut für Geologie, Mineralogie und Geophysik*. During this meeting, a comprehensive study plan, including module selection, is collaboratively established based on your interests. This plan is subject to approval by the examination committee and serves as a binding agreement. One adjustment is allowed within the first year, and additional changes are possible in unavoidable circumstances, such as the unavailability of a specific course. Your advisor, typically also your MSc thesis advisor, can be changed during your studies, if desired.

The *Institut für Geologie, Mineralogie und Geophysik* is committed to barrier-free learning. In order to offset disadvantages, the Institut offers individualized alternative plans for measurement of all kinds of performance to students with documented needs.

Board of Examination (Prüfungsausschuss): Should you have questions or problems that you cannot resolve with your advisor, members of the Board of Examinations or the Chair of the Board of Examinations are to be addressed.

Student council (Fachschaft): You can always seek tips, help and advice from your senior cohorts at the student council.

1.2. Plan of studies (Studienplan)

The plan of study is fully flexible and is set up individually for each student through discussions with the advisor (see above) at the beginning of the study program.

2. Module descriptions

Applied geophysics I					
Module number	Credits 10 CP	Workload 300 h	Term 1. + 3. Sem.	Frequency WS	Duration 2 semesters
Courses a) Geophysical inverse problems (WS, alternating with b) b) Seismic and electromagnetic field methods (WS, alternating with a)			Contact hours a) 3 SWS b) 3 SWS	Self-study a) 105 h b) 105 h	Group size acc. to demand
Prerequisites					
Formal: Textual: Sound mathematical skills (vector calculus, differential- and integral calculus), basic expertise in programming, basic knowledge of mechanics and electrodynamics. Preparation:					
Learning outcomes After successful completion of the module students <ul style="list-style-type: none"> • understand the theoretical foundations of seismic and electromagnetic field methods and know up-to-date measuring and data-acquisition procedures. They know and understand state-of-the-art methods of data analysis and interpretation. • understand the general philosophy of how to properly set up and solve geophysical inverse problems to create subsurface models from geophysical field surveys. They know different approaches to mathematically formulate an inverse problem and various techniques to obtain solutions in practice. They are able to solve small-scale problems themselves by writing a computer program. 					
Content					
a) Geophysical Inverse Problems Mathematical precursor on linear vector and Hilbert spaces, the continuous linear inverse problem with exact and uncertain data, discrete linear inverse problems with uncertain data, singular value decomposition, resolution analysis, conjugate gradient minimization, linearized iterative inverse problems.					
b) Seismic and electromagnetic field methods Data acquisition in reflection seismics, seismic data processing, ray and wave-equation migration, basic electromagnetic theory, electromagnetic fields in matter, geo-electric sounding and induced polarization, electromagnetic diffusion and waves in matter and ground penetrating radar.					
Teaching methods Lectures accompanied by assignments to be worked out and solved at home encompassing mathematical problems and programming tasks.					
Mode of assessment Written module examination (120 minutes)					
Requirement for the award of credit points Passed module examination, bonus points for voluntary presentation of solutions to exercises.					
Module applicability (to other study programs)					
Weight of the mark for the final score: 10 CP of 120 CP					
Module coordinator and lecturer(s): Prof. Dr. W. Friederich					
Further information Literature: Parker, R.: Geophysical Inverse Problems; Menke, W.: Geophysical Data Analysis, Discrete Inverse Theory; Feynman: Lectures on Electrodynamics; Telford, Geldart, Sheriff: Applied Geophysics, Everett, M., Near surface applied geophysics, 403 pp. Cambridge University Press, 2013					

Applied geophysics II							
Module number	Credits	Workload	Term	Frequency	Duration		
	10 CP	300 h	2. Sem.	SS	1 semester		
Courses		Contact hours		Self-Study	Group size		
a) Reservoir geophysics (SS) b) Rock physics (SS)		a) 3 SWS b) 3 SWS		a) 120 h b) 90 h	Acc. to demand, lab experiments in groups of 3 persons		
Prerequisites:							
Formal:							
Textual: Sound mathematical skills (vector calculus, differential- and integral calculus).							
Preparation: -							
Learning outcomes							
After successful completion of the module students							
<ul style="list-style-type: none"> • appreciate the scale-dependent approach to the physical characterization of rocks (micro- to decimeter-scale) and reservoirs (deci- to kilometer-scale). • understand the relation between physical properties of rocks and their chemical composition and microstructure. • learned the use and limits of empirical and theoretical concepts for the description of heterogeneous media. • know the practical aspects of a suite of methods in exploration geophysics. • are familiar with the mathematical description of physical processes on rock and reservoir scale. • understand the origin of the governing partial differential equations and master some approaches to their solution. 							
Content							
a) Reservoir geophysics (large-scale perspective)							
<ul style="list-style-type: none"> • Introduction to reservoirs (hydrocarbon, geothermal) • Physical properties of reservoir fluids • Hydraulic transport (Kozeny-Carman relation) and storage (linear poro-elasticity I: isostatic stress states) • Theory and practice of pumping tests (diffusion equation, scaling) • Geothermics (add advection to diffusion) • Aspects of waves in real media (wave equation, linear poro-elasticity II: add deviatoric stresses) 							
b) Rock physics (small-scale perspective)							
<ul style="list-style-type: none"> • Introduction to rocks and minerals • Porosity and interface phenomena • Hydraulic transport in rocks (Darcy's law, permeability models) • Elasticity (stress, strain, Hooke's law, averaging schemes) • Failure of rocks (fracture and friction) <p>+ Lab practical: students independently conduct simple experiments to determine basic physical properties of rocks (density, porosity, permeability) and fluids (density, viscosity)</p>							
Teaching methods							
Lectures, assignments (deepening of contents through own research, solving of analytic and numerical problems), laboratory experiments							
Mode of assessment							

Written final exam (3 hours), report on lab experiments

Requirements for the award of credit points

Passed module exam (at least 50%)

Module applicability (to other study programs)

Weight of the mark for the final score: 10 CP of 120 CP

Module coordinator and lecturer(s): Prof. Dr. Jörg Renner (coordinator)

Further information:

Literature: Jaeger, Cook, Zimmerman "Fundamentals of Rock Mechanics"; Gueguen, Palciauskas "Introduction to the physics of rocks"; Schön "Physical properties of rocks"; Mavko, Mukerji, Dvorkin "The rock physics handbook"; AGU reference shelf "Rock physics and phase relations"; Sully "Elements of petroleum geology"; Wang "Theory of linear poro-elasticity"; Fetter "Applied hydrogeology"; Zoback "Reservoir geomechanics"; Carcione "Wave-fields in real media"

Geophysical methods					
Module number	Credits	Workload	Term	Frequency	Duration
	14 CP	420 h	1. Sem.	WS	3 semesters
Courses			Contact hours	Self-Study	Group size
a) Field practical b) Scientific programming c) Geophysical seminar (2 x WS)			a) 6d field, 4d data analysis b) 3 SWS c) 4 SWS	a) 70h b) 105 h c) 60 h	a) 16 b) and c) according to demand
Prerequisites					
Formal:					
Textual: Basic programming experience					
Preparation: Field-practical guide, Python online documentation and tutorials, Metcalf, M.: Fortran 95/2003 explained, selected scientific papers					
Learning outcomes					
After successful completion of the module, students					
<ul style="list-style-type: none"> are able to plan and set up a field campaign, choose appropriate methods and instruments, carry out measurements and use available techniques to analyse the data when given a geophysical survey task. gained proficiency in a programming language (either Python or Fortran) to the extent that they can exploit advanced concepts, such as object-oriented programming, and thus are able to write programs to analyse data acquired in the field, numerically solve geophysical problems, and visualize the results. learned how to perform general and topical literature surveys and how to perform an exegesis of a scientific publication. applied their acquired knowledge and skills to understand and also summarize publications from different fields of geophysics. 					
Content					
a) Field practical					
Students plan and organize a geophysical field campaign to investigate a specific subsurface target using a specifically selected combination of geophysical survey methods, such as seismics, magnetics, geoelectrics, ground penetrating radar or gravimetry. Data are acquired in the field and analysed in the classroom using state-of-the-art techniques. Programming skills are employed to prepare and organize data and to visualize results for further interpretation.					
b) Scientific programming					
Data types, assignments, mathematical operations and functions, input/output, characters and strings, arrays and loops, conditional statements, subroutines and functions, modules, derived data types, polymorphic types and classes. Application of concepts to geophysical problems. Programming language: Python.					
c) Geophysical seminar					
Literature seminar about a specific geophysical topic where students read and work through selected publications to later report to their fellow students on the contents in a seminar. The student presenters take on the role of moderators during the subsequent discussion of the papers and their presentations.					
Teaching methods					
Field work, group and project work, oral presentations					
Mode of assessment					
Report for field practical, evaluation of written programs, oral presentations and attendance in seminar					
Requirement for the award of credit points					

Passed report, submission of programming work, and oral presentation
Module applicability (to other study programs)
Weight of the mark for the final score: 14 CP of 120 CP
Module coordinator and lecturer(s): Prof. Dr. Friederich (Coordinator), Prof. Dr. Renner
Further information
Literature: Python online documentation and tutorials, Metcalf, M.: Fortran 95/2003 explained

Geophysical practical							
Module number	Credits	Workload	Term	Frequency	Duration		
5 CP	150 h	1., 2. or 3. Sem	every semester	1 semester			
Courses		Contact hours	Self-Study	Group size			
Prerequisites: Formal: None Textual: None Preparation:							
Learning outcomes After successful completion of the module students <ul style="list-style-type: none"> • are able to formulate and continuously adapt a work plan for a month. • appreciate the integration of their work into a team effort. • have deepened their command of specific tools and their insight into specific geophysical problems. • are familiar with typical work processes in geophysics-related companies and are able to work through a well-defined geophysics-related operational task in a structured way within a given time. 							
Content Students spend 20 days in a company or a working group of the institute, where they are integrated into operational work processes and work on theoretical or practical tasks related to the research activities of the company or working group.							
Teaching methods Team work, project work							
Mode of assessment Report							
Requirements for the award of credit points Assessment of a written report by the advisor							
Module applicability (to other study programs)							
Weight of the mark for the final score: 5 CP of 120 CP							
Module coordinator and lecturer(s): Prof. Dr. Friederich, Prof. Dr. Renner, Prof. Dr. Bedford, Prof. Dr. Harrington							
Further information							

Physics of the solid Earth I					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. Sem.	SS	1 semester
Courses			Contact hours	Self-Study	Group size
a) Seismological data analysis b) Seismic waves: theory and numerical modelling			a) 3 SWS b) 3 SWS	a) 105 h b) 105 h	acc. to demand
Prerequisites:					
Formal:					
Textual: Sound mathematical skills (vector calculus, differential and integral calculus), basic knowledge of elasticity theory, basic expertise in programming.					
Preparation:					
Learning outcomes					
After successful completion of the module students					
<ul style="list-style-type: none"> • understand the theoretical foundations of seismic wave propagation, and understand and are able to apply selected numerical methods for simulation of seismic wave propagation. • know a selection of the most important methods for seismological data analysis, understand them, are able to apply them to simple datasets and to partially implement them by writing a computer program. 					
Content					
a) Seismological data analysis					
Digital signal recording, Nyquist theorem, Fourier transform, analogue and digital filtering, spectral analysis, time-frequency analysis by multiple filtering methods and moving window analysis, dispersion analysis, receiver function analysis, beam forming and splitting analysis, programming in Python.					
b) Seismic waves					
Stress and strain, seismic wave equation in 3D heterogeneous media, Green functions for 1D, 2D and 3D wave propagation, seismic waves from a point source in full space, description of seismic sources, moment tensor, seismic waves in layered media, numerical simulation methods, finite differences and finite volume, Galerkin finite element methods, programming in Python.					
Teaching methods					
Lectures are accompanied by assignments to be worked out and solved at home encompassing mathematical problems and programming tasks.					
Mode of assessment					
Written module examination (120 minutes)					
Requirements for the award of credit points					
Passed module examination, bonus points for voluntary presentation of solutions to exercises					
Module applicability (to other study programs)					
Weight of the mark for the final score: 10 CP of 120 CP					
Module coordinator and lecturer(s): Prof. Dr. Friederich					
Further information					
Literature: Aki & Richards: <i>Quantitative Seismology I+II</i> ; Igel: <i>Computational seismology</i> ; Robinson & Treitel: <i>Geophysical signal analysis</i>					

Physics of the solid Earth II					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. + 3. Sem.	WS	2 semesters
Courses			Contact hours	Self-Study	Group size
a) Continuum mechanics (WS, alternating with b)			a) 3 SWS b) 3 SWS	a) 110 h b) 100 h	acc. to demand
b) Physics of Earth materials (WS, alternating with a)					
Prerequisites					
Formal:					
Textual: Sound mathematical skills (vector calculus, differential and integral calculus)					
Preparation: -					
Learning outcomes					
After successful completion of the module students					
<ul style="list-style-type: none"> • know micromechanical/atomistic concepts behind bulk properties (in particular density and viscosity). • appreciate the basic theoretical concepts of solid-state physics and thermodynamics. • are familiar with the basic approaches and techniques in continuum mechanics. • understand the basic concept of numerical solution of differential equation master. • are capable of coding simple finite-difference schemes. • grasp the relevance of physical properties of rocks for geodynamic problems, such as subduction and delamination. • can apply the introduced mathematical tools to problems encountered for the three Earth spheres: atmosphere, hydrosphere, and geosphere. 					
Content					
a) Continuum Mechanics					
<ul style="list-style-type: none"> • Differentiation and integration of scalar and vectorial fields. • Kinematics (Euler and Lagrange description). • Conservation laws in differential and integral form (Navier-Stokes equations). • Applications (specific cases of the Navier-Stokes equations and similarity numbers). 					
b) Physics of Earth materials					
<ul style="list-style-type: none"> • Geophysical and geochemical Earth models. • Elastic constitutive equations for minerals at high temperature and pressure. • Crystal defects (point defects, dislocations, grain boundaries). • Deformation mechanisms at high temperatures (diffusion and dislocation creep). • Applications of flow laws to geodynamic problems. 					
Methods of teaching					
Lectures, assignments (deepening of contents through own research, solving of analytic and numerical problems including programming of a finite-difference algorithm).					
Modes of assessment					
Written module exam (3 hours)					
Requirement for the award of credit points					
Passed module exam (at least 50%)					
Module applicability (to other study programs)					
Weight of the mark of the final score: 10 CP of 120 CP					
Module coordinator and lecturer(s): Prof. Dr. Jörg Renner (Coordinator)					

Further information:

Literature: Schubert, Turcotte, Olson "Mantle convection in the Earth and Planets"; Karato "The dynamic structure of the deep Earth"; Anderson "New theory of the Earth"; Poirier "Creep of crystals"; Hirth, Lothe "Theory of dislocations"; Gerya "Numerical geodynamic modeling"; Holzapfel "Nonlinear solid mechanics"; Tritton "Physical fluid dynamics";

Applied hydrogeology							
Module number	Credits	Workload	Term	Frequency	Duration		
6 CP	160 h	2. Sem.	every WS	every WS	2 semesters		
Courses		Contact hours	Self-study	Group size			
a) Fissured rock hydrogeology (WS)		(a) 2 SWS	(a) 50 h	(a) 40 students			
b) Climate change and water resources (WS)		(b) 2 SWS	(b) 50 h	(b) 40 students			
Prerequisites							
For students in Master's programs							
Learning outcomes							
Upon completion of the module, students will be able to demonstrate insights into various aspects of applied hydrogeology and describe interrelationships. They							
<ul style="list-style-type: none">• deepen their knowledge in the field of fractured groundwater significantly beyond the level of the basic lectures.• are able to characterize and evaluate globally important water resources with regard to occurrence, genesis, use and sustainable management.• assess the impact of climate change on water resources and their management.							
Content							
a) Fissured rock hydrogeology							
Basics, terms and methods of describing fractured aquifers including occurrence and exploration of bedrock aquifers (magmatic, metamorphic, sedimentary), qualitative and quantitative aspects of water use from fractured aquifers.							
b) Climate change and water resources							
Fundamentals and concepts of climate change and methods to study its influence on water management including collection, presentation and interpretation of climate data, climate models, political climate targets and approaches to their implementation; global, regional and local impact on quality and quantity of usable water resources; methods of climate adaptation.							
Teaching methods							
Lectures with accompanying exercises.							
Mode of assessment							
Written exam on the contents of the courses a), b) duration 120 minutes at the end of the WS.							
Requirement for the award of credit points							
Passed module examination; passed ungraded lecture in a); participation in, and submission of at least 70% of each of the exercises in b).							
Module applicability (in other degree programs)							
Weight of the mark for the final score							
5 % of the total grade (6 out of 120 CP)							
Module coordinator and lecturer(s)							
Dr. A. Hachenberg							
Further information							
Relevant literature will be presented at the beginning of each session.							

Applied geothermal energy							
Module number	Credits	Workload	Term	Frequency	Duration		
8 CP	240 h	1.+ 2. Sem.	a) each WS b) each SS	2 semesters			
Courses a) Shallow geothermal energy (WS) b) Deep geothermal energy (SS)		Contact hours (a) 2 SWS (b) 3 SWS	Self-study (a) 65 h (b) 100 h	Group size 40 students			
Prerequisites For students in Master programs							
Learning outcomes After completion of the module, the participants will <ul style="list-style-type: none">• be able to dimension simple planning examples for geothermal plants and to determine the necessary parameters.• understand various sub-areas of geothermal energy (shallow and deep geothermal energy) as well as the different types of geothermal systems (hydrothermal, petrothermal, open and closed systems).• understand the theoretical background and current calculation methods.• know the legal principles and guidelines for the construction of geothermal plants and boreholes.• The deep geothermal energy course deals with physical heat transfer processes at greater depths and the associated processes that are important for the optimal energy yield of such systems.							
Content a) Shallow geothermal energy Overview of geothermal energy and energy in Germany, functioning of heat pumps, guidelines and legal bases, open and closed systems, dimensioning of geothermal probe systems, insight into seasonal heat reservoirs. b) Deep geothermal energy Fundamentals and methods of deep geothermal energy including potentials and uses in Germany and internationally, geophysical exploration and characterization of deep geothermal reservoirs.							
Teaching methods Lectures with accompanying exercises							
Mode of assessment Written examination on the contents of courses a) and b); duration: 120 minutes at the end of the summer semester.							
Requirements for the award of credit points Passed module examination; Participation in and submission of at least 70 % of the exercises in a) and b).							
Module applicability (in other programs)							
Weight of the mark for the final score 5 % of the total grade (8 of 120 CP)							
Module coordinator and lecturer(s) Prof. Dr. Stefan Wohnlich, Prof. Dr. Renner							
Other information Relevant technical literature will be presented at the beginning of each course.							

Groundwater hydraulics					
Module number	Credits	Workload	Term	Frequency	Duration
	12 CP	360 h	1. Sem	Every WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Introduction to groundwater hydraulics (WS)			(a) 4 SWS	(a) 120 h	(a) 40 students
b) Hydraulic groundwater modelling (WS)			(b) 4 SWS	(b) 120 h	(b) 40 students
Prerequisites					
For students in Master programs					
Learning outcomes					
At the end of the module, participants will					
<ul style="list-style-type: none"> • be able to describe and evaluate groundwater flow and conservative mass transport in the subsurface. • know methods of experimental investigation and determination of hydraulic parameters under different boundary conditions and can derive and evaluate these mathematically. • be familiar with the evaluation and interpretation of groundwater hydraulic parameters and use them to deal with classical hydrogeological problems. • be able to use numerical modelling approaches to effectively model groundwater flow based on existing hydrogeological information. • be in the position to estimate and describe the quality and limitations of hydraulic models and use them to predict future situations. 					
Content					
<p>a) Introduction to groundwater hydraulics</p> <ul style="list-style-type: none"> • Methods for the collection and evaluation of hydraulic parameters (Darcy-tests, pump tests, Slug&Bail tests). • Conveyance of knowledge about groundwater flow and the construction of groundwater level plans. • Execution and evaluation of pumping tests by means of graphical and analytical solutions. • Practical tasks for lowering the groundwater level through well systems in excavation pits or calculation of well yield. 					
<p>b) Hydraulic groundwater modelling</p> <ul style="list-style-type: none"> • Teaching of knowledge and methods for understanding and evaluation of mass transport processes in groundwater. • Methods for quantifying the subsurface (geostatistical approaches). • Knowledge transfer for the modelling of mass transport with regard to the structure of a model, boundary conditions, advantages and disadvantages of models and how modelling programs work. • Visualization and interpretation of model results. 					
Teaching methods					
Lectures with accompanying calculation exercises.					
Software exercises on the PC.					
Mode of assessment					
Written examination on the contents of the courses, 'Introduction to groundwater hydraulics' and 'Hydraulic groundwater modelling'; duration: 120 minutes.					
Requirements for the award of credit points					
Passed module examination					
Module applicability (in other programs)					

Weight of the mark for the final score 10 % of the total grade (12 of 120 CP)
Module coordinator and lecturer(s) Dr. Thomas Heinze
Other information Relevant technical literature will be presented at the beginning of each course.

Hydrochemistry					
Module number	Credits	Workload	Term	Frequency	Duration
	12 CP	360 h	1. Sem.	Every WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Inorganic hydrochemistry			(a) 4 SWS	(a) 120 h	(a) 40 students
b) Organic hydrochemistry			(b) 4 SWS	(b) 120 h	(b) 40 students
Prerequisites					
For students in Master programs					
Learning outcomes					
At the end of the module, participants will					
<ul style="list-style-type: none"> • understand the role of chemical processes in water-rock interactions. The fundamentals of thermodynamics enable them to recognize and evaluate hydrogeochemical equilibrium and imbalance states of different reaction types. • understand the hydrogeochemical basics, terms and methods. • be able to classify organic substances and pollutants in the subsurface. • know the relevant structures and properties, and thus understand their behaviour and mobility of contaminants in the environment. 					
Content					
a) Inorganic hydrochemistry					
Fundamentals, concepts and methods of inorganic hydrochemistry including law of mass action, concentration and activity, solubility and saturation, types of hydrochemical reactions, equilibrium and imbalance, sorption, toxicity and regulatory provisions.					
b) Organic hydrochemistry					
Fundamentals, concepts and methods of organic hydrochemistry including classes of substances, structures and properties of organic substances, phase formation, volatility, degradation, solubility, sources and legal regulations, cases of contamination and approaches of remediation.					
Teaching methods					
Lectures with accompanying calculation exercises					
Mode of assessment					
Written module examination on the contents of a) and b); duration: 120 minutes at the end of the winter semester.					
Requirements for the award of credit points					
Passed module examination					
Module applicability (in other programs)					
Weight of the mark for the final score					
10 % of the total grade (12 of 120 CP)					
Module coordinator and lecturer(s)					
Prof. Dr. Tobias Licha					
Other information					
Relevant technical literature will be presented at the beginning of each course.					

Hydrogeochemical methods I							
Module number	Credits	Workload	Term	Frequency	Duration		
	6 CP	180 h	1. Sem.	Every WS	1 semester		
Courses		Contact hours	Self-study	Group size			
a) Isotope hydrogeochemistry (lecture)		(a) 2 SWS	(a) 60 h	40 students			
b) Isotope hydrogeochemistry (exercise)		(b) 2 SWS	(b) 60 h				
Prerequisites							
For students in Master programs							
Learning outcomes							
Upon completion of the module, students will be able to grasp the importance of isotope ratios for the study of the origin of water and dissolved constituents in the hydrological cycle. They are familiar with a wide range of relevant isotope systems that are widely used in the fields of hydrogeochemistry and environmental geosciences for a wide variety of problems. They participants can use radiogenic isotopes for dating, determination of residence times, flow path of water, as tracer and for designation of origin. Stable isotopes will be used as geothermometer for determination of origin of water, elements, gases and pollutants, redox reactions and process determination. You will get familiar with analytical methods for sampling and determining of isotope data, and be able to process and evaluate them. The lecture is complemented by course-related exercises based on real case studies.							
Content							
a) Isotope hydrogeochemistry (lecture)							
Basics, terms and methods of isotope hydrogeochemistry including stable, radioactive and radiogenic isotopes, relevant isotope systems and ratios, fractionation processes, their applications and analytical methods, possibilities of interpretation in hydrogeological and hydrogeochemical questions.							
b) Isotope hydrogeochemistry (exercise)							
Application of theoretical background in guided exercises on real case studies.							
Teaching methods							
Lectures with accompanying exercises.							
Mode of assessment							
Written exam on the contents of the courses duration: 120 minutes. Evaluation of the exercises							
Requirement for the award of credit points							
Passed written module exam							
Participation in, and submission of at least 70% of the exercises							
Module applicability (all Master course of GMG)							
Weight of the mark for the final score							
5 % of the total grade							
Module coordinator and lecturer(s)							
Dr. Andrea Hachenberg							
Further information							
Relevant literature will be presented at the beginning of each course.							

Hydrogeochemical methods II							
Module number	Credits	Workload	Term	Frequency	Duration		
Courses		Contact hours		Self-study	Group size		
a) Environmental forensics b) Hydrogeochemical modelling		(a) 2 SWS (b) 4 SWS		(a) 60 h (b) 120 h	40 students		
Prerequisites							
Registered in Master programs							
Learning outcomes							
<p>(a) Anthropogenic use of groundwater is often associated with a contamination of the same. It is becoming increasingly relevant to identify the polluters of such contamination. For this purpose, the emerging field of environmental forensics offers some methodological possibilities, which the participants will learn to know and apply. Further, the students will learn about the recent development of reactive tracers for geothermal applications but also for studying subsurface processes. The participants will learn which tracers are useful for which problem by means of examples.</p> <p>(b) Hydrogeochemical modeling allows the students to gain a deeper understanding of the hydrogeochemical processes discussed and how to represent them in model form. They understand the added value of numerical equilibrium modeling for hydrochemical data, and can describe, evaluate, and predict the effects of different frameworks on solute distribution.</p>							
Content							
a) Environmental forensics							
Basics, terms and methods of environmental forensics including polluter pays principle and legal basis, hydrochemical proxies and indicators, possibilities of using reactive tracers, international and national case studies.							
b) Hydrogeochemical modelling							
Basics, terms and methods of hydrogeochemical modeling including models and databases, simulation of hydrochemical equilibrium reactions, mixing reactions, kinetically controlled reactions, inverse modeling, 1D reactive solute transport and isotopic fractionation, graphical presentation of the results with various programs.							
Teaching methods							
Lectures with accompanying exercises, software exercises (PhreeqC) on the PC							
Mode of assessment							
Written exam on the contents of the courses a) and b); duration 120 minutes. Evaluation of the exercises during the course in b and a final project in b.							
Requirement for the award of credit points							
Passed written module exam							
Participation in, and submission of at least 70% of each of the exercises and the final project in b.							
Module applicability (all Master course of GMG)							
Weight of the mark for the final score							
7.5 % of the total grade							
Module coordinator and lecturer(s)							
Dr. Andrea Hachenberg							
Further information							
Relevant literature will be presented at the beginning of each course.							

Scientific project in Hydrogeochemistry/Hydrogeology					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. Sem.	SS	1 semester
Courses			Contact hours	Self-study	Group size
a) Scientific soft skills			(a) 2 SWS	(a) 80 h	(a) 40 students
b) Project work			(b) 1 SWS	(b) 175 h	(b) 40 students
Prerequisites					
For students in Master programs					
Learning outcomes					
At the end of the module, participants will know how to					
<ul style="list-style-type: none"> • formulate a scientific research question, derive a hypothesis as well as identify necessary tasks to address the raised question. • obtain, manage, and organize scientific data. • find and organize relevant literature and how to extract core statements quickly. • extract and summarize relevant information from data. • structure, write and formulate a concise scientific report. • orally present scientific results and how to participate in a scientific discussion. 					
Content					
a) Scientific soft skills					
Writing of reports, oral presentations, data management and data analysis, literature search and bibliography management, strategies for scientific project management.					
b) Project work					
Conduction of a small research project to a self-selected or provided topic in the field of hydrogeology or hydrogeochemistry or in the field of work of a responsible supervisor in the department. Projects can involve field and/or laboratory work, mathematical/numerical modeling or be based on a literature study. In the research project module, the contents of the accompanying seminar of this module should be applied.					
Teaching methods					
Seminar with accompanying practical applications using software.					
Application of the theoretical content within a small research project.					
Mode of assessment					
Written report of max. 20 pages and an oral presentation.					
Requirements for the award of credit points					
Passed module examination					
Module applicability (in other programs)					
Weight of the mark for the final score					
8,33 % of the total grade (10 of 120 CP)					
Module coordinator and lecturer(s)					
Dr. Wiebke Warner, Dr. Thomas Heinze					
Other information					
Relevant technical literature will be presented at the beginning of each course.					

Instrumental environmental analysis					
Module number	Credits	Workload	Term	Frequency	Duration
	6 CP	180 h	3. Sem.	WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Basics in instrumental environmental analysis (Lecture) b) Environmental sampling and analysis (Lab course)			(a) 2 SWS (b) 2 SWS	(a) 60 h (b) 60 h	20 students
Prerequisites					
Students enrolled in a Geoscience Master program and related MSc programs.					
Learning outcomes					
After successful completion of the module, students will					
<ul style="list-style-type: none"> • gain a thorough understanding in instrumental methodologies, monitoring strategies to obtain meaningful data in anthropogenically influenced ecosystems • will be able to transfer theoretical knowledge in instrumental environmental analysis to plan sampling campaigns and analysis • obtain a general understanding of the complexity of environmental problems • raising awareness for contamination sampling procedures during field and lab analysis • be able to select appropriate analytical methods according to the research question or environmental problem and are able to interpret environmental data 					
Content					
a) Basics in Instrumental Environmental Analysis					
<ul style="list-style-type: none"> • Typical problems and questions in environmental forensics and lab methods to answer them. • Successful sampling strategies, storage and sample preparation. • Analytical methods in environmental forensics: in-field parameters, single compound analysis, sum parameter analysis, mass-spectrometry and chromatography and future developments. • Quality assurance, such as calibration, standards etc. and limitations of analytical methods • Data handling, quantitation, interpretation and presentation. • Understanding scientific publication and transfer to lab. 					
b) Environmental Sampling and Analysis					
<ul style="list-style-type: none"> • Handling of three environmental samples, from sampling to analysis and data interpretation. 					
Types of courses					
<ul style="list-style-type: none"> • Lectures, lab practical and project work in small groups. 					
Types of examination					
<ul style="list-style-type: none"> • 5-10 min presentation of a scientific publication regarding an analytical topic (no grade) • Three lab reports, which are the prerequisite for attending the written exam • Written exam (60 mins) 					
Requirements for the award of credit points:					
Passing grade for the final exam					
Module applicability: as agreed upon with the coordinator					
Weight of the mark for the final score					
5 % of the final grade (6 von 120 CP)					
Module coordinator and lecturer(s)					
Dr. Wiebke Warner					
Further information Will be communicated at the beginning via moodle.					

Drilling engineering 1 – Geotechnical and near-surface drilling							
Module number	Credits	Workload	Term	Frequency	Duration		
5 CP	150 h	3. Sem.	WS	1 semester			
Courses		Contact hours	Self-study	Group size			
Drilling 1		5 SWS	75 h	40 students			
Exercises in drilling 1							
Prerequisites							
For students in Master programs							
Learning outcomes							
The course presents an introduction to drilling technologies, focussing on shallow, near-surface applications like geothermal borehole heat exchangers, water and monitoring wells, geotechnical as well as environmental investigation. Dry, augering and mud drilling techniques will be compared and discussed, as well as sampling and coring for different applications.							
<ul style="list-style-type: none"> • Introduction to geotechnical investigations and selected standards. • Rotary drilling with direct circulation including tooling. • Rotary drilling with indirect circulation including tooling, applications, air lifting. • Mud losses, artisean conditions while drilling, cementing. • Water and monitoring wells, well testing, sampling. • Shallow geothermal, borehole heat exchanger systems. • Environmental Direct Push sampling, coring, on-site analysis. 							
Contents							
<ul style="list-style-type: none"> • Basics of shallow drilling. • Coring and cuttings. • Geotechnical exploration, probing and analysis (DIN 4021 / EN ISO 22475). • Foundation work and drilling. • Water well drilling and completion. • Shallow geothermal drilling, completion and applications including standard W 120. • Quality assurance and control of shallow geothermal BHE systems. 							
Teaching methods							
Classroom and hands on lectures, field work on the rig and its auxiliary equipment, laboratory experiments, practical case studies.							
Mode of assessment							
Written examination (60 Min.).							
Requirement for the award of credit points							
According to current examination regulations							
Module applicability							
Weight of the mark for the final score							
4,17 % der Gesamtnote (5 von 120 CP)							
Module coordinator and lecturer(s)							
Prof. Dr. Tobias Licha (Lehrtransfer IEG Bochum)							
Further information							
Relevant literature will be presented at the beginning of each session.							

Field courses in applied geology					
Module number	Credits	Workload	Term	Frequency	Duration
	7 CP	210 h	WS/SS	annual	1 semester
Courses Field courses in applied geology in various hydrogeological settings (Europe, South America, etc.)		Contact hours 14 days	Self-study 98 h	Group size Depending on the location of the courses: between 12 and 20 students	
Prerequisites For students in the Masters program Geosciences with the focus in Applied Geology, Sedimentology, Mineralogy, and Crystallography.					
Learning outcomes The learning aims are dependent on the topics of the field course. The field courses combine aspects of Applied Geology (Hydrogeology, Engineering Geology, Geothermal Energy, Economic Geology) with general geological knowledge like Structural Geology, Sedimentology, Geophysics etc. Generally, the aim is to give the students the possibility to combine knowledge from classes and laboratory exercises with field observation in order to construct a sound geological model, that can be applied to practical purposes like mining, engineering or geothermal applications. After the successful attendance of the module the students are able to understand the complexity of geological settings.					
Content Depends on the field area.					
Teaching methods Seminar before the field trip, discussions in the field, planning and independent work in the field.					
Mode of assessment The module is graded on the basis of the evaluation of the lecture and the report from the pre-seminar and the submitted sketches and reports. Mandatory participation in the fieldwork. The pro-seminar consists of a lecture on selected topics (10-15 minutes) and submission of an abstract of the talk (1-2 pages). Presentation of 4-5 sketches of the field settings (done in the field and refined in the evenings in the field camp). The original copy as well the refined copy are to be submitted.					
Requirement for the award of credit points Active participation in the field work, discussion and seminars. Inability to participate in more than 33% of the field days may be excused only on very well-founded medical grounds; otherwise such absence will lead to a failing grade in the module.					
Module applicability The module is open to students specializing in Sedimentology, Crystallography or Petrology as well. In exceptional cases, after discussion with the instructor, students specializing in other subfields of geosciences may also participate.					
Weight of the mark for the final score 5,8 % of the overall grade.					
Module coordinator and lecturer(s) Prof. Dr. S. Wohnlich (coordinator), in cooperation with other lecturers of GMG.					
Further information					

Please contact the instructor if you have questions.

Literature Relevant technical literature will be presented at the beginning of each course

Hydrogeological field methods (ab SS 2024)					
Modul number	Credits	Workload	Term	Frequency	Duration
	12 CP	360 h	2. Sem.	Every SS	1 semester
Courses			Contact hours	Self-study	Group size
a) Hydrogeological field exercises b) Analysis of measurement results (Seminar)			(a) 9 days (b) 2 SWS	(a) 90 h (b) 150 h	20 students
Prerequisites					
Knowledge of groundwater hydraulics, pumping tests, solute transport in groundwater, aquifer systems, groundwater recharge or passing of the examination of "Introduction to Groundwater Hydraulics". Basic knowledge in computer-based analysis using GIS, EXCEL, Python or Matlab.					
Learning outcomes					
Upon completion of the module, students are able to					
<ul style="list-style-type: none"> • perform, evaluate, and interpret hydrogeological field tests independently. • conduct a wide variety of hydrogeological experiments. • apply the concept of tracers for the investigation of hydraulic conditions in the subsurface. • carry out a tracer experiment and evaluate and interpret the data collected in the process. • transfer their knowledge from the lecture hall to real-world problems. 					
Content					
(a) Hydrogeological field exercises					
Performance of hydrogeologic field methods including pumping tests, seepage tests, discharge measurements, sampling and hydrochemical field laboratory, drilling and sediment retrieval, groundwater leveling plan preparation; basics, terms and methods of tracer hydrology including types and properties of tracers, solubility, sorption, planning and execution of tracer experiments: Input, sampling and measurements, recovery and interpretation of passage curves, derivation of hydraulic parameters, documentation, evaluation and ad-hoc interpretation of collected data.					
(b) Analysis of measurement results (seminar)					
Computer-based analysis of measurement results from the field exercises using GIS, EXCEL, MATLAB, and specialized software for the respective tasks: Analysis of pumping tests using curve matching to obtain aquifer properties & characterize aquifer; Curve matching of tracer passage curves to obtain transport properties; (Inverse) modeling of infiltration experiments to obtain infiltration capacity of the soil; GIS based catchment analysis and calculations of groundwater recharge.					
Teaching methods					
Lectures with accompanying calculation exercises and field exercises.					
Mode of assessment					
Grading of written reports and experiment analysis					
Requirement for the award of credit points					
Active participation in the field work, discussion, and seminars. Inability to participate in more than 2 field days may be excused only on very well-founded medical grounds; otherwise, such absence will lead to a failing grade in the module. Submission of a report covering the description of the field experiments, their results and an in-depth analysis according to the techniques covered in the course.					
Module applicability					
Weight of the mark for the final score					
10 % der Gesamtnote (12 von 120 CP)					
Module coordinator and lecturer(s)					
Dr. Thomas Heinze					

Further information

Relevant technical literature will be presented at the beginning of each course

Siedlungswasserwirtschaft							
Modul number	Credits	Workload	Term	Frequency	Duration		
Courses a) Siedlungswasserwirtschaft		Contact hours 3 SWS		Self-study 105 h	Group size 40 students		
Prerequisites							
Für Studierende in Master-Programmen							
Learning outcomes							
Studierende sind nach Beendigung des Moduls in der Lage,							
<ul style="list-style-type: none"> • Methoden, Zusammenhänge und Einflüsse im Bereich der Siedlungswasserwirtschaft zu beschreiben und zu bewerten. • kennen die grundlegenden hydrologischen Prozesse in natürlichen und anthropogenen Systemen und Ansätze zu deren Untersuchung. • kennen die komplexen Interaktionen des Menschen mit der Hydrosphäre. 							
Content							
Grundlagen, Begriffe und Methoden der Siedlungswasserwirtschaft: natürliche hydrologische Systeme und deren Erkundung, anthropogene Nutzung von Wasserressourcen: Wassergewinnung, Wasseraufbereitung, Wasserspeicherung, Wasserförderung und -verteilung, Betriebswasser, Abwasser und Klärschlamm, Regenwasserbewirtschaftung, Flächenversiegelung.							
Teaching methods							
Vorlesungen mit begleitenden Übungen							
Mode of assessment							
Schriftliche Klausur über die Inhalte der Lehrveranstaltungen, Dauer 90 Minuten am Ende des SS.							
Requirement for the award of credit points							
bestandene Modulprüfung Teilnahme an, und Abgabe von jeweils mindestens 70 % der Übungen							
Module applicability							
Weight of the mark for the final score							
4,17 % der Gesamtnote (5 von 120 CP)							
Module coordinator and lecturer(s)							
Prof. Dr. Tobias Licha (Lehrtransfer von Fakultät Bauingenieurwesen)							
Further information							
Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.							

Earthquake processes					
Module number	Credits	Workload	Term	Frequency	Duration
	6 CP	180 h	1. Sem.	WS	1 semester
Courses Earthquake seismology and the seismic cycle			Contact hours 4 SWS	Self-study 120 h	Group size 30 students
Prerequisites					
The course module is open to all MSc students with a background in the Earth sciences (BSc degree). It has a co-requisite of Physics of the Solid Earth II.					
Learning outcomes					
<p>After successful completion of the module, students will be able to</p> <ul style="list-style-type: none"> • understand and explain earthquake source parameters such as seismic moment, magnitude, static stress drop, radiated energy, and spectral corner frequency. • understand how earthquake source parameters are measured and quantified, such as via fault plane solutions, moment tensors, directivity. • understand and explain empirical earthquake relations, such as the Gutenberg-Richter magnitude-frequency relation, Omori's Law. • understand the basics of seismic signal processing and its applications to studies of earthquakes. • understand and explain the relation between earthquake occurrence and friction on fault surfaces, as well as fracture mechanics models of earthquakes. • understand and explain the earthquake cycle and the occurrence of intraplate and interpolate earthquakes. • relate earthquake triggering and induced earthquakes to tectonic and stress loading, and identify possible earthquake triggers. • understand and describe physical characteristics and underlying mechanisms of the various types of volcanic seismic signals observed at active volcanoes. 					
Content					
Topics included in the course include: Earthquake source studies (focal mechanisms, moment tensors, directivity, seismic moment, source spectra and scaling laws, energy partitioning, stress drop and radiated energy), earthquake statistics, fundamentals of seismic signal processing, fracture mechanics and its relation to rate-state friction, fault friction and the effects of temperature and pressure at depth, earthquake cycle deformation and the spectrum of fault slip, inter- and intraplate earthquakes, fault drilling, volcanic earthquakes, and triggered and induced earthquakes.					
All lecture materials are digitally available via the course Moodle, and student projects are strongly encouraged to incorporate digital data processing. Lectures and paper discussion occur in English.					
Teaching methods					
Lecture period of 1,5 hours/week followed by paper discussion and/or exercises of 1,5 hours/week.					
Mode of assessment					
Final report weighted 70% for the written component (with a 10-week working period), with the remaining 30% weight being placed on the oral presentation the last week of the lecture period. Paper discussion/exercises will be evaluated based on participation, and must be completed with a passing grade of 60% in order to submit the final report.					
Requirements for the award of credit points					

Passing grade for the paper discussion entitles the course participant to submit the Module Exam (term project). Term project presentation with a passing grade (written and oral parts will be combined for a total number of points).

Module applicability (in other majors)**Weight of the mark for the final score**

5% of the total Grade (6/120 CPs)

Module coordinator and lecturer(s)

Prof. Dr. Rebecca Harrington

Further information

Helpful texts (not required):

Stein, S. and M. Wyssession, Introduction to Seismology, Earthquakes, and Earth Structure, Blackwell Publishing, 2003

Scholz, C. H., The Mechanics of Earthquakes and Faulting, 2nd Ed., Cambridge University Press, 2002

Earthquake seminar and data analysis							
Module number	Credits 9 CP	Workload 270 h	Term WS/SS	Frequency Every semester	Duration 2 semesters		
Courses		Contact hours		Self-study	Group size		
a) Induced seismicity seminar (SS) b) Fault transition zones (WS) c) Seismic data and time series Analysis (WS)		(a) 2 SWS (b) 2 SWS (c) 2 SWS		(a) 60 h (b) 60 h (c) 60 h	(a) 30 students (b) 30 students (c) 18 students		
Prerequisites							
The course module is open to all MSc students with a background in the Earth sciences (BSc degree) who have completed either the Earthquake Processes module or the Seismotectonics and Seismic Hazard module.							
Learning outcomes							
After successful completion of the module, students will <ul style="list-style-type: none"> • understand the different causes of induced earthquakes, including fluid injection from unconventional energy production, mining, gas/fluid extraction. • be familiar with the geological settings and controls in which earthquakes are produced. • understand and describe the statistical properties of induced earthquakes, as well as the current understanding of correlations between injection parameters and event magnitude. • be familiar with the competing influence of effective vs. poroelastic stress transfer in the role of generating fault failure, as well the current related scientific studies. • understand the chemical and mechanical differences in the brittle-ductile transition zone, and the relation to seismic vs. aseismic slip generation. • have a quantitative understanding of the different types of slip events that generate a spectrum of seismic and aseismic signals, including tectonic tremor and LFEs, and slow-slip events. • have the programming skills to perform basic signal processing and data analysis on the different types of seismic signals listed above, and to visualize results digitally. 							
Content							
Overview of induced earthquakes in the context of fluid flow near faults and fault systems, the influence of lithology and geology on generating induced earthquakes, statistics and source properties of induce earthquakes, earthquakes induced by reservoir impoundment, gas extraction, enhanced geothermal systems, wastewater and hydraulic fracturing injection, physical mechanisms that induce fault slip, the seismogenic and brittle-ductile transition zone in the crust, seismic and geodetic signals from the seismogenic and fault transition zone, slow earthquakes and triggering of earthquakes at shallower depths, slow earthquakes as stress meters, the rock record of fault slip, experimental work on slow earthquakes, tectonic tremor, transition zone evolution after large earthquakes. Digital analysis of seismic signals including, installation and setup of seismic analysis software (Python), making maps, downloading and analyzing earthquake catalog data, picking seismic phases, analyzing earthquake source parameters, and visualizing all results.							
Teaching methods							
Courses (a) and (b) are held in a group discussion format, where (c) consists of digital teaching format with accompanying lectures.							
Mode of assessment							
The course consists of scientific paper discussion (a) and (b), as well as lecture and exercises for (c). The paper discussion in (a) and (b) as well as exercises in (c) must be evaluated a passing grade (70%) to complete the final report (due upon completion of (c)) on which the module grade will be based.							

The grade for the module is based on the grade assigned for course (c) (it is recommended, but not required, to complete both (a) and (b) before the completion of (c)). Courses (a) and (b) require leading at least one group discussion on a weekly reading topic, as well as active participation in discussions, and will be evaluated on a pass/no-pass (70%) basis. Courses (a) and (b) must be completed with a “pass” basis in order for the final module grade to be given upon completion of the report in (c).

Requirements for the award of credit points

Passing grades for courses (a) and (b) require the presentation/leading of one reading topic and active participation in 70% of the discussions. The report grade for (c) will be distributed once (a) and (b) have been successfully completed.

Module applicability**Weight of the mark for the final score**

7,5% of the total grade (9/120 CPs)

Module coordinator and lecturer(s)

Prof. Dr. Rebecca Harrington

Further information

Geology and geohazards in an active subduction zone							
Module number	Credits	Workload	Term	Frequency	Duration		
5 CP	150 h	2. Sem.	SS	1 semester			
Courses		Contact hours	Self-study	Group size			
Geology and geohazards in an active subduction zone		3 SWS	100 h	16 students (maximum)			
Prerequisites							
Open to all MSc students who have successfully completed either the "Earthquake Processes" or "Seismotectonics and Seismic Hazard" module. Successful completion of a structural geology and a fundamental geologic mapping course are also prerequisites.							
Learning outcomes							
After successful completion of the module, students will							
<ul style="list-style-type: none"> • be able to assess and quantify uplift associated with large thrust fault earthquakes (e.g., Mw 8.3 July 365 CE earthquake in the Hellenic subduction zone) and recent uplift based on current location of tectonic units. • recognize and map tsunami landscapes and associated deposits. • map fault surface trace orientations, measure kinematic indicators, and quantify associated displacement. Use observations collected in the field to estimate regional stress field orientations through stereographic projections. • measure fold elements and estimate the stress field through stereographic projections. • perform earthquake locations using NonLinLoc (open source program) and assess possible associated geo-hazards given the obtained hypocentral coordinates and magnitudes. • use the seismotectonic setting and earthquake locations to evaluate tsunami hazard and estimate an early warning time window. 							
Content							
This block course will give an introduction to the world of earthquake and tsunami hazards in an active subduction zone, associated geological and seismological observations, and the methods used to study them. It will explore the fundamental mechanics of faulting in an active subduction zone through a combination of fieldwork that examines along arc extension, compression related to the subduction thrust, and kinematic/structural indicators of deformation. It will also explore onshore evidence of subduction thrust movement, including normal faulting in the forearc, archeological evidence of large historical earthquakes, and tsunami deposits. In addition, current deformation as evidenced by earthquakes will be explored through exercises using seismic data and analysis that combines theoretical, observational, and field perspectives. A preparatory 3-hour lecture block will take place prior to a 7-day trip that will consist of 1.5 days of lecture/data analysis, and five days of field work. The course is open to MSc students.							
Teaching methods							
Course will consist of a combination of lecture format with digital materials, group discussion format, and exercises using open-source software and digital forms of data, and which digitize field observations.							
Mode of assessment							
Evaluation of the report due after the completion of course.							
Requirements for the award of credit points							
Passing grade for the course.							
Module applicability							
Weight of the mark for the final score							
4,2% of the total grade (5/120 CPs)							

Module coordinator and lecturer(s)

Prof. Dr. Rebecca Harrington, Dr. Gian Maria Bocchini, Dr. Alessandro Verdecchia

Further information

Seismotectonics and Seismic Hazard							
Module number	Credits	Workload	Term	Frequency	Duration		
6 CP	180 h	1. Sem.	SoSe	1 semester			
Courses		Contact hours	Self-study	Group size			
Seismotectonics and Seismic Hazard		4 SWS	120 h	15 students			
Prerequisites							
Students must have successfully completed a BSc in the earth sciences. The course consists of exercises and lecture; exercises must be completed with a passing grade (60%) to access to the final exam on which the module grade will be based. It has a co-requisite of Physics of the Solid Earth II.							
Learning outcomes							
After successful completion of the module, students will be able to <ul style="list-style-type: none"> • understand the relationship between lithosphere rheology and earthquake distribution. • understand the relationship between frictional properties and faulting. • understand the basics of earthquake detection and location. • understand the relationship among subsequent earthquakes (earthquake and fault interactions). • understand the primary (faulting) and secondary (liquefaction, landslides, etc.) effects produced by seismic events. • understand the basics of Tectonic Geodesy. • understand the basics of Tectonic Geomorphology. • understand the basics of Paleoseismology. • understand the basics of probabilistic and deterministic seismic hazard calculations. 							
Content							
A multidisciplinary approach is strongly needed in order to better quantify the seismic potential of any region in the world. Geological data give us a long-term (~1000 years) view of earthquake phenomena, but they are limited to the first meters of the crust. Seismological and geophysical data can generally better describe deformation processes occurring at depth, but usually with a smaller temporal (tens of years) and spatial resolution. This course will provide an introduction to the earthquake problem from both geological and geophysical points of view, with emphasis on the methodologies commonly used to produce the data necessary to understand and quantify the seismic hazard in any active region.							
Topics included in the course are: rheology of the lithosphere, frictional properties of faults, the seismic cycle, earthquake location, geological effects of earthquakes, tectonic geodesy, tectonic geomorphology, paleoseismology, earthquake and fault interactions, probabilistic and deterministic seismic hazard.							
In addition to theoretical information presented via lecture material, the practical exercises teach fundamental data analysis via MATLAB, and other software distributed during the course.							
Teaching methods							
Lecture period of 1,5 hours/week with practical exercises of 1,5 hours/week. Exercises are completed primarily in digital format (basic programming in Matlab).							
Mode of assessment							
Exercises must be completed with a passing grade of 60% in order to access the final exam. The grade of the module is based on the grade of the final written exam.							
Requirement for the award of credit points							
Exercises must be completed with a passing grade of 60% in order to access the final exam. The module grade is based on the final exam grade.							
Module applicability							

Weight of the mark for the final score 5% of the total grade (6/120 CPs)
Module coordinator and lecturer(s) Prof. Dr. Rebecca Harrington, Dr. Alessandro Verdecchia
Further Information <i>Helpful texts (not required):</i> Structural Geology , Haakon Fossen, Cambridge University Press, 2013. The Geology of Earthquakes , R. S. Yeats, K. Sieh and C. R. Allen, Oxford University Press, 1997. The Mechanics of Earthquakes and Faulting , C. H. Scholz, Cambridge University Press, 2012. Paleoseismology , J. P. McCalpin, Academic Press, 2nd Ed.

Measuring Earth surface motions with InSAR and GNSS							
Module number	Credits 6 CP	Workload 180 h	Term Summer	Frequency each SoSe	Duration 1 semester		
Courses Measuring Earth surface motions with InSAR and GNSS		Contact hours 4 SWS		Self-study 120 h	Group size 18 students		
Prerequisites							
<p>For students enrolled in MSc programs.</p> <p>For BSc this is a supplementary module (Ergänzungsmodul), prerequisites are successful completion of the BSc modules mathematics and physics.</p>							
Learning outcomes							
<ul style="list-style-type: none"> • After completion of the module the student will be able to: • Understand the principles of how GNSS and InSAR are used to measure surface deformation. • Understand and reproduce the static surface deformation induced by earthquake, volcanic, and anthropogenic processes using simple models. • Recognize the quality of solutions and diagnose sources of error in InSAR and GNSS measurements. • Recognize shallow (anthropogenic) and deep (solid-earth) signals in InSAR and GNSS data. • Recover earthquake, volcanic, and anthropogenic surface deformation signals from raw InSAR data using SNAP ESA software. 							
Content							
<p>This course will provide an introduction to the principles of Earth surface displacements derived from Global Navigation Satellite Systems (GNSS) and Interferometric Synthetic Aperture Radar (InSAR) applied to tectonic, volcanic, and anthropogenic signals. Interpretations of the data will be taught with simple models such as elastic surface loading models, fault-slip dislocation models, and Mogi-source models.</p> <p>For GNSS we will cover topics including reference frames, the earthquake cycle, volcanic signals, and seasonality. For InSAR, we will cover topics including SAR technology, amplitude and phase, the challenges in retrieving surface displacements due to tropospheric and topographic effects, and orbital errors.</p>							
Teaching methods							
<p>2 hours per week lecture. 2 hours per week practical in the computer lab.</p> <p>Each week, we will introduce new concepts in the 2 hour lectures. This will be followed by a 2 hour practical in which students learn how to explore features of surface deformation data. Notably, students will learn how to use an InSAR processing software, SNAP, to process their own surface deformation maps from raw InSAR SLC data.</p>							
Mode of assessment							
<p>Weekly quizzes during first 9 weeks: The best 5 results from 9 quizzes will be counted towards 60% of the final grade. 10% of the grade will be assessed from participation. 30% will come from a final and individual poster presentation that takes place at the end of the teaching semester. The preparation of these posters begins in week 9.</p>							
Requirement for the award of credit points							
Successful completion of weekly quizzes and poster.							
Module applicability							
<p>The course is open to students from both BSc and MSc programs, however, due to limited number of potential participants, priority is given to students from BSc and MSc programs in Geoscience.</p>							

Weight of the mark for the final score 5 % of the final score (6 of 120 CP) for MSc students. 3,3 % of the final score for BSc students.
Module coordinator and lecturer(s) Prof. Dr. Jonathan Bedford; Dr. Carlos Peña
Further information
Literature Teunissen, P.J. and Montenbruck, O. eds., 2017. Springer handbook of global navigation satellite systems (Vol. 10, pp. 978-3). Cham, Switzerland: Springer International Publishing. Hanssen, R. (2001), Radar Interferometric: Data and Error analysis, Kluwer academic publishers, ISBN 0-7923-6945-9 Ferretti, A. (2007) InSAR Principles: Guidelines for SAR Interferometric Processing and Interpretation, ISBN 92-9092-233-8 – www.esa.int Segall, P. (2010), Earthquake and Volcano Deformation, Princeton University Press, ISBN 9781400833856

Grundlagen des Geoingenieurwesens					
Module number	Credits	Workload	Semester	Frequency	Dauer
	6 CP	150-180 h	1. Sem.	Every WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Grundlagen der Ingenieurgeologie b) Darstellen und Analysieren geotechnischer Informationen			(a) 2 SWS (b) 2 SWS	(a) 60 h (b) 60 h	
Prerequisites					
Learning outcomes					
<p>Die Ingenieurgeologie ist eine interdisziplinäre Wissenschaft, welche den Baugrund erkundet und aus den Erkenntnissen ein geotechnisches Modell für bautechnische Zwecke erstellt. Die Erkundung des Baugrundes sollte hierbei immer unter Berücksichtigung der lokalen Geologie und deren Genese sowie der geodynamischen Prozesse erfolgen, um die Unsicherheiten des Models zu minimieren. Im Rahmen des Kurses werden die grundlegenden Verfahrensschritte der Erkundung und die normative Basis erläutert. Darüber hinaus wird phänomenologisch-deskriptiv ein Gefühl für das Verhalten von Festgestein, Fels und Lockergestein unter den typischen bautechnischen und geologisch-bedingten Belastungssituationen vermittelt. Aus dem Verständnis des rheologischen Verhaltens werden Parameter abgeleitet, welche den Baugrund charakterisieren.</p> <p>Die Darstellung von ingenieurgeologischen und geotechnischen Informationen bildet die Grundlage einer jeden Ergebnispräsentation; umgekehrt muss der/die Ingenieurgeolog:in in der Lage sein graphisch dargestellte technische und geotechnische Informationen zu erfassen und zu analysieren. Nach erfolgreichem Abschluss des Moduls (a) sind die Teilnehmerinnen und Teilnehmer mit der ingenieurgeologischen Fachterminologie zur fachgerechten Beschreibung und Benennung von Lockergestein, Festgestein und Fels vertraut, (b) verstehen sie die Zusammenhänge zwischen geologischen Verhältnissen, physikalischen, hydraulischen und mechanischen Eigenschaften von Boden und Fels, (c) kennen die Teilnehmerinnen und Teilnehmer die wichtigsten Parameter zur Beschreibung der Eigenschaften von Locker- und Festgesteinen und (d) sind sie mit den Grundlagen der Normung und Richtlinien vertraut. Darüber hinaus sind die Teilnehmerinnen und Teilnehmer mit den grundlegenden Methoden der Darstellung und Analyse geotechnischer Informationen vertraut. Dies umfasst das Erfassen markscheiderischer und technischer Darstellungen, das zeichnerische Darstellen von Aufschlüssen und Aufschlussdaten, das geometrisch-technisch-zeichnerische Darstellen von Ergebnissen, die Darstellung und Analyse von Festigkeits- und Gefügedaten, sowie das Verfassen von Berichten.</p>					
Content					
<ul style="list-style-type: none"> • Definition der Ingenieurgeologie; normativer Rahmen des Bauwesens inkl. EC 7; Ablauf einer Baugrunderkundung; Einordnung der Ingenieurgeologie in UN SDGs; Einführung des Homogenbereichskonzeptes; Definition Gestein, Fels, Lockergestein, Boden inkl. Boden und Fels als Mehrphasenmodell; Übersicht über Aufschlussverfahren; Benennen und Beschreiben von Locker- und Festgesteinen sowie Trennflächen und Fels; Einführung in Stoffmodelle für Trennflächen, Gestein und Boden; Hydrogeologie im Geoingenieurwesen; Spannungen im Untergrund aus Auflast und resultierende Spannungen und Setzungen unter Bauwerken; Klassifizieren und Bewerten von Boden und Fels für bautechnische Zwecke; Einführung in grundlegende Belastungsszenarien und Bemessungsansätze. • Konstruktion geologischer Schnitte; zeichnerische Darstellung geologischer Informationen in Form von Verwitterungsprofilen, Aufschlusszeichnungen und Abwicklungen; Bohrprofile; Operationen in der stereographischen Projektion; Spannungsdarstellung und -analyse mittels Mohr'schem Spannungskreis; Lesen und Analysieren technischer Darstellungen; Graphen und Tabellen; Risswerke; geotechnisches Berichtswesen. 					
Teaching methods					
Vorlesung mit integrierten Übungen					
Vorlesung, Übung					

Mode of assessment
Modulklausur
Requirement for the award of credit points
Übungsaufgaben (Testate), benotete Übungsaufgaben, Modulprüfung Grundlagen des Geoingenieurwesens
Module applicability

Weight of the mark for the final score
5 % der Gesamtnote (6 von 120 CP)
Module coordinator and lecturer(s)
Prof. Dr. Tobias Backers
Further information
Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Rock mass and stress field					
Module number	Credits	Workload	Term	Frequency	Duration
	6 CP	150-180 h	1. Sem.	Every WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Stress Field and Rock Mass behaviour			(a) 2 SWS	(a) 55 h	
b) Stress Field Modelling and Simulation			(b) 0,5 SWS	(b) 12 h	
c) Geological Engineering Research Project			(c) 2 SWS	(c) 75 h	
Prerequisites					
--/.					
Learning outcomes					
<p>Stresses in the Earth's crust are the driving 'force' of many processes and a definitive quantity of assessing the stability of geologic structures such as interfaces or faults. In addition, knowledge of the stresses at work is of extraordinary importance in the design of structures in the near-surface and deep subsurface. The English language course develops the mechanical principles for the representation of the stress field in the Earth's crust and discusses the sources of stress. Methods for estimating and measuring stresses are introduced.</p> <p>This includes modeling of the primary field (green and brown field) and the derivation of secondary stresses by civil engineering structural engineering measures.</p> <p>The simulation of the alteration of the in-situ stresses is in many rock and mining projects and mining projects to estimate the secondary stresses and the load on the geological structures and geological structures as well as civil engineering works. In addition to the lecture "Stress Field and Rock Mass behaviour", exemplary models are created autodidactically using standard software of rock are created autodidactically and the resulting stresses and their distribution are simulated.</p> <p>The rule is to work in teams; depending on the industry, these teams are composed internationally, depending on the industry. The English-language course takes this into account. Within the framework of a (partly) English-language project work, cooperation is practiced under real-life conditions. At the end of the collaborative work, which focuses not only on the actual shared development of the database as well as the coordination of the work, a technical-scientific publication will be drafted, which will be submitted to a professional publication, which will be submitted to a scientific journal if the quality is good enough.</p> <p>The students are familiar with rock and rock mass behavior and the sources of stress in the Earth's crust. They know how to estimate and measure rock mass stress. In addition, the enrolled students are familiar with the determination of stress alterations and redistributions by anthropogenic sources.</p> <p>The students are familiar with the numerical simulation of stress alterations due to geological or constructional features using a commercial software package.</p> <p>After the successful completion of the project, the students can plan, organize, conduct, and document a confined geological engineering research project. The projects always include an aspect of compliance with the UN SDG's.</p>					

Content Definition of stress, rock deformation, rock failure, rock mass definition, sources of stress in the earth crust, methods of stress measurement and stress modelling, determination of stress alterations and stress redistribution.
Teaching methods Lectures with exercises, self-educational homework Seminar, practical work and drafting a manuscript
Mode of assessment Oral exam at the end of the term
Requirement for the award of credit points successful submission (i.e. 50%) of 90% of the weekly homework active participation in the seminar and research work documented participation in the drafting of the manuscript
Module applicability
Weight of the mark for the final score 5 % der Gesamtnote (6 von 120 CP)
Module coordinator and lecturer(s) Prof. Dr. Tobias Backers, Dr. Mandy Duda; Daniel Bücken
Further information Relevant literature will be presented at the beginning of each session.

Grundbau und Bodenmechanik					
Module number	Credits	Workload	Semester	Frequency	Duration
	6 CP	150-180 h	1.+ 2. Sem.	Annually	2 semesters
Courses			Contact hours	Self-study	Group size
a) Grundbau b) Bodenmechanik c) Geotechnische Herausforderungen des Anthrozäns			(a) 3 SWS (b) 3 SWS (c) 0,5 SWS	(a) 50 h (b) 90 h (c) 25 h	
Prerequisites					
Modul Grundlagen des Geoingenieurwesens					
Learning outcomes					
<p>Die Inhalte von a) und b) sind den Beschreibungen des VLV zu entnehmen.</p> <p>c) Das jüngste Antropozän zeichnet sich durch u.a. massive Veränderungen der Geländemorphologie durch den Menschen, den Wandel des Klimas und damit verbundene extreme Wetterereignisse, die Notwendigkeit derendlagerung radioaktiver Abfälle oder die Notwendigkeit der massiven Erneuerung der Energieversorgung aus. Dies bedingt auch geotechnische Lösungen. Im Rahmen des Kurses erstellen die Kursteilnehmerinnen und -teilnehmer zu einem Thema ein Diskussionspapier, in dem Sie die Herausforderungen, die sich auch geologisch-geotechnischer Sicht ergeben, definieren und versuchen realistisch/creative Lösungsansätze unter Berücksichtigung der vorhandenen Literatur zu dem Thema zu skizzieren. In einem Impulsvortrag stellen Sie das Thema und Ihre Thesen vor und stellen den Bezug zu den UN SDGs her. Die Diskussionsergebnisse und Hinweise zum Impulsvortrag reflektieren Sie in Ihrem Diskussionspapier.</p> <p>Nach erfolgreichem Abschluss des Kurses sind die Teilnehmenden mit den grundlegenden Methoden der Beschreibung von Böden vertraut, wissen um das grundlegende Verhalten von Böden und dessen mathematisch idealisierte Beschreibung, besitzen die Fähigkeit, diese Konzepte auf die Bemessung von Grundbauwerken anzuwenden und haben das Verständnis Berechnungsergebnisse kritisch zu hinterfragen.</p> <p>Die Teilnehmerinnen und Teilnehmer sind mit den UN SDGs vertraut und üben die Auseinandersetzung mit einem gesellschaftlich relevanten, technischen Thema, welches geotechnische Lösungen verlangt. Durch den Impulsvortrag stärken die Teilnehmenden Ihre Präsentations- und Diskussionskompetenz</p>					
Content					
Beschreibung und Klassifizierung von Böden, Bodeneigenschaften und -kenngrößen, Baugrundkunde, Wirkungen von Grundwasser im Boden, Spannungsausbreitung im Baugrund, Setzungs- und Konsolidierungsberechnungen im Boden, Scherfestigkeit, Erddruck auf Wände und Stützmauern, Standsicherheit von Böschungen, Flachgründungen, Stützkonstruktionen, Grundwasserkontrollen, Baugruben, Pfahlgründungen, Baugrundverbesserung; Erstellung eines Diskussionspapiers; Impulsvortrag; Diskussion					
Teaching methods					
Vorlesung, Übung, Seminar					
Mode of assessment					
Klausur, Diskussionspapier					
Requirement for the award of credit points					
Bestandene Klausur, benotetes Diskussionspapier					
Module applicability					

Weight of the mark for the final score					

5 % der Gesamtnote (6 von 120 CP)

Module coordinator and lecturer(s)

Prof. Dr. Tobias Backers, Prof. Dr.-Ing. Torsten Wichtmann

Further information

Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Rock mass mechanics and rock engineering (Felsmechanik und Felsbau)					
Module number	Credits	Workload	Term	Frequency	Duration
	6 CP	150-180 h	2. Sem.	Every SS	1 semester
Courses			Contact hours	Self-study	Group size
a) Rock Mass Mechanics (Felsmechanik)			(a) 2 SWS	(a) 45 h	
b) Rock Engineering (Felsbau)			(b) 2 SWS	(b) 45 h	
Prerequisites					
Module 'Rock Mass Stress Fields' recommended for specialisation 'Geoingenieurwesen', mandatory for specialisation in 'Geological Engineering for Subsurface Energy Systems'					
Learning outcomes					
Als Teilgebiet der Geomechanik beschäftigt sich die Felsmechanik mit der Beschreibung der rheologischen Eigenschaften und assoziierten Stoffmodelle von Gestein und Trennflächen; durch die Integration kann das Deformationsverhalten von Fels (= Gestein + Trennflächen) durch eine Änderung der thermischen, hydraulischen oder mechanischen Randbedingungen abgeschätzt werden. Das Verständnis des mechanisch-hydraulisch-thermischen Verhaltens des Fels (vielfach auch als Gebirge bezeichnet) bildet die Grundlage für die bautechnische oder werkstoffliche Nutzung des Fels oder Gesteins.					
Der Felsbau beschäftigt sich mit den bautechnischen Maßnahmen im Fels; die Nachbardisziplin Erd-/Grundbau beschreibt die Methoden in Lockermaterialien. Die bautechnischen Maßnahmen umfassen das Lösen, das Sichern und die Gewinnung von Gestein, die Gründung im Fels und die Erstellung von Hohlräumen. Aufbauend auf den felsmechanischen Grundlagen werden die Prinzipien des Felsbaus besprochen.					
Die Simulation der Interaktion von Bauwerk und Baugrund hat zum Ziel, die Belastungen aus dem Bauwerk und die Reaktion des Baugrunds bei komplexen felsbaulichen Projekten umfassend beurteilen zu können. In Ergänzung zu den Vorlesungen Felsmechanik und Felsbau werden unter Verwendung einer Standardsoftware des Felsbaus beispielhafte Modelle autodidaktisch erstellt und die resultierenden Belastungen des Baugrunds simuliert und beurteilt.					
Die Teilnehmerinnen und Teilnehmer sind mit den Grundlagen der Rheologie der Gesteine, dem mechanischen Verhalten von Gestein und Trennflächen, Gebirgsklassifikationen und mechanischen Eigenschaften des Gebirges vertraut und kennen die typischen Kennwerte nach Bedeutung und Größe. Darüber hinaus sind die geomechanischen Grundlagen und Zusammenhänge vertieft. Die Teilnehmerinnen und Teilnehmer sind mit den Grundlagen der Erstellung und Sicherung von Felsbauwerken vertraut. Die Teilnehmerinnen und Teilnehmer sind mit der Anwendung einer Standardsoftware des Felsbaus vertraut und können für einfache felsbauliche Fragestellungen numerische Modelle erstellen und die Auswirkung der Bauwerkserstellung auf den Baugrund beurteilen.					
Content					
Deformation und Versagen von Gestein; Einführung in die Versuchstechnik; Deformation und Versagen von Trennflächen; Gebirgsklassifikationen; Deformation und Versagen von Fels; Charakteristika von Tunneln, Stollen und Felskavernen; Prinzipien des Hohlraumbaus; Gründungen auf Fels und Böschungen aus Fels; Aufgabenstellungen und Messgrößen bei der geotechnisch/geomechanischen Überwachung; felsmechanische numerische Simulation.					
Teaching methods					
Vorlesung, Übungen,					
Mode of assessment					
Modulklausur					
Requirement for the award of credit points					

Übungsaufgaben
Module applicability
Weight of the mark for the final score
5 % der Gesamtnote (6 von 120 CP)
Module coordinator and lecturer(s)
Dr. Mandy Duda
Further information
Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt. Brady B, Brown E. 2006. Rock Mechanics for underground mining. Springer Science

Baugrunderkundung- und Dokumentation							
Module number	Credits	Workload	Semester	Frequency	Duration		
6 CP	125-150 h	1. + 2. Sem.	yearly	2 semesters			
Courses		Contact hours	Self-study	Group size			
a) Baugrunderkundung und -modellierung b) Ingenieurgeologische Kartierung		(a) 2 SWS (b) 5 days	(a) 45 h (b) 50 h				
Prerequisites							
Modul Grundlagen der Ingenieurgeologie							
Learning outcomes							
Eine der Hauptaufgaben der klassischen Ingenieurgeologie ist die Erstellung des geotechnischen Baugrundmodells, welche die Basis für die weiteren fachplanerischen Maßnahmen darstellt. Die Modellbildung erfolgt hierbei auf Grundlage der geologisch-geotechnischen, also ingenieurgeologischen Erkundung. Im Rahmen des Kurses werden die Methoden der Baugrunderkundung und die Parametererhebung zur Charakterisierung des Baugrunds vorgestellt und diskutiert; dies umfasst die Charakterisierung des Gesteins, Fels, Bodens und Grundwassers. Hierauf aufbauend wird die Homogenisierung der Baugrundeigenschaften vor dem Hintergrund der gewerkespezifischen Homogenbereichsausweisung erläutert. Die Erstellung einfacher Baugrundmodelle mittels geotechnischer Standardsoftware wird praktiziert.							
Die Grundlage eines jeden geologischen und auch geotechnischen Modells ist ebenso die Aufnahme der geologischen Bedingungen im Gelände. Neben der Darstellung der Gesteine sollte eine ingenieurgeologische Kartierung auch weiterführende Hinweise auf geogene Besonderheiten oder Herausforderungen, welche später die bautechnischen Fachplanungen beeinflussen können, erheben. Die ingenieurgeologische Kartierung hat zum Ziel eine Karte zu erstellen, die neben den geologischen Informationen (Formationen, Verwerfungen) zusätzliche Daten wie Bodengruppe oder Felsart (Baugrundkarte), Hangrutschungspotential, altbergbauliche Anlagen und Hohlräume oder Subrosionspotential (Gefahrenhinweis- oder Risikokarte) darstellt.							
Die Teilnehmerinnen und Teilnehmer kennen die wesentlichen Methoden der Baugrunderkundung und die Parameter sowie deren Bestimmung zur Beschreibung des Baugrunds. Darüber hinaus wird das Verständnis des Homogenbereichskonzeptes intensiviert. Die Teilnehmerinnen und Teilnehmer sind mit der Anwendung einer Standardsoftware zur Erstellung eines Baugrundmodells vertraut.							
Content							
Baugrunderkundungsmethoden; Parameter von Gestein, Fels und Boden; Homogenbereiche; Baugrundmodellierung.							
Teaching methods							
Vorlesung, Übungen, Geländeübung							
Mode of assessment							
Modulklausur							
Requirement for the award of credit points							
Übungsaufgaben, Kartierbericht (benotet, bildet 30% der Modulnote)							
Module applicability							
Weight of the mark for the final score							
4 % der Gesamtnote (5 von 120 CP)							
Module coordinator and lecturer(s)							
Prof. Dr. Tobias Backers, Dr. Kirsten Bartmann							
Further information Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.							

Rock mass characterisation (Baugrundcharakterisierung Fels)							
Module number	Credits	Workload	Semester	Frequency	Dauer		
	5 CP	125-150 h	2.+3. Sem.	Annually	2 semesters		
Courses		Contact hours	Self-study	Group size			
a) Rock Mass Mapping b) Rock Mass lab		(a) 5 days (b) 2 SWS	(a) 40 h (b) 50 h	(a) 12 students (b) 18 students			
Prerequisites							
Modul Grundlagen der Ingenieurgeologie, Modul Baugrundkundung und Dokumentation; Modul Felsmechanik und Felsbau.							
Learning outcomes							
Im Rahmen der Baugrundmodellerstellung sind das Gestein und Trennflächen durch gesteins- bzw. felsmechanische Laborversuche zu charakterisieren. Der Kurs vermittelt die grundsätzlichen Arbeitsmethoden der gesteins- bzw. felsmechanischen Laborarbeit. Darüber hinaus werden eine Reihe von Standardversuchen vorgestellt, durchgeführt, ausgewertet und die Kennwerte eingeordnet.							
Für felsbauliche Projekte ist die Darstellung und Erhebung von felsmechanischen Kennwerten (hier insbesondere Gesteinseigenschaften, Trennflächengefüge und -charakteristika) von besonderer Bedeutung. Im Rahmen der Geländeübung wird die Aufnahme von Gesteins- und Gefügecharakteristika im Gelände erlernt. Einen besonderen Stellenwert nimmt hier die zeichnerische Darstellung des Aufschlusses und die graphische Dokumentation von Messdaten ein. Die erhobenen und ausgewerteten Daten werden graphisch als integrierte DIN A3 Darstellung zusammengefasst und durch einen zweiseitigen Kurzbericht eingeordnet.							
Die Teilnehmerinnen und Teilnehmer erlernen die methodischen Grundlagen der Bestimmung von Gesteins- und Trennflächenparameter. Darüber hinaus sind sie mit der prinzipiellen Durchführung und Auswertung wesentlicher Laborversuche vertraut. Weiterhin wird das dazugehörige normative Berichtswesen geübt.							
Die Teilnehmerinnen und Teilnehmer erlernen die Methoden der ingenieurgeologischen Felskartierung. Hierzu gehören die Ansprache der Gesteine im Aufschluss, das Einmessen von Flächen, die Beschreibung der Trennflächen und deren Charakteristika. Die Methodik der Auswertung und Darstellung der im Gelände aufgenommenen Messwerte wird geübt. Die Anwendung einer Gebirgsklassifikation wird gefestigt.							
Inhalt							
Grundlagen der Erhebung gesteins- und felsmechanischer Kennwerte; Durchführung und Auswertung von Standardversuchen; ingenieurgeologisch-felsmechanische Aufnahme und Beschreibung des Trennflächengefüges; Gesteinsansprache; zeichnerische Darstellung eines Aufschlusses; Scanlinemethodik; Bestimmung von Gesteins- und Trennflächenfestigkeiten im Feld; regionalgeologische Aspekte des Harz und nördlichen Vorharzes.							
Teaching methods							
Laborpraktikum, Geländeübung							
Mode of assessment							
Berichte							
Requirement for the award of credit points							
Berichte							
Module applicability							
Weight of the mark for the final score							
4 % der Gesamtnote (5 von 120 CP)							

Module coordinator and lecturer(s)

Prof. Dr. Tobias Backers

Further information

Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Baugrundcharakterisierung Boden					
Module number	Credits	Workload	Semester	Frequency	Duration
Courses		Contact hours		Self-study	Group size
a) Bodenmechanisches und -hydraulisches Laborpraktikum	5 CP	125-150 h	2.+3. Sem.	(a) 2 SWS (a) 40 h	(a) 12 students
b) Lockergesteinskartierung und hydrogeologisches Feldpraktikum				(b) 5 days (b) 50 h	(b) 18 students
Prerequisites					
Modul Grundlagen der Ingenieurgeologie, Modul Baugrundkunde und Dokumentation					
Learning outcomes					
Im Rahmen der Baugrundmodellerstellung ist das Lockergestein durch bodenmechanische Laborversuche zu charakterisieren. Der Kurs vermittelt die grundsätzlichen Arbeitsmethoden der bodenmechanischen Laborarbeit. Darüber hinaus werden eine Reihe von Standardversuchen vorgestellt, durchgeführt, ausgewertet und die Kennwerte eingeordnet.					
Der Baugrundkunde und -modellierung kommt in bautechnischen Projekten eine grundlegende Bedeutung zu. Es sind die wesentlichen Kennwerte zu bestimmen und ein Untergrundmodell zu erstellen. Im Rahmen der Geländeübung werden eine Reihe von Erkundungsbohrungen geteuft, der erbohrte Lockergesteinsbaugrund angesprochen und ein Untergrundmodell (Profilschnitt) erstellt. Darüber hinaus wird die Grundwassersituation dokumentiert und Proben für eine weitergehende Charakterisierung des Baugrunds genommen.					
Die Teilnehmerinnen und Teilnehmer erlernen die methodischen Grundlagen der Bestimmung von bodenmechanischen Parametern. Darüber hinaus sind sie mit der prinzipiellen Durchführung und Auswertung wesentlicher Laborversuche vertraut. Weiterhin wird das dazugehörige normative Berichtswesen geübt.					
Die Teilnehmerinnen und Teilnehmer erlernen die Baugrundkunde mittels leichtem und mittelschwerem Bohrgerät (u.a. Bohrstock, Schlitzsonde, Carl Hamm Argos), sind mit den Bohrwerkzeugen vertraut und kennen die Vor- und Nachteile bei der Probengewinnung, können Lockergestein normgerecht ansprechen und Proben nehmen. Darüber hinaus sind die Teilnehmerinnen und Teilnehmer mit der Darstellung der Ergebnisse als Profilschnitt mithilfe einer Standardsoftware vertraut.					
Inhalt					
Grundlagen der Erhebung bodenmechanischer Kennwerte; Durchführung und Auswertung von Standardversuchen; Durchführung einer Baugrundkunde in Lockergestein; Kenntnis der verfahrenstechnischen Schritte einer Erkundungsbohrung; Lockergesteinsansprache; Probennahme; Profilerstellung mittels Standardsoftware.					
Teaching methods					
Laborpraktikum, Geländeübung					
Mode of assessment					
Berichte					
Requirement for the award of credit points					
Berichte					

Module applicability
Weight of the mark for the final score
4 % der Gesamtnote (5 von 120 CP)
Module coordinator and lecturer(s)
Prof. Dr. Tobias Backers, Linus Eickhoff
Further information
Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Geomechanik					
Module number	Credits	Workload	Semester	Frequency	Duration
	10 CP	250-300 h	3. Sem.	Every WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Geomechanik und Geotechnik komplexer Systeme b) geomechanische numerische Simulation c) Geotechnisches Projekt			(a) 2 SWS (b) 1 SWS (c) 1 SWS	(a) 75 h (b) 55 h (c) 130 h	
Prerequisites					
Modul Grundlagen der Ingenieurgeologie, Modul Baugrundkundung und Dokumentation; Modul Felsmechanik und Felsbau					
Learning outcomes					
Geomechanik ist eine integrative Disziplin, welche das mechanische Verhalten des geologischen Untergrundes bei Änderungen von Spannungen, Verschiebungen, Porendruck, der Temperatur oder weiterer Randbedingungen quantifizierend beschreibt. Unter Geotechnik versteht man Methoden der bautechnischen Nutzbarmachung des Untergrundes, d.h. des Baugrundes. Für eine umfassende und nachhaltige Herangehensweise ist es dabei notwendig Kenntnisse der Geologie, Bodenmechanik, Felsmechanik, Gesteinsphysik und verschiedener bau- und verfahrenstechnischer Disziplinen integrativ anzuwenden.					
Im Rahmen des Kurses werden anhand von Anwendungsfeldern die einzelnen erlernten Kompetenzen des Curriculums zusammengeführt, um ein Verständnis für die notwendigen Maßnahmen zur Beschreibung des Untergrundes und das geoingenieurmäßige Herangehen an die Themenfelder zu generieren. Hierbei wird der Fokus auf die Diskussion geologisch oder bautechnisch komplexer Systeme gelegt.					
Die Bearbeitung von Projekten in der späteren Berufspraxis setzt im Allgemeinen die Zusammenarbeit in Teams voraus; dies bedingt sich häufig aus der Komplexität der Aufgaben. Im Rahmen des geotechnischen Projektes wird in Kleingruppen eine Fragestellung bearbeitet, welche sich an reale Daten und Fragestellungen anlehnt. Hierbei werden die Kursteilnehmer im Format eines Planspiels eine Firma gründen, sich um den Auftrag zur Bearbeitung einer Fragestellung bewerben und hierbei grundlegende Kenntnisse im Bereich der Unternehmensformen und Preisgestaltung autodidaktisch erlernen. Nach Erteilung des Auftrages erarbeiten die ‚Firmen‘ eine Lösung unter Anwendung und auch Intensivierung des im Rahmen des Curriculums des Geoingenieurwesens erlernten Kompetenzen. Die individuellen Stärken und Kompetenzen der ‚Firmenangehörigen‘ werden sich hierbei ergänzen, zu optimierten Lösungen führen und den anderen Teilnehmenden neue Aspekte aufzeigen.					
Zwischenergebnisse werden dem ‚Auftraggeber‘ vorgestellt; hier erhalten die Kursteilnehmer Feedback und profilieren ihre Präsentations- und Diskussionsfähigkeiten. Am Ende des Kurses steht eine Gesamtpräsentation der erarbeiteten Lösung und die Übergabe des Berichtes an den ‚Auftraggeber‘.					
Die Teilnehmerinnen und Teilnehmer sind in der Lage die Komplexität von geologischen, bzw geotechnischen Systemen zu erfassen und zu analysieren. Dabei wird die Kompetenz zur Identifikation der einzelnen geomechanischen Fragestellungen in komplexen Problemen profiliert, um die kritischen systemisch relevanten Randbedingungen zu isolieren. Darüber hinaus sind die Teilnehmerinnen und Teilnehmer mit den typischen Charakteristika von typischen Projekten vertraut.					
Die Teilnehmerinnen und Teilnehmer intensivieren ihre Präsentations- und Diskussionskompetenz. Durch die Gruppenarbeit wird die Teamfähigkeit gestärkt. Die intensive Beschäftigung mit einer komplexen Fragestellung wird ein tiefergehendes Verständnis der geologischen und bautechnischen Zusammenhänge generiert und dies trainiert die Berücksichtigung ingenieurgeologischer Aspekte zur Problemlösung					

Content Erkundungsanforderungen, Fragestellungen, Verfahrenstechnik und Bautechnik im u.a. Bereich des Tunnelbaus, der Erstellung von Tiefbohrungen, Entwicklung von tiefergeothermischen Reservoirn oder des Talsperrenbaus; Erarbeitung eines geotechnischen Berichtes; Teamarbeit; Anwendung der erlernten Grundlagen des Studiums des Geoingenieurwesens.
Teaching methods Vorlesung mit integrierten Übungen, Projekt
Mode of assessment Modulprüfung, Bericht
Requirement for the award of credit points Bericht, Präsentationen
Module applicability
Weight of the mark for the final score 8 % der Gesamtnote (10 von 120 CP)
Module coordinator and lecturer(s) Prof. Dr. Tobias Backers
Further information Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Geologie des Pleisto-, Holo- und Anthroponozäns					
Module number	Credits	Workload	Semester	Frequency	Duration
Courses		Contact hours		Self-study	Group size
a) Quartärgeologie b) Quartärgeologie und geogene Risiken		(a) 2 SWS (b) 2 days	(a) 50 h (b) 20 h		
Prerequisites					
Learning outcomes					
<p>Das Quartär hat in weiten Bereichen der nördlichen Hemisphäre deutliche Spuren hinterlassen. Die Sedimente des Quartärs sind vielfach nicht oder wenig verfestigt und haben dadurch besondere geotechnologische Eigenschaften, welche auch die zivilisatorische Nutzung beeinflussen. Ausgehend von einer Analyse des Klimas und der dadurch gegebenen Bedingungen werden die Liefergebiete, die Ablagerungsräume, die maßgeblichen Sedimente, deren Eigenschaften nebst deren Veränderlichkeit und die sich ausbildende Morphologie vermittelt. Im Rahmen des Kurses werden die speziellen Bedingungen, Prozesse und Ablagerungsräume des Pleistozäns und Holozäns besprochen; initial werden die alpidische Orogenie und die tertiären Ablagerungsräume umrissen, um die Ausgangssituation für das Quartär Deutschlands zu definieren.</p> <p>Das Erkennen dieser Sedimente ist für die Entwicklung von Untergrundmodellen unabdingbar. Ebenso gehen von den pleistozänen Sedimenten und den glazial geprägten Landschaften geogene Risiken aus. Im Rahmen der Geländeübung werden beispielhaft quartäre Formungen und deren Sedimente beschrieben und die Ansprache der Sedimente geübt. In dem Zusammenhang werden die Eigenschaften der Sedimente besprochen und die daraus sich ergebenden geogenen (sowohl natürlich aber auch anthropogen induzierten) Risiken abgeleitet. Nach erfolgreichem Abschluss des Kurses kennen und erkennen die Teilnehmerinnen und Teilnehmer die wichtigsten quartären Ablagerungsräume und deren Sedimente, kennen sie die grundlegenden Eigenschaften der quartären Sedimente und verstehen die Teilnehmerinnen und Teilnehmer die grundlegenden Mechanismen der Gletscher. Die Teilnehmerinnen und Teilnehmer können exemplarisch pleistozäne Formungen erkennen und die Sedimente ansprechen. Darüber hinaus kennen sie die wichtigsten von den quartären Formungen ausgehenden Georisiken und sind mit den wesentlichen Prozessen vertraut.</p>					
Content					
<p>Klimaentwicklung seit der Kreide; Bildung der Alpen; Tertiär in Deutschland als quartäre Basis; Gletscherbildung und -mechanik; glaziale Erosion und Transport; Ablagerungen und Ablagerungsformen; Eigenschaften der Sedimente; Die Kaltzeiten in Nord- und Süddeutschland; Glaziale Sedimentkörper, Sedimentansprache, Einflussfaktoren geologischer Prozesse; geogene Herausforderungen; Georisiko Mensch.</p>					
Teaching methods					
<p>Vorlesung mit integrierten Übungen Geländeübung</p>					
Mode of assessment					
Modulprüfung					
Requirement for the award of credit points					
Ausreichende Bewertung der Klausur, des Kurzprotokolls und einer Hausarbeit					
Module applicability					
Das Modul ist nur nach Rücksprache mit den Dozenten für Studierende anderer Studiengänge zugänglich					
Weight of the mark for the final score					

4 % der Gesamtnote (5 von 120 CP)

Module coordinator and lecturer(s)

Prof. Dr. Tobias Backers

Further information

Literature

Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Geological Engineering for Subsurface Energy Systems (from '24)							
Module number	Credits	Workload	Semester	Frequency	Duration		
10 CP	250-300 h	3. Sem.	Every WS	1 semester			
Courses		Contact hours	Self-study	Group size			
a) Reservoir Geomechanics		(a) 2 SWS	(a) 75 h				
b) Simulation of Geological Systems		(b) 1 SWS	(b) 55 h				
Behaviour		(c) 1 SWS	(c) 130 h				
c) Subsurface Energy Utilisation Project							
Prerequisites							
Module Rock Mass Stress Fields, Module Rock Mass Mechanics and Rock Engineering, Module Rock Mass Characterisation							
Learning outcomes							
Society is facing multiple challenges due to climate change and increasing energy demand. Sustainable solutions are needed. One area of engineering with a high potential to face the above mentioned societal challenges is geological engineering of the subsurface for sustainable energy extraction and storage.							
The brand new module will be available for students starting in autumn 2024. It will cover the basics of reservoir engineering for subsurface energy systems and give an introduction to numerical simulation of typical reservoir engineering questions. A project thesis will complement the teaching and foster team-work, self-guided canvassing of information and handling of incomplete geological engineering data sets.							
Content							
Reservoir Engineering							
Teaching methods							
Lectures, exercises, numerics lab, project							
Mode of assessment							
Module exam, report							
Requirement for the award of credit points							
report, presentations, exercises							
Module applicability							
Weight of the mark for the final score							
8 % der Gesamtnote (10 von 120 CP)							
Module coordinator and lecturer(s)							
Prof. Dr. Tobias Backers							
Further information							
to be announced							

Kristallchemie						
Module number	Credits	Workload	Term	Frequency	Duration	
	10 CP	300 h	2. + 3. Sem.	SS/WS	2 semesters	
Courses		Contact hours	Self-study	Group size		
a) Kristallchemie (Vorlesung und Übung)			(a) 2 SWS			
b) Realstrukturbau und Phasenumwandlungen (Vorlesung und Übung)			(b) 2 SWS			
c) Edelsteinkunde (Vorlesung)		(c) 2 SWS	(c) 70h	15 students		
Prerequisites						
Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.						
Textual: Kenntnisse über Aufbau und Symmetrieeigenschaften von Kristallen sowie Kenntnisse in der allgemeinen und anorganischen Chemie werden vorausgesetzt.						
Preparation: –						
Learning outcomes						
Nach dem erfolgreichen Abschluss des Moduls						
<ul style="list-style-type: none"> • kennen Studierende die grundlegenden Prinzipien, die zur Ausbildung einer spezifischen Kristallstruktur führen. • kennen Studierende strukturelle Grundtypen sowie wichtige Strukturfamilien und deren Eigenschaften. • können die Studierenden strukturelle Instabilitäten erkennen und daraus resultierende Phasenumwandlungen klassifizieren. • sind die Studierenden in der Lage, die Auswirkungen von Phasenumwandlungen auf physikalische Eigenschaften von Kristallen und deren mögliche Anwendungen abzuschätzen. • kennen Studierende die wichtigsten Kristallarten, die als Edelsteine gehandelt werden, können diese identifizieren und grundlegend gemmologisch bewerten. 						
Content						
<ul style="list-style-type: none"> • Atombau, Quantenzahlen. • Chemische Bindungen, Hybridisierung, Paulingsche Regeln. • Gitterenergie, Packungsmuster in Kristallen, Bindungsvalenzen, Strukturformeln. • Kristalfeldtheorie, Magnetismus. • Beschreibung und Darstellung von Kristallstrukturen. • Strukturelle Grundtypen, Spinelle, Perowskite, Silikate. • Komplexe Kristallstrukturen (Zeolithe, Schichtsilikate), Kristallchemie von H₂O. • Klassifikation von Gitterdefekten. • Fremdatome, thermische Punktdefekte, Diffusion. • Versetzungen, Plastizität. • Flächendefekte, Stapelfehler, Zwillinge, Formgedächtniseffekte. • Klassifikationen von Phasenumwandlungen. • Grundzüge der Landau-Theorie, kritische Phänomene. • Atomistische Ursachen struktureller Instabilitäten, Auswirkung auf physikalische Eigenschaften. • Natürliche und synthetische Edelsteine (Entstehung, Vorkommen bzw. Züchtung). • Kriterien zur Identifizierung und Bewertung von Edelsteinen. • Optische Eigenschaften von Edelsteinen (Farbe, Brechungsindex, Dispersion). 						
Teaching methods						
Vorlesung und schriftliche Übungsaufgaben.						
Mode of assessment						

Schriftliche Modulabschlussprüfung (Modulklausur) von 2 h.
Requirement for the award of credit points Bestandene Modulklausur, Bearbeitung aller schriftlichen Übungsaufgaben.
Module applicability
Weight of the mark for the final score 8,3 % der Gesamtnote (10 von 120 CP).
Module coordinator and lecturer(s) Prof. Dr. Jürgen Schreuer; Dr. Marie Münchhalfen
Further information Literatur: A.R. West: Grundlagen der Festkörperchemie, VCH Brown, LeMay, Bursten: Chemie, Studieren kompakt, Pearson R.C. Evans: Einführung In die Kristallchemie, deGruyter J. Bohm: Realstruktur von Kristallen, E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart 1995, ISBN 3-510-65160-X. T. Häger: Edelsteinkunde. Bestimmung, Eigenschaften und Behandlung. Springer Spektrum, ISBN 978-3-662-61305-4.

Kristallisation					
Modul number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. + 3. Sem.	SS/WS	2 semesters
Courses			Contact hours	Self-study	Group size
a) Mineralization in geothermal systems b) Synthetische Kristalle			(a) 4 SWS (b) 2 SWS	(a) 150 h (b) 60 h	12 students
Prerequisites					
<p>Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.</p> <p>Textual: Kenntnisse über Aufbau und Symmetrieeigenschaften von Kristallen werden vorausgesetzt, Kenntnisse über Röntgenbeugung sind wünschenswert.</p>					
Preparation: –					
Learning outcomes					
Nach dem erfolgreichen Abschluss des Moduls					
<ul style="list-style-type: none"> • kennen Studierende die grundlegenden Parameter und Prozesse, welche die Nukleation und das Wachstum von Keimkristallen in unterschiedlichen Milieus bestimmen. • sind Studierende in der Lage, Phasendiagramme zu lesen und unter Einbeziehung thermoanalytischer Daten mögliche Kristallisationsszenarien daraus abzuleiten. • kennen Studierende typische Verfahren zur Synthese bzw. Züchtung aus Lösung, Schmelze und Gasphase, und können diese im Hinblick auf das spezifische Züchtungsziel bewerten. • sind Studierende in der Lage, einfache Synthese-/Züchtungsaufgaben selbstständig durchzuführen und die Produkte strukturell und thermoanalytisch zu charakterisieren. 					
Content					
<ul style="list-style-type: none"> • Stoffsysteme, Zustandsgrößen, thermodynamische Potentiale, chemische Potentiale, Phasenumwandlungen. • Phasenregel, Phasendiagramme, Ein- und Zweistoffsysteme. • Verteilungskoeffizienten, Segregationseffekte, Stofftransport durch Diffusion und Konvektion, Viskosität, konstitutionelle Unterkühlung. • Konventionelle Nukleationsprozesse, homogene und heterogene Keimbildung, kritischer Keimradius, Ostwald-Miers-Bereich, Ostwaldsche Stufenregel. • Wachstumsprozesse, Anlagerungsenergien, Grenzflächenenergien, Flächenkeime, Wachstumsgeschwindigkeiten, Einfluss von Versetzungen, Morphologie von Kristallen. • Nichtkonventionelle Nukleation und Wachstumsprozesse. • Lösungseigenschaften von Fluiden unter Bedingungen der Erdkruste • Experimentelle und technische Verfahren zur Einkristallzüchtung aus Gasphasen, Lösungen und Schmelzen. • Verfahren zur Charakterisierung von Kristallisierungsprodukten (u.a. Differentialthermoanalyse, Röntgenbeugung). 					
Teaching methods					
Vorlesung, praktische Laborübungen unter Verwendung diverser Züchtungs- und Messgeräte.					
Mode of assessment					
Schriftliche Modulabschlussprüfung (Modulklausur) von 2 h.					
Requirement for the award of credit points					
Bestandene Modulklausur, Durchführung aller Laborübungen, erfolgreicher Bericht zu Laborübungen mit Auswertung der gewonnenen Beobachtungen/Messdaten.					
Module applicability					
Weight of the mark for the final score					
8,3 % der Gesamtnote (10 von 120 CP).					
Module coordinator and lecturer(s)					

Prof. Dr. Jürgen Schreuer; Dr. Marie Münchhalfen

Further information

Literature:

K.-Th. Wilke und J. Bohm: Kristallzüchtung, Leipzig 1993, ISBN 978-3326000923.

Kristallphysik					
Modul number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. + 2. Sem.	WS/SS	2 semesters
Courses			Contact hours	Self-study	Group size
a) Kristallphysik b) Physikalische Charakterisierung			(a) 3 SWS (b) 4 SWS	(a) 50 h (b) 145 h	12 students
Prerequisites					
<p>Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.</p> <p>Textual: Kenntnisse über Aufbau und Symmetrieeigenschaften von Kristallen werden vorausgesetzt.</p> <p>Preparation: –</p>					
Learning outcomes					
<p>Nach dem erfolgreichen Abschluss des Moduls</p> <ul style="list-style-type: none"> • kennen Studierende die grundlegenden Konzepte der tensoriellen Kristallphysik und verstehen die Zusammenhänge zwischen der atomaren Struktur von Kristallen und deren thermischen, mechanischen und elektrischen Eigenschaften. • sind Studierende befähigt, Strategien zur vollständigen Bestimmung tensorieller Eigenschaften von anisotropen Medien zu entwickeln. • kennen Studierende geeignete Messverfahren zur Untersuchung thermischer und elektromechanischer Eigenschaften und können entsprechende Messapparaturen nutzen sowie die dafür notwendigen Präparate herstellen. • sind Studierende in der Lage, Messergebnisse kritisch zu hinterfragen, mögliche Fehlerquellen zu diagnostizieren und deren Auswirkungen auf die Resultate zu quantifizieren. 					
Content					
<ul style="list-style-type: none"> • Kristallographische und kristallphysikalische Bezugssysteme. • Zustandsgrößen, thermodynamische Potentiale, Basiseigenschaften. • Nichttensorielle und tensorielle Eigenschaften, Transformationsverhalten. • Einfluss von Symmetrie, Neumannsches Prinzip, Curiesches Prinzip. • Herstellung von Präparaten für Messzwecke (Orientieren, Sägen, Schleifen). • Longitudinal- und Transversaleffekte, Bezugsflächen, Extremwerte von Eigenschaften. • Tensoren 0. Stufe: Dichte und Wärmekapazität, Verfahren zur Bestimmung der Dichte bzw. Wärmekapazität. • Tensoren 1. Stufe: Symmetriereduktion, pyroelektrischer Effekt, Messstrategien, Tensorfläche. • Tensoren 2. Stufe: Symmetriereduktion, Bezugsflächen, symmetrische und antisymmetrische Tensoren, Hauptachsentransformation, Dielektrizitätstensor, Ferroelektrizität, Deformationstensor, thermische Ausdehnung einschließlich der gängigen Messmethoden. • Tensoren 3. Stufe: Tensorfläche, Messstrategien, piezoelektrischer Effekt, Elektrostriktion, Verfahren zur Messung von druckinduzierten Ladungen bzw. feldinduzierten Deformationen. • Tensoren 4. Stufe: Symmetriereduktion, Elastizitätstensoren, Voigt-Notation, Elastostatik, Elastodynamik, Wellenausbreitung in Kristallen, diverse Messmethoden (insbesondere Ultraschallresonanzspektroskopie). • Nichttensorielle Eigenschaften. • Kritische Analyse von Messdaten und deren Aufbereitung für Berichte bzw. Publikationen. 					
Teaching methods					
Vorlesung, praktische Laborübungen an typischen Messgeräten.					
Mode of assessment					
Schriftliche Modulabschlussprüfung (Modulklausur) von 2 h.					

Requirement for the award of credit points Bestandene Modulklausur, Durchführung aller Laborübungen, erfolgreicher Bericht zu Laborübungen mit Auswertung der gewonnenen Messdaten.
Module applicability
Weight of the mark for the final score 8,3 % der Gesamtnote (10 von 120 CP).
Module coordinator and lecturer(s) Prof. Dr. Jürgen Schreuer
Further information Literatur: S. Haussühl: Physical properties of crystals. Wiley-VCH, Weinheim 2007, ISBN 978-3527405435. R.E. Newnham: Properties of materials: Anisotropy, symmetry, structure, Oxford University Press, New York 2005, ISBN 978-0198520764.

Festkörperspektroskopie					
Modul number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. + 3. Sem.	a)+c) SS b)+d) WS	2 semesters
Courses			Contact hours	Self-study	Group size
a) Festkörperspektroskopie I: NMR Spek. b) Festkörperspektroskopie II: Allg. Spek. c) Laborübungen zu FK I d) Laborübungen zu FK II			(a) 2 SWS (b) 2 SWS (c) 2 SWS (d) 2 SWS	(a) 12 h (b) 12 h (c) 80 h (d) 80 h	12 students
Prerequisites					
Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.					
Textual: Mathematische und physikalische Kenntnisse zur Analysis und Vektoralgebra, sowie Kenntnisse der Elektrodynamik und Mechanik müssen in einem mit > 50% bewerteten Eingangstest (Dauer 1h) nachgewiesen werden.					
Preparation: -					
Learning outcomes					
Nach dem erfolgreichen Abschluss des Moduls					
<ul style="list-style-type: none"> • kennen Studierende die grundlegenden Konzepte der Spektroskopie und Quantenmechanik und kennen die wichtigsten spektroskopischen Methoden, • sind Studierende befähigt, Strategien zur Aufklärung lokaler atomarer Umgebungen zu verfolgen und die korrekte spektroskopische Methode anzuwenden, • kennen Studierende geeignete spektroskopische Messverfahren zur Untersuchung von anorganischen Festkörpern, natürlichen und synthetischen Mineralen, • sind Studierende in der Lage, spektroskopische Messergebnisse kritisch zu hinterfragen, mögliche Fehlerquellen zu diagnostizieren und deren Auswirkungen auf die Resultate zu quantifizieren. 					
Content					
Festkörperspektroskopie I: Festkörper NMR Spektroskopie					
<ul style="list-style-type: none"> • Was ist NMR-Spektroskopie? • Die Zeemanwechselwirkung • Geschichtliche Entwicklung der Technik • Continous Wave- und Impulstechnik • Spin-Gitter-Relaxation und Dynamik • Magnetische dipolare Wechselwirkungen • Pulsverfahren (Spin-Echo) • Spin-Spin Relaxation • Die Chemische Verschiebung • Magic-Angle Spinning (MAS) • Korrelation von Kernnachbarschaften durch heteronukleare dipolare Wechselwirkung: Cross-Polarisation (CPMAS), Rotational Echo Double Resonance (REDOR) • Wirkungsweise der Quadrupolwechselwirkung • Wechselwirkungen 1. und 2. Ordnung, Anisotropie und Quadrupolshift • Magic Angle Spinning bei Quadrupolwechselwirkungen 2. Ordnung • Räumliche und Puls-Ausmittelungsmethoden: Double Rotation (DOR), Dynamic Angle Spinning (DAS), Multiquanten Magic Angle Spinning (MQMAS) 					
Festkörperspektroskopie II: Allgemeine Spektroskopie					
<ul style="list-style-type: none"> • Wozu braucht man Quantenmechanik: Physikalische Phänomene, die sich nicht klassisch erklären lassen • Plancks Quantelung von Energiezuständen, Welle-Teilchen Dualismus 					

- Wellenfunktion, Hamiltonoperator, Eigenwerte, -funktionen und Schrödinger-Gleichung, Heisenbergsche Unschärferelation
- Quantenmechanik einfacher eindimensionaler Systeme
- Die elektromagnetische Welle – Aufbau und Polarisation
- Wellenlängenbereiche und Anwendung in der Spektroskopie
- Intensität und Breite von Spektrallinien
- Absorption / Emissionsspektren – Einstein-Koeffizienten
- Energieniveaus und Übergangswahrscheinlichkeiten
- Rotations- und Schwingungsspektroskopie: Starrer und nicht-starrer Rotator, harmonischer und anharmonischer Oszillator
- Auswahlregeln Infrarotspektren, Aufbau moderner Infrarotspektrometer
- Raman-Spektroskopie: Rayleighstreuung, Stokes- und Anti-Stokes Linien
- Schwingungstypen und Gruppentheorie, Irreduzible Darstellungen, Charaktertafeln, Charaktere, Ordnung, Symmetriespezies, Bestimmung der Schwingungstypen mit Hilfe von Charaktertafeln, Bestimmung von erlaubten und verbotenen Übergängen
- Ramanspektren und Aufbau moderner Ramanspektrometer
- IR- und -Schwingungsspektren von Mineralen
- Elektronenspektroskopie: Ein- und Mehrelektronenatome, Elektronenübergänge, Auswahlregeln, Russell-Saunders Kopplung
- Atomabsorptions- und emissionsspektroskopie, Röntgenspektroskopie (XPS, EXAFS)
- Die Schwingungsstruktur der Elektronenübergänge: Feinstruktur und Franck-Condon-Prinzip
- Fluoreszenz und Phosphoreszenz, Funktion von LASERn
- UV-VIS Spektroskopie: Aufbau eines UV-VIS Spektrometers, Kristallfeldtheorie, Molekularorbitaltheorie, d-d Übergänge und Charge-Transfer Übergänge, Termsymbole, Jahn-Teller Verzerrung, Tanabe-Sugano Diagramme
- EPR Spektroskopie: Der Elektronen-Zeeman-Term
- Elektronenspinwechselwirkungen: Die Nullfeld-Aufspaltung (ZFS)
- Elektronen-Kernspinwechselwirkungen: Die Hyperfeinstruktur (HFS)
- Aufbau eines EPR cw-Spektrometers: Einkristallspektren und Rotationsdiagramme
- Der Mößbauereffekt: Rückstoßfreie Kernresonanzabsorption
- Das Mößbauerspektrometer: Ausnutzung des Dopplereffektes
- Isomerieverziehung, Quadrupol- und magnetische Hyperfeinaufspaltung
- Typischer Mößbauerkern in den Geowissenschaften: ^{57}Fe
- Mößbauerspektren von Mineralen: Bestimmung des $\text{Fe}^{2+} / \text{Fe}^{3+}$ -Verhältnisses

Teaching methods

Vorlesung, praktische Laborübungen an typischen Spektrometern (NMR, IR, UV-VIS).

Mode of assessment

Mündliche Modulabschlußprüfung von 30 min..

Requirement for the award of credit points

Bestandene mündliche Modulabschlußprüfung, verpflichtender Besuch der Vorlesungen, Durchführung aller Laborübungen, erfolgreiche Berichte zu Laborübungen mit Auswertung der gewonnenen Messdaten

Module applicability**Weight of the mark for the final score**

8,3 % der Gesamtnote (10 von 120 CP).

Module coordinator and lecturer(s)

Dr. Michael Fechtelkord

Crystal structure analysis					
Modul number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. + 3. Sem.	SS/WS	2 semesters
Courses			Contact hours	Self-study	Group size
a) Crystal structure analysis (Lectures) b) Single crystal X-ray diffraction: (Practical) c) Powder X-ray diffraction: (Practical)			(a) 2 SWS (b) 3 SWS (c) 3 SWS	(a) 60 h (b) 60 h (c) 60 h	12 students
Prerequisites					
Formal: Master students from natural science and engineering curriculum.					
Textual: Basic knowledge on crystal symmetry, crystal chemistry and crystal physics.					
Preparation: –					
Learning outcomes					
After completion of the module the students					
<ul style="list-style-type: none"> • know the principles of X-ray diffraction and structure solution methods. • know typical techniques and procedures of structural analysis and can apply the necessary correction factors. • are able to select a suitable procedure for a given problem and have a basics of the necessary computer programs. • are able to independently carry out a crystal structure analysis from single crystal and powder data on the basis of a given data set, obtain correct crystal structure solution, evaluate errors, and assess the quality of the result. 					
Content					
<ul style="list-style-type: none"> • reciprocal space, reciprocal lattice, Braggs and Laue laws, Ewald's sphere. • Bremsstrahlung and characteristic X-rays, X-ray absorption. • Interaction of X-rays with materials, atomic scattering factor. • Structure factor, phase factor. • Correction factors: polarisation, Lorentz, absorptions, scale, temperature, absorption, multiplicity factors. • Fourier transformation, Differential Fourier synthesis. • Crystal structure solution: heavy atom technique, direct method, direct space approach, Patterson function, anomalous scattering. • Crystal structure refinement, restraints und constraints, quality of fitting. • Representation of crystal structures. • Rietveld technique. • Texture and crystal size, real structure characterisation, radial and pair distribution function. • Qualitative and quantitative phase analysis. Crystal structure date banks. 					
Teaching methods					
Lectures, problems solving, practical laboratory work with X-ray diffractometers and computer software.					
Mode of assessment:					
Written exam – 2 h					
Requirement for the award of credit points					
Successful written exam, participation in all laboratory trainings, successful homework.					

Module applicability
Weight of the mark for the final score
8,3 % (10 von 120 CP).
Module coordinator and lecturer(s)
Dr. Kirill Yusenko
Further information
Literature:
Int. Tables for Crystallography. Vol. A: Space-group symmetry
Int. Tables for Crystallography. Vol. C: Mathematical, physical and chemical tables
Int. Tables for Crystallography. Vol. H: Powder diffraction
Pecharsky, Zavaliv: Fundamentals of Powder Diffraction and Structural Characterization of Materials

Analytical methods in rock analysis					
Module number	Credits	Workload	Term	Frequency	Duration
	5 CP	150 h	2. + 3. Sem.	SS/WS	2 semesters
Courses			Contact hours	Self-study	Group size
a) Methods of rock analysis			(a) 2 SWS	(a) 30 h	10 students
b) Practicals on rock analysis			(b) 2 SWS	(b) 60 h	
Prerequisites					
Learning outcomes					
After completion of the module the students					
<ul style="list-style-type: none"> • know methods to quantify the chemical content of solid materials. • can make qualified decisions about which analytical method is best suited for a given analytical problem. • are able to critically evaluate the results, to analyze possible sources of errors, and their influences on the results. 					
Content					
<ul style="list-style-type: none"> • Lecture in methods of rock analysis: Fundamentals of electromagnetic rays and interaction with matter. Atomic-Absorption Spectroscopy (AAS), X-ray fluorescence spectroscopy (XRF), coulorometry, potentiometric methods, nuclear methods (e.g. RBS, NRA), general principles of mass spectrometry and different kinds of mass spectrometry, laser-ablation inductively coupled mass spectrometry (LA-ICP-MS), secondary ion mass spectroscopy (SIMS). • Sample preparation methods. • Practicals on rock analysis: complete chemical analysis of a silicate rock will be carried out, and the errors and uncertainties in the results will be evaluated. 					
Types of courses					
Lecture, practicals					
Types of examinations					
Written exam of the contents of the lecture. A passed exam is a prerequisite for the attendance of the practical. Written report of the analyzed sample, determination of the P-T-condition of a metamorphic rock (computer program Perple X) or determination of the sample name and its geodynamic setting plus the crystallization history (computer programs GCD Kit and Pele).					
Prerequisites for earning the credit points					
Passed written exam and passed report. The written exam is graded and determines the grade of the module. The report of the practical is not graded.					
Module applicability					
Percentage of the grade for the overall examination					
4 %					
Head of the module					
Dr. Thomas Fockenberg					
Literature					
Potts: A Handbook of silicate rock analysis; Springer					
Potts et al.: Microprobe techniques in the Earth sciences; Springer					
Rollinson H.: Using Geochemical Data – evaluation, presentation and interpretation. Prentice Hall Press.					
Granger et al.: Instrumental analysis; Oxford university press					
Hughes & Hase: Measurements and their uncertainties, Oxford university press					

Kingston & Jassie: Introduction to microwave sample preparation; Oxford university pressc

Electron beam microanalysis					
Module number	Credits	Workload	Term	Frequency	Duration
	6 CP	180 h	2. Sem.	Every SS	1 semester
Courses			Contact hours	Self-study	Group size
a) Lecture: Electron beam microanalysis b) Practical exercises on electron beam microanalysis (SEM, CL, EMPA)			(a) 2 SWS (b) 2 SWS	(a) 60 h (b) 60 h	9 students
Prerequisites					
Learning outcomes					
After completion of this module the students					
<ul style="list-style-type: none"> • understand the applicability of electron beam microanalytical methods. • know different kinds of methods (SEM, EMPA, TEM, CL, Auger electron). • are able to evaluate the strengths and limitations and perform an analysis of errors. • gained practical experience of diverse electron beam analytical tools. 					
Content					
<p>a) Lecture: Electron beam microanalysis</p> <p>Overview of the use of electron beam methods for the analysis of solid materials. Electron – matter interaction (elastic scattering, inelastic scattering, production of X-rays, Auger electrons, and Cathodoluminescence). Construction principles and working of different instruments (TEM, SEM, EMPA, STEM, CL microscopes). Functionality of different parts of the instruments such as pumps, electron optic, generation of electron beams). Analytical methods and interpretation of analytical results (EELS, EBSD, electron optical images, EDX, WDX, diffraction images).</p>					
<p>b) Practical exercises on electron beam microanalysis (SEM, CL, EMPA)</p> <p>Familiarization with the equipment and their parts. Coating a sample with C or Au. Inserting and extracting a sample holder from the sample chamber under vacuum. Adjusting the electron beam. Navigation on the sample. Use of different detectors (SE, BSE, CL, EBSD) for imaging. Experiments on the effects of accelerating voltage and sample current. Qualitative analysis and identification of minerals with the help of the energy dispersive detectors. Collecting wavelength dispersive spectra in the electron microprobe. Comparison of results from EDX and WDS. Production of element distribution maps. Generation of crystallographic orientation images (SEM).</p> <p>Conceiving a quantitative analytical program. Determination of peak and background positions, choice of spectrometers, standard materials, counting times and beam parameters (EMPA).</p> <p>Evaluation of the analyses through the calculation of mineral formulae and estimate of errors.</p>					
Types of courses					
Lectures and practicals.					
Types of examinations					
Final examination on the lecture part. Passing this exam is a pre-requisite for participation in the practical exercises.					
Prerequisites for earning the credit points					
Active participation in the practical demonstrated through a detailed record of experiments in the lab book and a written report.					
Module applicability					
Percentage of the grade for the overall examination					
5,0 % of the overall grade (6 CP from 120)					
Head of the module					

Dr. René Hoffmann and Dr. Niels Jöns

Literature

- Potts et al.: Microprobe techniques in the Earth sciences; Springer
- Loretto (1984): Electron beam analysis of materials. 2nd ed., Springer-Verlag.
- Hughes & Hase (2010): Measurements and their uncertainties. 1st ed., Oxford University Press
- Goldstein et al. (2018): Scanning electron microscopy and X-ray microanalysis. 4th ed., Plenum Press.
- Reed (2005): Electron microprobe analysis and scanning electron microscopy in Geology, 2nd ed., Cambridge University Press.

Igneous petrology					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. Sem.	Every WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Petrology of igneous rocks b) Thin section exercises with igneous rocks c) Numerical exercises with data from igneous rocks			(a) 2 SWS (b) 2 SWS (c) 2 SWS	(a) 70 hours (b) 60 hours (c) 80 hours	15 students
Prerequisites					
Learning outcomes					
The students					
<ul style="list-style-type: none"> • gain an advanced understanding of igneous petrology. • master detailed microscopic and macroscopic descriptions and documentation of igneous rocks • are able to use textural and thermodynamic criteria to work out the genetic history of the rocks • know how to place the results in a geodynamic context of thermal evolution of the crust and the mantle 					
Content					
a) Petrology of igneous rocks					
<ul style="list-style-type: none"> • Thermal structure of the Earth and formation of melts. • Classification of igneous rocks. • Geochemical characteristics of igneous rocks. • Trace element and isotopic characteristics of igneous rocks. • Physical properties of silicate melts. • Phase equilibria and phase diagrams. • Melting in the mantle. • Igneous processes in selected tectonic settings: Mid ocean ridges, subduction zones. • Crustal melting and genesis of granitic rocks. • Volcanic processes and basics of volcanology and volcanic hazards. 					
b) Thin section exercises with igneous rocks					
<ul style="list-style-type: none"> • Igneous minerals in thin sections. • General information on documenting thin section reports. • Case studies of a range of volcanic and plutonic rocks to read the rock record to infer the processes that led to their formation. • An emphasis is on relating the observations to phase diagrams and on inferring multistage processes from the rock record. 					
c) Numerical exercises with data from igneous rocks					
<ul style="list-style-type: none"> • Calculation of CIPW Norm. • Trace element modelling. • Calculation of magma mixing, fractionation, assimilation and other igneous processes. • Use of thermodynamic software such as MELTS to calculate equilibrium assemblages and compositions as well as to model the evolution of magmatic systems. 					
Types of courses					
Lectures and practicals (microscopy and calculations).					
Types of examinations					
A final written examination including questions on microscopy of thin sections.					

Prerequisites for earning the credit points Passing the examination.
Module applicability
Percentage of the grade for the overall examination 8 % of the overall grade (10 CP from 120)
Head of the module Prof. Dr. Sumit Chakraborty
Literature A.R. Philpotts, J.J. Ague (2009): Principles of igneous and metamorphic petrology. Cambridge University Press. ISBN 978-0-521-88006-0 J.D. Winter (2014): Principles of igneous and metamorphic petrology. Pearson Education. ISBN 978-1-292-02153-9 R. Gill (2010) Igneous rocks and processes – a practical guide. Wiley Blackwell. ISBN 978-0-6320-6377-2. M. Wilson (1997) Igneous petrogenesis – A global tectonic approach. Chapman & Hall. ISBN 0 412 53310 3. L.A. Raymond (1995) The study of igneous, sedimentary and metamorphic rocks. Wm. C. Brown Communications Inc. ISBN 0-697-00190-3. McBirney, A. (2006) Igneous Petrology. Jones & Bartlett Publ. ISBN 10: 0763734489.

Kinetics					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	3. Sem.	Every WS	1 semester
Courses			Contact hours	Self-study	Group size
a) Principles of chemical kinetics (3 CP)			(a) 2 SWS	(a) 60 h	
b) Diffusion chronometry (4 CP)			(b) 2 SWS	(b) 90 h	
c) Kinetic modelling (3 CP)			(c) 2 SWS	(c) 60 h	
Prerequisites					
Learning outcomes					
Students understand					
<ul style="list-style-type: none"> • the basic principles of chemical kinetics. • how to use kinetics to determine timescales. • how frozen records are produced in rocks during cooling after a thermal event. 					
Content					
a) Principles of chemical kinetics					
<ul style="list-style-type: none"> • Rate laws of chemical kinetics. • Elementary reactions and reaction mechanisms. • Factors that control chemical kinetics. • Crystal growth kinetics (including discussion of crystal size distribution, CSD). • Nucleation rate laws. • Combined nucleation and growth – overall transformation and TTT diagrams. • Closure temperatures. • This course will have lectures. 					
b) Diffusion chronometry					
<ul style="list-style-type: none"> • Diffusion in solids. • Different kinds of diffusion coefficients. • Factors that control diffusion coefficients. • Experimental methods for determination of diffusion rates. • Setting up a diffusion model. • Different kinds of approaches to get timescales – isothermal systems. • Different kinds of approaches to get cooling and exhumation rates – non-isothermal systems. • Errors and uncertainties. • Case studies. • This course will have lectures and practicals. 					
c) Kinetic modelling					
<ul style="list-style-type: none"> • Coupled processes in series and parallel. • Rate limiting behavior. • Reaction mechanism maps. • Combination of chemical kinetics, fluid transport and chemical equilibrium. 					
Types of courses					
Lectures and practicals.					
Types of examinations					
A written final examination					
Prerequisites for earning the credit points					
Passing grades in the final examination					
Module applicability					
Percentage of the grade for the overall examination					

8,3 %
Head of the module
Prof. Dr. Sumit Chakraborty
Literature
Kinetic Theory in Earth Sciences. A.C. Lasaga (Princeton University Press, 1998)
Geochemical Kinetics. Y. Zhang (Princeton University Press, 2009)
Geochemical Rate Models. J. Donald Rimstidt (Cambridge University Press, 2013)
Chemical Kinetics of Solids. H. Schmalzried (VCH Verlag, 1995)
Atom movements: Diffusion and mass transport in solids. J. Philibert (EDP Sciences, 1991)
Phase transformations in metals and alloys. D.A. Porter and K.E. Easterling (Chapman & Hall, 1992)
Introduction to Geochemical Modelling. F. Albarede (Cambridge University Press, 1995)

Metamorphic petrology					
Module number	Credits	Workload	Term	Frequency	Duration
	12 CP	360 h	2. Sem.	Every SS	1 semester
Courses			Contact hours	Self-study	Group size
a) Petrology of metamorphic rocks b) Thin section exercises with metamorphic rocks c) Numerical exercises with data from metamorphic rocks d) THERMOCALC course			(a) 2 SWS (b) 2 SWS (c) 2 SWS (d) 1 SWS	(a) 70 h (b) 60 h (c) 80 h (d) 60 h	15 students
Prerequisites					
Learning outcomes					
The students					
<ul style="list-style-type: none"> gain an advanced understanding of metamorphic petrology. master detailed microscopic and macroscopic descriptions and documentation of metamorphic rocks. are able to use textural and thermodynamic criteria to work out the genetic history of the rocks. know how to place the results in a geodynamic context. 					
Content					
a) Petrology of metamorphic rocks					
<ul style="list-style-type: none"> Introduction to the basic questions in petrological research; how metamorphic rocks can be used to answer geodynamic questions. Crystal chemical basis (coordination polyhedra, exchange vectors). Representation of minerals in chemographic diagrams. Gibbs phase rule. Topology of phase diagrams and thermodynamic basis. Types of metamorphism: Regional – limited (cataclastic, mylonitic, contact); Regional – extended (burial, orogenic). P-T-t evolution due to crustal thickening and extension. Subduction, magmatic underplating. Metamorphic zones and facies series. Barrow type, Abukuma type, Subduction type. Types of metamorphic equilibria: Solid-gas equilibria (dehydration reactions, decarbonation reactions, redox reactions). Solid-solid reactions (Influence of solid solution on location of phase boundaries, divariant thermometers, divariant barometers). Trace element thermometers. Zoning in minerals (diffusion controlled growth, retrograde Fe-Mg exchange). Mass transport in metamorphism (fluid flow, metasomatism). Observations of metamorphic evolution of model systems (ultramafics, metabasics, calc-silicates, metapelites). Basics of geochronology of metamorphic rocks. 					
b) Thin section exercises with metamorphic rocks					
<ul style="list-style-type: none"> Identification of the most important metamorphic minerals in thin sections. General information on documenting thin section reports. Case studies of metapelites and metabasites (hand specimen description, petrographic description, texture analysis, discussion of possible protoliths, P-T evolution, phase relations, topology of phase diagrams). 					
c) Numerical exercises with data from metamorphic rocks					
<ul style="list-style-type: none"> Calculation of mineral formulae from chemical analyses. Representation of mineral compositions and phase relations. Schreinemakers Analysis. 					

- Application of Clausius-Clapeyron equation to construct phase boundaries in P-T space. Generation of compatibility diagrams.
- P-T sections, T-X sections, P-X sections and P-T pseudosections with the help of thermodynamic software. Interpretation of the results using examples from real metamorphic rocks. Geothermobarometric calculations. Derivation of P-T conditions of formation of rocks on the basis of P-T grids.

d) THERMOCALC course

Advanced pseudosection modelling course for more complex model systems involving solid solutions, based on case studies in metabasic rocks.

Types of courses

Lectures and practicals (microscopy and calculations).

Types of examinations

Graded final report. Each individual makes microscopic observations on a sample, interpret the results and carry out numerical calculations associated with the observations.

Prerequisites for earning the credit points

Report with passing grade.

Module applicability

Percentage of the grade for the overall examination

10 % of the overall grade (12 CP from 120)

Module coordinator and lecturer(s)

Niels Jöns, Ralf Dohmen, Annika Dziggel

Literature

F.S. Spear (1995); Metamorphic phase equilibria and pressure-temperature-time paths. Mineralogical Society of America Monograph. Washington DC. ISBN 0-939950-34-0

A.R. Philpotts, J.J. Ague (2021): Principles of igneous and metamorphic petrology (3rd Ed.). Cambridge University Press. ISBN 9781108492881

J.D. Winter (2014): Principles of igneous and metamorphic petrology. Pearson Education. ISBN 978-1-292-02153-9

D. Turcotte, G. Schubert (2014): Geodynamics. Cambridge University Press. ISBN 978-1107-00653-9

Thermodynamics									
Module number	Credits	Workload	Term	Frequency	Duration				
	10 CP	300 h	2. Sem.	Each SS	1 semester				
Courses		Contact hours		Self-study					
a) Principles of elementary thermodynamics		a) 4 SWS		a) 180 h					
b) Solution phase thermodynamics		b) 2 SWS		b) 30 h					
Prerequisites									
Learning outcomes									
Students understand									
<ul style="list-style-type: none"> • the basic principles of thermodynamics. • solution thermodynamics and know thermodynamic modelling. 									
Content									
<p>a) Principles of elementary thermodynamics</p> <ul style="list-style-type: none"> • Nature of thermodynamics; Definition of systems (open, closed, isolated), processes (reversible, irreversible etc.), time scales - to the extent it does or does not play a role. • Work, energy and functions of state • Heat, energy conservation and first law (i.e. What is possible?). • Heat capacity, enthalpy. • Irreversibility and entropy - second law and very brief mention of third law (i.e. What really happens?). • Combined first and second law and Master equation of thermodynamics - energy balance. • Mathematical digression - Exact and inexact differentials, Legendre transformation, Chain rule. • Accessory Functions - G, H and A. Maxwell's Laws. • P-V-T equation of state for solids, fluids and gases - What properties they should have and what they look like for some geomaterials. • Chemical equilibrium - I. Stoichiometric substances (Concept of G minimum, log K and Clausius-Clapeyron equation and P-T slopes). • This will have two hours of lecture and two hours of practical with homework problems to be solved outside of class contact hours. 									
<p>b) Solution phase thermodynamics</p> <ul style="list-style-type: none"> • Chemical potential, activity, fugacity. Raoult and Henry's law. Possibility of various standard states (i.e. nothing unique about it), e.g. 1bar, T vs. P,T. • Ideal and excess properties, activity – composition relations, dilute solutions and trace elements. • Free-energy composition relations i.e. G-X diagrams and stability of solutions. • Combine chemical equilibrium relations and mixtures to calculate - (i) Shift of equilibrium boundaries on solution formation (ii) Phase rule and Duhem's theorem, with various applications. (Introduction to various free energy minimization softwares) • Temperature (and pressure) dependence of reactions (Delta H) and melt phase diagrams (eutectic, binary solid solution loop). • Thermodynamics of electrolytes and ocean water. • This course will have lectures and discussions. 									
Types of courses									
Lectures and practicals									
Types of examinations									
A written final examination									
Prerequisites for earning the credit points									

Passing grade in the final examination
Module applicability
Percentage of the grade for the overall examination
8,3 %
Head of the module
Prof. Dr. Sumit Chakraborty
Literature
Thermodynamics of natural systems – Theory and Applications in Geochemistry and Environmental Sciences; G.M. Anderson (Cambridge University Press, 2017)
Thermodynamics in Earth and Planetary Sciences; J. Ganguly (Springer Verlag, 2019)
Thermodynamics of the Earth and Planets; Alberto Patino-Douce (Cambridge University Press, 2011)
Physical Chemistry; G.K. Vemulapalli (Prentice Hall International, 1993)
Applied Mineralogical Thermodynamics; N.D. Chatterjee (Springer Verlag, 1991)
Mixtures and Mineral Reactions; J. Ganguly and S.K. Saxena (Springer Verlag, 1987)
The Principles of Chemical Equilibrium; K. Denbigh (Cambridge University Press, 1984)

Mantle petrology					
Module Number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	3. + 4. Term	Annually	2 semesters
Courses			Contact hours	Self-study	Group size
a) Lecture + Paper seminar - Petrology of the deep Earth (WS)			(a) 3 SWS	80 h paper reading and literature research	No limitations in course a)
b) Lab course +Lecture – Experimental Petrology: The Earth in the laboratory (SS)			(b) 5 SWS	120 h of protocols and literature study	A maximum of 6 in course b)
Pre-requisites					
Students in the MSc. program of Geosciences and related MSc. programs. Prior attendance of Mineralogy (BSc) and Thermodynamics (MSc) is strongly encouraged.					
Learning outcomes					
After completion of the module the students will understand					
<ul style="list-style-type: none"> • the chemical and physical structure of the non-accessible Earth interior. • the basic experimental methods to obtain information on phase assemblages and physical properties of rocks and minerals (e.g. melting curves, densities). • how to treat and interpret experimentally derived data. • The structure of scientific papers and how to read them. • Writing experimental reports. 					
Content					
<p>a) Petrology of the deep Earth</p> <ul style="list-style-type: none"> • The physical state of all relevant layers of Earth, from the deep crust to the Earth's core. • Major rock-forming phases, phase relations at high pressures and high temperatures. • The effect of pressure, temperature and oxygen fugacity on phase relations and the equation of state of high-pressure phases (e.g. ringwoodite, bridgmanite). • The role of chemical and physical heterogeneities. • Volatile cycles, i.e. carbon, water, sulfur. • Modes of chemical exchange between the different mantle layers. Discussing the question of layered vs. whole mantle convection. • Reading and understanding research papers. 					
<p>b) Experimental Petrology: The Earth in the laboratory</p> <ul style="list-style-type: none"> • Theoretical background: What is a good experiment? • Overview of devices that are used to simulate conditions of Earth's interior – From the gas-mixing furnace to the laser-heated diamond anvil cell. • Calibration of experimental devices. • Dealing with measurement imperfections: Precision and accuracy. • Attainment of chemical equilibrium. • Hands-on experience in assembling and conducting experiments. • Treatment of synthetic and real experimental data, error propagation and basic data fitting. 					
Mode of assessment					
Written examination (90 minutes) or homework for course a) depending on the class size and a 15 minutes paper presentation. Experimental protocol for course b).					

Requirement for the award of credit points 50% or more in written examination/paper presentation, active performance in the laboratory course and a grade of pass for the protocol.
Module applicability This module is aimed at students who wish to pursue research or work in the fields of Petrology, Geochemistry and Geophysics.
Weight of the mark for the final score
Module coordinator and lecturer(s) Dr. Christopher Beyer
Further information Will be communicated at the beginning of each class. Students may contact the lecturer for more detailed information on course contents prior to the start of the semester.

High-temperature geochemistry									
Module Number	Credits	Workload	Term	Frequency	Duration				
	10 CP	300 h	2. + 4. Term	Annually	1 semester				
Courses			Contact hours	Self-study	Group size				
a) High-temperature geochemistry – application of radiogenic and stable isotopes to high-temperature geological systems and ore deposits (SS) b) Practical – Application of mass spectrometry to radiogenic and stable isotope systems. Data reduction and treatment. (SS)		(a) 3 SWS (b) 3 SWS	105 h case studies and exercises 105 h of exercises and protocols	No limitations in either course.					
Pre-requisites									
Students in the MSc. program of Geosciences and related MSc. programs. Prior attendance of Sedimentary Geochemistry (MSc.) and Einführung in die Geochemie (Introduction to Geochemistry - 5. Semester BSc.) is strongly encouraged.									
Learning outcomes									
After successful completion of the module the students will:									
<ul style="list-style-type: none"> • understand how isotope systems can be used to answer fundamental questions related to high-temperature geological. • know analytical techniques related to the acquisition of trace element and isotope data from magmatic, metamorphic and ore mineral samples. • be able to understand how to interpret these data to identify high-temperature processes occurring at various scales (e.g. from Earth's crust and mantle to solar system planetary differentiation). 									
Content									
The lecture will provide an overview of the application of radioactive and stable isotopes to high-temperature geological systems, including igneous and metamorphic samples, as well as magmatic and hydrothermal ore deposits. In the first half of the Module, students will learn to apply data from classic radioactive decay systems (i.e. Rb-Sr, U-Pb, Sm-Nd, Lu-Hf isotopes) to a different rock types produced as a result of high-temperature processes (metamorphism, melting and crystallization). Students will be introduced to other radioactive systems (both extant and extinct) that have seen increasing application in Earth Sciences, like Hf-W, Pd-Ag, Re-Os, Pt-Os etc.. All these systems can be used to identify specific processes, which range in scale from crystallization of silicate and sulfide minerals from magmas, to core formation in planetary bodies.									
The second half of the Module will deal with non-traditional stable isotope systems and how they can be used to complement data from radioactive decay systems in a variety of applications. These systems will include an overview of B, Si, Mo, Ti, V, Cr, and Fe isotopes to characterize processes and variables ranging from fluid-rock interaction, crustal recycling, redox conditions, mantle source compositions and many others.									
The lecture will be complemented by a practical (Übung) where geochemical data from natural and experimental samples will be discussed and evaluated. Moreover, case studies involving different high-temperature geological settings will be discussed.									
Requirement for the award of credit									
Teaching and practical work (Exercises).									
Mode of assessment									
Written examination and practical work report or oral exam, depending on class size									

(written examination 90 minutes, oral examination 30 minutes).
Requirement for the award of credit points 50 or more points in written examination, active performance in the laboratory course (weighing 80% written examination 20% practical course).
Module applicability This module is aimed at students who wish to pursue research or work in the fields of Petrology, Geochemistry, Tectonics and Ore Geology. This module is complementary to the WS MSc. Module "Sedimentary Geochemistry". As such, and for a greater overview of techniques and applications in Isotope Geochemistry, students are strongly encouraged to participate in both Modules.
Weight of the mark for the final score
Module coordinator and lecturer(s) Prof. Raúl Fonseca
Further information Will be communicated at the beginning of each class. Students may contact the lecturer for more detailed information on course contents prior to the start of the semester.

Field course in tectonics and resources					
Modul-Nr.	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. + 3. Sem.	Annually	10 days
Courses			Contact hours	Self-study	Group size:
a) Pre-field course seminar b) Field course			(a) 1 SWS (b) ~10 days	(a) 140 h (b) 70 h	14 students
Prerequisites					
Learning outcomes					
Upon successful completion of this module, the students					
<ul style="list-style-type: none"> • know how to document and interpret structural and petrological data. • are able to integrate field observations with theoretical knowledge in tectonics and/or economic geology. 					
Content					
The content and exact duration of the field course depend on the field area, which is variable each year (Scotland, South Africa, etc.). The field course is preceded by a seminar. The aim of this field course is to train the students' field skills in tectonics and economic geology, and to combine theoretical knowledge with field observations. The field course may include small mapping projects and visits to open pit and underground mines.					
Types of courses					
Field trip, seminar.					
Types of examinations					
Report.					
Requirements for the award of credit points					
Participation in the field trip and seminar. Passing grade for the report.					
Module applicability					
Weight of the mark for the final score					
8,3 % (10/120 CP)					
Module coordinator and lecturer(s)					
Prof. Annika Dziggel (Ph.D),					
Other information					
Relevant literature will be presented at the beginning of each course.					

Economic geology II					
Modul-Nr.	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. + 2. Sem.	WS, SS	2 semesters
Courses			Contact hours	Self-study	Group size:
a) Metallic mineral deposits b) Non-metallic mineral deposits c) Research project on ore deposits			(a) 2 SWS (b) 1 SWS (c) 3 SWS	(a) 70 h (b) 30 h (c) 110 h	20 students
Prerequisites					
Learning outcomes					
Upon successful completion of this module, the students					
<ul style="list-style-type: none"> • have an in-depth understanding on the processes of formation of metallic and non-metallic mineral deposits and their different geodynamic settings. • are able to identify and document the mineralogical and textural characteristics of a wide range of deposit types. • know how to evaluate the conditions and processes of element enrichment using a variety of analytical techniques as well as whole rock and mineral-chemical data. 					
Content					
(a) Metallic mineral deposits					
Introduction to ore forming processes, genetic concepts and classifications. Conceptual difference between mineral resources and ore reserves; economic aspects. Magmatic(-hydrothermal) ore forming systems: ortho-magmatic deposits, deposits related to granites, Cu-porphries, ore deposits in mid-ocean ridges and ophiolites. Hydrothermal ore-forming systems related to metamorphic processes; ore deposits in supergene and sedimentary settings.					
(b) Non-metallic mineral deposits					
Introduction into the use and properties of industrial minerals, earths and rocks, salt and gemstones (diamond only).					
(c) Research project on ore deposits					
This course encompasses the guided independent study of well-characterized hydrothermal ore deposits using hand specimens, thin- and polished sections and a range of whole rock and mineral-chemical data. This course introduces students to research-oriented learning and is aimed at preparing the students for their Master projects.					
Types of courses					
Lectures, practicals, project work in small teams					
Types of examinations					
Written examination on the contents of courses a) and b); extended abstract and oral presentation in c).					
Requirements for the award of credit points					
Passing grade for the written examination and extended abstract/oral presentation.					
Module applicability					
Weight of the mark for the final score					
8,3 % (10/120 CP)					
Module coordinator and lecturer(s)					
Prof. Annika Dziggel (Ph.D)					
Other information					
Relevant literature will be presented at the beginning of each course.					

Geochemical analyses by laser ablation-ICP-mass spectrometry							
Module-No.	Credits	Workload	Term	Frequency	Duration		
	5 CP	150 h	3. Sem.	Annually	1 semester		
Courses		Contact hours	Self-study	Group size: 8 students			
a) Methods of LA-ICPMS b) Practical course in LA-ICPMS		(a) 2 SWS (b) 2 SWS	(a) 30 h (b) 60 h				
Prerequisites							
The module is open to students with a BSc in Earth Sciences. Successful completion of the module "Analytical methods in rock analysis" is recommended.							
Learning outcomes							
Upon successful completion of this module, the students							
<ul style="list-style-type: none"> have an in-depth understanding of the principles of laser ablation and inductively coupled plasma-mass spectrometry methods (SF-, TQ-, MC-ICPMS). are able to choose the best-suited method for a given geoscientific research question. can critically evaluate the results, calculate the analytical uncertainty, and identify possible sources of analytical problems. 							
Content							
a) Lecture in methods of LA-ICPMS:							
1) Laser ablation: principles of laser radiation, analytical approaches (profile, spot, 3D analyses, mapping), interaction of the laser beam with solid matter, combination of LA-ICPMS and LIBS, split-line technique.							
2) Mass spectrometry: principles of (Inductively Coupled Plasma-) Mass Spectrometry, advantages and drawbacks of different mass spectrometer designs (e.g., SF, TQ, MC; reaction cell, high- vs. low-resolution), data evaluation (incl. analytical uncertainty, counting statistics).							
b) Practical course in LA-ICPMS: The students learn the basics about handling and tuning of a modern laser ablation system connected to a state-of-the-art triple-quadrupole-ICP-mass spectrometer. Analyses target a large variety of solid materials like glasses, alloys (e.g. welding rods, coins), mineral phases (e.g., zircons, olivines, garnets, ...), and samples from different ore deposits (e.g., hydrothermal settings). Age determinations of selected zircons (U-Pb ages) and/or garnets (Lu-Hf ages) are included, and calculation and evaluation of the age will be part of the practical course.							
This course is especially welcoming students who are interested in master projects that evolve around in-situ analyses of solid samples (e.g., glasses, minerals, alloys, small archaeological artefacts).							
Types of courses							
Lectures, practicals and project work in small teams.							
Types of examinations							
Written report including theoretical aspects of laser systems and mass spectrometers, the analytical procedure (and its challenges), and presentation and evaluation (including error calculations) of the results.							
Requirements for the award of credit points							
Attendance in the practical course and a passing grade for the written report.							
Module applicability							
Weight of the mark for the final score							
4 % (5/120 CP)							
Module coordinator and lecturer(s)							
Dr. Stephan Schuth							

Other information

Literature: Gill: Modern Analytical Geochemistry - Sigrist: Laser: Theorie, Typen und Anwendungen - Skoog & Leary: Instrumentelle Analytik - Sylvester: Laser ablation ICP-MS in the Earth Sciences - Thomas: Practical Guide to ICP-MS

Economic geology I					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. + 2. Sem.	Annually	2 semesters
Courses			Contact hours	Self-Study	Group size
(a) Petroleum geology I (WS)			(a) 2 SWS	(a) 75 h	12-20 students
(b) Petroleum geology II (SS)			(b) 2 SWS	(b) 120 h	
(c) Field trip (SS)			(c) 1 day	(c) 35 h	
Prerequisites					
Students enrolled in a Geosciences Master-Program					
Learning outcomes					
The module consists of a winter-term lecture (a), a summer-term lecture (b) and a summer term field trip (c).					
(a) Petroleum geology I					
The assessment center exercise aims at communicative interaction and gaining/deepening „soft-skills“ (team work, resilience to challenging time vs. content preparations, concept selection, short presentation, facing a managerial board, staying in control of a meeting, addressing challenging questions constructively and authentically).					
Students gain academic level knowledge and applied competences to gather, interpret and rank such reservoirs:					
<ul style="list-style-type: none"> • in their context of primary depositional environment, its fundamental controls on global, regional and local scale. • using systemically relevant geogenic alteration factors with positive and/or negative consequences on the reservoir properties and their economic relevance. • executing analysis, interpretation and assessment of pore fluids with respect to their geo-heritage and economic value. 					
(b) Petroleum geology II					
The students gain/learn:					
<ul style="list-style-type: none"> • systemic competencies of applying the competences of (a) in a different regional geo-context. • global and regional geological knowledge, analogous occurrences of subsurface architectures versus unique settings and their characteristics. • risks and opportunities derived from analogous versus unique settings, specifically with respect to economic exploration, development and production of the subsurface reservoir. • risk minimization in previously unknown regional settings through the use of analogues in the competency context of analysis – recollection – application – assessment. 					
Module part (b) is supplemented by an offering of a ½ day assessment center exercise. Participation is voluntary.					
(c) Field trip					
Conducted in the border region of the Netherlands, Lower Saxony and North Rhine-Westphalia. The field trip aims at acquiring the practical skills to combine prior knowledge gained in other field trips, prior regional geological knowledge and the economical geological skills of the lectures. As a result, a new/adjusted/different/professionally relevant assessment of the area is achieved and learning for later work life is performed.					
<ul style="list-style-type: none"> • The students learn the practical relevance of the theoretical systemic knowledge acquired in (a) and (b). • The students learn to integrate prior knowledge of fieldwork within the context of subsurface reservoir interpretation. • The students gather, describe, assess and interpret the outcrops based on rock samples taken. • The students integrate for each outcrop the new insights with those from previous outcrops. 					

- They form, then deepen or revise hypothesis and build a regional to subregional interpretation framework.
- They achieve a systemic and economic assessment of existing subsurface reservoirs in the region and their past, current and future utilization.

Digitalization: The relevance and importance of geological modeling of sedimentary basins, subsurface porous network flow modeling and economic assessments are introduced with respect to exemplary software packages. Digital interpretation methods, based on prior manual preparation of data and geological thinking, are taught. The importance of AI and ML (artificial intelligence/machine learning) methods for the consistent processing of large geological data sets, specifically in the context of subsurface reservoirs are discussed. Example data sets and scenarios are used in both economic and geotechnical exercises. Software is not developed in this course.

Content

One lecture date is used for a practical in-field exercise within the vicinity of the University. Interactively the acquired competences are applied, practiced and thereby deepened.

(a) Petroleum geology I

Presentation, questioning and feedback methods in English language

- The petroleum system and its controls.
- Sediments and facies.
- Reservoir petrology, petrophysics.
- Pore fluids.
- Reservoir fluid properties through time.
- Modelling.
- Assessment center (optional).

(b) Petroleum geology II

Building on (a) and taught for deepening regional geological knowledge with respect to regions with economically relevant subsurface reservoirs. Based on published data, gathering, interpreting and assessing subsurface data forms the core of the student learning. The repetitive evaluation of different regions in the context of the subsurface systemic concept learned in petroleum geology I enables the acquisition of skills to consistently apply prior knowledge and build portfolios differentiating between analogous and unique geological systems.

- Repetition: Petroleum system concept and controls.
- Economic and regional geology.

(c) Field trip

- Petroleum System Emsland.
- Bad Bentheim: sediments, stratigraphy, geological overview.
- Outcrops.
- Production units, history, economic importance.
- Composing an integrated geo-economic concept on the petroleum systems of the Emsland, integrated interpretation.

Teaching methods

Lecture, integrated exercises and field trip

Mode of assessment

One final written exam on (a) and (b) lectures combined, report on the field trip

Requirement for the award of credit points

Written exam: Sufficient level result ("Ausreichend"), successful participation in the field trip

Module applicability

not applicable

Weight of the mark for the final score 8,3 % of final M.Sc. score (10 of 120 CP)
Module coordinator and lecturer(s) Dr. Olaf Podlaha
Further information
Literature Textbook recommendations (English) for Lecture Petroleum geology I (self-studies, see timetable)
Detailed/Extensive material for each lecture (copies of all slides, exercise material) Pending presenting students sign-off, material presented by students is shared Detailed documentation for the field trip

Sedimentary geochemistry					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. + 3. Sem.	Annually	2 semester
Courses			Contact hours	Self-study	Group size
a) Isotope geochemistry _ Principles and applications (WS; 1. Sem.) b) Laboratory course isotope geochemistry (WS, two week block course, 3. Sem.)			(a) 4 SWS (b) 4 SWS	(a) 30 h exercises (b) 50 h supervised laboratory work	a) no limitations b) 1 group à max. 10 students
Prerequisites					
Students in the MSc programme Geosciences and related MSc programmes					
Learning outcomes					
After successful completion of the module the students					
<ul style="list-style-type: none"> • understand the principles of isotope geology including basics of decay systems and geochronology as well as stable isotope geochemistry. • know analytical techniques related to traditional and non-traditional stable isotope methods in sedimentary geology. • will be enabled to assess the application of isotope analytics in sedimentary (diagenetic/depositional/ alteration) processes, hydrology, (paleo)environmental and paleo(climate) research. 					
Content					
The lecture provides a basic overview on radiogenic isotope geology (radioactive dating methods) and stable isotope geology (traditional and non-traditional isotope systems) and their application in geological research. Complementary to the lecture the practical laboratory course aims at imparting the knowledge and know-how of selected (available) isotope techniques and methodologies in mass spectrometry.					
(a) Isotope Geochemistry - Principles and Applications					
Introduction to principles of isotopes, natural radioactivity and radioactive dating methods. Common radioactive dating methods (Rb-Sr, Sm-Nd, U-Th-Pb, Pb-Pb) are outlined and application examples are provided. In addition, U-series age determination methods (secular equilibrium and disequilibrium) and their application to sedimentary geology are introduced. The relevance of cosmogenic isotopes for research in applied geology, sedimentary systems and archaeology is taught and examples are given. The emphasis lies on the stable (traditional and so called non-traditional) isotope systems in sedimentary (carbonate) geology and hydrogeology. The isotope systems of H, N, C, O, S, Mg, Ca and Fe are outlined in detail. Their common use in (palaeo)environment and (palaeo)climate research, sedimentology, speleology, palaeontology and hydrogeology are discussed. The lecture is supported by exercises in the respective topics.					
(b) Laboratory course Isotope Geochemistry					
With regard to the actual research topics and instrumental equipment selected isotope analyses are performed. In general, students work supervised on a complete procedure from hand specimen to result. From a polished hand specimen of a carbonate rock genetically different material is sampled by micro-drilling. Elemental composition is determined by ICP-OES and subsequently aliquots of the material are prepared for C/O and Sr isotope analysis and following measured. Aim is the evaluation of the state of preservation of fossil carbonate material, the degree of diagenetic overprint and an assessment of the geological age based on Sr isotope stratigraphy. In addition, the carbon isotope composition of dissolved inorganic carbon (DIC) from water samples are analysed in order to determine the origin (biogenic/abiogenic) of the water sources. Finally, the carbon isotope signature of CO ₂ of respiratory air is measured, which					

provides information on the diet of the respective person. The lab course concludes with the final interpretation of the results and the evaluation of the geological significance of the data.

Teaching methods

Lecture, exercises and practical laboratory work

Mode of assessment

Written exam for (a) and laboratory work report for (b) (written exam (a) 90 minutes)

Requirement for the award of credit points

50 or more points in written exam and laboratory work report, active performance in the laboratory course; (weighing 60% for (a) and 40% for (b))

Module applicability

Please note that both courses of the module are in principle open for students from other disciplines. Due to the limitation of the number of students in the laboratory course, students who are planning an MSc thesis with focus on isotope geochemistry will be given preference. Exceptions are possible depending on the demand for the course. Prerequisite for participation in the laboratory course (b) is the active attendance of the lecture (a).

Weight of the mark for the final score

8.3% of the final score (10 of 120 CP)

Module coordinator and lecturer(s)

Dr. S. Riechelmann

Further information

Will be communicated at the beginning of each class

Structural geology							
Module number	Credits	Workload	Term	Frequency	Duration		
	10 CP	300 h	1. + 2. Sem.	Annually	2 semesters		
Courses		Contact hours		Self-study	Group size		
a) Lectures, seminars, exercises in structural geology		(a) 2 SWS		(a) 70 h	20 students		
b) Special methods in structural geology		(b) 2 SWS		(b) 70 h			
c) Structural geology field camp		(c) 2 SWS		(c) 70 h			
Prerequisites							
Attendance is compulsory in all courses of this module! For students enrolled in the MSc curriculum.							
Learning outcomes							
The purpose of the module is to make the students familiar with advanced concepts in structural geology and tectonics. The theoretical and practical teaching and training offered in the module is highly relevant for industry, in particular for exploitation of mineral and water resources. After achievement of the module the student							
<ul style="list-style-type: none"> • is acquainted with different applications of structural geology, • knows the mechanisms of tectonic fracture and fluid transfer, • to elaborate a coherent geological model from field data.. 							
Content							
The module is organised in three courses, progressing from general aspects in structural geology to specific aspects on tectonic fractures. Finally, a field camp consolidates the knowledge acquired in the classroom.							
a) Lectures, seminars, exercises in structural geology							
The aim of the lecture is to consolidate and deepen fundamental aspects in structural geology. During the two first sessions basic notions are recalled by the instructor. The following sessions consist of oral presentations by the students. The topics to be presented are selected by the participants according to a list of scientific papers proposed by the instructor. In addition, the writing of an essay following the oral presentation is required.							
b) Special methods in structural geology							
This lecture addresses various aspects of tectonic fractures. Firstly, the different types of fractures are introduced in detail with emphasis to their identification and correct interpretation in nature. In the following, fundamentals of fracture mechanics are presented in relation to specific characteristics of natural fractures. The discussion is then expanded to include the impact of fractures on fluid and heat transfer, in particular, and their relevance for operation of geo-energy systems.							
c) Structural geology field camp (8 days)							
The exercise involves the structural/geological mapping in fine detail of selected areas using traditional techniques and tools (i.e. compass, hammer, lens...). As such the field camp aims to strengthen field work experience and sharpen geologist skills. In the course of the writing of the report, the student will learn how to analyse field data and how to extract from them a coherent geological synthesis.							
Teaching methods							
Lectures, exercises and training in the field							
Mode of assessment							
Lectures: written exam (2h), oral presentation (20-30 mins), essay (30 p.)							
Field course: report							
Requirement for the award of credit points							

Positive evaluation of the exams and successful participation in the field course
Module applicability
Weight of the mark for the final score
8,3 % of the final score (10 of 120 CP)
Module coordinator and lecturer(s)
Prof. Dr. Christophe Pascal
Further information
Literature
Davis and Reynolds, 1996. Structural Geology of Rocks and Regions, John Wiley & Sons.
Twiss and Moores, 1992 (2007). Structural Geology, Freeman.

Mineralization in geothermal systems					
Modul number	Credits	Workload	Term	Frequency	Duration
	7 CP	210 h	1. or 3. Sem.		1 Semester
Courses			Contact hours	Self-study	Group size
a) Mineralization in geothermal systems (lecture)			1 SWS	30 h	12 Students
b) Mineralization in geothermal systems (laboratory course)			3 SWS	60 h	
Prerequisites					
Formal: Only for students in the bi-national Master's program „Applied Geothermics“					
Textual: Basic knowledge about thermodynamics, and structure and chemical behavior of minerals.					
Preparation: –					
Learning outcomes					
After the successful completion of the module					
<ul style="list-style-type: none"> • students know the basic parameters and processes that determine the nucleation and growth of seed crystals in different environments, • students are able to read basic phase diagrams and, taking thermoanalytical data into account, derive possible crystallization scenarios, • students are able to carry out simple synthesis/growth tasks independently and to characterize the products structurally and thermoanalytically. 					
Content					
Material systems, state variables, thermodynamic potentials, chemical potentials, phase transformations.					
Phase rule, phase diagrams, one- and two-component systems. Partitioning coefficients, segregation effects, mass transport by diffusion and convection, viscosity, constitutional supercooling.					
Conventional nucleation processes, homogeneous and heterogeneous nucleation, critical nucleus radius, Ostwald-Miers range, Ostwald's step rule.					
Growth processes, accumulation energies, interfacial energies, growth rates, influence of dislocations, morphology of crystals.					
Non-conventional nucleation and growth processes.					
Solution properties of fluids under conditions of the earth's crust.					
Methods for characterizing crystallization products (including differential thermal analysis, X-ray diffraction).					
Teaching methods					
Lecture and laboratory exercises.					
Mode of assessment					
Written exam of 2 h.					
Requirement for the award of credit points					
Passed module exam, processing of all laboratory exercises, successful report on laboratory					

exercises with evaluation of the observations/experimental data obtained.
Module applicability
Weight of the mark for the final score
5,8 % der Gesamtnote (7 von 120 CP).
Module coordinator and lecturer(s)
Prof. Dr. Jürgen Schreuer
Further information
Literature:
K.-Th. Wilke und J. Bohm: Kristallzüchtung, Leipzig 1993, ISBN 978-3326000923.