



Module Handbook

For the study program

Master of Science Geosciences

Institute of Geology, Mineralogy und Geophysics

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1. Introduction to the Handbook (Handbucheinleitung)

This module handbook summarizes the plan of organization and essential contents of the MSc curriculum in Geosciences at the *Institut für Geologie, Mineralogie und Geophysik* of the *Ruhr Universität Bochum*. This handbook outlines the modularization concept of the curriculum and provides information on places where advice is available at the planning stage, as well as during your studies. The core of the handbook consists of description of modules that are currently on offer.

1.1. Advice (Beratung)

Advisor (Fachberater): Before the start of your studies you have to schedule an advisory meeting with a Professor of your choice (your advisor / Fachberater) at the *Institut für Geologie, Mineralogie und Geophysik*. During this meeting, depending on the interests that you want to pursue, a complete study plan including the selection of modules is set up by mutual agreement. The plan is submitted to the examination committee for approval and constitutes a binding agreement. It may be changed once during the first year if desired. Further changes are possible under unavoidable circumstances (e.g. a course on the plan is not offered for some reason). Your advisor (Fachberater) would typically become your MSc thesis advisor as well, but this is not required – it is possible to change your advisor during the course of your studies.

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.

Examination committee (Prüfungsausschuss): Should you have questions or problems that you cannot resolve with your advisor, members of the examination committee or the Chair of the examination committee are the persons to turn to.

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

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.

1.2.1 Curriculum example (Musterstudienpläne)

Curriculum <u>Example Hydrogeology</u>			
Module	CP	SWS	Semester
Groundwater hydraulics	12		
Groundwater hydraulics		4	WS
Hydraulic groundwater modelling		4	WS
Hydrochemistry	12		
Inorganic hydrochemistry		4	WS
Organic hydrochemistry		4	WS
Hydrogeochemical methods I	6		
Isotope hydrogeochemistry (lecture)		2	WS
Isotope hydrogeochemistry (exercise))		2	WS
Hydrogeochemical methods II	9		
Environmental forensics and tracer development		2	WS
Hydrogeochemical modelling		4	WS
Drilling engineering I - Geotechnical and near-surface drilling	5		
Drilling I		5	WS, SS
Exercises in drilling I			WS, SS
Field course in applied geology	7		
Field course in applied geology (Europe, South America)			
Hydrogeological field methods	11		
Tracer techniques in hydrogeology		3	SS
3X 1 day field trips		1	SS
Hydrogeological field camp		3	SS
Applied Hydrogeology	9		
Fissured Rock Hydrogeology		2	SS
Climate Change and Water resources		2	WS, SS
Well Construction		2	WS, SS
Applied geothermal energy	8		
Shallow geothermal energy		2	WS
Deep geothermal energy		3	SS
Siedlungswasserwirtschaft	5		
Siedlungswasserwirtschaft		3	SS
Instrumental environmental analysis	6		
Basics in environmental analysis (lecture)		2	WS
Environmental sampling and analysis (lab)		2	WS
Master thesis	30		
Total	120		

<u>Curriculum</u> <u>Example Geological Engineering</u>	CP	SWS	Semester
Module			
Grundlagen des Geoingenieurwesen	6		
Grundlagen der Ingenieurgeologie		2	WS
Darstellen und Analysieren geotechnischer Informationen		2	WS
Geologie im Geoingenieurwesen	6		
Regionalgeologische Aspekte der Ingenieurgeologie		1	SS
Ingenieurgeologische Kartierung		5 Tage	WS
Geotechnische Herausforderungen des Antropozäns		1	SS
Baugrunderkundung und -dokumentation	5		
Baugrunderkundung und -modellierung		2	SS
Messtechnik		1	SS
Baugrundcharakterisierung Boden	5		
Lockergesteinskartierung und hydrogeologisches Feldpraktikum		5 Tage	SS
bodenmechanisches und hydraulisches Laborpraktikum		2	WS
Baugrundcharakterisierung Fels	5		
Felskartierung		5 Tage	SS
felsmechanisches Laborpraktikum		2	WS
Felsmechanik und Felsbau	6		
Felsmechanik		2	SS
Felsbau		2	SS
geomechanische numerische Simulation		1	SS
Rock Mass Stress Fields	6		
Stress field and rock mass		2	WS
Stress Field Modelling and Simulation		1	WS
Geological Engineering Research Project		1	WS
Geomechanik	10		
Geomechanik und Geotechnik komplexer Systeme		2	WS
geotechnisches Projekt		1	WS
Grundbau- und Bodenmechanik	6		
Grundbau- und Bodenmechanik		6	WS
Geologie des Pleistocene- und Holozäns (ggf.)	5		
Quartärgeologie		2	WS
Georisiken		1	WS
weitere Module (frei wählbar)	30		
Supplementary module (frei wählbar)			
Einführung in die Sprengtechnik (Beispiel)	2		WS
Einführung in den Bau von Schächten (Beispiel)	3		WS
weitere Kurse (frei wählbar)	25		
Master thesis	30		
Total	122		

Curriculum <u>Example Petrology</u>			
Module	CP	SWS	Semester
Analytic methods in rock analysis	5		
Methods of rock analysis		2	SS
Practicals on rock analysis		2	WS
Electron beam microanalysis	6		
Electron beam microanalysis (Lecture)		2	SS
Electron beam microanalysis (Practical exercises)		2	SS
Field course in petrology	6		
Field trip		10 days	WS
Analysis of results and preparation of report		2	WS
Igneous petrology	10		
Petrology of igneous rocks		2	WS
Thin section exercises with igneous rocks		2	WS
Numerical exercises with data from igneous rocks		2	WS
Metamorphic petrology	12		
Petrology of metamorphic rocks		2	SS
Thin section exercises with metamorphic rocks		2	SS
Numerical exerc. with data from metamorphic rocks		2	SS
THERMOCALC course		1	SS
Economic geology II	10		
Metallic mineral deposits		2	WS
Non-metallic mineral deposits		1	WS
Research project on ore deposits		3	SS
Thermodynamics	10		
Principles of elementary thermodynamics		4	SS
Solution phase thermodynamics		2	SS
High temperature geochemistry	10		
High-temperature geochemistry		5	SS
Practical – Application of mass spectrometry to radiogenic and stable isotope systems.		5	SS
Strukturbestimmung	10		
Strukturbestimmung			
Röntgenbeugung			
Supplementary module			
Georisiken	2	1	WS
Lecture, seminar and exercises in structural geology	4		WS
Quartärgeologie	3	2	WS
Spezielle Petrologie der Magamatite und Metamorphite	4	2	WS
Master thesis	30		
Total	122		

Curriculum <u>Example Geophysics</u>			
Module	CP	SWS	Semester
Applied geophysics I	10		
Geophysical inverse problems		3	WS
Seismic and electromagnetic field methods		3	WS
Applied geophysics II	10		
Reservoir geophysics		3	SS
Rock physics		3	SS
Geophysical methods	14		
Field practical			WS
Scientific programming		3	WS
Geophysical seminar		4	WS
Geophysical practical	5		
Geophysical practical			WS, SS
Physic of the solid Earth I	10		
Seismologic data analysis		3	SS
Seismic waves: theory and numerical modelling		3	SS
Physic of the solid Earth II	10		
Continuum mechanics		3	WS
Physic of earth materials		3	WS
Thermodynamics	10		
Principles of elementary thermodynamics		4	SS
Solution phase thermodynamics		2	SS
Earthquake processes	6		
Earthquake seismology and the seismic cycle		4	WS
Supplementary module	15		
Grundlagen der Mechanik und Elektrodynamik	10		SS
Mathematische Methoden der Physik	5		SS
Master thesis	30		
Total	120		

2. *Module descriptions*
(Modulbeschreibungen)

Applied geophysics I							
Module number	Credits 10 CP	Workload 300 h	Term 1. + 3. Sem.	Frequency WS	Duration 3 Semester		
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 Students 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. Students 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, geoelectric 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.	every semester	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):							
1) Introduction to reservoirs (hydrocarbon, geothermal)							
2) Physical properties of reservoir fluids							
3) Hydraulic transport (Kozeny-Carman relation) and storage (linear poro-elasticity I: isostatic stress states)							
4) Theory and practice of pumping tests (diffusion equation, scaling)							
5) Geothermics (add advection to diffusion)							
6) Aspects of waves in real media (wave equation, linear poro-elasticity II: add deviatoric stresses)							
b) Rock physics (small-scale perspective):							
1) Introduction to rocks and minerals							
2) Porosity and interface phenomena							
3) Hydraulic transport in rocks (Darcy's law, permeability models)							
4) Elasticity (stress, strain, Hooke's law, averaging schemes)							
5) Failure of rocks (fracture and friction)							
+ Lab practical: students independently conduct simple experiments to determine basic physical properties of rocks (density, porosity, permeability) and fluids (density, viscosity)							

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 Semester	
Courses		Contact hours	Self-Study	Group size	
a) Field practical		a) 6d field, 4d data analysis	a) 70h	a) 16	
b) Scientific programming		b) 3 SWS	b) 105 h	b) and c) according to demand	
c) Geophysical seminar		c) 4 SWS	c) 60 h		
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 setup 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 class-room 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 5 CP	Workload 150 h	Term 1., 2. or 3.	Frequency every semester	Duration 1 semester		
Courses		Contact hours 20 days	Self-Study	Group size			
Prerequisites:							
Formal: none							
Textual: none							
Preparation:							
Learning outcomes							
After successful completion of the module							
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. • Students 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							
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: good English language skills, 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 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	3 Semester
Courses			Contact hours	Self-Study	Group size
a) Continuum mechanics (WS, alternating with b) b) Physics of earth materials (WS, alternating with a)			a) 3 SWS b) 3 SWS	a) 110 h b) 100 h	acc. to demand
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					
<ol style="list-style-type: none"> 1) Differentiation and integration of scalar and vectorial fields 2) Kinematics (Euler and Lagrange description) 3) Conservation laws in differential and integral form (Navier-Stokes equations) 4) Applications (Specific cases of the Navier-Stokes equations and similarity numbers) 					
b) Physics of Earth materials					
<ol style="list-style-type: none"> 1) Geophysical and geochemical Earth models 2) Elastic constitutive equations for minerals at high temperature and pressure 3) Crystal defects (point defects, dislocations, grain boundaries) 4) Deformation mechanisms at high temperatures (diffusion and dislocation creep) 5) 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					
Passes 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
	8 CP	240 h	2.+3. Sem.	a) every SoSe b)+c) every WiSe	2 Semester
Courses			Contact hours	Self-study	Group size
a) Fissured rock hydrogeology			2 SWS	50 h	40 Students
b) Climate change and water resources			2 SWS	50 h	40 Students
c) Well construction			2 SWS	50 h	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 and predict • - gain in-depth geotechnical and (hydro)geological knowledge of the opportunities and challenges of using and investigating groundwater through well construction, including in unconsolidated rock units. 					
Content					
a) Basics, terms and methods of describing fractured aquifers: occurrence and exploration of bedrock aquifers (magmatic, metamorphic, sedimentary), qualitative and quantitative aspects of water use from fractured aquifers.					
b) Fundamentals and concepts of climate change and methods to study its influence on water management: 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					
c) Basics, concepts and methods of well construction: state of the art in science and technology, challenges and limitations, methods under different geological boundary conditions, global significance and development, approaches for different types of use.					
Teaching methods					
Lectures with accompanying exercises					
Mode of assessment					
Written exam on the contents of the courses a), b) and c); duration 120 minutes at the end of WiSe.					
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) and c)					
Module applicability (in other degree programs)					
Weight of the mark for the final score					

6.66 % of the total grade (8 out of 120 CP)
Module coordinator and lecturer(s)
Prof. Dr. Stefan Wohnlich
Further information
Relevant literature will be presented at the beginning of each session.

Applied geothermal energy							
Module number	Credits 6 CP	Workload 115 h	Term 1. + 2. Sem.	Frequency a) each WiSe b) each SoSe	Duration 2 Semesters		
Courses a) Shallow geothermal energy b) Deep geothermal energy		Contact hours 2 SWS 3 SWS		Self-study 50 h 65 h	Group size 40 students		
Prerequisites							
For students in Master programs							
Learning objectives							
<p>After completion of the module, the participants will</p> <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, <p>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.</p>							
Content							
a) General insight into 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) Fundamentals and methods of deep geothermal energy: Potentials and uses in Germany and internationally, geophysical exploration and characterisation 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 (6 of 120 CP)							
Module coordinator and lecturer(s)							
Prof. Dr. Stefan Wohnlich							
Other information							
Relevant technical literature will be presented at the beginning of each course.							

Groundwater hydraulics							
Module number	Credits 12 CP	Workload 360 h	Term 1.	Frequency Every WiSe	Duration 1 Semesters		
Courses		Contact hours		Self-study	Group size		
a) Groundwater hydraulics		4 SWS		120 h	40 students		
b) Hydraulic groundwater modelling		4 SWS		120 h	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							
a)- Methods for the collection and evaluation of hydraulic parameters (Darcy-tests, pump tests, Slug&Bail tests) <ul style="list-style-type: none"> - 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 b)- Teaching of knowledge and methods for understanding and evaluation of mass transport processes in groundwater <ul style="list-style-type: none"> - 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 '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 WiSe	1 semester		
Courses		Contact hours	Self-study	Group size			
a) Inorganic hydrochemistry		4 SWS	120 h	40 students			
b) Organic hydrochemistry		4 SWS	120 h	40 students			
Prerequisites							
For students in Master programs							
Learning objectives							
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) Fundamentals, concepts and methods of inorganic hydrochemistry: law of mass action, concentration and activity, solubility and saturation, types of hydrochemical reactions, equilibrium and imbalance, sorption, toxicity and regulatory provisions							
b) Fundamentals, concepts and methods of organic hydrochemistry: 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	180h	1. Sem.	Every WiSe	1 Semester			
Courses		Contact hours	Self-study	Group size			
a) Isotope hydrogeochemistry (lecture)		2 SWS	60 h	40 Students			
b) Isotope hydrogeochemistry (exercise)		2 SWS	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. 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 for geothermometer, 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) Basics, terms and methods of isotope hydrogeochemistry: 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) 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 a) and b); duration 60 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 each 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		
9 CP	270 h	3. Sem.	Every WiSe	1 Semester			
Courses		Contact hours	Self-study	Group size			
a) Environmental forensics		2 SWS	60 h	40 Students			
b) Hydrogeochemical modelling		4 SWS	120 h				
Prerequisites							
Registered in M.Sc. programs							
Learning outcomes							
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.							
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.							
Content							
a) Basics, terms and methods of environmental forensics: polluter pays principle and legal basis, hydrochemical proxies and indicators, possibilities of using reactive tracers, international and national case studies							
b) Basics, terms and methods of hydrogeochemical modeling: 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 90 minutes. Evaluation of the exercises 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 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.							

Instrumental environmental analysis							
Module number	Credits	Workload	Term	Frequency	Duration		
	6 CP	180 h	3. Term	WiSe	1 semester		
Courses		Contact hours		Self-study	Number of participants:		
a) Basics in instrumental environmental analysis (Lecture)		2 SWS		60 h	20		
b) Environmental sampling and analysis (Lab course)		2 SWS		60 h			
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 geosystems • 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							
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 							
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 5 CP	Workload 150 h	Term 3. Sem.	Frequency a) jedes WiSe	Duration 1 Semester		
Courses Drilling 1 Exercises in drilling 1		Contact hours 5 SWS		Self-study 75 h	Group size 40 Studierende		
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							
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, artesian conditions while drilling, cementing – Water and monitoring wells, well testing, sampling – Shallow geothermal, borehole heat exchanger systems – Environmental Direct Push sampling, coring, onsite analysis							
Contents							
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. Stefan Wohnlich (Lehrtransfer von Geothermie Zentrum 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	MSc	annual	14 days
Courses			Contact hours	Self-study	Group size
Field Courses in applied geology in various hydrogeological settings (Europe, South America, ...)			14 days	98 h	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 of 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. 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), Assistants in Hydrogeology 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							
Modul number	Credits	Workload	Term	Frequency	Duration		
	11 CP	330 h	2. Sem.	each SoSe	1 Semester		
Courses		Contact hours	Self-study	Group size			
a) Tracer techniques in hydrogeology		3 SWS	90 h	40 students			
b) Hydrogeological field camp		3 SWS	90 h				
c) 3 X 1 day field trips		1 SWS	30 h				
Prerequisites							
For students in Master programs							
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, • - apply the concept of using organic substances as tracers for the investigation of hydraulic compounds in the subsurface, • - develop and design a tracer experiment using fluorescent dyes, • - submit an application to the Environmental Protection Agency as required for a submission, • - actually carry out a tracer experiment and evaluate and interpret the data collected in the process. • - Conduct a wide variety of hydrogeological experiments. • - transfer their knowledge from the lecture hall to real-world problems. 							
Content							
a) Basics, terms and methods of tracer hydrology: 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.							
(b) Performance of hydrogeologic field methods: pumping tests, seepage tests, discharge measurements, sampling and hydrochemical field laboratory, drilling and sediment retrieval, groundwater leveling plan preparation; evaluation and interpretation of collected data.							
(c) 3 one day field trips on the local hydrogeology and related problems							
Teaching methods							
Lectures with accompanying calculation exercises, Field exercises							
Mode of assessment							
Written reports and calculations							
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							
Weight of the mark for the final score							
16 % der Gesamtnote (11 von 120 CP)							
Module coordinator and lecturer(s)							
Prof. Dr. Wohnlich (coordinator), Dr. Rolf Schiffer							
Further information							
Relevant technical literature will be presented at the beginning of each course							

Siedlungswasserwirtschaft					
Modul number	Credits	Workload	Term	Frequency	Duration
5 CP	150 h	2. Sem.	a) jedes SoSe	1 Semester	
Courses a) Siedlungswasserwirtschaft		Contact hours	Self-study	Group size	
3 SWS		90 h	40 Studierende		
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 SoSe.					
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. Stefan Wohnlich (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. MSc Sem.	WiSe	1 Semester		
Courses		Contact hours	Self-study	Group size			
a) Earthquake seismology and the seismic cycle		4 SWS	120 h	30 Students			
Prerequisites							
The module grade will be based. Final reports may be completed in German if desired							
Learning outcomes							
After successful completion of the module, students will be able to							
<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 2 hours/week followed by paper discussion of 2 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 will be evaluated based on participation, and must be completed with a passing grade of 60% in order to submit the final report. Final reports may be completed in German if desired							
Requirements for the award of credit points							
Passing grade for the paper discussion entitles the course participant to submit the Module Exam (Report). Module Report 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
<i>Helpful texts (not required):</i>
Stein, S. and M. Wyssession, <u>Introduction to Seismology, Earthquakes, and Earth Structure</u> , Blackwell Publishing, 2003
Scholz, C. H., <u>The Mechanics of Earthquakes and Faulting</u> , 2 nd Ed., Cambridge University Press, 2002

Earthquakes seminar and data analysis					
Module number	Credits	Workload	Term	Frequency	Duration
	9 CP	270 h	MSc	every Semester	2 Semesters
Courses			Contact hours	Self-study	Group size
a) Induced seismicity seminar			2 SWS	60 h	30 Students
b) Fault transition zones			2 SWS	60 h	30 Students
c) Seismic data and time series Analysis			2 SWS	60 h	18 Students
Prerequisites					
The course module is open to all MSc students with a background in the Earth sciences (BSc degree).					
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 transation 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 for the report due after the completion of 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

Reservoir and fault geomechanics					
Module number	Credits	Workload	Term	Frequency	Duration
	6 CP	180 h	2. Sem.	Every year	1 Semester
Courses		Contact hours	Self-study	Group size	
Hydrogeomechanics		4 SWS	120 h	30 Students	
Prerequisites					
The module is open to all MSc students with a background in the Earth sciences (BSc degree). Prior knowledge of Matlab is helpful, but not required.					
Learning outcomes					
After successful completion of the module, students will be able to:					
<ul style="list-style-type: none"> • explain the sources of stress in the earth's crust • understand and quantify forces, traction, and stress in a continuum • understand and describe the relationship between stress, strain and constitutive relations, and compute stress and strain using tensor algebra • understand and apply the basics of poroelastic stress formulation in a 2D poroelastic model • understand the fundamentals of rock failure, failure in boreholes, and fault formation • understand and describe the measurement of maximum and minimum horizontal stress • understand and calculate the conditions in which borehole failure occurs • understand geophysical measurements made in boreholes, and the measurements of orientation and magnitude of stresses in a borehole, and fundamentals of interpreting borehole logs • describe and understand the formation of fault systems, and how earthquakes can be used to measure regional stress orientations 					
Content					
<p>Hydrogeomechanics: This interdisciplinary course encompasses the fields of rock mechanics, structural geology, seismology and petroleum engineering to provide a background to tackle a range of geomechanical problems associated with fluid injection and/or extraction in wells and rock failure. Topics included in the course are: Forces, traction and stress, stress, strain, and constitutive relations, an introduction to poroelastic theory, applications of poroelastic models, rock failure in the lab and in the field, faults and fluid flow, probing the subsurface through logging, stresses around wells, and determining Sh_{min} and Sh_{max}.</p> <p>In addition to theoretical information presented via lecture material, the practical exercises teach fundamental data analysis via MATLAB, and poroelastic modeling (POEL open source code), and all course materials are transferred via an online interface (Moodle).</p>					
Teaching methods					
Lecture period of 2 hours/week with practical exercises of 2 hours/week. Exercises are mainly completed in digital format (basic programming in Matlab).					
Mode of assessment					
Module grade will be based on the final report in (b) weighted 70% for the written component (with a 6-week working period), with the remaining 30% weight being placed on the oral presentation the last week of the lecture period. Exercises in (a) and (b) must be completed with a passing grade of 60% in order to submit the final report. Final reports in (b) may be written in German, if desired.					

Requirement for the award of credit points

Passing grade for the exercises entitles the course participant to submit the Module Exam (Report). Module Report with a passing grade (written and oral parts will be combined for a total number of points).

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*Helpful texts (not required):*

Zang, A. Stephansson, O., Stress Field of the Earth's Crust, Springer, 2010.

Zoback, M. D., Reservoir Geomechanics, Cambridge, 2010

Middleton, G. V., and Wilcock, P. R. Mechanics in the Earth and Environmental Sciences, Cambridge, 1994

Allmendinger, R. W., Cardozo,N., Fisher, D. M. Structural Geology Algorithms, Vectors and Tensors, Cambridge, 1998

Mapping active faults							
Module number	Credits 6 CP	Workload 180 h	Term 1. Sem.	Frequency SoSe	Duration 1 Semester		
Courses a) Mapping active faults		Contact hours 4 SWS	Self-study 120 h	Group size 15 Students			
Prerequisites							
The module is open to students with a BSc in the Earth sciences. Additional requirements include successful completion of an introductory geological mapping course. Students must also have successfully completed the module “Seismotectonics and Seismic Hazard” offered during the Winter Semester							
Learning outcomes							
During a 5 days' field exercise the students will learn to:							
<ul style="list-style-type: none"> • recognize and map the geomorphic elements which characterize active normal faults (fault scarps); • Measure a coseismic fault scarp in order to define the “slip per event”; • measure a “multiple events” fault scarp in order to define the long term slip rate; • analyze and interpret a fault trench (gridding, logging); • use photogrammetry to reconstruct the 3D geometry of an outcrop; • process the collected data with dedicated software (GIS, stereonet, Agisoft PhotoScan) 							
This course module will use digital mapping tools (GeomapApp), and will have international scientists accompanying students in the field to provide local geological context.							
Content							
Recognizing and mapping the surface evidences of active faulting represent the first step towards a better understanding of the seismic hazard assessment of any region. Therefore, a practical experience in the field is of critical importance for all the geoscientists dealing with the “earthquake problem”. Central Italy is one of the most seismically active regions in Europe. Here thousands of years of earthquakes have created astonishing fault scarps and very peculiar geomorphic features which make this area a perfect laboratory for structural mapping. Topics included in the course are: Mapping and interpretation of geological structures characterized by active tectonics, geological data processing and analysis.							
Teaching methods							
5-days field exercise during the Pfingstwoche preceded by a 2-hours introductory class.							
Mode of assessment							
Course evaluation: The course will be evaluated on the basis of a field map handed in by the student at the conclusion of the field exercise, and a written field report due 4 weeks after the end of the field exercise. Field report (4 week working period). The module grade will be based on the final field report.							
Requirement for the award of credit points							
Module report with a passing 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

Helpful texts (not required):

The Mapping of Geological Structures, Ken McClay, Geological society of London Handbook.

The Geology of Earthquakes, R. S. Yeats, K. Sieh and C. R. Allen, Oxford University Press, 1997.

Tectonic Geomorphology, D. W. Burbank and R. S. Anderson, Wiley-Blackwell, 2nd Ed.

Seismotectonics and seismic hazard							
Module number	Credits	Workload	Term	Frequency	Duration		
6 CP	180 h	2. Sem.	WiSe	1 Semester			
Courses		Contact hours	Self-study	Group size			
a) 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 as well as lecture, and exercises must be completed with a passing grade (60%) to access to the final exam on which the module grade will be based.							
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 understand the seismic potential of any region in the world. Geological data give us a long-term (thousands of 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 2 hours/week with practical exercises of 2 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.

Grundlagen des Geoingenieurwesens					
Module number	Credits	Workload	Semester	Frequency	Dauer
	6 CP	150-180 h	1. Sem.	jährlich	1 Semester
Learning outcomes			Contact hours	Self-study	Group size
a) Grundlagen der Ingenieurgeologie		2 SWS		60 h	
b) Darstellen und Analysieren geotechnischer Informationen		2 SWS		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.</p> <p>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.	jährlich	1 Semester
Courses			Contact hours	Self-study	Group size
a) Stress Field and Rock Mass behaviour		2 SWS		55h	
b) Stress Field Modelling and Simulation		1 SWS		25 h	
c) Geological Engineering Research Project		2SWS		75 h	
Prerequisites					
--/.					
Learning outcomes					
<p>Spannungen in der Erdkruste sind die treibende ‚Kraft‘ vieler Prozesse und eine maßgebliche Größe der Beurteilung der Stabilität geologischer Strukturen wie Trennflächen oder Störungen. Darüber hinaus ist die Kenntnis der wirkenden Spannung bei der Planung von Bauwerken im oberflächennahen und tiefen Untergrund von außerordentlicher Bedeutung. Der englischsprachige Kurs erarbeitet die mechanischen Grundlagen zur Darstellung des Spannungsfeldes in der Erdkruste und diskutiert die Quellen der Spannung. Darauf aufbauend werden Methoden zur Abschätzung und Messung von Spannungen eingeführt. Dies umfasst neben der Modellierung des primären Spannungsfeldes (green und brown field) auch die Ableitung sekundärer Spannungen durch bautechnische Massnahmen.</p> <p>Die Simulation der Alteration der in-situ Spannungen ist in vielen fels- und bergbaulichen Projekten das gängige Vorgehen zur Abschätzung der sekundären Spannungen und der Belastung der geologischen Strukturen sowie Bauwerke. In Ergänzung der Vorlesung Stress Field and Rock Mass behaviour werden unter Verwendung einer Standartsoftware des Felsbaus beispielhafte Modelle autodidaktisch erstellt und die resultierenden Spannungen und deren Verteilung simuliert.</p> <p>Die Regel ist die Zusammenarbeit in Teams; je nach Industrie sind diese Teams international zusammengesetzt. Diesem Umstand trägt der englischsprachige Kurs Rechnung. Im Rahmen einer (zum Teil) englischsprachig durchgeführten Projektarbeit wird die Zusammenarbeit unter Realbedingungen geübt. Am Ende der gemeinschaftlichen Bearbeitung, in dessen Zentrum neben der eigentlichen geteilten Erarbeitung der Datenbasis auch die Koordination der Arbeiten und die Abstimmung steht, steht der Entwurf einer technisch-wissenschaftlichen Publikation, welche bei entsprechender Qualität bei einer Fachzeitschrift eingereicht wird.</p> <p>The students are familiar with rock and rock mass behaviour 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. The students are familiar with the numerical simulation of stress alterations due to geological or constructional features using an commercial software package.</p> <p>After the successful completion of the project the students are able to plan, organise, 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
Further information Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Geologie im Geoingenieurwesen					
Module number	Credits 6 CP	Workload 150-180 h	Semester 1.+ 2. Sem.	Frequency jährlich	Dauer 2 Semester
Learning outcomes					
a) Regionalgeologische Aspekte der Ingenieurgeologie b) Ingenieurgeologische Kartierung c) Geotechnische Herausforderungen des Anthropozäns			Contact hours 1 SWS 0,5 SWS	Self-study 50 h 90 h 25 h	Group size
Prerequisites					
Modul Grundlagen des Geoingenieurwesens					
Learning outcomes					
Die Geomorphologie Deutschlands ist sehr vielfältig. Norddeutschland sowie einige Regionen im Süddeutschen sind stark pleistozän geprägt. Die Eifel, der Oberreihngraben und das Hegau weisen Zeugen der vulkanischen Aktivität auf. Das Rheinische Schiefergebirge und der Harz zeigen eine charakteristische Lithologie und Genese. Der Bereich der schwäbischen und fränkischen Alb sowie das Thüringer Becken weisen eine typische Schichtstufung auf.					
Jede Region der BR Deutschland hat Ihre eigene Kombination aus Lithologie, strukturgeologischer Historie und Morphologie. Die spezifischen Ausbildungen der Geologie bringen daher spezifische geotechnische Herausforderungen und Besonderheiten mit sich. Im Rahmen des Kurses werden die regionalgeologischen Aspekte in Bezug auf Bautechnik, geotechnische Nutzung, Umweltverträglichkeit und Georisiken z.T. anhand von Projektbeispielen herausgearbeitet. Im Rahmen der Diskussion der Projektbeispiele werden darüber hinaus die technischen, ökologischen und ökonomischen Konsequenzen erarbeitet.					
Die Grundlage eines jeden geologischen und auch geotechnischen Modells ist 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.					
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 der Endlagerung 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/kreative 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.					
Nach erfolgreichem Abschluss des Kurses sind die Teilnehmerinnen und Teilnehmer mit den Aspekten, die sich aus den regionalgeologischen Gegebenheiten Deutschlands für geotechnische und bautechnische Fragestellungen ergeben, vertraut. Darüber hinaus wird					

eine Beurteilungsbasis für die Auswirkungen der geotechnischen Massnahmen entwickelt. Nach erfolgreichem Abschluss des Kurses haben die Teilnehmerinnen und Teilnehmer die Erstellung einer geologischen Karte intensiviert und sind mit der Identifikation und kartographischen Darstellung von weiterführenden ingenieurgeologischen Informationen als Baugrund-, Gefahrenhinweis- oder Risikokarte vertraut. 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

Content

großräumige Verteilung der Gesteine in der BRD Deutschland; typische bautechnische Eigenschaften der Gesteine; Aspekte, die die Umweltverträglichkeit beeinflussen; geotechnische Herausforderungen, welche sich aus Geomorphologie und Strukturgeologie ergeben; Überblick über typische Bau- und Sicherungsmaßnahmen; Erstellung einer geologischen Karte, Erstellung einer Baugrundkarte, Erstellung einer Gefahrenhinweis- und Risikokarte; Erstellung eines Diskussionspapiers; Impulsvortrag; Diskussion

Teaching methods

Vorlesung, Kartierung, Seminar

Mode of assessment

Klausur, Bericht, Diskussionspapier

Requirement for the award of credit points

Bestandene Klausur, benoteter Bericht, 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

Further information

Relevante Fachliteratur wird am Beginn der jeweiligen Veranstaltungen vorgestellt.

Felsmechanik und Felsbau					
Module number	Credits	Workload	Term	Frequency	Duration
	6 CP	150-180 h	2. Sem.	jährlich	1 Semester
Courses			Contact hours	Self-study	Group size
a) Felsmechanik		1,5 SWS		45 h	
b) Felsbau		1,5 SWS		45 h	
c) geomechanische numerische Simulation		1 SWS		55 h	
Prerequisites					
Modul 'Rock Mass Stress Fields' empfohlen					
Learning outcomes					
<p>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.</p>					
<p>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.</p>					
<p>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.</p>					
<p>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 Bauwerkserrichtung auf den Baugrund beurteilen.</p>					
Content					
<p>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.</p>					
Teaching methods					
Vorlesung, Übungen, Numeriklabor					

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		
5 CP	125-150 h	2. Sem.	jährlich	1 Semester			
Learning outcomes		Contact hours	Self-study	Group size			
a) Baugrunderkundung und -modellierung b) Messtechnik		2 SWS 1 SWS	45 h 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 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, Numeriklabor							
Mode of assessment							
Modulklausur							
Requirement for the award of credit points							
Übungsaufgaben							
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 Fels					
Module number	Credits	Workload	Semester	Frequency	Dauer
	5 CP	125-150 h	2.+3. Sem.	jährlich	2 Semester
Learning outcomes			Contact hours	Self-study	Group size
a) Felsmechanisches Laborpraktikum b) Felskartierung			2 SWS 5 Tage	40 h 50 h	12 18
Prerequisites					
Modul Grundlagen der Ingenieurgeologie, Modul Baugrunderkundung 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 Trennflächenparametern. 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	Dauer		
	5 CP	125-150 h	2.+3. Sem.	jährlich	2 Semester		
Learning outcomes		Contact hours	Self-study	Group size			
a) Bodenmechanisches und -hydraulisches Laborpraktikum b) Lockergesteinskartierung und hydrogeologisches Feldpraktikum		2 SWS 5 Tage	40 h 50 h	12 18			
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
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.	jährlich	1 Semester		
Learning outcomes		Contact hours	Self-study	Group size			
a) Geomechanik und Geotechnik komplexer Systeme b) geotechnisches Projekt		2 SWS	75 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 Gesamtpäsentation 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 tiefern geothermischen Reservoiren 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 Anthropozäns							
Module number	Credits	Workload	Semester	Frequency	Dauer		
	5 CP	125-150 h	1. Sem.	Jährlich	1 Semester		
Courses		Contact hours	Self-study	Group size			
a) Quartärgeologie b) Georisiken		2 SWS 1 SWS	50 h 20 h				
Prerequisites							
Für Studierende im Master -Programm Geowissenschaften, die nicht den B.Sc. Abschluss Geowissenschaften an der Ruhr-Universität Bochum erworben haben							
Learning outcomes							
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 beeinflusst. 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.							
Die geologischen und geodynamischen Prozesse verändern kontinuierlich unsere Umwelt. Diese Veränderungen geschehen zum Teil ohne menschliches Zutun, aber auch anthropogen. Im Rahmen des Kurses werden die wesentlichen Prozesse, welche geogene Risiken steuern, repetiert. Weiterhin werden die natürlich entstehenden geogenen Herausforderungen und Risiken vorgestellt und diskutiert. Darüber hinaus werden die anthropogenen und somit antropozän induzierten Herausforderungen besprochen.							
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. Nach erfolgreichem Abschluss des Kurses kennen und erkennen die Teilnehmerinnen und Teilnehmer die wichtigsten Georisiken und sind mit den wesentlichen Prozessen vertraut.							
Content							
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; Einflussfaktoren geologischer Prozesse; Verwitterung; Erdbeben; Verwerfungen; Vulkanismus; Bodensenkungen; Veränderung des Grundwasserstandes; Analyse der Umweltauswirkungen; Instabilität von Hängen und Böschungen; Georisiko Mensch							
Teaching methods							
Vorlesung mit integrierten Übungen							
Mode of assessment							
Modulkprüfung							
Requirement for the award of credit points							
Ausreichende Bewertung der Klausur und 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.

Kristallchemie					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. + 3. Sem.		2 Semester
Courses			Contact hours	Self-study	Group sizee
a) Kristallchemie (Vorlesung und Übung)			3 SWS	105 h	12 Studierende
b) Realstrukturbau und Phasenumwandlungen (Vorlesung und Übung)			3 SWS	105 h	
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. 					
Content					
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 H ₂ O.					
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.					
Ferroische Phasenumwandlungen, Domänenbildung.					
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)
Dr. Bernd Marler
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.

Synthese und Kristallisation					
Modul number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. + 3. Sem.		2 Semester
Courses			Contact hours	Self-study	Group sizee
a) Kristallisation			2 SWS	60 h	12 Studierende
b) Synthese und Kristallzüchtung			4 SWS	150 h	
Prerequisites					
Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.					
Textual: Kenntnisse über Aufbau und Symmetrieeigenschaften von Kristallen werden vorausgesetzt, Kenntnisse über Röntgenbeugung sind wünschenswert.					
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 Züchtungsstrategien für Einkristalle 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					
Stoffsysteme, Zustandsgrößen, thermodynamische Potentiale, chemische Potentiale, Phasenumwandlungen.					
Phasenregel, Phasendiagramme, Ein- und Zweistoffsysteme.					
Verteilungskoeffizienten, Segregationseffekte, Stofftransport durch Diffusion und Konvektion, Viskosität, konstitutionelle Unterkühlung.					
Nukleationsprozesse, homogene und heterogene Keimbildung, kritischer Keimradius, Ostwald-Miers-Bereich, Ostwaldsche Stufenregel.					
Wachstumsprozesse, Anlagerungsenergien, Grenzflächenenergien, Flächenkeime, Wachstumsgeschwindigkeiten, Einfluss von Versetzungen, Morphologie von Kristallen.					
Synthese von Gläsern, Pulvern und Keramiken.					
Experimentelle und technische Verfahren zur Einkristallzüchtung aus Gasphasen, Lösungen und Schmelzen.					
Verfahren zur Charakterisierung von Synthese- und Kristallisationsprodukten (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
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.		2 Semester
Courses			Contact hours	Self-study	Group size
a) Kristallphysik			3 SWS	50 h	12 Studierende
b) Physikalische Charakterisierung			4 SWS	145 h	
Prerequisites					
Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.					
Textual: Kenntnisse über Aufbau und Symmetrieeigenschaften von Kristallen werden vorausgesetzt.					
Preparation: –					
Learning outcomes					
Nach dem erfolgreichen Abschluss des Moduls					
<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					
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 10 CP	Workload 300 h	Term 2. + 3. Sem.	Frequency a)+c) SS b)+d) WS	Duration 2 Semester		
Courses		Contact hours		Self-study	Group size		
a) Festkörperspektroskopie I: NMR Spek.		2 SWS		12 h	12 Studierende		
b) Festkörperspektroskopie II: Allg. Spek.		2 SWS		12 h			
c) Laborübungen zu FK I		2 SWS		80 h			
d) Laborübungen zu FK II		2 SWS		80 h			
Prerequisites							
Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.							
Textual: Mathematische und physikalische Kenntnisse zur Analysis und Vektoralgebra, sowie Elektrodynamik und Mechanik werden vorausgesetzt.							
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							

- 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 Oszillatoren
- 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, 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

Further information

Strukturbestimmung					
Modul number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	2. + 3. Sem.		2 Semester
Courses			Contact hours	Self-study	Group size
a) Strukturbestimmung (Vorlesung)			3 SWS	75 h	12 Studierende
b) Röntgenbeugung (Übung)			4 SWS	120 h	
Prerequisites					
Formal: Für Studierende in natur- und ingenieurwissenschaftlichen Masterprogrammen.					
Textual: Kenntnisse über Aufbau und Symmetrieeigenschaften von Kristallen werden vorausgesetzt, Kenntnisse in der Kristallchemie und der Kristallphysik sind wünschenswert.					
Preparation: –					
Learning outcomes					
Nach dem erfolgreichen Abschluss des Moduls					
<ul style="list-style-type: none"> • kennen Studierende die grundlegenden Prinzipien der Symmetrielehre, der Röntgenbeugung und verschiedener Strukturbestimmungsverfahren, • kennen Studierende typische Techniken und Abläufe der Strukturanalyse und können erforderliche Korrekturfaktoren anwenden. • sind Studierende in der Lage, für ein gegebenes Problem eine passende Vorgehensweise auszuwählen und beherrschen in Grundzügen die erforderlichen Computerprogramme. • sind Studierende in der Lage, auf der Basis eines gegebenen Datensatzes eine Kristallstrukturbestimmung selbstständig durchzuführen und die Qualität des Ergebnisses zu beurteilen. 					
Content					
Kristallographische Grundbegriffe, Kristallsysteme, Kristallklassen, Raumgruppen, Bravais-Gitter, translationsbehaftete Symmetrieelemente.					
Das reziproke Gitter, Röntgenbeugung, die Braggsche Gleichung, die Ewald-Konstruktion Beugung an Netzebenenscharen.					
Erzeugung von Röntgenstrahlung, charakteristische Strahlung, Absorption, Berechnung von Absorptionskoeffizienten.					
Wechselwirkung von Röntgenstrahlung mit Materie, der Atomformfaktor.					
Der Strukturfaktor, Phasenwinkel.					
Auslöschungsgesetze, Zusammenhang von Reflexintensität und Strukturfaktor, Korrekturfaktoren					
Polarisationsfaktor, Lorentzfaktor, Absorptionsfaktor, Skalenfaktor, Temperaturfaktor, Extinktionsfaktor, Häufigkeitsfaktor, Polarisationsfaktor des Monochromators					
Die Fouriertransformation, Differenz-Fourier-Synthese					
Strukturbestimmungsverfahren, die Schweratommethode, Direkte Methoden, Methode des isomorphen Ersatzes, die Patterson-Methode, Anomale Dispersion					
Zwillinge					
Strukturverfeinerung, Restraints und Constraints, Qualitätsfaktoren					
Darstellung von Kristallstrukturen.					

Teaching methods
Vorlesung, Rechenübungen und praktische Laborübungen unter Verwendung von Röntgendiffraktometern.
Mode of assessment
Schriftliche Modulklausur (Modulklausur) von 2 h.
Requirement for the award of credit points
Bestandene Modulklausur, Durchführung aller Laborübungen, erfolgreiche Berichte zu Rechenübungen.
Module applicability
Weight of the mark for the final score
8,3 % der Gesamtnote (10 von 120 CP).
Module coordinator and lecturer(s)
Dr. Bernd Marler
Further information
Literatur: Kleber, Bautsch, Bohm: Einführung in die Kristallographie, Verlag Technik T. Hahn (ed.): Intern. Tables for Crystallography, Vol. A, D. Reidel Publ. Company C. Giacovazzo (ed.): Fundamentals of Crystallography, Int. Union of Crystallography Monographs, Band 15, Oxford Science Publications

Analytical methods in rock analysis							
Module number	Credits	Workload	Term	Frequency	Duration		
5 CP		150 h	2. + 3. Sem.	Each semester	2 semester		
Courses		Contact hours		Self-study	Number of participants		
a) Methods of rock analysis		2 SWS		30 h			
b) Practicals on rock analysis		2 SWS		60 h	10		
Prerequisites							
Learning outcomes							
After completion of the module the students							
• 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							
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 (LAB-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 report including the theory behind the operation of the devices, a brief description of the practical experiment and presentation of the results with an estimation of the errors. A discussion of the results.							
Prerequisites for earning the credit points							
Attendance in the practicals and a passed graded report.							
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 press							

Electron beam microanalysis							
Module number	Credits	Workload	Term	Frequency	Duration		
6 CP	180 h		2. Sem.	Annual	1 semester		
Courses		Contact hours	Self-study	Number of participants :			
a) Lecture: Electron beam microanalysis		2 SWS	60 hours				
b) Practical exercises on electron beam microanalysis (SEM, CL, EMPA)		2 SWS	60 hours				
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							
a) Lecture							
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).							
b) Practical exercises							
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).							
Conceiving a quantitative analytical program. Determination of peak and background positions, choice of spectrometers, standard materials, counting times and beam parameters (EMPA).							
Evaluation of the analyses through the calculation of mineral formulae and estimate of errors.							
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							
Passing grade in the exam. Active participation in the practical demonstrated through a detailed record of experiments in the lab book.							

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. 2 nd ed., Springer-Verlag.
Hughes & Hase (2010): Measurements and their uncertainties. 1 st ed., Oxford University Press
Goldstein et al. (2018): Scanning electron microscopy and X-ray microanalysis. 4 th ed., Plenum Press.
Reed (2005): Electron microprobe analysis and scanning electron microscopy in Geology, 2 nd ed., Cambridge University Press.

Field course in petrology							
Module number	Credits	Workload	Term	Frequency	Duration		
6 CP	180 h	3. Sem.	Each Winter semester	10 days			
Courses		Contact hours	Self-study	Number of participants :			
a) Field trip b) Analysis of results and preparation of report		a) 10 days b) 2 SWS	70 hours	10			
Prerequisites							
Attendance of a Master level course in either Igneous petrology or Metamorphic petrology.							
Learning outcomes							
Students learn how to integrate field observations with petrological concepts to work out the evolutionary history of an area.							
Content							
A ca. 10-day field trip (exact duration depending on locality; variable each year) to make petrological observations and integrate these with relevant field relations, structural observations and background geology of the area.							
Synthesis of these results with studies on thin sections and chemical data from the rocks to develop an evolutionary model of the area.							
Types of courses							
a) Field trip and b) Discussion sections.							
Types of examinations							
A report							
Prerequisites for earning the credit points							
Participation in the field trip as well as in preparatory and follow up discussions. Passed report.							
Module applicability							
Percentage of the grade for the overall examination							
5 %							
Head of the module							
Prof. Dr. Sumit Chakraborty							
Literature							
Variable depending on field area.							

Igneous petrology					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. Sem.	Annual	1 semester
Courses			Contact hours	Self-study	Number of participants :
a) Petrology of igneous rocks			2 SWS	70 hours	
b) Thin section exercises with igneous rocks			2 SWS	60 hours	
c) Numerical exercises with data from igneous rocks			2 SWS	80 hours	15
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					
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					
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					
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 10 CP	Workload 300 h	Term 3. Sem.	Frequency Each Winter semester	Duration 1 semester		
Courses		Contact hours		Self-study	Number of participants :		
a) Principles of chemical kinetics (3 CP)		2 SWS		60 h			
b) Diffusion chronometry (4 CP)		2 SWS		90 h			
c) Kinetic modelling (3 CP)		2 SWS		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							
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							
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							
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.	Annual	1 semester
Courses			Contact hours	Self-study	Number of participants:
a) Petrology of metamorphic rocks			2 SWS	70 hours	
b) Thin section exercises with metamorphic rocks			2 SWS	60 hours	
c) Numerical exercises with data from metamorphic rocks			2 SWS	80 hours	
d) THERMOCALC course			1 SWS	60 hours	
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					
Introduction to the basic questions in petrological research; how metamorphic rocks can be used to answer geodynamic questions. Crystal chemical basis (coordination polyhedral, 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					
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					
Calculation of mineral formulae from chemical analyses. Representation of mineral compositions and phase relations. Schreinemakers Analysis. Application of Clausius-					

<p>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.</p> <p>d) THERMOCALC course</p> <p>Advanced pseudosection modelling course for more complex model systems involving solid solutions, based on case studies in metabasic rocks.</p>
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)
Dr. Silvia Volante
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		
Courses		Contact hours		Self-study	Number of participants :		
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							
a) Principles of elementary thermodynamics							
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.							
b) Solution phase thermodynamics							
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. (introduce 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 10 CP	Workload 300 hours	Term 3. + 4. Term	Frequency Annually	Duration 2 Semesters
Courses			Contact hours	Self-study	Group size
a) Lecture + Paper seminar - Petrology of the deep Earth (WiSe) b) Lab course +Lecture – Experimental Petrology: The Earth in the laboratory (SoSe)			3 SWS 5 SWS	80 hours paper reading and literature research 120 hours of protocols and literature study	No limitations in course a) 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 und 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					
Course a) - Petrology of the deep Earth					
<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. 					
Course b) - Experimental Petrology: The Earth in the laboratory					
<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 points 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 10 CP	Workload 300 hours	Term 2. +4. Term	Frequency Annually	Duration I Semester		
Courses		Contact hours 3 SWS	Self-study 105 hours case studies and exercises 105 hours of exercises and protocols	Group size No limitations in either course.			
a) High-temperature geochemistry – application of radiogenic and stable isotopes to high-temperature geological systems and ore deposits (SoSe) b) Practical – Application of mass spectrometry to radiogenic and stable isotope systems. Data reduction and treatment. (SoSe)		3 SWS					
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							
<p>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.</p>							
<p>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.</p>							
<p>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.</p>							

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 WiSe 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.	Annual	10 days		
Courses		Contact hours	Self-study	Group size: 14 students			
a) Pre-field course seminar		1 SWS	140 hours				
b) Field course		~10 days	70 hours				
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, ...). The field course is preceded by a seminar. The aim of this field course is to train the student's 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), Dr. Silvia Volante							
Other information							
Relevant literature will be presented at the beginning of each course.							

Economic geology II					
Modul-Nr.	Credits 10 CP	Workload 300 h	Term 1. + 2. Sem.	Frequency WS, SS	Duration 2 Semester
Courses			Contact hours	Self-study	Group size: 20 students
a) Metallic mineral deposits			70 hours		
b) Non-metallic mineral deposits		2 SWS	30 hours		
c) Research project on ore deposits		1 SWS 3 SWS	110 hours		
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					
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-porphyries, ore deposits in mid-ocean ridges and ophiolites. Hydrothermal ore-forming systems related to metamorphic processes; ore deposits in supergene and sedimentary settings.					
Non-metallic mineral deposits: Introduction into the use and properties of industrial minerals, earths and rocks, salt and gemstones (diamond only).					
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	2nd+ 3rd sem.	Every year	1 semester		
Courses		Contact hours	Self-study	Group size:			
a) Methods of LA-ICPMS		2 SWS	30 hours	10 students			
b) Practical course in LA-ICPMS		2 SWS	60 hours				
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

Multi-disciplinary approaches to investigate poly-deformed terrains							
Module-No.	Credits 6 CP	Workload 180 h	Term 3rd semester	Frequency annual	Duration 1 semester		
Courses		Contact hours 2 SWS		Self-study 60 hours	Group size: 10 students		
a) Petrological and structural analysis		2 SWS		60 hours			
b) Petrochronology and phase equilibria modelling							
Prerequisites							
Student should have completed the modules of Metamorphic (semester 2) and Igneous (semester 1) petrology. The modules of Structural geology and High-temperature geochemistry are recommended.							
Learning outcomes							
After successful completion of this module, students will be able to:							
<ul style="list-style-type: none"> • Identify in papers relevant information to the topics studied. • Understand key features of sampling strategies in poly-deformed terrains. • Understand the relationships between mineral assemblages and fabrics. • Combine geochronological and geochemical information of accessory minerals (petrochronology) with metamorphic fabrics. • Have an in-depth understanding of thermodynamic modelling. • Integrate multi-disciplinary data to reconstruct P-T-d-t paths of poly-deformed and metamorphosed terrains. 							
Content:							
<p>a) Petrological and structural analysis</p> <p>During this first course the students will learn how to handle, process, and interpret field structural data, microstructural analysis and mineral-chemical data of the major mineral phases. Combined, these data allow to identify superimposed fabrics and their defining mineral assemblages. For the topics presented in this course, basic knowledge in electron beam microanalysis (semester 2) is an advantage.</p>							
<p>b) Petrochronology and phase equilibria modelling</p> <p>This course builds on to the first one. It will cover the fundamental aspects of petrochronology and its application to investigate poly-deformed terrains, with particular focus on dating mineral phases such as monazite, garnet and zircon. Petrochronology integrates geochronological and geochemical information of accessory minerals to constrain the timing and the conditions at which an accessory phase formed. In combination with structural and petrochronological data, phase equilibria modelling is utilised to reconstruct P-T-d-t paths for the investigated terrain and associate them with distinct tectonic environments.</p>							
Types of courses							
Lectures and practicals. The latter will be a project work in small teams (2 persons)							
Types of examinations							
Write a communications paper (c. 4 pages) that combines the contents of courses a) and b); prepare a short oral presentation (10') of the written paper.							
Requirements for the award of credit points							
Passing grade for the written examination (short paper) and the oral presentation							
Module applicability							
Weight of the mark for the final score 5 % (6/120 CP)							

Module coordinator and lecturer(s)

Dr. Silvia Volante

Other information

Helpful texts (not required)

Structural Geology, Haakon Fossen, Cambridge University Press, 2013;

Microtectonics, Cees W. Passchier & R.A.J. Trouw, SpringerLink2005;

Introduction to Rock-Forming Minerals, W.A. Deer, R.A. Howie, J. Zussman, Mineralogical Society of Great Britain and Ireland, 2013;

IsoplotR: <https://cran.r-project.org/web/packages/IsoplotR/IsoplotR.pdf>

<https://www.ucl.ac.uk/~ucfbpve/isoplotr/home/index.html>

Petrochronology, Matthew J. Kohn; Martin Engi; Pierre Lanari, Reviews in Mineralogy and Geochemistry August 01, 2017, Vol.83, iv.

doi:<https://doi.org/10.2138/rmg.2017.83.0>

Additional relevant literature will be provided during the course.

Economic geology I					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1 + 2.	Starts each Winter term	2 terms
Courses			Contact hours	Self-Study	Group size
(a) Petroleum geology I (b) Petroleum geology II (c) Field trip (Geländeübung)			2 SWS 2 SWS 1 D	75 hrs 120 hrs 35 hrs	12-20 Students
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).					
<p>Module part (a): 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:</p> <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. 					
<p>Module part (b): The students gain/learn:</p> <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.					
<p>Module part (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.</p> <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 					

<p>taken.</p> <ul style="list-style-type: none">• 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.
<p>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.</p>
<p>Content</p> <p>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.</p> <p>Module part (a), lecture in petroleum geology I:</p> <p>Presentation, questioning and feedback methods in English language</p> <ul style="list-style-type: none">- The petroleum system and its controls- Sediments and facies- Reservoir petrology, petrophysics- Pore fluids- Reservoir fluid properties through time- Modelling- Assessment center (optional) <p>Petroleum geology II:</p> <p>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.</p> <ul style="list-style-type: none">- Repetition: Petroleum system concept and controls- Economic and regional geology <p>Field trip:</p> <ul style="list-style-type: none">- 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
<p>Teaching methods</p> <p>Lecture, integrated exercises and field trip</p>
<p>Mode of assessment</p> <p>One final written exam on (a) and (b) lectures combined, report on the field trip</p>
<p>Requirement for the award of credit points</p>

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

Advanced sedimentology							
Module number	Credits	Workload	Term	Frequency	Duration		
	10 CP	300 h	1 + 2 Sem.	Annually (except Biomineraliza- tion taught every second year)	2 Semesters		
Courses		Contact hours	Self-study	Group size			
a) Sedimentary systems I (WiSe)		3 SWS	45 h				
b) Sedimentary systems II (SoSe)		4 SWS	60 h				
c) Biomineralization (WiSe)		3 SWS	45 h				
Prerequisites							
Learning outcomes							
Students that have successfully completed the module will understand:							
<ul style="list-style-type: none"> • sediments and sedimentary rocks from a broad and holistic approach to their origin and their depositional environments • how and why sediments and sedimentary rocks have differential properties depending on where they are deposited and how their diagenetic pathways proceeded • how sea level change, sediment transport and deposition and the interaction of life and physico-chemical processes shapes large-scale sediment bodies that have very significant fundamental and applied value • how biology and chemistry interact to form minerals that are in part indistinguishable from abiogenic minerals. 							
Content							
<p>Students will be given a broad overview on recent (fundamental and applied) research in sedimentology with focus on carbonates. Sedimentary Systems I is a general introduction to sedimentary depositional environments and environmental and biological factors that shape these environments. Sedimentary Systems II makes use of these basics and places sedimentology in the context of sequence stratigraphy. The course biomineralization is the most advanced course and discusses and documents the manner by which organisms secrete or induce minerals. Courses Sedimentary Systems I and II can be chosen as individual subjects and added to the optional module.</p> <p>Sedimentary Systems I: Following a general introduction, we discuss factors controlling carbonate (mainly marine) production and deposition. Next topic is an overview on carbonate factories (T, C, and M factory). We then discuss reefal facies through time commencing with microbial reefs in the Proterozoic and ending with modern scleractinian coral reefs. This is followed by classes on carbonate platforms, ramps, atolls and guyots as well as carbonate mounds. We conclude this part by an excursion into the evaporitic systems. The class continuously moves from fundamental to applied aspects and this is the type of teaching that is relevant for MSc and PhD students but also for applied scientists concerned with hydrocarbon reservoirs, geothermal energy and engineering perspectives.</p> <p>Sedimentary Systems II: Deals with the controls on sedimentary systems using carbonates, and to some degree evaporites, as main system of interest. We discuss topics such as the function of water depth and hydrodynamic level on sedimentary facies. The main focus is on sequences, parasequences and also to some degree of seismic stratigraphy. The course combines theoretical lectures and practical exercises. Note, the basic concepts of sequence stratigraphy come from the industry and particularly the aim to understand seismic lines and carbonate bodies in their four dimensions.</p>							

Biomineralization: This class has clear fundamental values and is relevant for those either aiming for an academic career or for students interested in material sciences. This implies that for instance students with focus on crystallography could be interested. We discuss the concept of life forming minerals with a broad range of topics including the early, primitive minerals induced by microbes to the extremely sophisticated organo-mineralic composite materials formed by mammals or some planktonic life forms.

Teaching methods

Teaching and practical aspects, presentation and exercises

Requirement for the award of credit points

Written examination (90') combining the material taught in Sedimentary Systems I and II

Oral presentation (15', 12 ppt slides) in class biomineralization with passed/not passed but no exam

Criteria to obtain credit points

50 or more points in written examination, active performance in the biomineralization class

Module applicability

Please note, the module open for students from other disciplines but only after confirmation with the teacher

Weight of the mark for the final score

10 % of total assessment (10 out of 120 CP)

Module coordinator and lecturer(s) Prof. Dr. A. Immenhauser

Additional Information and literature

Will be communicated at the beginning of each class

Sedimentary geochemistry							
Module number	Credits 10 CP	Workload 300 h	Term 1. + 3.	Frequency Annually	Duration 1 Semester		
Courses		Contact hours		Self-study	Group size		
a) Isotope geochemistry Principles and applications (WiSe 1. Term)		4 SWS		30h exercises	For a) and c) No limitations		
b) Laboratory course isotope geochemistry (WiSe 3. Term) alternatively		4 SWS		50h supervised laboratory work	b) 1 group à max. 6 students		
c) Basics of stable isotope geochemistry (WiSe 3. Term)		4 SWS		40h case studies and exercises			
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.							
The course Basics of stable isotope geochemistry encompasses a theoretical overview of analytical methods and the application of selected stable isotope systems in Earth sciences 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 and Ca are outlined in detail. Their common use in (palaeo)environment and (palaeo)climate research, sedimentology, speleology, palaeontology and hydrogeology are discussed.							
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, dissolved inorganic carbon (DIC) from water samples are analysed in order to determine the origin (biogenic/abiogenic) of the water sources. Depending on the availability of instruments O and H isotopes of water are analysed to determine the origin of the water samples. The lab course concludes with the final interpretation of the results and the evaluation of the geological significance of the data.

Basics of Stable Isotope Geochemistry:

This course introduces isotope geology and basic principles of isotope geochemistry. Selected stable isotope systems, relevant in geology, palaeontology, hydrology, archaeology etc. are then discussed in detail and examples are presented to highlight the fidelity of isotope geochemistry across disciplines. Given the importance of water in geology, specific emphasis is placed on stable oxygen and hydrogen isotopes in the water cycle and in carbonate geochemistry. The isotope systems of H, C, O and Sr are outlined in detail because of their importance for geology, geothermometry, (palaeo)climate research, palaeontology and hydrogeology.

Teaching methods

Lecture, exercises and practical laboratory work

Mode of assessment

Written exam for (a) and (c) and laboratory work report for (b) (written exam (a) 90 minutes, written exam (c) 30 minutes).

Requirement for the award of credit points

50 or more points in written exam(s) and laboratory work report, active performance in the laboratory course; (weighing 80% for (a) and 20% for (b) / (c))

Module applicability

Please note, Basics of Stable Isotope Geochemistry and Isotope Geochemistry - Principles and Applications are open for students from other disciplines. Due to the limitation of the number of students, the laboratory course is dedicated to students with a confirmed MSc. thesis with isotope geochemistry as a main topic.

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. Riehelmann

Further information

Will be communicated at the beginning of each class

Sedimentäre Geologie im Gelände					
Modul number	Credits	Workload	Term	Frequency	Duration
	8 CP	240 h	MSc	Jährlich	10 Tage
Courses			Contact hours	Self-study	Group size
Geländeübungen in wechselnden Gebieten (Dolomiten, Sibirien etc.).			10 Tage	160 h	Abhängig vom Ziel der Geländeübung zwischen 12 und 20 Studierende
Prerequisites					
Für Studierende im Masters Programm Geowissenschaften mit Fokus in Sedimentologie, Mineralogie-Petrologie und Kristallographie					
Learning outcomes					
Die Learning outcomes richten sich im Detail nach dem Ziel der Geländeübung. So vereinen wir Geländegeologie, Erdgeschichte, Sedimentologie, Stratigraphie, Vulkanologie, Petrologie und Kristallographie in der Geländeübung „Dolomiten“. In der Geländeübung „Sibirien“ vereinen wir Quartärgeologie, Geomorphologie, Glaziologie, Rohstoffe und die Interaktion von Mensch und Geologie. Grundsätzlich lässt sich sagen, dass wir anstreben, dass die Studierenden die in der Vorlesung und den Übungen erworbenen Fertigkeiten und Fähigkeiten im Gelände einsetzen. Dabei brechen wir konstant mit traditionellen Fächern wie Sedimentologie und Petrologie, sondern kombinieren immer wieder Elemente aus diesen Disziplinen. Die Studierendenden üben sich im Anfertigen von Skizzen im Gelände und beschreiben ihre Beobachtungen in kurzen Bereichen.					
Nach dem erfolgreichen Abschluss des Moduls					
Haben die Studierenden vertiefte Einblicke in die Geologie eines erstklassigen Feldgebietes mit hoher Relevanz für die Geowissenschaften allgemein.					
Verstehen die Studierenden, dass die traditionellen untrennten Fächer wie Sedimentologie, Strukturgeologie oder Petrologie in Wirklichkeit nur Teile eines Ganzen sind.					
Können Studierende Geländebeobachtungen in prägnanten Skizzen und kurzen und präzisen Bereichen wiedergeben.					
Internationalisierung: Geländekurse finden weltweit statt.					
Content					
Abhängig von Gebiet des Geländekurses das besucht wird.					
Teaching methods					
Seminar im Vorfeld des Geländekurses, Lehrgespräche im Gelände, Skizzieren und selbstständiges Arbeiten.					
Mode of assessment					
Die Modulnote setzt sich zusammen aus Bewertung Vortrag und Bericht Vorseminar, abgegebenen Skizzen und Berichten, sowie aktiver Teilnahme an den Geländeübungen.					
Das Vorseminar besteht aus Vorträgen zu ausgewählten Themen. Pro Teilnehmer muss ein Vortrag von 10-15' Dauer gehalten werden. Dazu ist eine Zusammenfassung zum selben Thema von 1-2 Seiten Länge bis zu einer definierten Frist einzureichen. Im Zuge der Geländeübung werden je nach Witterung 4-5 Skizzen an ausgewählten Aufschlüssen angefertigt. Die Skizzen werden als Rohskizze im Gelände erstellt und abends ausgearbeitet. Alle Reinskizzen müssen vor Ende der Geländeübung beim					

Dozenten eingereicht werden. Zum erfolgreichen Abschluss des Moduls wird eine aktive und interessierte Teilnahme der Studierenden bei den Geländeübungen erwartet. Medizinische Gründe (kleine Verletzungen) können als Begründung für ein Fernbleiben an einzelnen Exkursionstagen gewertet werden. Falls Studierende an 33% oder mehr aller Geländetage nicht teilnehmen, kann das Modul nur in sehr gut begründeten Ausnahmefällen angerechnet werden.

Requirement for the award of credit points

Ausreichende Bewertung der praktischen Beiträge (Seminar, Skizzen, Berichte) und hochaktive Teilnahme an der Geländeübung

Module applicability

Das Modul ist für Studierende der Geowissenschaften mit Fokus Sedimentologie, Mineralogie-Petrologie und Kristallographie offen. In Ausnahmefällen können nach Rücksprache mit dem Dozenten einzelne Studierende aus deren Bereichen teilnehmen.

Weight of the mark for the final score

9,6 % der Gesamtnote (8 von 120 CP).

Module coordinator and lecturer(s)

Prof. Dr. A. Immenhauser (Modulbeauftragter), Assistenten Sediment- und Isotopengeologie in Zusammenarbeit mit Prof. Dr. J. Schreuer (Kristallographie).

Further information

Suchen Sie den Kontakt zum Hauptdozenten falls Fragen auftreten.

Literatur

Sedimentologie: Ausführliches Beiheft in Moodle, Beiheft und individuelle Literaturempfehlungen zur Vorlesung und Geländeübung

Strukturgeologie: Fossen, 2010. Structural Geology, Cambridge University Press; Reuther, 2012. Grundlagen der Tektonik, Springer Spektrum;

<http://www.files.ethz.ch/structuralgeology/JPB/vorlesungen.htm>

Structural geology					
Module number	Credits	Workload	Term	Frequency	Duration
	10 CP	300 h	1. + 2. sem.	each semester	2 semesters
Courses			Contact hours	Self-study	Group size
a) Lectures, seminars, exercises in structural geology			2 SWS	70 h	20 students
b) Special methods in structural geology			2 SWS	70 h	
c) Structural geology field camp			2 SWS	70 h	
Prerequisites					
For students enrolled in the MSc curriculum					
Learning outcomes					
After completion of the module the student is					
<ul style="list-style-type: none"> • acquainted with different advanced concepts and applications of structural geology. • knows the most important mechanisms leading to basin formation and subsidence. • is able 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 the specific tectonics leading the evolution of sedimentary basins. 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 different aspects of basin tectonics. After an extensive review of the main characteristics of the different types of sedimentary basins (i.e. stretching, strike-slip and flexural), theoretical aspects on mechanisms driving basin subsidence are presented. In particular, emphasis is put on flexure mechanics, isostasy and the thermal regime of the lithosphere. Topics covered include global tectonics, tectonic structures, fault mechanics, lithospheric stresses, basin tectonics, subsidence, rift basins, McKenzie's model, flexure mechanics, foreland basins, and strike-slip basins.					
Preliminary knowledge in tectonics/structural geology, geodynamics and geophysics is an advantage.					
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.

Allen and Allen, 2013. Basin Analysis: Principles and Application to Petroleum Play Assessment, 3rd Edition, Wiley-Blackwell.

Twiss and Moores, 1992 (2007). Structural Geology, Freeman.

Geology and geohazards in an active subduction zone							
Module number	Credits	Workload	Term	Frequency	Duration		
Courses		Contact hours		Self-study	Group size		
Geology and geohazards in an active subduction zone		3 SWS		90 h	30 Students (maximum)		
Prerequisites							
Open to all MSc students. No prerequisites, but an introductory course in geophysics/seismology and/or structural geology will be helpful.							
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 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
Further information