Module Handbook

Master in Geosciences

Major in Palaeobiology and Earth Systems Research Lab

Presentation of the Master Programme in Geosciences

The Master course in Geosciences at FAU Erlangen-Nuremberg is composed of

- two majors,
- one compulsory course selected from a range of supplementary courses, and
- two "key qualifications" modules.

The first major consists of learning units amounting to 45 ECTS points and leads towards a Master thesis and defense worth 25 + 5 ECTS points. The second major comprises 30 ECTS points. Supplementary courses and key qualifications add further 15 ECTS points.

Six majors are offered in Geosciences at FAU. Palaeobiology and Earth Systems Research Lab are the only ones offered exclusively in English. Therefore, for non-German speakers, only a combination of these two majors is available. Students who have a documented knowledge of German at the B2 level (according to CEFR) can combine English and German majors.

Applied Geology (AG) (German/English) Career prospects as a consultant in engineering geological agencies and authorities or in water supply and environmental protection, as well as basic scientific research at universities and research institutions
Applied Mineralogy **(AM) (German)** Career prospects in research departments of the chemical industry or in material and process-oriented enterprise sectors
Applied Sedimentology and Geological Resources **(AS) (German/English)** Career prospects in extractive industries (oil, gas, coal, geothermal, metallic and non-metallic raw materials), in research institutes, authorities and engineering companies.
Petrology – Geodynamics – Geological Resources **(PG) (German)** Career prospects in basic scientific research, public authorities and extractive industries
Palaeobiology (PB) (English) Career prospects in basic scientific research, environmental management authorities and companies, as well as in extractive industries.
Earth Systems Research Lab (RL) (English and only as second Major) Prospects for sustainable scientific career with focus on international mobility. Target employers: universities, research institutions, museums, scientific publishing companies, geoparks, grant agencies, authorities.

The program is divided into the consolidation phase in the 1st and 2nd semester and the research phase in the 3rd and 4th semesters.

In the consolidation phase, the technical and methodological basis is created for the application of this knowledge and skills in practice during the research phase. The specialization modules V1 - V4 and research modules F1 & F2 provide the curriculum in both the 1st and 2nd major.

In the first major the curriculum is expanded by supplementary modules E1 & E2 and an additional research module F3. This major leads to the Master thesis and defense (see structure plan below).

The supplementary (EF) module includes adequate, balanced courses. As key qualifications (KQ) technically oriented industry internships, projects, mapping, or similar activities are available inside and outside the university and evaluated by an authorized examiner. Alternatively, coordinated courses from the university-wide listing are recognized as key qualifications modules (5 ECTS each).

Principally, each module corresponds to 5 ECTS points, ends with an exam, and takes place during the semester.

The schedule of the Master program is designed as follows:

1. Semester (winter term): Courses expanding basic knowledge acquired in the Bachelor's degree and introduction to the majors in order to prepare students for the field and laboratory courses offered in the following semesters. During the semester break: industrial internship, work on a mapping or research project, or Field Course Module
2. Semester (summer term): Regular lectures and exercises, key qualifications module (KQ) During the semester break: industrial internship, work on a mapping or research project, or Field Course Module
3. Semester (winter term): Consolidation of knowledge through research modules, comprising courses which serve as direct preparation for the Master thesis; key qualification module (KQ) During the semester break: industrial internship, work on a mapping or research project, or Field Course Module
4. Semester (summer term): Master thesis and defense

Consolidation (C) und Supplementary modules (S) in 1st & 2nd Semester

Research modules (R) in 3rd Semester

SC – Supplementary course, KQ – Key qualifications

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-V1: Consolidation of basics I	**5 ECTS**
2	Courses	Morphology, Systematics and Ecology of Invertebrates (L) 1 SWH[1] Morphology, Systematics and Ecology of Invertebrates (E) 3 SWH	GeoZentrum Nordbayern
3	Lecturers	Dr. M. Heinze	

4	**Responsible person**	**Dr. M. Heinze**
5	**Contents**	Combined lecture and exercises focus on the Bauplans of key invertebrate clades, with particular attention given to hard parts with high fossilization potential. The course provides essential information on life habits, stratigraphic distribution, importance as index taxa, and evolution. Overview of the classification and presentation of selected important representatives.
6	**Learning Objectives and Competences**	The students are able to: • draw and describe body plans of different invertebrate lineages, focusing on hard parts with high fossilization potential • present an overview of the classification, ecology, and morphology of invertebrate animals • associate phenotypic traits with ecological attributes
7	**Prerequisites**	
8	**Incorporation in sample study plan**	1. semester of master studies
9	**Usability of the module**	Obligatory for students majoring in Palaeobiology-Palaeoenvironments
10	**Examination criteria**	Written examination (60 min)
11	**Grading**	Written examination 100%
12	**Regular cycle**	Annual in the winter term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS

[1] Semester week hours – 1 SWH equals 45 min contact time per week

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Benton, M. & Harper, D.A.T. (2009) Introduction to Paleobiology and the Fossil Record Clarkson, E.N.K. (1998) Invertebrate Palaeontology & Evolution

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-V2: Consolidation of basics II	**5 ECTS**
2	Courses	a) Systematics, Ecology and Biostratigraphy of Microfossils (L) 2 SWH a) Systematics, Ecology and Biostratigraphy of Microfossils (E) 2 SWH b) Methods of Biostratigraphy (L) 1 SWH	
3	Lecturers	N.N.[2] Dr. Michael Heinze	

4	**Responsible person**	N.N.
5	**Contents**	<u>a) Systematics, Ecology and Biostratigraphy of Microfossils</u> Students learn to identify important microfossil groups through time and their application in biostratigraphy and environmental analysis. They understand constraints on these applications resulting from taphonomy and uncertain ecologies or affinities of these groups. Rates and patterns of microfossil evolution, with respect to environmental changes, lead the students to a broader understanding of the interaction between geo- and biosphere processes. <u>b) Methods of Biostratigraphy</u> The use of index macro- and microfossils based on their succession is demonstrated, starting from their definitions, and involving relevant examples from the Earth history. The methodology of lineage, range, and other types of biozones is explained based on representative case studies from marine and terrestrial systems. Modern quantitative methods of biostratigraphy are presented, such as constrained optimization and unitary associations. The integration of biostratigraphy and other stratigraphical methods is also presented.
6	**Learning Objectives and Competences**	The students are able to: • follow the rules of International Commission on Stratigraphy on identifying, naming, and correlating Biozones • outline the stratigraphic range, taxonomic position and ecology of key groups used in biostratigraphy • identify zones in a succession based on fossil occurrence data and compare it with different zonations

[2] New professor starting in the winter term 2017

		• perform graphical correlation • calculate confidence intervals on stratigraphic ranges • integrate biostratigraphic data with other types of stratigraphic information, e.g. sequence stratigraphy or chemostratigraphy
7	**Prerequisites**	
8	**Incorporation in sample study plan**	1. semester of master studies
9	**Usability of the module**	Obligatory for students majoring in Palaeobiology-Palaeoenvironments
10	**Examination criteria**	Written examination (60 min)
11	**Grading**	Written examination 100%
12	**Regular cycle**	Annual in the winter term
13	**Workload**	Attendance time:70 h Self-study: 80 h Total: 150 h equivalent to 5 ECTS Points
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Armstrong, H.A. & Brasier, M.D. (2005): Microfossils. Doyle, P., Bennett, M.R. & Baxter, A.N. (2001) The Key to Earth History: An Introduction to Stratigraphy Harries, P.J. (2008) High-Resolution Approaches in Stratigraphic Paleontology Mann, K.O. & Lane, H. R. (1995) Graphic Correlation: SEPM (Society for Sedimentary Geology) Special Publication 53 Gradstein, F., Ogg, J.G., Schmitz, M. & Ogg, G. (2012) The Geologic Time Scale 2012 Hammer, Ø. & Harper, D.A.T. (2008) Paleontological Data Analysis Sadler, P.M. (2004) Quantitative Biostratigraphy - achieving finer resolution in Global Correlation. Annual Reviews of Earth and Planetary Sciences, v. 32, p. 187-213.

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-E1: Consolidation of basics III	**5 ECTS**
2	Courses	Microfacies analysis and diagenesis of carbonate rocks (L) 1 SWH Microfacies analysis and diagenesis of carbonate rocks (E) 3 SWH	
3	Lecturers	Prof. Dr. A. Munnecke	

4	**Responsible person**	**Prof. Dr. A. Munnecke**
5	**Contents**	The course starts with an introduction to general carbonate sedimentology (climatic and oceanographic controls, global carbonate provinces, platform types, overview of components, classification of carbonates, SMF-types, etc.). This is followed by examples from various depositional environments and periods in the Earth history, studied during exercises (particularly thin sections, but also loose sediments) in terms of microfacies and diagenetic structures. The importance of these studies is also highlighted with respect to applications (e.g. of hydrocarbon exploration and geothermal energy). Great emphasis is placed on recent developments in carbonate sedimentology (e.g. cold water carbonates, deep-water reefs, bioerosion, cold-seep carbonates).
6	**Learning Objectives and Competences**	The students are able to: • give an introduction to carbonate sedimentology • analyse thin sections and loose sediments in terms of microfacies and diagenetic properties • use this knowledge in addressing applied questions, e.g. in geothermal energy • perform an independent sedimentological and microfacies analysis and interpretation of carbonate rocks
7	**Prerequisites**	
8	**Incorporation in sample study plan**	1. semester of master studies
9	**Usability of the module**	Obligatory for students majoring in Palaeobiology–Palaeoenvironments. Facultative for students majoring in Applied Sedimentology–Georesources
10	**Examination criteria**	Written examination (60 min)
11	**Grading**	Written examination 100%
12	**Regular cycle**	Annual in the winter term

13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Bathurst, E. (1975) Carbonate Sediments and their Diagenesis, Elsevier Flügel, E. (2004) Microfacies of Carbonate Rocks, Springer Roberts, J.M., Wheeler, A., Freiwald, A. & Cairns, S. (2009) Cold-Water Corals, Cambridge University Press Scholle, P.A., Bebout, D.G. & Moore, C.H. (1983) Carbonate Depositional Environments, AAPG Tucker, M.E. & Wright, V.P. (1991) Carbonate Sedimentology, Blackwell

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-V3: Palaeobiology I	**5 ECTS**
2	Courses	a) Macroevolution (L) 2 SWH b) Introduction to Phylogenetic Analysis (P) 1 SWH	GeoZentrum Nordbayern
3	Lecturers	Prof. Dr. Wolfgang Kiessling N.N.[3] Dr. Kenneth De Baets	

4	**Responsible person**	Prof. Dr. Wolfgang Kiessling
5	**Contents**	a) Macroevolution This lecture introduces large-scale evolutionary patterns and discusses underlying mechanisms. The lecture will confront students with current macroevolutionary theories. Metrics of evolutionary rates and the identification of relevant evolutionary factors are taught. The focus is on biotic and abiotic controls of extinctions and originations. Scales and hierarchies of evolution are discussed in depth, as are the causes of evolutionary trends. a) Introduction to Phylogenetic Analysis Phylogenetics is the study of evolutionary relationships through nucleotide or protein sequences or morphological traits under a model of evolution of these traits. The course introduces model-based methods of phylogenetic analysis in a hypothesis-testing framework. A computer lab introduces case studies most relevant to palaeontologists, e.g. fossil-calibrated phylogenies, ancestral state reconstruction, and historical biogeography.
6	**Learning Objectives and Competences**	The students are able to: • Recognize, understand and reproduce large-scale evolutionary patterns. • Know multi-level evolutionary theory • Describe the basics of phylogenetic reconstructions, the identification of evolutionary rates and relevant evolutionary factors. • Identify biotic and abiotic controls of extinction and origination • Present the proofs for a hierarchical organization of evolutionary processes • Describe relationships among gene sequences/ individuals/ species based on a phylogeny

[3] New professor starting in the winter term 2017

		• Build a character matrix based on morphological data, as well as an aligned sequence dataset and • Address macroevolutionary questions such as ancestral state reconstruction
7	**Prerequisites**	none, but the module "Consolidation of Basics I and II (or equivalent)" is recommended
8	**Incorporation in sample study plan**	2. semester of master studies
9	**Usability of the module**	Obligatory for students majoring in Palaeobiology–Palaeoenvironments
10	**Examination criteria**	Written examination (60 min)
11	**Grading**	Written examination 100%
12	**Regular cycle**	Annual in the summer term
13	**Workload**	Attendance time: 42 h Self-study: 108 h Total: 150 h equivalent to 5 ECTS Points
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Stanley, S.M. (1998) Macroevolution: patterns and processes Levinton, J.S. (2001) Genetics, Paleontology, and Macroevolution. Zimmer, C. & Emlen, D. (2012) Evolution: Making Sense of Life Foote, M. & Miller, A. I. (2006) Principles of paleontology. Benton, M. J. and Harper, D. A. T. (2009) Introduction to Paleobiology and the fossil record. Hammer, Ø. & Harper, D.A.T. (2008) Paleontological Data Analysis

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-V4: Palaeobiology II	**5 ECTS**
2	Courses	a) Macroecology (L) 1 SWH a) Macroecology (E) 1 SWH b) Biofacies and Palaeoecology (E) 2 SWH	GeoZentrum Nordbayern
3	Lecturers	N.N.[4] Dr. Michael Heinze	

4	**Responsible person**	N.N.
5	**Contents**	a) Macroecology Macroecology integrates data from ecology, systematics, evolutionary biology, palaeobiology and biogeography to identify patterns in ecosystems functioning at largest spatial and temporal scales. The course takes a hierarchical approach at patterns in abundance and distribution of species, palaeogeography, population dynamics and interactions, and implications for macroevolution and conservation biology. b) Biofacies and Palaeoecology Students perform a study identifying biofacies from outcrop data and fossils. The class covers the whole workflow from gathering fossils in the field to sample preparation, analysis and interpretation.
6	**Learning Objectives and Competences**	The students are able to: • Explain the large-scale patterns in species abundance, diversity and distribution • Understand and apply the key ecological models describing population dynamics and interactions within and between species • Report, describe and apply palaeontological methods for the interpretation and reconstruction of ancient habitats and ecosystems • Prepare and analyse fossil samples and present the results in a professional way
7	**Prerequisites**	none, but the module "PB-V1: Morphology, Systematics and Ecology of Invertebrates (or equivalent)" is recommended
8	**Incorporation in sample study plan**	2. semester of master studies

[4] New professor starting in the winter term 2017

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

9	**Usability of the module**	Obligatory for students majoring in Palaeobiology–Palaeoenvironments
10	**Examination criteria**	Written report (Assignment max. 10 Pages)
11	**Grading**	Written examination 100%
12	**Regular cycle**	Annual in the summer term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Brown, James H. (1995) Macroecology. 269 pp., The University of Chicago Press Smith, F., Gittleman, J.L. & Brown, J.H. (2014) Foundations of Macroecology: Classic Papers with Commentaries. 800 pp. The University of Chicago Press Witman, J.D. & Roy, K. (2009) Marine macroecology. The University of Chicago Press Rosenzweig, M.L. (1995) Species diversity in space and time. Brenchley, P.J. & Harper, D, A.T. 1998. Palaeoecology. Ecosystems, environments and evolution.- 402 pp., Chapman & Hall Goldring, R.G. 1999. Field Palaeontology.- 191 pp, Longman

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-E2: Analytical Palaeobiology	**5 ECTS**
2	Courses	Analytical Palaeobiology (E) 4 SWH	GeoZentrum Nordbayern
3	Lecturers	Prof. Dr. Wolfgang Kiessling	

4	**Responsible person**	**Prof. Dr. Wolfgang Kiessling**
5	**Contents**	This module presents modern methods of quantitative analyses of the fossil record. Computer exercises are introduced by short lectures on theoretical foundations. Students use R (www.r-project.org) and modify existing scripts to apply them to palaeobiological problems using data from the Paleobiology Database (www.paleobiodb.org) and other sources. Topics covered are reconstructions of biodiversity and their dynamics, measuring evolutionary rates, quality of the fossil record, and sampling standardization.
6	**Learning Objectives and Competences**	The students are able to: • Understand and apply modern quantitative methods of analyzing the fossil record at large • Use R and tailor existing scripts for palaeobiological problems • Apply statistics to separate biologically meaningful signals from random noise
7	**Prerequisites**	none, but the module “Consolidation of Basics I and II (or equivalent)” is recommended
8	**Incorporation in sample study plan**	2. semester of master studies
9	**Usability of the module**	Obligatory for students majoring in Palaeobiology–Palaeoenvironments
10	**Examination criteria**	Oral presentation (20 min) on a specific subject using the Palaeobiology Database and modified or own R scripts.
11	**Grading**	Oral presentation 100%
12	**Regular cycle**	Annual in the summer term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English

16	**Preparatory Reading**	Foote, M. & Miller, A.I. (2007): Principles of Paleontology (W.H. Freeman and Company, New York) Third Ed p 354. Knell, R.J. (2013). *Introductory R: A Beginner's Guide to Data Visualisation and Analysis using R*. http://www.introductoryr.co.uk/. http://paleobiodb.org

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-F1: Palaeontological Research I	**5 ECTS**
2	Courses	a) Proxies in palaeoenvironmental reconstructions (L) 1 SWH a) Proxies in palaeoenvironmental reconstructions (E) 1 SWH b) Laboratory methods in palaeontology (E) 2 SWH	
3	Lecturers	Dr. Michael Heinze Dr. Emilia Jarochowska Theresa Nohl	

4	**Responsible person**	**N.N.**[5]
5	**Contents**	<u>a) Proxies in palaeoenvironmental reconstructions</u> Environmental parameters such as productivity, redox conditions or salinity can be approximated with quantitative data derived from the geological record. The course emphasizes quantitative, testable palaeobiological proxies which can be used to make predictions and assessed in terms of their accuracy and precision. Students identify the type of data and statistical methods (ordination techniques and regression analysis) to build their own proxies for environmental gradients. <u>b) Laboratory methods in palaeontology</u> The course introduces research devices and analytical methods available for palaeoenvironmental studies. Depending on the availability of individual devices, it is supplemented with small exercises involving: - Scanning Electron Microscopy - EDX analysis (energy dispersive X-ray analysis) - µ-CT imaging - MicroMill (microsampler) - Light microscopy including digital image analysis - Thin-section preparation and staining - Vacuum-casting

[5] New professor starting in the winter term 2017

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

6	**Learning Objectives and Competences**	The students are able to: • apply, compare and evaluate palaeobiological proxy data (e.g. ichnofossils, biofabrics, biomarker etc) in the deep time • derive proxies from actualistic models and explain the limitations of this approach • design a tailored study to analyse an environmental gradient using fossil data • apply the analytical tools available in reconstruction of palaeoenvironments in theory and in practice (see above) • master advanced laboratory methods in palaeontology
7	**Prerequisites**	none, but the successful completion of 1. and 2. semesters of master studies is recommended
8	**Incorporation in sample study plan**	3. semester of master studies
9	**Usability of the module**	Obligatory for students majoring in Palaeobiology–Palaeoenvironments
10	**Examination criteria**	Written examination (60 min)
11	**Grading**	Written examination 100%
12	**Regular cycle**	Annual in the winter term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Dickson (1966): Carbonate identification and genesis as revealed by staining Dravis (1990): Carbonate petrography – update on new techniques and applications Nielsen & Maiboe (2000) Epofix and vacuum: an easy method to make casts of hard sub-strate Reed (2005): Electron Microprobe Analysis and Scanning Electron Microscopy in Geology Armstrong, H. & Brasier, M. D. (2005) Microfossils Buatois, L.A. & Mángano, M.G. (2011) Ichnology: Organism-Substrate Interactions in Space and Time Hill, W., Wyse, G.A. & Anderson, M. (2016) Animal Physiology

		Patzkowsky, M. & Holland, S.M. (2012) Stratigraphic Paleobiology Green, O.R. (2001) A Manual of Practical Laboratory and Field Techniques in Palaeobiology

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-F2: Palaeontological Research II	**5 ECTS**
2	Courses	a) Geobiology of reefs (L) 1 SWH a) Geobiology of reefs (E) 1 SWH b) Programming and statistics in palaeobiology (E) 2 SWH	
3	Lecturers	Prof. Dr. Wolfgang Kiessling	

4	**Responsible person**	**Prof. Dr. Wolfgang Kiessling**
5	**Contents**	a) Geobiology of reefs The course presents the methods for studying fossil reef systems, explains geological and biological control factors of reef development, and shows the geological history of reef systems. Reef data are analysed in practical exercises involving geographic information systems (GIS). b) Programming and statistics in palaeobiology Modern statistical and programming knowledge is imparted using the open-source R software (www.r-project.org) and additional packages specific to individual problems. The focus is on multivariate methods (cluster analysis, correspondence analysis, multiple regression).
6	**Learning Objectives and Competences**	The students are able to: • name methods for studying fossil reef systems • describe and explain geological and biological control factors over reef development • present the history of reef systems • evaluate reef data in practice using GIS • work independently with open-source R Software and topic-specific additional packages, and apply them to current paleobiological problems • create scripts with which palaeobiological hypotheses can be tested
7	**Prerequisites**	no, but the successful completion of 1. and 2. semesters of master studies, in particular the module „Analytical Palaeobiology“ is recommended
8	**Incorporation in sample study plan**	3. semester of master studies

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

9	**Usability of the module**	Obligatory for students majoring in Palaeobiology–Palaeoenvironments
10	**Examination criteria**	Oral presentation (20 min)
11	**Grading**	Oral presentation 100%
12	**Regular cycle**	Annual in the winter term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Roberts et al. (2009), Cold-water corals: The biology and Geology of deep-sea coral habitats Kiessling W., Flügel E., & Golonka J., eds., (2002) Phanerozoic Reef Patterns, SEPM Special Publications, Vol 72, p 775. Sheppard, C. R. C., Davy, S. K., and Pilling, G. M., (2009), The Biology of Coral Reefs, Oxford, Oxford University Press, 339 p. Wood R. (1999), Reef evolution (Oxford University Press), 414 p.

Major in Palaeobiology (PB), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	PB-F3: Palaeontological Research III	**5 ECTS**
2	Courses	a) Hypothesis testing in palaeobiology (S) 2 SWH b) Oceanography (L) 1 SWH Oceanography (E) 1 SWH	
3	Lecturers	Prof. Dr. Wolfgang Kiessling Prof. Dr. Axel Munnecke N.N.[6]	

4	**Responsible person**	N.N.
5	**Contents**	(a) Seminar: Hypothesis testing in palaeobiology The seminar takes place as a block near the end of the semester, when students choose their Master thesis topics. The seminar serves to sharpen the research question that will be addressed in the thesis and evaluate the proposed study design through discussion among students and teachers. Students summarize the state of the art, motivate the choice of the topic, explain which steps they will undertake to address it and discuss the feasibility of the approach. (b) Oceanography The purpose of the lecture is to convey the principles of oceanography and climate. For example, the mechanism of thermohaline circulation, the importance of water mass properties, the phenomenon of internal waves, ocean front systems, ocean acidification and its consequences, and relationships with the global climate.
6	**Learning Objectives and Competences**	The students are able to: • formulate a precise plan for their Master thesis and defend its concept in a presentation and discussion with all faculty members and students • summarize the principles of oceanography • understand, explain, and present global oceanographic and climatic relationships
7	**Prerequisites**	
8	**Incorporation in sample study plan**	3. semester of master studies
9	**Usability of the module**	Obligatory for students majoring in Palaeobiology–Palaeoenvironments

[6] New professor starting in the winter term 2017

10	**Examination criteria**	PL: Written exam (30 min) and SL: oral presentation (30 min)
11	**Grading**	Written exam 100%
12	**Regular cycle**	Annual in the winter term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Good, P.I. & Hardin, J.W. (2003) Common errors in statistics (and how to avoid them), Wiley Logan, M. (2010) Biostatistical Design and Data Analysis in R, Wiley Thurman (1990) Essentials of oceanography, Pearson Education Vallis, G.K. (2011) Climate and the Oceans, Princeton University Press

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	RL-V1: AS-F2 Sedimentary geochemistry	**5 ECTS**
2	**Course**	Geochemical proxies in palaeoenvironmental analysis (L) 2 SWH Geochemical proxies in palaeoenvironmental analysis - Lab (L) 1 SWH Geochemical proxies in palaeoenvironmental analysis - Lab (E) 1 SWH	GeoZentrum Nordbayern
3	**Lecturers**	Apl. Prof. Dr. Michael Joachimski	

4	**Responsible person**	**Apl. Prof. Michael Joachimski**
5	**Contents**	Geochemical proxies in palaeoenvironmental analysis Foundation of sedimentary geochemistry with special consideration to major and trace elements, Rare Earth Elements (REE), stable and radiogenic isotopes. Geochemical proxies in palaeoenvironmental analysis - lab: Application of geochemical proxies to reconstructions of palaeoclimate as well as palaeoenvironmental conditions. Geochemical development of sedimentary rocks in Earth history. Palaeoclimatic history of the Earth as reconstructed using geochemistry.
6	**Learning Objectives and Competences**	The students are able to: • present and explain the foundations of sedimentary geochemistry with special consideration to major and trace elements, Rare Earth Elements (REE), stable and radiogenic isotopes • apply geochemical proxies to reconstructions of palaeoclimate as well as palaeoenvironmental conditions – analyse, present and discuss the data • summarize the geochemical development of sedimentary rocks in Earth history. Palaeoclimatic history of the Earth as reconstructed using geochemistry
7	**Prerequisites**	
8	**Incorporation in study plan**	1. semester
9	**Usability of the module**	Obligatory for students of "Angewandte Sedimentologie und Georessourcen" and “Earth Systems Research Lab”. Students majoring in Palaeobiology-Palaeoenvironments
10	**Examination criteria**	Written exam (60 min)
11	**Grading**	Exam 100%
12	**Regular cycle**	Winter term
13	**Wrokload**	Attendance time: 56 h

		Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Burdige, D. (2006): Geochemistry of Marine Sediments.- Princeton (Princeton University Press). MacKenzie, F. (2005): Sediments, Diagenesis, and Sedimentary Rocks: Treatise on Geochemistry: Volume 7, Amsterdam (Elsevier). Sharp, Z. (2005): Principles of stable isotope geochemistry.- New York (Prentice Hall). Turekian, K. (2005): The Oceans and Marine Geochemistry: Treatise on Geochemistry, Volume 6. Amsterdam (Elsevier).

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	RL-V2: Earth Systems Research Lab I	**5 ECTS**
2	Course	a) Palaeobiology Seminar (S) 2 SWH b) Scientific English I - Research Project Design (P) 2 SWH	
3	Lecturers	Lecturers at Section Palaeobiology	

4	**Responsible person**	**N.N.**[7]
5	**Contents**	Students prepare a one-semester research project to be performed in Earth Systems Research Lab II (summer term), either as part of current projects in the Section Palaeobiology, or pursuing their own research questions developed with lecturers. Students become first integrated into the research environment by attending the Palaeobiology seminar, and in coordination with lecturers decide upon their project area. They perform a literature survey to identify the specific research question they will address and to find available methods. With the help of the lecturers, they identify relevant material (collections, database, field area) to be studied in their individual projects and assess the feasibility given the time available. They receive instructions on appropriate forms and constructions used in scientific texts. They write a small research proposal (the format of a small DFG application) motivating their study, outlining the study design and feasibility. Teachers provide feedback on both scientific and linguistic aspects of the proposals.
6	**Learning Objectives and Competences**	The students are able to: • identify and find scientific literature relevant to a given problem • read the literature critically, identifying gaps in current knowledge • develop a research topic addressing one of such gaps • can chose appropriate project design and methodology and evaluate the feasibility of the project • understand scientific English terms (spoken and written) • write an professional text in English, using appropriate terms and constructions
7	**Prerequisites**	none, but the successful completed previous courses are recommended
8	**Incorporation in study plan**	2. Semester
9	**Usability of the module**	Students majoring in Palaeobiology-Palaeoenvironments

[7] New professor starting in the winter term 2017

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling

10	**Examination criteria**	Project proposal in the DFG format (max. 15 pages)
11	**Grading**	Project proposal 100%
12	**Regular cycle**	Winter term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	To be identified by the student, based on suggestions from lecturers or own initiative.

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	RL-V3: Earth Systems Research Lab II	**5 ECTS**
2	Course	a) Scientific English II – Literature Seminar (S) 2 SWH b) Research Project Implementation (P) 2 SWH	GeoZentrum Nordbayern
3	Lecturers	Lecturers at Section Palaeobiology	

4	**Responsible person**	**N.N.**[8]
5	**Contents**	Scientific English II – Literature SeminarEach student presents one article relevant to their research project, explaining the main problem/hypothesis, the approach, and the conclusions. Together with other students and lecturers they discuss how the methods or findings could be related to their own project or research interests. Students learn how to develop a scientific argument in English using specialist terminology and forms appropriate in a professional environment. Research Project Implementation Students perform a one-semester research project designed during the winter term, either as part of current projects in the Section Palaeobiology, or pursuing their own research questions developed with lecturers. Data acquisition may take place in the field, in museum collections, through literature mining or examination of material available on site, e.g. the microfacies collection, and involve all available techniques, including ultrastructure, histology, µCT, geometric morphometrics, 3D model construction and others. Results of the research project are presented in an article following a PNAS format. Emphasis is also put on data handling and archiving, reproducibility of the results, as well as on soft skills: sharing lab space and equipment, communication with colleagues and fellow students, and handling unexpected problems in project preparation.
6	**Learning Objectives and Competences**	The students are able to: • to present the chosen problem to a broader professional audience and engage in a competent discussion on relevant methodology and importance of the topic • learn good practice in sample and data handling • gain the ability to work independently on data collection and analysis • write a research article in PNAS format, presenting the results of their work in a concise fashion

[8] New professor starting in the winter term 2017

		• become parts of research teams early and learn the organizational and social skills associated with teamwork
7	**Prerequisites**	none, but the successful completed previous courses are recommended
8	**Incorporation in study plan**	2. Semester
9	**Usability of the module**	Students majoring in Palaeobiology-Palaeoenvironments
10	**Examination criteria**	PL: research article (6 publication-formatted pages) SL: presentation of literature relevant to their selected (30 min)
11	**Grading**	Research article (100%)
12	**Regular cycle**	Summer term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	To be identified by the student, based on suggestions from lecturers or own initiative.

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	RL-V4: Environmental Hydrogeology AG-V3b: Environmental Hydrogeology	**5 ECTS**
2	**Course**	Tracers, Isotopes & Natural Attenuation (L) 3 SWH Tracers, Isotopes & Natural Attenuation (E) 1 SWH	GeoZentrum Nordbayern
3	**Lecturers**	Prof. PhD J. Barth	

4	**Responsible person**	**Prof. PhD J. Barth**
5	**Contents**	The course provides an overview of various aquifer tracer techniques involving colour and salt tracers to determine groundwater flow rates. Isotope tracers are presented and serve to introduce concepts of large-scale isotope hydrogeology. Here the focus is on environmental isotopes in geohydrological and carbon cycles. Principles are explained with several examples. The course also includes a 1.5 to 2-day tracer experiment.
6	**Learning Objectives and Competences**	The students are able to: • understand, plan and perform local tracer studies on surface and groundwater systems • understand and interpret large-scale mass balance of C, H, N and O isotopes • apply various tracer techniques for aquifers using color and salt tracers, and infer groundwater flow rates • understand the principle of mass balance of stable isotopes and apply it independently
7	**Prerequisites**	None, but basic knowledge of hydrogeology is recommended
8	**Incorporation in study plan**	2. Semester
9	**Usability of the module**	Obligatory for Master Students in „Angewandte Geologie“ and “Earth systems Research Lab”. Students majoring in Palaeobiology-Palaeoenvironments. The course is open to students of all majors.
10	**Examination criteria**	Report (max. 10 pages)
11	**Grading**	Report 100%
12	**Regular cycle**	Summer term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling	

14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Clark, I.D. & Fritz, P. (1997) Environmental Isotopes in Hydrogeology, CRC Press Mook, W.G. (2005) Introduction to Isotope Hydrology, Taylor & Francis Kendall, C. & McDonnell, J.J. (1999) Isotope Tracers in Catchment Hydrology, Elsevier Käss, W. (1998) Tracing Technique in Geohydrology , CRC Press

1	**Module**	RL-F1: Earth System Research Lab III	**5 ECTS**
2	Course	Data mining and Analysis in Earth System Research (P) 3 SWH Data mining and Analysis in Earth System Research (S) 1 SWH	GeoZentrum Nordbayern
3	Lecturers	Lecturers at Section Palaeobiology	

4	**Responsible person**	**Prof. Dr. Wolfgang Kiessling**
5	**Contents**	Students prepare a data mining project, either integrated into current research at the Section Palaeobiology, or proposed on their own and consulted with teachers. The results are delivered in the form of an oral presentation. The data mining is based on biological or palaeontological repositories (Paleobiology Database, PaleoReefs Database and others) complemented, when necessary, with literature mining. Students formulate research questions through discussion with all lecturers (and other scientific staff involved in respective projects) and identify the type of data, temporal resolution, and taxonomic level necessary to address the question. They perform data cleaning and statistical analyses independently.

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling		
6	**Learning Objectives and Competences**	The students are able to: • formulate larger research questions and specific hypotheses, which can be addressed and tested through data mining and analysis • identify appropriate statistical analysis and required data (sample size, geographical and stratigraphic range, taxonomic level and stratigraphic resolution) • handle data repositories and clean up the data • perform statistical analyses and code in a way that is accessible to another scientist
7	**Prerequisites**	none, but the successful completed previous courses are recommended
8	**Incorporation in study plan**	3. Semester
9	**Usability of the module**	Students majoring in Palaeobiology-Palaeoenvironments
10	**Examination criteria**	Presentation (30 min)
11	**Grading**	Presentation 100%
12	**Regular cycle**	Winter term
13	**Workload**	Attendance time: 56 h Self-study: 94 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	To be identified by the student, based on suggestions from lecturers or own initiative.

„Earth Systems Research Lab (RL), Coordinator: Prof. Dr. W. Kiessling

1	**Module**	RL-F2: Earth System Research Lab IV	**5 ECTS**
2	Course	Science communication (S) 3 SWH	GeoZentrum Nordbayern
3	Lecturers	Lecturers at Section Palaeobiology	

4	**Responsible person**	**Prof. Dr. Wolfgang Kiessling**
5	**Contents**	Students prepare a popular talk on their research project in the Earth System Research Lab III module, and a press release. They explain the broader context of their topic using attractive graphical material and a terms accessible to non-specialists. They explain the implications of their results and their meaning for the society.
6	**Learning Objectives and Competences**	The students are able to: • present the results of their analyses in a concise, comprehensive and attractive way • explain the motivation of their study and its implications to a non-specialist • prepare a short press release presenting their finding in an attractive way for non-specialists
7	**Prerequisites**	none, but the successful completed previous courses are recommended
8	**Incorporation in study plan**	3. Semester
9	**Usability of the module**	Students majoring in Palaeobiology-Palaeoenvironments
10	**Examination criteria**	Presentation (60 min)
11	**Grading**	Presentation 100%
12	**Regular cycle**	Winter term
13	**Workload**	Attendance time: 42 h Self-study: 108 h Total: 150 h equivalent to 5 ECTS
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	To be identified by the student, based on suggestions from lecturers or own initiative.

Key Qualifications

1	**Module**	**Key Qualifications I/II** KQ: Industry internships	**5 ECTS Points**
2	**Courses**	**Industry internships** 4 weeks	GeoZentrum Nordbayern
3	**Lecturers**	GeoZentrum faculty staff	

4	**Responsible person**	**Dean of Studies**
5	**Contents**	The internship serves to reinforce and apply theoretical knowledge in practice. It is intended to provide both knowledge from the specific discipline in natural sciences, as well as to introduce the student to management problems. Students work on an applied geological project. The task is usually complex and often requires an interdisciplinary team and a high degree of self-responsibility.
6	**Learning Objectives and Competences**	Students are able to: • assess their planned specialization with respect to the professional field • interact with non-specialists to build links between science and the society • seize the social aspect of work
7	**Prerequisites**	
8	**Incorporation in sample study plan**	From 1st semester
9	**Usability of the module**	Master program in geosciences
10	**Study and examination achievements**	Report (max. 20 pages)
11	**Grading**	Report (not graded)
12	**Regular cycle**	Each semester
13	**Workload**	Attendance: 133h Self-study: 17 h
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Individually assigned by lecturers

Key Qualifications

Key Qualifications

1	**Module**	**Key Qualifications I/II** KQ: Geological mapping	**5 ECTS Points**
2	**Courses**	Geological mapping 12 Days	GeoZentrum Nordbayern
3	**Lecturers**	GeoZentrum faculty staff	

4	**Responsible person**	**Dean of Studies**
5	**Contents**	Fundamentals of topographic and geological maps, construction of geological profiles, presentation and interpretation of tectonic structures on a geological map, interpretation of geological maps, construction of structure contour maps, introduction to classification of primary fabrics, measurement of geological orientation using a geological compass and interpretation of geological structures.
6	**Learning Objectives and Competences**	Students are able to: • Sketch and present outcrops and summarize the observations • Identify the orientation of geological structures • Read a topographic map and find their way using a map • Record field observations on a map and compile an orderly map-based report on field findings • Draw a tectonic profile • Perform assigned tasks in a team in a professional and responsible way • Evaluate their own motorical and physical abilities and use them adequately at work • Understand agreed rules concerning safety aspects and apply them in a responsible way to themselves and the team
7	**Prerequisites**	
8	**Incorporation in sample study plan**	From 1st semester
9	**Usability of the module**	Master program in geosciences
10	**Study and examination achievements**	Report (max. 20 pages)
11	**Grading**	Report (not graded)
12	**Regular cycle**	1 x yearly in winter term

Key Qualifications		
13	**Workload**	Attendance ca.: 60 h Self-study ca.: 90 h In total: 140 h or 5 ECTS points
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Individually assigned by lecturers

Key Qualifications

1	**Module**	**Key Qualifications I/II** KQ: Field excursion	**5 ECTS Points**
2	**Courses**	Field excursion 12 days	GeoZentrum Nordbayern
3	**Lecturers**	GeoZentrum faculty staff	

4	**Responsible person**	Dean of Studies
5	**Contents**	Foundations of regional geology of selected field areas; process-oriented observation of sedimentary, igneous and metamorphic rocks. Mapping and lithological characterization of differently deformed rock series. Analysis of sedimentary basins, igneous and metamorphic complexes. The structure of orogenic belts. Palaeobiogeography, palaeoecology.
6	**Learning Objectives and Competences**	Students are able to: • Describe the regional geology of selected field areas • Explain and present on a map the origin of given rock bodies based on individual sections in the field area • Describe and apply various field methods (sedimentological and palaeontological description of profiles, methods of structural geology, methods of engineering and hydrogeology, geophysical methods) and document the results adequately • Combine their two-dimensional observations from a geological section with theoretical knowledge and formulate a hypothesis concerning the three-dimensional field structure • Perform assigned tasks in a team in a professional and responsible way
7	**Prerequisites**	
8	**Incorporation in sample study plan**	From 1st semester
9	**Usability of the module**	Master program in geosciences
10	**Study and examination achievements**	Report (max. 20 pages)
11	**Grading**	Report (not graded)
12	**Regular cycle**	1 x yearly, in summer term

Key Qualifications		
13	**Workload**	Attendance ca.: 60 h Self-study ca.: 90 h
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	

Key Qualifications			
1	**Module**	**Key Qualifications I/II** KQ: Work on an individual project or comparable	**5 ECTS Points**
2	**Courses**	Work on an individual project or comparable 4 weeks	GeoZentrum Nordbayern
3	**Lecturers**	GeoZentrum faculty staff	

4	**Responsible person**	**Dean of Studies**
5	**Contents**	Contents depend on individual topics
6	**Learning Objectives and Competences**	Students can • Demonstrate their detailed knowledge in the field of geosciences. They can give an account of the state of the art, present examples of application, and discuss these critically with respect to current problems and conditions in science and society. • Explain in detail and critically discuss scientific methods which they have chosen for their own project. • Propose a strategy to solve a practical, theoretically grounded research question from the discipline of geosciences and outline the steps towards the solution. They can relate to theoretical knowledge and current state of the art concerning work safety, ecology, ethical and economic aspects, as well as the social context. • Independently select methods to be used in their work and justify this choice. They can demonstrate how these methods relate to the specific field of application adapt them to the application context. They can explain in broad terms the implications going beyond direct project results and give an outlook for further developments. • Present the relevance, the work steps and partial problems for discussion in a larger group, lead the discussion, and give other students feedback on their projects. • Independently, but under supervision, plan and document the steps and procedures necessary for performing the project within predetermined deadlines. This includes that they can find the latest scientific information in a targeted manner. Furthermore, they are able to follow feedback on the progress of their work from experts in order to achieve high quality results relevant to the state of science and technology.
7	**Prerequisites**	
8	**Incorporation in sample study plan**	From 1st semester
9	**Usability of the module**	Master program in geosciences

Key Qualifications		
10	**Study and examination achievements**	Report (max. 20 pages)
11	**Grading**	Report (not graded)
12	**Regular cycle**	Each semester
13	**Workload**	Attendance: 133 h Self-study: 17 h
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Individually selected with assistance from lecturers

Masterarbeit, Verantwortlicher: Dozenten GeoZentrum

1	**Module**	Master thesis	**5 ECTS Points**
2	**Courses**	Written Master thesis 750 h Master thesis defence 150h	
3	**Lecturers**	GeoZentrum faculty staff	

4	**Responsible person**	GeoZentrum faculty staff
5	**Contents**	Individually selected topic
6	**Learning Objectives and Competences**	Students: • Acquire the ability to pursue a scientific question over a longer period to process the relevant subject area independently and within a prescribed period • Develop their own ideas and concepts to solve scientific problems • Discuss critically theories, terminology, peculiarities, limitations, and opinions in their discipline and reflect upon them • Are able to work independently to manage and develop appropriate scientific methods - also in new and unfamiliar and multidisciplinary contexts - and present the results in an appropriate scientific form • Can present and discuss topics within their discipline in both oral and written form, in a clear way adjusted to the target audience • Develop their skills related to planning and structuring their work through the implementation of a thematic project
7	**Prerequisites**	
8	**Incorporation in sample study plan**	Starting from 4. semester
9	**Usability of the module**	Master program in geosciences
10	**Study and examination achievements**	Master thesis (40 – 60 pages) Presentation (20 min)
11	**Grading**	Master thesis 5/6 of the final grade Defence 1/6 of the final grade
12	**Regular cycle**	Summer term

Masterarbeit, Verantwortlicher: Dozenten GeoZentrum		
13	**Workload**	900 h in total
14	**Duration**	1 Semester
15	**Language**	English
16	**Preparatory Reading**	Provided individually