COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Rock investigation methods	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinators: assoc. prof. Donatas Kaminskas, assoc. prof. Gražina Skridlaitė	Department of Geology and Mineralogy, Faculty of Chemistry and Geosciences, Vilnius University, M.K. Čiurlionio str. 21/27, LT-03101 Vilnius

Study cycle	Type of the course unit (module)
Full-time studies (2nd stage, master)	Selective

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
Face-to-face	Spring semester (2nd semester).	Lithuanian/English

Requirements for students	
Prerequisites: secondary school basic knowledge on physics, chemistry and mathematics. Knowledge of introduction to mineralogy, petrology and geochemistry is recommended.	**Additional requirements (if any):** no

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
10	266	132	134

Purpose of the course unit (module): programme competences to be developed		
To study and understand Earth geological evolution and similar modern processes by means of up-to-date scientific investigation tools and approaches: obtain and improve the knowledge on rock-forming processes; acquire skills for application of the modern investigation approaches and tools for scientific investigations and practical application. Development of subject competences: formation of skills for the identification of major rock types under microscope; understanding of principles of geochemistry and geochronology as applied to the rock evolution; ability to explain and compare the obtained results in terms of rock evolutionary histories; ability to evaluate different investigation tools and to chose the most appropriate set for the solution of a particular scientific problem in the interest field. Development of general competences: capability of self-study and improvement; ability to convey knowledge in oral and written forms; competence in analysis; competence in decision making; ability for scientific research.		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
- understand and explain major geological processes implied from their compositional and chemical features; understand how rock composition and properties depend on their origin and tectonic setting; - understand how isotopic systems evolved through the geological time; relate isotopic abundances and ratios to distinct geological processes; choose the most comprehensive and appropriate set of analytical methods for	Problem-based, interactive learning (essay writing; seminars, exercises; self-study)	Formative assessment (interactions, ability to give/answer questions, self-study). Intermediate assessment (written colloquium. defense of the essay theses; recognition of major rock types under microscope); final examination; accumulative

identifying a rock or implication of its evolution; to interpret properly the results of the microscopic and isotopic investigations; - be able to apply practically some of the methods for a particular scientific problem; - be able to recognize the main rock types under a polarized light microscope and SEM. - be able to recognize most common types of rocks under polarizing and scanning electron microscope		score

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work	**Contact hours**	**Self-study hours**	**Assignments**
1. Introduction to microscopic methods of rock investigations: rock types, major minerals, their chemical and optical properties.	2						2	2	Self-study of reference material, preparation for exercises
2. Polarizing microscopy: thin section preparation, optical properties of different rock types, major rock forming minerals. Characteristic textures of igneous, sedimentary and metamorphic rocks under microscope, and implications for the rock origin.	2			2			4	2	Self-study of reference material, preparation for exercises
3. Scanning electron microscopy (SEM) and electron microprobe analysis (EMPA) in geology: principles and geological applications; secondary electron emission, X-ray production and absorption; cathodoluminescence; instrumentation; electron detectors; SEM imaging; X-ray spectrometers; Energy Dispersion Spectrometry (EDS) mapping; X-ray analysis; element and mineral identification; quantitative EDS analysis; sample preparation and specimen handling.	4			4			8	12	Self-study of reference material, preparation for exercises, writing assay
4. Protolith identification by isotopic means of investigations: Sm-Nd method; Sm-Nd isochrons, Nd isotope evolution and model ages. Magmatic and rock-forming age: U-Pb isochrons, U-Pb (zircon) datings. Metamorphic age: U-Pb-Th (monazite) age determinations;	4			2			6	5	Self-study of reference material, preparation for exercises
5. K-Ar ir $^{40}Ar/^{39}Ar$ dating methods: late geological processes and mineral closure.	4						4	4	Self-study of reference material, preparation for exercises
6. X-ray fluorescence analysis. Theory, sample preparation and application.	4			4			8	8	Self-study of reference material, preparation for exercises
7. Paleomagnetism and rock magnetic properties. Sample preparation and analysis.	4			4			8	6	Self-study of reference material, preparation for exercises
8. Sedimentary rocks sampling strategy. The main criteria describing taken sedimentary rocks samples.	4						4	4	Self-study of reference material, preparation for exercises
9. Unconsolidated and slightly cemented sedimentary rocks grain-size analysis. Grain-size analysis of sand and silt: preparation, sieve analysis. Consolidated clays preparation for grain-size analysis. Grain size analysis data graphic	4			4			8	8	Self-study of reference material, preparation for exercises

presentation; data characterization by statistical methods: median, mode, mean, sorting, skewnesis, kurtosis, standard deviation, effective diameter etc.									
10. Thin-section examination under a polarized light microscope. Description of major sedimentary rocks minerals and their groups characteristics: quartz, feldspar, mica, pyroxene, amphibole etc. Identification of carbonate, sulphate, phosphate groups minerals, staining of thin sections, fauna recognition and description. Examination and description of thin section of sedimentary rock under a polarized light microscope. Carbonate rocks classifications	6			8			14	8	Self-study of reference material, preparation for exercises
11. Spectrometry techniques: Atomic emission spectrometry, atomic absorption spectrometry, infrared spectrometry. Theory, instrumentation, principles of operation, sample for the analyses preparation, results (data) interpretation.	4						4	4	Self-study of reference material; preparation for lab-work defense. Focus on theoretical aspects of methods
12. X-ray powder diffraction of sediments. Theory, instrumentation, principles of operation. XRD of whole rock and clay minerals analysis. Qualitative analysis of mineralogical composition of „unknown „sedimentary rock from XRD diagram identification. Dolostone ordering degree and stochiometry calculation.	3			4			7	10	Self-study of reference material; preparation for lab-work defense
13. Cathodoluminescence analysis. Theory, instrumentation, principles of operation, sample for the analyses preparation, results (data) interpretation. Application for rocks cements and minerals study. Examine thin-section by cathodoluminescence technique.	4			6			10	8	Self-study of reference material. Focus on theoretical aspects of method.
14. Mass-spectrometry. Theory, instrumentation, principles of operation, sample for the analyses preparation, results (data) interpretation. Stable carbon and oxygen isotopes data application.	3						3	3	Self-study of reference material. Focus on theoretical aspects of method
15. Carbonate content analysis of sedimentary rock. Calculate calcite, dolomite and insoluble residue percentage and classify analysed rock samples.	4			4			8	8	Self-study of reference material. Sample preparation advantages and drawbacks
16. Sedimentary rock section clay content estimation from gamma-ray well-log.	4			2			6	6	Self-study of reference material
17. Peculiarities of analytical technique selection for chemical elements determination in sedimentary rocks.	4			2			6	6	Self-study of reference material
18. Statistical treatment of major and trace elements data of sedimentary rock: general statistics, correlation, factor and discriminant analysis	4			2			6	10	Self-study of reference material. Read “PAST” software user manual
19. Student‘s presentations	4			6			10	10	Self-study of reference material, preparation of presentation, seminar and defense, discussion.

20. Student's presentations, repetition, preparation for the exam					6			6	10	Self-study of reference material, preparation of presentation, seminar and defence, discussion.
Total	72				60			132	134	

Assessment strategy	**Weight,%**	**Deadline**	**Assessment criteria**
Assessment of the performance during seminars and exercises	10% (1 point)	During term	1 point– active in discussion, can answer to questions, analytical skills, performance in a course of the active involving lectures, ability to synthesize different kinds of presented information. 0.5 point – takes part in discussion, can answer to questions 0 point – passive in discussion, can't answer to questions
Assessment of exercises (main rock types identification)	10% (1 point)	During term	Skills are evaluated according recognition of various crystalline rocks. A point depends on the quantity of recognized samples (2x5).
Assessment of assay and presentation	20% (2 points)	End of April-beginning of May	The structure of assay and presentation, analysis of literature, interpretation and conclusions, scientific style and design, communication skills as well as ability to organize a work and work in the group (two students are preparing presentation on the same topic) is evaluated.
Final written examination	60% (6 points)	June	The written exam consists of 6 questions. Each question is evaluated: **1:** outstanding knowledge; **0,8:** good knowledge, can be minor mistakes; **0,6:** average knowledge, mistakes; **0,4:** knowledge is below average, important mistakes; **0,2:** minimum knowledge, many mistakes; **0:** knowledge is below the minimum requirement.

Author	**Year of publication**	**Title**	**Issue of a periodical or volume of a publication**	**Publishing place and house or web link**
Compulsory reading				
Dickin, A. P.,	2005	Radiogenic Isotope Geology (Second Edition)		Cambridge University Press
Faure, G. and Mensing T.M.	2005	Isotopes: principles and applications (Third Edition)		John Willey & Sons, Inc., Hoboken, New Jersey
Flugel E.	2004	Microfacies of carbonate rocks. Analysis, interpretation and application		Springer-Verlag. 976 p.
Gill R., ed.	2002	Modern Analytical Geochemistry. An introduction to Quantative Chemical Analysis Techniques for Earth, Environmental and Material Scientists		Pearson Education. 330 p.
Kaminskas D., Bičkauskas G., Brazauskas A.	2010	Silurian dolostones of eastern		http://www.kirj.ee/public/Estonian_Journal_of_Earth_Scie

		Lithuania		nces/2010/issue_2/earth-2010-2-180-186.pdf
Tucker M., ed.	1985	Techniques in Sedimentology		Blackwell Scientific publications. London..
Raith, M.M., Raase, P. &Reinhardt, J.	2012	Guide to thin section microscopy		ISB 978-3-00-37671-9(PDF) http://www.minsocam.org/msa/openaccess_publications/Thin_Sctn_Mcrscpy_2_rdcd_eng.pdf
Reed, S .J. B.	2005	Electron Microprobe Analysis and Scanning Electron Microscopy in Geology		Cambridge University Press
Rollinson H.	1995	Using geochemical data: evaluation, presentation, interpretation		Longman Ltd. 352 p.
Optional reading				
Allegre, C. J.,	2008	Isotope Geology		Cambridge University Press
Faure, G.	2001	Origin of Igneous Rocks: the Isotopic Evidence		Springer-Verlag
Motuza, G.	2006	Magminių ir metamorfinių uolienų petrologija		Vilnius, Vilniaus universiteto leidykla
Skridlaite, G, Whitehouse, M., Rimša, A.,	2007	Evidence for a pulse of 1.45 Ga anorthosite-mangerite-charnockite-granite (AMCG) plutonism in Lithuania: implications for the Mesoproterozoic evolution of the East European Craton	*Terra Nova*, Vol. 19, issue 4, 294-301	Blackwell publications
Skridlaite, G., Bogdanova S., Page L.	2006	Mesoproterozoic events in Eastern and Central Lithuania as recorded by 40Ar/39Ar ages	*Baltica*, Vol. 19 (2), 91-98	Vilnius