1. GENERAL INFORMATION

Study programme title	University graduate study programme in geology Subprogramme Geology of mineral resources and geophysical exploration		
Course title	Analyses of Mineral Parageneses	**Semester**	I.
Teacher	VESNICA GARAŠIĆ, Associate Professor	**Course code**	26940
Course type	☒ obligatory ☐ elective	**ECTS**	5
Location	Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb		
Language	☒ Croatian ☒ English		

Class type	Weekly hours	Teaching staff	Office hours	Room	E-mail
Class	2	Vesnica Garašić	8'00-10'00	V315	vesnica.garasic@rgn.hr
Practice	2	Vesnica Garašić	10'00-12'00	V315	vesnica.garasic@rgn.hr
Field lecture					

E-learning level		**Percentage of on-line class (max. 20%)**	0 %

2. COURSE DESCRIPTION

Course aims	The aim of the course is to develop skills required for virtual recognition and distinction of different generation of the paragenetic minerals in thin sections of igneous and metamorphic rocks and the recognition and interpretation of micro-texture features in order to clarify petrogenetic history, to make a precise rock classification, to determine the quality of rock as a raw material and to set the steps for further investigations by sophisticated analytical methods.
Requirements for applicants	The students have to be familiar with main optical properties of rock-forming minerals that can be recognized under the polarizing microscope and with the basic concepts of magmatic and metamorphic rocks.
Programme level learning outcomes with course contribution	The course contribution to programme level learning outcomes includes: a) the competence in basic knowledge in natural science placing emphasis on geology of mineral resources b) the implementation of theoretical knowledge in laboratory work

	c) the detection, investigation and evaluation of mineral deposits d) the drafting of mineral resources reports, studies and projects
Expected course level learning outcomes (4-10 outcomes)	The students will be able to: a) to distinguish different generations of paragenetic minerals in the thin sections of magmatic and metamorphic rocks b) to understand multicomponent phase diagrams being relevant for the origin of primary mineral parageneses of felsic, intermediate, mafic and ultramafic magmatic rocks c) to detect and explain the numerous micro-texture features of magmatic and metamorphic rocks in order to correctly interpret different sequences in their history d) to make precise classification of investigated magmatic and metamorphic rocks

Course contents by individual lessons

Class	Practice
Lecture 1: Primary mineral parageneses of magmatic rocks and their micro-texture. Alterations of igneous rocks.	**Exercise 1:** The recognition of the typical rock-forming minerals in different magmatic rocks (pyroxene, amphibole, olivine, muscovite, biotite, quartz, plagioclase, sanidine, microcline, orthoclase, garnet, spinel) and micro-textures of magmatic rocks.
Lecture 2: The binary phase diagrams with eutectic: diopside-anorthite phase diagram. Ophitic texture. Solid solution phase diagram: Plagioclase diagram. Plagioclase features under microscope: zoning in plagioclase; sieve texture in plagioclase. The effect of water pressure on plagioclase crystallization.	**Exercise 2:** Basalt, diabase and gabbro. Description of their mineral parageneses, micro-textures and the recognition of different alterations (chloritization, uralitisation, prehnitization, epidotization, sericitization). Zonation of plagioclase and sieve texture. The order of crystallization between diopside and plagioclase. Ophitic and intergranular texture.
Lecture 3: The binary phase diagrams with limited solid solution: albite-orthoclase phase diagram. Perthite and antiperhite. Definition of solvus.The effect of water pressure on albite-orthoclase crystallization. The virtual manifestation of different Na-K composition of the magma.	**Exercise 3:** Granite, granodiorite, syenite, diorite rocks. Recognition of their mineral composition and micro-texture of rocks. Perthite and antiperthite in thin section. Typical alterations of felzic and neutral rocks. Sericitization and kaolinitization of feldspars, chloritization of biotite.
Lecture 4: The binary phase diagrams with incongruent melting. Peritectic point. Forsterite-Quartz diagram. Leucite-Quartz diagram.	**Exercise 4:** Olivine gabbro, norite and troctolite, Description of their mineral compositions and micr-textures. Typical alterations of basic magmatic rocks: chloritizaton, prehnitization, serpentinitization.

Lecture 5: Ternary phase diagrams. Cotectic lines and ternary eutectic. Ternary phase diagram without ternary eutectic: diopside-albite-anorthite diagram. Intergranular texture. Ternary phase diagram with ternary eutectic: diopside-anorthite-forsterite diagram.	**Exercise 5:** Lherzolite and harzburgite rocks. Description of their mineral composition and micro-texture. Alteration of ultramafic rocks. Determination of the order of mineral crystallization.
Lecture 6: Ternary phase diagram with ternary eutectic: albite-K-feldspar-quartz. Cotectic crystallization and origin of graphic, micrographic and granophyric texture. Myrmekitic texture	**Exercise 6:** Pegmatite, monzogranite. Determination of their minerals, their alterations and micro-texture of rocks. Explanation of order of mineral crystallization and myrmekitic and micrographic texture.
Lecture 7: Ternary phase diagram with peritectic curve: forsterite-anorthite-quartz. Order of mineral crystallization in igneous rocks. Rosenbusch rule. The effect of pressure and water on melting point in different igneous rocks. Ophiolite: rock units, micro-texture, origin.	**Exercise 7:** Porphyroclastic lherzolite and harzburgite. Poikilitc micro-texture in granular lherzolite. Plagioclase, spinel and garnet lherzolite. Difference in mineral composition of peridotites from crust and mantle.
Lecture 8: Mineral parageneses in metamorphic rocks. Origin of new mineral paragenesis in solid state. Symplectite. Kelyphite. Different mineralogical-geochemical systems of protoliths. Types of metamorphism. Metamorphic facies.	**Exercise 8:** First colloquium: magmatic rocks. Recognition of symplectite and kelyphite in metamorphic rocks in thin sections.
Lecture 9: Metamorphic mineral growth. Different types of porphyroblasts (pre-kinematic, syn-kinematic, pos-tkinematic). Recrystallization during ductile deformation. Grain boundary migration, subgrain rotation.	**Exercise 9:** Results of first colloquium. Recognition of grain boundary migration and sugrain rotation and different types of porphyroblasts in rocks in thin sections.
Lecture 10: Metamorphism of mafic rocks (basalt, diabase, andesite, gabbro). Hydratation of mafic rocks. Chemical and mineralogical composition of mafic magmatic rocks. Metamorphic minerals originated by metamorphism of basic rocks in: greenshists subfacies, greenschists facies, amphibolite facies, granulite facies, eclogite facies and blueschists facies.	**Exercise 10:** Greenschists, blueschists, amphibolite, mafic granulite and eclogite: the determination of their mineral paragenesis in thin section and interpretation of their genesis.
Lecture 11: Metamorhpism of carbonate rocks. Marbles. Metamorpic reactions in carbonate rocks in different p-T condititons. Stability of talc, tremolite, diopside, forsterite, wollastonite, periclase, monticellite and clinohumite in marbles. Dependance of metamorphic minerals on CO_2 concentration in system.	**Exercise 11:** Marble and dolomitic marble: their mineral parageneses in thin sections and interpretation of their genesis.

Lecture 12: Metamorphism of pelitic rocks. Chemical composition of pelitic rocks. Typical minerals of metamorphosed pelitic rocks: chloritoide, biotite, garnet, staurolite, sillimanite, andalusite, cordierite and their stability in different p-T conditions. Slate, phyllite, micashists, gneiss, migmatite.	**Exercise 12:** Slate, phyllite, micaschists, gneiss: their mineral parageneses in thin sections and interpretation of their genesis.
Lecture 13: Metamorphism of quartz-feldspar rocks. Typical metamorphic reaction in this rocks. Augen gneiss, felsic granulite.	**Exercise 13:** Augen gneiss, felsic granulite: their mineral paragenesis in thin sections and interpretation of their genesis.
Lecture 14: Different types of metamorphic reactions. Phase transformaton reaction, exsolution reaction, solid-solid net transfer reaction, devolatilization reaction, continuous reaction, exchange reaction, redox reaction, rection involving dissolved species.	**Exercise 14:** The repetition of all studied rock samples in thin sections.
Lecture 15: Geothermobarometry. Exchange reaction (garnet-biotite). Solvus thermometer (calcite-dolomite, albite-K-feldspar, clinopyroxene-orthopyroxene). Trace element supstitution in some minerals (Ti in quartz). „Net transfer“ barometers. Pressure-temperature-time path, clockwise and anti-clockwise.	**Exercise 15:** The second colloquium: metamorphic rocks.

Students' obligations	Lecture and exercise attendance. The absence up to 3x from lectures and up to 3x from practical work is allowed. Positive results of two colloquiums. Submitted written report of magmatic and metamorphic rocks in thin sections, being studied during the semester.			
Students' work track *(indicate share in ECTS points for each activity so that overall ECTS number corresponds to class credits score):*	Class attendance	0,5	Research	
	Project		Report	1
	Colloquium	2	Seminar paper	
	Practical work	0,5	Oral exam	1
	Written exam		(Extra)	
Type of exam, grades and evaluation of students work during class and on final exam	The final exam consists of a submitted written report of analysed and interpreted thin sections of magmatic and metamorphic rocks being studied in the frame of practical work during the semester, and an oral exam. In order of continuously monitoring of student's progress over the semester two written colloquium will be performed. The positive results of both colloquium and class are examination requirements.			
Mandatory literature (available in the Library and via other media)	1. **Vernon, R.H.** (2004): A practical guide to Rock Microstructure. Cambridge University Press, Cambridge, 594 str. 2. **MacKenzie, W.S., Donaldson, C.H. & Guilford, C.** (1987): Atlas of igneous rocks and their textures. Longman Scientific and Technical, Essex, 148 str.			

	3. **Yardley, B.W.D., MacKenzie, W.S. & Guilford, C.** (1990): Atlas of metamorphic rocks and their textures. Longman, Essex, 120 str.
Aditional literature (at the moment of study program proposition application)	
Examination terms	30st January, 2019; 8st February 2019; 20st February 2019; 25st April 2019; 19st June 2019; 1st July 2019; 10st July 2019; 28st August 2019; 6st September 2019; 18st September 2019
Other	

Course Teacher:

Associate professor Vesnica Garašić