Raw Materials Exploration and Sustainability

COURSE NAME: Environmental Impact and Analysis

CONTACT INFORMATION

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COURSE CONTENT AND INTENDED LEARNING OUTCOMES (ILOs)

The objective of this course is giving the students an introduction to the geochemical processes, analytical techniques, and methods that are necessary to quantify and model the genesis of primary mineral deposits (typical ore bodies), recover secondary raw materials (mine tailings or industrial waste), quantity rock-fluid-gas interactions in geological environments, evaluate the interactions between mine fluids (or other waste fluids) and solids from the mineral deposit industry, and also evaluate environmental risks and rehabilitation good practices associated to mineral deposit exploitation. The course contents will include bulk composition of the earth and early earth differentiation; fundamental phase diagrams; major element compositions; mixing/extraction processes; trace element behaviour during melting and crystallisation; concepts of equilibrium thermodynamics; redox reactions, Eh-pH diagrams and their application; metal solubility and transport in natural aqueous solutions; solubility of ore and gangue minerals; mass transfer calculations; activity-activity diagrams and their application; mine drainage issues (generation, issues, remediation options); stable isotope systems (H, O, C, S); isotope fractionation, global reservoirs in water, bulk compositions.

Class teaching will be combined with practical exercises and with reference to the geochemical analytical techniques that are used in raw material studies. At the end of the course the students will gain the fundamental geochemical tools to mineral deposit exploration, recovery, and evaluation of environmental impact. A number of seminars from international academic guests (defined each year) and institutional partners (Rames partner) will provide hands-on knowledge and case studies of applications of geochemical tools.

Summary bullet list of expected, course-specific learning outcomes:

At the end of the course, students will:

- have an integrated and quantitative understanding of the geochemical processes leading to the genesis of mineral deposits;
- have an integrated and quantitative understanding of the environmental impact of mineral deposits, and the analytical questions linking them.

We divided the course in two modules that consider all the course topics, which will be taught considering the practical analytical approaches and will involve international researchers, industry representatives and institutional partners.

Aligning with the EIT OLOs: *please tick* X *at least two EIT OLOs that your course contributes to reach.*

X EIT OLO 1 - Making value judgments and sustainability competencies
The ability to identify short- and long-term future consequences of plans and decisions from an integrated scientific, ethical and intergenerational perspective and to merge this into a solution-focused approach, moving towards a sustainable society.

1 = peripherally relevant to the course content

This course is intended as a conceptual and technical toolbox that students may use for entangling a range of processes that include ore deposit genesis, geochemistry of mine rehabilitation, and the definition of good practices dealing with raw material geochemistry in general. The range of applications of such a toolbox is so broad that many future applications and solution-focused approaches are possible.

□ EIT OLO 2 - Entrepreneurship skills and competencies
The ability to translate innovations into feasible business solutions

□ EIT OLO 3 - Creativity skills and competencies

The ability to think beyond boundaries and systematically explore and generate new ideas.

X EIT OLO 4 - Innovation skills and competencies
The ability to use knowledge, ideas and technology to create new or significantly improve products, services, processes, policies, new business models or jobs.

2 = highly relevant to course content

The "geochemical toolbox" is an established set of concepts, analytical techniques, and methodologies that is ideal and necessary to handle an uncountable number of processes dealing with the geochemistry of raw materials. Laboratory exercises and seminars by industry/university researchers, add particular efficiency in the use of the toolbox. We believe that such combination is ideal to foster trans-disciplinary thinking and a broad range of competencies in the students. For instance, within module II the toolbox will be used to analyze volcanic systems as analogues of magmatic-hydrothermal ore-forming environments.

X EIT OLO 5 - Research skills and competencies
The ability to use cutting-edge research methods, processes and techniques towards new venture creation and growth and to apply these also in cross-disciplinary teams and contexts

1 = peripherally relevant to the course content

The "geochemical toolbox" taught in this course is the same that we use for our research, and the case studies we present to the students are taken from the publication record. Similarly, the case studies presented by the international researchers, the industry representatives, and the institutional partners contributing to this course will show up-to-date applications of geochemistry to the exploration and exploitation of mineral deposits, mine rehabilitation, and environmental studies. We will try to scan the evolution of the scientific methods in this field, which will inevitably reveal pioneering key researches. Students will elaborate on the literature provided by the instructors, and will prepare written outputs/essays and seminars that are part of the final grade. We believe that this approach, in combination with a venture attitude of the students, will be useful to foster venture creation.

X EIT OLO 6 - Intellectual transforming skills and competencies
The ability to transform practical experiences into research problems and challenges
2 = highly relevant to course content

The relevance of the studied examples (e.g., hydrothermal-geothermal systems, degassing volcanoes, rehabilitation of mine sites) will provide explicit problems and research challenges. We will try to use these topics to tease intellectual skills and creativity.

□ EIT OLO 7 - Leadership skills and competencies
The ability of decision-making and leadership, based on a holistic understanding of the contributions of higher education, research and business to value creation, in limited sized teams and contexts.

ASSESSMENT METHODS AND GRADING SYSTEM

Considering the learning objectives and the teaching methods, the assessment will take into account the following components:
1. Level of independence and effectiveness of individual students during exercises
2. Class presentation (group or personal)
4. Written test
5. Oral exam.

Individual performance will be evaluated through a critical reflection on the personal work carried out during assignments. These components will allow the evaluation of EIT OLOs 4 and 6, which are the most relevant of the course. The oral part of the exam, in particular, has the objective to assess the level of competencies and knowledge creativity. EIT OLOs 1 and 5, which are peripherally relevant, will evaluated mainly by the level of participation and effectiveness during laboratory exercises and in-class discussions and presentations.
The grades in the Italian university system are expressed out of thirty. The passing grade is 18/30. In case of full grade (30/30) the Professor(s) may also decide to award honors (lode).

Below there is the breakdown of the final grade:

ASSESSMENT METHOD	WEIGHT ON FINAL GRADE
Laboratory exercises	30%
Class participation	20%
Written test	25%
Oral test	25%

COURSE SESSIONS

In detail, these are the topics included in modules I and II of the course:

MODULE I – Nicholas Pearce

Bulk composition of the earth and early earth differentiation. Fundamental phase diagrams. Major element compositions. Mixing/extraction processes. Trace element behaviour during melting and crystallisation. Redox reactions. Eh-pH diagrams and their application. Mine drainage issues (generation, issues, and remediation options). Stable isotope systems (H, O, C, S) and isotope fractionation. Global reservoirs in water. Bulk compositions.

MODULE II – P.S. Garofalo

Electrolyte theory. Equilibrium constants in geochemistry. Metal solubility and transport of metals in natural aqueous solutions. Solubility of ore and gangue minerals. Mass transfer calculations. Fluid-mineral equilibria in ore deposits. Chemical potential diagrams. Mineral stability diagrams.