Departamento de Geologia

COURSE SYNTHETIC FORM: ORE DEPOSITS

1 – Name, Credits and Functioning	
Course	Ore Deposits
Degree(s)	Geology and Natural Resources (compulsory) Applied Geology and Environment (optional)
Level [i] / Positioning in the Curricular Plan	4 / 4th year, 7º semester
Credits *(European Credit Transfer System)*	6 (4 of Lectures + 2 of Lab work)
Teaching (during 15 weeks)	30 h + 45 h (2 h Lect + 3 h Lab per week)
Contact hours (during 15 weeks)	30 h (2 h per week of open tutorial)
Required time for learning (school semester)	60 h (including the time needed for assessment preparation)

2 – Rationale / Objectives (200 words maximum)

This discipline is mainly intended for students planning a professional career in Economic Geology or otherwise interested in enhancing their understanding of fluids dynamics in the Lithosphere, fluid/rock interaction and processes responsible for the development of geochemical anomalies. The main focus is, therefore, on the major types of ore-forming systems, identifying the fundamental physical and chemical features, as well as the geodynamic framework, of paradigmatic examples of each one. Additionally, the elements that allow understanding the critical issues related to ore-forming processes and to realise the reasons that justify the methods (geological, geophysical and geochemical) commonly used in mineral exploration, will be reported and interpreted. In order to support this approach, several other topics are addressed, namely those related to: *i)* the processes that favour both the development of sustained heat flow anomalies and effective mass-heat transfer in Lithosphere; *ii)* the sources of metals and fluids; *iii)* the compositional variation shown by common ore-forming fluids and the constraints usually imposed to their crustal circulation in large volumes; and *iv)* the main mechanisms involved in metal solubility, transport and deposition.

3 – Background requirements (70 words maximum)

The proposed contents and learning methods assume that students are able to mobilise their knowledge in different issues, thus presupposing achievement in disciplines of lower levels, namely: Mineralogy, Geochemistry, Igneous Petrology, Metamorphic Petrology, Sedimentary Petrology, Structural Geology, Mineral Resources and Environmental Impact, besides all the compulsory disciplines on Physics, Chemistry and Mathematics. Competences usually developed in Computation Applied to Geology, Geo-mathematics and Marine Geology, are also useful.

4 – Syllabus Plan and Content (250 words maximum)

Lecture Programme

I – Base concepts and Methodologies (8 h): Metal Solubility, Transport and Precipitation; Fluid/Rock Interaction; Fluid Inclusion Studies; Isotopic (stable and radiogenic) Studies.

II – Ore-forming Systems (19 h): Classification; Systems related to endogenous processes (hydrothermal, magmatogenic and metamorphogenic); Systems related to exogenous processes (sedimentary, of chemical precipitation and of chemical weathering). Paradigmatic examples; general characterisation and metallogenic models.

III – Final Syntheses (3 h): Heat flow anomalies in Lithosphere and their relation to metallogenesis; Ore-forming fluids: origin, compositional variability and circulation regimes; Geochemical zoning at larger scale and metallogenic provinces.

Lab Programme

Sets of Lab works designed to facilitate understanding of themes covered in Lectures, particularly the analysis of regular geological settings and the characterisation of representative ore and host-rock samples (hand-specimens and respective polished this sections) belonging to distinct mineralisations: *i)* massive (polymetallic) sulphides; *ii)* precious metals; *iii)* porphyry Cu and Mo; *iv)* Sn-W lodes; *v)* pegmatite lodes; *vi)* magmatic Cr, Ni-Cu(-PGE) and Fe-Ti-V; *vii)* skarn; *viii)* stratiform Fe (and Mn); and *ix)* U.

5 – Learning Outcomes / Competences [ii]

- Demonstrate the role and relative importance of the major variables involved in the metal solubility, transport and precipitation processes in different earth systems.
- Construct, manage and assess the adequate referential of analysis for the main ore-forming systems related to exogenous and endogenous processes, considering their fundamental characteristics (lithological, geochemical, structural and stratigraphical).
- Select and use the methodologies suitable for ore characterisation, as well as to determine their age and to elucidate the major sources of metals.
- Recognise and evaluate the importance of weathering on metal dispersion or concentration in addition to the efficiency of the sedimentary processes *s.l.* on the development of metal anomalies.
- Decide on the methodologies adequate to characterise the compositional variability usually shown by magmas and mineralising fluids, as well as to conclude on their origin.
- Be aware and know how to evaluate either the major mechanisms of mass-heat transfer in Lithosphere or the imposed constraints and the inherent consequences of fluid circulation (and residence) in rock media.
- Gain an understanding and operate the diverse parameters used in the classification of Ore Deposits and, accordingly, appraise both the singularity of each deposit and the analogies that support the notion of typology (and class).
- Identify, describe and compare (by combination of summarised elements) the critical characteristics of the main types of Ore Deposits, reporting their metal specificity and economic significance (in the past, present and future).
- Integrate the available factual elements of different nature in order to illustrate and discriminate the complexity of the ore-forming systems and to realise the multiple factors intervening in their formation and evolution.
- Comprehend the importance of multidisciplinary approaches designed to the integrative construction of metallogenic models useful to ore exploration and know to point out their weakness and strongest features.
- Identify, compare and evaluate the most appropriate methodologies for the exploration of different ore types in function of different factors (geological, geomorphic, climatic, economic, available resources and timing).

6 – Indicative reading list (text books and supplementary sources of information)

Major

- Robb L. (2005). *Introduction to Ore-forming Processes.* Blackwell Publishing, Oxford, 373 pp.
- Guilbert J.M., Park C.F. (1986). *The Geology of Ore Deposits.* Freeman, San Francisco, 985 pp.
- Sawkins F.J. (1990). *Metal Deposits in Relation to Plate Tectonics.* 2nd Ed., Springer Verlag, Berlin, 461 pp.

Additional

- Several sets of papers and book chapters of recommended reading and optional consult, including selected information on particular case studies concerning, particularly, ore-forming systems located in the Variscan Orogen.

7 – Other Elements of Study and Classroom Guiding

Lectures

- Detailed summaries of lectures, study guides and self-evaluation forms

Labs

- Specific assignments for each mineralisation type studied
- *Tables For Microscopic Identification of Ore Minerals*. Economic Geology ♦
- Ramdohr P. (1969). *The Ore Minerals and Their Intergrowths.* 2nd Ed., Pergamon press, Osford, 1205 pp. ♦
- Carisg J.R., Vaughan F.J. (1994). *Ore Microscopy and Ore petrography.* 2nd Ed., John Wiley & Sons, New York, 434 pp.

♦ Available for use in Lab sessions.

8 – Assessment	
	Relative Weight in the Final Grade (%)
Alternative 1 (*)	
• Formative Assessment	
o 4 Self-evaluation forms (lecture programme)	10
o 9 Lab works	50
• Summative Assessment	
o 2 interim tests including multiple choice and constructed (short and long written) responses of questions regarding the lecture programme.	40
Alternative 2	
• Final Examination (**)	100
(*) Continuous assessment and tutorial work that measure the individual student progress during the school semester. In each component, students must demonstrate an acceptable level of achievement of the course outcomes, *i.e.* a threshold criterion of 50% of the respective mark. (**) It consists of a mixture of selected (multiple choice) and constructed (short and long written) response items plus 3 questions concerning Lab problems (numerical performance and results discussion).	

[i] Both Degrees (in *Geology and Natural Resources* and in *Applied Geology and Environment*) have a curricular programme of 8 semesters (4 years long). Disciplines included in these programmes are ordered according to a gradual and coherent sequence of levels (1 to 4) that follow a framework of learning outcomes, recognising a student progression characterised by an increase of its autonomy and of the responsibility that is expected of the learner in the guidance given and the tasks set. Disciplines of level 1 assume no previous knowledge of Geology, thus having an introductory (and transversal) character. Disciplines of level 2 provide an essential grounding in many fundamental concepts and techniques common to all branches of Geology. Disciplines of level 3 offer a core programme of advanced and integrative topics oriented to: (1) the manipulation of relatively complex database and production of simple numerical modelling included in quantitative approaches to common problems in Geology; and (2) the use of key-concepts in solving either transversal problems (eventually as a project work) or specific issues preferentially dealing with questions directly related to the course (Degree) objectives. Disciplines of level 4 are designed in order to favour the consolidation of the professional profile defined for the course (Degree) and should also include advanced themes of synthesis demanding the rational use of the knowledge obtained along the entire learning path.

[ii] Learning outcomes are here used in the sense given by the glossary of the *Tuning Educational Structures*, i.e.: (...) *statements of what learner is expected to know, understand and/or be able to demonstrate* (and do) *after a completion of a process of learning* (…). Therefore, competences represent a combination of attributes (broadly referring to aptitude, proficiency, capability, skills and understanding, *etc.*) that reflect the qualification (degree or extent) to which a person is able of performing them.