Grado en Geología
26408 - Structural Geology

Course 2010 - 2011

Curso: 2, Semestre: 1, Créditos: 9.0

Basic information

Teachers

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Recommendations to attend this course

This branch of the Geology requires the development of a 3-D visualization of the tectonic structures, as well as observation and interpretation abilities both in the lab and in the field. This course in Structural Geology values the comprehension and the reasoning capabilities as much as the rote learning.

Course Schedule and Deadlines

The 9 ECTS of this subject correspond to 90 hours of presential education, which will be arranged in the following way:

- 30 hours of theoretical classes (3 h /week): Monday, Tuesday: 11:00 -12:00; Wed.: 10:00 - 11:00 h.

- 5 hours of seminars.

- 25 hours of lab sessions (2.5 h / week, 10 sessions): Monday, 16:00-18:30 h

- 30 hours of field-work

+ Field trip 1: Friday, 8 OCT.

+ Field trip 2: Friday, 5 NOV.

+ Field trips 3 and 4: Friday and Saturday, 26 and 27 NOV.

+ Field trip 5: Friday, 10 DEC.

- Third week of September: Beggining of theoretical classes

- Fourth week of September: Beggining of practical sessions

- Second week of January: End of theoretical and practical classes

- End of January- beggining of February: Written exercises

Home

Learning outcomes that define this course

The student, in order to pass the course, will have to show her/his competence in the following skills:

1:

To pass the subject the student should be able to ...

1) Identify the main type of tectonic structures as well as to know their geometric characteristics and genetic mechanisms

2) Construct geologic maps as well as schemes showing the geometry and relationship of the structures in the field

3) Measure the attitude of planes and lines using the geologic compass

4) Represent and read structural elements (planes and lines) by means of orthographic projection, stereographic projection, cross sections and block diagrams

5) Find and read scientific articles as well as select and understand the most relevant information.

6) Work alone and in a group, as well as to defend scientific results with reasonable arguments.

Introduction

Brief presentation of the course

Structural Geology is a branch of Geology concerning rock deformation, mainly that which has been caused by the action of the internal forces of the Earth. This subject provides essential background firstly for identifying, and secondly for analyzing the geometry, kinematics and dynamics of the main tectonic structures.

Teacher of the course *Structural Geology*: Prof. Héctor Millán.

Competences

General aims of the course

The expected results of the course respond to the following general aims

The general goals of the subject are brought up at three levels:

(a) Learning of conceptual and methodological aspects through theoretical and practical classes (deductive learning)

(b) Practical use of techniques for analytical treatment and plotting of structural data.

(c) Development of research capabilities using empiric methodologies, from field-data collection to final interpretation.

General goals:

The student should:

1) know the different types of tectonic structures: definitions, classifications; as well as geometric, kinematic, and dynamic characteristics at different scales.

2) develop observation abilities and collect field data.

3) learn the main techniques to represent and analyze tectonic structures.

4) know how to apply the concepts and models of Structural Geology to regional scale interpretations.

5**)** be able to work alone and in a group.

6) learn to be critical with scientific information, and be able to express clearly his/her scientific results.

Context/Importance of the course for the master degree

Structural Geology is a fundamental tool to decipher the geology of deformed areas and thus it should be considered an indispensable knowledge for any geologist. On the other hand, Structural Geology deals with geometrical aspects of deformation and thus it is closely related with disciplines like Geological Mapping, Geophysics and Tectonics.

After completing the course, the student will be competent in the following skills:

1:

The student should be able to:

1) Recognize, describe and classify the main tectonic structures.

2) Interpret the genetic mechanism of the studied structures.

3) Apply the most appropriate geometric, kinematic or dynamic method to study a specific structure or group of structures.

4) Identify in the field deformational structures and their geometric elements.

5) Collect structural data in the field. Be able to recognize outcrop and regional scale structures and to draw schemes and geologic cross-sections. Measure linear and planar elements in the field.

6) Identify deformational structures at hand and thin-section scale.

7) Have a good command of the main structural techniques related with the representation and analysis of geometric data: stereographic projection, orthographic projection, cross sections, block diagrams, contour maps.

8) Reconstruct the genetic mechanisms of real structures, as well as their kinematic and dynamic evolution, and in the case of poliphasic deformations, their chronological sequence.

Relevance of the skills acquired in the course

Geologic structures provide part of the basis for recognizing and reconstructing the profound changes that have marked the physical evolution of the Earth's outer layers, as observed from the scale of the plates down to the scale of the microscopic. Understanding the nature and extensiveness of deformational structures in the Earth's crust has both scientific value and practical benefit. But, there is a philosophical value as well. Our perceptions of who we are and where we are in time and space are shaped by facts and interpretations regarding the historical development of the crust of the planet on which we live. Knowing fully the extent to which our planet is dynamic, not static, is a reminder of the lively and special environment we inhabit ..... Once the conceptual framework within which structural geologists operate is grasped, the Earth begins to look different. In fact, natural physical processes and natural physical phenomena, whether geologic or not, never quite look the same again (*from Davis and Reynolds, 1996*).

Evaluation

Assessment tasks

The student will prove that he/she has achieved the expected learning results by means of the following assessment tasks:

1:

1) Question papers. The students will have to answer to question papers, alone and in groups, dealing with conceptual and methodological aspects. This activity will be mainly related with the seminar exercises. (Evaluation of skills 1, 5 and 6).

2) Laboratory exercises. The practical exercises carried out in the lab will be corrected every week. (Evaluation of skill 4).

3) Field work. The attendance to the field trips is compulsory. The personal work, expressed in the student's note-book, and the attitude of the student in the field, will be evaluated. (Evaluation of skills 2, 3 and 6).

4) Written exercises. A theoretical-practical exercise and a practical exercise will be carried out during the period of exams. The theoretical-practical exercise will be constituted by two parts: a) a test and/or a set of short questions, and b) questions that must be answered by means of drawings. The practical exercise will be closely related with the practical sessions of the course. (Evaluation of skills 1, 2 and 4).

Assesment

(a) As a general rule, to pass the course it will be necessary to:

1.- Participate in the laboratory and seminar activities and attend the field trips.

2.- Obtain a grade higher than 5 in the theoretical-practical exam.

3.- Obtain a grade higher than 5 in the practical exam.

(b) Assessment of the course:

- Lab work ..... 5 %

- Seminars ..... 20 %

- Field work ..... 10 %

- Practical exercise ..... 30 %

- Theoretical-practical exercise ..... 35 %

Activities and resources

Course methodology

The learning process that has been designed for this course is based on the following activities:

The program of the subject is just the framework that should guide the active learning of the students. The students will have class-notes given by the professor as the basis for their learning, but they must extend the information given in class using that coming from technical books and scientific journals. The practical learning will prevail over the theoretical one. The laboratory sessions will be mainly devoted to the analysis of the most common tectonic structures. The field work will focus on the recognition of the studied structures, the determination of their geometries, structural relationships, ages, ..., and the obtained data will be represented on the student's note-book by means of tectonic schemes, cross-sections, etc, and by simple geological maps. The tutorials will be considered another academic activity where the student will be free to ask any doubt related with the subject.

It is important to note that the specific terminology used in this course will also be taught in Spanish.

Outline of the Programme

The programme offered to the students to help them achieve the learning results includes the following activities :

1:

Activity 1: Conceptual, descriptive and genetic aspects of tectonic structures. The most common geometric, kinematic and dynamic methods.

Methodology:

- **Theoretical-practical classes** (3 ECTS)

- **Seminars**: oral presentations and discussions. (0,5 ECTS).

Part 1: INTRODUCTION

1. Introduction to the course. Structural Geology: Goals and methods; history. Geometry, kinematics and dynamics in Structural Geology.

2. Representing structural data. Maps and geologic cross sections; block diagrams. Attitude of lanes and lines. Strike and dip; apparent dip, plunge and pitch. Orthographic and stereographic projection.

3. Stress, strain and rheological behavior. Concepts and parameters of stress and strain. Stress-strain relationship; experimental testing. Rheological behavior: elastic, plastic, viscous, fragile; limiting factors (pressure, temperature, ...). Structural levels.

Part 2: DUCTILE STRUCTURES

4. **Basic concepts of deformation**. Longitudinal strain and shear strain. Homogeneous and inhomogeneous deformation. Continous and non-continous deformation. Finite and infinitesimal deformation. 2-D and 3-D homogeneous deformation. Strain ellipse and strain ellipsoide. Principal strain axes. Homogeneous simple shear.

5. **Tectonic fabrics**. Prefered orientation of lines and planes caused by ductile deformation. Tectonic fabrics and their relation with the strain ellipsoide. Continous and non-continous foliations: mechanisms and classifications. Linear fabrics.

6. **Textural scale deformation mechanisms.** Grane-scale and extra-crystalline scale pressure-solution mechanisms; diffusion mechanism; preassure shadows. Physical mechanisms: rotation, *microboudinage*, cataclasis. Mecanismos físicos: rotación, *microboudinage*, cataclasis. Lattice deformation: sliding along cristallographic planes, mechanical twining. Crystallization; hardening. Strain and metamorphic crystallization relationships.

7. **Ductile shear zones**. General characteristics. Ductile shear zones and passive markers. Associated folds. Ductile shear zones and internal fabrics. S-C fabrics. Conjugated ductile shear zones.

8. **Fold geometry**. Geometric elements of a fold. Determination of the axis and the axial surface of a fold. 2-D and 3-D folding classifications.

9. **Folding mechanisms**. Genetic fold classification; kinematic mechanisms and their relation with the geometric types. Kinematics of flexural folds: buckling, kinking, bending; bed internal deformation; flexural slip and flexural flow. Passive folding. Flexure and flattening in folding. Axial plane cleavage; cleavage refraction.

Part 3: BRITTLE STRUCTURES

10. **Basic concepts of stress**. Stress as a vector. Normal and shear components. State of stress at a point: stress tensor; stress ellipse and stress ellipsoide; principal axes. 2-D Mohr circle. Field and stress trajectories. Lithostatic stress.

11. **Mechanics of fracturing and faulting.** Coulomb fracture criterion: failure envelopes. Cohesion and angle of internal friction. Griffith theory. Influence of pore fluid preassure. Sliding over fractured rocks.

12. **Stylolitic surfaces and extension veins.** Different types of discontinous structures taking into account the fracture theory. Stylolites and stylolitic surfaces. Geometric and genetic classifications. Relationships with the stress axes. Extension veins; geometry and fillings; normal and oblique extension veins; relatioship with the stress axes.

13. **Faults**. Geometry; classifications. Kinematics; classifications: normal, reverse and strike-slip faults. Net displacement and fault separation; determining strike, sense and magnitude of fault displacement; kinematic indicators. Dynamics: Anderson conjugate fault system; relationship with stress axes. Fault rocks: breccias, gouges, mylonites, ...

14. Joints. Geometric analysis: orientations and "architectural" styles; size and spacing. Photographic analysis: ornamentation, associated microstructures and joint propagation. Interaction between joints and relative chronology. Joints and stress axes.

15. **Semibrittle shear zones.** Riedel experiment: secondary fractures R y R'. T and S structures. Progressive deformation. Conjugated semibrittle shear zones.

Part 4: STRUCTURAL ASSOCIATIONS

16. **Compressional tectonics in the lower structural.** Orogens: types; general architecture; evolution. Deformation in the lower structural level. Pliegues de aplastamiento: foliaciones y lineaciones asociadas; *rods, mullions, boudinage*. Zonas de cizalla dúctil y pliegues pasivos. Complejos gnéisicos y migmatíticos.

17. **Thrust systems.** Geometric elements; map expression; Thin skinned and thick skinned tectonics. Associated folding: fault-bend folds, fault-propagation folds and detachment folds. Kinematics and evolution of the thrust systems; imbricates; duplexes. Dynamic aspects; Orogenic wedge. Syntectonic sedimentation: foreland basins and piggy-back basins.

18. **Extensional tectonics.** *Rifts*: types; general architecture; evolution. Normal faults: geometry; listric faults. Associated faults: drag folds and roll-overs. Normal fault systems; *horst* y *grabens*; extensional duplexes. Syntectonic sedimentation in extensional basins. Stress fields: uniaxial, triaxial and multidirectional extension. Late extension in orogens.

19. **Strike-slip tectonics.** Geometric elements and fault kinematic patterns. Extensional and compressional relay zones. Splay faults; duplexes; transfer faults. Transpression and transtension: positive and negative flower patterns. Dynamic aspects: Stress fields; stress field perturbations; plate-boundary strike-slip tectonics and intraplate strike-slip tectonics.

20. **Poliphasic deformation.** Uncertanties on the progressive and poliphasic deformation; deformation phases and evolution of the stress fields. Superposed folding affecting passive and flexural folds. Analysis of superposed foliations and lineations. Inversion tectonics; Fault reactivation; positive and negative inversion.

21. **Other structural associations.** Gravitational tectonics; landslides; slumps; olistholiths. Diapirs: geometry and mechanisms. Impact structures. Intrusive bodies and their relation with the regional stress field.

Activity 2: How to function in the field.

Methodology: **Field work** (3 ECTS)

Fiel Trip 1

- Locality: Cerveruela - Puerto de Paniza (Zaragoza); Paleozoic.

- Date: Friday, 8th October.

- Activities: Construction of a regional scale cross-section. Study of ductile and brittle tectonic structures.

Jornada 2

-Locality: Isuela - Pico del Águila (Huesca); Mesozoic - Tertiary.

- Date: Friday, 5th November.

- Activities: Construction of a regional scale cross-section. Study of brittle tectonic structures. Synsedimentary structures.

Field trips 3 and 4

- Locality: Aliaga (Teruel); Cretaceous and Tertiary.

- Date: Friday, 26th / 27th November.

- Activities: Study of poliphasic deformation. Geometric and kinematic reconstruction of superposed folding. Tecto-sedimentary relationships.

Field trip 5

-Locality: Montalbán-Molinos (Teruel); Mesozoic and Tertiary.

- Date: Friday, 10th December.

- Activities: Construction of a regional cross section of a thrust system and associated folds. Study of brittle structures (faults, stylolites, extension veins): Field schemes, measuring of linear and planar elements, timing of deformation.

Activity 3: How to analyze meso and micro-scale structures. Reconstructing and analyzing the geometry, kinematic and dynamic of tectonic structures.

Methodology: **laboratory sessions**

(2,5 ECTS).

1. Geologic cross sections (I) constructed from geologic maps with folds, normal faults and unconformities.

2. Stereographic projection (I). Lines and planes; angles. Stereographic projection (II). Relationship between lines and planes. Poles to planes, pitch; plane intersection; true and apparent dips; projection of lines onto planes.

3. Tectonic fabrics at large scale. Identifying linear and planar elements. Relationship with the strain ellipsoide. Orthographic projection. True and apparent dips. 3 points problem. Intersection of planes.

4. Stereographic projection (III). Fitting lines and planes to small and large circles; tilting and rotations; geometric and kinematic analysis of flexural folds.

5. Stereographic projection (IV). Using computer programs to plot lines and planes. Geometric and kinematic analysis of folds generated by flattening. Stereographic projection (V). Using computer programs to analyze deformation caused by stylolites, extension veins and faults.

6. Stress analysis using Mohr circle in 2D.

7. Riedel experiment: shear zones in semibrittle rocks..

8. Geologic cross sections (II). From geologic maps presenting folds, thrusts and angular unconformities.

9. 3D methods (I). Contour maps. Fault net slip.

10. 3D methods (II). Blocks diagrams.

Course planning

Calendar of actual sessions and presentation of works

- 20-SEP-10: Starting of theoretical classes.
- 21-SEP-10: Starting of practical sessions.
- 08-OCT-10: 1st field trip.
- 05-NOV-10: 2nd field trip.
- 26-27 NOV-10: 3rd and 4th field trip.
- 11-NOV-11: End practical sessions.
- 10-DEC-11: 5th field trip.
- 12-JAN-11: End theoretical classes.
- JAN-FEB 2011: Written exercises.

TUTORIALS:

Monday, Tuesday: 9.00-11:00; Wednesday: 9:00-10:00 and 13:00-14:00.

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