Grado en Geología
26408 - Structural Geology

Course 2012 - 2013

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

- 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:

A) ASSESSMENT OF STUDENTS THAT ATTEND CLASS REGULARLY

To track the improvement and knowledge of the students, part of the assessment will be carried out during the learning process (continuous assessment) and part at the end of the course (final assessment)

A.1. Continuous assessment

1) *Question papers/questions for oral answer.* The students will have to answer to question papers or questions for oral answer, alone or 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).

A.2. Final assessment

4) Written exercises. A theoretical-practical exercise and a practical exercise will be carried out during the period of exams (4-5 hours). The theoretical-practical exercise will be constituted by two parts: a) a test and/or a set of short questions, and b) questions that, in most cases, may 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).

B) ASSESSMENT OF STUDENTS THAT DO NOT ATTEND CLASS REGULARLY

Global assessment

Those students that have not attended the course regularly, as well as those who wish to, may take a global exam:

February exam: It may be an oral (speaking) exam or a written exam. The evaluation may include any activity related to field work.

September exam: It may be an oral (speaking) exam or a written exam. The evaluation may include any activity related to field work.

1) oral exam or a written exam. Duration of the exam: 3-5 hours.

2) a practical exam where the student will have to solve laboratory and field exercises similar to those carried out during the course. Duration of the exam: 3-5 hours.

Assesement criteria

(a) Assessment of the course for students that attend classes regularly:

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.

Evaluation of skills:

- Lab work .... 5 %

- Seminars .... 15 %

- Field work .... 10 %

- Practical exercise .... 30 %

- Theoretical-practical exercise .... 40 %

(b) Assessment of the course for students that do not attend classes regularly:

- Written exam .... 50 %

- Practical exam .... 50 %

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. Lines and planes in Structural Geology. Orientation of lines and planes. True and apparent dips. Field notes. Conventional signs. Analysis of the orientation of lines and planes. The Stereographic projection.

3. Stress. Definition of force and units. Definition of stress and units. Simple calculation of stress. Lithostatic stress. Stress due to contact forces. Components of stress. State of stress in a point. Tensor and stress ellipspoid. Types of state of stress. Mohr stress diagram, Mean stress, deviatoric and differential stress. Stress field and styress trajectories.

Part 2: DUCTILE STRUCTURES

4. **Strain**. Definition and types of deformation. Classification of internal deformation: continuous/discontinuous, fragile/ductil and homogeneous/inhomogeneous. Vector, trajectory and displacement field. Finite, infinitesimal and progressive deformation.

5. **Rheology and mechanical behavior of rocks.** Concept. Mechanical analogies. Laboratory tests. Rock behavior during deformation: short-duration loading and long-duration loading (creep). Factors that influence the rock behavior. Fragile/ductil material and competent/incompetent rock. Rheological behavior and depth: structural levels.

6. **Deformation mechanisms and microstructures.** Introduction. Brittle deformation mechanisms. Ductile deformation mechanisms. Recovery, recrystallization and neomineralization. Deformation mechanisms and physical conditions during deformation.

7. **Rock fabrics**. Introduction: concept of fabric. Types of fabrics. Tectonites. Foliations. Lineations.

8. **Folds**. Definition. Geometrical and physical elements. Fold description: shape, tightness, size and attitude. Fold clasifications. Major and minor folds. Harmonic and disharmonic folds. Fold termination and fold associations. Large scale folding.

9. **Folding mechanisms**. Introduction: main types of folding mechanisms. Flexure: buckling and bending. Internal strain in flexural folding. Longitudinal strain in the hinge zone. Shear strain in the flanks. Flattening: homogeneous ans inhomogeneous. Flow: passive folding. Donathe and Parker (1964): genetic classification.

Part 3: BRITTLE STRUCTURES

10. **Rock mechanics / rock fracturing**. The fundamental fracture modes. Intoduction to rock mechanics. Griffith, Coulomb and von Mises' fracture criteria. Testing prefractured rocks. Influence of pore fluid pressure. Classification of fractures.

11. **Joints and shear fractures.** Introduction: joints and shear fractures. Geometry: shape and descriptive parameters. Joint patterns. Systems of joints. Relative chronology. Spacing. Recording data. Dynamic interpretation.

12. **Stylolites surfaces and extension veins.** Definition of stylolitic surface and stylolite. Pressure solution mechanism. Geometry of stylolites. Normal and oblique stylolitic surfaces. Relationship between stylolites and stress axes. Quantifying shortening. Genesis of stylolitic surfaces. Definition and characteristics of extension veins. Relationship between extension veins and stress axes. Relationship between stylolites and extension veins: dynamic implications.

13. **Faults**. Definition. Classification based on the fault surface attitude. Geometric elements. Net slip: components. Normal. reverse and strike-slip faults. Displacement criteria. Extensional and contractional faults. Fault systems. Conjugate faults: Anderson's theory and kinematics. Fault rocks.

14. Thrusts. Definition. Geometric elements and geometric characteristics. Thin and thick-skinned tectonics. Map view. Associated folding: detachment folds, faul-bend fold, and fault-propagation folds. Trishear folding. Thrust sequences and kinematics. Tectonic environment for thrust faulting.

15. Normal faults. Definition. General characteristics. Geometric elements. Folds associates to normal folds, drag folds, roll-over anticline and other fault-bend folds. Normal fault systems and terminology: horst, graben, half-graben, listric fan,etc. Tectonic environment for normal faults. Normal fault kinematic model.

16. Strike-slip faults. General characteristics. Geometry and terminology for bends and step overs. Pull-apart basins and pop-ups. Strike-slip duplexes.Tectonic environment for strike slip faulting. Modelling.

Part 4: Seminars.

17. **The nature of shear zones and types of shear zones.**

18. Salt structures. Diapirs.

19. Gravitational structures.

20. Impact structures. Meteorites.

21. Superposed folding.

22. Tectonic structures in plutons.

23. Non tectonic structures in Structural Geology

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, 7 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 - Cenozoic.

- Date: Friday, 4 November.

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

Field trip 3

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

- Date: Friday, 17 November.

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

Field trip 4

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

- Date: Friday, 26 November.

- 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.

Field trip 5

- Locality: Vadiello (Huesca); Mesozoic and Cenozoic.

- Date: Friday, 16 December.

- Activities: Collecting field data along a structural traverse in the External Sierras. Study of brittle tectonic structures. Tecto-sedimentary relationships. Construction of a geolocical cross section.

<u>Activity 3</u>**: 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. Geologic cross sections (II) constructed from geologic maps with folds, thrust faults and angular unconformities.

3. Stereographic projection (I). Lines and planes. Poles to planes. True and apparent dips. Pitch of a line. Intersection between planes.

4. Stereographic projection (II). Angles between lines and planes. Projection of lines onto planes. Fitting lines and planes to small and large circles. Tilting and rotations.

5. A) Tectonic fabrics: Identifying linear and planar elements. Relationship with the strain ellipsoide.
B) Orthographic projection: True and apparent dips. Three points problem.

6. Density diagrams. Using a dendity diagram to calculate a fold axis. Determining the paleo-orientation of a fold situated below an angular unconformity.

7. 3D methods (I). Contour maps. Stress analysis using Mohr circle in 2D (homework)

8. Computer programs: using computer programs to plot lines and planes as well as to determine their geometric relationships. Density diagrams.

9. Geologic cross section. Recumbent fold. Geologic history of different geologic cross-sections.

10. Riedel experiment: shear zones in semibrittle rocks.

Course planning

Calendar of actual sessions and presentation of works

- Starting of theoretical classes: First week of official period of classes
- Starting of practical sessions: First week of official period of classes
- November: End practical sessions.
- January: End theoretical classes.

- JAN-FEB: Written exercises.

TUTORIALS:

Monday, Tuesday, Wednesday: 9:00-10:00

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