26430 - Structural Analysis: Techniques and Applications

Información del Plan Docente

Academic Year	2017/18
Faculty / School	100 - Facultad de Ciencias
Degree	296 - Degree in Geology
ECTS	5.0
Year	4
Semester	First semester
Subject Type	Optional
Module	---

1.General information

1.1.Introduction

Brief presentation of the course

Structural Analysis is a branch of Structural Geology concerning detail study of deformation mechanisms in rocks, characterizing geometry and kinematics of deformation structures, and reconstruction of stress systems linked to them. This course focusses on using the main methods of observation, processing and analysing structural information at micro- and mesoscale, and applying their results to regional tectonics, resource prospection or engineering geology.

1.2.Recommendations to take this course

This course requires development of capabilities of observation, spatial visualization, representation and graphical analysis of the tectonic structures, as well as their evolutionary reconstruction (4D logic). It values comprehension and reasoning capabilities more than learning by rote. It is recommended: (i) to attend every theoretical and practical session and to take an active participation in them; (ii) to have passed a previous, basic course on Structural Geology; (iii) knowledge of basic Spanish and English.

1.3.Context and importance of this course in the degree

Structural Analysis makes a part of section 'Applied Geology' within the Geology Degree. It deals with geometrical, kinematical and dynamical aspects of deformation, and it is therefore related to the following disciplines:

1. Based on concepts and techniques of 'Structural Geology' (2d year), and 'Geological Mapping' and 'Geophysics and Global Tectonics' (3rd year).
2. Linked and coordinated with 'Geotechnics and Geophysical Prospection', 'Tectonics' and 'Engineering Geology' (4th year).

As an additional aspect, 1 ECTS is developed in English.

1.4.Activities and key dates

- Third week september: beginning of theoretical sessions.

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- Fourth week september: beginning of practical sessions.

- Each week: anwers to questions.

- Weeks 4th, 8th y 13th: writen exercises.

- Second week october: 1st field trip.

- Second week december: 2nd field trip.

- Third week december: field work report.

- Mid january: end of theoretical and practical sessions; report of practical sessions.

- According to the academic calendar: final writen exercise.

2.Learning goals

2.1.Learning goals

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

1) Knowledge on terms, mechanisms, geometry, kinematics and dynamics of tectonic deformations from microscopic to map scale.

2) Using common techniques of field observation and data collecting of tectonic structures; in particular, measuring of orientations using a compass.

3) Using representation techniques (maps, cross sections, field sketches, stereographic projection).

4) Using the main methods of geometrical, kinematical and dynamical analysis of continuous and discontinuous structures.

5) Knowledge on criteria for applying the results of structural analysis to regional tectonic interpretation and to economic geology (resource prospection, engineering geology).

6) Developing capabilities for scientific work: to select and process critically bibliographic information in Spanish and English; to communicate efficiently scientific contents, both oral and writen (in Spanish and, at a basic level, in English); to work alone and within a group.

2.2.Importance of learning goals

Structural Geology is an essential piece within the framework of Earth Sciences. After learning basic concepts and methods of Structural Geology in 2nd year, 'Structural Analysis' allows advanced development of work techniques at

micro- and mesoscale and their applications. It involves training in detail observation and rigurous interpretation, as well as stablishing relationships with sedimentary, magmatic, metamorphic, geomorfologic or hidrologic processes, which is useful for both a general geologist and a specialist.

Structural Analysis has important applications. Tectonics determines development of sedimentary basins, distribution of ore and energetic resources, mechanical features of industrial rocks, or geomechanics of rock massifs, and hence their stability. Knowledge of behaviour of active faults is critical for assessing seismic hazard. Other natural disasters, as those related to slope instability or karstic subsidence, are also related to mechanical properties of rocks and kinematics of deformation processes.

3.Aims of the course and competences

3.1.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 clases (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.

3.2.Competences

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

1) Identify the different types of tectonic structures at different scales, know their morphological and genetical classifications.

2) Make observations and collect field data on tectonic structures at different scales (mapping, outcrop sketches, compass measurements...).

3) Apply the main techniques for representing and analyzing tectonic structures from the geometrical, kinematical and dynamical point of view.

4) Interpret genetic mechanisms of tectonic structures, their kinematical evolution and their chronological relationships.

5) Interpret local stress systems linked to development of brittle structures, and reconstruct regional stress fields.

6) Apply the results of structural analysis to tectonic interpretations, as well as to resource prospection or engineering geology.

7) Learn to be critical with scientific information in Spanish and English, and be able to express clearly scientific results.

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Be able to work alone and in a group.

4.Assessment (1st and 2nd call)

4.1.Assessment tasks (description of tasks, marking system and assessment criteria)

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

(a) Continuous assessment

(modality of evaluation for the students who attended the normal development of the subject)

a.1) **Question papers** . Each week, approximately, students will have to answer to question papers dealing with conceptual and methodological aspects, or short practical exercises (20 % in English). They will work alone or in groups, and the results will be discussed in the classroom. Evaluation of skills 1, 4, 5 and 6.

a.2) **Laboratory exercises** . Reports on practical exercises carried out in the lab will be prepared every week, and supervised by the teacher in tutorials. A final dossier including all reports will be submitted at the end of the course. Evaluation of skills 3, 4 and 5.

a.3) **Field work** . The attendance to the field trips is compulsory. The personal work, expressed in the student's notebook, and the attitude of the student in the field, will be evaluated. Before final assessment of the course, a report containing field observations, analysis of structures and interpretatuon will be submitted. Students also will make an orl exposition of field results Evaluation of skills 2, 3, 4, 5 y 6.

a.4) **Partial writen exercises** . During weeks 4th, 8th and 13th, partial writen examinations on each of the three parts of the course will take place, including questions and short practical exercises (20 % in English). Students will be allowed to look at any handbook, paper or notebook. Evaluation of skills 1, 4, 5 and 6.

a.5) **Final written exercise** . A practical exercise will be carried out during the

final assessment period, consisting of (i) questions and short practical exercises on the three parts of the course (20 % in English), for those studients that had not pass partial writen exercises, (ii) open questions about a case study, using bibliographic information (Spanish and English) and field data. Students will be allowed to look at any handbook, paper or notebook. Evaluation of skills 1, 4, 5 y 6.

(b) Global test of evaluation

(modality of evaluation for the students who did no attend the subject, or students who, still being it done, wish to take refuge in their right to a global evaluation)

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b.1) **Global written exercise** . Similar to the final written exercise carried out during the final assessment period (parts i and ii). Evaluation of skills 1, 4, 5 y 6.

b.2) **Practical exercise** ,similar to those made on practical sessions during the course. Evaluation of skills 3, 4 and 5.

b.3) **Practical exercise from field information** (photographs, small samples, orientation of structural elements...), including analysis and interpretation, abstract (in English) and **oral exposition** (in Spanish and English). Evaluation of skills 2, 3, 4, 5 y 6.

Assessment criteria

(a) Assessment criteria in the continuous assessment modality

(a.1) For passing the course, the student must:

1) Submit regularly anwers to question papers and participate in common discussions of results.

2) Attend both field trips and submit the corresponding notebook.

3) Submit an adequate final dossier of reports on practical exercises.

4) Submit an adequate final report of field work, and make the corresponding oral presentation.

5) Obtain a grade equal or higher than 65% in either each of the three partial writen exercises, or in part (i) of the final written exercise.

6) Obtain a grade equal or higher than 50% in part (ii) of the final written exercise.

(a.2) Evaluation of skills :

- Answers to question papers . . . . . 14 %

- Dossier of practical exercises . . . . . 16 %

- Field note-book . . . . . 4 %

- Field work report . . . . . 10 %

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- Oral expositions . . . . . 6 %

- Partial writen exercises (or final written exercise, part i) (8+12+15%) . . 35 %

- Final written exercise, part ii . . . . . 15 %

(b) Criteria in the global evaluation modality

(b.1) For passing the course, the student must :

1) Obtain a grade equal or higher than 65% in part (i) of the global written exercise (b.1).

2) Obtain a grade equal or higher than 50% in part (ii) of the global written exercise (b.1).

3) Obtain a grade equal or higher than 50% in practical exercises (parts b.2 and b.3) within the global assessment examination.

(b.2) Evaluation of skills :

- Part (i) of the global written exercise . . . . . 49 %

- Part (ii) of the global written exercise . . . . . 15 %

- Practical exercise (part b.2) . . . . . 16 %

- Practical exercise from field information and oral exposition (b.3) . . . 20 %

5.Methodology, learning tasks, syllabus and resources

5.1.Methodological overview

The programme of the course is not the target, but a framework for developing personal work of students. These will have got class-notes given by the professor as the basis for their personal learning, together with bibliographic references. In this way, time devoted to theoretical lectures will be reduced to a minimum, in benefit of collective discussion on practical exercises and case studies.

Laboratory sessions will be mainly devoted to analysis of the most common tectonic structures. Fieldwork will focus on the recognition of the studied structures, collection of detailed observations and orientation measurements on them. The obtained data will be represented on the student's notebook by means of tectonic schemes and cross-sections.

Tutorials will be considered another academic activity where the student will be free to: (i) ask any doubt related with the

subject, including question papers; (ii) receive orientation about information sources; (iii) ask for guidelines about personal work and report elaboration.

5.2.Learning tasks

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

Activity 1 : Learning conceptual bases on macro-, meso- and microscale tectonic structures. Advanced methods of geometrical, kinematical and dynamical analysis.

Methodology :

- **Participating theoretical classes** (2 ECTS).

- **Seminars** : case studies from question papers and English bibliography (0,3 ECTS)

Activity 2: Using advanced methods of representation and analysis of meso- and microscale structures.

Methodology :

- **Practical sessions** (0,525 ECTS; 3 sessions of 1 h 45').

- **Laboratory sessions** (0,35 ECTS; 2 sessions of 1 h 45').

- **Computer sessions** (0,525 ECTS; 3 sessions of 1 h 45').

Activity 3 : Practical work on application of structural analysis.

Methodology :

- **Field work** (1,2 ECTS; 2 journeys, 6 h).

- Seminars for presentation and discussion of works (0,1 ECTS; 1 session of 1 h).

The following activities are developed in English, representing 1 ECTS:

- Answers to question papers (evaluation activity a.1): 20 % of questions.

- Case studies: bibliography.

- Practical sessions 2 and 4.

- Report abstract and oral exposition of field work (evaluation activity a.3); associated bibliography.

- Partial and final writen exercises (evaluation activities a.4 and a.5), first part: 20 % of questions.

- Final writen exercise (evaluation activity a.5), second part: 20 % of questions; associated bibliography.

- Global written exercise (evaluation activity b.1): as the final writen exercise a.5.

- Practical exercise from field information (evaluation activity b.3): abstract and oral exposition.

5.3.Syllabus

I. THEORY PROGRAM

First part : Continuous deformation and tectonic fabrics

1 . **Stress, deformation and rheological behaviour of rocks** . Concepts on deformation and stress. Stress-strain relationships.

2 . **Homogeneous deformation in two dimensions** . Numerical parameters of deformation. The strain ellipse. Aproach to quantittive analysis.

3. Homogeneous simple shear in two dimensions. Analysis from active and passive markers. Progressive deformation.

4 . **Homogeneous deformation in three dimensions** . The strain ellipsoid. Preferred orientations of planes and lines produced by deformation. Planar and linear fabrics related to the strain ellipsoid.

5 . **Tectonic fabrics: classifications and genetic mechanisms.** Continuous and discontinuous cleavage. Deformation mechanisms at texture-scale and lattice-scale.

6 . **Analysis os simple shear zones** . Geometric and kinematic features. Analysis from passive markers and internal fabrics.

Second part : Fold analysis

7 . **Geometrical analysis of folds** . Geometric elements; determination of fold axis and axial plane. Geometrical clasifications of folds.

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8 . **Kinematical analysis of folds (I)** . Kinematical clasifications of folds. **Buckling folds.** Internal strain in buckled beds: limb and hinge-zone deformation.

9 . **Kinematical analysis of folds (II)** . **Bending folds.** Accommodation folds associated to thrusts and normal faults. Kink folds.

10 . **Kinematical analysis of folds (III)** . **Folds developed by buckling and homogeneous strain (flattening)** . Basic analysis in monophase cases. Quantification of homogeneous strain. Interpretation of fold mechanisms from internal strain.

11 . **Analysis of poliphase folding** . Fold superposition models by Ramsay (passive folding). Analysis of superposed cleavages and lineations. Buckle fold superposition.

Third part : Discontinuous deformation and palaeostress analysis

12 . **Stress analysis in two dimensions** . Stress vectors and stress tensors in two dimensionses. The stress ellipse. The Mohr circle.

13 . **Mechanics of rock fractures (I)** . Shear fractures: the Mohr-Coulomb criterion. Tensile fractures: the Griffith theory.

14 . **Mechanics of rock fractures (II)** . Influence of pore pressure. Slip on previous discontinuities.

15. Stylolitic joints and veins. General criteria for analysing discontinuous structures.. Geometrical, kinematical and dynamical analysis of stylolitic joints and veins.

16 . **Fault analysis (I): geometry and kinematics.** Geometrical and kinematical description and classification of faults. Determining orientation, sense and magnitude of fault displacements. Fault rocks.

17 . **Fault analysis (II): dynamics.** Basic concepts of stress in three dimensions. Dynamic analysis: Anderson's model of conjugate faults. Palaeostress analysis from randomly oriented fault populations: deviatoric stress tensors.

18. Analysis of joints . Geometry: orientation, size, spacing. Fractography: plumose marks and associated microstructures. Joint interaction and relative chronology of joint sets. Dynamical interpretation.

19 . **Reconstruction of stress fields** . Lithostatic stresses. Tectonic stress fields. Stress perturbations at fault tips and fault relay zones.

20 . **Analysis of semibrittle shear zones** . Riedel's model: R and R' fractures. Other secondary structures and their relationship with the strain and stress ellipsoids. Progresive deformation in semibrittle shear zones.

II. PROGRAMME OF PRACTICAL SESSIONS

1 . Geometrical and kinematical analysis of simple shear.

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2 . Observation and classification of tectonic fabrics from small samples (in English).

3 . Analysis of ductile deformation structures using stereographic projection.

4 . Geometrical and kinematical analysis of folds using stereographic projection (I, in English).

5 . Geometrical and kinematical analysis of folds using stereographic projection (II).

6 . Stress analysis using Mohr circle.

7 . Exercises on fracture mechanics.

8 . Analysis of discontinuous structures: stylolitic joints, veins, conjugate faults.

III. PROGRAMME OF FIELDWORK SESSIONS

1ª JOURNEY (mid october): Field survey on folds and associated ductile mesostructures in Eocene *flysch* units of the Pyrenees (Hecho valley).

2ª JOURNEY (mid december): Field survey on faults and joints in Miocene units of the Ebro Basin (Tudela-Fustiñana, Navarra).

5.4.Course planning and calendar

The course includes 5 ECTS, equivalent to classroom sessions totalizing 50 hours and distributed in this way:

- 20 hours of theoretical sessions (two 1-hour sessions each week).

- 14 hours of practical sessions (one 1h 45' session each week).

- 4 hours of seminars (two 1h 30' sessions and one 1-hour session), incluided within the former timetable.

- 12 hours of field work (two one-day fieltrips).

- 6 hours each week for personal tutorials.

SCHEDULE

26430 - Structural Analysis: Techniques and Applications

- Third week september: beginning of theoretical sessions.

- Fourth week september: beginning of practical sessions.

- Third week october: writen exercise 1.

- Second week october: 1st field trip.

- Third week november: writen exercise 2.

- Second week december: 2nd field trip.

- Third week december: field work report.

- Third week december: writen exercise 3.

- Mid january: end of theoretical and practical sessions; report of practical sessions.

- According to the academic calendar: final writen exercise.

5.5.Bibliography and recommended resources

BB	Basic methods of structural geology. Part I, Elementary techniques / by Stephen Marshak, Gautam Mitra. Part II, Special topics. Englewood Cliffs, New Jersey : Prentice Hall, cop. 1988
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BB	Hobbs, Bruce E.. An outline of structural geology / Bruce E. Hobbs, Winthrop D. Means, Paul F. Williams New York [etc.] : John Wiley & Sons, cop. 1976
BB	Lisle, Richard J.. Geological structures and maps : a practical guide / by Richard J.

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BB	MacClay, K.R.. The mapping of geological structures / K. R. McClay . - [1st. ed.] Milton Keynes : Open University Press ; New York : Halsted Press, 1989
BB	Mattauer, Maurice. Las deformaciones de los materiales de la corteza terrestre / Maurice Mattauer ; [traducido por Mateo Gutiérrez Elorza y Jesús Aguado Sánchez] . - [2a ed.] Barcelona : Omega, D.L. 1989
BB	Park, R.G.. Foundations of structural geology / R.G. Park . - 2nd ed. Glasgow [etc.] : Blackie, 1989
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BB	Twiss, Robert J.. Structural geology / Robert J. Twiss, Eldridge M. Moores. New York : W.H. Freeman, cop. 1992.