Universidad Zaragoza

Academic Year/course: 2022/23

26430 - Structural Analysis: Techniques and Applications

Syllabus Information

Academic Year: 2022/23
Subject: 26430 - Structural Analysis: Techniques and Applications
Faculty / School: 100 - Facultad de Ciencias
Degree: 296 - Degree in Geology
588 - Degree in Geology
ECTS: 5.0
Year: 4
Semester: First semester
Subject Type: Optional
Module:

1. General information

1.1. Aims 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.

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.

These approaches and objectives are aligned with the following Sustainable Development Goals (SDGs) of the United Nations, 2030 Agenda:

SDG 3: Healthy lives and well?being

SDG 4: Quality education

SDG 6: Availability and sustainable management of water

SDG 7: Affordable, reliable, sustainable and modern energy

SDG 11: Cities and human settlements inclusive, safe, resilient and sustainable

1.2. 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? (2nd 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).

1.3. 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.

2. Learning goals

2.1. 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.

7) Use the hypothetical-deductive method as a research method, and make a critical reflection on the processes of acquisition and transfer of knowledge.

8) Learn to be critical with scientific information in Spanish and English, and be able to express clearly scientific results. Be able to work alone and in a group.

2.2. 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.

2.3. 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. Assessment (1st and 2nd call)

3.1. 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**. Within the context of a problem-based-learning methodology, each week the students will have to answer to question papers dealing with: (i) how to address each problem; (ii) conceptual and methodological aspects (some of them in English). The results will be discussed in the classroom. Evaluation of skills 1, 2, 3 and 4.

a.2) **Report of practical work and oral presentation**. Following a learning methodology based on the study of cases, the student keeps a logbook of the work carried out by means of a hypothetical-deductive method. The hypotheses and their contrasting process are collected, highlighting the role played by structural analysis. The final report includes the results obtained in the two field days, linked respectively to the study of cases 1 and 3. On returning from Christmas holidays, this logbook is handed out, and its contents are the subject of a brief oral presentation shared by all the students in a seminar session. Learning outcomes 2, 3, 4, 5 and 6 are assessed.

a.3) **Partial writen exercises**. By weeks 4th, 8th and 13th, three partial writen examinations on each part of the course will

take place, including questions and short practical exercises (some of them in English). Students will be allowed to look at any handbook, paper or notebook. Evaluation of skills 1, 4, 5 and 6.

a.4) **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 (some of them 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)

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 on a real case from field information** (photographs, small samples, orientation of structural elements?), including analysis and interpretation, abstract (in English) and a brief **oral exposition**. 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 (at least 12 of them).

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

3) Submit the report of practical work (logbook), including the results of field work, and achieve an oral presentation summarizing its content.

4) 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 . . . . . 18 %
- Report of practical exercises (logbook)..... . . . . 22 %
- Field note-book . . . . . 4 %
- Oral exposition . . . . . 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 . . . . . 53 %
- Part (ii) of the global written exercise . . . . . 15 %
- Practical exercise (part b.2) . . . . . 16 %
- Practical exercise from field information and oral exposition (b.3) . . . . . 16 %

4. Methodology, learning tasks, syllabus and resources

4.1. 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, problems 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.

4.2. Learning tasks

This course is organized as follows:

- **Lectures** (2 ECTS) and **Seminars** (0.3 ECTS). Learning conceptual bases on macro-, meso- and microscale tectonic structures. Advanced methods of geometrical, kinematical and dynamical analysis.
- **Practice sessions.** Using advanced methods of representation and analysis of meso- and microscale structures.
    - **Practical sessions** (0,5 ECTS; 5 hours).
    - **Laboratory sessions** (0,4 ECTS; 4 hours).
    - **Computer sessions** (0,5 ECTS; 5 hours).
- **Fieldwork** and **Seminar of discussion.** Practical work on application of structural analysis.
    - **Field work** (1 ECTS; 2 days x 5 h).
    - **Seminar of discussion** (0,3 ECTS; 3 hours).

Teaching and assessment activities will be carried out on site for as long and as much as possible. This scenario could change if safety regulations related to the covid19 crisis recommended online activities.

4.3. Syllabus

This course will address the following topics:

I. Lectures

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. Approach to quantitative 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.
- *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. Practice sessions: Cabinet (G), Lab (L) and Computer (O)

II.A) Resolution od issues (G)
16 short exercises to do in class or at home. Interspersed and directly linked with the successive themes of theory.

II.B) Case study following the hypothetical-deductive method
1. Geometric and kinematic analysis of flexural folds (linked to field day 1).
2. Geometric and kinematic analysis of bending and buckling folds.
3. Analysis of discontinuous structures: faults and joints (linked to the 2nd field day).
4. Kinematic analysis of thrusts.

III. Fieldwork

- 1st DAY: Geometric and kinematic analysis of folds and thrusts in the Iberian Chain.
- 2nd DAY: Geometric and kinematic analysis of faults and joints in the Ebro Basin.

4.4. 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 (twenty 1-hour sessions).

- 14 hours of practical sessions (seven 2-hour sessions).

- 6 hours of seminars (three 2-hour sessions).

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

- 6 hours each week for personal tutorials.

SCHEDULE

- Third week September: beginning of theoretical sessions.

- Fourth week September: beginning of practical sessions.

- Second week October: 1st field trip.

- First week December: 2nd field trip.

- Each week: Answers to questions.

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

- Third week december: report of practical sessions and field work.

- Mid January: end of theoretical and practical sessions.

- According to the academic calendar: final written exercise.

Further information concerning the timetable, classroom, office hours, assessment dates and other details regarding this course will be provided on the first day of class or please refer to the Faculty of Sciences and Earth Sciences Department websites (https://ciencias.unizar.es, https://cienciastierra.unizar.es) and Moodle.

4.5. Bibliography and recommended resources

http://psfunizar10.unizar.es/br13/egAsignaturas.php?codigo=26430&Identificador=C74882