University of Salahaddin- Erbil

College of Science

Department of Earth Sciences and Petroleum

Course Book

Subject: Brittle Structural geology (Theory) – Third Year

Lecturer's name: Dr. Hassan Ghazi KakAmeen

Academic Year: 2023/2024

1. Course name	**Brittle Structural Geology(Theory)**
2. Lecturer in charge	**Dr. Hasan Ghazi KakAmeen**
3. Department/ College	**Earth sciences and Petroleum/Science**
4. Contact	**e-mail: HassanKakAmeen@yahoo.com** **Tel: (07504821465)**
5. Time (in hours) per week	**Theory: 2 hrs.** **Practical: 2 hrs-3group**
6. Office hours	**22 hours per week**
7. Course code	
8. Teacher's academic profile	**I employed as assistant research in geology department since 1995.Iobtained M.Sc. and PhD in structural geology from geology department-college of science-university of salahaddin in 2004 and 2019. I contributed in teaching several practical geological subjects: igneous and metamorphic rocks, Stratigraphy, Biostratigraphy, Paleoecology, Remote sensing, Field work, Crystallography, Paleontology and sedimentary rock. Also, I contributed about ten times in summer field application course, as well as, I supervised several research project of under graduated students. But, now I teaching Ductile Structural Geology and Brittle Structural Geology for third year-geology department-college of science.**
9. Keywords	**Structural Geology, Ductile Structural Geology, Brittle Structural Geology, Folds, Faults ,Fractures**

10. Course overview:

Brittle Structural Geology provides an introduction to the theory and principles of rock deformation and classifications of common geologic structures. Two main crustal deformation will be introduced first one structures formed due to ductile deformation, while the second part concerning structures formed due to brittle deformation within the crust of the earths. Conceptual, theoretical, and historical aspects of structural geology are covered in the lecture, whereas the laboratory focuses on methods of analysis and problem solving. Topics are discussed in the contexts of case studies and plate tectonics. This course is intended to be the undergraduate student's first course in brittle structural geology.

11. Course objective:

This course is concerned with the deformation of rock in the Earth's lithosphere, as viewed from the outcrop scale, and the mountain range scale. A deformational feature observed on one scale typically reflects processes occurring on other scales. Brittle Structural Geology has significant role in deciphering many geological problems for example; we can't understand continental deformation without understanding mountains, we can't understand mountains without understanding folding and faulting, and we can't understand folding and faulting without understanding ductile and brittle deformation mechanisms at the atomic scale.

12. Student's obligation

In this course the students participate in the lectures through answering questions and asking any question about subjects that taken at each lecture/lesson. Furthermore, they have homework about lectures. All of the students are approximately attend to the lectures. Whereas, all of the students are obliged to do all tests throughout the academic year.

13. Forms of teaching

As structural geology required imagination and visualization to understand their subjects. Therefore, different forms of teaching are used in the lectures to reach the objectives of the course,such as:

a- Power point slides and occasionally white board at each lecture, for explanation, as well as, block diagrams and figures representing field/natural picture of the structures.

b- Debate part at each lecture, allowing students to discuss any part of given lecture.

c- Homework presents in the lecture to strengthen abilities of students.

d-Three dimensional models used as explanatory devices.

14. Assessment scheme

Two monthly examinations achieved for Brittle structural geology (Theory). Besides, quiz tests in the begging of the lectures.
The final score of Brittle Structural Geology-Theory equals 15% which represents quiz and monthly tests. Thus, the total score of structural Geology-Theory is 65%, throughout academic year.

15. Student learning outcome:

Since structural geology represents as principal science among geological sciences, in addition to petrology and paleontology. Therefore, taking principles of structural geology will help graduated students to be qualified to work in different specialties such as oil exploration, hydrology, hydrogeology, ore deposits, geophysics, engineering geology, geomorphology, stratigraphy……etc.
Therefore, graduated students could benefit from structural geology information to tackle many problems that face them especially during their field work for various aspects. Moreover, the essential role of structural geology in oil and gas exploration, investigation of ground water, construction of huge and infrastructural projects like dams, main roads, railways, tunnels.....etc.

In the last decade several oil companies come to Kurdistan Region for oil exploration and production, in Iraqi Kurdistan Zagros Fold and Thrust Belt. Many graduated geologists are appointed in these companies and others are work with the geological survey. Some of the graduated students employed in water resources companies in public and private sectors.

16. Course Reading List and References:

Billings, M.P., 1972. Structural geology. 3rd ed. Prentice-Hall, USA.606p.

Bles, J.L. and Feuga, B., 1986. The fracture of rocks. North Oxford Academic Publishers Ltd, 131p

Davis G. H. and Reynolds S. J.,1996. Structural Geology of rock and Regions, second edition, Joun

Wiley & Sons, Inc. 790p.

DeSitter, L. U., 1964. Structural geology, 2nd ed., McGraw Hill, New York, 551p.

Fossen, H. (2016) Structural Geology. Cambridge University Press, Cambridge. 463p.

Groshong, R.H. (2006) 3-D Structural Geology. Berlin, Springer-Verlag.324pp.

Hills, E. S., 1962, Outlines of structural geology, 4th ed., Methuen and Co. Ltd., London, 182P.

Hobbs, B. E., Means, W. D. and Williams, P.F., 1976. An outline of structural geology. John Wiley

and sons, USA, 571p.

Marshak, S. and Mitra, G., 1988. Basic methods of structural geology, Prentice- Hall, Inc., New Jersey, 446P.

Ragan, D.M.,2012. Structural Geology: An Introduction to geometrical Techniques, John Wiley

&Sons, New York,393p.

Ramsay, J. G., 1967. Folding and fracturing of rocks. McGraw-Hill book Co., New York, 568p.

Ramsay, J. G and Huber, M. I., 1983. Basic methods of structural geology. Vol (1), Academic press,

London.

Ramsay, J. G and Huber, M. I., 1987. The techniques of modern structural geology. V.2, Folds and Fractures. Academic press, London, 700p.

Ramsay, J. G. and Lisle, R. J., 2000. The technique of modern structural geology. V.3, Applications of continuum mechanics in structural geology. Academic press, USA, 1061p.

Rowland, S. M. and Duebendorfer, E. M., 2007, Structural Analysis and Synthesis. Oxford: Blackwell Science.
Schultz, R.A., 2019, Geologic Fracture Mechanics. Cambridge University Press, Cambridge. 527p.

Suppe, J., 2005. Principle of Structural geology. Prentice-Hall, Inc, New Jersey, 537p.

Twiss, R. J., and Moores, E.M. (2007) Structural geology. W.H. Freeman, USA, 717p.

Van der Pluijm, B. A., and Marshak, S. (2004) Earth structure: An introduction to structural geology

and tectonics, WCB/ McGraw-Hill, USA. P.468-479

Wilson., (1982) Introduction to Small-scale Geological Structures. George Allen & Unwin

(Publishers) Ltd,112p.

Woodward, N.B., Boyer, S.E., Suppe, J. (1989) Balanced Geological cross-sections: An Essential Technique in Geological Research and Exploration. Short Course in Geology, Washington, DC. American Geophysical Union. v. 6. 132p ,Blackwell Publishing Ltd.30IP.

- Theoretical lectures
- Journal of structural geology and geology
- Internet sites relevant to structural geology

17. The Topics of the Ductile Structural Geology-Theory:

Lectures 1&2: Brittle deformation structures: Deforming Rocks in the Laboratory, Mohr circle and diagram, Mechanics of fracturing, extension fractures, shear fractures, Modes of Crack-Surface Displacement, Exploring Tensile Crack Development, Tensile fracture (cracks), A fracture criterion for tension fractures, Shear fractures, Shear-Fracture Criteria and Failure Envelopes. **Lectures 3&4: Joints: joint set, joint system, systematic joint, nonsystematic joint, dihedral angle, orthogonal system, conjugate system, Joint trace, Joint spacing, Joint density, Importance of joints, Joint classification, classification of joints with respect to the bedding, Geometrical Classification, ab joints, ac joints, bc**	

joints, hko system, hol system, synthetic set and antithetic set, okl system, hkl system. **Differentiation/Distinction between extension and shear joints, Plumose structure.** **Lecture 5: Relative timing of joint formation (Joint sequence) Veins, Vein fill, types of fibrous veins, Tension gash or (gash fractures), Sigmoidal tension gashes, Stylolite, Bedding-parallel stylolite, Tectonic stylolite, Fissures.** **Lectures 6&7: Faults, Fault Geometry, Nature of movement along the faults, Translational movement, Rotational movement Relative movement (Net Slip), Shear sense, Types of the net slip, Dip-slip, Strike-slip, Oblique slip, cissors(rotational) fault, Fault separation, Classification of faults, Geometrical Classification, classification based on net slip, classification based on attitude of fault relative to attitude of adjacent beds or fold axis, classification based on fault pattern, classification based on dip angle of fault, classification based on Pitch(rake) angle, Slickensides, Genetic classification of the faults, Reverse/thrust faults, Normal faults, strike –slip faults, Relation of faulting to stress (Anderson's theory of faulting), Recognizing faults, Features Intrinsic to Faults, Criteria for determining the sense of slip, Effects of faulting on geologic or stratigraphic units, Repetition of strata or omission of strata, deep-seated faults inferred by seismic data, Drag folds, Rollover anticlines Physiographic Criteria for Faulting, Scarps.** **Lecture 8: Normal faults (extensional regime), Normal fault settings, Displacement on Normal Faults, STRUCTURAL ASSOCIATIONS OF NORMAL FAULTS, KINEMATIC MODELS OF NORMAL FAULT SYSTEMS, DETERMINATION O F EXTENSION ASSOCIATED W ITH NORMAL FAULTS, Estimates of Extension Based on Fault Geometry** **Lectures 9&10: Thrust faults (contractional regime) and thrust faults system, definitions, Thrust fault settings, Thrusts at Compressive Plate Boundaries, Thrust Faults in Secondary Settings, Structures associated with thrust faults, Geometry of fold-thrust belt, Movement direction of thrust faults, GEOMETRY AND KINEMATICS OF THRUST SYSTEMS IN THE HINTERLAND, Main types of thrust-related structures, Imbricate fans, Compressional duplex.** **Lecture 11: Strike –slip fault faults; definitions, Tear faults, Transpression, Transtension; Geometry, displacement, and Related structures; Releasing bend, Restraining bend, Pull-apart basin, Strike-slip Duplexes, Flower structures, Subsidiary structures associated with strike-slip shear zone.** **Lecture 12: Tectonic inversion**	

Lecture 13: Growth structures **Lecture 14 : Foreland basin**	
18. Practical Topics (If there is any)	

	Week 1: Stereographic projection. *Basic concepts; spherical projection, lower hemisphere; schmidt net, great circle, small circle, primitive circle; technique of plotting; plotting line, plane and its pole; visualization through lower hemisphere.* *Week 2: Stereographic projection.* *Finding angle between two lines and attitude of the plane, which containing two lines itself.* *Week 3: Stereographic Projection-Apparent dip and True dip. Finding apparent dip. construction and finding true dip and strike.* *Week 4: Stereographic projection intersection between planes. Finding the attitude of intersection line between two plane, measuring pitch (rake) angle.* *Week 5: Stereographic projection-attitude of axial surface. Finding folding angle; interlimb angle; fold orientations; attitude of hinge line, attitude of axial surface.* *Week 6: Stereographic Projection-Pi and Beta diagrams. Perfect cylindrical fold, cylindrical fold, sub-cylindrical fold, non-cylindrical fold, tightness of folds (fleuty, 1964), calculating the mean orientation of fold axes.* *Week 7: Stereographic projection Extension and shear fractures classification. Geometrical classification of extension joints, tectonic axes of Turner& Weiss (1963) and Price (1968), systematic joint, extension and shear joints, joint set, conjugate joint system.* *Week 8: Stereographic projection-shear fracture analyses. Geometrical classification of shear joints; bisector of the acute angle; bisector of the obtuse angle; intersection line of two set of joints; principal stress directions.* *Week 9: Stereographic projection-faults and stresses. Normal and reverse fault; lineation, movement plane, slip direction, determining principal stress directions.* *Week 10: Balancing cross section-local balancing. Rules of balancing, pin lines, restored cross section, line length balancing, area balancing, criteria of balanced cross section.* *WeeK 11, 12, 13 &14: Application of the soft ware's which are relevant to structural geology.*	Dr. Hasan Ghazi Mr. Soran Hasan

19. Examinations:

Salahaddin University- Erbil **Final Examination 2022**

College of Science **Brittle Structural Geology; 3rd year**

Department of Earth Sciences and Petroleum **Time: 2 hours**

Note: Support your answer by diagram, where it's necessary

Q·1) Respond to the following statements with true or false, and correct the underlined word(s) if they are wrong. *(14 Marks)*

1- In triaxial stress the state of stress equals σ1 = - σ 3 and σ 2 = 0.
2- A antithetic fault is a relatively uplifted block bounded by two conjugate normal faults that dip away from the uplifted block on both sides.
3- (T) and (+) shapes characterize conjugate sets of hybrid and shear fractures.
4- A kinematic model of any fault system is a description of the deposition that has occurred on the faults in the system.
5- Slickenfibers may result from scratching and from the development of irregularities in the fault surface itself.
6- Extension joints develop as (σ2 - σ3) > 8T.
7- Tear faults is a traditional term for strike-slip faults that occur in a thrust sheet.

Q.2) Complete these sentences with the correct structural word(s). *(14 Marks)*

1- …… is the angle between the σ1 and the normal to the fracture plane.
2- ……..is a combination of strike-slip and compressional deformation.
3- hko /a joint may develop to the ……. faults.
4- Stylolite are surfaces of dissolution associated with ……strains.
5- Joint ……is the total trace length of the all joints in the unit area.
6-…… are used as evidence for recognizing the stages of joint development.
7- If the shear stress acting on the fracture continues to exceed the ……..to sliding, the fracture grows.

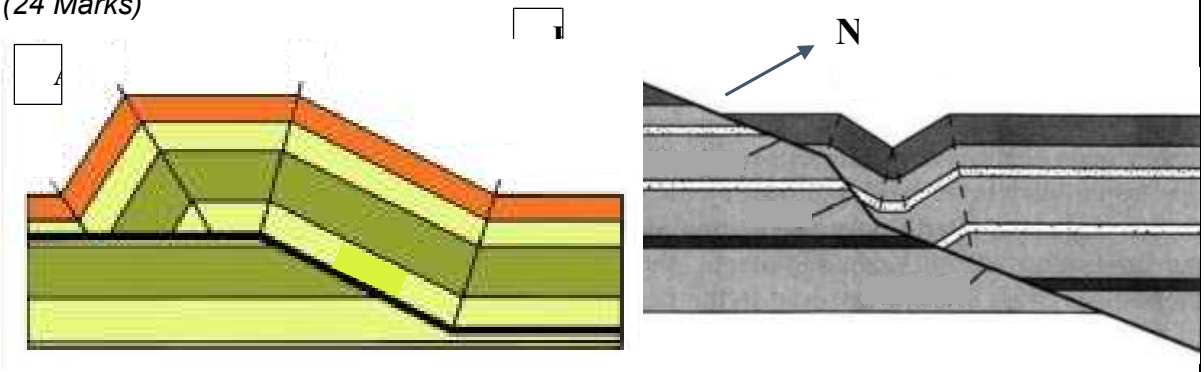
Q.3) What are differences between: *(24 Marks)*

1- tension fracture and extension fracture.
2- second model and third model of slip on listric normal faults.
3- plumose structures and slickensides.

Q.4) Talk about: *(24 Marks)*

1- Thrust duplex. 2- Gash fractures. 3- Fault-propagation folds.

Q.5) Answer these questions about the structure A (left figure) and structure B (right figure): *(24 Marks)*



1- Classify the fault A based on net slip. *(1M)*

2- Find dip direction of the fault B. *(1M)*

3- Classify the faults A and B based on genetic classification. *(4M)*

4- What's the name of structure that developed in hanging wall of the faults A and B. *(6M)*

5- Describe geometrical relationship between orientation of the principal stresses (σ1, σ2 and σ3) and fault planes A and B. *(12M)*

20. Extra notes:

►A major problem appeared during education processes is absence of modern scientific equipment and laboratories for research projects.

►Modern subjects will introduce in the new course and about 10% of the syllabus will be changed in new academic year. Moreover, some details are introduced within subsidiary subjects.

21. Peer review پێداچوونەوەی هاوەڵ