University of Salahaddin- Erbil

College of Science

Department of Earth Sciences and Petroleum

Course Book

Subject: Ductile Structural geology (Theory) – Third Year

Lecturer's name: Dr. Hassan Ghazi KakAmeen

Academic Year: 2023/2024

1. Course name	**Ductile Structural Geology(Theory)**
2. Lecturer in charge	**Hasan Ghazi KakAmeen**
3. Department/ College	**Earth sciences and Petroleum/Science**
4. Contact	**e-mail: HassanKakAmeen@yahoo.com** **Tel: (0750)**
5. Time (in hours) per week	**Theory: 2 hrs.** **Practical: 2 hrs-4group**
6. Office hours	**20 hours per week**
7. Course code	
8. Teacher's academic profile	**I employed as assistant research in geology department since 1995. I obtained 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, Micropaleontology, Paleontology and sedimentary rock. Also, I contributed in teaching theoretical geomorphology. Furthermore, 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-Earth sciences and petroleum department-college of science.**
9. Keywords	**Structural Geology, Ductile Structural Geology, Brittle Structural Geology, Folds, Faults ,Fractures**

10. Course overview:

Ductile Structural Geology has an essential geological significance in various geological aspects especially Petroleum geology, Ore geology, Geophysics, Stratigraphy, Geomorphology, Geotectonics, and Engineering geology.

Ductile Geological structures have an economic benefits due to its a vital role in oil and gas explorations, and selecting sites of huge projects like dams, main roads, tunnels, railways .....etc.

Principles of Ductile Structural Geology is designed to be a concise introduction to the deformation of the earth's crust, encompassing the wide –ranging subject matter of introductory courses in ductile structural geology.

Practical material including geometrical methods for the study of structures. These geometric methods are presented in earlier laboratory, focusing on the common problems of deciphering outcrop-scale and map-scale structures. Also, laboratory exercises embrace several laboratories about geological maps and at each of these laboratory, certain type of geological structures presented. Besides, stereographic projection exercises about linear structures and planar structures presented, and each of these laboratory constructed to solved specified problem like finding angle between two planes, attitude of folds, plotting pi diagrams.....etc. Furthermore, few exercises about different subjects like Ramsay's classification and balanced cross sections presented at the end of the academic year.

11. Course objective:

The successful student in this course will achieve the following:

- Understand the legacy of modern ductile structural geology technologies.
- Build the basic skills of Earth crust structure for distinguishing and interpretation.
- Build a foundation in ductile structural geology that will enable a comprehensive understanding of the processing and interpretation of structural features for analysis of surface features.
- Survey the various types of structural softwares that are available on web sites, and gain an understanding of the uses and applications as well as the limitations of each type.

12. Student's obligation

The student’s obligation during the course is attendance in the class for two hours for studying the theoretical part of the course and they applied it in the laboratory (about two hours). 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. There are many tests before the beginning of the lectures and labs. Attendance and participation will be considered in the final grade.

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 obtain 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.

e-There are classroom discussions at the last ten minutes of the lecture.

To get the best of the course, it is suggested that students attend classroom as much as possible, read the required lectures before the time of lecture, teacher's notes regularly as all of them are foundations for the course. Try as much as possible to participate in classroom discussions.

14. Assessment scheme

Two monthly examinations achieved for ductile structural geology (Theory). Besides, quiz tests in the begging of the lecture.

The final score of 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 regards as fundamental subject among geological subjects, in addition to petrology and paleontology. Therefore, taking principles of ductile 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 ductile 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, construct ion of huge and infrastructural projects like dams, main roads, railways, tunnels.....etc..

Many oil companies in the last decade 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. Blackwell Publishing Ltd.30IP.

Schultz, R.A., 2019, Geologic Fracture Mechanics. Cambridge University Press, Cambridge. 527p.

Spencer, E. W., 1988, Introduction to the Structure of the Earth, McGraw-Hill, 551 p. ISBN 0-07-060198-4 2nd edition.

Suppe, J.1985.Principles of Structural Geology. Prentice-Hall, Englewood cliffs, 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/ Mc Graw-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 EssentialTechnique in Geological Research and Exploration. Short Course in Geology, Washington, DC. American Geophysical Union. v. 6. 132p.

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

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

Lecture 1: Introduction definitions; classification of geological structures Structural data sets; Categories of Structural analysis; Scale of Observation; References. **Lecture 2: Force, stress, Two dimensional stress: Normal and shear stress, Three –Dimensional stress: Principal planes and Principal stresses, deformation, strain, Factors controlling mechanical behavior of materials.** **Lectures 3: Folds and geometry of folds: Fold facing, Geometric parts of folds, Cylindricity and Orientation of Hinge Line, The Dimensions (size) of Folds, The Attitude (orientation) of Folds.** **Lecture 4: Fold Classification(I): Symmetrical folds, Asymmetric folds, Overturned folds, Recumbent folds, Cylindricity of folds, classification of Fleuty 1964, Kink folds, Chevron folds, Box Folds, parallel folds, concentric folds, Similar folds, classification of Rickard (1971).** **Lecture 5: Fold Classification (II), Aspect ratio (P), Tightness of folding, bluntness, Ramsay's classification 1967; style of a folded layer, dip isogons, Homocline, Monocline, Structural terrace.** **Lecture 6: Minor Folds, Drag-folds and Parasitic folds, The order of folds, Pumpelly's rule, congruent folds, incongruent folds, Usefulness of Drag Folds,** **Lecture 7: Superposed folding (Refolded folds): Fold generation, fold interference patterns, The Principle of Fold Superposition, Harmony of folding, Harmonic and disharmonic folds, Fold vergence (Vergence of the fold).** **Lecture 8: Study of the folds, Recognition of Folds, Direct observation, Lineations formed by boudins, mullions structures, Boudin, Mullion.** **Lecture 9&10: The mechanics of folding, Passive folding, Active Folding, bending and buckling, Biot-Ramberg equation Mechanical stratigraphy,** **Lecture 11: orthogonal flexure or flexural slip or volume-loss folding models.** **Lecture 12: Shear Folding, Calculation the amount of slip in the flexuralslip model, Fold Shape Modification, Homogenous flattening of folds in a layer, Homogeneous deformation, Heterogeneous deformation, Homogeneous strain, Heterogeneous strain.** **Lecture 13: Cases of Folding, Tectonic processes, Thin skin and thick skin deformation, Nontectonic processes.** **Lecture 14: fault related folds.**	
18. Practical Topics (If there is any)	

Week l&2: Attitude of structures *Attitude of plane and line: geometrical elements measurements, pitch, trend, conventions of attitude: Azimuth convention, quarter form; right handed method.* **Week3&4:** Projection; descriptive geometrical method. *Elements of projection, plane of projection, direction of projection. Normal projection: horizontal plane (map), vertical plane (structure section), rotation, folding line.* **Week5:** Apparent dip. *Definitions; Finding of apparent dip, for given true dip by descriptive geometrical method.* **Week6:** True dip and strike. *Definitions; Finding of true dip and strike from given the apparent dip directions, by descriptive geometrical method.* From Lab. (2-5), solution of the exercises illustrated, by block diagrams. **Week7:** Three- point problem. *Advantages, conditions. Finding attitude of structural plane graphically, by three points, which have known elevations and form a triangle*	Dr. Hasan Ghazi Mr. Soran Hasan

Week8: Structural plane and topography. *Exposures on horizontal surface and topographic relief shape of topographic contour lines in valleys, shape of strata outcrops in valleys; Rule of Vs; Construction of block diagrams.* **Week9:** Geological maps-Horizontal Beds. *Basic concepts, stratum contour; recognition of the horizontal beds in geological maps; finding thickness of horizontal beds; drawing cross section for horizontal beds.* **Week10:** Geological maps-Uniformly dipping strata. *Distinction of the inclined strata; construction and labelling of strike lines; finding attitude of inclined beds; calculation of vertical thickness of beds, drawing cross section for inclined strata.* **Week11:** Geological maps-Folded strata. *Recognition of the folds from geological map, symmetrical folds, asymmetrical folds; finding attitude of hinge line,*	

amplitude and wave length of the fold; drawing cross section for folded strata

Week 12: Geological maps-plunged folds.

Geological map interpretation, symmetrical plunged fold, asymmetrical plunged fold, construction of hinge line, finding orientation of hinge line.

Week 13: Geological maps-vertical faults. *Distinction of vertical faults from geological maps; vertical faults in horizontal beds and*
inclined beds, attitude of vertical fault, determining up throw and down

throw blocks, calculating vertical displacement; drawing cross section for vertical faulted strata.

Week14: Geological maps-inclined faults.
Recognition of inclined faults, inclined faults in horizontal and inclined strata; finding attitude of inclined fault and hade angle, horizontal and vertical displacement, determining reverse and normal faults on geological map, drawing cross section for inclined faults.
Week15: Geological map-combination structures.Geological map interpretation;
given a map embrace fold, fault and unconformity surface; distinction of the unconformity surface from map; finding attitude of unconformity surface.
Week16: The style of folded Layer: Ramsay s classification. Geometric parameter: dip isogons, orthogonal thickness, axial trace thickness; relating classification with mechanism of folding.

19. Examinations:

Salahaddin University- Erbil **Final Examination 2021- 2022; 1st attempt**

College of Science **Ductile 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) ***Are these sentences right (/) or wrong(X)? Correct the underlined word(s) in these sentences, if they are wrong.*** *(16 Marks)*

1- Flexural Slip Folding is accommodated by simple shear <u>perpendicular</u> to the layer.
2- In the <u>class 3</u>, t is a maximum at the hinge and T is a minimum at the hinge.
3- The <u>plastic</u> deformation is less common near the surface of the earth.
4- <u>Rheology</u> deals with the flow of rocks.
5- The <u>gentle</u> limb of the fold is direction of the fold vergence.
6- Bending may occur during the development of <u>homocline</u> over fault blocks.
7- If the axial surface of a fold dips 79NW, the hinge line of the same fold is trending <u>SE</u>.
8- Dynamic analysis is the development of an understanding of stress and its relation to <u>deposition</u>.

Q.2) ***Choose the correct word between brackets to complete these sentences.*** *(16 Marks)*

1- The …… of folding is *equal to the ratio of the depth of folding* to *the half-wavelength*. *(vergence/ closure/ harmony)*

2- Fold …… is a set of folds of regional extent having a comparable geometry and presumably a common origin. (train/ closure/ system)
3- …… formed before full lithification, but after initial deposition. (Penecontemporaneous/ Syn-formational/ Post-formational)
4- *Higher-order folds are sometimes called ……. fold because they are related to a larger structure*. (first order folds/ minor folds/ upright folds)
5- According to Fleuty (1964), if the dip of axial surface of a fold = 81°and plunge of hinge line of same fold = 9°, the fold is called …… fold. (Horizontal folds/ Horizontal Upright folds/ Upright folds)
6- There is an immediate surface of no strain which called ……...in the orthogonal flexure folding. (outer arc/ inner arc/ neutral surface)
7- …… stress in which all three principal stresses have equal magnitude. (Isotropic/ Anisotropic/ Shear)
8- …… folds are the amplification of natural irregularities in the layers, or are a consequence of differential flow in a volume of this.(Active/ passive/ flexural)

Q.3) ***Define:*** *(20 Marks)*

1- Volume-Loss folding. **2- Similar folds.** **3- Fold generation.** **4- Synformal anticline.**

Q.4) ***What are differences between:*** **(***28 Marks)*

1- Cylindrical folds and Noncylindrical folds.
2- Normal kink band and Reverse kink band.
3- *Structural terrace* and Monocline.
4- Type 0 and Type 1 of fold interference patterns.

Q.5) ***The figures a, b, and c are anticlinal folds with theirs north direction. Answer these questions:*** *(20 Marks)*

please, turn over your exam paper

1- Describe geometry of the axial surface in the fold C. *(2 Marks)*

2- Describe geometry of the hinge line in the fold B. *(2 Marks)*

3- Classify the folds A, B and C based on curvature of axial surface and Cylindricity. *(6 Marks)*

4- Find trend of the hinge line in the fold A. *(2 Marks)*

5- Find dip angle and dip direction of the axial surface in the fold A. *(4 Marks)*

6- Can you determine the direction of vergence for the fold B? Yes, or No. Why? *(4 Marks)*

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