CENTRAL UNIVERSITY OF PUNJAB

M. Sc. Geology

(Two Years)

2 semester Course work and Two Semester of Research (2 + 2)

Batch 2026 - 2028

Department of Geology

School of Environment and Earth Sciences

Graduate Attributes

The graduates of this MSc Geology program will develop deep level of disciplinary knowledge and ability to apply/practice this knowledge in multidisciplinary or multi-professional context to tackle the future challenges. They will be able to acquire, analyze and interpret data generated from the laboratory or field, and can decipher the result to the scientific community. Graduates shall be capable of expanding their knowledge boundary through research and training; and take lead in cross-disciplinary studies. After completion of these programs, graduates will possess critical, creative and evidence-based thinking to solve local/regional/global problems; attain good communication skills and professionalism with ethical competency to work individually as well as in a team; will be capable enough to become an efficient entrepreneur and to take up leadership role. Additionally, they will be self-aware about the recent developments and emerging challenges; and to be a responsible global citizen. Graduates will be competent and technically adept geoscientists for building careers in research, teaching, government, industry and non-governmental organizations.

Program Outcomes

M.Sc. geology program provides the holistic knowledge about the Earth System Science and its relationship with other branches of science. Thus, by studying this program, students are prepared to pursue higher research in different field of geosciences. The program also makes them ready to prepare for different National and International level competitive examination for different scientific, professions and other posts related to civil and administration, etc. This program trains the students to be ready to become a professional geologist, to assume in different responsible positions in industry or in government agencies; to serve as academician; to pursue research as a career at universities and certain scientific organizations of Nation and International level; and further to become a global citizen.

Course Structure of the M.Sc. Geology Program with 2 semester Course work and Two Semester of Research (2 + 2)

Semester-I

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.401	Mineralogy and Crystallography	*Discipline Specific Core*	3	0	0	3
MEGS.402	Mineralogy and Crystallography (Practical)	*Ability Enhancement*	0	0	4	2
MEGS.403	Structural Geology and Geotectonics	*Discipline Specific Core*	3	0	0	3
MEGS.404	Structural Geology (Practical)	*Ability Enhancement*	0	0	2	1
MEGS.413	Applied Paleontology and Paleobiology	*Discipline Specific Core*	3	0	0	3
MEGS.414	Applied Paleontology and Paleobiology (Practical)	*Skill Based*	0	0	2	1
MEGS.517	Hydrogeology, Remote Sensing and GIS	*Discipline Specific Core*	3	0	0	3
MEGS.518	Hydrogeology, Remote Sensing and GIS(Practical)	*Ability Enhancement*	0	0	4	2
MEGS.596	Field Training	*Skill Based*	0	0	4	2
	Tutorial	*Remedial class*	0	2	0	0
Select any one from the following Discipline Elective course$						
MEGS.408	Geomorphology	*Discipline Elective*	3	0	0	3
MEGS.409	Natural Resource Management		3	0	0	3
MEGS.410	Meteorites & Planetary Sciences		3	0	0	3
MEGS. 522	Oceanography		3	0	0	3
		Total	**15**	**2**	**16**	**23**

Semester-II

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.415	Igneous Petrology	*Discipline Specific Core*	3	0	0	3
MEGS.416	Igneous Petrology (Practical)	*Skill Based*	0	0	2	1
MEGS.417	Metamorphic Petrology	*Discipline Specific Core*	3	0	0	3
MEGS.418	Metamorphic Petrology (Practical)	*Skill Based*	0	0	2	1
MEGS.516	Geochemistry and Isotope Geology	*Discipline Specific Core*	3	0	0	3
MEGS.536	Solid Earth Geophysics	*Ability Enhancement*	3	0	0	3
MEGS.539	Ore Geology	*Discipline Specific Core*	3	0	0	3
MEGS.540	Ore Geology (Practical)	*Ability Enhancement*	0	0	2	1
Select Any One Value Added Course (VAC)$						
MEGS.513	Mining methods and fossil fuel exploration	*VAC*	2	0	0	2
MEGS.514	Sequence Stratigraphy & Basin Analysis		2	0	0	2
	Tutorial	*Remedial class*	0	2	0	0
Interdisciplinary course						
	Interdisciplinary course#	*IDC*	2	0	0	2
Interdisciplinary course offered by the Department$						
MEGS.506	Introduction to Disaster Management	*IDC*	2	0	0	2
MEGS.507	Introduction to Earth System Science	*IDC*	2	0	0	2
MEGS.508	Geoheritage and Geotourism	*IDC*	2	0	0	2
Total			**19**	**2**	**6**	**22**

Students, who opt to exit the program with PG-Diploma in Geology at the end of the 1st year, need to complete internship/mini project/industrial training/MOOC course of minimum 2 credits in addition to above courses.

Semester-III

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.599-1	Dissertation Part I	Dissertation	0	0	40	20
		Total	**0**	**0**	**40**	**20**

Semester-IV

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.599-2	Dissertation Part II	Dissertation	0	0	40	20
		Total	**0**	**0**	**40**	**20**
Grand total for all semester (I+II+III+IV)			**33**	**4**	**100**	**85**

L: Lectures, **T:** Tutorial, **P:** Practical, **Cr:** Credit (Two Practical credit hours = One credit)

Students may opt any Inter disciplinary course offered by other departments. Students are not allowed to take IDC course offered by the parent department.

$ Based on the availability of infrastructural facility and faculty, limited course(s) will be offered to the batch.

➔ **Students, who opt to exit the program with PG-Diploma in Geology at the end of the 1st year, need to complete internship/mini project/industrial training/MOOC course of minimum 2 credits in addition to above courses.**

➔ Students may opt any internship/ academic or industrial training during semester break with approval from department. Above experiential learning/internship equivalent to 40–45 contact hours will be considered as one credit (as per NCrF guidelines).

➔ MOOCs may be taken up 40% of the total credits (excluding dissertation credits). MOOC may be taken in lieu of any course but content of that course should match minimum 70%. However, students need to consult with the Head of the department prior to the registration of the MOOC.

➔ Students will have an option to carryout dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking. Group dissertation may be opted, with a group consisting of a maximum of four students. These students may work using single approach or multidisciplinary approach. Research project can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

Evaluation Criteria for Theory Courses: Total Marks 100

A. Continuous/Internal Assessment: [25 Marks]
[Internal assessment for different courses will be conducted using any two or more of the following given methods: Surprise Tests, in-depth interview, unstructured interview, Jigsaw method, Think-Pair Share, Students Teams Achievement Division (STAD), portfolios, case based evaluation, video based evaluation, Kahoot, Padlet, Directed paraphrasing, Approximate analogies, one sentence summary, Pro and con grid, student generated questions, case analysis, simulated problem solving, media assisted evaluation, Application cards, Minute paper, open book techniques, classroom assignments, homework assignments, term paper]

B. Mid Semester Test: Based on Subjective Type Test [25 Marks]
C. End Semester (50 Marks): Subjective Test up to 100%, Objective up to 30% [15 marks].

Evaluation Criteria for Practical Courses: Total Marks 100

End semester exam (50 marks)
Continues assessment (30 marks)
Lab record (10 marks)
Viva (10 marks)

Evaluation Criteria for Entrepreneurship Course: Total Marks 100

Mid Semester Test (50 Marks): Subjective test up to 100%, Objective up to 30% and Preparing a business plan/innovative idea.
End semester exam (50 marks): Subjective Test up to 100%, Objective up to 30% [15 marks]

Evaluation Criteria for Dissertation/ Field training / specialized courses are given in the detailed syllabus.

Examination pattern from 2025-2026 sessions onwards:

Core, Discipline Elective, and Compulsory Foundation Courses			IDC, VAC, Entrepreneurship, Innovation and Skill Development Courses (≤2 credits) or any other theory course of ≤2 credits	
	Marks	Evaluation	Marks	Evaluation
Internal Assessment	25	Various methods	-	-
Mid-semester test (MST)	25	Descriptive	50	Descriptive (up to 100%) Objective (up to 30%)
End-semester exam (ESE)	50	Descriptive (up to 100%) Objective (up to 30%)	50	Descriptive (up to 100%) Objective (up to 30%)

Dissertation Part I (Third Semester)			**Dissertation Part II (Fourth Semester)**		
	Marks	Evaluation		Marks	Evaluation
Supervisor	50	Dissertation proposal and presentation	Supervisor/ co-supervisor(s)	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
HoD and senior-most faculty of the department	50	Dissertation proposal and presentation	External expert	50	Report of dissertation (25), presentation (10), novelty/ originality (5) and final viva-voce (10).

Marks for internship shall be given by the supervisor/internal mentor and external mentor.

Semester – I

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.401	Mineralogy and Crystallography	*Discipline Specific Core*	3	0	0	3
MEGS.402	Mineralogy and Crystallography (Practical)	*Ability Enhancement*	0	0	4	2
MEGS.403	Structural Geology and Geotectonics	*Discipline Specific Core*	3	0	0	3
MEGS.404	Structural Geology (Practical)	*Ability Enhancement*	0	0	2	1
MEGS.413	Applied Paleontology and Paleobiology	*Discipline Specific Core*	3	0	0	3
MEGS.414	Applied Paleontology and Paleobiology (Practical)	*Skill Based*	0	0	2	1
MEGS.517	Hydrogeology, Remote Sensing and GIS	*Discipline Specific Core*	3	0	0	3
MEGS.518	Hydrogeology, Remote Sensing and GIS(Practical)	*Ability Enhancement*	0	0	4	2
MEGS.596	Field Training	*Skill Based*	0	0	4	2
	Tutorial	*Remedial class*	0	2	0	0
Select any one from the following Discipline Elective course[$]						
MEGS.408	Geomorphology	*Discipline Elective*	3	0	0	3
MEGS.409	Natural Resource Management		3	0	0	3
MEGS.410	Meteorites & Planetary Sciences		3	0	0	3
MEGS.522	Oceanography		3	0	0	3
		Total	**15**	**2**	**16**	**23**

Course Code: MEGS.401

Course Title: Mineralogy and Crystallography

L	T	P	Credits
3	0	0	3

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Apprise how the internal structure of minerals affects the external structure and physical properties of minerals and crystals.

CLO2: Compare the mineralogical concepts of polymorphism, solid solution and exsolution.

CLO3: Interpret the basic properties and chemistry of common rock-forming minerals.

CLO4: Solve the difficulties of mineral identification and mineralogical assemblage by applying polarizing microscope, x-ray diffraction and electron microprobe.

Unit/ Hour	Contents	Mapping with CLO
I/10	**Mineralogy:** Introduction to mineralogy, broad classification, properties of minerals & environments of formation. Crystal chemistry: bonding and packing in mineral, coordination number and Pauling's Rules, chemical analysis of minerals, general and structural mineral formulae. Rules of substitution, Introduction to phase diagram and solid solution series. **Learning Activities:** Hands on exercise of mineral specimens, Use of stick-ball model to check bonding and packing.	**CLO1 CLO4**
II/11	**Crystallography:** Crystal Morphology, Crystal Symmetry, Crystallographic Axes, Crystal systems, Introduction to symmetry, 32 classes of symmetry; 2D and 3D lattice, 14 Bravais lattice; Introduction to space group. Study of stereogram and stereographic projections. Twinning, Polymorphism, Polytypism, Pseudomorphism, Crystal defects, twinning and twin laws: common types of twins and their examples in minerals. Introduction to X-ray crystallography, and Bragg's equation. **Learning Activities:** Hands on exercise of crystal models, drawing of stereographic projections, Powder XRD data analysis.	**CLO2 CLO4**
III/12	**Optical Mineralogy:** Petrological microscope; Introduction to optics, Isotropic and anisotropic minerals, Interference Phenomena, Compensation, and Optic Sign, optical crystallography of uniaxial and biaxial crystals, indicatrix, pleochroism, interference figures, crystal orientation,	**CLO4**

	determination of optic sign, 2V and 2E. **Learning Activities:** Use of petrological microscope and analyzing each parameter.	
IV/12	A detailed study of the important silicates (listed below) mineral (a) Nesosilicates/Orthosilicates: olivine group, garnet group, aluminosilicate group, humite group, zircon. (b) Sorosilicates: melilite, axinite and epidote group. (c) Cyclosilicates: beryl, tourmaline, cordierite, eudialyte (d) Inosilicates: pyroxene group, amphibole group and wollastonite (e) Phyllosilicates: mica group, kaolinite-serpentine group, talc-pyrophyllite, chlorite, smectite. (f) Tectosilicates: silica group, feldspar group, zeolite and feldspathoid **Learning Activities:** Mini project and student presentation on different silicate and non-silicate minerals, Group discussion	**CLO2** **CLO3** **CLO4**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem solving, Tools used: PPT, Video, Animation, Whatsapp, Software Tool: Mineralogical interactive software, crystal maker, XRD data analysis tool, website: Mindat, Web minerals.

Suggested Readings:

1. Dyar M. D., Gunter M. E., and Tasa D., 2020. *Mineralogy and Optical Mineralogy*, Mineralogical, Society of America, ISBN 978-1-946850-02-7.
2. William D. Nesse & Graham B. Baird. 2025. *Introduction to Mineralogy.* Oxford University Press Inc. ISBN13: 9780197614600.
3. Perkins Dexter, 2012. *Mineralogy*, Pearson Education.
4. William E. Ford, 2006. *Dana's Textbook of Mineralogy (With Extended Treatise on Crystallography and Physical Mineralogy*), CBS Publishers & Distributors Pvt. Ltd., ISBN 10: 8123908091.
5. Bloss, 1999. *Optical Crystallography*, Mineralogical Society of America.
6. Bloss, 1994. *Crystallography and Crystal Chemistry*, Mineralogical Society of America.
7. William Nesse, 2011. *Introduction to Mineralogy*, Oxford University Press, ISBN: 9780199827381.
8. William Nesse, 2012. *Introduction to Optical Mineralogy*, Oxford University Press, ISBN: 9780199846276.
9. Cornelius Klein, 2007. *Minerals and Rocks-Exercises in Crystallography, Mineralogy and Hand Specimen Petrology*, Wiley publisher.
10. Berry, L.G., Mason, B. and Dietrich, R.V., 2004.*Mineralogy*, CBS Publishers, ISBN 10: 8123911483, ISBN 13: 9788123911489.

11. Introduction to the Rock-Forming Minerals by Deer W.A., Howie R.A. and Zussman, J., 2013, Mineralogical Society of America.
12. Gribble, 2005. *Rutley's Elements of Mineralogy*, CBS Publishers, ISBN-10: 8123909160.
13. Ram.S. Sharma and Anurag Sharma, 2013. *Crystallography and Mineralogy Concepts and Methods*, Geological society of India, Bengaluru.

Web Resources: http://webmineral.com/
https://www.mindat.org/
http://www.jsu.edu/depart/geography/mhill/earthsci/mineralID/virtualminlab.html
https://sketchfab.com/tags/minerals
http://www.minsocam.org/

Course Code: MEGS.402

L	T	P	Credits
0	0	4	2

Course Title: Mineralogy and Crystallography (Practical)

Total hours: 60

Course Learning Outcomes (CLO): Upon successful completion of this Course, the student will be able to:

CLO1: Demonstrate the different minerals in hand specimen and under petrological microscope.
CLO2: Interpret the crystal parameter and to identify the mineral phase
CLO3: Compare the different crystals system in hand specimen and under petrological microscope.
CLO4: Solve mineralogical and crystallographic problems using XRD data.
CLO5: Formulate empirical formula of the mineralogical phases and the impurities present in the minerals.

Unit/ Hour	Contents	Mapping with CLO
I/60	Identification of rock-forming minerals in hand specimens	**CLO1**
	Identification of crystal model using symmetry elements	**CLO2 CLO3**
	Use of Goniometer to measure interfacial angle of crystals and calculation of axial ratio.	
	Representation of symmetry elements of crystals belonging to 32 classes of symmetry using stereonet	
	Scheme of pleochroism and absorption of a given mineral in thin section	**CLO1 CLO3**
	Determination of extinction angle, Determination of order of interference colours, length fast and length-slow characters of minerals	
	Study of interference figures of uniaxial and biaxial crystals, determination of optic signs	

	Identification of rock forming minerals using optical properties	
	Analysis of powder XRD spectrum of minerals	**CLO2 CLO4**
	Empirical formula of the mineralogical phases and the impurities present in the minerals	**CLO5**

Transactional Modes: Demonstration, practical with real specimens, Problem solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: Mineralogical interactive software, crystal maker, website: Mindat, Web minerals.

Evaluation Criteria: Total Marks – 100,
End semester exam (50 marks), Continuous assessment (30marks), Lab record (10marks), Viva (10marks).

Suggested Readings:

1. Cornelius Klein, 2007. *Minerals and Rocks-Exercises in Crystallography, Mineralogy and Hand Specimen Petrology*, Wiley.
2. Perkins Dexter, 2012. *Mineralogy*, Pearson Education.
3. William E. Ford, 2006. *Dana's Textbook of Mineralogy (With Extended Treatise on Crystallography and Physical Mineralogy)*, CBS Publishers & Distributors Pvt. Ltd.
4. Dyar M. D., Gunter M. E., and Tasa, D., 2008. *Mineralogy and Optical Mineralogy*, Mineralogical, Society of America.
5. Bloss, 1999.*Optical Crystallography*, Mineralogical Society of America.
6. Bloss, 1994.*Crystallography and Crystal Chemistry*, Mineralogical Society of America.
7. William Nesse, 2011. *Introduction to Mineralogy*, Oxford University Press.
8. William Nesse, 2012. *Introduction to Optical Mineralogy*, Oxford University Press.
9. Berry, L. G., Mason, B. and Dietrich, R. V., 2004. *Mineralogy*, CBS Publishers.
10. Deer, W. A., Howie, R. A. and Zussman, J., 2013.*Introduction to the Rock-Forming Minerals*, Mineralogical Society of America.

Web Resources: http://webmineral.com/
https://www.mindat.org/
https://sketchfab.com/tags/minerals
http://www.minsocam.org/

Course Code: MEGS.403

L	T	P	Credits
3	0	0	3

Course Title: Structural Geology and Geotectonics

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Determine the geological structures related to stress and strain.
CLO2: Develop the idea regarding rock failures in compressional an extensional regime.
CLO3: Understand about the structural features formed due to folding and faulting.
CLO4: Build concepts on crust building process in various geological time.
CLO5: Differentiate between the various elements of plate tectonics.
CLO6: Recognize the elements of paleomagnetism and appreciate the geodynamic evolution of the Great Himalaya.

Unit/ Hour	Contents	Mapping with CLO
I/10	Structural elements and measurements, Stress and analysis of stress in two and three dimensions; Plane stress analysis and Mohr stress circle, and its relationship with faulting and fracture mechanics; Theory of rock failure: brittle failure – shear and tensile failures. Fault plane solution; Fault related folds; Ductile deformation; Dynamic recrystallization; Pure shear vs. simple shear deformation; Strain analysis– finite and infinitesimal, homogeneous and inhomogeneous strains; Progressive deformation. **Learning Activities:** Determination of strain in naturally deformed rocks. Hands on exercises on the stress and strain analysis of deformed rocks, assignment and group discussion.	**CLO1** **CLO2**
II/15	Mechanism of folding, Classification of folds, fold development and distribution of strains in folds; Buckling and shearing process; Analysis and interpretation of superimposed folding. Mechanics and geometric aspects of thrust, normal and strike-slip faults, and associated structural features. Planar and linear fabrics (Foliation and Lineation) in deformed rocks: description, classification, genesis and significance. Brittle and ductile shear zones, Geometry and products of shear zones, Mylonites and Cataclasites. **Learning Activities:** Assignment, student Seminar, group discussion on rock deformation patterns at different regimes.	**CLO2** **CLO3**
III/10	Crustal evolution: Crust building process during Archean and Proterozoic Era; Archean Nuclei and their geotectonic appraisal; Concepts of Mobile Belts; Indian Mobile Belts; Major tectonic features of the oceanic and continental crust; Seafloor spreading and plate tectonics. **Learning Activities:** Assignment, Group discussions, seminars on the geotectonic features of different cratons and mobile belts in India.	**CLO4** **CLO5**
IV/10	Extensional tectonics: Mantle convection cells, block rotation models, Basin and ridge provinces, fault scarp retreat; Magnetic polarity on	**CLO5** **CLO6**

	the ocean floor; Transform and transcurrent faults; Euler pole and its significance; Concepts of declination and inclination; Apparent polar wandering path; Pull-apart basins; Compressional tectonics: Flip-flop subduction, Passive and active continental margin, Magmatic polarity at the subduction zone; Stability of Triple junction; Geodynamic Evolution of Himalaya through time. Geodynamics of the Indian plate. **Learning Activities:** Student seminar, group discussion on global geodynamics and orogeny.	

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, flipped learning, focused group discussion, Team teaching, Field visit, Brain storming, Mobile teaching, Collaborative learning, E-tutoring, Problem solving.

Suggested Readings:

1. Marland P. Billings, 2016. *Structural Geology*, Phi Learning, 3rd edition.
2. Robert J. Twiss and Eldridge M. Moores, 2006. *Structural Geology*, W. H. Freeman publisher.
3. Haakon Fossen, 2016. *Structural Geology*, Cambridge University Press.
4. Donal M. Ragan, 2009. *Structural Geology: An Introduction to Geometrical Techniques, Cambridge University Press*.
5. Ramsay, J.G. and Huber, M.I., 1983. *Techniques of Modern Structural Geology. Vol. I. Strain Analysis*, Academic Press.
6. Ramsay, J.G. and Huber, M. I., 1987. *Techniques of Modern Structural Geology. Vol. II. Folds and Fractures, Academic Press*.
7. Ramsay, J. G.,1967. *Folding and Fracturing of Rocks, McGraw-Hill*.
8. Stephen Marshak and Gautam Mitra, 1988. Basic Methods of Structural Geology, Prentice Hall.
9. Hobbs, B.E., Means, W. D. and Williams, P. F., 1976. *An outline of Structural Geology*, John Wiley and Sons. New York.
10. Ghosh, S.K., 2014. *Structural Geology: Fundamental and Modern Developments*, Kidlington: Elsevier Science.
11. Condie, K. C., 1997. *Plate Tectonics and Crustal Evolution*, Butterworth-Heinemann.
12. Alan E. Mussett, M. Aftab Khan, 2000. Looking Into the Earth: An Introduction to Geological Geophysics, Cambridge University Press.
13. *Passchier, C. W. & Trouw, R. A. J. 2006.* Microtectonics,*: 2nd ed. xvi + 366 pp. Berlin, Heidelberg, New York: Springer-Verlag.*

Web Resources:

https://www.gsi.gov.in/webcenter/portal/OCBIS/pageQuickLinks/pageTIStructuralGeology?_afrLoop=21149378600749056&_adf.ctrlstate=zil7ujw74_38#!%40%40%3F_afrLoop%3D21149378600749056%26_adf.ctrl-state%3Dzil7ujw74_42

http://www.geo.cornell.edu/geology/classes/RWA/GS_326/

https://serc.carleton.edu/NAGTWorkshops/structure/index.html

https://onlinecourses.nptel.ac.in/noc21_ce37/previewhttps://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-113-structural-geology-fall- 005/
https://uh.edu/~jbutler/anon/anoncoursestructure.htm
(1233) STRUCTURAL GEOLOGY (Prof. Santanu Misra, IIT Kanpur) - YouTube

Course Code: MEGS.404

L	T	P	Credits
0	0	2	1

Course Title: Structural Geology (Practical)

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Solve the stratum contours, V-rule, geometric, and borehole problems related to Structural geology.
CLO2: Solve various stereo net problems and construct stereographic projection of the field data.
CLO3: Interpret various maps and identify the geological structures of deformed continental regimes with microstructural analysis.

Unit/ Hour	Contents	Mapping with CLO
I/30	Study of stratum contours and their relation with the dip of the beds	**CLO1**
	Relation between true thickness and width of outcrop of a bed using 'V' rule	**CLO1**
	Graphical solution of structural problems using geometrical methods	**CLO1**
	Bore-hole problems (Three-pin problems)	**CLO1**
	Structural problems based on orthographic and stereographic projections, concerning the economic deposit	**CLO2**
	Preparation and interpretation of Geological maps and sections	**CLO3**
	Recording and plotting of the structural data on base map	**CLO3**

Transactional Modes:
Demonstration, practical with real specimens, Problem-solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: Sedilog, Photoshop.
Evaluation Criteria:
Total Marks–100,
End semester exam (50marks), Continues assessment (30marks), Lab record (10marks), Viva (10marks).

Suggested Readings:

1. Stephen Marshak and Gautam Mitra. 1988.Basic Methods of Structural Geology, Prentice Hall.
2. Ghosh, S.K., 1993. *Structural Geology: Fundamental and Modern Developments*, Pergamon Press.
3. Ramsay, J.G. and Huber, M.I., 1987. *Techniques of Modern Structural Geology. Vol. II. Folds and Fractures, Academic Press*.
4. Ramsay, J. G. and Huber, M.I., 1983. *Techniques of Modern Structural Geology. Vol. I. Strain Analysis*, Academic Press.
5. Donal M. Ragan, 2009. *Structural Geology: An Introduction to Geometrical Techniques, Cambridge University Press*. Structural analysis of Metamorphic Tectonites by Turner, F.J. & Weiss, L.E. 1963, McGraw-Hill.

Web Resources:

https://serc.carleton.edu/NAGTWorkshops/structure/index.html
https://onlinecourses.nptel.ac.in/noc21_ce37/preview
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-113-structural-geology-fall-2005/
https://uh.edu/~jbutler/anon/anoncoursestructure.html
https://iah.org/education/
https://www.routledge.com/Hydrogeology
https:// www.youtube.com/watch?v=G7CnE5NBxZs
https://geologyscience.com/applied-geology/hydrogeology/(1233)
STRUCTURAL GEOLOGY (Prof. Santanu Misra, IIT Kanpur) - YouTube

Course Code: MEGS.413

L	T	P	Credits
3	0	0	3

Course Title: Applied Paleontology and Paleobiology

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 Interpret the basic idea about the process of fossilization, the origin and the diversification of life. Knowledge of important invertebrate fossil fauna.
CLO2 Knowledge of important invertebrate fossil fauna.
CLO3 Basic ideas about the evolution of vertebrate life and the important fossil flora of India.
CLO4 Understanding important groups of microfossils, their significance in understanding paleoecology, paleoclimate and paleoenvironments
CLO5 Application of fossils in solving geological problems in space and time, Recent developments in understanding the evolution of biota.
CLO6 Application of fossils in climate studies and hydrocarbon exploration.

Units	Contents	Mapping with CLO

I/10	Taphonomy and its application; Condition and modes of fossilization; Origin and evolution of life; Concept of species and speciation; Precambrian microbiota and its significance Shell morphology, geological distribution and evolutionary trend of Bivalvia, Gastropoda, Brachiopoda, Cephalopoda, Echinoidea, and Trilobites. **Learning Activities:** Sessions on the evolution of life, assignments, take-home exercises, peer learning, seminars, and group discussions.	**CLO1** **CLO2**
II/10	Vertebrate life through the ages; Evolution and extinction of dinosaurs with emphasis on Indian dinosaurs, Evolution of *Homo* and Indian record; Approach to palaeobotany. Pre-Gondwana and Gondwana flora and the significance of Gondwana flora in paleoclimatic studies; Indian Paleogene flora. **Learning Activities:** Mini projects on vertebrate life, assignment, home exercise, peer learning, seminar and group discussion.	**CLO3**
III/15	Types of Microfossils; Introduction to phytoliths and their significance in geosciences; Foraminifera: morphology of foraminifers and their role in understanding palaeoceanography, paleoclimate and biostratigraphy; Basic morphology of spores/pollen; Concept of palynofacies and its application; Introduction to dinoflagellates and acritarchs: their significance in stratigraphy and shoreline studies; Introduction to ostracods and their significance in geoscience; Calcareous nanoplanktons and their significance in paleoecological studies. **Learning Activities:** Assignment, take home exercise, peer learning, seminar and group discussion.	**CLO4**
IV/10	Micro and macroevolution; Introduction to phylogenetic analysis and molecular biology; Dendrochronology and its application; Application of plants in paleoclimate and depositional environment interpretation; Application of oxygen and carbon isotopes in climate studies; Response of fossils to Milankovitch and Wolf Gleissberg solar cycles; Major extinction events and their impact on biodiversity; Measures of biodiversity sustainability on the Earth. **Learning Activities:** Exercise on the application of fossils and correlation with other co-relatable sections, student seminar.	**CLO5** **CLO6**

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Team teaching, Brain storming, Mobile teaching, Collaborative learning, Case

based study, Through SOLE (Self Organized Learning Environment).

L	T	P	Credits
0	0	2	1

Suggested Readings

1. Clarksons, E.N.K. (1998) *Invertebrate Paleontology and Evolution*, Allen and Unwin London.
2. Raup, D.M. and Stanley, S.M. (1985) *Principles of Paleontology*, CBS Publishers, New Delhi 2. Taylor, T.N., E.L. Taylor and M. Krings. 2009. *Palaeobotany- The Biology and Evolution of Fossil Plants*. Elsevier.
3. Anis Kumar Ray (2016) *Fossils in Earth Sciences* PHI learning Pvt ltd, pp 443
4. Alfred Traverse, 2008. *Paleopalynology*. Springer, 3rd Edition.
5. Willis, K.J., and J.C. McElwain. 2002. *The Evolution of Plants*. Oxford University Press, New York.
6. Jones, T.P. and Rowe, N.P. 1999. *Fossil Plants and Spores: Modern Techniques*. The Geological Society, London.
7. Stewart, W.N. and Rothwell, G.W. 1993. *Paleobotany and the Evolution of Plants*. Cambridge University Press; 2nd edition
8. Agashe, S.N. and Andrews, H.N. 1997. *Paleobotony: Plants of the Past, Their Evolution, Paleoenvironment and Application in Exploration of Fossil Fuels*. Science Publishers, U.S.
9. Stoermer, E.F. and Smol, J.P. (1999)(Eds.) *The Diatoms: Applications for the Environmental and Earth Sciences*, Cambridge University Press, 469p
10. Kathal, P.K. (4011) *Applied Geological Micropaleontology*, Scientific Publishers, Jodhpur.
11. Saraswati, P.K. and Srinivasan, MS (2016) *Micropaleontology Principles and Application*, Springer. pp 219.
12. Braiser, M. D., 1980. *Microfossils*, George Allen and Unwin.
13. Shrock, N., 2005. *Principles of Invertebrate Paleontology*, CBS publication.

Web Resource

https://www.ucl.ac.uk/GeolSci/micropal/welcome.html
https://www.sciencedaily.com/news/fossils_ruins/paleontology
https://sites.google.com/site/paleoplant/home
http://lifeofplant.blogspot.com/2011/03/paleobotany.html
http://www1.biologie.uni-hamburg.de/bonline/kerp/links.html
http://www.equisetites.de/palbot/teach/palbotteach.html
https://www.floridamuseum.ufl.edu/paleobotany/resources/link
https://www.priweb.org/science-education-programs-and-resources/digitas atlas-of-ancient-life

Course Code: MEGS. 414

Course Title: Applied Paleontology and Paleobiology (Practical)

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Understand techniques in the extraction of microfossils and apply the sample preparation methods for the separation of fossils. Cataloguing of samples for research and industrial applications.
CLO2: Understand modes of preservation of fossils.
CLO3: Understanding the morphology of important microfossils.
CLO4: Knowing the morphology of important fossils of invertebrates and plants for paleoenvironment and paleoclimatic interpretation

Unit/ hour	Contents	Mapping with CLO
I/30	Techniques for the processing of microfossils	**CLO 1**
	Study of modes of preservation of fossils.	**CLO 2**
	Morphology and description of foraminifera	**CLO 3**
	Morphology and description of pollen and spores	**CLO 3**
	Study of the Morphology of Gastropods and bivalves	**CLO 4**
	Study of the Morphology of Cephalopods and Trilobites	**CLO 4**
	Study of the Morphology of Brachiopods and Echinoids.	**CLO 4**
	Study of important plant fossils	**CLO 4**

Transactional Modes: Demonstration, practical with real specimens, Problem solving, Group discussion, Tools used: PPT, Video, Animation, Software Tool: Sedilog, Photoshop

Suggested Readings:

1.Henry Wood, 2004. *Paleontology Invertebrate*, CBS Publication
2. Bignot, G., 1985. *Elements of Micropaleontology*, Graham and Trottman, London.
3. Haq and Boersma, 1978.*Introduction to Marine Micropaleontology*, Elsevier.
4. Smith, A. B., 1994. *Systematics & Fossil Record-Documenting Evolutionary Patterns*, Blackwell publisher.
5. Jones, R. W., 1996. *Micropaleontology in Petroleum exploration*, Clarendon Press Oxford.
6. Saraswati, P.K. and Srinivasan, MS (2016) Micropaleontology Principles and Application, Springer. pp 219.
7. Kathal, P.K. 2011 *Applied Micropaleontology*, Scientific Publishers, Jodhpur.
8. Agashe, S.N. and Andrews, H.N. 1997. *Paleobotony: Plants of the Past, Their Evolution, Paleoenvironment and Application in Exploration of Fossil Fuels*. Science Publishers, U.S.

Web Resources:

https://serc.carleton.edu/research_education/paleontology/general.html
https://www.palaeontologyonline.com/?doing_wp_cron=1621058580.7671799659729003906250
https://www.priweb.org/blog-post/learn-at-home
https://www.nationalgeographic.org/encyclopedia/paleontology/
https://naturalhistory.si.edu/education/teaching-resources/paleontology

https://www.priweb.org/science-education-programs-and-resources/digital-atlas-of-ancient-life

Course Code: MEGS.517

Course Title: Hydrogeology, Remote Sensing and GIS

L	T	P	Credits
3	0	0	3

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Appraise the role of groundwater in the hydrological cycle, groundwater flow pattern in different terrains.
CLO2: Estimate quantity and assess quality aspects of groundwater for better management.
CLO3: Formulate the evolution of water chemistry through hydro-geochemical processes across different terrains.
CLO4: Develop utilization of satellite data in various applications such as geology, hydrogeology, climatology, forestry, town planning, etc.
CLO5: Maximize digital image processing techniques of satellite data for various applications such as land use/land cover, digital elevation model (DEM).

Unit/ Hour	Contents	Mapping with CLO
I/11	Hydrosphere and groundwater system: hydrological cycle; groundwater origin, type, and occurrences. Scope and importance of hydrogeology. Occurrence, distribution, and quality of groundwater: vertical distribution of subsurface water. Principles of groundwater flow: Darcy's law and its validity, concept of permeameter, water table, and piezometric surface. Tracing of groundwater movement with flow nets; Pumping tests: principles, types of pumping tests, procedures, data analysis. **Learning Activities:** Design a model of the hydrologic cycle and the concept of Darcy's law.	**CLO1** **CLO2**
II/12	Hydrologic properties of rocks: porosity, permeability, hydraulic conductivity, storativity. Types of aquifers: unconfined and confined aquifers. Behavior of sedimentary, crystalline, and volcanic rocks as aquifers. Impact of climate change in aquifer groundwater system. Groundwater quality assessment: the concept of clean water; hydrochemical parameters; hydrochemical data presentation and data analysis. Concept and evaluation of hydrochemical facies. Use of environmental isotopes in groundwater studies.	**CLO1** **CLO2** **CLO3**

	Learning Activities: Group discussion on local major aquifer types and groundwater occurrence.	
III/11	**Fundamentals of Remote Sensing:** Electromagnetic spectrum; scattering, absorption, refraction, path radiance, reflection, transmission, absorption. Energy-Earth interaction. Atmospheric windows. types of satellites: Polar sun-synchronous, geo-stationary. Platforms: types and their orbital characteristics; sensor types: active and passive; sensor systems: whiskbroom and push broom. Characteristics of resolutions of sensor: spatial, spectral, radiometric, and temporal; Basics of digital Image Processing; image enhancement, radiometric correction, image classification. **Learning Activities:** Group discussion on recent developments in satellite technology, exercises on satellite data mining from open sources, and development of different thematic layers using open data sources.	**CLO4** **CLO5**
IV/11	**Applications of Remote Sensing and GIS in Geology:** Concept and applications of GIS. Geographic information database management system: datatypes (map, attributes, image data) and structure; spatial and non-spatial data. Applications of remote sensing: in geological mapping; in groundwater exploration; in geomorphic mapping, in identification of rocks, structures, and drainages; in mineral exploration. **Learning Activities:** Brainstorming on the impacts of engineering projects on the environment and their importance to highlight the salient points, student seminar.	**CLO4** **CLO5**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Seminar, Group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching, Collaborative learning, Case analysis, Case study, Case-based study, Through SOLE (Self-Organized Learning Environment).

Suggested readings:

1. Todd D.K., 2007. *Groundwater Hydrology*, John Wiley and Sons
2. Gupta, S.K., 2011. *Modern Hydrology and Sustainable Water Development*, Wiley-Blackwell.
3. Raghunath, H.M., 1985.*Groundwater*, Wiley Eastern Ltd.
4. Karanth, K.R.,1987. *Groundwater Assessment Development and Management, McGraw-Hill* Publishers

5. Freeze and Cherry, 1979. *Groundwater*, Prentice-Hall.
6. Singh, C.K. (2018). *Geospatial Applications for Natural Resources Management, CRC Press*.
7. Shellito, B. (2017). *Geospatial Technologies,4th edition, W. H. Freeman Publisher*.
8. Shamsi, U.M. (2012). *GIS Applications for Water, Wastewater, and Stormwater Systems, CRC Press*.
9. Bhatt, B. (2011). *Remote Sensing and GIS, New Delhi: Oxford University Press*.
10. Skidmore, A. (2010). *Environmental Modeling with GIS and Remote Sensing, New Delhi, CRC Press*.
11. Abbasi, T. (2010). *Remote Sensing, GIS and Wetland Management, Discovery Publishing House*.
12. Lillisand,T.M.,Keifer,R.W.(2007).*Remote Sensing and Image Interpretation, USA: John Wiley and* Sons.
13. Joseph, G. (2003). *Fundamentals of Remote Sensing,* Hyderabad: Universities Press.
14. Chang, K. (2002). *Introduction to Geographic Information Systems, USA: Tata McGraw-Hill*.
15. Barrett, E.C. and Curtis, L.F. (1999). *Introduction to Environmental Remote Sensing, USA: Chapman and Hall Publishers*.
16. Curran, P.J. (1988). *Principles of Remote Sensing, ELBS: Harlow, Longman Scientific and Technical*.

Web Resources:

https://iah.org/education/
https://www.routledge.com/Hydrogeologyhttps://www.youtube.com watch?v=G7CnE5NBxZshttps://geologyscience.com/applied-geology/hydrogeology/
https://bhuvan.nrsc.gov.in/bhuvan_links.php
https://landsat.gsfc.nasa.gov/data
https://www.esri.com/en-us/home

Course Code: MEGS.518

L	T	P	Credits
0	0	4	2

Course Title: Hydrogeology,Remote Sensing and GIS (Practical)

Total hours: 60

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Construct water table maps for evaluation of groundwater flow and discharge site identification

CLO2: Maximize exploration of groundwater resources using hydrogeology and GIS GIS-integrated approach

CLO3: Assess the quality of groundwater for different uses and top propose the development and management of groundwater resources

CLO4: Design various experiments for familiarization with satellite images mapping, and layout

CLO5: Apply remote sensing and GIS software for image interpretation

CLO6: Develop the analytical skills for pre-processing, image classification, and post-processing

Unit/ Hour	Contents	Mapping with CLO
I/30	• The following exercise will be conducted in the lab • Water table contour mapping • Interpretation of flow network: groundwater flow movement, delineation of recharge and discharge areas • Representation of hydrochemical data in various graphical diagrams and interpretation • Evaluation of hydrochemical facies in the Trilinear diagram and interpretation	**CLO1 CLO2 CLO3**
II/30	• Photogeology: Interpretation of aerial photographs. • Stereoscopic Vision: The Process of perceiving stereoscopic vision using a stereoscope. • Types of Stereoscopes: Use of the Pocket and Mirror stereoscope • Satellite data mining: downloading and familiarization of satellite imagery, reading metadata, and basic characteristics of images. • Preprocessing: geometric and radiometric correction, FCC generation, mosaicking, subletting, and atmospheric correction • GIS database mining: point, polygon, and line features capture, editing and manipulation, topology building, joining attribute table with spatial data.	**CLO4 CLO5 CLO6**

Transactional Modes: Demonstration, Group discussion, Problem solving, Case analysis, Case study, Self-learning, Case-based study, Through SOLE (Self-Organized Learning Environment), Experimentation.

Evaluation Criteria: Total Marks–100,
End semester exam (50 marks), Continuous assessment (30 marks), Lab record (10 marks), Viva (10 marks).

Suggested readings:

1. Todd D.K., 2007. *Groundwater Hydrology*, John Wiley and Sons
2. Gupta, S.K., 2011. *Modern Hydrology and Sustainable Water Development*, Wiley-Blackwell.
3. Raghunath, H.M., 1985. *Groundwater*, Wiley Eastern Ltd.
4. Karanth, K. R., 1987. *Groundwater Assessment Development and Management,* McGraw-Hill Publishers
5. Freeze and Cherry,1979. *Groundwater*, Prentice-Hall.
6. Singh, C.K. (2018). *Geospatial Applications for Natural Resources Management, CRC Press*.
7. Shellito, B. (2017). *Geospatial Technologies,4th edition, W. H. Freeman Publisher*.
8. Shamsi, U.M. (2012). *GIS Applications for Water, Wastewater, and Stormwater Systems, CRC Press*.
9. Bhatt, B. (2011). *Remote Sensing and GIS, New Delhi: Oxford University Press*.
10. Skidmore, A. (2010). *Environmental Modeling with GIS and Remote Sensing, New Delhi, CRC Press*.
11. Abbasi, T. (2010). *Remote Sensing, GIS and Wetland Management, Discovery Publishing House*.
12. Lillisand, T.M., Keifer, R.W. (2007). *Remote Sensing and Image Interpretation,* USA: John Willey and Sons.
13. Joseph, G. (2003). *Fundamentals of Remote Sensing,* Hyderabad: Universities Press.
14. Chang, K. (2002). *Introduction to Geographic Information Systems,* USA: Tata McGraw-Hill.
15. Barrett, E.C. and Curtis, L.F. (1999). *Introduction to Environmental Remote Sensing,* USA: Chapman and Hall Publishers.
16. Curran, P.J. (1988). *Principles of Remote Sensing,* ELBS: Harlow Longman Scientific and Technical.

Web Resources:

https://iah.org/education/https://www.routledge.com/Hydrogeology
https://www.youtube.com/watch?v=G7CnE5NBxZshttps://geologyscience.com/applied-geology/hydrogeology/
http://www.tulane.edu/~sanelson/eens212/https://bhuvan.nrsc.gov.in/bhuvan_links.phphttps://landsat.gsfc.nasa.gov/data
https://www.esri.com/en-us/home

Course Code: MEGS.596

L	T	P	Credits
0	0	4	2

Course Title: Field Training

Total Hours: 60

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Apply geological theories and classroom knowledge to field

observations and develop essential geological field skills.

CLO2: Identify and classify different rock types, minerals, fossils, and geological structures in the field and interpret the geological processes responsible for their formation.

CLO3: Analyze and document structural and stratigraphic features, including folds, faults, joints, lithological contacts, and depositional structures, during geological field investigations.

CL04: Prepare geological maps, field sketches, lithologs, and geological cross-sections using standard field techniques and geological tools.

CLO5: Collect, record, and interpret field data systematically and communicate geological findings through field reports and presentations.

Unit/ Hour	Contents	Mapping with CLO
I/60	Field training will be conducted during this semester or in the semester break between I and II or II and III at a suitable time. Geological field training will be carried out according to the guidelines of the University at selected sites for about two weeks.	**CLO1 CLO2 CLO3 CLO4 CLO5**

Transactional Modes: During the fieldwork, students will do the geological mapping of an areas (depend on the prospective mining or continental elevated region); will learn different rock type, fossils, different deformational structures, such as fold, fault, lithology and depositional features; will visit mining/drilling sites; sample and fossils collections if available in the area. Evaluation of this course will be based on the field activity, daily field report, final report submission presentation during the end semester exam. Prior to fieldwork, a literature review on the selected/proposed field area will be carried out by the students, and basic information will be provided to students.
Due to any unavoidable circumstance, if the fieldwork is not conducted in the allocated semester or before, then the students will be assigned a seminar, report writing, and partial lab work/mathematical modelling work to fulfill the credit requirement, and a separate evaluation criterion will be used for assessment.

Evaluation Criteria: Full Marks–100
Field activity (10 marks), Evaluation of field dairy during every day of fieldwork and final submission (20 marks), Final field report (40 marks), Presentation (30 marks) – Presentation will be evaluated using rubrics: Speak clearly (4 marks), Posture and Eye contact (3 marks), Content (4 marks), Preparation (5marks), stay in topic (4 marks); Response to questions (10 marks).

Suggested readings:

1. Angela L.C., 2010.*Geological field techniques*, Blackwell Publishing Ltd.
2. Lisle, R.J., Brabham, P. and Barnes, J.W.,2011. *Basic Geological Mapping (Geological Field Guide)*, Wiley-Blackwell.
3. Mathur, S.M., 2001. *Guide to Field Geology*, PHI Learning Private Limited, New Delhi.

4. Maley, T.S., 1994. *Field Geology (Illustrated), Mineral Land Publications*.
5. Lahee, F.H.,1961. *Field Geology*, McGraw-Hill.

Additional material will be provided to the students prior to the field visit based on the locality/geological sites selected for that year.

Tutorial/ Remedial Class

L	T	P	Credits
0	2	0	0

A two-hour non-credit tutorial class is designed for remedial teaching. Scheduled classes will be assigned in the timetable. As per the requirement of students, remedial classes will be conducted in these periods.

Discipline Elective course

Course Code: MEGS.408

L	T	P	Credits
3	0	0	3

Course Title: Geomorphology **Total Hours: 45**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 : Demonstrate the principal theories and models for landscape evolution.

CLO2 : Assess the mode of formation, age, and history of landforms in

India.

CLO3 : Distinguish landforms and their processes of formation in different climate zones and tectonic regimes.

CLO4 : Develop a relevant solution to elucidate geomorphologic problems.

Unit/ Hours	Content	Mapping with CLO
I/11	Historical development in geomorphology, geomorphic processes: weathering, mass movement, erosion, transportation and deposition, landforms: Characterization and process involved in their formation. **Learning Activities:** Design a note on the concept of origin, the evolution of landforms, historical development, scope, etc.	**CLO1, CLO2**
II/12	Geomorphic processes and landforms- fluvial, glacial, aeolian, coastal, and karst. River forms and processes- streamflow, Environmental change- causes, effects on processes and landforms. **Learning Activities:** Brainstorming on geomorphic processes for landform development, landforms under different environments, etc.	**CLO3**
III/12	Physiographic division of India, Landscape evolution and the involved process. Concept of Form-Process relationship in landscape evolution, Submarine relief **Learning Activities:** Design a conceptual model on the importance of topography, DEM, and maps in geomorphology.	**CLO1, CLO4**
IV/10	Definition and scope of tectonic geomorphology, Eustatic sea-level change and impact of coastal geomorphology, Applications of geomorphology in mineral prospecting, civil engineering, hydrology, and environmental studies. **Learning Activities:** Student seminar on recent advancements in geomorphological studies.	**CLO2**

Transactional Modes: Lecture, Demonstration, Problem-solving, Seminar, Assignment, Group discussion, Tools used, ICT, PPT, Video, Animation.

Suggested Readings:

1. Thornbury, W.D., 2004.*Principles of Geomorphology, CBS Publisher & Distributor Private Ltd*.
2. Philip Kearey, Keith A.K., Frederick J.V., 2009.Global Tectonics, Wiley-Blackwell.
3. Richard John Huggett, 2007.Fundamentals of Geomorphology,

Taylor & Francis.
4. AngelaL. Coe (edt), 2010.*Geological Field Techniques, by Wiley-Blackwell*.
5. Richard J.L., Peter B., and John W.B., 2011. *Basic Geological Mapping (Geological Field Guide),* Wiley-Blackwell; ISBN-13:978-0470686348.
6. Michael A. Summerfield (Editor), 2000. *Geomorphology and Global Tectonics*, Wiley, ISBN:978-0-471-97193-1.
7. P. Mc L.D. Duff, 1993. *Holmes ' Principles of Physical Geology, Chapman and Hall*, London.
8. R.J. Allison, 2002. *Applied Geomorphology: Theory and Practice*, Wiley.
9. Douglas W.B., and Robert S.A., 2011. *Tectonic Geomorphology*, Wiley-Blackwell; ISBN-13:978-1444338867
10. Robert S.A., and Suzanne P.A., 2010.Geomorphology: The Mechanics and Chemistry of Landscapes, Cambridge University Press.
11. Paul R.B., and David R.M., 2013. *Key Concepts in Geomorphology, W.H. Freeman*.
12. Sharma, H.S., 1991. *Indian Geomorphology*, Concept Publishing Co., New Delhi.
13. Mahapatra, G.B., 2008. *Text book of Physical Geology, CBS Publishers & Distributors Private Ltd*.

Web Resources:

https://www.geomorphology.org.uk/https://www.nature.com/subjects/geomorphology
https://www.usgs.gov/centers/umid-water/science/fluvial-geomorphologyhttps://onlinecourses.nptel.ac.in/noc20_ce28/preview

Course Code: MEGS.409

L	T	P	Credits
3	0	0	3

Course Title: Natural Resource Management

Total Hours: 45

Course Learning Outcomes (CLO):

Upon successful completion of this course, the student will be able to integrate and apply technical knowledge in the following key areas.

CLO1 : Appraisal of the types of natural resources available and their relation to geological processes

CLO2 : Invention of new ideas to conserve, manage, and develop the Earth's natural resources available

CLO3 : Evaluation of the validity and limitations of new scientific theories and their claims about the environment.

CLO4 : Appraising the interactions among physical, biological, chemical, and human components of our environment.

Units/ Hours	Content	Mapping with CLO
I/11	Natural resources: Classification of natural resources; natural resource degradation and conservation; Environmental impacts of resource depletion. Forest Resources: Forest cover of India and world; forest types, Conservation of forests, Exploitation of forest resources, Afforestation, Desertification, Forest policy **Learning Activities:** Develop a sustainable model on the natural resources of India. Presentation on the forest resources of India	**CLO1, CLO2**
II/12	Water Resources: Surface, groundwater, resources assessment and utilization; Rivers and Lakes in India; hydrological cycle; Groundwater depletion; Water logging and salinity; Water Conservation and management techniques; Rainwater harvesting; Watershed management; Restoration of Lakes; Interlinking of rivers; conflicts over water. **Learning Activities:** Design a concept model on water resources, drought, flood issues of India, restoration etc.	**CLO1, CLO2**
III/12	Land resources: Land degradation due to mining, exploration, industrialization, irrigation, and natural disasters; Soil erosion, loss of soil fertility, Soil conservation methods; **Learning Activities:** Group discussion on organic farming, green manuring, etc., to highlight the salient points	**CLO2, CLO3**
IV/10	Mineral resource: Type of mineral resources, reserve, policy, and management. Rock and other building materials. Ocean resources, International territorial policy, and geopolitics. Mineral resource management using geospatial technologies. SDG goals. **Learning Activities:** Group discussion on the ocean resources of India. Student seminar.	**CLO1, CLO2, CLO4**

Transactional Modes: Lecture, Demonstration, Tutorial, Problem-solving, Seminar, Assignment, Group Discussion, Tools Used: PPT, Video, Animation.

Suggested Readings:

1. David A., 2013. *Environmental economics and natural resource management,* Routledge.
2. Gurdev Singh and Vinod Ahuja, 1992. Land resource management, Oxford & IBH Pub. Co.
3. Kathy Wilson Peacock, 2008. *Natural resources and sustainable developments, Facts on File Inc.*
4. Daniel R.L., 2009. *Sustainable natural resource management for scientists and engineers*, Cambridge University Press
5. Jaidev Somesh, 2010. Natural *Resources in the 21st Century, ABD Publisher.*
6. Panday, S.N. and Misra, S.P. (Eds.), 2008. *Essential Environmental Studies*, CRC Press.

Web Resources:

https://www.icar.org.in/content/natural_resource_management_division
https://www.india.gov.in/topics/environment-forest/natural-resources
https://www.youtube.com/watch?v=ZFD13WoyUGw

Course Code: MEGS.410

L	T	P	Credits
3	0	0	3

Course Title: Meteorites and Planetary Science

Total Hours: 45

Course Learning Outcomes (CLO):

Upon successful completion of this course, the student will be able to:

CLO1: Understand thoroughly the different types of meteorites, their classification, composition, and physical characteristics.

CLO2: insights into the processes that govern the formation and evolution of planetary bodies, including asteroids and other celestial objects.

CLO3: learn how meteorites provide valuable geological records of early solar system history and planetary differentiation processes.

CLO4: enhance their critical thinking abilities by evaluating the significance of meteorite research in addressing broader questions in planetary science and geology.

Unit/Hour	Contents	Mapping with CLO
I/12	Introduction to meteorites, Classification of meteorites, Oxygen isotopes, Asteroids, Asteroid-meteorite connection, chondritic and differentiated meteorites **Learning Activities:** Assignment, take-home exercise, and	**CLO1 CLO3 CLO4**

	student seminar.	
II/12	Chondrules and Calcium-aluminum-rich inclusions (CAIs), Volatility and metal fractionation in the solar nebula, Early timescales, Formation of Moon. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO1** **CLO2** **CLO3** **CLO4**
III/11	Stellar life cycles and nucleosynthesis, pre-solar grains, Organic matter in meteorites, Differentiation **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO2** **CLO3** **CLO4**
IV/10	Thermal models, Impacts and collisions, Lunar meteorites, Martian meteorites, Lunar Geology, Martian Geology. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO2** **CLO3** **CLO4**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Seminar, Group discussion, Blended learning, flipped learning, Focused group discussion, Brain storming, Mobile teaching, Collaborative learning, E-tutoring, Problem solving.

Suggested Readings:

1. Krot A.N., K. Keil, E.R.D. Scott, C.A. Goodrich and M.K. Weisberg (2014) Classification of meteorites and their genetic relationships. In Treatise on Geochemistry, 2nd Ed., Elsevier, pp. 1-63. classification.
2. Gaffey M.J., E.A. Cloutis, M.S. Kelley and K.L. Reed (2002) Mineralogy of asteroids. In Asteroids III (eds. W.F. Bottke, Jr., A. Cellino, P. Paolicchi, and R. Binzel), pp. 183-204.
3. Burbine T.H., T.J. McCoy, A. Meibom, B. Gladman and K. Keil (2002) Meteoritic parent bodies: Their number and identification. In Asteroids III (eds. W.F. Bottke, Jr., A. Cellino, P. Paolicchi, and R. Binzel), pp. 653-667.
4. Hewins R.H. (1997) Chondrules. In Ann. Rev. Earth Planet. Sci. 25, 61-83. A short review of evidence pertaining to chondrules and what they might tell us about the solar nebula.
5. MacPherson G. J., S.B. Simon, A.M. Davis, L. Grossman and A.N. Krot (2005) Calcium-aluminum-rich inclusions: major unanswered questions. In Chondrites and the Protoplanetary Disk (eds. A.N. Krot, E.R.D. Scott, and B. Reipurth), pp. 225-250. ASP Conference Series, vol. 341. Astronomical Society of the Pacific: San Francisco.
6. Jones R.H., T. Lee, H.C. Connolly Jr., S.G. Love and H. Sheng (2000) Formation of chondrules and CAIs: Theory vs. observation. In Protostars and Planets IV (eds. V. Mannings, A.P. Boss, S.S. Russell), pp. 927-962.
7. Davis A. (2006) Volatile evolution and loss. In Meteorites and the Early Solar System II (eds. D.S. Lauretta and H.Y. McSween Jr.), pp. 295-307.
8. Wood J. (2005) The chondrite types and their origins. In Chondrites and the Protoplanetary Disk (eds. A.N. Krot, E.R.D. Scott, and B. Reipurth), pp. 953-971. ASP Conference Series, vol. 341. Astronomical Society of the Pacific: San Francisco.

9. Dauphas N. and M. Chaussidon (2011) A perspective from extinct radionuclides on a young stellar object: The sun and its accretion disk. In Ann. Rev. Earth Planet. Sci. 39, 351-386.
10. Lugmair G.W. and A. Shukolyukov (2001) Early solar system events and timescales. Meteorite. Planet. Sci. 36, 1017-1026.
11. Huss G.R., A.E. Rubin and J.N. Grossman (2006) Thermal metamorphism in chondrites. In Meteorites and the Early Solar System II (eds. D.S. Lauretta and H.Y. McSween Jr.), pp. 567-586. University of Arizona Press: Tucson.
12. Brearley A. (2006) The action of water. In Meteorites and the Early Solar System II (eds. D.S. Lauretta and H.Y. McSween Jr.), pp. 587-624. University of Arizona Press: Tucson.
13. Clayton D.D. and L.R. Nittler (2004) Astrophysics with presolar stardust. In Annu. Rev. Astron. Astrophys. 42, 39-78.
14. Gilmour I. (2005) Structural and isotopic analysis of organic matter in carbonaceous chondrites. In Meteorites, Comets, and Planets (ed. A.M. Davis), Ch. 1.10, pp. 269-290. Elsevier: Amsterdam.
15. McSween H.Y.Jr. (1989) Achondrites and igneous processes on asteroids. Ann. Rev. Earth Planet. Sci. 17, 119-140.
16. Wasson J.T. (1985) Iron meteorites: Evidence for and against core origins. In Meteorites- Their Record of Early Solar-system History, Ch. IV, pp.76-99. W.H. Freeman & Co.: New York.
17. McSween H.Y., Jr, A. Ghosh, R.E. Grimm, L. Wilson, E.D. Young (2002) Thermal evolution models of asteroids. In Asteroids III (eds. W.F. Bottke, Jr., A. Cellino, P. Paolicchi, R.P. Binzel, pp. 559-571. University of Arizona Press: Tucson.
18. Stöffler D., A. Bischoff, V. Buchwald and A.E. Rubin (1988) Shock effects in meteorites. In Meteorites and the Early Solar System (eds. J.F. Kerridge and M.S. Matthews), pp. 165-202.
19. Scott E.R.D. and R.S. Rajan (1981) Metallic minerals, thermal histories and parent bodies of some xenolithic, ordinary chondrite meteorites. Geochim.Cosmochim.Acta 45, 53-67.
20. Udry A. et al. (2020) What martian meteorites reveal about the interior and surface of Mars. JGR Planets 125, https://doi.org/10.1029/2020JE006523.

Web Resources:

https://meteorites.pdx.edu/
https://web.pdx.edu/~ruzickaa/meteorites/gallery/gallery.html

Course Code: MEGS.522

L	T	P	Credits
3	0	0	3

Course Title: Oceanography

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Explain the theories related to the origin and evolution of the oceans.
CLO2: Understand the various topographical features associated with the ocean systems.
CLO3: Describe the process, causes, and effects of ocean water circulation.
CLO4: Grasp the concepts of ocean currents and their distribution in all the major oceans of the Earth's surface.
CLO5: Develop an understanding of the Indian Monsoon and its impacts.
CLO6: Learn the important concepts related to the waves, tides, and tsunamis.
CLO7: Expand their knowledge in the field of ocean chemistry and sedimentation.

Unit/ Hour	Contents	Mapping with CLO
I/11	Origin and evolution of ocean basins; Importance of oceans; Paleoceanography: Theories, proxies and significance; Hydrological cycle; Hypsometric Curve; Ocean bottom relief; Bottom relief of Pacific, Atlantic and Indian Ocean; Salinity of the ocean: Sources, factors and distribution; Salt budget. **Learning Activities:** Assignment, take-home exercise, peer learning on oceanic topography.	**CLO1 CLO2**
II/12	Ocean water circulation; Convection cells of the Earth; Coriolis forces: Its cause and effects; Wind drags; Ekman Spiral; Mechanism of Hurricanes and its difference from Tornadoes; Storm surges; Gyres; Geostrophic currents; Western Intensifications. **Learning Activities:** Exercise on the mechanics of atmospheric and oceanic circulation.	**CLO3**
III/11	Ocean currents: causes and impacts; Currents of Pacific, Atlantic, and Indian Ocean; Gulf Stream; Concepts of Indian Monsoon; Retreat Monsoon; Walker Circulation; Southern Oscillation; El Niño and La Niña; El Niño Southern Oscillation (ENSO); Indian Ocean Dipole (IOD). **Learning Activities:** Group discussions, Assignments, Term papers.	**CLO4 CLO5**

IV/11	Ocean waves: Wave dynamics, deep water waves, shallow water waves, progressive waves, wave interference, wave dispersion, wave transformation and wave breaks; Tsunami; Tides; chemical properties of seawater; Principal of constant proportion; Ocean acidification and pH buffer; Ocean sediments and marine deposits; Coral reefs: Origin, distribution and significance; Coral bleaching; Exclusive Economic Zone (EEZ); India's Exclusive Economic Zone (EEZ)..; **Learning Activities:** Assignment on wave dynamics and ocean chemistry, group discussion on EEZ of the Indian Ocean.	**CLO6** **CLO7**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry Training, Seminar, Group discussion, Blended learning, flipped learning, Focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching, Collaborative learning, Case-based study, Through SOLE (Self-Organized Learning Environment).

Suggested readings:

1. Garrison, T., 1996.*Oceanography-An invitation to Marine Science*, Wadsworth Publishing Company
2. Gross, M.G.,1972. *Oceanography: A View of the Earth*, Prentice-Hall.
3. Thurman, B.Y., 1978. *Introductory Oceanography*, Charles E. Merrill Publishing Company.
4. Kale, V.S. and Gupta, A., 2001.*Introduction to Geomorphology, Orient Longman*, Bangalore.
5. Singh, S., 2011.*Physical Geography, Prayag Pustak Bhavan*, Allahabad.
6. Strahler, A.N. and Strahler, 1996.*An Introduction to Physical Geography, John Wiley & Sons*, UK.
7. S. Davis, R.A. Jr., 1972. *Principles of Oceanography, Addison-Wesley Publishing Company*.
8. Roonwal, G.S.,1986. *The Indian Ocean: Exploitable Mineral and Petroleum Resources, Narosa Publishing House*.
9. Francis P. Shepard, 1977. Geological Oceanography: Evolution of Coasts, Continental Margins & the Deep-Sea Floor, Pan Publication.
10. Bhatt J.J., 1978. *Oceanography–Exploring the Planet Ocean, D. van Nostrand Company*.

Web Resources:

https://www.nationalgeographic.org/https://www.nio.org/
https://science.nasa.gov/earth-science/focus-areas/oceanography

Semester-II

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.415	Igneous Petrology	*Discipline Specific Core*	3	0	0	3
MEGS.416	Igneous Petrology (Practical)	*Skill Based*	0	0	2	1
MEGS.417	Metamorphic Petrology	*Discipline Specific Core*	3	0	0	3
MEGS.418	Metamorphic Petrology (Practical)	*Skill Based*	0	0	2	1
MEGS.516	Geochemistry and Isotope Geology	*Discipline Specific Core*	3	0	0	3
MEGS.536	Solid Earth Geophysics	*Ability Enhancement*	3	0	0	3
MEGS.539	Ore Geology	*Discipline Specific Core*	3	0	0	3
MEGS.540	Ore Geology (Practical)	*Ability Enhancement*	0	0	2	1
Select Any One Value Added Course (VAC)[$]						
MEGS.513	Mining methods and fossil fuel exploration	*VAC*	2	0	0	2
MEGS.514	Sequence Stratigraphy & Basin Analysis		2	0	0	2
	Tutorial	*Remedial class*	0	2	0	0
Interdisciplinary course						
	Interdisciplinary course#	*IDC*	2	0	0	2
Interdisciplinary course offered by the Department[$]						
MEGS.506	Introduction to Disaster Management	*IDC*	2	0	0	2
MEGS.507	Introduction to Earth System Science	*IDC*	2	0	0	2
MEGS.508	Geoheritage and Geotourism	*IDC*	2	0	0	2
Total			**19**	**2**	**6**	**22**

Course Code: MEGS.415

L	T	P	Credits
3	0	0	3

Course title: Igneous Petrology **Total Hours: 45**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Understand the genesis and evolution of magma.
CLO2: Evaluate key textural/microstructural features of igneous rocks.
CLO3: Do the nomenclature of igneous rocks using IUGS recommendations.
CLO4: Understand the Magmatic processes using multiple proxies.
CLO5: Explain the petrogenesis of igneous rocks using phase diagrams and thermodynamics.
CLO6: Apprise the geochemical behavior during the igneous processes.
CLO7: comprehend the mantle petrology.

Unit/ Hour	Contents	Mapping with CLO
I/12	Physical properties of magma: viscosity, density, temperature; Magma Generation & Evolution: Partial melting (batch, fractional), fractional crystallization, assimilation, liquid immiscibility, double diffusion, and magma-mixing. **Learning Activities:** Assignment, Take-home exercise, mini projects.	**CLO1** **CLO4**
II/11	Introduction to thermodynamics and its application in Igneous petrology; The phase equilibrium of unary, binary, and ternary systems and its relation to magma genesis and crystallization; Nucleation and crystal growth; Igneous textures. **Learning Activities:** Group discussion and take-home exercise.	**CLO1** **CLO2** **CLO4** **CLO5**
III/11	Mineralogical and chemical classification (IUGS system); CIPW Norm; Petrology and petrogenesis of ultramafic, basaltic, granitic, alkaline igneous rocks; layered igneous complex; Tectonic settings of magmatism. **Learning Activities:** Assignment, Take-home exercise, mini projects.	**CLO1** **CLO2** **CLO4** **CLO5** **CLO6**
IV/11	Mantel Petrology: Composition and structure of the mantle, Mantle plumes and hotspots; Geochemistry of Igneous Rocks; Geochemical modeling and its application to magmatic and allied processes. **Learning Activities:** Student seminar, assignment, and mini	**CLO1** **CLO4** **CLO5** **CLO6** **CL07**

	projects.	

Transactional Modes: Lecture, Demonstration, Seminar, Group discussion, Cooperative learning, Blended learning, flipped learning, focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching and tutoring, Problem solving, Self-learning, Case-based study, etc.

Suggested readings:

1. Winter, J.D., 2001. An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.
2. Philpotts, A.R. 1994. *Principles of Igneous and Metamorphic Petrology*, Prentice Hall.
3. Cox, K.G., Bell, J.D. and Pankhurst, R.J., 1993. *The Interpretation of Igneous Rocks, Chapman & Hall*, London.
4. Turner, F.J., and Verhoogen, J., 1987. *Igneous and Metamorphic Petrology*, CBS.
5. Faure, G., 2001. Origin of Igneous Rocks–The Isotopic Evidence, Springer.
6. HallA.,1997. *Igneous Petrology*, Longman.
7. Le Maitre, R.W., 2002. Igneous Rocks: A Classification and Glossary of Terms, Cambridge University Press.
8. Mc Birney, 1994. *Igneous Petrology*, CBSPublishers, Delhi.
9. Sood, M.K., 1982. *Modern Igneous Petrology, Wiley-Interscience Publ., New York*.
10. Srivastava Rajesh, K., Chandra, R. and Balkema, A.A., 1997. *Magmatism in Relation to Diverse Tectonic Settings, Oxford University Press*.
11. Spear, F.S. 1993. Mineralogical Phase Equilibria and Pressure–Temperature–Time Paths, Mineralogical Society of America.
12. Powell, R.1978. *Equilibrium Thermodynamics in Petrology: An Introduction, Harper & Row Publishers*, London.
13. Bose, M.K.,1997. *Igneous Petrology, World Press*, Kolkata.

Web Resources:

https://www.southalabama.edu/geography/allison/gy303/GY303Lectures.html
http://www1.mans.edu.eg/FacSciM/english/courses/geology/Dr_Mahrous/Abu%20El-nen%20Metamorphic%20Petrology%20Course/Metamorphic%20Petrology%20-%20Lecture%20I.ppt
http://academic.sun.ac.za/natural/geology/undergraduate/modules/G214_course_notes_e.htm
https://serc.carleton.edu/resources/22102.html
http://eps.mcgill.ca/~courses/c212/Igneous14/IgPetClass/IntoPet212-14.pptx
http://www.geosciences.fau.edu/Resources/CourseWebPages/Spring2012/GLY4310_S12/index.4310_S10.htm
https://ocw.mak.ac.ug/courses/earth-atmospheric-and-planetary-sciences/12-479-trace-element-geochemistry-spring-2013/lecture-notes/
http://www.tulane.edu/~sanelson/eens212/

Course Code: MEGS.416

L	T	P	Credits
0	0	2	1

Course Title: Igneous Petrology (Practical) **Total Hours: 30**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Identify and inspect key textural/microstructural features of igneous rocks in hand specimens as well as under the microscope.

CLO2: Do nomenclature igneous rock based on its mineralogical and textural characteristics as recommended by IUGS.

CLO3: explain petrogenesis of igneous Rocks.

Unit/ Hour	Contents	Mapping with CLO
I/30	The following exercise will be conducted in the lab • Megascopic and microscopic study of different igneous rocks. • Textural identification and establishment of crystallization sequence. • Textural interpretation and petrogenesis using phase diagram. • Calculation of CIPW Norms. • Magma density calculation using geochemistry. • Crystal Size distribution (CSD) exercise. • Preparation of classification and variation diagrams and their interpretation.	**CLO1** **CLO2** **CLO3**

Transactional Modes: Demonstration, Group discussion, Problem solving, Case analysis, Case study, Self-learning, Case based study, Through SOLE (Self Organized Learning Environment), Experimentation.

Evaluation Criteria: Total Marks – 100,
End semester exam (50 marks), Continues assessment (30 marks), Lab record (10 marks), Viva (10marks).

Suggested readings:

1. Le Maitre, R. W., 2002. I*gneous Rocks: A Classification and Glossary of Terms*, Cambridge University Press.
2. Winter, J.D., 2001. *An introduction to Igneous and Metamorphic Petrology*, Prentice Hall.
3. Philpotts, A. R., 1994. *Principles of Igneous and Metamorphic Petrology*, Prentice Hall.
4. Cox, K.G., Bell, J.D., and Pankhurst, R.J., 1993. *The Interpretation of Igneous Rocks*, Champman & Hall, London.
5. Myron G., 2002. Igneous and Metamorphic Petrology, Blackwell Science.
6. Faure, G., 2001. *Origin of Igneous Rocks – The Isotopic Evidence*,

Springer.
7. Hall A., 1997. *Igneous Petrology*, Longman.

Web Resources:

http://academic.sun.ac.za/natural/geology/undergraduate/modules/G214_course_notes_e.htm
https://serc.carleton.edu/resources/22102.html
http://eps.mcgill.ca/~courses/c212/Igneous14/IgPetClass/IntoPet212-14.pptx
https://ocw.mak.ac.ug/courses/earth-atmospheric-and-planetary-sciences/12-479-trace-element-geochemistry-spring-2013/lecture-notes/
http://www.tulane.edu/~sanelson/eens212/

Course Code: MEGS.417

L	T	P	Credits
3	0	0	3

Course Title: Metamorphic Petrology

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1: Interpret mineral behavior in metamorphic environments
CLO2: Differentiate textures formed under various metamorphic conditions
CLO3: Analyze petrogenetic grids to solve metamorphic petrological problems
CLO4: Identifying equilibrium mineral assemblages through textural and mineralogical observations
CLO5: Explain the fundamental laws of thermodynamics in geological systems
CLO6: Analyze phase relationships and component behavior in metamorphic systems
CLO7: Apply metamorphic concepts to solve petrological and geological problems

Unit/ Hour	Contents	Mapping with CLO
I/12	Introduction- Significance of metamorphic studies, Definition and limits of metamorphism, Overview of different types of metamorphism; Factors controlling transformations, Heat flow, Minerals as pure and impure phases, Textures of contact and regional metamorphism, Tectonic context of metamorphic transformations, Concept and Classification of Metamorphic Facies and Facies Series. **Learning Activities:** Assignment, Take-home exercise, mini projects.	**CLO1 CLO2**
II/11	Isograds and Reaction Isograds, Advantages of Reaction Isograd concept over the concept of Isograd, Schrienemakers Rule and	**CLO3 CLO4**

	Construction of Petrogenetic Grids (Pseudosection Modelling): their application to petrological problems, Metamorphic Differentiation, Regional Metamorphism and Paired Metamorphic Belts in relation to Plate Tectonics, Pressure – temperature – time paths from a plate tectonic view. **Learning Activities:** Group discussion and take-home exercise.	
III/11	Laws of Thermodynamics, Gibb's Free – Energy, Entropy, Δ G of Metamorphic Reactions (Solid-Solid and Dehydration Reactions). Clausius – Clapeyron Equation, Application of equilibrium thermodynamics to rocks, Geothermobarometry. **Learning Activities:** Group discussion and take-home exercise.	**CLO5**
IV/11	Mineralogical Phase Rule for Closed and Open Systems. Nature of Metamorphic Reactions, Introduction to Ultrahigh Temperature and Ultrahigh Pressure Metamorphism, Extremities of metamorphism: Introduction and challenges of UHT and UHP metamorphism. Anatexis and Origin of Migmatites in the light of experimental studies: its implications for petrological problems. **Learning Activities:** Student seminar, assignment, and mini projects.	**CLO6** **CLO7**

Transactional Modes: Lecture, Demonstration, Seminar, Group discussion, Cooperative learning, Blended learning, flipped learning, focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching and tutoring, Problem solving, Self-learning, Case-based study, etc.

Suggested readings:

1. Winter, J.D., 2001. An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.
2. Philpotts, A.R. 1994. *Principles of Igneous and Metamorphic Petrology*, Prentice Hall.
3. Cox, K.G., Bell, J.D. and Pankhurst, R.J., 1993. *The* Turner, F.J., and Verhoogen, J., 1987. *Igneous and Metamorphic Petrology*, CBS.
4. Myron G., 2002. Igneous *and Metamorphic Petrology, Blackwell Science*.
5. Bucher, K. and Martin, F., 2002. *Petrogenesis of Metamorphic Rocks, Springer–Verlag*.
6. Yardley, B.W.D., 1989. *An Introduction to Metamorphic Petrology, Longman Scientific & Technical, New York*.
7. Spear, F.S. 1993. Mineralogical Phase Equilibria and Pressure–Temperature–Time Paths, Mineralogical Society of America.
8. Powell, R.1978. *Equilibrium Thermodynamics in Petrology: An Introduction, Harper & Row Publishers*, London.
9. Bose, M.K.,1997. *Igneous Petrology, World Press*, Kolkata.
10. Sharma, Ram. S., 2016. Metamorphic Petrology: Concepts and Methods, Geological Society of India.
11. Bucher, K. and Martin, F. 2002. Petrogenesis of Metamorphic Rocks, Springer –

Verlag, 7th Revised Edition • Frost, B.R. and Frost, C.D. 2014, Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.

Web Resources:

https://www.southalabama.edu/geography/allison/gy303/GY303Lectures.html
http://www1.mans.edu.eg/FacSciM/english/courses/geology/Dr_Mahrous/Abu%20El-nen%20Metamorphic%20Petrology%20Course/Metamorphic%20Petrology%20-%20Lecture%20I.ppt
http://www.tulane.edu/~sanelson/eens212/

Course Code: MEGS.418

L	T	P	Credits
0	0	2	1

Course Title: Metamorphic Petrology (Practical)

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 Analyze hand specimens to interpret the sequence and timing of deformation phases and mineral recrystallization in rocks.

CLO2 Identify metamorphic rocks in thin sections and interpret their facies, origin, and mineral assemblages with graphical representation.

CLO3 Understand the graphical representation ACF, AKF, and AFM values from mineral chemistry.

CLO4 Estimate pressure and temperature using geothermo-barometric models.

Unit/ Hour	Contents	Mapping with CLO
I/30	• A detailed study of rocks, with emphasis on hand specimens, focusing on the temporal relationships between deformation phases and mineral recrystallization. • Study of Metamorphic Rocks in thin sections belonging to different facies with emphasis on texture/structure, mineral composition, parent rock, metamorphic facies / sub-facies / zone to which the rock can be assigned and graphical representation of the assemblage. • Calculation of ACF, AKF and AFM values from chemical and structural formulation of minerals and their graphical representation. • Estimation of Pressure and Temperature from important models of Geothermobarometry.	**CLO1 CLO2 CLO3 CLO4**

Transactional Modes: Demonstration, Microscopic study, Group discussion, Problem solving, Case analysis, Case study, Self-learning, Case based study, Through SOLE (Self Organized Learning Environment), Experimentation.

Suggested readings:

1. Winter, J.D., 2001. An Introduction to Igneous and Metamorphic Petrology, Prentice Hall.
2. Philpotts, A.R. 1994. *Principles of Igneous and Metamorphic Petrology*, Prentice Hall.
3. Cox, K.G., Bell, J.D. and Pankhurst, R.J., 1993. *The* Turner, F.J., and Verhoogen, J., 1987. *Igneous and Metamorphic Petrology*, CBS.
4. Myron G., 2002. Igneous *and Metamorphic Petrology, Blackwell Science*.
5. Bucher, K. and Martin, F., 2002. *Petrogenesis of Metamorphic Rocks, Springer–Verlag*.
6. Yardley, B.W.D., 1989. *An Introduction to Metamorphic Petrology, Longman Scientific & Technical, New York*.
7. Spear, F.S. 1993. Mineralogical Phase Equilibria and Pressure–Temperature–Time Paths, Mineralogical Society of America.
8. Powell, R.1978. *Equilibrium Thermodynamics in Petrology: An Introduction, Harper & Row Publishers*, London.
9. Sharma, Ram. S., 2016. Metamorphic Petrology: Concepts and Methods, Geological Society of India
10. Bucher, K. and Martin, F. 2002. Petrogenesis of Metamorphic Rocks, Springer – Verlag, 7th Revised Edition .
11. Frost, B.R. and Frost, C.D. 2014, Essentials of Igneous and Metamorphic Petrology, Cambridge University Press.

Web Resources:

https://www.southalabama.edu/geography/allison/gy303/GY303Lectures.html
http://www1.mans.edu.eg/FacSciM/english/courses/geology/Dr_Mahrous/Abu%20El-nen%20Metamorphic%20Petrology%20Course/Metamorphic%20Petrology%20-%20Lecture%20I.ppt
http://www.tulane.edu/~sanelson/eens212/

Course Code: MEGS.516

L	T	P	Credits
3	0	0	3

Course Title: Geochemistry and Isotope Geology

Total Hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 : Appraise behaviors of elements in the formation of primary and secondary rocks
CLO2 : Formulate the basics of isotope systematics and radioactive decay.
CLO3 : Design the geochemical aspects for the assessment of elements in and on Earth.
CLO4 : Discuss the principles and applications of radiogenic isotope systems to study geological processes and date rock-forming events.
CLO5 : Adapt the principles and applications of stable isotope systematics.

Unit/ Hour	Contents	Mapping with CLO
I/11	Introduction to geochemistry and cosmochemistry. The abundance of elements in the solar system and the chemical composition and properties of Earth's layers. Atmosphere: its layers, chemical composition, and evolution of the atmosphere. Meteorites, classification, mineralogy, origin, significance, and phenomena of fall. **Learning Activities:** Assignments, Take-home exercises, and Group discussions.	**CLO1** **CLO2**
II/10	Geochemical classification of elements. Chemical Bonds, Ionic Radii, and Crystals, Distribution coefficient; Behavior of major and trace, including rare earth elements during magmatic crystallization, Oddo-Harkins rule. Elemental mobility in surface environment, Eh-pH diagram. Concept of geochemical-biogeochemical cycling: Minor cycle and major cycle. Chemical weathering of minerals and rocks. **Learning Activities:** Take-home exercise, peer learning, and plotting of Eh-pH diagram for stability of different species/complexes of elements.	**CLO3**
III/12	**Isotope Geology:** The law of radioactive decay; principles of mass spectrometry; Principles, methods, and applications of K-Ar method, Ar-Ar method, Rb-Sr method, Sm-Nd Method, U-Th-Pb Method: decay schemes, U-Pb isochron, U-Pb mineral dating, and application. **Learning Activities:** Hands-on exercise during class, take-home exercise, assignment, and student seminar.	**CLO4** **CLO5**
IV/12	Stable isotopes and their fractionation; ratio Mass Spectrometry; principles of oxygen, carbon, and sulphur isotope geochemistry and their application in Geology. Application of Cosmogenic	**CLO4** **CLO5**

	radionuclides in the geosciences. Principles and application of Fission Track and Radiocarbon methods of dating. **Learning Activities:** Assignment, student seminar, and group discussion.	

Transactional Modes: Lecture, Project Method, Seminar, Co-operative Learning, Focused Group Discussion, Team Teaching, Mobile Teaching, Collaborative Learning, E-tutoring, Problem-solving, Case Analysis, Self-learning, Case-based Study, Experimentation.

Suggested readings:

1. Gunter Faure, 1998. *Principles and Applications of Geochemistry, Prentice Hall.*
2. John V. Walther, 2010.*Essentials of Geochemistry, Jones and Bartlett Publications*.
3. Claude Allegre, 2008. *Isotope Geology, Cambridge University Press*.
4. Dickin, A.P., 2005.*Radiogenic Isotope Geology*. Cambridge University Press.
5. Jochen Hoefs, 2015. *Stable Isotope Geochemistry*, Springer International Publishing.
6. Gunter Faure, 1986.*Principles of Isotope Geology*, Wiley.
7. Gunter Faure and Teresa M. M, 2004. *Isotopes: Principles and Applications*, Wiley.
8. Francis Albarede, 2003. *Geochemistry: An Introduction, Cambridge University Press*.
9. William M. W.,2013. *Geochemistry*, Wiley-Blackwell.
10. Mc Sween Jr., H. Y., Richardson, S. M., and Uhle, M. E.,2003. *Geochemistry: Pathways and Processes*, Columbia University Press,
11. Mason, B., and Moore, C.B., 1991.*Introduction to Geochemistry, Wiley Eastern.*
12. Krauskopf, K.B., 1967. *Introduction to Geochemistry, McGraw-Hill.*

Web Resources:

https://www.uvm.edu›GEOL195-Geochemistryhttp://www.geo.cornell.edu/geology/classes/Geo656/656notes03.html
https://wwwrcamnl.wr.usgs.gov/isoig/isopubs/itchch2.html
https://www.southalabama.edu/geology/haywick/GY112/ppt/112-pp8a.pdf
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-742-marine-chemistry-fall-2006/lecture-notes/lecture_2_notes.pdf

Course Code: MEGS.536

Course Title: Solid Earth Geophysics

L	T	P	Credits
3	0	0	3

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of course, the student will be able to

CLO1: Able to understand the application of Geophysics

CLO2: Evaluate and assess data quality and different information sources in geophysics

CLO3: Formulate, process, and implement strategies for data and theoretical analysis.

CLO4: Develop the ability to perform geophysical data analysis, interpretation, and use seismological data for understanding the Earth's subsurface.

Unit/ Hour	Contents	Mapping with CLO
I/11	Introduction to geophysics; shape and size of the Earth; gravitational field of the Earth; variation of gravity on the Earth's surface; principles of gravity methods and instruments used; The Bouguer anomaly; regional and residual anomalies; Relative motion of plates, Stability of triple junction. **Learning Activities:** Assignment, take-home exercise, group discussion.	**CLO1**
II/11	Geomagnetic field of the earth; magnetic properties of rocks; principles of magnetic methods; Variation of magnetic fields over earth's surface, magnetic declination, Inclination, magnetic susceptibilities, type of magnetizations. Rock magnetism, Magnetic domains, Anisotropy of magnetic susceptibility. **Learning Activities:** Problem solving after each method, take-home exercise.	**CLO1 CLO2**
III/12	Seismic methods: principles and instruments used; seismic velocity, Derivation of travel time calculation in Seismic refraction and reflection methods. Geometry of refraction and reflection paths in layered earth. Seismic noise, reflection, and refraction field methods. Conventional and modern (CDP) methods of acquisition of seismic reflection data. **Learning Activities:** Assignment, take-home exercise, lab-based exercise.	**CLO3**
IV/11	Electrical methods: basic principles and various types of electrode configuration: Wenner and Schlumberger; Electrical resistivity method, self-potential and resistive surveying; field procedures and interpretation of field data. Applications of electricity in groundwater exploration.	**CLO4**

	Learning Activities: Assignment, student's seminar, and a mini project.	

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Seminar, Group discussion, Team teaching, Brainstorming, Mobile teaching, Collaborative learning, Case analysis, Case study, Case-based study, Through SOLE (Self-Organized Learning Environment).

Suggested readings:

1. Lowrie, W., 1997. *Fundamentals of Geophysics, Cambridge Univ.* Press. London.
2. Fowler, 2005. *The Solid Earth: An Introduction to Global Geophysics, Cambridge University Press*.
3. Telford, W.M., Geldart, L.P. and Sheriff, R.E., 1990.Applied Geophysics, Cambridge University Press.
4. Peter Shearer,1999. *Introduction to Seismology, Cambridge University Press*, Cambridge.
5. Alan E. Mussett, M. Aftab Khan, 2000.*Looking into the Earth: An Introduction to Geological Geophysics, Cambridge University Press*.
6. Lillie, R.J., 1998. Whole Earth Geophysics: An Introductory Book for Geologists and Geophysicists, Pearson Education.
7. Parasnis, D.S., 1986. Principles of Applied Geophysics, Chapman and Hall.
8. Dobrin, M.B. and Savit, C.H., 2014. Introduction to Geophysical Prospecting, McGraw-Hill Exclusive.
9. Gadallah, Mamdouh R. and Fischer, R.L., 2009. Exploration Geophysics, Springer-Verlag Berlin Heidelberg.
10. AlbertTarantola,2005.InverseProblemTheoryandModelParameterEstimation.SIAM
11. Thorne Lay and Terry Wallace, 1995. Modern Global Seismology, Academic Press.

Web Resources:

https://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Revised%20Course/OVERVIEW.htm
https://www.bu.edu/pasi/files/2011/01/MarcSpiegelman1-06-1330.pdf
https://www.irsm.cas.cz/ext/ethiopia/resources/lecture_notes.pdf
http://www-gpsg.mit.edu/12.201_12.501/
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-201-essentials-of-geophysics-fall-2004/lecture-notes/

Course Code: MEGS.539

L	T	P	Credits
3	0	0	3

Course title: Ore Geology

Total hours: 45

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 : Improve their knowledge of the basic concepts of ore geology, ore localization and spatial and temporal distribution.

CLO2 : Understand the various process associated with ore formation in specific environment.

CLO3 : Elaborate overall geometry, texture, zonation, and alteration patterns of rock associations to specific classes of metallic mineral deposits.

CLO4: Describe the various types of ore metallogenesis and their overall assemblages.

CLO5: Explain the distribution pattern of ore minerals in India in terms of their strategic, critical, and essential perspectives.

CLO6: Build their concepts on Fuel geology, especially on coal, petroleum, and nuclear resources.

CLO7: Evaluate the importance and applications of fluid inclusion in ore geology.

Unit/ Hour	Contents	Mapping with CLO
I/11	Modern concept of ore genesis; mode of occurrence of ore bodies – morphology and relationship of host rock and migration, wall-rock alteration; Structural, physicochemical and stratigraphic controls of ore localization; processes of formations of ore mineral deposits; Spatial and temporal distribution of ore deposits – a global perspective. Ore deposits in relation to plate tectonics. **Learning Activities:** Assignment, take home exercise, seminars, Group discussions	**CLO1** **CLO2**
II/11	Texture, paragenesis and zoning of ores and their significance; Introduction to Ore microscopy: Qualitative and Quantitative methods in the identification of Ore minerals; Ore deposits and their distributions; VMS, SEDEX, MVT, Porphyry, Skarn, IOCG deposits; **Learning Activities:** Hands on exercise and group discussion.	**CLO3** **CLO4**
III/12	Study of ore minerals related to the following metals such as Fe, Mn, Cr, Cu, Pb, Zn, Al, Mg, Au, Sn, and W with special reference to their mineralogy, genesis, uses in important industries, and their distribution in India. Critical mineral and green/clean energy; Strategic, and essential minerals. Fundamentals of coal petrology;	**CLO5** **CLO6**

	Petroleum geology; Nuclear and Non-conventional source of energy. **Learning Activities:** Student seminar, assignment and take-home exercise.	
IV/11	Principle of Fluid inclusion study and its applications in ore genesis: Basic definitions and history; Types of fluid inclusions; formation mechanism; Fluid inclusion petrography; Sample preparation techniques; Principles of micro-thermometry; Binary and ternary systems of related to fluid inclusion studies. **Learning Activities:** Assignment, take home exercise, seminar.	**CLO7**

Transactional Modes: Lecture, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Focused group discussion, Team teaching, Mobile teaching, Collaborative learning, Problem solving, Case analysis, Self-learning, Case based study.

Suggested readings:

1. Robb, L., 2005. *Introduction to Ore-forming processes*, Blackwell Publ., Oxford.
2. Evans, A.M., 1992. *Oregeology and Industrial Minerals, Blackwell Science*.
3. Misra, K.C. 1999.*Understanding mineral deposits, Kluwer Academic Publishers*.
4. Sinha, R.K. and Sharma, N.L., 1970. *Mineral economics*, Oxford & IBH.
5. Jensen, M.L. and Bateman, A.M., 1981. *Economic mineral deposits*, John Wiley & Sons.
6. Stanton, R.L., 1972. *Ore Petrology*, McGraw-Hill.
7. Guilbert, J.M. and Park, Jr. C.F., 1986. *The Geology of Ore Deposits*, Freeman.
8. Barnes, H.L., 1979. *Geochemistry of Hydrothermal Ore Deposits*, John Wiley.
9. Umeshwar Prasad, 2014. *Economic Geology: Economic Mineral Deposits (Second Edition),* CBS Publishers & Distributors Pvt. Ltd., New Delhi.
10. T. J. Shepherd, A. H. Rankin, D. H. M. Alderton, 1985, *A Practical Guide to Fluid Inclusion Studies*, Publisher: Blackie, Page: 239. ISBN-0412006014, 9780412006012.

Web Resources:

https://www.southalabama.edu/geology/haywick/GY111/111-8.pdf
http://earthsci.org/mineral/mindep/class_dep/class_dep.html

https://pubs.usgs.gov/bul/0225/report.pdf
https://www.mlsu.ac.in/econtents/1911_Mineral%20Deposits%20in%20India.pdf
https://gsi.gov.in/webcenter/portal/OCBIS/pagePublications/pageViewGSIPublication?_adf.ctrl-state=w5w97un87_5&_afrLoop=2133991338489583 6#!

L	T	P	Credits
0	0	2	1

Course Code: MEGS.540

Course Title: Ore Geology (Practical)

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Identify and inspect common ore minerals in hand samples and under the microscope
CLO2: Get familiar with a wide range of mineral deposits, including recognizing the overall geometry, zonation, and alteration patterns, grade and tonnage associated with specific classes of metallic mineral deposits
CLO3: understand the methods to identify various fluid inclusions associated with minerals and their application in ore geology.

Unit/ Hour	Contents	Mapping with CLO
I/30	• Megascopic study of Indian metallic ores and industrial minerals in hand specimens • Study of optical properties and identification of important ore minerals under ore-microscope. • Preparation of maps showing distribution of metallic and industrial minerals in India and classical world mineral deposits • Estimation of grade, tonnage of ore deposits • Practical on fluid inclusion petrography	**CLO1 CLO2 CLO3**

Transactional Modes: Demonstration, Group discussion, Problem solving, Case analysis, Case study, Self-learning, Case-based study, Through SOLE (Self-Organized Learning Environment), Experimentation.
Evaluation Criteria: Total Marks–100, End semester exam (50 marks), Continuous assessment (30 marks), Lab record (10 marks), Viva (10 marks).

Suggested readings:

1. Evans, A.M. (1992). *Ore geology and industrial minerals*, Blackwell Science.
2. A.E. Annels, (1992). *Mineral deposit evaluation*, Chapman and Hall, London.
3. Sinha, R.K. and Sharma, N.L.,1970. *Mineral economics*, Oxford & IBH.
4. Umeshwar Prasad, 2014. *Economic Geology: Economic Mineral Deposits (Second Edition),* CBS Publishers & Distributors Pvt. Ltd., New Delhi
5. T. J. Shepherd, A. H. Rankin, D. H. M. Alderton, 1985, *A Practical Guide to Fluid Inclusion Studies*, Publisher: Blackie, Page: 239. ISBN-0412006014, 9780412006012.

Web Resources:

https://pubs.usgs.gov/bul/0225/report.pdf
https://www.mlsu.ac.in/econtents/1911_Mineral%20Deposits%20in%20India.pdf
https://gsi.gov.in/webcenter/portal/OCBIS/pagePublications/pageViewGSIPublication?_adf.ctrl-state=w5w97un87_5&_afrLoop=2133991338489583 6#!

Tutorial/ Remedial Class

L	T	P	Credits
0	2	0	0

Two hours non-credit tutorial class is designed for remedial teaching. Scheduled classes will be assigned in the timetable. As per the requirement of students, remedial classes will be conducted in these periods.

Value Added Course

Course Code: MEGS. 513

L	T	P	Credits
2	0	0	2

Course Title: Mining methods and fossil fuel Exploration

Total hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Demonstrate comprehensive knowledge of the stages, strategies, and national policy frameworks governing mineral and fossil fuel exploration in India.

CLO2: Classify and evaluate the types and characteristics of mineral deposits and fossil fuels, with emphasis on their distribution, sampling, and economic significance.

CLO3: Apply geological, geochemical, and geophysical exploration techniques for identifying and characterizing subsurface mineral and petroleum resources.

CLO4: Critically analyze petroleum systems including source, migration, reservoir characteristics, traps, and basin structures to assess hydrocarbon potential.

CLO5: Examine and compare surface and underground mining techniques, coal mining methods, and evaluate their operational and environmental implications.

CLO6: Interpret drilling, logging, and subsurface correlation data for petroleum reservoirs, and assess environmental impacts associated with mining and exploration activities.

Unit/ Hour	Contents	Mapping with CLO
I/7	Introduction to mineral exploration, reconnaissance, detailed survey, National Mineral Policy, Mineral resources in National Economy, Mining – definition and economic importance, History of mining, Applicability and limitations comparison of opencast vs underground mining. **Learning Activities:** Assignment, Take home exercise, peer learning.	**CLO1** **CLO5**
II/8	Mineral deposit – different types and their classification, Distribution of mineral resources and fossil fuel in India, Sampling, and evaluation of mineral deposits; Methods of coal mining, Rank, characteristics and important constituents of coal, Gas hydrates and coal bed methane exploration. **Learning Activities:** Assignment, take home exercise, group discussion.	**CLO2** **CLO5**

III/7	Geological, geochemical, geophysical and geo-botanical methods of surface and sub-surface exploration. Method of petroleum exploration, physical properties of petroleum; Occurrence of petroleum; Nature of source rock, Kerogen: Composition and types; Reservoir rocks; Reservoir Traps; Origin, migration and accumulation of petroleum. **Learning Activities:** Case study by different group followed by discussion and assignment.	**CLO3,** **CLO4**
IV/8	Petroleum reserves of India, Oil-bearing basins of India; Geophysical prospecting for petroleum; Importance of micropaleontology in petroleum exploration, Drilling, logging and subsurface correlation, core-sampling, assaying, and RQD (Rock Quality Designation) measurements for Rock Mass characterization. Environmental Impact of Mineral Resource Exploitation – exploration, mining, processing and post processing scenarios. **Learning Activities:** Student seminar and brain storming.	**CLO4** **CLO6**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching, Collaborative learning, Case based study.

Suggested readings:

1. Leverson, 2006.*Geology of Petroleum*, CBS.
2. Selley, R.C., 1997. *Elements of Petroleum Geology*, Atlantic publishers & distribution Pvt. Ltd, Delhi.
3. Emmons, W. H., 2015. *Geology of Petroleum*, Sagwan press.
4. Dobrin, M. B., and Savit, C. H., 1988. *Introduction to geophysical prospecting*, McGraw-Hill Inc.
5. Kearey, P., Brooks, M. and Hill, I., 2002. *An Introduction to Geophysical Exploration,* Wiley-Blackwell.
6. Parasnis, D. S., 1986. *Principles of Applied Geophysics*, Chapman and Hall.
7. Hawkes, H. E., Webb J. S., 2012. *Geochemistry in mineral exploration*, Literary Licensing, LLC.
8. Haldar, S. K., 2013. Mineral Exploration: Principles and Application, Elsevier.
9. Moon C. J., Whateley, M. K. G., and Evans, A. M., 2005. *Introduction to Mineral Exploration*, Blackwell Science.
10. Dobrin, M. B., and Savit C. H., 1988.*Introduction to geophysical prospecting*, McGraw-Hill Inc.
11. Kearey, P., Brooks M. and Hill, I., 2002. *An Introduction to Geophysical Exploration*, Wiley-Blackwell.

Web Resources:

https://pubs.usgs.gov/of/1995/ofr-95-0831/CHAP3.pdf
https://www.osti.gov/servlets/purl/895050
http://faculty.washington.edu/dersh/Files/Geophysics2006.pdf
https://eclass.uoa.gr/modules/document/file.php/GEOL312/Geophysical%20methods/Forte_L1_Introduction%20to%20geophysical%20methods.pdf
https://www.gsi.ie/en-ie/programmes-and-projects/minerals/activities/mineral-exploration/Pages/Geophysical-Methods.aspx

Course Code: MEGS.514

L	T	P	Credits
2	0	0	2

Course Title: Sequence Stratigraphy & Basin Analysis

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to

CLO1 Explain the concept and evolution of sequence stratigraphy, analyses the orders and duration of sequences, apply sequence stratigraphic principles to geological interpretations

CLO2 Apply sequence stratigraphic principles to interpret depositional systems and outcrop records.

CLO3 Classify sedimentary basins, and analyze controls on sedimentation.

CLO4 Explain sedimentary facies, analyze sediment dispersal, and evaluate depositional environments.

Unit/ Hour	Contents	Mapping with CLO
I/6	Sequence stratigraphy, its concept and evolution; order and duration of sequences; application and significance of sequence stratigraphy. **Learning Activities:** Assignment, Take-home exercise, mini projects.	CLO1
II/9	Fundamentals of sequence stratigraphy: depositional sequence, boundaries and its types, conformity and unconformities; Flooding surface, marine flooding surface; Parasequence, its boundary and sets; System tracts, overlap, off-lap, top-lap and on-lap, aggradation, progradation, retrogradation, transgression and regression; Outcrop sequence stratigraphy with Indian examples. **Learning Activities:** Group discussion and take-home	CLO2

	exercise.	
1/7	Concept of basin analysis; Tectonic classification and geothermal evolution of sedimentary basins; Allogenic and autogenic controls on sedimentation. Sea level changes, sediment supply, basin subsidence rate, and accommodation. **Learning Activities:** Group discussion and take-home exercise.	CLO3
1/8	Sedimentary facies and facies models with Indian analogues; Paleocurrent analysis and sediment dispersal patterns; Quaternary Sedimentology. Processes and characteristics of different depositional environments. **Learning Activities:** Group discussion and take-home exercise	CLO4

Transactional Modes: Lecture, Demonstration, Seminar, Group discussion, Cooperative learning, blended learning, flipped learning, focused group discussion, Team teaching, Field visit, Brainstorming, Mobile teaching and tutoring, Problem solving, Self-learning, Case-based study, etc.

Suggested readings:

1. Allen (2005): Basin Analysis: Principles and Application, Blackwell Publ.
2. Miall, A.D. (2000): Principles of Basin Analysis, Springer-Verlag.
3. Perry, C.T. and Taylor, K.G. (2006): Envoronmental Sedimentology, Blackwell Publ., U.K.
4. Reading, H.G. (1996): Sedimentary Environments and facies, Blackwell Scientific Publ.
5. Reineck, H.E. and Singh, I.B. (1978): Depositional Sedimentary Environments, Springer-Verlag.

Web Resources:

https://onlinecourses.nptel.ac.in/noc25_ce140/preview
An Introduction to Sequence Stratigraphy - Geosciences LibreTexts
Text W10-D1The Elements of Sequence Stratigraphy-12004050505041212.pdf
Basin Analysis Overview and Methods | PDF | Plate Tectonics | Sedimentary Basin

Interdisciplinary Course (IDC) offered by the department

L	T	P	Credits
2	0	0	2

Course Code: MEGS.506

Course Title: Introduction to Disaster Management

Total hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: Define key terms in disaster management and explain the disaster management cycle.

CLO 2: Classify types of natural and human-made disasters, with emphasis on those affecting India.

CLO 3: Describe the main national and international disaster management frameworks and policies.

CLO 4: Identify the roles and responsibilities of institutions and stakeholders in disaster management.

Unit/ Hour	Contents	Mapping with CLO
I/7	Disaster Management: definition, scope, Objectives and Approaches, Definitions and concepts of Hazard, Vulnerability, Risk, Resilience, Concept of Disaster Management Cycle – Response, Recovery, Mitigation and Preparedness. **Learning Activities:** Group Discussion and brainstorming session on disaster and hazards.	**CLO1**
II/9	Introduction to various Hazards both Natural and Man-Made Hazards- earthquake, volcanoes landslide, flood, cyclone, tsunami, droughts, forest fires, industrial accidents, biological disasters, climate change, global warming etc. **Learning Activities:** Student seminar, discussion and brain storming session	**CLO2**
III/8	Introduction to National Disaster Management Plan-2019, PM's Ten-Point Agenda for Disaster Risk Reduction, Main Pillars of NDMP, Global Frameworks— Disasters, Sustainable Development and Climate Change, objectives of the National Policy on Disaster Management, Disaster Management Act, Disaster mitigation: Concept, importance, tools, strategies with reference to specific disasters; **Learning Activities:** Student presentation and group discussion on the case study on Indian disasters, and their mitigation and preparedness techniques.	**CLO3** **CLO 4**

IV/7	Basic Institutional Framework- national, state-level disaster management, Key National-Level Decision-Making Bodies for Disaster Management, Role and responsibility of Central, State, District, and Local Administration, Armed Forces, NGOs, media, etc. Disaster relief; Reconstruction planning; **Learning Activities:** Student Seminar and brainstorming session on the disaster management system of India.	**CLO3** **CLO4**

Transactional Modes: Lecture, Project Method, Inquiry Training, Seminar, Group Discussion, Blended Learning, Flipped Learning, Focused Group Discussion, Mobile Teaching, Collaborative Learning, Case-Based Study.

Suggested reading:

1. Srivastava, A.K. 2021. Textbook of disaster management. Scientific Publishers.
2. Coppola, D. 2015. Introduction to International Disaster Management. Elsevier. 3rd Edition.
3. Ahmad, A., 2010.*Disaster Management: Through the New Millennium, Anmol Publications, New Delhi*.
4. Ahmed, Shaik Iftikhar, 2008. Disaster Management in the Wake of a Flood, Twenty-First Century Publications, Patiala.
5. Bilham, R. 2009. *The seismic future of cities, Bulletin of Earthquake Engineering*.
6. Bryant, E.,2005. *Natural Hazards, Cambridge University Press*, U.K.
7. Bureau ofIndian Standards (2002). Indian Standards: Criteria for Earthquake-Resistant Design of Structures, Part I, Fifth Revision.
8. Burton, I., Kates, R.W., and White, G.F.,1993. *Environment as Hazard, 2nd edition, Guilford Press, New York*.

Web Resource:

http://www.onlinenidm.gov.in/
https://ndma.gov.in/
https://ndmindia.mha.gov.in/#
https://www.mha.gov.in/division_of_mha/disaster-management-division
https://www.undp.org/
https://library.wmo.int

Course Code: MEGS.507

L	T	P	Credits
2	0	0	2

Course Title: Introduction to Earth System Science **Total hours: 30**

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1 : Develop a basic understanding of the origin of Earth, major components and processes of the Earth systems, and the Evolution of life.

CLO2: Develop the essential properties of Earth's components, including its core, mantle, asthenosphere, lithosphere, cryosphere, hydrosphere, atmosphere, and biosphere.

CLO3: Explain the plate tectonic theory and its relationship to earth processes; identify common rocks and minerals and interpret their genesis; recognize the events in geologic history using geological shreds of evidence and discover how Earth works as a system of interacting components across geological timescales.

CLO4: Demonstrate how the oceans are connected to the atmosphere and plate tectonics.

Unit/ Hours	Contents	Mapping with CLO
I/7	Branches and scopes of Earth Sciences; General characteristics and origin of the Universe, solar system and its planets; Concepts of Meteorites its classification and implications to solar system formation; Planet Earth: Origin, size, shape, mass, density, rotation and revolution parameters; Origin of atmosphere, ocean and life; Mechanical layering of the Earth and its internal composition; Concepts of Convection currents and Earth's magnetic field. **Learning Activities:** Student seminar, discussion and brain storming session	**CLO1, CLO2**
II/8	Concept of isostasy and geothermal gradient of the Earth; Plate tectonics: Continental drift and Sea floor spreading; Plates and plate boundaries: Convergent, Divergent and Transform Plate Boundaries; Seismic Waves and Earthquakes; Volcanoes and volcanic landforms. **Learning Activities:** Take-home exercise on isostasy, finding earthquake epicenters, and online monitoring the intensity map of earthquakes.	**CLO2, CLO3**
III/8	Cosmic abundance of elements: Distribution of elements in solar system and in Earth; Geochemical cycles; Concepts of uniformitarianism, catastrophism and neptunism; Laws of superposition and faunal succession; Concept of Geological Time Scale and Mass Extinction; Minerals and their characteristics; Rocks: Classification, origin and characteristics; Soils: types, soil profile, processes of formation of soil; Concept of weathering and erosion.	**CLO2, CLO3**

	Learning Activities: Group discussion on important geochemical cycles and theories.	
IV/7	Hydrologic cycle and groundwater system; Concepts of eustasy and Land-air-sea interaction; Ocean and atmospheric circulations; Bathymetry of the ocean floor; Oceanic current system and effect of Coriolis force; Natural resources and their management; Global Carbon Cycle. **Learning Activities:** take-home exercise, budgeting of carbon in the different systems	**CLO4**

Transactional Modes: Lecture, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Mobile teaching, Collaborative learning, Case-based study.

Suggested reading:

1. Bangar, K.M., 2020, Principles of Engineering Geology. Standard Publishers Distributors, ISBN: 978-8180141157.
2. Mahapatra, G.B., 2019, A Textbook of Geology. CBS Publishers, ISBN: 978-0824794446.
3. McConnell, D., Steer, D., Knight, C., Owens, K., and Park, L., 2016, The Good Earth: Introduction to Earth Science. McGraw Hill Publication, 1st Ed., ISBN: 978-0-07-301847-8.
4. Christiansen E.H., and Hamblin, W.K., 2015, Dynamic Earth: An Introduction to Physical Geology. 1st Ed., Jones and Bartlett Publishers, Inc., ISBN: 9781449659844.
5. Dasgupta, A., 2013, An Introduction to Earth Science. World Press, ISBN: 978-9382878001.
6. Mukherjee, P.K., 2013, Textbook of Geology. World Press, ISBN: 978-8187567547.
7. Grotzinger, J., Jordan, T.H., Press, F., and Siever, R., 2007, Understanding Earth (Fifth Edition). W. H. Freeman and company, New York.
8. Kump, L.R., Kasting, J.F., and Crane, R.G., 2004 The Earth System, Prentice Hall, 2nd Ed., ISBN 0-13-142059-3.
9. Jacobson, M. C., Charlson, R. J., Rodhe, H., and Orians, G. H., 2000, Earth System Science: San Diego, CA, Academic Press, 523 p., ISBN 0-12-379370-X
10. Patwardhan, A.M., 2004, The Dynamic Earth System, Prentice Hall India Learning Private Limited, New Delhi. ISBN -978-81-203-1496-2.
11. Duff, P.M.D., and Duff, D., (Eds.) 1993. Holmes' principles of physical geology. Taylor and Francis.

Web Resources:

https://open.uci.educourses/ess_1_introduction_to_earth_system_science.html
https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-001-introduction-to-geology-fall-2013/lecture-notes-and-slides/
https://cosmolearning.org/courses/introduction-earth-system-science/
https://www.tulane.edu/~sanelson/Natural_Disasters/struct&materials.htm

https://www.eolss.net/sample-chapters/C12/E1-01-02.pdf
https://www.soas.ac.uk/cedep-demos/000_P500_ESM_K3736-Demo/module/pdfs/p500_unit_01.pdf
https://ucdavis.mediaspace.kaltura.com/media/Lecture+1+-+Intro+to+Earth+System+Science+-+ESM+120+%28Winter+2021%29/1_th0lfkw5

Course Code: MEGS.508

L	T	P	Credits
2	0	0	2

Course Title: Geoheritage and Geotourism

Total Hours: 30

Course Learning Outcomes (CLO): Upon successful completion of this course, the student will be able to:

CLO1: familiar with the general concepts of the world's geological heritage and India.
CLO2: Understand the major contemporary evolutionary trends in Geoheritage and Geotourism.
CLO3: Know the different institutional figures of nature conservation areas and their importance in Geoheritage and Geotourism.
CLO4: Curate and communicate geoheritage inventory.

Unit/ Hour	Contents	Mapping with CLO
I/7	Concepts of geodiversity, geosites, geoheritage, geoconservation, geotourism, and geoparks. Classification and significance. International geoconservation designations: World Heritage Sites, Ramsar Sites, European Designations **Learning Activities:** Assignment, take-home exercise, and student seminar.	**CLO1 CLO3 CLO4**
II/18	Geoheritage elements across the Indian sub-continent. National Geological Monuments (NGM). Aspiring and prospective geopark localities of India. Organizational efforts towards geoconservation. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO1 CLO2 CLO3 CLO4**
III/7	Definition of geoparks. Objectives of geoparks. History of development of geoparks: role of UNESCO, international promotional events. Infrastructural elements of geoparks: geoguides and georangers, geopaths, georoutes, information panels and signages, geomuseums, geoshops, geohotels, geoproducts. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO2 CLO3 CLO4**
IV/8	Geotourism routes: inventory, evaluation, conservation, and	**CLO2**

	enhancement of Geoheritage. Case studies of the Geoheritage sites of India and the world. International Geopark Networks. **Learning Activities:** Assignment, student seminar, and group discussion.	**CLO3** **CLO4**

Transactional Modes: Lecture, Demonstration, Lecture cum demonstration, Project Method, Inquiry training, Seminar, Group discussion, Blended learning, Flipped learning, Focused group discussion, Team teaching, Brain storming, Mobile teaching, Collaborative learning, E-tutoring, Problem solving.

Suggested Readings:

1. C. Anze, L. Yunting and C.Y. Ng. Young (2015). The Principles of Geotourism, Science Press, Beijing
2. C.V. Burek and C.D. Prosser (2008). The History of Geoconservation, The Geological Society, London, Special Publications, 300
3. D.R. Reddy (2020). A Monograph on Potential Geoparks of India, INTACH, New Delhi
4. 36th IGC (2016). Geotourism Hotspots of Indian Subcontinent, GSI, New Delhi
5. C. Sharples (2002). Concepts and Principles of Geoconservation, Tasmanian Parks and Wildlife Service, Australia
6. R.K. Dowling and D. Newsome (2006). Geotourism – Sustainability, Impacts and Management, Elsevier Butterworth-Heinemann, Oxford
7. R, Crofts, J.E. Gordon, J. Brilha, M. Gray, J. Gunn, J. Larwood, V.L. Santucci, D. Tormey and G.L. Worboys (2020). Guidelines for Geoconservation in Protected and Conserved Areas, Best Practice Protected Area Guidelines, Series No. 31, IUCN, Switzerland
8. M.H. Henriques, R.P. dos Reis, J. Brilha, T. Mota (2011). Geoconservation as an Emerging Geoscience. Geoheritage, 3, 117–128.

Web Resources:

http://www.globalgeopark.org/homepageaux/tupai/6513.htm
IUGS | International Commission on Geoheritage
Geodiversity, World Heritage and IUCN | IUCN
IUGS Geological Heritage sites | UNESCO
UNESCO Global Geoparks | UNESCO
International Geoscience and Geoparks Programme | UNESCO
Guardians of GEOHERITAGE:-A 'THE SOCIETY OF EARTH SCIENTISTS' Initiative

Semester-III

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.599-1	Dissertation Part I	Dissertation	0	0	40	20
		Total	**0**	**0**	**40**	**20**

Course Code: MEGS.599-1

L	T	P	Credits
0	0	40	20

Course Title: Dissertation Part I

Total hours: 600

Course Learning Outcomes (CLO): After completion of the course, students will be able to

CLO1 Identify the research gap
CLO2 Potential literature review
CLO3 Develop hypothesis to solve the problem
CLO4 Make their own research proposal

Unit/ Hour	Contents	Mapping with CLO
I/600	Each candidate required submitting a dissertation proposal / synopsis of research work carried out towards the fulfillment of his/her M.Sc. dissertation. It will have following components: (a) Origin of the research problem and literature review (b) Objective of the research work (c) Methodology of the work, field observations (if any) and data recorded by the candidate, (d) Proposed laboratory investigation (if any) carried out by the candidate, (e) Expected Outcome For those opting for short-term Internship / short-term Industrial Training in the third semester should continue the same in the fourth semester. Students are advised to take up the internship/training program during vacations with prior approval from the department.*	**CLO1** **CLO2** **CLO3** **CLO4**

Evaluation Criteria: The evaluation of dissertation proposal in the third semester will carry 50% weightage by supervisor and 50% by HoD and senior- most faculty of the department. Distribution of marks will be based on report of dissertation (30%), presentation (10%), and final viva-voce (10%). The final viva-voce will be through offline or online mode.

For Dissertation Part I		
Evaluator	**Marks**	**Evaluation**
Supervisor	50	Dissertation proposal and presentation
HoD and senior-most faculty of the department	50	Dissertation proposal and presentation

* Students may opt any internship/ academic or industrial training during semester break with approval from department. Above experiential learning/internship equivalent to 40–45 contact hours will be considered as one credit (as per NCrF guidelines). Evaluation pattern similar to third semester dissertation will apply for internship/industrial training where supervisor and external co-supervisor will award 50% marks; HoD and senior-most faculty will award 50% marks. Student need to submit their report to the department; and present his/her work and attended the viva-voce for the assessment.

Semester-IV

Course Code	Course Title	Course Type	Contact Hours			Credit
			L	T	P	Cr
MEGS.599-2	Dissertation Part II	Dissertation	0	0	40	20
		Total	**0**	**0**	**40**	**20**

Course Code: MEGS.599-2

L	T	P	Credits
0	0	40	20

Course Title: Dissertation / Internship / Industrial Training

Total hours: 600

Course Learning Outcomes (CLO): After completion of the course, students will be able to

CLO1 : Formulate a research problem and identify
CLO2 : Know the limitations and expected outcome
CLO3 : Synthesis and interpret the field and lab data
CLO4 : Draw the Inference from the result
CLO5 : Decipher the future direction of research from the result
CLO6 : Take-up research for solving local/regional/global challenges

Unit/ Hour	Contents	Mapping with CLO
I/600	Each candidate required to submit a dissertation based on his/her research work carried out towards the fulfillment of his/her M.Sc. dissertation. It will have the following components: (a) Origin of the research problem and literature review (b) Objective of the research work (c) Methodology of the work, field observations (if any), and data recorded by the candidate, (d) Details of laboratory investigation (if any) carried out by the candidate, (e) Synthesis of results and interpretation (f) Concluding remarks and future direction For those opting for Internship / Industrial Training in the fourth semester should submit their report to the department; and present his/her work and attended the viva-voce for the assessment.	**CLO1** **CLO2** **CLO3** **CLO4** **CLO5** **CLO6**

Evaluation Criteria: The evaluation of the dissertation in the fourth semester will carry 50% weightage by the supervisor and 50% by the external expert. Distribution of marks as per the table given below. Marks for internship shall be given by the supervisor/internal mentor and external

mentor. The final viva-voce will be through offline or online mode. The workload of one contact hour per student will be calculated for the dissertation in the fourth semester.

Dissertation (Fourth Semester)		
	Marks	**Evaluation**
Supervisor/ co-supervisor(s)	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
External expert	50	Report of dissertation (25), presentation (10), Novelty/ originality (5) and final viva-voce (10).

Students may opt for any internship/ academic or industrial training during the semester break with approval from the department. Above experiential learning/internship equivalent to 40–45 contact hours will be considered as one credit (as per NCrF guidelines). Students will have an option to carry out dissertation work in industry, national institutes, or universities in the top 100 NIR ranking. Group dissertation may be opted for, with a group consisting of a maximum of four students. These students may work using a single approach or a multidisciplinary approach. The research project can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.
