Course Structure and Detailed Syllabus

M.Sc. Applied Geology

(Under NEP 2020)

Effective from 2024-25

Rajiv Gandhi University

Rono Hills, Doimukh

Arunachal Pradesh - 791112

Programme Educational Objectives (PEO)

Two Year Postgraduate Programme in Applied Geology (NEP-2020)

PEOs	*PEO Descriptor*
PEO 1	To provide detailed knowledge on the principles and applications of different branches of earth science.
PEO 2	To develop analytical and experimental skills for solving complex geological problems.
PEO 3	To equip the students to get acquainted to work in diverse geological terrains and to provide knowledge in utilizing sophisticated analytical instruments.
PEO 4	To develop the abilities of students to work independently as well as in groups as professionals or to carry out geoscientific research.

Programme Outcomes (PO)

Two Year <u>Postgraduate Programme</u> in Applied Geology (NEP-2020)

	Type of Programme Outcome (PO)	*Programme Outcome (PO) Descriptor*
PO 1	**Problem-Solving**	A postgraduate student should be able to demonstrate the capability to: • solve problems of familiar and non-familiar contexts that are best approached with critical thinking and apply the learning to real-life situations**.**
PO 2	**Analytical Reasoning & Critical Thinking**	The postgraduates should be able to demonstrate the capability to: • apply analytical thought to a body of knowledge, including the analysis, evaluation and practices, as well as evidence, arguments, claims, beliefs, and the reliability and relevance of evidence, • identify relevant assumptions or implications; and formulate coherent arguments, • identify logical flaws in the arguments, • analyse and synthesise data from various sources, draw valid conclusions and support them with evidence and examples.
PO 3	**Creativity**	The postgraduates should be able to demonstrate the ability to: • create, perform, or think in different and diverse ways about the same objects or scenarios, • deal with problems and situations that do not have simple solutions, • innovate and perform tasks in a better manner, • view a problem or a situation from multiple perspectives, • think 'out of the box' and generate solutions to complex problems in unfamiliar contexts, • adopt innovative, imaginative, lateral thinking, interpersonal skills and emotional intelligence.

PO 4	**Communication Skills**	The postgraduates should be able to demonstrate the skills that enable them to: • listen carefully, read texts and research papers analytically, and present complex information clearly and concisely to peers and the public at large, • express thoughts and ideas effectively in writing and orally and communicate with others using appropriate media, • confidently share views and express herself/himself, • construct logical arguments using correct technical language related to a field of learning, work/vocation, or an area of professional practice, • convey ideas, thoughts, and arguments using respectful and sensitive language to gender and other minority groups.
PO 5	**Research-related Skills**	The postgraduates should be able to demonstrate: • a keen sense of observation, inquiry, and capability for asking relevant/ appropriate questions, • the ability to problematise, synthesize and articulate issues and design research proposals, • the ability to define problems, formulate appropriate and relevant research questions, formulate hypotheses, test hypotheses using quantitative and qualitative data, establish hypotheses, make inferences based on the analysis and interpretation of data, and predict cause-and-effect relationships, • the capacity to develop appropriate methodology and tools of data collection, • the appropriate use of statistical and other analytical tools and techniques, • the ability to plan, execute and report the results of an experiment or investigation, • the ability to understand basic research ethics and skills in practising/doing ethics in the field/ in personal research work, regardless of the funding authority or field of study.
PO 6	**Coordinating / Collaborating with others**	The postgraduates should be able to demonstrate the ability to: • work effectively and respectfully with diverse teams, • facilitate cooperative or coordinated effort on the part of a group, • act together as a group or a team in the interests of a common cause and work efficiently as a member of a team.

PO 7	**Leadership Development**	The postgraduates should be able to demonstrate the capability for: • mapping out the tasks of a team or an organization and setting direction. • formulating an inspiring vision and building a team that can help achieve the vision, motivating and inspiring team members to engage with that vision. • using management skills to guide people to the right destination.
PO 8	**Digital and technological skills**	The postgraduates should be able to demonstrate the capability to: • use ICT in a variety of learning and work situations, • access, evaluate, and use a variety of relevant information sources, • use appropriate software for analysis of data.
PO 9	**Environmental awareness and action**	The postgraduates should be able to demonstrate the acquisition of and ability to apply the knowledge, skills, attitudes, and values required to take appropriate actions for: • recognize environmental and sustainability issues and participate in actions to promote sustainable development. • mitigating the effects of environmental degradation, climate change, and pollution, • effective waste management, conservation of biological diversity, management of biological resources and biodiversity,

Programme Specific Outcomes (PSO)

Two Year Postgraduate Programme in Applied Geology (NEP-2020)

	Type of PSO	*PSO Descriptor*
PSO 1	**Knowledge and understanding**	Postgraduates in geology should be able to demonstrate the acquisition of: • comprehensive knowledge and coherent understanding in theoretical knowledge in diverse branches of geology such as physical geology, historical geology, applied geology etc. and understanding of the relationship among these branches and recent developments. • procedural knowledge to carry out experimental studies and analyses towards understanding the complex earth materials and processes by applying broader knowledge in geology and other disciplines.
PSO 2	**Skills related to one's specialization**	• Imparting skills such as understanding diverse geological terrains through intense fieldwork and industrial visits towards the better knowledge on earth system and related disciplines.
PSO 3	**Application of knowledge and skills**	• learning to solve complex geological problems by applying knowledge on diverse branches of geology and to developing critical thinking.
PSO 4	**Quantitative, analytical and instrument-based skills**	• hands-on training in learning analytical techniques and understanding geological terrains in order to pursue higher education or grabbing job opportunities or developing self-employment.

Course Structure for Postgraduate Programme (M.Sc.) in Applied Geology with Research

NCrF Credit Level	Semester	Course Type	Course Code	Course Name	Credit
6.0	M.Sc. I	Major Course (Core)	**GEL-CC-4110**	Advanced Mineralogy	4
			GEL-CC-4120	Advanced Structural Geology	4
			GEL-CC-4130	Advanced Petrology	4
			GEL-CC-4140	Advanced Sedimentology	4
		Research Course	**GEL-RC-4110**	Research Methodology	4
	M.Sc. II	Major Course (Core)	**GEL-CC-4210**	Geological Fieldwork	4
		Major Course (Department Specific Elective): Students should take *any three* courses	**GEL-DE-4210**	Remote Sensing and GIS for Geology	4
			GEL-DE-4220	Advanced Palaeontology	4
			GEL-DE-4230	Isotope Geology	4
			GEL-DE-4240	Geohazard and Disaster Management	4
			GEL-DE-4250	Marine Science	4
			GEL-DE-4260	Mineral Resources of India and World	4
			GEL-DE-4270	Statistics and Data Analysis in Geology	4
			GEL-DE-4280	Advanced Hydrogeology	4
			GEL-DE-4290	Geotechnical Engineering	4
		Research Course	**GEL-RC-4210**	Research and Publication Ethics	4
Students exiting the programme after securing 40 credits will be awarded PG Diploma in Geology					
6.5	M.Sc. III	Major Course (Core)	**GEL-CC-5310**	Geology of India	4
			GEL-CC-5320	Himalayan Geology	4
			GEL-CC-5330	Ore Geology	4
			GEL-CC-5340	Geophysics	4
		Major Course (Department Specific Elective): Students should take *any one* course	**GEL-DE-5310**	Non-conventional Energy Sources	4
			GEL-DE-5320	Coal Geology	4
			GEL-DE-5330	Petroleum Geology	4
	M.Sc. IV	Research Project	**GEL-RP-5410**	Research Project	20
				Total Credit	**80**

FIRST SEMESTER

GEL-CC-4110

Advanced Mineralogy

Credit: 4 (L-3:T-0:P-1)

Course Objective

The important objectives of the course are to provide in depth knowledge in the field of crystallography and mineralogy. Learners will be taught external symmetry, internal symmetry in atomic structure and resulting physical properties of crystals. The course will introduce advanced analytical techniques in analysing minerals and its geological inference. The course is also intended to teach physical and optical characteristics, and chemistry of mineral groups.

Course Learning Outcome

CO 1: Detailed knowledge about principles of crystallography.
CO 2: Understanding of influence of elements in crystal structure, its chemical composition, diversification and stability in different geological environments.
CO 3: Detailed knowledge on the physical and optical characteristics, composition, origin and economic importance of silicate and non-silicate minerals.
CO 4: Knowledge on the optical properties of minerals.

Detailed Syllabus

Unit 1 ***15 Lectures***

Crystallography: elements of point symmetry - rotation, reflection, inversion and rotoinversion; combination of symmetry operations; 32 point groups; Hermann-Mauguin notation; Miller Indices; translational symmetry - plane lattice, space lattice, and unit cell; Bravais lattice; screw axis and glide planes; space group.

Unit 2 ***10 Lectures***

Atomic structure: ionic packing in two dimensions and three dimensions; Pauling's rules; compositional variation in minerals - element substitution and solid solution; crystal growth and crystal defects; principles and applications of different analytical techniques for studying mineral morphology, crystal structure and composition.

Unit 3 ***10 Lectures***

Silicate and non-silicate structures; systematic study of important silicates, carbonates, oxides, and sulphides.

Unit 4 ***10 Lectures***

Optical mineralogy: interaction of light and matter; optics of isotropic and anisotropic minerals; determination of sample thickness and birefringence; uniaxial optics - uniaxial indicatrix, uniaxial interference figure, and determining indices of refraction; biaxial optics - biaxial indicatrix, biaxial interference figure and determining optic sign and 2V; optical properties of important silicate and non-silicate minerals.

Practical ***30 Hours***

1. Stereographic projection of holohedral classes of different crystal systems.
2. Calculation of cell parameters using XRD data.
3. Systematic description of minerals in hand specimen and under polarizing microscope.
4. Determination of refractive index, sign of elongation, order of interference colour and optic sign.

5. Determination of plagioclase composition using Michel-Levy method.
6. Recalculation of mineral formula from chemical analysis.
7. Practical Record.
8. Viva-voce.

Recommended Books

Text Books:

1. **An Introduction to the Rock-Forming Minerals** - W.A. Deer, R.A. Howie and J. Zussman, The Mineralogical Society London.
2. **Crystallography and Mineralogy: Concepts and Methods** - R. S. Sharma and Anurag Sharma, Geological Society of India.
3. **Introduction to Mineralogy** - William D. Nesse, Oxford University Press.
4. **Introduction to Optical Mineralogy** - William D. Nesse, Oxford University Press.
5. **Mineralogy** - Dexter Perkins, Pearson.
6. **Mineralogy** - L.G. Berry, Brian Mason and R.V. Dietrich, CBS Publishers and Distributors.
7. **Optical Mineralogy** - P. F. Kerr, McGraw Hill.
8. **Practical Approach to Mineralogy and Crystallography** - R.N. Hota, CBS Publishers and Distributors.
9. **The Manual of Mineral Science** - Cornelis Klein and Barbara Dutrow, Wiley.

Reference Books:

1. **A Key for Identification of Rock-forming Minerals in Thin Section** - Andrew J. Barker, CRC Press.
2. **A Practical Introduction to Optical Mineralogy** - C. D. Gribble and A. J. Hall, Springer.
3. **Atlas of Rock-Forming Minerals in Thin Section** - W. S. MacKenzie and C. Guilford, Routledge.
4. **Dana's Textbook of Mineralogy** - William E. Ford, CBS Publishers and Distributors.
5. **Earth Materials: Introduction to Mineralogy and Petrology** - Cornelis Klein and Anothony Philpotts, Cambridge.
6. **Introduction to Mineralogy and Petrology** - S.K. Haldar and Josip Tisljar, Elsevier.
7. **Rock Forming Minerals, Volume 3A: Micas** - W. A. Deer, R. A. Howie and J. Zussman, The Geological Society of London.
8. **Rock Forming Minerals, Volume 4A: Framework Silicates (Feldspars)** - W. A. Deer, R. A. Howie and J. Zussman, The Geological Society of London.
9. **Rock Forming Minerals, Volume 4B: Framework Silicates (Silica Minerals, Feldspathoids and the Zeolites)** - W. A. Deer, R. A. Howie and J. Zussman, The Geological Society of London.
10. **Rock-Forming Minerals, Volume 3B: Layered Silicates (Excluding Micas and Clay Minerals)** - W. A. Deer, R. A. Howie and J. Zussman, The Geological Society of London.
11. **Rock-Forming Minerals, Volume 3C: Sheet Silicates (Clay Minerals)** - W. A. Deer, R. A. Howie and J. Zussman, The Geological Society of London.
12. **Rocks and Minerals in Thin Section** - W.S. MacKenzie, A.E. Adams and K.H. Brodie, CRC Press.
13. **Rutley's Elements of Mineralogy** - C.D. Gribble, CBS Publishers and Distributors.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	0	2	1	1	2	1	3	2	3	1
CO2	2	2	1	0	1	1	0	1	1	2	2	1	1
CO3	2	2	1	1	2	0	0	1	2	3	2	3	1
CO4	3	1	1	1	1	0	0	1	0	3	3	2	3
Average	**2.50**	**1.75**	**1.25**	**0.50**	**1.50**	**0.50**	**0.25**	**1.25**	**1.00**	**2.75**	**2.25**	**2.25**	**1.50**

GEL-CC-4120

Advanced Structural Geology

Credit: 4 (L-3:T-0:P-1)

Course Objective

The main objective of this course is to introduce the students to rock deformation mechanisms and their interpretation. Also, this course will introduce the students to the plate tectonics and the tectonic setup of different types of plate boundaries.

Course Learning Outcome

CO 1: After completing this course, the students will have the basic understanding of stress and strain and behaviour of rocks under stress.
CO 2: Learning the geometry and morphology of different brittle and ductile structures.
CO 3: Understanding the significance of rock structures and interpret the deformation history.
CO 4: Inferring tectonic history through structural analysis.

Detailed Syllabus

Unit 1 ***15 Lectures***

Force and stress: two-dimensional stress and three-dimensional stress; principal planes and principal stresses; Mohr diagram for stress; mean and deviatoric stress; stress tensor.

Unit 2 ***10 Lectures***

Deformation and strain; finite homogeneous deformation; progressive deformation; measurement of strain; behaviour of rocks under stress; rheology: strain rate, the creep curve; deformation mechanisms.

Unit 3 ***10 Lectures***

Joints: surface morphology and arrays; origin and interpretation of joints; veins and vein arrays; lineaments; faults and faulting: fault geometry and displacement; mechanism of faulting, relation of faulting to stress; fault systems: geometrical classification.

Unit 4 ***10 Lectures***

Folds and folding: anatomy of a folded surface, classification of fold, superposed folding, mechanics of folding; foliations: geometry and relationship with folds and fault zones; lineation: categories and tectonic interpretation; shear zones: nature and types; shear zone rocks; shear-sense indicators; strain in shear zones; shear zone development; boudinage.

Practical ***30 Hours***

1. Interpretation of structure from hand specimen, photograph and map.
2. Preparation of cross sections representing different structural settings.
3. Completion of outcrop in a map.
4. Stereographic analysis of structural data.
5. Construction and study of dip isogon from fold profile.
6. Strain analysis of rocks using deformed objects.
7. Practical Records.
8. Viva-voce.

Recommended Books

Text Books:

1. **An Introduction to Structural Geology -** A. K. Jain, *Geological Society of India*
2. **Earth structure: An Introduction to Structural Geology and Tectonics** - B. A. van derPluijm and S. Marshak, *W. W. Norton & Company*
3. **Structural Geology** - H. Fossen, *Cambridge University Press*
4. **Structural Geology** - R. J. Twiss and E. M. Moors, *W. H. Freeman & Co.*
5. **Structural Geology of Rocks and Regions** - G. H. Davis, S. J. Reynolds and C. Kluth, *Wiley*
6. **Structural Geology: Fundamentals and Modern Developments -** S. K. Ghosh, *Pergamon Press*

Reference Books:

1. **Atlas of Structural Geology** - Soumyajit Mukherjee, *Elsevier*.
2. **Basic methods of structural geology** - S. Marshak and G. Mitra, *Prentice Hall*
3. **Evolution of Geological Structures in Micro- to Macro-scales** - Sudipta Sengupta, *Springer*
4. **Folding and Fracturing of Rocks** - John G. Ramsay, *McGraw Hills Book Company*
5. **Structural Geology: An Introduction to Geometrical Techniques** - D. M. Ragan, *Cambridge University Press*
6. **Structural Geology: The Mechanics of Deforming Metamorphic Rocks** - Bruce E. Hobbs and Alison Ord, *Elsevier*
7. **Tectonics and Structural Geology: Indian Context** - Soumyajit Mukherjee, *Springer*
8. **The Techniques of Modern Structural Geology Vol. 1: Strain Analysis** - J. G. Ramsay and M. I. Huber, *Elsevier.*
9. **The Techniques of Modern Structural Geology Vol. 2: Folds and Fractures** - J. G. Ramsay and M. I. Huber, *Elsevier*.
10. **The Techniques of Modern Structural Geology Vol. 3: Applications of Continuum Mechanics in Structural Geology** -J. G. Ramsay and Richard Lisle, *Elsevier.*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	1	0	0	1	1	1	3	3	2	3
CO2	2	1	2	0	1	0	1	2	1	3	1	2	1
CO3	2	1	1	1	0	0	1	1	1	2	1	2	1
CO4	1	3	2	0	3	0	1	2	1	3	1	3	3
Average	**2.00**	**1.75**	**1.75**	**0.50**	**1.00**	**0.00**	**1.00**	**1.50**	**1.00**	**2.75**	**1.50**	**2.25**	**2.00**

GEL-CC-4130

Advanced Petrology

Credit: 4 (L-3:T-0:P-1)

Course Objective

The course is designed to provide in depth knowledge on the magmatic processes, use of thermodynamics in petrology and magmatism in different tectonic regimes on the earth. This course will also teach metamorphic processes taking place within the earth. The learners will be provided hands-on training on studying igneous and metamorphic rock textures and mineral assemblages and interpreting them to identify the responsible geologic processes.

Course Learning Outcome

CO 1: knowledge on diverse types of magma and their nature, origin and diverse magmatic processes.
CO 2: learnt the concepts of thermodynamics and its applications in understanding magmatic systems to predict texture, mineral assemblages and rocks by using phase diagrams.
CO 3: understanding on the metamorphic processes and on the study of metamorphic terrain.
CO 4: learnt to apply the knowledge of thermodynamics in solving problems on the origin of metamorphic rocks.
CO 5: Sound knowledge on the texture and mineral assemblage of diverse igneous and metamorphic rocks by studying in hand specimen and under microscope.

Detailed Syllabus

Unit 1 ***15 Lectures***

Magma - physical properties and chemical composition; magma generation, intrusion and cooling; introduction to thermodynamics; laws of thermodynamics; concept of Gibbs phase rule; phase equilibrium studies of unary, binary, and ternary systems and their petrogenetic implications.

Unit 2 ***10 Lectures***

Magmatic processes - crystal nucleation, crystal settling, magma convection, diffusion, magma mixing, and magma assimilation and fractional crystallization (AFC); role of volatiles in magmatic systems; applications of trace elements and radiogenic isotopes in understanding igneous processes; magmatism in mid-oceanic ridges and subduction zones; continental flood basalts; large layered igneous complexes; granitoid rocks.

Unit 3 ***10 Lectures***

Basic concepts of metamorphism; paired metamorphic belts; metamorphic reactions; phase rule and phase equilibrium studies in metamorphic rocks; petrogenetic grid and Schirenmaker's rule; construction and projection of ACF, AKF and AFM diagrams; geothermometric and geobarometric studies; P-T-time path.

Unit 4 ***10 Lectures***

Anatexis and origin of migmatites; charnockites; metamorphism of carbonate rocks, pelitic rocks, mafic and ultramafic rocks and granitoid rocks.

Practical ***30 Hours***

1. Study of structure, texture, and mineral assemblages of igneous and metamorphic rocks in hand specimen and in thin sections.
2. Calculation of mode and CIPW norm.

3. Nomenclature of igneous rocks using classification diagrams.
4. Interpreting petrogenetic process using trace element composition.
5. Construction and interpretation of ACF, AKF and AFM diagrams.
6. Practical records.
7. Viva-voce.

Recommended Books

Text Books:

1. **Essentials of igneous and metamorphic petrology** - B. R. Frost and C. D. Frost, Cambridge University Press.
2. **Igneous and metamorphic petrology** - Myron G. Best, Wiley-Blackwell.
3. **Petrology: The study of igneous, sedimentary, and metamorphic rocks** - Loren A. Raymond, Waveland Press Inc.
4. **Principles of igneous and metamorphic petrology** - Anthony R. Philpotts and Jay J. Ague, Cambridge University Press.
5. **Principles of igneous and metamorphic petrology** - John D. Winter, Pearson India.

Reference Books:

1. **An Introduction to Metamorphic Petrology** - Bruce W. D. Yardley, Longman.
2. **Earth Materials** - Cornelis Klein and Anthony R. Philpotts, Cambridge University Press.
3. **Igneous Petrogenesis: A Global Tectonic Approach** - Marjorie Wilson, Springer.
4. **Igneous Rocks and Processes: A Practical Guide** - Robin Gill, Wiley-Blackwell.
5. **Igneous Rocks: A Classification and Glossary of Terms** - R. W. Le Maitre, Cambridge University Press.
6. **Petrogenesis of Metamorphic Rocks** - Kurt Bucher and Rodney Grapes, Springer-Verlag.
7. **Petrography of Igneous and Metamorphic Rocks** - Anthony R. Philpotts, CBS Publishers and Distributors.
8. **Petrography: An Introduction to the Study of Rocks in Thin Section** - H. Williams, F. C. Turner and C. M. Gilbert, CBS Publishers and Distributors.
9. **Petrology: Principles and Practice** - Gautam Sen, Springer.
10. **Principles of Metamorphic Petrology** - Ron H. Vernon and Geoffrey L. Clarke, Cambridge University Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	2	1	1	1	1	0	0	1	2	1	1	1
CO2	1	2	1	0	1	1	0	0	1	3	1	2	2
CO3	1	2	1	0	1	1	0	0	1	2	1	1	1
CO4	2	3	2	0	2	1	1	1	0	2	2	2	3
CO5	2	3	2	0	2	1	0	1	0	2	2	2	3
Average	**1.40**	**2.40**	**1.40**	**0.20**	**1.40**	**1.00**	**0.20**	**0.40**	**0.60**	**2.20**	**1.40**	**1.60**	**2.00**

GEL-CC-4140

Advanced Sedimentology

Credit: 4 (L-3:T-0:P-1)

Course Objective

The main objective of this course is to learn sedimentary rock forming processes, types of sedimentary rocks, sedimentary environment and facies. They will also be taught principles of stratigraphy and types of stratigraphic units.

Course Learning Outcome

CO 1: Learning the formation of sediments and sedimentary rocks, its structures and textures.
CO 2: Learning the classification schemes, composition and characteristics of different types of sedimentary rocks.
CO 3: Analysis of sediments and sedimentary rocks for facies modelling.
CO 4: Learning different stratigraphic units and their correlation.

Detailed Syllabus

Unit 1 ***15 Lectures***

Formation of sedimentary rock: weathering processes; generation of sediment; fluid flow mechanics, entrainment and sediment transport; flow regime and bedforms; lithification and diagenesis; sedimentary structures; sedimentary textures.

Unit 2 ***10 Lectures***

Sandstones: composition and classification; conglomerates and breccias; mudstones and shales; provenance of siliciclastic sedimentary rocks; limestones: composition, classification and texture; other chemical and biochemical sedimentary rocks.

Unit 3 ***10 Lectures***

Sedimentation and tectonics; sedimentary basins and basin analysis; grain size analysis; heavy mineral assemblage; palaeocurrent analysis, sedimentary environment and facies; facies analysis and facies models.

Unit 4 ***10 Lectures***

Evolution of stratigraphic concept; code of stratigraphic nomenclature; principles and methods of correlation of stratigraphic units; lithostratigraphy; chronostratigraphy; biostratigraphy; sequence stratigraphy; event stratigraphy; magnetostratigraphy; chemostratigraphy; Applications of sequence stratigraphy, magnetotratigraphy, and chemostratigraphy.

Practical ***30 Hours***

1. Study of sedimentary rocks in hand specimen.
2. Study of sedimentary structures.
3. Petrography of clastics and non-clastics.
4. Preparation of lithologs from field data.
5. Granulometry - plotting of grain size data and statistical analysis.
6. Separation of heavy minerals and their study under microscope.
7. Paleocurrent analysis.
8. Practical Records.
9. Viva-voce.

Recommended Books

Text Books:

1. **Applied Sedimentology** - Richard C. Selley, *Academic Press*
2. **Introduction to Sedimentology**- S. M. Sengupta, *CBS Publishers*
3. **Principles of Sedimentology and Stratigraphy**- S. Boggs Jr, *Pearson Education India*
4. **Sedimentary Geology: An Introduction to Sedimentary Rocks and Stratigraphy -** D. R. Prothero, *W. H. Freeman and Co.*
5. **Sedimentary Structure** - J. D. Collinson, N. P. Mountney and D. B. Thompson, *Terra Publishing*
6. **Sedimentology and Stratigraphy** - G. Nichols, *CBS Publishers*

Reference Books:

1. **Applied Sedimentology**- R. K. Sukhtankar, *CBS Publishers*
2. **Depositional Sedimentary Environments** - H. E. Reineck and I. B. Singh, *Springer-Verlag*
3. **International Stratigraphic Guide: A Guide to Stratigraphic Classification, Terminology and Procedure** - Amos Salvador, *The International Union of Geological Sciences & Geological Society of America*
4. **Petrology of Sedimentary Rocks** - Sam Boggs Jr., *Cambridge University Press*
5. **Petrology: The study of Igneous, Sedimentary, and Metamorphic Rocks** - Loren A. Raymond, *Waveland Press Inc*
6. **Sedimentary Petrology** - M. E. Tucker, *CBS Publishers*
7. **Sedimentary Rocks** - F. J. Pettijohn, *CBS Publishers*
8. **Stratigraphy: A Modern Synthesis** - Andrew D. Miall, *Springer*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	2	1	0	1	0	0	1	1	2	2	1	2
CO2	3	2	2	1	2	0	0	1	1	2	3	2	2
CO3	3	3	3	1	3	0	0	1	2	3	2	3	2
CO4	2	1	1	0	1	0	0	1	1	2	1	2	1
Average	**2.25**	**2.00**	**1.75**	**0.50**	**1.75**	**0.00**	**0.00**	**1.00**	**1.25**	**2.25**	**2.00**	**2.00**	**1.75**

GEL-RC-4110

Research Methodology

Credit: 4 (L-4:T-0:P-0)

Course Objective

The main objective of the course is to introduce the students to the fundamentals of scientific research including identification of research problem, research planning, research design, use of statistical tools and computer application in geoscientific research.

Course Learning Outcome

CO 1: Understanding the techniques of geoscientific research.
CO 2: Learning different methods of data collection and interpreting of geologic data.
CO 3: Developing skills on scientific writing.
CO 4: Learning to utilize computers and statistical tools for efficient handling of geologic data.

Detailed Syllabus

Unit 1 ***10 Lectures***

Fundamentals of scientific research; identification and definition of research problem; basic concepts of research design; review of literature; significance and status of research in geology.

Unit 2 ***18 Lectures***

Methods of data collection; processing and analysis of data; data display and interpretation; basic mathematical and statistical methods; trend surface analysis; cluster analysis; principal component analysis (PCA), Markov chain analysis; test of significance.

Unit 3 ***15 Lectures***

Developing a research proposal in geology; writing research report and scientific paper; peer review process for journals; writing a thesis/dissertation; abstract and summary writing.

Unit 4 ***17 Lectures***

Fundamentals of computer; operating system; common application software; open-source software; application software used in geology.

Recommended Books

Text Books:

1. **Research Methodologies for Beginners** - Kitsakorn Locharoenrat, *CRC Press*
2. **Research Methodology: A Step-by-Step Guide for Beginners** - Ranjit Kumar, *Sage Publications*
3. **Research Methodology: Methods and Techniques** - C. R. Kothari, *New Age Publications*
4. **Statistics and Data Analysis in Geology** - J. C. Davis, *Wiley India*

Reference Books:

1. **A Concise Guide to Writing a Thesis of Dissertation: Educational research and Beyond** - Halyna M. Kornuta and Ron W. Germaine, *Routledge*
2. **Authoring a PhD: How to Plan, Draft, Write and Finish a Doctoral Thesis or Dissertation** - Patrick Dunleavy, *Palgrave Macmillan*
3. **Fundamental of Research Methodology and Statistics** - Yogesh Kumar Singh, *New Age Publications*
4. **McGraw-Hill's Concise Guide to Writing Research Papers** - Carol Ellison, *McGraw-Hill*
5. **Research Design: Qualitative, Quantitative, and Mixed Method Approaches** - John W. Creswell, *Sage Publications*
6. **Research Methodology: The Aims, Practice and Ethics of Science** - Peter Pruzan, *Springer*
7. **Thesis Writing for Master's and Ph.D. Program** - Subhash Chandra Parija and Vikram Kate, *Springer*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	3	2	2	3	1	3	3	3	3
CO2	2	3	3	2	3	2	2	3	1	3	3	3	3
CO3	3	3	3	3	3	1	1	3	2	3	3	3	3
CO4	2	3	2	2	3	2	1	3	1	3	3	3	3
Average	**2.50**	**3.00**	**2.75**	**2.25**	**3.00**	**1.75**	**1.50**	**3.00**	**1.25**	**3.00**	**3.00**	**3.00**	**3.00**

SECOND SEMESTER

GEL-CC-4210

Geological Fieldwork

Credit: 4 (L-3:T-0:P-1)

Course Objective

The main objective of the course is visit and study diverse geological terrain within India, visit to exploration sites, mines, construction sites and oil fields to study the methods and activities.

Course Learning Outcome

CO 1: Carrying out geological mapping in different types of terrains.
CO 2: Learning advanced geological field techniques.
CO 3: Visiting different mines, construction and exploration sites to develop field knowledge.
CO 4: Developing skills in preparing geological maps, field reports and presentation.

Detailed Syllabus

Practical ***120 Hours***

In this course, students shall carryout geological field work for period of ten days in diverse geological terrains of India, visit to geologically important areas where exploration and mining activities are going on as well as to engineering construction sites and to oil fields. Seminar presentation by students in the field will be evaluated by the concerned teacher in-charge. Report on the fieldwork shall be submitted by the students individually or in groups, as decided by the teacher in-charge, before the commencement of semester examinations, which will be followed by viva-voce.

Marks Distribution:

1. Field Performance: 40%
2. Field Report : 40%
3. Viva-voce : 20%

Recommended Books

Text Books:

1. **A Guide to Field Geology** - N. W. Gokhale, *CBS Publishers*
2. **Field Geology** - F. H. Lahee, *CBS Publishers*
3. **Geological Field Techniques** - A. L. Coe, *Wiley-Blackwell*
4. **Geology in The Field** - R. R. Compton, *Earthspun Books*

Reference Books:

1. **Geology of India (Vol. 1 & 2)** - R. Vaidyanandhan and M. Ramakrishnan, *Geological Society of India*
2. **Sedimentary Rocks in the Field** - M. E. Tucker, *Wiley-Blackwell*
3. **Sedimentary Rocks in the Field: A Colour Guide** - D. A. V. Stow, *Manson Publishing*
4. **The Field Description of Igneous Rocks** - D. Jerram and N.Petford, *Wiley-Blackwell*
5. **The Field Description of Metamorphic Rocks** - N. Fry, *Wiley-Blackwell*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	2	2	3	2	3	2	2	3	1	3	3	3	3
CO2	2	2	2	1	3	1	1	3	0	3	3	2	3
CO3	1	1	2	2	1	2	2	1	1	3	1	0	0
CO4	2	3	3	1	3	2	1	2	1	3	3	3	3
Average	**1.75**	**2.00**	**2.50**	**1.50**	**2.50**	**1.75**	**1.50**	**2.25**	**0.75**	**3.00**	**2.50**	**2.00**	**2.25**

GEL-DE-4210

Remote Sensing and GIS for Geology

Credit: 4 (L-3:T-0:P-1)

Course Objective

The main objective of this course is to introduce students to the principles of remote sensing and digital image processing, and their application in geology for mapping and analysis.

Course Learning Outcome

CO 1: Understand principles of remote sensing, processing and interpretation of multispectral images for geological application.
CO 2: Understand the principles of microwave, thermal, hyperspectral and LiDAR remote sensing.
CO 3: Interpret radar, thermal, hyperspectral and LiDAR data and their application in geology.
CO 4: Learning about the spatial data acquisition, management and analysis for different applications using GIS techniques.

Detailed Syllabus

Unit 1 ***15 Lectures***

Principles of remote sensing; sensors and platforms; digital image data formats; visual image interpretation; digital image processing: image pre-processing, image enhancement, multi-image manipulation, image classification and accuracy assessment.

Unit 2 ***10 Lectures***

Microwave remote sensing; transmission characteristics of microwave signals; characteristics of radar image; geometric distortions in radar images; synthetic aperture radar (SAR); processing and interpretation of radar data; SAR interferometry; application of radar data in geology.

Unit 3 ***10 Lectures***

Principles of thermal radiation; thermal properties of materials; thermal image characteristics; interpretation of thermal images for application in geology; imaging spectrometers; hyperspectral image analysis; application of hyperspectral data in geology; principles of LiDAR remote sensing; processing and application of LiDAR data.

Unit 4 ***10 Lectures***

Spatial data and spatial data models; GIS data acquisition, spatial data accuracy and quality; data editing and management; vector data analysis; raster data analysis; terrain mapping and analysis; watershed analysis; spatial interpolation; GIS applications.

Practical ***30 Hours***

1. Digital image processing using various software.
2. Satellite image interpretation.
3. Georeferencing of satellite images and maps.
4. Creation and editing of GIS database.
5. Spatial data analysis and terrain analysis.
6. Map composition in GIS.
7. Practical Record.
8. Viva-voce.

Recommended Books

Text Books:

1. **An Introduction to Geographical Information Systems** - I. Heywood, S. Cornelius and S. Carver, *Pearson*
2. **Fundamentals of Remote Sensing** - George Joseph and C. Jeganathan, *Universities Press*
3. **Image Interpretation in Geology** - S. A. Drury, *Nelson Thornes*
4. **Remote Sensing and GIS** - Basudeb Bhatta, *Oxford University Press*
5. **Remote Sensing and Image Interpretation** - T. M. Lillesand, R. W. Kiefer and J. W. Chipman, *John Wiley and Sons*

Reference Books:

1. **Concepts and Techniques of Geographic Information Systems** - C. P. Lo and A. K. W. Yeung, *Pearson*
2. **ERDAS IMAGINE Tour Guides** - *ERDAS Inc.*
3. **Getting to Know ArcGIS Desktop** - Michael Law, *ESRI Press*
4. **Introducing Geographic Information Systems with ArcGIS: A Workbook Approach to Learning GIS** - Michael D. Kennedy, Michael F. Goodchild and Jack Dangermond, *Wiley*
5. **Introduction to Geographic Information Systems** - Kang-tsung Chang, *McGraw-Hill*
6. **Introduction to Microwave Remote Sensing** - Iain H. Woodhouse, *CRC Press*
7. **Introductory Digital Image Processing: A Remote Sensing Perspective** - John R. Jensen, *Pearson Education, Inc.*
8. **Learning QGIS** - Anita Graser, *Packt Publishing Limited*
9. **Principles of Geographical Information Systems** - P. A. Burrough, R. A. McDonnell and C. D. Lloyd, *Oxford University Press*
10. **Remote Sensing Geology** - R. P. Gupta, *Springer-Verlag*
11. **Remote Sensing Handbook (Vols. 1-3)** - Prasad S. Thenkabali, *CRC Press*
12. **Remote Sensing of the Environment** - J. R. Jensen, *Pearson Education*
13. **Textbook of Remote Sensing and Geographical Information Systems** – M. Anji Reddy, *B. S. Publications*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	2	3	1	0	2	0	0	2	0	3	2	1	1
CO2	1	3	1	0	2	0	0	2	0	3	2	1	1
CO3	1	3	2	1	3	0	0	3	0	3	3	2	3
CO4	2	3	2	1	3	1	0	3	1	3	2	1	2
Average	**1.50**	**3.00**	**1.50**	**0.50**	**2.50**	**0.25**	**0.00**	**2.50**	**0.25**	**3.00**	**2.25**	**1.25**	**1.75**

GEL-DE-4220

Advanced Palaeontology

Credit: 4 (L-3:T-0:P-1)

Course Objective

The main objective of the course is to introduce the students to different types of vertebrate and invertebrate fossils, microfossils and plant fossils, their geological significance, and applications.

Course Learning Outcome

CO 1: Understanding evolution of life through time and geological events that influenced the evolution.
CO 2: Understanding the geologic evolution of vertebrates through time.
CO 3: Knowledge on the study of microfossils and its applications.
CO 4: Learning the preservation methods, morphology and significance of plant fossils.

Detailed Syllabus

Unit 1 ***15 Lectures***

Mechanism of evolution and speciation; adaptation and functional morphology; exaptation and its causes; bio-stratigraphic correlation; palaeo-biogeography and the relation of fossil diversity with plate tectonics; mass extinction with special reference to the Permian-Triassic and Cretaceous-Palaeogene boundary.

Unit 2 ***10 Lectures***

Evolution and geological significance of vertebrates; study of fossil vertebrates; origin and evolution of dinosaur, horse, elephant, and human; vertebrate fossil records of Siwaliks; Mesozoic reptiles of India.

Unit 3 ***10 Lectures***

Classification, sampling methods and sample processing of microfossils; morphology, classification, composition, ecology, and geologic history of foraminifera, ostracoda, radiolaria, diatoms, conodonts, and dinoflagellates; applications of microfossils with special reference to hydrocarbon exploration.

Unit 4 ***10 Lectures***

Sample processing of plant fossils; morphology, classification and geological significance of spores and pollens; Gondwana plant fossils and their significances.

Practical ***30 Hours***

1. Ecological interpretation from molluscs, brachiopods, echinoids, and trilobites.
2. Study of microfossils.
3. Megascopic study of important plant fossils of Gondwana.
4. Microscopic study of spores, pollens, and dinoflagellate.
5. Practical Records.
6. Viva-voce.

Recommended Books

Text Books:

1. **Introduction to Palaeontology –** Amal Dasgupta*, World press*
2. **Micropaleontology: Principles and Applications** - Pratul K. Saraswati and M.S. Srinivasan, *Springer*
3. **Palaeontology (Palaeobiology): Evolution and Animal Distribution** - P. C. Jain and M. S. Anantharaman, *Vishal Publishing Co.*
4. **Paleobotany: The Biology and Evolution of Fossil Plants** - E. Taylor, T. Taylor and M. Krings, *Elsevier*
5. **Principles of Paleontology** - David M. Raup and Steven M. Stanley, *CBS Publishers & Distributors*

Reference Books:

1. **Bringing Fossils to Life: An Introduction to Paleobiology** - Donald Prothero, *Columbia University Press*
2. **Fundamentals of Invertebrate Palaeontology: Macrofossils** - Sreepat Jain, *Springer*
3. **Fundamentals of Invertebrate Palaeontology: Microfossils** - Sreepat Jain, *Springer*
4. **Introduction to Paleobiology and the Fossil Record** - Michael J. Benton, David A. T. Harper, *Wiley-Blackwell*
5. **Invertebrate Fossils** - Raymond C. Moore, Cecil G. Lalicker and Alfred G. Fischer, *CBS Publishers & Distributors*
6. **Invertebrate Palaeontology and Evolution –** E. N. K. Clarkson, *ALBS, Allen and Unwin*
7. **Organic Evolution** - Veer Bala Rastogi, *Medtech*
8. **Principles of Invertebrate Paleontology** - Robert R. Shrock and William H. Twenhofel, *CBS Publishers*
9. **Understanding Fossils: An introduction to Invertebrate Palaeontology** - Peter Doyle, *John Wiley & Sons*
10. **Vertebrate Paleontology** - Michael Benton, *Wiley Blackwell*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	0	2	0	0	1	0	0	1	0	3	1	2	1
CO2	0	2	0	0	1	0	0	0	0	3	1	2	1
CO3	1	1	1	0	1	0	0	2	0	3	1	2	1
CO4	1	1	2	0	3	1	0	3	1	3	2	2	3
Average	**0.50**	**1.50**	**0.75**	**0.00**	**1.50**	**0.25**	**0.00**	**1.50**	**0.25**	**3.00**	**1.25**	**2.00**	**1.50**

GEL-DE-4230

Isotope Geology

Credit: 4 (L-4:T-0:P-0)

Course Objective

The main objective of the course is to introduce the students to basic principles of radioactivity and isotopes, their applications in geosciences, instruments that is used to carry out isotopic studies, and various isotopic systematics and their applications in geology. The course is also aimed to introduce basic principles of stable and cosmogenic isotopes, and their applications in geosciences.

Course Learning Outcome

CO 1: Understanding of historical development of isotope geology and concepts of radioactive decay mechanisms.

CO 2: Theoretical knowledge about the laboratory techniques and mass spectrometers employed in precise measurements of isotopic composition of earth materials.

CO 3: Knowledge about the principles of different radiogenic isotope systematics and its applications in earth sciences.

CO 4: Understanding the stable isotope composition of earth's reservoirs and its applications to understand geological processes.

Detailed Syllabus

Unit 1 ***16 Lectures***

Discovery of radioactivity; historical development of radioactive studies and its impact on geology; nucleosynthesis and nuclear stability; stable and radiogenic isotopes; decay mechanisms of radioactive atoms; radioactive decay and growth.

Unit 2 ***15 Lectures***

Mass spectrometer - principles and instrumentation; chemical separation and isotope dilution technique; isochron.

Unit 3 ***12 Lectures***

Principles and applications of K-Ar, Rb-Sr, Sm-Nd, Lu-Hf and U-Th-Pb isotopic systematics in earth sciences.

Unit 4 ***17 Lectures***

Stable isotopes: the δ notation and fractionation factor; theory of mass dependent isotope fractionation; stable isotopes of hydrogen, carbon, oxygen, nitrogen, and sulphur; fractionation of stable isotopes in biosphere, lithosphere, and hydrosphere; stable isotope composition of mantle; cosmogenic nuclides and their applications in geology.

Recommended Books

Text Books:

1. **Geochemistry: An introduction** - Francis Albarede, Cambridge University Press.
2. **Isotope geochemistry** - W.M. White, Wiley.
3. **Isotope geology** - Claude J. Allegre, Cambridge University Press.
4. **Isotopes: principles and applications** - Gunter Faure and Teresa M. Mensing, Wiley.
5. **Radiogenic isotope geology** - A.P. Dickin, Cambridge University Press.
6. **Stable isotope geochemistry** - Hoefs, Springer.

Reference Books:

1. **Chemical fundamentals of geology and environmental geoscience** - Robin Gill, Wiley-Blackwell.
2. **Geochemistry** - W.M. White, Wiley-Blackwell.
3. **Introduction to geochemistry: Principles and applications** - K.C. Misra, Wiley-Blackwell.
4. **Treatise on geochemistry (Volume-1): Meteorites, comets and planets** - A.M. Davis, H.D. Holland and K.K. Turekian, Elsevier.
5. **Using geochemical data to understand geological processes** - Hugh Rollinson and Victoria Pease, Cambridge University Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	1	0	2	0	0	0	1	3	2	2	1
CO2	2	1	2	0	3	0	0	1	1	3	1	2	3
CO3	1	1	2	0	3	0	0	1	2	3	2	2	3
CO4	1	2	2	1	3	0	0	0	2	3	1	2	3
Average	**1.25**	**1.25**	**1.75**	**0.25**	**2.75**	**0.00**	**0.00**	**0.50**	**1.50**	**3.00**	**1.50**	**2.00**	**2.50**

GEL-DE-4240

Geohazard and Disaster Management

Credit: 4 (L-4:T-0:P-0)

Course Objective

The main objective of this course is to introduce the students to various geological hazards and disasters, their causes, vulnerability, risk assessment, mitigation measures and their management at different stages to reduce the loss of life and property.

Course Learning Outcome

CO 1: Learning about different hazardous natural processes and associated risk.
CO 2: Understanding earthquake, volcanic eruptions and related processes as hazard and its mitigation measures.
CO 3: Understanding landslide, flooding and coastal process as natural hazard and its mitigation measures.
CO 4: Understanding the natural hazards resulting due to meteoritic impact and mining activities.

Detailed Syllabus

Unit 1 ***15 Lectures***

Hazardous natural processes and energy sources; hazard, risk, disaster, and catastrophe; fundamental concepts for understanding natural processes as hazards; man-made hazards and disasters; risk assessment.

Unit 2 ***15 Lectures***

Earthquake: magnitude and intensity; seismicity of the world; reduction of earthquake hazard; introduction to tsunamis; tsunami risk and its minimization; volcanic hazards; distribution of active volcanoes; minimizing the volcanic hazard.

Unit 3 ***15 Lectures***

Introduction to landslides; types of landslides; identification of potential landslides; prevention of landslides; landslide warning systems; hazards from ground subsidence and snow avalanche. river flooding as natural hazard; magnitude and frequency of floods; nature and extent of flood hazards; adjustments to flood hazards.

Unit 4 ***15 Lectures***

Coastal hazards; coastal processes; sea-level change; perception and mitigation of coastal hazards; meteoritic impact and impact hazard; mass extinction; hazards and disaster related to mining activities; management of mining related hazards and disasters.

Recommended Books

Text Books:

1. **Disaster Education and Management: A Joyride for Students, Teachers and Disaster Managers -** Rajendra Kumar Bhandari, *Springer*
2. **Geological Hazards** - B. A. Bolt, W. L. Horn, G. A. Macdonald and R. F. Scott, *Springer-Verlag*
3. **Natural Hazards: Earth's Processes as Hazards, Disasters, and Catastrophes -** Edward A. Keller, Duane E. DeVecchio and Robert H. Blodgett, *Pearson*

Reference Books:

1. **Environmental Hazards and Disasters: Contexts, Perspectives and Management -** B. K. Paul, *Wiley-Blackwell*
2. **Environmental Hazards: Assessing Risk and Reducing Disaster** - Keith Smith and David N. Petley, *Routledge*
3. **Introduction to Emergency Management** - Michael K. Lindell, Carla Prater and Ronald W. Perry, *Wiley*
4. **Natural Disasters** - Patrick L. Abbott, *McGraw-Hill*
5. **Natural Hazards and Disasters -** Donald Hyndman and David Hyndman, *Brooks-Cole*
6. **Natural Hazards: Earthquakes, Volcanoes and Landslides -** Ramesh P. Singh and Darius Bartlett, *CRC Press*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	0	2	0	0	2	0	0	2	3	3	1	2	2
CO2	1	2	1	1	3	2	0	3	3	3	2	3	3
CO3	1	2	1	1	3	2	0	3	3	3	2	3	3
CO4	1	2	1	1	3	2	0	3	3	3	2	3	3
Average	**0.75**	**2.00**	**0.75**	**0.75**	**2.75**	**1.50**	**0.00**	**2.75**	**3.00**	**3.00**	**1.75**	**2.75**	**2.75**

GEL-DE-4250

Marine Science

Credit: 4 (L-4:T-0:P-0)

Course Objective

The main objectives of the course are to introduce the students to basic concepts of marine science and associated geological phenomena. The course is also aimed to introduce morphological features, sediment nature, interactions of ocean water with various spheres of the Earth and life in marine environment.

Course Learning Outcome

CO 1: Learning the concepts of marine science and physical and chemical nature of seawater.
CO 2: Understanding the characteristics of marine sediments and its significance.
CO 3: Knowledge on the interactions between ocean and atmosphere and resulting effects on climate.
CO 4: Understanding on the resources of ocean.

Detailed Syllabus

Unit 1 ***15 Lectures***

Introduction, history and development of marine science;; origin and dimensions of the ocean; bathymetry; turbidity currents; physical and chemical properties of sea water.; Deep-Ocean Drilling Programmes.

Unit 2 ***15 Lectures***

Ocean sediments: classification, composition and source; geochronology of oceanic sediments; proxy indicators for palaeoceanographic interpretation; reconstruction of monsoon variability using marine proxy records.

Unit 3 ***15 Lectures***

Atmosphere-ocean interaction; Coriolis effect and Ekman spiral; ocean water circulation; El Nino and La Nina; Indian Ocean Dipole (IOD) and Indian monsoon; global oceanic conveyor belt and its control on earth's climate; cyclones and anticyclones; waves and tides.

Unit 4 ***15 Lectures***

Productivity of the ocean; thermocline and its implications; life in the ocean; resources of the ocean; abuses of the ocean, ocean in changing world: the Keeling curve; ocean circulation in a warming climate.

Recommended Books

Text Books:

1. **Climatology and Oceanography** - D. S. Lal, *Sharda Pustak Bhawan*
2. **Essentials of oceanography** - Tom Garrison, *Cengage Learning*
3. **Oceanography: A Brief Introduction** - K. Siddhartha, *Kitab mahal*
4. **Oceanography: An Invitation to Marine Science** - Tom Garrison and Robert Ellis, *Cengage Learning*
5. **The Sea Floor: An Introduction to Marine Geology** - Eugen Seibold and Wolfgang Berger, *Springer*

Reference Books:

1. **Essentials of Oceanography** - Alan P. Trujillo and Harold V. Thurman, *Pearson*
2. **Introduction to Physical Oceanography** - Robert H. Stewart, *Prentice Hall*
3. **Invitation to Oceanography** - Paul R. Pinet, *Jones and Bartlett Publishers*
4. **Marine Geology: Exploring the New Frontiers of the Ocean** - Jon Erickson, *Facts On File, Inc.*
5. **Oceanography** - Savindra Singh, *Pravalika Publications*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	0	1	2	0	0	2	1	3	2	0	3
CO2	1	1	0	1	2	0	0	1	1	3	2	0	3
CO3	2	3	3	2	3	1	0	2	3	3	2	1	3
CO4	1	1	1	1	1	1	0	1	1	3	1	0	1
Average	**1.25**	**1.50**	**1.00**	**1.25**	**2.00**	**0.50**	**0.00**	**1.50**	**1.50**	**3.00**	**1.75**	**0.25**	**2.50**

GEL-DE-4260

Mineral Resources of India and World

Credit: 4 (L-4:T-0:P-0)

Course Objective

The course is designed to provide knowledge about the important acts and policies of the Government of India to the students. The course is also intended to teach the geological aspects and distribution of different metallic, non-metallic deposits and energy resources of the country. The learners will also be introduced about the major metallic deposits of the world, for providing understanding of the global mineral deposits.

Course Learning Outcome

CO 1: Learning acts and policies of the government which will help them during their profession as geologists.
CO 2: Knowledge on recent activities by government agencies.
CO 3: Geology and distribution of economic mineral and energy resources of the nation.
CO 4: Knowledge about important world class mineral deposits.

Detailed Syllabus

Unit 1 ***10 Lectures***

Brief outline of distribution of mineral resources in India; Mines and Mineral (Development and Regulations) Act; The Offshore Area Mineral Act; Act on Illegal Mining; National Mineral Policy; national and international mineral scenario; recent report on exploration activities by GSI.

Unit 2 ***15 Lectures***

Study on physical characteristics, mode of occurrence, uses and distribution of important non-metallic deposits of India; study on physical characteristics, mineralogy, mode of occurrence, uses and distribution of important metallic deposits in India.

Unit 3 ***17 Lectures***

Geological and geographical distribution of coal in India; geology of large coal fields of the world; geology and distribution of petroleum resources and natural gas in India; strategy of non-conventional energy resources such as atomic minerals, geothermal energy, and solar energy in India.

Unit 4 ***18 Lectures***

Geology and global distribution of the following world class deposits: chromite, copper, platinum group elements, volcanic massive sulphide deposits, sediment-hosted massive Pb-Zn deposits, uranium, iron, and gold.

Recommended Books

Text Books:

1. **Economic Geology: Economic Mineral Deposits** - U. Prasad, *CBS Publishers and Distributors*.
2. **India's Mineral Resources** - S. Krishnaswamy, *Oxford and IBH.*
3. **Mineral Resources and Policy in India** - K. N. Jetli, *Ingram.*
4. **Minerals and Allied Natural Resources and Their Sustainable Development: Principles, Perspective with Emphasis on the India Scenario** - Mihir Deb and S. C. Sarkar, *Springer.*
5. **Non-Conventional Energy Resources** - B. H. Khan, *Tata McGraw-Hill.*
6. **Non-conventional Energy Resources** - N. K. Bansal, *Vikas.*
7. **Understanding mineral deposits** - Kula C. Misra, *Springer.*
8. **World Petroleum Resources and Reserves** - Joseph Riva, *Routledge.*

Reference Books:

1. **Hydrocarbon Exploration and Production (V-46)** - Frank Jahn, *Elsevier.*
2. **Mineral Economics: An Indian Perspective** - K. Randive and S. Jawadand, *Nova Scientific Series.*
3. **Mineral Resources of India** - D. K. Banerjee, *World Press Pvt. Ltd*.
4. **Non-conventional Energy Resources** - S. N. Singh, *Pearson.*
5. **The Indian Ocean: Exploitable Mineral and Petroleum Resources** - G.S. Roonwal, *Springer.*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	0	1	0	0	2	1	0	2	1	2	1	2	1
CO2	0	1	0	0	2	0	0	1	1	2	1	1	2
CO3	1	2	1	0	1	0	0	1	0	1	2	1	3
CO4	2	1	0	0	2	0	0	2	0	3	3	3	3
Average	**0.75**	**1.25**	**0.25**	**0.00**	**1.75**	**0.25**	**0.00**	**1.50**	**0.50**	**2.00**	**1.75**	**1.75**	**2.25**

GEL-DE-4270

Statistics and Data Analysis in Geology

Credit: 4 (L-4:T-0:P-0)

Course Objective

The main objective of this course is to introduce students to the fundamentals of statistical methods and its application in analysing various geological data.

Course Learning Outcome

CO 1: Learning the use of different statistical tools for geology.
CO 2: Understanding the concepts of probability and its applications in geology.
CO 3: Learning the techniques of statistical data analysis in geology.
CO 4: Understanding the distribution of geological data and test of significance.

Detailed Syllabus

Unit 1 ***10 Lectures***

Collection, tabulation and display of geological data; measure of central tendency and dispersion; measurement of moments, skewness and kurtosis.

Unit 2 ***10 Lectures***

Probability concept; elements of set theory; statistical independence and conditional probability; Bayes' theorem; mathematical expectation.

Unit 3 ***20 Lectures***

Correlation and regression; trend surface analysis; kriging; cluster analysis; principal component analysis; Markov chain analysis; analysis of directional data, analytical hierarchy process.

Unit 4 ***20 Lectures***

Binomial distribution, Gaussian distribution and Poisson distribution; sampling distribution of mean; confidence interval and test of significance; z-test, t-test, F-test, chi-square ($\chi 2$) test.

Recommended Books

Text Books:

1. **Applied Geostatistics** - Edward H. Isaaks and R. Mohan Srivastava, *Oxford University Press*
2. **Geostatistics Explained: An Introductory Guide for Earth Scientists** - Steve McKillup and Melinda Darby Dyar, *Cambridge University Press*
3. **Statistical Methods**- S. P. Gupta, *Sultan Chand*
4. **Statistics and Data Analysis in Geology**- J. C. Davis, *Wiley India*

Reference Books:

1. **Fundamentals of Mathematical Statistics** - S. C. Gupta and V. K. Kapoor, *Sultan Chand*
2. **Geostatistics with Applications in Earth Sciences -** D. D. Sarma, *Springer*
3. **Statistics and Analysis of Scientific Data** - Massimiliano Bonamente, *Springer*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	0	3	0	0	2	0	3	2	3	3
CO2	3	3	3	1	3	0	0	2	1	3	2	3	3
CO3	3	3	2	1	3	0	0	3	0	3	3	3	3
CO4	3	3	3	1	3	0	0	1	0	3	2	3	3
Average	**3.00**	**3.00**	**2.50**	**0.75**	**3.00**	**0.00**	**0.00**	**2.00**	**0.25**	**3.00**	**2.25**	**3.00**	**3.00**

GEL-DE-4280

Advanced Hydrogeology

Credit: 4 (L-4:T-0:P-0)

Course Objective

The objectives of the course are to master the knowledge in hydrogeology and solve related problems. The course is aimed to teach principles of hydrogeology and their applicability in real world. The course is also aimed to teach construction of different types of wells, and effective management of groundwater.

Course Learning Outcome

CO 1: Understanding concepts of hydrogeology, properties of aquifer and groundwater flow.
CO 2: Knowledge about groundwater occurrence in natural environments, its interactions with rocks and sea water and methods of constructing wells.
CO 3: Knowledge about physical, chemical, and biological characteristics of groundwater and different causes for contamination of groundwater.
CO 4: Knowledge about management of groundwater.

Detailed Syllabus

Unit 1 ***15 Lectures***

Hydrogeology: aquifer properties; hydraulic conductivity; groundwater flow; transmissivity and storativity; aquifer test; sources of information, ethical and business aspects; hydrographs; hydrologic budget.

Unit 2 ***15 Lectures***

Occurrence of groundwater in different rock types and in unconsolidated sediments; water wells: test holes and well logs; methods of constructing shallow and deep wells; well completion and well development; well protection and rehabilitation.

Unit 3 ***15 Lectures***

Types of chemical reactions in groundwater; carbonate equilibrium; ion exchange; isotope hydrology; major ion chemistry; piper diagram; physical, chemical and biological properties of groundwater; water quality standards; groundwater monitoring; groundwater contamination and restoration.

Unit 4 ***15 Lectures***

Groundwater management: groundwater budget; management of potential aquifers; water law; water quality protection in aquifers; global water issues; groundwater models and its applications; MODFLOW.

Recommended Books

Text Books:

1. **Applied Hydrogeology** - C.W. Fetter Jr, *Pearson*
2. **Groundwater Hydrology** - David Keith Todd and Larry W. Mays, *John Wiley*.
3. **Hydrogeology: Principles and Practice** - Kevin M. Hiscock and Victor F. Bense, *Wiley Blackwell*.

Reference Books:

1. **Ground Water Assessment Development and Management** - K. R. Karanth, *Tata McGraw Hills*
2. **Hydrogeology Problems with Solutions** - Nandipati Subba Rao, *Prentice Hall India Learning Pvt. Limited*
3. **Hydrogeology: Objectives, Methods and Applications** - Eric Gilli, Christian Mangan and Jacques Mudry, *CRC Press.*
4. **Hydrology: Principles, Analysis, Design** - H.M. Raghunath, *New Age International Publishers.*
5. **Principles of Hydrogeology** - Paul F. Hudak, *CRC Press*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	0	2	0	0	2	0	0	1	1	2	1	1	1
CO2	1	1	1	0	3	0	0	1	1	3	1	1	1
CO3	1	1	1	0	2	0	0	1	2	3	1	2	2
CO4	1	2	1	0	1	0	0	1	1	3	2	1	1
Average	**0.75**	**1.50**	**0.75**	**0.00**	**2.00**	**0.00**	**0.00**	**1.00**	**1.25**	**2.75**	**1.25**	**1.25**	**1.25**

GEL-DE-4290

Geotechnical Engineering

Credit: 4 (L-3:T-0:P-1)

Course Objective

The main objective of the course is to introduce the students to the application of geology in civil engineering and construction purposes. The course should also train the geology students to apply geological knowledge in solving engineering problems.

Course Learning Outcome

CO 1: Learning the concepts of geotechnical engineering and soil mechanics.
CO 2: Understanding the basic characteristics and classification of engineering soil.
CO 3: Learning the behaviour of soils to different stress conditions.
CO 4: Understanding slope stability, bearing capacity and subsoil exploration.

Detailed Syllabus

Unit 1 ***15 Lectures***

Origin and type of soil; soil phases; soil mechanics; rock mechanics; weight-volume relationships; plasticity and structure of soil.

Unit 2 ***10 Lectures***

Classification of soil - textural classification, classification by engineering behaviour, AASHTO classification system, unified soil classification system, Indian standard soil classification system.

Unit 3 ***10 Lectures***

Soil compaction and compaction test; permeability and seepage; in-situ stress; stress in soil mass; compressibility of soil; shear strength of soil.

Unit 4 ***10 Lectures***

Lateral earth pressure; slope stability; soil bearing capacity for shallow foundations; determination of bearing capacity of soil.

Practical ***30 Hours***

1. Determination of index properties of soil.
2. Determination of strength of soil.
3. Determination of consistency limit of soil.
4. Calculation of shear strength parameters of soil by direct shear test and triaxial test.
5. Numerical and graphical solution of slope stability problems.
6. Practical Record.
7. Viva-voce.

Recommended Books

Text Books:

1. **Engineering Geology** - S. Gangopadhyay, *Oxford University Press*
2. **Engineering Properties of Soils and Rocks** - F. G. Bell, *Wiley-Blackwell*
3. **Principles of Engineering Geology and Geotectonics** - D. K. Krynine and W. R. Judd, *CBS Publishers*
4. **Principles of Geotechnical Engineering** - Braja M. Das, Khaled Sobhan*, Cengage*

Reference Books:

1. **Engineering Geology** - F. G. Bell, *CBS Publishers*
2. **Geotechnical Engineering (Soil Mechanics) -** T. G. Sitharam and T. N. Ramamurthy**,** *S. Chand*
3. **Engineering and General Geology** - P. Singh, *S. K. Kataria & Sons*
4. **Soil Mechanics in Engineering Practice** - Karl Terzaghi, Ralph B. Peck and Gholamreza Mesri, *John Wiley & Sons*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	0	0	2	0	0	2	1	2	1	1	2
CO2	1	1	0	0	2	0	0	2	0	1	1	1	2
CO3	2	2	1	0	3	0	0	3	1	3	3	1	2
CO4	2	1	1	0	3	0	0	2	3	3	3	1	3
Average	**1.50**	**1.25**	**0.50**	**0.00**	**2.50**	**0.00**	**0.00**	**2.25**	**1.25**	**2.25**	**2.00**	**1.00**	**2.25**

GEL-RC-4210

Research and Publication Ethics

Credit: 4 (L-4:T-0:P-0)

Course Objective

The main objective of the course is to introduce the students to research and publication ethics and misconducts.

Course Learning Outcome

CO 1: Learning the objectives of philosophy and ethics in scientific research.
CO 2: Understanding the intellectual honesty and research integrity to orient themselves into carrying out genuine research activities.
CO 3: Understanding the nitty-gritty in publishing research works.
CO 4: Identifying research misconduct and predatory publications.

Detailed Syllabus

Unit 1 ***15 Lectures***

Philosophy - definition, nature and scope, concept, and branches; ethics: definition, moral philosophy, nature of moral judgements and reactions.

Unit 2 ***15 Lectures***

Ethics with respect to science and research; intellectual honesty and research integrity; scientific misconducts; redundant publications.

Unit 3 ***15 Lectures***

Publication ethics - definition, introduction and importance; best practices/standards setting initiatives and guidelines - COPE, WAME, etc.; conflicts of interest.

Unit 4 ***30 Hours***

Publication misconduct - definition, concept, problems that lead to unethical behaviour and vice versa, types; violation of publication ethics, authorship and contributorship; predatory publishers and journals.

Recommended Books

Text Books:

1. **Handbook of Research and Publication Ethics** - Nimit Chowdhary and Sarah Hussain, *Bharti Publications*
2. **Research and Publication Ethics** - Santosh Kymar Yadav, *Springer*
3. **Text Book of Research and Publication Ethics** - Yogita Sharma and Aarti Sharma, Kalyani Publishers
4. **The Student's Guide to Research Ethics** - Paul Oliver, *Open University Press*

Reference Books:

1. **Ethics in Science: Ethical Misconduct in Scientific Research** - John D'Angelo, *CRC Press*
2. **McGraw-Hill's Concise Guide to Writing Research Papers** - Carol Ellison, *McGraw-Hill*
3. **Philosophy in Educational Research: Epistemology, Ethics, Politics and Quality** - David Bridges, *Springer*
4. **Research Methodology: The Aims, Practice and Ethics of Science** - Peter Pruzan, *Springer*
5. **Scientific Integrity and Research Ethics: An Approach from the Ethos of Science** - David Koepsell, *Springer*
6. **Textbook of Research Ethics**: Theory and Practice - Sana Loue, *Springer*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	2	3	2	2	2	2	2	3	3	2
CO2	2	2	1	2	3	2	2	2	2	2	1	2	2
CO3	2	3	2	3	3	3	2	3	1	3	2	2	2
CO4	2	3	2	3	3	3	2	2	1	3	2	2	2
Average	2.00	2.50	1.75	2.50	3.00	2.50	2.00	2.25	1.50	2.50	2.00	2.25	2.00

THIRD SEMESTER

GEL-CC-5310

Geology of India

Credit:4 (L-4:T-0:P-0)

Course Objective

The main objectives of the course are to teach the students to the structure, stratigraphy, tectonics, age and evolution and mineral wealth of various geological terrains and formations of India, and to study important geological events such as K/Pg boundary, Mesozoic volcanism, evolution of eastern Himalaya and sedimentary basins in eastern India.

Course Learning Outcome

CO 1: Understanding the geology of Archean cratons, Proterozoic, Palaeozoic, Mesozoic and Cenozoic formations of India.

CO 2: Learning the structure, distribution and tectonic evolution of diverse geological formations.

CO 3: Understanding the distribution of economic mineral deposits and fossils in Indian continent.

CO 4: Knowledge on the geology, tectonics and economic importance of NE India.

Detailed Syllabus

Unit 1 ***15 Lectures***

Structure, stratigraphic succession, tectonic settings, evolution and mineral wealth of Archaean cratons, Proterozoic mobile belts and Proterozoic sedimentary basins of India.

Unit 2 ***15 Lectures***

Structure, stratigraphic succession, distribution, fossil assemblages, evolution and economic importance of Gondwana formations; Pan-African orogeny; Palaeozoic rock formations in India.

Unit 3 ***15 Lectures***

Stratigraphic succession, distribution, fossil assemblage, economic importance of Mesozoic formations; Cretaceous-Palaeogene boundary; volcanism in Mesozoic.

Unit 4 ***15 Lectures***

Stratigraphic succession, distribution, classification, fossil assemblage and igneous activity of Cenozoic formations; geology of NE India.

Recommended Books

Text Books:

1. **Fundamentals of Historical Geology and Stratigraphy of India** - Ravindra Kumar, *New Age International*
2. **Geodynamics of Northeastern India and the Adjoining Region** - D. R. Nandy, *Scientific Book Centre*
3. **Geology of Arunachal Pradesh** - G. Kumar, *Geological Society of India*
4. **Geology of Assam** - A. B. Das Gupta and A. K. Biswas, *Geological Society* of *India*
5. **Geology of India (Vol. 1 & 2)** - R. Vaidyanandhan and M. Ramakrishnan, *Geological Society of India*
6. **Historical Geology of India** - S. K. Shah, *Scientific Publishers (India)*
7. **The Making of India: Geodynamic Evolution** - K. S. Validya, *Springer*

Reference Books:

1. **Geology and Evolution of the Indian Plate (From Hadean to Holocene 4 Ga to 4 Ka)** - S. M. Naqvi, *Capital Publishing Company*
2. **Geology and Mineral Resources of Arunachal Pradesh -** *Geological Survey of India*
3. **Geology and Mineral Resources of Assam -** *Geological Survey of India*
4. **Geology of the Himalayan Belt: Deformation, Metamorphism, Stratigraphy** - B. K. Chakrabarti, *Elsevier*
5. **Understanding an Orogenic Belt: Structural Evolution of the Himalaya** - A. K. Dubey, *Springer*
6. **Geology of India and Burma** - M. S. Krishnan, *CBS Publishers*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	0	0	1	0	0	1	1	3	1	1	1
CO2	1	1	0	0	1	0	0	1	1	3	1	1	1
CO3	2	2	1	1	2	1	0	1	1	3	1	1	1
CO4	1	1	0	1	1	1	0	1	1	2	1	1	1
Average	**1.25**	**1.25**	**0.25**	**0.50**	**1.25**	**0.50**	**0.00**	**1.00**	**1.00**	**2.75**	**1.00**	**1.00**	**1.00**

GEL-CC-5320

Himalayan Geology

Credit:4 (L-4:T-0:P-0)

Course Objective

The main objective of this course is to introduce the students to the litho-tectonic subdivisions, origin, and evolution of the Himalaya as well as problems and challenges in Himalayas.

Course Learning Outcome

CO 1: Knowledge on the tectonic framework the Himalaya.
CO 2: Understanding the geologic evolution of the Himalaya.
CO 3: Understanding metamorphism and magmatism in relation to Himalayan orogeny.
CO 4: Knowledge on the tectonic activities in the Himalayan region and natural hazards.

Detailed Syllabus

Unit 1 ***15 Lectures***

Litho-tectonic subdivisions of the Himalaya: Sub-Himalaya, Lesser Himalaya, Higher Himalaya and Tethyan Himalaya; major Himalayan structures: Main Frontal Thrust, Main Boundary Thrust, Main Central Thrust, South Tibetan Detachment System and Indus-Tsangpo Suture Zone.

Unit 2 ***20 Lectures***

India-Asia convergence; evolution of volcanic island arc; collision of India with Asia; breaking of Himalayan crust; development of Lesser Himalayan terrane and foreland basin; Siwalik sedimentation; metamorphism and magmatism in the Himalaya; Himalayan syntaxial bends.

Unit 3 ***10 Lectures***

Arunachal Himalaya: geology of eastern Himalayan belt, Mishmi block and south-eastern Arunachal Pradesh; structure and tectonics of Arunachal Himalaya.

Unit 4 ***15 Lectures***

Landslide problems in Himalayan region; migration and variability of Himalayan rivers; seismicity and active tectonics along Himalayan belt; Himalayan glaciers; Himalayan climate.

Recommended Books

Text Books:

1. **Geodynamics of Northeastern India and the Adjoining Region** - D.R. Nandy, *Scientific Book Centre, Guwahati*
2. **Geology of Arunachal Pradesh** - G. Kumar, *Geological Society of India*
3. **Geology of the Himalayan Belt: Deformation, Metamorphism, Stratigraphy** - B. K. Chakrabarti, *Elsevier*
4. **The Making of India: Geodynamic Evolution** - K. S. Validya, *Springer*

Reference Books:

1. **Colliding Continents: A Geological Exploration of the Himalaya, Karakoram and Tibet** - Mike Searle, *Oxford University Press*
2. **Dimensions of Himalayan Geology** - A. K. Biyani, *Satish Serial Publishing House*
3. **Geology of India (Vol. 2)** - R. Vaidyanandhan and M. Ramakrishnan, *Geological Society of India*
4. **Himalaya to the Sea: Geology, geomorphology and the Quaternary -** John F. Shroder, jr., *Routledge*
5. **Himalaya: Geological Aspects (Vols. 1-5)** - P. S. Saklani, *Satish Serial Publishing House*
6. **Historical Geology of India** - S. K. Shah, *Scientific Publishers (India)*
7. **Understanding an Orogenic Belt: Structural Evolution of the Himalaya** - A. K. Dubey, *Springer*
8. **Zagros - Hindu Kush - Himalaya: Geodynamic Evolution -** Harsh K. Gupta and Frances M. Delany, *American Geophysical Union*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	1	0	1	1	0	1	1	3	1	1	1
CO2	1	1	1	0	1	1	0	1	0	2	1	1	1
CO3	1	1	1	0	1	0	0	1	0	3	2	1	2
CO4	1	1	1	0	1	0	0	1	0	3	1	1	1
Average	**1.00**	**1.00**	**1.00**	**0.00**	**1.00**	**0.50**	**0.00**	**1.00**	**0.25**	**2.75**	**1.25**	**1.00**	**1.25**

GEL-CC-5330

Ore Geology

Credit:4 (L-3:T-0:P-1)

Course Objective

The main objectives of the course are to teach ore deposits, major ore forming processes, ore formation and related geological phenomena, ore microscopy and its application, and application of geochemistry in ore genesis. The course is also aimed to teach characteristics of some of the important mineral deposits.

Course Learning Outcome

CO 1: Understanding the mode of occurrence of ore deposits, its spatial and temporal distribution, geochemical characteristics, and relation to plate tectonics.
CO 2: Knowledge on fluid inclusion studies and its importance in understanding ore genesis.
CO 3: Critical knowledge on genesis of different types of ore deposits.
CO 4: Knowledge on world class deposits.

Detailed Syllabus

Unit 1 ***10 Lectures***

Ore deposit: nature and morphology; major ore forming processes: magmatic, hydrothermal, sedimentary, and metamorphic processes; metallogenic provinces and epochs; plate tectonics and ore deposits; ore mineralization through geologic time.

Unit 2 ***10 Lectures***

Ore microscopy and its applications; ore-gangue texture; wall rock alteration; zoning; fluid inclusion studies: principles, applications, and limitations; isochore; trace element distribution; applications of stable isotopes in ore genetic studies.

Unit 3 ***15 Lectures***

Geology of mineral deposits associated with (i) ultramafic-mafic-intermediate-acid igneous rocks, (ii) low grade and high grade metamorphic rocks, (iii) sedimentary and volcano-sedimentary sequences and (iv) placers.

Unit 4 ***10 Lectures***

Distribution of economic mineral deposits in India; study of important world class deposits: chromite, nickel-copper sulphide, platinum group of elements, skarn, iron, gold, lead and zinc, REE, and lithium.

Practical ***30 Hours***

1. Megascopic and microscopic study of metallic ores.
2. Textural studies of ore and associated minerals under microscope.
3. Preparation of polished section for ore petrography.
4. Fluid petrography of wafer sections.
5. Practical Records.
6. Viva-voce.

Recommended Books

Text Books:

1. **The Geology of Ore Deposits** - J. M. Guilbert and C. F. Park (Jr), *Freeman*
2. **Metal Deposits in Relation to Plate Tectonics** - F. J. Sawkins, Springer *Verlag*
3. **Ore Geology and Industrial Minerals -** A. M Evans, *Blackwell*
4. **Introduction to Ore Microscopy** - J. P. Shrivastava and Nishi Rani, *Prentice Hall India*
5. **Ore Microscopy and Ore Petrography** - J. M. Craig and D. J Vaughan, *Mineralogical Society of America*
6. **Ore Deposits: Origin, Exploration, and Exploitation** - Sophie Decree and Laurence Robb, *Wiley*

Reference Books:

1. **Geochemistry of Hydrothermal Ore Deposits** - H. L Barnes, *John Wiley and Sons*
2. **Time and Stratabound Ore Deposits** - D. D. Klemm and H. J. Schneider, *Springer Verlag*
3. **The Ore Minerals and Their Intergrowths** - P. Ramdohr, *Pergamon Press*
4. **Handbook of Stratabound and Stratiform Ore Deposits** - K. H. Wolf, *Elsevier*
5. **Ore Deposit Geology** - John Ridley, *Cambridge University Press*
6. **Ore Deposit Geology and Its Influence on Mineral Exploration** - R. Edwards and K. Atkinson, *Chapman and Hall*
7. **Ore Deposits in an Evolving Earth** - G. R. T. Jenkin, P. A. J. Lusty, I. McDonald, M. P. Smith, A. J. Boyce, and J. J. Wilkinson, *The Geological Society London*
8. **Ore Genesis: A Holistic Approach** - A. Mookherjee, *Allied Publishers*
9. **The Ore Minerals Under the Microscope: An Optical Guide** - Bernhard Pracejus, *Elsevier*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	0	0	1	0	0	1	1	3	1	1	1
CO2	1	2	1	1	1	0	0	1	1	3	1	1	1
CO3	2	2	1	0	2	1	1	1	0	3	2	2	2
CO4	1	1	1	0	1	1	0	1	1	2	1	1	1
Average	**1.25**	**1.50**	**0.75**	**0.25**	**1.25**	**0.50**	**0.25**	**1.00**	**0.75**	**2.75**	**1.25**	**1.25**	**1.25**

GEL-CC-5340

Geophysics

Credit: 4 (L-3:T-0:P-1)

Course Objective

The main objective of this course is to introduce the students to the principles and techniques of different geophysical methods such as gravity, magnetic, electrical, and seismic methods and their applications.

Course Learning Outcome

CO 1: Learning the principles of various geophysical methods employed in geological studies.
CO 2: Knowledge on the geophysical data acquisition techniques using different instruments.
CO 3: Understanding the methods of geophysical data analysis and interpretation.
CO 4: Acquainting with the applications of various geophysical techniques.

Detailed Syllabus

Unit 1 ***13 Lectures***

Principles of gravity; earth's gravity field; gravity instruments and field operations; processing and interpretation of gravity data; principles of magnetism; geomagnetism and rock magnetism; measurement of the Earth's magnetic field; reduction of magnetic data; processing and interpretation of magnetic data.

Unit 2 ***12 Lectures***

Electrical properties of earth materials; resistivity method: resistivity of rocks and minerals; electrode configuration; field measurement techniques and instruments; induced polarization method: principles and measurements; self-potential method: principles, equipment and measurements; borehole logging; basic information on different types of wireline logs.

Unit 3 ***10 Lectures***

Principles of electromagnetic surveying; detection of electromagnetic field; time-domain electromagnetic survey; non-contacting conductivity measurement; airborne electromagnetic survey; telluric and magneto-telluric survey; ground penetrating radar.

Unit 4 ***10 Lectures***

Seismic theory; propagation of seismic waves within earth; acquisition and processing of seismic data; seismic reflection method; interpretation of seismic reflection data; seismic refraction method; application of seismic survey.

Practical ***30 Hours***

1. Interpretation of gravity data and applications of gravity correction.
2. Study and interpreting magnetic data in exploration and tectonics.
3. Use of seismic data in exploration.
4. Determination of seismic active zones from seismic data.
5. Application of geophysics in hydrocarbon exploration.
6. Practical record.
7. Viva-voce.

Recommended Books

Text Books:

1. **An Introduction to Geophysical Exploration** - P. Kearey, M. Brooks and I. Hill, *Wiley-Blackwell*
2. **Applied Geophysics** - W.M. Telford, L.P. Geldart and R.E. Sheriff, *Cambridge University Press*
3. **Basic Geophysics** - E.A. Robinson and D. Clark, *Society of Exploration Geophysicists*
4. **Fundamentals of Geophysics** - W. Lowrie, *Cambridge University Press*
5. **The Solid Earth: An Introduction to Global Geophysics** - C. M. R Fowler, *Cambridge University Press*

Reference Books:

1. **Encyclopedia of Solid Earth Geophysics** - Harsh K. Gupta, *Springer*
2. **Environmental and Engineering Geophysics** - Prem V. Sharma, *Cambridge University Press*
3. **Exploration Geophysics** - M.R. Gaddalla and R. Fisher, *Springer*
4. **Exploration Geophysics** - Mamdouh R. Gadallah and Ray Fisher, *Springer*
5. **Field Geophysics** - John Milsom and Asger Eriksen, *John Wiley & Sons*
6. **Geophysical Methods in Geology** - P.V. Sharma, Elsevier
7. **Geophysics for the Mineral Exploration Geoscientist** - M. Dentith and S.T. Mudge, *Cambridge University Press*
8. **Geophysics for the Mineral Exploration Geoscientist -** M. Dentith and S. Mudge, *Cambridge University Press*
9. **Geophysics: A Very Short Introduction** - William Lowrie, *Oxford University Press*
10. **Introduction to Applied Geophysics** - H.R. Burger, C.H. Jones and A.F. Sheehan, *W.W. Norton & Company*
11. **Physics for the Earth** - F.D. Stacey and P.M. Davis, *Cambridge University Press*
12. **Practical Seismic Data Analysis** - H.W. Zhou, *Cambridge University Press*
13. **The Encyclopedia of Solid Earth Geophysics** - David E. James, *Van Nostrand Reinhold*
14. **Whole Earth Geophysics: An Introductory Textbook for Geologists and Geophysicists** - Robert J. Lillie, *Prentice Hall*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	1	0	1	1	0	2	1	3	1	3	2
CO2	2	2	2	0	2	0	0	2	0	3	3	2	2
CO3	3	3	1	1	1	0	0	2	0	2	2	3	2
CO4	2	3	2	1	1	1	0	2	0	2	2	2	3
Average	**2.00**	**2.25**	**1.50**	**0.50**	**1.25**	**0.50**	**0.00**	**2.00**	**0.25**	**2.50**	**2.00**	**2.50**	**2.25**

GEL-DE-5310

Non-conventional Energy Sources

Credit: 4 (L-4:T-0:P-0)

Course Objective

The major objectives of the course are to teach different types of non-conventional energy resources, their availability, harvesting techniques, and applications. The course will also emphasize on the availability of such resources in India.

Course Learning Outcome

CO 1: Learning the importance of non-conventional energy sources for sustainable development.
CO 2: Understanding the methods of collecting and storing different types of non-conventional energy sources.
CO 3: Knowledge on the instruments employed in harvesting the energy from non-conventional sources.
CO 4: Learning the applications and limitation of non-conventional energy sources.

Detailed Syllabus

Unit 1 ***8 Lectures***

Introduction to conventional and non-conventional energy sources; non-conventional energy sources; advantages of non-conventional energy; prospects of non-conventional energy sources.

Unit 2 ***20 Lectures***

Solar energy: Extra-terrestrial and terrestrial radiations; measurement of solar radiation; solar energy collector; solar energy storage systems; solar pond; applications of solar energy; wind energy: nature and origin of winds; applications of wind power; principles of wind energy conversion; Wind Energy Conversion System (WECS); wind energy collectors; wind energy program in India.

Unit 3 ***20 Lectures***

Biomass energy: usable forms of biomass, their composition and fuel properties; biomass resources; biomass conversion technology; biomass gasification and liquefaction; production of biogas from waste biomass; biogas and its applications; introduction to tidal, wave and ocean thermal energy.

Unit 4 ***12 Lectures***

Geothermal energy - introduction, origin, distribution and applications; types of geothermal resources; exploration of geothermal resources; environmental considerations; geothermal energy in India.

Recommended Books

Text Books:

1. **Non-Conventional Energy Resources** - B.H. Khan, *Tata McGraw-Hill*
2. **Non-conventional Energy Resources** - N.K. Bansal, *Vika*
3. **Non-conventional Energy Resources** - S.N. Singh, *Pearson*

Reference Books:

1. **Bioenergy: Biomass to Biofuels and Waste to Energy** – Anju DDahiya, *Elsevier*
2. **Fundamentals of Ocean Renewable Energy: Generating Electricity from the Sea** - Simon P. Neill and M, Reza Hashemi, *Elsevier*
3. **Geologic Fundamentals of Geothermal Energy** - David R. Boden, *CRC Press*
4. **Geothermal Energy: Renewable Energy and the Environment** - William E. Glassley, *CRC Press*
5. **Solar Energy for Beginners: The Complete Guide to Solar Power Systems, Panels & Cells** - Catherine Gregory, *CreateSpace Independent Publishing*
6. **Solar Energy: Renewable Energy and the Environment** - Robert Foster, Majid Ghassemi and Alma Cota, *CRC Press*
7. **Wind Energy Explained: Theory, Design and Application** - James F. Manwell, Jon G. McGowan and Anthony L. Rogers, *Wiley*
8. **Wind Energy: Theory and Practice** – Siraj Ahmed, *PHI Learning*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	0	0	1	1	0	1	3	3	2	2	1
CO2	3	3	2	0	2	1	0	1	1	3	2	3	3
CO3	2	3	2	0	2	1	0	2	1	3	2	3	3
CO4	2	2	2	1	2	1	1	2	1	2	2	3	1
Average	**2.00**	**2.25**	**1.50**	**0.25**	**1.75**	**1.00**	**0.25**	**1.50**	**1.50**	**2.75**	**2.00**	**2.75**	**2.00**

GEL-DE-5320

Coal Geology

Credit: 4 (L-3:T-0:P-1)

Course Objective

The important objectives of the course are to introduce the students to coal, their physical and chemical properties, origin, mode of occurrences, classification, distribution and problems in exploitation. The course is also aimed to give detailed geologic knowledge of important coal fields of the country

Course Learning Outcome

CO 1: Gaining knowledge on the physical and chemical characteristics, ranking, classification, and analysis of coal.
CO 2: Understanding the origin, geologic and geographic distribution and uses of coal.
CO 3: Knowledge on origin, association and distribution of CBM.
CO 4: Critical understanding on the exploitation of coal and CBM and risk associated with it.

Detailed Syllabus

Unit 1 ***15 Lectures***

Coal as rock; structures in coal seams; physical and chemical characteristics of coal; proximate and ultimate analyses; macroscopic characteristics of soft and hard coal; coal petrography: thin section and polished section methods; microscopic constituents of coal: macerals and microlithotypes.

Unit 2 ***10 Lectures***

Theories on the origin of coal; classification of coal; Indian coal grading; preparation of coal: coal sizing and washing; beneficiation of Indian coals; utilization of coal: combustion, carbonization, gasification and liquefaction.

Unit 3 ***10 Lectures***

Coal bed methane: a new energy resource; maturation of coal and generation of methane in coal beds; CBM vs. conventional reservoir; coal rank significance in natural gas reservoirs; gas flow in coal deposits; extraction methods of CBM deposits; problems in CBM mining.

Unit 4 ***10 Lectures***

Exploration and mining of coal; problems in underground mining; mining hazards; environmental pollution associated with coal; geological and geographical distribution of coal in India; coal reserves and production in India.

Practical ***30 Hours***

1. Study of different ranks of coal in hand specimens.
2. Megascopic characteristics.
3. Proximate and ultimate analysis of coal.
4. Identification of macerals under microscope.
5. Practical records.
6. Viva-voce.

Recommended Books

Text Books:

1. **Coal Geology -** Larry Thomas, *Wiley Blackwell*
2. **Coal and Organic Petrology** - M. P. Singh, *Hindustan Publishing Corp*
3. **Textbook of Coal** - D. Chandra, R. M. Singh and M. P. Singh, *Tara Book Agency, Varanasi*
4. **Coalbed Methane: Principles and Practice** - Rudy Rogers, Kumar Ramurthy, Gary Rodvelt and Mike Mullen, *Oktibbeha Publishing*

Reference Books:

1. **Coal Geology and Coal Technology** - Colin R. Ward, *Blackwell Scientific Publications*
2. **Coal Gassification and its applications -** David A. Bell, Brian F. Towler and Maohong Fan, *Elsevier*
3. **Coal and Coalbed Gas: Fueling the Future** - Romeo M. Flores, *Elsevier*
4. **Handbook of Coal Analysis** - James G Speight, *Wiley-Interscience*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	1	1	0	0	1	1	1	1	2	3	1	2	1
CO2	2	2	1	1	2	1	0	1	2	3	1	2	2
CO3	2	2	1	1	2	1	0	2	2	3	2	2	2
CO4	3	3	2	2	2	1	1	2	2	3	2	3	3
Average	**2.00**	**2.00**	**1.00**	**1.00**	**1.75**	**1.00**	**0.50**	**1.50**	**2.00**	**3.00**	**1.50**	**2.25**	**2.00**

GEL-DE-5330

Petroleum Geology

Credit: 4 (L-3:T-0:P-1)

Course Objective

The course aims at providing the students the geological knowledge of the petroleum resources, generation of hydrocarbon, migration and different trapping mechanisms. This course also aims to provide detailed information's about the petroleum fields of the country with special reference to NE India.

Course Learning Outcome

CO 1: Understanding the origin, migration and entrapment of hydrocarbons.
CO 2: Knowledge on the characteristics of the reservoir.
CO 3: Learning the principles of hydrocarbon exploration, oil well drilling, logging and reservoir drive mechanisms.
CO 4: Knowledge on the distribution of hydrocarbon resources in India.

Detailed Syllabus

Unit 1 ***15 Lectures***

Basic components of petroleum; physical and chemical properties of petroleum; origin of petroleum: organic and inorganic; migration and accumulation of petroleum; source rock; source rock evaluation; Rock Eval Pyrolysis;.

Unit 2 ***10 Lectures***

Reservoir rock types and its properties; porosities in clastic and non-clastic reservoir rocks; reservoir pore fluids; trapping mechanism for oil and gas; reservoir pressure condition;. Various reservoir driving mechanisms.

Unit 3 ***10 Lectures***

Oil well drilling: exploration, appraisal and development wells; vertical, deviated, horizontal and multi-lateral drilling; drilling fluids - types, properties and functions; duties of well site geologist; well logging; enhanced oil recovery.

Unit 4 ***10 Lectures***

Different categories of proliferous basins of Inda; geology and hydrocarbon deposits in Assam-Arakan basin, Cambay basin, Bombay offshore basin and Krishna-Godavari basin; distribution of oil and gas fields in NE India.

Practical ***30 Hours***

1. Source rock characterization.
2. Study of structure-contour, isopach and isopay maps.
3. Estimation of oil and gas reserve.
4. Study of wireline logs.
5. Evaluation of high pressure zones and calculation of mud density.
6. Practical Records.
7. Viva-voce.

Recommended Books

Text Books:

1. **Elements of Petroleum Geology**- Richard C. Selley and Stephen A. Sonnenberg, *Academic Press*
2. **Geology of Petroleum** - A. L. Leverson, *CBS Publishers*
3. Petroleum Geoscience: From Sedimentary Environment to Rock Physics - Knut Bjørlykke, *Springer*

Reference Books:

1. **Petroleum Geoscience** - Jon Gluyas and Richard Swarbrick, *Blackwell Publishing*
2. **Petroleum Geoscience: From Sedimentary Environments to Rock Physics** - Knut Bjorlykke, *Springer*
3. **Petroleum Geosciences: Indian Contexts** - Soumyajit Mukherjee, *Springer*
4. **Unconventional Petroleum Geology** - Caineng Zou, *Elsevier*

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	1	2	1	1	2	2	3	2	1	1
CO2	2	3	2	1	2	1	1	2	2	3	1	2	1
CO3	3	3	1	1	2	1	1	3	2	3	2	2	2
CO4	2	2	2	1	1	1	1	1	1	2	1	1	1
Average	**2.25**	**2.50**	**1.75**	**1.00**	**1.75**	**1.00**	**1.00**	**2.00**	**1.75**	**2.75**	**1.50**	**1.50**	**1.25**

FOURTH SEMESTER

GEL-RP-5410

Research Project

Credit: 20

Course Objective

The main objective of the course is to learn in identifying geological research problems and solving them using appropriate methods. The students will also be learning to carry out detailed literature survey, analysis and interpretation of geological data and report writing.

Course Learning Outcome

CO 1: Abilities to identify a research problem in geoscience and solving them with appropriate methods.

CO 2: Demonstrate their ability to apply knowledge, understanding, and skills with an appropriate degree of independence.

CO 3: Work independently, identify appropriate resources required for a project, and manage a project through to completion.

CO 4: Exercise responsibility and demonstrate accountability in applying knowledge and skills in work and learning contexts.

Keywords

Detailed Syllabus

Students have to carry out a research project mandatorily during fourth semester of M.Sc. programme. Supervisor will be assigned to the student during the third semester. Progress of the research work will be evaluated periodically through power point presentation in front of duly constituted committee by the department and submission of progress report attested by the concerned supervisor. The final research project report must be submitted to the department for evaluation before the commencement of the fourth semester examination. The report will be evaluated by one external examiner and the concerned supervisor. The students must present their work in the form of seminar followed by viva-voce. The students are also encouraged to write a research article from their work for publication in a standard journal.

Distribution of Marks:

1. **Internal Assessment: 20%**
2. **Report : 50%**
3. **Presentation : 20%**
4. **Viva-voce : 10%**

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	3	2	2	3	0	3	3	3	2
CO2	3	3	3	2	3	2	2	3	1	2	3	3	2
CO3	3	3	3	2	3	2	3	3	1	3	3	3	3
CO4	2	3	2	2	3	2	2	2	1	2	2	3	3
Average	2.75	3.00	2.75	2.00	3.00	2.00	2.25	2.75	0.75	2.50	2.75	3.00	2.50