MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL
ACADEMY of HIGHER EDUCATION
(Deemed to be University under Section 3 of the UGC Act, 1956)

Department of Sciences

M.Sc. in Geology

Choice Based Credit System - 2020 (CBCS - 2020)

(To be implemented from the academic year 2020-21)

COURSE STRUCTURE AND SYLLABUS

2020

Course Structure (MSc Geology)

I SEMESTER

Course Code	Course	L	T	P	C
GEO 5101	Crystallography & Mineralogy	4	0	0	4
GEO 5102	Physical Geology, Meteorology and Geomorphology	4	0	0	4
GEO 5103	Palaeontology & Stratigraphy	4	0	0	4
GEO 5104	Igneous Petrology	4	0	0	4
GEO 5105	Structural Geology	4	0	0	4
GEO 5106	Crystallography & Mineralogy laboratory	0	0	3	2
GEO 5107	Palaeontology laboratory	0	0	3	2
GEO 5108	Seminar – I	0	0	2	1
	TOTAL				25

II SEMESTER

Course Code	Course	L	T	P	C
GEO 5201	Sedimentary Petrology	4	0	0	4
GEO 5202	Metamorphic Petrology	4	0	0	4
GEO 5203	Indian Stratigraphy and their Economic importance	4	0	0	4
GEO 5204	Petrology laboratory	0	0	2	1
GEO 5205	Structural Geology laboratory	0	0	2	1
GEO 5206	Seminar – II	0	0	2	1
GEO 5001	Elective I	3	0	0	3
GEO 5002	Elective II	3	0	0	3
HUM 5207	Research Methodology and Technical communication (RMTC)	3	0	0	3
	TOTAL				**24**

III SEMESTER

Course Code	Course	L	T	P	C
GEO 6101	Hydrogeology	4	0	0	4
GEO 6102	Photo Geology, Remote Sensing & GIS	4	0	0	4
GEO 6103	Environmental Geology and Engineering Geology	3	0	0	3
GEO 6104	Ore Genesis and Mineral Exploration	4	0	0	4
GEO 6001	Elective-III (Practical)	0	0	2	1
SUB[$] 6061	Open Elective (Common to all MSc)	3	0	0	3
	TOTAL				**19**

[$] SUB refers to the Elective subject code prefix.

IV SEMESTER

Course Code	Course	L	T	P	C
GEO 6201	Project	-	-	-	9
GEO 6202	Field training[*]	-	-	-	1
GEO 6203	Summer Internship[#]	-	-	-	1
GEO 6204	Mine/Lab visits[^]	-	-	-	1
	TOTAL				**12**

Total: 80 Credits

[*]Taken up in the first semester.

[#]Taken up at the end of the second semester, during the summer vacation.

[^]Taken up during the third semester.

Open Elective: (offered by Geology faculty in III Semester)

1. **Earth and Environment**
2. **Remote sensing and GIS**

Subject Electives offered in II Semester

Elective I

1. Geochemistry
2. Geophysics

Elective II

1. Oceanography
2. Gemmology

Subject Electives offered in III Semester

Elective III (Laboratory)

1. **Field Geology and Mapping Laboratory**
2. **Remote Sensing Laboratory**
3. **Hydrogeology Laboratory**

OPEN ELECTIVES

Open Elective: **EARTH AND ENVIRONMENT** (for MSc Physics, Chemistry and Mathematics) - 3 Credits

[3-0-0-3]

Internal structure of the earth. Natural resources: - Renewable resources, non-renewable resources. Sustainable management of resources. Land, its uses and management, Resources of the ocean floor. Mineral Resources: Conservation, management and sustainable development.

Natural hazards- prediction, mitigation, preparedness, control: Earthquakes, Coastal Hazards, Landslides, droughts and floods

Waste Management: Solid, liquid, gaseous and radioactive wastes and their management - Waste generation due to mining, environmental impacts of mining activities on land, air and water environment.

Pollution: Problems of pollution of geospheres and its management. Pollution and climatic changes. Greenhouse Effect and Ozone Layer Depletion. Radioactive pollution, Soil pollution, Groundwater pollution, Marine Pollution

Geology and urban planning. Problems of urbanization. Desertification – causes, symptoms and prevention.

Books Recommended:

1. Valdiya, K.S., 2001: Environmental Geology-Indian Context-Tata McGraw Hill
2. Keller, E.A., 2004: Environmental Geology-Bell and Howell, USA
3. Bryant, E., 1999: Natural Hazards-Cambridge University Press
4. Patwardhan, A.M., 1999: The Dynamic Earth System-Prentice Hall
5. Smith, K., 1992: Environmental Hazards-Routledge, London
6. Environmental Concerns and Strategies by Khoshoo, T. L. 1988. Ashish Publ., New Delhi.

Open Elective: **REMOTE SENSING AND GIS** (for MSc Physics, Chemistry and Mathematics) -3 Credits

REMOTE SENSING

Remote Sensing: Fundamental concepts. Remote sensing platforms: Active and passive systems; Satellites: geosynchronous and sun synchronous satellites; types of sensors and scanners;

Resolutions: Spectral, spatial, radiometric and temporal resolutions

Different satellite exploration programmes and their characteristics, LANDSAT, METEOSAT, SEASAT, SPOT, IRS.

Imageries: Types of imageries, visual interpretation;

Digital image processing. Various image processing softwares, their environments and working principles of data interpretation. Digital image processing techniques: data formats, enhancement, filtering, preparation of false colour composite image.

Remote sensing applications in geosciences

Remote Sensing applications - Case studies in India.

GEOGRAPHIC INFORMATION SYSTEM (GIS):

Principles and application of geographic information system, introduction, definition and scope, components of GIS (hardware and software requirement for GIS application); Maps: Maps and their different features/themes/layers, map projections-different types and their properties, GIS software in use;

Database: Definition and types of database, vector and raster data and their relative merits; Data management: Data quality, data manipulation and analysis, advantages and disadvantages of

database approach; GIS Project: Planning and implementation; Utility of GIS and GPS: Application of GIS and GPS, advantages, uses in different fields

Books Recommended:

1. Sabbins, F.F.,1985 Remote Sensing-Principles and Applications. Freeman
2. Lillesand, T.M. and Kieffer, R.W., 1987: Remote Sensing and Image Interpretation-John Wiley
3. Fundamentals of GIS – M. Demers
4. Remote Sensing and Geographical Information System - M.Anji Reddy.
5. Remote sensing and Geographic Information System by A.M. Chandra
6. Fundamentals of Remote Sensing by George Joseph

I SEMESTER

Course Code	Course	L	T	P	C
GEO 5101	Crystallography & Mineralogy	4	0	0	4
GEO 5102	Physical Geology, Meteorology and Geomorphology	4	0	0	4
GEO 5103	Palaeontology	4	0	0	4
GEO 5104	Igneous Petrology	4	0	0	4
GEO 5105	Structural Geology	4	0	0	4
GEO 5106	Crystallography & Mineralogy laboratory	0	0	3	2
GEO 5107	Palaeontology laboratory	0	0	3	2
GEO 5108	Seminar – I	0	0	2	1
	TOTAL				25

I SEMESTER

GEO.5101: CRYSTALLOGRAPHY AND MINERALOGY

Course Outcome:

At the end of the course students will be able to:

- To understand the crystal symmetry, crystallography, and atomic structure
- Explain the characteristics of major rock forming mineral groups
- Explain the formation environments and associations of rock-forming minerals
- To understand the techniques of mineral characterization.

Pre-requisites:

B.Sc. Geology background

CRYSTALLOGRAPHY

Crystallography: Crystalline, amorphous state and the concept of symmetry of crystals. Zone and Zone symbols, Axial ratio of all crystal systems. Napier's rule and its application in crystallography.

Crystal projections: Spherical, Stereographic and Gnomonic projections. Application of stereographic projections in crystallography. Principles of X-ray study in Crystallography and Mineralogy.

Construction of stereograms and gnomonograms. Stereographic projection of class 4/m, 32/m, 2/m.

Measurement of interfacial angles and determination of axial ratios of Normal class of Orthorhombic, Tetragonal and Monoclinic systems.

Study of twin crystals.

MINERALOGY AND OPTICS

Atomic structure, Bonding in minerals, Mineral stability, Ionic radii, Co-ordination polyhedra, Pauling's rule, Ionic substitution, Solid solution, Isomorphism, Polymorphism, Pseudomorphism, Silicate structures. Fluid inclusions-formation, composition and importance. Partitioning of elements between melt and silicates

Systematic study of the following common mineral groups with reference to their structure, chemical composition, physical-optical properties and paragenesis: Olivine, Pyroxene, Amphibole, Mica, Feldspar, Silica, Spinel, Garnet, Epidote, Feldspathoid, Alumino-silicates, Zeolites, Carbonates and Clay minerals

Properties of light, interference of light waves, Concept of plane polarized and cross polarized light, Petrological microscope, Behavior of light under petrological microscope, Optical properties of minerals, Measurement of Refractive Index.

Conoscopic light, Accessory plates, Concept of uniaxial and biaxial indicatrix, Interference figure, Determination of optic sign of uniaxial and biaxial minerals, Optic orientation in different crystallographic systems, Measurement of birefringence, Universal stage.

Space lattice, Unit cell and space group / point group, 32 classes of symmetry, Goniometry, Crystal projections- spherical, stereographic and goniometric, Twinning, Irregularities and imperfections of crystals- discoloration and pleochroic haloes.

Analytical methods in mineralogy - Introduction to Multiple differential thermal analysis, Electron microscope analysis, Scanning and transmission electron microscopy, Electron-Probe Micro-Analysis (EPMA), Cathodoluminiscence, thermoluminescence and X ray diffraction method.

Reference Books

1. Dana, E.S. and Ford, W.E.: A textbook of Mineralogy. Wiley Eastern Limited.
2. Elements of Mineralogy: Berry Masson.
3. Deer, W.A., Howie, R.A. & Zussman, J.: An Introduction to the rock forming minerals, ELBS
4. Berry, L.G., Mason, B. and Dietrich, R.V.: Mineralogy, CBS Publishers
1. and Longman
5. Rock Forming Minerals, Volumes 1 to 5: W. A. Deer, R. A. Howie and J. Zussman; Longman
6. Optical Mineralogy: Paul F. Kerr.
7. Optical Crystallography: E. E. Wahlstrom.
8. Optical Mineralogy: U. M. Revell, Phillips and Dana, T. Griffien; CBS Edition.
9. A practical Introduction to Optical Mineralogy: C. D. Gribble, A. J. Hall.
10. An Introduction to Crystallography: Phillips
11. Minerals and Rocks: Exercises in Crystallography, Mineralogy, and Hand Specimens: Corneis Klein
12. Manual of Mineralogy: Klein, C. and Hurlbut, Jr.CS. 1993; John Wiley.
13. Gemstones Enchanting Gifts of Nature: Dr.Karanth Geological Society of India, Banglore, Publication.
14. Crystals and their structure: Cracknell.
15. Kerr, P.F.: Optical Mineralogy. McGraw Hill Book Company.
16. Moorhouse, W.W.: Optical Mineralogy.
17. Winchell, E.N.: Elements of Optical Mineralogy.
18. Nesse, D.W.: Optical Mineralogy, McGraw Hill

GEO 5102: PHYSICAL GEOLOGY, METEOROLOGY AND GEOMORPHOLOGY

Course Outcome:

At the end of the course students will be able to

- To understand the earth surface and interior structure.
- To explain various process controls formation of earth's interior and surface features.
- To understand the fundamental principles of Climatology.
- To understand the different process influencing our climate.
- To explain the basic concepts and significance of Geomorphology

Pre-requisites:

B.Sc. Geology background

PHYSICAL GEOLOGY

The broad features of the Earth including layered structure.

Earth's orbital parameters, Kepler's laws of planetary motion

The Continental Crust: Structure based on seismological data

Isostatic equilibrium and Gravity anomalies

The Oceanic Crust: structure based on seismic data, velocity - depth distribution. Mid-oceanic ridges and continental margin system.

The Mantle: Seismological methods of investigating mantle structure. Temperature-depth distribution. Composition of mantle. Significance of asthenosphere and outer core in geodynamics

The Core: It's Structure, Physical state and composition. The earth's magnetic field, main field and secular variation.

Terrestrial Heat Flow: Measurement of heat flow. The pattern of heat flow. Thermal properties of rocks. The Earth's internal sources of heat. Transfer of heat within the earth; Adam-Williamson's Equation. Rheology of rocks and fluids (Newtonian and non-Newtonian liquids)

Plate Tectonics: Continental drift – Geological and palaeomagnetic lines of evidence, ocean floor spreading, subduction zone, collision of continents, mid-oceanic ridges and transform faults.

The Origin of Earth's Surface Features: Contraction hypothesis. Expanding earth hypothesis. The convection hypothesis. Orogeny and epeirogeny processes, anatomy of orogenic belts. Tectonic elements of Indian subcontinent.

METEOROLOGY:

Fundamental principles of Climatology, Earth's radiation balance; latitudinal and seasonal variation of insolation, temperature, pressure, wind belts, humidity, cloud formation and precipitation, water balance; Instruments used in meteorological studies; Air masses, monsoon, Jet streams, tropical cyclones; Classification of climates – Koppen's and Thornthwaite's scheme of classification. Climate change; General Circulation and Climate Modeling; Solar radiation interaction with the neutral atmosphere.

GEOMORPHOLOGY

Introduction, basic concepts and significance of Geomorphology

Geomorphic processes – Epigene processes: degradation and aggradation. Hypogene processes - Diastrophism and volcanism: Extra-terrestrial processes - meteorites and tektites.

Weathering – Mechanical, chemical, biological weathering. Factors controlling weathering.

Soil formation - soil profile, classification and geomorphic significance

Hillslope processes: slope profiles, Slope development, slope stability.

Drainage Basin: Drainage network, basin morphology, basin denudation and evolution.

Fluvial Processes: River channels, sediment in channels, the Quasi - equilibrium condition, channel patterns, rivers, equilibrium and time.

Geomorphic processes and evolution of landforms – fluvial, glacial, eolian, coastal and karst. An elementary idea about morphogenesis and morphography; Morphometric analysis; Morphochronology, Geomagnetism.

Geomorphology and topographic analysis including DEM, Environmental change– causes, effects on processes and landforms. Extra-terrestrial geomorphology.

Geomorphology of India – Peninsular, extra-peninsular and Indo-Gangetic Plains.

Application of Geomorphology in Mineral Prospecting, Civil Engineering, Hydrogeology and Environmental studies.

REFERENCE BOOKS

1. Moores. E and Twiss. R.J., 2000: Tectonics. Freeman.
2. Keary. P and Vine. F.J., 2003: Global Tectonics. Blackwell.
3. Storetvedt. K.N., 2005: Our Evolving Planet: Earth‟s History in New Perspective. Bergen (Norway). Alma Mater Fortag.
4. Valdiya. K.S., 1998: Dynamic Himalaya. Universities Press. Hyderabad.
5. Summerfield. M.A., 2000: Geomorphology and Global Tectonics. Springer Verlag.
6. Naqvi, S.M. 2005, Geology and Evolution of the Indian Plate (From Headen to Holocene-4 Ga to 4Ka). Capital Publishing Company.
7. Willam.D, Thornbury, 2004: Principles of Geomorphology. Wiley Eastern.
8. Drury, G.H. 2006: Essays in Geomorphology. Heinman Educational Books Ltd.

9. Hart, M.G. 2000: Geomorphology Pure and Applied. Allen and Unwin
10. Walther Penck, 2004: Morphological analysis of Landforms. Hafner Publishing Co.
11. Derbyshire, E. Gregory, K.J. and J.R. Hills, 2000: Geomorphological process. Dawson & Sons Ltd.
12. Manglesdorf, Weib Scheurmann, 1990: River Morphology. Springer - Verlag.
13. Anderson, M.G. (Ed) 2000: Modelling of Geomorphological Systems. John Wiley.
14. Hemalatha Singh, 2002: Study in Applied Geomorphology. Anupam Publishing.
15. Condie, K.C 2001: Plate Tectonic and Crustal Evolution. Elsevier Publications.
16. Condie, K.C 2005: Earth as an evolving Planetary System. Elsevier Publications.
17. Monroe, 2006: Physical Geology – Exploring the Earth. Elsevier Publications.
18. Lutgens and Tarbuck (2013) - The atmosphere: an introduction to meteorology, 12th Edition, Pearson.
19. Huggett, R. J. (2006). Fundamentals of Geomorphology, Routledge Publishers.

GEO 5103: PALAEONTOLOGY & STRATIGRAPHY

Course Outcome:

At the end of the course students will be able to

- Identify and describe basic features of invertebrate.
- To understand diversity in invertebrates and learn major steps in invertebrate evolution.
- To critically analyze the evidences regarding origin, evolution and extinction of major invertebrate groups and their interrelationships.
- To understand the classification and brief morphology of microfossils.
- To have a knowledge in basic principles and definitions of stratigraphy.

Pre-requisites:

B.Sc. Geology background

PALAEONTOLOGY

Classification of fossils. Nature of fossil record.

Fossilization: mode of preservation and their importance.

Origin and evolution of life.

Importance of fossils in palaeoclimatic and palaeogeographic studies.

Study of the following groups of invertebrate fossils: Corals, Graptolites, Brachiopods, Lamellibranches, Cephalopods, Echinoids and Trilobites

A general review of Vertebrates through geologic time. Principal groups of vertebrates in Gondwana and Siwalik formations.

A general review of plant fossils through geologic time.

MICROPALAEONTOLOGY

Micropalaeontology: scope and subdivision – microfossils.

Foraminifera: morphology and classification- Stable isotope studies on foraminifera and their paleoecologic and paleoclimatic significance - their application in petroleum exploration.

Brief morphology, palaeoecology, biostratigrphy and classification of Radiolaria, Diatoms, Ostracoda, Conodonts and calcareous nanofossils. Application of microfossils in petroleum exploration. Stratigraphic and environmental significance of microfossils.

Palynology: branches and application in various disciplines

Palynofossils: morphology of spores and pollens - Use of palynofossils in paleoclimatic and paleogeographic interpretation – their biostratigraphic use with special reference to Indian stratigraphy.

STRATIGARAPHY

Concepts in stratigraphy: Basic principles and definitions. Concept of time and resolution.

Evolution of Geological Time Scale.

Stratigraphic classification and code of nomenclature. Stratigraphic correlation.

Concept of facies including Walther's Law of facies succession.

Applications of stratigraphy: Techniques in stratigraphic correlation (local, regional and intercontinental).

Elements of magneto- seismic-, sequence-, isotope- and high-resolution event stratigraphy.

World stratigraphy; Brief description of principal stratigraphic units of the world in type areas only. Major geological events during the Precambrian. Cratons, Shield areas and Precambrian Mobile belts. Greenstone belts--origins, rock associations, structure, metamorphism and models for evolution.

REFERENCE BOOKS

1. Danbar, C.O. and Rodgers, J. (1957): Principles of Stratigraphy, John Viley and Sons.
2. McAlester, L.A, 1969: History of life. Prentice Hall Inc.,
3. Moore, R.C., Lalicker, C.G., Fischer, A.G, 2004: Invertebrate fossils. McGraw, Hill, Book Co,
4. Ruap, D.M, Stanley, S.M, 1999: Principles of Palaeontology.W.H. Freeman and Co, Toppan Co. Ltd.
5. Shrock, R.A. 2002: Principles of Invertebrate Paleontology. Twenhofel. Company, Ltd.
6. Romer, A.S. 2004: Vertebrate Palaeontology, (3rd edition). Chicago University Press.
7. Woods H, 1982: Palaeontology Invetebrate. CBS Publications and distributors
8. Clarkson, E.N.K., 1998: Invertebrate Palaeontology and Evolution.IV Ed.-Blackwell
9. Stearn, C.W. & Carroll, R.L, 1989: Palaeontology-the Record of Life-John Wiley
10. Principles of Paleontology by David M. Raup and Steven M. Stanley. CBS Publishers
2. and Distributers.
11. Evolution of Vertebrates by E.H. Colbert. Wiely Eastern Ltd.
12. Pomerol, C., 1982: The Cenozoic Era: Tertiary and Quaternary-Ellis Harwood Ltd.
13. Goodwin, A.M.,1991: Precambrian Geology: The Dynamic Evolution of Continental Crust-Academic Press
14. Boggs, Sam Jr., 1995: Principles of Sedimentology and Stratigraphy-Prentice Hall
15. Doyle, P. and Bennett, M.R., 1996: Unlocking the Stratigraphic Record-John Wiley
16. Brenner, R.E. and McHargue, T.R.,1988: Integrative Stratigraphy: Concepts and Applications-Prentice Hall
17. Naqvi, S.M. and Rogers, J.J.W., 1987: Precambrian Geology of India-Oxford University Press
18. Pascoe, E.H., 1968: A Manual of Geology of India and Burma, Vol. I-IV-Govt. of India Press
19. Haq, B.V. and Boersma, A., 1998: Introduction to Marine Micropalaeontology-Elsevier
20. Haynes, J.R., 1981: Foraminifera-John Wiley
21. Bignot, G., 1985: Elements of Micropalaeontology-Graham and Trotman

GEO 5104: IGNEOUS PETROLOGY
Course Outcome:

At the end of the course students will be able to

- To understand melt generation and crystallization mechanisms.
- To explain diverse rock types and their link to tectonic settings.
- To understand the petrogenesis of large igneous provinces of the world.

Pre-requisites:

B.Sc. Geology background

IGNEOUS PETROLOGY

Physics of magma generation in the mantle and their nature. Physical properties of magma: temperature, density, viscosity, volatile components and their nature, Factors affecting magma and evolution of magma. Crystallization of magmas-nucleation and growth of crystals, quench crystals.

Physico-chemical interpretation of igneous textures including spinifex, rapakivi, mixed crystals, intergrowths and reaction rims.

Genetic significance of structures and textures of igneous rocks.

Isotopic signatures of source-rock relation. Mantle heterogeneity and importance of strontium isotopic ratios. Bowen's Reaction Principle and Series. Magmatic evolution. Fractional Crystallization. Magmatic differentiation and Assimilation.

Importance of Le Chatelier's principle and Phase rule in igneous petrology. Norms - CIPW, Niggli values and Peacock's Alkali Lime Index. Criteria for classification of igneous rocks and IUGS classification.

Detailed study of IUGS Classification of volcanic, plutonic, mafic and ultramafic rocks. TAS classification and Irvin-Baraggar classification. Use of Variation Diagrams and Ternary (FMA) diagrams for igneous rock classification.

Introduction to igneous rock series. Rock suite: petrographic provinces and associations.

Magmatism in relation to plate tectonics. Mantle plumes and associated magmatism. Phase equilibrium of the following silicate systems, its relation to magma genesis and crystallization in the light of modern experimental work: Single Systems-Silica and Carbon.

Binary Systems-Albite-Anorthite, Diopside-Anorthite.

Ternary Systems- Nepheline- Kalsilite-Silica, Forsterite – Anorthite - Silica, Diopside- Forsterite-Silica.

Igneous rocks and associations: Igneous rocks of oceanic regions, Igneous rocks associated with convergent plate boundaries, continental flood basalts and associated rocks, large layered igneous complexes, continental alkaline rocks.

Study of the following rocks with special reference to genetic history and petrotectonics: Ultramafic (Peridotite and Picrite, Komatiite), Basalts, Andesites, Granites (I, S and A types), Syenite, Carbonatite, Anorthosite, Igneous intrusives of Karnataka.

Books Recommended:

1. John D Winter, 2010: Principles of Igneous and Metamorphic Petrology- PHI publishers
2. Philipotts, A., 1992: Igneous and Metamorphic Petrology-Prentice Hall
3. Best, M.G., 1986: Igneous Petrology-CBS Publ.
4. McBirney, A.R., 1993: Igneous Petrology-John & Bartlet Publ.
5. Bose, M.K., 1997: Igneous Petrology-World Press
6. Perchuk, L.L. and Kushiro, I (eds), 1991: Physical Chemistry of Magmas-Springer Verlag
7. Alok Gupta, 1998, Igneous Petrology. Allied Publishers

GEO. 5105: STRUCTURAL GEOLOGY

Course Outcome:

At the end of the course students will be able to

- To understand accurate geometric description of the structures observed in natural deformed rocks.
- To understand the measurement of various orientation data from the structures, plotting them in suitable diagrams and make a quantitative analysis.
- To explain the mechanisms controlling on the deformation processes.

Pre-requisites:

B.Sc. Geology background

STRUCTURAL GEOLOGY

Concept of stress and strain, stress strain relationship of elastic, plastic and viscous materials. Theory of rock failure, Behavior of rocks and minerals with respect to stress and strain. Common types of finite strain ellipsoids. Mohr circles for stress and strain. Various states of stress and their representation by Mohr circles.

Mechanism of folding, Classification of folds, folding in shear zones.

Faults: Classifications and Genesis. Thrust belts and Nappes. Brittle and Ductile Shear zones: Sense of movement. Joints: Classification and Genesis. Origin and significance of different types of minor

structures within shear zones. Joints in relation with folds.

Rock cleavages, Fabrics: foliation and lineation- their morphological variations and genesis.

Unconformity – Development and Types. Significance in stratigraphy. Geometry and mechanics of fracturing. Reactivation of pre-existing discontinuities.Structural Analysis: Principles, phases, Scale, homogeneity and symmetry of structural analysis. Structural analysis on microscopic, mesoscopic and megascopic scales. Structural analysis of areas of one, two and three phases of deformation. Interference structures (such as folds and shear zones) of different scales and their origin. Concept of Plate tectonics (in detail). Plate Tectonic model of the origin of folded mountain belts. Interplate and intraplate seismicity. Tectonic model of the evolution of Himalayas-Geodynamics of the Indian plate.

Reference Books

1. Earth Structure: An Introduction to Structural Geology and Tectonics (2nd Edition): Ben A. van der Pluijm and Stephen Marshak, W.W. Norton & Company, New York and London.
2. Structural Geology: Billings M. P.
3. Structural Geology- Fundamental and Modern Developments: Ghosh, S. K.
4. Structural Geology: Davis, G. A.
5. Plate Tectonics and Crustal Evolution: K. C. Condie
6. Ghosh, S.K. (1993): Structural Geology: Fundamental and Modern Development. Pergamon Press.
7. Hobbs, B.E., Means, W.D. and Williams, P.F. (1976): An outline of Structural Geology, John Wiley and Sons, New York.
8. Ramsay, J.G. (1967): Folding and fracturing of rocks, McGraw Hill.
9. Ramsay, J.G. and Huber, M.I. (1983): Techniques of Modern Structural Geology, Vol. I,Strain Analysis, Academic Press.
10. Ramsay, J.G. and Huber, M.I. (1987): Techniques of Modern Structural Geology, Vol. II, Foldsand Fractures, Academic Press.
11. Ramsay, J.G. and Huber, M.I. (2000): Techniques of Modern Structural Geology, Vol. III (Application of continuum mechanics), Academic Press.
12. Turner, F.J. and Weiss, L.E. (1963): Structural analysis of Metamorphic Tectonites, McGraw Hill.

GEO. 5106: PRACTICALS CRYSTALLOGRAPHY AND MINERALOGY

Course Outcome:

At the end of the course students will be able to

- Distinguish between different crystals based on the systems and classes.
- To understand the optical properties of minerals.
- To identify minerals in thin section by its optical properties.

Pre-requisites:

B.Sc. Geology background

CRYSTALLOGRAPHY

Derivation of 32 classes of symmetry.

International system of crystallographic notation and study of Stereograms.

Different types of crystal projections – spherical and stereographic and their uses.

Twinning and Twin Laws: common types of twins and their examples in minerals.

Liquid Crystals.

Space Lattice and Symmetry of internal structures – 14 Bravais Lattice. Introduction to space group.

Historical development of X-ray Crystallography, and Bragg's Equation.

Powder method in X-ray crystallography

Practical Mineralogy: Megascopic and microscopic study of major rock forming minerals with emphasis on distinguishing features.

Calculation of mineral formula of the following- olivine, pyroxene, amphibole, and

garnet. Determination of anorthite content of plagioclase by optical properties.

Sample preparation and obtaining XRD pattern, Indexing an XRD pattern, Calculation

of 2θ and d spacing values.

OPTICAL MINERALOGY

Determination of length fast and length-slow characters of minerals. Determination of order of interference colours.

Scheme of pleochroism and absorption of a given mineral in thin section.

Determination of extinction angle and composition of plagioclase.

Study of interference figures of uniaxial and biaxial crystals, determination of optic signs.

Determination of birefringence with the help of Michael Levy chart, quartz wedge and

Bereck compensator.

Determination of Refractive Index of uniaxial and biaxial minerals using various

methods.

GEO 5107: PRACTICALS: PALEONTOLOGY

Course Outcome:

At the end of the course students will be able to

- Distinguish between invertebrate fossils.
- To understand the identification features of different fossils.
- To identify the given fossils using various observations and measurements.

Pre-requisites:

B.Sc. Geology background.

PALEONTOLOGY

Identification and study of invertebrate fossils, illustrating functional morphology and classification.

Identification of plant fossils- Gondwana and intertrappean flora.

Sample preparation for micropalaeontological studies, Identification of microfossils- Foraminifera and Ostracoda

Study of the morphological characters of some important Invertebrate Fossils belonging to Brachiopoda, Bivalvia, Gastropoda, Ammonoidea, Trilobita, Echinoidea and Corals. Determination of valves and dental formula of Heterodont Bivalves. Shell petrography of Bivalves and Brachiopods.

Study of an assorted group of trace fossils.

Study of ammonoid suture pattern, coiling, whorl section and ontogenic variation; exercises in ammonoid heterochrony.

Measurements of dimensional parameters and preparation of elementary bivariate growth curves and scatter plots

II SEMESTER

Course Code	Course	L	T	P	C
GEO 5201	Sedimentary Petrology	4	0	0	4
GEO 5202	Metamorphic Petrology	4	0	0	4
GEO 5203	Indian Stratigraphy and their Economic importance	4	0	0	4
GEO 5204	Petrology laboratory	0	0	2	1
GEO 5205	Structural Geology laboratory	0	0	2	1
GEO 5206	Seminar – II	0	0	2	1
GEO 5001	Elective I	3	0	0	3
GEO 5002	Elective II	3	0	0	3
HUM 5207	Research Methodology and Technical communication (RMTC)	3	0	0	3
	TOTAL				24

GEO 5201: SEDIMENTARY PETROLOGY

Course Outcome:

At the end of the course students will be able to

To understand fundamentals of fluid flow, fluid- sediment interaction and formation of bedforms at various scales in different flow regime conditions

To describe scales of sedimentary grain size measurement and statistical analysis of data to interpret provenance, transportation history or depositional environment

To understand texture and structure of clastic sedimentary rocks; procedure and importance of paleocurrent analysis

To comprehend concept of sedimentary environment and description of processes and products of different sedimentary environments viz. continental, marginal marine and marine

To understand origin, mineralogy and signatures of diagentic overprinting of chemical sedimentary rocks viz. carbonate, chert, phosphorite, Evaporite etc.

To comprehend relationship between tectonics and sedimentary basin formation vis-a-vis their depositional motif.

Pre-requisites:

B.Sc. Geology background.

SEDIMENTARY PETROLOGY

Origin and classification of sediments – Parent rocks and their products, Sediment transport mechanism; Deposition by fluids- simple fluid flow concepts- Reynold number and Froude number. Lithification and Diagenesis: Definition, principles, major stages in lithification and diagenesis of clastic and chemical rocks with reference to sandstones and limestones. Sedimentary Textures: Textural elements of clastic and non-clastic rocks, Concept of size and shape, Shape aspects- sphericity, roundness, form; Surface textures, *fractal*, fabric- their measurement, statistical treatment and interpretation, Methods of mineral separation and quantitative and qualitative analysis.

Genesis and Significance of Sedimentary structures - Syndepositional and Post-depositional,

Principles of statistical treatment of palaeocurrent analysis.

Application of textures and structures in sediment dispersal and basin analysis studies.

Purpose and scope of basin analysis.

Provenance: Introduction, definition and concepts, Minerals and source rocks; Mineral stability in the soil profile and during transit, intrastratal mineral stability, Heavy mineral zones, Theoretical and other considerations related to mineral stability, Reading provenance history.

Sedimentary Environments: Classification of environments- continental, marine, transitional; their physical and chemical parameters, lithology and lithological associations; Importance of Structures in interpretation of alluvial, fluvial, deltaic, laccustrine, coastal, shallow marine, deep marine, glacial and aeolian environments.

Concept of sedimentary facies - Extrabasinal and Intrabasinal.

Sandstones: Classification, light and heavy minerals, tectonic setting; Limestones: Classification, mineralogy, environment of deposition, Dolomitisation and dedolomitisation; Evaporites, phosphorites, Chert and Fe-Mn rich rocks- genesis and environment of deposition. Volcanogenic sedimentary rocks, Banded Iron Formation.

Sedimentation and Tectonics: Tectonic controls of sedimentation, diastrophic cycle, Sediment cycle, Sedimentary basins of India; Basin classification in relation to plate tectonic setting.

Reference Books

1. Sedimentary Petrology 3rd edition: Pettijohn, F. J., 1984, CBS Publi.

2. Origin of Sedimentary Rocks, 2nd edition: Blatt, Middleton and Murray.

3. Depositional Sedimentary Environments: Reineck and Singh.

4. An Introduction to Sedimentary Rocks: R. C. Selley.

5. Sedimentary Rocks: R. K. Sukhatankar.

6. Palaeocurrent and Basin Analysis: Potter, Pettijohn and Siever.

7. Sam Boggs Jr (5^{th} Edition). Petrology of Sedimentary rocks. Cambridge University Press.

8. Gary Nichols (2^{nd} Edition). Sedimentology and Stratigraphy. Wiley Blackwell. 9. Kenneth J. Hsu. (2^{nd} Edition) Physics of Sedimentology. Springer.

GEO 5202: METAMORPHIC PETROLOGY

Course Outcome:

At the end of the course students will be able to

- Identify the equilibrium mineral assemblages through textural and mineralogical observations.
- To plot the quantitative as well as qualitative mineral and mineral assemblage data to interpret the discontinuous reactions and to infer the nature of continuous reactions.
- To make a theoretical framework of study of metamorphic rocks as chemical systems.
- To understand progressive metamorphic transformations in selected rock types.
- To understand thee quantitative estimation of P and T; integration of quantitative and qualitative observations for geodynamic interpretations.

Pre-requisites:

B.Sc. Geology background

METAMORPHIC PETROLOGY

Mineralogical Phase rule of closed and open systems.

Kinds, factors and kinetics of metamorphism. Fabric of metamorphic rocks. Metasomatism

Metamorphic reactions. Isograds and Reaction Isograds.

Solid-solid reactions, role of fluid phases, concentration of CO2 and

Oxygen in the fluid phases. Prograde and Retrograde metamorphism. P-T-t paths and their implications.

Metamorphic facies- with special reference to characteristic metamorphic

zones and sub facies: albite-epidote hornfels, hornblende- hornfels, pyroxene hornfels,

sanidinite, greenschist, amphibolite, granulite, prehenite-pumpellite, glaucophane lawsonite

(blue-schist) and eclogite. Geothermometry and geobarometry, fluid inclusions.

Schreinmakers rule and construction of petrogenetic grids. Graphical representation: ACF, AKF, AFM.

Metamorphic differentiation.Anatexis and origin of migmatites in the light of experimental studies.

Regional metamorphism and paired metamorphic belts.

Metamorphism and Tectonics.

Ultra-high temperature, ultra-high pressure and ocean-floor metamorphism.

Partial melting during granulite metamorphism.

Petrogenesis and petrography of the following rocks:

Charnockites, Migmatites, Gneisses, Schists, Slates, Phyllites, Amphibolites, Granulites, Marble and Quartzites.

Granulite facies rocks with special reference to Charnockites and Khondalites of South India.

Books Recommended:

1. John D Winter, 2010: Principles of Igneous and Metamorphic Petrology- PHI publishers
2. Turner, F.J., 1990: Metamorphic Petrology, McGraw Hill, New York
3. Yardley, B.w., 1989: An Introduction to Metamorphic Petrology-Longman, New York

4. Bucher, K. and Frey, M., 1994: Petrogenesis of Metamorphic Rocks-Springer Verlag
5. Philipotts, A., 1992: Igneous and Metamorphic Petrology-Prentice Hall
6. Kretz, R., 1994: Metamorphic Crystallization-John Wiley
7. Winkler, H.G.F., 1974, Petrogenesis of Metamorphic Rocks, 5th edn., Springer-Verlag.

GEO 5203: INDIAN STRATIGRAPHY and their ECONOMIC IMPORTANCE

Course Outcome:

At the end of the course students will be able to

- To understand basic principles of stratigraphy, different types of stratigraphic units and how they are named.
- To know the crustal evolution during the Precambrian in peninsular India and how the biosphere responded to the Precambrian-Cambrian boundary events.
- To appreciate how plate tectonic movements separated India from contiguous landmasses and shaped the depositional basins of the Indian Phanerozoic, and what were their effects on climate and life.

Pre-requisites:

B.Sc. Geology background

INDIAN STRATIGRAPHY and their ECONOMIC IMPORTANCE

Concept of sequence stratigraphy. Chief divisions of Indian sub-continent and their physiographic characters.

Archaean Era. Distribution and classification in Peninsula (Mysore, Bihar, M. P. and Rajasthan) and extrapeninsular regions. Their correlation and economic importance.

Dharwar Supergroup (Classification, Distribution, Economic importance) - Granulites belts of South India.

Classification and stratigraphy of Indian Proterozoic rocks -- Cuddapah and Vindhyan Supergroups – equivalents – economic importance.

Palaeozic formations of extra peninsular regions with special reference to their classification distribution and correlation.

Distribution, geological succession, classification and climate of Gondwana Supergroup. Age and correlation of Gondwana formations.

Jurassic system of rocks – in extrapeninsular region. Distribution, Classification & correlation of cretaceous formations of Peninsula and extra peninsulas regions of India. Stratigraphy and fossils of Jurassic of Kutch and Cretaceous of Tiruchirappally.

Distribution, structural features and age of the Deccan Traps.

Inter-trappeans and infra-trappeans of India.

Problems of Permo-triaassic and Cretaceous – Palaeocene boundaries.

Distribution, succession, correlation and life of Siwalik formations.

Distribution, lithology, correlation & life of the Cenozoics of Assam & Western India

and Pleistocence (Quaternary) deposits, Karewa Beds, Indogangetic Alluvium.

Geology of Karnataka.

Books Recommended:

1. Krishnan,M.S. (1982): Geology of India and Burma, C.B.S. Publ. and Distributors, Delhi.
2. Naqvi, S.M. and Rogers, J.J.W. (1987): Precambrian Geology of India, Oxford University Press.
3. Pascoe, E.H. (1968): A Manual of the Geology of India and Burma (Vols.I-IV), Govt. of India Press, Delhi.
4. Pomerol, C. (1982): The Cenozoic Era? Tertiary and Quaternary, Ellis Harwood Ltd., Halsted Press.
5. Schoch, Robert, M. (1989): Stratigraphy: Principles and Methods, Van Nostrand Reinhold, New York.
6. Krumbein and Sloss (1963): Stratigraphy and sedimentation II Ed.Freeman & Co.
7. Wadia: Geology of India.

HUM 5207: RESEARCH METHODOLOGY AND TECHNICAL COMMUNICATION (RMTC-36 h)

Course Outcomes:
At the end of the course students will be able to

- Explain certain key concepts in research
- Use these concepts in problem solving and data analysis
- Practice these concepts in writing thesis and research communications

Pre-requisites:

B.Sc. background

Introduction to Research methodology:

Types of research, Significance of research, Research framework, Case study method, Experimental method, Sources of data, Data collection using questionnaire, interviewing, and experimentation.

Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem.

Criterion for hypothesis construction, Nature of hypothesis, need for having a working hypothesis, Characteristics and Types of hypothesis, Procedure for hypothesis testing.

Sampling methods and data analysis:

Measurement and Scaling Techniques, Methods of Data Collection, Processing & Analysis of Data, Measures of Central Tendency, Dispersion, Skewness Regression Analysis and Correlation, Sampling Fundamentals, Central Limit Theorem.

Estimation Testing of Hypotheses, Chi-Square Test.

Literature Review and Journal communications:

Importance of literature review. Performance of literature review and identification of research gap, defining scope and objectives of the research problem, IEEE and Harvard styles of referencing. Preparation of conference presentations (Oral and Poster) through case study, Effective Presentation. Journal communication, Copyrights, and avoiding plagiarism. Preparation of dissertation.

References:

1. R. Kumar, Research Methodology; A Step-by-Step Guide for Beginners, SAGE 2005
2. G. R. Marczyk, D. De Matteo and D. Festinger, Essentials of Research Design and Methodology, John Wiley &Sons 2004
3. J. W. Creswel, Research Design: Qualitative, Quantitative, and Mixed Methods approaches, SAGE 2004
4. S. C. Sinha, A. K. Dhiman, Research Methodology, Vedam Books 2006
5. C. R. Kothari, Research Methodology; Methods & Techniques, New age international publishers, New Delhi 2008

ELECTIVE I GEO 5001– GEOCHEMISTRY & ISOTOPE GEOLOGY

Course Outcomes:

At the end of the course students will be able to

- To understand the evolution of the early Earth from proto-planetary material and its differentiation to present day state.
- To describe the composition of the Earth´s main geochemical reservoirs.
- To explain element fractionation and how this can be used to understand geochemical processes.
- To understand the mode of geochemical analysis and associated instrumentation
- To apply radiogenic isotope signatures to trace the source of minerals, rocks and to date magmatic and metamorphic events.
- To know the applications of isotope geology in various fields.

GEOCHEMISTRY

Geochemistry: Historical development and scope. Origin and cosmic abundance of elements. Geochemical classification of elements. Primary differentiation of elements: Distribution and behaviour of major, trace and Rare Earth Elements (REE) in igneous, sedimentary and metamorphic environments. Applications of major, minor, Rare Earth Elements and Platinum Group of Elements in geochemistry.

Geochemistry of crust, mantle and core of the earth. Geochemistry of meteorites. Geochemical Cycle. Mobility of elements, Isomorphism, polymorphism and atomic substitution. Application of Thermodynamics in Geochemistry: Phase rule, Eh, pH, limits of Eh and pH in nature. Eh-pH diagrams. Free energy: Definition of free energy and its limitations. Free energies of formation, Gibb's free energy; change of enthalpy and entropy; Chemical potential, fugacity and Oxidation-Reduction potentials. Phase rule formulation: one component system and two component system; Eutectics and solid solution.

Analytical techniques: methods based on emission and absorption spectra, principles and methodology. Flame Photometer, Spectrophotometer, Atomic Absorption Spectrometer (AAS), Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) and Isotope Mass Spectrometers. Methods based on electron properties: X-ray diffraction. Methods based on magnetic properties.

Geochemical cycle, planning- oriented surveys. Geochemical data analysis- evaluation of quality of data, presentation and statistical treatment of data. Interpretation of data Advanced analytical methods- AAS, XRF, ICP-ES, ICP-MS, NAA, IDMS, SSMS, Ion microprobe, EPMA.

Distribution of elements, primary dispersion, secondary dispersion. Geochemical exploration methods - lithogeochemical, hydrogeochemical and atmogeochemistry.

ISOTOPE GEOLOGY

Introduction to isotope geology: Isotopes, isobars and isotones, stable and radioactive isotopes. Various decay mechanisms- alpha, beta (positron and negatron), gamma decay, electron capture and branched decay. Radioactive decay, half-life and basic equation for age calculation.

Study of different radioactive systematics: Rb-Sr –model age and isochron age, mineral and whole rock isochrones, their merits and demerits. Importance of Sr initial concentration in understanding the source characteristics of igneous and metamorphic rocks K-Ar systematics-model age and isochron age, the problem of Ar loss, metamorphic veil and rate of cooling intrusives.

Sm-Nd sytematics, isochron ages, isotopic evolution of Nd, CHUR model, epsilon Nd parameter and nature of mantle source, crustal residence of igneous and metamorphic rocks. U-Th-Pb systematics-model age, 207Pb-206Pb method, U-Pb Concordia-discordia method, U-Pb, Th-Pb isochron methods, Zircon dating- analysis of single zircon and SHRIMP analysis. 14C and fission track methods of dating. significance of stable isotopes of Carbon, Oxygen and

Sulphur in petrology. Isotope hydrogeology -δ^{18}O and δ^{2}H- Global meteoric water line, altitude, attitude and latitudinal effects on rainwater.

Books Recommended:

1. Albarede F. (2003) Geochemistry- An introduction, Cambridge university press.
2. Brownlow, A.N., 1979, Geochemistry, Prentice Hall.
3. Gill, R. (1989) Chemical fundamentals of geology, Unwin Hyman, London
4. Faure, G., 1986: Principles of Isotope Geology-John Wiley
5. Hoefs, J., 1980: Stable isotope Geochemistry –Springer Verlag
6. Marshal, C.P. and Fairbridge, R.W., 1999: Encyclopaedia of Geochemistry-Kluwer Academic
7. Govett, G.J.S. (Ed.), 1983: Handbook of Exploration Geochemistry-Elsevier
8. Mason, B. and Moore, C.B., 1991: Introduction to Geochemistry-Wiley Eastern
9. Nordstrorm, D.K. and Munoz, J.L., 1986: Geochemical Thermodynamics-Blackwell
10. Henderson, P., 1987: Inorganic Geochemistry-Pergamon Press
11. Krauskopf, E.B. (1979) Introduction to geochemistry, McGraw Hill Book Company, New Delhi.

12. Krauskopf, K.B., 1967, Introduction to Geochemistry, McGraw Hill.
13. Paul Henderson, Inorganic Geochemistry, Pergamon Press.
14. Rankama, K. & Sahama, T.H.C., 1950, Geochemistry, University of Chicago Press.
15. Rankama, K., 1963, Progress in Isotope Geology, Interscience.
16. Rollinson, H.R. (1993) Using geochemical data: Evaluation, presentation, interpretation. Longman scientific and Technical, New York.

ELECTIVE I: GEO 5001 GEOPHYSICS

At the end of the course students will be able to

Course Outcomes:

- To understand methodology of geophysical data acquisition and reduction.
- Comprehend Earth Gravity, Isostasy, gravity anomaly, reduction and processing of gravity data and interpretation of gravity anomaly for objects of various density and geometry
- Describe Magnetism, residual magnetism and Paleomagnetism. Reconstruct paleopole position, Apparent Polar wandering (APW) curve.
- Understand seismic refraction, reflection, fundamentals of earthquake seismicity Describe principles of well logging, different logging techniques, data patterns and their interpretations.

GEOPHYSICS

Introduction to Geophysical Exploration

Magnetic methods: Principles of magnetism, magnetometers, interpretation of magnetic data; marine and terrestrial magnetic surveys. Prospecting using magnetic methods.

Gravity methods: Principles of gravity and earth's gravity field; gravimeters: interpretation of gravity data; prospecting for hydrocarbons and mineral deposits.

Seismic methods: Elastic properties and outlines of wave propagation in the earth.; geophones and hydrophones; seismic surveys: OBS deployment of seismic equipment 2D, 3D and 4D for hydrocarbon exploration.

Electrical methods: Wenner and Schlumberger electrode configuration, profiling and VES's, curve matching techniques, AHQK curves, SP techniques and magnetotelluric methods. Prospecting for ore and groundwater deposits.

Electromagnetic surveying: Introduction, Depth of penetration of electromagnetic fields, Detection of electromagnetic fields. Telluric and magneto telluric field methods, Surveying with

telluric currents, Magneto telluric surveying, Ground-penetrating radar, Applications of electromagnetic surveying.

Well-logging techniques: Introduction and classifications, Applications of well-logging in oil exploration.

Reference Books:

1. M.B. Dobrin – Introduction to Geophysical Prospecting
2. G.D. Garland – Introduction to Geophysics
3. M.B.R. Rao – Outlines of Geophysical Prospecting – A manual for Geologists
4. D.S. Parsanis – Principles of Applied Geophysics
5. L. Smith – Topics in Geophysics
6. L.K. Nettleton – Geophysical Prospecting for Oil
7. M.R. Gadallah and R. Fisher – Exploration Geophysics
8. Sharma: Geophysical Prospecting for Geologists and Engineers
9. Bhattacharya & Patra: D.C. Geoelectric Sounding: Principles and Interpretation
10. Patra & Nath: Schlumberger Geoelectric Sounding in Ground Water

ELECTIVE II GEO 5002: OCEANOGRAPHY

Course Outcomes:

At the end of the course students will be able to

- To get an idea about the mechanism of ocean circulation and deep-water formations.
- To understand the relationship between ocean current dynamics and its effect on distribution of microorganisms.
- To understand the variability in the distribution of water mass sensitive microorganisms help in deciphering the cause and their effect in the geological records.
- To understand the palaeoceanographic condition through the geological records and their effect on paleoclimatic variability.

OCEANOGRAPHY

Physical Oceanography: T-S diagrams; mixing processes in the oceans; characteristics of important water masses. Instruments used in Physical Oceanography. Wind generated waves in the oceans; their characteristics; shallow and deep-water waves. Propagation, refraction, and reflection of waves. Tide-producing forces and their magnitudes; tides and tidal currents in shallow seas, estuaries and rivers. Factors influencing coastal processes; transformation of waves in shallow water; effects of stratification; effect of bottom friction, phenomena of wave reflection, refraction and diffraction; breakers and surf; littoral currents; wave action on sediments –

movement to beach material; rip currents; beach stability, ocean beach nourishment; harbour resonance; seiches; tsunami; interaction of waves and structure. Estuaries: classification and nomenclature; estuarine circulation and mixing; sedimentation in estuaries; salinity intrusion in estuaries; effect of stratification; coastal pollution; mixing and dispersal of pollutants in estuaries and near-shore areas; coastal zone management. The global wind system; action of wind on ocean surface; Ekman's theory; Sverdrup, Stommel and Munk's theories; upwelling and sinking with special reference to the Indian Ocean. Inertial currents; divergences and convergences; geostrophic motion; oceanic eddies, Characteristics of the global conveyor belt circulation and its causes. Formation of subtropical gyres; Ocean circulation (different types of currents); El Nino Southern Oscillation and La Nina; monsoonal winds and currents over the North Indian Ocean; Somali current; Southern Ocean. Upwelling process in the Arabian Sea.

Chemical Oceanography: Composition of seawater – Classification of elements based on their distribution; major and minor elements, their behavior and chemical exchanges across interfaces and residence times in seawater. Instruments used in Chemical Oceanography. Temperature, density and salinity variations in the ocean. Element chemistry in atypical conditions-estuaries, hydrothermal vents, anoxic basins, HNLC waters, sediment pore fluid and anthropogenic inputs. Chemical and biological interactions – Ionic interactions; biochemical cycling of nutrients, trace metals and organic matter. Air-sea exchange of important biogenic dissolved gases; carbon dioxide-carbonate system; alkalinity and control of pH; biological pump. Factors affecting sedimentary deposits-CaCO3, Silicate, Manganese nodules, phosphorites and massive single deposits.

Geological Oceanography: Morphologic and tectonic domains of the ocean floor. Structure, composition and mechanism of the formation of oceanic crust. hydrothermal vents-. Ocean margins and their significance. Instruments used in Geological Oceanography. Oceanic sediments: Factors controlling the deposition and distribution of oceanic sediments; geochronology of oceanic sediments, diagenetic changes in oxic and anoxic environments. Tectonic evolution of the ocean basins. Mineral resources. Paleoceanography – Approaches to paleoceanographic reconstructions; various proxy indicators for paleoceanographic interpretation. Reconstruction of Indian summer monsoon variability by using marine proxy records. Opening and closing of ocean gateways and their effect on circulation and climate during the Cenozoic. Sea level processes and Sea level changes.

Biological Oceanography: Classification of the marine environment and marine organisms. Physio-chemical factors affecting marine life – light, temperature, salinity, pressure, nutrients, dissolved gases; adaptation and biological processes. Instruments used in Biological Oceanography. Primary and secondary production; factors controlling phytoplankton and zooplankton abundance and diversity; nekton and fisheries oceanography; benthic organisms; coastal marine communities and community ecology – estuaries, coral reefs and mangrove

communities, deep-sea ecology including hydrothermal vent communities. Energy flow and mineral cycling – energy transfer and transfer efficiencies through different trophic levels; food webs including the microbial loop. Human impacts on marine communities; impacts of climate change on marine biodiversity. Impact of marine pollution on marine environments including fisheries – case studies.

Law of the Seas-UNCLOS, EEZ—coastal zone environment and its protection—CRZ Act and CZM plans.

Books Recommended

1. Trujillo and Thurman (10th Edition; 2011). Essentials of Oceanography. Pearson.
2. Garrison and Ellis (9th Edition; 2016). Oceanography: An invitation to Marine Science. National Geographic Learning.
3. Paul R Pinet (5th Edition; 2009). Invitation to Oceanography. Jones and Bartlett Publishers.
4. Submarine Geology- Shephard, F. P. 1973, Harper and Raw
5. The Sea Floor – Seabold, E. and Berger, W. H., 1982, Springer Verlag
6. Geological Oceanography- Shephard, F.P. 1978, Heinmann, London
7. Coastal and estuarine sediment dynamics- Dyer, K. R., 1986, John Wiley and Sons
8. Beach Process and sedimentation – Komar, P. D., 1976, Prentice Hall
9. Depositional Sedimentary environments – Reinek, H. E. and Singh, I. B., 1986,
3. Springer Verlag
10. Chemical Oceanography (Vol.1 to 3)- Riley, J. P. and Skirrow, G., 1975.
11. Marine chemistry- Home, R. A. 1969.
12. Introduction to Marine Micropalaeontology- B.U.Hag and A. Boersma
13. Microfossils – Brasier M.D.
14. Elements of Micropalaeontology – B'gnor B.
15. Waves and Beaches- The dynamics of the ocean surface –Basiom W.
16. Coastal Sedimentary Dynamics – Daris R.A.
17. CRC Handbook of coastal process and erosion – Komar P.D.
18. Principles of Physical Oceanography- G. Neumann and W. J. Pierson
19. Mineral wealth of ocean – A. K. Ghosh and Randhir Mukhopadhyay
20. The mineral resources of the sea – J. L. Mero
21. Handbook of marine mineral deposits- D. S. Cronon
22. The Indian Ocean- Exploitable mineral and Petroleum resources – Roonwal G. S.

ELECTIVE II GEO 5002: GEMMOLOGY

Course Outcomes:

At the end of the course students will be able to:

- To get an idea about gem and gemstones.
- To understand the application of gemstones.

Gem and Gemstones. General characteristics and chemical composition of gemstones: Physical characteristics: Form, cleavage, fracture, hardness and specific gravity; Optical characteristics: colour, luster, play of colour, refractive index, reflectivity, pleochroism, dispersion.

Application of ultraviolet rays, X-rays and Infra-red rays in gem identification.

Electrical thermal and magnetic characters of gem. Classification of gemstones.

Systematic description, genesis, mode of occurrence, distribution in India and also important world occurrences of important precious and semi-precious stones.

Synthetic gemstones: methods of synthesis, and its characteristics and identification. Gem enhancement methods and their identification: colourless/coloured impregnation, heat treatment, coating, irradiation, diffusion, treatment, etc.

Application of gemstones: (1) Technical application and (2) Application as jewels

PRACTICALS

1. Identification of important minerals and their gem varieties in hand specimens.

2. Study of optical properties of important minerals and their gem varieties.

3. Study of faults in gemstones.

4. Identification of synthetic gemstones.

Books Recommended

1. Brocardo, G. (1981) Minerals and Gemstones – An identification Guide
2. Orlov YuL (1973) The Mineralogy of the Diamond
3. Max Bauer (1968) Precious stones, Vol. I and II
4. Bruton Eric F.G.A. (1970) Diamonds
5. Wilson, M. (1967) Gems

GEO 5204: PRACTICAL PETROLOGY

Course Outcomes:

At the end of the course students will be able to

- To identify the rocks in hand specimen.
- To understand the textures and structures.
- To analysis rock compositions using various tools.

IGNEOUS PETROLOGY

Megascopic and microscopic study of representative igneous rocks. Calculation of

CIPW norms. Niggli calculations. Preparation of variation diagrams. Quantitative

mineralogical studies in thin section and rock classification. Use of computer

programming in Petrological studies.

SEDIMENTARY PETROLOGY

Megascopic and microscopic characters of clastic and non-clastic rocks,

Study of sedimentary textures, structures and their significance.

Identification of types of sandstones and limestones in micro-sections.

Study of heavy minerals.

Determination of sphericity and roundness of grains, Sieve analysis, Graphical presentation of data and determination of statistical parameters.

Detailed study of diagenetic features under thin sections, Exercise on mineralogic and geochemical data plots for environmental interpretation by using computer.

Paleocurrent analysis for different depositional environments. Litho-facies analysis (both lateral as well as vertical).

METAMORPHIC PETROLOGY

Megascopic and microscopic study of textures, structures and minerals in metamorphic rocks and their classification.

Study of representative metamorphic rocks.

Calculation and plotting of ACF, AFM and AKF diagrams and their interpretation.

Modal Analysis and its significance in determination of parentage of metamorphic rocks.

GEO 5205: PRACTICALS- STRUCTURAL GEOLOGY
Course Outcomes:

At the end of the course students will be able to

- To give description of structural geological maps, draw their sections and give structural interpretation of maps.

STRUCTURAL GEOLOGY

Cross-section balancing

Description of structural geological maps and drawing their sections, Exercises in determination of finite strain, Exercises in Ramsay's fold analysis. Exercises in shear zones (strain analysis).

III SEMESTER

Course Code	Course	L	T	P	C
GEO 6101	Hydrogeology	4	0	0	4
GEO 6102	Photo Geology, Remote Sensing & GIS	4	0	0	4
GEO 6103	Environmental and Engg. Geology	3	0	0	3
GEO 6104	Ore Genesis and Mineral exploration	4	0	0	4
GEO 6001	Elective-III (Practical)	0	0	2	1
SUB[$] 6061	Open Elective (Common to all MSc)	3	0	0	3
	TOTAL				19

[$] SUB refers to the Elective subject code prefix.

GEO 6101: HYDROGEOLOGY

Course Outcomes:

At the end of the course students will be able

- To learn about occurrence of groundwater, water bearing properties of formations, aquifer types and aquifer parameters.
- To understand construction, design and development of water wells, aquifer parameter estimation and the science of groundwater flow under different conditions.
- To understand the concepts of groundwater exploration in an integrated way and also about groundwater chemistry.

HYDROGEOLOGY

Groundwater- Origin, occurrence and distribution of water in the earth crust. Hydrological cycle – Precipitation, runoff, infiltration and evapotranspiration. Groundwater reservoir and Groundwater movement. Renewable and non-renewable ground water resources.

Hydrologic properties of rocks: porosity, permeability, specific yield, specific retention, hydraulic conductivity, transmissivity, storage coefficient, Darcy's law. Hydrographs, water table contour map, Hydrostratigraphic units. Well hydraulics, confined unconfined, steady, unsteady and radial flow, Water level fluctuations, causative factors and their measurements, Methods of pumping test and analysis of text data, Evaluation of aquifer parameters.

Problems of over exploitation of groundwater. Water management in rural and urban areas, Rainwater harvesting, Artificial recharge of groundwater.

Seawater intrusion in coastal aquifers and remedial measures, Submarine Groundwater Discharge (SGD) and determination methods. Surface and sub-surface geophysical and geological methods of ground water exploration. Hydrogeomorphic mapping using various remote sensing techniques.

Radio isotopes in hydrogeological studies. Water quality – major and minor constituents and their characters, Water well technology, types of wells, Drilling methods, construction, development and maintenance of well. Groundwater bill, Ground water quality of India, Hydro-stratigraphic units of India, Paleo-hydrological studies. Ground water Modeling.

Books Recommended

1. Groundwater hydrogeology – D. K. Todd
2. Hydrogeology – S. N. Davis and R. J. M. Dewiest
3. Groundwater studies – R. H. Brown and others

4. Groundwater Hydrology – Herman Bouver
5. Groundwater Resources Evaluation – W. C. Walton
6. Hydrogeology – C. F. Fetter
7. Handbook of applied hydrology – Ven Te Chew
8. Groundwater and wells – Hohnson publication
9. Physical and chemical hydrogeology – Patrick A. D. Dominics
10. Applied hydrogeology – Chow M. Mays, Mac Graw Hil Publicaiton
11. Hydrogeology and wet housed conservation – Gulman – wiley publication
12. Groundwater survey and investigation – Gautham Mahajan ApH puls.
13. Hydrogeology – Raghunath HM
14. Hydrogeology – Karanth K R, Tata Mac Graw Hill
15. Groundwater Assessment Development and Management – Karanth KR, Tata Mac Graw Hill
16. Groundwater – S. Ramakrishnan
17. Paleo-hydrology and Environmental change: Bemite, V R Babar and K. J. Gregong, Wiley, Chichester
18. Global Environment Changes, the context of paleohydrology, J. Brauson. A. G.
19. Brown, K. S. Gregory, Wiley Chichester.5
20. Applied hydrogeology – Fetter C. V. (1990)
21. Regional Groundwater Quality – Alley W. M. (1993) VNR, New York
22. Groundwater. Freez, R. A & Cherry, J.A., 1979. Prentice Hall
23. Applied Hydrogeology. Fetter, C.W., 1990. Merill Publishing.
24. Regional Groundwater Quality. Alley. W. M., 1993: VNR, New York.
25. Water. Subramaniam, V., 2000. Kingston Publ. London.
26. Geophysical Prospecting for Groundwater. Shankar Kumar Nath, Hari Pada Patra and Shamsuddin Shahid., 2000. Oxford IBH Publishing Co. Pvt. Ltd., New Delhi.

GEO 6102: PHOTOGEOLOGY REMOTE SENSING AND GIS
PHOTOGEOLOGY

Course Outcomes:

At the end of the course students will be able

- To understand the various aspects and methods of information technology in daily life and its applications in delineating the geomorphological characteristics of planetary bodies.
- To know the significant role in the planning and implementation of all development projects.
- Handle the software which has been used in this platform.

PHOTOGEOLOGY REMOTE SENSING

Introduction to Photogrammetry: Recent advancements and applications. Cameras, lenses, flight planning, scale of photographs, fiducial marks, overlap and sidelaps. Ground co-ordinates, relief displacement, flying height and tilt displacement in aerial photograph. Map and aerial photograph, stereopairs and mosaics. Types and geometry of photograph. Stereoscopy- Stereoscope, vertical exaggeration and height determinations. Types of stereoscope: mirror and pocket stereoscope. Modern photogrammetric techniques. Parallaxes: parallax bar, Parallax formula, height and slope determination. Scale determination of photographs on uniform and variable terrain. Digital Photogrammetry: Geological studies, Land-Use/Land-Cover (LULC) classification, Mineral mapping, Digital Elevation Model (DEM), Terrain analysis, Lineament extraction.

REMOTE SENSING

Remote Sensing: Definition, methods, scope and limitations, energy source and its interaction with atmosphere and Earth features; Electromagnetic spectrum: Laws of radiation, black body radiation. Remote sensing platforms: Active and passive systems; Satellites: High-level and low-level satellites, geosynchronous and sun-synchronous satellites; types of sensors and scanners, swath, satellite orbits; Resolutions: Spectral, spatial, radiometric and temporal resolutions. Space missions: Global and Indian space missions. Exploration programs: LANDSAT, METEOSAT, SEASAT, SPOT, IRS, Sentinel. Digital image processing- Image processing software (ERDAS, ENVI), principles of data interpretation. Digital image processing: data formats, enhancement, filtering, false-colour composite image, unsupervised and supervised classification, training sets, feature extraction.

Remote sensing applications in geosciences: visual interpretation of satellite images for geological, geomorphological and structural features. Techniques of image interpretation using spectral, spatial and temporal information. Spectral signatures of natural objects, interpretation of lithology, rock types land-use/land-cover under different setup.

Terrain classification, terrain mapping, applications of remote sensing techniques. Watershed characterization and mapping. Groundwater targeting in various terrains. Case studies from India

GEOGRAPHIC INFORMATION SYSTEM (GIS):

Principles and application of geographic information system, Introduction, definition and scope. Maps: thematic maps, map layers, map projections, raster and vector files, digitization, topology and their attributes, overlays and analysis. Map generation and composition.

Database: Definition and types of database, vector and raster data and their relative merits; Data management: Data quality, data manipulation and analysis, advantages and disadvantages of database approach. Application of GIS and GPS, advantages, uses in different fields

Books Recommended:

1. Millor, V.C., 1961 Photogeology. Mc Graw Hill
2. Sabbins, F.F.,1985 Remote Sensing-Principles and Applications. Freeman
3. Moffitt, F.H. and Mikhail, E.M., 1980 Photogrammetry-Harper and Row
4. Lillesand, T.M. and Kieffer, R.W., 1987: Remote Sensing and Image Interpretation-John wiley
5. Pandey, S.N., 1987: Princdiples and Applications of Photogeology-Wiley Eastern
6. Fundamentals of GIS – M. Demers
7. Encyclopedia of Applied Geology – Finkie
8. Remote Sensing and Geographical Information System-M.Anji Reddy.
9. Remote sensing and Geographic Information System by A.M. Chandra
10. Fundamentals of Remote Sensing by George Joseph
11. Remote Sensing of Environment by A.R. Jensen
12. Analysis of landforms By Twidale, C.R.,
13. Elements of Photogrammetry By Wolfe, P.R.,
14. Image interpretation in Geology. By Drury,S.A.,
15. Image interpretation By Lender
16. Geographic Information Systems By Stan Arnoff.,
17. Principle of Geographical Information
18. Systems for Earth Resources Assessment. By Burrough, P.A.

GEO– 6103 ENVIRONMENTAL GEOLOGY and ENGINEERING GEOLOGY

Course Outcomes:

At the end of the course students will be able

- To understand the concepts of environmental geology.
- To manage geological resources.
- To learn appropriate use of the geological environment for waste disposal, and recognition of natural hazards and mitigation of their human impacts.
- To understand the basic concepts and its application in engineering practices.
- To identify the suitable sites for different engineering constructions.
- To identify potential geological hazards and manage various structures to prevent and control them.

ENVIRONMENTAL GEOLOGY

Natural resources- Renewable, non-renewable. Sustainable management of resources. Conservation and preservation. Alternative energy sources – biomass energy, wind energy, solar energy, geothermal energy, tidal energy, wave energy, ocean thermal energy and others.

Natural hazards: Earthquakes and seismic hazards, earthquake prediction and protection. Cyclones-effects and control measures. Coastal hazards--Tsunamis, coastal erosion, sea-level changes and impact on coastal areas. Landslides--Identification of landslide-prone areas – Flood hazards and its management. Droughts—Causes and prevention. Zoning and risk assessment--Hazard Zonation maps. Disaster Management: introduction, identification of areas, causes, prevention and management. the Mine site decommissioning. Impacts of mining on depositional environments, reservoirs, lakes, lagoons and estuarine environments. Landslides: Engineering classification –graphical analysis of slope stability—calculation of Factor of safety—causes and prevention of landslides. Hazard zonation mapping and application of Remote sensing data.

Mass movements with special emphasis on landslides and causes of hill slope instability.

Radioactive pollution – Radioactivity, characteristics of radioactive waste. Classification – low level, intermediate level and high level. Disposal of high-level radioactive waste. Groundwater pollution – Sources of groundwater pollution- heavy metals, radioactive materials, acid mine drainage, fluoride, pesticide, fertilizers and arsenic contaminations. Collection and treatment, detoxification and biodegradation, health hazards due to ground water pollution, microbes, BOD and COD. Controls of groundwater pollution. Marine Pollution: Sources of marine pollution – industrial effluents, marine ship effluents, oil spill, inflow of fertilizers and pesticides, nuclear waste.

Environmental impact assessment (EIA): Introduction, Definition, aim, principles and concept. Relationship of EIA in sustainable development. Methods for preparing EIA: Socio-economic aspects, making inventories, sampling and data process, baseline study. Impact prediction: Positive and negative impact, primary and secondary impact, impact on physical, social and biotic environment. evaluation of proposed action: Risk assessment and risk management, mitigation measures, comparison of alternatives, Review and decision making, Practices and guidelines in India. EIA for different environmental programs: Industries, urban development, land use, Energy Projects-Hydel, Thermal, Nuclear, oil and gas. Environmental Impact Analysis of dams, buildings, highways and tunnels. EIA case studies.

ENGINEERING GEOLOGY

Role of Geology in Civil Engineering: Rock as construction material, Types of rocks- igneous, sedimentary, metamorphic rocks. Engineering properties of construction materials. Influence of

geological factors on engineering properties. Structural discontinuities and nature of fillings. Rock-water interaction. Soils, classification and Engineering properties.

Stages of geotechnical investigation for river valley projects.

Dams: types of dams--general criteria for selection of dam sites—foundation rocks—topography, availability of construction materials. Grouting—abutment and reservoir problems—environmental impact of dams—Seismicity—Reservoir Induced Seismicity—post-construction problems: leakage, seepage and water logging.

Foundation investigations for bridges and multi-storey structures. Geotechnical investigations for route locations in hilly terrains for road and rail alignments. Tunnels: Classification and terminology--geological factors in tunneling in igneous, sedimentary and metamorphic terrains.

Basic engineering and geological principles in shoreline engineering structures-Tsunami resistant structures. Terrain modeling-Lineament and Tectonics.

Role of engineering geology in civil construction and mining industry, various stages of

engineering geological investigation for civil engineering projects. Improvements of properties of rock mass: grouting, gnuting, rock bolting, cable anchorage.

Earthquakes and seismicity, seismic zones of India, aseismic design of building.

Engineering properties of soil, Atterberg limits, cohesive and noncohesive soils. Soil classification: textural classification, unified soil classification systems. Basic idea about engineering problems and performance of aeolian, alluvial, glacial, lacustrine and volcanic ash related soils Geological causes for mishaps and failures of engineering structures. Geological consideration for evaluation of dams and reservoir sites, dam foundation rock problems. Geotechnical evaluation of tunnel alignments and transportation routes, methods of tunneling, classification of ground for tunneling purposes, various types of support. Geotechnical investigations for bridges and coastal barriers.

Case history of the following engineering projects:

(a) Sardar Sarovar hydroelectric project (b) Tehri hydroelectric project (c) Banqiao Dam disaster

Books Recommended:

1. Valdiya, K.S., 2001: Environmental Geology-Indian Context-Tata McGraw Hill
2. Keller, E.A., 2004: Environmental Geology-Bell and Howell, USA
3. Bryant, E., 1999: Natural Hazards-Cambridge University Press
4. Patwardhan, A.M., 1999: The Dynamic Earth System-Prentice Hall
5. Subramaniam, V., 2001: Textbook in Environmental Science-Narosa International
6. Bell, F.G., 2003: Geological Hazards-Routledge, London

7. Smith, K., 1992: Environmental Hazards-Routledge, London
8. Environmental Concerns and Strategies By Khoshoo, T. L. 1988. Ashish Publ., New Delhi.

GEO 6104: ORE GENESIS AND MINERAL EXPLORATION

Course Outcomes:

At the end of the course students will be able

- To understand the modern concept of ore genesis.
- To understand the different types of controlling mechanisms involved in the formation of ores.
- To understand the various mining terminologies and different methods practiced in alluvial, open cast and underground mining according to the type of deposits.

ORE GENESIS

Modern concept of ore genesis. Mode of occurrence of ore bodies-morphology and relationship of host rocks. Textures, paragenesis and zoning of ores and their significance. Ore bearing fluids, their origin and migration. Wall-rock alteration. Structural, physico-chemical and stratigraphic controls of ore localization.

Geothermometry of ore deposits: Fluid inclusions, Inversion points, exsolution textures and stable isotopes. Geochemistry of ores- major, trace elements, REE and isotopic studies Ores of mafic-ultramafic association- diamonds in kimberlite; REE in carbonatites; Ti-V ores; chromite and PGE; Ni ores; Cu, Pb-Zn. Ores of silicic igneous rocks with special reference to disseminated and stock work deposits, porphyry associations. Origin, migration and entrapment of petroleum; properties of source and reservoir rocks; structural, stratigraphic and combination traps. Methods of petroleum exploration. Concepts of petrophysics, Petroliferous basins of India. Origin of peat, lignite, bitumen and anthracite. Classification, rank and grading of coal; coal petrography, coal resources of India. Gas hydrates and coal bed methane.

Ores of sedimentary affiliation-chemical and clastic sedimentation, stratiform and stratabound ore deposits (Mn, Fe, non-ferrous ores), placers and palaeoplacers. Ores of metamorphic affiliations-metamorphism of ores, Ores related to weathering and weathered surfaces laterite, bauxite, Ni/Au laterite. Contemporary ore-forming systems e.g., black smokers, mineralized crusts, Mn nodules. Mineralogy, genesis and important Indian distribution of ore minerals related to: Mn, Au, Sn, W and U.

MINERAL EXPLORATION

Mining methods: elements of mining; Mineral processing; environmental system management of mineral resources and sustainable development.

Exploration Geochemistry: pathfinder elements, regional-, district-, and local-scale geochemistry, field procedure, data interpretation and geochemical methods.

Exploration Geophysics: Gravity survey - Variation of gravity over the surface of the earth, principle of gravimeters, gravity field surveys, various types of corrections applied to gravity data, preparation of gravity anomaly maps and their interpretation in terms of shape, size and depth. Magnetic survey - Geomagnetic field of the earth, magnetic properties of rocks, working principle of magnetometers. Field surveys and data reductions, preparation of magnetic anomaly maps and their interpretation. Magnetic anomalies due to single pole and dipole. Introduction to aeromagnetic survey, three-dimensional current flow, potential due to a print current source. Electrical survey - basic principles, various types of electrode configuration, field procedure: profiling and sounding. Application of electrical methods in ground water prospecting and civil engineering problems. Seismic survey - fundamental principles of wave propagation, refraction and reflection surveys for single interface, horizontal and dipping cases, concept of seismic channel and multi-channel recording of seismic data, end-on and split spread shooting techniques, CDP method of data acquisition, sorting, gather stacking and record section. Seismic velocity and interpretation of seismic data, application in mineral and petroleum exploration. Borehole/well-logging - Description of borehole environment, brief outline of various well-logging techniques. Principles of electrical logging and its application in petroleum, groundwater and mineral exploration.

Books Recommended:

1. Craig, J.M. & Vaughan, D.J., 1981: Ore Petrography and Mineralogy-John wiley
2. Evans, A.M., 1993: Ore Geology and Industrial Minerals-Blackwell
3. Sawkins, F.J., 1984: Metal deposits in relation to plate tectonics-Springer Verlag
4. Stanton, R.L., 1972: Ore Petrography-McGraw Hill
5. Torling, D.H., 1981: Economic Geology and Geotectonics-blackwell Sci publ.
6. Barnes, H.L., 1979: Geochemistry of Hydrothermal Ore Deposits-John Wiley
7. Klemm, D.D. and Schneider, H.J., 1977: Time and Strata Bound Ore Deposits-Springer Verlag
8. Guibert, J.M. and Park, Jr. C.F., 1986: The Geology of Ore Deposits-Freeman
9. Mookherjee, A., 2000: Ore genesis-a Holistic Approach-Allied Publisher
10. Mckinstry, H.E., 1962: Mining Geology. II Ed.-Asia Publishing House
11. Clark, G.B., 1967: Elements of Mining.III Ed.-John Wiley
12. Arogyaswami, R.P.N., 1996: Courses in Mining Geology.IV Ed.-Oxford

13. Sharma, P.V., 1986: Geophysical Methods in Geology-Elsevier
14. Sharma, P.V., 1997: Environmental and Engineering Geophysics-Cambridge Univ.
27. Press
15. Vogelsang, D., 1995: Environmental Geophysics-A Practical Guide-Springer Verlag
16. Dobrin, M.B., 1976: Introduction to Geophysical Prospecting-McGraw Hill
17. Parasnis, D.S., 1975: Principles of Applied Geophysics-Chapman and Hall
18. Stanislave, M., 1984: Introduction to Applied Geophysics-Reidel Pub
19. Laurence Robb (2005). An Introduction to Ore forming processes. Blackwell publishing.
20. Kearey, Brooks and Hill (3rd edition; 2002). An Introduction to Geophysical Exploration. Blackwell Publishing.
21. Swapan Haldar (2018). Mineral Exploration – Principles and applications, Second Edition, Elsevier Publications, Netherlands.

GEO 6001- ELECTIVE III FIELD GEOLOGY AND MAPPING (PRACTICAL)
Course Outcomes:

At the end of the course students will be able

- To understand the basic procedures in the field work.
- To understand the mapping rock units and structures.

FIELD GEOLOGY

Scope and importance of Field Geology-- geologic maps and mapping, types of mapping, map symbols, reconnaissance, preparations. Basic equipment required for mapping and their uses: base map- Topographic map or aerial photograph, Brunton/Clinometer compass, hand lens, hammer, chisel, pen knife, hand lens, pocket magnet, fieldnote book, etc.

Basic procedures in the field: Taking a compass bearing, taping and pacing, locating the position in the map, Use of GPS. Observations in the field, interpretation of the outcrop, taking field notes, drawing and photographing outcrops, measuring attitudes of planar and linear features, finding and collecting fossils, collecting rock samples-their identification and naming.

Mapping rock units and structures: Geologic pace and compass traverse, finding and tracing contacts between rock units, correlating geologic units, mapping geologic structures, outcrop maps, locating points in the field. Selecting and preparing a base map—locating field data and geologic features.

Field studies and Mapping in sedimentary terrain: Beds and bedding, depositional bed forms and structures, palaeocurrent direction and palaeo slope direction, trace fossils, bioturbation, unconformities, beach and shelf deposits, marginal basin deposits of the deep sea. Subdividing and

describing a section. Covered, deformed or laterally variable strata-- Preparing and presenting stratigraphic sections.

Field studies and mapping in igneous terrain: Rock units, ages, inclusions in plutons, layering in plutons, schlieren and related structures, pegmatites and fracture systems in plutons.

Volcanic structures and field relations: map units, stratigraphy and ages, subaerial and subaqueous basaltic lavas, pyroclastic deposits.

Field studies and mapping in metamorphic terrain: Protoliths of metamorphic rocks, mineral reactions and zones based on minerals and textures. Metasomatism, segregated metamorphic rocks, gneisses, migmatites, hydrothermal alterations, age of metamorphism and sequence of metamorphic events.

Structural mapping: Identification and Mapping of Faults—folds—foliations, cleavages, lineations, joints, shear zones.

Preparing final geological map and reports: Field study to report writing, major illustrations, photographs, drawings, diagrams, designing the report, format and specific parts of the report.

BOOKS RECOMMENDED:

1. Field Geology by Lahee

2. Field Geology by Compton

ELECTIVE III GEO 6001 REMOTE SENSING (PRACTICAL)
Course Outcomes:

At the end of the course students will be able

- To understand digital image processing.
- To work in GIS based softwares
- To extrapolate the data.

REMOTE SENSING

1. Study of Satellite data; Digital image techniques; Software etc.

2. Interpretation of satellite images – False Color Composites.

3. Visual image interpretation and extraction of thematic layers.

4. Identification of structures and lineaments.

5. Delineation of land forms, study of geomorphology and hydro geomorphology.

6. Study of land use and land cover and demarcation of drainage basin.

7. Identification of rock types and minerals.

8. Integration of various thematic layers, ground truth.

9. Aerial photo interpretation: scale, height, and slope from aerial photos; study of inclined and vertical photographs.

10. Report writing for reconnaissance survey; detailed survey and targeting.

GEOGRAPHIC INFORMATION SYSTEM (GIS)

1. Introduction to computers, data input devices, key board, scanner, output devices, monitor, printer and plotter.

2. Auto-CAD, digitization techniques, Auto-CAD software, import of images, creation of layers, digitization etc.

3. GIS, software's, ARC INFO, ARC-GIS, ILWIS.

4. Exploring and planning data sets for GIS.

5. Preparing data sets for input in GIS environment.

6. Integration of spatial and temporal data

7. Analysis and manipulation of data in GIS.

8. Graphical representation of data.

9. Modelling and extrapolation of data.

10. Report writing.

ELECTIVE III GEO 6001 HYDROGEOLOGY (PRACTICAL)
Course Outcomes:

At the end of the course students will be able

- To prepare of water table contours.
- To represent water chemistry in plots.
- To study the ground water exploration techniques.

Preparation of water table contours. Estimation permeability. Analysis of hydrographs and estimation of infiltration capacity. Chemical analysis of ground water. Pumping test – Time, Draw down and time recovery tests. Evaluation of aquifer parameters, step draw down test. Study of depth and yields of bore wells. Electric resistivity – sounding for delineation of fresh and saline aquifers. Study of geophysical well logs. Exercises on groundwater exploration using remote sensing techniques. Exercises related on ground water modeling with given data.

IV SEMESTER

Course Code	Course	L	T	P	C
GEO 6201	Project	-	-	-	9
GEO 6202	Field training*	-	-	-	1
GEO 6203	Summer Internship#	-	-	-	1
GEO 6204	Mine/Lab visits^	-	-	-	1
	TOTAL				12

*Taken up in the first semester.

#Taken up at the end of the second semester, during the summer vacation.

^Taken up during the third semester.

GEO 6202 FIELD TRAINING

One week of geological field training to be taken up in the first semester. The training to be provided either by the Geological Survey of India (depending on availability of the time slots) or in-house faculty in locations that has diverse rock types, structures and landscape. Submission of a detailed field report which will be evaluated at the end of the fourth semester.

GEO 6203 SUMMER INTERNSHIP

Summer internship has to be carried out at the end of the second semester during the vacation time. Eight weeks of summer internship is recommended. This has to be carried out preferably at reputed research laboratories, petroleum and mining companies, GSI, universities in India or abroad. The summer internship report will be evaluated at the end of the fourth semester.

GEO 6204 MINE/ LAB VISITS

A Geological excursion will be taken up for about five days in the third semester. In this excursion students will be taken to an open cast and underground mining in Karnataka and / or neighboring states. They will also be taken to reputed research laboratories nearby to get an exposure to the cutting edge research done by the scientist in geological sciences. The excursion report will be evaluated at the end of the fourth semester.